Space Human Factors:
Research to Application

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Overview

- NASA research focuses on results that are critical to successful spaceflight
- Researchers work with engineers and crew to answer questions
- Dr. Tina Holden describes making procedures and equipment for medical emergencies much faster and easier to use

Overview, Contd.

- Dr. Edna Fiedler describes work from the National Space Biomedical Research Institute which is changing both flight operations rules and design of future spacecraft
- Dr. Rob McCann describes a special test that was requested by the Constellation Program to understand the effects of the Thrust Oscillation problem on crew performance.

Overview, Contd.

- Laura Duvall, who was unable to travel, prepared information on feedback from flight crews to the researchers, that describes the crew debrief and lessons learned process.
- Mario Ferrante of Thales Alenia Space describes a research activity in Human Error Avoidance Techniques and its application on Columbus.

Designing for Safety in Space Medical and Cockpit Operations

Kritina L. Holden, Ph.D., Lockheed Martin
Usability Testing and Analysis Facility (UTAF)
NASA Johnson Space Center, Houston, TX
October 22, 2008

Safety Critical Space Operations

- Medical Operations
  - No guarantee that onboard crewmembers will have advanced medical training
    - While some crewmembers are doctors, most receive only 40 hours of medical training before a mission
    - If there is a medical doctor crewmember, he/she may be the one injured
  - Current crews have relatively easy access to medical experts on the ground in the case of an onboard emergency
    - Future missions will travel to the moon and Mars, requiring much greater autonomy from the ground, and requiring onboard crewmembers to deal with medical emergencies themselves

- Cockpit Operations
  - The next generation of crewmembers will be flying and controlling a brand new vehicle called *Orion*
    - Orion is very different from shuttle, and will require training on new equipment and new methods of operation
    - Orion will be controlled almost exclusively with software controls – very different from the space vehicles of the past

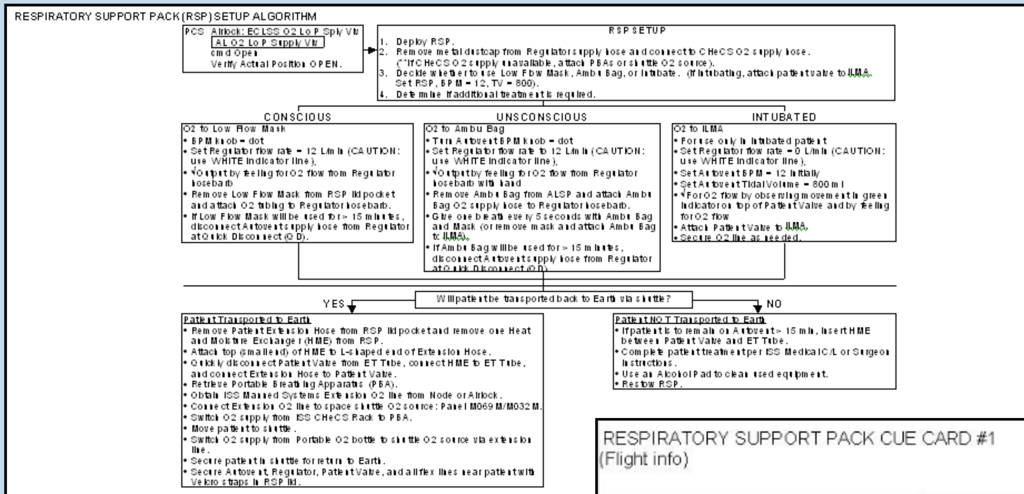
NASA/JSC Human Factors Work on Medical Operations

- Medical procedure checklist redesigns
- Medical pack organization and labeling
- Electronic procedure formatting
- Emergency cue card design
  - Respiratory Support Pack (RSP) Cue Card Redesign

