A Space Suit for Productive and Safe
Extravehicular Activity (EVA)

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Abstract

An innovative space suit called the Command/Control Pressure Suit (CCPS) is described in terms of productivity and safety.(Fig 1) Conceived as a cockpit for Extravehicular Activity (EVA), the CCPS provides astronauts with the

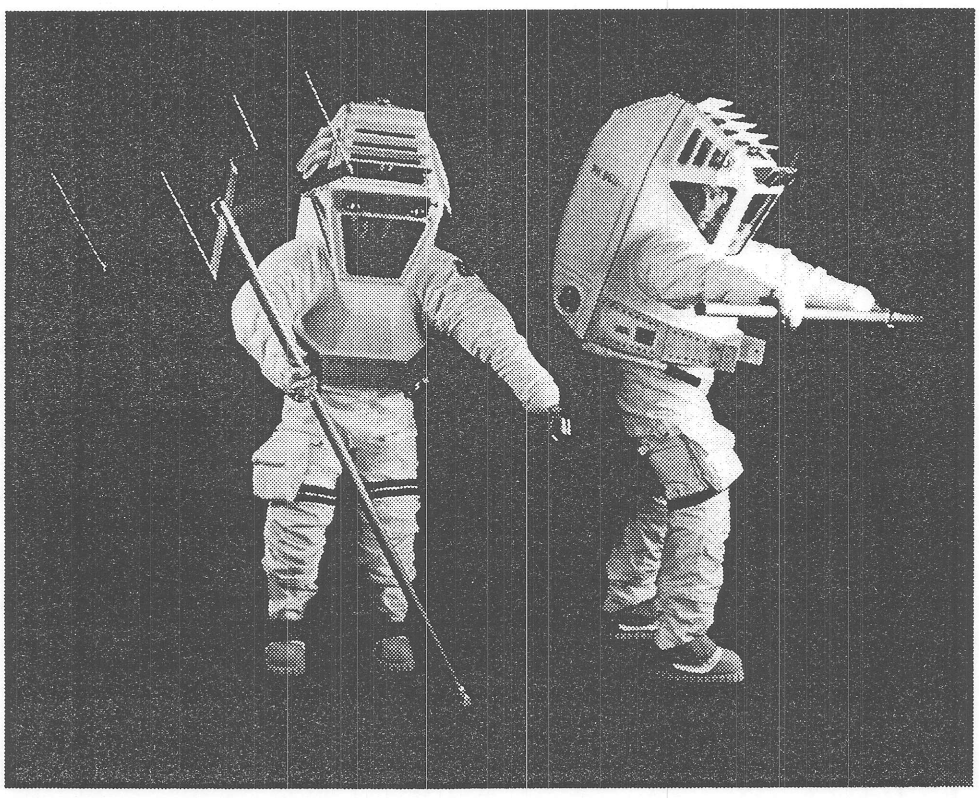

Figure 1 The CCPS is a cockpit for EVA

information for rapid and informed decisions. On-board systems display real-time information on mission procedures, consumables, navigation and emergency operations.

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The Rigid Upper Torso/Helmet (TRUTH) assembly is the control center for the CCPS. It features integrated internal displays with distortion-free outside visibility resulting in an unusual faceted helmet design. Astronaut evaluation of full scale engineering test article was used to resolve uncertainty over the unconventional configuration. Apollo 17 astronaut H.H. Schmitt was invited to try on the CCPS engineering test article because he brought a user/scientist's perspective and the experience of 3 lunar EVAs. He said of the suit configured with worst-case 1.9 cm (.75 inch) panes, "Visibility in the CCPS is obviously superior to the A7-LB (Moon suit)" and gave it a thumbs up.

Key features of the suit are described. Chief among them are: 1. an on-board information management system for greater crew autonomy, 2. cockpit-like control authority over external systems and 3) cost avoidance through a generic suit concept with operational capability in weightless, lunar and Mars environments.

Introduction

With the current space suits, astronauts memorize complex procedures and use cumbersome cuff-mounted checklists for single purpose missions. For exploration missions, emphasis is on autonomy because field judgement requires information on-hand and communication links are compromised by line-of-sight interruptions and time-delay. The existing suit is not designed for walking or operations in a dusty planetary environment. The don/doff procedure is complex and the connection to a propulsion package like the Manned Maneuvering Unit (MMU) is a backward motion, blind operation.

