History of Rocketry and Astronautics

Proceedings of the Fifteenth and Sixteenth
History Symposia of the International Academy of Astronautics

Rome, Italy, 1981
Paris, France, 1982

Roger D. Launius, Volume Editor

R. Cargill Hall, Series Editor

AAS History Series, Volume 11

A Supplement to Advances in the Astronautical Sciences

IAA History Symposia, Volume 6

AAS Publications Office
P.O. Box 28130
San Diego, California 92198

Affiliated with the American Association for the Advancement of Science
Member of the International Astronautical Federation

First Printing 1994

ISSN 0730-3564

ISBN 0-87703-382-X (Hard Cover)
ISBN 0-87703-383-8 (Soft Cover)

Published for the American Astronautical Society
by Univelt, Incorporated, P.O. Box 28130, San Diego, California 92198

Printed and Bound in the U.S.A.

Chapter 12

The History of Extravehicular Activity (EVA) in U.S. Human Spaceflight[1]

R. Scott Millican[2]

The history of extravehicular activity (EVA) in U.S. human space flight goes back to the early 1960s. It has become a major part of American activities, and perhaps Lunar surface exploration would not have been practical without the astronaut's capability to leave the spacecraft to retrieve lunar samples, deploy experiments, and make on-the-spot observations, judgments, and decisions relative to acquiring scientific data. EVA capability was further demonstrated during the Skylab Program when several major space station repairs were accomplished by EVA astronauts. These repairs allowed mission continuation and were considered the major factor in successful completion of the Skylab program objectives. EVA is now such a vital and integral part of U.S. manned space flight that most advanced spacecraft and space station studies include EVA capability for routine maintenance, construction, and servicing tasks.

Requirements for EVA

Although early requirements for EVA seemed to be associated with expanding humanity's general capability to work in space, the primary objective was to develop and demonstrate EVA systems and operations for eventual lunar exploration. In 1959, NASA's Ten Year Plan projected manned lunar flights no earlier than the 1970s. On 25

---

[1] Presented at the Fifteenth History Symposium of the International Academy of Astronautics, Rome, Italy, 1981.

[2] Scott Science and Technology, Houston, Texas, U.S.A.

May 1961, however, President John F. Kennedy committed the United States to landing an American on the Moon before the end of the decade. This objective resulted in the requirement for a much earlier development of EVA capability than had been expected.

Project Mercury was just beginning as Alan B. Shepard made the first suborbital flight on 6 May 1961. A "Mark II" version of the Mercury capsule came under immediate development to bridge the gap between the one-person capsule and a three-person lunar spacecraft, already on the drawing boards. This two-person spacecraft was required to support the development of rendezvous and docking, in addition to other requirements, such as EVA.

Early Leaders in EVA Development

In 1958 NASA established a Space Task Group at Langley Laboratory, Hampton Roads, Virginia, to put an American in space. Robert Gilruth, who had spent years as an engineer with NASA's immediate predecessor, the National Advisory Committee for Aeronautics, headed this organization, and by mid-1959 three divisions had been formalized. Maxime Faget was leader of the Flight Systems Division, Charles Mathews managed the Operations Division, and James Chamberlin led the Engineering and Contracts Division. Although primarily charged with developing the Mercury Program, in 1961 this group moved into what was later called Project Gemini, when it was determined that an improved Mercury capsule was needed.

Chamberlin took the early lead in managing the upgraded design effort which the contractor, McDonnell Aircraft, was supporting. The Mercury spacecraft required new operational features to support EVA, such as more volume, an egress hatch, and a second pilot capability. Since it was apparent that the Mercury had to be redesigned, Max Faget requested that John Yardley, McDonnell's manager for Mercury operations at Cape Canaveral, look into the possibility of a two-person spacecraft for the purpose of supporting EVA, in addition to other reasons. This occurred in March 1961. The requirement became almost imperative when the President made his Moon landing commitment in May. Chamberlin then pursued the Mercury Mark II two-person version with considerable effort, and NASA's head of Space Flight Programs, Abe Silvertein, endorsed the design by mid-year.

