Nationaal Lucht- en Ruimtevaartlaboratorium
National Aerospace Laboratory NLR

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The advanced crew terminal, an integrated, common, low cost and configurable toolset for operations activities

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Abstract

As space station missions become extended with a longer and longer duration there is an increased need for common software tools which suit many operations activities. The Advanced Crew Terminal (ACT) provides a common, integrated and configurable system for use on-board a space station as well as in the ground segment. ORIGIN and partner NLR have gained experience in a number of ESA studies and Dutch nationally funded (NIVR) studies for executing payload operations in general but also for particular missions (e.g. MIR, Shuttle).

The ACT is extendible in a straightforward manner. As an example, ACT has been selected as the user interface for experiments operating the Muscle Atrophy Research and Exercise System (MARES). MARES is part of NASA's Human Research Facility on-board the International Space Station. Other examples are the near-future flight opportunity of ACT supporting a dedicated payload, SloshSat FLEVO, on the NASA Space Shutle, and ACT for SPLC Software Maintenance.
This paper presents the background to establishing the ACT, its capabilities and technology, latest results in MARES and other ongoing development and associated standardization activities for the International Space Station.

1. Introduction

The Technology and Research Center of the European Space Agency (ESA / Estec) is promoting and supporting a common computer "look & feel" for payload operational support. The Internal Space Station (ISS) and as part of that the European contribution the Colombus Orbital Facility (COF) will contain payload facilities which will be operational for many years, such as the European Drawer Rack (EDR). The Advanced Crew Terminal (ACT) aims to provide the integrated, common, low-cost and configurable toolset to operate these facilities and its payloads. Besides that, ACT continues to provide the computer interface for dedicated missions e.g. on-board the NASA Space Shuttle.

Experience from actual flights such as the speech equipped ACT "SPACT" on euromir, Video Integrated Support Computer "VISC", and ground simulations such as conducted in the ESTEC Crew Workstation Testbed shows that mission success depends highly on the quality of the computer systems used. Quality in this sense is a combination of system reliability and effectiveness.

This experience led to the Advanced Crew Terminal, a toolset beneficial for crew (reduced training and cross payload common user interface), payload developers (risk and cost reducing development environment), investigator teams (telescience, collaborative working) and ground support personnel. Based on open commercial-off-the-shelf web technology ACT provides software tools for preparing operations procedures, (multi-media) reference documentation, data acquisition and command & monitoring displays. During mission operation ACT provides the environment for executing these procedures and displays, and on-line documentation access in a set of integrated displays.

Adding it all up, ACT fulfills the needs of ESA Utilization Facility Responsible Centers dealing with multiple payloads.

This paper focuses on the use of ACT in actual applications, putting less emphasis on the technical implementation. More detailed information on the technical aspects of ACT as well as other information is available and can be obtained from the paper authors.

2. Operations

2.1. Operational Concept

A mission is defined as consisting of two phases: mission preparation and mission operation. Fig 1: ACT Operational Concept pictures the ideas behind this concept, which is applicable for both dedicated as well as ISS missions. Each phase has its specific users and corresponding support requirements. As will be described further on, ACT provides the tools needed in both phases and ensures that they fit together. ACT can be supplied to the users for instance by a Facility Responsible Center (FRC) or User Support and Operation Center (USOC).

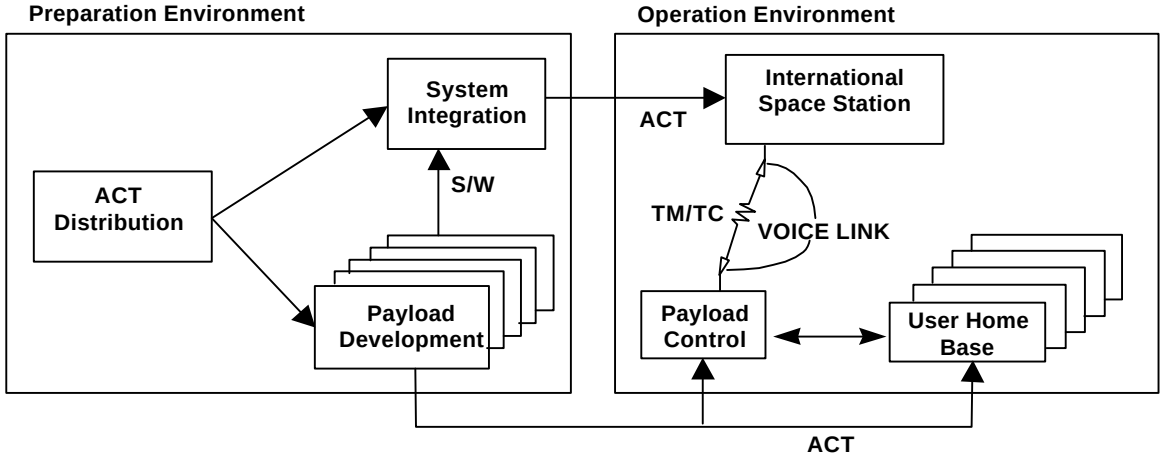

Fig 1: ACT Operational Concept

2.2. Mission Preparation Users

Payload developers, ground support personnel and investigator teams are the main users of ACT during mission preparation. However, crew also has to prepare themselves in this phase prior to flight in training activities.

