NASA TECHNICAL NOTE

NASA TN D-3291

NASA TN D-3291

LOAN COPY: RETUR
AFWL (WLIL-2)
KIRTLAND AFB, N M
0079781
TECH LIBRARY KAFB, NM

SPACE SUIT DEVELOPMENT STATUS

by Richard S. Johnston, James V. Correale, and Matthew I. Radnofsky

Manned Spacecraft Center
Houston, Texas

RECEIVED
7 MAR 1966
Technical Library
AF Weapons Laboratory

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • FEBRUARY 1966

TECH LIBRARY KAFB, NM
0079781
NASA TN D-3291

SPACE SUIT DEVELOPMENT STATUS

By Richard S. Johnston, James V. Correale,
and Matthew I. Radnofsky

Manned Spacecraft Center
Houston, Texas

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

For sale by the Clearinghouse for Federal Scientific and Technical Information
Springfield, Virginia 22151 – Price $1.00

ABSTRACT

Space suit development, starting with the Mercury program, has progressed to its present status as a result of the changing goals of each manned spacecraft mission. The first space suits were designed primarily for protection of flight crews against the possibility of cabin pressure failure. Longer flights and extravehicular activities required design philosophies to change drastically, particularly in the areas of comfort, mobility, reliability, and life-sustaining systems. Future mission goals will require new design objectives and requirements.

SPACE SUIT DEVELOPMENT STATUS

By Richard S. Johnston, James V. Correale,
and Matthew I. Radnofsky
Manned Spacecraft Center

SUMMARY

Space suits for the Mercury missions were designed primarily for protection of flight crews against the possibility of cabin pressure failure. However, goals of the Gemini program, particularly extravehicular activities, caused space suit design philosophies to change drastically. The suit had to sustain life. A basic design was selected to satisfy all mission requirements. Extravehicular activities were to be accomplished by adding thermal and micrometeroid protective layers to the basic suit.

The Gemini program was changed, eliminating extravehicular activities on a long-term mission. For this reason, and because of flight crew reports that spacecraft operations are compromised by restrictive space suits, a suit to be used strictly for intravehicular operations was developed. The suit (G-5C) meets basic design objectives of reduced bulk and weight, and improved comfort and mobility.

Since the objective of the Apollo program is manned exploration of the moon, a space suit for this program must provide an overall system (called the extravehicular mobility unit) which will permit crewmen to explore the lunar surface. Since the Apollo command module is large enough that crewmen can remove and put on the space suit in flight, it will be worn only during critical mission periods. The extravehicular mobility unit space suit assembly contains all life-sustaining and protective features to meet the extreme conditions expected during lunar exploration.

Post-Apollo missions will require new approaches in space suit design and operation. For extended interplanetary travel, a true shirt-sleeve environment is desirable. However, lightweight, emergency-type pressure suits may be required. A space suit for long-term lunar exploration must meet design objectives of long-term reliability, improved mobility, low suit leakage, high durability to repeated wear, and lightweight construction. Such a suit is currently under development, and refinement of this basic suit design is being pursued for future manned space flight use.

INTRODUCTION

Space suits were considered vital to spacecraft reliability and mission success for the Mercury, Gemini, and Apollo missions. Prior to the manned Mercury flights, the ability of an astronaut to perform all required functions in a decompressed cabin, while wearing a pressurized suit, was established. Thus, space suits have been a system requirement for all manned spacecraft missions. The prime use for space suits in Project Mercury was to provide protection to the flight crews if cabin pressure was lost because of mechanical failure, leakage, or other reasons. The Mercury space suits provided adequate comfort, ventilation, and pressurized mobility for the relatively short missions. However, the goals of the Gemini program, particularly of extravehicular activity, caused the space suit to become for the first time a prime system - a system required to sustain life. Space suit design philosophies thus changed significantly. Redundancies had to be provided in the suit to insure reliability; the suit had to permit full body mobility; and micrometeoroid, thermal, and visual protection systems had to be integrated into the suit design.

GEMINI SPACE SUITS

The development of the Gemini space suit was based on specific mission-oriented requirements: 14 days continuous wear, pressurized mobility compatible with spacecraft crew-station design, maximum unpressurized comfort and mobility, 3.7 psia pressurized operation, and free-space extravehicular activities. To provide such a space suit, three development contracts were established to provide various approaches to "partial wear" suits. These suits would permit the crew to remove as many suit components (helmet, gloves, and boots) as possible while in flight, thus enhancing crew comfort. Figure 1 shows one of these early space suit prototypes. Evaluation of these suits indicated that the removable leg sections did not provide sufficient improvement in long-term comfort and that the gloves could be attached at the wrists rather than at the elbow or higher.

Early in 1963 a basic space suit design was selected based on the philosophy that it would satisfy all mission requirements. Extravehicular activities would be accomplished through the addition of thermal and micrometeoroid protective layers.

NASA-S-62-1795

Figure 1. - Early Gemini space suit with removable legs and arms.

Description

The size of the Gemini spacecraft does not permit the crewmen to don or doff the conventional Gemini space suit completely in flight; therefore, one of the prime space suit design requirements was long-term comfort. To accomplish this, a completely soft suit was developed which, in normal flight, serves primarily as a flight suit. Figure 2 is a photograph of the Gemini space suit used in the first manned flight. The outer layer of the suit is made of a high-temperature-resistant nylon material (HT-1) which can withstand temperatures as high as 500° F. This layer of the suit is primarily a protective and thermal reflective layer. The next layer of the space suit is made of a link-net material, specially designed to provide pressurized mobility and to control pressurized suit ballooning. The gas retention layer of the suit is a neoprene-coated nylon which, under pressurized operation, is maintained at a pressure differential of 3.7 ± 0.2 psia. An inner layer of nylon oxford is included to enhance comfort and to reduce pressure points from various space suit components. The torso portion of the garment is worn throughout the flight. This garment is donned through a pressure-sealing zipper which runs from the small of the back through the crotch of the suit. Two connectors are provided on the suit torso for the environmental control system (ECS) inlet and outlet fittings. A combined bioinstrumentation and communication connector is also located on the suit torso.