Several years passed as the Mercury Program was completed and two unmanned Gemini flights were conducted before serious EVA talks arose. The Soviets had performed the first EVA during the *Voskhod 2* mission on 18 March 1965. With the first Gemini manned flight scheduled for 23 March of the same year, the Americans would have to settle for an EVA on *Gemini 4*, scheduled for June 1965, to stay in the "space race." Had it not been for *Gemini 4* astronauts pressing for early delivery of EVA spacesuits, the opportunity for EVA would have been delayed until later in the Gemini program. Gilruth, by then director of the newly created Manned Spacecraft Center at Houston, Texas, convinced NASA Administrator, James Webb, that the crew was trained and all EVA hardware was qualified, including a hand-held maneuvering unit (HHMU). On 25 May 1965, the press was notified that Edward H. White II would become the first American astronaut to walk in space.

The Gemini Experience

EVA was performed on five of the ten piloted Gemini missions. The apparent successful EVA by Ed White on *Gemini 4* was quite dramatic as colorful EVA photos were returned from this flight (Figure 1). For one-half hour, White floated around with no disorientation attached to a life-support umbilical, and he successfully operated an HHMU. Two problems arose in this first experience with EVA. First, the heat removal capability of the EVA life-support unit was insufficient to handle the body heat generated by the astronaut's exertion, and White became too hot inside the suit. This had to be dealt with in a redesign of the spacesuit. The astronauts also had difficulty closing the hatch. This was an especially important problem because if the hatch could not be resecured, the astronauts could not return safely to Earth. They jostled and muscled the hatch closed, and it, too, had to be modified for future flights. The next EVA, scheduled for *Gemini 8*, was to evaluate a new life-support system and a backpack mounted Astronaut Maneuvering Unit. Due to a spacecraft problem resulting in early mission termination, however, Dave Scott was unable to perform the EVA.

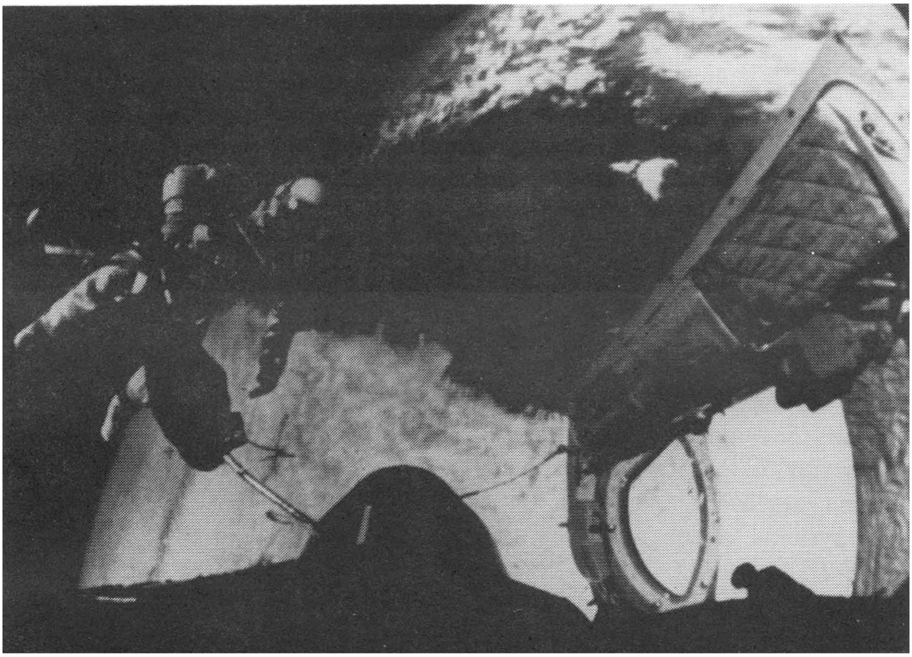

Figure 1 Edward H. White II is shown performing his *Gemini 4* EVA during the third orbit. White floats into space, secured to the 25-ft umbilical line and a 23-ft tether line, both wrapped together with gold tape to form one cord. White became the first American astronaut to egress his spacecraft while in orbit. He remained outside the spacecraft for a total of 21 minutes. White wears a specially designed space suit for his EVA. He is holding a Hand-Held Self-Maneuvering Unit which he used to move about in the weightless environment. White and the GT-4 command pilot, James A. McDivitt, performed other scientific and engineering experiments before completing their 62 revolution mission and returning safely to Earth (NASA Photo No. 65-H-1024).

