Human factors for the design, operation and maintenance of mining equipment

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What is Human Factors?

Designing workplaces, equipment & systems to accommodate human abilities, limitations, and variability to improve safety, maintainability, efficiency & productivity.

Part of wider field of **H**uman **S**ystems **I**ntegration eg.,"*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*"(US DOD instruction 5000.02, 2008)

Selected Human Factors Issues

- Workstation Design
- Controls
- Displays
- Maintainability
- Whole Body Vibration
- Remote Control & Automation
- Training & Simulation

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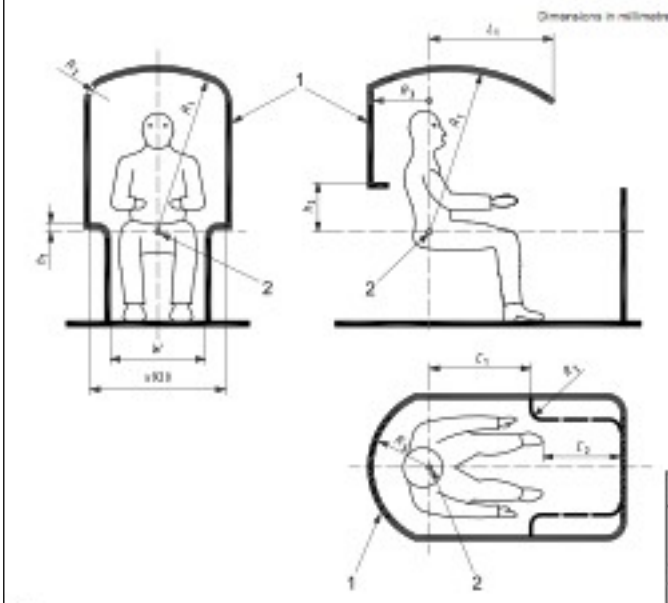
Workstation Design

- Access / Egress
- Clearances
- Seating
- Location & arrangement of controls & displays
- Visibility (and lighting)

- Environment - Temperature / Dust /

Anthropometric variability

Clearance



Key

1 Interior space envelope (ISE)

2 seat index point (SIP)

NOTE Width dimensions shown are symmetrical. See Table 1 for the values of the dimensions shown here.

Figure 4 — Normal minimum operator interior space envelope for enclosure — Seated operator

INTERNATIONAL STANDARD **ISO 3411**

Fourth edition
2007-07-15

Earth-moving machinery — Physical dimensions of operators and minimum operator space envelope

Table 1 — Dimensions (see Figures 4 and 5)

Symbol	Designation	Dimension mm
A_1	Distance between SIP and enclosure ceiling, in transverse plane	[1]
	— with operator wearing protective helmet, on seat with suspension and adjustment	≥1 050
	— with operator not wearing protective helmet, on seat with suspension and adjustment	≥1 000
A_2	Radius at intersection of enclosure's internal walls with each other and with ceiling	≤ 350
A_3	Distance towards rear	[1]
J_1	Horizontal distance between SIP and enclosure, in which J_1 is to be maintained	≥ 500
A_4	Vertical distance between SIP and lower end of upper side walls of enclosure	≤ 150
A_5	Vertical distance between SIP and lower end of upper back wall of enclosure	[2]
W	Width within space for legs	≥ 560
C_1	Clearance for forearm/hand within upper side areas of enclosure	≥ 600
C_2	Clearance between enclosure and operator's shoe working pedal or foot control, in any position	≥ 30

