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

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Usability Testing and Analysis Facility (UTAF)
NASA Johnson Space Center, Houston, TX
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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
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 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
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

- 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
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
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
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.
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
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
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)
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
    - Communication
    - Environment
    - Human Computer Interaction
    - Habitability
    - Labels
    - Hardware & Maintenance
    - Planning
    - Restraints & Mobility Aids
    - Stowage
    - Training
    - Transfer
    - Procedures
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 Desensitization
  - 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?