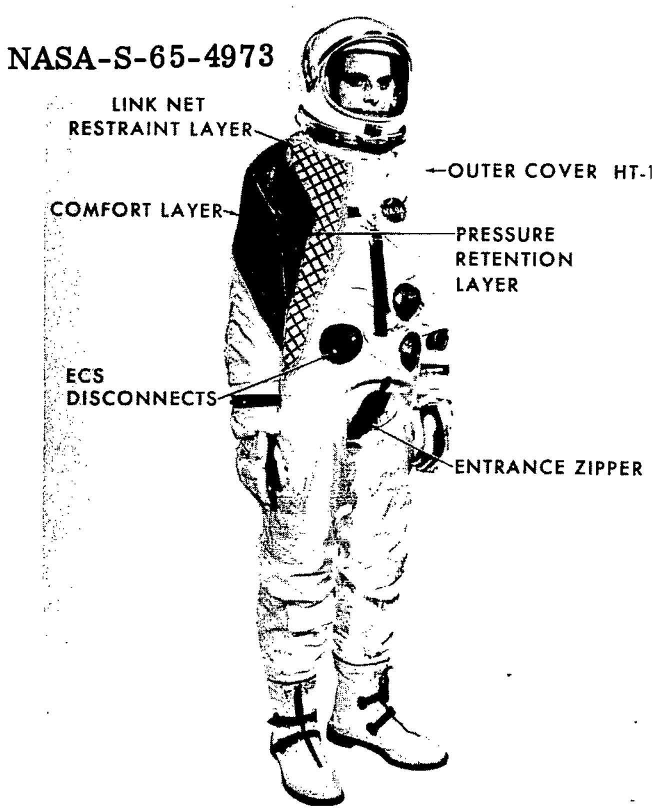

Figure 2. - Gemini GT-3 space suit.

Helmet. - The Gemini helmet (fig. 3) provides integral communications equipment, impact attenuation protection, and a quick doff-don capability. Redundant microphones and headsets are installed for spacecraft communications. The helmet-to-torso engagement was designed to permit the astronaut to connect the helmet to the torso without assistance in less than 5 seconds. The torso portion also contains a rotating bearing, permitting the astronaut to turn

NASA-S-65-4976

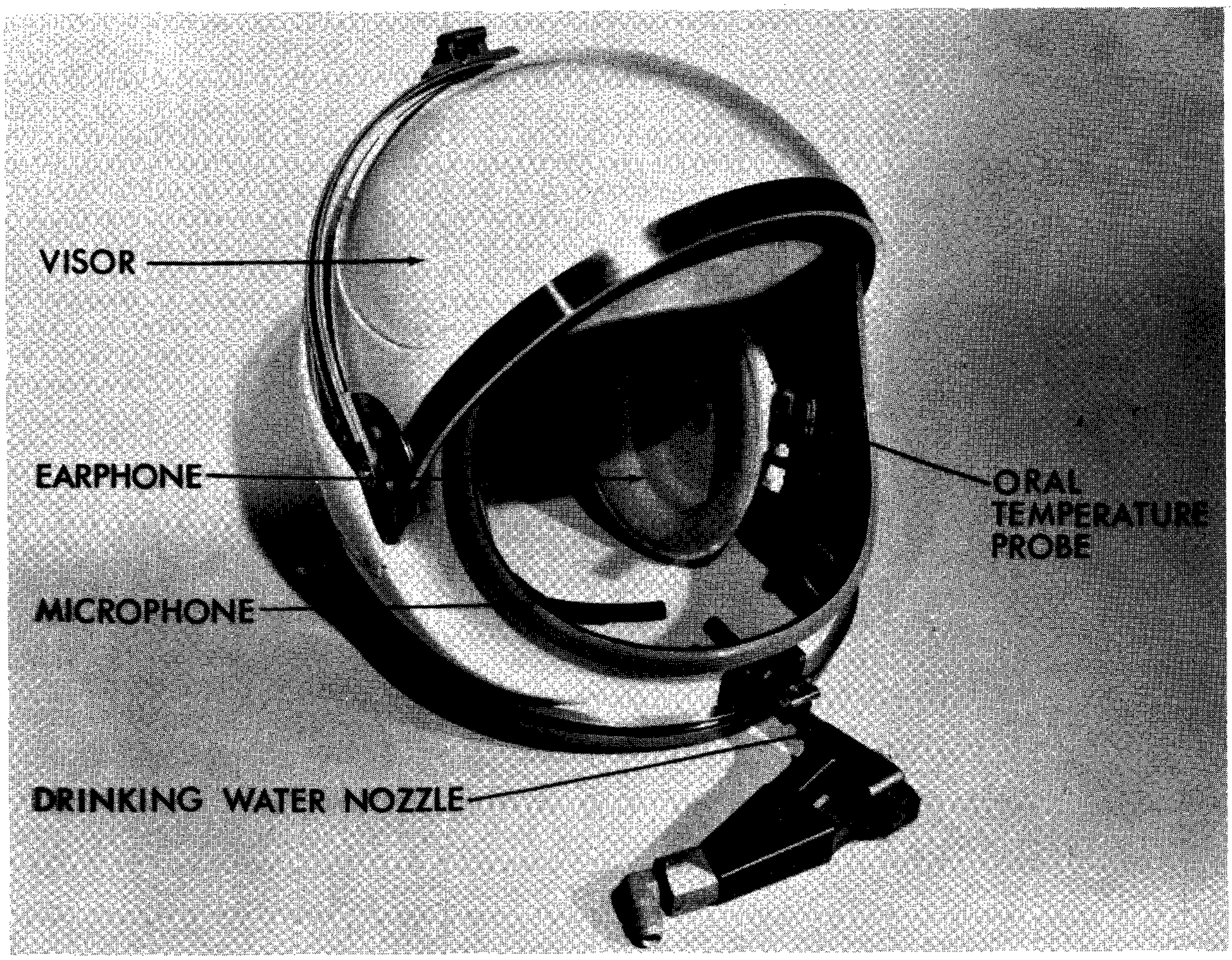

Figure 3. - Gemini space suit helmet.

his head with relative ease. The retractable helmet visor is mechanically sealed by an off-center bail-bar assembly. The pressure-sealing visor used in the GT-3, 4, and 5 flights was made of plexiglass. In the GT-4 flight an additional visor using a polycarbonate material, having a strength of approximately 30 times that of plexiglass, was incorporated to provide additional impact protection. In later flights, an improved polycarbonate material will be utilized for the primary visor, providing its optical properties can be improved. The helmet is equipped with a feeding port which permits the astronaut to drink while operating in the pressurized condition. Figure 3 shows the water nozzle inserted through the helmet feed port.