Typical software support tools in this phase are software development environments, procedure editors, (multi-media) documentation editors, and configuration management and test environments. Procedures play a key role in payload user interfaces. They instruct step by step the crew-member and/or ground-operator with manual tasks or they can execute automatic actions such as payload commands.

An ACT Usability Handbook is available for payload developers as additional support for achieving effective, common "look & feel" ACT user interfaces. The handbook, in Web format, provides support not only in the classical area of user interface building blocks but also addresses layout aspects of procedural and reference material in multimedia format, as well as user interface navigation issues.

2.3. Mission Operation Users

Ground support personnel, investigator teams and crew are the users of ACT during mission operation. It is possible for payloads to run in an (semi-) autonomous mode in which case there is little or no crew involvement. Typical software support tools in this phase are the command & monitoring displays , electronic procedure execution, data acquisition, logging and (on-line) reference documentation.

2.4. Experienced Demands

ACT has evolved over the past years starting as a dedicated computer interface (for one specific payload) towards a generic multi-purpose toolset. From the beginning, it was clear that there was a need for a user friendly system providing good situational awareness to the crew and ground. During the years the usage of ACT in demonstrators and actual flight projects has confirmed that situational awareness is indeed a key element. As our experience deepened, other demands particularly in the field of payload development, automated procedure support operation and mission preparation also became important. These demands stemmed from the need to re-use software and commercial-of-the-shelf (COTS) products for lower-costs and software reliability, from the demands of automated supported and ground operation in order to limit scarce and expensive crew time, and from better preparation tools such as a graphical procedure editor. Computer operation reliability also led to the need to minimize the impact of so called radiation hits in space, which can occur quite often, with tools such as the ESA Radiation Shield software.
Summarizing, in operations it is essential to have a reliable, low-cost, user friendly toolset which minimizes the chance for human or system error.

3. Advanced Crew Terminal

ACT offers a set of software products that provides the tools for both mission preparation and operation users. It is generic in the sense that it has been designed and implemented to be used by different payloads and payload facilities.

With ACT, a payload developer has the functionality which is common for every payload and with the addition of payload specific functionality he can tailor and configure it to his needs. The resulting system will be an integrated computer interface and will share the common, integrated look and feel of other payload computer interfaces.
Recently, ACT's implementation has evolved towards web-based technology, maintaining the overall concept, architecture, and application. Not every product available in the previous implementation has been ported. User demands led us to focus on a subset of essential core products: procedure editing and execution, reference documentation interaction, command & monitoring displays, and an integrated display. Other ACT products, for instance the annotation and speech I/O tools, will be ported in follow-on work and as the need occurs. Mainstream development will be aimed at the further enhancement of the essential products.

ACT provides the following generic products for mission preparation tasks:
- graphical procedure editor;
- on-line multi-media reference documentation (help) for payload developers and procedure authors;
- multi-media reference documentation editing facilities based on COTS products.

For mission operation, ACT provides:
- electronic procedure execution;
- multi-media reference documentation
- integration with specific payload command & monitoring displays;
- logging;
- flexible, integrated display within a web browser;
- navigation.

3.1. Integrated Computer Display

An integrated computer display has several aspects.
First, it is the way the ACT software products work together to accomplish a certain task. When following an electronic procedure a crew-member may need additional information or an explanation about the current procedure step. He can select the applicable documentation from the procedure by clicking a predefined hyperlink or he can activate a command and monitoring. Vice versa, a command and monitoring display can call-up a procedure to support the crew-member.
Second, the computer interface is integrated within a web browser. The look and feel of the different products is similar and payload-specific software can be added to this interface as well.

3.2. Common Computer Displays

The international space station community has initiated standardization activities for computer interfaces (Display and Graphics Commonality Standards, DGCS) and procedures (Operations Data File, ODF) and thereby expresses the need for commonality. Web-based displays have been put forward by ESA in the DGCS standard as payload interface, with ACT as example template of such an interface.