The EVAs that took place on the flights of *Gemini 9* and *11* saw a replay of basically the same problems as White had encountered on *Gemini 4*. Both Gene Cernan and Dick Gordon became overworked due to inadequate heat venting in the suits. The life-support system was not capable of removing the high heat loads as helmets fogged and sweat ran into their eyes causing early EVA termination. *Gemini 10*, however, flown between these missions, produced more favorable results. Mike Collins successfully used an HHMU and retrieved an experiment from a docking target vehicle. The EVA was planned for only one daylight pass but was shortened due to a spacecraft problem to only 39 minutes.

In spite of these earlier efforts, prior to *Gemini 12* NASA still had not successfully demonstrated the operational capability of EVA to satisfy the lunar landing commitment. The training for the final EVA concentrated on short tasks with rest breaks, improved foot restraints, and brought about EVA end-to-end underwater crew training. These features, along with more disciplined, well-organized EVA pre-egress procedures, led to a totally successful *Gemini 12* EVA performed by Buzz Aldrin.

Adequate simulation of the EVA environment, proper foot restraints, and sizing the life-support system for greater heat dissipation were major lessons learned during Gemini. By the conclusion of the Gemini program EVA was considered an operational capability of U.S. human spaceflight.

Apollo

Of the four piloted Apollo test flights, only one EVA evaluation was conducted. With the Lunar Module and Command Module docked, *Apollo 9* astronauts depressurized both spacecraft to demonstrate a contingency EVA transfer procedure in the event of a blocked tunnel passageway. Astronaut Rusty Scheickart, wearing a new spacesuit and portable life-support system, egressed the Lunar Module and, using foot restraints and hand rails developed on Gemini, successfully moved to the Command Module. Dave Scott waited in the opened Command Module hatch during his standup EVA.

All lunar surface EVAs were very successful. *Apollo 11*, *12*, and *14* backpack life-support systems, attached to the A7L spacesuit, provided four to five hours EVA time (Figure 2). *Apollo 15*, *16*, and *17* missions utilized a life-support system providing seven to eight hours EVA time. An improved spacesuit, the A7LB, also allowed more waist mobility, making it possible for astronauts to ride the Lunar Rover in a sitting position during these missions (Figure 3).

The last three flights also required EVA during the return to Earth phase, in order to retrieve film from a lunar surface mapping camera located in the service module (Figure 4). An umbilical cord attached to the spacecraft was used for life-support.

Zero-gravity EVA training was conducted using, primarily, underwater facilities for simulation, while lunar surface training was effectively accomplished by one-gravity walk-throughs. The Apollo Program was designed specifically with EVA as a primary requirement for mission success. All aspects of EVA operations performed well, including life-support equipment, procedures, real-time systems monitoring inflight and on the ground, EVA support equipment, and training.

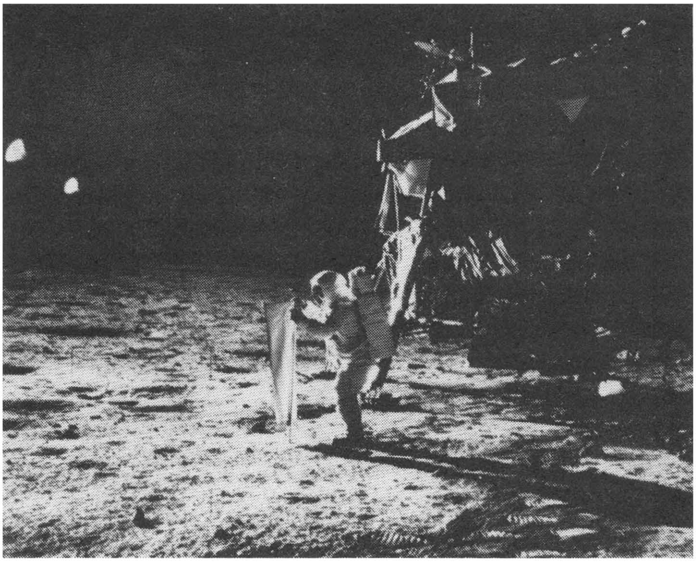

Figure 2 *Apollo 11* EVA. Neil A. Armstrong, Michael Collins and Buzz Aldrin were launched to the Moon by a Saturn V launch vehicle 9:32 a.m. EDT July 16, 1969 from Complex 39A, Cape Kennedy, Florida. Armstrong and Aldrin landed on the Moon on July 20, 1969 and, after take-off from the Moon on July 21, joined Collins in the Command Module circling the Moon. The astronauts splashed down in the Pacific Ocean and recovery was made by the U.S.S. *Hornet* at 12:50 p.m. EDT July 24, 1969 (NASA Photo Nos. 69-HC-695, 69-H-1266, AS11-40-5872).

