Health Hazard Assessment in System Safety Evaluation

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Overview – Tutorial Outline
Health Hazard Assessment in System Safety Evaluation

• Scope of issues/risks addressed by health hazard evaluation
• Describe the basic principles of health hazard evaluation.
• Illustrate use of the process outlined in Military Standard 882, Task 207 Health Hazard Evaluation, with examples and case studies.
• Basic introductory lecture on the general topic
• Introduction(s) to specific areas and exercises with working group review of problems.
Participant Introductions
# Tutorial Health Hazard Assessment

<table>
<thead>
<tr>
<th>Time</th>
<th>Topics</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>0800-0850</td>
<td>• Introduction and Overview</td>
<td>• Relevance of health hazard assessment to the systems engineering process</td>
</tr>
<tr>
<td></td>
<td>• Health hazard assessment process</td>
<td>• Focus areas – why worry</td>
</tr>
<tr>
<td></td>
<td>• Physical hazards</td>
<td>• Ergonomic and physical hazards- heat stress as an example</td>
</tr>
<tr>
<td>0900-0950</td>
<td>• Chemical hazards</td>
<td>Dose-response concepts</td>
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<tr>
<td></td>
<td></td>
<td>Preliminary Hazard Assessment</td>
</tr>
<tr>
<td>1030-1130</td>
<td>• Noise overview</td>
<td>-Noise the most prevalent occupational health hazard- it can be evaluated and often controlled</td>
</tr>
<tr>
<td></td>
<td>• Exercises in health hazard assessment</td>
<td>Health hazard assessment of a single hazard (noise, physical agent or chemical)</td>
</tr>
</tbody>
</table>
Why focus on health hazards?

• System safety is intended to be a risk-based process encompassing all categories of hazards
  – See tasks in Mil Standard 882E Task 207

• The systems engineering and system safety process has been very successful in prevention/control of common system and mechanical failures

• Many of the more prevalent and persistent risks are associated with health hazards
  – Some physical safety hazards also may need to be considered. (another discussion)

• Systems engineering/system safety/human systems integration considers the system as the sum of equipment/hardware-software/people and process

• Failures are often at the interfaces of people/software/equipment/

• Health hazards are common in maintenance and sustainment
<table>
<thead>
<tr>
<th>Hazard Category</th>
<th>Common Relevance to Defense systems</th>
<th>Areas of common concern</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical hazards</td>
<td>Maintenance, production (for manufactures); disposal</td>
<td>Use, disposal, selection of least hazardous products</td>
</tr>
<tr>
<td>Physical agent hazards</td>
<td>Acoustical energy, vibration, acceleration, barostress (pressure), heat or cold</td>
<td>Noise as the most common health hazard in DOD and general industry; vibration</td>
</tr>
<tr>
<td>Biological hazards</td>
<td>Travel especially in warzone or areas of public health concern</td>
<td>Disease exposure from travel; lab and medical</td>
</tr>
<tr>
<td>Ergonomic hazards</td>
<td>Efficiency, common but diverse source of injuries and long-term disease</td>
<td>Materials handling, maintenance, repetitive motion issues</td>
</tr>
<tr>
<td>Non-ionizing radiation</td>
<td>Radiofrequency radiation, RF Laser, infrared</td>
<td>RF signals, HERP, HERO (ordnance)</td>
</tr>
<tr>
<td>Ionizing radiation</td>
<td>Nuclear power, medical and scientific applications</td>
<td>Accidents, conflicts</td>
</tr>
<tr>
<td>Other hazardous material that may be formed by test, maintenance, operation or disposal of the system</td>
<td>Welding byproducts, hydrogen sulfide from bacterial fermentation</td>
<td></td>
</tr>
</tbody>
</table>
Applied Health Hazard Assessment at the end of the tutorial

• Exercise: A single hazard (risk factor) will be reviewed with a general assessment of potential exposure; level of risk and potential control approaches.

