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Human Systems Integration is worth the money and effort! The argument for the implementation of Human Systems Integration processes in Defence capability acquisition

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FOREWORD

Welcome to Defence's Human Systems Integration Framework Literature Review.

This work, entitled *Human Systems Integration is worth the money and effort! The argument for the implementation of Human Systems Integration processes in Defence capability acquisition* makes the case for human systems integration (HSI) as an important consideration in Defence capability acquisitions, both small and large. HSI is significant because Defence people are a fundamental input to capability. The development of capability is nothing without people, and its operational use must not only be effective and efficient, but also safe from foreseeable mishap, harm and long term injury to our people.

The work, prepared by a team of academics from the University of Queensland as part of a Defence Occupational Health and Safety Committee (DOHSC) funded program, will inform the scope and nature of further work envisaged by Defence in the area of human systems integration. There is a cogent argument for addressing the development of HSI plans and implementation of HSI programs early in the acquisition process. Moreover, there is evidence for a conclusion that investment in HSI implementation has a positive and probably large return on investment for Defence and its people.

In 2006, the DOHSC directed OHS Branch, to assess where Defence was in regard to the application of "Safe Design" principles within the Defence Capability Lifecycle (DCL). A Gap Analysis Report, concluded that there was significant scope for improving the systematic application of Safe Design in all phases of the DCL.

The DOHSC endorsed a phased implementation of a Human Systems Integration Framework (HSIF), aiming to achieve not only the intent of Safe Design, but also extending beyond this by improving whole-of-capability performance through ensuring that people capabilities and needs are appropriately considered and incorporated into system design and development from the outset.

The HSIF Project is being progressed by OHS Branch to deliver policy, guidance material and reports. The review of contemporary national and international literature was identified as an early guide for the project. Military operations are inherently hazardous: the likelihood of mistakes is elevated and the consequences increasingly serious. The challenge is to learn and incorporate those lessons from operational use and to avoid the mistakes of the past. A literature review ensures those outcomes are shared.

Of particular interest is the evidence in relation to a number of key research questions, including

- How has HSI been implemented in Defence or other industries?
- Does HSI improve safety in Defence or other industries?
- Does HSI improve productivity, effectiveness or efficiency in Defence or other industries?
- How has the cost–benefit of HSI been assessed for Defence products (materiél), Defence infrastructure or in other industries?
- Is HSI cost-effective in Defence or other industries?

HSIF Project staff have witnessed a growing interest in HSI amongst the Defence acquisition community and HSI influence on a number of policy and major program outcomes, including SEA 1000, Land 121 and 400 Project activities.

The People Imperative in Defence document "*People in Defence*" and the Strategic Reform Program 2009, "*Delivering Force 2030*" and their attendant reforms also accommodate the argument for investment in HSI. Analysis of local and international literature affirms that implementing HSI processes reduces the probability of adverse safety and health outcomes, reduces the chance of program failure, improves equipment effectiveness and reduces overall costs. The pursuit of cumulative risk reduction across projects provides corresponding reductions in acquisition and through-life costs, and these outcomes impact on how we do business now and into the future.

This literature review offers HSI/Domain practitioners, scientists, project staff and desk officers an improved understanding of why HSI is important as well as access to a robust examination of existing HSI considerations including case studies, research on the application of safety design and human factors on equipment, platforms and systems, and a searchable EndNote® database. This database facilitates access to a range of tools, techniques and guidance materials. It will be a useful resource to support Defence HSI activities.

We would like to acknowledge a small group of dedicated personnel, all of whom worked with much enthusiasm and commitment over the course of this work including the three authors Associate Professor Robin Burgess-Limerick PhD CPE, Ms Cristina Cotea BSc (Hons) and Ms Eva Pietrzak PhD from the University of Queensland, and Mr PJ Fleming, HSI Framework Project Manager and Mr Anthony Jonkergouw, Project Officer, OHS Branch.

The challenge as we move forward is to encourage senior managers, scientists, capability desk officers and project staff to harness this resource to protect Defence people, improve productivity, effectiveness and efficiency, procure better equipment and capability, and reduce the probability of acquisition program failure.

We commend this document to you and encourage your continued discussion and utilisation of the HSI capability.

Craig Orme
Major General (J1 ADF)
Head People Capability

Lindsay Kranz
Director General
Occupational Health and Safety Branch
People Strategies and Policy Group

November 2010

EXECUTIVE SUMMARY

The aim of this review is to inform Department of Defence activities in the area of Human Systems Integration (HSI). Evidence is collated to address the following questions:

- How has HSI been implemented in Defence or other industries?
- Does HSI improve safety in Defence or other industries?
- Does HSI improve productivity, effectiveness, or efficiency in Defence or other industries?
- How has the cost–benefit of HSI been assessed for Defence products (matériel); Defence infrastructure; or in other industries?
- Is HSI cost-effective in Defence, or other industries?

Three independent search strategies were employed to ensure the comprehensive identification of relevant literature: (i) database searches; (ii) an iterative manual identification of references cited in recent review papers; and (iii) identification of documents which cite seminal works in the area.

Formal HSI implementation programs have been established within the United States Department of Defense (DOD), and more recently in the United Kingdom Ministry of Defence (MOD), as well as civilian agencies such as the US National Aeronautics and Space Administration (NASA) and the US Federal Aviation Authority (FAA). Program managers within these agencies are required to develop and implement a HSI Plan in order to

> optimize total system performance, minimize total ownership costs, and ensure that the system is built to accommodate the characteristics of the user population that will operate, maintain, and support the system (DOD Instruction 5000.02 enclosure 8).

A large range of HSI methods and tools are available, and extensive direction, guidance and advisory documentation is provided by these agencies, and others such as the United Kingdom Human Factors Integration Defence Technology Centre and the European Agency for the Safety of Air Navigation. A searchable EndNote® database including 308 relevant items was created, with each item coded by domain, research area, and document type (appendix A).

The literature was examined for evidence that implementation of Human Systems Integration throughout the Defence Capability Lifecycle results in increased safety, effectiveness, efficiency, or productivity. Information of varying detail is available regarding the outcomes of implementation of HSI in Defence acquisition, and relevant case studies are summarised. While there are some notable examples referred to in the literature, the primary sources are typically difficult, if not impossible, to access. Few well-documented civilian examples are available.

However, sufficient evidence exists to sustain the conclusion that investments in HSI implementation during capability acquisition will have a positive, and probably large, return on investment in terms of:

- reduced probability of adverse safety and health outcomes
- reduced probability of acquisition program failure
- improved equipment effectiveness
- reduced overall costs

Financial returns are greatest, or at least most straight forward to estimate, where HSI implementation allows personnel levels to be reduced. Guidance in the evaluation of cost-benefit and cost-effectiveness is available, and while not a trivial exercise, efforts are justified to ensure that cost-benefit and cost-effectiveness of HSI implementation is systematically assessed.

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Acronym List

ALFCS	(Canadian) Advanced Land Fire Control System
Defence	(Australian) Department of Defence
DOD	(United States) Department of Defense
FAA	(United States) Federal Aviation Authority
HF	Human Factors
HFE	Human Factors Engineering
HFI	Human Factors Integration
HFI DTC	(United Kingdom) Human Factors Integration Defence Technology Centre
HSI	Human Systems Integration
IMPRINT	Improved Performance Research Integration Tool
MANPRINT	Manpower and Personnel Integration
MHP	(Canadian) Maritime Helicopter Project
MOD	(United Kingdom) Ministry of Defence
NASA	(United States) National Aeronautics and Space Administration
ROI	Return on Investment
SHERPA	Systematic Human Error Reduction and Prediction Approach
SAGAT	Situation Awareness Global Assessment Technique
UAV	Unmanned Aerial Vehicle

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INTRODUCTION

1. Human Systems Integration (HSI) (Booher 2003) is the process of integrating the domains of Human Factors Engineering, System Safety, Training, Personnel, Manpower (crewing), Health Hazards, and Survivability into each stage of the Defence Capability Lifecycle (Needs, Requirements, Acquisition, Service, and Disposal) where:

   a. **Human Factors Engineering** (HFE) is defined as the systematic application of information about human capabilities, limitations, characteristics, behaviour and motivation to the design of equipment, facilities, systems and environments;

   b. **System Safety** is the process of minimising safety and health risks through identifying, assessing and controlling hazards associated with the system;

   c. **Manpower** (crewing) refers to the number of persons required to operate, maintain, sustain and provide training for systems;

   d. **Personnel** refers to the aptitudes, experience and other personal characteristics required;

   e. **Training** refers to the instruction and training required to fulfill the person's role in the system;

   f. **Health Hazards** refers to conditions inherent in operation and use of a system that may cause death, injury, illness, disability or reduce the performance of personnel; and

   g. **Survivability** refers to the characteristics of a system in order to reduce fratricide, detectability and probability of being attacked and minimise system damage, war fighter injury, cognitive and physical fatigue.

AIM

2. The aim of this review is to inform Department of Defence (Defence) activities in the area of HSI by collating the evidence which exists in relation to the following research questions:

   a. How has HSI been implemented in Defence or other industries?

   b. Does HSI improve safety in Defence or other industries?

   c. Does HSI improve productivity, effectiveness, or efficiency in Defence or other industries?

   d. How has the cost–benefit of HSI been assessed for Defence products (matériel); Defence infrastructure; or in other industries?

   e. Is HSI cost-effective in Defence, or other industries?

METHODS

3. The scope of information sources considered includes:

   a. scientific publications;

   b. previous reviews;

   c. government and industry reports;

d. case studies (descriptions or evaluations) of HSI;

e. policies and practices adopted worldwide; and

f. Defence documentation.

4. Three independent search strategies were employed to ensure the identification of relevant literature was comprehensive: (i) database searches; (ii) an iterative manual identification of references cited in recent review papers; and (iii) identification of documents which cite seminal works in the area.

5. **Database searches**. Table 1 provides a list of search terms employed in searches of databases including Web of Knowledge (Science Citation Index & Social Science Citation Index) and Medline. The search strategy identified publications dated 1990 or later in which a Group A, a Group B, and a Group C term are identified. Additional database searches were undertaken using Google and Google Scholar to locate non-peer reviewed and government literature.

6. **Manual reference search**. An iterative manual search for relevant literature in both conventional and digital media was undertaken commencing with recent reviews of the area (for example, Adelstein et al 2006, "Design, Development, Testing, and Evaluation: Human Factors Engineering" NASA/TM-2006-214535 and Pew et al 2007 *Human-System Integration in the System Development Process: A New Look*), and the contents of websites including: Human Factors Integration Defence Technology Centre. (www.hfidtc.com/); Human System Integration Division NASA Ames (http://human-factors.arc.nasa.gov/); and US Army Manprint directorate (http://www.manprint.army.mil/index.htm); as well as existing Defence, and Defence Science and Technology Organisation documents.

Table 1: Search Terms

Group A	Group B	Group C
Human Systems Integration	Implementation	Defence Forces
Human Factors Integration	Procurement	Aviation
Manpower-Personnel Integration	Effectiveness	Road Transport
Manprint	Productivity	Military Personnel
Safety in Design	Efficiency	Navy
Safe Design	Cost-benefit	Air Force
System Safety	Task Performance	Railroads
Human Factors Engineering	Measures of Effectiveness	Medical devices
Defence Capability Lifecycle	Measures of Performance	Mining
Matériel	Computer Simulation	Maritime
Man-machine systems	Analysis	Space Army Ordnance Aerospace

7. **Seminal literature citation search**. A third strategy employed was to identify recent literature which cites seminal works in the area. For example, a search for citations of Booher (2003) *Handbook of Human System Integration* and Booher (1990) *Manprint: An Approach to Systems Integration* yielded 185 unique publications.

8. **Search outcomes**. A search of Web of Knowledge and Medline databases identified 672 publications, 119 of which were considered to be potentially relevant following perusal of titles and abstracts. Searches utilising Google and Google Scholar located 266 publications, of which 225 were judged to be potentially relevant. These results were supplemented by 94 potentially relevant publications located manually, yielding a total of 426 potentially relevant items (excluding duplicates). Perusal of the full text of these items resulted in the identification of 308 relevant items.

9. The literature identified was categorised for analysis by:

   a. defence domain or other industry (land, maritime, aerospace, ordnance, other industry);

   b. country (US, UK, Australia, etc);

   c. DCL stage (design: needs, requirements; acquisition/construction; service/operation; disposal);

   d. HSI domain (manpower, personnel, training, human factors engineering, system safety);

   e. research area (safety, reliability, productivity, effectiveness, efficiency, cost-benefit, cost-effectiveness); and

   f. information type (scientific publication, review, government and industry reports, case studies, policies and practices, internal Defence documentation).

10. An EndNote® database was constructed which includes the category codes within a "label" field. Use of these terms allows the references to be filtered and searched. The EndNote® database forms appendix A of this report, and the contents of the database are also provided as a Portable Document Format file (appendix B). Uniform Resource Locators are provided where available.

RESULTS

Defence HSI Programs

11. The US DOD and UK MOD agencies have formal HSI policies in place for major systems acquisition, and the Canadian Department of National Defence is in the process of establishing such a program (Greenley et al 2006). While the details vary, the general procedure is to place responsibility on the Program Manager to ensure that implementation of HSI occurs during equipment acquisition. For example, The US DOD Instruction 5000.02 (2008) includes Enclosure 8 which deals with HSI, and requires the Program Manager to "have a plan for HSI in place early in the acquisition process to optimize total system performance, minimize total ownership costs, and ensure that the system is built to accommodate the characteristics of the user population that will operate, maintain, and support the system". The US DOD (2009) *Human Systems Integration Management Plan* sets out a plan for HSI management within the DOD, and describes formal responsibilities, authorities, and accountabilities. The plan encompasses the organisational structures, roles, responsibilities, processes, tasks, metrics and enabling resources provided for the implementation of HSI.

12. A range of guidance material is provided by the DOD, including a comprehensive on-line *Defense Acquisition Guidebook* (US DOD 2010). Chapter 6 of this handbook "provides the Program Manager with the necessary background and understanding to design and develop systems that effectively and affordably integrate with human capabilities and limitations". The US DOD (2005) "Manpower and Personnel Integration (MANPRINT)

in the System Acquisition Process" provides advice and recommendations for the implementation of the US Army's long-standing MANPRINT program which aims to ensure that human considerations are integrated into the system acquisition process. This is achieved by ensuring that personnel are fully, and continuously, considered as part of the total system in the development and/or requisition of all systems. Human performance is considered to be a key factor in "total system performance" and it is recognised that enhancements to human performance will correlate directly to enhanced total system performance, and reduced life cycle costs. MIL-HDBK-46855A *Human Engineering Program Process and Procedures* (DOD 1999) also provides useful guidance.

13. Similarly, the US Air Force (2009) *Air Force Human Systems Integration Handbook* provides a description of the Air Force HSI process and identifies key considerations for the development of HSI plans and implementation of HSI programs. The US Navy undertakes a SEAPRINT program (Dolan & Narkevicius 2005) which aims to insert HSI throughout the systems engineering process. Wallace et al (2007) and Landsburg et al (2008) provide further commentary on the importance of the implementation of HSI within the US Navy.

14. The UK MOD refers to Human Factors Integration (HFI), rather than HSI, however the intent is similar. The formal requirements are set out in a series of Defence Standards "Human Factors for Designers of Systems" Def Stan 00-250 (2008): parts 1-4. (http://www.dstan.mod.uk/00e.php). Part four of these standards provides information about a large array of HFI methods, tools and techniques. Additional guidance is also available in an "HFI Technical Guide" (MAP-01-011) provided by the UK Ministry of Defence, Sea Systems Group (2006), and detailed guidance for high speed craft has also been sponsored by the Directorate of Sea Systems (Dobbins et al 2008).

15. The UK Human Factors Integration Defence Technology Centre (HFIDTC) is a virtual centre of excellence funded by the MOD which undertakes research to develop and evaluate processes methods and tools (Newman et al 2008). Reviews of a wide range of HF design and evaluation methods (Borras & Groom 2003; Salmon 2004) are provided, as well as a series of advisory documents including *The People in Systems TLCM Handbook* (UK HFIDTC 2009) which deals with the consideration of the human element during "Through Life Capability Management". A 2006 HFIDTC document provides "Cost arguments and evidence for human factors integration", while a more recent HFIDTC document (Bruseberg 2009) provides more detailed guidance regarding the methods to be employed to make the cost case for HFI projects or programs.

Civilian HSI Programs

16. A range of civilian agencies including NASA, the FAA, and the European Organisation for the Safety of Air Navigation (eg Kjaer-Hansen 1999; Shorrock et al 2004) include HSI within equipment procurement policies and provide a range of guidance material. For example, the FAA Acquisition Management policy requires that:

> planning, analysis, development, implementation, and in-service activities for equipment, software, facilities, and services include human factors engineering to ensure performance requirements and objectives are consistent with human capabilities and limitations. Human factors engineering should be integrated with the systems engineering and development effort throughout the lifecycle management process, starting with concept and requirements definition and continuing through solution implementation and in-service management. (fasteditapp.faa.gov/ams/, section 4.7)

The FAA (2003) provides the *Human Factors Acquisition Job Aid* and the FAA Human Factors Design Standard (FAA 2009) to assist this process.

17. Similarly, NASA Procedural Requirements include "Human-Rating Requirements for Space Systems" NPR8705.2B (NASA 2008) which explicitly mandates the application of HFE throughout the development life-cycle (Adelstein 2006). The requirement currently includes reference to the NASA-Standard-3000 Man-Systems Integration Standards (NASA 2005), however these standards are to be superseded by NASA-STD-3001, Volume 1 (Crew Health) (NASA 2007); the *Human Integration Design Handbook* (NASA 2010) which provides guidance for the crew health, habitability, environment, and HF design of all NASA human space flight programs and projects; and, when completed, NASA-STD-3001, Volume 2, (Human Factors, Habitability, and Environmental Health).

18. The European Organisation for the Safety of Air Navigation provides extensive guidance material via the "Human Factors Integration in Future ATM Systems (HFIA)" website. The site includes a "HFIA data" database which:

> brings together a large amount of data and information concerning all of the Human Factors activities that typically should be performed during the development of an ATM system (or indeed any other human-machine system). It identifies the human factors issues that need to be considered during each phase of the system development life-cycle, and specifies the tasks to be carried out. It describes the many human factors methods and tools for performing those tasks. In addition, it explains the human factors integration domains and the roles and responsibilities of those involved. (http://www.eurocontrol.int/hifa/public/subsite_homepage/homepage.html)

Methods and Tools

19. Regardless of the domain of application, a similar set of tools and methods are utilised. Particular emphasis is placed on methods such as Scenario-based requirements capture (Gregoriades & Sutcliffe 2006; MacLeod 2008); and HSI top-down requirements analysis (Johnson et al 2005; Malone & Carson 2003; Malone et al 2003) which are applicable early in the design process. Similarly, Rhodes et al (2009) describe the extension of systems engineering leading indicators to HSI as a means of enhancing the consideration of HSI early in the design process. Newman et al (2008) describe management tools developed by the UK HFIDTC including the Desktop Support Tool, and Human Factors Impact Tracking Tool.

20. Modelling and simulation techniques are commonly employed throughout the defence equipment lifecycle (eg Cox & Hariri 2007; Hunn et al 2008). "The Human View Handbook for MODAF" (Bruseberg 2009) describes how "Human Views" are employed in a systems engineering modelling approach to communicate human-related design concerns to engineers with the aim of enabling early application of HF methods in the cognitive systems engineering process (Bruseberg 2008, see also Handley & Smillie 2010).

21. Adelstein et al (2006) emphasise the use of Preliminary Hazard Analysis to identify potential human errors early in the design process. The use of Fault Tree Analysis (a top-down approach) in conjunction with Human Factors Process Failure Modes and Effects Analysis (a bottom-up approach) is suggested. Other methods and tools commonly utilised include: task analysis techniques (eg Hierarchical Task Analysis, see Stanton et al 2006 for an extensive review); cognitive task analysis techniques (eg Critical Decision Methods); field observations and ethnography; participatory analysis; charting techniques; human error identification techniques (eg Systematic Human Error Reduction and Prediction Approach - SHERPA); situation awareness measurement techniques (Situation Awareness Global Assessment Technique - SAGAT); mental workload assessment techniques (eg NASA-Task Load Index); team performance analysis techniques; interface analysis techniques (eg link analysis); performance time assessment techniques (Salmon 2004; Pew & Mavor 2007), along with physical ergonomics techniques (see Salvendy 2006 for general human factors

/ ergonomics tools and methods). Recent publications have focused in particular on the assessment of team performance (eg Bolia & Nelson 2007; Gorman et al 2006; Stanton et al 2006; Walker et al 2006).

HSI Benefits

22. Evidence available regarding the effectiveness, efficiency, productivity, and safety of HSI was collated. Appendix C summarises case studies identified in the literature which describe successful implementation of HSI or the undesired consequences of failing to implement HSI in either military or civilian domains. While cost-benefit has been of interest (eg Booher 1997) and techniques for estimating the health costs associated with Army matériel have existed for some time (Bratt et al 1997), detailed guidance for assessing cost-benefit associated with HSI has only been provided relatively recently (eg Bruseberg 2008; 2009; Rouse & Boff 2003; 2006), and relatively few detailed cost-benefit case studies are available in the public literature.

Defence Case Studies

23. The most widely cited example, and one of the most detailed available, is the Comanche helicopter acquisition program. Booher (1997) and Booher and Minninger (2003) cite a 1995 report by Minninger (which unfortunately is not readily accessible) as demonstrating that the implementation of HSI within the acquisition program for a design investment of 4% of the research and development budget (or $75M) resulted in cost avoidance of $3.29B, a 44:1 return on investment (ROI); in addition to avoiding 91 fatalities and 116 disabling injuries over 20 years. Other examples reported in some detail by Booher and Minninger (2003) include: critical design improvements to the Apache Longbow helicopter, where costs savings of $269M were attributed to a HSI investment of $12M (22:1 ROI); and the Fox NBC reconnaissance vehicle where a 33:1 ROI was calculated.

24. The US Air Force (2009), *Air Force Human Systems Integration Handbook* suggests that HSI typically comprises 2-4.2 % total system acquisition cost and leads to a ROI of between 40-60 times that investment. This Handbook cites an evaluation of the implementation of HSI within a fighter jet program as leading to lifecycle cost savings in maintenance, manpower and support in excess of $4B.

25. Defence Research and Development Canada applied a HSI program to a range of acquisition projects (Greenley et al 2006) and estimated the resulting cost-benefit. $3.3M was invested in HSI application across 8 case studies (Joint Intelligent Information Fusion Capability; Advanced Land Fire Control System (ALFCS); Future Armoured Vehicle System; Maritime Helicopter Project (MHP); MHP modeling; MHP workload; Very Short Range Air Defence), resulting in $3.5M in immediate savings, ie an immediate cost benefit of 106%. An extrapolated savings for one system (ALFCS) of $131M resulted from reduced manning levels; and $2M was assessed as the consequence of the elimination of an unnecessary display on a shipboard system (MHP). The report also includes an instructive summary of "lessons learned" during the project, which includes the conclusion that:

> Simulation-based, iterative design and experimentation cycles, can effectively address a range of HSI variables. Military operators are able to effectively extrapolate their experiences in medium fidelity virtual simulation environments to provide structured feedback on task performance, workload, situational awareness, usability, Training, System Safety, Health Hazard, and Personnel impacts of future system designs. Objective measures used in virtual simulation-based experimentation can provide data sets on task performance, workload, usability, and learning time. (Greenley et al 2006, p. 49)

26. The largest demonstrated savings in the Canadian program resulted from reduced manning, and this is a common theme across US Navy case studies. For example:

a. Anderson et al (1997) described an application of decision-aiding techniques which allowed the reduction in aircraft carrier manning levels by 11%, while at the same time reducing the time taken for aircraft launch and recovery by 20%.

b. Anderson et al (1998) suggests that implementing HSI achieved reduced manning while retaining or improving system operability and effectiveness. The DD21 program manning levels versus the previous DDG79 were noted to be a reduction of 144 sailors (from 188 to 44); an annual cost avoidance of $9.4M, and assuming 40 ships and 30 years life, a total saving of $11.3B.

c. Militello et al (1998) reviewed a number of optimised manning case studies including the first ship to be outfitted as a Smart Ship, the USS Yorktown, and documented the methods used to achieve reduced manning, and reduced workloads and improved quality of life for the remaining personnel. Spindel et al (2000) similarly cited the "Smart ship" program as demonstrating that technology and process improvements can reduce manning, maintain capability and improve shipboard quality of life.

d. Johnson et al (2005) describe in some detail the execution of a Top-Down Requirements Analysis which suggested that a 25% reduction in manning of LHD amphibious-assault-class ships can be achieved using mature or relatively mature technologies and no major redesign, leading to life cycle savings of $1B per ship, with 35% manning reductions being a realistic goal for the future.

e. Malone et al (2003) reported that the use of Top-Down Requirements Analysis reduced the manning requirements for the Fast Sealift Ships from 47 to 12, and described a similar process for the JCC(X) command ship. The results suggested a 30% reduction in workload was possible through the introduction technology and expanded use of automation.

f. A US General Accounting Office (2003) investigation estimated that an emphasis on HSI early in the DD(X) destroyer program reduced personnel by 70% leading to $18B saving over the life of the 32 ship class. The report recommendations included:

> that the Secretary of the Navy (1) require that ship programs use human systems integration to establish crew sizes and help achieve them, (2) clearly define the human systems integration certification standards for new ships, (3) formally establish a policy evaluation function to examine and facilitate the adoption of cost-saving technologies and best practices across Navy systems. (p.5).

27. An example from the French navy (Blin & Bry 2005) describes the use of the *Illustrateur de Besoin d'Exploitation Operationnelle* (IBEO) process and simulation tools to specify and assess work organisation, automation, human computer interaction modes, and training needs for future naval platforms featuring reduced manning levels. The process features the iterative use of full-scale models running realistic operational scenarios with current and future operators.

28. The need to reduce naval crewing levels was also the impetus for a report to the Canadian Forces (Beevis et al 2001) which catalogued techniques for achieving such reductions and concluded that the Canadian navy should develop its own capability to evaluate workload and crewing reduction technologies. Reducing naval costs, and in particular the costs of a Future Aircraft Carrier Programme, was the subject of a report to the UK MOD (Schank et al 2005). This report reviewed complement reduction options employed internationally, and identified six particularly promising options, all of which were dependent on HSI implementation for success.

29. Cost reductions from effective HSI have also been demonstrated by the US Air Force. Lizza et al (2008) cite a 2007 DOD review as finding that a $2M analysis of manpower, personnel and training associated with the F-22 Raptor resulted in an estimated $700M in lifetime cost avoidance, and subsequent manpower implementation was credited with approximately $3B in lifecycle savings. HSI evaluations during the C-12 acquisition process were also cited as leading to the automation of tasks previously requiring a flight engineer, with a consequent reduction in crew complement, and lifecycle cost savings greater than $3B.

30. Human factors issues associated with remotely piloted vehicles, or unmanned vehicles, have been the subject of considerable attention (eg Barnes et al 2000; Mulgaonka et al 2002), and have been reviewed by Hopcroft et al (2006). Tvaryanas et al (2005) highlighted HF causes of US military unmanned aerial vehicle mishaps, and concluded that attending to HSI is critical for the design of such equipment (Tvaryanas 2006). Questions addressed by these analyses include the operator training needs, workload issues, and the role of automation. Hunn and Heuckeroth (2006) in particular, provide a detailed description of the use of an Improved Performance Research Integration Tool (IMPRINT) model to assess operator workload levels associated with the Shadow UAV.

31. Other publications describe success in achieving improvements in military equipment design at a more restricted level. For example:

    a. Improved maintainability of the F119 engine (F-22 Raptor) is described by Liu et al, (2009; 2010) as a consequence of implementing HSI. Only five hand tools are required to service the engine; all line replaceable units are designed to be serviceable without replacing any other; each unit is replaceable using a single tool within 20 minutes; and maintenance is possible while wearing hazardous environment protection clothing. Importantly, the extensive commitment by the manufacturer to improving maintainability was a direct consequence of the emphasis placed on this issue by the US Air Force during the acquisition process, and was central to the manufacturer's competitive strategy.

    b. Hamburger (2008) describes the use of a bridge design mock up to identify design deficiencies in the DDG-1000 program, suggesting that a $20k investment achieved cost avoidance of $10M.

    c. Hendrick (1996) claimed that $500k in HF efforts saved more than $5M for the USAF C-141 aircraft.

    d. Mulgaonka et al (2002) provides examples of HFE benefits including redesign of transport aircraft for parachutists; antisubmarine warfare system and experimental helicopter technological integration; shoulder launched missile system; gunship aft-scanner workstation redesign; efficient helicopter tool kit. Further details of these examples are provided in MIL-HDBK-46855A (DOD 1999).

    e. Osga (2003) describes a multi-modal watch station project and highlights the improved performance demonstrated over the legacy Aegis system.

    f. Runnerstrom (2003) describes an example of effective HSI for ship board damage control. Tests in an environment replicating the effects of an anti-ship missile hit demonstrated that effective damage control was possible in the redesigned systems with 60% fewer personnel.

    g. Dobbins et al (2008) provide a series of case studies of the implementation of HFI within the design of high speed craft with defence purposes. The examples provided demonstrate improved performance, reduced manning, improved maintainability, and increased occupant comfort and safety benefits. The examples also demonstrate the appropriate use of a range of HF methods in the design process.

h. Folds et al (2008) cite "astonishing" improvements in engine change time for a High Mobility Multipurpose Wheeled Vehicle (HMMWV) arising from a HSI approach.

Civilian Case Studies

32. Relatively few examples of well-documented case studies of HSI implementation exist in the civilian arena. Examples which are available include:

    a. NASA authors (Adelstein et al 2006; Baggerman et al 2009) refer to successful HSI implementation in civilian aerospace, including references to historical successes of HFE in the Apollo program, as well as more recent examples such as the Constellation program Crew Exploration Vehicle, Lunar Lander, and EVA systems.

    b. HSI implementations in the oil and gas industry are described by a number of authors, (Cullen 2007; Khan et al 2002; McSweeney et al 2008), claiming improvements in safety as a result.

    c. Kirwan (2003) describes the implementation of a HF program for a new nuclear power plant which identified important safety issues.

    d. Hastings et al (2000) describe the implementation of an organisational change to the work of FAA safety inspectors (OASIS) which allowed inspectors to log their work using portable computers. An evaluation found that better usability was accompanied by a 19% time saving.

    e. Becker (2008) describes the design of a complex intensive care workstation through use-cases and a set of safety goals.

    f. Heape and Low (2009) describe HFI in the design of signal and train control systems for the Victoria line upgrade of the London Metro rail.

Sub-optimal Outcomes

33. Another avenue for assessing the value of HSI implementation is to examine situations in which HSI was insufficient. For example, a 2006 HFIDTC document titled "Cost Arguments and Evidence for Human Factors Integration" lists MOD acquisition failures resulting from poor HSI as including: the Bowman man-portable radio; RB44 light vehicles; SA80 Rifle and Light Support Weapon; and the single role mine hunter's recovery of remote control mine disposal system.

34. Other examples referred to in the literature include:

    a. Deficiencies of HF, manpower, personnel and training were identified during the reverse-engineering of the Black Hawk helicopter acquisition program (Hartel & Kaplan 1984).

    b. Many HSI problems discovered during testing and development of the Aquila remotely piloted vehicle led to the cancellation of the program (Stewart 1989).

    c. A premature decision regarding manning levels constraints for the Oliver Hazard Perry Class guided missile frigate (FFG 7 class) led to expensive redesign of accommodations, and difficulties manning the vessels upon completion (Schwartz 1981).

    d. Patriot air and missile defence units were involved in two incidents occurring during Operation Iraqi Freedom (18% of engagements) in which fatalities of allied forces resulted. Hawley (2007) examined the HSI lessons to be learned from this unacceptable fratricide rate, concluding that the causes of operator errors can be traced to decisions made by designers and others responsible for the development of the system over 25 years. The dominant mode of control changed from manual control to supervisory control as increasing levels of automation were added, however the operators' role change was not reflected in design and evaluation, or training practices.

e. MIL-HDBK-46855A (DOD 1999) provides details of several catastrophic events caused by failure to consider human capabilities, including the downing of Korean Air Lines Flight 007 which strayed into Soviet air space; the Three Mile Island nuclear accident; the downing of Iranian Air Line Flight 655 by the USS Vincennes; the Bhopal release of methyl isocyanate; the 1972 crash of a Lockheed L-1011 in the Florida everglades; and additional lessons learned from more minor incidents.

f. Hobbs et al (2008) cite the fatal decompression of Salyut 11 as an example of a failure to consider human capabilities in design.

g. Tvaryanas et al (2005) highlighted HF causes of US military UAV mishaps, and concluded that attending to HSI is critical for the design of such equipment (Tvaryanas 2006).

h. Cockshell and Hanna (2006) nominate two Australian Defence examples of sub-optimal HSI, noting that: (i) the Operations room of the ANZAC class frigates required redesign to correct deficiencies which resulted in poor situation awareness for the command team; space restrictions; excessive reach distances; and visibility issues; and (ii) Seasprite helicopter cockpit design issues with detrimental operational consequences costing an estimated $100–200M to rectify.

i. An insufficient focus on 'the incorporation of OHS concerns into engineering design' was identified as a factor which contributed to the chemical exposure of Air Force maintenance workers during F-111 fuel tank maintenance, leading to recommendations 6.1 and 7.2 of the Board of Inquiry, viz: 'Occupational health and safety should be integrated into the engineering change management process. This means, in particular, that designs should undergo a risk management process.' and 'The Air Force should review its acquisition policies to ensure that suppliers have systematically identified the hazards posed to personnel who use or maintain the equipment and, as far as possible, designed out these hazards' (RAAF 2001).

CONCLUSIONS

How has HSI been implemented in Defence or other industries?

35. Formal HSI implementation programs have been established within the US DOD, and more recently in the UK MOD, as well as civilian agencies such as NASA, the FAA and the European Organisation for the Safety of Air Navigation. Program managers within these agencies are required to develop and implement a HSI Plan. Program managers require support to develop and implement HSI plans, and extensive direction, guidance and advisory documentation is provided by these agencies, and others such as the UK HFIDTC. An extensive range of tools and techniques have been developed for use within HSI activities. Deliverables of the review include a searchable EndNote® database (appendix A) to facilitate location and access to these guidance materials and tools. This database will be a useful resource to support Defence HSI activities.

Does HSI improve safety in Defence or other industries?

36. Quantification of safety benefits arising from HSI is problematic because of the relatively low baseline incident rates, and is generally not attempted. An exception is the evaluation of the Comanche helicopter acquisition program by Minninger (1995, cited by Booher & Minninger 2003) which estimates the HSI implementation as avoiding 91 fatalities and

116 disabling injuries over 20 years. Claims for safety improvements arising from the implementation of HSI in civilian oil and gas, and nuclear industries have also been made (Cullen 2007; Khan et al 2002; Kirwan 2003; McSweeney et al 2008). The number of fatalities, injuries and illnesses which have been attributed to sub-optimal HSI (eg DOD 1999; Hawley 2007; Hobbs et al 2008; RAAF 2001) also lends weight to the potential for effective HSI implementation to prevent fatalities, injuries and illnesses. The evidence sustains a conclusion that effective implementation of HSI will reduce the probability of adverse safety and health outcomes.

Does HSI improve productivity, effectiveness, or efficiency in Defence or other industries?

37. Productivity, effectiveness and efficiency have been assessed in a variety of ways. Anderson et al (1997), Osga (2003) and Dobbins et al (2008) provide examples of improved ability to undertake mission critical tasks resulting from HSI, while improved platform availability will results from the improved F-22 engine maintainability described by Liu et al (2009, 2010), and dramatically reduced engine change times cited by Folds et al (2008). Increased efficiency through decision aiding and increased automation leading to reduced workload and manning has been well documented (eg Blin & Bry 2005; Johnson et al 2005; Malone et al 2003; Runnerstrom 2003; Schank et al 2005), and HSI is essential for successful introduction of automation (Hawley 2007). Numerous sub-optimal effectiveness outcomes have also been attributed to insufficient HSI (Cockshell & Hanna 2006; HFIDTC 2006; Schwartz 1981; Stewart et al 1989, Tvaryanas et al 2005). Implementing HSI will improve productivity, effectiveness and efficiency; as a corollary, these actions will reduce the probability of acquisition program failure.

How has the cost–benefit of HSI been assessed for Defence products (Matériel); Defence infrastructure; or in other industries?

38. Assessments of cost-benefit of HSI of varying complexity have been conducted. Booher (1997) and Booher and Minninger (2003) cite a 1995 report by Minninger as demonstrating that the implementation of HSI within the acquisition program for a design investment of 4% of the research and development budget (or $75M) resulted in cost avoidance of $3.29B, a 44:1 return on investment (ROI) Other examples reported in some detail by Booher and Minninger (2003) include: critical design improvements to the Apache Longbow helicopter, where costs savings of $269M were attributed to a HSI investment of $12M (22:1 ROI); and the Fox NBC reconnaissance vehicle where a 33:1 ROI was calculated. A number of assessments have estimated the benefits of reduced naval manning levels, typically estimating very large lifetime savings (Anderson et al 1998; Johnson et al 2005; US General Accounting Office 2003).

39. More recently, Defence Research and Development Canada applied a HSI program to a range of acquisition projects (Greenley et al 2006) and estimated the resulting cost-benefit. $3.3M invested in HSI application across 8 case studies resulted in $3.5M in immediate savings, ie, an immediate cost benefit of 106%. An extrapolated savings for one system of $131M resulted from reduced manning levels; and $2M in savings were assessed as the consequence of the elimination of an unnecessary display on a shipboard system. The project also included an evaluation of the implementation process and derived valuable “lessons learned” as an outcome.

40. Considerable direction, guidance and advisory material is available to assist in the implementation of HSI, and this literature includes guidance in the evaluation of cost-benefit and cost-effectiveness (eg Bruseberg 2008; 2009; Rouse & Boff 2003; 2006). The assessments are not straight forward however, because investments occur over time, returns are uncertain, and may be indirect and/or intangible. Even tangible outcomes, such

as reduced injury rates, are difficult to translate to economic gain (although see Bratt et al 1997). Rouse and Boff (2003) describe a seven step method utilising a multi-attribute utility model, and provide three examples of the application of this technique to assess performance improvements resulting from HSI in military systems. More recently, the UK HFIDTC (Bruseberg 2009) has provided a "practical guide" for cost-benefit analysis which describes a six step process (establish objectives; identify and quantify project risks; specify HFI influence; quantify required HFI effort; specify options; choose preferred option).

Is HSI cost-effective in Defence, or other industries?

41. Mature HSI programs have been implemented in US and UK Defence agencies, and a number of civilian agencies. Relatively few detailed case studies of the consequences of HSI implementation during equipment acquisition are available in the public literature. However, on the basis of the evidence cited above, a conclusion is justified that investments in HSI implementation will have a positive, and probably large, return on investment in terms of:

- reduced probability of adverse safety and health outcomes
- reduced probability of program failure
- improved equipment effectiveness
- reduced overall costs

Financial returns are likely to be greatest, or at least most straight forward to estimate, where HSI implementation allows personnel levels to be reduced.

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READER'S NOTES

APPENDIX A: HSI RESOURCES ENDNOTE® DATABASE

The EndNote® library can be downloaded from the following locations

- Internet > http://www.defence.gov.au/dpe/ohsc/publications/
- Defence intranet > http://ohsc.defence.gov.au/Programs/HumanSystemsIntegration/

For readers without EndNote®, the library contents have been extracted in full into appendix B.

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APPENDIX B: HSI RESOURCES

Adelstein, B., Hobbs, A., O'Hara, J, & Null, C. (2006). Design, Development, Testing and Evaluation: Human Factors Engineering. Hampton, VA, NASA, Langley Research Center: 47. http://ntrs.nasa.gov

civilian, aerospace, USA, acquisition, human factors engineering, review,

While human-system interaction occurs in all phases of system development and operation, this chapter on Human Factors in the DDT&E for Reliable Spacecraft Systems is restricted to the elements that involve "direct contact" with spacecraft systems. Such interactions will encompass all phases of human activity during the design, fabrication, testing, operation, and maintenance phases of the spacecraft lifespan. This section will therefore consider practices that would accommodate and promote effective, safe, reliable, and robust human interaction with spacecraft systems. By restricting this chapter to what the team terms "direct contact" with the spacecraft, "remote" factors not directly involved in the development and operation of the vehicle, such as management and organizational issues, have been purposely excluded. However, the design of vehicle elements that enable and promote ground control activities such as monitoring, feedback, correction and reversal (override) of on-board human and automation process are considered as per NPR8705.2A, Section 3.3.

Albery, W. (2007). "Multisensory cueing for enhancing orientation information during flight." Aviation, space, and environmental medicine 78(Supplement 1): B186-B190. http://www.ingentaconnect.com/content/asma/asem/2007/00000078/A00105s1/art00027

Defence, Military, Airforce, USA, design, human factors engineering, safety, scientific

The U.S. Air Force still regards spatial disorientation (SD) and loss of situational awareness (SA) as major contributing factors in operational Class A aircraft mishaps ($1M in aircraft loss and/or pilot fatality). Air Force Safety Agency data show 71 Class A SD mishaps from 1991-2004 in both fixed and rotary-wing aircraft. These mishaps resulted in 62 fatalities and an aircraft cost of over $2.0B. These losses account for 21% of the USAF's Class A mishaps during that 14-yr period. Even non-mishap SD events negatively impact aircrew performance and reduce mission effectiveness. A multisensory system has been developed called the Spatial Orientation Retention Device (SORD) to enhance the aircraft attitude information to the pilot. SORD incorporates multisensory aids including helmet mounted symbology and tactile and audio cues. SORD has been prototyped and demonstrated in the Air Force Research Laboratory at Wright-Patterson AFB, OH. The technology has now been transitioned to a Rotary Wing Brownout program. This paper discusses the development of SORD and a potential application, including an augmented cognition application. Unlike automatic ground collision avoidance systems, SORD does not take over the aircraft if a pre-set altitude is broached by the pilot; rather, SORD provides complementary attitude cues to the pilot via the tactile, audio, and visual systems that allow the pilot to continue flying through disorienting conditions.

Alves, E. R. and C. M. Kelsey (2010). "Combating vigilance decrement in a single-operator radar platform." Ergonomics in Design 18(2): 6-9.

defence, military, experimental, manning, workload

Anderson, D., Oberman, FR, Malone, TB, & Baker, CC. (1997). "Influence of human engineering on manning levels and human performance on ships." Naval Engineers Journal: 67-75. http://www3.interscience.wiley.com/journal/122188546/abstract?CRETRY=1&SRETRY=0

Defence, USA, Navy, Acquisition, manpower, human factors engineering, productivity, safety, workload

ABSTRACT The objectives of Human Engineering (HE) are generally viewed as increasing human performance, reducing human error, enhancing personnel and equipment safety, and reducing training and related personnel costs. There are other benefits that are thoroughly consistent with the direction of the Navy of the future, chief among these is reduction of required numbers of personnel to operate and maintain Navy ships. The Naval Research Advisory Committee (NRAC) report on Man-Machine Technology in the Navy estimated that one of the benefits from increased application of man-machine technology to Navy ship design is personnel reduction as well as improving system availability, effectiveness, and safety. The objective of this paper is to discuss aspects of the human engineering design of ships and systems that affect manning requirements, and impact human performance and safety. The paper will also discuss how the application of human engineering leads to improved performance, and crew safety, and reduced workload, all of which influence manning levels. Finally, the paper presents a discussion of tools and case studies of good human engineering design practices which reduce manning.

Anderson, D., T. Malone, et al. (1998). "Recapitalizing the navy through optimized manning and improved reliability." Naval Engineers Journal 110(6): 61-72. http://www3.interscience.wiley.com/journal/122188415/abstract?CRETRY=1&SRETRY=0

Military, Defence, Navy, Acquiistion, Manpower, Discussion (practices), Research (reliability, safety, methods)

Reduced manning is the process (and the result) of removing human functions from a system while retaining or improving system operability and effectiveness. Reliability and maintainability characterize a system's operability and effectiveness. Reduced manning impacts system reliability by changing the characteristics of (1)human error associated with system operation and maintenance, (2) time to repair failed components, and (3) mean-time-between-failures (MBTF) in a reduced manning environment.Simply reducing manning without compensating for system dependence on human involvement generally has a negative impact on system maintainability. Methods to address this include (1) human-system integration design of maintenance interfaces and (2) design of operations activities that are closely related to device failures.

After demonstrating reliable performance through testing and operation, ship commanders can be assured that fewer people can effectively operate and maintain Navy ships and systems.

Archer, R. D., D. Rick, et al. (2009). Human Performance Modeling of Reduced Manning Concepts for Navy Ships. Human Factors and Ergonomics Society Annual Meeting Proceedings, System Development HFES. 5: pp. 987-99. http://www.ingentaconnect.com/content/hfes/hfproc/1996/00000040/00000019/art00007

Defence, Military, USA, Navy, manning, manpower, tools, case study

WinCrew is a human performance assessment tool developed by the Army Research Laboratory, Human Research and Engineering Directorate that implements the Wickens' Theory of Multiple Resources. WinCrew supports the hierarchical decomposition of missions into functions and tasks. As a demonstration of the capability of WinCrew, simulation models of the activities performed by bridge personnel on a Navy Guided Missile Destroyer DDG51 were developed. The scenarios were chosen to illustrate the potential of task network based human performance modeling to address reduced manning issues for naval ship operations. In order to fully exercise the functionality of WinCrew, four bridge models were developed. One scenario was modeled for four different manning, automation, and task allocation configurations. The scenario modeled was entry into San Diego Harbor. The major events for the bridge team were: bearing fixes, gyro error checks, turns, precision anchoring, and obstacle avoidance. Results of the effort demonstrated the utility of workload modeling for assessing human system integration alternatives for shipboard manning.

Archer, S., D. Headley, et al. (2003). Manpower, personnel, and training integration methods and tools. Handbook of human systems integration. H. R. Booher, John Wiley & Sons, Inc.: 379-431. http://www3.interscience.wiley.com/cgi-bin/bookhome/109868385

Defence, navy, airforce, HSI methods, manpower, personnel, training, review

A key concept in personnel staffing and systems integration is determining, acquiring, training, and retaining the proper number of people with the right skills for the jobs required to operate and maintain systems. Traditionally, most organizations attempt to match the number and skills of people necessary to meet acceptable performance at minimum cost. More recently, organizations have begun to recognize that the introduction of new technology-ranging from information technology, process monitoring and control, and robotic manufacturing to weapons technology-can significantly increase the difficulty of maintaining a proper mix of numbers and skills of people in the workplace. Some technology may help to reduce numbers and skills required as well as reduce the workload (both physical and mental) on employees. In other cases technology may, through its sophistication, cause an increase in the need for, and therefore the cost of, skilled individuals to operate the systems. Also, technology may not reduce workload but simply shift it from physical workload to mental workload. The technology-people trade- off in the workplace is a job design issue that can be addressed via the human systems integration (HSI) approach. The primary objective of this chapter is to describe the state of the art for HSI methods and tools particularly useful for analysis and assessment of manpower, personnel, and training (MPT) issues on system design and development programs.

The complexity and universality of the workforce problem facing organizations that procure, manufacture, and use systems and products can be appreciated from the following overview of workforce challenges facing the military, other government activities, and commercial industry.

Askeland, R. W., S. McGrane, et al. (2008). "Improving transfusion safety: implementation of a comprehensive computerized bar code-based tracking system for detecting and preventing errors." Transfusion 48(7): 1308-1317. http://www3.interscience.wiley.com/journal/120121327/abstract

Civilian, medical, operation, safety, case study

BACKGROUND: To transfuse blood products safely, health care workers must accurately identify patients, blood samples, and the blood components. A comprehensive bar code-based computerized tracking system was developed and implemented to identify and prevent transfusion errors.

STUDY DESIGN AND METHODS: A data network, wireless devices, and barcoded labels were pilot tested before the system was introduced hospital wide. The system provided a complete audit trail for all transactions. Data from before and after implementation were analyzed.

RESULTS: Incident reports decreased from a mean of 41.5 reports per month in the 6 months before the system was implemented to a mean of 7.2 reports per month after implementation. The blood sample rejection rate decreased from 1.82 percent to a mean of 0.17 percent after implementation. Errors detected by the new system were sorted into misscans, skipped steps, wrong steps, and prevented identification errors (PIEs). Misscans and skipped steps were the most common errors in the first 10 months after implementation. During the final transfusion step, PIEs occurred at the rate of about one per month and scans were omitted approximately 1 percent of the time. Therefore, it is estimated that mistransfusions could occur about once every 100 months on average with the new system.

CONCLUSIONS: The bar code-based computerized tracking system detected and prevented identification and matching errors, thereby reducing the proportion of blood samples rejected and increasing patient safety.

Australian Defence OHS Program Office (2006). Safe Design in the Defence Capability Lifecycle: Gap Analysis Report.

Defence, Military (Navy, Air Force, Army), (land, maritime, aerospace), Australia, DCL (design, acquisition, service, disposal), HSI (HFE,safety, training, personnel, manpower), review, discussion, description, performance, safety, cost, methods, tools

Following the F111 Deseal/Reseal Board of Inquiry (BOI), a number of recommendations were made regarding the incorporation of Occupational Health and Safety (OHS) input into the design process for materiel being acquired for the Australian Defence Force (ADF). The requirement for the incorporation of OHS input to the design process was further reinforced in the Defence OHS Strategic Plan, and articulated as Enabling Priority 7, which states, “Improve the identification, elimination and management of hazards at the design and planning stages1. Priority 7 seeks to improve safety in design in Defence. The expected outcomes for this Priority include:

Australian Defence OHS Program Office (2006). Safe Design in the Defence Capability Lifecycle: Options Paper.

Defence, Military (Navy, Air Force, Army), (land, maritime, aerospace), Australia, DCL (design, acquisition, service, disposal), HSI (HFE,safety, training, personnel, manpower), discussion, description, performance, safety, cost,

Purpose

1. The purpose of this Options Paper is to:

    - present the status of ‘Safe Design’ within the Defence Capability Lifecycle (DCL);
    - recommend options to improve the identification, elimination and management of hazards at the design and planning stages of capability systems; and
    - highlight benefits of recommended ‘Safe Design’ improvements in Defence.

Background

2. The F111 Deseal/Reseal Board of Inquiry (BOI) made a number of recommendations regarding the incorporation of Occupational Health and Safety (OHS) input into the design process for materiel being acquired for the Australian Defence Force (ADF). The requirement for OHS input to the design process was further reinforced in the Defence OHS Strategic Plan, articulated as Enabling Priority 7, which states: “Improve the identification, elimination and management of hazards at the design and planning stages.

3. The incorporation of OHS input to the design process has become known colloquially as ‘Safe Design’. Safe Design is not just intended to minimise health hazards, but to improve Human-System interface, maximising the effective utilisation of the capability system or

materiel and thus improve defence capability. The engagement of Safe Design will be most effective if it commences as early as possible in the Capability Development process.

4. The March 2006 Defence OHS Committee (DOHSC) directed Defence OHS Program Office (DOHSPO) to comprehensively assess where Defence is in regard to 'Safe Design' principles within the Defence Capability Lifecycle (DCL). The Safe Design Review (SDR) project was limited to the review of processes and practices involved in Major, Minor and Rapid Acquisition programmes conducted throughout the DCL.

Australian Defence OHS Program Office (2008). Human System Integration Framework Implementation Project (HSIFIP): Business Case.

Defence, Military (Navy, Air Force, Army), (land, maritime, aerospace), Australia, DCL (design, acquisition, service, disposal), HSI (HFE,safety, training, personnel, manpower), discussion, description,

Australian Defence OHS Program Office (2008). Human System Integration Framework Implementation Project (HSIFIP): Outline Project Management Plan.

Defence, Military (Navy, Air Force, Army), (land, maritime, aerospace), Australia, DCL (design, acquisition, service, disposal), HSI (HFE,safety, training, personnel, manpower), discussion, description,

Australian Department of Defence (2006). Defence Capability Development Manual. D. P. Service. ACT, Australia. http://www.defence.gov.au/publications/dcdm.pdf

Defence, Military (Navy, Air Force, Army), (land, maritime, aerospace), Australia, DCL (design, acquisition, service, disposal), discussion, description, performance, safety, cost, methods, tools

In ordinary usage, 'capability' means the capacity to be or do or affect something. The term can refer to a quality, capacity or ability. In the context of the Australian Defence Organisation (ADO), being a complex and diverse organisation, the term can similarly have a variety of meanings. In the context of the Capability Development Group (CDG), however, which focuses on developing proposals for Major Capital Equipment (MCE) to be used by the Australian Defence Force (ADF), 'capability' has a more specific meaning, namely, the capacity or ability of the ADF to achieve a particular operational effect. That operational effect may be defined or described in terms of the nature of the effect and of how, when, where, and for how long it is produced.

1.2 'Capability' in the Defence context is the combined effect of multiple inputs. It is not the sum of those inputs, but the synergy that arises from the way those inputs are combined and applied that determines the level of capability in a particular context. In Defence, the 'Fundamental Inputs to Capability' (FIC), are categorised and broadly defined as:

a. Personnel. All people within Defence, both military (permanent and Reserves) and civilian. The input incorporates recruiting, individual training and all conditions of service and employment, including entitlements, salaries and wages, superannuation and allowances;

b. Organisation. Flexible functional groupings with an appropriate balance of competency, structure and command and control to accomplish their tasks. This input also includes critical organisations that directly support the ADF effort;

c. Collective training. A defined training regime undertaken by organisations that is validated against the preparedness requirements for operations, derived from

Government guidance. The regime is to include frequency and depth of competency in skills with a particular emphasis on long-term readiness critical war fighting skills;

d. Major Systems. Systems that have a unit cost of A$1m or more, or have significant Defence policy or joint Service implications designed to enhance Defence's ability to engage military power. Input includes, but is not limited to, ships, tanks, missile systems, armoured personnel carriers, major surveillance or electronic systems, and aircraft;

e. Supplies. Supplies needed for Defence to operate including stock holdings, provisioning lead times, serviceability and configuration status. Ten supply classes are described in Australian Defence Doctrine Publication (ADDP) 4-Defence Logistics and ADDP 4.2-Support to Operations;

f. Facilities. Buildings, structures, property, plant, equipment, training areas, civil engineering works, through life maintenance and utilities necessary to support capabilities, both at the home base and at a deployed location. Input may involve direct ownership or leasing; Support. Infrastructure and services from the wider national support base within Australia or offshore which are integral to the maintenance of Defence effort. The input is encompassing and could originate from civil/private industry/contractors, other Government agencies and international support base agencies; and

h. Command and Management. Written guidance such as regulations, instructions, publications, directions, doctrine, tactical level procedures and preparedness documents required for Defence to support decision making, administration and operations. Input also includes funding not readily attributable to any other FIC element (eg. discretionary funding).

1.3 When developing capability proposals for Government approval, CDG ensures that all of the capability elements listed above are examined with a view to determining how individual FIC need to change in order to bring about a desired change in ADF capability. This comprehensive approach to capability not only focuses attention on the combination and integration of the FIC, rather than on the individual inputs separately, but also enables Defence to better understand the whole of life funding implications of the new capability. Capability is thus viewed as a 'system' of interlocking and interdependent FIC.

1.4 The definition of capability used in CDG, incorporating both the operational and systems aspects outlined above is: Capability is the power to achieve a desired operational effect in a nominated environment, within a specified time, and to sustain that effect for a designated period. Capability is generated by Fundamental Inputs to Capability comprising organisation, personnel, collective training, major systems, supplies, facilities, support, command and management.

Capability Life Cycles

1.5 Capability systems have a 'life cycle' that begin with the identification of the need to address a current or prospective capability gap. This need is progressively translated into a working capability system that is operated and supported until it is ultimately withdrawn from service. Once a capability is withdrawn from service, the associated physical and personnel assets can either be disposed of (for physical assets), redeployed or reallocated as an offset for another capability.

1.6 The capability life cycle is divided into the following phases:

a. Needs - capability gaps, derived from consideration of strategic guidance, current and future operational concepts, future technology and the current and emerging force structure, are identified by Defence. Government endorses the need to address the identified gaps and approves the inclusion of a project with an indicative budget provision in the Defence Capability Plan (DCP);

b. Requirements - each capability need endorsed by Government is transformed progressively into a costed, defined solution to that need, and approved by Government with a schedule for acquisition leading to operational release, and budgetary provision to both acquire the capability solution and to fund through-life personnel and operating costs;

c. Acquisition - an approved capability solution is acquired/established and, in the case of platforms, weapons systems and other materiel, entered into service; In-service - the individual FIC that make up the capability system are operated, supported, modified as necessary and managed by the relevant authorities in Defence (who are referred to generically in Defence as Capability Managers (CM)); and

e. Disposal - the capability system as a whole is withdrawn from service (in what is usually a process rather than an event) and disposed of or redeployed, depending on the nature of the individual capability input.

1.7 In Defence, capability is developed and managed with both a system perspective and a life cycle perspective. The key challenges of capability management in Defence are to:

a. optimise the design and development of the system to satisfy the capability gap(s), meet operational requirements and manage risk;

b. manage the system in the most cost-effective way over the whole life cycle, that is, optimise the capability system Life Cycle Costs (LCC); and

c. orchestrate the development and life cycles of various capabilities so that collectively they optimise the ability of the ADO to carry out its missions and roles.

1.8 Capability development can occur via a number of means, but will primarily be conducted through Major & Minor Capital Acquisition Programs. This manual relates specifically to the framework for developing MCE proposals, and does not detail the Minor Capital Acquisition Program or other capability programs (such as Rapid Acquisition), as these processes are specific to each Service/Group. It should be noted that minor capital equipment can contribute to rectifying capability deficiencies, and CMs coordinate their Minors programs along processes aligned to the capability life cycle. Reviews of relevant minors documentation by appropriate Branches within Capability Systems Division (CS Div) and CMs ensures appropriate coordination and integration between the Major and Minor Programs.

1.9 This manual focuses on the two life cycle phases within the MCE Program for which CDG is responsible, being the Needs and Requirements phases. CDG must, however, consider all phases when identifying and assessing capability needs and requirements, and CDG shares responsibility across other phases as detailed below.

Baggermann, S., Berdich, D., & Whitmore, M. (2009). Human Systems Integration (HSI) Case Studies from NASA Constellation Program. Human Systems Integration 2009. http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20090001318_2008049077.pdf

Civilian, Aerospace, USA, needs, requirements, acquisition, review

The National Aeronautics and Space Administration (NASA) Constellation Program is responsible for planning and implementing those programs necessary to send human explorers back to the moon, onward to Mars and other destinations in the solar system, and to support missions to the International Space Station. The Constellation Program has the technical management responsibility for all Constellation Projects, including both human rated and non-human rated vehicles such as the Crew Exploration Vehicle, EVA Systems, the Lunar Lander, Lunar Surface Systems, and the Ares I and Ares V rockets.

With NASA's new Vision for Space Exploration to send humans beyond Earth orbit, it is critical to consider the human as a system that demands early and continuous user involvement, inclusion in trade offs and analyses, and an iterative "prototype/test/ redesign" process. Personnel at the NASA Johnson Space Center are involved in the Constellation Program at both the Program and Project levels as human system integrators. They ensure that the human is considered as a system, equal to hardware and software vehicle systems. Systems to deliver and support extended human habitation on the moon are extremely complex and unique, presenting new opportunities to employ Human Systems Integration, or HSI practices in the Constellation Program. The purpose of the paper is to show examples of where human systems integration work is successfully employed in the Constellation Program and related Projects, such as in the areas of habitation and early requirements and design concepts.

