SMART SPACE SUITS FOR SPACE EXPLORATION

Brand Norman Griffin*
Paul Hudson
Griffin-Hudson
Huntsville, Alabama

ABSTRACT

The internal displays that distinguish the Command/Control Pressure Suit (CCPS) and provide astronauts with important visual information are described. A background of the smart space suit is presented including a discussion on the necessity of increased autonomy for space exploration Extravehicular Activity (EVA). Key features of the CCPS are detailed with emphasis on the information mangement and visual display system.

INTRODUCTION

In 1987, the CCPS was conceived in response to the expanding demands of space exploration and construction. (Figure 1) The concept progressed from measured drawings through sub-scale model to full-scale mockup on to an engineering test article. In 1990, evaluations of the test article were made including a positive appraisal from Dr. H. H. Schmitt, Apollo 17 astronaut/scientist. (Figure 2) Dr. Schmitt's evaluation is particularly relevant because he is one of only 12 men to walk on the Moon, the only scientist and he conducted 3 EVAs.

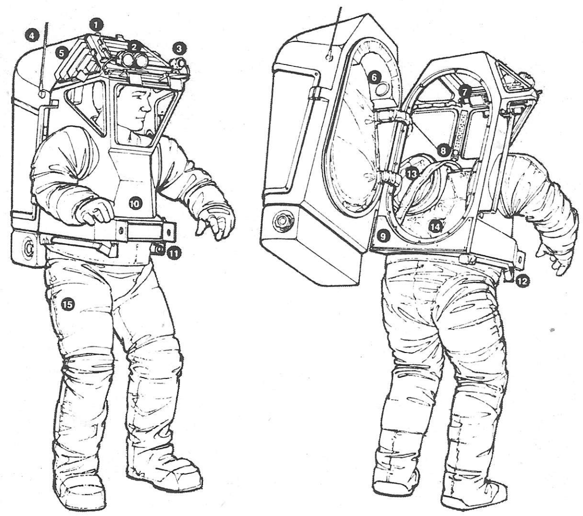
Among the many factors contributing to the CCPS design, the following played key roles:

1. The CCPS is **an intergal part of the exploration architecture**. This means that the role of the CCPS has been expanded beyond EVA to benefit from combined operations with other elements of the architecture, such as rovers, to realize improved total system efficiency.

2. Much improved **information management is essential** for planetary exploration and development. The CCPS provides astronauts with critical information on the suit, mission, environment and attached systems.

3. **Safe and routine access to space is required** for construction, servicing, repair and exploration, A modular CCPS provides the benefits of interchangeable hardware and lower cost through commonality while allowing a core suit to be tailored for operations on the Moon, Mars or interplanetary space.

4. The CCPS **improves EVA productivity** by minimizing the ground communications and giving the astronauts personal control and immediate access to information.



Command/Control Pressure Suit—Key Elements

1. Emergency strobe light
2. Lights
3. Video camera
4. Communications
5. Protective visors
6. Speakers
7. Internal displays
8. Microphones
9. Rear entry
10. The Rigid Upper Torso/Helmet (TRUTH) assembly
11. Portable Life Support Systems (PLSS) umbilical
12. PLSS backpack close/open handle
13. Shoulder straps (for gravity field)
14. Comfort liner
15. Thermal/micrometeoroid/dust garment

Figure 1 *The CCPS combines internal displays with excellent visibility for safe and productive EVA.*