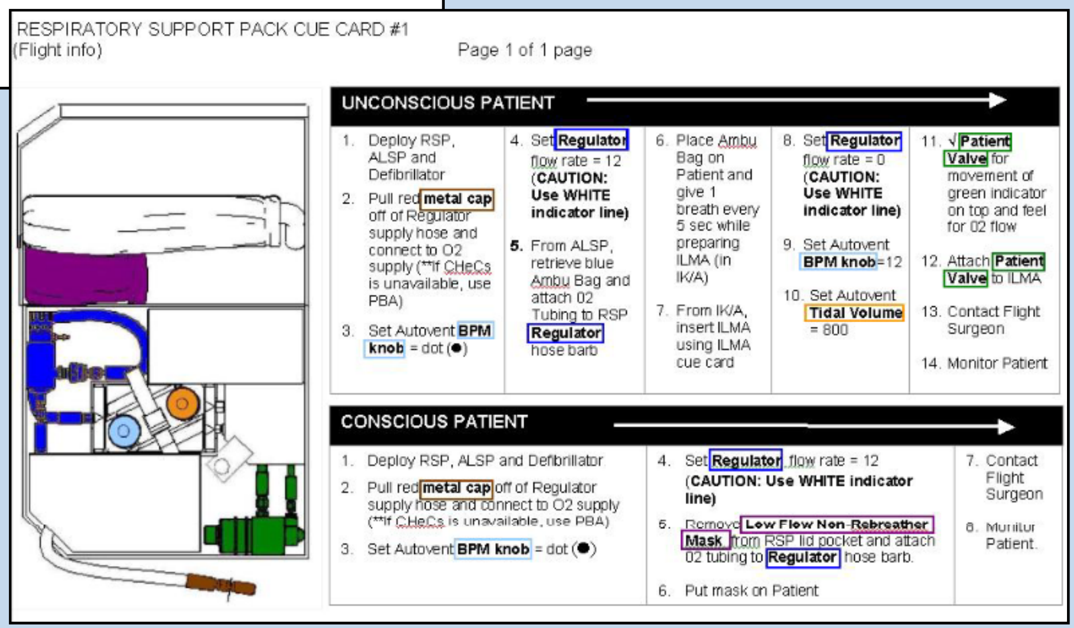
Respiratory Support Pack (RSP) Cue Card Redesign (cont.)

- During training simulations, ISS crew noted that the RSP cue card was a bit difficult to use due to the large amount of text and arrows
- Three cue card redesigns and three evaluations were completed.
- Modifications to cue card
  - Irrelevant or extraneous text removed
  - Schematic of medical pack contents added
  - Color coding tying the procedural steps to the contents shown in the schematic added
- Other modifications
  - Labels for RSP medical pack contents improved

Result of RSP Cue Card Redesign



Original



Redesign

Respiratory Support Pack (RSP) Cue Card Redesign (cont.)

- Evaluation Methodology (3 studies)
  - Non-medically trained participants used the an original, or redesigned RSP cue card to complete 2 respiratory distress scenarios with a medical mannequin
  - The procedure consisted of locating, connecting, and activating various pieces of medical equipment from the medical pack
  - Completion times, errors, and subjective comments and recommendations were collected

RSP Cue Card Final Results

- The final evaluation showed an improvement in procedure completion time of 3 minutes!
- The results and new recommended design were presented to the ISS program and accepted for deployment on ISS
- A final redesign and evaluation was performed to ensure colors are distinguishable in ISS lighting
- The new cue card is currently in use onboard ISS

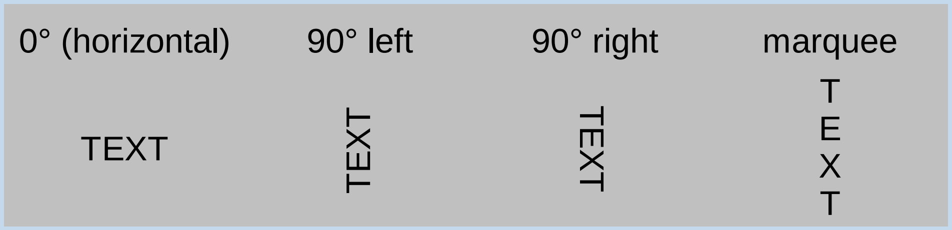
NASA/JSC Work on Cockpit Operations

- Orion is the new vehicle under development that will take humans to the moon and Mars
- The vehicle is being developed by the prime contractor (Lockheed Martin) and NASA, working together on many of the issues
- Human factors is a core member of the Cockpit Working Group (CWG)
  - Multidisciplinary group of NASA and prime contractor members working Orion design issues

Orion Cockpit Design Activities

- Orion project funding and research funding supports human factors work on Orion
- Example projects
  - Label Design
  - Cursor Control Device Design

