The Rapid Prototyping Laboratory: The Shortest Space-Time Between Dream and Reality

Lee Morin, *Johnson Space Center*
Patrick Henry, *Johnson Space Center*
Tim Verborgh, *Johnson Space Center*
Patrick Laport, *Johnson Space Center*
George Scheuch, *Johnson Space Center*

Prototyping is like evolution. Prototypes evolve because experienced engineers and users find some models are more fit than others to survive.

The Rapid Prototype Lab (RPL) is small team of developers led from within the Astronaut Office. The lab is located in Houston, Texas, at the Johnson Space Center (JSC) and is dedicated to providing quick and correct solutions to challenges in human space flight vehicle interfaces. This work has led to the development of the generic "glass cockpit."

The Glass Cockpit

Successive approximations to a safe and functionally correct glass cockpit require that the RPL prototype the hardware and software of an avionics suite for a spacecraft; drive the prototype cockpit with simulators and other mathematical models; fly the test bed in representative tasks from each phase of flight; evaluate displays, controls, and user interface elements; correct deficiencies; and repeat until the prototype is correct and complete.

The RPL, in conjunction with subject matter experts from all flight disciplines, is in the process of designing the complete suite of Orion displays and controls. Early conceptual design began in 2006. The design matured with the vehicle and by 2009 reached a state of maturity that enabled comprehensive evaluations. These evaluations began in 2010 and continue through 2011.

Proximity and access to flight crew permit the prototypes to be evaluated and validated by experienced operators—an essential ingredient of the RPL's effectiveness.

Orion will be the first spacecraft with a glass cockpit. Unlike previous spacecraft, the user interface will be almost entirely through graphics displays on console screens. These screens are Honeywell's DU 1310 glass, currently flown on the Boeing 787 (figure 1). Orion's systems will be operated by manipulating graphical screen objects, not by throwing physical switches or circuit breakers. While the shuttle employed approximately 2000 physical controls and 10 display screens, Orion will have about 50 physical controls and three DU 1310 screens.

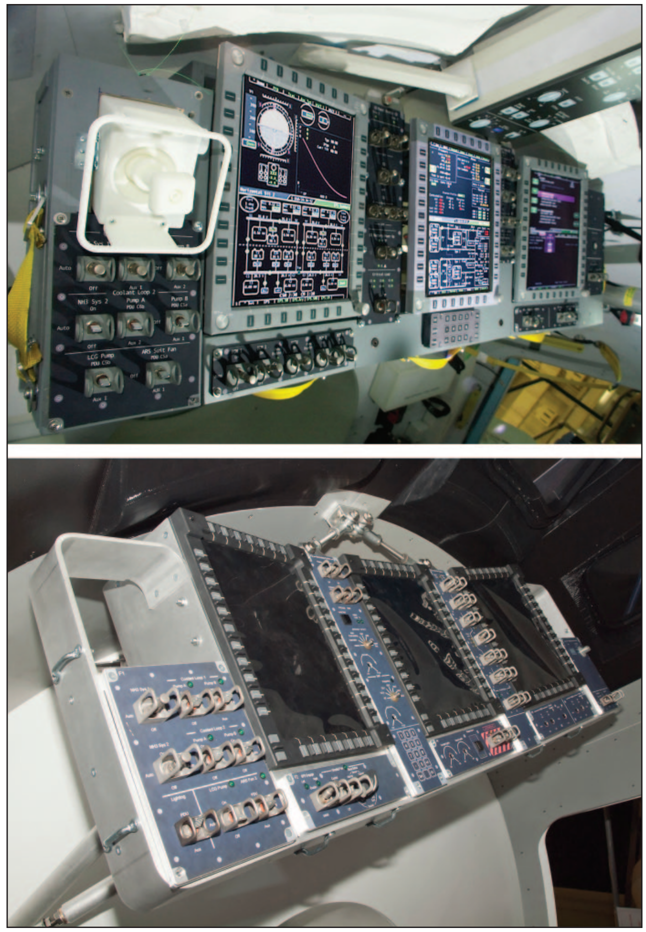

Fig. 1. *Faux DU 1310 display units mounted in the low (top) and medium (bottom) fidelity mock-ups in Building 9 at Johnson Space Center. The low-fidelity console flew and was tested aboard the Reduced Gravity C-9 aircraft.*

The RPL is adept at using immediate feedback and close collaboration from a multidisciplinary JSC team (including Mission Operations, Human Factors, Engineering, and crew) to integrate conceptual designs and successfully apply the rapid prototyping model. This work allows the RPL to apply 40 years of JSC space flight knowledge and experience to operations in the next generation of spacecraft cockpits. Over the past decade, the RPL has prototyped, evaluated, and helped define glass cockpit hardware and software for the Shuttle Cockpit Avionics Upgrade, the X-38 Crew Return Vehicle, and Orion.

