A 21st Century cockpit

A joint FCOD/MOD team brings the new cockpit to life

By Bruce Hilty, Brent Jett and Jeff Williams

While many at Johnson Space Center have been focused on the challenges of flying Space Shuttle missions and building the International Space Station, a small team of Shuttle trainers, flight controllers, engineers and astronauts have been putting the finishing touches on a new suite of displays for a revolutionary Space Shuttle upgrade.

They are focused on creating a 21st Century Space Shuttle cockpit. While the first flight of the new cockpit is projected to be in 2006, the project is already experiencing great success.

The team reached a major milestone on June 29 when it completed the detailed requirements for 10 flight displays and more than 100 systems displays, and delivered them to United Space Alliance (USA) for conversion into software requirements specifications for what the Program is referring to as Increment 1.

The Space Shuttle Cockpit Avionics Upgrade (CAU) is the Program's No. 1 safety upgrade, and Increment 1 is the term used for the first-flight capability of CAU. The approach used for developing the requirements has been somewhat unique.

Traditionally, the operations community would not be directly responsible for such an effort but, instead, would provide a consulting role only. For CAU, however, the roles were reversed. The operations community, in the form of the Space Shuttle Cockpit Council (SSCC), was directly responsible for the development requirements.

CAU will be developed over the next several years. The Project Manager is Mike Brieden of the Shuttle Vehicle Office. USA is the prime contractor for the program, Boeing Reusable Space Systems is providing Vehicle Integration services, and Lockheed Martin Systems Integration-Owego is developing the CDP's.

The 'skunkworks' approach

The SSCC was designed to partner the Mission Operations Directorate (MOD) and the Flight Crew Operations Directorate (FCOD) in the development and prototyping of requirements for the new Shuttle cockpit. The new approach to development was the brainchild of the original SSCC Co-chairs–astronaut Steve Lindsey and MOD's Bruce Hilty–nearly two years ago.

The SSCC development team was structured to include system trainers from the Shuttle Training Division, flight controllers from both the Systems Division and Flight Design and Dynamics Division, and several astronauts. The Engineering Directorate, USA and BRSS provided engineering support.

The SSCC concept put the responsibility for requirements development directly on the users of the cockpit, the flight and ground crew. The team began the development with a detailed definition of the current cockpit shortcomings and crew task analysis over an entire mission profile.

A series of "white papers" followed, which detailed the concepts of operations for the new cockpit and the avionics architecture, enabling requirements necessary to implement those concepts.

How can CAU be a 'safety' upgrade?

The CAU does not fit into the traditional category of safety upgrades. Shuttle safety and reliability metrics are normally defined in terms such as MTBF (Mean Time Between Failure) or PRA (Probability Risk Assessment), which focus on the likelihood that components will fail during operation.

The criticality of a component then determines its impact to safety of the crew and vehicle. The CAU does not address risks in those terms but in terms of crew workload and situational awareness (SA) in the midst of nominal and off-nominal crew procedures.

Studies of commercial and military aviation show that more than 60 percent of all accidents are attributed to crew error. Crew error increases as the workload increases, and increased workload results in a reduction of SA.

Although the Space Shuttle is still among the most technologically advanced aerospace vehicles ever built, its avionics architecture and crew displays were designed in the 1970s. When a system failure occurs onboard today's Space Shuttle, the crew has to collect the data from several complex displays and integrate other indirect information in the cockpit to diagnose the failure and determine the necessary corrective action.

The signatures presented with a given failure are often not intuitive and prone to misdiagnosis or procedural error. There is also a high dependence on the ground crew for diagnosing system problems and directing the appropriate response, which takes additional time and relies on continuous communications.

Another area of concern is the crew's ability to manage abort options during ascent and energy during entry. In today's cockpit, the crew relies on cue cards in the cockpit to determine the abort options in the event of an engine failure, which do not account for such things as a change in the launch time or engine performance degradation.

Given that the Shuttle will fly another 20 to 30 years, closing the flight crew SA gap has become the Space Shuttle Program's top safety issue.

The key to CAU's safety improvement is what the SSCC and the CAU Project specified as enabling requirements. CAU will build on the new "glass cockpit," referred to as MEDS (Multipurpose Electronic Display System), which was first flown on *Atlantis.*

The heart of the CAU comes in the form of a new Command and Display Processor, or CDP. Whereas most of today's data are available only to Mission Control, the CDP will integrate all on-board data for use on crew displays.

It will also allow for highly graphical and intuitive displays to be called on any of the Space Shuttle's 11 display units for both monitoring data and commanding to the vehicle systems, as well as an intuitive display navigation scheme.

The CDP will have the processing power necessary for software applications to monitor abort capability, provide for enhanced caution and warning, and failure diagnosis, as well as future growth. ■

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Space Shuttle Cockpit Council

Key players on an important team

Display development for CAU

With the enabling requirements defined, the SSCC began in July 2000 to work toward June's milestone.

Astronaut Jeff Williams relieved Steve Lindsey as SSCC Co-chair while Lindsey trained for STS-104. Astronaut Brent Jett joined the SSCC leadership in January after completing STS-97.

Williams and Bruce Hilty organized the development team into three principle groups: display development, user interface standards development and prototyping and test and evaluation.

Greg Hite, of the Engineering Directorate, led the effort to define the processes used for the group's development effort. Astronauts Willie McCool and Rick Mastracchio led and integrated the display development effort.

Display leads included: Tori Palmer, Andy Hamilton, Mike Grabois, Bill Miller, Al Park, Wes Penny and Alan Fox of the Training Division; Dean Lenort and Ray Miessler of the Systems Division; Dennis Bentley and Larry Hendrickson of the Flight Dynamics Division and Billy Oefelin, Greg "Box" Johnson and George Zamka of the Astronaut Office.

Astronaut Nick Patrick led the user interface standards development with support from human factors engineers from Ames Research Center and Integradyne.

Astronauts Paul Lockhart and Lee Archambault led the test and evaluation effort and worked with Kevin Taylor and his team of software programmers in the display prototyping effort in MOD's Jupiter Facility, along with Bodan Scharunovych and his team in the data integration.

Abort management

Howard Hu of the Engineering Directorate led a team of engineers and flight controllers to develop the requirements for the Shuttle Abort Flight Management (SAFM) application, which will provide the crew insight into abort capability during ascent and energy management during entry. SAFM will provide one of the most significant improvements to the crew's SA for Increment 1 of CAU.

System integration

Additionally, among the biggest challenges facing the CAU team was the integration of the new architecture into the current Shuttle Data Processing System–particularly in the areas of CAU system operation and Orbiter vehicle ground processing.

Tori Palmer led a "tiger team" composed of SSCC team members, CAU hardware and software architects from USA, Shuttle flight software engineers and KSC Shuttle engineers to meet that challenge.

Astronaut Paul Lockhart and his team brief part of the STS-107 crew on the new cockpit as display author Ray Miessler and Jupiter Facility programmers look on.