Software Label Design



- Two studies completed on label orientation
- Participants were asked to respond to labels in different orientations as quickly as possible
- Results
  - Horizontal labels improve reading time compared to vertical labels
  - Marquee text was less preferred, and in general led to worse performance

Left alignment

microgravity	14
period	out
ventilation	yes
output time	23

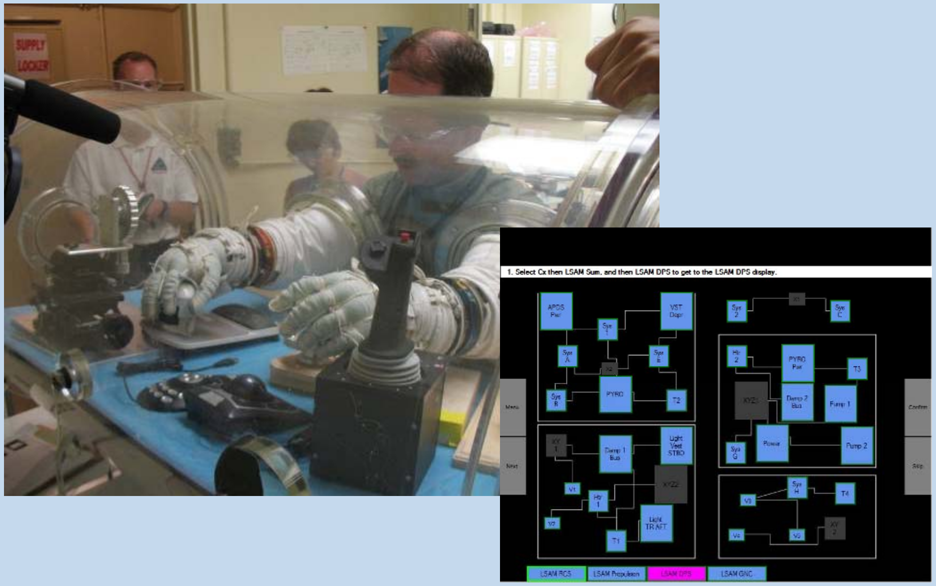
Data alignment

valve	out
period	34
error count	50
extravehicular	true

- Three studies completed on label alignment
- Participants were asked to respond to labels of different alignments as quickly as possible
- Results
  - For large data groupings, data-alignment is better than left-alignment in terms of response time.
- More research in progress

Research results will yield standards for software label design.

Cursor Control Device Evaluation



- GOAL: Identify/design a cursor control device for Orion that works in vibration, high-g and micro-g
  - Commercial and proprietary cursor control devices tested with and without EVA gloves
  - Five evaluations completed in the lab and pressurized glovebox
  - Research continuing

Research results will help make design decisions and yield standards for Orion and future vehicle device design.

Space Human Factors: Research to Application
Sleep Related Fatigue, Workload and Circadian Rhythm

IAASS International Space Safety Conference

21-23 October 2008, Rome, Italy

Edna R Fiedler, PhD

National Space Biomedical Research Institute

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decompressor
are needed to see this picture.

Overview of Research Process

- End Users: Operations (Constellation, Space Medicine)
  - Present the problem and solution parameters: Non-invasive, acceptable, useable in microgravity, volume
- NASA and NSBRI Scientists
  - Define the problem
  - Methods (lab? Field? Analog?)
  - Results verified, move to next step of applied research until field tested
  - Knowledge --->standards, design handbook
  - Technology---> monitors, feedback
- Iterative Process

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decompressor
are needed to see this picture.

End Users Requests

- Ultimate Questions: Safety & Performance
- Knowledge and mitigation of circadian shifts in astronaut quarters before launch; during flight
- Knowledge of sleep deprivation and effects on performance and safety during critical events
- Non-pharmaceutical mitigation of problem (pharmaceutical / nutrition is not part of this presentation)
- Feedback Loops to crew and ground:
  - Predictive model of sleep related performance fatigue
  - Measurement of performance decrements

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decompressor
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NSBRI Deliverables- developed with NASA experts and operations

- wavelength and intensity of artificial environmental lighting in the crew habitat
- light-dark schedules for crewmembers; specifications for visor and window light transmission characteristics
- work-rest policies to facilitate maintenance of alertness and performance during extended-duration missions
- mathematical modeling tool to evaluate the impact of actual work-rest/sleep-wake and light-dark schedules on the alertness and performance of crew members
- research and tool development required to fulfill the medical standards on sleep schedules.