Barfield, W., C. Rosenberg, et al. (1995). "Situation awareness as a function of frame of reference, computer-graphics eyepoint elevation, and geometric field of view." International Journal of Aviation Psychology 5(3): 233-56. http://www.ncbi.nlm.nih.gov/pubmed/11541915

Civilian, aviation, HFE (computer simulation), performance, case study,

The purpose of this study was to determine how 3 variables for the design of a "heads-down" spatial display—the frame of reference (pilot's eye vs. God's eye), geometric field of view, and elevation of the computer graphics eyepoint—influenced situation awareness. Thirteen flight-naive subjects each flew a simulated F-16 over a computer-generated flight environment to lock onto and intercept a series of sequentially appearing targets. The flight scene consisted of both an "out-the-window" view and a computer-generated heads-down spatial display showing an airplane symbol superimposed on a perspective view of the flight environment. During the interactive phase of the experiment, root mean square flight-path error, target lock-on time, and target acquisition time were measured. After the interactive phase of the study was completed, subjects were required to mark the location of the targets from memory on a computer-generated top-down view of the flight scene in an attempt to reconstruct the spatial mental model which subjects formed of the flight environment. The results for the interactive phase of the study indicated that performance was superior using the pilot's-eye display. However, for the spatial reconstruction task, performance was better using the God's-eye display. It was also shown that the ability to maintain the optimal flight-path using the more top-down view of the scene (600 eyepoint) was superior to the 300 eyepoint elevation. Implications of the results for the design of spatial instruments are discussed.

Barnes, M. and D. Beevis (2003). Human System Measurements and Trade-offs in System Design. Handbook of human systems integration. H. R. Booher, John Wiley & Sons, Inc.: 233-263. http://www3.interscience.wiley.com/cgi-bin/bookhome/109868385

Defence, Military, productivity, effectiveness, efficiency, methods, review

The aim of human systems integration (HSI) for military systems is to ensure that ''human considerations . . . shall be effectively integrated into the design effort for defense systems to improve total system performance and reduce costs of ownership" [U.S. Department of Defense (DoD), 1991a]. The purpose of this chapter is to discuss human performance measurement issues related to system design, particularly those issues that require trade-off decisions. The basic approach is to measure performance in terms of system goals and to choose measurement processes that reflect the context of the environment the system is being designed to operate within. This is similar to use-centered and ecological interface design philosophies that are currently being investigated in the cognitive engineering domain (Flach et al., 1998). That is to say, measurement is not concerned with human limitations per se or even environmental or technological problems but rather how these problems in concert affect the accomplishment of overall system goals (cf. interface design issues; Rasmussen and Vicente, 1989). The measurement problem is difficult because of the complexity of the design space, which includes not only volatile operational environ- ments but also changing technological and human requirements as well. The solution is to develop a flexible measurement strategy that addresses system goals and top-level requirements while it adjusts to the various contingencies of the evolving design process. In effect, a successful measurement paradigm allows the design team to answer the ''show me the payoff" question implicit in all design decisions.

Barnes, M., B. G. Knapp, et al. (2000). Crew systems analysis of unmanned aerial vehicle (UAV) huture job and tasking environments., Army Research Laboratory, Aderdeen Proving Ground. http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA374230&Location=U2&doc=GetTRDoc.pdf

defence, aviation, manning, training

The purpose of the research project was to understand the future crew environments for developing unmanned aerial vehicle (UAV) systems. A variety of human engineering tools job assessment software system JASS, enhanced computer-aided testing ECAT, and MicroSaint(Trademark)) were used to address crew issues related to the utility of having rated aviators as crew members, supplementing current crews with imagery and intelligence specialists, and the use of automation to improve systems efficiency. Data from 70 soldiers and experts from Fort Huachuca, Arizona, Fort Hood, Texas, and Hondo, Texas, were collected as part of this effort. The general finding was that the use of cognitive methods and computerized tool sets to understand future crew environments proved to be cost-effective and useful. Specifically, no evidence was found to support a requirement for rated aviators in future Army missions, but the use of cognitively oriented embedded training simulators was suggested to aid novices in developing the cognitive skills evinced by experts. The efficacy of adding imagery specialists to 96U crews was discussed, and specific recommendations related to automation were derived from the workload modeling.

Bass, E. (1998). Towards an intelligent tutoring system for situation awareness training in complex, dynamic environments. in: Intelligent Tutoring Systems. (Series: Lecture Notes in Computer Science), Springer Berlin / Heidelberg 1452: 26-35 http://www.springerlink.com/content/m8846t3721g02168/

Civilian, aviation, operation, training (simulation), performance, technical/scientific/guidance

Some accidents in complex systems have been attributed to a lack of situation awareness. Despite increased use of automation and improvements in display design, accidents of these types have not been eliminated. One option is to train operators to acquire and to maintain situation awareness. This paper describes an instructional design, human-computer interface, and the computational architecture for implementing an intelligent tutoring system for training situation awareness. The system furnishes detailed guidance in the early practice stages of training and provides performance feedback in the reinforcement stages of training. The system includes a debriefing capability to structure the review after performance and aid in the evaluation of student performance.

Baxter, G., D. Besnard, et al. (2007). "Cognitive mismatches in the cockpit: will they ever be a thing of the past?" Applied Ergonomics 38(4): 417-23. http://bscw.cs.ncl.ac.uk/pub/nj_bscw.cgi/S4a6750e1/d61458/BaxterBesnardRileySubmitted.pdf

Civilian, aviation, UK, operation, HFI, safety, case study

Changes in aviation over the last 30 years have dramatically affected the way that flight crews fly aircraft. The implementation and evolution of the glass cockpit, however, has happened in an almost ad hoc fashion, meaning that it does not always properly support the flight crew in carrying out their tasks. In such situations, the crew's mental model of what is happening does not always match the real state of affairs. In other words, there is a cognitive mismatch. An initial taxonomy of cognitive mismatches is defined, and the problem illustrated using an example from an aviation accident. Consideration is then given to how cognitive mismatches can be managed. A call is made for the development of an integrated cockpit architecture that takes better account of human capabilities and allows for new developments to be added to the cockpit in a more seamless manner.

Becker, U. (2008). Applying Safety Goals to a New Intensive Care Workstation System. Computer Safety, Reliability, and Security, Proceedings 27th International Conference, Newcastle upon Tyne, UK.5219: 263-276 http://www.springerlink.com/index/l47738k70322j4mr.pdf

Civilian, medical, operation, safety, case study

In hospitals today, there is a trend towards the integration of diffierent devices. Clinical work flow demands are growing for the integration of formally independent devices Such as ventilator systems and patient monitoring systems. On one hand, this optimizes workflow and reduces training costs. On the other hand, testing complexity and effort required to ensure safety increase. This in turn gives rise to new challenges in the design of such systems. System designers must change their mindset because they are now designing a set of distributed systems instead of a single system which is only connected to a central Monitoring system. In addition. the complexity of such workstation systems is Much higher than that of individual devices. This paper presents I case-study on an intensive care workstation. To cope with this complexity, different use-cases have been devised and a set of safety goals have been defined for each Use-case. The influence of the environment on the Use-cases is highlighted and some Measures to ensure data integrity within the workstation system are shown.

Beevis, D. (2003). "Ergonomics—Costs and Benefits Revisited." Applied Ergonomics 34(5): 491-496. http://linkinghub.elsevier.com/retrieve/pii/S0003687003000681

Civilian, Canada, HSI (HFE [ergonomics]), scientific publication / review, cost-benefit, cost-effectiveness, methods

An earlier review reported a dozen cases where ergonomics applications had resulted in cost savings. A large number of publications which refer to the topics of the cost-effectiveness and cost-benefits of ergonomics can now be found. However, data showing the value of ergonomics applications remain scarce. Cost-benefit and cost-effectiveness studies are difficult to conduct for a number of reasons. While it is unlikely that the general case for the value of ergonomics can be proven, ergonomists must be in a position to discuss the potential costs and benefits of their work with clients. The Business case model is suggested as one way to structure an analysis of where a potential ergonomics application might reduce the risks to costs or the possibility of lost benefits.

Beevis, D., A. Vallerand, et al. (2001). "Technologies for workload and crewing reduction." http://oai.dtic.mil/oai/oai?verb=getRecord&metadataPrefix=html&identifier=ADA398371

Defence, Military (Navy), (maritime), Canada, DCL, HSI (HFE [workload analysis], Manpower), Review (discussion, evaluation), Research (methods, effectiveness, cost-benefit, methods)

At the request of DGMDO, DRDC conducted a study of technologies for crewing reduction to catalogue known technologies, identify those that are applicable to the Canadian navy, and prepare proposals for a way ahead. Information received from contacts in Australia, The Netherlands, UK and USA, together with the results of two extensive literature reviews and world-wide-web searches was assembled into a matrix of technologies. The categories include whether the technology can be implemented at no cost to the ship, at minor cost, at major cost such as a refit, can be implemented in new ship builds, or will require further development to implement. Two workshops with the Working Group representatives and four focus groups with fleet operators were held to evaluate the applicability of these technologies to Canadian navy ships. Recommendations for the way ahead are that the Canadian navy should develop its own capability to evaluate workload and crewing reduction technologies and ship complements for existing and future ships. It is also recommended that DRDC should support that effort with short-term and longer-term activities.

Bergquist, T. and A. L. B. A. TX (1991). "Air Force Manpower, Personnel, and Training (MPT) in Systems Acquisition Research Program." http://oai.dtic.mil/oai/oai?verb=getRecord&metadataPrefix=html&identifier=ADA235973

EP185, full-text, Military (Air Force), (aerospace) US, DCL (Acquisition), HSI manpower / personnel / training, Discussion (practices), Research (methods, tools)

The **Manpower, Personnel, and Training (MPT)** Integration Branch is engaged in an extensive research and development (R&D) program aimed at providing the analytical tools and data base linkages needed by decision makers, analysts, and planning personnel to ensure MPT issues are an integral early part of the acquisition of major weapon systems. Congress and the Department of Defense have established specific MPT requirements in law and directive. The Air Force's IMPACTS (Integrated Manpower, Personnel, and Comprehensive Training and Safety) program is relying heavily on currently existing tools and data bases. But these are not integrated or appropriate for the specific MPT acquisition issues. Therefore, a long-term R&D program is underway to provide these integrated tools to assist System Program Offices (SPOs) and Major Air Command (MAJCOM) planners. **Descriptions of the eight projects currently underway are provided**: Specialty Structuring System (S3), MPT Functional Relationships, MPT Decision Support System (DSS), Weapon System Optimization Model (SYSMOD), Training Systems for Maintenance (TRANSFORM), Logistics Composite Model (LCOM) enhancements, Occupational Research Data Bank (ORDB), and Weapon System Data Base Linkages. Cooperation with other governmental agencies, including the Army and Navy, is on-going to ensure compatibility between models and to enhance each service's capability to meet the MPT requirements. An extensive bibliography completes this description of the MPT Integration Branch's R&D program.

Bisantz, A. and E. Roth (2007). "Analysis of cognitive work." Reviews of human factors and ergonomics 3(1): 1-43. http://www.ingentaconnect.com/content/hfes/rhfe/2007/00000003/00000001/art00002

Human Factors Engineering, methods, tools, cognitive task analysis

Cognitive task and work analyses are approaches to the analysis and support of cognitive work (rather than primarily physical or perceptual activities). Although a variety of methods exist for performing cognitive task and work analyses, they share a common goal of providing information about two mutually reinforcing perspectives. One perspective focuses on the fundamental characteristics of the work domain and the cognitive demands they impose. The other focuses on how current practitioners respond to the demands of the domain. This includes a description of the knowledge and skills practitioners have developed to operate effectively as well as any limitations in knowledge and strategies that contribute to performance problems. This chapter provides a broad survey of cognitive task analysis and cognitive work analysis methods. Some of the methods highlight techniques for knowledge gathering, whereas others focus on aspects of analysis and representation. Still other techniques emphasize process outputs, such as formal (computational) models of cognitive activities or design artifacts and associated rationales. In this chapter we review specific cognitive task and work analysis methods and describe through illustration how these methods can be adapted to meet specific project objectives and pragmatic constraints.

Blin, M. P. and A. Bry (2005). Human factor integration method in complex naval systems design: An example, military integrated bridge IBEO (Illustrateur de Besoin d'Exploitation Operationnelle). Oceans 2005 - Europe, Vols 1 and 2, Brest, FRANCE: 86-89 http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=1511689&tag=1

Military, Navy, France, HSI-all, HSI tool, manpower, methods, tools, needs, requirements, case study

In order to match to the French Navy major goal on crew reduction, the Navy Staff and DGA have developed a prospective human centered design approach based on realistic dynamic future work organisation representation using the IBEO process and simulation tools. The IBEOs are developed to specify and assess the new work organisations, new automation level, new human computer interaction modes, as well as the new training characteristics. These tools allow an active and reasoned participation of final users since the very early stages of a program. The IBEO "Military Integrated Bridge System" is presented as a use case.

Boldovici, J. and D. Bessemer (1994). Training Research with Distributed Interactive Simulations: Lessons Learned from Simulation Networking, Storming Media. http://oai.dtic.mil/oai/oai?verb=getRecord&metadataPrefix=html&identifier=ADA285584

Military (Army), (land) US, HSI (HFE [simulations]), Discussion (practices), Research (reliability, effectiveness, efficiency, cost-benefit, methods, tools)

Empirical and analytic evaluations of Simulation Networking (SIMNET) were reviewed to derive recommendations for planning evaluations of the Close Combat Tactical Trainer (CCTT), Lessons learned from SIMNET evaluations are as follows:

(1) One-shot empirical evaluations of the kind performed to **meet acquisition, test, and evaluation regulations** are costly and unlikely to meet CCTT evaluation objectives;

(2) analytic evaluations of SIMNET produced low-cost informatior that can be applied to improving CCTT design and use and in budget justifications; and

(3) empirical evaluation alternatives to past methods should be considered to support CCTT evaluation objectives that pertain (a) to establishing the relation between CCTT **training and soldier performance in the field** and (b) to complying with acquisition, test, and evaluation regulations.

Evaluation alternatives were presented for CCTT, with discussions of the advantages and disadvantages of each. The evaluation alternatives included indevice learning experiments, quasi-transfer experiments, correlation of scores achieved in SIMNET or CCTT training with scores obtained during rotations at Combat Training Centers, efficient experimental designs (randomized block designs, repeated-measure Latin squares, and analyses of covariance), quasi-experimental designs, improved methods for documenting training, and analytic evaluations.

Recommendations included

(1) Evaluations should address how the CCTT complements or supplements existing training alternatives to support and implement Combined Arms Training Strategy while remaining within contemporary and future budgetary limitations;

(2) CCTT evaluation should be a part of a larger program of Total Quality Management (TQM) applied to the **Army training system** and directed toward continuous improvement in training; and (3) the CCTT evaluation process should be incorporated as a continuous part of the TQM process.

Bolia, R. S. and W. T. Nelson (2007). "Characterizing team performance in network-centric operations: philosophical and methodological issues." Aviation Space & Environmental Medicine 78(5 Suppl): B71-6. http://www.ingentaconnect.com/content/asma/asem/2007/00000078/A00105s1/art00011

Military, operation, personnel, performance, review/discussion, methods, situation awareness

The recently promulgated doctrine of network-centric warfare suggests that increases in shared situation awareness and self-synchronization will be emergent properties of densely connected military networks. What it fails to say is how these enhancements are to be measured. The present article frames the discussion as a question of how to characterize team performance, and considers such performance in the context of its hypothetical components: situation awareness, workload, and error. This examination concludes that reliable measures of these constructs are lacking for teams, even when they exist for individual operators, and that this is due to philosophical and/or methodological flaws in their conceptual development. Additional research is recommended to overcome these deficiencies, as well as consideration of novel multidisciplinary approaches that draw on methodologies employed in the social, physical, and biological sciences. [References: 25]

Booher, H. (1991). "MANPRINT implications for product design and manufacture." International Journal of Industrial Ergonomics 7(3): 197-206. http://www.scopus.com/record/display.url?eid=2-s2.0-44949274930&origin=inward&txGid=80455y6NYV3xX8sYwNY7nXs%3a2

Defence, military, manpower

MANPRINT is a U.S. Department of Defense initiative which changes the focus of industry from a products view only toward a total system view that considers human performance and product reliability together as a system. Socioeconomic environments reflected in manpower demographical restrictions, global competition, and constraints in fiscal resources are creating similar pressures on both the military and commercial sectors. This paper outlines several of the social, economic, and technical trends in government and industry which have created a favorable environment for MANPRINT. Through its initiatives in government policy and technical advancement of design and decision-making tools, MANPRINT is helping to define an expanding role for ergonomics in designing products and processes for manufacturability. MANPRINT also has implications for ergonomics research and offers new challenges to ergonomics education.

Booher, H. (1997). Human Factors Integration: Cost and Performance Benefits on Army Systems. http://oai.dtic.mil/oai/oai?verb=getRecord&metadataPrefix=html&identifier=ADA330776

Military, US, DCL (design, acquisition, service), HSI HFE, case study (description) / discussion (practices), Research (safety, cost-benefit,methods)

This report documents and, to the degree possible, quantifies the benefits of human factors integration (HFI) effort to selected Army programs. Four Army weapon systems were identified for documenting HFI lessons learned and quantitative benefits. These systems are two aviation systems, Comanche and Apache; one nuclear, biological, chemical (NBC) reconnaissance vehicle, Fox; and the Army's advanced howitzer program, Crusader. The Comanche aircraft provides the most comprehensive lessons learned for HFI, based on its application of the Army's manpower and personnel integration (MANPRINT) program from its inception. The Apache helicopter provides some quantitative examples of benefits from HFI applications on design and development of changes to a system already in the Army inventory. The Fox reconnaissance vehicle (XM93E1 NBC) demonstrates quantitative benefits and lessons learned from HFI applications on a non-major system. The Crusader was chosen because it illustrates the critical role played by HFI technologies in conducting realistic battlefield scenarios in war games. Attention is given to the effects of HFI in five major areas: (1) The acquisition process; (2) System design and development; (3) Operational performance and testing; (4) Cost avoidance, and (5) Safety benefits.

Booher, H. (2003). Handbook of human systems integration, Wiley. http://books.google.com.au/books?hl=en&lr=&id=FKh-DO48ApgC&oi=fnd&pg=PR13&dq=%22Handbook+of+human+systems+integration%22&ots=p-fd6JbqJJ&sig=iPpr03cl8J1Ar3nLsSgHaeDPQoU

Military / Civilian, (land, maritime, aerospace, other), US, DCL (Design Acquisition Service Disposal), HSI HFE Manpower Personnel System safety, training, Case study / Review / Discussion, Research (safety, reliability, effectiveness, efficiency, productivity, cost-benefit, cost-effectiveness, tools, methods)

A groundbreaking look at how technology with a human touch is revolutionizing government and industry

Human Systems Integration (HSI) is very attractive as a new integrating discipline designed to help move business and engineering cultures toward a more people-technology orientation. Over the past decade, the United States and foreign governments have developed a wide range of tools, techniques, and technologies aimed at integrating human factors into engineering systems in order to achieve important cost and performance benefits that otherwise would not have been accomplished. In order for this new discipline to be effective, however, a cultural change is needed that must start with organizational leadership.

Handbook of Human Systems Integration outlines the principles and methods that can be used to help integrate people, technology, and organizations with a common objective toward designing, developing, and operating systems effectively and efficiently. Handbook of Human Systems Integration is broad in scope, covering both public and commercial processes as they interface with systems engineering processes. Emphasizing the importance of management and organization concepts as well as the technical uniqueness of HSI, Handbook of Human Systems Integration features:

- More than ninety contributors, technical advisors, and reviewers from government, industry, and academia
- Comprehensive coverage of the most recent HSI developments, particularly in presenting the cutting-edge tools, techniques, and methodologies utilized by each of the HSI domains
- Chapters representing the governments and industries of the United Kingdom and Canada
- Contributions from three services of the Department of Defense along with the Federal Aviation Administration and the National Academy of Sciences
- Many chapters covering both military and nonmilitary applications
- Concepts widely used by government contractors both in the United States and abroad

This book will be of special interest to HSI practitioners, systems engineers, and managers, as well as government and industry decision-makers who must weigh the recommendations of all multidisciplines contributing to systems performance, safety, and costs in order to make sound systems acquisition decisions.

Booher, H. R. (1990). MANPRINT: An approach to systems integration. New York, Van Nostrand Reinhold. http://openlibrary.org/books/OL1858894M/Manprint_an_approach_to_systems_integration

Defence, USA, militatry, manpower, personnel, training, human factors engineeriring, safety

Booher, H. R. M., J. (2003). Human Systems Integration in Army Systems Acquisition. Handbook of Human Systems Integration. H. R. Booher, Wiley: 663-698. http://ritter.ist.psu.edu/ist521/papers/booherM03.pdf

Military, USA, cost-benefit

MANPRINT (Manpower and Personnel Integration), the U.S. Army's human systems integration (HSI) program, has been identified as one of the most promising programs ever developed by the military for providing effective human systems performance. (Minninger et al., 1995; Skelton, 1997). This has been supported by other studies [U.S. Army Audit Agency (AAA), 1997; Booher, 1997; 1998; General Officer Steering Committee (GOSC), 1998] that show the vast range and depth of influence that HSI has had upon the army systems whenever its methodologies have been applied. Generally, performance improved, safety increased, and costs were avoided.

In spite of these impressive results, the HSI practitioner often finds it difficult to convince program managers of the full value of the HSI discipline. Part of the difficulty is that the HSI concept is not fully appreciated, even among many practitioners, so the positive benefits that could accrue for a program are never presented in a way that convinces decision makers HSI can make a significant (and affordable) difference in achieving their objectives. Another difficulty is that very few systems throughout the defense and commercial sectors have actually been quantitatively documented for performance and cost benefits resulting from HSI. Finally, it must be realized that the acquisition world has changed such that strategies that worked with past systems may not work with future systems.

This chapter is designed to help the HSI practitioner better formulate arguments that will be convincing to program managers of the need for HSI on future systems. Set within the framework of those HSI factors identified in the literature (Booher, 1996-1999; GOSC, 1998) as crucial organizational and technical principles to the success of HSI programs, the specific army applications provided here should help the reader better understand the importance of the factors and their interactions to a successful systems acquisition program. A large number of specific examples are provided as supporting evidence for the value of HSI in terms program managers can appreciate such as (1) technology advancements, (2) acquisition process efficiencies, (3) system design enhancements, (4) safety increases, and (5) returns on investment.

Borras, C. and M. Goom (2003). HFI DTC: HFI Methods and Processes Literature Review.

Defence, militatry, methods, tools, review

This work package is concerned with researching the effectiveness of Human Factors Integration (HFI) within the whole development life cycle of military and civil equipment. A review of existing HFI guidance, literature and research was undertaken specifically to identify the barriers to the application of HFI. From this, the report suggests research areas to direct future concerned with a more effective approach to HFI that addresses the identified shortcomings.

Boyd, C., R. Collyer, et al. (2005). "Characterisation of Combat Identification Technologies." www.concepts.aero/system/files/private/CID-tencon-2005.pdf

Military (army, navy), (land, maritime) Australia, HSI (command and control), discussion (practices), research (cost-benefit, methods)

Network centric warfare combines sensors, communications, and computation systems with tactics, techniques and procedures to provide battlespace awareness. An element of this awareness is the ability to identify friendly combat entities, known as Combat Identification (CID). This paper describes current technologies used in combat identification and defines technology groups that will play a role in both current and future CID implementation.

Bratt, G. M., D. M. Doganiero, et al. (1997). "Estimating the Health Hazard Costs of Army Materiel: A Method for Helping Program Managers Make Informed Health Risk Decisions." Acquisition Review Quarterly: 443-455. http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA487774&Location=U2&doc=GetTRDoc.pdf

defence, cost-benefit

We have developed a model to assist the U.S. Army estimate weapon system health hazard costs based on the probability of a hazard occurring and the severity of that hazard. We linked health hazard categories to types of clinic services that might be required as a result of exposure to a specific health hazard; and diagnostic categories based on the potential medical effects that could occur as a result of exposure to a specific health hazard. We researched incidence rates and calculated costs based on industry-wide data on injuries, lost time, hospitalization, and disability, and this framework provides a method to reasonably estimate the medical and lost military manpower costs of unabated health hazards associated with Army materiel. Using the outputs of the model will increase the effectiveness of health risk assessment and management, and better enable the Army to eliminate or control materiel health hazards and control life-cycle costs. Application of this model to other prevention disciplines in acquisition and preventive medicine will provide decision makers with invaluable quantitative information regarding cost avoidance.

Bratt, G. M., J. Evenden, et al. (1998). Documentation of the process, data elements, and data sources used to develop the model for estimating costs for army materiel health hazards., US Army Center for Health Promotion and Preventative Medicine. http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA357803&Location=U2&doc=GetTRDoc.pdf

defence, cost-benefit

This report provides supporting documentation for the cost estimating model for Army materiel health hazards, including 1) An overview of the cost estimating process, 2) an explanation of the selection or development of each data element, 3) the sources of data used to provide input to the model, and 4) the equations used to estimate each cost. It also provides background information critical to understanding the Army Health Hazard Assessment Program.

Braune, R., D. Jahns, et al. (1996). Human factors systems engineering as a requirement for the safe and efficient transition to free flight, Human Factors and Ergonomics Society.40: 102-105 http://www.ingentaconnect.com/content/hfes/hfproc/1996/00000040/00000002/art00020

Civilian, aviation, methods

This paper discusses a top-down analysis methodology for the design, development and evaluation of advanced technological systems like those being considered for General Aviation Free Flight and also the Advanced General Aviation Technology Experiment (AGATE). A current project sponsored by the FAA's Civil Aeromedical Institute is being introduced as an example.

Brown, J. (2009). Evaluation of Tactile Situation Awareness System as an Aid for Improving Aircraft Control During Periods of Impaired Vision, NAVAL POSTGRADUATE SCHOOL. http://www.dtic.mil/cgi-bin/GetTRDoc?Location=U2&doc=GetTRDoc.pdf&AD=ADA501130

Military (Navy), (aerospace), US, HFE, safety / reliability, case study

This thesis describes the use of a prototype Tactile Situational Awareness System (TSAS) as an approach to aid pilot performance following simulated laser blindness modeled during a virtual approach in an SH-60 helicopter. Situational awareness and spatial awareness remain critical factors for successful control of manned aircraft. Helicopters and fixed winged aircraft pilots react to spatial orientation challenges during take-off, and landing phases of flight. U.S. and NATO aircraft pilot surveys **examined the human machine** interaction and revealed degraded vision as an important human factor contributing to mishaps or near **mishaps**. Vision was identified as an information chokepoint limiting command and control of the aircraft.

Fortunately, vision can be augmented with an available technology called “haptics” during r stricted or limited human vision. Therefore, an experiment using X-Plane output for haptics-generated input from a torso-worn TSAS was developed. Participants received haptic cues during runway approaches after experiencing simulated loss of vision. Participant performance after simulated laser blinding with and without the TSAS compared time advantage and navigation accuracy. Simulator performance data indicated pilots using TSAS following simulated laser blindness **responded to haptic cues, had more time to** prevent the aircraft from obtaining an unsafe pitch or roll condition, and could position the aircraft closer to the landing zone.

Bruseberg, A. (2008). “Presenting the value of Human Factors Integration: guidance, arguments and evidence.” Cognition, Technology & Work 10(3): 181-189. http://dx.doi.org/10.1007/s10111-007-0100-1

Military (Air force, navy, army) / civilian, (maritime, land, aerospace, other), UK, HSI (HFE,safety, training, personnel, manpower), Case study / review (description , evaluation), Research (safety, reliability, effectiveness, efficiency, productivity, cost-benefit, cost-effectiveness, tools, methods)

Consideration of the human elements of socio-technical systems is critical to ensure safe, effective and efficient system performance. However, when decisions about budget allocations are being made, Human Factors Integration (HFI) is not always considered as an important component activity. Both HFI practitioners and non-HFI practitioners often find it difficult to express the cost benefits of HFI. Moreover, in the military domain, we need to provide a comprehensive case, covering issues within all of the six HFI domains. In this paper, we take a broad view and approach the task of cost-justifying HFI through a combination of prospective and retrospective perspectives. By comparing approaches, evidence, and arguments from all HFI domains, we establish a generic set of arguments for HFI, supported by an initial set of evidence.

Bruseberg, A. (2008). “Human Views for MODAF as a Bridge Between Human Factors Integration and Systems Engineering.” Journal of Cognitive Engineering and Decision Making 2: 220-248.

Defence, military, methods, tools

The paper describes the human views for the UK Ministry of Defence Architectural Framework (MODAF) as essential concepts to enable a common modeling approach between the fields of systems engineering and human factors integration. Human views express high-level human factors design decisions through a systems engineering modeling approach to better communicate human-related design concerns to engineers and to enable early application of human factors methods in the systems engineering process. Integration barriers attributable to differing approaches between human factors integration and systems engineering are outlined. Cognitive systems engineering is considered under the umbrella of human factors integration. The paper discusses how selected cognitive systems engineering approaches and methods provide an invaluable resource in supporting the underlying philosophy and application of the human views as part of MODAF.

Bruseberg, A. (2009). Cost-Benefit Analysis for Human Factors Integration: A Practical Guide. http://www.hfidtc.com/research/process/hfi-process-phase-2.htm

Military (Navy, Air Force, Army), (land, maritime, aerospace), UK, DCL (design, acquisition, service, disposal), HSI (HFE,safety, training, personnel, manpower), scientific, case study, review, discussion, evaluation, description, performance, safety, cost, methods, tools

It is increasingly accepted that Human Factors Integration (HFI) is critical to ensure that system performance is safe, effective, and efficient. However, HFI is often considered a costly process. The cost benefits of HFI are frequently perceived as intangible. The potential losses due to not applying HFI are rarely assessed early enough for adequate consideration in budget allocations. The financial value of HFI through cost savings is often poorly understood. HFI professionals often find it difficult to express HFI cost benefits and produce early budget plans when uncertainty is still high. Thus, project budget plans often do not allow sufficient resources for HFI.

To be able to argue against the various preconceptions that prevent the practical application of HFI, a sound cost-benefit analysis is needed to express both HFI efforts and benefits in business terms. Cost-benefit analysis for HFI technical and management activities is often recognised as a difficult task. This is especially so for larger HFI projects, and during early project stages. It is not always easy to argue that there are situations where it is necessary to spend money in order to save money.

Bruseberg, A. (2009). The human view handbook for MODAF, second issue, HFIDTC.

Burnett, S. (2006). Modeling Macro-Cognitive Influence on Information Sharing between Joint Team Members. http://oai.dtic.mil/oai/oai?verb=getRecord&metadataPrefix=html&identifier=ADA463222

Military (Navy, Air Force, Army), (maritime, land, aerospace), US, HSI (HFE, training, personnel, manpower), Review (description, evaluation), Research (reliability, effectiveness, Methods, tools)

This paper examines the impact of the macro-cognitive processes, culture orientation and personality stereotype, on information sharing between members of military joint teams. The exploration extends to include the development of Human Behavior Representation (HBR) within agent-based models to assist in describing and understanding those macro-cognitive influential characteristic on information processing . Cebrowski (2005)

asserted the key principle to successful transformation centers on human behavior and requires quantitative as well as qualitative methods investigating the social and behavioral domains more than technical ones (Garstka & Alberts, 2004). The initial approach to this project capitalizes on a substantial literature review of the work accomplished in the business and psychological domains. A review of this literature reveals that reliable and valid methods exist to explore these macro-cognitive processes (Garstka & Alberts, 2004). The methods established within the business and psychological communities provide the framework to explore the military reluctance to change and the possible negative impact differing orientations and bias have on the optimal interoperable state of the joint team. Additionally, advances in the Verification, Validation and Accreditation (VVA) process of the modeling and simulations community allow the development of input variables from reliable and valid human behavior data sets resulting in outputs more resemblant of realistic descriptions of behavior (Defense Modeling and Simulations &

Office, 2005). To accomplish this subjective survey, objective measures and team effectiveness methods coupled with high performance computing agent-based simulations to assess and analyze the actual and simulated outcomes from experimentation are used. Further, to insure experimentally sound concept of design and analysis, a matrix for insuring the guidelines for measurement for Modeling/ Simulations (VVA) and Human Behavior

(Reliability/Validity) is described.

Cacciabue, P. C. (1997). "A methodology of human factors analysis for systems engineering: Theory and applications." Ieee Transactions on Systems Man and Cybernetics Part a-Systems and Humans 27(3): 325-339. http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=00568741

Civilian, aviation, nuclear reactor, HSI tool (modelling), HFE, system safety, review/discussion, case studies

This paper discusses a methodology for studying human erroneous behavior that comprises four modeling phases, namely: 1) a paradigm of human behavior; 2) a taxonomy and related tables for human erroneous actions; 3) a set of data and correlations from the real working environment; and 4) a procedure for application of the methodology to different types of analysis, at different levels of complexity. The methodology has been developed to support possible applications of human factors to design and safety assessment of technological systems, The results of some applications are presented for prospective and retrospective studies in the domains of nuclear reactor and civil aviation.

Cacciabue, P. C. and G. Vella (2008). "Human factors engineering in healthcare systems: The problem of human error and accident management." International Journal of Medical Informatics 79(4): E1-E17. http://dx.doi.org/10.1016/j.ijmedinf.2008.10.005

Civilian, aviation, medical, HSI tool, system safety (risk and hazard identification), case studies

This paper discusses some crucial issues associated with the exploitation of data and information about health care for the improvement of patient safety. In particular, the issues of human factors and safety management are analysed in relation to exploitation of reports about non-conformity events and field observations. A methodology for integrating field observation and theoretical approaches for safety studies is described. Two sample cases are discussed in detail: the first one makes reference to the use of data collected in the aviation domain and shows how these can be utilised to de. ne hazard and risk; the second one concerns a typical ethnographic study in a large hospital structure for the identification of most relevant areas of intervention. The results show that, if national authorities find away to harmonise and formalise critical aspects, such as the severity of standard events, it is possible to estimate risk and de. ne auditing needs, well before the occurrence of serious incidents, and to indicate practical ways forward for improving safety standards.

Caldwell, B. S. (2008). "Knowledge sharing and expertise coordination of event response in organizations." Applied Ergonomics 39(4): 427-38. http://dx.doi.org/10.1016/j.apergo.2008.02.010

Civilian, aerospace, healthcare, HSI tool (project management, system operation) HFE, review, discussion and case studies

This paper provides an overview of opportunities and challenges for expert coordination, knowledge sharing, and task performance using advanced information and communication technologies. Evolving in part from [Hendrick, 1991] discussion of macroergonomics, this paper describes the author's framework for systems engineering analysis of information flow and performance at team and organizational units of analysis. Work in the author's research lab has focused on several aspects of information technology use and team interactions to support shared understandings, task demands, and effective responses in responses to events. Multiple empirical studies are summarized describing evaluations of technology use, task cycles and expert knowledge coordination in several settings, including aerospace, healthcare, and project management.

Calleja, J. and J. Troost (2005). A Fuzzy Expert System for Task Distribution in Teams under Unbalanced Workload Conditions. Proceedings of the International Conference on Computational Intelligence for Modelling, Control and Automation and International Conference on Intelligent Agents, Web Technologies and Internet Commerce Vol-1 (CIMCA-IAWTIC'06).1: 549 - 556 http://www.computer.org/portal/web/csdl/doi/10.1109/CIMCA.2005.1631321

Defence, military, navy,workload, personnel, training,methods

Inappropriate workload levels on the team members of a naval force have been detected as a problem that can threaten the performance and safety of future naval operations. A suitable distribution of tasks among the members of a team is a crucial issue in order to prevent high and low workload levels. In this paper, we propose a rule-based expert system, the Task Distribution Expert System (TDES), which assists team leaders to manage mental workload in a team by suggesting appropriate task assignments. The TDES emulates the behavior of a team leader deciding which member of the team should perform a task and how. The system handles mental workload as an uncertain fuzzy concept comprising three fuzzy variables that represent the way mental workload affects performance. Automation issues and different recommendations for effective workload management in teams are analyzed and incorporated. A prototype demonstrates the system.

Calleja, J., J. Troost, et al. (2005). Dealing with high workload in future naval command and control systems. Systems, Man and Cybernetics, 2005 IEEE International Conference.1http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=1571234&userType=inst

Defence, military, navy, workload, personnel, methods,

In this paper we propose a system, the distributed adaptive task management system (DATMS), which assists operators and commanders to decide what tasks to perform, when, and by whom. It ensures that an acceptable level of workload is kept while tasks are carried out properly. The four modules that form the DATMS architecture are analyzed and solutions are provided: some guidelines are described for the workload measure module; a model based on relevant task and operator's features is considered for the workload prediction module; a rule based expert system handling four workload segments and dealing with uncertainty and fuzziness is proposed for the task distribution module; and Jensen's time/ utility functions are applied in the task scheduling module. A prototype demonstrates both the system architecture and the different solutions introduced in the modules.

Casner, S. M. (2009). "Perceived vs. measured effects of advanced cockpit systems on pilot workload and error: are pilots' beliefs misaligned with reality?" Applied Ergonomics 40(3): 448-56. http://dx.doi.org/10.1016/j.apergo.2008.10.002

Civilian, aviation, operation, personnel/training/workload, safety/errors, case study/ scientific (experimental)

Four types of advanced cockpit systems were tested in an in-flight experiment for their effect on pilot workload and error. Twelve experienced pilots flew conventional cockpit and advanced cockpit versions of the same make and model airplane. In both airplanes, the experimenter dictated selected combinations of cockpit systems for each pilot to use while soliciting subjective workload measures and recording any errors that pilots made. The results indicate that the use of a GPS navigation computer helped reduce workload and errors during some phases of flight but raised them in others. Autopilots helped reduce some aspects of workload in the advanced cockpit airplane but did not appear to reduce workload in the conventional cockpit. Electronic flight and navigation instruments appeared to have no effect on workload or error. Despite this modest showing for advanced cockpit systems, pilots stated an overwhelming preference for using them during all phases of flight.

Casper, P. (1997). A full mission simulation success story: RPA simulation at CSRDF yields promising results, Human Factors and Ergonomics Society.41: 95-99 http://www.ingentaconnect.com/content/hfes/hfproc/1997/00000041/00000002/art00022

Defence, military,air force,simulation, performance

In support of the US Army's Rotorcraft Pilot's Associate Advanced Technology Demonstration Program, the Crew Station Research and Development Branch (CSRDB) at NASA's Ames Research Center has recently completed a full mission simulation (FMS) experiment testing two alternative mission equipment packages (MEPs). Four crews of Army helicopter pilots flew 64 trials, performing representative combat helicopter tasks. Objective and subjective performance metrics provided statistically significant data supporting a priori hypotheses about performance differences between the two systems. Crews flying the advanced MEP killed more targets more efficiently, and were killed fewer times than when flying the baseline MEP. In addition, their workload was lower, and subjectively assessed situation awareness was higher with the advanced system. These results are encouraging for full mission simulation research, and suggest that a standard empirical model may in fact be applicable to full mission simulation.

Chen, J. Y. C. and P. I. Terrence (2009). "Effects of imperfect automation and individual differences on concurrent performance of military and robotics tasks in a simulated multitasking environment." Ergonomics 52(8): 907-20. http://www.ncbi.nlm.nih.gov/pubmed/19629806

Defence, Army, Military, ordnance, gunnery, operation, automation, personnel, performance, workload, scientific (experimental), (intercorelation between individual abilities and imperfect machine systems)

This study investigated the performance and workload of the combined position of gunner and robotics operator in a simulated military multitasking environment. Specifically, the study investigated how aided target recognition (AiTR) capabilities for the gunnery task with imperfect reliability (false-alarm-prone vs. miss-prone) might affect the concurrent robotics and communication tasks. Additionally, the study examined whether performance was affected by individual differences in spatial ability and attentional control. Results showed that when the robotics task was simply monitoring the video, participants had the best performance in their gunnery and communication tasks and the lowest perceived workload, compared with the other robotics tasking conditions. There was a strong interaction between the type of

AiTR unreliability and participants' perceived attentional control. Overall, for participants with higher perceived attentional control, false-alarm-prone alerts were more detrimental; for low attentional control participants, conversely, miss-prone automation was more harmful. Low spatial ability participants preferred visual cueing and high spatial ability participants favoured tactile cueing. Potential applications of the findings include personnel selection for robotics operation, robotics user interface designs and training development. The present results will provide further understanding of the interplays among automation reliability, multitasking performance and individual differences in military tasking environments. These results will also facilitate the implementation of robots in military settings and will provide useful data to military system designs.

Chudy, P., A. Tomczyk, et al. (2009). "Safety enhanced digital flight control system." Aircraft Engineering and Aerospace Technology 81(5): 416-423. http://www.emeraldinsight.com/Insight/ViewContentServlet?contentType=Article&Filename=/published/emeraldfulltextarticle/pdf/1270810504.pdf

Civilian, aviation, design (development of the control system), system safety,safety, technical

Purpose - The purpose of this paper is to describe the general idea, design, and implementation of control system for general aviation aircraft which reduces pilot workload. Design/methodology/approach - Proposed indirect flight control system framework is intended to simplify piloting, reduce pilot workload, and allow low-end general aviation aircraft to operate under deteriorated meteorological conditions. Classical control theory is used for the design of the flight control laws. Although not inherently robust, controllers with classical control logic are made sufficiently stable using a correct and updated controller structure. Findings - Despite controversies between perception of a modern manned aerial vehicle and limitations imposed by legacy airworthiness codes it is shown that a pilot workload reducing system can be successfully implemented onboard of a low-end general aviation aircraft. Research limitations/implications - Hi-level control laws and optimization of handling qualities can lead to unfavourable and unpredictable forms of man-machine interactions, e,g. pilot-induced oscillations. Practical implications - General aviation aircraft are mostly flown by a single pilot, who could benefit from an intelligent system or "virtual copilot" assisting in or supervising the aircraft's safe operation under any conditions. Aircraft with this capability represents a next step in the evolution that might ultimately lead to trajectory-based free-flight concept of aircraft operations. Originality/value - The paper introduces a safety enhanced digital flight control system on board small general aviation aircraft.

Clarkson, P. J., P. Buckle, et al. (2004). "Design for patient safety: a review of the effectiveness of design in the UK health service." Journal of Engineering Design 15(2): 123-140. http://www.informaworld.com/smpp/content~db=all~content=a713937704

Civilian, medical, UK, design, HSI all/FSE, safety, review

In 2002 the UK Department of Health and the Design Council jointly commissioned a scoping study to deliver ideas and practical recommendations for a design approach to reduce the risk of medical error and improve patient safety across the National Health Service (NHS). The research was undertaken by the Engineering Design Centre at the University of Cambridge, the Robens Institute for Health Ergonomics at the University of Surrey and the Helen Hamlyn Research Centre at the Royal College of Art. The research team employed diverse methods to gather evidence from literature, key stakeholders, and experts from within healthcare and other safety-critical industries in order to ascertain how the design of systems—equipment and other physical artefacts, working practices and information—could contribute to patient safety. Despite the multiplicity of activities and methodologies employed, what emerged from the research was a very consistent picture. This convergence pointed to the need to better understand the healthcare system, including the users of that system, as the context into which specific design solutions must be delivered. Without that broader understanding there can be no certainty that any single design will contribute to reducing medical error and the consequential cost thereof.

Cockshell, S. and S. Hanna (2006). Human Systems Integration for the Australian Defence Force: Integration of human needs and requirements into the capability lifecycle. M. O. Division. Australia, Defence Science and Technology Organisation. DSTO-Cr-20006-0209.

Military (maritime), Navy, DCL (design, acquisition, service, disposal), HSI (HFE,safety, training, personnel, manpower), review, case study, discussion, performance, safety, cost, methods

Human Systems Integration (HSI) is a series of management and technical processes utilised inside a systems engineering1 framework that addresses the human requirements of technical systems. Defence Science Technology Organisation (DSTO) has conducted research into defining a HSI process for the Australian Defence Organisation (ADO) that can be included into the Defence Capability Development Lifecycle (DCDL) in order to facilitate the implementation of human requirements into a capability. HSI enables projects to make informed choices regarding human, technical and financial considerations at each stage of the design and acquisition of a capability2. HSI is divided into the domains of Human Factors Engineering; Crewing; Training; Personnel; and Systems Safety: which incorporates Environment, Safety, and Occupational Health, Personnel Survivability and Habitability. Currently, these domains are considered in an ad-hoc manner, often too late to influence acquisition choices, or are not considered jointly in a way that allows human considerations to be prioritised with technical considerations in an informed manner to optimise capability decisions.

Following the F111 Deseal/Reseal Board of Inquiry, specific recommendations were made to the Centre of Occupational Health (COH) regarding the incorporation of Occupational Health and Safety (OHS) input into the design and procurement of capability. These recommendations were termed the “Safe Design” model. The Safe Design recommendations require integration into the Defence Capability Development Lifecycle (DCDL) in order to be effectively implemented into capability. One of the proposed methods of inclusion of Safe Design into the procurement process was its incorporation into what is called Human Systems Integration (HSI), which provides a holistic approach to integrating the human into capability acquisitions. DSTO considers that safety processes recommended by the COH will only be best practice for the ADO if they are implemented as part of a HSI programme.

Formal HSI programmes are currently used in the UK, Canada and the US to ensure that projects adequately address the needs of the human when procuring or designing platforms or equipment, in contrast to the ADO that does not utilise a similar process. Analysis of overseas HSI processes by the DSTO MOD human factors team in consultation with DSTO human factors specialists suggests that the use of a human factors integration framework or methodology similar to those currently utilised by the UK, Canada and the US can be adapted for the ADO to effectively trade off decisions between human and technology project areas.

The HSI framework is predicated upon its ability to be mapped onto existing processes that the Australian Defence Organisation (ADO) currently use to procure capability, termed as the Defence Capability Development Lifecycle (DCDL). The lifecycle is divided into phases that each have a different focus and responsibility. The DCDL was mapped onto a flowchart that articulated each of the processes pertinent to each phase, and HSI principles and activities were assigned to key DCDL documents, which allows for the consistent application and consideration of human issues and requirements throughout the design and procurement of a capability. The integration and coordination of HSI principles is managed by the HSI Plan (HSIP), which coordinates the HSI systems engineering approach, planned efforts, stake-holder concerns, and risk issues and ensures HSI domains are considered throughout the DCDL. DSTO considers that HSI represents a best practice approach to ensure that safety issues are adequately addressed during capability acquisition.

Cohn, J. and P. O'Connor (2009). Human Performance Enhancement in High-Risk Environments: Insights, Developments, and Future Directions from Military Research. http://books.google.com.au/books?id=Xz96-VBKZtAC&printsec=frontcover&dq=Human+Performance+Enhancement+in+High-Risk+Environments:+Insights,+Developments,+and+Future+Directions+from+Military+Research&source=bl&ots=ew4-3mb4bQ&sig=3-IWXLgi5Q9kaIG5iIrImx26Sro&hl=en&ei=SLEyTPSnA46TkAXQvuCgDA&sa=X&oi=book_result&ct=result&resnum=1&ved=0CBQQ6AEwAA#v=onepage&q&f=false

Defence, military, performance, personnel, training

Human Performance Enhancement in High-Risk Environments: Insights, Developments, and Future Directions from Military Research takes the breakthrough work being done by the military on human performance issues and presents it in a way that is applicable to a wider audience of high risk professions and industries, including police forces, fire fighting, the security industry, military contracting, and more. Human Performance Enhancement in High-Risk Environments focuses on selection, training, safety, and design essential steps in the process of putting the right people in the right position to handle dangerous work. The book's 16 chapters are each written by military experts, emphasizing lessons learn from their own experiences and research, while highlighting the relevance of their findings to other domains in which highly trained personnel operate complex machinery with high consequences of error.

Coles, G. A. (2008). "Prospective system assessment used to enhance patient safety case studies from a collbaoration of enginners and hospitals in Southwest Washington State." Proceedings of the Asme International Mechanical Engineering Congress and Exposition 2007, Vol 14: 117-125. http://link.aip.org/link/abstract/ASMECP/v2007/i43084/p117/s1

Civilian, medical, HSI tool (system assessment methods), system safety, safety, case studies

It is no secret that healthcare, in general, has become art increasingly complicated mixture of technical systems complex processes and intricate skilled human interactions, Patient care processes have followed this same trend. The healthcare Industry, itself. has acknowledged that it is fraught with high-risk and error prone processes and cite medication management systems. invasive procedures and diagnostic methods. Complexity represents opportunity for unanticipated events, process failures and undesirabic outcomes. Traditionally a patierit care process fails, accountability was focused on the individual clinician error. However increasing, healthcare is following the lead of other high-risk industries (e.g, chemical, aerospace. nuclear, etc.) that attention to the characteristics the overall system that contribute to the failure. The focus has shifted to identification of systematic weaknesses and vulnerabilities. Increasing the healthcare industry is using prospective system assessment methods to evaluate the hi-h-risk systems and processes. This paper describes results of collaboration between engineers and community hospitals in Southwest Washington State between 2002 and 2007, in applying prospective system assessment methods to a range of the high-risk healthcare systems and processes. The methods used are Failure Mode Effects and Criticality Analysis and Probabilistic Risk Assessment. The two case studies presented are: 1) an hospital,hospital FMEA oil patient transfer and 2) a risk assessment of mental health patients Who present themselves in a hospital Emergency Department.

Cooke, N. and O. Connor (2006). Human factors of remotely operated vehicles, Emerald Group Pub Ltd. http://books.google.com.au/books?hl=en&lr=&id=ZRHzDothAqAC&oi=fnd&pg=PR11&dq=Human+factors+of+remotely+operated+vehicles&ots=gigs_Jg7e5&sig=rUNQvMJhqKL-7VMiWcOINXyvIEs#v=onepage&q&f=false

Military / Civilian, UK, HSI (HFE, Manpower), Review (description of HSI), Research (tools, methods)

The commonly used terms, "unmanned" or "uninhabited," are misleading in the context of remotely operated vehicles. In the case of Unmanned Aerial Vehicles (UAVs), there are many people involved on the ground ranging from those operating the vehicle from a ground control station, to the people coordinating multiple UAVs in an air operations or air traffic control center.

The complexity of remote vehicle operations is also often underestimated and seen as a simple navigation task, neglecting the more complex functions associated with remote camera operations, data gathering, and even weapons activity. In addition, trends in the military and civilian sectors involving reduced staffing, increased number of vehicles to control, and integration with other operations are associated with critical human factors issues. For example, the integration of UAVs with manned aircraft in the national airspace poses numerous human factors challenges.

In summary, though these vehicles may be unmanned they are not unoperated, unsupervised, or uncontrolled. The role of the human in these systems is critical and raises a number of human factors research and design issues ranging from multiple vehicle control and adaptive automation to spatial disorientation and synthetic vision.

The purpose of this book is to highlight the pressing human factors issues associated with remotely operated vehicles and to showcase some of the state of the art human-oriented research and design that speaks to these issues. In this book the human components of the "unmanned" system take center stage compared to the vehicle technology that often captures immediate attention.

Corona, B. M. and E. R. Fiedler (2007). "Potential paradigm for assessments of biomedical technologies in the operational environment." Aviation Space & Environmental Medicine 78(5 Suppl): B245-51. http://www.donhcs.com/hsr/13_june/doc/Corona%20&%20Fiedler%20Assessing%20Biomedical%20Technologies%20in%20Oper.%20Environment.pdf

Military, USA, Operation, personnel, performance, review/technical

The U.S. Army Medical Research and Materiel Command Cognitive Performance, Judgment, Decision-making Research Program (CPJDRP) was initiated in part to prevent/mitigate performance shortfalls associated with cognitive-psychological combat stressors such as workload, fatigue, sleep, and nutritional aspects. An Operational Processes and Cognitive Mapping Focus Team (OPCMFT) was established for the purposes of integrating laboratory-based research into operational environments, embedding metrics into appropriate operational platforms, and providing an operational perspective to research that may veer off pragmatic and utilitarian courses. The OPCMFT's goal as originally formulated in 2004 was to determine operational requirements and test environments for evaluating cognitive performance metrics and models, pharmacological countermeasures, and neurocognitive monitors for the purpose of sustaining warfighter cognitive performance in operational environments (2). This preface first reviews the OPCMFT's major deliverables as developed from the CPJDRP workshop in 2005 (6). Next, a gap/needs analysis of cognitive research products and test and evaluation platforms is presented. Lastly, a summary of each of the three articles—one on the role and mitigation of stress, a second on the development of intellectual ability norms and statistical methods to interpolate an individual's post-morbid capabilities, and a third on a specific measure to assess physiological reactions to cognitive stressors—illustrates how each contributes to the effort to help improve warfighter cognitive performance. The preface authors emphasize the need for an integrated research program focused on the Battle Laboratory (1) with a solid infrastructure and an integration of the operational end-user, human factors, medical practitioners, and research and development expertise.

Cosenzo, K., L. Fatkin, et al. (2007). "Ready or not: enhancing operational effectiveness through use of readiness measures." Aviation, space, and environmental medicine 78(Supplement 1): B96-B106. http://www.ingentaconnect.com/content/asma/asem/2007/00000078/A00105s1/art00014

Military, USA, personnel/HSI tool, performance, review

Current and future military operations require personnel to perform a multitude of mission tasks. Military personnel are required to execute these tasks, and to perform to high levels of expectation. Many of these tasks are complex and demand substantial cognitive readiness, which may optimize and enhance cognitive performance. Technologies are being developed to aid individual soldiers to successfully complete their missions; however, the proliferation of new technologies, coupled with the varying operational missions, make leveraging cognitive readiness a mandate for the achievement of military effectiveness and enhanced overall performance. It is important to have a militarily relevant psychological battery that can be used to assess each individual's cognitive capabilities and appraisals, factors that enhance military operational effectiveness. Assessing individual cognitive readiness becomes particularly important when researchers broaden their examinations of military effectiveness to assess team cognition, team behavior, and team effectiveness. We discuss the theoretical development and the components of the U.S. Army Research Laboratory's Readiness Assessment and Monitoring System (RAMS). Data from several studies are presented to illustrate the behavioral profiles of individuals in extreme operational environments. Data show how specific factors (e.g., personality, coping) contribute to performance in operational settings (e.g., command and control, chemical decontamination operations). Understanding the effect of cognitive readiness on overall military effectiveness not only has implications for selection, training, and system design, but also provides the basis for the proactive development and sustainment of optimal performance, both in individual soldiers, and in small teams or military units.

Cox, D. and S. Hariri (2007). Efficacy of modeling & simulation in defense life cycle engineering, Society for Computer Simulation International: 1105-1111 http://portal.acm.org/citation.cfm?id=1358083

Military, US, DCL design / acquisition / service, HSI, discussion, description, tools Google Scholar ("cost effectiveness" * defense "Human systems integration"),

Modeling and Simulation (M&S) is an increasingly important tool in product life cycle engineering. Contractually demanded by many government programs, M&S is usable in the early stages of product functional and operational conceptualization as well as manufacturing process analysis, optimization and management. The application of M&S as a support tool in mission support (logistics) management has lagged behind that of design engineering and manufacturing process analysis and optimization. One reason is that the DoD has historically provided all logistics and mission support services. This trend is changing. Post acquisition mission support management programs have been identified by DoD and industry decision makers as a positive discriminating factor in the source selection decision. This paper presents a review of M&S technology and tools and suggestions of how M&S can be applied in support of proposal capture, program management and mission support for defense programs.

Cullen, L. (2007). "Human factors integration - Bridging the gap between designers and end-users: A case study." Safety Science 45: 621-629. http://dx.doi.org/10.1016/j.ssci.2007.01.002

civilian, petroleum, gas, case study,

Within any high hazard industry such as chemical, oil and gas, rail or nuclear, it is necessary to involve system end-users within the design process if system design is to be optimised. To facilitate the identiWcation and assessment of end user requirements it is necessary to integrate human factors (HF) into design from the start of the design lifecycle.

During 2004, the author facilitated the integration of HF into a development project being imple- mented at a major gas processing facility on mainland Britain. The approach taken to HF integration on the project is commonly applied across the high hazard industries. This paper will provide information on this process and the benefits that this provided to the operator. Details will be provided on the approach taken in terms of:

- Liaison between HF and other design disciplines.
- Analysis undertaken and tools used.
- HF topic areas covered.
- Specific issues raised and how these were resolved.

It will demonstrate the advantage of the early integrated approach as compared to the later audit- ing or assurance approach sometimes taken in relation to HF.

Cunio, P. and M. Cummings (2009). A Framework for an HSI Downselection Tool, MIT Humans and Automation Laboratory. web.mit.edu/aeroastro/labs/halab/papers/HAL2009_03.pdf

Civilian, HSI, methods, tools

This technical report describes the concept and development of SITHE, the Systems Integration Tool for HSI Evaluation. SITHE is a framework for selecting tools to be used in evaluating complex technical systems in terms of Human-Systems Integration, or HSI.

HSI, or Human-Systems Integration, is the process of integrating people, technology, and an organization at a systems level, with full consideration given to the human requirements of the user (Booher, 2003). HSI focuses on the human aspects of system definition, development, and deployment, and integrates considerations related to personnel, training, human factors, habitability, and other human-related concerns into the overall systems acquisition process (US Department of Defense, 2004). HSI is a field of interest to researchers in academia and industry because, although systems continue to grow more complex, they have not achieved the level of autonomy that would permit them to operate successfully without humans either in or on the loop. Humans are still an essential component of most complex systems, especially when the context of operation for the complex system is subject to uncertainty, as in military applications. However, HSI as a broad field can encompass a large number of types of interaction between humans and systems, including but not necessarily limited to supervisory control, mechanics and ergonomics of control operation, and visualization and decision support.

The universe of tools for HSI (including hardware, software, processes, and techniques used to evaluate HSI aspects of complex systems) is already large and growing quickly. Many HSI tools are developed for research purposes only, or in an ad-hoc fashion for specific projects, and as such there is no such thing as a standard catalogue of HSI tools. In addition, the need to consider downstream competencies such as flexibility, robustness, and usability, is increasing as HSI systems become more complex. Thus the HSI cost-benefit trade space is ever increasing, making it difficult for decision makers to determine if and to what degree a system actually meets some pre-specified HSI criteria.

Dahlbäck, G., D. Lindholm, et al. (2006). Crisis management: What is required - How to design. Human Factors and Economic Aspects on Safety: 19 http://www.humanfactorsnetwork.se/Publications/Proceedings2006.pdf#page=22

Military / Civilian, Sweden, DCL design, HSI-all, discussion paper (industry), tools

All activities, business or governmental, requires a well defined framework regarding basic values, the main idea for the activities and the context (actual scenarios). Running the activities requires processes, organisational structures, hardware and software but above all people. The success of the design of such a complex activity depends on the design process used throughout the entire life cycle from the initial concept to actual uses/deployments. The human centred design process we propose is based on the needs, capabilities and constraints of the people involved. The technology used must be a consequence of the process not a driving force for the design. One essential part of a crisis management system is that the decision making demands well prepared structures such as who will have the authority and what support is available (rule of engagements).

Designing a complex system like a crisis management involves in our evolutionary process which is based on the principles of systems engineering and axiomatic design four main steps:

- An information bloc with a database for the basic requirements and constraints.
- A design bloc based on a well defined process (incl. principles from “Axiomatic Design”).
- An evaluation bloc used throughout the life cycle including simulations, exercises and actual uses.
- A decision bloc where further design steps are decided, the different versions of the system are documented and approved (a base for the configuration management).

Every bloc includes active engagement of certified user groups and all four blocs are run through during every iteration.

Running a design process like the one we propose requires the support from a team who has the experience of this type of designs, well acquainted with the context but not involved in the system to be designed.

Dainoff, M. (2009). “Can’t We All Just Get Along? Some Alternative Views of the Knowledge Worker in Complex HCI Systems.” International Journal of Human-Computer Interaction 25(5): 328-347. http://www.informaworld.com/index/912361662.pdf

Military / Civilian, DCL, HSI (HFE), review, discussion

What kind of understanding can be extracted from this brief and necessarily idiosyncratic overview of these multiple perspectives on the knowledge worker? Several interrelated points may be made.

At the foundational level, there seems to be consistent agreement on high-level goals and objectives. Macroergonomics is concerned with joint optimization across five different classes of human-system interfaces, cognitive systems engineering defines joint cognitive systems as a mutual relationship between human and artifact, and human systems integration, by definition, is about overall system optimization taking into account constraints across different domain boundaries.