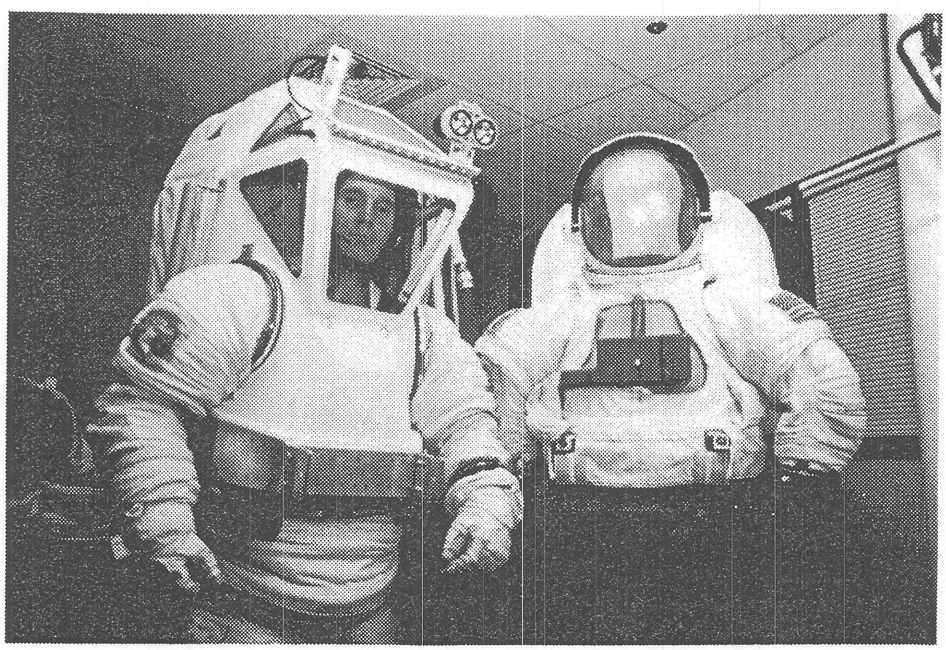


Figure 2 CCPS and Space Shuttle side by side

Furthermore, at 122.5 kg (270 lbs), the Shuttle Extravehicular Mobility Unit (EMU) is too heavy for sustained planetary operations and requires an extensive 1050 hrs of hands-on servicing between flights.(Lutz et al, 1991)

All of these factors conspire against effective space exploration. But, a space suit that responds to the exploration requirements has been designed. Called the Command/Control Pressure Suit (CCPS), the concept integrates the best of existing suits with capabilities for future EVA operations.(Fig. 2) The CCPS has an on-board information management system with internal visual displays. This improves productivity and safety by reducing memorization, eliminating the cuff checklist and presenting important information in effective graphic form. The CCPS is designed for zero-g and planetary walking and has single point entry that minimizes the severe problems with dust contamination. A front-facing attachment provides for easy connections within direct view and the chest-mounted Display and Control Module has been removed significantly enlarging the EVA prime work area.

Productivity Multiplier

Productivity is important for all space activities but improvements in EVA yield enormous leverage. Considered a hazardous and strenuous activity, it is severely constrained by time and life-critical resources. With the required buddy system (two astronauts, two suits) and necessary airlock, support equipment, tools and spares, it is labor and equipment intensive. Also, each EVA hour corresponds to countless hours of planning, simulation and training involving unique facilities and many highly skilled people. For example, the 4 astronauts preparing for the Hubble Space Telescope repair mission spent over one year in training and close to 400 hours in underwater simulation at two NASA centers.(Burkey,1993) This is why EVA hours are the highest priced hours in space. The CCPS improves EVA performance, reduces support equipment and minimizes training.(Fig. 3)

TOP PRODUCTIVITY ENHANCEMENTS	
FEATURE	**BENEFIT**
Generic Suit	•Single suit system=low cost
Visual Display	•Improved accuracy and recognition
Internal Displays and Controls	•Unobscured visibility, larger prime work area and hands stay on the job
Recall	•Menu driven allows random access for quick retrival
Training	•Inherent quality of graphic and video instruction reduces training
Review	•In-suit procedure review on-orbit
Simultaneous Access	•Comparative assessment of parameters for better decisions
Complex Operations	•Graphic and video are best for comprehending complex operations
Concentration	•Hands and eyes can stay on the job while retaining voice control
Comprehension	•Graphics are international and require no intrepretation

Figure 3, CCPS features make EVA more productive

EVA Cockpit

In the same way that a cockpit provides a pilot with information for control of the aircraft, the CCPS is a cockpit for EVA. Internal controls and displays give astronauts ready access to suit parameters as well as information on environmental conditions, navigation, communications, mission procedures and emergency operations. Because space suits are tools for EVA, they must be designed for productivity while still functioning as a protective garment. The CCPS integrates a complete information management control center within an seamless Rigid Upper Torso/Helmet (TRUTH) assembly. Joining the helmet and upper torso not only eliminates the neck ring as operable hardware and potential leak path but allows a configuration that has both excellent internal and external visibility.

