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## A SIMULATION SYSTEM FOR SPACE STATION EXTRAVEHICULAR ACTIVITY

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### INTRODUCTION

America's next major step into space will be the construction of a permanently manned Space Station which is currently under development and scheduled for full operation in the mid-1990s. Most of the construction of the Space Station will be performed over several flights by suited crewmembers during an extravehicular activity (EVA) from the Space Shuttle. Once fully operational, EVAs will be performed from the Space Station on a routine basis to provide, among other services, maintenance and repair operations of satellites currently in Earth orbit.

### BACKGROUND

When a crewmember ventures outside the spacecraft, an extravehicular activity (EVA) is performed. To perform an EVA from the Space Shuttle, an astronaut must don an extravehicular mobility unit (EMU) — a space suit assembly and portable life-support backpack that provides, respectively, the pressure retention and habitable atmosphere that a human requires to perform a productive umbilical-free EVA in the vacuum of space. Attached to the front of the Shuttle EMU shown in Figure 1 is a display and control module (DCM), a large chestpack with life-support controls and a 12-character red LED display located just beneath the helmet visor. Through the DCM display, the astronaut is able to read various life-support parameters (e.g., oxygen pressure, suit pressure, etc.). These parameters are continuously measured and monitored by a caution and warning

system (CWS) microcomputer located within the backpack. If any anomalous conditions are detected, caution or warning messages are generated and then relayed from the CWS to the EVA crewmember via the DCM display. Should any of these messages be reported by the CWS, the astronaut then refers to corrective instructions in the EMU cuff checklist, a "flip-through" reference booklet attached to the wrist of the suit. (In addition to these corrective instructions, the cuff checklist also contains information about general mission procedures and EVA equipment operation.)

### LIMITATIONS TO THE SHUTTLE EMU INFORMATION SYSTEM

Although several spectacular EVAs have been performed from the Shuttle, a number of limitations with the Shuttle EMU information-exchange system have been identified. These limitations relate to the DCM visibility, information accessibility, information capacity, and the DCM size. Both the display and the controls on the DCM are difficult to view. The location of the DCM display requires the crewmember to look down at an uncomfortable angle. Since its viewing distance is so small, some astronauts require the use of a special lens to read the characters. In addition, bright environments "wash out" the red LED characters, sometimes forcing the crewmember to cup his hands over the display for viewing. Difficulties also exist in viewing the controls located on the front of the DCM, requiring the EVA crewmember to wear a wrist mirror to read the reflected images.

Information retrieval during EVA must be manually sequenced. The astronaut must

toggle a switch to receive each 12-character line of DCM data, and referring to the cuff checklist is a two-hand operation.

The amount of data that may be presented is severely limited. The entire library available during EVA consists of a number of twelve-character messages (an astronaut would have to toggle 24 times just to read this paragraph) and 40 to 50 pages of a 3.25-inch x 4.5 inch cuff checklist.

The DCM not only invades the astronaut's prime work envelope (i. e., the area directly in front of the chest), but its mere presence has restricted improvements to the reach capability and arm mobility of the EMU.

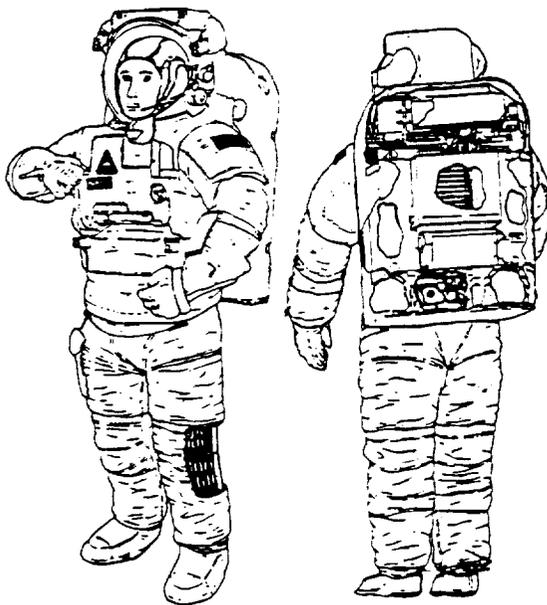


Figure 1. Space Shuttle Extravehicular Mobility Unit (EMU).