This is, perhaps, not surprising given the roots of all three perspectives in sociotechnical systems theory. According to the International Committee on Systems Engineering (INCOSE; 2001), a system can be broadly defined as an integrated set of elements that accomplish a defined objective. Sociotechnical systems theory provides a broadly based framework on how such integration might be conceptualized; focusing on technical, personnel, and work design subsystems. Macroergonomics, cognitive systems engineering, and human systems integration each represent approaches to characterizing the relationships among the three subsystems.

However, at the level of analysis and method there is a wide divergence of conceptual approaches. Comparing macroergonomic and cognitive systems engineering, the former appears to address health and safety, and stress-related issues, whereas the latter is more focused on cognitive functioning. There is certainly opportunity for overlapping interest. Balance theory, as a major exemplar of macroergonomics, could in principle be integrated with joint cognitive systems or cognitive work analysis. (See Dainoff, 2006, for how this might be approached.) A useful text that describes many of the methods and principles discussed in this article (including cognitive task analysis, critical decision method, situation awareness, and others) is Stanton, Salmon, Walker, Baber, and Jenkins (2005).

A deeper question relates to the extent to which specific practice-oriented methods rest on basic scientific research. In the case of many of the cognitive system engineering approaches, ecological psychology provides a foundation. However, ecological psychology has itself been in opposition to the mainstream of academic cognitive/information-processing approaches. It is of some interest that, as just discussed, the core concept of mutual interaction between human and artifact shared by all three perspectives has its roots in the ecological concepts of affordance and perception-action cycle. The following quotation from Hollnagel and Woods (2006) takes, as its point of departure, the traditional information processing (decomposed human machine) view:

The decomposed human machine view became so accepted that the distinctive issue became interaction with the interface (computer) rather than interaction through the interface. The separation between humans and machines achieved the status of a real problem as shown by Norman's notions of the gulfs of evaluation and execution . . . and the very idea of usability engineering (Neilsen, 1993), and it became almost impossible to see it for what it really was-an artifact of the psychological application of the Shannon-Weaver model. (Holnagel and woods, 2006, p. 17)

Degani, A. and M. Heymann (2002). "Formal verification of human-automation interaction." Human Factors 44(1): 28-43. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.118.3892&rep=rep1&type=pdf

Civilian, aviation, HSI tool/operation, HFE/training, review/technical/case study

This paper discusses a formal and rigorous approach to the analysis of operator interaction with machines. It addresses the acute problem of detecting design errors in human-machine interaction and focuses on verifying the correctness of the interaction in complex and automated control systems. The paper describes a systematic methodology for evaluating whether the interface provides the necessary information about the machine to enable the operator to perform a specified task successfully and unambiguously. It also addresses the adequacy of information provided to the user via training material (e.g., user manual) about the machine's behavior. The essentials of the methodology, which can be automated and applied to the verification of large systems, are illustrated by several examples and through a case study of pilot interaction with an autopilot aboard a modern commercial aircraft. The expected application of this methodology is an augmentation and enhancement, by formal verification, of human-automation interfaces.

Degani, A. and E. L. Wiener (1997). "Procedures in complex systems: the airline cockpit." IEEE Transactions on Systems, Man, & Cybernetics Part A: Systems & Humans 27(3): 302-12. http://ti.arc.nasa.gov/m/profile/adegani/Procedures%20in%20Complex%20 Systems.pdf

Civilian, aviation, HSI tool (procedure development), training, performance, discussion/ technical

In complex human-machine systems, successful operations depend on an elaborate set of procedures which are specified by the operational management of the organization. These procedures indicate to the human operator (in this case the pilot) the manner in which operational management intends to have various tasks done. The intent is to provide guidance to the pilots and to ensure a safe, logical, efficient, and predictable (standardized) means of carrying out the objectives of the job. However, procedures can become a hodge-podge. Inconsistent or illogical procedures may lead to noncompliance by operators. Based on a field study with three major airlines, the authors propose a model for procedure development called the "Four P's": philosophy, policies, procedures, and practices. Using this model as a framework, the authors discuss the intricate issue of designing flight-deck procedures, and propose a conceptual approach for designing any set of procedures. The various factors, both external and internal to the cockpit, that must be considered for procedure design are presented. In particular, the paper addresses the development of procedures for automated cockpits—a decade-long, and highly controversial issue in commercial aviation. Although this paper is based on airline operations, we assume that the principles discussed here are also applicable to other high-risk supervisory control systems, such as space flight, manufacturing process control, nuclear power production, and military operations.

Di Giulio, A., P. Trucco, et al. (2003). "Towards a systematic organizational analysis for improving safety assessment of the maritime transport system." Safety and Reliability, Vols 1 and 2: 513-521. http://books.google.com.au/books?id=3LTJ4miALEsC&pg=PA513&lpg=PA513&dq=%22Towards+a+systematic+organizational+analysis+for+improving+safety+assessment+of+the+maritime+transport+system%22&source=bl&ots=DCPuYNLnKB&sig=haRLMCuPLxxr0wEGvD0N-C13ELc&hl=en&ei=BRA0TKu_I9GTkAXRI5SgDA&sa=X&oi=book_result&ct=result&resnum=1&ved=0CBQQ6AEwAA#v=onepage&q=%22Towards%20a%20systematic%20organizational%20analysis%20for%20improving%20safety%20assessment%20of%20the%20maritime%20transport%20system%22&f=false

Civilian, maritime, HSI tool (development of functional model/approach), system safety, safety, discussion/technical

Safety in maritime operations has become a serious issue in the last 10 years, following the occurrence of an increasing number of incidents and accidents at sea. In this paper we propose a systematic approach that supports safety analyses of the Maritime Transport System (MTS); particular emphasis is put on High Speed Craft (HSC). The approach is mainly based on the development of a functional model that provides a systemic vision of the NITS from the safety point of view; in the early design stage of its development, the model was inspired by a similar approach developed in the air transport system. The functional model supports the validation of Formal Risk Assessment, but can be also used as an aid for the optimisation of resources allocation within the NITS in order to reach a target safety level. An application of the functional model will be shown for the quantification in a more coherent way of the conditional probability of some Basic Event (BE) of an accident (collision) scenario represented as a Fault Tree (FT). Indeed, the potential contribution of human and organisational factors can be quantified by linking the BE of the FT to appropriate variables of the functional model.

Di Nocera, F., R. Fabrizi, et al. (2006). "Procedural errors in air traffic control: effects of traffic density, expertise, and automation." Aviation Space & Environmental Medicine 77(6): 639-43. http://w3.uniroma1.it/dinocera/stuff/papers/asem2006.pdf

Civilian, aviation, operation, HFE/training (computer simualation), safety, scientific (experimental)

INTRODUCTION: Air traffic management requires operators to frequently shift between multiple tasks and/or goals with different levels of accomplishment. Procedural errors can occur when a controller accomplishes one of the tasks before the entire operation has been completed. The present study had two goals: first, to verify the occurrence of post-completion errors in air traffic control (ATC) tasks; and second, to assess effects on performance of medium term conflict detection (MTCD) tools.

METHODS: There were 18 military controllers who performed a simulated ATC task with and without automation support (MTCD vs. manual) in high and low air traffic density conditions. During the task, which consisted of managing several simulated flights in an enroute ATC scenario, a trace suddenly disappeared "after" the operator took the aircraft in charge, "during" the management of the trace, or "before" the pilot's first contact.

RESULTS: In the manual condition, only the fault type "during" was found to be significantly different from the other two. On the contrary, when in the MTCD condition, the fault type "after" generated significantly less errors than the fault type "before." Additionally, automation was found to affect performance of junior controllers, whereas seniors' performance was not affected.

DISCUSSION: Procedural errors can happen in ATC, but automation can mitigate this effect. Lack of benefits for the "before" fault type may be due to the fact that operators extend their reliance to a part of the task that is unsupported by the automated system.

Dillon, D. and E. Styers (2009). Analyzing Systems Integration Best Practices and Assessment in DoD Space Systems Acquisition. http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA511606&Location=U2&doc=GetTRDoc.pdf

Military (Air Force), aerospace, US, DCL (acquisition), HSI (HFE,safety, training, personnel, manpower), review (technical and discussion)

Senior leadership of the Air Force's Space and Missile Center suggested an investigation of systems integration within the space acquisition community in the fall of 2008. This thesis performs that investigation. A review concluded that while Systems Integration (SI) is extensively discussed as an area deserving considerable attention in the Systems Engineering literature, definitions are weak and methods and tools non-existent. Known SI activities are not being traced and assessed for adequacy throughout system development. Employing the Space System Acquisition Lifecycle Framework as the environment for this research, a method of characterizing and tracing SI throughout a program's lifecycle by using technical reviews and audits (TR&A) is proposed. Subsequent to a SI trace of an acquisition program, an assessment can be performed to determine the adequacy of the integration of Systems Engineering (SE) tasks. Using this assessment, prudent adjustments to program resources (e.g., SE, finance, research and development, program management, etc.) can be considered that will mitigate or resolve program deficiencies caused by insufficient SI. The proposed method is demonstrated across technical reviews and audits of the Global Positioning Systems (GPS) program. The results of this thesis should accentuate the value of SI during space system acquisition - a key consideration which is rarely recognized.

Dobbins, T., I. Rowley, et al. (2008). High speed craft human factors engineering design guide, Human Sciences and Engineering Ltd: 120. http://www.highspeedcraft.org/HSC_HFE_Design_Guide_v1.0.pdf

This Guide supports the High Speed Craft (HSC) community by providing Human Factors Engineering guidance to enhance the specification, design, evaluation and operation of HSC. It provides guidance on many topics including assisting the designer with the inclusion of features than can reduce exposure to high levels of shock & vibration. This will help to reduce the risk of fatigue, acute and chronic injuries, and therefore enhance operational effectiveness and readiness, and the health & safety of the crew and passengers. The Guide also provides assistance with man-machine interface issues than will enhance situational awareness and therefore safety. The Guide has been produced with the cooperation of the ABCD Working Group on Human Performance at Sea and significant contributions have been received from the UK RNLI and the US Navy.

Dolan, N. and J. Narkevicius (2005). Systems Engineering, Acquisition and Personnel Integration (SEAPRINT): Achieving the Promise of Human Systems Integration. Strategies to Maintain Combat Readiness during Extended Deployments – A Human Systems Approach. Neuilly-sur-Seine, France: 1-1 – 1-6. http://www.rta.nato.int/Abstracts.aspx

Military (Navy), maritime, USA, DCL, HSI

Emphasis on mission systems performance has focused on the development and implementation of technology. The success of these systems hinges on the successful performance of the humans interacting with these systems to meet the desired operational capabilities. The Systems Engineering, Acqusition, and Personnel Integration (SEAPRINT) program identified and documented the processes and tool sets that allow successful implementation of mission systems that work and are scalable across organizational structures and working within the current structure while it transforms.

Donmez, B., M. L. Cummings, et al. (2009). “Auditory decision aiding in supervisory control of multiple unmanned aerial vehicles.” Human Factors 51(5): 718-29. http://web.mit.edu/aeroastro/labs/halab/papers/Donmez_Cummings_Graham_draft.pdf

Military, aviation, design, HFE, performance, scientific (experimental)

OBJECTIVE: This article is an investigation of the effectiveness of sonifications, which are continuous auditory alerts mapped to the state of a monitored task, in supporting unmanned aerial vehicle (UAV) supervisory control.

BACKGROUND: UAV supervisory control requires monitoring a UAV across multiple tasks (e.g., course maintenance) via a predominantly visual display, which currently is supported with discrete auditory alerts. Sonification has been shown to enhance monitoring performance in domains such as anesthesiology by allowing an operator to immediately determine an entity’s (e.g., patient) current and projected states, and is a promising alternative to discrete alerts in UAV control. However, minimal research compares sonification to discrete alerts, and no research assesses the effectiveness of sonification for monitoring multiple entities (e.g., multiple UAVs).

METHOD: The authors conducted an experiment with 39 military personnel, using a simulated setup. Participants controlled single and multiple UAVs and received sonifications or discrete alerts based on UAV course deviations and late target arrivals.

RESULTS: Regardless of the number of UAVs supervised, the course deviation sonification resulted in reactions to course deviations that were 1.9 s faster, a 19% enhancement, compared with discrete alerts. However, course deviation sonifications interfered with the effectiveness of discrete late arrival alerts in general and with operator responses to late arrivals when supervising multiple vehicles.

CONCLUSIONS: Sonifications can outperform discrete alerts when designed to aid operators to predict future states of monitored tasks. However, sonifications may mask other auditory alerts and interfere with other monitoring tasks that require divided attention.

APPLICATIONS: This research has implications for supervisory control display design.

Donovan, S. and T. Triggs (2006). Investigating the Effects of Display Design on Unmanned Underwater Vehicle Pilot Performance, DEFENSE SCIENCE AND TECHNOLOGY ORGANIZATION VICTORIA (AUSTRALIA) MARITIME PLATFORMS DIV. Investigating the Effects of Display Design on Unmanned Underwater Vehicle Pilot Performance

Military (Navy), (maritime, land, aerospace), Australia, DCL , HSI (HFE), case study, discussion, evaluation, description, performance, methods, tools

The aim of this research was to investigate the effect of different user interface designs on the performance of an Unmanned Underwater Vehicle (UUV) pilot. Participants in this study were 23 males and 3 females who took part in a remote piloting experiment. Participants were each presented with three display designs; a display analogous to the current Mine Disposal Vehicle (MDV) Baseline display, an Inside-Out (fixed vehicle) design and an Outside-In (moving vehicle) design and were asked to fly a simulated mission. During each condition, Situation Awareness (SA) and Human Performance (HP) measurements were taken. Results indicated a significant relationship between display design and level of situation awareness and human performance on a number of measures. Significant differences in situation awareness were observed between display designs for vehicle roll and depth. Results also indicated significant differences between the display designs for the number of control reversal errors observed for roll, the number of waypoints reached, the final odometer reading and the speed of approach to the first waypoint. A significant preference was revealed for the Outside-In display design. Results from this study indicate that UUV pilot situation awareness and performance can be enhanced by modifying and improving display design. Results of this study have implications for the use of unmanned vehicles in the wider air and land domains, as well as the underwater domain.

Dwyer, J. and S. Landry (2009). Separation Assurance and Collision Avoidance Concepts for the Next Generation Air Transportation System. Human Interface and the Management of Information. Information and Interaction. Smith MJ and Salvendy G. Springer-Verlag Berlin Heidelberg. LNCS 5618: 748-757. http://www.springerlink.com/index/G23X61T104M85WQL.pdf

Civilian, aviation, HSI tool, safety, review

A review was conducted of separation assurance and collision avoidance operational concepts for the next generation air transportation system. The concepts can be distributed along two axes: the degree to which responsibility for separation assurance and collision avoidance is assigned to the controller verses the pilot(s), and the degree to which automation augments or replaces controller and pilot functions. Based on an analysis of the implications of these concepts from a human factors standpoint, as well as the technological readiness of the concepts, it appears that some form of supervisory control of separation by controllers is the most viable concept.

Elischer, P. and M. R. Grech (2008). Human Systems Integration: How does it fit into Warship Design? M. P. Division. Australia, Defence Science and Technology Organisation. http://hdl.handle.net/1947/9261

Military (Navy), maritime, Australia, HSI, DCL

Evans, S. M. and N. A. Ritchie (1992). "Requirements for an Automated Human Factors, Manpower, Personnel, and Training (HMPT) Planning Tool." http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA258531&Location=U2&doc=GetTRDoc.pdf

Military (Air Force), aerospace, US, DCL (design, acquisition), HSI (HFE, training, personnel, manpower), case study, discussion, evaluation, performance, safety, cost, methods, tools

This Phase I Small Business Innovative Research (SBIR) project investigated the impact of system design decisions on human operator performance during concept development. The research established the functional and information requirements for an effective automated design analysis and crew performance assessment methodology for use in Premilestone I planning. The information structure included process, task, dynamic crew performance, operator graphic and human factors parameters, and training requirements. Existing automated tools such as the IDEF sub 0 structured analysis methodology, the SAINT task network simulation model and various operator graphic and human factors models were evaluated, along with other proven methodologies such as IDEAL and the Air Force's Instructional Systems Development (ISD) process. Insights from designers and other potential users identified special functional, information, and hardware requirements which were included in the methodology. The requirements will direct the implementation of an automated Human Factors, Manpower, Personnel, and Training System in Phase II. The resulting system will make a significant contribution to the complex problems of considering HMPT issues early in system planning. It has potential application by elements in DoD program offices and organizations, and would also be of use in the private sector by those who are involved with the early concept phases in the design of complex human-operated systems.

Farrington-Darby, T., J. R. Wilson, et al. (2006). "A naturalistic study of railway controllers." Ergonomics 49(12-13): 1370-94. http://www.informaworld.com/smpp/content~db=all~content=a757998753

Civilian, UK, other industry (railroad), HSI tool, system safety, review

There is an increasing prevalence for work to be analysed through naturalistic study, especially using ethnographically derived methods of enquiry and qualitative field research. The relatively unexplored domain of railway control (in comparison to signalling) in the UK is described in terms of features derived from observations and semi-structured interviews. In addition, task diagrams (a technique taken from the Applied Cognitive Task Analysis toolkit) are used to represent controllers' core elements of work, i.e. to manage events or incidents, and to identify the challenging steps in the process. The work features identified, the task diagrams, and the steps identified as challenging form a basis from which future ergonomics studies on railway controllers in the UK will be carried out.

Fass, D. (2007). Integrative Physiological Design: A Theoretical and Experimental Approach of Human Systems Integration. <u>Engineering Psychology and Cognitive Ergonomics</u>: 52-61. http://www.springerlink.com/content/g544410760744556/

Civilian, France, design, HSI-all, effectiveness / efficiency / HSI tool, technical report (scientific)

Human modeling in design consists of human system integration (HSI), human factors integrated with systems engineering. That involves augmenting human capabilities and improving human-in-the-loop systems global performance, robustness and safety by behavioral technologies. For such human-in-the-loop systems design, this paper proposes an integrative physiological approach based on Chauvet's mathematical theory of integrative physiology (MTIP). By applying MTIP principles as theoretical framework, the integrative physiological modeling is used to model HIS and experiment a gesture-based method for virtual environment (VE) design and human system integration assessment. To demonstrate the pertinence and practicability of the developed integrative approach, we apply it to a wearable interactive system made up of virtual environment technologies for gesture assistance. The design prototype was evaluated in weightlessness during parabolic flights and confirms the effectiveness of the integrative physiological modeling. Keywords: human modeling design, human system integration,

Fass, D. and R. Lieber (2009). Rationale for human modelling in human in the loop systems design. 3rd Annual IEEE International Systems Conference, SysCon, Vancouver : Canada http://hal.archives-ouvertes.fr/docs/00/39/46/08/PDF/Rationale_for_human_modeling_in_human_in_the_loop_systems_design.pdf

civilian, france, design, HSI-all, HSI tool, technical report (scientific)

Human modelling in human-in-the-loop systems (HITLS) design can be a complex and dynamic endeavour. Thereby it needs a theoretical framework for grounding methods and models on verified principals and an integrative approach that takes into consideration the specificity of biological organization of living systems, according to the principles of physics, and a coherent way to organize and integrate structural and functional artificial elements. This paper focuses on the rationale of human modelling for HITLS design, in the context of a conceptual framework based on Chauvet's mathematical theory of integrative physiology (MTIP).

Federal Aviation Authority (2003). Human factors acquisition job aid, Department of Transport. http://www.hf.faa.gov/docs/508/docs/jobaid.pdf

civilian, aviation, aerospace, hsi implementation, acquisistion

The purpose of this Human Factors Job Aid is to serve as a desk reference for human factors integration during the lifecycle acquisition management process. The first chapter contains an overview of the FAA human factors process. The remaining chapters each represent a function that must be accomplished to produce a successful human factors program. The chapters offer one way that has proven successful during previously conducted acquisition programs to accomplish the integration of human factors. The "How To" section of each chapter provides the steps to complete the function. Checklists are included to assist in the execution and implementation of a human factors program. References are provided in Appendix D.

The processes described in this Job Aid apply to all types of acquisition programs (systems, software, facilities, and services). As used in this Job Aid, the term "acquisition" refers to all four program types in the lifecycle acquisition management process. The emphasis of this Job Aid is primarily on systems and software because these acquisitions often afford the greatest opportunities for human factors influences; the activities and terminology may need to be tailored for facility and services acquisitions.

Federal Aviation Authority (2009). Human factors design standard (HFDS), Department of Transport. http://hf.tc.faa.gov/hfds/

civilian, aviation, human factors, standard

The Human Factors Design Standard (HFDS) provides reference information to assist in the selection, analysis, design, development, and evaluation of new and modified Federal Aviation

Administration (FAA) systems and equipment. This document is based largely on the 1996 Human Factors Design Guide (HFDG) produced by the FAA in 1996. It converts the original guidelines document to a standard and incorporates updated information, including the newly revised chapters on automation and human-computer interface. The updated document includes extensive reorganization of material based on user feedback on how the document has been used in the past. Additional information has been also been added to help the users better understand tradeoffs involved with specific design criteria. This standard covers a broad range of human factors topics that pertain to automation, maintenance, displays and printers, controls and visual indicators, alarms, alerts and voice output, input devices, workplace design, system security, safety, the environment, and anthropometry documentation. This document also includes extensive human-computer interface information.

Felici, M. (2006). Modeling Safety Case Evolution-Examples from the Air Traffic Management Domain. in: Rapid Integration of Software Engineering Techniques. Book Series Lecture Notes in Computer Science, Springer Berlin / Heidelberg 3946: 81-96. http://www.springerlink.com/content/x004185867k07113/

Civilian, aviation, HSI tool, safety, technical/review

In order realistically and cost-effectively to realize the ATM (Air Traffic Management) 2000+ Strategy, systems from different suppliers will be interconnected to form a complete functional and operational environment, covering ground segments and aerospace. Industry will be involved as early as possible in the lifecycle of ATM projects. EUROCONTROL manages the processes that involve the definition and validation of new ATM solutions using Industry capabilities (e.g., SMEs). In practice, safety analyses adapt and reuse system design models (produced by third parties). Technical, organisational and cost-related reasons often determine this choice, although design models are unfit for safety analysis. This paper is concerned with evolutionary aspects in judging safety for ATM systems. The main objective is to highlight a model specifically targeted to support evolutionary safety analysis. The systematic production of safety analysis (models) will decrease the cost of conducting safety analysis by supporting reuse in future ATM projects.

Ferreira, J. and S. Hignett (2005). "Reviewing ambulance design for clinical efficiency and paramedic safety." Applied Ergonomics 36(1): 97-105. http://dx.doi.org/10.1016/j.apergo.2004.07.003

Civilian, medical, operation, HFE, performance, case study

This study aimed to review the layout of the patient compartment in a UK ambulance for paramedic efficiency and safety using: (1) link analysis; (2) postural analysis. Paramedics were observed over 16 shifts (130h) carrying out a range of clinical tasks. The most frequently occurring clinical tasks were checking blood oxygen saturation, oxygen administration, monitoring the heart and checking blood pressure. Access to the equipment and consumables to support these tasks had been designed for the attendant seat (head end of the stretcher), however, a link analysis found that paramedics preferred to sit along side the stretcher which resulted in increased reach distances. The higher frequency tasks were found to include over 40% of working postures which required corrective measures. It was concluded that future ambulance design should be based on an ergonomics analysis (including link analysis and postural analysis) of clinical activities. (C) 2004 Elsevier Ltd. All rights reserved.

Folds, D., D. Gardner, et al. (2008). "Building Up to the Human Systems Integration demonstration." INCOSE INSIGHT 11(2): 15-18.

HSI process, tools, defence, review

Frank, M. V. and W. E. Kastenberg (2007). "Probabilistic risk management using risk-based safety goals for the design of spacecraft with onboard nuclear reactor systems." Nuclear Technology 159(1): 25-38. http://cat.inist.fr/?aModele=afficheN&cpsidt=18877219

Civilian, other industry (space, nuclear reactor), HSI tool (development of risk management), safety, case study

A risk-management framework for space mission launches of nuclear reactors is presented in this paper. The framework is based on a set of risk-based safety goals and relies on decision-theoretic principles that advance system design from concept through operation. Because time-dependent behavior is inherent in space missions, a quasi-dynamic probabilistic risk assessment framework is described. We illustrate a use of the framework with a risk management example. A rationale for, and a trial set of, qualitative safety goals and quantitative design objectives for launching space nuclear power plants are presented. The rationale is based on background risks to the general public, on accident risks to the population in the area of the launch site and on other large-consequence single-event catastrophes. Guidance is also obtained from the safety goals developed by the U.S. Nuclear Regulatory Commission, the U.S. Department of Energy, and the Federal Aviation Administration. The quantitative design objectives developed and presented are also compared to the calculated risks of previous launches with radioisotope thermal-electric generators such as for the Galileo, Ulysses, and Cassini missions.

Fulfaro, A. and F. Testa (2004). Integration of safety studies into a detailed design phase for a navy ship. Risk Analysis Iv (International Conference on Computer Simulation in Risk Analysis and Hazard Mitigation). Rhodes, Greece, Management information systems, WIT Press. 9: 799-807. http://library.witpress.com/pages/PaperInfo.asp?PaperID=14354

Military, Navy, Maritime, Italy, design, system safety, safety, review

The latest generation of Italian Navy ships has moved a giant step forward in the approach to the main relevant transwarship activities which have an impact on all the design phases and at the whole warship level. Among all the activities developed, the safety topics have been implemented more and more, shifting from prescriptions essentially based on past experience to goals based on risk considerations, that were included in the scope of the contractual specifications. In its supplier role, Fincantieri for the first time has been challenged with the requirement of demonstrating the vessel safety by means of risk assessment studies during the developed design phases. The studies followed a twofold stream of activities, that is, analysis of the ship's systems (including Platform and Combat System) and analysis of the health and safety of the persons onboard. The safety analysis was essentially based on the study of some contractual hazards already selected by the Client. By means of the typical risk assessment tools (such as Fault Tree Analysis), properly injected as far as possible with Navy operating experience, a level of probability and severity was associated to each hazard, a risk matrix was constructed and the results checked against the Navy acceptance criteria. The process has been completed with the integration of the main safety requirements into the design. The aim of the present paper is to give an overview of the process.

Funk, K. and R. Braune (1999). The AgendaManager: A knowledge-based system to facilitate the management of flight deck activities. Sae Transactions.108: 922-936 http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.23.1868&rep=rep1&type=pdf

civilian (aerospace / maritime), US, design, HSI-all, safety / effectiveness / HSI tool, technical report (case study)

Cockpit Task Management (CTM) is the process by which pilots selectively attend to tasks in such a way as to achieve their mission goal. Through our research we have found that CTM is a significant factor in flight safety, at least partly accounting for a substantial number of aircraft incidents and accidents. We developed an experimental knowledge-based system called the AgendaManager to facilitate Agenda Management (a superset of CTM) and demonstrated its superiority to a conventional crew monitoring and alerting system in a controlled evaluation study. The success of the Agenda- Manager is attributable not to its use of artificial intelligence technology. Rather, it is effective because it was developed using a sound human factors research and development approach. This approach and its application in AgendaManager development are the topics of this paper.

Furniss, D. and A. Blandford (2006). "Understanding emergency medical dispatch in terms of distributed cognition: a case study." Ergonomics 49(12-13): 1174-203. http://www.informaworld.com/smpp/content~db=all~content=a757998745

Civilian, medical, operation/HSI tool, personnel/distributed cognition, performance, scientific/ case study

Emergency medical dispatch (EMD) is typically a team activity, requiring fluid coordination and communication between team members. Such working situations have often been described in terms of distributed cognition (DC), a framework for understanding team working. DC takes account of factors such as shared representations and artefacts to support reasoning about team working. Although the language of DC has been developed over several years, little attention has been paid to developing a methodology or reusable representation which supports reasoning about an interactive system from a DC perspective. We present a case study in which we developed a method for constructing a DC account of team working in the domain of EMD, focusing on the use of the method for describing an existing EMD work system, identifying sources of weakness in that system, and reasoning about the likely consequences of redesign of the system. The resulting DC descriptions have yielded new insights into the design of EMD work and of tools to support that work within a large EMD centre.

Geddie, J., L. Boer, et al. (2001). NATO Guidelines on Human Engineering Testing and Evaluation. http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA392142&Location=U2&doc=GetTRDoc.pdf

Military, France, DCL (design, acquisition), HSI (HFE,safety, training, personnel, manpower), discussion, evaluation, description, performance, methods, tools

The purpose of this report is to document the efforts of RSG-24, which was initiated by DRG Panel 8 in 1992, and was sponsored after the merger of DRG and AGARD by the Human Factors and Medicine (HFM) Panel of NATO's Research and Technology Organization (RTO). The report presents the RSG's recommended guidelines for accomplishing human engineering test and evaluation. The goal was standardization of test content, procedures and conditions/ sequence of test events. The intent was not to impose standardization of system engineering design. The guidelines are expected to facilitate the sharing of data and evaluations, which will cut test costs by reducing duplication and the quantity of test data, required to support decisions.

Human engineering test and evaluation can occur at any point during the acquisition process, but is most often done when a system is undergoing developmental and operational testing. Developmental testing usually occurs earlier and is primarily oriented toward validating the system design, but may include an early assessment of the system's performance in an operational environment. It is often characterized by testing partial systems under benign test conditions, using test subjects who are considerably more knowledgeable of the system than the eventual users of the system will be. Operational testing generally concentrates on testing the whole system, under realistic conditions, using as test subjects, either real users or personnel who closely represent the user in terms of selection, training, and experience. The primary focus of operational testing is to assess the system's ability to perform its mission under realistic conditions.

Human engineering test and evaluation includes data in the following categories:

(a) Data collected to describe relevant characteristics of test participants. Commonality of data in this area is necessary so the test specialist can more accurately use previous test results to make performance predictions for a different system, set of test conditions etc.

(b) Measurement of operator workload. It is important to understand how much of an operator's resources are required to produce satisfactory system performance.

(c) Measurement of human performance. A system's hardware may meet all human engineering design criteria and be liked by operators and maintainers, yet fall short of performance expectations unless one verifies that operators and maintainers satisfactorily perform critical tasks, both under normal, benign conditions and under degraded conditions.

(d) Assessment of user acceptance of the system. Even a system that has been well human engineered for performance and safety may have characteristics that are negatively appreciated by users and that thereby cause system performance to be limited.

(e) Measurements of hardware characteristics. The environment and physical attributes of a system can have positive or negative influences on human performance. Therefore, it is important to measure physical characteristics of the system such as size, weight, light levels, noise levels, crew workspace layout, ingress and egress provisions, temperature, vibration, the brightness, legibility and labeling of displays, and the placement, configuration and force requirements of controls.

Gentner, F. and M. Crissey (1992). Livewire survey of human systems integration (HSI) technologies:Need for comprehensive survey and available database, Human Factors and Ergonomics Society.36: 1133-1137 http://ieeexplore.ieee.org/iel2/655/5765/00220516.pdf?arnumber=220516

Military, manpower, manning, tools

Downsizing the Department of Defense (DoD) means accomplishing more with fewer people. Enlightened design that considers all requirement and interaction issues simultaneously is the key to productivity. In the past, human issues have been difficult to quantify or depict during the systems engineering process. Recently, there has been an explosion of affordable HSI technologies. Despite the new DoD directives that require HSI analyses throughout acquisition, it is difficult to identify the most appropriate technology for HSI analyses. Defense acquisition managers, contractors, and the HSI research and development (R&D) community need a database of information about HSI tools, databases, and test facilities. They need this database to identify technology available in each of the Liveware domains of Manpower, Personnel, Training, (MPT) Safety, Health Hazard Prevention, and Human Factors Engineering (HFE) and to fully integrate human consideration into the acquisition process. However, no comprehensive catalog of HSI technology exists. Under the sponsorship of the Office of the Assistant

Secretary of Defense (Force Management and Personnel) HSI office and North Atlantic Treaty Organization (NATO) Research Study Group.21 (RSG.2I), TPDC and CSERIAC are surveying the HSI community for a comprehensive database of HSI technologies, an ambitious effort requiring the help of all HSI technology developers, owners, and users.

Ginsburg, G. (2005). "Human factors engineering: A tool for medical device evaluation in hospital procurement decision-making." Journal of Biomedical Informatics 38(3): 213-219. http://www.sciencedirect.com/science?_ob=MImg&_imagekey=B6WHD-4F01KDT-1-1&_cdi=6848&_user=331728&_pii=S1532046404001601&_orig=search&_coverDate=06%2F30%2F2005&_sk=999619996&view=c&wchp=dGLzVzz-zSkzk&md5=fa677eb351ae5c3bac6c1f469651c63c&ie=/sdarticle.pdf

Civilian, medical, aquisition/operation, HFE, usability/performance (results of user testing informing aquisition), scientific/case study

A human factors evaluation was conducted to inform hospital procurement decision-making in selecting a general-purpose infusion pump to be used hospital-wide. Three infusion pumps from different vendors were involved in the evaluation, which consisted of two phases: a human factors heuristic assessment of the pumps according to several criteria, and user testing in five clinical areas. The clinical areas were: Oncology, Medical/Surgical, Pediatric, ICU, and Anaesthesiology. Fourteen nurses and three anaesthetists participated in the user testing. Reasonable agreement was observed between results of both phases of the evaluation, and overall results clearly favoured one of the infusion pumps over the others. It is recommended that a human factors evaluation should be performed to influence all hospital procurement decisions when purchasing medical devices, to ensure the best devices are selected for the end users and to ultimately enhance patient safety.

Goldin, D. S., S. L. Venneri, et al. (1999). "New frontiers in design synthesis." Acta Astronautica 44(7-12): 407-18. http://www.sciencedirect.com/

Civilian, other industry (aerospace), USA, HSI tool, HSI all, review

The Intelligent Synthesis Environment (ISE), which is one of the major strategic technologies under development at NASA centers and the University of Virginia, is described. One of the major objectives of ISE is to significantly enhance the rapid creation of innovative affordable products and missions. ISE uses a synergistic combination of leading-edge technologies, including high performance computing, high capacity communications and networking, human-centered computing, knowledge-based engineering, computational intelligence, virtual product development, and product information management. The environment will link scientists, design teams, manufacturers, suppliers, and consultants who participate in the mission synthesis as well as in the creation and operation of the aerospace system. It will radically advance the process by which complex science missions are synthesized, and high-tech engineering Systems are designed, manufactured and operated. The five major components critical to ISE are human-centered computing, infrastructure for distributed collaboration, rapid synthesis and simulation tools, life cycle integration and validation, and cultural change in both the engineering and science creative process. The five components and their subelements are described. Related U.S. government programs are outlined and the future impact of ISE on engineering research and education is discussed.

Gorman, J. C., N. J. Cooke, et al. (2006). "Measuring team situation awareness in decentralized command and control environments." Ergonomics 49(12-13): 1312-25. http://www.informaworld.com/index/757998750.pdf

Military/all, US, operation, personnel (team situation awareness), review with a case study

Decentralized command and control settings like those found in the military are rife with complexity and change. These settings typically involve dozens, if not hundreds to thousands, of heterogeneous players coordinating in a distributed fashion in a dynamically networked battlefield laden with sensor data, intelligence reports, communications, and plans emanating from many different perspectives. Consider the concept of team situation awareness in this setting. What does it mean for a team to be aware of a situation or, more importantly, of a critical change in a situation? Is it sufficient or necessary for all individuals on the team to be independently aware? Or is there some more holistic awareness that emerges as team members interact? We re-examine the concept of team situation awareness in decentralized systems beyond an individual-oriented knowledge-based construct by considering it as a team interaction-based phenomenon. A theoretical framework for a process-based measure called 'coordinated awareness of situations by teams' is outlined.

Gosakan, M. and S. Murray (2010). Maintenance Manpower Modeling: A Tool for Human Systems Integration Practitioners to Estimate Manpower, Personnel, and Training Requirements. Simulation Methods for Reliability and Availability of Complex Systems: 217-232. http://www.springerlink.com/content/k742h5x42xvr3153/

Military (Army), land, USA, DCL (Design Acquisition Service), HSI (Manpower), discussion (practices), Research (effectiveness, reliability, tools) maintenance

This chapter discusses the maintenance manpower modeling capability in the Improved Performance Research Integration Tool (IMPRINT) that supports the Army's unit of action. IMPRINT has been developed by the US Army Research Laboratory (ARL) Human Research and Engineering Directorate (HRED) in order to support the Army's need to consider soldiers' capabilities during the early phases of the weapon system acquisition process. The purpose of IMPRINT modeling is to consider soldiers' performance as one element of the total system readiness equation. IMPRINT has been available since the mid 1990s, but the newest version includes significant advances.

The application includes a graphical user interface (GUI) shell that elicits information from the user needed to assess human performance issues associated with the operations and maintenance tasks of a weapon system. The simulation and analysis capabilities in IMPRINT along with the embedded data and GUI have been demonstrated to enable human factors professionals to impact system design and acquisition decisions based on early estimation of soldiers' abilities to operate, maintain, and support the system

Gould, K. (2009). Faster, better, safer? Studies of safety, workload and performance in naval high-speed ship navigation, The University of Bergen. https://bora.uib.no/handle/1956/3484

Military (Navy), maritime, Norway, DCL (design, acquisition), HSI (HFE,safety, training, personnel, manpower), scientific, evaluation, description, performance, cost, methods, tools

Ship navigation in the Royal Norwegian Navy (RNoN) involves high demands on navigators, who are required to work under a number of dangers. Operations are carried out in poor weather and darkness, at day and night, in restricted waters, and at high speeds. Accidents are frequent, and sometimes serious. Currently, the RNoN is in the process of replacing its Hauk-class fast patrol boats with the new Skjold-class littoral combat ship. Fast patrol boats play an important role in Norway's coastal defence. Since this transition will involve a major change in manning levels and task characteristics, it is expected to have a considerable impact on the navigator's demands. The aims for this project were to a) examine the situation characteristics of past navigation accidents in the RNoN, and b) investigate the consequences of the Hauk-Skjold transition on workload and performance in navigation. This was accomplished through three individual studies.

The first study in this project examined the presence of performance-shaping factors in investigation reports following 35 navigation accidents in the Royal Norwegian Navy between 1990 and 2005. This was done to provide an overview of the situation characteristics present at the time of the accidents, related to either the human, task, system or environment. Performance-shaping factors (PSFs) are defined as any factors which influence the likelihood of an error occurring. Factors related to task requirements and individual cognitive characteristics were shown to be most common, followed by operational characteristics of the system. Eight PSF clusters were found, indicating a pattern in accident circumstances. It was shown that accidents almost always have a high number of different factors influencing accident risk.

The second study examined mental workload and performance in simulated high-speed ship navigation. Two navigations methods were compared; these were based on electronic chart display and information system (ECDIS) and a conventional system using paper charts. Twenty naval cadets navigated in high-fidelity simulators through 50 nautical mile-courses with varying levels of difficulty. Results showed...

Greenley, M., A. Scipione, et al. (2008). The Development and Validation of a Human Systems Integration (HSI) Program for the Canadian Department of National Defence (DND), Defence Research and Development Canada. http://cradpdf.drdc.gc.ca/PDFS/unc00/p525282_A1b.pdf

Military (Air force, navy, army), maritime, land, aerospace, Canada, DCL (design, acquisition, service, disposal), HSI (HFE,safety, training, personnel, manpower), cost-benefit, discussion (case study) / Review, evaluation, description, performance, safety, cost, methods, tools

Google Scholar Search "Human systems integration" cost-benefit,

From 2000 to 2004, Defence Research and Development Canada conducted multi-year Research and Development (R&D) activities under contract to develop, demonstrate and validate a Human Systems Integration (HSI) approach for the Canadian Department of National Defence (DND) with the aim to transition this approach to an operational program within the DND's Material Acquisition and Support community. The foundation of an HSI Program was applied to 31 Defence acquisition projects from 2001-2004. Various components of the HSI Program were researched, developed, demonstrated, and iteratively improved. A cost benefit analysis derived from this effort was used to determine whether a permanent HSI Program within the DND would be worthwhile. $3,331,000.00 was spent on exercising a full or partial HSI process. This resulted in $3,515,000.00 in immediate savings based on observed data, providing a 106% payback. The cost of HSI application compared with immediate savings plus at least $133,000,000.00 in extrapolated savings (based on the impact the application of HSI had on projected life cycle costs) resulted in a 4000% payback, suggesting that HSI is a worthwhile investment. The possibility in hundreds of millions of dollars in further downstream savings based on lives saved or re-engineering costs avoided also existed but was not calculated. This study found that HSI costs ranged from 4 20% of a project's engineering budget and that Canada's integrated approach to HSI, whereby analyses are shared between HSI domains, can save up to 25% of HSI costs. This R&D effort developed and validated the Canadian HSI approach and supports the implementation of a formalized and enhanced HSI program within the Canadian DND.

Gregoriades, A. and A. G. Sutcliffe (2006). "Automated assistance for human factors analysis in complex systems." Ergonomics 49(12-13): 1265-87. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.100.3104&rep=rep1&type=pdf

Military, Navy, design/operation, personnel (workload), performance, case study

A tool and a method for scenario-based workload assessment and performance validation in complex socio-technical systems design, such as command and control rooms of military vessels, are described. We assess workload in terms of communication and the task load that each agent is able to handle. The method employs subjective task and communication estimates used to calculate the workload of human operators, using static and scenario-based analyses. This enables the identification of bottlenecks to be addressed by the designer with the appropriate allocation of function between humans and smart technology. This task is supported by the functional allocation adviser tool. A case study demonstrating the use of the tool for the design of the command and control room of a military vessel is presented.

Grootjen, M., M. A. Neerincx, et al. (2006). "Cognitive task load in a naval ship control centre: from identification to prediction." Ergonomics 49(12-13): 1238-64. http://www.informaworld.com/index/757998747.pdf

Military, Navy, Netherlands, operation/HSI tool, training, performance (prediction of taskload), scientific (experimental) workload tools

Deployment of information and communication technology will lead to further automation of control centre tasks and an increasing amount of information to be processed. A method for establishing adequate levels of cognitive task load for the operators in such complex environments has been developed. It is based on a model distinguishing three load factors: time occupied, task-set switching, and level of information processing. Application of the method resulted in eight scenarios for eight extremes of task load (i.e. low and high values for each load factor). These scenarios were performed by 13 teams in a high-fidelity control centre simulator of the Royal Netherlands Navy. The results show that the method provides good prediction of the task load that will actually appear in the simulator. The model allowed identification of under- and overload situations showing negative effects on operator performance corresponding to controlled experiments in a less realistic task environment. Tools proposed to keep the operator at an optimum task load are (adaptive) task allocation and interface support.

Haas, E. C., C. Gainer, et al. (1997). Enhancing system safety with 3-D audio displays. Proceedings of the Human Factors and Ergonomics Society 41st Annual Meeting, 1997, Vols 1 and 2: 868-872 http://www.ingentaconnect.com/content/hfes/hfproc/1997/00000041/00000016/art00016

Civilian, aviation, operation, HFE, performance, scientific (experimental)

The enhancement of multiple radio communications can be an important system safety consideration. This study was conducted to determine how accurately helicopter pilots could process radio communications information in a simulated cockpit environment when the messages were presented under different modes (diotic, dichotic and 3-D audio). The dependent variable was the total number of points scored in the radio communications identification task. Subjects were II certified U.S. Army AH-64 pilots between the ages of 18 and 35 who possessed hearing and visual acuity within thresholds acceptable to the U.S. Army (U.S. Army, 1989). Multivariate statistical analysis indicated that presentation mode was significant. Pilots scored the greatest number of points in the identification task while using 3-D audio, fewer with dichotic presentation, and the least with dietic presentation. There was a statistically significant difference between the 3-D and the dietic presentation. The data imply that 3-D audio provides an effective mode of message presentation in systems with multiple radio communications.

Hamburger, P. S. (2008). "Ten Questions: An interview with Patricia S. Hamburger, Director, Human Systems Integration Engineering, Naval Sea Systems Command (NAVSEA)." Naval Engineers Journal 120: 15-21. http://www3.interscience.wiley.com/journal/120175268/abstract?CRETRY=1&SRETRY=0

Defence, military, navy, maritime, HSI, interview

Hamilton, W., C. Lowe, et al. (2004). Cognitive Task Analysis and Performance Modelling for Early Human Systems Integration, Human Factors and Ergonomics Society.48: 2406-2410 http://www.ingentaconnect.com/content/hfes/hfproc/2004/00000048/00000020/art00007?crawler=true

civilian, transport, rail, cognitive taska analysis, workload, training

Successful human systems integration demands early involvement of human factors professionals, using a range of model-based analysis and assessment methods. Typically these rely on task analysis data supported by various algorithms that provide measures of performance quality. This paper reports on a validation study with one such method, for cognitive task analysis of skilled operator performance, task performance time estimation, workload assessment, and human error analysis. This was used to model train drivers' response to route features and derive performance time and workload estimates. The modelled scenarios were run in a cab simulator with N=17 driver subjects. Observational data were used to compare their strategy, performance times and workload profiles against predictions. The results show that the method produces data that are a useful approximation of real performance strategy, timings and workload.

Hamilton, W., H. Rowbotham, et al. (2005). Generic and integrated human factors guidance for air systems acquisition. IEE and MOD HFI DTC Symposium on People and Systems - Who are we Designing for? , London: 1-8 http://link.aip.org/link/abstract/IEESEM/v2005/i11078/p1/s1

Defence, Military, air force, acquisition, guidance material

This paper reports on a project concerned with developing guidance on human factors integration for air systems projects. The concept of human factors integration in support of defence acquisition projects has been current for almost fifteen years. There are now many examples of the benefits of human factors integration, as well as the costs and risks associated with ignoring it. The purpose of this paper was to identify requirements for improved guidance on human factors integration that would ensure its consistent application across programmes. The work involved a survey of acquisition projects to identify user requirements and the development of Web based guidance material. The guidance is true to the established concept of human factors integration but offers a clearer strategy for integration with projects by stage of development, and defines key performance indicators criteria to assess the successful completion of human factors inputs to projects.

Hancock, P. (1999). Human performance and ergonomics, Academic Press. http://www.sciencedirect.com/science/book/9780123227355

civilian

Human Performance and Ergonomics brings together a comprehensive and modern account of how the context of performance is crucial to understanding behavior. Environment provides both constraints and opportunities to individuals, such that external conditions may have reciprocal or interactive effects on behavior.

The book begins with an account of research in human factors and engineering, with application of research to real world environments, methodological concerns, and rumination on current and future trends. The book proceeds to how technology has moved from being designed to help human physical survival to helping humans achieve "quality of life" improvements. Real world examples are explored in detail including hearing technology, driving, and aviation. Issues of control, maneuvering, and planning are discussed in conjunction with how intention and expectancy affect behavior. The fit between human and environment is examined as a dynamic interaction, and many chapters address the all important human-machine communication, particularly that between humans and computers.

The book closes with a reminder that even our technological environment is filled with other people, with whom we must interact personally or via technology, to achieve our larger goals. Teamwork is thus discussed for its integration of cognitive, behavioral, and affective components toward our achieving desired aims.

- Includes the application of research in human factors in engineering to real world environments
- Discussion of both current and future trends is included
- Real-world examples of how technology is now helping humans to achieve "quality of life" improvements are explored in detail including hearing technology, driving and aviation
- Many chapters examine the all important human/machine communication, particularly human-computer interaction (HCI)

Hancock, P. A. and R. Parasuraman (1992). "Human-factors and safety in the design of intelligent vehicle-highway systems (IVHS)." Journal of Safety Research 23(4): 181-198. http://linkinghub.elsevier.com/retrieve/pii/002243759290001P

Civilian, other industry (transport, road, traffic), design, HFE, productivity (functionality), technical/discussion

Intelligent Vehicle-Highway Systems (IVHS) have been proposed in the wake of rapid worldwide growth in traffic volume and density. These systems involve the application of advanced sensor, communications, computational, and control technologies to the design of highways and vehicles to improve traffic flow and safety. Similar technologies have been applied in other transportation systems such as aviation and air-traffic control, and it is suggested that the human factors insights derived from these systems can be usefully applied, proactively rather than retroactively, in IVHS design. Several safety and human factors issues relevant to the design of IVHS technologies, both near-term and long-term, are discussed, including: (a) the optimization of driver mental workload in highly-automated 'hybrid" systems; (b) the design of in-vehicle navigation aids and the resolution of display conflicts; (c) individual and group differences in driver behavior and their implications for training and licensure; (d) the evolution and integration of IVHS technologies; and (e) traffic management and the regulation of driver trust in IVHS. Successful resolution of these issues and their incorporation in IVHS design will provide for fully functional systems that will serve the twin needs of reducing traffic congestion and improving highway safety.

Handley, H. A. A. and R. J. Smillie (2010). "Human View Dynamics- The NATO approach." Systems Engineering 13: 72-79. http://www3.interscience.wiley.com/journal/123235686/issue

A methodology was established to use the data captured in the NATO Human View to populate a simulation model; this provides a dynamic instantiation of the Human View data. The Improved Performance Research Integration Tool (IMPRINT), provided by the U.S. Army Research Laboratory was used as the simulation environment. By creating the Human View Dynamics, the data captured in the static products can be evaluated through tradeoff analysis and performance criteria. The demonstrated interoperability of the Human View static products and the IMPRINT dynamic modeling capability resulted in a mapping between the two domains. Additionally, the capability of the Integrated Performance Modeling Environment (IPME) used by Canada and the United Kingdom as a simulation environment was reviewed

Hanser, L., J. Campbell, et al. (2008). Final Report of the Panel on the Department of Defense Human Capital Strategy. http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA488975&Location=U2&doc=GetTRDoc.pdf

Military, USA, DCL, HSI, discussion, description, perfomance, cost, methods, tools

In February 2006, the Department of Defense (DoD) published its Quadrennial Defense Review (QDR). As part of the process of producing the QDR, the Department internally published a **human capital strategy (HCS), which focused on developing the right mix of people and skills to help DoD** and the military services carry out the missions necessary for the security of the United States. Although the HCS has been distributed, it would be inappropriate to view it as static. Almost from the time it was initially published and disseminated, the strategy has been shifting as DoD and the military services incorporate its spirit into their day-to-day development and management of human capital. Thus, the HCS is best seen as a living document.

The Under Secretary of Defense for Personnel and Readiness asked the RAND Corporation's National Defense Research Institute (NDRI) to provide an independent review of the HCS and to help refine its implementation. To carry out that review, NDRI convened a panel of experts in military personnel and organizational analysis. In addition to commentary on the original version of the strategy, the review and the material in this report constitute a **blueprint for developing a DoD HCS suited to the 21st century**. We believe that the insights in this report will be useful to DoD and the military services as they move forward in developing their human capital policies and systems.

This research was sponsored by the Under Secretary of Defense for Personnel and Readiness and conducted within the Forces and Resources Policy Center of the RAND National Defense Research Institute, a federally funded research and development center (FFRDC) sponsored by the Office of the Secretary of Defense, the Joint Staff, the Unified Combatant Commands, the Department of the Navy, the Marine Corps, the defense agencies, and the defense intelligence community. For further information about this document, please contact the panel chairman, Lawrence M. Hanser, at Lawrence_Hanser@rand.org.

For more information on RAND's Forces and Resources Policy Center, contact the Director, James Hosek. He can be reached by e-mail at James_Hosek@rand.org; by phone at 310-393-0411, extension 7183; or by mail at the RAND Corporation, 1776 Main Street, P.O. Box 2138, Santa Monica, California 90407-2138. More information about RAND is available at www.rand.org.

Hardman, N. and J. Colombi (2009). A Mapping from the Human Factors Analysis and Classification System (DOD-HFACS) to the Domains of Human Systems Integration (HSI), Air Force Institute of Technology. http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA509912&Location=U2&doc=GetTRDoc.pdf

Military (Air Force), USA, DCL (Operation), HSI, Discussion (practices), Research (safety, tools, methods)

This technical report is part of the research efforts to improve human systems integration (HSI) in the systems engineering (SE) technical processes. It documents the mapping of human error codes used in accident investigations with teh established domains of HSI. This will enable the application of legacy mishap data to new system design.

Hardman, N., J. Colombi, et al. (2009). The Challenges of Human Consideration in the Systems Engineering Technical Processes. 7th Annual Conference on Systems Engineering Research http://cser.lboro.ac.uk/papers/S11-66.pdf

Military (Air Force), DCL (acquisition, service), HSI, review / discussion (practices, policies, description, evaluation, Research (safety, effectiveness, cost-effectiveness)

In this paper, we distill the most significant current systems engineering challenges by examining acquisition oversight reports, aircraft mishap investigations, and current systems engineering literature. We then discuss how to better meet those challenges in light of the domains of human systems integration; specifically, manpower, personnel, training, human factors, health, safety, habitability, survivability, and environment. The findings in this paper indicate that the system engineering technical processes are fundamentally sound, but that the application of those processes is frequently inconsistent and ineffective. Causes for this include a need for sound systems engineering earlier in system development, more quantitative methods and tools to support the application of technical processes, and more effective management of interfaces. This is observed in both the commercial and government sectors, and the consequences have proven to be very costly and dangerous.

Harris, D. (2004). Human factors for civil flight deck design. Burlington, Ashgate. http://books.google.com.au/books?hl=en&lr=&id=LvhHXKQtPjMC&oi=fnd&pg=PR7&dq=Human+factors+for+civil+flight+deck+design&ots=QY5Gz7VobF&sig=RQyxqM_dF9EBR9nYVWKDk8qyO0g#v=onepage&q&f=false

civilian, aerospace, human factors engineering

Human error is now the main cause of aircraft accidents. However, in many cases the pilot simply falls into a trap that has been left for him/her by the poor design of the flight deck. This book addresses the human factors issues pertinent to the design of modern flight decks.Comprising of invited chapters from internationally recognised experts in human factors and flight deck design, contributions span the world of industry, government research establishments and academia. The book brings together the practical experience of professionals across the human factors and flight deck design disciplines to provide a single, all-encompassing volume. Divided into two main parts, part one of the book examines: the benefits of human engineering; flight deck design process; head down display design; head-up display design; auditory warning systems; flight control systems, control inceptors and aircraft handling qualities; flight deck automation; and human-computer interaction on the flight deck and anthropometrics for flight deck design. Part two is concerned with flight deck evaluation - the human factors evaluation of flight decks; human factors in flight test and the regulatory viewpoint.

Harris, D. (2008). "Human factors integration in defence: preface." Cognition, Technology & Work 10(3): 169-172. http://dx.doi.org/10.1007/s10111-007-0096-6

Military, UK DCL (Acquisition), HSI, discussion, description

In the acquisition of large, complex pieces of equipment, such as many of those procured by the military, humancentred design is no longer enough to ensure the effectiveness of a system. Human factors integration (HFI) or human-system integration (HSI) as it is referred to in the US, is essentially a human-centric acquisition management process. HFI considers not just the specification, design and development of the user-centric aspects of the system, it also takes into account other processes, such as training, personnel skills and availability, and other organisational issues. It is the systematic process for identifying, tracking and resolving issues to ensure a balanced development of technological and human aspects of capability. The ''I'' in ''HFI'' refers to three aspects of integration: integration of humans and machines; integration between the HFI domains; and integration of Human Factors into the system acquisition process. It can broadly be characterised as a socio-technical systems based approach for the requirements specification, design, development and in-service monitoring of large pieces of equipment. HFI is a process which probably best lives within a system engineering context. The philosophy of human centred design (HCD) resides within HFI but it should be noted that HCD by itself is a necessary but not sufficient component of the HFI process. HCD alone is no longer sufficient to ensure system effectiveness.

Hartel, C. R. and J. Kaplan (1984). Reverse Engineering of the BLACK HAWK (UH-60A) Helicopter: Human Factors, Manpower, Personnel, and Training in the Weapons System Acquisition Process, US Army Research Instutute for the Behavioral and Social Sciences. http://handle.dtic.mil/100.2/ADA163479

Defence, air force, acquisition, case studies

In a briefing format, this report on the BLACK HAWK (UH-60A) helicopter summarizes an examination of human factors, manpower, personnel and training (HMPT) issues during the systems acquisition process. The report is one of four reverse engineering studies prepared at the request of GEN M. R. Thurman, Army Vice Chief of Staff. The four systems were studied as a representative sample of Army weapons systems. They serve as the basis for drawing conclusions about aspects of the weapon system acquisition process which most affect HMPT considerations. A synthesis of the four system studies appears in the final report of the Reverse Engineering Task Force, U.S. Army Research Institute.

Harvey, R. (2004). Human factors and cost benefits. Human Factors for Engineers. C. Sandom and R. S. Harvey. London, Institution of Engineering and Technology: 1-9. http://books.google.com.au/books?hl=en&lr=&id=Rj7N5j52kowC&oi=fnd&pg=PA1&dq=Human+factors+and+cost+benefits&ots=ri9GBQKnRK&sig=6LULyxQPaBsHcqbPBliqrrzNnKI#v=onepage&q=Human%20factors%20and%20cost%20benefits&f=false

Defence, Military, cost-benefit

This book introduces the reader to the subject matter coverage of human factors and provides practical and pragmatic advice to assist engineers in designing interactive systems that are safer, more secure and easier to use - thereby reducing accidents due to human error, increasing system integrity and enabling more efficient process operations. The book discusses human factors integration methodology and reviews the issues that underpin consideration of key topics such as human error, automation and human reliability assessment. There are also design considerations including control room and interface design and acceptance and verification considerations.

Harvey, R. S., R. Wicksman, et al. (2002). Human factors investment strategies within equipment procurement. Contemporary Ergonomics 2002. P. T. McCabe. London, Taylor & Francis: 496-501. http://www.informaworld.com/smpp/content~content=a728497787~db=all~jumptype=rss

Defence, acquisistion, cost-benefit

Hasse, C., C. Bruder, et al. (2009). Future Ability Requirements for Human Operators in Aviation. in: Engineering Psychology and Cognitive Ergonomics . Book Series Lecture Notes in Computer Science, Publisher Springer Berlin / Heidelberg 5639: 537-546. http://www.springerlink.com/index/1526GM043542662V.pdf

Civilian, aviation, Germany, operation, training/personnel selection, performance, technical/scientific

The present study addresses the optimal fit between technical innovations in aviation and aircraft operators. Because of the increase in computerization, an accurate and efficient monitoring of the automation poses a key challenge to future operators. As the German Aerospace Center's Department of Aviation and Space Psychology is responsible for personnel selection of pilots and air traffic controllers, our objective for the selection of future personnel is to distinguish good monitoring operators from bad operators. In order to identify good monitoring behavior we developed a simulation tool that represents tasks of pilots and controllers within a dynamic air traffic flow. Participants have either to monitor the automatic process or to control the dynamic traffic manually. Monitoring behavior is measured by recording eye movement parameters. The identification of accurate monitoring behavior enables us to adapt selection profiles to future ability requirements.

Hastings, P. A., M. Merriken, et al. (2000). "An analysis of the costs and benefits of a system for FAA safety inspections." International Journal of Industrial Ergonomics 26(2): 231-248. http://linkinghub.elsevier.com/retrieve/pii/S0169814199000682

*Civilian, aviation, HSI tool (organisational change), personnel (workload), cost-benefit, case study

Utility analysis is a special case of cost-benefit analysis in which the targeted benefit is an improvement in work performance. Utility analysis is ordinarily used to estimate the dollar value of implementing one hiring procedure over a previous hiring procedure with a lower validity. Utility analysis can also be extended to situations in which workforce productivity changes as a result of an organizational intervention. In the present study utility methods were applied to an organizational change within the Federal Aviation Administration (FAA) that attempted to improve the workflow of aviation safety inspectors. The On-line Aviation Safety Inspection System (OASIS) allows FAA safety inspectors to log inspections using portable computers. This study estimates performance gains in dollars after the implementation of OASIS. The study found that aside from qualitative benefits such as better usability, the new system also saved labor time (about 19.2% of an inspector's workday). Conservative estimation procedures based on time data estimated by aviation safety inspectors indicated a net value derived from saved labor cost in excess of $16 million over the course of four years. Relevance to industry Many types of qualitative and quantitative data can support the effectiveness of performance improvement programs. However, much of this data is poorly understood by decision-makers. Utility analyses provide well-understood financial evaluations of human capital investments that are readily comparable to other business investments. (C) 2000 Elsevier Science B.V. All rights reserved.