No More Box on the Chest

Some day, vintage space suits will be identified by the box on the chest. This box or Display and Control Module (DCM) will represent a era when astronauts had awkward control and limited display of their suit systems. Operating the DCM required the head to be at an uncomfortable angle and in some cases, a fresnel lens are needed to read the characters.(Gernux et al, 1989) The controls are either obscured from view or difficult to see and require astronauts to wear a wrist mirror to read the images.(Fig. 4) Also, for planetary operations, Apollo proved that dust will interfere with external mechanical controls and make displays unreadable. For weightless operations, the hand is particularly important for body restraint and stability. Removing a hand from the job to operate the DCM means forfeiting a well earned grip, breaking concentration and compromising a critical work position.

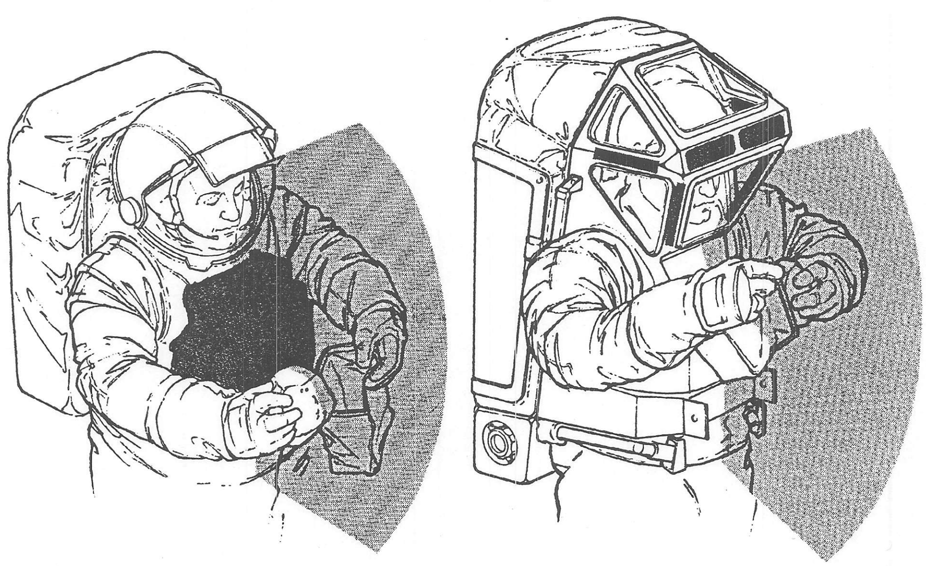


Figure 4 The CCPS enlarges the EVA prime work area

These drawbacks combined with the extremely limited single-line, 12 character, alpha-numeric display revealed the deficiencies for exploration and prompted development of the Command/Control pressure Suit (CCPS).

For planetary operations rovers and hoppers are simplified. Astronauts in the CCPS control vehicles from their conformal cockpit; no pressurized cab or vehicle airlock is required. This means that without compromise to performance, vehicles are lighter and EVA time is better utilized.

Eyes, Ears and Mouth

Compared to other methods of communication, vision has the greatest information density, is the quickest and most accurate. The CCPS was designed around internal graphic displays. Two liquid crystal displays (LCDs) present a full range of information in alpha-numeric, gauge-display, diagram and video formats.(Fig. 5) Color and blinking features are