• Anticipated hazards are a single “uncomplicated” noise exposure, chemical exposure (probably a solvent) and possibly a physical agent (probably a single “simple” ergonomic stressor such as lifting heavy objects) will be reviewed with regard to;
  – Identification/recognition of potential health risks
  – Assessment/measurement relative to accepted exposure standards
  – Identification of potential mitigating/control approaches
  – Brief summary for the class, describing the above
Health Hazard Evaluation
Part 1

• Outline of the Mil Std 882 Task 207 Health Hazard Assessment Process
• Application of the Health Hazard Evaluation Process to;
  – Heat Stress
  – Ergonomic Hazards
• Links to process improvement and systems engineering (time permitting)
Task 207
Health Hazard Analysis Process

1. Purpose-Perform and document a health hazard assessment to identify human health hazards
   – Evaluate proposed hazardous material and processes
   – Propose measures to eliminate hazards
     • Or to reduce risks when the hazards can’t be eliminated
Task 207
Health Hazard Analysis (HHA) Process

2. Task Description: Perform and document HHA including potential effects from exposure to hazards

-What is a health hazard- a condition inherent to operation, maintenance, storage, transport, use or disposal that can cause death, injury, acute or chronic illness, disability or reduced job performance
Health Hazard Analysis (HHA) Process

2. Task Description: Specific health hazards and impacts to be considered

a. Chemical hazards
b. Physical hazard (acoustical energy, vibration, acceleration, barostress (pressure), heat or cold

c. Biological hazards
d. Ergonomic hazards
e. Other hazardous material that may be formed by test, maintenance, operation or disposal of the system
f. Non-ionizing radiation (RF, laser, IR)
g. Ionizing radiation
Health Hazard Analysis (HHA) Process

3. Categories of Information

a. Hazard identification – name and affected system components and processes (where it’s occurs)
   1. Exposure pathway - how people can be exposed to include mode of transmission (inhalation, absorption, ingestion)
   2. Exposure characterization – level of energy or concentration - what type of models can be used?
   3. Sometimes the evaluation will be quantitative (versus qualitative)

b. Severity and probability of exposures
   - Describe the potential acute and chronic health risks

c. Mitigation strategy for each hazard
   - Describe a target mitigation strategy for each hazard based on the degree of risk reduction
Hazard identification – name **Heat Stress**

**Affected human system components:** Heat stress imposes an additional metabolic load for cooling

- Heart and circulatory system
- The brain is a heat-sensitive organ
  - Cognitive functions affected
  - Potential permanent
- The kidney - hazardous metabolites

**Discussion:**
- Conditioning and acclimatization increase tolerance
- A cascading series of acute impacts from fatigue and lower performance to more severe effects
- Can potentially lead to circulatory failure, neurological effects; even heat stroke and potentially death
Heat Stress

• Washington Post: American workers die needlessly in the heat every year — 31 deaths and over 4,000 illnesses in 2012 resulted from working in the heat; OSHA advises that workers who will be exposed to heat seek shade, rest, and drink water.


• Military medical focus area due to operation in hot areas and training in hot climates.

• Increased risks due to protective clothing

• DOD developed many of the initial standards for heat and cold stress and has developed detailed standards of practice
Health Hazard Analysis (HHA) Process
Heat Stress as an Example

Hazard identification – name **Heat Stress**

**Processes:** (where it occurs)

- Associated with machinery and hot processes (welding, laundry, cooking, power plants) especially vehicles and ships
- Hot outside environments (increased by protective clothing)
Health Hazard Analysis (HHA) Process

Heat Stress as an example

1. **Exposure pathway** - how people can be exposed to include mode of transmission (inhalation, absorption, ingestion, radiation, contact with air and hot surfaces)

2. **Exposure characterization** – level of energy or concentration - what type of models can be used?
   - Simple but often insufficient - Measurement of temperature and
   - More complex but effective Combined evaluation of radiant heat, humidity and temperature

Sometimes the evaluation will be quantitative (versus qualitative)
Heat Stress Evaluation (Characterization)
Wet bulb Globe temperature (WBGT)

<table>
<thead>
<tr>
<th>Component</th>
<th>Measurement</th>
<th>Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry heat</td>
<td>Thermometer</td>
<td>Source control-insulation, reduce process temperature</td>
</tr>
<tr>
<td>Radiant heat</td>
<td>Globe thermometer</td>
<td>Radiant heat-insulation and shielding</td>
</tr>
<tr>
<td>Humidity (reduced evaporative cooling)</td>
<td>Wet bulb temperature (evaluates relative humidity)</td>
<td>Reduce steam and water leakage; Clothing that allows evaporative cooling</td>
</tr>
</tbody>
</table>