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Process - An Example of Ground Based Research Review

- Bonnet and Arrand Review:
  - physicians sleep an average of only 2.8 hours during on-call nights
  - 10% of fatal automobile accidents are due to drowsiness
  - 57% of fatal truck accidents are due to sleep loss
  - Effects of drowsiness on performance: vigilance, selective attention, behavioral output

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Examples of the Iterative Process User Need, Review, Lab, Field, Operational

From Lab to Field -- Effective? Acceptable? Feasible?

- Astronaut Quarters and bright, polychromatic light: Charles Czeisler and his team at Harvard
- Blue light as mitigation for circadian adjustment: George Brainard and his team at Thomas Jefferson University
- NASA Johnson Space Center and Kennedy Space Center light experts
- Predictive model of fatigue Elizabeth Klerman and her team at Harvard
- Noninvasive measure of vigilance: David Dinges and his team at the University of Pennsylvania

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Conclusions

- Academic research
  - Specialty expertise
  - An outside voice
  - Ideas expanded to earth based applications
  - Expands the base of civilians interested in space flight
  - Useful for future civilian / commercial applications
- NASA operations, research experts
  - Specialty expertise
  - Real life / Operational information and needs
  - Years of experience dealing with spaceflight
  - Provides initiative and feedback
  - Useful for future civilian / commercial applications

- Dr Rob McCann’s presentation goes here. (Being reviewed for export control through the Ames process)

Habitability and Human Factors: Lessons Learned From The International Space Station

IAASS Conference
October 21-23, 2008

Laura Duvall, NASA Johnson Space Center
Susan Schuh, MEI Technologies, NASA Johnson Space Center
Cynthia Rando, MEI Technologies, NASA Johnson Space Center

October 21, 2008

Introduction:

- NASA HF experts have collected, analyzed, & applied post-Expedition crew debrief data & lessons learned to meet the crewmembers' needs to live & work safely & productively in space

Data Collection Process:

- The first modules of the International Space Station were launched in 2000
  - Have allowed 17 international crews to experience long duration space habitation
  - Each Expedition crew stays 3-6 months
  - 6-crew are expected on-board in May of 2009
  - Returning crew are debriefed in the U.S. and Russia
    - 21 U.S. crew debriefed to-date
    - 23 international crew debriefed

Data Collection Process:

- Data is collected from all ISS debriefs (25-30 per crewmember) and maintained in a confidential database to support identification, tracking and trending of ISS Lessons Learned
  - ~20,000+ crew comments
  - Sorted into Key Habitability Categories including:

Architecture	Planning
Communication	Restraints & Mobility Aids
Environment	Stowage
Human Computer Interaction	Training
Habitability	Transfer
Labels	Procedures
Hardware & Maintenance	

Analysis & Research:

- Multiple internal products are generated from the collected crew data
  - Expedition Summaries (presented to the ISS Program)
    - Expedition-specific summaries detailing the main issues and successes during a 6 month Expedition
  - Lessons Learned (presented to the ISS Program)
    - Identification of the top habitability issues and proposed resolutions pertaining to each Expedition
  - Special Topics (requested via Data Request Form)
    - A detailed, historical compilation of data summarizing key findings collected over lifetime of ISS on specific topics e.g., acoustics, lighting, dining, etc.
  - Trending Analyses (presented to the ISS Program)
    - Captures and tracks top habitability concerns and monitors them as reported across all Expeditions

Application of Data Collected:

- ISS Lessons Learned & trending analyses guide the development of hardware & system requirements and designs
  - Requirements development and application
  - Concept design and user analysis
  - Development of mockups, prototypes & training protocols

Application of Data Collected:

- ISS Lessons Learned data have identified several critical issues in terms of on-orbit habitability & operational safety
  - Procedures
    - Caution & Warning Desensitizatio
  - Stowage
    - Inadequate Volume
    - Manifesting Issues
  - Labeling
    - Confusing, Missing, Acronyms
  - Training