Orion Displays and Controls

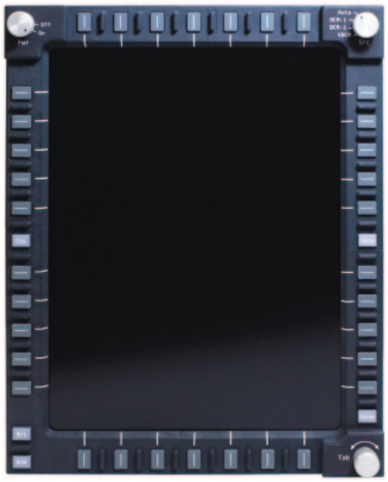

Fig. 2. *The Faux DU 1310 Mark 3 uses a Liquid Crystal Display panel with high viewing angles in all directions. The knob on the lower right is the tab control.*

Of course, a glass cockpit includes the physical display units and the edge keys and other devices used to manipulate them. But equally in need of evolution by prototype are abstractions, such as the design of data structures and of the images shown on the display units. Prototyping the glass cockpit for Orion involves mocking up display units, creating the data and flight formats shown on them, and providing navigation for cursor control and data entry. Physically, edge keys and a rotational tabber allow selection and data manipulation (figure 2).

When crew members are suited and restrained, such as during liftoff and landing, they cannot directly operate the display's switches and controls. A left-handed Cursor Control Device was prototyped to permit the crew to operate the spacecraft during these periods. A great deal of effort went into proving that the displays could be operated by this device by a crew member wearing a pressurized glove.

The Evolution of a Hand Controller

Designs for the left-handed Cursor Control Device evolved over time, guided by observations and comments by Astronaut Office participants in studies conducted by RPL and NASA's Human Research Program. The crude first approximation varied greatly in shape, construction, and functionality from subsequent iterations. The large foam core box quickly evolved into a "steam iron," which was electrically functional—the switches worked; it didn't iron cloths. The steam iron was better, but it was still unfit. An intermediate shape arose and was deemed adequate by the users, but the controls were still not right. Subsequently, various kinds, numbers, and locations of buttons were tried. Figure 3 shows the surface migrations of two rocker switches (green), and two castle switches (red). Ultimately, the testing led to consensus about the type, number, location, and function of the buttons.

Fig. 3. *The evolution of the Cursor Control Device included changes in form as well as in function. Rocker switches (green) and castle switches (red) changed positions, and jobs, several times before the final design was achieved.*

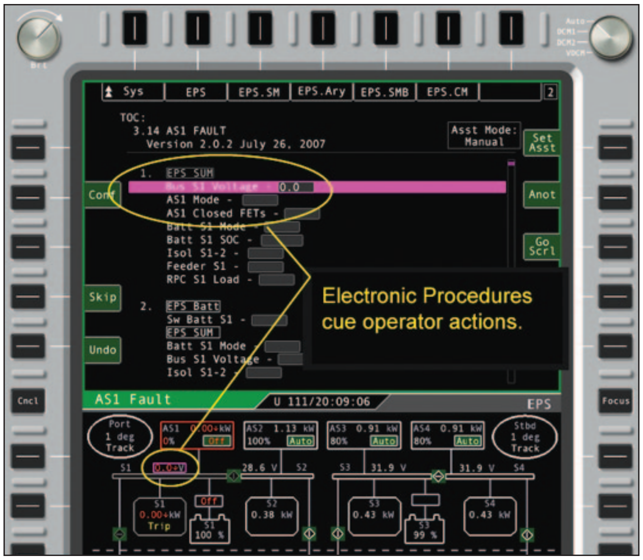

Fig. 4. Electronic procedures weigh nothing and take up nothing but disk space, yet they provide far better insight into—and control of—spacecraft operations than their paper counterparts.

Electronic Procedures

In previous spacecraft, hundreds of pounds of payload and several cubic feet of storage space were provided for paper documents. Electronic procedures (dubbed “eProcs”) will eliminate this mass and storage requirement from future vehicles (figure 4). Not only that, eProc guides the crew by automatically locating and displaying essential information as it is needed. eProcs direct an operator’s attention to critical items and actions. This reduces stimulus clutter, enhances situational awareness, and reduces task workload to help ensure safe, error-free flight.

The RPL strives to encapsulate glass cockpit concepts developed at JSC over the past decade in a way that they can be communicated and shared with NASA organizations and commercial partners under Space Act Agreements.