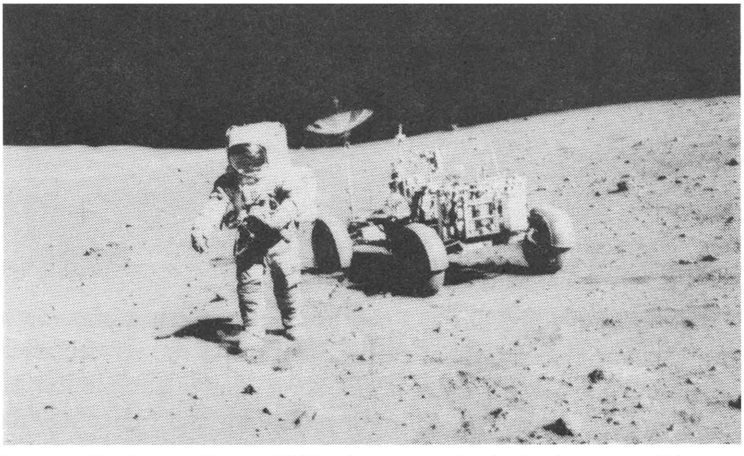

Figure 3 Apollo Lunar Rover EVA. Astronaut Irwin is shown walking away from the Rover which is parked near the edge of Hadley Rille, far wall of the rille is in the distance at extreme upper left. *Apollo 15* was launched July 26, 1971 at 9:34 a.m. EDT and touched down at the Hadley-Apennine site at 6:16 p.m. EDT, July 30—staying a total time of 66 hours and 55 minutes. Splashdown in the Pacific Ocean was on August 7 at 4:46 p.m. EDT. Astronaut Alfred Worden was the command module pilot, James Irwin, lunar module pilot and David Scott, commander (NASA Photo Nos. 71-H-1418, AS15-82-11168).

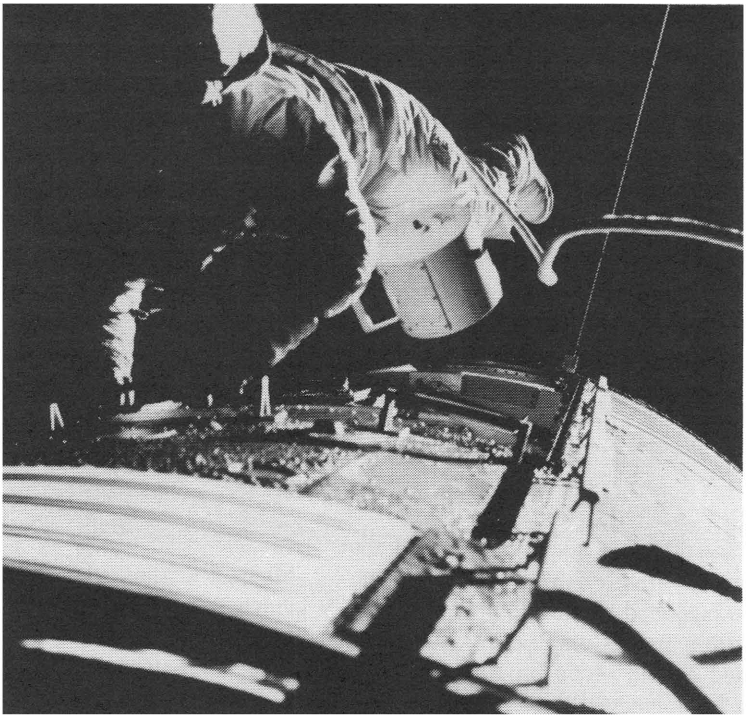

Figure 4 *Apollo 17* astronaut Ronald E. Evans as he performs an EVA—retrieving film canisters from the Lunar Mapping Camera and Panoramic Camera during the *Apollo 17* spacecraft's trans-Earth coast. The cylindrical object at Evans' left side is the Mapping Camera cassette. The total time for the trans-Earth EVA was one hour seven minutes 18 seconds, starting at ground elapsed time of 257:25 (2:28 p.m.) and ending at ground elapsed time of 258:42 (3:35 p.m.) on Sunday, December 17, 1972 (NASA Photo Nos. 72-HC-925, 72-H-1574, AS17-152-23391).