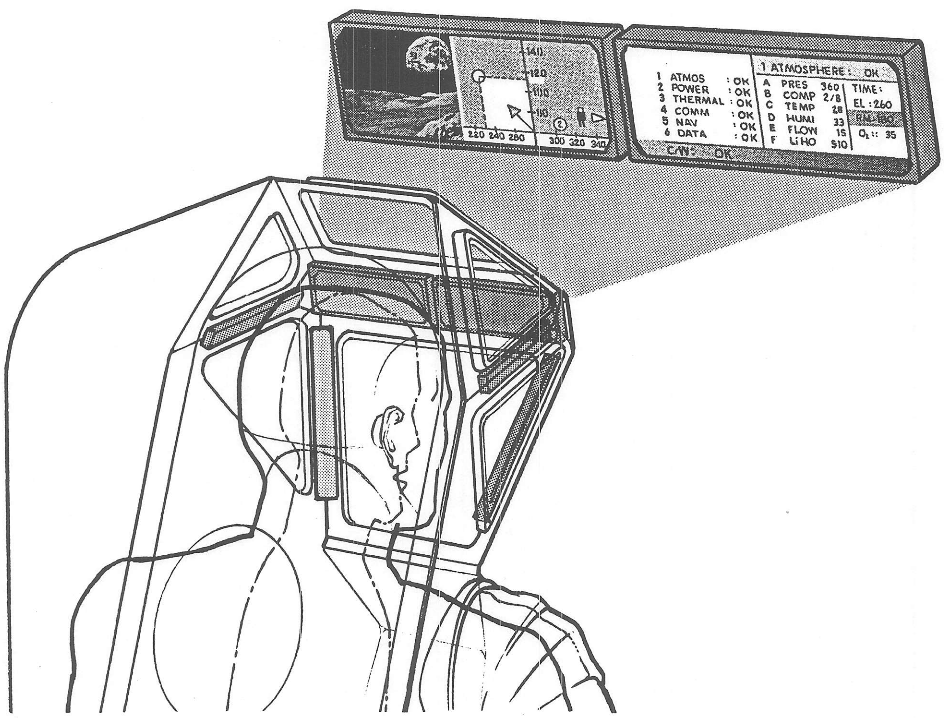


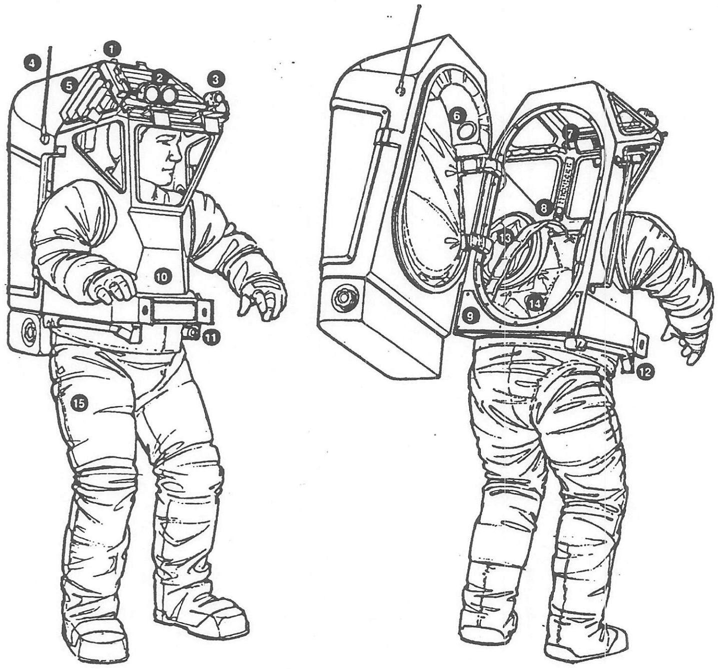
Figure 5 Internal displays provide legible and reliable information

incorporated for coding and criticality ranking. In addition, like cross-checking temperature and oil pressure, the CCPS offers simultaneous viewing of multiple parameters for a comparative assessment. Another important point is that by having most information presented in a visual format, hearing remains available for essential communications among EVA crew members and base operations. Like aircraft, the CCPS has a quiet/dark cockpit using visual and aural signals to inform and alert the astronaut.

Voice activated systems offer compelling benefits for EVA. The eyes and hands remain on the job while natural language affects control. Commercial systems are mature and routinely operate in high-noise environments.

Head-to-Toe Enhancements

The following is a description of some of the key features of the CCPS.(Fig. 6)



CCPS Key Features
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 System (PLSS) umbilcal
12. PLSS backpack handle
13. Shoulder straps (for gravity field)
14. Comfort liner
15. Thermal/micrometeoroid/ dust garment

Figure 6 Key Features of the CCPS

Apollo experience demonstrated the abrasive and debilitating characteristics of lunar dust. "...despite crew efforts to keep wrist rings, neck rings, zippers, and hose connectors clean and lubricated, these became stiff and balky with use and exposure to lunar dust."(Jones and Schmitt, 1992) With routine mating at the neck, both wrists and mid torso, the current EMU presents substantial opportunities for dust contamination. The CCPS has a **single rear entry** which minimizes exposure by keeping all joints attached between maintenance periods.(Fig 7) This also focuses dust control by having one easily cleaned and inspectable interface.