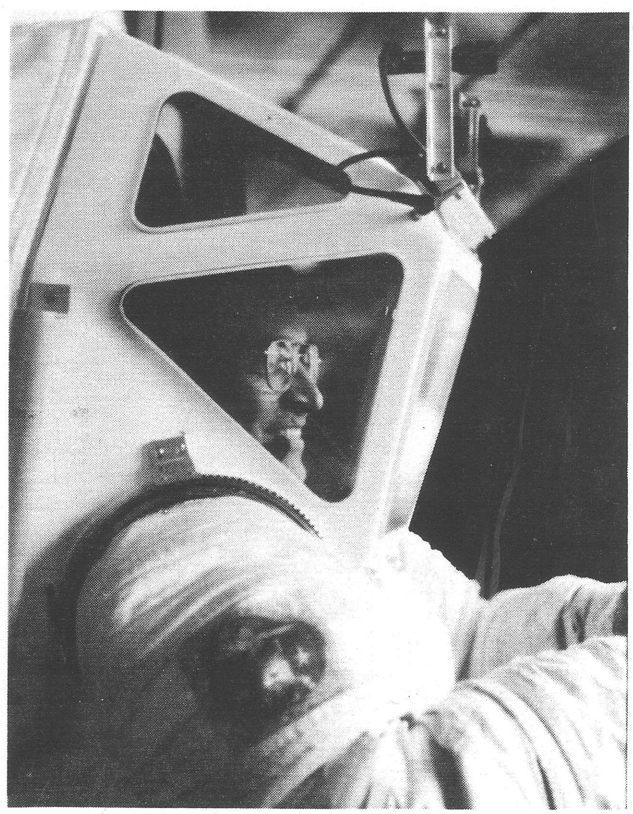
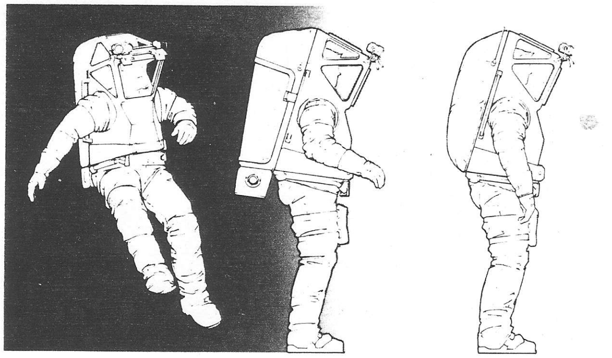


Figure 2 *Apollo 17 astronaut, Dr. H.H.Schmitt evauates the CCPS engineering test article.*

*Senior Member AIAA



ZERO-g MOON MARS

Figure 3 CCPS modularity allows tailoring for operations in three environments.

The result of the design process is a space suit with faceted face plates and an interior looking more like a cockpit than a helmet. Also, the traditional chest-mounted displays and controls are missing. Although these changes give the CCPS an unconventional look, the suit is a hybrid retaining much of NASA's suit development while incorporating improvements for planetary operations. The A7-LB space suit was tailored to each astronaut and designed for lunar operations during the short Apollo stay times. It's successor, the Extravehilcular Mobility Unit (EMU) is designed for weightless operations from the Shuttle in low Earth orbit. The CCPS is designed for a more comprehensive mission assignment supporting Moon, Mars and weightless operations. (Figure 3)

KEY FEATURES

At the heart of the CCPS is **The Rigid Upper Torso/Helmet (TRUTH)** assembly. TRUTH forms a seamless union between helmet and upper torso integrating internal displays and external visibility to provide astronauts with a portable command center for improved autonomy, safety and productivity.

Reliable, low cost, low power **in-helmet displays** replace the conventional chest mounted display and control module. This not only significantly improves visibility of displays but enlarges the prime work area. (Figure 4) Internal displays provide direct viewing of checklists, diagrams and video while allowing astronauts to keep both hands on the job.

By reducing the number of pressure connections made for each EVA, the CCPS minimizes leak paths. TRUTH eliminates neck ring connections and incorporates a single point **rear-entry**. (Figure 5) These features combined with a policy of keeping gloves attached between EVAs reduces wear and contamination of joints while contributing to long life pressure integrity. Figure 6 shows the CCPS don and doff procedure requiring only one seal closure for EVA.

Modularity and shared resources between the CCPS and attached vehicles are essential characteristics for operations is three environments. **Modularity** allows configuration options. Backpacks of different sizes and capabilities can be easily attached to TRUTH allowing suit range and mass to be adjusted

