The International Space Station

Mikael Wolff

European Space Agency
Laptops Onboard

• ISS Laptop for
  – Routine Monitoring
  – Global Emergency, Caution and Warning
• Columbus Laptop for Subsystem Operations
• Payload Laptop
Other Devices

- Headset for voice communication with ground control center (<70% coverage)
- Emergency, Caution and Warning panels, including auditory alarms
CAUTION AND WARNING

FIRE  Δ P  ATM  WARNING  CAUTION

TEST

CAUTION AND WARNING
ISS Laptop
1. This manual procedure operates the simulated Columbus TCS for the MPV2G. It covers:
2. TCS Activation
3. Payload Activation

1. TCS Initial Activation

1.1. Check initial TCS configuration
   - Synoptic TCS Display
     - Payloads 1, 2, and 3 all: Status: OFF - TRUE
     - TCSP1 and TCSP2, both: PWR OFF - TRUE
     - NV1 Status: Open
     - NV2 Status: Close

   ******************************
   If any of the above states wrong: Command the correct setting above and verify
   ******************************

1.2. Activate TCSP1
   - sel Show - TCSP1
   - cmd - TCSP1 Pwr On Execute (✓ - TRUE)
   - after 30 seconds verify flows:
     - Verify DPSB1 Flow MV1 >= 0.1 Kg/sec
     - Verify Radi Flow >= 0.1 Kg/sec
     - Verify TCSP1 Flow >= 0.4 Kg/sec

1.3. Verify nominal temperature
   - Temperature: 18.8 degC
   - Verify Temperature >= 12.0 degC

Columbus TCS OpNom (incomplete)

<table>
<thead>
<tr>
<th>Abbreviation / Acronym</th>
<th>Full Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACCU</td>
<td>Accumulator</td>
</tr>
<tr>
<td>ACP</td>
<td>Automated Crew Procedure</td>
</tr>
<tr>
<td>APS</td>
<td>Absolute Pressure Sensor Assembly</td>
</tr>
<tr>
<td>BV</td>
<td>Blocking Valve</td>
</tr>
<tr>
<td>CDT</td>
<td>Crew Documentation Tool</td>
</tr>
</tbody>
</table>
Guiding Procedure & Display Development for Manned Space Missions

Mark Neerincx & Mikael Wolff
Mental Load Model
Usability Engineering Process

- Mental load and user interface guidelines
- Human task, cognitive support and interface
- Effectiveness, efficiency and satisfaction
- Operational requirements

specification

assessment

data task or process
Specification

- user requirements
- cognitive task analysis
- “storyboard”
- prototype
Assessment

- expert review
- user walkthrough
- usage test

- In lab, on location or remotely
Usability Engineering Method

- standards, guidelines and conventions
- specification techniques and tools
- assessment techniques and tools
- experiences and examples
- utilization of current UI technology
Usability Handbook: guidelines

engineering techniques

example design
A Usability Engineering Method
Specification and Assessment of User Interfaces for International Space Station Laptops

Method
- Introduction
- Analysis
- Design
- Implementation

Example
- Introduction
- Analysis
- Design
- Implementation

Guidelines
Standards
References

Release date: May 26th, 1998
Version: 1.0

The Handbook
To Analysis Stage
The task level of the user interface, comprises the users' goals, the corresponding information needs and support needs. Usability at the task level is...
Principles for Cooperation Support

When working in teams (like the astronauts/cosmonauts and ground-control units), Computer-Supported Cooperative Work (CSCW) applications can provide effective cooperation support, such as tools allowing several people to work on one document or drawing at the same time ("shared workspaces"), message templates to support human-human communication and software agents, i.e. collections of rule-based heuristics, which help to organize and filter the messages.

An important consideration for CSCW is the decision of who is going to keep-up, a task of updating information or discussion it is often necessary from different locations, and (e.g. the user does not sense the implications of a plan added to the workspace by another, because he or she was not involved in the planning process itself).

For human-human communication, it is important that the intention of a message can be exchanged, which is often provided via non-verbal communication. In many situations, people prefer "face-to-face" contacts more than electronic communication for which less non-verbal cues can be exchanged. A "sender" wants to see that his or her message is being interpreted correctly. Message exchange should be structured well (e.g. via message templates), but next to the formal exchange of information, it should also be possible to exchange informal information.

Software agents can be developed for automatically filtering of information when a user is overloaded with messages or for acquiring up-to-date information that is relevant. Users should have control of these agents and understand what they do.