Skylab

For the Skylab Orbital Laboratory, EVA became not just a planned mode for acquiring scientific data but also a critical skill in activating the spacecraft after damage during launch. Planning for Skylab EVA began shortly after completion of the Gemini Program; it was emphasized as a technique for retrieving and replacing film from solar observation cameras. Four complete changeouts of film canisters were to be included in six 2-1/2 EVA periods.

In addition to the successful film operations, major repair activities were undertaken on each of the three Skylab missions. A total of 10 EVAs were actually performed, for a total of over 82 hours, two-thirds more than planned. Eighteen new mission objectives and 13 inflight repair tasks were added to the originally planned EVA requirements, and all were accomplished. Three significant EVA repairs prevented mission termination; these included manual deployment of a solar array panel, covering a portion of the Orbital Workshop with a reflective heat shield, and replacement of a rate gyro processor (Figure 5).

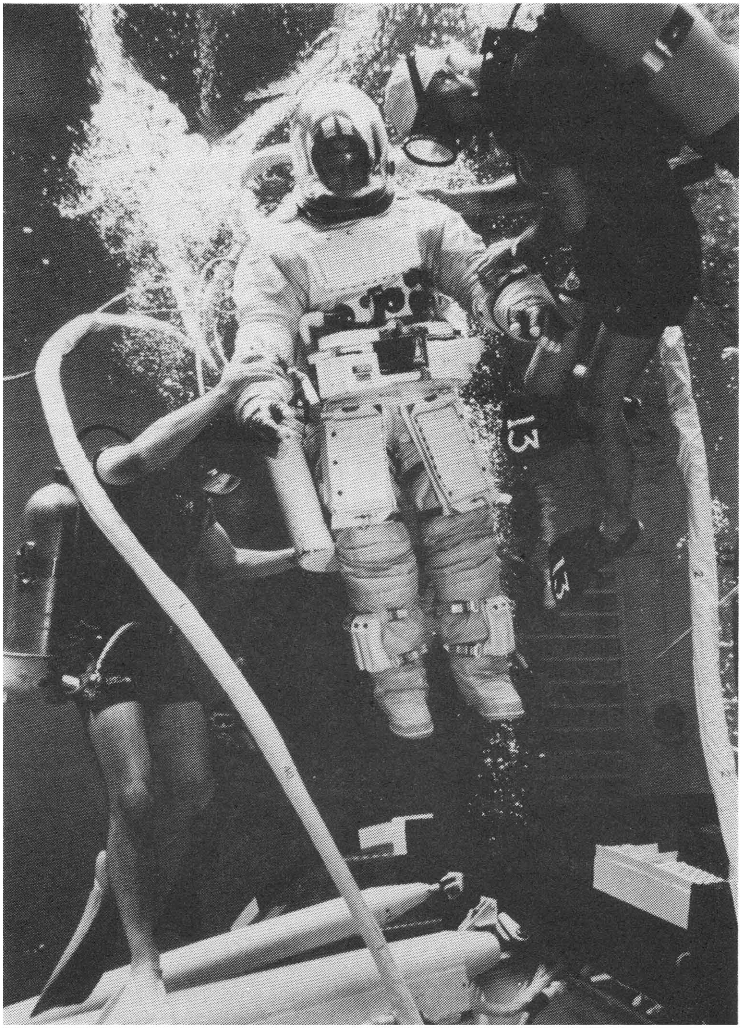

Figure 5 Two astronauts selected for the Skylab mission are assisted by scuba divers during an Neutral Buoyancy Simulator (NBS) test for Skylab EVA training. During the three manned missions of the Skylab program, a number of EVAs were necessary to install and retrieve ATM film and experiment D024. The NBS at Marshall Space Flight Center had an important role during the design phase of the Skylab systems, and is presently being used effectively to simulate EVA maneuvers. The purpose of underwater Skylab EVA simulation was twofold: (1) to provide time-motion data for updating and finalizing the crew EVA checklists; (2) to train the crew for the actual EVAs by running them fully pressure-suited through simulated zero-g EVA maneuvers on a second-by-second basis using preliminary and actual flight check-lists (NASA Photo Nos. 72-H-1093, 72-HC-607).