Gloves. - The Gemini space suit gloves (fig. 4) have been designed to provide maximum hand mobility and finger dexterity. The gloves are attached

NASA-S-65-4975

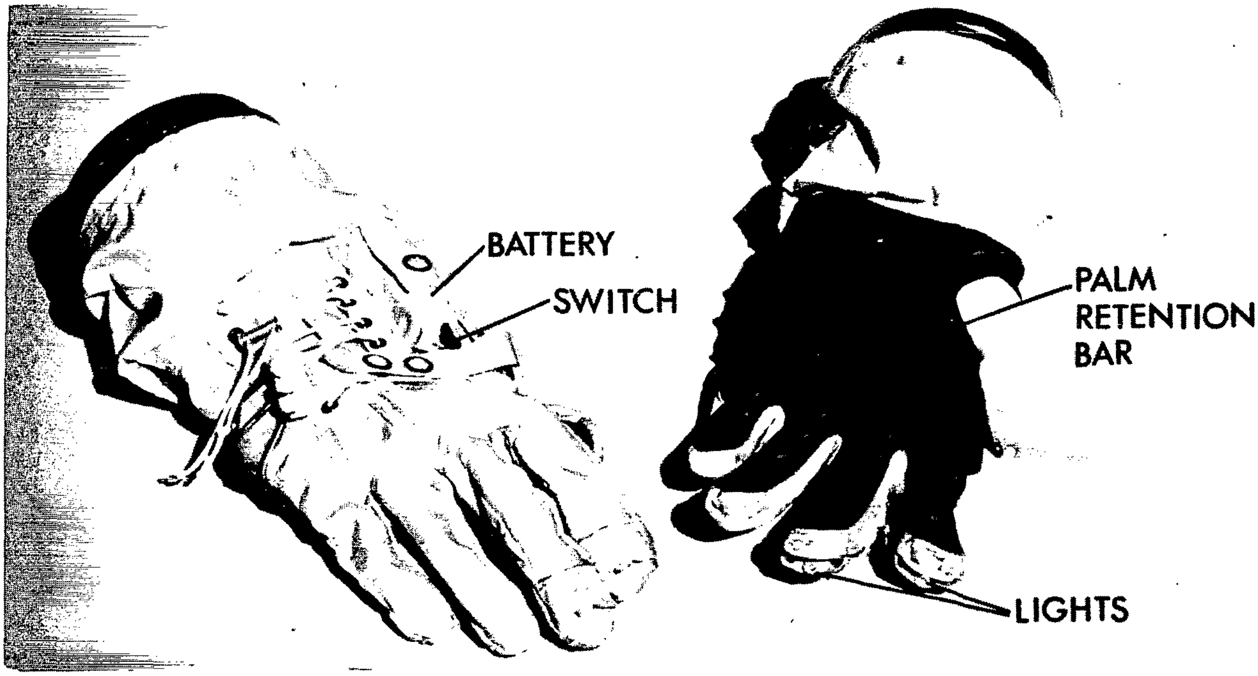

Figure 4. - Gemini space suit and gloves.

to the suit with positive-locking disconnects which contain rotating wrist bearings to decrease the torque required to rotate the hand. These disconnects have been designed to permit the astronaut to don and doff the gloves without assistance. The palms contain a retention device to preclude pressurized ballooning of the glove. This permits positive gripping of spacecraft controls. The light, parallel stripes running through the palm contain this retention bar. The space gloves are equipped with self-contained fingertip lights. A small battery with a switch is located on the back of the glove. Wires from this battery lead to miniature light bulbs located on the back of two fingers of the gloves. In flight, the astronaut used these lights to scan the instrument panel or for other such uses while the spacecraft is on the dark side of the earth. These lights are used to insure that the astronaut's adaptation to the dark is not disturbed by full illumination of the spacecraft.

Ventilation system. - The space suit vent system (fig. 5) has been designed to free the helmet completely of any external connections. This design approach has been followed to simplify donning and doffing and to improve operational use of the space suit. The inlet line from the spacecraft ECS is connected to a self-sealing torso connection. The ventilation gas is ducted by a

NASA-S-65-4971

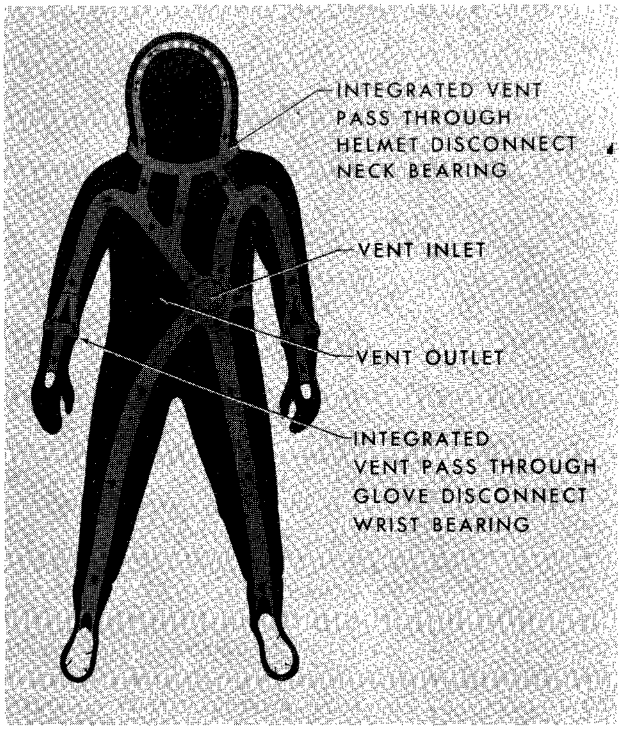

Figure 5. - Ventilation distribution system.

manifold system to the boots, gloves, and helmet of the suit. This gas flows back over the legs, arms, and torso to remove metabolic heat and maintain satisfactory thermal comfort. The remainder of the inlet gas passes through an integral duct in the helmet neck ring and is directed across the visor to reduce fogging. It is also directed to the oral-nasal area to provide breathing oxygen and to remove carbon dioxide. The resulting gas mixture of oxygen, carbon dioxide, and water vapor is ducted out of the suit at a torso outlet fitting. A flexible hose connects this outlet fitting to the spacecraft environmental control system. This ventilation system has proven to be quite satisfactory and, in all missions to date, the crew has been able to maintain thermal comfort throughout the flights.

Bioinstrumentation. - The Gemini bioinstrumentation system is an integral part of the space suit assembly. This bioinstrumentation system (fig. 6) is worn at all times under the torso garment. The basic flight-safety bioinstrumentation measurements are blood pressure, electrocardiogram, body temperature, and respiration rate. The electrocardiogram and respiration measurements are taken with electrodes which are fixed to the astronaut's body. Body temperature is measured orally with a thermistor which is used at the command of the monitoring flight surgeon on the ground. Blood pressure is measured by a manually-inflated cuff and microphone system. The cuff is inflated to the desired pressure and then allowed to decay linearily. The arterial sounds are picked up by the microphone and are superimposed on the decaying pressure signal. In this way, systolic and diastolic blood pressure measurements are made. The signals from all of these sensors are carried by leads to signal conditioners located in pockets on the space suit underwear. These signal conditioners amplify the signals. The output of the signal conditioners is transmitted by an electrical harness to the bioconnector in the space suit. Provisions have been made for additional medical measurements in future Gemini flights.