An **Information Management System** with **internal visual displays** is the heart (and brain) of the CCPS. This personal control center provides astronauts with the autonomy for safer and more productive EVA.

The CCPS is equipped with a **safety strobe light** attached to the top of the backpack. It serves as a visual locator and, by a flashing pattern, signals situational status. The voice activated light provides identification when separation distance and certain lighting conditions make

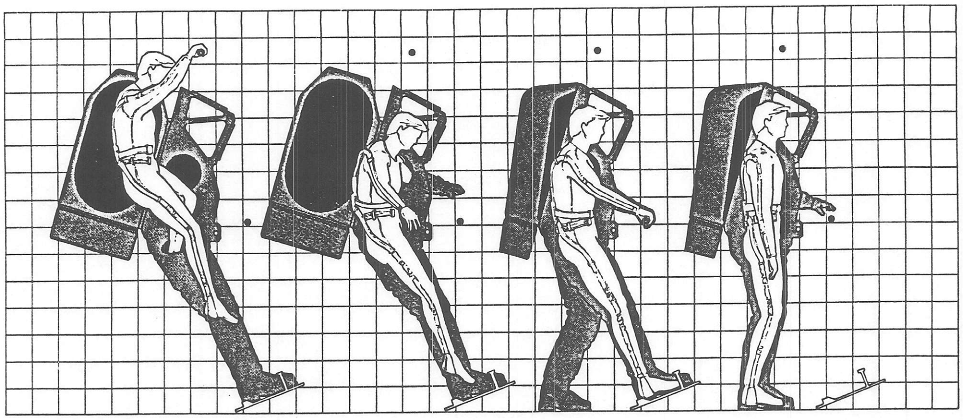


Figure 7 Single point entry minimizes dust contamination

astronauts difficult to see. Because of limited resources, rescue time is critical. For rapid identification, the CCPS has both a RF emergency locator signal and a safety strobe.

Mounted to the outside brow portion of TRUTH is a **video and light assembly**. This provides external lighting and camera for in-suit or broadcast viewing. Voice control of the assembly keeps hands free for carrying, repairing and exploration.

Protective visors cover all panes and are configured for each mission. Louver panels control heat gain yet allow for overhead viewing on demand and other visors provide glare control and scratch protection.

Unlike bubble helmets, the CCPS **flat "window" panes** offer distortion-free visibility regardless of glass thickness. Also, like in attack helicopters, faceted panes are used to control internal reflections.

The CCPS **modular backpack** provides a clean and logical interface for changeout and upgrade of life support systems. This improves operational readiness by having an easily installed backup standing-by and reduces life-cycle costs by having a single suit design for all missions. Backpacks for different environments, including nonbackpack umbilical plates, use a common interface.

Working against the pressure in a space suit glove causes fatigue that directly effects performance and safety. To reduce fatigue and enhance grasping, strength and rotational capabilities, a CCPS **glove-manipulator** is a mission specific option.(Fig. 8)

The **structural mid-section** is a unique feature offering stiffness and strength for the suit as well as the interface to attached systems.

A **forward-facing interconnect** is an important productivity feature that takes advantage of normal forward movement and forward visibility for EVA operations. Two blade-like tines extend from the structural mid-section providing a strong mechanical connection with external systems. A data connection enables the coupling of a CCPS cockpit with attached systems including propulsive maneuvering units, hoppers and rovers. This has profound system-level benefits by reducing hardware mass and complexity while improving operational time lines. This is

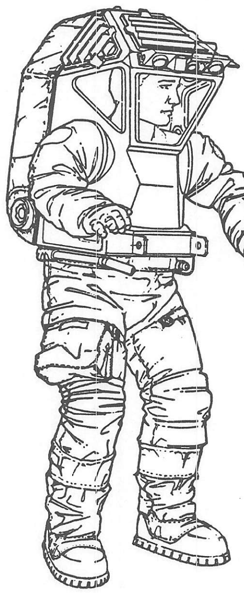


Figure 8 Mars configuration with glove-manipulator

an improvement over the existing MMU because it substantially reduces support equipment, provides for an easier and more natural method of entry/exit and includes an integrated docking element rather than a separate attachment.(Fig. 9)

