CLDP Human Systems Integration Workshop

April 2-4, 2024

Crew Interfaces
Kritina Holden, Ph.D.

COMMERCIAL LEO
DEVELOPMENT
PROGRAM

Crew Interfaces

- Overview/Background:
  - Crew interfaces are the means by which astronauts interact with the vehicle/habitat.
  - Crew interfaces allow for human-system information exchange, that can include crew inputting information to the system through controls, and the system providing information to the crew via visual displays, auditory tones/messages, or haptic feedback.
  - A crew interface can be a hand controller, a hatch crank, an electronic display, a flashing hardware light, an alert tone, a vibration, or a wall placard.

- Importance
  - Crew interfaces are one of the most important aspects of vehicle/habitat design, necessary for:
    - manual piloting
    - commanding safety-critical actions
    - presenting system health and status information to the crew
    - presenting alerts
    - directing crew activities and ensuring safe operations

Impacts of Poor Crew Interface Design

- Examples of poorly designed crew interfaces:
  - Hand controllers that have grips too large for smaller hands
  - Hatch doors that are too heavy and bulky to manage
  - Control panels that cannot be reached under g-loads or acceleration
  - Unlabeled or poorly labeled switch panels
  - Displays that have text too small to read
  - Colors or icons that mean something different than what has been learned or used on prior spacecraft
  - Displays that contain an excessive amount of information, and appear cluttered
  - Hazardous controls that are accidentally activated by bumping into them

- What is the impact of poorly designed crew interfaces?
  - Need for increased training
  - Failed tasks or tasks that need to be reworked
  - Longer task times, which push the activity timeline, leading to less free time and more crew stress
  - Errors that can lead to safety issues
  - Higher workload, resulting in fatigue, stress, and errors
  - Excessive communication with MCC for additional training, explanations, workarounds, and corrective actions

Leveraging Prior Programs

- Leveraging good designs from prior space programs makes sense:
  - Proven designs
  - Crew familiarity and reduced training
  - Cost savings
- ISS is a Low Earth Orbit space station with a long history of success – continuously occupied since 2000.
  - Primarily commanded from the ground
  - Primary display interface: commercial laptop computer
  - Display Graphics and Commonality Standard (SSP 50313 DGCS) provides guidance on display design; deviations for each international partner.
- Orion is a dynamic vehicle designed for long-duration space travel – crew interface design fairly complete.
  - Sets the initial standard for Artemis – first vehicle
  - Primary display interface: custom avionics display units
  - Significant crew and Human Factors involvement in design
  - Significant amount of Human-in-the-Loop (HITL) testing
  - Orion Display Format Standard (MPCV 72242) provides guidance on display design.

Leveraging Prior Programs, cont.

- Gateway is an Artemis space station – crew interface design in progress now
  - Design emphasis is consistency with Orion and across Artemis where possible.
  - Primary display interface: commercial laptop computers
  - Significant Crew and Human Factors involvement in design
  - Early HITL testing in progress now
  - Gateway Graphical User Interface (GUI) Standard (GP10056) is soon likely to be replaced with the Artemis GUI Standard once baselined (M2M-30040).

- HLS is an Artemis lunar lander (SpaceX and Blue Origin vehicles).
  - Very early in design
  - HLS Program Graphical User Interface (GUI) Standard (HLS-STD-002) provides guidance on display design.

- The Artemis GUI Standard (soon to be M2M-30040) is the generally recommended GUI reference for CLDP.
  - Artemis Standard <- HLS Standard <-Gateway Standard <- Orion Standard

Common Conventions

- Ground vs. flight displays
  - Ground displays may or may not be similar to flight displays
  - Typically ground displays more detailed than flight displays
- Common display characteristics
  - High-level System Summary display
  - “Quiet/dark” approach
  - Electronic procedures
  - Status bar with key parameters viewable at all times
- Common control characteristics
  - Software controls for most functions
  - Hardware controls for safety-critical and time-critical responses
  - Guards on hazardous controls to prevent accidental actuation

Key Design Considerations

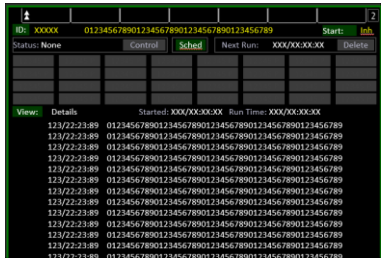
- Design consistency
  - Create designs that are internally and externally consistent, especially for safety-critical functions.
  - Consistency reduces training, workload, and errors.
  - Judging consistency can be challenging - NASA is developing methods for measuring consistency.
- Display density
  - Only display information needed for the task by default.
  - There is often a desire to provide as much information as possible on a display.
    - Every visual item draws attention. Having a cluttered display makes searching for the desired item take longer and increases risk for errors.
- Cognitive resources
  - Think about function allocation.
    - ❖ Crew should not have to do mental math or rely on memory – computers are better at that.
    - Crew cognitive resources should be reserved for creative thinking and problem solving.