Maximum use of humanity's adaptability in space was demonstrated by including basic EVA provisions. Since all Skylab astronauts had received extensive EVA underwater training for planned film changeout tasks, new real-time EVA requirements presented no major difficulties, if adequate translation aids and foot restraints could be provided. All new tasks were evaluated in a large water tank, which contained a full scale model of the Skylab Workshop where EVA operations were performed. Common hand tools and special application tools were frequently used.

The life-support system was a new design and relied on a 60-foot umbilical to supply needed consumables from the spacecraft to the belly mounted pressure control unit which was attached to the A7LB spacesuit. A secondary oxygen pack provided a 30-minute emergency reserve and was attached to the leg.

Space Shuttle

EVA during the Space Shuttle era may become as common as space flight itself. Every flight will have two qualified EVA crewmen. Accommodations include a new spacesuit and an integral backpack life-support system capable of fitting a wide range of male and female crew members. Flood lights and a TV camera are built into the helmet (Figure 6). Also available are standard EVA hand tools, portable foot restraints, and a Manned Maneuvering Unit. The MMU is a propulsive backpack device which will allow the crewman to translate to areas beyond the cargo bay. It has six-degree-of-freedom control authority and an automatic attitude-hold capability. Range will be up to 100 meters or more.

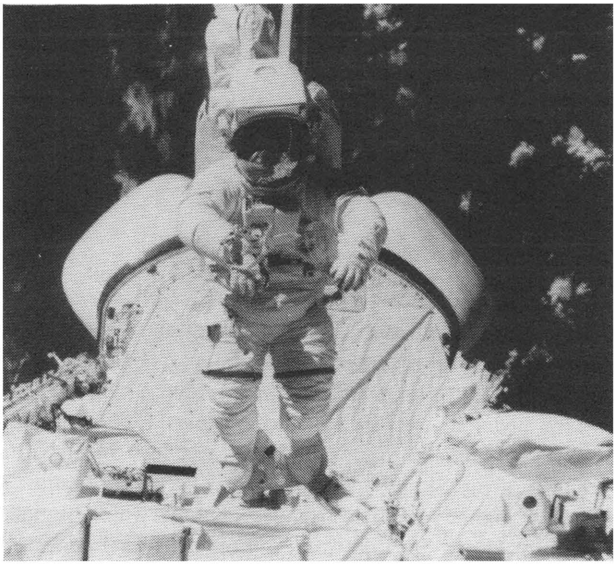

Figure 6 Space Shuttle EVA. Bruce McCandless II, on February 7, 1984 used the combination of the Remote Manipulator System (RMS) arm and the Mobile Foot Restraint (MFR) to experiment with a "Cherry-Picker" concept (NASA Photo Nos. 84-HC-96, 84-H-93, 584-27039).

The astronauts on the first Shuttle flight were trained for several potential contingency operations. Simple EVA features have been designed into the payload bay doors to allow manual, backup door closing by an EVA crewman. A thermal tile EVA repair capability was under development for the first flight but was not carried. It included a uniquely designed work restraint unit that could be secured to the spacecraft exterior by a crewman flying the MMU (Figure 7). Carrying tools, repair materials, and foot restraints, it could be moved from one location to another.

Various studies have shown that use of EVA in payload systems design can enhance operational success for tasks such as deployment, retrieval, and maintenance, as well as for correcting malfunctions. Experienced EVA operations personnel participating in early STS payload design activities can assist in achieving simple, cost effective operational concepts.

Current studies being conducted by NASA on permanent space stations include EVA for construction of large structures and for satellite servicing. History has shown that maximum space flight operational flexibility is achieved when EVA capability is provided.