NASA-S-65-4974

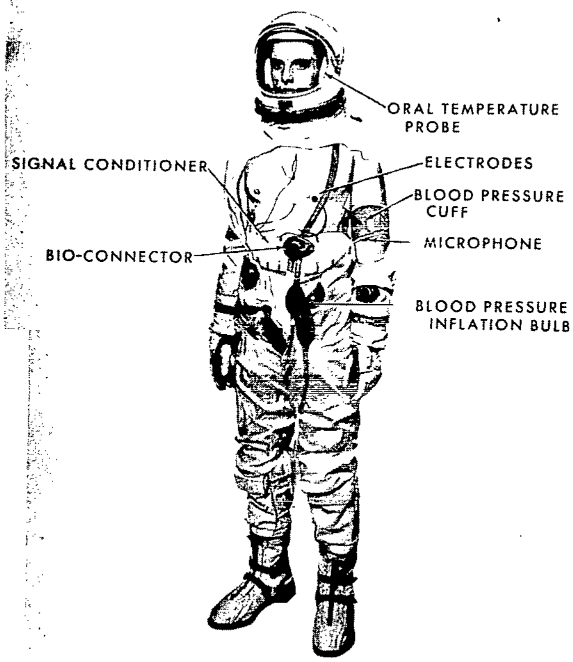

Figure 6. - Gemini bioinstrumentation system.

NASA-S-65-4698

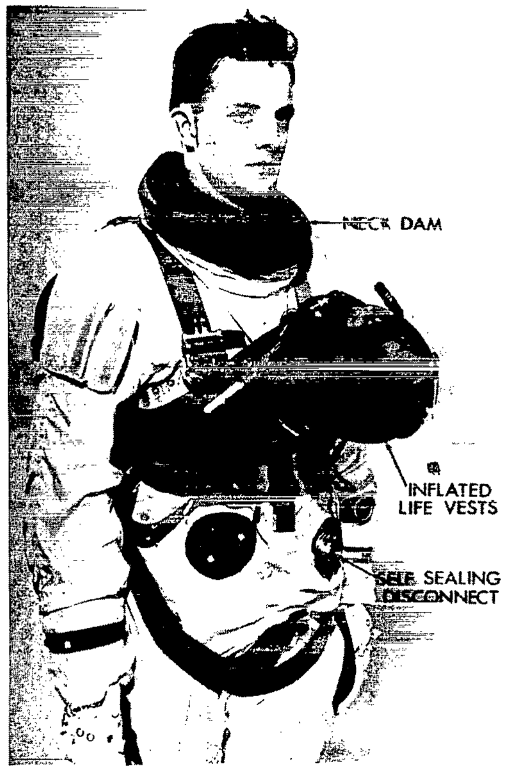

Figure 7. - Gemini space suit assembly.

Flotation equipment. - The Gemini suit assembly as worn by the astronaut at the time of leaving the spacecraft and entering the water is shown in figure 7. A twofold harness system is worn over the suit. This harness is used for body restraint in the spacecraft and is employed as a parachute harness in the Gemini ejection seat system. Attached to this harness are two life vests which are provided for flotation purposes. The life vests are manually inflated by pulling lanyards which actuate integral carbon dioxide cylinders. In addition to the life vests, a neck dam is stowed in a suit pocket. Before entering the water from the spacecraft, the astronaut removes his helmet and dons the neck dam to make a seal around the suit neck ring and his neck. This prevents the suit from filling with water and traps gas within the suit torso to provide additional buoyancy.

Qualification and evaluation program. - The Gemini space suit has undergone an extensive and comprehensive qualification and evaluation program prior to flight use. This has included explosive decompressions, both manned and unmanned, to simulate a spacecraft emergency decompression. This allowed the suit to be evaluated under rapid pressure changes. Long-term manned tests at both reduced pressure and sea-level pressure have been made. Normal environmental qualification tests (heat, oxygen, acceleration, etc.) have been conducted; all mechanical components have been life-cycle tested; and many spacecraft compatibility tests have been made. Prior to the manned flights, thousands of test hours had been accumulated without a major failure.

Extravehicular suit. - The Gemini extravehicular space suit is shown in figure 8. The basic suit used in the flight of Grissom and Young has been modified to provide thermal, micrometeoroid, and visual protection, and to provide certain redundancies to enhance crew safety. The outer cover of the GT-3 space suit was replaced with a multilayered overgarment, the outer cover of which is fabricated from a high-temperature-resistant nylon. A layer of felt is used as a spacer layer; several layers of a highly reflective Mylar are provided to serve as a superinsulator; and two additional layers of high-temperature-resistant nylon complete the multilayered overgarment. The remaining layers are as previously described for the flight suit. This basic garment is fully qualified for the predicted thermal and micrometeoroid environments encountered in orbital flights. The helmet is equipped with a removable extravehicular visor assembly. The outer visor serves as a reflecting layer to attenuate the visible spectrum. An inner visor provides protection from impact, attenuates ultraviolet, and is coated with a low emissivity coating to prevent visor fogging while operating in deep space. Redundant zippers are provided to relieve the strain, caused by normal operation, imposed on the main closure. Thermal gloves are provided for the extravehicular crewman. In the Gemini 4 flight, Astronaut White was equipped with the extravehicular suit while McDivitt

NASA-S-65-4970

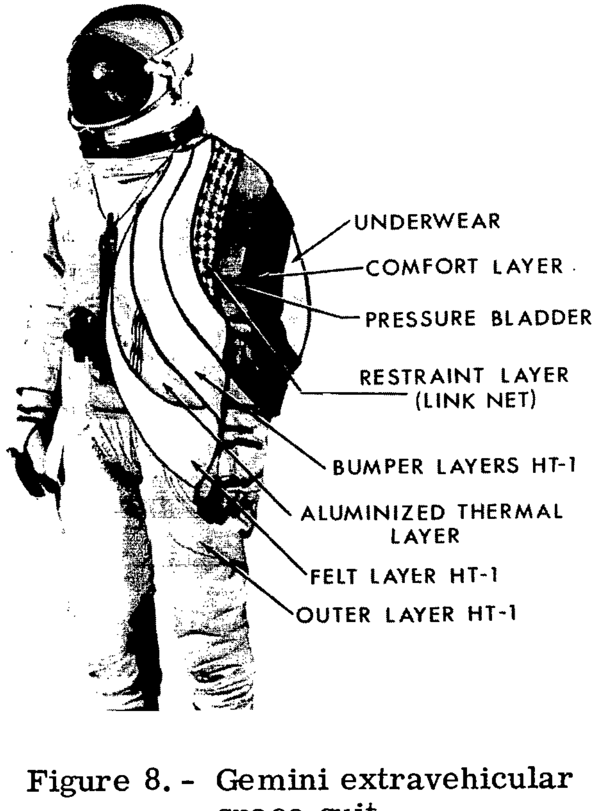

Figure 8. - Gemini extravehicular space suit.

wore a G4-C type space suit, without the additional cover layers and visor material.