Hawley, J. K. (2007). Looking Back at 20 Years of MANPRINT on Patriot: Observations and Lessons, Army Research Laboratory. http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA472740&Location=U2&doc=GetTRDoc.pdf

defence, army, ordnance, case study

During the combat operations phase of Operation Iraqi Freedom (OIF), Patriot air and missile defense units were involved in two fratricide incidents. Patriot's unacceptable fratricide rate during OIF (18% of engagements) prompted the commanding general of the Army Air and Missile Defense Center to request a human-performance-oriented assessment of the fratricide incidents to complement the official Army board if inquiry investigation. This report summarizes the results and recommendations from that assessment. Recommendations for a solution to the fratricide problem involved both command and control and training modifications. The paper's primary focus is MANPRINT observations and lessons from the Army's 25-year developmental effort with Patriot. Specific observations on the Patriot MANPRINT program gleaned from a review of assessments and test reports going back 20 years are presented and discussed. This material is followed by a discussion of broader lessons from the Patriot MANPRINT program. These broader lessons include: (1) going-in concepts really matter, (2) training issues really matter, (3) testing must be more comprehensive and rigorous, and (4) lessons must be learned. Implications of the specific observations and broader lessons for the MANPRINT program going forward also are presented and discussed. The observations and lessons discussed in the report are presented in the spirit of action research, defined as research that any community of practice can do to improve its methods. In this sense, the spirit of the report is institutional learning and practice improvement rather than after-the-fact criticism.

Heape, S. and C. Lowe (2009). Effective human factors integration in the design of a signalling and train control system for the metro rail industry. Third International Conference on Rail Human Factors. http://www.liv-systems.com/documents/EffectiveHFI.pdf

civilian, rail, human factors integration implementation

This paper describes an approach to Human Factors Integration (HFI) in a Metro based context where assurance standards based on goals and process are used. We describe how different elements of a HFI programme can be united into a successful approach that is compatible with the wider processes in engineering and assurance. Central to this process was the Human Factors Integration Plan (HFIP) and engagement of the user group through structured and incremental operability evaluation.

We found that the HFIP must remain flexible to the inevitable changing project circumstances and management and engineering demands. Thus helping to keep the HFI timely and effective and responding to current and future project concerns. This maintained project acceptance and belief in the value of Human Factors (HF).

Hendrick, H. W. (1996). Good ergonomics is good economics. Proceedings of the Human Factors and Ergonomics Society 40th Annual Meeting, Human Factors and Ergonomics Society. http://www.hfes.org/web/pubpages/goodergo.pdf

civilian, military, cost-benefit, case studies

Hiltz, J. A. (2005). Damage Control and Crew Optimization, Defence R&D Canada - Atlantic. http://www.dtic.mil/cgi-bin/GetTRDoc?Location=U2&doc=GetTRDoc.pdf&AD=ADA436391

defence, navy, canada, manning, crewing

The Canadian Navy has identified the reduction of through life costs of ships as a priority. As crewing levels are the major contributor to through-life (total operating) costs, this has led to an increased interest in how crewing levels can be reduced without jeopardizing the ship's ability to complete its mission. Labour intensive operations, such as fire and damage control, become a major concern when ships are being designed to operate with reduced crewing levels.

To aid in addressing the challenges arising from attempts to reduce crewing levels and maintain or enhance damage control, DRDC Atlantic has initiated a project entitled Damage Control and Crew Optimization. In this memorandum, the elements of the proposed program are discussed.

Results

The proposed work plan for this project has four elements. These are the use of functional analysis in conjunction with modeling and simulation to evaluate the effectiveness of several crewing level/automation for damage control technology configurations, reviews of damage and fire control technologies, the identification of materials with enhanced damage and fire tolerance, and the evaluation and demonstration of remote condition monitoring systems.

Significance

Functional analysis in conjunction with modeling and simulation will be used to determine how automation will affect crewing level requirements. Conversely, if crew levels are mandated this type of analysis can be used to determine the level of automation required to ensure that damage control can be carried out effectively.

The reviews of damage and fire control technologies will indicate the current state-of-the-art and indicate gaps in these technologies. These reviews will be used to provide input of automation levels in the modeling and simulation studies.

Materials with enhanced damage and fire tolerance improve ship survivability. A critical review of the availability of these materials will also indicate opportunities and requirements for further research and development.

Condition monitoring systems are critical to reduced crewing levels and damage control systems.

Hobbs, A., B. Adelstein, et al. (2008). Three principles of human-system integration. Proceedings of the 8th Australian Aviation Psychology Symposium. Sydney.1 http://humansystems.arc.nasa.gov/publications/3Principles_HSI.pdf

civilian (aerospace), US, HSI, Review / discussion (description, practices), Research (safety, reliability, methods)

Early spacecraft such as Gemini and Apollo were developed at a time when the field of human factors was still in its adolescence. Nevertheless, human factors design principles were applied to controls and displays. In recent years, human factors considerations were key determinants of planned upgrades to the avionics of the space shuttle. The field of human factors has matured significantly since the first days of manned spaceflight. It is reasonable to expect that the profession can now make a greater contribution to the design and construction of complex equipment than was the case 40 years ago.

NASA has announced that the space shuttle fleet will be retired in 2010 and will be replaced by a new launch vehicle “Orion” to enter service in 2015. As NASA embarks on the development of the new space transport system, it must evaluate whether the design optimizes human-system integration.

Inadequate human system integration has costs not only in terms of safety and mission effectiveness, but also increases the overall complexity of the system, increases the time needed to perform tasks, complicates training and maintenance, while decreasing the capabilities of the system.

In 2006, the Astronaut Office at NASA Johnson Space Center (JSC) requested the NASA Engineering and Safety Center (NESC) to assess best practices for developing a crewed space vehicle that is both reliable and robust. The NESC defined reliability as being “free of failures throughout its mission” and robustness as “tolerant of unexpected conditions should they arise”. Groups were assigned to the range of spacecraft subsystems including propulsion, structures, avionics, software, and the human element, and in each case consider how reliability and robustness can be achieved. The conclusions of the human factors group are briefly summarized in this paper. The full report can be found in Adelstein, Hobbs, O'Hara & Null (2006).

Although the terms reliability and robustness are widely used, it is no simple matter for a customer to evaluate whether a system has been designed to maximize these characteristics. A common pattern in many industries is for human factors expertise to be called in once the system design has been finalized, either to help solve problems stemming from poor design, or to certify that the system meets requirements. This paper, in contrast, is about the involvement of human factors at all stages of the design and construction process, from concept development, through to operation.

Booher (2003) distinguishes between six levels of complexity in socio-technical systems, ranging from very highly complex systems that often operate in unpredictable environments (Level A) through to devices and parts that serve limited functions in more predictable environments (Level F), see Table 1. Human/system interactions occur at all levels of the hierarchy. Good human/system interface of subsystems and parts at the D-F level is a necessary pre-condition for satisfactory system performance at higher levels, but in no way guarantees the effectiveness of the overall system.

The safety performance of complex systems is a growing area of research (see Hollnagel, Woods and Leveson, 2006). While acknowledging the need to understand the performance of complex organizations, our focus in this report was on how the human-system interfaces at the D-F level on board the Orion crew vehicle could be designed to maximize reliability and robustness. Many thousands of people perform key roles in the operation of a space transport system, from managers to control room operators. In this document however, we deal with the human factors associated with direct physical contact with the Orion vehicle during construction, testing, operation and maintenance.

Holness, K. (2003). Personnel assignment from a human factors perspective, Human Factors and Ergonomics Society.47: 1394-1398 http://www.ingentaconnect.com/content/hfes/hfproc/2003/00000047/00000012/art00003

EP185, DOWNLOAD

This paper presents a review of the personnel assignment problem, including summaries of its key factors and objectives. Previous military research in this field, such as the MANPRINT initiative and recent personnel assignment research in operations research are briefly reviewed. The relevance of personnel assignment research with a primarily human factors focus is discussed, with an emphasis on macroergonomics for achieving optimal personnel assignment solutions.

Hosman, R. and H. Stassen (1999). "Pilot's perception in the control of aircraft motions." Control Engineering Practice 7(11): 1421-8. http://linkinghub.elsevier.com/retrieve/pii/S0967066199001112

Civilian, aviation, HSI tool (modelling operation/perception), HFE, performance, technical/discussion

For proper manual aircraft control, the pilot has to perceive the motion state of the aircraft. In this perception process both the visual and the vestibular systems play an important role. To understand this perception process and its impact on a pilot's control behavior a descriptive model was developed. The single-channel information-processor model was applied as the basic structure of the final model. Three groups of experiments were performed to refine the model structure and to define the majority of the model parameters. The model has been evaluated by measuring the control behavior in tracking tasks.

Hosman, R. J. and M. Mulder (1997). "Perception of flight information from EFIS displays." Control Engineering Practice 5(3): 383-90. http://www.sciencedirect.com/

Civilian, aviation, operation, HFE, performance, scientific/ experimental

A pilot's perception of variables presented on the Electronic Flight Instrument System, EFIS, was investigated. A stimulus response technique was used to determine the accuracy and speed of the perception process. By varying the exposure time of the stimuli, it is shown that the perception of a variable's magnitude is faster and more accurate than the perception of the first derivative or rate of that variable. Results of experiments on roll and pitch attitude perception, the influence of scale division, and the perception of the indicated airspeed, are shown.

Houghton, R., C. Baber, et al. (2008). "WESTT (workload, error, situational awareness, time and teamwork): an analytical prototyping system for command and control." Cognition, Technology & Work 10(3): 199-207. http://dx.doi.org/10.1007/s10111-007-0098-4

Military, UK, DCL, HSI (HFE, training, personnel), discussion, description, performance, tools

Modern developments in the use of information technology within command and control allow unprecedented scope for flexibility in the way teams deal with tasks. These developments, together with the increased recognition of the importance of knowledge management within teams present difficulties for the analyst in terms of evaluating the impacts of changes to task composition or team membership. In this paper an approach to this problem is presented that represents team behaviour in terms of three linked networks (representing task, social network structure and knowledge) within the integrative WESTT software tool. In addition, by automating analyses of workload and error based on the same data that generate the networks, WESTT allows the user to engage in the process of rapid and iterative "analytical prototyping". For purposes of illustration an example of the use of this technique with regard to a simple tactical vignette is presented.

Houghton, R. J., C. Baber, et al. (2006). "Command and control in emergency services operations: a social network analysis." Ergonomics 49(12-13): 1204-25. http://bura.brunel.ac.uk/bitstream/2438/1737/1/Command_and_Control_in_emergency_services_operations_Houghton_et_al.pdf

Civilian, other industries (police, fire), HSI tool, (team) performance, simulated case studies

There is increasing interest in the use of social network analysis as a tool to study the performance of teams and organizations. In this paper, processes of command and control in the emergency services are explored from the perspective of social network theory. We report a set of network analyses (comprising visualization, a selection of mathematical metrics, and a discussion of procedures) based on the observation of six emergency service incidents: three fire service operations involving the treatment of hazardous chemicals, and three police operations involving immediate response to emergency calls. The findings are discussed in terms of our attempts to categorize the network structures against a set of extant command and control network archetypes and the relationship between those structures; comments on the qualities the networks display are put into the contexts of the incidents reported. We suggest that social network analysis may have a valuable part to play in the general study of command and control.

Hoyland, S. and K. Aase (2009). Does change challenge safety? Complexity in the civil aviation transport system. Safety, Reliability and Risk Analysis: Theory, Methods and Applications, Vols 1-4: 1385-1393 http://www.annals.org/content/142/9/756.full

Civilian, aviation, HSI tool (system change), HSI all, safety, case studies

The paper describes our attempt at mapping the complexity of the civil aviation system, in terms of how changes affect safety and interactions between actors within the system. Three cases were selected to represent three distinct levels of the transport system: the civil aviation authority case, the air traffic control/airport operation case and the maintenance case. Through the complexity perspective, we identified several positive system characteristics or mechanisms that contributed to maintain and improve safety during change processes, including a strong safety consciousness, collective coordination among individuals, and safety practices based on flexibility and knowledge sharing. These system characteristics were strengthened by changes with a positive perceived influence on safety, such as new technology improving flight safety. However, changes involving efficiency, merging and relocation were perceived to influence safety negatively by creating conflicts of priorities and reducing safety margins. The mixed effects of changes represented a common challenge across the three case organizations.

Human Factors Integration Defence Technology Centre (2006). Cost Arguments and Evidence for Human Factors Integration. http://www.hfidtc.com/pdf/cost_justifying_hfi.pdf

military, UK, DCL (design, acquisition, service, disposal), HSI (HFE,safety, training, personnel, manpower), Research-all, review (technical, discussion), case study, review, discussion, evaluation, description, performance, safety, cost, methods, tools

Considering the human elements of socio-technical systems is critical to ensure safe and efficient system performance. However, quantifying cost benefits of Human Factors Integration (HFI) efforts is often perceived as difficult. This is largely due to the indirect nature of HFI effects, and the problems of clearly linking HFI activities to the breadth of savings. This is the case both retrospectively, when identifying evidence of past HFI benefits or oversights - and prospectively, when allocating budgets at early project stages when uncertainty is high.

When making the case for HFI through its potential for cost savings, the argument has to consist of two sides. Firstly, major cost areas need to be identified that HFI may have an influence on. Secondly, the ways through which HFI can affect these costs need to be shown clearly. This paper identifies specific functions and benefit categories through which HFI can add value. The focus is on identifying the central influences of HFI activities, as part of a complete HFI process throughout the system lifecycle. This paper identifies requirements and approaches for cost-justifying HFI grounded in suitable evidence, and supported by suitable arguments.

This report was produced by combining:

Cost-Justifying HFI (WP 3.7.2): A comprehensive approach to provide evidence and guidance

Cost-Justifying HFI (WP 3.7.2): Case Studies

Human Factors Integration Defence Technology Centre (2008). "Developing Guidelines for Distributed Teamwork: Review of the Literature and the HFI DTC's Distributed Teamwork Studies." http://www.hfidtc.com/research/command/c-and-c-reports/phase-2/HFIDTC-2-8-6-2-1-dis-teamwork-guidelines.pdf

Military, UK, DCL, HSI (HFE, training, personnel, manpower), review, case study, description, evaluation discussion, performance, methods, tools

Distributed teams are increasingly being employed within complex systems and rapid technological advances are affecting the ways in which they work and can potentially work. Despite this, guidance on how distributed teams should work, how they should be organised and trained, what communications technology they should use and how support systems should be designed is not readily available. This report presents, based on a review of the relevant literature and also a series of naturalistic case studies undertaken previously by the HFI DTC, a series of initial guidelines on how teams, systems, technology and procedures should be designed and organised in order to enhance distributed team working performance

Human Factors Integration Defence Technology Centre (2008). "HFI DTC: Guidance for Improving HFI in Design Trade-offs."

Defence, military, UK, HSI, case study

The principal aim of this work was to enable Human Factors (HF) stakeholders to influence and contribute to trade-off decisions. This task was carried out in two stages: a research stage and a validation stage. The initial study examined the problems that exist with getting Human Factors issues considered in trade-off studies, explained the trade-off process and described the potential challenges. It then outlined a way of carrying out trade-offs that does include HF. In the validation stage, the trade-off process, along with the methods that support the process, was applied to a real project as a case study.

Human Factors Integration Defence Technology Centre (2008). "Social Network Analysis, Team Cohesion and Meaningfulness of Tasks: A Comparison Between Two Different Command and Control Paradigms." http://www.hfidtc.com/research/command/c-and-c-reports/phase-2/HFIDTC-2-2-17-3-team-cohesion.pdf

Military UK, DCL HSI (HFE, training, personnel, manpower), discussion, description, performance, methods

What is this report about?

This report is about subjecting commonly held beliefs about the benefits of Network Enabled Capability (NEC) to direct empirical tests from a Sociotechnical Systems perspective. It is hypothesised that NEC should not just lead to widespread changes in the type and structure of communication but that this should be mirrored in a corresponding improvement in the experience of people working within it.

Background and reasoning behind the work:

There is good reason for wanting to endow command and control with open systems behaviour under the aegis of NEC. One reason is that experience within various civilian domains is encouraging; in particular, the use of Sociotechnical Systems theory has been bestowing NEC-like properties upon organisations for over fifty years and has an impressive track record of success. This provides the theoretical background necessary for exploring not just the technical effectiveness of NEC systems but also their success in terms of the experience of people working within them; an experience that is shown to be critical for eliciting the type of self-synchronisation hoped for.

What was undertaken in the research?

The Brunel University NEC test-bed enabled a traditional hierarchical command and control organisation to be pitted against a network centric alternative on a common task, performed thirty times, by two teams. Social Network Analysis provided a means to analyse the content and structure of communications which was complemented by a selfreport cohesion questionnaire.

What was discovered?

The results of a Social Network Analysis show that the NEC condition facilitated more communications and informationally richer ones too. There was also structural evidence to suggest the presence of elevated levels of distributed leadership and autonomy. The main finding was that this translated into a subjective experience of the same, as measured by a simple self-report team cohesion scale.

Military relevance of the work:

The current study provides an interesting advance on existing methods and an empirical basis to support one of the central assumptions driving forward the implementation of NEC.

Human Factors Integration Defence Technology Centre (2009). "A Review of After Action Review Practice for Collective Training in the British Army." http://www.hfidtc.com/research/training/training-reports/phase-2/HFIDTC-2-12.1.2-1-aar-british-army.pdf

Military (Army), (land), UK, HSI (training, personnel, manpower), review, discussion, evaluation, description, performance, methods, tools

The Training Development Team based at the Land Warfare Centre (LWC), Warminster, is considering ways of improving the effectiveness of the After Action Review (AAR) by way of gaining a deeper understanding of current AAR practice - both in the UK and in the USA and Canada. A qualitative approach was taken and analysis of unstructured information from a number of sources enabled insight into attitudes and behaviours with relation to the AAR process. The data sources were:

a) Literature review.

b) Army doctrine.

c) Visits to UK Army training establishments to carry out observations and interviews.

The literature review showed that the effectiveness of the AAR can be impacted by many different factors, not just the AAR event itself, starting with the training design process.

These factors include training design and measurement, timing and attendance, format and content of the AAR, facilitation of the AAR, training and the take home package.

The results showed that current Army documentation is, generally, in-line with best practice. There were some instances where the literature made recommendations which were not covered by the Army Field Manual (2004), these included design of metrics, time post-training to consolidate learning and audience familiarity with the AAR. There are also some instances where the Army Field Manual (2004) gives guidance, for example the person specification for Observer/Controllers (O/Cs) and details of roles and responsibilities, but nothing quite so specific was found in the literature.

Following the review of the literature and the Army Field Manual, the data from the interviews was analysed. Grounded Theory analysis was carried out which enabled the development of a model to show the tenets of best practice from the point of view of those involved in the process. The components of the model are as follows: Pre-exercise considerations; Metrics; AAR strategy; The Analyst and their role; The O/C; Content of AAR; Delivery of the AAR; Data gathering; and Technology.

The research concluded that the procedures the Army currently have in place essentially match the 'best practice' identified from the literature review. The data gathered during the interviews suggests that current practice is largely carried out in accordance with Army documentation, although there are some issues which might be reviewed and considered for the future.

The following recommendations were made:

1. Ensure that current Army procedures are followed correctly across all training establishments.

2. Development of a framework of metrics for use throughout collective training establishments is recommended.

Human Factors Integration Defence Technology Centre (2009). The people in systems TLCM handbook. www.hfidtc.com/pdf/TLCM-handbook.pdf

Defence, military, HSI

Hunn, B. P. and O. H. Heuckeroth (2006). A Shadow Unmanned Aerial Vehicle (UAV) Improved Performance Research Integration Tool (IMPRINT) Model Supporting Future Combat Systems, U.S. Army Research Laboratory, Aberdeen Proving Ground. http://www.arl.army.mil/arlreports/2006/ARL-TR-3731.pdf

Defence, aviation, military, workload, modelling

This study describes the creation of an IMPRINT (Improved Performance Research Integration Tool) model to describe crew workload levels in the Shadow unmanned aerial vehicle (UAV). Field data were collected for tasks performed by Shadow UAV crews. This model was developed to support the Army's Future Combat System, human robotics interaction Army Technology Objective. The design and operation of this model are discussed, along with several workload conclusions based on the model's operation. Workload for individual crew members and as a crew entity is discussed.

Hunn, B. P., K. M. Schweitzer, et al. (2008). IMPRINT Analysis of an Unmanned Air System Geospatial Information Process, U.S. Army Research Laboratory, Aberdeen Proving Ground. http://www.dtic.mil/cgi-bin/GetTRDoc?Location=U2&doc=GetTRDoc.pdf&AD=ADA486680

defence, aviation, workload modelling, manning

This study evaluated the streaming video analysis portion of the geospatial intelligence process associated with an unmanned aircraft system, which provides information to a four-person, military intelligence, geospatial analysis cell. The Improved Performance Research Integration Tool (IMPRINT) modeling program was used to understand this process and to assess crew workload during several test scenarios. Based on the use of IMPRINT, recommendations are made regarding the level of staffing for this type of system, based on crew workload characteristics discovered. This initial model was the first segment of a more comprehensive model to be developed to look at full mission conditions for a 12-hour shift.

Johnson, J. A., D. B. Osborn, et al. (2005). "Human Systems Integration/Manning Reduction for LHD-Type Ships." <u>**Technology Review Journal**</u> **Fall/ Winter 2005. http://www.incose.org/hra/upcoming_events/05FW_Johnson.pdf**

military (Navy), maritime, US, DCL, HSI, manning, manpower, cost-benefit, case study

Sailors are the source of one of the U.S. Navy's highest operating costs. Recognizing that potential cost savings lie in shipboard manning reductions, the U.S. Naval Sea Systems Command contracted in December 2002 with Northrop Grumman Ship Systems to develop a manning-reduction strategy for LHD amphibious-assault-class ships. Our analysis was carried out jointly with Northrop Grumman's Information Technology, Newport News, and Electronic Systems sectors, as well as a major subcontractor, Micro Analysis & Design.

The study results showed that a reduction in manning (over legacy LHD 1 ships) of nearly 35% can be achieved using mature or relatively mature technologies and with no major modifications to the current LHD 8 design.

The reduced billet structure proved, in principle, capable of handling all manning conditions, producing an estimated life-cycle cost savings of over $1 billion per ship.

Jones, D. (2009). An Evaluation of the Effectiveness of US Naval Aviation Crew Resource Management Training Programs: A Reassessment for the Twenty-First Century Operating Environment, NAVAL POSTGRADUATE SCHOOL MONTEREY CA. http://edocs.nps.edu/npspubs/scholarly/theses/2009/Jun/09Jun_Jones.pdf

Military (Navy Aviation), US, training, safety, technical report (scientific),

Google Search "Human systems integration" cost-benefit

This thesis describes a multi-faceted evaluation of the U.S. Naval Aviation Crew Resource Management (CRM) program. CRM training is used to instruct naval aviators in safety critical, non-technical behaviors. Reactions were evaluated by using a single item from command safety climate questionnaires (n=51, 570 observations over nine years). Attitudes were assessed using a 37-item survey (364 responses). Knowledge was evaluated using a 10-item multiple-choice test (123 responses). Finally, the causes of naval aviation mishaps from fiscal years 1997-2007 (238 mishaps) were examined to identify how many were attributed to failings related to CRM concepts. It was found that aviators perceived CRM training to be useful, had positive attitudes towards concepts addressed in the training, and the level of knowledge was constant across rank and aircraft type. Nevertheless, human error still accounts for more than 80% of all mishaps in naval aviation, and over 65% of those are attributed to at least one failure in CRM. As human error continues to plague naval aviation, routine evaluations of CRM's effectiveness are critical to ensure it is achieving its goal to "improve mission effectiveness by minimizing crew preventable errors, maximizing crew coordination, and optimizing risk management" (CNO, 2001).

Aviators perceived CRM training to be useful, had positive attitudes towards concepts addressed in the training, and the level of knowledge was constant across rank and aircraft type

Jones, M. and R. Kennedy (1996). "Isoperformance Curves in Applied Psychology." <u>Human Factors</u> 38(1). http://www.ingentaconnect.com/content/hfes/hf/1996/00000038/00000001/art00013

Civilian, US, Scientific paper, Research (cost-effectiveness)

Isoperformance is based on an old idea. The usual relationship between two variables involves a determinant and an effect or, somewhat more generally, an independent and a dependent variable. Typically the determinant or independent variable is presented on the abscissa and the effect or dependent variable on the ordinate. Thus response is plotted as a function of dose, or income as a function of age or schooling.

Occasionally one sees a different relationship between two variables - namely, the relationship between two determinants that together produce a constant effect. In such a case both abscissa and ordinate are determinants. The plotted points represent equivalent combinations of the two determinants - equivalent in the sense that any one such combination produces the same specified effect as any other. In economics, relationships of this second type are usually called indifference curves. In sensory psychology and physiology, they are often called isofrequency, isochronal, or isoelectric curves or contours, or something else with the prefix iso-.

Psychophysics is the only psychological science in which plots of constant effect are frequently found. Figure 1 presents a familiar example, the scotopic luminosity curve. The abscissa is wavelength in [[micro]meter] and the ordinate, luminosity, is the reciprocal of the radiant flux at a given wavelength sufficient to produce a constant visual effect (e.g., threshold or matching brightness), relative to the maximum at 510 [[micro]meter]. There is no suggestion here that wavelength is a determinant of radiant flux. Rather, the point is that the amount of radiant flux necessary to produce the same effect on the eye varies with wavelength.

Isoperformance is not merely a formal device - that much it shares with isoappearance. It also carries a burden of content and context that contrasts sharply with that carried by the psychophysical curves, in two respects especially. First, isoperformance always involves an objective that the user is trying to achieve, a goal, an applied purpose that he or she is trying to realize. Isoappearance involves nothing of the sort. There is, after all, no difficulty in seeing a patch of light or matching brightnesses. A luminosity curve is simply an effective way to organize information.

Second, although isoappearance curves are, in fact, trade-off functions, psychophysicists do not think of them that way. A luminosity curve is primarily a way of describing the sensitivity of the eye to light of different wavelengths. The trade-off between radiant flux and wavelength is incidental. It has no interest or importance of its own.

In isoperformance, however, trade-off functions are central, mainly because of what is being traded off. It costs money to train workers or military personnel. It also costs money to recruit high-aptitude people or to engineer equipment to be usable by low-aptitude people. Trading off is an economic idea, and it is important outside economics only when the stakes involved, when the variations traded off, have heavy economic or human implications.

Isoperformance is a cost-effectiveness method. The usual approach to cost-effectiveness is to maximize effectiveness subject to constraints such as cost, safety, and feasibility. The same elements reappear in isoperformance but in altered roles. Effectiveness is no longer to be maximized. Instead, a particular level of effectiveness is to be singled out in advance and stated as an objective. Maximization is replaced by the derivation of isoperformance curves. The constraints, too, are still there, but they no longer serve as boundaries on a maximization process. In isoperformance, considerations such as cost, safety, feasibility, and (usually, to some degree) arbitrary decisions serve as secondary criteria for the selection of a single solution out of the many defined by an isoperformance curve. Altogether, isoperformance is less goal-oriented than the usual approach and more involved with means - that is, with the interplay of determinants both with one another and with what we have just called secondary criteria.

All this is foreign to isoappearance curves. The sensitivity of the eye is not in itself an economic issue. Costs and cost-effectiveness belong to a realm of discourse other than psychophysics. The formal core of the isoperformance readout may be the same as that in, say, the luminosity curve, but it arose in so different a context and in response to such different demands that it amounts (almost) to a new idea. In the next section we review the origins of the isoperformance idea. We then discuss the trade-off used in developing isoperformance - namely, that between aptitude and time on ...

Jou, Y.-T., C. Lin, et al. (2009). “The implementation of a human factors engineering checklist for human-system interfaces upgrade in nuclear power plants.” Safety Science 47: 1016-1025.

Nuclear, civilian, HFE tools

The primary purpose of this paper is to provide a human factors engineering (HFE) checklist for human- system interfaces (HSIs) upgrades in nuclear power plants (NPPs). The HFE checklist is used to review the HSIs design submittals prepared by licensees or applicants for a license or design certification of a HSI upgrade. NUREG-series regulation documents are used to develop the main frame of the initial HFE checklist. The contents of the HFE checklist are constructed by the theories and principles governing human factors. Then, verification and validation (V&V) of the HFE checklist is accomplished by validity and reliability evaluation. The results show that the HFE checklist has sufficient validity and reliability for the review of HSI upgrades in NPPs.

Jung, H. (2001). "Establishment of overall workload assessment technique for various tasks and workplaces." <u>International Journal of Industrial Ergonomics</u> 28(6): 341-353. http://www.sciencedirect.com/

Civilian, HSI methods, workload

A model for assessing workloads called overall workload level (OWL) was developed by introducing linguistic variable sets and applying the analytic hierarchy process (AHP) to estimate the external workload imposed on a human operator in man-machine systems. To do this, a five-point linguistic variable set scale was constructed and their hierarchical prioritization procedures were set up. The task and workplace variables (e.g., physical, environmental, postural, and mental job demand workloads) which can obtain the operator's perception of workload are selected as workload factors and the AHP technique is used to collect different weights. Finally, OWL is calculated using a computer-assisted system to determine the level of overall workload impinged on an operator. The OWL was implemented in an actual industrial environment from a physiological and epidemiological viewpoint to determine the validity of the model. Furthermore, the results obtained by applying OWL were compared to the results obtained by applying the overall workload (OW) of the NASA task load index (TLX). The results show that there is a close linear relationship among the physiological measurements, the severity of injury and illness rates, OW, and OWL. Thus, this approach can be used for problem identification and for solving widespread occupational workloads.

Relevance to industry

The determination of workloads imposed on a human operator plays an important role in designing and evaluating an existing man-machine system. Therefore, a model for assessing workloads was developed to estimate the external workload imposed on a human operator in man-machine systems. This model can be used for problem identification and for solving widespread occupational workload.

Author Keywords: Overall workload level; Workload assessment; External workload estimation; Workload perception

Kaber, D. B., M. C. Wright, et al. (2005). "Adaptive automation of human-machine system information-processing functions." <u>Human Factors</u> 47(4): 730-41. http://hfs.sagepub.com/cgi/content/abstract/47/4/730

Civilian, aviation, training (computer simulation), HFE, performance, scientific (experimental)

The goal of this research was to describe the ability of human operators to interact with adaptive automation (AA) applied to various stages of complex systems information processing, defined in a model of human-automation interaction. Forty participants operated a simulation of an air traffic control task. Automated assistance was adaptively applied to information acquisition, information analysis, decision making, and action implementation aspects of the task based on operator workload states, which were measured using a secondary task. The differential effects of the forms of automation were determined and compared with a manual control condition. Results of two 20-min trials of AA or manual control revealed a significant effect of the type of automation on performance, particularly during manual control periods as part of the adaptive conditions. Humans appear to better adapt to AA applied to sensory and psychomotor information-processing functions (action implementation) than to AA applied to cognitive functions (information analysis and decision making), and AA is superior to completely manual control. Potential applications of this research include the design of automation to support air traffic controller information processing.

Karwowski, W. and T. Ahram (2009). "Interactive Management of Human Factors Knowledge for Human Systems Integration Using Systems Modeling Language." Information Systems Management 26(3): 262-274. http://www.informaworld.com/index/913050095.pdf

Military (Navy, Air Force, Army), (land, maritime, aerospace), Australia, DCL (design, acquisition, service, disposal), HSI (HFE,safety, training, personnel, manpower), scientific, case study, review, discussion, evaluation, description, performance, safety, cost, methods, tools

The field of Human Factors in Knowledge Management is often seen as a problem of capturing, organizing, and retrieving information to build knowledge. This process is inextricably bound up with human cognition and, as such, the management of knowledge occurs within an intricately structured behavioral, cultural, and social context. This paper emphasizes the importance of interactive human factors in knowledge management and introduces a model-based human systems integration framework based on systems modeling language (SysML).

Keywords: human systems integration; knowledge management; systems modeling language

Kelly, C. (2010) Urgent Operational Requirements - Improving effectiveness through Human Factors Integration (HFI). HFI DTC Newsletter 6-7 http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA330776&Location=U2&doc=GetTRDoc.pdf

military (army), land, UK, DCL (acquisition), HSI (HFE, training), case study, description, performance, methods

Urgent Operational Requirements (UORs) are a major and increasingly important feature of today's Operations.

As its name implies, a UOR is a requirement for the rapid procurement of defence capability in support of a current or imminent military Operation. The UOR has to be procured for a theatre-specific purpose, and it must be introduced into service in time to contribute to the Operation. Because such requirements cannot be met within the timescale of the normal acquisition cycle of the Equipment Programme (EP), UORs are procured through a separate, fast-tracked acquisition process. Numerous UORs have been procured in recent years and successfully deployed in theatre, testifying to the effectiveness of both the process and the delivered capabilities.

Kemmerer, K. (2008). Tactical Decision Making under Categorical Uncertainty with Applications to Modeling and Simulation. NAVAL POSTGRADUATE SCHOOL MONTEREY CA. http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA493954&Location=U2&doc=GetTRDoc.pdf

Military (Navy), (maritime), US, DCL (design), HSI (HFE), discussion, description, performance, methods

The field of Human Factors in Knowledge Management is often seen as a problem of capturing, organizing, and retrieving information to build knowledge. This process is inextricably bound up with human cognition and, as such, the management of knowledge occurs within an intricately structured behavioral, cultural, and social context. This paper emphasizes the importance of interactive human factors in knowledge management and introduces a model-based human systems integration framework based on systems modeling language (SysML).

Keywords: human systems integration; knowledge management; systems modeling language

Kennedy, J. and M. McCauley (2007). "A Human-Automation Interface Model to Guide Automation Design of System Functions." Naval Engineers Journal 119(1): 109-124. http://www3.interscience.wiley.com/journal/120175185/abstract

Military (Army), land, US, DCL (design), HSI HFE discussion description tools,

A major component of the US Army's Future Combat Systems (FCS) will be a fleet of eight different manned ground vehicles (MGV). There are promises that ''advanced automation" will accomplish many of the tasks formerly performed by soldiers in legacy vehicle systems. However, the current approach to **automation design** does not relieve the soldier operator of tasks; rather, it changes the role of the soldiers and the work they must do, often in ways unintended and unanticipated. This paper proposes a coherent, top-down, overarching approach to the design of a human-automation interaction model. First, a qualitative model is proposed to drive the functional architecture and human-automation interface scheme for the MGV fleet. Second, the proposed model is applied to a portion of the functional flow of the common crew station on the MGV fleet. Finally, the proposed model is demonstrated quantitatively via a computational task-network modeling program (Improved Performance Research and Integration Tool). The modeling approach offers insights into the impacts on human task-loading, workload, and human performance. Implications for human systems integration domains are discussed, including Manpower and Personnel, Human Factors Engineering, Training, System Safety, and Soldier Survivability. The proposed model gives engineers and scientists a top-down approach to explicitly define and design the interactions between proposed automation schemes and the human crew. Although this paper focuses on the Army's FCS MGV fleet, the model and analytical processes proposed, or similar approaches, are appropriate for many manned systems in multiple domains (aviation, space, maritime, ground transportation, manufacturing, etc.).

Kennedy, R. S. and M. B. Jones (1992). Simulating the Impact of MPTS Trade-off Decisions by Application of the Isoperformance Methodology. http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA274607&Location=U2&doc=GetTRDoc.pdf

Military, Navy, HSI tool, performance (isoperformance), cost-effectiveness, discussion with practical examples of using trade-offs

Isoperformance is a trade-off methodology. Given a desired or good-enough level of performance, it indicates all combinations of performance determinants that will produce that level of performance. The traded-off determinants may be personnel aptitude and training, two equipment variants, two kinds of training (for example, simulator and field training or simulator alone and distributed interactive simulation), or any other pair of determinants. Visual presentation of isoperformance outcomes becomes a problem, but extensions to three or more determinants are also possible and, analytically, uncomplicated. The present report begins with a discussion of isoperformance methodology in relation to HARDMAN III. Very briefly, isoperformance methods and HARDMAN III are complementary. HARDMAN III determines manpower, personnel, and training constraints within which a design solution adequate to produce the required level of system performance must be found. Isoperformance eventuates in isoperformance curves (trade-off functions) adequate to produce the required level of system performance. If one starts with HARDAMA III, isoperformance methodology fills in the solution space within the HARDIN constraints. If one starts with isoperformance curves, HARDNAN constraints can then be imposed to exclude unacceptable solutions. The result (a set of acceptable determinant combinations) Is the same in either case. A final design solution can then be determined by costbenefit analysis, which isoperformance curves allow. Following this discussion, the report takes up the case of trade-offs either from simulator training to field training or from one training simulator to another. A showing is made that Roscoe's treatment of this case (transfer effectiveness ratios) is derivative from isoperformance theory. Finally, a series of real-world isoperformance curves are constructed from data archived at the Navy Training and Performance Data Center (TPDC). The curves concern tank-maintenance mechanics and all four involve the trade-off between aptitude and training plus time-in-unit. The results indicate that low-aptitude mechanics (the bottom third) require as much as six months longer to become proficient than do average or high-aptitude mechanics (the upper two thirds).

Khan, F. I., R. Sadiq, et al. (2002). "Risk-based process safety assessment and control measures design for offshore process facilities." Journal of Hazardous Materials 94(1): 1-36. http://www.engr.mun.ca/~fkhan/EN-6601/Case%20study.pdf

Civilian, other industry (offshore drilling), design, HFE, safety, case study

Process operation is the most hazardous activity next to the transportation and drilling operation on an offshore oil and gas (OOG) platform. Past experiences of onshore and offshore oil and gas activities have revealed that a small mis-happening in the process operation might escalate to a catastrophe. This is of especial concern in the OOG platform due to the limited space and compact geometry of the process area, less ventilation, and difficult escape routes. On an OOG platform, each extra control measure, which is implemented, not only occupies space on the platform and increases congestion but also adds extra load to the platform. Eventualities in the OOG platform process operation can be avoided through incorporating the appropriate control measures at the early design stage. In this paper, the authors describe a methodology for risk-based process safety decision making for OOG activities. The methodology is applied to various offshore process units, that is, the compressor, separators, flash drum and driers of an OOG platform. Based on the risk potential, appropriate safety measures are designed for each unit. This paper also illustrates that implementation of the designed safety measures reduces the high Fatal accident rate (FAR) values to an acceptable level. (C) 2002 Elsevier Science B.V. All rights reserved.

King, R. B. (1999). "Performance Measurement in Operational and Complex Simulation Environments." Ergonomics Australia. http://ergonomics.uq.edu.au/eaol/dec99.pdf

military, Australia, HSI tool, discussion paper (academic)

Recent times have seen increasing importance placed on the human factors engineering (HFE) evaluation of new military systems. HF specialists generally agree that these systems should be tested and evaluated in their intended operational settings with the measure of greatest interest being complex, meaningful task performance. However, HF practitioners have encountered co siderable difficulties controlling and collecting data in operational environments. It was anticipated that complex full-mission simulation would offer a solution to these problems with control being exerted through appropriate scenario generation and simulator architectures allowing hundreds of environmental, system or task performance variables to be electronically logged. Unfortunately, the (gigabytes of) data logged in simulation studies has proven to be too low-level to be useful in evaluating task performance. A software tool implemented in PROLOG has demonstrated the viability of automatically recoding low-level data into an empirical record of meaningful task performance. This tool has been used extensively in applied work for a specific system. A generic tool of this nature would be a benefit for human factors analysts using man-in-the-loop architectures to design, test and evaluate new systems.

Kirwan, B. (2003). "An overview of a nuclear reprocessing plant human factors programme." Applied Ergonomics 34: 441-452. http://linkinghub.elsevier.com/retrieve/pii/S0003687003000644

civilian, nuclear, human factors, case study

This paper presents a case study of a large Human Factors programme applied in the nuclear fuel reprocessing industry (1987- 1991). The paper outlines the key Human Factors issues addressed, as well as the impacts achieved, and gives an indication of the resources utilised (approximately 15 person-years of effort). It also considers the starting point of the programme, in terms of the factors that led to the need for such an extensive programme. Some general lessons learned are given at the end of the paper.

Kjaer-Hansen, J. (1999). Human factors module: A business case for human factors investment., European Organisation for the Safety of Air Navigation. www.eurocontrol.int/humanfactors/.../HF17%20(HUM.ET1.ST13.4000-REP- 02)%20Released.pdf

civilian, aerospace, HSI implementation, cost benefit

Kleiner, B. (2008). "Macroegonomics: Work System Analysis and Design." Human Factors 50(3): 461. http://hfs.sagepub.com/cgi/reprint/50/3/461.pdf

Civilian HSI methods

Objective: Our goal was to briefly describe how macroergonomics was developed to fill a void in human factors and ergonomics. Background:A study commissioned by the Human Factors Society in 1978 resulted in the formalization of a new subdiscipline of human factors, called organizational design and management, which eventually was coined macroergonomics. Method: Differentiators of macroergonomics are presented along with methods adapted from other domains as well as unique methods.

Results: Based on laboratory and field studies conducted at multiple universities, government facilities, and industries, work system factors can be manipulated in the laboratory and studied in the field successfully. Also, case studies in academia, industry, and government demonstrate 60% to 90% performance impact and positive qualitative changes such as culture change.

Conclusion: Macroergonomics offers a perspective as well as methods and tools for more successful human factors and ergonomics design, development, intervention, and implementation. Application: Human factors engineers or psychologists and ergonomists can use the perspective of macroergonomics to achieve better results or can expand their involvement of macroergonomics through the use of methods and tools.

Knecht, W. R. (2008). "Testing a multidimensional nonveridical aircraft collision avoidance system." Human Factors 50(4): 565-75. http://hfs.sagepub.com/cgi/content/abstract/50/4/565

Civilian, aviation, training (computer simulation), performance, scientific (experimental)

OBJECTIVE: This study explores operators' ability to use a multidimensional, nonveridical control display.

BACKGROUND: Veridical displays represent realistic scenes. State space displays represent nonveridical n-dimensional information based on informative coordinate axes plus variable features such as color and shading. Empirical investigation of state space displays is relatively new to human factors research.

METHOD: Twelve licensed general aviation pilots flew flight scenarios, trying to deviate as little as possible from a preassigned course while still maintaining standard en route separation from traffic. Flight performance using only a veridical cockpit display of traffic information (CDTI) was compared with performance using the CDTI augmented by a 4-D nonveridical state space collision avoidance system (CDTI+4CAS). RESULTS: Using moderate traffic density and complex traffic geometry, the CDTI+4CAS condition showed performance superiority over the baseline CDTI-only condition for five of five dependent measures of maneuver efficiency, four of four measures of maneuver safety, and six of nine measures of user workload.

CONCLUSION: Results suggest that nonveridical information display may enhance operator performance on a control task involving simultaneous processing of multidimensional information.

APPLICATION: Nonveridical information displays have potential application wherever human control of multidimensional processes is involved.

Korteling, J. E. and W. van der Borg (1997). Partial camera automation in an unmanned air vehicle. IEEE Transactions on Systems, Man, & Cybernetics Part A: Systems & Humans.27:(2) 256-62 http://ieeexplore.ieee.org/iel1/3468/12081/00554688.pdf

Civilian, aviation (unmanned air vehicle), operation, HFE, performance, scientific (experimental)

The present study focused on an intelligent, semiautonomous, interface for a camera operator of a simulated unmanned air vehicle (UAV). This interface used system "knowledge" concerning UAV motion in order to assist a camera operator in tracking an object moving through the landscape below. The semiautomated system compensated for the translations of the UAV relative to the earth. This compensation was accompanied by the appropriate joystick movements ensuring tactile (haptic) feedback of these system interventions. The operator had to superimpose self-initiated joystick manipulations over these system-initiated joystick motions in order to track the motion of a target (a driving truck) relative to the terrain. Tracking data showed that subjects performed substantially better with the active system. Apparently, the subjects had no difficulty in maintaining control, i.e., "following" the active stick while superimposing self-initiated control movements over the system-interventions. Furthermore, tracking performance with an active interface was clearly superior relative to the passive system. The magnitude of this effect was equal to the effect of update-frequency (2-5 Hz) of the monitor image. The benefits of update frequency enhancement and semiautomated tracking were the greatest under difficult steering conditions. Mental workload scores indicated that, for the difficult tracking-dynamics condition, both semiautomation and update frequency increase resulted in less experienced mental effort. For the easier dynamics this effect was only seen for update frequency.

Koscheyev, V. S., G. R. Leon, et al. (2006). "Physiological design of a space suit cooling/warming garment and thermal control as keys to improve astronaut comfort, performance, and safety." Habitation 11(1-2): 15-25. http://www.ingentaconnect.com/content/cog/habit/2006/00000011/00000001/art00003

Civilian, other industry (space), design, HFE, performance, safety

We describe our past and current program of research focused on the application of physiological principles of heat transfer to advance the effectiveness of space suits currently used by astronauts and for future lunar or Mars missions. The output of these investigations is as follows: 1) a physiologically based more lightweight shortened liquid cooling/warming garment (SLCWG) designed to increase effectiveness while minimizing circulating water volume, flow rate, and energy consumption; 2) physiologically designed warming gloves with tubing bypass to mitigate hand/finger discomfort and augment heat delivery cry by blood flow; 3) augmentation of heat delivery by blood flow to improve lower limb blood circulation and sustain comfort; 4) an adequate index of thermal balance/imbalance and comfort with potential to initiate automatic thermal feedback to an advanced spacesuit portable life support system.

Kratz, E., S. Reader, et al. (2008). A Qualitative Analysis of the Navy's HSI Billet Structure, NAVAL POSTGRADUATE SCHOOL MONTEREY CA. http://edocs.nps.edu/npspubs/scholarly/theses/2008/Jun/08Jun_Kratz.pdf

Military (Navy), (maritime), US, DCL (dacquisition), HSI (HFE,safety, training, personnel, manpower), discussion, evaluation, description, methods, tools

This research was conducted in response to a request by Chief of Naval Personnel and examined the Navy's Human Systems Integration billet structure, the work requirements of the 4600 (Human Systems Integration) coded billets and the work done by officers who had a 4600 subspecialty code. The research results support the hypothesis that the work requirements of the July 2007 data set of 4600P-coded billets (billets requiring graduate education in Human

Systems Integration) was not properly representative of the Human Systems Integration competencies as developed through the Educational Skill Requirements; not all Navy Human Systems Integration work was identified by a 4600 subspecialty; and the 4600 billet structure did not allow sufficient career progression opportunities. **Despite the focus on the defense acquisition process in the Human Systems Integration curriculum at Naval Postgraduate School, the billets did not reflect this priority. In order for Human Systems Integration to be a viable subspecialty requiring graduate education, relevant billets need to be identified in the Navy. The research recommends conducting an in depth** needs analysis to better identify the Human Systems Integration work of the Navy by organiztion and subsequently leading to a better "fit" of officer category, designator, grade, education, and work experience.

Krueger, G. P. and L. E. Banderet (2007). "Implications for studying team cognition and team performance in network-centric warfare paradigms." Aviation Space & Environmental Medicine 78(5 Suppl): B58-62. Implications for studying team cognition and team performance in network-centric warfare paradigms

Military (Network-centric warfare), operation, personnel, performance, review

Network-centric warfare's (NCW) information-rich systems involving sophisticated sensors, tracking systems, smart weapons, and enhanced digital communications threaten to overload combatants with voluminous amounts of data. It is unclear whether warfighters will perceive such extensive data as actionable information to which they will respond accurately in a timely enough manner. Members of small teams in command and control centers, operating in crew-served vehicles, or simply "grunting it out" as ground-pounding infantrymen, may be disparately separated by space, but will communicate and be connected by electronic linkages, e.g., radio, text messages, situation displays, or global positioning data. However, team members will also have to remember shared mental models of tasks at hand, pay attention to and share common situation awareness in complex operational environments, perform team cognition and team coordination, and integrate both lower and higher cognitive processes with those of team behaviors. Such exceptional capabilities are required more now than ever before; such capabilities today are far from assured. After two workshops to establish performance metrics for assessing cognitive performance of military personnel in NCW, **this preface introduces five manuscripts addressing team cognition and team performance from both a theoretical and a practical perspective**. The authors of this preface question if NCW, and perhaps the politico-social ramifications of modern warfare, have already outstripped behavioral scientists' approach to researching team cognition and team performance-expertise that is so crucially needed for combatants on the rapidly changing 21st-century battlegrounds.

Landsburg, A., L. Avery, et al. (2008). "The art of successfully applying human systems integration." Naval Engineers Journal 120(1): 77-107. http://www3.interscience.wiley.com/journal/120175267/abstract

Military (Navy, Air Force, Army), (land, maritime, aerospace), US, DCL (design, acquisition, service), HSI (HFE,safety, training, personnel, manpower), case study, review, discussion, evaluation, description, performance, safety, cost, methods, tools

This paper reviews developments in human factors and then draws from a number of ''best practice" cases in studying how best to apply behavioral science principles, knowledge, and analytical tools to the engineering design or improvement of systems. Government and other commercial experiences are examined with a focus on the Navy human system integration (HSI) process. Included are discussions facilitated at a workshop session sponsored by the Transportation Research Board of the National Academies. There is general consensus that in addition to using a well-designed or proven process and doing the right things, success is dependent upon attending to a prioritized short list of critical elements. Continued focus on these elements is necessary to successfully apply human be- havioral sciences effectively during design, construction, and operation of systems to improve safety, reliability, effectiveness, efficiency, and quality of life.

Lang, J. and P. McLaughlin (2009). Analysis of the Integrated Defense Acquisition, Technology, and Logistics Life Cycle Management Framework for Human Systems Integration Documentation. NAVAL POSTGRADUATE SCHOOL MONTEREY CA. http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA514431&Location=U2&doc=GetTRDoc.pdf

Military (Navy), US, DCL (acquisition), HSI (HFE,safety, training, personnel, manpower), discussion, description, performance, safety, cost, methods

The objective of this thesis is to conduct a thorough analysis of the documentation and policy that currently exists within the Department of Defense (DoD) framework. There are numerous gaps within this documentation pertaining to Human Systems Integration (HSI) in the Integrated Defense Acquisition, Technology, and Logistics (IDAT&L)

Life Cycle. The U.S. Navy currently implements HSI at different stages throughout the Life C cle, but it lacks continuity throughout the entire process. A detailed analysis of the IDAT&L framework can potentially aid in redefining how the Navy should address HSI, by identifying areas where HSI policies and guidelines should exist, but currently do not (i.e., gaps), and then proposing ways to close those gaps and streamline the HSI process as a whole

throughout the Navy. This thesis suggests a potential, **strengthened framework for HSI in the Navy, based on the information and findings gathered from not only the current framework, but also current Navy policies**. The outcome **of this thesis is to improve the entire HSI process throughout the Navy and help ensure that HSI is used effectively throughout the acquisition process.**

Larsen, G. (1998). Event Sequence Analysis of the Air Intelligence Agency Information Operations Center Flight Operations, ADROIT SYSTEMS INC FAIRBORN OH. http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA357589&Location=U2&doc=GetTRDoc.pdf

Defence, tools, incident analysis

This report applies Event Sequence Analysis, methodology adapted from aircraft mishap investigation, to an investigation of the performance of the Air Intelligence Agency's Information Operations Center (IOC) Flight Operations crew on duty at the time of the bombing of crew quarters in the Khobar Towers building in Dhahran, Saudi Arabia. The focus of the investigation is the identification of information gathering and information transfer activities that supported the formation of crew member decision making strategies. An assessment is made of the efficacy of these activities and their utility in supporting crew member situation awareness and the formulation of decisions under stress. The events under analysis are classified as tractable, relevant, and informational, in order to identity critical areas of interest. The report includes observations and recommendations for improving information flow (eliminating bottlenecks and duplications of effort), enhancing team performance and eliminating unnecessary stressors.

Laux, L., R. Small, et al. (2008). Human System Integration Support Tools With Links to DoD System Acquisition Phases, ALION SCIENCE TECHNOLOGY. http://www.stormingmedia.us/11/1173/A117315.html

Defence, military, acquisition, tools

This report is designed to help proceduralize the human-systems integration (HSI) process by linking the flow of HSI analyses in the systems acquisition process to tools that can support those analyses. The initial sections of this report describe how this report is intended to be used, define acquisition-process and HSI terminology, and provide some HSI metrics. All HSI domains are explicitly addressed with the exception of habitability. Techniques for confirming that HSI requirements have been satisfied are also addressed. The following are included in tabular form with links that reflect the flow of analyses as HSI is integrated within the system acquisition process: - The DoD acquisition process and milestones - The acquisition phases and associated HSI activities - Tool categories for responding to different HSI questions - Detailed information about specific HSI tools including: (1) a description of the tool, (2) the tool inputs, (3) the tool outputs, (4) specific HSI metrics the tool supports, and (5) a rough estimate of the level of effort expected to use the tool.

Lazzaretti, P. (2008). HSI in the USN Frigate Community: Operational Readiness and Safety as a Function of Manning Levels. NAVAL POSTGRADUATE SCHOOL, MONTEREY, CALIFORNIA. http://www.dtic.mil/cgi-bin/GetTRDoc?Location=U2&doc=GetTRDoc.pdf&AD=ADA494067

Military (Navy), US, Manpower, safety, efficiency, technical report (case study)

Human Systems Integration (HSI) is a process designed to reduce life-cycle costs and improve system performance by considering human-related domains. Acquisition specialists lack objective, quantitative research findings on which to base trade-off analyses. This thesis used eight fiscal years of historical safety (mishaps), manpower (manning levels) and system performance (SORTS) data on the U.S. Navy's Frigates, collected from computer databases of routine reports, to explore relationships in an existing notional model of HSI. Three hypotheses were tested, there is a negative relationship between manning and SORTS levels, there is a negative relationship between manning and mishaps, and there is a positive relationship between mishaps and SORTS levels. No significant relationships were found between SORTS levels and manning or mishaps. When all of the ships were ranked for each month based on percent of total manning and number of reportable mishaps, a positive correlation (Spearman's rho = 0.4194, p-value = 0.0294) was found corresponding to a negative relationship between manning levels and mishap rates. More detailed research is needed to isolate the relationship between manning levels and mishap rates from numerous other influences and any noise that may be present in the data set.

Lee, J. and T. Sanquist (1993). Human factors plan for maritime safety: Annotated bibliography, BATTELLE HUMAN AFFAIRS RESEARCH CENTERS SEATTLE WA. http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA265392&Location=U2&doc=GetTRDoc.pdf

Civilian, maritime, HFE /HSI all, review with case studies.

This report summarizes a collection of papers related to the application of human factors to the maritime industry. These papers describe: human factors problems in the maritime industry, research designed to offer solutions, and research in other domains that may apply to these and other potential problems encountered in the maritime industry. This report has been divided into six sections, each dealing with a particular area of interest: automation, fatigue/incapacitation, manning, navigation, organizational factors, and training. Each summary includes the complete citation, a synopsis of the methodology used, issues addressed, principal findings, and any technical problems or deficiencies.... Maritime safety, Manning, Automation, Navigation, Fatigue, Organizational factors, Incapacitation, Training.

Lee, J. and B. Seppelt (2009). Human Factors in Automation Design. Springer Handbook of Automation, Springer: 417-436. http://www.springerlink.com/content/p6j697p4403g3352/

Civilian (land, maritime, aerospace, other), US, HSI (HFE, personnel, training), scientific, description, performance, safety, cost, methods, tools

Designers frequently look toward automation as a way to increase system efficiency and safety by reducing human involvement. This approach often leads to disappointment because the role of people becomes more, not less, important as automation becomes more powerfull and prevalent. Developing automation without consideration of the human operator leads to new and more catastrophic failures.

For automation to fulfill its promise, designers must avoid a technology-centered approach and adopt an approach that considers the joint operator-automation system. Automation-related problems arise because introducing automation changes the type and extent of feedback that operators receive, as well as the nature and structure of tasks. In addition, operators' behavioral, cognitive, and emotional responses to these changes can leave the system vulnerable to failure. Automation is not a homogenous technology. There are many types of automation and each poses different design challenges.

This chapter describes how different types of automation place different demands on operators.

It also presents strategies that can help designers achieve the promise of automation. The chapter concludes with future challenges in automation design.

Lenior, D., W. Janssen, et al. (2006). "Human-factors engineering for smart transport: decision support for car drivers and train traffic controllers." Applied Ergonomics 37(4): 479-90. http://www.sciencedirect.com/

Civilian, other industry (transport), design, HFE, performance, review/technical (with case studies?)

The theme Smart Transport can be described as adequate human-system symbiosis to realize effective, efficient and human-friendly transport of goods and information. This paper addresses how to attune automation to human (cognitive) capacities (e.g. to take care of information uncertainty, operator trust and mutual man-machine adaptations). An introduction to smart transport is presented, including examples of best practice for engineering human factors in the vehicle ergonomics and train traffic control domain. The examples are representative of an ongoing trend in automation and they show how the human role changes from controller to supervisor. Section 2 focuses on the car driver and systems that support, or sometimes even take over, critical parts of the driving task. Due to the diversity of driver ability, driving context and dependence between driver and context factors, there is a need for personalised, adaptive and integrated support. Systematic research is needed to establish sound systems. Section 3 focuses on the train dispatcher support systems that predict train movements, detect potential conflicts and show the dispatcher the possibilities available to solve the detected problems. Via thorough analysis of both the process to be controlled and the dispatcher's tasks and cognitive needs, support functions were developed as part of an already very complex supervision and control system. The two examples, although from a different field, both show the need for further development in cognitive modelling as well as for the value of sound ergonomics task analysis in design practice. [References: 36]

Leva, M. C., J. Cahill, et al. (2010). "The advancement of a new human factors report - 'The Unique Report' - facilitating flight crew auditing of performance/operations as part of an airline's safety management system." Ergonomics 53(2): 164-183. http://www.informaworld.com/index/918815420.pdf

Civilian, aviation, HSI tool, system safety/HSI all, review/technical

This paper presents the findings of research relating to the specification of a new human factors report, conducted as part of the work requirements for the Human Integration into the Lifecycle of Aviation Systems project, sponsored by the European Commission. Specifically, it describes the proposed concept for a unique report, which will form the basis for all operational and safety reports completed by flight crew. This includes all mandatory and optional reports. Critically, this form is central to the advancement of improved processes and technology tools, supporting airline performance management, safety management, organisational learning and knowledge integration/information-sharing activities. Specifically, this paper describes the background to the development of this reporting form, the logic and contents of this form and how reporting data will be made use of by airline personnel. This includes a description of the proposed intelligent planning process and the associated intelligent flight plan concept, which makes use of airline operational and safety analyses information. Primarily, this new reporting form has been developed in collaboration with a major Spanish airline. In addition, it has involved research with five other airlines. Overall, this has involved extensive field research, collaborative prototyping and evaluation of new reports/flight plan concepts and a number of evaluation activities. Participants have included both operational and management personnel, across different airline flight operations processes. Statement of Relevance: This paper presents the development of a reporting concept outlined through field research and collaborative prototyping within an airline. The resulting reporting function, embedded in the journey log compiled at the end of each flight, aims at enabling employees to audit the operations of the company they work for.

Leva, M. C., A. Kay, et al. (2009). Unique Reporting Form: Flight Crew Auditing of Everyday Performance in an Airline Safety Management System. Human Interface and the Management of Information: Information and Interaction. G. S. Salvendy, Michael J. (Eds.), Symposium on Human Interface 2009, Held as Part of HCI International 2009, San Diego, CA, USA, July 19-24, 2009, Proceedings, Part II. 5618: 806-815. http://www.informaworld.com/smpp/content~db=all~content=a918815420

Civilian, aviation, HSI tool, system safety/HSI all, technical.