Human Factors Principles for Cooperation Support (Neerincx & Van Doorne, 1997)

1. Shared functionality: it should be shown to all participants who has the authority to change the content (e.g. delete) or view (e.g. zoom) of the database, and who is in charge to deal with conflicts.
2. Shared information: it should be clear where the information originated from (e.g. astronaut/cosmonaut, ground control center, one of the systems).
3. Computer-mediated communication: users should understand what the communication support does and keep control of it (e.g. software agents.
To Design Stage
The Design Stage

<table>
<thead>
<tr>
<th>Development stage</th>
<th>Human Factors Principles</th>
<th>Specification Techniques</th>
<th>Assessment Techniques</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design</td>
<td>Attune User Interface at the communication level, principles for specifying interaction style, interaction load, individualization</td>
<td>Map analysis specification on specific interaction style and requirements. Specification in product description and interaction models.</td>
<td>Analytical, heuristic, and user testing. Translation of interaction requirements into product requirements.</td>
</tr>
</tbody>
</table>

The *communication level* of the user interface describes the dialogue language. At this level, a system designer has to choose a type of dialogue, such as text or auditory dialogues. In particular, the communication is simple for DM- (Direct Manipulation) or WIMP-interfaces (Windows, Icons, Mouse and Pull-down/popup menus). Learning how to control such interfaces is easy, because the icons, menus and windows provide information about the actions which can be done with the system. For example, a menu-item "mean data-set" informs the user that he or she can accomplish this specific goal with the system (task level) and with minor experience the user even knows how to accomplish this goal (i.e. simple communication: clicking on this menu-item with the mouse). For the communication level of graphical user interfaces, detailed guidelines and style guides have been established.
Principles for the Design Stage

To integrate user characteristics into the design of human-machine interfaces or, more general, human-machine systems, general design objectives can be discerned such as formulated by Williges et al. (1987):

- **Compatibility:** minimise the amount of information recoding that will be necessary
- **Consistency:** minimise the difference in dialogue both within and across various user interfaces
- **Memory:** minimise the amount of information that the user must maintain in short-term memory
- **Structure:** assist the user in developing a conceptual representation of the structure of the system so that they can navigate through the interface

The design principles distinguish between the contents of speech, navigation, media allocation and control panels.

1. User interface designs (among other things) the range of controls required by the user. This range may be difficult and may require control by two hands simultaneously. For functions that are used often or must be activated very quickly, function keys (like "F7" etc.) can be defined.
2. The relevant international standards should be addressed.
3. Human-computer interaction experiences of the specific domain should be taken care of ("lessons learned"). Based on the experiences of the Gagarin Cosmonaut Training Centre, a number of guidelines were specified.
4. The following guidelines that are specific for the current task and interface setting should be addressed:

<table>
<thead>
<tr>
<th>Content</th>
<th>Navigation</th>
<th>Media Allocation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speech</td>
<td>Control Panels</td>
<td>Instructions</td>
</tr>
</tbody>
</table>
Control Panel Guidelines

Monitoring, compensation and anticipation are important aspects of the operators' tasks. Based on these aspects, the following guidelines for the design of the different information elements on the Virtual Control Panels (VCP's) are formulated. See for example the VCP for the GBX.

Show references.

- The user should be provided with clear feedback with respect to payload status and alarms.
- The actual and desired state and state changes of the payload system can be compared to each other with a minimum of transformations or activities.
- Besides the actual state information, related information is available regarding future references.
- Knowledge on the future references is available in a comprehensible format with effective anticipation.

Use coding principles (e.g. colors).

- Establish a good visual separation of the different information categories, such that each category can easily be selected for further processing.
- Establish a well-balanced visual integration of the supporting reference structure as background information and foreground information categories. A dominant presentation of (static) background flow structuring will certainly interfere with the perception of (dynamic) foreground information, and slow down the processing of this information.

Support the detection of state changes.

- Use an indicator type that supports the detection of change. See the section on 'Widgets design'.
- Group status information of related process aspects and present them according to some uniform scaling (see the example in Fig. 10).
- Provide the possibility to present trend information.

Support the user in minimising deviations between the actual and desired payload state.

- Important controller settings should be clearly recognizable and directly accessible by the user.
- The definition of the different control elements, such as function keys, menu items and graphic icons should be meaningful to the user.
- The structuring of commands in different menu items should be functional and clear to the user.
An Example of a Virtual Control Panel

Following the guidelines for content and control panels, an example Virtual Control Panel (VCP) was designed for the control of the glovebox:

- The display clearly distinguishes 5 functional components.
- The process information is presented in well-defined locations with a coherent layout ("columns"), so that the information can be immediately perceived.
- The variable name is presented before the current value, while the measure units are displayed after the value.

Among other things to display whether functions are on or off (e.g., in the Figure below the power is on).
Example: Design

The actual GBX support application includes three man-machine interfaces: the interface to the GBX facility, the voice link interface and the ACT interface. Ideally, design should cover all three interfaces to ensure uniformity and consistency across the interfaces. In this case, two of the three interfaces, the interface of the GBX facility and the voice link interface, are fixed beforehand by the intended use of the interfaces. The interface should, of course, be designed so that it becomes consistent with the given interface. This interface involves defining the communication level of the man-machine interaction, i.e., the user's role and responsibilities. The focus is on those parts of the interface that relate to PES, MMD, and VCP as well as the results of the task analysis.