Source: www.frecuenciamedica.org/Wbgt
b. Severity and probability of exposures

- Describe the potential acute and chronic health risks related to the effective temperature,
- related work-rest cycle
- and risk of heat injuries
Hazard Identification
- Characterization
- Severity- Probability
- Mitigation

**Layman’s Color-coded dose-response and risk relationships**

<table>
<thead>
<tr>
<th>Risk</th>
<th>Temp</th>
<th>Risk Mitigation</th>
<th>Heat Injury Signs and Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>White Flag</td>
<td>&lt; 82 WBGT</td>
<td>Time to exercise! Drink water/sports before/after exercise</td>
<td>Recognize early symptoms and take appropriate action to prevent serious heat disorders in yourself and others.</td>
</tr>
<tr>
<td>MINIMAL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Green Flag</td>
<td>82-84.9 WBGT</td>
<td>Drink at least 1 qrt of water/ sports drink every 20 min</td>
<td>Recognize early symptoms and take appropriate action to prevent serious heat disorders in yourself and others.</td>
</tr>
<tr>
<td>LOW</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yellow Flag</td>
<td>85-87.9 WBGT</td>
<td>Take rest breaks during exercise and keep drinking fluids</td>
<td><strong>HEAT CRAMPS LIKELY:</strong> Painful contraction of muscles, weakness</td>
</tr>
<tr>
<td>MEDIUM</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red Flag</td>
<td>88-89.9 WBGT</td>
<td>Consider reducing workout intensity</td>
<td><strong>HEAT EXHAUSTION LIKELY:</strong> Dizziness, nausea, vomiting, headache, fainting, disorientation, weakness</td>
</tr>
<tr>
<td>HIGH</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black Flag</td>
<td>&gt; 90 WBGT</td>
<td>Extreme Caution! Exercise indoors in a cooler setting</td>
<td><strong>HEAT STROKE HIGHLY LIKELY:</strong> Extremely high body temp, confusion, convulsions, unconsciousness, death</td>
</tr>
<tr>
<td>EXTREMELY</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HIGH</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**CAUTION:** If you experience a heat related injury, call 911 immediately! Move to a shaded area and treat for shock (lie down, cool body with cold compresses, elevate feet).
# Heat Stress Hazards

<table>
<thead>
<tr>
<th>Heat effect</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decreased performance</td>
<td>Mental and physical effects</td>
</tr>
<tr>
<td>Sunburn</td>
<td></td>
</tr>
<tr>
<td>Heat Cramps</td>
<td>Electrolyte imbalance</td>
</tr>
<tr>
<td>Heat Syncope</td>
<td>Temporary loss of blood supply to brain</td>
</tr>
<tr>
<td>Heat Exhaustion</td>
<td>Excessive loss of water and electrolytes. Get medical aid</td>
</tr>
<tr>
<td>Heat Stroke</td>
<td>Life threatening loss of water and salts. Sweating stops. Body is unable to regulate temperature</td>
</tr>
</tbody>
</table>
Health Hazard Analysis (HHA) Process
Heat Stress as an Example

c. Mitigation strategy for each hazard

Describe a target mitigation strategy for each hazard based on the degree of risk reduction

Common approaches – using the hierarchy of controls

<table>
<thead>
<tr>
<th>Control</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elimination</td>
<td>Process change</td>
</tr>
<tr>
<td>Containment/ control</td>
<td>Shielding, insulation of hot surfaces, process temperature controls, remote monitoring, ventilation (local exhaust at source and general ventilation/cooling)</td>
</tr>
<tr>
<td>Training and procedures</td>
<td>Work-rest cycle; water-hydration; work scheduling, acclimatization</td>
</tr>
<tr>
<td>Protective equipment</td>
<td>Equipment with lower heat retention; shielding in some hot areas; protect the head- the brain is a heat sensitive organ</td>
</tr>
</tbody>
</table>
Ergonomics/Human Systems Integrations

The Problem

• Continued high incidence of human injury associated with poor design.

Source: Analyzing the Navy’s Safety Data by the Center for Naval Analysis, December 2001

These figures represent Navy costs, but are estimated to be representative of other Services.
The Problem (con’t)

• Human engineering and safety usually don’t consistently focus upon ergonomic injuries.