### INFORMATION SYSTEM IMPROVEMENTS

Although the DCM and cuff checklist are suitable for the occasional EVAs performed from the Shuttle, the nearly routine EVA anticipated for the Space Station dictates that productivity be maximized. Ideally for Space Station EVA, the access to information should be a "hands-free" operation, especially for labor-intensive EVA scenarios such as satellite servicing, unplanned maintenance, or emer-

gency operations. Furthermore, the display medium should support text, graphical, and video formats in all EVA environments. To meet these ambitious goals, NASA is developing a voice recognition and control system to provide "hands-free" operations and a helmet-mounted projection device to display information to the EVA crewmember.

Although space is inherently a harsh environment, the rather benign conditions inside the EMU facilitate the use of speech recognition technology. First, sounds within the EMU are absent of noises that commonly cause problems for speech recognizers, such as background voices and extraneous clamor found at industrial workstations or breathing noises inherent with masked fighter pilots. The EMU helmet contains only fan and airflow noises which are high-frequency sounds that can be easily filtered. Second, an extensive vocabulary is not required for the EMU since a vocabulary of about 50 words will suffice for the procedurally oriented tasks of EVA. Furthermore, even though a connected-word recognizer may allow more flexibility, an isolated-word recognizer is all that is necessary. Finally, the voice recognition system need not be speaker-independent to allow multiple users since each EVA-qualified crewmember aboard the Space Station will have an EMU. Similar to military helmet-mounted and heads-up displays, the EMU helmet-mounted display (HMD) consists of projection optics and image/illumination source electronics that permit convenient viewing of text, graphics, and video on a transparent display deposited onto the helmet visor. With a transparent screen, the astronaut can read information overlaid onto the real world when the HMD is active. When the HMD is off, the screen is practically invisible. Displayed images are located conveniently above the astronaut's prime field-of-view to prevent visual interference while performing EVA tasks.

Through control system electronics, the voice recognizer can select imagery on the HMD, thus providing a powerful and valuable tool for the Station EVA astronaut (other functions are also available). The combined system will

replace the need for the DCM, the cuff checklist, and the EMU wrist mirror, thus enhancing EVA productivity while sacrificing none of their services.

With the HMD and the aid of a voice recognition system, almost unlimited amounts of information are conveniently available to the astronaut during the EVA. The astronaut may review EMU status information, receive EMU alarms with corrective action, obtain general EVA operational information (previously supplied by the cuff checklist), control EMU switches by voice, monitor transmissions from the astronaut's personal TV camera, and access the Station's main computer (which can provide data retrieval from onboard memory or a ground database).

### NASA EVA SIMULATION

At the NASA Johnson Space Center, the data available to a Space Station EVA astronaut may be simulated in an Advanced EVA Systems Laboratory. This simulation concentrates on the anticipated Space Station EMU data logic flow required to efficiently provide the EVA crewmember with various informational types while maximizing the usefulness of the voice recognition/control system and helmet mounted display. The simulation program is run on a MacIntosh II and operates in conjunction with a bench model of the HMD and a speaker-dependent voice recognition system. The simulation allows the user to perform the pre-EVA series of checklists required to exit the spacecraft, offers the user all informational data types (including alarms) available during the EVA, and provides the series of checklists to return safely inside the vehicle. Below is a brief description of the simulation program.

### PRE-EVA

Pre-EVA procedures are performed within the airlock prior to exiting the spacecraft. After the EMU is donned and powered up, the HMD supports a preparation mode where the astronaut user is led through a series of checks prior to depressurizing the airlock. Detailed instructions including illustrations for depressurization and subsequent airlock egress

are provided. In the simulation, the pre-EVA HMD screens are split into three fields (excluding the header). The top field contains procedural information, the middle field contains a series of switches that may be manipulated by voice, and the bottom field lists valid functions selectable by voice. The pre-EVA checks and switch manipulations are controlled by voice commands. The following is the sequence of events required to perform the pre-EVA operation. (Note the quoted commands spoken by the user.)