This paper presents the proposed prototype for a Unique report form, which will constitute the basis for all operational and safety related reports completed by Flight Crew. This reporting form provides an opportunity for operational personnel to audit their own company's processes and procedures and has been developed in collaboration with a major Spanish Airline as pan of the Human Integration into the Lifecycle of Aviation Systems (HILAS) project. This research involved extensive fieldwork, including process workshops, task analysis and collaborative prototyping of new concepts. Traditionally airlines use performance monitoring tools to evaluate human performance and by implication their organizational/system safety. Feedback from these tools is used to direct improvements (re-design procedures, enhance training etc.). The Line Operation Safety Audit (LOSA) methodology constitutes the current state of the art in terms of performance monitoring. Building on this concept, end user requirements elicited were the main focus for the design of this reporting form.

Li, W., D. Harris, et al. (2009). The Application of Human Error Template (HET) for Redesigning Standard Operational Procedures in Aviation Operations. in: Engineering Psychology and Cognitive Ergonomics, Springer-Verlag Berlin Heidelberg. LNAI 5639: 547-553. http://www.springerlink.com/index/H2V5134384276485.pdf

Military, aviation, HSI tool, safety, technical/guidance/SOP

Human Error Template (HET) is a checklist style approach to predict human errors in the cockpit for developing accident prevention strategies. It is applied to each bottom level task step in a hierarchical task analysis (HTA) of the task in question. This research applies the latest technique for human error prediction- Human Error Template to predict the potential design-induced human errors in the IDF during the landing phase of flight and provide a basis for improving software design and hardware equipment to enhance flight safety. In military operations emphasis is on the fulfillment of SOPs in an attempt to prevent incidents/accidents resulting from human factors. By the use of the scientific approach of HTA to evaluate current SOPs together with formal error analysis of the pilot's, interface design and procedures, the air force's combat effectiveness will be improved and a user-friendly cockpit interface can be developed.

Liang, G., J. Lin, et al. (2009). Web-Based Training System for Improving Aviation Maintenance Performance. in: Human-Computer Interaction. Interacting in Various Application Domains, Springer Berlin / Heidelberg. 5613: 731-740. http://www.springerlink.com/index/R1N93Q22465363P6.pdf

Civilian, aviation, operation, training, simulation, performance, scientific/experimental

To increase aviation maintenance and inspection safety, we propose a web-based training system (WBTS) for technician training and performing maintenance tasks. Toward this goal, the risks of human errors were considered for each procedure from the perspectives of performance shaping factors (PSFs). WBTS functions include English and Chinese explanations, human error effects on human-machine system, human errors relative to serious rankings and frequency, and graphic information aid in each component removal and installation procedure. To verify the proposed platform, experiments were conducted on a JT8D engine during the inaugural flight of Boeing's 727 to compare traditional workcard and proposed WBTS in two complex teamwork tasks. The results revealed that teams' risk cognition, situation awareness, and performance have been increased by proposed WBTS comparing to that by the traditional work-card instructions.

Lin, L., K. J. Vicente, et al. (2001). “Patient safety, potential adverse drug events, and medical device design: A human factors engineering approach.” Journal of Biomedical Informatics 34(4): 274-284. http://linkinghub.elsevier.com/retrieve/pii/S1532046401910287

Civilian, medical, design, HFE, safety/performance, scientific (experimental)

Adverse drug events are the single leading threat to patient safety. Human factors engineering has been repeatedly proposed, but largely untested, as the key to improving patient safety. The value of this approach was investigated in the context of a commercially available patient-controlled analgesia device that has been linked with several alleged patient injuries and deaths. Several reports have stated that errors in programming drug concentration were made during these adverse drug events. A simulation of the commercially available interface was compared experimentally with a simulated prototype of a new inter-face designed according to a human factors process. Professional nurses, averaging over 5 years of clinical experience with the commercially available interface and only minimal experience with the new interface, programmed both interfaces. The new interface eliminated drug concentration errors, whereas the simulated commercially available interface did not. Also, the new interface led to significantly fewer total errors and faster performance. These findings may have broad implications for the design, regulation, and procurement of biomedical devices, products, or systems that improve patient safety in clinical settings. (C) 2001 Elsevier Science (USA).

Lindberg, R. and L. Carr (2007). “Human Systems Integration in Education and Training: A Grassroots Effort to Obtain Total Systems Performance at an Affordable Cost.” Naval Engineers Journal 119(1): 71-81. http://www3.interscience.wiley.com/journal/120175182/abstract

Military (Navy, Air Force, Army), (land, maritime, aerospace), US, DCL , HSI (HFE,safety, training, personnel, manpower), review, discussion, description, performance, safety, cost, methods, tools

Human systems integration (HSI) requires highly qualified practitioners who can effectively and affordably integrate human capabilities into new and existing weapons systems. Over the past fewyears, Congressional support of National Defense Act (HR1522) for HSI continues as evident by this statement, ‘’The committee recognizes HSI initiatives as a means for reducing total ownership costs of weapons programs, and continues to support efforts to more formally consider HSI issues earlier in the acquisition cycle.”

To do so, organizations must focus attention within the Joint Capabilities Integration and Development System (CJCSI 3170.01) and the Department of Defense (DoD) acquisition framework (DoDI 5000.2) processes. More specifically, HSI practitioners center attention on total system performance by integrating trade-offs within and across the HSI domains of manpower, personnel, training, human factors engineering, environment, safety, occupational health, survivability, and habitability.

By conducting system-level integration from concept inception to operational employment to eventual disposal, HSI practitioners can enable optimized total systems performance and reduce life-cycle costs. Because very few qualified HSI practitioners are available and/or affordable, three critical ingredients need to be addressed:

(1) greater demand for HSI as a result of better HSI requirements,

(2) senior leadership and organizational motivation of subject matter experts to become HSI practitioners, and

(3) availability of comprehensive education and training programs across the spectrum for new personnel to become HSI practitioners and existing practitioners to maintain proficiency and currency with changing technology.

Education and training opportunities need to be cohesive and coherent across the spectrum of learning: initial qualification, continuing education, professional development, advanced credentials, and ultimately professional certification. These opportunities should be sufficient to create a near-term DoD and industry certification standard and process that will support the growing demand for HSI in DoD systems acquisition and the industries that support the process.

Litynski, D. M., M. Grabowski, et al. (1997). The relationship between three-dimensional imaging and group decision making: an exploratory study. IEEE Transactions on Systems, Man, & Cybernetics Part A: Systems & Humans.27: (4) 402-11 http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=594908&userType=&tag=1

Military, US, operation, personnel (simulation/perception), performance, scientific (experimental)

This paper describes an empirical investigation of the effect of three dimensional (3-D) imaging on group performance in a tactical planning task. The objective of the study is to examine the role that stereoscopic imaging can play in supporting face-to-face group problem solving and decision making-in particular, the alternative generation and evaluation processes in teams.

It was hypothesized that with the stereoscopic display, group members would better visualize the information concerning the task environment, producing open communication and information exchanges. The experimental setting was a tactical command and control task, and the quality of the decisions and nature of the group decision process were investigated with three treatments:

1) noncomputerized, i.e., topographic maps with depth cues;

2) two-dimensional (2-D) imaging; and

3) stereoscopic imaging.

The results were mixed on group performance. However, those groups with the stereoscopic displays generated more alternatives and spent less time on evaluation. In addition, the stereoscopic decision aid did not interfere with the group problem solving and decision-making processes. The paper concludes with a discussion of potential benefits, and the need to resolve demonstrated weaknesses of the technology.

Liu, K., R. Valerdi, et al. (2009). Economics of Human Systems Integration: The Pratt & Whitney F119 Engine. Human Systems Integration Symposium 2009 http://seari.mit.edu/documents/preprints/LIU_HSIS09.pdf

(HFE,safety, training, personnel, manpower), review, discussion, description, performance, safety, cost, methods, tools, case study

Human Systems Integration is a comprehensive management and technical approach for ad-dressing the human element in weapon system development and acquisition. The primary objec-tive of human systems integration is to integrate the human as a critical system element, regardless of whether humans in the system function as individuals, teams, or organizations. This discipline seeks to treat humans as equally important to system design as are other system elements, such as hardware and software.

HSI has been defined by many stakeholders, particularly government agencies that advocate the “total system” approach, which incorporates humans, technology, the operational context, and the necessary interfaces between. The human considerations include the following nine domains: manpower, personnel, training, human factors engineering, environment, safety, occupational health, habitability, and survivability. This paper introduces one area of a larger research project, sponsored by the U.S Air Force, which seeks to develop an approach for determining what per-centage of the overall systems engineering activity should be allocated to HSI in order to effec-tively consider these nine domains as part of the overall systems engineering effort. To determine the appropriate systems engineering effort needed for a program, we examine a case study that represents an exemplar outcome.

The Pratt & Whitney F119-PW-100 engine is an example of a US Air Force project that suc-cessfully employed HSI principles, even though it was not called HSI at the time, throughout its development in the 1980s. The engine powers the F-22 Raptor air superiority fighter aircraft and has been praised both for its performance and supportability. Although the successes of the F119 project are apparent, the effort spent specifically on HSI was not well documented, and this will be examined during the study. This paper first provides a brief background of HSI and relevant re-search in the field. We use previous work on HSI best practices to focus our case study on the activities most important to HSI success. Our case study shows that Pratt & Whitney adopted HSI principles and methods early in the development process in response to continued Air Force emphasis on Reliability, Maintainability & Supportability (RM&S). We also document the effort and resources Pratt & Whitney voluntarily put into HSI activities and explain how that effort led to reduced life cycle cost for the Air Force

Liu, K., R. Valerdi, et al. (2009). Economics of Human Systems Integration: A Systems Engineering Perspective. 7th Annual Conference on Systems Engineering Research 2009 (CSER 2009). http://seari.mit.edu/documents/preprints/LIU_CSER09.pdf

Military (Navy, Air Force, Army), (land, maritime, aerospace),US, DCL, HSI (HFE,safety, training, personnel, manpower), review, discussion, description, performance, safety, cost, methods, tools

Human Systems Integration (HSI) is the collection of interdisciplinary technical and management processes for integrating human considerations within and across all system elements. This discipline seeks to treat humans as equally important to system design as are other system elements, such as hardware and software. HSI has been defined by many stakeholders, particularly government agencies that advocate the “total system” approach, which incorporates humans, technology, the operational context, and the necessary interfaces between. HSI considerations include the following nine domains: manpower, personnel, training, human factors engineering, environment, safety, occupational health, habitability, and survivability. This paper introduces one area of a larger research project, sponsored by the U.S Air Force, which seeks to develop an approach for determining what percentage of the overall systems engineering activity should be allocated to HSI in order to effectively consider these nine domains as part of the overall systems engineering effort. We describe previous relevant work, including a case study of our own, related to the development of “HSI Size” as a function of HSI Requirements, and discuss how those requirements can be integrated into a parametric cost estimation model

Liu, K., R. Valerdi, et al. (2010). The F119 Engine: A Success Story of Human Systems Integration in Acquisition. DEFENSE ACQUISITION UNIV FT BELVOIR VA. http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA518530&Location=U2&doc=GetTRDoc.pdf

Military (Air Force), US, DCL (design), HSI (HFE, system safety, training, personnel, manpower), case study, description, performance, safety, cost, methods, tools

The Department of Defense recently mandated the incorporation of Human Systems Integration (HSI) early in the acquisition cycle to improve system performance and reduce ownership cost. However, little documentation of successful examples of HSI within the context of systems engineering exists, making it difficult for the acquisition community to disseminate and apply best practices. This article presents a case study of a large Air Force project that represents a successful application of HSI. The authors explore the influence of both the Air Force and the project contractor. Additionally, they identify top-level leadership support for integrating

HSI into systems engineering processes as key to HSI success, reinforcing the importance of treating HSI as an integral part of pre-Milestone A activities.

Lizza, G., J. Lockett, et al. (2008). "Human Systems Integration: Synergy Across the United States Military Services." INCOSE INSIGHT 11(2): 28-30.

HSI, Systems engineering, review, defence

Lucas, J. D., R. P. McMahan, et al. (2008). Improving Health and Safety Through Conveyor System Training in a Virtual Environment. First International Future Mining Conference and Exhibition 2008, Proceedings: 161-166 http://www.itcon.org/data/works/att/2008_40.content.09404.pdf

Civilian, mining, training (computer simulation), safety (hazard assesment), scientific

Preventing injuries and fatalities related to conveyor system use in the mining industry is important and increases uptime while decreasing lost time. The research presented here is funded by the National Institute for Occupational Safety and Health (NIOSH), and intended to accomplish this prevention by the use virtual environments (VEs) to improve training and help miners better understand the hazards of working around conveyor systems. Two conveyor system VEs designed to teach miners about hazards and to safely complete tasks around conveyor systems were developed for this project. The first conveyor system VE, called the instructional tour, gives the miner a semi-automated tour of a conveyor system and teaches the miner about possible hazards (eg, missing guarding) and how to safely fix conveyor problems (eg, a stuck idler) using lock-out, tag-out procedures. The second, called the virtual shift, allows the miner to freely navigate around a conveyor system to detect and avoid hazards. The miner is presented with equipment failures that need to be safely repaired during the virtual shift. If the miner fails to identify and avoid it hazard or fix a failure in a side manner, an animation of the consequences is shown to the miner, who must stall the virtual shift over. The models for the conveyor system VEs were created using 3DS Max. Desktop versions of the VEs were then created using Deep Creator (TM), an authoring application for creating interactive 3D environments. Later, more realistic versions of the VEs were created for CAVE (TM), a room-sized visualisation system, using DIVERSE, an application programming interface. In initial evaluations of the conveyor system VEs, mining colleagues have indicated great interest in such training tools. According to their feedback, these and similar VEs would provide excellent alternatives to normal classroom training and serve as positive precursors to hands-on experience. These VEs provide new miners it chance to experience hazards associated with working around conveyor systems without being in possible danger.

Lüdtke, A., L. Weber, et al. (2009). Modeling Pilot and Driver Behavior for Human Error Simulation. Digital Human Modeling. Book Series Lecture Notes in Computer Science Springer Berlin / Heidelberg 5620: 403-412. http://www.springerlink.com/index/4T31158H28163243.pdf

Civilian, aviation/automotive, HSI tool/training/simulation,

In order to reduce human errors in the interaction with in safety critical assistance systems it is crucial to consequently include the characteristics of the human operator already in the early phases of the design process. In this paper we present a cognitive architecture for simulating man-machine interaction in the aeronautics and automotive domain. Though both domains have their own characteristics we think that it is possible to apply the same core architecture to support pilot as well driver centered design of assistance systems. This text shows how phenomena relevant in the automobile or aviation environment can be integrated in the same cognitive architecture.

Lundin, M. (2004). Simulating the effects of mental workload on tactical and operational performance in tankcrew. http://liu.diva-portal.org/smash/get/diva2:20034/FULLTEXT01

Military (Army), land, DCL , (HSI (HFE, training, personnel, manpower) Sweden, performance, discussion, evaluation, description

Battletank crew must perform many diverse tasks during a normal mission: Crewmembers have to navigate, communicate, control on-board systems, and engage with the enemy, to mention a few. As human processing capacity is limited, the crewmembers will find themselves in situations where task requirements, due to the number of tasks and task complexity, exceed their mental capacity. The stress that results from mental overload has documented quantitative and qualitative effects on performance; effects that could lead to mission failure.

This thesis **describes a simulation of tankcrew during a mission where mental workload is a key factor to the outcome of mission performance**. The thesis work has given rise to a number of results. First, conceptual models have been developed of the tank crewmembers. Mental workload is represented in these models as a behavior moderator, which can be manipulated to demonstrate and predict behavioral effects. Second, cognitive models of the tank crewmembers are implemented as Soar agents, which interact with tanks in a 3D simulated battlefield. **The empirical data underlying these models was collected from experiments with tankcrew, and involved first hand observations and task analyses**. Afterwards, the model's behavior was verified against an a priori established behavioral pattern and successfully face validated with two subject matter experts.

Mack, D. D., L. A. Higgins, et al. (2007). "Applying human systems integration to the rapid acquisition process." Naval Engineers Journal 119: 97-108. http://www3.interscience.wiley.com/journal/120175184/abstract

Military, Army, US, aquisition, HFI/system safety, safety, review/technical (development of a new risk assessment system)

The rapidly changing complexity of the Global War on Terrorism has changed the approach to equipping forward-deployed military forces. Combatant Commanders conducting operations now require timely materiel solutions to enhance mission capabilities and reduce the risk for individual soldiers. To address this challenge, the US Army established the Rapid Equipping Force to assess emerging requirements, to propose solutions to those requirements, and to implement those solutions in an expedient time frame. Unfortunately, the REF lacks a consistent analytical methodology for assessing alternative materiel solutions. To address the need for a human systems integration (HSI) analysis method, the authors developed an Assessment-Based Rapid Acquisition HSI Analysis Method (ABRAHAM) capable of generating tailored surveys and evaluating these surveys for unacceptable risks to soldiers. To validate ABRAHAM's concept and content, ABRAHAM was showcased in three Department of Defense settings: the Human Factors Engineering Technical Advisory Group, the REF, and the US Marine Corps' Operational Test and Evaluation Activity. The ABRAHAM appears to fill a gap in the current library of HSI tools. Based on the feedback provided during the product showcases, there is sufficient interest and technological maturity to further develop ABRAHAM to serve both the traditional and rapid acquisition processes.

MacLeod, I. (2008). "Scenario-based requirements capture for human factors integration." Cognition, Technology & Work 10(3): 191-198. http://dx.doi.org/10.1007/s10111-007-0099-3

Military, UK, HSI (HFE), discussion, description, methods starting point document

Scenarios have been used by many engineering disciplines to assist the quality of their professional application to systems throughout a system life-cycle. At early phases of the system life-cycle, Systems and Software Engineers have adopted the Use Case as a means of representing system requirements through the address of user functions. Furthermore, usability engineers also use scenarios as a means of promoting better usability of systems throughout the system life-cycle. Moreover, all practitioners of the mentioned disciplines use some form of requirements capture and trace throughout the system life-cycle. However, in general Human Factors (HF) and Human Factors Integration (HFI) practitioners do not. This paper examines the efficacy of the multi disciplinary use of scenarios to assist the capture of HFI and system requirements. Such an approach benefits the early establishment of requirements and thus supports system life-cycle trace and matching of both physical and cognitive functions.

Madni, A. M. (2010, in press). "Towards a generalizable aiding-training continuum for human performance enhancement." Systems Engineering. http://dx.doi.org/10.1002/sys.20166

Military / Civilian, US, Discussion paper (academic) HSI methods

We are living in an era in which the need to train and aid people is becoming paramount due to ever increasing job and task complexities. Despite this recognition, the aiding and training of individuals and teams has not kept pace with the times. Furthermore, even though aiding and training are complementary approaches to enhancing human performance, they have largely been pursued separately. Today, there is a growing recognition that aiding and training are not distinct approaches but, in fact, lie along a human-systems integration continuum. This paper presents a systems approach to developing standards-compliant, integrated aiding-training framework that is potentially generalizable to other application domains. The framework employs key architectural constructs such as dynamic content provisioning and service-oriented architecture to achieve seamless shifts along the aiding-training continuum. The key benefits of the aiding-training architectural framework are improved human performance in a variety of operational contexts. (c) 2010 Wiley Periodicals, Inc. Syst Eng

Malone, T. and F. Carson (2003). "HSI top down requirements analysis." Naval Engineers Journal 115: 37-48. http://www3.interscience.wiley.com/journal/121489396/abstract?CRETRY=1&SRETRY=0

military, hsi, methods, requirements analysis, navy

The major objective of the discipline of human systems integration (HSI) in system development is to ensure that requirements and considerations for the human element of the system will influence design. The system must be designed to facilitate and support human performance capability, safety, reliability, survivability and accommodation. This objective is achieved by addressing human requirements early in system design and development, in fact, at the very outset of the design process. How this is accomplished is through application of the HSI top down requirements analysis (TDRA). This paper describes the TDRA process, discusses applications of the TDRA, and compares TDRA with bottom-up analysis.

Malone, T., F. R. Oberman, et al. (2003). Human Systems Integration (HSI) Top Down Requirements Analysis for JCC(X). HSIS Symposium 2003. http://faculty.nps.edu/nlmiller/Fatigue/HSISymposium/cdr_pdfs/indexed/2b_4.pdf

military, defence, navy, requirements, manning, case study

This paper describes the results of applying the HSI TDRA process to the acquisition of the JCC(X) command ship. The Operations Department was selected for TDRA application due to the diversity of its associated requirements. The Operations Department consists of two Divisions: OE Division, concerned with maintenance of electronic equipment and systems; and OI Division, concerned with electronic warfare supervision, operations, and repair, CIC supervision and operation, and operational intelligence analysis. The results of this effort are not limited to the JCC(X) platform, nor to the Operations Department of the JCC(X), since the results are generalizable to other maintenance and operations activities in other Departments and platforms.

In the application of an HSI TDRA to OE and OI Divisions, the objectives were to:

- Significantly reduce the workload associated with Division tasks in legacy systems, leading to a significant manpower reduction in the emerging ship;
- Identify HSI High Driver functions and tasks in legacy systems which should receive emphasis in the design of JCC(X) human machine interfaces (HMI) to reduce workload and improve human performance;

Malone, T. B., M. A. Creedon, et al. (1998). Human factors engineering for maritime systems. Maritime Engineering and Ports. C. A. Brebbia, Wessex Institute of Technology, United Kingdom & G. Sciutto Universita degli Studi di Genova Italy, The Built Environment volume 39: 41-45. http://library.witpress.com/pages/listpapers.asp?q_bid=141

*Civilian, maritime, manpower, cost-benefit/ safety/ performance

The major challenges to maritime systems in the 1990's include: escalating operating costs; adaptation of advanced technology in an operational environment; and the high rate of human error as a cause of ship and port system accidents. Each of these challenges can be addressed by the discipline of Human Factors Engineering (HFE). The major component of maritime system operating costs is costs associated with personnel in the system. Operating costs can be significantly lowered through a system design approach that results in reductions in manning levels (and costs associated with system manpower), training time, system downtime, and accident rates. HFE is the formal discipline concerned with reducing manning with no adverse impact on human performance and safety. Application of HFE also results in increased efficiency in training improved system availability, and reduced accident rates through reduced human error rates. HFE contributes to improved human performance in highly automated systems and enhances the interactions between the human and advanced technology. Finally HFE results in reduced human error through application of HFE design standards, simulation and modeling of human tasks and workloads, and design to reduce both the incidence and the impact of human errors. thereby making systems error tolerant.

Marshak, W. P., M. Waltensperger, et al. (1996). Human factors engineering use of distributed simulations: Advantages and limitations. Human Interaction with Complex Systems: Conceptual Principles and Design Practice. C. A. Ntuen and E. H. Park, Kluwer Academic Publishers: 133-140. http://books.google.com.au/books?hl=en&lr=&id=REAg2s1mfBIC&oi=fnd&pg=PA133&dq=Human+factors+engineering+use+of+distributed+simulations:+Advantages+and+limitations&ots=vWMnELfCiC&sig=XrAN4VMIBJ8oB_8w5a5w3C5VCtQ#

Military, US, operation, training (simulation), HSI tool, discussion/technical

Department of Defense (DoD) has pioneered in the use of large scale distributed simulations for troop training, notional weapon testing and tactics development. The original Simulation Network (SIMNET) for Army training has evolved into the more capable current generation Distributed Interactive Simulation (DIS) network. Distributed simulations offer human factors engineers the opportunity to test of prototype operator stations against human-in-the-loop (HITL) and fully automated simulations operating at different geographic locations. Although DIS has not yet seen significant human engineering activities, it is inevitable that DIS will be used for such testing. The distributed simulation environment provides significant advantages over stand-alone simulations but also has other characteristics which require careful consideration. These characteristics of DIS are discussed along with ways to compensate for their effect on human factors evaluations.

McCarley, J. S. (2009). "Effects of speed-accuracy instructions on oculomotor scanning and target recognition in a simulated baggage X-ray screening task." Ergonomics 52(3): 325-33. http://www.informaworld.com/index/909680941.pdf

Civilian, aviation, training/simulation, baggage screening, performance, scientific

Visual search tasks are often carried out under high levels of time stress. Transportation security screeners, for example, face demands to achieve high levels of accuracy while maintaining rapid passenger throughput. An experiment examined the strategies by which operators regulate visual search performance under such conditions. Observers performed a simulated baggage-screening task under instructions to emphasise either response speed or accuracy. Behavioural measures and eye movements were recorded. Observers made fewer and briefer fixations under emphasise-speed than under emphasise-accuracy instructions. Losses in accuracy were produced by more frequent failures to fixate on targets and a decrease in the detection rate of non-fixated targets. The likelihood with which observers detected a fixated target was similar across speed-accuracy instructions. Results will inform efforts to model visual search in naturalistic tasks, allowing more accurate prediction of response times and error rate and may aid the design of training programmes and other interventions to improve search performance under stress.

McDonald, N. (2007). Human integration in the lifecycle of aviation systems. International Conference on Engineering Psychology and Cognitive Ergonomics, Beijing, China: 760-769 http://www.springerlink.com/index/r90324pj05125812.pdf

Civilian, aviation, HSI tool, HFE, performance, technical/discussion

While Human Factors is perhaps the most critical discipline to improving aviation safety, research and development is disproportionately small-scale, fragmented and unsustained. The key issue is the delivery of Human Factors knowledge throughout the system to improve design, operation or monitoring. A systems integration approach to technology development and innovation incorporates user requirements at all stages of the system life-cycle. The goal of the HILAS project is to develop and demonstrate such an integrated model of Human Factors research, practice and integrated application, linking design and operation - in a 'system life-cycle approach'. A central challenge is to demonstrate how to integrate models of the human operator, which demonstrate the influences on human performance, with wider system models that encompass the influences on system performance.

McNeer, R. R., J. Bohorquez, et al. (2007). "A new paradigm for the design of audible alarms that convey urgency information." Journal of Clinical Monitoring & Computing 21(6): 353-63. http://www.springerlink.com/index/r2226042g5w77515.pdf

Civilian, medical, HFE, safety, scientific (experimental)

OBJECTIVE: The current international standard (IEC 60601-1-8) stipulates that medical device audible alarms should be priority-encoded and validated for efficacy. Evidence suggests that the melodic alarms described in the standard are not functioning as originally intended. We present a multi-disciplinary, human factors paradigm for audible alarm development whereby urgency information is encoded via modulation of the physical characteristics of sounds. We also test the feasibility of this approach using information measures.

METHODS: We designed series of experimental sounds that varied along controlled physical and acoustical dimensions. Subjects rated these sound series for perceived urgency. Based on these ratings, selected sounds from each series were assigned a priority category from 'low' to 'high' - we call these resulting sets of sounds 'urgency-codecs'. The method of categorical judgments (based on information theory) was used to compare each urgency-codec for ability to convey urgency information.

RESULTS: Subjects were consistent in their ratings of the three series of experimental sounds for perceived urgency. The urgency data pertaining to one of the series (harmonic interval) was successfully fit to a psychophysical empirical law. The urgency-codec derived from another sound series (melodic interval) was found to have the highest signal (correct interpretation of urgency level by subjects) transmission rate.

CONCLUSIONS: The proposed paradigm is feasible, and it offers an evidence-based strategy for alarm sound design and testing. This approach would be performed before implementation of new alarm sounds in clinical settings, and should result in development of alarm sounds that satisfy the requirements of priority-encoding and validation.

McSweeney, K. P., T. De Koker, et al. (2008). "A human factors engineering implementation program used on offshore installations." Naval Engineers Journal 120: 37-49. http://www3.interscience.wiley.com/journal/122197796/abstract

This paper discusses a practical and successful approach for Human Factors Engineering (HFE) Im- plementation Program (HFEIP) development and integration in the design of offshore installations. This HFEIP strategy has evolved over many years with numerous successes in the offshore industry. This paper focuses on:

- The different tasks that should be included in an HFEIP. & Examples of the application of the different tasks in the HFEIP. & HFEIP lessons learned.

Note: The examples of the application of the HFEIP Program tasks in this paper have been reported by the HFE professionals principally responsible for the development of the HFEIP described herein. The examples are from current and past experiences involving major offshore Engineering, Procure- ment, Construction, and Installation projects. These projects include but are not limited to: Tension Leg Platforms, Spar's, and a Floating Platform for Storage and Offloading unit.

McSweeney, K. P., J. Pray, et al. (2009). Integration of human factors into design- An applied approach. RINA Conference on Human Element in Design. London. http://www.eagle.org/eagleExternalPortalWEB/ShowProperty/BEA%20Repository/References/Technical%20Papers/2009/Integ%20of%20Human%20Factors%20Eng%20into%20Design

civilian, human factors engineering, marine

To help reduce the potential for human error, it is important to effectively integrate Human Factors Engineering (HFE) principles into the design so that that systems encompass human capabilities and limitations, while increasing system availability/safety/performance, and personnel satisfaction. This paper discusses an applied approach for HFE integration and implementation into the design, whether it be a new vessel, a facility construction project, or the expansion, modernization, or upgrading of an existing vessel or facility. This successful strategy has evolved over many years in the marine industry. This strategy integrates HFE throughout the various life cycle phases of a project with the objective of efficiently executing relevant HFE activities throughout conceptual, preliminary, and detail design as well as during construction and operation. Success factors are discussed and illustrated with examples from current and past design experiences.

Metzger, U. and R. Parasuraman (2005). "Automation in future air traffic management: effects of decision aid reliability on controller performance and mental workload." Human Factors 47(1): 35-49. http://archlab.gmu.edu/people/rparasur/Documents/Metzger.pdf

Civilian, aviation, HFE, performance, scientific (experimental)

Future air traffic management concepts envisage shared decision-making responsibilities between controllers and pilots, necessitating that controllers be supported by automated decision aids. Even as automation tools are being introduced, however, their impact on the air traffic controller is not well understood. The present experiments examined the effects of an aircraft-to-aircraft conflict decision aid on performance and mental workload of experienced, full-performance level controllers in a simulated Free Flight environment. Performance was examined with both reliable (Experiment 1) and inaccurate automation (Experiment 2). The aid improved controller performance and reduced mental workload when it functioned reliably. However, detection of a particular conflict was better under manual conditions than under automated conditions when the automation was imperfect. Potential or actual applications of the results include the design of automation and procedures for future air traffic control systems.

Middlebrooks, S. E. (2009). An Annotated Bibliography of MANPRINT Related Assessments and Evaluations Conducted by the U.S. Army From 1953-2008, Army Research Laboratory. http://www.arl.army.mil/www/default.cfm?page=515&id=1769

Military, Army, US, manpower (MANPRINT), review/annotated bibliography

This report documents 499 Manpower and Personnel Integration (MANPRINT) Assessments and evaluations conducted by the U.S. Army between 1953 and 2008. While the MANPRINT program was officially established in the early 1990s, ongoing work in what was to become many of the MANPRINT domains has been going on for many years. Searches of the available archives in various Army organizational databases and files produced study reports from 1953 onward. The intent of this report is to consolidate and preserve the historical knowledge contained in previous MANPRINT and MANPRINT-related investigations and assessments conducted by the U.S. Army, up to the date of this bibliography, for use as a reference tool by future MANPRINT practitioners and principal investigators. Although this project identified many MANPRINTstudies and evaluations conducted by the other Services, the intent of this publication is to document studies conducted by the Army. Users of this bibliography are encouraged to contact the author if additional studies and reports not included in this work are discovered or are known to exist, so that they can be included in future editions of this work.

Militello, L., G. Klein, et al. (1998). Optimized Manning Case Studies. http://mentalmodels.mitre.org/cog_eng/reference_documents/klein-optimized%20manning%20case%20study.pdf

Military (Navy), (maritime), US, DCL (design), HSI (HFE, manpower), case study, description, performance, safety, cost, tools

This project is one component of the SC-21 Manning Affordability Initiative sponsored by the Office of Naval Research to develop a suite of methodologies and tools that will allow designers to anticipate the role of the human operator in platforms of the future. There are a number of issues under study within the program, including the application of new and developing technologies to traditional shipboard staffing and organization of work. Critical to the success of these design efforts is the ability of designers to identify leverage points or areas of potential change with high payoff, and to envision and implement an effective re-engineering strategy.

The goal of the case studies effort has been to examine previous re-engineering efforts and extract lessons learned and recommendations for the U.S. Navy in its efforts to design future ships to operate with dramatically fewer people. This has been accomplished via interviews using Cognitive Task Analysis (CTA) methods and a review of the literature. Approximately 20 case accounts were gathered from interviews with Subject Matter Experts and from the existing literature.

This paper presents an important study of re-engineering. It goes beyond previous compilations of case studies in focus. Specifically, the cases investigated here involve organizations that have undergone dramatic personnel reduction and introduced new technology. Previous case studies have focused predominantly on proceduralized tasks. We have emphasized command and control settings and tasks that require considerable teamwork. Furthermore, our analysis includes an in-depth examination of what steps organizations have taken and steps that have been avoided. We have gone beyond recommendations that are little more than slogans found in similar efforts, to a level of specificity that provides a view of how previous efforts were accomplished.

Primary accomplishments include:

- two examples of highly successful manning reduction efforts,
- a set of leverage points that can be used to identify areas in which personnel reduction is likely to pay off,
- lessons learned from previous re-engineering efforts,
- guidelines and recommendations for achieving successful manning reduction, and
- a proposed set of tools that can help the design community achieve dramatic reductions in staffing.

Mittler, E., Hewitt, G.M., Vehow, C.A. (1990). Management Integration Methods. MANPRINT: An Approach to Systems Integration. H. R. M. Booher, J. New York, Van Nostrand Reinhold: 95-125. http://openlibrary.org/books/OL1858894M/Manprint_an_approach_to_systems_integration

Mock, M. and C. Baber (2005). "The Identification of Interdisciplinary Synergies: Lessons for HFI from other Human-Centred Design Approaches." http://www.hfidtc.com/research/process/reports/phase-1/3-3-1-interdis-synergies.pdf

civilian, tools

The aim of this study (Task 3.3.1) was to review other domains and industries for techniques or perspectives that might benefit Human Factors Integration (HFI). The range of domains and topics reviewed was wide and included such things as user-centred design methodologies, software design and management approaches, social, political and advertising research perspectives, and industries such as oil and gas production, mobile phones, architectural design and theme park "imagineering". Useful discoveries ranged from individual techniques that might be used in the practice of HFI to more general lessons learned in the evolution of practice in other domains that provide talking points for how the practice and culture of HFI might develop in the future.

A general theme to emerge was that many industries are increasing the role that the end users of technology play in its design, in some cases not only working alongside designers and engineers but actually driving the design process rather than merely having input into it. Involving end users increases the likelihood of their needs being met, encourages a sense of shared ownership and ultimately has impact in increasing the chances of user acceptance of new equipment. Within the report we discuss a number of methodologies that could be used as frameworks for facilitating end user involvement in HFI in the Concept stage of CADMID, and also provide outputs that complement more traditional investigations such as workload and task analyses by providing an insight into the subjective feelings of end users.

The success of “auteur”-led approaches in which individuals are empowered to imprint a consistent vision within their creative field suggests that there may be gains to be made from empowering HFI specialists to step beyond traditional constraints upon their area of action and thus to avoid the pitfalls of “design by committee” which may lead to a fragmented, inconsistent form of HFI input into a project.

A matrix-based approach for relating HFI requirements to technical design decisions is described (the Quality Function Deployment or QFD technique). This would seem to be very usable within HFI as a tool for linking HFI requirements to aspects of the User Requirements Document and the System Requirements Document. The QFD technique has other benefits as it can act as a compact audit record illustrating the decisions behind trade-offs and also includes a simple system for estimating the scale of risk inherent in each element of a design.

Consideration of the development of a common design documentation approach for computer programming suggests that HFI could similarly benefit from having an industry standard scheme for presenting findings and data in a visual form to make its outputs more accessible. Other issues discussed include the way in which collaborative design methods can have side-benefits in addressing “soft issues” of team cohesion and morale that might beset integrative disciplines like HFI and how a tightly-nested iterative design process can address the difficulty that is posed by changing requirements in response to the assessment of prototypes.

Moroney, W., D. Biers, et al. (1995). “Some measurement and methodological considerations in the application of subjective workload measurement techniques.” The International Journal of Aviation Psychology 5(1): 87-106. http://www.informaworld.com/smpp/content~db=all~content=a784772542

Civilian (Aerospace [Aviation]), DCL (Design), Research (Tools [subjective assessment])

Previous research with the NASA Task Load Index (TLX) and the Subjective Workload Assessment Technique (SWAT) has demonstrated their sensitivity to variations in workload under flight and other complex work conditions but has not addressed some important measurement and methodological issues regarding their application. This article reviews data that address several such issues including the effects of delayed workload ratings, the effects of previous workload levels on ratings, and procedures used to combine subscale ratings into one overall estimate of subjective workload.

Moroney, W., D. Biers, et al. (1992). A comparison of two scoring procedures with the NASA task load index in a simulated flight task. Aerospace and Electronics Conference, 1992. NAECON 1992, Dayton, OH 734-740 http://ieeexplore.ieee.org/iel2/655/5765/00220513.pdf?arnumber=220513

Civilian (Aerospace [Aviation]), Research (Tools)

Two issues which pertain to NASA task load index (TLX) application procedures and scoring techniques were investigated. One issue concerned the procedure used to combine ratings on the TLX dimensions into one overall rating. The second issue dealt with the delay of TLX workload ratings for a time period subsequent to completion of a rated flight segment. Participants flew several simulated flight missions under three difficulty levels and rated the workload either immediately following a flight segment or after 15-minute or 48-hour delays. Overall workload ratings were derived through the use of either a weighted or an unweighted combination of TLX dimensions. The results of the scaling techniques were highly correlated (r=0.94), and analyses revealed no differences between the resulting scaling procedures. It was found that the time-consuming use of weighting scales is not necessary and that delaying TLX reports up to 15 minutes does not significantly interfere with recall of workload ratings

Mulgaonkar, P. e. a. (2002). Ad hoc study on human robot interface issues, Army Science Board. http://www.stormingmedia.us/43/4381/A438114.html

Defence, military, air force, army, navy, uav,

The Army Science Board Panel was tasked to: (1) Examine Army, DARPA, Navy, Air Force and NASA unmanned ground vehicle (UGV) and unmanned aerial vehicle (UAV) research and development efforts focused on human-machine interfaces, command and control of robots and supervisory control; (2) Project technologies and capabilities into the 2015-2020 timeframe and assess technology voids that may remain; (3) Determine the availability issues for applicable commercial systems and technologies; and (4) Propose cost-effective options or strategies for addressing identified technology voids. The Panel's findings discuss the absence of a systematic study of human-robot interface design and a disconnect between end-users and the development process. The Panel's overall recommendations include: (1) development of an operational architecture with support from experimental data collected in operationally relevant scenarios in realistic environments; (2) Formulation of an FCS Block I human-robot interaction architecture consistent the FCS Operational Requirements Document in time for the FCS Milestone B decision; and (3) Establishment of a Science and Technology program aimed at developing a technical architecture for human robot interactions focused on autonomous ground robots.

Nakatani, T., K. Honda, et al. (2007). Improvement approach of the automation system in aviation for flight safety. Universal Access in Human-Computer Interaction: Ambient Interaction, Pt 2, Proceedings.4555: 497-506 http://www.springerlink.com/content/6323865285072383/

Civilian, aviation, HFE (simulation), performance, scientific/technical

Next generation cockpit concept aiming to reduce the risk of pilot-error-induced accident was studied. This new cockpit concept, called Human-Centered Cockpit incorporates several ideas which aim to improve the pilot's situation awareness for the terrain and the aircraft situation without increasing the pilot's cognitive workload. This concept is built on task analysis and accident analysis, and through several times of the airline pilot reviews using partial task simulation of new functions, design issues were identified and the design was brushed up. Fully functional cockpit simulator was finally developed to evaluate the effectiveness of this cockpit concept in the realistic commercial aircraft operational environment from preflight to spot-in, including the ATC. Six pilots participated in the final evaluation and the result showed that this cockpit concept enhances the pilot's situation awareness in the actual operation environment, and improves the pilot's cognitive workload in flight.

Narkevicius, J. (2008). Human Factors and Systems Engineering Integrating for Successful Systems Development. Human Factors and Ergonomics Society Annual Meeting, Human Factors and Ergonomics Society.52: 1961-1963 http://www.ingentaconnect.com/content/hfes/hfproc/2008/00000052/00000024/art00009

All systems are populated by users, operators, maintainers, support personnel, managers, supervisors, and others. Therefore Systems Design must include human considerations via Human Factors participation in Human Systems Integration tradeoffs and by extension the Systems Engineering process. This paper explores the contributions of Human Factors and Human Systems Integration in the Systems Design process and the greater Systems Engineering Process. The linkages between Human Factors, Human Systems Integration, and Systems Engineering will be illustrated and the need for those linkages to be strengthened by tools will be discussed.

Narkevicius, J. (2008). Human Systems Integration (HSI) into Joint Capabilities Integration and Development System: Analysis and Development of HSI Domain Specific Capabilities Language and Metrics. US, Texas, 711th Human Performance Wing Human Performance Integration Directorate Human Performance Optimization Division. http://www.wpafb.af.mil/shared/media/document/AFD-090123-069.pdf

Military (Air Force), (aerospace), US, DCL (design, acquisition), HSI (HFE, safety, training, personnel, manpower), discussion, description, performance, safety, cost, methods, tools

This report documents a year long effort to analyze human systems integration (HSI) requirements in the AIRPRINT Capability Document Analysis Report (311 HSW Report No HSWPE-BE-TR-2007-0001) (AIRPRINT Report), write HSI domain specific, Joint Capabilities Integration and Development System compatible capability statements and identify suggested performance thresholds, objectives, and assessment metrics. Additionally, 60 capabilities documents were analyzed, which revealed a variety of approaches to writing HSI requirements. The results of this study confirm those of the AIRPRINT Report, provide recommended language for HSI requirements writers and include a Work Aid to improve the ability to write HSI requirements.

The AIRPRINT Capability Document Analysis Report HSW-PE-BR-TR-2007-0001 (AIRPRINT Report) is a recent study conducted for the 311th Human Systems Wing (HSW). This effort reviewed 43 weapons systems requirements documents and identified approximately 1,900 HSI related requirements. The current effort analyzed both the AIRPRINT Report and additional requirements documents provided by the 711th Human Performance Wing (HPW). This study moved forward from this previous effort to identifying human based requirements that are measurable, testable and stated in language that contributes to the overarching systems engineering and acquisition activity.

This study was sponsored by AF 711th HPW to identify the potential human-oriented key performance parameters and requirements for systems engineering and acquisition that reflect this integration of humans, hardware, and software.

The processes for identifying and codifying needed warfighting capabilities are identified in the Chairman Joint Chiefs of Staff Instruction (CJCSI) 3170.01F. How to develop requirements is set forth in Chairman Joint Chiefs of Staff Manual (CJCSM) 3170.01C, including the preparation of requirements, appropriate language for measurable and testable requirements, with thresholds and objectives for mission performance of the weapons system appropriate to the document and phase. Air Force Instruction (AFI) 10-601 provides the specific direction to assure AF requirements meet the systems engineering and acquisition language essential to move forward to develop the weapons system.

The 711th HPW is the implementation arm for the policy and guidance promulgated from the AF HSI Office, ensuring that all levels of the organization are focused on delivering the Air Force mission. HSI is fundamental to meeting the Air Force mission, from recruiting and training Airmen to providing capabilities through mission accomplishment with technologically advanced systems that are safe and effective. Implementing policy, processes and professional development are all needed to ensure Air Force systems deliver dominance.

Barriers to successfully integrating HSI into Systems Engineering and Acquisition include:

Narkevicius, J. M. (2008). Human systems integration in rail: Developing the interface for integration *in*: Contemporary Ergonomics 2008, Nottingham, England: 529-533 http://books.google.com.au/books?id=O___vAihVsUC&pg=PA529&lpg=PA529&dq=%22Human+system s+integration+in+rail:+Developing+the+interface+for+integration%22&source=bl&ots=14p9 PoPdm6&sig=DX94GpuHbiH3RnjGzT-3-P6ZagE&hl=en&ei=v6kyTMTxCM6TkAWdyPyfDA& sa=X&oi=book_result&ct=result&resnum=1&ved=0CBgQ6AEwAA#v=onepage&q=%22Hum an%20systems%20integration%20in%20rail%3A%20Developing%20the%20interface%20 for%20integration%22&f=false

Civilian, other industry (rail), HSI tool, discussion

Human System Integration (HSI) is the management and technical approach to incorporating human considerations into the design and implementation of systems. HSI can contribute to improved system performance, safety, and reduced cost in Rail applications. While primarily used in military acquisition, application of HSI in transportation organizations such as railroads to achieve the safety and operational effectiveness goals will translate to long term reduced operational costs. Work to define the application of HSI to rail transportation is ongoing.

National Aeronautics and Space Administration (1995). Man-Systems Integration Standards, Revision B. http://msis.jsc.nasa.gov/

civilian, aerospace, human factors, standard

The NASA-STD-3000 was created to provide a single, comprehensive document defining all generic requirements for space facilities and related equipment which directly interface with crewmembers.

This document provides specific user information to ensure proper integration of human-system interface requirements with those of other aerospace disciplines. Video images from relevant space missions are also provided to illustrate human factors design concerns.

National Aeronautics and Space Administration (2007). Systems Engineering Handbook. http://education.ksc.nasa.gov/esmdspacegrant/Documents/NASA%20SP-2007-6105%20 Rev%201%20Final%2031Dec2007.pdf

civilian, aerospace, systems engineering

This handbook is intended to provide general guidance and information on systems engineering that will be useful to the NASA community. It provides a generic de- scription of Systems Engineering (SE) as it should be ap- plied throughout NASA. A goal of the handbook is to in- crease awareness and consistency across the Agency and advance the practice of SE. This handbook provides per- spectives relevant to NASA and data particular to NASA.

This handbook should be used as a companion for im- plementing NPR 7123.1, Systems Engineering Processes and Requirements, as well as the Center-specific hand- books and directives developed for implementing sys- tems engineering at NASA. It provides a companion reference book for the various systems engineering related courses being offered under NASA's auspices.

National Aeronautics and Space Administration (2007). NASA space flight human system standard volume 1: Crew health. http://standards.nasa.gov/documents/detail/3315622

civilian, aerospace, health, standard

NASA policy for establishing standards to protect the health and safety of crew, and for providing health and medical programs for crewmembers during all phases of space flight, is authorized by NPD 1000.3, The NASA Organization, and NPD 8900.5, NASA Health and

Medical Policy for Human Space Exploration. NPD 8900.1, Medical Operations Responsibilities in Support of Human Space Flight Programs and NPD 8900.3, Astronaut Medical and Dental Observation Study and Care Program, authorize the specific provision of health and medical programs for crewmembers. NASA's policy is to establish standards for providing a healthy and safe environment for crewmembers, and to provide health and medical programs for crewmembers during all phases of space flight. Standards are established to optimize crew health and performance, thus contributing to overall mission success, and to prevent negative long-term health consequences due to space flight. In this document, the Office of the Chief Health and Medical Officer establishes NASA's space flight Crew Health standards for the pre-flight, in-flight, and post-flight phases of human space flight.

Human system standards are established to guide and focus the development of the crew health requirements as a means of protecting space-faring crews. The standards presented in this document, NASA Space Flight Human System Standards, Volume I: Crew Health, are intended to complement the overall set of human standards for space flight, which also includes NASA Space Flight Human Systems Standards, Volume II: Habitability and Environmental Health; NASA Medical Standard for Crewmembers; and current medical standards of clinical practice. Combined, these standards provide Agency technical requirements for an appropriate environment for human habitation, certification of human participants, the necessary level of medical care, and risk-mitigation strategies against the deleterious effects of space flight. The standards described in this document include levels of care, permissible exposure limits, fitness- for-duty criteria, and permissible outcome limits as a means of defining successful operating criteria for the human system. These standards help ensure mission completion, limit morbidity, and reduce the risk of mortality during space flight missions. See Appendix A for an overview document map.

National Aeronautics and Space Administration (2008). Human-Rating Requirements for Space Systems http://nodis3.gsfc.nasa.gov/npg_img/N_PR_8705_002B_/N_PR_8705_002B_.pdf

civilian, aerospace, requirements, HSI implementation

P.1 Purpose

P.1.1 NASA's policy is to protect the health and safety of humans involved in or exposed to space activities, specifically the public, crew, passengers, and ground personnel. This policy is implemented through the application of NASA directives and standards.

P.1.2 The significant monetary investment for complex space hardware requires all missions to meet high standards of reliability and mission success. The purpose of this NASA Procedural Requirements (NPR) document is to define and implement the additional processes, procedures, and requirements necessary to produce human-rated space systems that protect the safety of crew members and passengers on NASA space missions.

P.1.3 A human-rated system accommodates human needs, effectively utilizes human capabilities, controls hazards and manages safety risk associated with human spaceflight, and provides, to the maximum extent practical, the capability to safely recover the crew from hazardous situations. Human-rating is not and should not be construed as certification for any activities other than carefully managed missions where safety risks are evaluated and determined to be acceptable for human spaceflight.

P.1.4 Human-rating must be an integral part of all program activities throughout the life cycle of the system, including design and development; test and verification; program management and control; flight readiness certification; mission operations; sustaining engineering; maintenance, upgrades, and disposal.

P.1.5 This NPR requires applicable space systems as defined in paragraph P.2 to obtain a Human-Rating Certification prior to the first crewed mission and maintain the rating throughout the system life cycle.

National Aeronautics and Space Administration (2010). Human integration design handbook. http://ston.jsc.nasa.gov/collections/TRS/_techrep/SP-2010-3407.pdf

civilian, aerospace, hsi implementation, human factors standard

The Human Integration Design Handbook (HIDH), NASA/SP-2010-3407, provides guidance for the crew health, habitability, environment, and human factors design of all NASA human space flight programs and projects.

The two primary uses for the handbook are to

- Help requirement writers prepare contractual program-specific human interface requirements - Users include program managers and system requirement writers.
- Help designers develop designs and operations for human interfaces in spacecraft - Users include human factors practitioners, engineers and designers, crews and mission / flight controllers, and training and operations developers.

The handbook is a resource document for NASA Space Flight Human Systems Standard (SFHSS), NASA-STD-3001. The SFHSS is a two-volume set of NASA Agency-level standards, established by the Office of the Chief Health and Medical Officer, that defines levels of acceptable risks to crew health and performance that result from space flight. Volume 1 of the SFHSS, Crew Health, sets standards related to crew health. Volume 2, Habitability and Environmental Health, defines the environmental, habitability, and human factors standards that are related to environmental health and human-system interfaces during human space flight.

The handbook is a resource for implementing the requirements in the SFHSS, and it provides the data and guidance necessary to derive and implement program-specific requirements that are in compliance with the SFHSS.

The scope of the handbook includes all crew operations both inside and outside the spacecraft in space and on lunar and planetary surfaces. It includes

- Design guidelines for crew interface with workstations, architecture, habitation facilities, and extravehicular activity (EVA) systems.
- Information describing crew human capabilities and limitations (both physical and cognitive)
- Environmental support parameters

The document uses the term “spacecraft” and “system” to refer to the volume in which humans live and work. The “humans” addressed in this document are the crew of the spacecraft. Spacecraft and system refer to all aspects of the crewmembers’ living and working conditions including the hardware, equipment, software, and environment. The term “human space flight program” is used to refer to the infrastructure assigned to design, develop, and deploy the spacecraft system.

NATO (2010). Human Systems Integration for Network Centric Warfare. : 306p. http://ftp.rta.nato.int/public//PubFullText/RTO/TR/RTO-TR-HFM-155///$$TR-HFM-155-ALL.pdf

Military/all, US/Europe (NATO), operation, HSI tool, review

Network Enabled Capabilities (NEC) allows platforms and Command and Control (C2) capabilities to exploit shared awareness and collaborative planning, to communicate and understand command intent and to enable seamless battlespace management. The NEC environment consists of a highly uncertain and unpredictable situation, with coalition forces, multiple distributed units, limited resources, but operating network based. The challenge is to effectively use information, take initiative, and exploit ad-hoc collaboration to achieve timely coordinated massed effects. Problems arising from the role of humans in NEC systems, such as the inability to use the information in an accurate and timely manner, is the concern of Human System Integration (HSI). HSI integrates human capabilities and limitations into system definition, design, development, and evaluation to optimize total system performance in operational environments. It is part of the total systems engineering approach to analysis, design, development, and testing.

The goal of HFM-155 was to focus on those aspects of networked enabled capability and operations that are human centric and to use the processes and methods afforded by HSI as the means to identify, define, and document a solution approach for challenges faced by key decision-makers in the Defense enterprise (e.g., warfighters, policy-makers, capability specifiers, acquisition managers, system engineers). This solution approach includes appropriate focusing on the human-network issues in design, as well as, acquisition.

This report describes and documents the Human View (HV) as a viable method for HSI to identify and assess the human specific aspects of a total systems engineering approach (architecture framework) for system design and development. Modeling and simulation extends the HV to illustrate and capture the dynamic nature of human performance in a variable environment. Experimentation provides the data to populate HVs and the resultant models and, to validate the modeled simulation.

HVs provide a means by which HSI activity can be related to Systems Engineering so that Human Factors can be represented in systems design and development. This provides an opportunity for the Human Factors engineer to _'talk the language_' of the Systems Engineer. It also means that some of the considerations that relate to humans in systems operation, which may have been previously difficult to consider because they were deemed _'non-functional requirements_' can now have an expression in Systems Engineering. The implications of this proposal can be considered in terms of three primary recommendations:

- HSI should be described in terms which are amenable to HVs. This should allow conventional representation practices, e.g., in the form of diagrams, tables or other formats, to make up the appropriate HVs. This provides a means of communicating the recommendations and information from different HSI domains to System Engineering.
- System engineering should incorporate HVs into current practices surrounding Architecture Frameworks. This would provide an opportunity for the 'non-functional requirements' that often describe human factors to be given greater focus and attention.
- In addition to proposing changes to the communication between HSI and systems engineering, the report suggests integrated roles for modelling and simulation and experimentation as vehicles for testing, exploring and developing operational concepts that have strong human factors foundations. This would not only require traditional approaches, but would ultimately see novel developments by which HVs would become central to experimental design or model specification.

Natter, M., J. Ockerman, et al. (2008). Review of Cognitive Metrics for C2. Proceedings of the 13th International Command and Control Research and Technology Symposium (ICCRTS). http://www.dodccrp.org/events/13th_iccrts_2008/CD/html/papers/061.pdf

Military, US, HSI (MANPRINT, command and control), Review (description of HSI), Research (methods)

Human cognitive knowledge, skills, and abilities are a significant component of complex command and control (C2), hence measuring cognitive aspects of C2 can provide critical valueadded.

Cognitive measures provide a consistent gauge to measure C2 cognitive effects. These measures can be used to compare cognitive impacts both between and within systems. Also, these measures help to analyze specific cognitive strengths and weaknesses, so that C2 systems can be improved. Likewise, they can be used to analyze training strengths and weaknesses, and improve training so that it is better suited to user needs.

This paper summarizes an extensive literature review on macrocognitive metrics that apply to complex C2 assessment. Since a suite of cognitive metrics is required to assess C2 warfighters' actual and perceived effectiveness, guidance is provided on selecting appropriate macrocognitive metrics. Mental constructs researched in complex C2 domains including workload, situational awareness, decision making, and collaboration are highlighted. This paper defines each construct, provides measurement tools and techniques, and reviews the costs and benefits of each technique. The paper concludes with an explanation of how the mental constructs and their metrics are inter-related and suggests using several metrics together to assess and explore C2 in complex endeavors.

Naval Research Advisory Committee (2000). Optimized Surface Ship Manning. Naval Research Advisory Committee Report: 111p. http://www.nrac.navy.mil/docs/2000_rpt_optimizing_surface_ship_manning.pdf

Military, Navy, US, operation, manpower, review/case study

NRAC assessed Navy efforts to optimize manning on surface ships. This included a review of previous relevant studies, current programs in US and foreign navies, and relevant technology opportunities. The panel reviewed system life cycle cost initiatives designed to produce savings for recapitalization and modernization. They found a growing cost database under development; however, they recommended continued expansion, cost methodology improvements and further identification of manpower cost components.

The Smart Ship demonstrated that technology insertion and process improvements can reduce manning, maintain capability and improve shipboard quality of life. The Navy has not diffused the Smart Ship lessons learned throughout the Fleet. This is attributed to a lack of top-down leadership and implementation strategy. This situation highlights the enormity of the problem the Navy faces to adapt the revolutionary changes anticipated in DD-21.

Recommendations: (1) CNO appoint a Flag Board responsible for strategy implementation to ensure technological, procedural and organizational changes are adopted throughout the Navy; (2) modify the ship design process to include human engineering to achieve optimal human/system performance; (3) align R&D efforts so that compatible processes and specifications are incorporated for ship components and subsystems for optimally manned ships; and (4) modify recruitment, training, compensation and career progression strategies to reflect changes in organization, skills, and expanded decision-making authority required on optimally manned ships.

Newman, P., A. Bruseberg, et al. (2008). "Improving HFI within systems acquisition: methods, tools and future directions." Cognition, Technology & Work 10(3): 173-180. http://dx.doi.org/10.1007/s10111-007-0101-0

Military, UK, DCL (Acquisition), HSI, Review (Description / Evaluation), Research (methods)

Recent years have seen an increased recognition of the role of the human operator in both the development and use of military systems. Human Factors Integration (HFI), the structured management process for ensuring the capture and accommodation of human capabilities and limitations in design has, however, a mixed record of success within military system developments. This paper describes research conducted by the HFI Defence Technology Centre (HFI DTC) to identify and address the barriers to HFI through the development of processes, methods and tools. Future changes in the operational context and military doctrine are also discussed in terms of the likely adaptations to the HFI process.

Nikolic, M. I. and N. B. Sarter (2007). "Flight deck disturbance management: a simulator study of diagnosis and recovery from breakdowns in pilot-automation coordination." Human Factors 49(4): 553-63. http://hfs.sagepub.com/cgi/content/abstract/49/4/553

Civilian, aviation, US, training (simulation), performance, scientific (experimental)

OBJECTIVE: To examine operator strategies for diagnosing and recovering from errors and disturbances as well as the impact of automation design and time pressure on these processes.

BACKGROUND: Considerable efforts have been directed at error prevention through training and design. However, because errors cannot be eliminated completely, their detection, diagnosis, and recovery must also be supported. Research has focused almost exclusively on error detection. Little is known about error diagnosis and recovery, especially in the context of event-driven tasks and domains.

METHOD: With a confederate pilot, 12 airline pilots flew a 1-hr simulator scenario that involved three challenging automation-related tasks and events that were likely to produce erroneous actions or assessments. Behavioral data were compared with a canonical path to examine pilots' error and disturbance management strategies. Debriefings were conducted to probe pilots' system knowledge.

RESULTS: Pilots seldom followed the canonical path to cope with the scenario events. Detection of a disturbance was often delayed. Diagnostic episodes were rare because of pilots' knowledge gaps and time criticality. In many cases, generic inefficient recovery strategies were observed, and pilots relied on high levels of automation to manage the consequences of an error.

CONCLUSION: Our findings describe and explain the nature and shortcomings of pilots' error management activities. They highlight the need for improved automation training and design to achieve more timely detection, accurate explanation, and effective recovery from errors and disturbances.

APPLICATION: Our findings can inform the design of tools and techniques that support disturbance management in various complex, event-driven environments.