• Increased life cycle costs associated with human injury
  – Estimated costs of ergonomic injury in the Navy to exceed $100M by 2009

• DoD needs a better way to reduce design-induced injuries as part of the acquisition process
### Recognition of Basic Categories of Ergonomic Risks

DOD Ergonomics Working Group: Caution Zone Checklist


- Hazard Identification
- (Preliminary) Characterization
- Severity
- Probability
- Mitigation

<table>
<thead>
<tr>
<th>Caution Zone Checklist</th>
<th>Use one sheet for each position evaluated.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Movements or postures that are a regular and foreseeable part of the job, occurring more than one day per week, and more frequently than one week per year.</td>
<td>If done in this job position:</td>
</tr>
<tr>
<td></td>
<td>Yes</td>
</tr>
</tbody>
</table>

#### Awkward Posture

##### Comments/Observations

| 1. Working with the hand(s) above the head, or the elbow(s) above the shoulders more than 2 hours total per day. | □ |
| 2. Working with the neck or back bent more than 30 degrees (without support and without the ability to vary posture) more than 2 hours total per day. | □ |
| 3. Squatting more than 2 hours total per day. | □ |
| 4. Kneeling more than 2 hours total per day. | □ |

#### High Hand Force

##### Comments/Observations

| 5. Pinching an unsupported object(s) weighing 2 or more pounds per hand, or pinching with a force of 4 or more pounds per hand, more than 2 hours total per day (comparable to pinching half a ream of paper). | □ |
| 6. Gripping an unsupported object(s) weighing 10 or more pounds per hand, or gripping with a force of 10 or more pounds per hand, more than 2 hours total per day (comparable to clamping light duty automotive jumper cables onto a battery). | □ |
### Recognition of Basic Categories of Ergonomic Risks

#### Highly Repetitive Motion

<table>
<thead>
<tr>
<th>Number</th>
<th>Description</th>
<th>Comments/Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.</td>
<td>Repeating the same motion with the neck, shoulders, elbows, wrists, or hands (excluding keying activities) with little or no variation every few seconds, more than 2 hours total per day.</td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>Performing intensive keying more than 4 hours total per day.</td>
<td></td>
</tr>
</tbody>
</table>

#### Repeated Impact

<table>
<thead>
<tr>
<th>Number</th>
<th>Description</th>
<th>Comments/Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.</td>
<td>Using the hand (heel/base of palm) or knee as a hammer more than 10 times per hour, more than 2 hours total per day.</td>
<td></td>
</tr>
</tbody>
</table>

#### Heavy, Frequent or Awkward Lifting (A simple scale can be used to determine the weight of materials)

<table>
<thead>
<tr>
<th>Number</th>
<th>Description</th>
<th>Comments/Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>10.</td>
<td>Lifting object weighing more than 75 pounds once per day or more than 55 pounds more than 10 times per day.</td>
<td></td>
</tr>
<tr>
<td>11.</td>
<td>Lifting objects weighing more than 10 pounds if done more than twice per minute, more than 2 hours total per day.</td>
<td></td>
</tr>
<tr>
<td>12.</td>
<td>Lifting objects weighing more than 25 pounds above the shoulders, below the knees or at arm’s length more than 25 times per day.</td>
<td></td>
</tr>
</tbody>
</table>

#### Moderate to High Hand-Arm Vibration (Closely estimate or obtain the vibration value of the tool in use)

<table>
<thead>
<tr>
<th>Number</th>
<th>Description</th>
<th>Comments/Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>13.</td>
<td>Using impact wrenches, carpet strippers, chain saws, percussive tools (jack hammers, scalers, riveting or chipping hammers) or other tools that typically have high vibration levels, more than 30 minutes total per day.</td>
<td></td>
</tr>
<tr>
<td>14.</td>
<td>Using grinders, sanders, jigsaws or other hand tools that typically have moderate vibration levels more than 2 hours total per day.</td>
<td></td>
</tr>
</tbody>
</table>
Early recognition of safety and health risk can reduce life cycle costs and risk

- Initial analysis—what manpower intensive tasks and safety-health risks drive later costs?
  - Movement of equipment and supplies
  - Management of chemical materials (and related safety, health and environmental measures)
  - Excessive maintenance demands (and increased failures from systems that are difficult to maintain)
  - Environmental conditions that reduce efficiency, comfort and safety
Movement of materials

• Movement of materials should be considered as an aspect of process management. Labor intensive activities may be identified for improved support systems and equipment.
Need to integrate multiple disciplines approaches

*Issue depends on perspective*

*Consider interface issues - people to system*

• Human systems integration
  – Ineffective use of manpower
  – Would training help?