- (1) Simulating power applied to the EMU, the HMD will display a power restart message and a Systems Check of the EMU (See Figure 2).

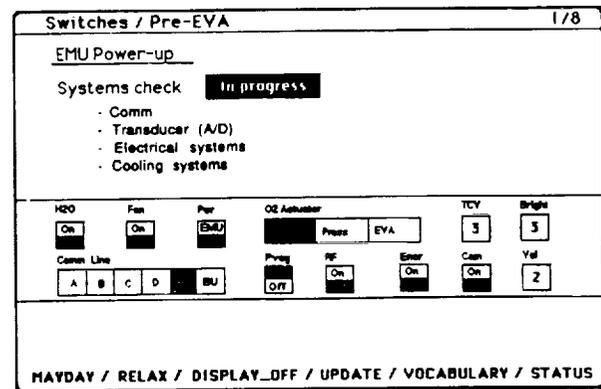


Figure 2. EMU Power-up and Systems Check

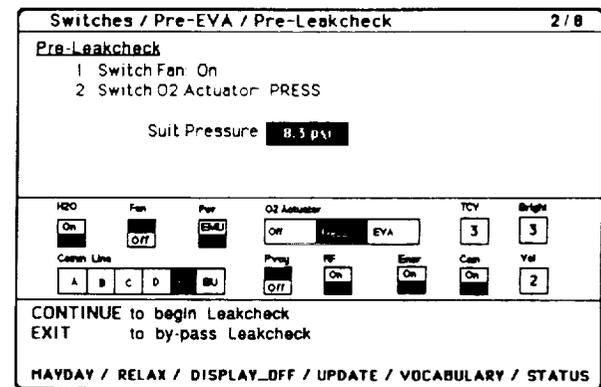


Figure 3. Pre-EVA Checklist

- (2) Following the systems status check (and if OK), the first page of the pre-EVA file is shown (see Figure 3). The crewmember is directed to turn the EMU fan on and then to

pressurize the suit. To activate the fan, the crewmember simply says "FAN ON." The FAN block in the middle field will then toggle position. In a similar fashion, the suit is pressurized by first selecting "O2 ACTUATOR" followed by "PRESS." After the suit is fully pressurized, the next page, suit leak check, will be shown.

(3) A leak check (to determine suit integrity) is performed automatically in the simulation. During the leak check simulation, a status of the check including time left, suit pressure, and O2 actuator positions are displayed (See Figure 4). The leak check may be aborted in progress by saying "EXIT." An aborted leak check may be either restarted ("ACKNOWLEDGE") or by-passed entirely ("CONTINUE"). An un-aborted leak check with positive results is shown in Figure 5. (Note that a second test, if desired, can be conducted by saying "ACKNOWLEDGE.")

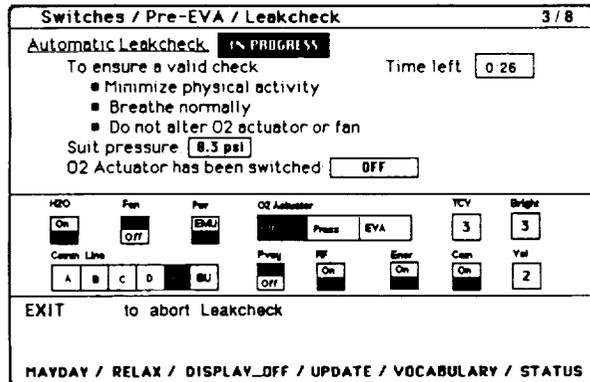


Figure 4. Pre-EVA Leak Check (in-progress)

(4) By saying "CONTINUE," the crewmember will proceed to the Airlock Depress Checklist, a series of procedures to depressurize the airlock to vacuum (see Figure 6). Note the use of graphics. (A "GO BACK" command at this point will display Figure 5, but will *not* redo the actual check unless the previous leak check was aborted or was not satisfactory.) By saying "CONTINUE" again, the crewmember will enter the second page of the checklist (see Figure 7). Note that airlock

pressure is located within the checklist step requiring the monitoring.