The extravehicular life support system used in the GT-4 flight is shown in figure 9. This system utilized a 25-foot umbilical assembly. This length permitted the astronaut to move back to the spacecraft adapter section. The umbilical assembly served three purposes: first, electrical wires were provided to continue communications and bioinstrumentation measurements while extravehicular operations were underway; second, a 1000-pound test tether line was provided to attach the astronaut to the spacecraft; and, third, an oxygen hose was used to duct spacecraft oxygen to the suit. The astronaut was attached to both the spacecraft ECS and the extravehicular life support system by Y-connectors on the space suit. These connectors were developed with self-sealing features which would have allowed the crewman to switch from one system to another in a decompressed cabin. The extravehicular life support system is shown schematically in figure 9. The demand regulator was used to maintain suit pressure at 4.0 ± 0.1 psia. Emergency oxygen was provided by a high pressure oxygen bottle. If the umbilical oxygen failed, the astronaut would have manually actuated the emergency supply. This emergency oxygen supply would have flowed into the helmet area through the feed port. Space suit pressure would have been maintained by the demand regulator or by a space suit relief valve. This system is the first of a family of extravehicular life support systems under development.

In the GT-8 mission, a more advanced chest pack will be provided for the extravehicular crewman. This chest pack system (fig. 10) will be operated with spacecraft oxygen from an umbilical line in normal operation. Oxygen will be circulated through the space suit by an injector pump which utilizes the umbilical line oxygen supply (70 psi). Metabolic heat will be removed by a water evaporative heat exchanger. Carbon dioxide will be vented out of the pack. Emergency oxygen will be provided by a high-pressure oxygen tank in the chest pack. The umbilical line will also contain a mechanical tether and electrical leads for communications and bioinstrumentation.

Proposed Gemini Intravehicular Space Suit

The problems associated with long-term flights in Gemini spacecraft have raised questions as to whether the crew should operate in a true shirt-sleeve environment (that is, without the use of space suits). Gemini crews have indicated that some spacecraft operations are compromised by the use of the somewhat restrictive space suits. Shirt-sleeve operations for Gemini have been studied and it was concluded that the spacecraft cabin pressurization system has sufficient reliability to permit shirt-sleeve operations. In Gemini, however, the space suit also performs the important function of providing

NASA-S-65-5699

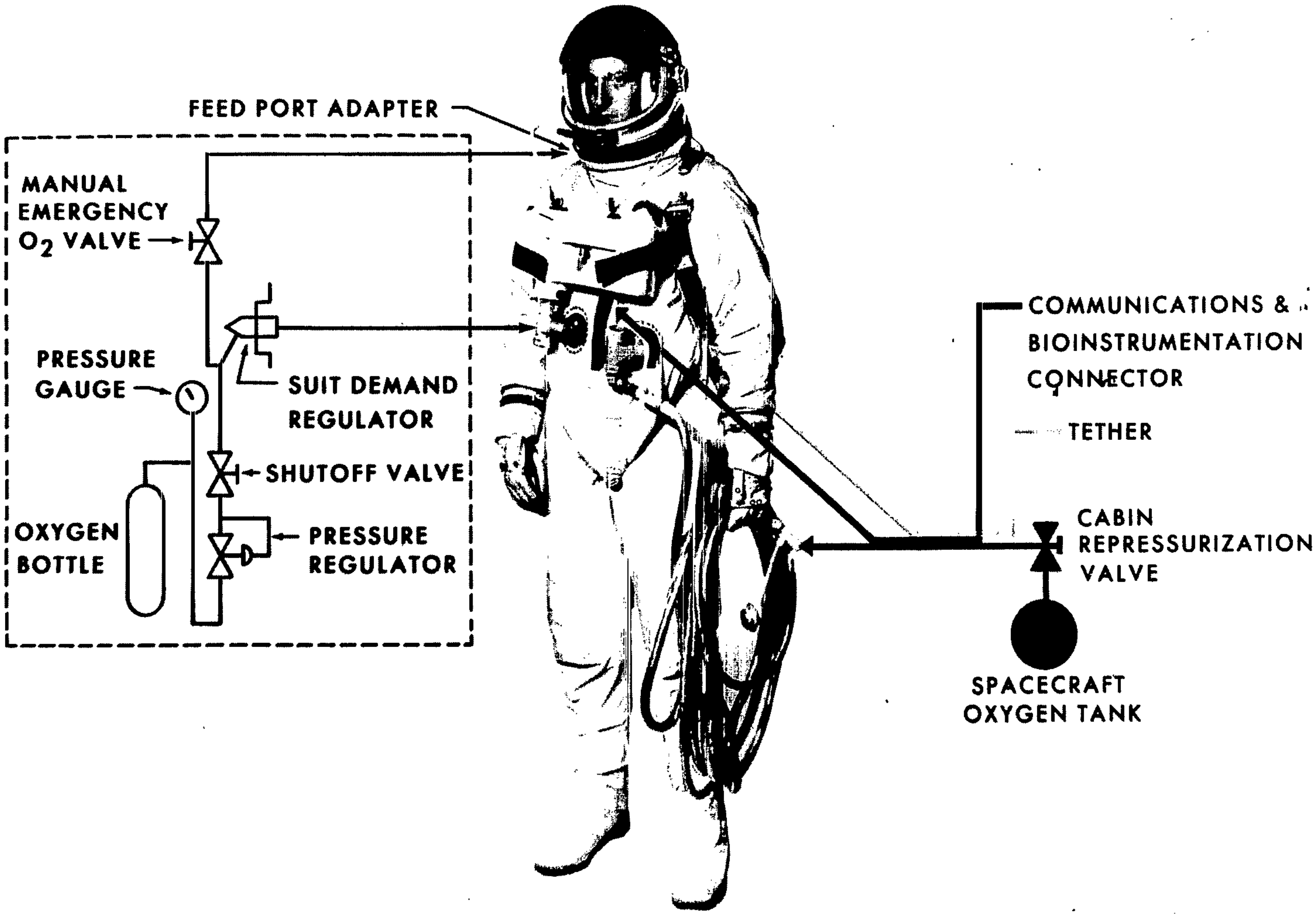

Figure 9. - Gemini GT-4 extravehicular life support system.