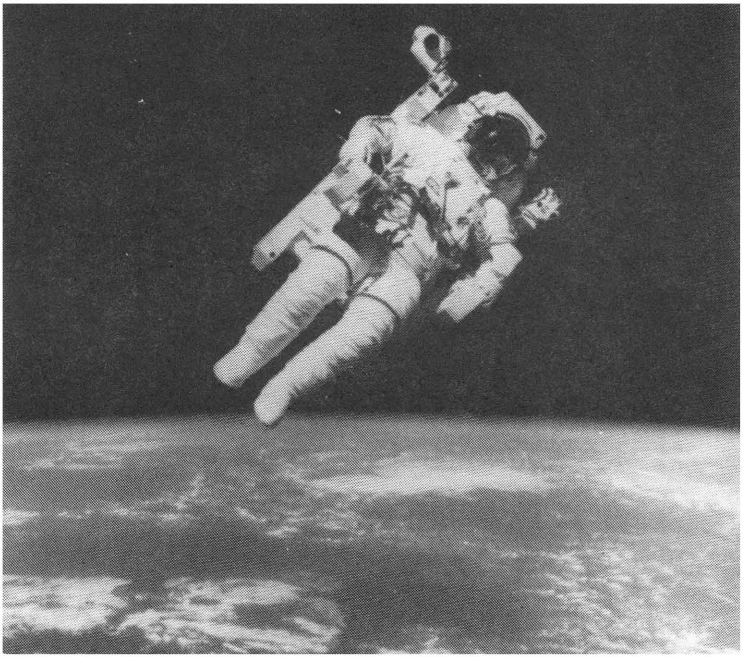

Figure 7 Space Shuttle Manned Maneuvering Unit. On February 8, 1984, Bruce McCandless II, one of two 41-B mission specialists, participated in an historical EVA. He is shown a few meters away from the cabin of the Earth-orbiting Space Shuttle *Challenger* in this 70 mm frame. This spacewalk represented the first use of a nitrogen-propelled, hand-controlled device called the Manned Maneuvering Unit (MMU), which allows for much greater mobility than that afforded previous space-walkers who had to use restrictive tethers. Robert L. Stewart, tested another similar unit two days later. Inside the spacecraft were Astronauts Vance D. Brand, commander; Robert L. Gibson pilot; and Ronald E. McNair, mission specialist (NASA Photo Nos. 84-HC-74, 84-H-71).

Table 1

EVA EXPERIENCE SUMMARY

MISSION DATE	EVA NO. / CREWMAN	EVA TIME			OBJECTIVE	REMARKS
		TYPE	TIME	CUM		
Gemini IV June 1965	1/White	UMB	:36	:36	Prove EVA feasibility; maneuver with Hand Held Maneuvering Unit (HHMU)	EVA worked as planned, including HHMU.
Gemini VIII March 1966	1/Scott	-	-	- :36	Evaluate new self-contained life support system and freefly HHMU.	Mission aborted prior to EVA.
Gemini IX June 1966	1/Cernan	UMB	2:07	2:43	Evaluate new life support system; fly new Astronaut Maneuvering Unit; retrieve experiment	High workload and helmet fogging caused early termination. Maneuvering Unit not used.
Gemini X July 1966	1/Collins 2/Collins	STUP UMB	:50 :39	4:12	EVA familiarzation; retrieve experiment evaluate HHMU, photography.	First transfer of tethered crewman between undocked vehicles.
Gemini XI September 1966	1/Gordon 2/Gordon	STUP UMB	2:10 :33	6:55	Perform simple work tasks, evaluate HHMU, photography.	High workload led to early EVA termination. Standup EVA provided familiarization.
Gemini XII Nov. 1966	1/Aldrin 2/Aldrin	STUP UMB	3:24 2:06	12:25	Evaluate matrix of simple tasks, evaluate translation and restraint aids, photography.	Underwater training led to first tangible results of EVA capabilities.
Apollo 9 March 1969	1/Schweickart Scott	Free STUP	:47 :47	13:59	Demonstrate LM to CM transfer capability, demonstrate adequacy of Apollo EVA equipment and procedures.	All objectives satisfied.

Table 1

EVA EXPERIENCE SUMMARY (CONTINUED)