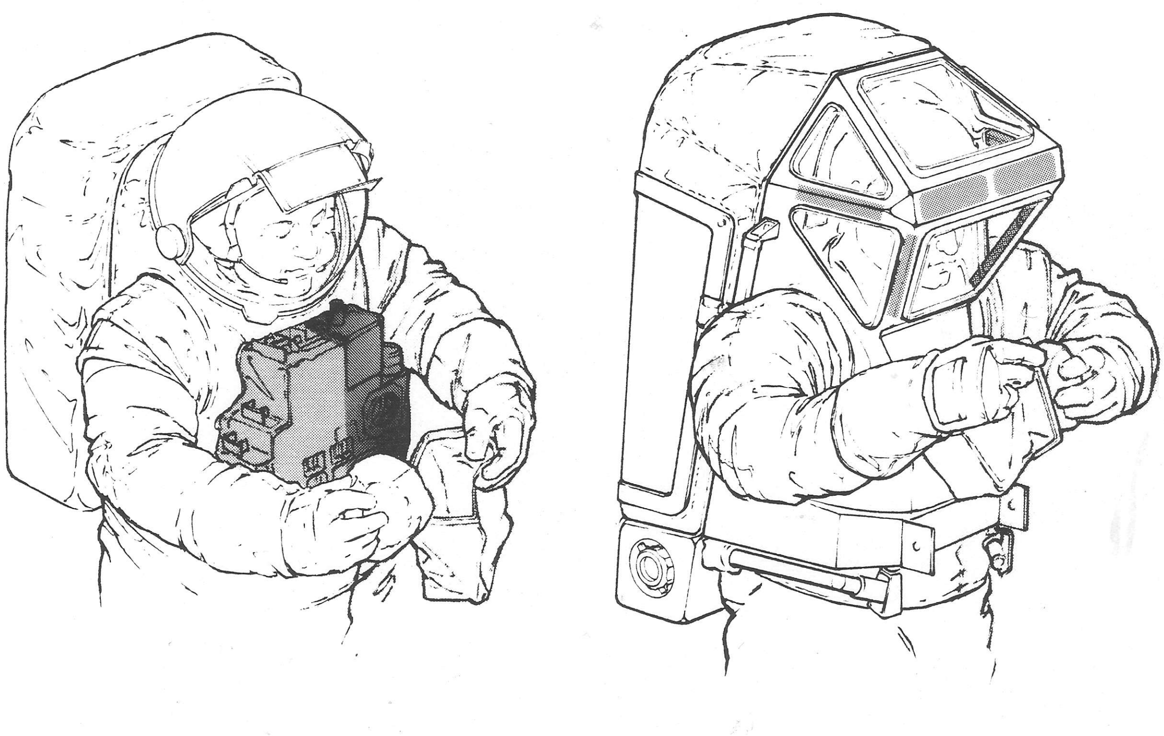


Figure 4 The CCPS relocates chest-mounted controls and displays enlarging the EVA prime work area.

Figure 5 The rear entry of the CCPS engineering test article accommodates modular backpack options.

to the mission. Owing to the suit's unique forward attach mechanism, backpack modularity does not affect vehicle or airlock interfaces. An important feature of the CCPS is the ability to **share resources** with attached systems such as rovers and hoppers. (Figure 7) This mode of operation is the most efficient and productive combination of elements allowing life-support, navigation and other functions to be partitioned and time-shared for total system optimization. The CCPS test stand shown in Figure 8, was designed to evaluate the interface for shared resources and emulates a lunar hopper flight deck.

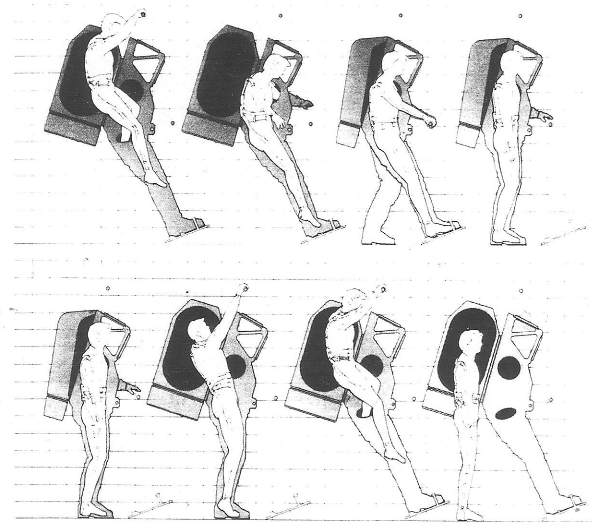


Figure 6 The don/doff sequence of the CCPS shows how only the ***backpack*** *seal needs to be closed for routine EVA .*