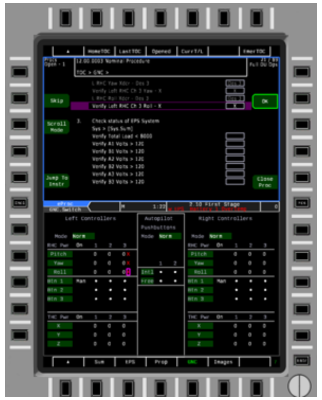
Key Design Considerations, cont.

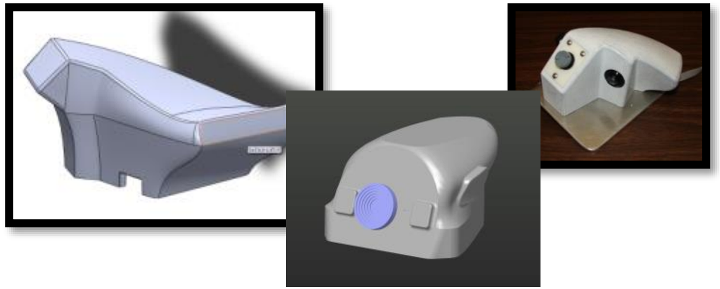
- Color
  - Use color sparingly.
    - Color is a powerful attention grabber, so make sure it is used where most appropriate (i.e., drawing attention to fault conditions or alerts).
  - Use standard/common color meanings.
- Icons
  - Resist the urge to create cool, custom icons for common things.
    - Use a standard library of icons, or at minimum use icons that people will automatically recognize from their home/work devices or from prior training.
- System response time
  - Think about system response time early in design.
    - A laggy system causes frustration and encourages reissuing of commands, which can sometimes result in issues.
- Feedback
  - Provide feedback in response to control inputs .
    - Crew need to know the input has been registered and the command is in progress.
    - The crew also needs to know when the command is successful, failed, or timed out.

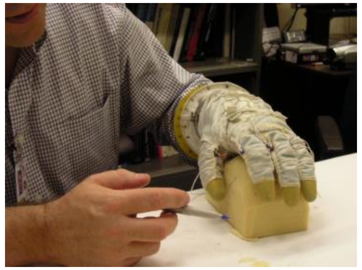
Crew Interface Human-Centered Design

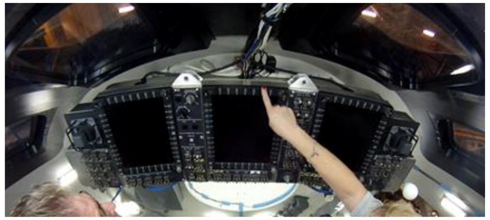
- Design to user needs – not technology (Task Analysis and HEA).
  - What tasks does the interface needs to support?
  - What kind of protection against errors is needed?
- *Know thy user* - and they are not you (Early user/crew involvement).
  - It is important to understand the crew's needs and perspectives with respect to the vehicle. It is important to hear their lessons learned, expectations, and training.
- Employ a design-test-redesign approach (Iterative prototyping).
  - Begin with a low-fidelity conceptual product and mature it to a high-fidelity interactive product.
  - ❖ Ensure that prototypers are talking to design engineers to ensure prototypes reflect system capabilities (HSI).











Display Standards

- Display standards help ensure a common design framework for crew interfaces, which promotes:
  - Ease of use
  - Reduced training
  - An increase in situation awareness
  - A reduction in cognitive workload
  - Reduced errors and improved mission safety
  - Fewer cost and schedule impacts
- Icon and symbol libraries are a companion to display standards. They promote:
  - Reduced workload for developers
  - Increased consistency within the system
  - Cost savings for the program

Display standards are the first line of defense in reducing risk.