The design is supported by the development of a ACT storyboard for selected task scenarios. The storyboard is intended to illustrate the concepts of design and for use in the evaluation of the design. It is implemented as a Web presentation that is operated on using the Netscape Communicator browser.
Check air circulation function (FS)

- Check that louver in Work Area is fully open. Louver knob should be pulled to the front.
- Switch of the Control and Monitor Panel to ON.
- Turn AIR CIRC rotary switch on Control and Monitor Panel to position "6". Position "6" is fully clockwise.
- Check displays and LEDs
- Turn AIR CIRC rotary switch on Control and Monitor Panel counterclockwise through successive positions, while observing "mB WA" numerical display of the STATUS field. Check that reading goes down to 1 mB.
## Standards: ISO | ISO/CD 13406-2 - Flat Panel Display Ergonomic Requirements

<table>
<thead>
<tr>
<th>Topics</th>
<th>Keywords</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Legibility</strong></td>
<td>- design viewing distance, &gt; 400 mm</td>
</tr>
<tr>
<td></td>
<td>- design viewing direction</td>
</tr>
<tr>
<td></td>
<td>- shall conform to all optical requirements over a relevant range of</td>
</tr>
<tr>
<td></td>
<td>viewing directions</td>
</tr>
<tr>
<td></td>
<td>- character height, &gt; 16 arcmin</td>
</tr>
<tr>
<td></td>
<td>- stroke width, number of pixels in a stroke: 8-20% of number of pixels</td>
</tr>
<tr>
<td></td>
<td>in character height</td>
</tr>
<tr>
<td></td>
<td>- char. width-to-height ratio, between 0.5:1 and 1:1</td>
</tr>
<tr>
<td></td>
<td>- character format (matrix), numeric and upper-case: &gt;= 5 x 7</td>
</tr>
<tr>
<td></td>
<td>- display luminance, &gt; 20 cd/m²</td>
</tr>
<tr>
<td></td>
<td>- contrast ratio (of the higher and lower luminance): &gt;= 1 + 10. ( L_H ) = ( 0.5 )</td>
</tr>
</tbody>
</table>

The visual properties of single characters or symbols should provide easy recognition.
A Usability Engineering Method
Specification and Assessment of User Interfaces for International Space Station Laptops

Method
- Introduction
- Analysis
- Design
- Implementation

Example
- Introduction
- Analysis
- Design
- Implementation

Guidelines
Standards
References

Release date: May, 26th 1998
Version: 1.0

To Guidelines
Guidelines Based on Russian Experiences

The Gagarin Cosmonaut Training Center (GCTC) has a lot of experience with space-missions that should be used for the development of new user interfaces for international space laboratories. For the ACTUS-project, GCTC provided a report that describes the relevant characteristics of cosmonauts' tasks and their vision on user requirements for future user interfaces. Subsequently, in a workshop GCTC clarified this report and commented on the ACT framework. Based on this information, usability guidelines were formulated for four interface issues:

- **Information & Coding**
- **Control panels and displays**
- **Support**
- **Physical attributes**

- There is a lack of possibilities to interact with remote systems (i.e. the systems of the separate MIR-complexes).
- Cosmonauts have a need for better filtering and integration of information.
- There has been minimal attention to 'dealing with anomalies', both during the analysis- and the design stage of software development. This aspect needs more attention in future software developments.
- The 'mapping' of tasks on user interface functions should be revised. The physical lay-out prohibited efficient interaction and caused several problems. Also the allocation of tasks in time and the resulting action sequences of cosmonauts are not optimal. Switching between tasks takes time and is therefore not preferred.
- Illumination and image quality is very critical and should be optimized for the specific environmental conditions and task demands in space laboratories.

---

Information & Coding

- **Information flow should be bilateral of direction for effective control.**
  - The information flow in the MIR was unilateral, which prohibited effective control.
- **To avoid overload, information has to be preliminary processed and integrated as far as possible.**
  - To reduce task complexity only the useful information should be available at any time, so that the cosmonauts can focus their attention on the critical signals rather easily. These critical signals should not exceed the short-term memory of the cosmonaut.
  - Experience showed that cosmonauts have a large scope of information to process and were burdened by overload.
Validating Guidelines: navigation aid integrated interface
Check air circulation function (FS)

- Check that louvers in Work Area are fully open. Louver knob should be pulled to the front.
- Check that AIR CIRC rotary switch on Control and Monitor Panel is in position "A". Position "A" is fully clockwise.
- Turn AIR CIRC rotary switch on Control and Monitor Panel to position "6". Position "6" is fully clockwise.
- Check displays and LEDs.
- Turn AIR CIRC rotary switch on Control and Monitor Panel counterclockwise through successive positions, while observing "mB WA" numerical display of the STATUS field. Check that reading goes down to 1 mB.

Navigation Aid

- Upper Control Panel
- Video Drawer
- Lower Control Panel
Selection and Display of Services

Procedural Help

Integrated Interface
- Integrated Interface
- Navigation Aid
=> Improved Performance
Handbook Completion

- review by HCI and domain experts
- experiences of users
- attune to NASA approach
- enhanced accessibility
- up-to-date and complete content
- process support
ISS Expedition Crew Feedback

• Navigation is difficult and time-consuming because there are so many displays

• Consistency between procedure and displays needs to be improved

• Consistency between US and Russian Laptops need to be improved