DISPLAYS AND CONTROLS

Most EVA has been performed for a specific task often rehearsed many times before the mission. This allows astronauts to become familiar with the hardware and refine procedures. To aid in these operations, cuff-mounted checklists have served as a useful reminder for corrective action and procedural instructions. The problem with cuff checklists is the

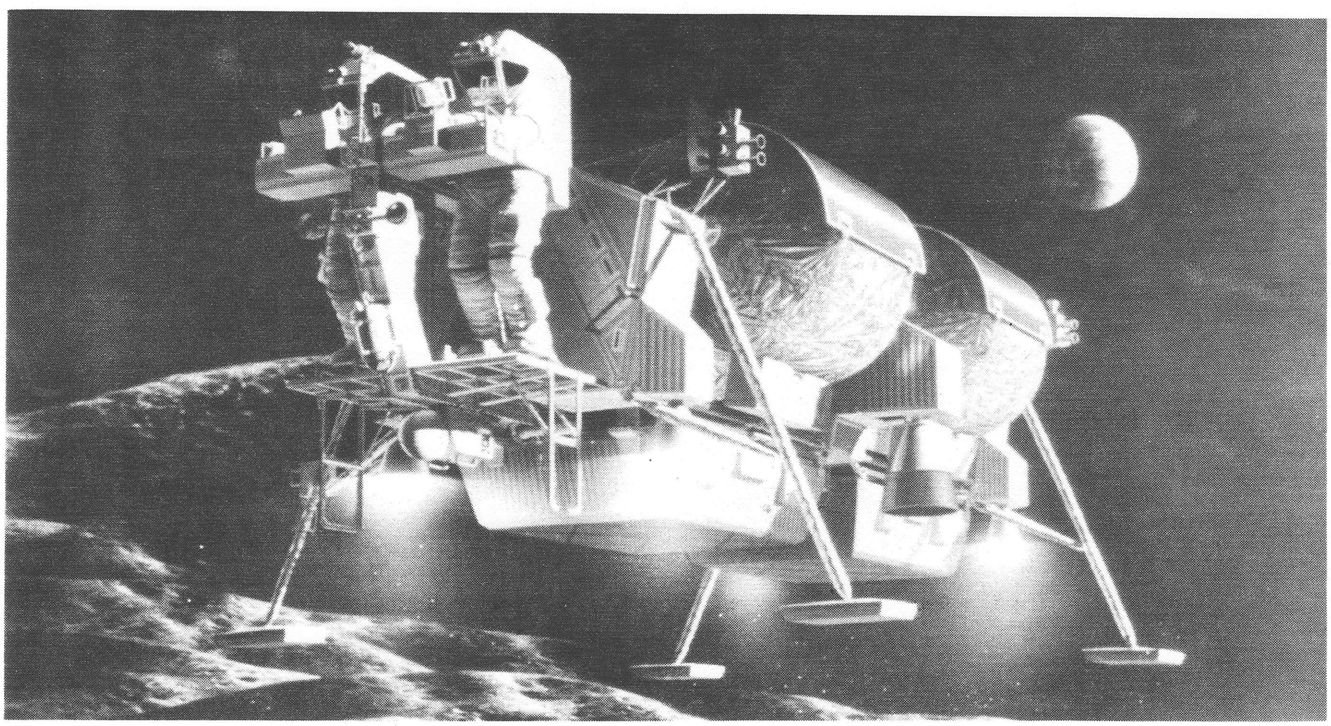


Figure 7 Astronauts in CCPSs fly a lunar hopper using internal displays and hand controllers mounted on the flight deck.