MISSION DATE	EVA NO. / CREWMAN	EVA TIME			OBJECTIVE	REMARKS
		TYPE	TIME	CUM		
Apollo 11 July 1969	1/ Armstrong Aldrin	Free Free	2:48 2:48	19:35	Demonstrate lunar surface EVA capability, gather lunar samples.	All objectives satisfied.
Apollo 12 Nov. 1969	1/Conrad Bean 2/same	Free Free Free	4:00 4:00 3:46 3:46	35:07	Deploy experiment hardware, retrieve lunar samles, retrieve samples from Surveyor spacecraft.	All objectives satisfied.
Apollo 13 April 1970	1/Lovell Haise 2/same	- -	- -	35:07	Deploy scientific equipment, collect lunar samples.	Mission aborted prior to EVA.
Apollo 14 Jan. 1971	1/ Shephard Mitchell 2/same	Free Free Free	4:48 4:48 4:35 4:35	53:53	Deploy scientific equipment, collect lunar samples.	All objectives satisfied.
Apollo 15 July 1971	1/Scott 2/Scott Irwin 3/same 4/same 5/Worden Irwin	STUP Free Free Free Free UMB STUP	:33 6:33 6:33 7:12 7:12 4:50 4:50 :38 :38	92:52	Deploy scientific equipment, collect lunar samples, retrieve film from CSM SIM Bay during transearth coast.	All objectives satisfied. Modified LM and EVA equipment allowed longer stay time and EVA time. First use of lunar rover. Only standup EVA from LM during Apollo.
Apollo 16 April 1972	1/Young Duke 2/same 3/same 4/ Mattingly Duke	Free Free Free Free UMB STUP	7:11 7:11 7:23 7:23 5:40 5:40 1:23 1:23	136:06	Deploy scientific equipment, collect lunar samples, retrieve film from CSM SIM Bay.	All objectives Satisfied.
Apollo 17 Dec. 1972	1/Cernan Schmitt 2/same 3/same 4/Evans Schmitt	Free Free Free Free UMB STUP	7:12 7:12 7:37 7:37 7:15 7:15 1:06 1:06	182:26	Deploy scientific equipment, collect lunar samples, retrieve film from CSM SIM Bay.	All objectives satisfied.

Table 1
EVA EXPERIENCE SUMMARY (CONTINUED)

MISSION DATE	EVA NO./CREWMAN	EVA TIME TYPE	EVA TIME TIME	EVA TIME CUM	OBJECTIVES	REMARKS
Skylab 2 May 1973	1/Weitz	STUP	:35		Attempt to free solar array system for full deployment.	Task unsuccessful during standup EVA from CM.
	2/Conrad	UMB	1:36		Deploy OWS solar array system.	Task successful most significant contingency EVA to date.
	Kerwin		1:36			
	3/same	UMB	3:23		Retrieve and install film cannisters.	Film changeout successful. Also repair one camera and an electrical current regulator.
		UMB	3:23	192:59		
Skylab 3 July 1973	1/Lousma	UMB	6:31		Deploy twin pole sunshade (contingency operation), install film cannisters. Repair camera. Deploy experiment.	All tasks successful.
	Garriott	UMB	6:31			
	2/same	UMB	4:30		Replace film, repair two cameras and rate gyroscopes.	All tasks successful.
		UMB	4:30			
	3/Beam	UMB	2:41		Retrieve film, repair one camera, retrieve samples.	All tasks successful.
	Garriott	UMB	2:41	220:23		
Skylab 4 Nov. 1973	1/Gibson	UMB	6:34		Install film, repair one camera, operate experiment, install another experiment, deploy samples, repair experiment pointing antenna.	All tasks successful.
	Pogue	UMB	6:34			
	2/Carr	UMB	6:53		Replace film, retrieve experiment repair two cameras, operate several experiments.	All tasks successful.
	Pogue	UMB	6:53			
	3/Carr	UMB	3:29		Retrieve samples, operate several experiments, measure experiment temperature.	All tasks successful.
	Gibson	UMB	3:29			
	4/Carr	UMB	5:19		Retrieve film, operate experiment, retrieve experiments	All tasks successful.
	Gibson	UMB	5:19	264:53		

Bibliography

Bland, Daniel A., *Space Shuttle EVA Opportunities*. Houston, TX: Johnson Space Center, JSC-11391, 1976.

Covington, J. H., and Millican R. S., *Apollo EVA Postflight Report*, Internal Johnson Space Center Memorandums, 1962-1972, Houston, TX.

Hacker, Barton C., and Greenwood, James M., *On the Shoulders of Titans: A History of the Gemini Project*. Washington, D.C.: National Aeronautics and Space Administration, 1977.

Machell, R. M., editor. *Summary of Gemini Extravehicular Activity*. Washington, D.C.: National Aeronautics and Space Administration, NASA SP-149, 1967.

Schultz, D. C., *Extravehicular Activity Experience in Manned Space Operations*, NASA General Working Paper, MSC-05878, 1970.

Schultz, D. C., Kain, R. R., and Millican, R. S., "Skylab Extravehicular Activity," *Advances in the Astronautical Sciences* (The Skylab Results), Vol. 31, Part I, American Astronautical Society, AAS 74-120, 1975.