 NASA-S-64-2573

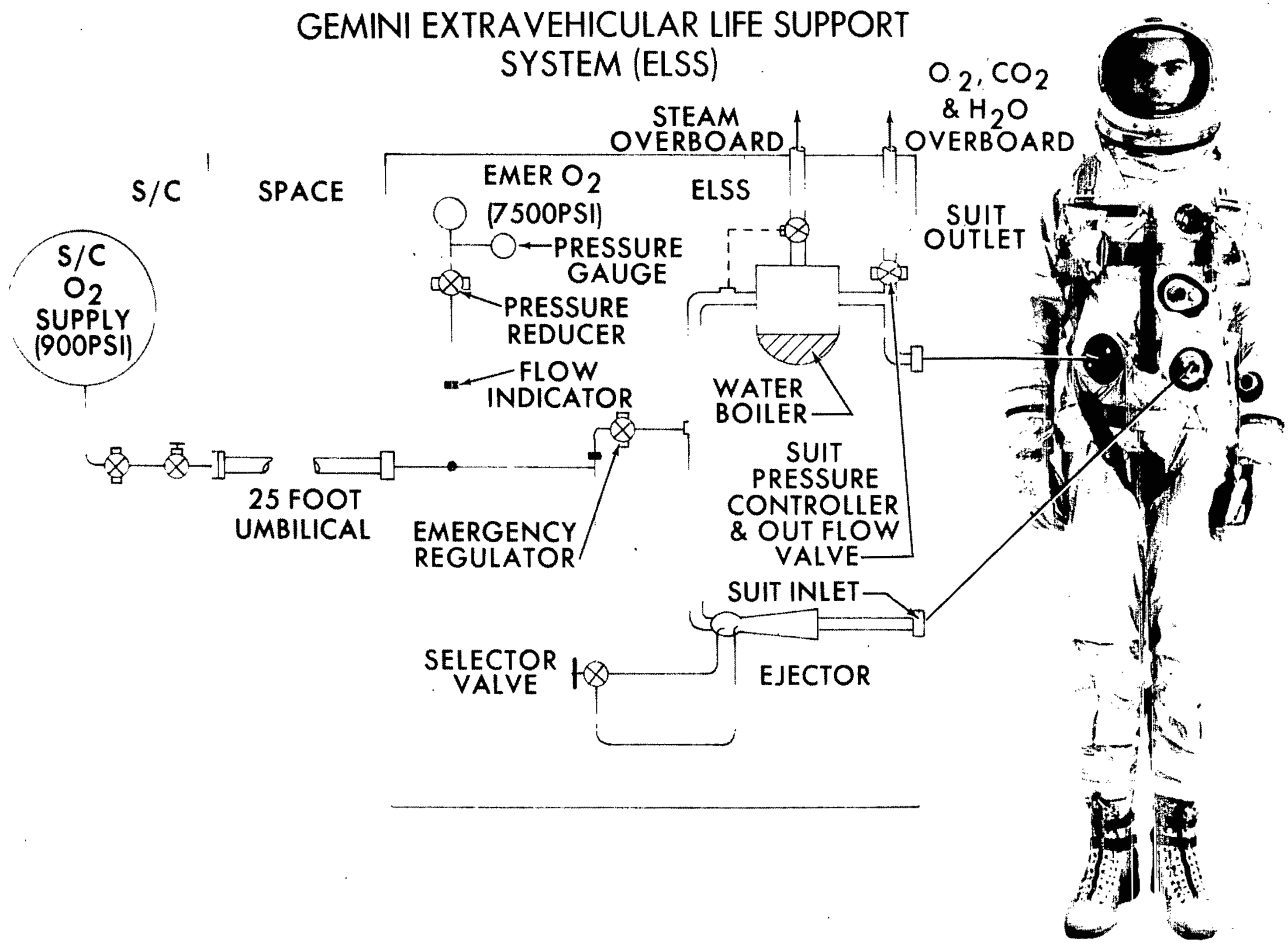

Figure 10. - GT-8 portable life support system chest pack.

protection to the astronaut against the hazards of encountering a possible fireball during ejection seat escape. Additionally, it provides ventilation and cooling to the astronaut, along with maintaining pressure in case cabin pressure is lost. Excluding pressure protection, a special garment would have to replace the space suit to provide adequate blast protection and positive ventilation to the crews during weightless flights. Furthermore, if cabin pressurization fails, the astronauts wearing pressure suits have the capability to reenter the atmosphere at a time and place of their choice rather than immediately terminating the flight.

Based on these considerations, the shirt-sleeve approach was therefore abandoned for the Gemini 7 mission and a strictly intravehicular-usage space suit approach was pursued and is presently proposed. This suit will provide adequate blast protection, ventilation, and, incidentally, emergency pressurization. The term "strictly intravehicular" space suit is explained as follows. The original concept for the space suit development program was that one basic suit configuration would be provided to satisfy all Gemini missions. This was considered a sound approach since extravehicular activity was programed on long-term missions and could be accomplished with the addition of a thermal-micrometeoroid outer cover layer. The program was changed to eliminate extravehicular activity on the long-term mission. This made possible the consideration of a suit to be used strictly for intravehicular operations emphasizing comfort, reduced bulk, and unpressurized mobility. This, along with the crew's adverse comments on bulk and mobility restrictions as an imposition on the 14-day flight, constitutes valid reasoning for changing the original one-suit concept. The suit, shown in figure 11 (in both partial wear and fully-donned states) and designated as the G-5C, has been developed to meet the basic design objectives of reduced bulk and weight and improved unpressurized comfort and mobility. At the same time, it provides satisfactory pressurized mobility to control the spacecraft for earth reentry in the event this proves necessary.

Table I is a physical data comparison chart of the G-3C and G-5C suits. Table II lists the advantages of the G-5C suit over the G-3C suit for the Gemini 7 mission. Two layers in the G-5C suit were eliminated to reduce overall suit bulk. The soft helmet with the internally-worn crash helmet provides for easier stowage in the partial wear mode. The elimination of the large rotating neck bearing and helmet tiedown system not only provides additional comfort and clears up the front of the suit, but also permits quicker emergency donning. The capability of removing the outer jump boots without reducing suit pressure integrity also contributes to long-term wear comfort. The pliability of the suit allows easier waste management and accessibility to spacecraft remote stowage areas. The elimination of excess bulk makes possible complete doffing of the suit within the confines of the spacecraft.