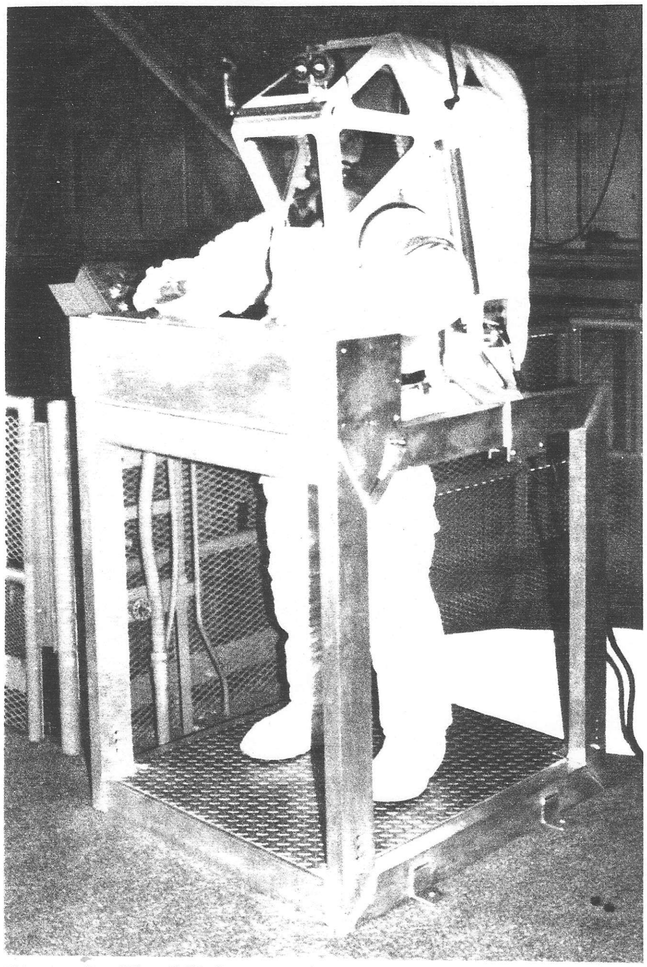


Figure 8 The CCPS test stand was designed to evaluate suit to vehicle interfaces.

wrist is not always in the best position for reading and at least one hand is required for turning pages. Furthermore, information is limited to 3.25-inch by 4.5-inch pages which require a restraint to keep in position.

EVA tasks will be less predictable for longer missions such as Space Station *Freedom* , returning to the Moon and exploration of Mars. Also, because of the mission length, the variety of unplanned tasks and the communications time-delay, astronauts will need to rely more on local resources than an Earth based mission support. Astronauts will be required to inspect, repair and service unfamiliar hardware and for these jobs, a cuff checklist list is inadequate. There have been attempts to equip suits with better information systems. In 1986, a voice activated/voice synthesized system was developed and evaluated in a series of neutral buoyancy tests[1]. In 1988, an external helmet-mounted display was delivered and tested under a NASA contract to the Hamilton Standard Division of United Technologies[2]. The voice system was an improvement over the cuff checklist allowing both hands on the job while moving through procedures but created a lot of disruptive "chatter" and interfered with communications. The Hamilton Standard display removed the chatter problem, but its external mounting exposes equipment to the harsh space environment and requires suit penetration for connection to internal systems. For the Moon and Mars, abrasive dust will compromise legibility of external displays. Like the Apollo missions, dust will coat visors and external equipment putting into question the utility of any external display.

DATA DISPLAY

The CCPS information management system controls executive level functions including display priority. Similar to advanced aircraft flight decks, a "quiet-dark" philosophy governs what and when information should be displayed. To the astronaut, this means that information for doing the job is on-board and available without interfering with normal operations. Visual display of information was selected for the suit beacause it is more precise, can be color-coded, flash for attention, be viewed simultaneously and can be used in parallel with aural information.

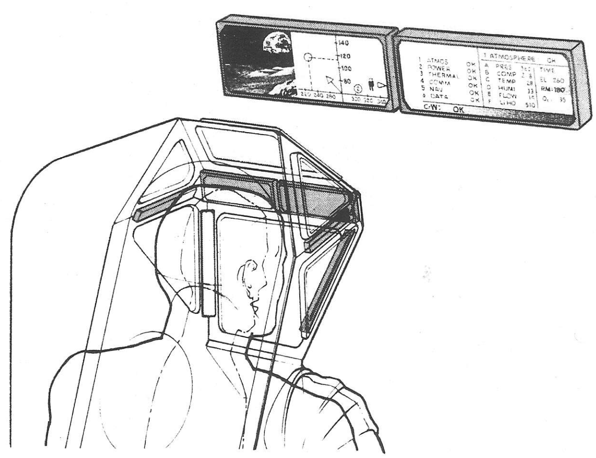


Figure 9 The CCPS internal displays provide status on the suit, mission and attached systems.