Olsen, N. S. and S. T. Shorrock (2010). "Evaluation of the HFACS-ADF safety classification system: Inter-coder consensus and intra-coder consistency." Accident Analysis and Prevention **42(2): 437-444. http://linkinghub.elsevier.com/retrieve/pii/S0001457509002334**

Military, Air Force, Australia, HSI tool/operation, system safety (incident reporting), reliability, case studies (3 field studies)

This article evaluates an adaptation of the human factors analysis and classification system (HFACS) adopted by the Australian Defence Force (ADF) to classify factors that contribute to incidents. Three field studies were undertaken to assess the reliability of HFACS-ADF in the context of a particular ADF air traffic control (ATC) unit. Study one was designed to assess inter-coder consensus between many coders for two incident reports. Study two was designed to assess inter-coder consensus between one participant and the previous original analysts fora large set of incident reports. Study three was designed to test intra-coder consistency for four participants over many months. For all studies, agreement was low at the level of both fine-level HFACS-ADF descriptors and high-level HFACS-type categories. A survey of participants suggested that they were not confident that HFACS-ADF could be used consistently. The three field studies reported suggest that the ADF adaptation of HFACS is unreliable for incident analysis at the ATC unit level, and may therefore be invalid in this context. Several reasons for the results are proposed, associated with the underlying HFACS model and categories, the HFACS-ADF adaptations, the context of use, and the conduct of the studies.

Olson, W. A. and N. B. Sarter (2001). "Management by consent in human-machine systems: when and why it breaks down." Human Factors **43(2): 255-66. http://hfs.sagepub.com/cgi/content/abstract/43/2/255**

Military, aviation, design/training (simulation/automation), performance, scientific (experimental)

This study examined the effects of conflict type, time pressure, and display design on operators' ability to make informed decisions about proposed machine goals and actions in a management-by-consent context. A group of 30 B757 pilots were asked to fly eight descent scenarios while responding to a series of air traffic control clearances. Each scenario presented pilots with a different conflict that arose from either incompatible goals contained in the clearance or inappropriate implementation of the clearance by automated flight deck systems. Pilots were often unable to detect these conflicts, especially under time pressure, and thus failed to disallow or intervene with proposed machine actions. Detection performance was particularly poor for conflicts related to clearance implementation. These conflicts were most likely to be missed when automated systems did more than the pilot expected of them. Performance and verbal protocol data indicate that the observed difficulties can be explained by a combination of poor system feedback and pilots' difficulties with generating expectations of future system behavior. Our results are discussed in terms of their implications for the choice and implementation of automation management strategies in general and, more specifically, with respect to risks involved in envisioned forms of digital air-ground communication in the future aviation system. Actual or potential applications of this research include the design of future data link systems and procedures, as well as the design of future automated systems in any domain that rely on operator consent as a mechanism for human-machine coordination.

Osga, G. (2003). Human-Centered Shipboard Systems and Operations. Handbook of Human Systems Integration. H. R. Booher, Wiley: 743-793. http://books.google.com.au/books?hl=en&lr=&id=FKh-DO48ApgC&oi=fnd&pg=PR13&dq=%22Handbook+of+human+systems+integration%22&ots=p-fd6JbqJJ&sig=iPpr03cl8J1Ar3nLsSgHaeDPQoU

military, navy, maritime, case study, manning, manpower

One of the primary principles of successful human systems integration (HSI) in systems engineering and management is utilizing a human-centered design (HCD) approach throughout the systems acquisition process (Chapters 1, 10, and 18). Several other chapters (Chapters 4, 6, 7, and 9, in particular) have pointed out the need to establish HSI requirements early in the process, if the HCD principle is to be fully effective. Unfortunately, system design requirements based upon human capabilities and limitations may not be considered early in the design process, leading to costly changes during implementation. Often, new systems simply evolve from past systems approaches using established procedural and design methods.

The designer may rely on the user during the requirements stage to consider the human component, but user input must be carefully considered in that it can maintain previous designer flaws relative to human performance. User input and design qualities must be abstracted into basic task requirements. Unless the methods and procedures used in establishing requirements are specifically analyzed for impact on human performance and efficiency, neither the user or the designer is likely to fully recognize the effect the design will have on the human component when the system is fielded.

A major requirement for improved user interface and decision support aboard ships has arisen from the need for crew size optimization. Optimization must be achieved without sacrifice of performance, mission risk, and without crew overload. Crew optimization in future ships has been recognized as a significant cost factor and therefore has become a performance capability objective for newer classes of ships [Naval Sea Systems Command (NAVSEA), 1996, 1997]. When the U.S. Navy required a drastic reduction of crew size from 350 to 95 personnel on DD 21 ships, it recognized the need to use HSI principles for equipment design requirements and design solutions to successfully achieve mission objectives (Bush et. al., 1999).

Consequently the Multimodal Watchstation (MMWS) project was conceived as a risk-reduction research effort to create concept designs that aid in HSI with optimized crews. The concept designs also demonstrated a task-centered approach to requirements determination during the system definition stage, without major restrictions imposed by current design practice.

Osga, G. and G. Galdorisi (2003). Human Factors Engineering: An Enabler for Military Transformation Through Effective Integration of Technology and Personnel, Space and Naval Warfare Systems Center San Diego Office of Science, Technology and Engineering. http://www.dtic.mil/cgi-bin/GetTRDoc?Location=U2&doc=GetTRDoc.pdf&AD=ADA467381

Military (Navy), (maritime), US, DCL (design, acquisition), HSI (HFE, safety, training, personnel, manpower), discussion, description, performance, cost, methods, tools

Transformation of the United States military requires new ways of defining both design and mission processes to improve warfighting performance and reduce system costs.

New technologies engendered through the discipline of human-factors engineering enable warfighters to make more effective decisions in a timelier manner with fewer personnel.

While the tradeoffs between new technologies and numbers of operators needed are complex, strong anecdotal evidence suggests that these manpower savings can be significant and have the potential to accelerate military transformation. The human factors engineering community has documented and quantified the enhanced mission effectiveness of fewer warfighters operating enhanced combat systems. What is less well quantified _- due to a number of institutional factors - is the true life cycle cost of military operators. This paper discusses design factors that support reduced crew workload and factors that influence crew cost estimation and size. The conclusion is that although we have identified good candidate designs to support reduced crew workload, we cannot adequately trade off their cost with personnel costs until we can more accurately quantify personnel costs.

Parasuraman, R., M. Mouloua, et al. (1996). "Effects of adaptive task allocation on monitoring of automated systems." Human Factors 38(4): 665-79. http://archlab.gmu.edu/People/rparasur/Documents/Paraetal%201996adap.pdf

Civilian, aviation, training (simulation) safety (risk perception), scientific (experimental)

The effects of adaptive task allocation on monitoring for automation failure during multitask flight simulation were examined. Participants monitored an automated engine status task while simultaneously performing tracking and fuel management tasks over three 30-min sessions. Two methods of adaptive task allocation, both involving temporary return of the automated engine status task to the human operator ("human control"), were examined as a possible countermeasure to monitoring inefficiency. For the model-based adaptive group, the engine status task was allocated to all participants in the middle of the second session for 10 min, following which it was again returned to automation control. The same occurred for the performance-based adaptive group, but only if an individual participant's monitoring performance up to that point did not meet a specified criterion. For the nonadaptive control groups, the engine status task remained automated throughout the experiment. All groups had low probabilities of detection of automation failures for the first 40 min spent with automation. However, following the 10-min intervening period of human control, both adaptive groups detected significantly more automation failures during the subsequent blocks under automation control. The results show that adaptive task allocation can enhance monitoring of automated systems. Both model-based and performance-based allocation improved monitoring of automation. Implications for the design of automated systems are discussed.

Patrick, J., N. James, et al. (2006). "Human processes of control: tracing the goals and strategies of control room teams." Ergonomics 49(12-13): 1395-414. http://www.informaworld.com/smpp/content~db=all~content=a757998754

Civilian, other industry (nuclear plant), operation, training (simulated scenarios), safety (risk detection), scientific/case study

This study utilized a process tracing methodology to analyse the goals and strategies of control room teams in dealing with an unpredicted plant disturbance. The human processes of control used by operators and their supervisors, and interactions between them, were analysed during phases of detection, diagnosis, and control of a small plant leak. Five control room teams were videotaped tackling this simulated scenario on a full-scale simulator. The results found substantial differences both within and between teams in how the goals of monitoring and implementing procedures during the detection phase, and problem-solving and plant control during the diagnosis phase were achieved. The temporal patterning of the activities associated with these goals revealed that the teams used different strategies. The training implications of these findings are discussed, in particular with respect to the control room supervisor who had a pivotal role.

Perry, S. J. (2004). "An overlooked alliance: using human factors engineering to reduce patient harm." Joint Commission Journal on Quality & Safety **30**(8): 455-9. http://www.ingentaconnect.com/content/jcaho/jcjqs/2004/00000030/00000008/art00006

Civilian, medical, HFE, safety, discussion/case studies

BACKGROUND: Although human factors engineering (HFE) is considered only in relationship to the design of medical devices or information systems technology, human factors issues arise in many aspects of work in health care organizations.

HFE ANALYSIS: In one scenario, the resuscitation stretcher would not pass through the ED door closest to radiology. Many clinical work spaces were never formally designed for the work currently being performed in them; instead, they were adapted from existing space originally designed for a different use. In a second scenario, infusion pump malfunction was not apparent. The patient experienced a near miss secondary to poor design; users thought that the infusion pump had been turned off when it was not.

RECOMMENDATIONS: Health care can significantly benefit from the incorporation of HFE into the workplace. Introductory classes in medical and nursing schools on HFE will assist students in detecting HFE-related issues, making them less likely to suffer with them or overlook them once in clinical practice. More extensive training for patient safety and risk managers, that is, at a minimum, a certificate-level course from an HFE program, would enhance case and root cause analyses since these issues are rarely factored in. CONCLUSION: Collaboration with HFE experts and use of HFE principles may not make health care fool-proof, but it will make it less dependent on improvisation and ingenuity to protect patients from the system's vulnerabilities.

Pew, R. (2008). "More Than 50 Years of History and Accomplishments in Human Performance Model Development." Human Factors **50**(3): 489-496. http://hfs.sagepub.com/cgi/content/abstract/50/3/489

performance modelling

Objective: I provide a summary that introduces three significant threads in the development of human performance models (HPMs) - manual control models derived from engineering control theory, network models founded on the definition of human reliability, and models derived from cognitive architectures.

Background: HPMs are important because they allow the quantification of human performance capacities and limitations to be included in the analysis and simulation of engineering systems.

Method: For each thread, founding articles and contemporary developments are cited that illustrate the range of innovation that has taken place.

Results: Many contemporary concepts are rooted in this modeling history.

Conclusion: The most successful models represent circumstances for which the situational and temporal environment in which the human performance takes place is most heavily constrained.

Application: Applied illustrations are drawn from vehicle handling qualities, unmanned aerial systems, and mission training, for example.

Pew, R. (2008). "Some New Perspectives for Introducing Human-Systems Integration into the System Development Process." Journal of Cognitive Engineering and Decision Making 2: 165-180.

As further background for this Special Issue, this paper introduces a sampling of the findings of a National Research Council Committee on Human-Systems Design Support for Changing Technology. The paper introduces the Incremental Commitment Model of system development that was designed to accommodate the needs of the human-system integration (HSI) community. The committee viewed effective integration of human-system issues as requiring (a) stakeholder satisficing- solutions that meet acceptability criteria of all stakeholders; (b) incremental growth of system definition and stakeholder commitment; (c) iterative and concurrent system definition and development; (d) HSI risk analysis and risk management in concert with that of the other engineering disciplines involved in a project; and (e) HSI outcomes or deliverables designed specifically to be shared and understood by the other stake- holders. As the committee members looked to the future, they envisioned a point when it would be possible to develop a fully integrated HSI development methodology. They also foresaw a time when HSI might become an independently recognized discipline and more HSI specialists would be qualified to lead project teams, placing the discipline in a more commanding role in the system development process.

Pew, R. and A. Mavor (2007). Human-system integration in the system development process: A new look, National Academies Press. http://books.google.com.au/books?hl=en&lr=&id=47_fqrsFT14C&oi=fnd&pg=PA1&dq=Human-system+integration+in+the+system+development+process:+A+new+look&ots=WLFK4qf56N&sig=RnVxyWrFoyaWtJG3CI00zrhUI4M#v=onepage&q&f=false

Civilian

In April 1991 Business Week ran a cover story entitled, "I Can't Work This ?#!!@ Thing," about the difficulties many people have with consumer products, such as cell phones and VCRs. Today, more than 15 years later, the situation is much the same. At quite a different level of scale and consequence of the disconnect between people and technology are the major large-scale systems accidents for which human error was paramount, such as those at Three Mile Island and Chernobyl. Similarly, a major, expensive console update to the nation's air traffic control operations was cancelled because the operational personnel concluded that it would be too complicated and difficult to operate. These examples illustrate the pressures on industry and government as the complexity of the systems they seek to develop increase at the same time they are challenged to shorten the development cycle for those systems. These problems are magnified by the increasing prevalence of systems of systems. Systems of systems arise when a collection of different systems, originally designed for their own purposes, are combined and coordinated to produce a very large system with new issues and challenges.

These problems can be traced to a significant challenge-that human capabilities and needs must be considered early and throughout system design and development. One aspect of the challenge has been providing the background and data needed for the seamless integration of humans into the design process from various perspectives (human factors engineering, manpower, personnel, training, safety and health, and, in the military, habitability and survivability). This collection of development activities has come to be called human-system integration (HSI). A second aspect has been a lack of commitment by funders and program managers to assign priority to these activities. A third aspect has been a lack of effective communication between the system engineers and human-system domain experts.

To address these challenges, the Army Research Laboratory and the Air Force Research Laboratory of the U.S. Department of Defense asked the National Academies, through its Committee on Human Factors, to undertake a study of the current state of methods, tools, and approaches for analyzing human capabilities and needs and to develop a vision for creating an integrated, multidisciplinary, generalizable, human-system design methodology. The Committee on Human-System Design Support for Changing Technology was specifically charged with four tasks:

1. Provide a comprehensive review of issues involved in design throughout the system life cycle that need to be addressed by a consideration of human cognitive and physical performance characteristics. This review will be used as a framework for further analysis of methodologies.
2. Evaluate the state of the art in human-system engineering and (a) product development processes, (b) product design methodologies, and (c) product design tools.
3. Develop a vision for an integrated, multidisciplinary, generalizable, human-system design support methodology and tool set. Identify a set of core methods and tools needed to support design activities associated with a variety of systems.
4. Recommend a research plan suggesting how to achieve this ideal.

In carrying out its work, the committee's goal was to make recommendations that are relevant not only to the project's military sponsors, but also to other government departments and the private sector, including the process control, manufacturing, and service industries.

Pharmer, J. A. (2007). "The challenges and opportunities of implementing human systems integration into the navy acquisitions process." Defense Acquisition Review Journal. http://www.thefreelibrary.com/The+challenges+and+opportunities+of+implementing+human+systems...-a0167026980

Military (Navy/Aviation), US, DCL (Acquisition), HSI, Discussion (policies, practices) / Review

Over the last decade, the Department of Defense has placed increased emphasis on including considerations of human capabilities and limitations into systems engineering and acquisition processes. The purpose of this article is to provide an overview of how the Navy is implementing Human Systems Integration (HSI), the process of incorporating considerations, characteristics, capabilities, and limitations of human operators and maintainers within acquisition decision making at a level commensurate with decisions regarding hardware and software. More specifically, this article will address some of the policy initiatives, organizational changes, and implementation challenges of incorporating HSI into the acquisition life cycle to insure better total system performance and lower total ownership cost.

Poisson, R. (2006). The case for a convincing argument: a DRDC human systems integration case study. TTCP Human Systems Integration Symposium, Canberra, Australia http://www.dsto.defence.gov.au/attachments/RPoisson%20TTCP%202006.pdf

Military, Canada, DCL, HSI, case study (cost-benefit)

The Generic Case for an IntegratedApproach to Human Systems Integration

- Direct Benefits from an Integrated Approach
  - Integrated core behavioural analysis of operator and maintainer tasks.
  - Integrated design evaluations.
- Potential Savings of Least 25% of HSI Project Costs by Integrating Domains

Raffetti, A., F. Marangon, et al. (2000). "Integrated navigation system safety assessment methodology." Journal of Navigation 53(3): 425-435. http://journals.cambridge.org/action/displayAbstract?fromPage=online&aid=58983

Civilian, maritime, design, system safety, safety (risk assessment and analysis), case study

The introduction of modern navigation systems highlights the need for efficient tools to assess the possible impact of these systems on the safety levels currently associated with the operation of a ship. In recent years this has led to investigation of the advanced safety/risk assessment techniques already applied in other industrial sectors, with encouraging results. The scope of this paper is to show a quantified safety assessment methodology that can be applied while designing or retrofitting navigation systems. The methodology adopted is the result of the review of the IMO Formal Safety Assessment (FSA) technique and comprises the development of a functional analysis, a hazard identification analysis and a risk assessment. The paper provides details on a specific application of this model to an integrated navigation system. This application is included in the work performed under the ATOMOS II research project, partly funded by the DGVII Directorate of the European Commission within the 4th Framework Programme in the field of Maritime Transport.

Rantanen, E., C. Wickens, et al. (2004). Developing and Validating Human Factors Certification Criteria for Cockpit Displays of Traffic Information Avionics, AHFD-04-1/FAA-04-1). Savoy, IL: Aviation Human Factors Division. http://www.tc.faa.gov/LOGISTICS/GRANTS/pdf/2002/02-G-032.pdf

Civilian (Aerospace [Aviation]),

This report examines issues associated with traffic awareness and conflict detection and resolution applications, particularly the predictive and planning support offered by the Cockpit Display of Traffic Information (CDTI). However, inferences about future trajectories of ownship and traffic made by the CDTI logic will, by nature, be imperfect, leading to an apparent loss of reliability of the prediction/planning tools. This loss of reliability and its impact on pilots' behavior and cognition is the focus of this report. Three specific aspects of the CDTI are distinguished: Alerts, visual symbology, and planning tools.

The report draws from general human factors literature. The tradeoff between false alarms (FAs) and misses (or late alerts), how these tradeoffs affect trust and reliance in the alerting system, and how low base-rate events necessarily create a high false alarm rate (FAR), if highcost misses are to be minimized, are examined. The report concludes with general recommendations emerging from the literature on solutions to mitigate the problems of FAs, with an emphasis on multi-level alerts. Also literature that has addressed the FA-late alert tradeoff and evaluated the CDTI alerts with pilot-in-the-loop (PIL) data was reviewed. Lessons learned from implementation of Traffic Alert and Collision Avoidance System (TCAS) were assessed and results of the analysis of ASRS reports from TCAS system are reported. From this review, guidance will emerge regarding what aspects of conflict situations make detection and response difficult from a pilot's point of view, and therefore should be targeted for inclusion in certification and approval. Also documents by RTCA and FAA were carefully reviewed for guidelines on alerts as well as for their origins, human factors data to back them up, and potentially overlooked issues. Finally, a full taxonomy of possible conflict scenarios was developed, from which-based of the literature reviewed-a subset of scenarios was detailed for bench testing. Finally, recommendations for evaluation of CDTIs during bench testing are offered.

Each section in this report is concluded with a summary, and where appropriate, a set of recommendations. Based on the review of general human factors literature on automated alerting systems in section 2, Non-CDTI Alerting and Alarm Studies, the following conclusions are drawn:

- CDTI Alerts are necessarily imperfect, given that the future of a probabilistic airspace is to be predicted.
- These alerts should produce more FAs than misses (late alerts) because of low base rate and the high cost of misses.
- While humans may lose trust with imperfection, they can learn to calibrate their reliance to the actual reliability of the system.
- Misses (late alerts) probably have a different consequence on trust and reliance than FAs, although more research is needed to understand this tradeoff.
- Human trust and reliance problems may be mitigated by training, status displays, and likelihood alarms although the optimum number of alarm states for likelihood alarms is not well established and research should address this issue.

Reinach, S. and M. Jones (2007). "An Introduction to Human Systems Integration (HSI) in the U.S. Railroad Industry." http://www.fra.dot.gov/downloads/Research/AnIntroToHSI.pdf

Civilian transport (Railroad), US, HSI

Human systems integration (HSI) is a systematic, organization-wide approach to implementing new technologies and modernizing existing systems. It is a combination of managerial philosophy, methods, techniques, and tools designed to emphasize, during the acquisition process, the central role and importance of end-users in organizational processes or technologies. This approach optimizes the safety and efficiency of these systems through the consideration of all the system's elements. Traditional approaches to technological implementation focus on mechanical, hardware, and software design challenges. Often, little attention is paid to the end-user and his/her capabilities and limitations. An assumption is made that the introduction of the technology automatically will be acceptable to the users and will improve job performance. This does not always hold true.

The safety and reliability of new and modernized technologies and systems ultimately depend on their interaction with end-users-operators and maintainers. Even the most sophisticated technologies, when designed and implemented without proper consideration of user needs and requirements, may not achieve optimal system performance because of mismatches between the technology and human operator limitations or capabilities. To help achieve optimal overall system success, the human operator should be viewed as a central part of the system. Careful evaluation of an operator's interaction with a system during its initial design eliminates potential mismatches downstream during the system's implementation and operation.

The Federal Railroad Administration (FRA) is interested in introducing HSI to the railroad industry to help railroads further improve the safety and efficiency of their operations. An HSI approach to railroad technology acquisition and implementation can increase user acceptance of the technology, increase usability of the technology, and increase the likelihood of successful technology deployment. Investing in a systems approach to technology acquisition and modernization can provide a return on investment that is both tangible (e.g., cost savings) and intangible (e.g., improved labor relations).

Over time, U.S. railroads have incorporated individual elements of an HSI approach (e.g., user testing, consideration of training requirements, etc.) into the acquisition of various technological systems. The purpose of this paper is to provide an introduction of HSI concepts to the U.S. railroad industry and stimulate discussion of an HSI framework that can support railroads' technology acquisition processes, since it is in these processes that railroads have the ability to economically and efficiently specify system requirements and most successfully implement technology.

The U.S. military is currently the largest HSI practitioner in the United States. The U.S. Army articulates the following seven topical areas where the impact of a new technology must be considered before the technology is approved, acquired, and deployed (or modernized):

Page 3

1. Manpower. The manpower domain includes consideration of the staff required to operate, maintain, sustain, and train for the technology or system under consideration.
2. Personnel. This domain focuses on the knowledge, skills, abilities, and other characteristics (KSAOs) necessary to train for, operate, maintain, and sustain the new or modernized technology or system.
3. Training. The training domain addresses the instructional requirements crucial to instill the KSAOs that are necessary to operate, maintain, and sustain the new or modernized technology or system.
4. Human factors engineering. Human factors engineering focuses on designing human system interfaces to optimize user performance and reduce the likelihood of user errors.
5. System safety. System safety addresses the potential for new or modernized systems to contribute to, or cause, errors or failures that can lead to accidents.
6. Health hazards. The health hazards domain focuses on mitigating the potential for regular and routine use of the system to result in bodily harm; that is, injury, illness, and death, as well as reduced system performance that may result from bodily harm.
7. Survivability. This domain addresses the need to increase the likelihood that soldiers survive attacks of various natures, including fratricide. In the context of railroad operations, this domain might focus on designing systems to improve occupant protection and survivability.

Advantages of HSI include the potential to:

- Increase U.S. railroad safety.
- Improve operator performance and operational efficiency.
- Increase user acceptance.
- Reduce training time and costs.
- Reduce the likelihood of, and costs associated with, system upgrades and midcourse design changes.
- Reduce system lifecycle costs.

To gain the full benefit of HSI and its integrated systems approach to technology and modernization programs, railroads, including management, labor, and trade associations, can:

- Allocate sufficient monetary and staff resources to develop an HSI program to support system acquisitions and modernizations.
- Develop an overarching HSI policy and process that governs how HSI will be applied to new system or technology acquisitions and modernization programs.
- Develop a human systems integration plan (HSIP) for each new or modernization program.

Rhodes, D., A. Ross, et al. (2009). Extending Systems Engineering Leading Indicators for Human Systems Integration Effectiveness. 7th Annual Conference on Systems Engineering Research 2009 (CSER 2009), US http://seari.mit.edu/documents/preprints/RHODES_CSER09.pdf

Military (Air Force), US, DCL (design, acquisition), HSI (HFE, safety, training, personnel, manpower), discussion, description, performance, cost, methods tools

Human Systems Integration (HSI) is the integrated, comprehensive analysis, design and assessment of requirements, concepts, and resources for system Manpower; Personnel, Training, Environment, Safety, Occupational Heath, Habitability, Survivability and Human Factors Engineering. This paper describes a new research effort to extend a set of systems engineering leading indicators developed in prior research, to more effectively address HSI considerations. HSI is tightly coupled with the systems

engineering process, particularly in large defense and government programs, making it challenging to determine if HSI is sufficiently considered to ensure a successful program. It is also challenging to isolate and identify HSI issues, particularly in the early stages of acquisition and program development. The objective of the research is to augment and extend the current

systems engineering leading indicators, including interpretive guidance, to enhance the predic ability of programmatic and technical performance on a program to include adequate HSI consideration.

Riley, J. M., M. R. Endsley, et al. (2006). "Collaborative planning and situation awareness in Army command and control." Ergonomics 49(12-13): 1139-53. http://www.informaworld.com/index/757998423.pdf

Military, Army, US, HSI tool/design (synergy dispaly suite for C2), HFE/training, discussion/technical with a case study

We conducted a theoretical investigation of a complex command and control (C2) operation—the manoeuvres planning processes in Army land-battle situations, to improve understanding of how technology can best be designed to support planning and course of action development. We drew upon results from cognitive task analyses and interviews with subject matter experts and insights gleaned from observations of Army training exercises and experiments to make inferences on the C2 activities carried out in preparation for tactical manoeuvres. In this paper, we summarize several critical human factors issues associated with planning in a rapidly evolving environment, as identified in our investigation, and describe system design concepts aimed at addressing these challenges to distributed collaborative planning of C2 activities. We conclude with implications for the application of these findings to other C2 domains.

Rose, T., C. Blake, et al. (2007). "Improving patient safety through device design and usability." Contemporary Ergonomics 2007: 469-474. http://direct.bl.uk/bld/PlaceOrder.do?UIN=211959391&ETOC=RN&from=searchengine

Civilian, medical, acquisition, HFE, safety, review of case studies

The promotion of patient safety by reducing error is a key priority for major health services around the world. One way of reducing the number of patient safety incidents is by eliminating errors in the programming and usage of medical devices. This paper describes a project to support the procurement of medical devices by ensuring that device ergonomics and usability are considered as key criteria in the purchasing process. It is based on an analysis of 392 device-related events reported to the NPSA via its National Reporting and Learning System (NRLS) during 2005. This paper reviews that data, describes the analysis and presents some of the overall themes to emerge.

Rouse, W. B. (2007). <u>People and organizations: explorations of human-centered design</u>, Wiley-Interscience. http://books.google.com.au/books?hl=en&lr=&id=42uCaj1fgpcC&oi=fnd&pg=PR19&dq=People+and+organizations:+explorations+of+human-centered+design&ots=9XoKlp-cr_&sig=L07Si-5ZnaRshCwHYK5bBYr3Ljc#v=onepage&q&f=false

civilian

This book is about people who operate, maintain, design, research, and manage complex systems, ranging from air traffic control systems, process control plants and manufacturing facilities to industrial enterprises, government agencies and universities. The focus is on the nature of the work these types of people perform, as well as the human abilities and limitations that usually enable and sometimes hinder their work. In particular, this book addresses how to best enhance abilities and overcome limitations, as well as foster acceptance of the means to these ends.

Rouse, W. B. and K. R. Boff (2003). Cost-benefit analysis for human systems integration. <u>Handbook of Human Systems Integration</u>. H. R. Booher. Hoboken, Wiley: 631-657.

Rouse, W. B. and K. R. Boff (2006). Cost-benefit analysis of human systems investments. <u>Handbook of Human Factors and Ergonomics</u>. G. Salvendy. Hoboken, NJ, Wiley: 1133-1149.

cost-benefit, civilian, military

Rovira, E., K. McGarry, et al. (2007). "Effects of imperfect automation on decision making in a simulated command and control task." <u>Human Factors</u> 49(1): 76-87. http://hfs.sagepub.com/cgi/content/abstract/49/1/76

*Military, operation, HFE (automation), performance, scientific (experimental)

OBJECTIVE: Effects of four types of automation support and two levels of automation reliability were examined. The objective was to examine the differential impact of information and decision automation and to investigate the costs of automation unreliability.

BACKGROUND: Research has shown that imperfect automation can lead to differential effects of stages and levels of automation on human performance.

METHOD: Eighteen participants performed a "sensor to shooter" targeting simulation of command and control. Dependent variables included accuracy and response time of target engagement decisions, secondary task performance, and subjective ratings of mental work-load, trust, and self-confidence.

RESULTS: Compared with manual performance, reliable automation significantly reduced decision times. Unreliable automation led to greater cost in decision-making accuracy under the higher automation reliability condition for three different forms of decision automation relative to information automation. At low automation reliability, however, there was a cost in performance for both information and decision automation.

CONCLUSION: The results are consistent with a model of human-automation interaction that requires evaluation of the different stages of information processing to which automation support can be applied.

APPLICATION: If fully reliable decision automation cannot be guaranteed, designers should provide users with information automation support or other tools that allow for inspection and analysis of raw data.

Royal Australian Airforce (2001). Chemical exposure of Air Force maintenance workers: Report of the Board of Inquiry into F-111 (fuel tank) deseal/reseal and spray seal programs., Royal Australian Air Force. http://www.airforce.gov.au/projects/f111/Volume1.htm

defense, military, air force, case study

PREFACE

During the course of this Inquiry into the chemical exposure of Air Force maintenance workers some 1.5 million documents, covering a period of 27 years, have been researched. Some 40, 000 documents totalling 151, 000 pages have been entered into the Board's database, Casebook. Statements were taken from over 650 people.

Whilst the aim of this report is to address the extensive Terms of Reference, it has also been designed to facilitate the work of the Chief of Air Force's follow-on team for accepted recommendations.

For clarity, and utility as a management tool, this report is presented in three volumes. The purpose of Volume 1 is to present a line of argument which answers three main questions:

what happened;

why; and

what can be done to prevent recurrence.

Volume 1 also sets out the Board's recommendations. The Board's approach to its overall task is explained in detail in Appendix 1 to Volume 1. Volume 1 also contains a copy of the Terms of Reference and identifies the issues and points of interest during the Inquiry.

Volume 2 of the report provides a more comprehensive answer to the detail of the individual Terms of Reference. It will be of most use to individuals seeking to work through the detail of the evidence. For example, the sequence of events and information such as lists of chemicals and individuals working in the programs at specific times. This part has also been edited by text hyper link to enable ease of electronic access.

Volume 3 is extensive reference material which in hard copy presently fills a room in Victoria Barracks, Brisbane. The whole of the material before the Board has also been recorded on CD ROM.

Ruishan, S., W. Lei, et al. (2007). Analysis of human factors integration aspects for aviation accidents and incidents. Engineering Psychology and Cognitive Ergonomics, Proceedings.4562: 834-841 http://www.springerlink.com/content/at07pm023w426q68/

Civilian, aviation, HSI tool, safety, technical

Aviation accidents have been contributed mostly by human factors since commercial flight. So it is a key of improving aviation safety to analyze accidents, incidents and other occurrence through human factors model and make preventing measure. The paper presents an analysis method named EEAM based human factors integration.

Runnerstrom, E. (2003). "Human systems integration and shipboard damage control." **Naval Engineers Journal** **115(4): 71-79. http://www3.interscience.wiley.com/journal/121489366/abstract**

*Military, Navy, US, design/acquisition, manpower (crewing), system safety (damage control), case study

As the United States and other maritime nations move towards operating combatant ships with fewer people, human-systems integration (HSI), or human-centered design, is getting increasing attention in new ship designs. Aboard most ships operating today, damage control is a mostly manual, manpower intensive function. Consequently, it is a key area of concern for ship acquisition programs that need to produce ships that will operate with fewer people. Damage control also is critical to the survival of a warship and the safety of the crew. Consequently, it is very important to ship operators. It is no surprise, therefore, that damage control is a key function of concern when designing new ships to operate with fewer people. This paper discusses the state-of-the-art in HSI and damage control aboard ships today as evidenced by the damage control performance of some of today's ships. The paper draws conclusions about the importance of HSI for effective damage control in new ship designs. The successful application of a human-centered design approach in the development of a damage control supervisory control system for the U.S.Navy's Damage Control Automation for Reduced Manning (DC-ARM) Program is described. Finally, major challenges to achieving effective HSI in new ship designs are presented.

Salas, E., M. Rosen, et al. (2007). "Markers for enhancing team cognition in complex environments: the power of team performance diagnosis." **Aviation, space, and environmental medicine** **78(Supplement 1): B77-B85. http://www.ingentaconnect.com/content/asma/asem/2007/00000078/A00105s1/art00012**

Military, operation, personnel (team cognition), performance, scientific/review

Team cognition has been identified as a key component to achieve mission goals in dynamic, team-based, stressful, distributed and multicultural operations.

Effective team performance in complex environments requires that team members hold a shared understanding of the task, their equipment, and their teammates. So, many of the simulation-based training (SBT) systems and programs have been designed (partly) to enhance shared/team cognition. However, these simulation systems lack the sufficient robustness in their performance assessment tools or capabilities (if they have any) to allow for a rich and deep understanding of team cognition. Therefore, the purpose of this article is fourfold: 1) to present a brief account of team cognition; 2) to develop the concept of performance diagnosis and present SBT as an approach to the performance diagnosis of team cognition; 3) to present a set of illustrative behavioral markers of team cognition; and 4) to explicate how these elements (performance diagnosis, team cognition, and SBT) can be leveraged to increase training effectiveness through the development of performance profilesâ€"a rich, detailed, and informative set of metricsâ€"and cognitive and behavioral indicators or illustrative markers of team cognition. Research needs are discussed in terms of realizing the potential of this approach in operational and embedded training contexts.

Salmon, P., N. Stanton, et al. (2004). Human factors design & evaluation methods review, Human Factors Integration Defence Technoogy Centre. http://www.hfidtc.com/research/abstracts/hf-design-and-evaluation-methods.htm

human factors, methods, tools, review

This report describes the Human Factors (HF) methods review that was conducted for work packages 1.3.2 - Design methods review, and 1.3.3 - Evaluation methods review and is part of work package 1, 'Human Factors Integration for C4i Systems'. The overall aim of work packages 1.3.2 and 1.3.3 was to review and evaluate HF methods and techniques suitable for use in the design and evaluation process of future C4 (command, control, communication and computer) systems. Each HF technique is described and reviewed using a set of pre-determined methods evaluation criteria and the output of the review acts as a guide for HF practitioners in the selection and use of appropriate HF techniques.

Salmon, P., N. Stanton, et al. (2007). "What really is going on? Review, critique and extension of situation awareness theory." Engineering Psychology and Cognitive Ergonomics: 407-416. http://portal.acm.org/citation.cfm?id=1784244

PJ, full-text, Military, UK, DCL, HSI [situation awareness], Review (description), Research (effectiveness, methods)

Theoretically, Situation Awareness (SA) remains predominantly an individual construct. The majority of the models presented in the literature focus on SA from an individual perspective and in comparison, the concept of team SA has received less attention. SA in complex, collaborative environments thus remains a challenge for the human factors community, both in terms of the development of theoretical perspectives and of valid measures, and also in the development of guidelines for system, training and procedure design. This article presents **a review and critique of what is currently known about SA and team SA**, including a comparison of the most prominent individual and team **models** presented in the literature. In **conclusion**, we argue that recently proposed systems level Distributed Situation Awareness (DSA) approaches are the most suited to describing and assessing SA in real world collaborative environments.

Salmon, P., N. Stanton, et al. (2009). Distributed Situation Awareness: Theory, Measurement and Application to Teamwork., Ashgate Publishing. http://eprints.soton.ac.uk/76018/

Military, UK, DCL, HSI [situation awareness, command and control systems], Case study / Review (description / evaluation), Research (safety, reliability, efficiency, effectiveness, tools, Methods)

Having an accurate understanding of what is going on is a key commodity for teams working within military systems. 'Situation awareness' (SA) is the term that is used within human factors circles to describe the level of awareness that operators have of the situation that they are engaged in; it focuses on how operators develop and maintain a sufficient understanding of 'what is going on' in order to achieve success in task performance. Over the past two decades, the construct has become a fundamental theme within the areas of system design and evaluation and has received considerable attention from the human factors research community. Despite this, there is still considerable debate over how SA operates in complex collaborative systems and how SA achievement and maintenance is best supported through system, procedure and interface design.

This book focuses on the recently developed concept of distributed situation awareness, which takes a systems perspective on the concept and moves the focus on situation awareness out of the heads of individual operators and on to the overall joint cognitive system consisting of human and technological agents. Situation awareness is viewed as an emergent property of collaborative systems, something that resides in the interaction between elements of the system and not in the heads of individual operators working in that system.

The first part of the book presents a **comprehensive review and critique of existing SA theory and measurement approaches**, following which a novel model for complex collaborative systems, the distributed SA model, and a new modelling procedure, the propositional network approach, are outlined and demonstrated.

The next part focuses on **real-world applications of the model and modelling procedure, and presents four case studies undertaken in the land warfare, multinational warfare and**

energy distribution domains. Each case study is described in terms of the domain in question, the methodology employed, and the findings derived in relation to situation awareness theory.

The third and final part of the book then concentrates on theoretical development, and uses the academic literature and the findings from the case study applications to validate and extend the distributed SA model described at the beginning of the book. In closing, the utility of the distributed SA model and modeling procedure are outlined and a series of initial guidelines for supporting distributed SA through system design are articulated.

Salmon, P., N. Stanton, et al. (2006). "Situation awareness measurement: A review of applicability for C4i environments." Applied Ergonomics 37(2): 225-238. http://www.sciencedirect.com/

full-text, Military, UK, DCL, HSI [situation awareness], Review, Research (Methods, reliability, effectiveness)

The construct of situation awareness (SA) has become a core theme within the human factors (HF) research community. Consequently, there have been numerous attempts to develop reliable and valid measures of SA. Despite this, it is apparent that there are a lack of techniques that have been developed specifically for the assessment of SA in C4i (command, control, communication, computers and intelligence) environments. During the design, development and evaluation of novel systems, technology and procedures, valid and reliable situation awareness measurement techniques are required for the assessment of individual and team SA. SA is assessed in order to determine the improvements (or in some cases decrements) resulting from proposed design and technological interventions. The following paper presents a **review of existing situation awareness measurement techniques** conducted in order to assess their suitability for use in the assessment of SA in C4i environments. Seventeen SA measures were evaluated against a set of HF methods criteria. It was concluded that current SA measurement techniques are inadequate for use in the assessment of SA in C4i environments, and a multiple-measure approach utilising different approaches is recommended.

Keywords: Situation Awareness, measurement, C4i systems

Salmon, P., G. Walker, et al. (2007). Measuring situation awareness in command and control: comparison of methods study, ACM: 27-34 http://portal.acm.org/citation.cfm?id=1362550.1362559

Military, UK, DCL, HSI [situation awareness, command and control], case study [evaluation], Research (efficiency, effectiveness, methods)

Motivation - This research sought to **compare three different approaches for measuring Situation Awareness (SA)** during a command and control scenario.

Research approach - A total of 20 participants undertook question one of the Combat Estimate, a military planning process, in an experimental command and control test bed environment. Participant SA was measured using three different SA measures: a freeze probe technique, a post trial subjective rating technique, and a critical incident technique interview approach.

Comparisons were then made between the measures of SA obtained during the study.

Findings/Design - The results show that the freeze probe measure (SAGAT) was the only measure that had a statistically significant correlation with participant performance. The findings also demonstrate that there was no significant correlation between the three SA measures used.

Research Implications - The findings offer validation evidence for the SAGAT approach when used to measure participant SA during a command and control task and suggest that the three approaches used view SA in a different manner.

Originality/Value - The research explores the measurement of SA during command and control activity and makes judgements on the suitability of each method for application in this context.

Take away message - Analogous to the different theoretical perspectives on SA presented in the literature, these findings suggest that the methods compared view and assess SA in a very different manner.

Keywords

Situation Awareness, Command and Control, SA measurement

Salvendy, G. (2006). Handbook of Human Factors and Ergonomics, Third Ed. Hoboken, NJ, Wiley.

civilian, methods, tools

Sarter, N. B. and H. M. Alexander (2000). "Error types and related error detection mechanisms in the aviation domain: An analysis of Aviation Safety Reporting System incident reports." International Journal of Aviation Psychology 10(2): 189-206. http://www.informaworld.com/index/784773237.pdf

Civilian, aviation, HSI tool (error analysis), system safety, review

Human error is considered a contributing factor in 70% to 80% of all aviation accidents. Because errors can never be eliminated completely, a further reduction of the already low accident rate in this domain will require investments in better support for error management. In particular, a better understanding of the nature and effectiveness of error detection mechanisms is needed. With this goal in mind, NASA Aviation Safety Reporting System incident reports were analyzed in terms of the formal characteristics of underlying errors, the cognitive stage, and the performance level at which these errors occurred, and with respect to the processes that led to their detection and, thus, prevented these incidents from turning into accidents. The majority of incidents involved lapses (i.e., failures to perform a required action) or mistakes, such as errors in intention formation and strategy choice. These errors were most often detected based on routine checks and the observed outcome of an action, respectively. Most slips appear to have been discovered by the crew before they could lead to a problem worth reporting. Our findings suggest a need for more effective feedback in support of data-driven monitoring, especially in the case of errors of omission and for shared knowledge of intent between airborne and ground-based operators to promote the more timely and reliable detection of mistakes.

Sarter, N. B., R. J. Mumaw, et al. (2007). "Pilots' monitoring strategies and performance on automated flight decks: an empirical study combining behavioral and eye-tracking data." Human Factors 49(3): 347-57. http://hfs.sagepub.com/cgi/reprint/49/3/347.pdf

Civilian, aviation, operation, personnel/training, performance, scientific (experimental)

OBJECTIVE: The objective of the study was to examine pilots' automation monitoring strategies and performance on highly automated commercial flight decks.

BACKGROUND: A considerable body of research and operational experience has documented breakdowns in pilot-automation coordination on modern flight decks. These breakdowns are often considered symptoms of monitoring failures even though, to date, only limited and mostly anecdotal data exist concerning pilots' monitoring strategies and performance.

METHOD: Twenty experienced B-747-400 airline pilots flew a 1-hr scenario involving challenging automation-related events on a full-mission simulator. Behavioral, mental model, and eye-tracking data were collected.

RESULTS: The findings from this study confirm that pilots monitor basic flight parameters to a much greater extent than visual indications of the automation configuration. More specifically, they frequently fail to verify manual mode selections or notice automatic mode changes. In other cases, they do not process mode annunciations in sufficient depth to understand their implications for aircraft behavior. Low system observability and gaps in pilots' understanding of complex automation modes were shown to contribute to these problems.

CONCLUSION: Our findings describe and explain shortcomings in pilot's automation monitoring strategies and performance based on converging behavioral, eye-tracking, and mental model data. They confirm that monitoring failures are one major contributor to breakdowns in pilot-automation interaction.

APPLICATION: The findings from this research can inform the design of improved training programs and automation interfaces that support more effective system monitoring.

Schank, J., R. Yardley, et al. (2005). Options for reducing costs in the United Kingdom's future aircraft carrier (CVF) programme, RAND Corporation. http://books.google.com.au/books?id=uqhm0jNLOaUC&printsec=frontcover&dq=Options+for+reducing+costs+in+the+United+Kingdom's+future+aircraft+carrier+(CVF)+programme&source=bl&ots=WImCc7Agre&sig=hsd_3UZk2sUBd9VkWLsTNL6INH8&hl=en&ei=sKQyTKKEJ5aekQWE-qygDA&sa=X&oi=book_result&ct=result&resnum=1&ved=0CBcQ6AEwAA#v=onepage&q&f=false

Defence, military, navy, manning, manpower, cost-benefit

The United Kingdom's Future Aircraft Carrier (CVF) acquisition project has been designated a 'Beacon' programme by the Ministry of Defence (MOD) because of the opportunity for substantial whole-life savings. To help realise the project's Beacon potential, the MOD called for an independent, objective analysis of new technologies and alternative manufacturing options. The RAND Corporation was asked to perform that analysis and, in particular, to identify and evaluate options for reducing support costs and other whole-life costs (WLCs) and for reducing manpower.

The research was undertaken when the project was in its com- petitive stage, which included two competing companies. In January 2003, it was announced that an alliance comprising the MOD, BAE Systems, and Thales UK had been selected for the project. Following this announcement, the Thales design was selected to take forward. This design has subsequently been developed and matured.

The precision of the RAND analysis has been limited by the fact that, at the time of the study, the design of the CVF was still evolv- ing; therefore, there was an unavailability of detailed design and manning data. However, we derive qualitative judgements and pre- sent some analytic paradigms that should be of value to the MOD.Cost Analysis Tools

The evaluation of initiatives to reduce CVF WLCs requires a set of analytical tools to understand the trade-offs among various cost ele- ments. We present four such analytic paradigms:

- A total WLC model that examines the interactions among acquisition, operating, maintenance, and personnel costs and permits the quick evaluation of trade-offs and cost-reduction initiatives.
- A method for understanding the cost of each day of carrier operations. We calculate a daily cost exceeding £500,000.

- A means of trading off acquisition and operating costs. This approach suggests that a £1,000 per year savings for each of the two planned carriers would justify a £25,962 up-front invest- ment across both ships.
- A way of making a similar trade-off between initial technology and subsequent manpower costs. Replacing the median crew- member would save £1.2 million.2

Acquisition Cost Savings

While the focus of our efforts was on support costs and manpower, we identified several options that might lead to lower CVF construc- tion costs:

- using more advanced outfitting, especially for electrical, piping, and HVAC (heating, ventilation, and air conditioning), than is currently used by most UK shipbuilders
- setting the start of the second ship to minimise total labour costs at the shipyards constructing the large blocks
- centralising the procurement of material and equipment
- considering the use of commercial systems and equipment in place of military standard equipment wherever there is no adverse impact on operations or safety
- ensuring that comprehensive design reviews by all functional parties are complete so that the design of the ship is acceptable to all before construction commences
- minimising changes during ship construction and quickly resolving any that must be made.

Support Cost Savings

To identify ways of reducing support costs, we first consider avenues through which annual costs might be reduced, regardless of who is responsible for doing so. Second, we consider contractor logistics support (CLS), in which the burden for most cost-reduction choices is shifted to the contractor.

Minimising Annual Support Costs

The MOD faces challenges in maintaining the CVFs. The drop in fleet size from three ships to two will end the current arrangement in which there is always one carrier in refit. That arrangement has cer- tain advantages, e.g., a ship off which to cannibalise parts and work-load stability at the refit facility. The MOD and its support contrac- tor will also have to maintain the CVFs with vastly less reliance on dry-docking.

The MOD might gain from designing some systems to com- mercial standards. We infer from studies for the US Navy that the use of certain hotel-related commercial systems in the CVF might save as much as a net £400 million in WLCs across both ships.

Paint is also a major maintenance expense. If higher-quality paint were used, the scheduled sixth-year dry-docking might be eliminated, which could yield substantial savings.

Contractor Logistics Support

We do not think the MOD can have a CLS arrangement in which the contractor is responsible for every aspect of making a carrier avail- able and is paid solely for available vessel days. The ship is too costly and complicated for a contractor to assume full financial risk for not having the ship operate.

Instead, CLS on the CVF will be a modified version in which considerable responsibilities are left to the Defence Logistics Organi- sation or the weapon system manufacturers. However, such modified CLS might be prone to 'seam' problems in which different partici- pants blame one another for why the ship does not operate correctly.

CLS implementation difficulties aside, there is reason to be optimistic about CVF maintenance costs. Because the MOD has expressed considerable ambition for cost reduction through new maintenance paradigms, long-run advantages may accrue. Further- more, many of the most problematic aspects of carrier maintenance may well have been addressed in the choice of ship design.

Personnel Cost Savings

As background, we begin with a review of how the Royal Navy and its original design contractor, Thales UK,3 approached complement- ing, then suggest some ways of improving the practice. Next, we identify a number of complement-reduction initiatives on other naval platforms. Finally, drawing from these case studies, we identify and evaluate a number of complement-reducing measures and suggest directions for the future.

Estimating the CVF Complement

The Royal Navy's complementing process takes technology as a given and uses inherited assumptions about hours of work and mix of trades and rates. The process may be regarded as a review and assess-ment by an honest, experienced broker. It does not produce any recommendations for reorganising work or for adding technology, materials, or equipment. With no systematic evaluation of the complement-reducing potential of evolving technologies and work processes, decisions in the current complementing system may be overly influenced by culture and by outdated policies and practices.

Thales UK, in contrast, appears to have taken a zero-based approach to complementing. It has estimated the work to be done and computed the number of manpower slots necessary to accom- plish it. Thales' complementing process yielded a distribution of labour that differed substantially from the Royal Navy's breakdown for the CVF.

As further complementing work is done, the following points should be kept in mind:

- A principal, persisting goal must be observed. Minimising WLCs and minimising crew size, for example, will each result in a different complement.
- Some CVF systems will be inherited from the current carrier class. These systems might bring inefficient manning with them.
- Ambitious plans to cut manpower by investing in technology can be impeded by constraints on the up-front funding.
- Operational commanders may be reluctant to accept smaller complements because they would reduce the margin for error in situations threatening ship safety.

Complement-Reducing Initiatives on Other Platforms

To assist in identifying manpower-reduction options potentially rele- vant to the CVF, we reviewed several efforts by various navies to reduce complements:

- Transfer of US ships to the Military Sealift Command (MSC). As sealift ships have been shifted from US Navy manning to MSC manning, largely with civilians, billets have dropped dra- matically.
- US carriers. Of particular interest is the Smart Carrier pro- gramme, a series of innovations implemented chiefly during Nimitz-class refits.
- The US Navy's Smart Ship. In an experiment aboard the guided-missile cruiser USS Yorktown, significant complement reductions were achieved with core/flex manning, e.g., forgoing underway watches in reduced-threat environments, making more manpower available for other duties.

- The US Navy's Optimal Manning Experiment. Innovations on the destroyer USS Milius and the cruiser USS Mobile Bay per- mitted reductions in crew size without affecting performance.
- The LPD-17 and other amphibious ships. Smart Ship prin- ciples were applied; e.g., ship system operators were brought into the design process to suggest efficiency improvements.
- The Royal Netherlands Navy. The Dutch are constrained by tighter manpower ceilings than apply in the United Kingdom and therefore accept somewhat higher risks while spreading out most predictable tasks to permit accomplishment by small crews.
- DD(X). This is a set of technologies that will be used on future US surface combatants.

The more incremental initiatives such as the various Smart Ship programmes have either shown or are intended to show complement reductions of 15 to 20 percent. Much higher reductions are hoped for in the case of DD(X) and certain Dutch ships.

Identifying and Evaluating Complement-Reduction Options

We identified 57 feasible complement-reduction options of potential relevance to the CVF. Of those, we judged 12 to have appreciable potential for complement reduction and to be advantageous in other respects. Six of these twelve emerged as particularly promising:

- Leaving machinery spaces unmanned policy change facilitated by technologies such as remote sensing of spaces.
- Consolidating watches.
- Employing a core/flex manning concept.
- Using civilians to augment the ship's crew for non warfare responsibilities.
- Emphasising broad skills and a cross-trained workforce, so that a smaller crew could perform the same number of activities.
- Using conveyors to aid crew members in loading stores from the shore to the ship.

We do not know what options have been assumed in the plan- ning complement estimate devised for the CVF and thus do not know if the target is optimistic. There are reasons, though, to believe that the target will be reached:

- There is strong fiscal motivation to realise savings.
- Complement reduction is a key CVF design goal.
- The immaturity of the design may allow for further savings.
- Operating and personnel policies will continue evolving towards sailor multi functionality.
- As new technologies prove their worth, old manpower-intensive approaches to tasks will fall away.

Initial complement targets have historically proved optimistic, however, and progress toward the complement goal could be complicated by some remaining challenges. For example, many complement-reducing options are not technological but procedural, and efforts to implement such changes can encounter institutional resistance.

We conclude by offering some general guidelines towards better defining complement-reduction options and pushing them closer to realisation:

- Consider the implications of a revolutionary CVF complement for the Royal Navy personnel structure.

- As CVF design proceeds, continue the emphasis on complement reduction and human systems integration.
- Focus on manpower-intensive activities for possible reductions.
- Place a premium on designing or selecting systems that do not require highly specialised personnel to operate.

Schwartz, M. A. (1981). Austere manning in the guided missile frigate (FFG7 class): Lessons learned., Navy Personnel Research and Development Center: 13. http://www.dtic.mil/cgi-bin/GetTRDoc?Location=U2&doc=GetTRDoc.pdf&AD=ADA099215

Defence, military, navy, manning, manpower, case study

A manpower constraint imposed on designers of the FFG 7 influenced equipment design, maintenance and support strategies, training requirements, and ship organization. Results of a brief examination of the impact of this contraint on FFG 7 design, maintenance strategy, and training needs indicated that the original manpower accommodation constraint was premature and led the ship acquiistion manager to make manpower, personnel, and training assumptions which could not be realized. An important deficiency in early system planning was the failure to consider projected manpower availability for critical ares. The attempt to design systems for austere manning can result in low tolerance of the system for degradation to personnel levels, especially highly skilled personnel in short supply.

Shafer, J. B. (1990). MANPRINT in a Systems Engineering Organisation. MANPRINT: An Approach to Systems Integration. H. R. Booher. New York, Van Nostrand Reinhold: 127-156. http://openlibrary.org/books/OL1858894M/Manprint_an_approach_to_systems_integration

Shepherd, W. (1991). Human Factors in Aviation Maintenance: Phase I Progress Report Washington, U.S. Dept. of Transportation, Federal Aviation Administration, Office of Aviation Medicine. http://www.faa.gov/library/reports/medical/oamtechreports/1990s/media/AM91-16.pdf

Military (Air Force), US, maintenance, training

The performance of aviation maintenance and inspection personnel is directly related to the design of their tasks, the training given to them, the tools they work with, and the nature of their work environment. The goal of the aviation maintenance system is to ensure the continued safe and efficient operation of aircraft. Toward that goal the Federal Aviation Administration instituted the Human Factors in Aviation Maintenance Research Team to focus on a variety of human factors aspects associated with the aviation maintenance technician and other personnel supporting the maintenance system goals.

The team was comprised of personnel from government, private industry, and academia with strong expertise in human factors. They were assisted by experienced industry maintenance personnel and certified airframe and powerplant technicians. The results of their efforts are included in five chapters, this first chapter being the combined executive summaries of the other four. Specifically:

Chapter 1 - Executive Summary

Chapter 2 - Study of the Maintenance Organization

Chapter 3 - Study of the Maintenance Technician in Inspection

Chapter 4 - Study of Advanced Technology for Maintenance Training

Chapter 5 - Study of Job Performance Aids

In addition, information dissemination was achieved through the conduct of four conferences relating to the material of the four chapters. The results of these are also included in this summary.

Each of the chapters listed above, 2 through 5, have been treated so as to be a "stand alone" or independent research report. This chapter, the Overall Executive Summary, provides the rationale for the overall program and highlights the methods, primary findings, and subsequently planned research and development.

This research is designed to provide information that will enable maintenance managers in government and industry to more effectively manage the integration of technology into the work place. The information in this chapter will aid in assessing the capability of technologies and possible applications.

It will provide a basis to judge various approaches of implementing technology. The information will contribute to efforts for estimating the time, expense, and utility of fielding Job Performance Aids (JPAs) and technology in maintenance operations. Principally, the information will help determine the return that can be expected from an investment in technology. A primary focus is on developing approaches for technology implementation that complement human capabilities (see Table 5.1). This is accomplished through research in two areas.

Shepherd, W. (1995). Human Factors in Aviation Maintenance: Phase IV Progress Report, Office of Aviation Medicine: 169. http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA294756&Location=U2&doc=GetTRDoc.pdf

Military (Air Force), (aerospace), US, DCL, HSI , discussion, description, performance, safety, cost, methods, tools

The fourth phase of research on human factors in aviation maintenance continued to look at the human's role in the aviation maintenance system via investigations, demonstrations, and evaluations of the research program outputs. This report describes the field evaluation plan for the Performance Enhancement System, a computer-based tool designed to aid Aviation Safety Inspectors in performing their oversight duties (Chapter 2). Chapter 3 describes the design of a computer-based workcard system. The report also discusses the development of an ergonomic audit program for visual inspection, which contains a method of choosing tasks to be audited, an audit checklist, and a computer program to evaluate check-list response against national and international standards (Chapter 4). Chapter 5 reports on an investigation of ergonomic factors that may cause increased inspector stress, fatigue, and workload, particularly in restrictive spaces that cause extreme postures. The continued development and expansion of the hypermedia information system is reported on in Chapter 6. Chapter 7 describes an investigation of individual differences in nondestructive inspection performance. Chapter 8 describes an investigation to determine the effect of an Intelligent Help Agent on the effectiveness of computer-based training. Chapter 9 reports on a joint CAMFAA investigation of reliability in aircraft inspection in the United Kingdom and United States. Chapter 10 is a bibliographic overview of selected issues in designing computer-based training systems.

Shorrock, S. T. and O. Straeter (2006). "A framework for managing system disturbances and insights from air traffic management." Ergonomics 49(12-13): 1326-44. http://www.informaworld.com/index/757998751.pdf

Civilian, aviation, operation, personnel, performance, case studies

System disturbances are likely to be a key factor affecting the acceptance and safety of future automation. Since hardware and software are rarely totally reliable, humans are always required in socio-technical command and control environments such as air traffic management (ATM).

Unfortunately, human-automation interaction is known to be problematic, particularly when the human assumes a monitoring or back-up role. Hence an understanding of how humans manage system disturbances is required, together with a method of looking at the problem for new systems. In this paper we outline a contextual framework of the process by which people recover from system disturbances, together with literature data and findings from 31 interviews with ATM personnel. The framework describes the context and causes of a problem, the problem itself, the effect and exposure, the recovery process, and the outcome. The framework, together with the research findings and operational experience, is also the basis for a performance prediction tool called the Recovery from Automation Failure Tool (RAFT).

Shorrock, S. T., M. Woldring, et al. (2004). The human factors case: Guidance for human factors integration, European Organisation for the Safety of Air Navigation. http://www.eurocontrol.int/humanfactors/gallery/content/public/docs/DELIVERABLES/HF42%20(HRS-HSP-003-GUI.01)%20Released-withsig.pdf

civilian, aviation, aerospace, hsi implementation

Shute, S., M. Bartram, et al. (n.d.). HSI Design Influence on a Mature Department of Defense Acquisition Program. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.112.6657&rep=rep1&type=pdf

Military (Navy), (maritime), US, DCL (acquisition), HSI, discussion, description, performance, cost, methods, tools

Successful Department of Defense (DoD) acquisition programs that have gone through several design iterations can sometimes offer limited opportunities for significant Human Systems Integration (HSI) design influence. This paper describes examples of the selection and application of HSI methods on a large, multi-iteration DoD program, and the resulting increased scope of HSI's design influence on the program.

In the early stages of a traditional DoD development program, user needs, task definitions/analysis, and function allocation between systems and humans are typically determined. The results of these early HSI activities are most effective when their findings are available before engineering requirements are firmly established. Some of the HSI methodologies used (e.g., task analysis, contextual inquiry, user needs analysis, knowledge engineering) may also be useful for identifying and managing risk in subsequent design iterations. An example involving knowledge engineering will be provided to illustrate this point.

Once task flows and function allocations have been drafted, workload modeling can proceed, to verify that concurrent tasks may be performed effectively and without excessive operator fatigue. Workload modeling may reveal that modifications to previously-derived function allocation solutions may be needed (e.g., introducing automation, shifting task assignments).

Many system components feature critical user interfaces that support operator decision-making and tactical actions. When display/control design requirements have been drafted, but before they are finalized, using a rapid, low-cost usability assessment technique can provide engineering teams with constructive usability feedback within schedule and cost constraints. An example application of heuristic evaluation (Nielsen, 1994) will illustrate this concept.

