Usability is defined as the effectiveness, efficiency, and satisfaction with which the crewmember can achieve their goals according to the operational procedures:

- **Effectiveness** is the accuracy and completeness with which the crewmembers can achieve their goals.
- **Efficiency** is the relationship between the resources expended and the accuracy and completeness with which crewmembers achieve their goals.
- **Satisfaction** is the comfort and acceptability of use.
- **Learnability** refers to the resources expended to acquire and maintain the knowledge and skills for effective and efficient operations.

(Adapted from ISO 9241–II)
development teams more closely. In subsequent activities sponsored by ESA and the Netherlands Institute for Space Research (NIVR), TNO-HF has validated the concept and put forward a plan for major restructuring of the Handbook which will provide improved support to ESA-funded developers of Columbus payloads.

The usability engineering process

The method proposed is an iterative one that provides a human factors contribution to the life cycle of laptop-based crew interfaces. During analysis, design and implementation, the method addresses both development and assessment. For example, during analysis, simple paper-based storyboards may be produced and evaluated. The method also addresses which kind of group (engineers, end-users, human factors experts, ...) needs to be involved at the various assessment milestones. It is, for example, crucial to fully understand operational telemetry and commanding requirements early on so that the underlying processor network indeed can support them — a major redesign of embedded software close to equipment acceptance test must be avoided.

Some of the usability engineering principles for crew interfaces that are supported by the method, and exemplified in the Handbook, are:

- rely on short-term memory use as little as possible;
- ensure that interaction choices (e.g. menu selection) are based on recognition, not memory recall;
- the interface must have a consistent 'look and feel';
- the operator must always be given feedback regarding his or her actions;
- the user interface should provide navigation support that helps users to maintain a contextual overview;
- error recovery must always be provided.

The Handbook presents material on principles, techniques and tools that should be applied at the various development stages. For design, an interactive storyboard is featured, as one of the many examples provided by the Handbook. It also includes Reference and ISO standards sections. Note that standards on actual 'look and feel' of the software interface is not part of the Handbook. The usability engineering method is independent of which operating system or graphical display building toolkit will be used.

Validation of the Handbook

The usability engineering method contains state-of-the-art guidelines for developers of user interfaces who employ new Web-technology like the ESA-funded WebACT demonstrator. To validate the method, an experiment was conducted at the TNO-HF usability laboratory to test two central design principles of the laptop interface: the integration of procedures (i.e. procedural instruction) and other operator services like VCP's (Figure 1), and the provision of support for navigation through the content of the operations support services. Students had to supervise and control simulated experiments in the field of physics and chemistry with a prototype payload interface. The integration of procedures and VCP's and the navigation support proved to increase the efficiency of payload operations substantially. The experiment has provided the first validation of the interface concept, but further testing is required. The Handbook is being developed iteratively; a second re-engineered version is being prepared in order to incorporate new insights (e.g. resulting from user feedback) and to adapt it to developments at NASA in this area.

Conclusions

The usability engineering process described in, and supported by the Handbook, can provide high quality support to teams developing ESA-sponsored payloads for Columbus. In particular, teams at the facility responsible center (FRC) associated with the European drawer rack (EDR) are expected to benefit, since new crew interfaces are required to be developed as drawers are exchanged onboard. The Handbook will be a cost-effective tool for supporting payload teams engaged in recurring developments of crew interfaces based on the use of laptop computers.

Figure 1.
Design example taken from the Handbook.