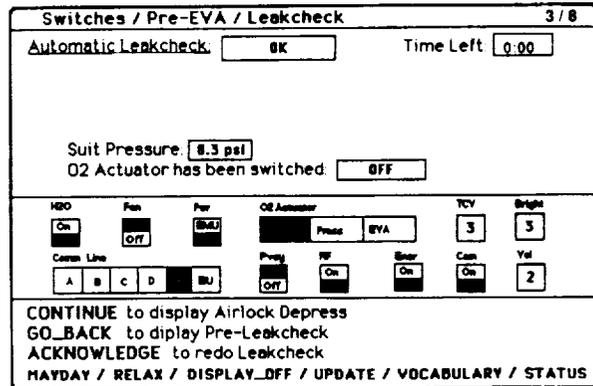


Figure 5. Pre-EVA Leak Check (completed)

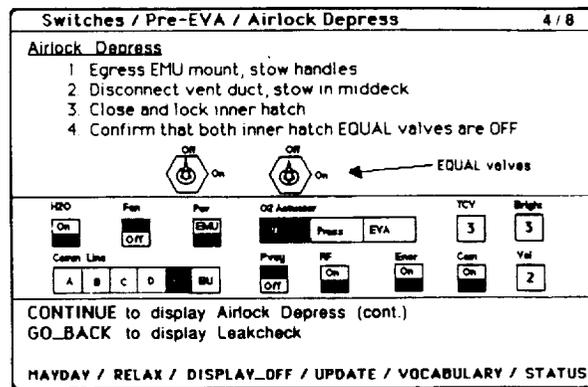


Figure 6. Airlock Depress Checklist (page 1)

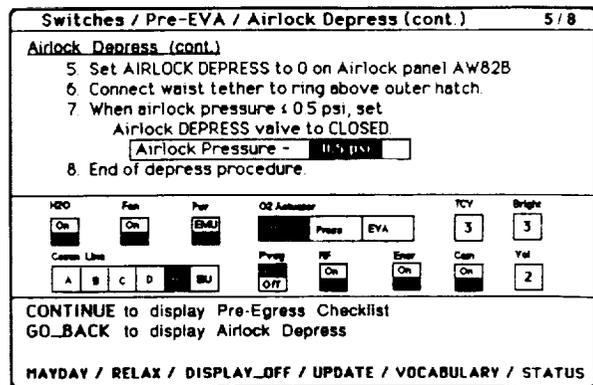


Figure 7. Airlock Depress Checklist (page 2)

(5) Once the simulated depressurization to vacuum is accomplished, the crewmember will "CONTINUE" to the Pre-Egress Checklist (see Figure 8). (Note that the crewmember may switch several controls with a single voice command.) Once he has completed this checklist, he will "CONTINUE" to the Egress Checklist (Figure 9). The Pre-Egress and Egress procedures lead the crewmember safely out of the airlock to perform the actual EVA. After the final page of this checklist has been read, an "EXIT" command will display the Normal EMU Status page for use during the EVA.

## EVA

The actual EVA, by definition, begins when the crewmember leaves the airlock. This begins the operational portion of the astronaut's venture. Nearly all of the HMD's functions are available to the EVA crewmember at this time. During this period, the EVA astronaut may view EMU status information, access general EVA operational information, control EMU switches by voice, monitor transmissions from the astronaut's personal TV camera, and obtain data directly from the Space Station's main computers via radio link. The simulated functions are described below along with a description of other available functions.

*EMU Status* - The EMU Status file is the base state of the simulation program. Each page is split into two fields (excluding the header) as shown in Figure 10. The top field displays specific EMU parameters and consumable values in two formats: on a quick-read bar graph format and actual (or calculated) values. This method allows the astronaut to quickly and accurately assess the performance of the EMU. The lower field lists valid available functions.