• System Safety
  – Will they drop it?
  – If so, what happens?

• Ergonomics (and occupational safety)
  – Will this create a back injury?

Is this approach consistent with systems engineering?

Need to integrate systems engineering approach across multiple disciplines and show economic benefits of early design for users
Discussion

Risk Evaluation

• Evaluate severity (weight in this example)
• Frequency (frequency of lifting in this example)
• Compare to available standards/recommended criteria

Possible Mitigation (Depend on level of risk)

• Reduce weight of material lifted
• Provide mechanical assistance
• Provide training and procedures
## TLVs® for Lifting Tasks

≤ 2 hours/day with ≤ 60 lifts/hour or > 2 hours/day with ≤ 12 lifts/hour

<table>
<thead>
<tr>
<th>Vertical Zone</th>
<th>Horizontal Zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Close to body &lt; 30 cm</td>
<td>Intermediate 30-60 cm</td>
</tr>
<tr>
<td>Reach limits 2 or 30 cm above shoulder to 8 cm below shoulder height</td>
<td>16 kg</td>
</tr>
<tr>
<td>Knuckle height to below shoulder</td>
<td>32 kg</td>
</tr>
<tr>
<td>Middle shin to knuckle height</td>
<td>18 kg</td>
</tr>
<tr>
<td>Floor to middle shin height</td>
<td>14 kg</td>
</tr>
</tbody>
</table>

- **Extended** > 60-80 cm
  - No known safe limits for repetitive lifting

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1. Reproduced from 2013 Threshold Limit Values TLVs® for purposes of illustration. Should only be used with accompanying footnotes and information. Published by American Conference of Governmental Industrial Hygienists
2. Routine lifting tasks should not start or end at heights 30 cm above shoulder to 8 cm below shoulder height
Example: Excessive Load Carriage
– Heavy Army Field Infantry Load

Excessive Extrinsic Load
- Load Carriage - Head Supported Mass

<table>
<thead>
<tr>
<th>Position</th>
<th>Ave FL¹</th>
<th>Ave EAML³</th>
<th>EAML %BW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rifleman</td>
<td>63 lb</td>
<td>127.3</td>
<td>71%</td>
</tr>
<tr>
<td>M240B Ammo Bearer</td>
<td>69 lb</td>
<td>144 lb</td>
<td>80%</td>
</tr>
</tbody>
</table>

¹FL = Fighting Load
³EAML = Emergency Approach March Load

Soldiers Expected to Carry Heavy Equipment Load
Example provided by Don Goddard, US Army Center for Health Promotion and Preventive Medicine

Rule of thumb- limit load to 1/3 of body weight
Possible Mitigations
Older Technology? Modified Newer Technology?

- militaryhorse.org
- Mortar section, approved pack
- Low-tech?
- http://www.golfdigest.com/blogs/the-loop/golf-cart
Next evolutionary step in combat support? Legged Soldier Support Systems = LS3

• The Army has identified physical overburden as one of its top five science and technology challenges.
• To help alleviate physical weight on troops, DARPA is developing a four-legged robot, the Legged Squad Support System (LS3), to integrate with a squad of Marines or Soldiers.
Summary (part 1)

• Scope of issues/risks addressed by health hazard evaluation
• Basic introduction/overview on the general topics
• Common physical agent hazard
  – Recognition
  – Evaluation
  – Controls
• Basic principles of health hazard evaluation.
• Links to systems engineering and process improvement
• Illustrate use of the process outlined in Military Standard 882, Task 207 Health Hazard Evaluation, using heat stress and common ergonomic risk factors

• After the break – Part 2 Chemical hazards
Break

• Please return at 0900

• Next - Chemical risk evaluation
Ergonomics Resources

- Army Manprint program http://www.manprint.army.mil/

- Naval Safety Center Acquisition Safety pages
  http://www.public.navy.mil/comnavsafecen/Pages/acquisition/ergonomics.aspx

- DOD Industrial Hygiene and Ergonomics Working Groups
  http://www.denix.osd.mil/ergoworkinggroup/index.cfm