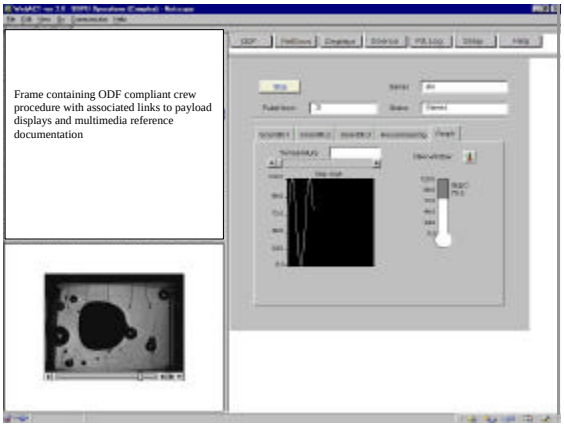

Fig 2: ACT web based display template

As more and more displays will comply to the DGCS standard, commonality among the interfaces will increase. ACT already has the concepts, templates and implementation for DGCS compliance.

3.3. Low-Cost Development

By re-using ACT in many projects, the costs of development for each of these projects is minimized. ACT has the cost advantage of COTS products. Since ACT has been developed within the space community, it is based on experience within space projects, and fulfills the needs of these projects. Cost savings in terms of crew training can also be expected once multiple payloads use similar computer interfaces.

3.4. Configurable System

ACT is a toolset of generic software products providing the functionality which is common for multiple payloads. The payload developer configures the ACT (laptop) computer which interfaces with the payload. He only selects the products he needs and adds dedicated payload software.
Moreover, the crew-member has the facility for configuring his ACT laptop. He can choose the computer interface he prefers from a set of templates.

4. Applications

ACT is a common tool for multi-payload facility operations. Continuous improvement of ACT is achieved by feedback from current flight missions and also from projects which use ACT to develop ISS payload facilities.

4.1. MARES

The Muscle Atrophy Research and Exercise System (MARES) facility developed by ESA as part of NASA's Human Research Facility (HRF). MARES is capable of measuring a crew-member's muscle atrophy when he is performing exercise experiments set-up by investigator teams.

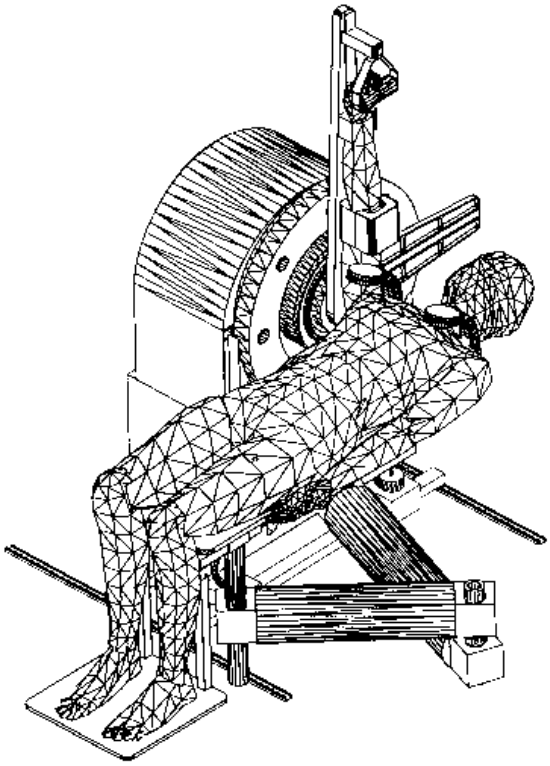

Fig 3: Schematic drawing of MARES (NASA)

ACT has been selected as the tool by which the crew-member will be instructed and by which MARES will be controlled during operation. Furthermore, ACT will provide the functionality for investigator teams to set-up their experiments by means of a graphical experiment editor. Experiments in MARES terminology are very much like procedures in ACT terminology, combining a mixture of manual and automatic steps. To fulfill the needs of MARES, ACT's procedure execution and editing products will be enhanced with automated procedure capabilities and a graphical authoring tool. ACT for MARES has been evaluated and will be reviewed early 2000 by NASA crew representatives at the MARES Critical Design Review.

Experience we have gained so far from this project shows that the gap between manual and automated procedure execution is large. Operating a hardware device combined with human instructions by means of procedures which are written by experimenters requires that the software be flexible and easy to use yet reliable and safe. Other potential ACT users will benefit from the experience gained in this project and the requirements put upon the ACT products.