Switches / Pre-EVA / Pre-Egress						7 / 8
<b>Pre-Egress Checklist</b>						
Note: "Acknowledge" selects all of the following at once						
1 Switch H2O On						
2 Switch PWR: EMU						
3 Switch Comm Line A						
4 Switch O2 Actuator EVA						
5 Switch RF ON						
H2O	Fan	Pwr	O2 Actuator	TCV	Bright	
<input type="checkbox"/> Off	<input type="checkbox"/> Off	<input checked="" type="checkbox"/> ECU	<input type="checkbox"/> Off <input type="checkbox"/> Press	<input type="checkbox"/> 3	<input type="checkbox"/> 3	
Comm Line			Prvay	RF	Emar	Can
<input type="checkbox"/> B <input type="checkbox"/> C <input type="checkbox"/> D <input type="checkbox"/> HL <input type="checkbox"/> BU			<input type="checkbox"/> Off	<input type="checkbox"/> Off	<input type="checkbox"/> On	<input type="checkbox"/> On
ACKNOWLEDGE to select all settings						
CONTINUE to display Pre-Egress checklist (cont.)						
GO_BACK to display Airlock Depress (cont.)						
MAYDAY / RELAX / DISPLAY_OFF / UPDATE / VOCABULARY / STATUS						

Figure 8. Pre-Egress Checklist

Switches / Pre-EVA / Airlock Egress Checklist						8 / 8
<b>EV1</b>						
1. Egress the airlock.						
2. Right waist tethers (both) attach to reel						
3. Reels - remove from containers and unlock						
<b>EV2</b>						
4. Left waist tethers (both) - unhook and attach to crew						
<b>Both</b>						
5. Egress the airlock						
6. Tether line - Unsnap strap and release slidewire cover						
7. Pre-EVA procedure complete.						
H2O	Fan	Pwr	O2 Actuator	TCV	Bright	
<input type="checkbox"/> Off	<input type="checkbox"/> Off	<input checked="" type="checkbox"/> ECU	<input type="checkbox"/> Off <input type="checkbox"/> Press	<input type="checkbox"/> 3	<input type="checkbox"/> 3	
Comm Line			Prvay	RF	Emar	Can
<input type="checkbox"/> B <input type="checkbox"/> C <input type="checkbox"/> D <input type="checkbox"/> HL <input type="checkbox"/> BU			<input type="checkbox"/> Off	<input type="checkbox"/> Off	<input type="checkbox"/> On	<input type="checkbox"/> On
CONTINUE to quit Pre-EVA and display EVA Status						
GO_BACK to display Pre-Egress Checklist						
MAYDAY / RELAX / DISPLAY_OFF / UPDATE / VOCABULARY / STATUS						

Figure 9. Egress Checklist

It should be noted that during the pre-EVA simulation (as will be in the flight system) other functions which include display on/off and brightness controls, for example, will be available to the user.

Status		1 / 3															
8.2	Suit Pressure	<table border="1"> <tr> <td>Warning</td> <td>Caution</td> <td>Norm</td> <td>Caution</td> <td>Warning</td> </tr> <tr> <td>Low</td> <td>Low</td> <td></td> <td>High</td> <td>High</td> </tr> <tr> <td colspan="5"> </td> </tr> </table>	Warning	Caution	Norm	Caution	Warning	Low	Low		High	High					
Warning	Caution		Norm	Caution	Warning												
Low	Low			High	High												
4295.0	Prim O2 Pressure																
0.3	CO2 Level																
29.3	DC Stack Voltage																
4.5	DC Stack Ampe																
2840.0	Fan RPM																
97.5	% Limiting Consumable	<table border="1"> <tr> <td>0%</td> <td>50%</td> <td>100%</td> </tr> <tr> <td colspan="3"> </td> </tr> </table>	0%	50%	100%												
0%	50%	100%															
Oxygen		Time EVA: 0:01:00    Time Left: 6:58:52															
CONTINUE/GO_BACK to view other Status pages EXIT to go to Post-EVA file CAMERA/CHECKLIST/DISPLAY_OFF/MAINTENANCE/MAYDAY/ RELAX/SWITCHES/UPDATE/UPLINK/VOCABULARY																	