- AIHA Ergonomics Committee Website https://www.aiha.org/get-involved/VolunteerGroups/Pages/Ergonomics-Committee.aspx
- OSHA Video display terminal checklist
  https://www.osha.gov/Publications/videoDisplay/videoDisplay.html
Ergonomics Resources

• **Ergonomic chair selection guide**

• **NIOSH Ergonomic Guidelines for Material Handling**

• **How to Cost-Justify Ergonomic Improvements**
Maritime Resources

• American Bureau of Shipping (ABS) www.eagle.org
• http://www.eagle.org/absdownloads/
  • Publication #: 0086      Price: $27.00
  • Publication #: 0119      Price: $15.00
  • Publication #: 0094      Price: $5.00
• Guide for Passenger Comfort on Ships (2001) Publication #: 0103      Price: $15.00
  • Publication #: 0116      Price: $5.00
• Guidance Notes on Job Safety Analysis for the Marine and Offshore Industries (2013)
  • Publication #: 0198      Price: $15.00
• Guidance Notes on Noise and Vibration Control for Inhabited Spaces (2014)
  • Publication #: 0209      Price: $18.00
Heat Stress Resources


• Human Performance in Hot Environments

• OSHA Fact Sheet
  Workshop-safety-factsheet-heat-stress
Back-up
Tasks in Mil Std 882E Relevant to Health Hazard Evaluation

Prediction/Recognition

• Task 106 Hazard Tracking System
• Task 107 Hazard Management Report
• Task 108 Hazardous Material Management Plan
• Task 201 Preliminary Hazard List

Evaluation/Analysis

• Task 202 Preliminary Hazard Analysis
• Task 203 System Requirements Hazard Analysis
• Task 206 Operating and Support Hazard Analysis
• Task 207 Health Hazard Analysis
• Task 210 Environmental Hazard Analysis

Control (or elimination)

• Task 301 Safety Assessment Report
• Task 302 Hazard Management Assessment Report
• Task 304 Review of Engineering Change Proposals
Human Factors Engineering Benefit$

• The U.S. Naval Research Advisory Committee (NRAC) estimated that including human elements in the initial design phases of ships and equipment could
  – Improve their effectiveness and availability by 30%,
  – Increase survivability by 15%
  – Reduce the number of casualties by 10%
  – Reduce personnel by 20%.

• Potential for creating significant life cycle cost savings for the Navy
Integration of approaches needed
Material handling issue as an example

**Human Systems Integration/Manpower analysis**
- Manpower evaluation
- Life cycle cost evaluation
- Risk reduction through designs minimizing cognitive errors
- Well connected with acquisition
- Often omits physical safety issues
- Often omits maintenance

**Ergonomics**
- Proven approach to life-cycle cost and risk reduction
- Control of physical safety hazards
- Addresses the most common sources of injuries
- Typically addresses retrofits
- Poorly connected to acquisition

**System Safety**
- Recognized risk management process
- Effective methodology for process evaluation through systems engineering
- Well connected to acquisition
- Often limited in evaluation of common “OSH” hazards
- Inconsistent attention to manpower and life-cycle costs
Issue type: Material Handling
Space arrangements and traffic flow

Present route from freezer (below decks) to thaw refrigerator (in galley)
8 person manual chain from package conveyor through passageway via galley
8 persons x 2-3 hours/day > 1 man year
Issue type: Material Handling
Space arrangements and traffic flow

Present route from freezer (below decks) to thaw refrigerator (in galley)
8 person manual chain from package conveyor through passageway via galley
8 persons x 2-3 hours/day > 1 man year

Potential alternative # 1 for newer ships –
Refrigerator with two doors
(Could save ½ man year)
Ron Casto Port Engineer LHD-7

Potential alternative # 2
Refrigerator and freezer aligned one deck above the other
Package conveyer inside freezer
(Could save even more manpower)
Don Goddard US Army Public Health Command
Next evolutionary step in combat support?
Robotic 'pack mule' displays stunning reflexes

New Scientist Tech 03 March 2006 by David Hambling

A nimble, four-legged robot is so surefooted it can recover its balance even after being given a hefty kick. The machine, which moves like a cross between a goat and a pantomime horse, is being developed as a robotic pack mule for the US military.

BigDog is described by its developers Boston Dynamics as "the most advanced quadruped robot on Earth". The company have released a new video of the robot negotiating steep slopes, crossing rocky ground and dealing with the sharp kick.