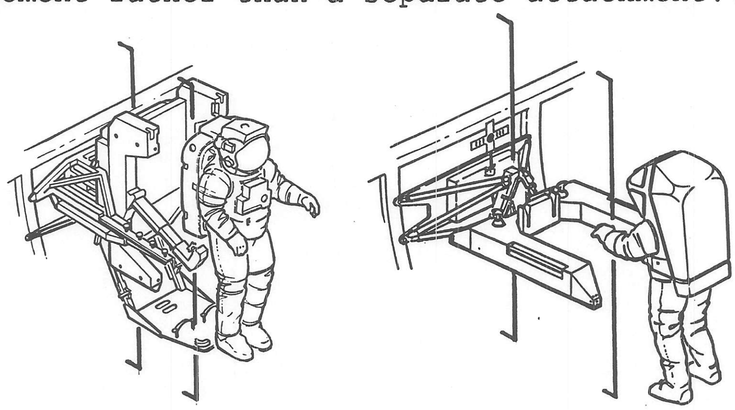
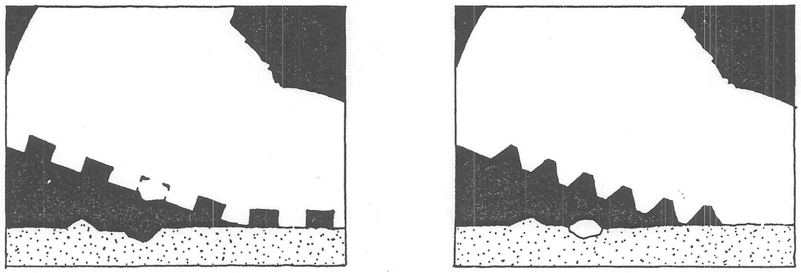


Figure 9 The Forward-Facing Interconnect simplifies 0-g maneuvering

Sure footing is essential for safe and effective planetary activity. For weightless operations, foot restraints react forces and in reduced gravity boot traction performs the same function. The CCPS has a **sure-grip overboot** specifically designed to improve traction.(Fig 10) A triangular rib, rather than the Apollo square cross-section, eliminates slipping due to rocks being lodged in the boot tread. Flex points along the sides and a special radial toe grip further improves the ground contact.

Falling down Safe

Suits designed for planetary operations must accommodate walking and other gravity related activities. At the same time, suits must be designed to fall down. "On three-day



Apollo Square Rib CCPS Triangular Rib

Figure 10 CCPS tread improves traction

missions, astronauts fell repeatedly. On one occasion, Charlie Duke landed on his backpack, fortunately without consequence" (Duke and Duke, 1990) The CCPS is intended to be *falling down safe*. This translates into a philosophy of conservative design including provisions for contingencies. Design safety measures include generous safety margins for the entire pressure structure with stronger/thicker helmet glass and well understood material and processes. (Fig 11)

TOP SAFETY ENHANCEMENTS	
FEATURE	**BENEFIT**
Fewer seals	•Long life, minimum leak and fewer failures
Buddy-breathe	•Emergency shared breathing system
Flat "windows"	•Thicker panels without distortion and no internal display reflection
Guardian Angel	•On-board software for emergency help
Strobe	•Visual signal for location and status (steady or flashing)
Voice Control	•Allows communications with hands occupied or injured
Visual Display	•Clear, direct information, ie., vectors on the quickest path to shelter

Figure 11, The CCPS is designed for safe operations

Human exploration of space relies on long and frequent EVAs. For NASA's First Lunar Outpost, 34, 8 hr EVAs are proposed for a 45 day mission. A suit accommodating a target of 200, 8 hr EVAs is recommended for planetary visits by E.M. Jones and H.H. Schmitt.

Unlike the EMU, the CCPS has a **buddy breathing system** with an easily reached umbilical designed for side-by-side walking. As part of the information management system, **a guardian angel** stands watch awaiting activation and providing emergency instructions.

Coordination and stability are linked to managing the combined suit/astronaut center-of-gravity (C.G). The CCPS is designed with this in mind and unlike other suits, the CCPS backpack does not physically attach to the back. To provide a favorable C.G, the CCPS "backpack" slopes forward and in essence wraps around the body. In addition, the condition is further improved by locating high mass elements such as the batteries within the structural mid-section.

Summary

The expansion into space 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 accomplish the mission without having to recall complex procedures and terminology learned many months or years earlier. For distant EVA, 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 for 30 years of productive EVA.

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