Identified Issues: Desensitization to Caution & Warnings in Procedures

- Expedition 1-15 crews have repeatedly commented on the overuse of C&W blocks within on-orbit procedures
  - Desensitization to C&Ws due to denoting every hazard, regardless of severity level
  - Tendency to ignore C&Ws due to excessive number
- Human Factors and Safety were tasked with resolution of this potential hazard

Identified Issues: Desensitization to Caution & Warnings in Procedures (con't)

Process:

A review team was formed under Human Factors and Safety guidance

- A broad data evaluation was conducted
  - All crew debrief data reviewed and analyzed against:
    - Sample set of procedures analyzed
    - NASA Standards reviewed (dictate procedure development)
    - Industry Standards researched (for applicability to caution and warning standards for on-orbit)

- The data analysis led to a crew usability evaluation
  - Determined procedure content usability and "intuitiveness" of caution & warnings within the procedures

Identified Issues: Desensitization to Caution & Warnings in Procedures (con't)

Results:

- NASA documentation governing the on-orbit crew procedures was clarified and updated based on user evaluation results

  - Improved consistency in procedure development processes

  - Removed redundant, intuitive and low-level cautions and warnings from procedures

Identified Issues: Excessive Stowage

Poor Stowage Management
- Over manifestation of items
- Costly Up/Down mass concerns

Inadequate stowage volume
- Exacerbated by use of packing materials that require disposal
- Obsolete equipment on-board
- Safety constraints violated when fire ports and/or critical equipment are blocked
- Increased crew time required to find equipment or to manipulate stowage

Identified Issues: Excessive Stowage (con't)

Process:

- Team of experts assembled (Operations, Habitability, Safety, various working groups)
- Manifest process analyzed
  - Survey of all existing and planned cargo
- Stowage allocations for cargo established
  - Coordination with Manifesting Boards
- Obsolete/excess on-board equipment identified
  - Coordination with Hardware Providers and Operations

Identified Issues: Excessive Stowage (con't)

Results:

- Requests to manifest cargo reviewed against stowage allocations
- Stowage limits monitored for compliance to cargo allocations through continuous review of ground tracking records
- Periodic on-orbit audits performed by the crew on all items
- Process developed to dispose of excess or obsolete on-board equipment
- Packing materials reduced

Identified Issues: Inconsistent Labeling Practices

- Label requirements have been confusing and hard to apply

- Multi-cultural labeling issues
  - standardization of design and terminology

- Overuse of acronyms on labels
  - Acronyms not intuitive, especially for international crewmembers

- Many items flown with no label, missing labels or inconsistent labeling

- Flight Hazard labeling not clear to ground

Identified Issues: Inconsistent Labeling Practices

Process:

- Reviewed current label processes
- Proposed changes to involved parties
- Captured a standard process in a document
- Presented document to ISS Program for approval and implementation

Identified Issues: Inconsistent Labeling Practices

Results:

- Standardization of ISS Program labeling requirements and processes
  - Alleviated inconsistencies in label application on hardware and systems
  - Increased conformance to operational nomenclature requirements

- Increased efficiency of existing label processes
  - Pre-flight label reviews more thorough

Identified Issues: Training Philosophies

- Focus on task-based rather than skills-based
  - Task-based training may not prepare crewmembers for all necessary operational skills
- Intensive preflight training for daily operations & mission roles & responsibilities
  - Mission objectives change
  - Excessive travel required (ESA, JAXA, RSA crew)
  - Over-trained for tasks that may not be performed (Payloads)
- Inadequate training resources
  - Fidelity of sims and mock-ups
    - Not always “flight-like”
    - Difficult to model all aspects of 0-g, no true floor and ceiling

Identified Issues: Training Philosophies

Process and Results:

- Integration with the ISS training program is still in progress, however initial efforts have begun to resolve the training concerns:
  - Human Factors personnel assessment of current training methods
  - Analysis of individual crew training flows, and subsequent comparison to collected crew training comments

Conclusions

- Human Factors has been instrumental in preventing potential on-orbit hazards and increasing overall crew safety
  - Poor performance & operational learning curves on-orbit are mitigated
  - Human-centered design is applied to optimize design and minimize potentially hazardous conditions, especially with larger crew sizes and habitat constraints
  - Lunar and Mars requirements and design developments are enhanced, based on ISS Lessons Learned

Questions?