Figure 10. Normal EVA Status

*EVA Operational Information* - This subroutine allows the astronaut to select and read various data files from a main menu by voice commands. By saying "MAINTENANCE," the user obtains the menu as shown in Figure 11. This file and the "CHECKLIST" file

provide information about maintenance procedures, equipment operation, and contingency or troubleshooting flow charts, among other information subfiles in text and graphical formats. Once accessed, the user may page back and forth through the file. As an example, if "THREE" were selected, the crewmember would retrieve the "PAM Large Sunshield" file, which details a procedure for installing "sunglasses" on the Space Shuttle's windows. Page one of the "PAM Large Sunshield" file lists the tools the EVA crewmember must collect to perform the job (see Figure 12). From here, the astronaut may "CONTINUE" to obtain the next page of information. An "EXIT" within a file would bring the user back to the main menu. Another "EXIT" would bring the user to the base state, the first Status page.

*EMU Switch Manipulation* - (This procedure is identical to that described in the pre-EVA section.)

*EMU Camera Monitoring* - Shuttle EVA astronauts are not capable of monitoring TV cameras. They depend on ground or Shuttle communication for feedback on pointing the camera. On the other hand, with the Station EMU, an astronaut can say "CAMERA" and receive live video from his TV camera directly on his HMD. Currently the simulation program only displays still graphics to the user. An enhancement to the simulation program will soon be added to allow the crewmember to move and position a camera by voice.

*Accessing Information From The Station* - From the Station's central computer, the EVA astronaut may receive unlimited amounts of information via a radio frequency link to the crewmember. This information, in the form of files, will be accessed by the EVA crewmember much like the operational information described above. These files may have been produced prior to launch, prior to the EVA by that astronaut, or by someone on the ground to be transmitted, real-time, to an EVA astronaut. A procedure to simulate this function is currently being developed.

Maintenance / Main Menu		1 / 1
1	Trash Disposal	(ONE)
2	Standard Sunshield Manual Opening	(TWO)
3	PAM Large Sunshield	(THREE)
4	MMU Donning Procedure	(FOUR)
ONE-FOUR to select file EXIT to return to status		
MAYDAY / RELAX / CLEAR DISPLAY		

Figure 11. EMU Maintenance File

Maintenance / PAM Large Sunshield / Tools		1 / 2
Tool box		
1.	Probe & hammer	
2.	Trash container	
3.	3/8" drive ratchet	
4.	Adj wrist tether	
5.	Cable cutters	
Airlock		
1.	IFM tool (7/16")	
2.	PAM tool (Spreader)	
3.	IFM driver handle with 3/8" socket	
CONTINUE to display next page EXIT to return to main menu		
MAYDAY / RELAX / CLEAR DISPLAY		

Figure 12. PAM Large Sunfield File

*Other Functions* - Other functions are also available to the crewmember while receipt of alarms with corrective action, notifying Station astronauts of anomalous conditions (which includes an option for sending them EMU transmitted data), a complete recognizer vocabulary menu, and updating voice templates by voice.

*Post-EVA* - To complete the EVA, the astronaut enters the airlock and connects his umbilical line to the EMU. Post-EVA instructions are provided to the crewmember via the HMD and are basically a reverse sequence of the pre-EVA set of events, concluding with a power-down and doff of the EMU.

## *CONCLUSION*

Both voice recognition and helmet-mounted display technologies can improve the productivity of workers in space by potentially reducing the time, risk, and cost involved in performing manned extravehicular activity. NASA has recognized this potential and is currently developing a voice-controlled information system for Space Station EVA. Two bench-model helmet-mounted displays and an EVA simulation program have been developed to demonstrate the functionality and practicality of the system.