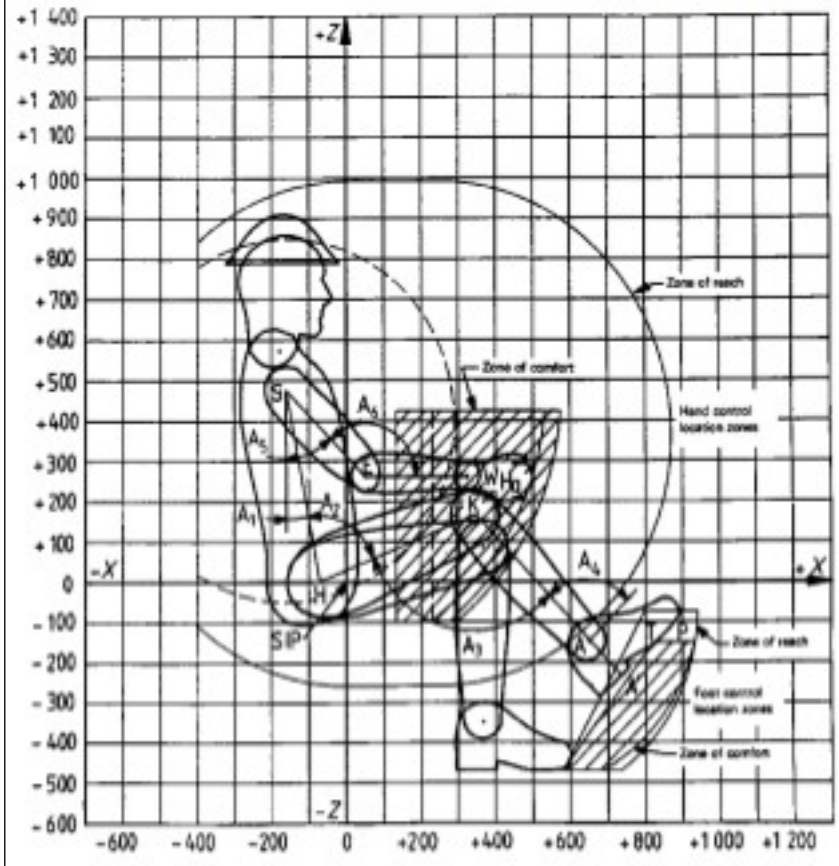
[1] The minimum distance from the SIP to a window reflected above the operator head shall be 600 mm.

[2] At least $A_5 = 400$ mm, where L is equal to half the horizontal seat adjustment dimension. See 5.2.5.

[3] This dimension shall be equal to or less than the vertical distance between the SIP and the top of the seat back cushion adjusted to its lowest position.

Location and arrangement of controls & displays

- Control location - reach distances, spacing
- Control arrangement - Sequence of use, Functional grouping, Frequency of use, Importance, Consistency
- Location compatibility - proximity of controls & related displays
- Optimal display location straight ahead and below eye height, avoiding glare



Control location

AS2965.5 / ISO8882

✻ Controls

Choice of control type, resistance, sensitivity and order

Directional compatibility

Prevent inadvertent operation, selection errors, & mode errors

Directional Control-Response Compatibility

"... Consistency of Movement - Controls shall be selected so that the direction of movements of the control will be consistent with the related movement of an associated display, equipment component, or vehicle."

NASA-STD-3000 Man-Systems Integration Standard, 1995.

"...the movement of the lever shall produce a movement of the controlled component in the same direction."

ISO 447-1984 Machine Tools - Direction of operation of controls

LITTLE EGG HARBOR, N.J., Dec., 17, 2004

Pilot Blamed In NJ School Strafing

Report Also Cites F-16 Design Flaws For November Incident

By Joel Roberts

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Jet Fires On NJ School

During a nighttime operation, an Air National Guard F-16 fighter jet fired 25 rounds into and around a New Jersey school. The jet's real target was over three miles away, WCBS's Hazel Sanchez reports.

(AP) An Air National Guard pilot who fired on a New Jersey school during a training exercise was to blame for the incident, but poorly designed controls in the F-16 also played a role, the Air Force concluded Friday.

The report, obtained by The Associated Press, also disclosed that there have been three other incidents this year in which an F-16 pilot unintentionally fired during nighttime strafing missions. It did not say where and when the other incidents occurred, but the report noted that, like the New Jersey case, no one was hurt.

The report called the Nov. 3 New Jersey incident an "unfortunate and unintentional mistake." It said the pilot never intended to strafe the Little Egg Harbor Township Intermediate School and suggested computer software changes to the aircraft control systems to prevent another incident.