Voice is used as the primary method of control. This technology is over 30 years old and there are existing commercial systems being used efficiently in high noise environments. Voice commands bring up displays and affect control. To move through menus, astronauts use simple, natural commands like "next", "skip" and "go to". In some cases, a "yes" or "no" response is enough to initiate action, however certain critical decisions have built-in safe guards protecting against inadvertent activation.

Identical, color liquid crystal displays are used for video, graphic and alpha-numeric information. (Figure 9) Although the system is dual fault tolerant, allowing critical data to be displayed on any monitor, the two monitors in the brow location are used for system status and situational information. The monitor in the chin location is used for instructional information such as check lists. Four side bars, two positioned on either side of the front face plate and two overhead are discrete multi-function displays. The monitors display 1) map-type graphics for navigation, 2) video for prerecorded instructions and remote camera viewing and 3) gauge readings for consumables. The illuminated displays in engineering test article were used to assess the location, size and characteristics of each display type. The formating of information is an important task and is continuing to be developed for future testing.

Information displayed in the CCPS is categorized as either a suit, mission or attached system. **Suit systems** include life-support functions, navigation, communications, caution/warning, lights and camera. **Mission systems** are unique to each EVA and provide time and location taging of samples, data recording, voice note taking, environmental data and calculator functions. The data displayed on **attached systems** provides the astronaut the ability to status, control and record vehicle functions. For example, the battery discharge rate of an attached rover can be viewed in the CCPS simplifying the combined assembly and avoiding the visibility problems of obscured rover mounted displays due to dust buildup, scratched surfaces or sun washout.

A feature called the **guardian angel** is incorporated into the caution/warning system. In addition to alerting the astronaut of a problem, the guardian angel uses expert systems to present action plans. This unique aspect of the CCPS is important for lunar and Mars missions where mission length may affect accurate recall of critical emergency procedures.

SUMMARY

The expansion into space from *Freedom* to Mars can be characterized by progressively longer and more complex missions. Preparing for planned operations and retaining proficiency will challenge even the most skilled astronauts.The improvements offered by the CCPS will provide astronauts with the necessary autonomy to make safe and informed decisions even for the unplanned events. The CCPS is designed to allow astronauts to focus on construction and exploration without having to recall complex procedures and terminology learned many months or years earlier. For EVA on Mars, the CCPS information management system provides guidance when real-time, two-way communication is impossible. The suit combines internal displays and voice control to provide the most productive system for routine, long-life operations in the space environment. Modular construction and a design approach that incorporates shared resources between the CCPS and attached systems enables the suit to be easily tailored and upgraded to meet missions and programs for the next 30 years.

REFERENCES

1. "Zero-G Simulation Verifies EVA Servicing of Space Station Modules" B.N. Griffin, AIAA Space Station in the Twenty-First Century, AIAA-86-2312, September 3-5, 1986/Reno, Nevada
2. "A Helmet Mounted Display Demonstration Unit or a Space Station Application", C.G. Gernudand, R.W. Blaser, Jose Marmolejo, SAE891583
3. "Development of a Zero-Prebreathe Spacesuit", C.W. Flegel, J.J. Kosmo and J.R. Rayfield, SAE Technical Paper Series 840981, July 16-19, 1984
4. "Working on the Moon: The Apollo Experience" E.M. Jones, Engineering, Construction, and Operations in Space, Proceedings of Space 90
5. "Extravehicular Mobility Unit.", M.A. Carson, M.N. Rover, C.C. Jutz, and J.W. McBarron, Biomedical Results of Apollo
6. "Development of the NASA ZPS Mark III 57.2kN/m2 (8.3psi) Space Suit", J.J. Kosmo, W.E. Spenny, R. Grady, and P. Spampinato
7. Technical Discussions with Former Astronaut, H. H. Schmitt, Apollo 17
8. Technical Discussions with Former Astronaut, W. Pogue, Skylab IV
9. Technical Discussions with Former Astronaut, G. Carr, Skylab IV
10. "A Space Suit for Lunar Construction and Exploration", B.N.Griffin, AIAA Space Programs and Technologies Conference, AIAA-90-3885, September 27, 1990/Huntsville, Alabama

Acknowledgement
Mr. Nicholas Shields is recognized for his contribution in display analysis and design and Mr. Steven Suchting for the electrical and electronic integration of the CCPS engineering test article.