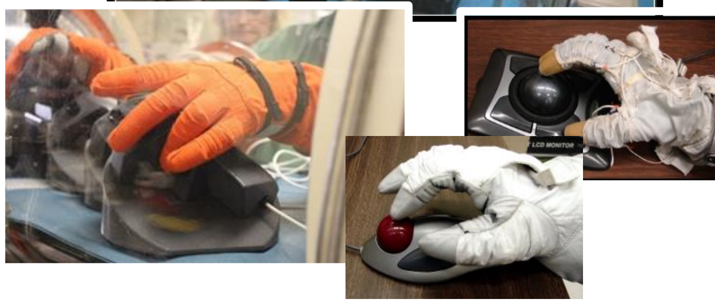
Display Standards Lessons Learned

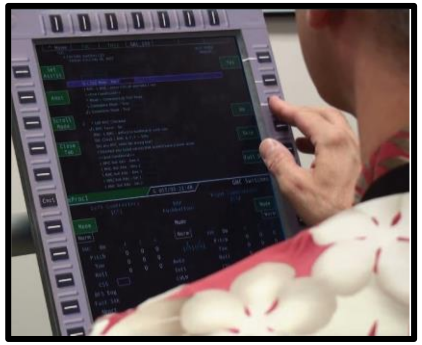
- Orion and Gateway
  - Orion and Gateway teams developed display standards at the beginning of the program.
    - Benefit – Early awareness among developers as to what constitutes as good, consistent design.
    - No need for many design decisions throughout development - basic look and feel has been documented up front.
  - At verification, these display standards are verified through a checklist for each display. A board determines if the number/type of deviations are acceptable.
- Commercial provider
  - Provider did not follow a best practice display standard.
    - Concern: At verification, there were participant comments about non-standard color use, unconventional icon designs, and small font sizes.
    - These comments occurring at verification are concerning, given schedule and cost pressures.
    - Issues discovered at verification are often challenging to fix.

Any one deviation is not necessarily a problem; the cumulative effect of many small deviations raises workload, frustration, and the risk of errors.

Crew Interface Testing

- Perform developmental testing leading up to verification (usability, workload, errors).
  - Increase fidelity over time.
  - Use verification measures for practice in administration, and to track progress on path to verification.
  - Interfaces not tested early and often are at risk of failing.
- Use scenario-based, realistic tasks (Task Analysis).
- For verification, use flight-like environment and components (TLYF).
  - ❖ Do not ask the participant to imagine using the flight-like component in their ratings.
  - It can be valid to ask experienced, flown crew how they think a task will work in microgravity.





Early Testing is Important!

- Testing of displays and display hardware (across several vehicles) has found:
  - Display monitors needed to be canted for accurate viewing by two crewmembers (found early)
  - Display colors changed when viewed off angle (found early)
  - Response times were much slower than expected (found late)
  - Small crew could not reach critical equipment (found late)
  - Confusing color use resulted in a near failed verification task (found late)

Testing is the second line of defense in reducing risk.

Additional Design Considerations

- Consider the effects of microgravity and the space environment.
  - COTS hardware may not work well or reliably.
  - Crew need a way to stabilize their position when using display and controls.
  - Crew moving in 3 dimensions can bump into and activate controls (hard switches and touchscreens).
- Consider the characteristics of your crew.
  - ❖ Age and eyesight
  - Changes in microgravity
- Consider timing of critical tasks.
  - Humans take time to adjust to the microgravity environment – accuracy of their movements and accuracy on computer interfaces may be affected, especially in the first week of flight.
- Consider your crew's prior experience and training.
  - Consistency and cross training will be important.

Crew Interface Requirements

- Governing/related requirements in CLDP-1130 draft:
  - [R.CLDS.104] TOLERATE INADVERTENT ACTION
  - [R.CLDS.106] TOLERATE INADVERTENT ACTION DURING FAILURE
  - [R.CLDS.112] DATA AVAILABILITY
  - [R.CLDS.117] DESIGN OF CONTROLS
  - [R.CLDS.119] CONTROL CODING
  - [R.CLDS.120] PROTECT FOR INADVERTENT OPERATION
  - [R.CLDS.111] USE OF COLOR
  - [R.CLDS.032] RECORD AND DISPLAY HEALTH AND STATUS
  - [R.CLDS.041] MANUALLY OVERRIDE SOFTWARE
  - [R.CLDS.242] DESIGN INDUCED CREW ERRORS
  - [R.CLDS.109] CREW INTERFACE USABILITY
  - [R.CLDS.110] CREW INTERFACE WORKLOAD
  - [R.CLDS.148] ANTHROPOMETRIC DIMENSIONS STANDARDS
  - [R.CLDS.247] OPERABILITY OF CONTROLS

Final Takeaways

- The Human System is one of the most important aspects of your design.
  - Build crew interfaces around the capabilities and limitations of the crew; don’t make them adapt to your system or waste their time figuring out a poor design.
  - Follow requirements and best practice HSI principles.
  - Avoid dense displays and overuse of color.
  - Make sure controls provide feedback – crew need to know what the system is doing with their inputs.
- Engage crew early and often; learn lessons from testing early so issues can be fixed.
- Inconsistency costs money and increases risk – more to learn, more to get confused
  - Consider using standard, proven designs, especially for safety critical components.
  - Be innovative but be sure to perform developmental testing to ensure success.

Thank you!