Siemieniuch, C. and M. Sinclair (2006). "Systems integration." Applied Ergonomics 37(1): 91-110. http://linkinghub.elsevier.com/retrieve/pii/S0003687005001018

Civilian

The paper presents a view of systems integration, from an ergonomics/human factors perspective, emphasising the process of systems integration as is carried out by humans. The first section discusses some of the fundamental issues in systems integration, such as the significance of systems boundaries, systems lifecycle and systems entropy, issues arising from complexity, the implications of systems immortality, and so on. The next section outlines various generic processes for executing systems integration, to act as guides for practitioners. These address both the design of the system to be integrated and the preparation of the wider system in which the integration will occur. Then the next section outlines some of the human-specific issues that would need to be addressed in such processes; for example, indeterminacy and incompleteness, the prediction of human reliability, workload issues, extended situation awareness, and knowledge lifecycle management. For all of these, suggestions and further readings are proposed. Finally, the conclusions section reiterates in condensed form the major issues arising from the above.

Simpson, M. (2006). Toward an Improved Method of HSI Evaluation in Defense Acquisition. NAVAL POSTGRADUATE SCHOOL MONTEREY CA. http://oai.dtic.mil/oai/oai?verb=getRecord&metadataPrefix=html&identifier=ADA462695

Military (Navy, Air Force, Army), (land, maritime, aerospace), US, DCL (acquisition), HSI (HFE,safety, training, personnel, manpower), review, discussion, evaluation, description, performance, safety, cost, tools

Each of the domains of HSI is of itself a discipline with vast amounts of research, analytic techniques, educational programs, and methods for evaluating the effectiveness of the system with respect to the specific domain. Relatively recently, domains with a logical similarity have been the focus of interest for researchers studying the plausibility of creating evaluative tools which take into account the constraints of multiple domains. This interest has led to the creation of **various tools with which acquisition** professionals can more accurately determine the impact of design decisions on the system as a whole.

However, no single tool has yet been created which takes into consideration the constraints of all the domains which HSI encompasses. The development of such a tool would give decision-makers the ability to quickly and accurately determine the system-wide trade-offs associated with changes in a single domain. In order for this to occur, an in-depth study of the current tools associated with each of the HSI domains must be conducted. The most accurate tools from each domain must be integrated with a single interface. However, this step will only be realized after a common language has been identified which can speak to the effectiveness of the system in each of the domains. Finally, the interface must be intuitive, and designed with the end-user in mind. This study identified the various resources currently available for **evaluating each of the HSI domains**. These resources were compiled in a searchable database for use by the HSI professional in the planning of HSI evaluations. Following a description of how HSI relates to the Department of Defense acquisition process, the design effort to produce an overarching interface was presented. This interface would allow the acquisition professional to evaluate the trade-offs between all relevant domains and make well-informed decisions with respect to the overall effectiveness of the human in the system. Next, a plan for insertion of the process and software into the acquisition community, making the tool available to all acquisition professionals, was discussed. Finally, as with all research, the limitations of the present study were discussed, as well as recommendations for future research.

Skinner, M. and P. Simpson (2002). "Workload issues in military tactical airlift." The International Journal of Aviation Psychology 12(1): 79-93. http://www.informaworld.com/smpp/content~db=all~content=a784771675

Military (Air Force), (aerospace), Australia, DCL, HSI (HFE), scientific, discussion, evaluation, description, performance, methods

Military airlift is following the trend in commercial aviation to 2-pilot flightdecks with significant levels of automation. A critical issue is whether the reduced crew can handle the workload involved in military tactical missions, which have many high workload elements the crew do not encounter in the commercial aviation environment. This article outlines a workload assessment strategy based on direct measures of aircrew and mission performance, aircrew subjective evaluations of workload, and psychophysiological indexes and describes its application to tactical airlift missions. The article discusses significant workload challenges one must address in the transition to 2-pilot tactical airlift.

Skoog, A. I., S. Berthier, et al. (1991). "The European space suit, a design for productivity and crew safety." Acta Astronautica 23: 207-216. http://www.ncbi.nlm.nih.gov/pubmed/11537126

Civilian, aerospace, design, HFE, productivity and safety, case study

In order to fulfil the two major mission objectivess, i.e. support planned and unplanned external servicing of the COLUMBUS FFL and support the HERMES vehicle for safety critical operations and emergencies, the European Space Suit System baseline configuration incorporates a number of design features, which shall enhance the productivity and the crew safety of EVA astronauts. The work in EVA is today - and will be for several years - a manual work. Consequently, to improve productivity, the first challenge is to design a suit enclosure which minimizes movement restrictions and crew fatigue. It is covered by the "ergonomic" aspect of the suit design. Furthermore, it is also necessary to help the EVA crewmember in his work, by giving him the right information at the right time. Many solutions exist in this field of Man-Machine Interface, from a very simple system, based on cuff check lists, up to advanced systems, including Head-Up Displays. The design concept for improved productivity encompasses following features: easy donning/doffing thru rear entry, suit ergonomy optimisation, display of operational information in alpha-numerical and graphical from, and voice processing for operations and safety critical information. Concerning crew safety the major design features are: a lower R-factor for emergency EVA operations thru increased suit pressure, zero prebreath conditions for normal operations, visual and voice processing of all safety critical functions, and an autonomous life support system to permit unrestricted operations around HERMES and the CFFL. The paper analyses crew safety and productivity criteria and describes how these features are being built into the design of the European Space Suit System.

Smith, C., M. Cummings, et al. (2008). "Developing Lunar Landing Vehicle Display Requirements Through Content Analysis of Apollo Lunar Landing Voice Communications." The International Journal of Aviation Psychology 18(3): 237-254. http://www.informaworld.com/smpp/content~db=all~content=a794084331

Civilian (Aerospace)

The lengthy period since the Apollo landings limits present-day engineers attempts to draw from the experiences of veteran Apollo engineers and astronauts in the design of a new lunar lander. To circumvent these limitations, content analyses were performed on the voice transcripts of the Apollo lunar landing missions. The analyses highlighted numerous inefficiencies in the design of the Apollo Lunar Module displays, particularly in the substantial use of the cognitive resources of the Lunar Module Pilot in the performance of low-level tasks. The results were used to generate functional and information requirements for the next-generation lunar lander cockpit.

Spindel, R., Laska, S., Cannon-Bowers, J., Cooper, D., Hengmann, K., Hogan, R., Hubbard, J., Johnson, J., Katz, E., Roberts, K., Sheridan, T., Skalka, S., Smith, J. (2000). Optimized surface ship manning. Naval Research Advisory Committee Report. http://www.stormingmedia.us/55/5504/A550454.html

Defence, military, navy, maritime, manning, manpower

Purpose of Study

The panel was chartered to review and assess efforts to optimize manning on surface ships. This included the review of previous studies of the subject, current programs within the U.S. and foreign navies, and relevant technology efforts. The panel was also asked to identify technology opportunities and to recommend changes in procedures and policy that would hasten and improve efforts to optimize ship manning in the Navy.

Background

The Navy's total budget has declined by 40% since 1985, but Operation and Support (O&S) costs have remained almost constant. Unless the O&S portion of the budget can be decreased, funding that is essential to recapitalize and modernize the Fleet will be insufficient. Because personnel costs comprise over 50% of O&S costs, it is imperative to reduce the number of people necessary to fight ships of the future as well as the legacy ships of today's Fleet. There is also a realization that the Navy operates in a new political/military/social environment, and modern Sailors are very different from those in the past. Career alternatives, quality of life issues, and family responsibilities make recruiting and retention more difficult for the Navy. These factors all point to the importance of focusing on optimizing manning in our Surface Navy.

Recommendations

The panel reviewed several initiatives the Navy has undertaken to understand and manage ownership costs throughout the life cycle of systems to produce savings for recapitalization and modernization. New requirements to plan for Total Ownership Cost (TOC) in acquisition programs have caused a growing body of cost data to be developed. But continued efforts are required to expand this database, improve the cost methodology, and clearly identify the components of manpower costs.

Smart Ship has been a significant program to demonstrate how technology insertion and changes in procedure can reduce manning, maintain capability and improve shipboard quality of life. However, the Navy has encountered several obstacles in diffusing the lessons learned, adopting improvements in process, and extending technology innovations throughout the Surface Navy because it lacks top-down leadership and an articulated implementation strategy. This experience points to the enormity of the problem the Navy faces in adapting to the revolutionary changes anticipated in the Navy's Land Attack Destroyer DD 21 and other optimally manned ship development programs. In order to accomplish such revolutionary change the Navy must:

(1) Provide top-down leadership in the form of a Chief of Naval Operations (CNO) appointed Flag Board that is responsible for implementing strategies to ensure that required technological, procedural, and organizational changes are adopted throughout the Navy.

(2) Modify the ship design process to include Human Engineering so that optimal human/system performance is achieved with as few Sailors as possible.

(3) Align the execution of Research and Development (R&D) efforts so that ship components and subsystems for optimally manned ships incorporate the same kind of processes and specifications utilized for the platform.

(4) Modify recruitment, training, compensation and career progression strategies to reflect the changes in organization structure, skill mix, and expanded decision making required on more automated, optimally manned ships.

Stanton, N., C. Baber, et al. (2008). "Development of a generic activities model of command and control." Cognition, Technology & Work 10(3): 209-220. http://dx.doi.org/10.1007/s10111-007-0097-5

Military (Army)/ Civilian, land, UK, DCL, HSI (command and control), discussion, description, methods

This paper reports on five different models of command and control. Four different models are reviewed: a process model, a contextual control model, a decision ladder model and a functional model. Further to this, command and control activities are analysed in three distinct domains: armed forces, emergency services and civilian services. From this analysis, taxonomies of command and control activities are developed that give rise to an activities model of command and control. This model will be used to guide further research into technological support of command and control activities.

Stanton, N. A., R. Stewart, et al. (2006). "Distributed situation awareness in dynamic systems: theoretical development and application of an ergonomics methodology." Ergonomics 49(12-13): 1288-311. http://www.informaworld.com/index/M636226574831055.pdf

Civilian/military, HSI tool (situation awareness model), personnel, discussion with a case study (HMS frigate Dryad)

The purpose of this paper is to propose foundations for a theory of situation awareness based on the analysis of interactions between agents (i.e. both human and non-human) in subsystems. This approach may help to promote a better understanding of technology-mediated interaction in systems, as well as helping in the formulation of hypotheses and predictions concerning distributed situation awareness. It is proposed that agents within a system each hold their own situation awareness, which may be very different from (although compatible with) that of other agents. It is argued that we should not always hope for, or indeed want, sharing of this awareness, as different system agents have different purposes. This view marks situation awareness as a dynamic and collaborative process binding agents together on tasks on a moment-by-moment basis. Implications of this viewpoint for the development of a new theory of, and accompanying methodology for, distributed situation awareness are offered.

Stark, R. F. and C. Kokini (2010). "Reducing risk in system design through human-system integration." Ergonomics in Design 18(2): 18-22.

civilian, case studies

Stewart, J., E. Smootz, et al. (1989). "MANPRINT Support of Aquila, the Army's Remotely Piloted Vehicle: Lessons Learned, Research Report 1525." Alexandra, VA: US Army Research Institute for the Behavioral and Social Sciences. http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA211207&Location=U2&doc=GetTRDoc.pdf

Military (Army), US, DCL (design), HSI (HFE, safety, training, personnel, manpower), case study, discussion, evaluation, description, performance, methods

The U.S. Army Research Institute (ARI) Systems Research laboratory (SRL) supports the Army's manpower and personnel integration (MANPRINT) initiative in the testing and development of new systems. Operational Testing II (OT II) of the Aquila Remotely Piloted Vehicle revealed disappointing system performance thought to be due in part to manpower, personnel, training , and human factors problems. The SRL MANPRINT Task Force, headed by the Fort Hood Field Unit, was asked by Headquarters Training and Doctrine Command and the U.S. Army Field Artillery School to help identify the problems and recommend ways to resolve them. The SRL Task Force **examined operator and maintainer MANPRINT concerns** (e.g., target detection, mission planning, and maintenance manpower) and **was able to recommend concrete ways to minimize the impact of these problems on total system performance**. Keywords: Operational testing, Human factors, Remotely piloted vehicles.

Stewart, R., N. Stanton, et al. (2008). "Distributed situation awareness in an Airborne Warning and Control System: application of novel ergonomics methodology." Cognition, Technology & Work 10(3): 221-229. http://dx.doi.org/10.1007/s10111-007-0094-8

Defence, air force, situation awareness tools

This paper applies a distributed theory of situation awareness based upon the analysis of interactions between agents (both human and non-human) in an Airborne Warning and Control System (Boeing E3D Sentry). The basic tenet of this approach is that agents within a system each hold their own component(s) of situation awareness, which may be very different from, but compatible with, other agent's view of the situation. However, it is argued that it is not always necessary to have complete sharing of this awareness, as different system agents have different purposes. Situation awareness is regarded as a dynamic and collaborative process that binds agents together on tasks on a moment-by-moment basis. Situation awareness is conceptualised as residing at a system, not an individual level. Data were collected from crew-members in the E3D during a series of simulated air battles. These data pertained to task structure, communications between the crew and the collection and analysis of crew actions at critical decision points. All phases of operations were considered. From these data propositional networks were developed in which key knowledge objects were identified. Analysis of these networks clearly shows how the location and nature of distributed situation awareness changes across agents with regard to the phase of operation/air battle.

Strain, J. and D. Preece (1999). "Project management and the integration of human factors in military system procurement." International Journal of Project Management 17(5): 283-292. http://www.sciencedirect.com/

Military, UK, DCL (design, acquisition), HSI (HFE,safety, training, personnel, manpower), discussion, description, performance, safety, cost, methods, tools

The emerging discipline of Human Factors Integration (HFI) within defence systems procurement aims to improve the operational effectiveness of military systems by co-ordinating a number of human resource aspects in the system acquisition process. Interest in HFI within the defence community is mirrored by, and is in part a development of, a growing recognition within civil projects that human aspects of system use (for example, the provision of training and reduction in health hazards) require formal methodologies and links to project Work Breakdown structures. HFI requires that linkages are established between the activities of scientists and project managers, but the absence of a clear framework as a basis for these linkages has hindered the goals of HFI. This paper shows how HFI can be effectively coordinated with other technical and management activities in project management. It focuses on, and identifies certain key relationships between, that sub-set of procurement disciplines which have particular relevance for HFI.

Stringfellow, M. V., N. G. Leveson, et al. (2010). Safety-Driven Design for Software-Intensive Aerospace and Automotive Systems. Proceedings of the IEEE. 98: (4) 515-525 http://cat.inist.fr/?aModele=afficheN&cpsidt=22729035

Civilian other industry (automotive and aerospace software-intensive systems), HSI tool/design, safety, technical

Too often, systems are designed and then an attempt is made to add safety features or to prove that the design is safe after the fact. Safety has to be designed into a system from the start-it cannot be effectively added on to a mature design. In addition, the increasing use of software is changing the nature of accident causation in software-intensive systems and our safety engineering techniques must change accordingly. This article will describe a new hazard analysis technique, called STPA, which is effective on software-intensive systems. An advantage of this technique is that it can be used to drive the earliest design decisions and then proceed in parallel with ensuing design decisions and design refinement. Not only is this approach more effective, but the cost is no more than a more conventional design process and potentially much cheaper.

Svensson, J. and J. Andersson (2006). "Speech acts, communication problems, and fighter pilot team performance." Ergonomics 49(12-13): 1226-37. http://www.informaworld.com/index/757998746.pdf

Military, Air Force, Sweden, operation (flight simulation), personnel (communication problems in multitask situation), performance, scientific (experimental)

Two aspects of team communication, speech acts and communication problems, and their relation to team performance in a team air combat simulator were studied. The purpose was to enhance the understanding of how team performance is related to team communication. Ten Swedish fighter pilots and four fighter controllers of varying experience participated. Data were collected during fighter simulator training involving four pilots and one fighter controller in each of two teams. Speech acts were collapsed over seven categories and communication problems over five categories. Communication was studied from two perspectives: critical situation outcome and mission outcome. Some problems were closely related to particular speech acts. Speech act frequency, especially meta-communications and tactics, was highest when winning. However, the timing of tactics in critical situations needs further research. Communication problem frequency was highest for runs which ended equally. The most common problem was simultaneous speech, possibly because of the simulator radio system. The number of speech acts was related to enhanced performance but in a complex manner. Thus in order to work efficiently team members need to communicate, but to communicate sufficiently and at appropriate times. This work has applications for fighter pilot and controller team training and the development of communication standards.

Thomas, L. C. and C. D. Wickens (2006). "Effects of battlefield display frames of reference on navigation tasks, spatial judgements, and change detection." Ergonomics 49(12-13): 1154-73. http://www.informaworld.com/smpp/content~db=all~content=a757998744

Civilian and military, aviation, operation (battlefield flight simulation), HFE/personnel (effect of display design on cognition/attention), performance, scientific (experimental)

This paper describes an experiment which illustrates the cause of 'cognitive tunnelling' as it affects information gathering and perception-based task performance in computer-generated terrain displays of varying frames of reference. Cognitive tunnelling refers to the effect where observers focus attention on information from specific areas of a display to the exclusion of information presented outside these areas. Previous research suggests that cognitive tunnelling is induced by more immersive or egocentric visual displays. Results from our preceding study suggested that an immersed split-screen display induces cognitive tunnelling and results in poorer information extraction and situation awareness than an exocentric display of the same information. The current study determined that failure of the observers to integrate information across the two views of the immersed display led to the cognitive tunnelling effect. Cognitive tunnelling was also affected by primacy of information initially presented within the larger egocentric view in the immersed display.

Thomas, M. L. and M. B. Russo (2007). "Neurocognitive monitors: toward the prevention of cognitive performance decrements and catastrophic failures in the operational environment." Aviation Space & Environmental Medicine 78(5 Suppl): B144-52. http://www.ingentaconnect.com/content/asma/asem/2007/00000078/A00105s1/art00023

Military, Army, US, operation, personnel, performance, review of 4 case studies or scientific papers

Network-centric doctrine and the proposed C41SR (command, control, communications, computers, intelligence, surveillance and reconnaissance) distributions to the individual warfighter require that the cognitive performance, judgment, and decision making of warfighters must be sustained and effectively managed in the forward operating environment, where various physiological and psychological stressors abound, in order to reduce human errors and catastrophic failures.

The U.S. Army Medical Research and Materiel Command (USAMRMC) established the Cognitive Performance, Judgment, and Decision-Making Research Program (CPJDRP) in 2004 to direct research to this issue. A Neurophysiological Measures and Cognition Focus Team (NMFCT) was formed to work with augmented cognition investigators and to specifically address the development of neurophysiological measures as potential monitors of alertness-cognitive state in warfighters. The USAM-RMC approach complemented the Defense Advanced Research Projects Agency (DARPA) Augmented Cognition approach, which focused on the detection of workload-related impaired cognitive state, and subsequent modification of information flow through automation. In this preface, the premise for neurophysiological measures as neurocognitive monitors is explained using an example of a neurophysiological index: the oculomotor measure, saccadic velocity.

The progress of the NMFCT on the development of a neurocognitive monitor is described, as well as the recommendations of a 2005 USAMRMC/Telemedicine and Advanced Technology Research Center (TATRC)-sponsored workshop. Awareness of neurocognitive monitoring is discussed, as are future endeavors related to operational testing and fieldability. Four papers are summarized in this Neurophysiological Monitoring and Augmented Cognition section involving technologies to enhance cognitive performance in the operational environment: one on dynamic cortical electroencephalography, two on oculometrics, and one on a spatial orientation enhancement system.

Thompson, W. and S. Constable (2005). The US Military Unmanned Aerial Vehicle (UAV) Experience: Evidence-Based Human Systems Integration Lessons Learned http://www.wpafb.af.mil/shared/media/document/AFD-090415-076.pdf

Military (Navy, Air Force, Army), (land, maritime, aerospace), US, DCL (design, acquisition), HSI (HFE,safety, training, personnel, manpower), scientific, case study, review, discussion, evaluation, description, performance, safety, cost, methods, tools

Background: This study was a 10-year cross sectional analysis of human factors in U.S. military UAV mishaps.

Methods: Class A-C UAV mishap reports were reviewed and human factors coded using the Human Factors Analysis and Classification System (HFACS). HFACS codes were linked to human systems integration (HSI) domains. Binary logistic regression was used to create models predicting operator error.

Results: 133/221 (60.2%) UAV mishaps involved human factors. Predictors of operator error were technological environment and cognitive factors in the Air Force ($P < 0.010$), organizational process, psycho-behavioral factors, and crew resource management in the Army ($P < 0.001$), and organizational process, inadequate supervision, planned inappropriate operations, physical and technological environments, and cognitive and psycho-behavioral factors in the Navy ($P < 0.025$). The frequency of specific types of unsafe acts differed between the services with skill-based errors more common in the Air Force ($P = 0.001$) and violations in the Army ($P = 0.016$). HSI failures associated with operator error involved the human factors (functional and cognitive interfaces) and personnel domains in the Air Force ($P < 0.001$), the human factors (cooperational, cognitive, and physical interfaces) and training domains in the Army ($P < 0.001$), and the human factors (environmental, cooperational, organizational, and cognitive interfaces) and training domains in the Navy ($P < 0.001$).

Conclusion: Recurring latent failures at the organizational, supervisory, and preconditions levels contributed to more than half of UAV mishaps. The patterns of latent failures and unsafe acts differed between the services. HSI issues pertaining to the human factors domain were common to all services.

Tomter, A. (2003). A Safety Program Framework and its application on a Weapon Control System. Safety and Reliability, Vols 1 and 2, Proceedings of the ESREL 2003 Conference, Maastricht, the Netherlands: 1561-1566 http://books.google.com.au/books?hl=en&lr=&id=ENxYDxQjMb8C&oi=fnd&pg=PR17&dq=%22A+Safety+Program+Framework+and+its+application+on+a+Weapon+Control+System%22&ots=NblgJxVYx1&sig=3SitvuhuwQAYZlyfYCHGz5A34Bo#v=onepage&q=%22A%20Safety%20Program%20Framework%20and%20its%20application%20on%20a%20Weapon%20Control%20System%22&f=false

Military, aerospace, HSI tool, HSI all, safety, technical (case study?)

This paper presents a real-life Safety Program Framework, which has been applied on some Weapon Control System projects at Kongsberg Defence & Aerospace. It starts with preparing the plan for the safety effort throughout the project and specifying the safety requirements (including hazard acceptance criteria). It continues with identifying potential hazards based on a checklist of energies present in or controlled by the system. The potential hazards are highlighted and brought to the attention to the design and construction team. Safety is considered an inherent property of the system to be developed, thus emphasizing the important role and responsibility of this team. The system resulting from the design and construction process is then subject to Safety verification. Each residual hazard is evaluated with respect to hazard control measures, and resulting combination of hazard probability and severity (the risk assessment code) is assessed and compared with specified hazard acceptance criteria. The safety program concludes with a summary of the safety tasks conducted, including a final statement of the safety of the system.

Torenvliet, G., Jamieson, G., Cournoyer, L. (2006). Functional Modelling, Scenario Development, and Options Analysis to Support Optimized Crewing for Damage Control Phase 1: Functional Modelling, Defence R&D Canada - Toronto: 94. http://oai.dtic.mil/oai/oai?verb=getRecord&metadataPrefix=html&identifier=ADA473053

Defence, Military, Canada, Navy, manning, manpower, tools

The Canadian Navy hopes to achieve significant lifetime cost reductions by implementing optimized crew levels across its next-generation fleet. Defence Research and Development Canada (DRDC) has recognized that optimized crewing can only be achieved through a thorough Human-Systems Integration (HSI) effort, and that this effort will require systems modelling techniques to help the Navy predict the effectiveness of technologies and work strategies that aim to reduce operator workload and improve mission success. This report describes the first phase of a project undertaken to provide DRDC with such a technique, and details the development of an Abstraction Hierarchy (AH) functional model of the domain of damage control. Two subsequent phases of analysis are planned: to develop damage control scenarios, and to identify emerging damage control technologies and the reduced crew levels required to support them. These will be used as inputs for a follow-on project to develop a simulation of human and automated work in the damage control domain. The AH model documented in this report is a strong basis for the subsequent phases of this project, and the follow-on simulation development effort.

Tsang, P. S. and M. A. Vidulich (2003). Principles and practice of aviation psychology. Mahwah, NJ, Lawrence Erlbaum. http://books.google.com.au/books?hl=en&lr=&id=IQWB8UfvQy0C&oi=fnd&pg=PR17&dq=Principles+and+practice+of+aviation+psychology&ots=NkK5l7uzwJ&sig=LYgOHdFxKDJzi-kus6QIs13wHis#v=onepage&q&f=false

civilian aviation

Principles and Practice of Aviation Psychology is an important addition to the literature in aviation psychology. Covering the history of aviation to the actual pilot actions and tasks today, the editors have brought together a wonderful set of contributors who are leaders in this field.

The text presents psychological principles and research pertinent to the interface between a pilot and the cockpit. Understanding the cognitive demands and the capabilities and limitations of the pilot has important implications on selection and training of pilots and display/control designs in the cockpit. Emphasis is placed on the scientific methods of achieving this understanding together with the view that theories and principles of human behavior would have much to learn from practical problems and applied studies.

Tvaryanas, A. (2006). "Human systems integration in remotely piloted aircraft operations." Aviat Space Environ Med 77(12): 1278-82. http://www.ncbi.nlm.nih.gov/entrez/query.fcgi?cmd=Retrieve&db=PubMed&dopt=Citation&list_uids=17183926

Military (Air force) aerospace, US, DCL, HSI (training, personnel, manpower), discussion, description, performance, methods

BACKGROUND: The role of humans in **remotely piloted aircraft (RPAs)** is qualitatively different from manned aviation, lessening the applicability of aerospace medicine human factors knowledge derived from traditional cockpits. Aerospace medicine practitioners should expect to be challenged in addressing RPA crewmember performance.

METHODS: Human systems integration (HSI) provides a model for explaining human performance as a function of the domains of: human factors engineering; personnel; training; manpower; environment, safety, and occupational health (ESOH); habitability; and survivability. RPA crewmember performance is being particularly impacted by issues involving the domains of human factors engineering, personnel, training, manpower, ESOH, and habitability.

RESULTS: Specific HSI challenges include: 1) changes in large RPA operator selection and training; 2) human factors engineering deficiencies in current RPA ground control station design and their impact on human error including considerations pertaining to multi-aircraft control; and 3) the combined impact of manpower shortfalls, shiftwork-related fatigue, and degraded crew member effectiveness. Limited experience and available research makes it difficult to qualitatively or quantitatively predict the collective impact of these issues on RPA crew member performance.

CONCLUSION: Attending to HSI will be critical for the success of current and future RPA crewmembers. Aerospace medicine practitioners working with RPA crewmembers should gain first-hand knowledge of their task environment while the larger aerospace medicine community needs to address the limited information available on RPA-related aerospace medicine human factors. In the meantime, aeromedical decisions will need to be made based on what is known about other aerospace occupations, realizing this knowledge may have only partial applicability.

Tvaryanas, A. P., W. T. Thompson, et al. (2005). U.S. Military Unmanned Aerial Vehicle Mishaps: Assessment of the Role of Human Factors Using Human Factors Analysis and Classification System (HFACS), 311th Performance Enhancement Directorate Performance Enhancement Research Division. http://www.dtic.mil/cgi-bin/GetTRDoc?AD=ADA435063.

Defence, military, air force, errors, accident analysis, human factors

Background: This study was a 10-year cross sectional analysis of human factors in U.S. military UAV mishaps.

Methods: Class A-C UAV mishap reports were reviewed and human factors coded using the Human Factors Analysis and Classification System (HFACS). Binary logistic regression was used to create models predicting unsafe operator acts.

Results: 133/221 (60.2%) UAV mishaps were human related. Predictors of unsafe acts were technological environment and cognitive factors in the Air Force ($P < 0.010$), organizational processes, psycho-behavioral factors, and crew resource management in the Army ($P < 0.001$), and work and attention and risk management in the Navy ($P < 0.025$). The frequency of specific types of unsafe acts differed between the services with skill-based errors more common in the Air Force ($P = 0.001$) and violations in the Army ($P = 0.016$).

Conclusion: Recurring latent failures at the organizational, supervisory, and preconditions levels contributed to more than half of UAV mishaps. The patterns of latent failures and unsafe acts differed between the services.

UK MOD (2008). Human Factors for Designers of Systems. http://www.dstan.mod.uk/00e.php

defence, military, human factors engineering, standards, methods, tools, techniques

UK MOD Sea Systems Group (2006). Maritime Acquisition Publication No 01-011. Human Factors Integration (HFI) Technical Guide (STGP 11): 629p. http://www.hfidtc.com/pdf/MAP-01-010.pdf

Military, Navy, UK, Design/acquisition/HSI all, HFE, review/guidelines

Human Factors Integration (HFI) has been shown to be a key factor in the continued drive to improve military capability, overall cost-effectiveness and safety. The guidance contained in the HFI Management Guide (MAP 01-010) and the HFI Technical Guide (MAP 01-011) has been distilled from the experience gained over at least a decade of ship and equipment development and construction. Consequently they represent the best currently available practice in HFI. IPTs and supporting contractors will find these publications of considerable value in ensuring the appropriate application of HFI to their Project and in providing the necessary assurance that their efforts are being effectively applied. With allowance for variations in terminology and applicability and the overall policy lead given by the TES Human Factors Group, these guides have also been found useful in the Land and Air domains.

Objectives of the HFI Technical Guide

- To describe the Human Factors Integration (HFI) design process as part of the systems engineering approach for naval equipment procurement.
- To identify HFI technical issues for platforms, Combat Systems and marine engineering equipment.

- To provide supporting information about the HFI process, activities, outputs, standards and stakeholders of relevance to platforms and equipment.
- To describe the HFI activities that are typically conducted at each Phase of procurement.

US Air Force (2009). Air Force Human Systems Integration Handbook. Directorate of Human Performance Integration. Washington, DC. http://www.wpafb.af.mil/shared/media/document/AFD-090121-054.pdf

Military (Air Force), aerospace, US, DCL (design, acquisition), HSI (HFE,safety, training, personnel, manpower), discussion, evaluation, description, performance, safety, cost, methods, tools

The purpose of the U.S. Air Force Human Systems Integration (AFHSI) Handbook is to provide a detailed look at the Air Force Human Systems Integration (HSI) process and identify key considerations for the development of HSI plans and implementation of HSI programs. The Handbook can serve as a training aid for new Air Force HSI practitioners and requirements developers, as well as an introduction to HSI for those unfamiliar with the process. It may also serve as a desktop reference to HSI processes and general guidelines for experienced professionals. The instructions and processes addressed here are best used as a starting point for thinking about system concepts and designs. The user should not assume that the Handbook provides comprehensive coverage of all possible elements; general guidelines and lessons learned should be used as appropriate.

This Handbook is intended to provide the practitioner with an introduction to HSI and an imnce of addressing HSI earlproved understanding of why HSI is important. This includes consideration of the relationship between HSI and the Systems Acquisition Process, emphasizing the importay in system design and acquisition. Early consideration of HSI is necessary in order to maximize system performance benefits and reap maximum return on investment, resulting in minimal redesigns required later in the acquisition process. This Handbook addresses the integration of the HSI domains of human factors, manpower, personnel, training, environment, safety, occupational health, survivability, and habitability such that interdependencies can be organized and influenced and optimal design can be achieved.

US Air Force Institute of Technology (2009). Systems Engineering Case Studies, Synopsis of the Learning Principles. http://oai.dtic.mil/oai/oai?verb=getRecord&metadataPrefix=html&identifier=ADA507854

Military (Air Force), aerospace, US, DCL (acquisition), HSI (HFE,safety, training, personnel, manpower), review (technical, case study) ***, evaluation, description, performance, safety, cost, methods, tools

The Department of Defense is exponentially increasing the acquisition of joint complex systems that deliver needed capabilities demanded by our warfighter. Systems engineering is the technical and technical management process that focuses explicitly on delivering and sustaining robust, high-quality, affordable solutions. Air Force leadership has collectively stated the need to mature a sound systems engineering process throughout the Air Force.

Gaining an understanding of the past and distilling lessons learned that are then shared with others through formal education and practitioner support are critical to achieving continuous improvement.

This synopsis conveys the salient results of case studies focused on the application of systems engineering principles within various programs. Salient results are conveyed as learning principles to facilitate pedagogy. But these results are also useful to practicing engineers and managers as they apply systems engineering throughout a weapon system's life cycle. The reader is encouraged to delve into the details contained in the complete case study should a particular learning principle relate to a situation on your program.

Each learning principle is identified as follows:

(short name) / (learning principle number)

The short name key is as follows:

F-111 refers to the F-111 Systems Engineering Case Study

B-2 refers to the B-2 Systems Engineering Case Study

C-5 refers to the C-5A Galaxy Systems Engineering Case Study

GPS refers to the Global Positioning System Systems Engineering Case Study

HST refers to the Hubble Space Telescope Systems Engineering Case Study

TBMCS refers to the Theater Battle Management Core System Systems Engineering Case

Study

Peacekeeper refers to the Peacekeeper Intercontinental Ballistic Missile Systems Engineering

Case Study

A-10 refers to the A-10 Thunderbolt II (Warthog) Systems Engineering Case Study

GH refers to the Global Hawk Systems Engineering Case Study

KC-135 refers to the KC-135 Simulator Systems Engineering Case Study

The learning principle title is highlighted green if it contains information related to an application of systems engineering that one should consider adopting. The learning principle title is highlighted yellow if it contains information related to problems that should be avoided in the application of systems engineering.

Complete case studies are available on the Air Force Center for Systems Engineering website at [http://www.afit.edu/cse].

US Department of Defense (1999). Human Engineering Program, Process and Procedures. http://www.hf.faa.gov/docs/508/docs/46855a.pdf

Military (Army, Air Force, Navy), (land, maritime, aerospace), US, DCL (design, acquisition), HSI (HFE, safety, training, personnel, manpower), Review, discussion, description, performance, safety, cost, methods, tools

This handbook is approved for use by all Departments and Agencies of the Department of Defense.

2. This handbook is for guidance only. This handbook cannot be cited as a requirement. If it is, the contractor does not have to comply.

3. The individual services require the application of human engineering (HE) to military system design to achieve required performance by operator and maintenance personnel and to minimize personnel skills and training requirements. Department of Defense (DoD) and service policies require that HE be applied within the limits of time, cost, and performance tradeoffs.

   Although such service policies and regulations may change, there will continue to be a need for HE in the development of systems, equipment, and facilities and in product improvement and modification. This handbook provides HE program task guidance (Section 4), describes the significance of the analysis, design, and test aspects of the HE program (Section 5), outlines procedures found effective in implementing such guidance (Sections 6 - 7), and provides summaries of methods (Section 8).

4. Section 4 of this handbook (previously MIL-HDBK-46855) is the primary source used by the services to specify HE efforts during system acquisition and is now considered to be a set of guidelines or preferred practices, rather than rigid requirements. Section 4 is designed to support the human factors engineering discipline independently or as a part of Human Systems Integration (HSI) initiatives. Its guidelines and preferred practices serve as a baseline for obtaining HE program information to be provided by offerors during the solicitation process.

5. Section 4 expresses analysis, design, test, and related preferred practices, and strives to accommodate all service HSI initiatives, all acquisition phases, and a wide range of products, including small equipment items as well as major systems. To accomplish these ends, Section 4 is written as general, nonrestrictive, program task guidance that also provides latitude for contractors to apply technical/program judgment and innovation consistent with specific procurements. As a result, Section 4 is expressed as general guidelines or preferred practices. A collateral result, however, is lack of detail. Accordingly, Sections 5 - 7 provide background, procedures, task options, and rationale to assist military customer (or requiring organization) and contractor (or performing organization) program managers and HE practitioners to understand and apply HE in the system acquisition process. Finally, Section 8 summarizes HE methods that can be considered for application to the HE effort. Sections 5 - 8 of this handbook provide guidelines in the following areas:

- HE documentation and requirements applicable to the program
- Source data supporting definition of the HE effort
- Planning and scheduling needed to accomplish the program

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- Coordination of HE with other disciplines and with the program manager
- Possible allocation of effort to laboratories, consultants, or subcontractors
- Tailoring
- Preparation by the government of the HE portion of the request for proposal
- Preparation of the proposal by the contractor
- Evaluation of the proposal by the government
- Contractor task accomplishment, including details of several analysis, design, and test and evaluation (T&E) methods
- Government monitoring of and interaction with the contractor

6. Beneficial comments (recommendations, additions, deletions) and any pertinent data that may be of use in improving this document should be addressed to Commander, U.S. Army Aviation and Missile Command, ATTN: AMSAM-RD-SE-TD-ST, Redstone Arsenal, AL 35898-5270, by using the Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

US Department of Defense (2005). MANPRINT handbook. Office of the Deputy Chief of Staff G1, MANPRINT Directorate. www.manprint.army.mil/manprint/docs/MPTHandbook.pdf

Military (Army), land, US, DCL (acquisition) HSI (HFE,safety, training, personnel, manpower), discussion, description, performance, safety, cost, methods, tools

This handbook provides insight into the Army's Manpower and Personnel Integration (MANPRINT) Program, as well as, advice and recommendations. It has been prepared for Branch, Specified, Functional Proponent (FP), Materiel Developer (MATDEV), Program/Project/ Product Manager (PM) and MANPRINT Action Officers (AO). These are the professionals who are responsible for coordinating, guiding, implementing and managing MANPRINT in the acquisition of Automated Information Systems (AIS) and/or materiel systems and for the leadership that has ultimate responsibility for MANPRINT. The term MANPRINT AO refers to a responsibility rather than an official duty title. This AO may come from any of the acquisition disciplines or domains.

This handbook is also designed to accommodate the reader by providing text underlined in blue that is linked to Chapters and Appendices in this document, as well as, very useful web sites.

The U.S. Army Human Resources Command (HRC) uses a secure web site. If you are not on a secure Government operated computer network, you will have to copy the web address to your internet browser and select "Go" to gain access.

Department of Defense Instruction (DoDI) 5000.2 E7. Enclosure 7, paragraph E7.1, requires that a comprehensive management and technical strategy for Human Systems Integration (HSI) be initiated early in the acquisition process, specifically in the System Development and Demonstration (SDD) phase within the Defense Acquisition Management Framework. The entrance point for the SDD phase is at Milestone (MS) B approval and it is this milestone that marks the initiation of an acquisition program. The MANPRINT Program is the Army's implementation of the direction given by the Under Secretary of Defense for Acquisition, Technology, and Logistics (USD (AT&L)) for HSI and the Army's compliance with Title 10 of the United States Code. The program was established in 1984 with a primary objective to place the human element (functioning as individual, crew/team, unit and organization) on equal footing with other design criteria such as hardware and software. The entry point of MANPRINT in the acquisition process is through capability documents and studies. The Training and Doctrine

Command (TRADOC) Pamphlet (Pam) 71-20 provides excellent guidance.

US Department of Defense (2008). Instruction number 5000.02. http://www.dtic.mil/whs/directives/corres/pdf/500002p.pdf

1. PURPOSE. This Instruction:

NUMBER 5000.02 December 8, 2008

USD(A T&L)

a. Reissues Reference (a) to implement DoD Directive 5000.01 (Reference (b)), the guidelines of Office of Management and Budget (OMB) Circular A-11 (Reference (c)), and the various laws, policy, and regulations listed in Enclosure 1 of this issuance.

b. Establishes a simplified and flexible management framework for translating capability needs and technology opportunities, based on approved capability needs, into stable, affordable, and well-managed acquisition programs that include weapon systems, services, and automated information systems (AISs).

c. Consistent with statutory requirements and Reference (b), authorizes Milestone Decision Authorities (MDAs) to tailor the regulatory information requirements and acquisition process procedures in this Instruction to achieve cost, schedule, and performance goals.

US Department of Defense (2009). Human Systems Integration Management Plan (Version 1.0.). Washington, DC, ODUSD(A&T), ODUSD(S&T) Director of Biological Systems. http://www.acq.osd.mil/se/docs/FY09-DoD-HSI-Management-Plan.pdf

Military (Army Navy Air Force, US, DCL (design, acquisition, service, disposal), HSI (HFE,safety, training, personnel, manpower), discussion, evaluation, description, methods, tools

1.1 Purpose

The purpose of this document is to provide a comprehensive management plan for Human Systems Integration (HSI) for the Department of Defense (DoD).

1.2 Background

Congress and the Office of the Under Secretary of Defense for Acquisition, Technology and Logistics (OUSD(AT&L)) see the potential for HSI in its ability to enhance overall system effectiveness and lower life cycle ownership costs. A recent report to Congress [Ref: DoD HSI Coverage and ROI Report, 2008] documents many examples where Services have successfully implemented HSI on programs and have realized significant returns on investment (ROIs). However, in general, the DoD has not been successful at implementing HSI as a normal method of doing business even though strong acquisition policy and guidance is in place. As a result, Congress has taken a more forceful position in directing OSD to manage HSI and develop a comprehensive plan for funding and implementing HSI throughout the DoD. For complete details on the Congressional language, refer to Appendix B in this document.

This Congressional language prompted OUSD(AT&L), on April 3, 2008, to issue a memorandum [Young, 2008] (Refer to Appendix C) that stated:

"The Deputy Under Secretary of Defense for Acquisition and Technology (DUSD(A&T)) is hereby designated as the senior official responsible for the coordination and management of HSI activities throughout the DoD acquisition programs. The Deputy Under Secretary of Defense for Science and Technology (DUSD(S&T)), Director of Biological Systems, is designated co-lead for S&T related matters."

And hence, this memorandum has prompted the establishment of an HSI Management Plan that establishes OSD formal responsibility and accountability for the management of HSI within the DoD.

1.3 Objective

The objective of this plan is to establish formal responsibility, authority, and accountability for Human Systems Integration within the DoD.

This plan encompasses the HSI organizational structure, roles, responsibilities, processes, tasks, metrics, and enabling resources, and formalizes both horizontal and vertical communications between Office of the Secretary of Defense (OSD)

US Department of Defense (2010). Defense Acquisition Guidebook. US, Defence Acquisition University. https://dag.dau.mil/

Military, (Navy, Air Force, Army), (land, maritime, aerospace), US, DCL (design, acquisition, service, disposal), HSI (HFE,safety, training, personnel, manpower), case study, review, discussion, description, performance, safety, cost, methods, tools

The Defense Acquisition System exists to manage the Nation's investments in technologies, programs, and product support necessary to achieve the National Security Strategy and support the United States Armed Forces. In that context, our continued objective is to rapidly acquire quality products that satisfy user needs with measurable improvements to mission capability at a fair and reasonable price. The fundamental principles and procedures that the

Department follows in achieving those objectives are described in DoD Directive 5000.01 and DoD Instruction 5000.02.

The Defense Acquisition Guidebook is designed to complement those policy documents by providing the acquisition workforce with discretionary best practice that should be tailored to the needs of each program.

Acquisition professionals should use this Guidebook as a reference source supporting their management responsibilities. As an “on-line” resource, the information is limited only by the user’s interest or need. Some chapters contain general content; they provide individual topic discussions and describe processes and considerations that will improve the effectiveness of program planning. Some chapters may provide a tutorial on the application of these topics to the acquisition framework. Depending on the subject matter, a chapter may contain general background information, tutorial discussions, and/or discussions of the detailed requirements for each milestone decision and phase. All chapters contain non-mandatory staff expectations for satisfying the mandatory requirements in DoD Instruction 5000.02

Each chapter is designed to improve understanding of the acquisition process and ensure adequate knowledge of the statutory and regulatory requirements associated with the process. Discussions, explanations, and electronic links to related information enable the “reader” to be efficient, effective, innovative, and disciplined, and to responsively provide warfighting capability. Each chapter lists potential ways the program manager or assigned manager can satisfy mandatory process requirements and meet staff expectations for other activities. Differences of view regarding discretionary practice will be resolved by the Milestone Decision Authority.

The Guidebook is intended to be an electronic reference source rather than a “book.” The “reader” “navigates” the information instead of “leafing” through hundreds of physical, collated pages. “Navigation” is electronic movement through the reference system.

Chapter 1, Department of Defense Decision Support Systems, presents an overview of the Defense Department’s decision support systems for strategic planning and resource allocation, the determination of capability needs, and the acquisition of systems.

Chapter 2, Defense Acquisition Program Goals and Strategy, discusses acquisition program goals and the topics the program manager should consider in developing a strategy for the acquisition program. It addresses the required information associated with the Acquisition Program Baseline, the Technology Development Strategy, and the program’s Acquisition Strategy.

US General Accounting Office (2003). Military personnel: Navy actions needed to optimize ship crew size and reduce total ownership costs. www.gao.gov/new.items/d03520.pdf

Defence, military, navy, manning, cost-benefit

The Navy’s use of human systems integration principles and crew size reduction goals varied significantly for the four ships GAO reviewed. Only the DD(X) destroyer program emphasized human systems integration early in the acquisition process and established an aggressive goal to reduce crew size. The Navy’s goal is to cut personnel on the DD(X) by about 70 percent from that of the previous destroyer class-a reduction GAO estimated could eventually save about $18 billion over the life of a 32-ship class. The goal was included in key program documents to which program managers are held accountable. Although the Navy did not set specific crew reduction goals for the T-AKE cargo ship, it made some use of human systems integration principles and expects to require a somewhat smaller crew than similar legacy ships. The two other ships-the recently cancelled JCC(X) command ship and the LHA(R) amphibious assault ship-did not establish human systems integration plans early in the acquisition programs, and did not establish ambitious crew size reduction goals. Unless the Navy more consistently applies human systems integration early in the acquisition process and establishes meaningful goals for crew size reduction, the Navy may miss opportunities to lower total ownership costs for new ships, which are determined by decisions made early in the acquisition process (see figure). For example, the Navy has not clearly defined the human systems integration certification standards for new ships.

Several factors may impede the Navy's consistent application of human systems integration principles and its use of innovations to optimize crew size: (1) DOD acquisition policies and discretionary Navy guidance that allow program managers latitude in optimizing crew size and using human systems integration, (2) funding challenges that encourage the use of legacy systems to save near-term costs and discourage research and investment in labor-saving technology that could reduce long-term costs, (3) unclear Navy organizational authority to require human systems integration's use in acquisition programs, and (4) the Navy's lack of cultural acceptance of new concepts to optimize crew size and its layers of personnel policies that require consensus from numerous stakeholders to revise.

van Erp, J. B. F., L. Eriksson, et al. (2007). "Tactile cueing effects on performance in simulated aerial combat with high acceleration." Aviation Space & Environmental Medicine 78(12): 1128-34. http://www.ingentaconnect.com/content/asma/asem/2007/00000078/00000012/art00006

Civilian, aviation, Sweden, operation, HFE, performance, scientific (experimental)

INTRODUCTION: Recent evidence indicates that vibrotactile displays can potentially reduce the risk of sensory and cognitive overload. Before these displays can be introduced in super agile aircraft, it must be ascertained that vibratory stimuli can be sensed and interpreted by pilots subjected to high G loads.

METHODS: Each of 9 pilots intercepted 32 targets in the Swedish Dynamic Flight Simulator. Targets were indicated on simulated standard Gripen visual displays. In addition, in half of the trials target direction was also displayed on a 60-element tactile torso display. Performance measures and subjective ratings were recorded.

RESULTS: Each pilot pulled G peaks above +8 Gz. With tactile cueing present, mean reaction time was reduced from 1458 ms (SE = 54) to 1245 ms (SE = 88). Mean total chase time for targets that popped up behind the pilot's aircraft was reduced from 13 s (SE = 0.45) to 12 s (SE = 0.41). Pilots rated the tactile display favorably over the visual displays at target pop-up on the easiness of detecting a threat presence and on the clarity of initial position of the threats.

DISCUSSION: This study is the first to show that tactile display information is perceivable and useful in hypergravity (up to +9 Gz). The results show that the tactile display can capture attention at threat pop-up and improve threat awareness for threats in the back, even in the presence of high-end visual displays. It is expected that the added value of tactile displays may further increase after formal training and in situations of unexpected target pop-up.

van Hemmen, H. (2009). "Human Factors Analysis and the Shipboard Environmental Department." Marine Technology 46(4): 200-212. http://www.ingentaconnect.com/content/sname/mt/2009/00000046/00000004/art00003

civilian, maritime, manning, manpower, workload

COMSEAPRINT Human System Integration (HSI) is used to analyze the effect of reduced crew sizes and increased crew workloads resulting from increased regulatory requirements on oceangoing commercial vessels (as defined as ships with crew between 10 and 30). Most of the increased crew workloads are driven by recent environmental regulations and the analysis indicates that the creation of an environmental department in addition to the traditional deck and engine departments would efficiently address HSI existing and emerging problems on commercial ships.

Venturi, G. and J. Troost (2005). An agile, user-centric approach to combat system concept design. 10th International Command and Control Research and Technology Symposium, THALES NEDERLAND HENGELO (NETHERLANDS) http://oai.dtic.mil/oai/oai?verb=getRecord&metadataPrefix=html&identifier=ADA464266

Military (Navy), maritime Netherlands, DCL (design), HSI HFE, Research (discussion [practices]), performance, safety, cost, methods, tools

Purpose of this paper is defining a framework for the "Warfighter-Centered Design" (WCD) of new concepts for naval combat systems. This framework explicitly takes into account the business value of WCD with respect to safety, optimal manning and reduced lifecycle costs.

WCD improves safety because lack-of usability can lead to serious consequences; the analysis of the accident of USS Vincennes clearly shows that the combat system exhibited serious usability problems both in estimating the altitude trend of an air track and in the IFF identification. WCD holds also a significant economic value because it reduces the lifecycle costs related to ship manning and training and allows optimal solutions to the evolution to asymmetric and littoral warfare. Warfighter-Centered Design is not a methodology or a set of techniques, but an integrated approach to product concept design that focuses explicitly on the needs and limitations of the warfighter. It is based on user involvement, iterative prototyping and user-based assessment and it can focus on the different levels of the Command Information Centre organization and consoles.

Verwey, W. and H. Veltman (1996). "Detecting short periods of elevated workload: A comparison of nine workload assessment techniques." Journal of Experimental Psychology: Applied 2(3): 270-285. http://doc.utwente.nl/55531/

Civilian, HFE methods [workload assessment]

The present experiment tested the merits of 9 common workload assessment techniques with relatively short periods of workload in a car-driving task. Twelve participants drove an instrumented car and performed a visually loading task and a mentally loading task for 10, 30, and 60 s. The results show that 10-s periods of visual and mental workload can be measured successfully with subjective ratings and secondary task performance. With respect to longer loading periods (30 and 60 s), steering frequency was found to be sensitive to visual workload, and skin conductance response (SCR) was sensitive to mental workload. The results lead to preliminary guidelines that will help applied researchers to determine which techniques are best suited for assessing visual and mental workload.

Vinnem, J. and J. Liyanage (2008). "Human-Technical Interface of Collision Risk Under Dynamic Conditions: An Exploratory learning Case from the North sea." International Journal of Technology and Human Interaction 4(1): 34-47. http://www.csa.com/partners/viewrecord.php?requester=gs&collection=TRD&recid=20071235133975CI

Civilian (Maritime) safety

The collision risk between a Shuttle tanker and a FPSO (Floating, Production, Storage, and Offloading) is substantial during oil off-loading operations. Various human and organizational factors are in fact said to have major shares in this collision risk exposure. The purpose of this paper is to look into this collision risk scenario and to explore issues related to, for instance, demands on the operational role of human, critical human and organizational factors that contribute to risk level, and potential early measures for risk mitigation under dynamic conditions. This was in fact a learning case that brought a number of interesting but critical issues to the surface as elaborated in the paper.

Vitense, H., J. Jacko, et al. (2003). "Multimodal feedback: An assessment of performance and mental workload." Ergonomics 46(1): 68-87. http://www.informaworld.com/index/WRFPDXGWLXX2BH4R.pdf

Civilian, US, HFI (HFE methods [workload assessment]), scientific paper [evaluation of HSI]

Multimodal interfaces offer great potential to humanize interactions with computers by employing a multitude of perceptual channels. This paper reports on a novel multimodal interface using auditory, haptic and visual feedback in a direct manipulation task to establish new recommendations for multimodal feedback, in particular uni-, bi- and trimodal feedback. A close examination of combinations of uni-, bi- and trimodal feedback is necessary to determine which enhances performance without increasing workload. Thirty-two participants were asked to complete a task consisting of a series of 'drag-and-drops' while the type of feedback was manipulated. Each participant was exposed to three unimodal feedback conditions, three bimodal feedback conditions and one trimodal feedback condition that used auditory, visual and haptic feedback alone, and in combination. Performance under the different conditions was assessed with measures of trial completion time, target highlight time and a self-reported workload assessment captured by the NASA Task Load Index (NASA-TLX). The findings suggest that certain types of bimodal feedback can enhance performance while lowering self-perceived mental demand.

Walker, G. H., H. Gibson, et al. (2006). "Event Analysis of Systemic Teamwork (EAST): a novel integration of ergonomics methods to analyse C4i activity." Ergonomics 49(12-13): 1345-69. http://www.informaworld.com/index/757998752.pdf

C4i is defined as the management infrastructure needed for the execution of a common goal supported by multiple agents in multiple locations and technology. In order to extract data from complex and diverse C4i scenarios a descriptive methodology called Event Analysis for Systemic Teamwork (EAST) has been developed. With over 90 existing ergonomics methodologies already available, the approach taken was to integrate a hierarchical task analysis, a coordination demand analysis, a communications usage diagram, a social network analysis, and the critical decision method. The outputs of these methods provide two summary representations in the form of an enhanced operation sequence diagram and a propositional network. These offer multiple overlapping perspectives on key descriptive constructs including who the agents are in a scenario, when tasks occur, where agents are located, how agents collaborate and communicate, what information is used, and what knowledge is shared. The application of these methods to live data drawn from the UK rail industry demonstrates how alternative scenarios can be compared on key metrics, how multiple perspectives on the same data can be taken, and what further detailed insights can be extracted. The ultimate aim of EAST is, by applying it across a number of scenarios in different civil and military domains, to provide data to develop generic models of C4i activity and to improve the design of systems aimed at enhancing this management infrastructure.

Wallace, D. F., J. R. Bost, et al. (2007). "Importance of addressing human systems integration issues early in the science and technology process." Naval Engineers Journal 119: 59-64. http://www3.interscience.wiley.com/journal/120175180/abstract

Military/all, US, design,HSI all, performance/safety/cost, discussion

Historically, human systems integration (HSI) and other operational issues are not addressed during the science and technology (S&T) phase because the focus is on technology development. That view is to solve the "tough science" first, and the rest is simple application by a program office or operational forces. An imbalance between technology development efforts and total system performance considerations, e.g., total ownership cost, workload, manning, training, operational concept, skills, and human performance, leads to suboptimal solutions at best, and at worst prevents the technology's benefits from transitioning out of S&T

at all. If HSI is not addressed during the S&T phase, the responsibility falls to the acquisition programs to ensure that operator, maintainer, and total system performance are optimized in the final design. By this point, cost and schedule constraints can make this prohibitive, limiting the options to either using a legacy system or accepting the technology with suboptimal performance and high life-cycle costs (because design problems lead to manpower, training, and human error problems). However, if the S&T community uses HSI in their technology readiness level evaluation criteria, the Department of Defense can reduce its out-year costs and recapitalize that funding to buy required weapons systems and platforms while still reaping the tactical benefits that a new technology offers.

Walsh, T. and P. C. W. Beatty (2002). "Human factors error and patient monitoring." Physiological Measurement 23(3): R111-32. http://iopscience.iop.org/0967-3334/23/3/201

*Civilian, medical, HFE (patient monitoring), effectiveness/safety, review

A wide range of studies have shown that human factors errors are the major cause of critical incidents that threaten patient safety in the medical environments where patient monitoring takes place, contributing to approximately 87% of all such incidents. Studies have also shown that good cognitively ergonomic design of monitoring equipment for use in these environments should reduce the human factors errors associated with the information they provide. The purpose of this review is to consider the current state of knowledge concerning human factors engineering in its application to patient monitoring. It considers the prevalence of human factors error, principles of good human factors design, the effect of specific design features and the problem of the measurement of the effectiveness of designs in reducing human factors error. The conclusion of the review is that whilst the focus of human factors studies has, in recent years, moved from instrument design to organizational issues, patient monitor designers still have an important contribution to make to improving the safety of the monitored patient. Further, whilst better psychological understanding of the causes of human factors errors will in future guide better human factors engineering, in this area there are still many practical avenues of research that need exploring from the current base of understanding. [References: 105]

Wang, J. and T. Ruxton (1998). "A design-for-safety methodology for large engineering systems." Journal of Engineering Design 9(2): 159-170. http://www.informaworld.com/smpp/content~db=all~content=a713676298

Civilian, maritime, operation, system safety, safety, technical/discussion based on a case study (Piper Alpha disaster)

Both the Cullen report of the Piper Alpha disaster and the Carver report on ship safety have proposed that safety should be incorporated into maritime design processes from the initial stages and that more scientific and objective approaches are required in order to help prevent major accidents, to demonstrate safety, and to describe the safe operational requirements of large made-to-order products such as offshore platforms and ships effectively and efficiently. In this paper, the characteristics of large made-to-order products are described and their design process is studied together with a proposed design framework. After investigating the current design-for-safety status of large made-to-order products, a generic design-far-safety methodology is proposed and discussed in the context of the general design process. This proposed design-for-safety methodology may form the basis for the further development of safety assessment procedures and safety-based decision-making modelling techniques. The phases in the proposed design-for-safety methodology are studied together with their objectives and requirements. Finally, concluding remarks are given.

Waterson, P. and S. L. Kolose (2010). "Exploring the social and organisational aspects of human factors integration: A framework and case study." Safety Science 48(4): 482-490. http://www.sciencedirect.com/science/article/B6VF9-4Y7NJKF-1/2/a62947a826c4714d0cb60dec7424ee54

Military, UK, HSI general, review with a case study

In this paper we first outline a framework which aims to capture some of the social and organisational aspects of human factors integration (HFI) which have been outlined by previous research. The framework was partly used to design a set of interview questions that were used with a case study of a human factors team working with the UK defence industry. The findings from the case study revealed a number of barriers which accord with previous research in the domain of HFI (e.g., attitudes and perceptions towards HF), as well as providing insights into the improvement strategies used by the HF team in order to improve HFI. These included attempts to build relationships and establish a working rapport with other groups in the company, as well as other activities aimed at addressing the organisational culture within the company as a whole (e.g., attempts to raise the profile of HF within the company). We use the framework for social and organisational aspects of HFI to discuss our findings alongside other research on group behaviour and boundary management within large organisations. The conclusions of the paper point to the utility of the framework as a means of planning HFI improvement strategies which can help to overcome some of the social and organisational barriers to HFI.

Welch, D. L. (1998). "Human factors in the health care facility." Biomedical Instrumentation & Technology 32(3): 311-6. http://www.ncbi.nlm.nih.gov/pubmed/9619261

Civilian, medical, HSI tool, HFE, safety, technical/discussion

Previous articles in this series have investigated the role of human factors engineering (HFE) in the design and development of medical devices and instrumentation. This article turns its focus to HFE within health care facilities—hospitals, clinics, nursing homes, HMOs, etc. The objective of HFE for the device manufacturer is to produce effective and safe systems. The health care facility is concerned with maintaining the safety of patients and staff, enhancing the cost efficiency of its operations, and controlling liability. Human factors engineering can be effective in realizing all of these goals. Proactive measures include (1) evaluation of currently employed systems for efficiency and error potential, (2) evaluation of systems prior to purchase, (3) evaluation and enhancement of facilities, and (4) design and evaluation of procedures. Retroactively, HFE participation in accident/incident investigations can carry such investigations beyond the placing of blame to determining what made a human error possible or even inevitable.

Wickens, C. (2008). "Multiple resources and mental workload." Human Factors 50(3): 449. http://hfs.sagepub.com/cgi/content/abstract/50/3/449

Civilian, US, HSI (HFE Methods [workload analysis]), Review (evaluation of HSI), Research (methods)

Objective: The objective is to lay out the rationale for multiple resource theory and the particular 4-D multiple resource model, as well as to show how the model is useful both as a design tool and as a means of predicting multitask workload overload. Background: I describe the discoveries and developments regarding multiple resource theory that have emerged over the past 50 years that contribute to performance and workload prediction.