4.2. ACT for SPLC Software Maintenance

Colombus Orbital Facility (COF), the European contribution to the ISS will contain several microgravity payload facilities, such as the European Drawer rack. These facilities will be equipped with a Standard Payload Computer (SPLC) supplied by ESA as Standard Payload Outfitting Equipment (SPOE) item.
It is inevitable that during the lifetime of these facilities the software on the SPLC's will need to be updated. ESA has identified this need and has initiated a project supported by the Netherlands Agency for Aerospace Programs (NIVR) to provide an ACT for SPLC Software Maintenance. This ACT will be capable of replacing software on each of the facilities SPLC's and test their proper functioning. Up until now the necessary specific software needed to communicate with the SPLC and capable of replacing its software has been produced. The project awaits the delivery of the first SPLC for continuation with software testing and ACT configuration. The generic ACT fulfills the required functionality without modification.

4.3. SloshSat FLEVO

A near-future flight opportunity for ACT will be in supporting the Sloshsat FLEVO experimental satellite, launched as a hitchhiker payload from the Space Shuttle in 2001. Sloshsat FLEVO is a fluid science experiment to investigate fluid dynamics behavior under micro-gravity conditions.

Fig 4: Sloshsat FLEVO satellite, schematic overview without solar panels

The satellite contains a partially-filled water tank and instrumentation for liquid motion diagnostics and spacecraft motion measurement. The satellite data needs to be stored on a NASA laptop computer (Payload and General Support Computer, PGSC) in the Shuttle Middeck. The ACT software enhances and guides the data storage process, the main support priority.

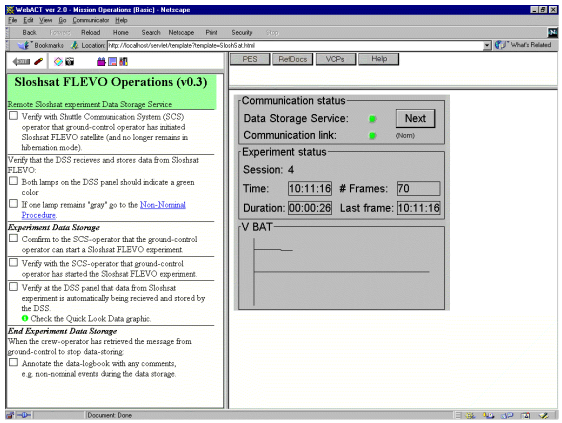

Fig 5: Typical screendump of ACT with Sloshsat FLEVO procedure and data-acquisition tool

For the ACT partners, the ACT supporting Sloshsat FLEVO will give valuable feedback on major core-elements of the ACT capabilities and technology:

- Mission preparation and execution of procedures;
- Data acquisition and annotation features;
- Command & monitoring displays for data storage and down-link;
- Reference documents and non-nominal support;
- Support from a ground terminal and data distribution via internet to PI's.

5. Future

For sure the future for the coming decade will be the International Space Station. The first modules have been launched and integrated, and within a few years, the payload facilities will be on-board. In the ISS ground segment, Facility Responsibility Centers are in preparation and will become operational.
ACT is nominated by an ISS human research facility, a dedicated mission and foreseen to be used in support of SPLC as part of an ESA SPOE item. Also the Facility Responsible Center for the European Drawer Rack (FRC/EDR) is a candidate ground ACT user, preparations are underway to support EDR users with ACT items. ESA, NIVR, Origin and NLR continue to support these activities and aim at broadening the customer base.

From an ACT development point of view, the further standardization of displays and procedures as put forward by the DGCS and ODF ISS multilateral committees will be welcomed and implemented to the fullest possible extent. We believe that with actual flights and ISS projects we can provide the standardization committees useful feedback also. We note, that the ODF standard does not yet cover the area of payload operation by means of automated procedures. As this is an area for which there is a great demand and potential use, this is an aspect that needs standardization.

Web technology evolves almost on a daily basis. Interesting developments such as XML are considered in ACT's continued enhancement.

6. Acknowledgements

Many people have contributed over the past years to ACT's conception and development. Origin and its partner NLR especially thank ESA/ESTEC and NIVR for the opportunity to develop ACT and for their continuous support. Also the projects who have adopted ACT and thereby supply us with invaluable feedback and experience have our gratitude.

MARES is an ESA contribution to NASA's Human Research Facility (HRF). Main contractor is NTE (Spain) with among others Origin as subcontractor.

ACT for SPLC Software Maintenance is a harmonized project between ESA and Netherlands Agency for Aerospace Programs (NIVR). Contractor for ACT for SPLC Software Maintenance is Origin (The Netherlands), the main SPLC contractor is DASA.

Sloshsat FLEVO is a harmonized programme between ESA and Netherlands Agency for Aerospace Programs (NIVR). Main contractor is the National Aerospace Laboratory NLR (The Netherlands) with participation of Fokker Space and Origin (The Netherlands), Verheart and Newtec (Belgium), Rafael (Israel) and NASA (USA).