NASA-S-65-9612

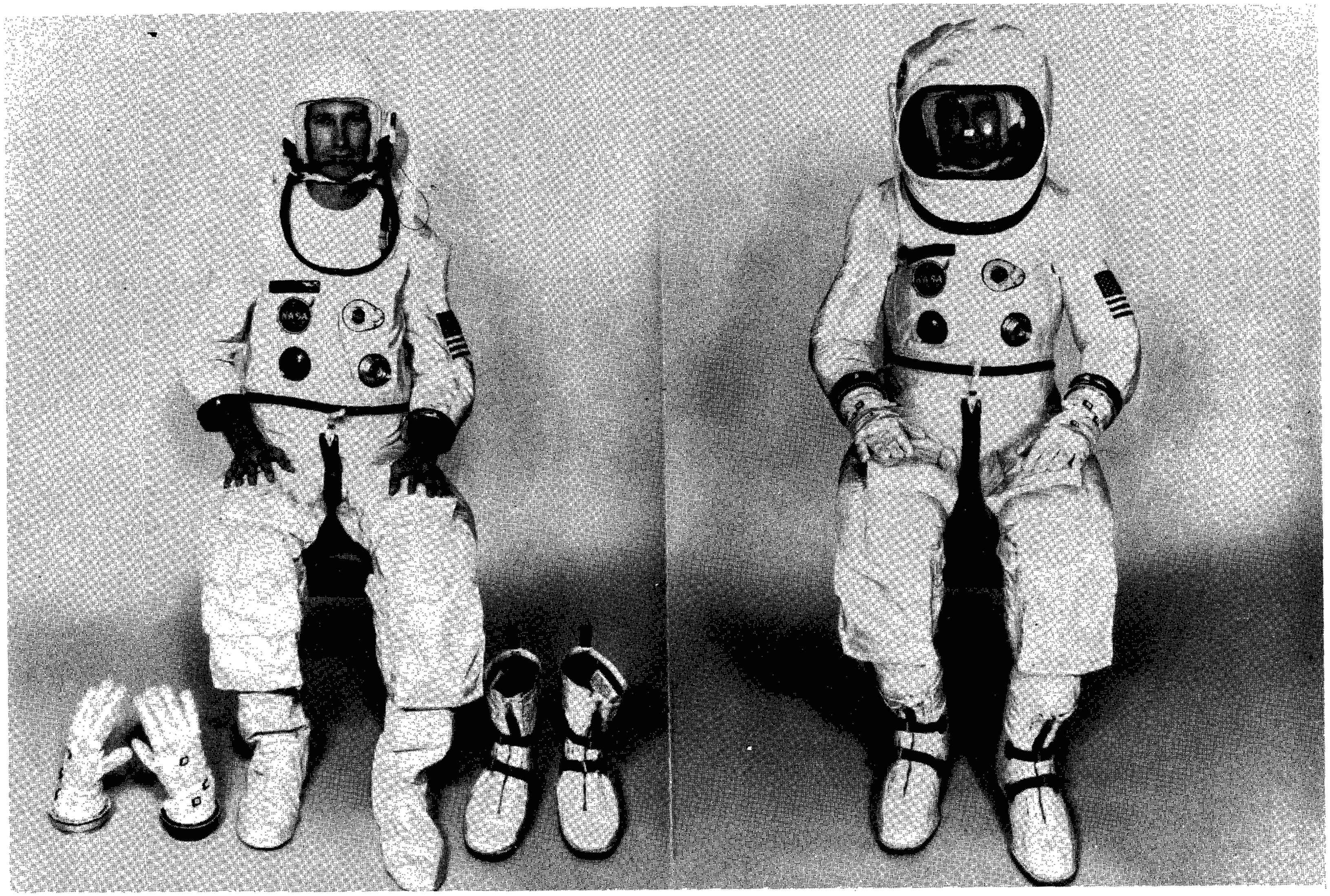

Figure 11. - Gemini G-5C space suit.

TABLE I. - PHYSICAL COMPARATIVE DATA OF G-3C AND G-5C

Item	G-3C	G-5C
Helmet	Fiberglass shell with plexiglass visor - hard helmet with neck disconnect and bearings. Helmet liner inside hard shell for impact and shock.	Soft cloth shell with polycarbonate visor and pressure sealing zipper, bubble configuration. Fighter pilot type helmet provided for impact and shock protection.
Torso	Layup: 1. Comfort liner of nylon oxford 2. Pressure container of Neoprene-coated nylon 3. Link net - HT-1 cords 4. 6 oz HT-1 coverlayer	Layup: 1. Pressure-retaining layer of Neoprene-coated nylon 2. Coverlayer of 6 oz HT-1 Small sections of link net are used in the shoulders for improved mobility.
Gloves	Gloves with wrist bearing disconnect	Gloves with wrist bearing disconnect
Boots	Soft boots with ankle restraint and Neoprene sole. Boots are laced onto the torso.	Soft boots with ankle restraints and Neoprene sole. Boots are removable in flight.
Communication system	Redundant communications in helmet - lightweight headset for use in helmet-off operation.	Same as G-3C/G-4C.
Ventilation system	Internal system with ducting to extremities	External system with ducting to extremities
Comfort liner	Nylon oxford cloth	Not required.
Weight	23.5 lb total	12 lb suit - 4 lb internal crash helmet
Hardware	Automatic locking vent fittings, microdot electrical connector, blood pressure cuff fitting, wrist disconnects.	Same as G-3C/G-4C

TABLE II. - GEMINI SPACE SUIT COMPARISON CHART

Category	G-3C	G-5C
Bulk		X
Weight		X
Partial wear stowage		X
Complete suit stowage		X
Comfort		X
Mobility pressurized	X	
Mobility unpressurized		X
Pressure protection	-	-
Maintainability		X
Unit cost		X
Emergency don time		X
Visual field		X
Visual clarity	X	
Fireball protection	-	-
Ejection clearance	-	-
Exposure protection	-	-
Ventilation performance (completely donned)	-	-
Ventilation performance (partially donned)	-	-

X indicates advantage for long duration mission without extravehicular activity.

- indicates equal performance for long duration mission without extravehicular activity.

APOLLO

The objective of the Apollo space flight program is manned exploration of the moon. To accomplish this mission, two manned spacecraft are being developed and fabricated. The first spacecraft is the command module (fig. 12). This module will be used by the crewmen for the launch phase; it will serve as the living quarters during the entire mission; and it will be used for reentry into the earth's atmosphere and landing. The lunar excursion module, the second craft, is a two-man spacecraft which will be used to ferry the crewmen to the lunar surface and back to the command module. In operation, the three crewmen will enter the command module prior to launch. Following launch into earth orbit, the lunar excursion module will be moved to a docked position as shown in figure 12. The two spacecraft will then be placed into a lunar orbit, and two of the crewmen will enter the lunar excursion module. This module will be separated from the command module and will be slowed by