Method: The article presents a history of the multiple resource concept, a computational version of the multiple resource model applied to multitask driving simulation data, and the relation of multiple resources to workload.

Results: Research revealed the importance of the four dimensions in accounting for task interference and the association of resources with brain structure. Multiple resource models yielded high correlations between model predictions and data. Lower correlations also identified the existence of additional resources.

Conclusion: The model was shown to be partially relevant to the concept of mental workload, with greatest relevance to performance breakdowns related to dual-task overload. Future challenges are identified.

Application: The most important application of the multiple resource model is to recommend design changes when conditions of multitask resource overload exist.

Wickens, C. and A. Colcombe (2007). "Dual-task performance consequences of imperfect alerting associated with a cockpit display of traffic information." Human Factors 49(5): 839-50. http://hfs.sagepub.com/cgi/content/abstract/49/5/839

Civilian, aviation, operation, HFE, performance, scientific (experimental)

OBJECTIVE: Performance consequences related to integrating an imperfect alert within a complex task domain were examined in two experiments.

BACKGROUND: Cockpit displays of traffic information (CDTIs) are being designed for use in airplane cockpits as responsibility for safe separation becomes shared between pilots and controllers. Of interest in this work is how characteristics of the alarm system such as threshold, modality, and number of alert levels impact concurrent task (flight control) performance and response to potential conflicts.

METHODS: Student pilots performed a tracking task analogous to flight control while simultaneously monitoring for air traffic conflicts with the aid of a CDTI alert as the threshold, modality, and level of alert was varied.

RESULTS: As the alerting system became more prone to false alerts, pilot compliance decreased and concurrent performance improved. There was some evidence of auditory preemption with auditory alerts as the false alarm rate increased. Finally, there was no benefit to a three-level system over a two-level system.

CONCLUSION: There is justification for increased false alarm rates, as miss-prone systems appear to be costly. The 4:1 false alarm to miss ratio employed here improved accuracy and concurrent task performance. More research needs to address the potential benefits of likelihood alerting.

APPLICATION: The issues addressed in this research can be applied to any imperfect alerting system such as in aviation, driving, or air traffic control. It is crucial to understand the performance consequences of new technology and the efficacy of potential mitigating design features within the specific context desired.

Wickens, C. D., J. Goh, et al. (2003). "Attentional models of multitask pilot performance using advanced display technology." Human Factors 45(3): 360-80. http://hfs.sagepub.com/cgi/content/abstract/45/3/360

Civilian, aviation, operation, HFE/personnel, performance, scientific (experimental)

In the first part of the reported research, 12 instrument-rated pilots flew a high-fidelity simulation, in which air traffic control presentation of auditory (voice) information regarding traffic and flight parameters was compared with advanced display technology presentation of equivalent information regarding traffic (cockpit display of traffic information) and flight parameters (data link display). Redundant combinations were also examined while pilots flew the aircraft simulation, monitored for outside traffic, and read back communications messages.

The data suggested a modest cost for visual presentation over auditory presentation, a cost mediated by head-down visual scanning, and no benefit for redundant presentation. The effects in Part 1 were modeled by multiple-resource and preemption models of divided attention. In the second part of the research, visual scanning in all conditions was fit by an expected value model of selective attention derived from a previous experiment. This model accounted for 94% of the variance in the scanning data and 90% of the variance in a second validation experiment. Actual or potential applications of this research include guidance on choosing the appropriate modality for presenting in-cockpit information and understanding task strategies induced by introducing new aviation technology.

Wickens, C. D., B. L. Hooey, et al. (2009). "Identifying black swans in NextGen: predicting human performance in off-nominal conditions." Human Factors 51(5): 638-51. http://hfs.sagepub.com/cgi/rapidpdf/0018720809349709v1.pdf

Civilian, aviation, HSI tool, system safety, safety/performance, technical/review

OBJECTIVE: The objective is to validate a computational model of visual attention against empirical data—derived from a meta-analysis—of pilots' failure to notice safety-critical unexpected events.

BACKGROUND: Many aircraft accidents have resulted, in part, because of failure to notice nonsalient unexpected events outside of foveal vision, illustrating the phenomenon of change blindness. A model of visual noticing, N-SEEV (noticing-salience, expectancy, effort, and value), was developed to predict these failures.

METHOD: First, 25 studies that reported objective data on miss rate for unexpected events in high-fidelity cockpit simulations were identified, and their miss rate data pooled across five variables (phase of flight, event expectancy, event location, presence of a head-up display, and presence of a highway-in-the-sky display). Second, the parameters of the N-SEEV model were tailored to mimic these dichotomies.

RESULTS: The N-SEEV model output predicted variance in the obtained miss rate ($r = .73$). The individual miss rates of all six dichotomous conditions were predicted within 14%, and four of these were predicted within 7%.

CONCLUSION: The N-SEEV model, developed on the basis of an independent data set, was able to successfully predict variance in this safety-critical measure of pilot response to abnormal circumstances, as collected from the literature.

APPLICATIONS: As new technology and procedures are envisioned for the future airspace, it is important to predict if these may compromise safety in terms of pilots' failing to notice unexpected events. Computational models such as N-SEEV support cost-effective means of making such predictions.

Wickens, C. D. and K. S. Seidler (1997). "Information access in a dual-task context: testing a model of optimal strategy selection." Journal of Experimental Psychology: Applied 3(3): 196-215. http://www.ncbi.nlm.nih.gov/pubmed/11540969

Civilian, aviation, operation, HFE, performance, scientific (experimental)

Pilots were required to access information from a hierarchical aviation database by navigating under single-task conditions (Experiment 1) and when this task was time-shared with an altitude-monitoring task of varying bandwidth and priority (Experiment 2). In dual-task conditions, pilots had 2 viewports available, 1 always used for the information task and the other to be allocated to either task. Dual-task strategy, inferred from the decision of which task to allocate to the 2nd viewport, revealed that allocation was generally biased in favor of the monitoring task and was only partly sensitive to the difficulty of the 2 tasks and their relative priorities. Some dominant sources of navigational difficulties failed to adaptively influence selection strategy. The implications of the results are to provide tools for jumping to the top of the database, to provide 2 viewports into the common database, and to provide training as to the optimum viewport management strategy in a multitask environment.

Wierwille, W., L. Tijerina, et al. (1996). Heavy Vehicle Driver Workload Assessment Task 4: Review of Workload and Related Research. U. S. D. o. T. National Highway TrafficSafety Administration (NHTSA). http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.116.9438&rep=rep1&type=pdf

Civilian (Other industry [transportation]), US, HSI (HFE [workload analysis], safety), Review (description of HSI), Research (methods)

This report reviews literature on workload measures and related research. It depicts the preliminary development of a theoretical basis for relating driving workload to highway safety and a selective review of driver performance evaluation, workload evaluation in driving contexts, and risk-taking and risk adapation behavior. An actuarial approach to establish the safety relevance of workload measures in discussed in conjunction with a driver resources allocation model of in-cab device workload. The report concludes with the presentation of a driver resources-based taxonomy of in-cab tasks and candidate workload measures and their potential sensitivity to tasks described in the taxonomy.

Williams, K. E. and J. R. Voigt (2004). "Evaluation of a computerized aid for creating human behavioral representations of human-computer interaction." Human Factors 46(2): 288-303. http://hfs.sagepub.com/cgi/content/abstract/46/2/288

Military, Army, US, operation, training (simulation), productivity, technical/case study?

The research reported herein presents the results of an empirical evaluation that focused on the accuracy and reliability of cognitive models created using a computerized tool: the cognitive analysis tool for human-computer interaction (CAT-HCI). A sample of participants, expert in interacting with a newly developed tactical display for the U.S. Army's Bradley Fighting Vehicle, individually modeled their knowledge of 4 specific tasks employing the CAT-HCI tool. Measures of the accuracy and consistency of task models created by these task domain experts using the tool were compared with task models created by a double expert. The findings indicated a high degree of consistency and accuracy between the different "single experts" in the task domain in terms of the resultant models generated using the tool. Actual or potential applications of this research include assessing human-computer interaction complexity, determining the productivity of human-computer interfaces, and analyzing an interface design to determine whether methods can be automated.

Wilson, G. F. and C. A. Russell (2007). "Performance enhancement in an uninhabited air vehicle task using psychophysiologically determined adaptive aiding." Human Factors 49(6): 1005-18. http://hfs.sagepub.com/cgi/content/abstract/49/6/1005

Civilian, aviation, HFE (adding automated aid)/training, performance, scientific (experimental)

OBJECTIVE: We show that psychophysiologically driven real-time adaptive aiding significantly enhances performance in a complex aviation task. A further goal was to assess the importance of individual operator capabilities when providing adaptive aiding.

BACKGROUND: Psychophysiological measures are useful for monitoring cognitive workload in laboratory and real-world settings. They can be recorded without intruding into task performance and can be analyzed in real time, making them candidates for providing operator functional state estimates. These estimates could be used to determine if and when system intervention should be provided to assist the operator to improve system performance.

METHODS: Adaptive automation was implemented while operators performed an uninhabited aerial vehicle task. Psychophysiological data were collected and an artificial neural network was used to detect periods of high and low mental workload in real time. The high-difficulty task levels used to initiate the adaptive automation were determined separately for each operator, and a group-derived mean difficulty level was also used.

RESULTS: Psychophysiologically determined aiding significantly improved performance when compared with the no-aiding conditions. Improvement was greater when adaptive aiding was provided based on individualized criteria rather than on group-derived criteria. The improvements were significantly greater than when the aiding was randomly provided.

CONCLUSION: These results show that psychophysiologically determined operator functional state assessment in real time led to performance improvement when included in closed loop adaptive automation with a complex task.

APPLICATION: Potential future applications of this research include enhanced workstations using adaptive aiding that would be driven by operator functional state.

Wright, M. C. and D. B. Kaber (2005). "Effects of automation of information-processing functions on teamwork." Human Factors 47(1): 50-66. http://hfs.sagepub.com/cgi/content/abstract/47/1/50

Military, aviation, operation, HFE/training (computer simulation), performance, scientific (experimental)

We investigated the effects of automation as applied to different stages of information processing on team performance in a complex decision-making task. Forty teams of 2 individuals performed a simulated Theater Defense Task. Four automation conditions were simulated with computer assistance applied to realistic combinations of information acquisition, information analysis, and decision selection functions across two levels of task difficulty. Multiple measures of team effectiveness and team coordination were used. Results indicated different forms of automation have different effects on teamwork. Compared with a baseline condition, an increase in automation of information acquisition led to an increase in the ratio of information transferred to information requested; an increase in automation of information analysis resulted in higher team coordination ratings; and automation of decision selection led to better team effectiveness under low levels of task difficulty but at the cost of higher workload. The results support the use of early and intermediate forms of automation related to acquisition and analysis of information in the design of team tasks. Decision-making automation may provide benefits in more limited contexts. Applications of this research include the design and evaluation of automation in team environments.

Yee, S., L. Nguyen, et al. (2007). Visual, Auditory, Cognitive, and Psychomotor Demands of Real In-Vehicle Tasks. http://deepblue.lib.umich.edu/bitstream/2027.42/64456/1/102428.pdf

Military (Army) / Civilian, (land), US, HSI (HFE Methods [workload analysis]), Case study (Evaluation of HSI), Research (tools, methods)

Two analysts rated the visual, auditory, cognitive, and psychomotor demands of 68 subtasks (e.g., prepare to eat/drink, converse on the cell phone) performed while driving. Ratings were relative to anchors from the U.S. Army IMPRINT modeling tool (0-to-7 scale). Video clips of those subtasks were sampled from the advanced collision avoidance system (ACAS) field operational test (FOT) database, a naturalistic study of driving previously performed by UMTRI.

Key findings were:

1. The most demanding tasks were dialing a phone, answering a phone, lighting a cigar or cigarette, dealing with pet and insect distractions, dealing with spilled drinks and food, typing with 2 thumbs, and drinking from a cup, in that order.

2. Demand levels within subtasks were moderately correlated (visual-cognitive=0.68, visual-psychomotor=0.48, cognitive-auditory=0.42, cognitive -psychomotor=0.34) or close to 0.

3. In terms of these ratings, cognitive demands, both per unit time and when weighted by exposure, were consiste ntly double the value of others.

4. Demands varied to a limited degree among road types.

5. There were consistent differences in demand due to driver age and sex.

Researchers are encouraged to use the demand ratings provided and extend them to other tasks so tasks can be compared across experiments.

Zupanc, C. M., R. J. Burgess-Limerick, et al. (2007). "Performance consequences of alternating directional control-response compatibility: evidence from a coal mine shuttle car simulator." Human Factors 49(4): 628-36. http://hfs.sagepub.com/cgi/content/abstract/49/4/628

Civilian, mining, operation, personnel/training (simulation), performance, scientific (experimental)

OBJECTIVE: To investigate error and reaction time consequences of alternating compatible and incompatible steering arrangements during a simulated obstacle avoidance task.

BACKGROUND: Underground coal mine shuttle cars provide an example of a vehicle in which operators are required to alternate between compatible and incompatible steering configurations.

METHODS: This experiment examines the performance of 48 novice participants in a virtual analogy of an underground coal mine shuttle car. Participants were randomly assigned to a compatible condition, an incompatible condition, an alternating condition in which compatibility alternated within and between hands, or an alternating condition in which compatibility alternated between hands.

RESULTS: Participants made fewer steering direction errors and made correct steering responses more quickly in the compatible condition. Error rate decreased over time in the incompatible condition. A compatibility effect for both errors and reaction time was also found when the control-response relationship alternated; however, performance improvements over time were not consistent. Isolating compatibility to a hand resulted in reduced error rate and faster reaction time than when compatibility alternated within and between hands.

CONCLUSION: The consequences of alternating control-response relationships are higher error rates and slower responses, at least in the early stages of learning.

APPLICATION: This research highlights the importance of ensuring consistently compatible human-machine directional control-response relationships.

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APPENDIX C: HSI CASE STUDY SUMMARY

This appendix provides summary information describing HSI case studies identified during the literature review. The case studies are categorised as either:

(i) a case study in which cost-benefit was calculated for HSI implementation (Success Case Studies);

(ii) a case study of sub-optimal acquisition programs arising from insufficient implementation of HSI (Sub-optimal Outcomes Case Studies); or

(iii) a case study describing the implementation of HSI without assessment of outcomes (Observations/ Description Case Studies).

For Success and Sub-optimal Cases four assessment criteria were used:

(i) acquisition efficiency;

(ii) system design improvements; (iii) safety increases; and

(iv) cost avoidance/ROI.

Success Case Studies

Case Study	Description	Acquisition Efficiency	System Design Improve-ments	Safety Increases	Cost Avoid-ance/ ROI	Conclusions
			MILITARY			
Comanche Helicopter & T-800 Engine (US Army) **(Booher 2003[1], Chapter 18 p677)** (Minninger et al., 1995) HFI DTC 2006[2] ADF DSTO-CR-2006-0209[3]	The Comanche program provides the best documented example of HSI influence on the systems acquisition process. To achieve a "total system," as opposed to an "equipment-oriented" perspective, HSI principles were applied to the design and development of the Comanche aircraft.	✓	✓	✓	✓	The programme is cited by Booher and Minninger (2003) as an example for the benefits of HFI (MANPRINT). They claim that the adoption of MANPRINT on the programme avoided costs totalling $3.29 billion against a cost of implementing MANPRINT of $74.9 million. The cost saving figure is estimated by comparing manpower and training costs of the Comanche to those of the existing capability and adding to that an estimated saving through the influence of MANPRINT on the avoidance of safety/health hazard costs. The breakdown of savings is as follows: • Manpower – cost reduction over existing capability: $2.67 billion • Personnel, Training – cost reduction over existing capability: $440 million • Safety, health hazards, soldier survivability – costs avoided: $180 million 44:1 Cost-benefit ratio for the Comanche helicopter - (cost savings of $3.29B, HSI investment of $75M)
Crusader Battlelab Experiment **(Booher 2003[1], Chapter 18 p680)** (Pierce, 1996)		✓	✓			

Case Study	Description	Acquisition Efficiency	System Design Improve-ments	Safety Increases	Cost Avoid-ance/ ROI	Conclusions
Apache Longbow Design Improvements **Booher 2003[1], Chapter 18 p684)** (Irving, 1994) Cockshell & Hanna, 2006			✓		✓	22:1 Cost-benefit ratio for the Apache helicopter - (cost savings of $269M, HSI investment of $12M)
Fox Vehicle HSI Modeling **Booher 2003[1], Chapter 18 p685 HFI DTC 2006** ADF DSTO-CR-2006-0209[3] HFI DTC 2006[2]	The US Army Fox M93A1 Nuclear, Biological and Chemical (NBC) Reconnaissance System is a mobile laboratory, integrated into a six-wheeled, all-wheel-drive armoured vehicle. It takes samples of the air, water and ground and analyses them for signs of NBC agents. It can collect samples for subsequent analysis, mark areas of contamination and transmit real time NBC information to unit commanders.		✓	✓	✓	At a key test to assess work to upgrade the operational system and reduce its crew complement from 4 to 3 soldiers, the test variant (the XM93E1) was declared unsuitable and ineffective. After this assessment HF tools and methods were applied in the redesign to address issues of workstation design and operator workload. They were also used to reduce the cost of operational testing by reducing the length of costly physical trials, by augmenting them with HF modelling which verified that the reduced crew would be able to successfully operate the enhanced design (Booher and Minninger 2003). 33:1 Cost-benefit ratio for the Fox NBC Reconnaissance vehicle - (cost savings of $2-4M, investment of $60k)

Case Study	Description	Acquisition Efficiency	System Design Improve-ments	Safety Increases	Cost Avoid-ance/ ROI	Conclusions
DD(X) family of advanced technology surface combat ships (U.S Navy). HFI DTC 2006[2] Landsburg 2008[4]	The DD(X) is a family of advanced technology surface combat ships (U.S Navy). The programme is cited by the United States General Accounting Office (2003), as an example of a programme where HSI (HFI) has made a significant contribution to reducing costs. Landsburg: Implementation of the Navy's HSI approach in the acquisition program for the DDG 1000 destroyer design is a best practice example with HSI effectively enabling improved reliability, maintainability, and safety of the design while significantly reducing manpower levels. HSI as the combination of engineering disciplines to define the role of the human versus automation was able to identify requirements associated with the human roles. Through application of HSI's emphasis on improving human reliability and reducing human errors, innovative design approaches for equipment, software, procedures, information, environments, communications, and organizations could be shown to satisfy operational requirements. Today's demand to reduce manning aboard US Navy ships stems almost completely from the need to reduce the human costs incurred to operate and maintain the fleet (Bost, Mellis, and Dent 1994). A significant manning reduction effort was initiated in the SC-21 program, later to become the DD(X) or DDG 1000 program. Using this effort as an example of the extent of cost savings via reduced manning, review the following projected benefits, which consider only the unlisted mariners involved with meeting "Total Maintenance and Support Requirements"				✓	The programme has introduced changes to crew roles and responsibilities to achieve a more compact and flexible watch team. It involved producing HSI plans, developing conceptual designs to meet the crew reduction goals, and validating assumptions through a number of studies. The General Accounting Office estimates a through life cost saving of about US$600 million per ship in personnel related costs, based on a reduction in the crew complement of between 60 and 70 percent, in comparison with that of the Arleigh Burke-class destroyer, the existing capability. It was estimated that 32 ships would be procured representing a total saving of around US$18 billion. It should be noted that at the time of the report the DD(X) is at a relatively early stage in the acquisition process with construction due to start in 2007. Landsburg: Extensive application of human engineering through the Navy DDG 1000 HSI process is predicted to provide significant cost savings through the lowered manning levels planned. only the unlisted mariners involved with meeting "Total Maintenance and Support Requirements": &Enlisted manning profiles of the DDG 79 used to baseline the manning reduction for the DD– 21 included a reduction of 188 warriors. &The DD–21 goal was 44 warriors, a difference of 144 people. &The "average" enlisted maintainer is an E–5, and yearly cost to the Navy for E–5s in this area assumed to be about $65,329.00 (based on ASN RD&A data, which include all of the costs incurred by the Navy, e.g., medical, housing, family welfare, and estimates of retirement costs for those who stay in service until retirement). &The resulting yearly cost avoidance, per ship, at the lower manning level is then $9.4 million. &With the assumed operational life cycle for the DD-21 of 30 years, and 40 ships in the class, the total cost savings can be expected to be on the order of $11.3 billion.

Case Study	Description	Acquisition Efficiency	System Design Improvements	Safety Increases	Cost Avoidance/ ROI	Conclusions
Type 23 Frigate (UK) / M-Class Frigate ADF DSTO-CR-2006-0209[3] (DERA, 2000; USGAO, 2003)					✓	Achieved a 30 to 40 per cent reduction in crew size relative to the previous generation of ships by employing a HSI approach.
Canadian Defence Force ADF DSTO-CR-2006-0209[3] (Poisson, 2006)[5]	The Canadian Defence Force have made a considerable investment into the utility of HSI since 1998, spending $5.6 million on development of a HSI program ($1.5 million), exercising the HSI process (full process $3 million, partial HSI process $231 000), development of HSI tool case studies ($160 000) and providing HSI support to new application areas or strategic projects ($627 000).	✓	✓	✓	✓	Benefits for the $3.3 million spent on case studies include $2.9 million in direct savings during the analysis execution, an estimate of at least $169 million in indirect observable savings on the projects and a claimed possibility of hundreds of millions of dollars in further downstream indirect savings based on re-engineering costs avoided or lives saved.

Case Study	Description	Acquisition Efficiency	System Design Improvements	Safety Increases	Cost Avoidance/ ROI	Conclusions
US NAVY HSI PROCESS Landsburg 2008[4] (Anderson, Malone, and Baker 1998)	The Navy HSI process itself could be considered a case study in that it represents a "best practice." It is presented here briefly so that it can be compared with the other "best practices" described, although the current audience for this paper at this conference should be quite familiar with the process. The overall objective of HSI for reduced manning of ships is to enhance the affordability and reduce risks of acquiring and operating each ship throughout its life cycle. This is done through the application of systems engineering and advanced technology to produce a ship/system design requiring the minimum number of personnel while maximizing ship and system performance effectiveness, readiness, and reliability, and optimizing the ship crew's performance, workload, and safety. This is what is meant by "optimized manning." The HSI application is a "clean sheet" approach to implement a top-down systems engineering approach directed at analyzing functions and requirements; defining the roles of humans vice automation in ship systems; defining requirements for human machine interfaces; and providing and sustaining the required levels of shipboard human performance, workload, reliability, and safety.	✓		✓		The Navy HSI process provides an established and proven system that is part of the formal acquisition process through which to implement HSI principles and tools without which implementation would be ad hoc and far more difficult to perform. Application of HSI in the Navy implements a systems engineering approach that addresses requirements for workload reduction and manpower optimization initially for systems and subsystems, and then for the total ship. At the same time, technology is developed or adapted that will reduce cognitive and physical workloads on a ship's crew through function automation, consolidation, simplification, and elimination. Technology is also developed to reduce the incidence of human errors and accidents, and to make ship systems error tolerant.

Case Study	Description	Acquisition Efficiency	System Design Improve-ments	Safety Increases	Cost Avoid-ance/ ROI	Conclusions
F119 Engine **(US DoD)** Liu2010	The Department of Defense recently mandated the incorporation of Human Systems Integration (HSI) early in the acquisition cycle to improve system performance and reduce ownership cost. However, little documentation of successful examples of HSI within the context of systems engineering exists, making it di!cult for the acquisition community to disseminate and apply best practices. This article presents a case study of a large Air Force project that represents a successful application of HSI. The authors explore the influence of both the Air Force and the project contractor. Additionally, they identify top-level leadership support for integrating HSI into systems engineering processes as key to HSI success, reinforcing the importance of treating HSI as an integral part of pre-Milestone A activities.		✓	✓	✓	Gillette also insisted on the development of several full-scale mock-ups of the F119. These mock-ups came at a considerable cost (over $2 million each, while the cost of an engine was then about $7 million) but allowed engineers to see whether their designs had really achieved maintainability goals. Engineers were asked to service LRUs on the mock-ups by hand to ensure that they were each indeed only "one-deep." When an LRU was shown to not meet that requirement, the teams responsible for those LRUs were asked to redesign them.
CIVILIAN						
Usability engineering in IT organisations HFI DTC 2006[2] (Bias & Mayhew, 1994)	With its origins in human factors, usability engineering has had considerable success improving productivity in IT organizations. For instance, a major computer company spent $20,700 on usability work to improve the sign-on procedure in a system used by several thousand people. The resulting productivity improvement saved the company $41,700 the first day the system was used. On a system used by over 100,000 people, for a usability outlay of $68,000, the same company recognized a benefit of $6,800,000 within the first year of the system's implementation. This is a cost-benefit ratio of 1:100		✓		✓	Usability improvements resulted in cost-benefits (e.g. 1:100 cost-benefit ratio).
Aircraft Throttle System HFI DTC 2006[2] Hendrick (1996)	A case was reported where the expenses of a last-minute redesign of an aircraft throttle system were significantly reduced through HF studies determining the pilot's ability to control throttle movements using a full-scale mock-up of the controls.		✓		✓	Inefficient development processes (one-off effects) HFI not only affects in-service costs, but also development costs. HFI activities can influence design decisions early, before costly commitments have been made. For example, if expensive product functions are identified as unwanted by users in the final assessment phases, then opportunities for major process costs savings have been missed. Validated insight can help making more efficient design decisions by reducing the options

Case Study	Description	Acquisition Efficiency	System Design Improve-ments	Safety Increases	Cost Avoid-ance/ ROI	Conclusions
Usability improvements examples HFI DTC 2006[2] (Bias & Mayhew, 1994) (Karat, 1990) (Wixon and Jones, 1994)	In the usability domain, the following examples of savings during the development process have been reported: • Usability techniques allowed a high-tech company to reduce the time spent on one tedious development task by 40% (Bias & Mayhew, 1994). • By correcting usability problems in the design phase, using usability engineering techniques, American Airlines reduced the cost of those fixes by 60-90% (Bias & Mayhew, 1994). • Design changes due to usability work at IBM resulted in an average reduction of 9.6 minutes per task, with projected internal savings at IBM of $6.8 Million in 1991 alone (Karat, 1990). • A usability study of the first version of a fourth-generation database system revealed 75 usability problems. Twenty of the most serious problems were fixed in the second release, which generated 80% higher product revenues than the first release (Wixon and Jones, 1994).		✓		✓	

Case Study	Description	Acquisition Efficiency	System Design Improve-ments	Safety Increases	Cost Avoid-ance/ ROI	Conclusions
Human Factors Integration Plan - Atkins Consultants HFI DTC 2006[2] (Cullen 2005)	Atkins Consultants were asked to provide HF support to a project to build a new chemical plant and became involved at a stage in the design process which enabled HF issues to be addressed before the design became fixed The team produced a Human Factors Integration Plan (HFIP) to specify the work in key HF areas. HFI input resulted in several design changes: operators were optimally located in relation to each other and their equipment; changes were made to the Human Machine Interface (HMI) for the legacy Distributed Control System to reflect the population stereotypes of the intended British operators; the alarm system design was changed so that alarms were appropriately prioritised with differentiation between acknowledged and unacknowledged alarms. Representative end users were consulted during the design process. Cullen (2005) reports that HFI costs were relatively small in relation to the overall project budget and that the HFI work did not adversely impact the project's schedule. They compare the success story with an example where Atkins were called in at a late stage in the design, requiring costly redesign efforts.					
HFI DTC 2006[2] Bruseberg 2008[6] (Bias & Mayhew, 1994)	"At one company, end-user training for a usability-engineered internal system was one hour compared to a full week of training for a similar system that had no usability work. Usability engineering allowed another company to eliminate training and save $140,000. As a result of usability improvements at AT&T, the company saved $2,500,000 in training expenses."				✓	Training and recruitment needs Training and recruitment costs are considered as major cost factors in the Military. HFI can affect these costs through many routes.

Case Study	Description	Acquisition Efficiency	System Design Improve-ments	Safety Increases	Cost Avoid-ance/ ROI	Conclusions
Design of a new Thermal Oxide Reprocessing Plant for British Nuclear Fuels HFI DTC 2006[2] Bruseberg 2008[6] (Kirwan 2003)	Kirwan (2003) reports multiple benefits of a major HF programme for the design of a new plant (a Thermal Oxide Reprocessing Plant) for British Nuclear Fuels. It identified a number of HF safety issues that, had they remained in the design plans, would have caused costs leading to the economic ruin of the design organisation. The team influenced user interface design, training, maintenance, staffing levels and emergency response capabilities. The cost of this work, at around 15 person years of effort, could be justified by the hazard reduction achieved. The HF team worked within the safety department and had the role of assessing the developing design and giving feedback on design decisions and proposals. Application of Human Factors standards and principles was ensured. A range of HF analyses was carried out, and new methods were developed as part of the process. The benefits included longer-term effects by establishing new methods, processes and expertise.			✓		Kirwan (2003) reports an HF programme for the design of a new nuclear power processing plant that identified a number of HF safety issues that, had they remained in the design plans, would have caused costs leading to the economic ruin of the design organisation. HFI activities often have multiple benefits The generation of knowledge about envisaged human behaviour and performance in relation to new products often has several benefits. For example, a task analysis study can inform not only the design requirements, but also, with adaptations and extensions, areas including identification of selection criteria, training design, procedural design, user manuals, and safety assessments. Moreover, HFI is an investment creating long-term benefits. For example, Kirwan (2003) reports multiple benefits of a major HF programme, including longer-term effects by establishing new methods, processes and expertise.
EFFECTS OF A CENTERED HIGHMOUNTED BRAKE LIGHT ON AUTOMOBILE REAR-END ACCIDENT RATES Landsburg 2008[4] (Kohl et al. 1977)	The National Highway Transportation Safety Administration (NHTSA) of the DOT conducted a study of the effectiveness of alternate brake light configurations on the rate of rear-end collisions. Primary findings of the study indicated that cabs equipped with a centered, high-mounted brake light experienced a rear-end accident rate 54% lower than that for cabs in the control group. It was also found to reduce the extent of damage of vehicles involved in accidents by 38%.			✓	✓	Research of an operational safety issue resulted in implementation of a federal government design requirement that reduced the number of highway accidents. For the 3.2 million accidents occurring in 1977 that could have been affected by the centered high-mounted brake light the resultant savings were estimated at $1.465 billion. This estimate considered the cost of installation on 10 million vehicles, the expected reduction in accidents, and the cost savings of repair; the resulting cost-benefit ratio was 1465/40 or 37:1. Such research studies using human factors behavioral testing are able to definitively show system improvement and the estimated cost-benefit of savings can be convincing, enabling significant improvements to be made.

Case Study	Description	Acquisition Efficiency	System Design Improvements	Safety Increases	Cost Avoidance/ ROI	Conclusions
ALTITUDE DEVIATION HUMAN ERROR Landsburg 2008[4] (Granda and Vingelis 1992)	A series of investigations were conducted by Carlow International for the Federal Aviation Administration (FAA), the Airline Pilots Association, and USAir to look at reducing the number of altitude deviations (Granda and Vingelis 1992). Pilots must maintain certain altitudes at different parts of their flight as specified by regulation and the air traffic control. Deviations occur largely from human error and put the aircraft in jeopardy of a mid-air collision. The approach taken toward reducing the number of deviations was to enhance the awareness and appreciation for such errors by the pilots and air traffic controllers through explaining the situation, the errors, and the causes of errors to these groups. It also involved reconstruction of altitude deviation incidents in a USAir flight simulator, with the actual crew and controllers involved in the actual situation.			✓		Research of an operational safety issue resulted in an educational awareness outreach effort that reduced the number of accident precursors in individuals studied. Carlow personnel measured the altitude deviation error rates (defined as the number of altitude deviations per 100,000 departures) before and after application of altitude awareness enhancement procedures in the simulation exercises. The rate was shown to be reduced from 2.23 to 1.10 errors per 100,000 departures through the awareness enhancement effort, a 50.7% reduction.
FATIGUE MANAGEMENT APPLICATIONS Landsburg 2008[4]	The DOT Human Factors Coordinating Committee, a group of human factors program managers from across the department, collaboratively designed a research initiative to develop tools to fill gaps in the technology for addressing operator human fatigue and alertness. The Operator Fatigue Management (OFM) program research and development efforts provided advances in the tools and approaches available through applying behavioral science techniques that organizations could use to actively “manage” fatigue in a tailored and non-prescriptive way (i.e., avoiding prescribing maximum hours of service). Restricting hours of service has been shown to be at best largely ineffective, and at worst, prevents better industry-based solutions from prevailing. Perhaps most important is the establishment of a collaborative method of working to address these goals using human factors trained people working in quite different industry infrastructures and cultures.			✓		Research collaboratively performed resulted in filling knowledge gaps and developing tools useful in user and regulatory operational environments for managing fatigue. In the end, four contracts and five products were produced through this effort and made available for downloading on the program website. These tools included software for evaluating work schedules, a process to validate fatigue models, a compendium of information known from the scientific literature about fatigue and its mitigation, a logic model showing what is known and not known about operator fatigue (i.e., what additional research needs to be accomplished to support DOT fatigue reduction efforts), and a business case support tool that presents a fatigue management advocate within an organization, the tools and process necessary to justify building a program and ensuring its success. These products have been well received and the HFCC is planning a second iteration of development and testing of these tools, but this time also including the ability for government regulators to be able to more easily evaluate the impact and merit of hours of service regulations as compared with non-prescriptive efforts.

Case Study	Description	Acquisition Efficiency	System Design Improve-ments	Safety Increases	Cost Avoid-ance/ ROI	Conclusions
IMPLEMENTING CREW ENDURANCE MANAGEMENT SYSTEM (CEMS) IN THE INLAND WATERWAY INDUSTRY Landsburg 2008[4] (Comperatore, Rivera, and Kingsley 2005)	CEMS is used today to control endemic stressors in many commercial and USCG maritime work environments. Managing shipboard stressors requires a systems approach to identify and control specific sources of stress embedded in mission goals, company operational practices, industry traditions, environmental conditions, ship's habitability, and local culture. CEMS identifies behaviors, choices, policies, practices, and environmental conditions that contribute to the generation of shipboard stressors. The successful implementation of CEMS requires an aggressive education program to provide company management as well as crew-members a clear understanding of their contribution to the management of workplace stressors. Also, the same Headquarters Coast Guard Division offers and coordinates training on CEMS. This training provides specific information on how to design work schedules supporting crew readiness during duty hours and appropriate rest during time-off periods as well as the use of practices to prevent the desynchronization of personnel's biological clock during rotations from day to night or night to day watch. In addition, students learn specifics on how to manage caffeine intake, appropriate hydration practices, best diet choices, sleep management, and control of environmental stressors.			✓		The process developed engaged stakeholders to improve performance and safety through applying behavioral science to change design and procedures that reduce fatigue levels. When implemented properly, the CEMS has been shown to result in a three-way stakeholder win, namely: • Crewmembers—Safer, more satisfactory environment. • Company—More productive, safer, and more satisfied workers resulting in increased productivity, reduced employee turnover, and reduced costs from accidents. • USCG—Reduced risk of marine casualties related to endurance, and commensurately reduced risk to people and the environment.

Case Study	Description	Acquisition Efficiency	System Design Improve-ments	Safety Increases	Cost Avoid-ance/ ROI	Conclusions
HUMAN–AUTOMATION INTERACTION IN THE FAA NEXT GENERATION AIR TRANSPORTATION SYSTEM: RESEARCH NEEDS AND DESIGN METHODS Landsburg 2008[4]	The FAA and the National Aeronautics and Space Administration are working together with industry to develop the "Next Generation Air Transportation System" (NextGen). The new system will revolutionize how aviation is currently performed requiring considerable attention to implementation of the new humanautomation interactions of the new system. There is recognition that there are human factor requirements that transcend the current NextGen plan and the operational evolution plan. These cross-cutting requirements must be considered high priority in the research portfolio to form a basis for understanding human–system performance requirements across implementation of the new system. However, with a system this safety critical, waiting until the technical designs are mostly in place (as has been so often the case in the past in large system developments) is likely to prove disastrous.		✓	✓		The need is identified for applying behavioral science to study anticipated operational problems when implementing technology improvements to improve the commercial aviation transportation system.
ALTERNATIVE COMPLIANCE PROGRAMS Landsburg 2008[4]	Two examples of best practices come from safety regulatory agencies within the US government. OSHA and the USCG have both successfully instituted "alternative" compliance programs. These programs permit "good" companies to follow innovative approaches in complying with safety requirements. These programs basically provide for relaxed inspection and penalties for infractions when the companies have good safety records and take on the process of selfexamination and making of corrective actions internally.			✓		Change in organizational relationships for some situations is a more effective tool than standard enforcement techniques for maintaining desired government required safety levels.
SHIP OPERATOR AND UNION WORKING GROUPS Landsburg 2008[4]	Commercial shipping is an extremely competitive market. With manning costs overshadowing most other costs in the shipping business, application of automation to reduce the number of mariners required for ship operations has long been a focus in the international commercial industry.			✓		Significantly improved operational procedures and effectiveness result through change in organizational relationships and management and worker team developments.

Case Study	Description	Acquisition Efficiency	System Design Improve-ments	Safety Increases	Cost Avoid-ance/ ROI	Conclusions
USCG PREVENTION THROUGH PEOPLE PROGRAM Landsburg 2008[4]	In addition to its traditional regulatory role, the USCG refocused its mechanism for ensuring safety of commercial shipping operations by implementing a "Prevention through People" program. This effort enabled a revolutionary cultural change in government–industry relationships to facilitate safer operations. The cultural change and traditional incentives in industry and government were essentially enlightened through recognizing that the individual mariner and ship operator needs to take ownership of safety concerns versus increasing government design or operational requirements and enforcement efforts.			✓		Change in organizational relationships shifting safety responsibility from government to commercial proves effective. The continual engagement of all levels with this effort within USCG and in industry has been extremely effective in changing the culture of the industry to one of safety.
T-AKE Lewis and Clark Ship Class Landsburg 2008[4]	This case study describes a very successful method for performing design reviews using 3D CAD modeling tools. As part of a comprehensive HFE program for the development of the first of the T-AKE Lewis and Clark ship class, HFE specialists worked with ship design and engineering as a team to perform a comprehensive HFE design review. The purpose of the HFE review was to identify HFE issues with the design and to provide solutions to minimize impacts. In addition to using a 3D CAD model based on an approach pioneered by Gerry Miller (Miller et al. 2005), the HFE program also included "HFE 101" training for ship designers, providing HFE review and language for requirements and vendor supplied equipment as well as implementing a hazard tracking system to document and mitigate HFE design issues to closure.		✓			A visual approach to engaging stakeholders and experts in shared and active review of a design improves HSI effectiveness by improving the effectiveness of the review and engaging the design team with HSI principles.
Usability example Bruseberg 2008[6] (Landauer 1995)	The average UI has some 40 flaws. Correcting the easiest 20 of these yields an average improvement in usability of 50%. The big win, however, occurs when usability is factored in from the beginning. This can yield efficiency improvements of over 700%."		✓			

Case Study	Description	Acquisition Efficiency	System Design Improve-ments	Safety Increases	Cost Avoid-ance/ ROI	Conclusions
Usability example Bruseberg 2008[6] (Pressman 1992)	One (well-known) study found that 80% of software life-cycle costs occur during the maintenance phase. Most maintenance costs are associated with “unmet or unforeseen” user requirements and other usability problems.		✓		✓	Early HFI involvement can ensure that budgets are spent on the right developments. Early HFI studies (e.g. expert evaluation, literature survey, observational studies) are central to identifying key areas of HFI influence, and the right focus for more in-depth empirical studies. By establishing essential requirements of use before making major design investment decisions, significant savings can be made. In the usability domain, a 1:10:100 rule-of-thumb has been established through experience values and case studies: if it costs £1 to fix a usability problem during design, it will cost £10 to fix once the system is developed, and £100 once it is operational (Pressman 1992)
Usability example Bruseberg 2008[6] (Bias and Mayhew 1994)	With its origins in human factors, usability engineering has had considerable success improving productivity in IT organizations. For instance, a major computer company spent $20,700 on usability work to improve the sign-on procedure in a system used by several thousand people. The resulting productivity mprovement saved the company $41,700 the first day the system was used. On a system used by over 100,000 people, for a usability outlay of $68,000, the same company recognized a benefit of $6,800,000 within the first year of the system’s implementation. This is a cost-benefit ratio of $1:$100”		✓			
Usability example Bruseberg 2008[6] (Bias and Mayhew 1994)	One company saw its data-entry staff decrease by a third after usability improvements of an internal system		✓			
Usability example Bruseberg 2008[6] (Bias and Mayhew 1994)	At Microsoft several years ago, Word for Windows’s print merge feature was generating a lot of lengthy (average = 45 min) support calls. As a result of usability testing and other techniques, the UI for the feature was adjusted. In the next release, support calls ‘dropped dramatically’; Microsoft recognized ‘significant cost savings’		✓			

Sub-optimal Outcomes Case Studies

Case Study	Description	Acquisition Efficiency	System Design Improvements	Safety Increases	Cost Avoidance/ ROI	Conclusions
MILITARY						
SEA1411 Seasprite Helicopter (ADF) ADF DSTO-CR-2006-0209[3] Australian Defence Magazine issue (July 2006)	The Seasprite project has had a number of HF issues that may have been resolved or addressed through the application of HSI. There are significant challenges regarding its human machine interface, which has produced problems in the flight control system, and in the physical dimensions of the cockpit: the pilot's leg restricts the joystick movement due to cockpit design changes, specifically, "the extension of the aircraft's centreline console to the left to accommodate additional electronic equipment", which prevents full control of the helicopter.		✓		✓	The use of HF techniques such as critical task analysis and cockpit mockups (e.g. cardboard or 3D computer models) may have identified and prevented such problems, the cost of which to rectify has been estimated at between $100 to $200 million, and a period of two years at a minimum where the capability will not be available.
ANZAC class Frigates - Operations Room (ADF) ADF DSTO-CR-2006-0209[3]	The Operations Room of the ANZAC class Frigates is undergoing redesign to correct design deficiencies which have resulted in: Poor situation awareness for the command team; a lack of space to conduct some operations; operator's inability to reach equipment; operator's inability to see task-critical information; and operational hazards. Crews have tried to circumvent these problems by relocating operators during certain operations. Several variants of these work-arounds have been tried, with each one suffering its own limitations. The room's original design included no HF considerations. The cost of changing only the ops room would normally be unacceptably high and is only now being performed because it can be combined with work being undertaken during a capability upgrade.		✓	✓	✓	Failure to originally capture and integrate human requirements with technology requirements has resulted in a loss of operational performance, increased hazards and additional costs to remedy these deficiencies.

Case Study	Description	Acquisition Efficiency	System Design Improve-ments	Safety In-creases	Cost Avoid-ance/ ROI	Conclusions
BOWMAN Land Digitisation Project-Man-Portable Radios (British Army) HFI DTC 2006[2] (Daily Telegraph 2004; House of Commons 2003; MoD Web Site 2005) Bruseberg 2008[6]	As part of the BOWMAN Land Digitisation, 47,000 radios and 26,000 computer terminals are being procured and approximately 75,000 Service personnel need to be trained.	✓			✓	The BOWMAN man-portable radio (British Army) was assessed by the infantry as 'not fightable'. There have also been press reports regarding problems with their durability; inflexibility of use because they are tied to a single call sign; wiring which becomes tangled in webbing; problems with the battery life.
RB44 Light Vehicles (British Army) HFI DTC 2006[2] (National Audit Office 2000)		✓			✓	RB44 Light Vehicles (British Army) procured with automatic transmissions were found to be inadequate for driving off-road, with the result that the vehicles <u>had to have manual transmissions retro-fitted</u>. Some of the problems of the RB44 were also blamed on maintenance regimes that were intolerant to small deviations from standard practices.

Case Study	Description	Acquisition Efficiency	System Design Improvements	Safety Increases	Cost Avoidance/ ROI	Conclusions
SA80 Rifle and Light Support Weapon (British Army) HFI DTC 2006[2] (House of Commons, 1993)	The SA80 Rifle and Light Support Weapon (British Army) was beset by a series of problems over a period from 1985 to 1992. A significant proportion of the problems were related to operability/ fitness for purpose, including: • Accidental discharge – the weapon could accidentally discharge if dropped on its muzzle when the safety catch was on; • Trigger reassertion – sometimes the weapon's trigger had to be manually flicked back into position after firing; • Bipod deployment – the weapon's bipod stand would sometimes accidentally fall down from its stowed position; • Problems with bayonet – it was possible for the bayonet to fall off if the weapon had been left resting on the bayonet release catch; it was difficult to sharpen; some bayonets broke off at the tip; the wire cutters on the bayonet were inadequate; • Magazine release catch – the weapon's magazine could be accidentally released by the release catch snagging on webbing/clothing etc; • Cleaning kit – the cleaning kit was found to be inadequate and had to be completely replaced; • Reliability in sandy conditions – the weapon was prone to stoppages in sandy conditions.	✓		✓	✓	The estimated cost for the modifications to fix these problems was £24 million.

Case Study	Description	Acquisition Efficiency	System Design Improvements	Safety Increases	Cost Avoidance/ ROI	Conclusions
Single Role Minehunters HFI DTC 2006[2] (National Audit Office 2000) Bruseberg 2008[6]	After accepting the first of five Single Role Minehunters into service, it was discovered that it was difficult to recover the Remote Control Mine Disposal System from the sea back on board the ship in high seas, due to the pitching and rolling of the ship. To rectify the problem, it was necessary to install a better crane with a remote control facility, a platform for the operator to get nearer to the water line, and an additional recovery hook and hook pole. This problem can clearly be identified as a manual handling problem, the likelihood of which had been underestimated during development. Since the operational problems became apparent soon after initial deployment, and redesign actions were taken, the potential for significant financial losses due to injuries, damage or loss was averted. However, there was a cost of £1.9 million associated with design changes to overcome these difficulties (Public Accounts Committee, 2000). Since the suppliers had met their requirements, they were not liable for any of the rework costs. The cost was carried by the MoD as the procuring organisation. Redesign cost (one-off effects) For example, the Single Role Minehunters' release into service required an additional cost of £1.9 million to the MoD, to mitigate the potential of a much higher risk of damage, loss and injury (Public Accounts Committee 2000; National Audit Office 2000).		✓		✓	The case of the Single Role Minehunters (National Audit Office 2000) is an example for how insufficient consideration of HFI can lead to significant costs. It seems reasonable to assume that the difficulties of recovering the Minehunter in high seas had not been identified as a risk with high-enough priority. <u>It can be argued that HF activities applied much earlier in the design process could have prevented the costs</u> (e.g. as part of requirements specification and prototype testing activities). A standard HFI process may have prevented the problems.

Case Study	Description	Acquisition Efficiency	System Design Improvements	Safety Increases	Cost Avoidance/ ROI	Conclusions
Urgent Operational Requirement (UOR) **ELSA (Enhanced Low latency Situational Awareness)** Kelly2010[7]	As various reports have indicated, not all UORs are as effective as they could be, and some UORs that have been deployed have not been used. The reasons for this lack of effectiveness are many and varied (each UOR being quite different), but integration with existing equipment is often a cause of difficulties. Insufficient training on UOR equipments is also recognised as a key problem area (many UOR weapon systems being fired for the first time in theatre). Another problem is that HFI issues are not adequately considered during procurement, resulting in (some) UORs that are less effective than ideal or possibly even unusable. This problem is the focus of the HFI DTC's current research project on 'Process and tools for UORs'.	✓				The first task was to gain an understanding of the range of requirements that UORs actually cover. Clearly UORs vary enormously in terms of their types and complexity: from body armour to electronic countermeasures; from assault ladders to Protected Patrol Vehicles (PPVs); from UAVs to dog kennels! According to the MoD, some 85% of UOR expenditure is related to Force Protection including armour upgrades and aircraft Defensive Aids Suites. Also, very evidently, the fighting soldier has been extensively reclothed from helmet to boots, and re-equipped with an array of new or enhanced weapons. Not all of these UORs have HFI implications, but a large majority do. The second task was to examine the UOR process. Numerous stakeholders are involved, but in short, Theatre generates the requirement; PJHQ and Secretariat (Equipment Capability) (SEC(EC)) endorse; Capability Branch and DE&S procure (from Industry); and FLC integrate and field. Several conclusions can be drawn. The UOR process has improved markedly compared to a few years ago when it was generally considered slow and laborious; now it is much more 'fast-tracked' and it has been possible for some requirements to have been met (i.e. arrive in theatre) in a little over three months (e.g. Combat Shotgun). Ironically, there is some evidence that the UOR process delivers capability more effectively than the standard Equipment Procurement Process (EPP), and that there may be lessons which can drawn from this process to inform improvement in the EPP process2. However, notwithstanding this improvement in the process, there are also concerns that the focus on delivering equipment is losing sight of the real objective, which is to deliver capability; the two are not the same. Other conclusions concern the role and needs of industry, which is responsible for engineering the products that must satisfy the requirements. The HFI process appears weak at this stage and there is no explicit strategy for HFI involvement (unless the UOR is clearly a large, multi-equipment integration project). Regrettably, HFI is often perceived as adding time to the process.

Case Study	Description	Acquisition Efficiency	System Design Improvements	Safety Increases	Cost Avoidance/ ROI	Conclusions
						One example is ELSA (Enhanced Low latency Situational Awareness). This equipment was intended to enable section and platoon commanders to keep track of their troops both for C2 and rapid location of casualties. However, despite initially promising trials, the equipment was only partially deployed in theatre and then finally cancelled. This failure was attributed to various HFI issues (Human-Machine Interface (HMI), training, reliability, etc) that outweighed the claimed benefits. Although ELSA is perhaps an extreme example, it illustrates the importance of HFI not being neglected. It is, of course, important that the HFI guidance does not add any burden to the current process, but at the same time draws attention to what could be called the HFI "non-negotiables".
CIVILIAN						
London Ambulance Computer Aided Despatch System HFI DTC 2006[2] (Communications Directorate 1993)	The London Ambulance Computer Aided Despatch System commissioned an automated computer aided despatch system to replace a manual system in the early 1990s. The system sometimes made incorrect allocations or failed to allocate ambulances to incidents. User interface problems and understaffing in the control centre combined with slowly responding software and an increase in telephone and radio traffic from frustrated ambulance crews and members of the public, quickly resulted in the system slowing to unacceptable levels. On the 4th November 1992, the system failed completely after a programming error.		✓	✓	✓	Various technical and HF issues resulted in communication difficulties that meant the system often could not return the location and/or status of resources.
Financial Services company HFI DTC 2006[2] (Dray, 1995)	A financial services company had to scrap an application it had developed, when, shortly before implementation, developers doing a User Acceptance test found a fatal flaw in their assumptions about how data would be entered. By this time, it was too late to change the underlying structure, and the application was never Implemented.		✓		✓	

Observations/Description Case Studies

Case Study	Description	Conclusions
MILITARY		
F/A-18 Hornet Aircraft (Canadian Armed Forces) **(Booher 2003, 8.7.1 p254)** (Davidson, 1991) (Beevis, 1996) (Merriman and Moore, 1984) (Newsbreaks, 1994) (the MICMAC method of Godet, 1991) (RSG.21, 1994) (DoD, 1991b) (DoD, 1991c) (RSG.21, 1994)	To better understand interactions between the HSI domains and their effects on operator and system performance of the F/A-18 Hornet aircraft.	Overall, the analysis of HSI factors in F-18 squadrons showed that the pattern of the interactions is complex and does not lead to simple statements about trade-offs among the HSI domains. Rather than operating in isolation, operational practice, developmental training, manning levels, and the experience levels of personnel interact with the design resulting from the human factors engineering effort to affect the overall level of performance, effectiveness, and safety of an operational unit.
Efficiency in Human Resources HFI DTC 2006[2] Bruseberg 2008[6]	As part of a study by Atkinson (1995) to provide cost predictions for military operations, it was identified that the principal cost elements for deployments in recent conflicts included manpower, besides additional equipment, spares, attrition, ammunition, and movement (together accounting for about 90% of all costs). Thus, efficient use of human resources appears to be of prime importance for minimising costs.	Training and recruitment needs Training and recruitment costs are considered as major cost factors in the Military.
HFI DTC 2006[2] Bruseberg 2008[6]	Ergonomics problems can cause significant losses in personnel time. The US Department of Defense (DoD) provides figures for the effects of lost time and associated medical and compensation costs due to injuries and illnesses incurred to the DoD (DoD 2004). “Between 2001 and 2003, the Military Services lost 4.6M hours of productive work time to occupational injuries and illnesses. This is equivalent to losing approximately: 2660 full time equivalents (full time workers) 1.2 Marine Expeditionary Units 88% of an Army Brigade 1 embarked Navy Air Wing 50% of a mid-size Air Force Fighter Wing Between 1996 and 2003, 14 sites identified with using best practices were able to avoid $46M in workers’ compensation costs when compared with their appropriate Service average. If all DoD sites had performed like the examined best practice sites, DoD could have avoided $421M in workers’ compensation costs during this time period – enough funding for 10,300 GS-07 employees or approximately 98 M-1 tanks.”	People and resources not available Injuries and illnesses not only require recovery and rehabilitation costs, but covering for lost time, and insurance expenses—e.g. DoD (2004). Equipment downtime may result in mission failure, wasted personnel time, and high maintenance costs. Loss of personnel due to either survivability issues or fluctuation requires expensive re-recruitment and training.

Case Study	Description	Conclusions
Aviation Accidents Costs (US Navy & Marine Corps) HFI DTC 2006[2] (Erwin, 2002)	Aviation accidents cost the U.S. Navy and Marine Corps $4.3 billion between 1997 and 2002. Aviation accidents cost the U.S. Navy and Marine Corps $4.3 billion between 1997 and 2002. The $4.3 billion in losses only include the direct costs, such as the actual aircraft. The Navy additionally incurred at least $20 billion to $30 billion in other "indirect" costs related to aviation accidents, such as litigation, investigations and program delays. The Marine Corps V-22 tilt-rotor aircraft, for example, is at least 10 years behind schedule as a result of mishaps. Most of the aviation mishaps during that period – about 85 percent – were attributed to human error. Whilst the number of accidents has dropped significantly due to technical advances (i.e. 15 aircraft lost to the Navy in 2001, and 16 in 2002, compared to 776 in 1954), the cause of most accidents – human error – has not changed much in the past 25 years (Erwin, 2002).	
CIVILIAN		
Software Maintenance HFI DTC 2006[2] (Pressman 1992)	80 percent of software life-cycle costs occur during the maintenance phase. Most maintenance costs are associated with "unmet or unforeseen" user requirements and other usability problems	
Human Error Statistics HFI DTC 2006[2]	Human error statistics provide a measurement of the magnitude of the problem of not involving HFI into interface design processes for complex systems. Human Factors was listed as one of the major causes of fatal civil aviation accidents in 2004 (8 out of 28), along with controlled flight into terrain accidents (Learmount 2005). Further figures on human error are cited by Khandpur (2000): Human error has been attributed to 90% of nuclear facility emergencies; 65% of all airline accidents; 90% of all auto accidents. Approximately 80% of all marine casualties are caused by human error. 80% of offshore accidents are caused by human error and 64% of these occur during operations. 66% of offshore crane accidents are caused by human error. A 1993 Report on Maritime Accidents found that human error incidents outnumbered machinery failure incidents five to one. 25% of shipboard accidents are due to poor design (i.e. human error caused by poor design).	
Accidents & Design Issues HFI DTC 2006[2]	A report by Eurocontrol, the European Agency for Air Traffic Control, studied accidents across aviation and nuclear industries and concluded that approximately 50% of all accidents have a root cause in design. Although not specifically aiming at HF issues, it established that central design problems leading to accidents are caused by: designers' misconceptions about operators, operators' intentions, and the operating environment; operators' misconceptions about the design, its rationale and boundaries of safe operation (Roelen et al 2004).	

Case Study	Description	Conclusions
Introduction of new computer technologies HFI DTC 2006[2]	Landauer (1995) identifies a range of compelling examples, and types of problems, observed after introducing new computer technologies. Mostly, the short-term cost savings were usurped by: • added requirements for servicing, maintenance, updating, translation and data entry jobs; • restructuring, retraining, re-recruiting jobs; • lowered productivity and effectiveness due to usability problems and added complexity; • the effects of technical failures; • failure to interact with the system and get the required results at all. • Knock-on effects, apart from the productivity loss, are low staff morale and high turnover, loss of confidence by customers, lost business and re-design costs.	
Human Factors Harmonisation Working Group HFI DTC 2006[2]	In the civil airworthiness certification, changes are being made to existing standards to reflect the increased perception of the importance of HF. The Human Factors Harmonisation Working Group, consisting of both authority and industry participants, was formed in October 1999. It developed a new harmonised rule (§ 25.1302) and advisory material for HF in flightdeck design and assessment, specifically related to addressing the problem of human error. This is intended to supersede the JAA's (Joint Aviation Authority) Interim Policy on "Human Factors Aspects of Flight Deck Design" for JAR-25 aeroplanes (INT/POL/25/14), issued in March 2001.	
Usability example HFI DTC 2006[2]	"The average User Interface has some 40 flaws. Correcting the easiest 20 of these yields an average improvement in usability of 50%. The big win, however, occurs when usability is factored in from the beginning. This can yield efficiency improvements of over 700%." (Landauer, 1995)	
The Chaos Report & similar study HFI DTC 2006[2] (Standish Group 1994) Keil et al (1998) Cockshell2006 [3] Bruseberg 2008[6]	The Chaos Report established that users' involvement is the most important factor for the success of IT projects – through a large survey (the total sample size was 365 respondents and represented 8,380 applications, covering a wide range of business sizes and types). The study found that the highest-rated reason for why IT projects succeed is users' involvement during the development process (15.9 % of respondents saw user involvement as success factor; 12.8% saw lack of involvement as failure factor). Likewise, the task of dealing with changing requirements was identified as one of the major issues for project failures. A study with similar results was produced by Keil et al. (1998).	User involvement in development programmes is crucial for cost Savings.

Case Study	Description	Conclusions
UK MoD Human Factors Integration Plan HFI DTC 2006[2]	A Human Factors Integration Plan (HFIP) is an essential tool that outlines which HF activities are needed, and how they should be integrated into the overall engineering and management processes. It is periodically updated. Likewise, maintaining an HFI log from the early project stages ensures that any potential operational risks are not only identified but also acted upon depending on their criticality in relation to other issues. The UK MoD has now defined HFI key integration parameters as part of the MoD's System Readiness Levels. They provide major milestones to assess how well a standard HFI process is being followed.	
STGP10 / STGP11 (UK MoD) Bruseberg 2008[6] (Sea Technology Group 2002a & b).	HFI provides a process that ensures avoidance and mitigation of HFI problems Through a standard HFI process, problematic issues can be raised, investigated and addressed effectively. Many organisational mechanisms are available to ensure that technical HFI activities are carried out in conjunction with other development activities, and to ensure close involvement of HFI practitioners within design processes (e.g. Human Factors Integration Plan, HFI issues log). The UK MoD has now defined HFI System Readiness Levels to assess how well a standard HFI process is being followed. Support for HFI management is given, for example, in STGP10 (Sea Technology Group 2002a). HFI can draw on established theories, methods and materials HFI can make reference to established expertise and science. A wide range of methods, standards, research findings, design principles, as well as technical and process guidance is available for HFI—captured, for example, in STGP11 (Sea Technology Group 2002b). By following a standard HFI process, the likelihood of financial benefit from HFI is much higher.	
Usability for interface design HFI DTC 2006[2] (Pressman 1992)	In the domain of usability for interface design, a 1:10:100 rule-ofthumb has been established through experience values and case studies. If it costs £1 to fix a usability problem during design, it will cost £10 to fix once the system is developed, and £100 once it is operational (Pressman 1992). In other words, usability employed too late shows little return on investment. Such figures have been reproduced by many authors since.	

READER'S NOTES

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