In an F-16, the same trigger is used to produce a laser marker to focus on a target and to fire the gun in certain modes of operation.

"In my opinion, using the same trigger for both laser marking and firing the aircraft's gun significantly increases the risk of human error and an unintentional gun discharge," Col. Kevin W. Bradley, the president of the Accident Investigation Board, said in the report.

The pilot was identified as Maj. Roberto Balzano of the 113th Wing of the District of Columbia National Guard, based at Andrews Air Force Base in Maryland. The report said his commander will determine if any punitive or administrative action should be taken, and whether any retraining is necessary. Balzano has more than 2,000 hours of experience flying planes, 975 hours of which were in the F-16s.

✻ Displays

Design principles

Relative rather than absolute judgements
Redundancy
Pictorial realism
Frequently required information easily accessed
Predictive aiding
Consistency across equipment

✻ Maintainability

Reduce manual task
injury risks

Access without fall risk

Reduce error potential

Isolation

✻ Whole Body Vibration

Exposure to WBV strongly linked to back pain

AS2670

The relevant literature on the effects of long-term high-intensity whole-body vibration indicates an increased health risk to the lumbar spine and the connected nervous system of the segments affected. This may be due to the biodynamic behaviour of the spine: horizontal displacement and torsion of the segments of the vertebral column. Excessive mechanical stress and/or disturbances of nutrition of and diffusion to the disc tissue may contribute to degenerative processes in the lumbar segments (spondylosis deformans, osteochondrosis intervertebralis, arthrosis deformans). Whole-body vibration exposure may also worsen certain endogenous pathologic disturbances of the spine. Although a dose-effect relationship is generally assumed, there is at present no quantitative relationship available.

With a lower probability, the digestive system, the genital/urinary system, and the female reproductive organs are also assumed to be affected.

It generally takes several years for health changes caused by whole-body vibration to occur. It is therefore important that exposure measurements are representative of the whole exposure period.

WBV control

Remote control / automation
Roadway maintenance
Vehicle suspension
Seating
Maintenance of suspension & seat
Accelerometer data logging?

✻ Remote Control & Automation

Levels of automation (warnings to full automation)

Potential issues:

- ✤ Sources of information (eg., auditory)
- ✤ Poor usability - information overload & distraction, lack of feedback, temporal lag, display design
- ✤ Poor operator acceptance
- ✤ Operator de-skilling
- ✤ Loss of situation awareness
- ✤ Risk homeostasis

✻ Training & Simulation

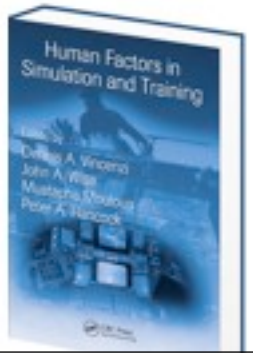
Design can't do everything.

Training in equipment operation and maintenance essential to provide skills & knowledge, leading to automaticity, perceptual expertise, problem solving / fault detection, appropriate response to emergency.

Simulation is an effective training tool.

Human Factors in Training Design

- Analysis of situation, task (Cognitive Task Analysis), equipment interface, trainees, & resources
- Define competency components, and assessment
- Definition of functional specifications for training
- Design & development, prototyping, usability
- Evaluation of training



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Conclusions

Optimising safety, maintainability & productivity requires careful application of Human Factors principles and tools throughout the design and procurement process, as part of overall Human-Systems Integration activities.

2-4% total system design & manufacture budget spent on HSI leads to ROI 40-60 times (US Airforce 2009)

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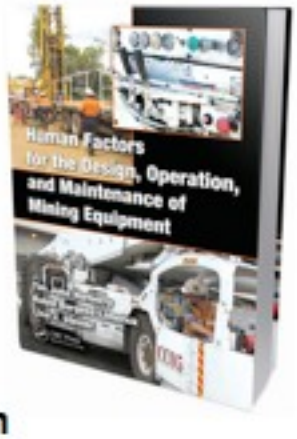

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