NASA-S-65-4977

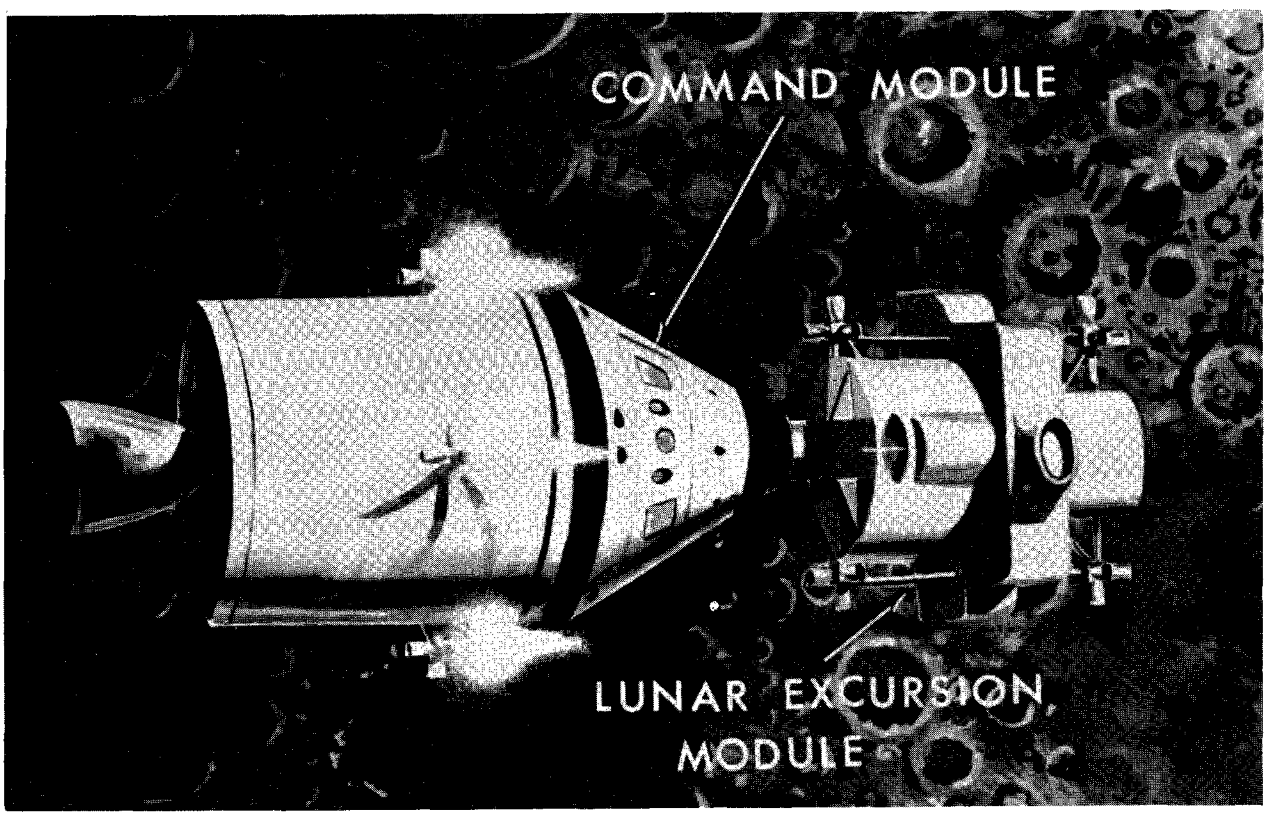

Figure 12. - Apollo spacecraft.

rockets to effect a descent to the lunar surface. Final touchdown on the moon will be controlled by landing rockets. On the lunar surface, one of the crewmen will exit from the spacecraft to perform assigned scientific tasks. Upon completion of this mission, the lunar excursion module will be flown back into a lunar orbit where it will rendezvous and dock with the command module. The two crewmen will enter the command module, the lunar excursion module will be separated, and the command module will start the return trip to earth. Following entry into the earth's atmosphere, three parachutes will be deployed for earth landing. The entire trip will take approximately seven days.

Space Suit Design Objectives

The Apollo command module is large enough to permit the crewmen to doff and don space suits in flight. Thus space suits will be worn in the spacecraft at critical mission periods such as launch, docking with the lunar excursion module, and lunar operation, and then removed during normal flight, which will be conducted in "shirt-sleeves". The Apollo space suit is the only piece of operational equipment which will be taken to the lunar surface and returned to earth.

The major design objective of the Apollo space suit program is to provide an overall system, called the extravehicular mobility unit, which will permit one or more of the Apollo crewmen to explore the lunar surface. The space suit must provide unlimited mobility with thermal, micrometeoroid, and visual protective systems, and the capability of operating on the lunar surface for periods up to 4 hours. A secondary objective is to provide a space suit compatible with the command module under both pressurized and unpressurized conditions. The development of such a space suit system is one of the most complex and difficult crew-equipment development programs undertaken in the short history of the manned-space-flight era. From the conception of this development program, redundancy, reliability, and quality control have been prime goals.

Design Requirements

The lunar surface is an extremely hostile environment to man. Table III summarizes the environmental extremes in which the extravehicular mobility unit must function. The ambient pressure of the moon is 10^{-10} torr; this, of course, requires that an artificial atmosphere must be provided to sustain life. This atmosphere must provide oxygen for breathing and pressurization. Accordingly, in the Apollo program, the space suit pressurization level has been established at 3.7 ± 0.2 psia with 100 percent oxygen. Also, lunar operation in the $\frac{1}{6}$ gravity field has necessitated certain space suit design features to permit

TABLE III. - SUMMARY OF LUNAR ENVIRONMENTAL CONDITIONS

Ambient pressure	10^{-10} torr
Gravity	1/6 earth gravity
Thermal	Surface temperature $\pm 250^{\circ}$ F
. . . .	Solar flux 440 Btu/hr/ft^2
Meteoroid	Primary flux:
	Velocity - 30 km/sec
	Diameter - 0.0316 cm
	Density - 0.5 gm/cm^3
. . . .	Secondary flux:
	Velocity - 0.2 km/sec
	Diameter - 0.24 cm
	Density - 3.5 gm/cm^3
Visual	Lunar day:
	High ultraviolet
	Visible and infrared

adequate suit mobility and locomotion. Test programs are being continually conducted with various simulators to study the $\frac{1}{6}$ g effects on suit design and crew performance.

The lunar thermal environment has posed a variety of problems in selecting space suit materials and in system design. The external surface of the extravehicular mobility unit may vary in temperature from 250° F in the lunar day to -250° F in the lunar night. Lunar day solar heat flux has been calculated as 440 Btu/hr/ft^2 or a total of 10 000 Btu/hr. A super-insulation material has thus been developed which will limit this heat leak into the suit to approximately 250 Btu/hr during lunar day, and 350 Btu/hr out of the suit during lunar night.

The micrometeoroid problem is one of the most difficult to solve because of the poor definition of the lunar meteoroid flux and because of the space suit encumbrance imposed by certain approaches to protective suit layers. Primary meteoroid particles traveling at velocities of approximately 30 km/sec must be prevented from penetrating the space suit. In addition, secondary ejected particles caused by the primary meteoroids striking the lunar surface must also be stopped from penetrating the space suit proper. Studies have shown that a combination of lightweight fabrics in an overgarment will preclude penetrations of meteoroid particles within design and reliability limits.

On the lunar surface, the space suit must have the capability of providing protection against the lack of atmosphere and the reflective properties of the moon which create vision hazards. Special visors are being developed to provide protection from solar ultraviolet, infrared, and visible spectrums. In addition, provisions are being made for artificial lights for lunar operations.

Description of Extravehicular Mobility Unit

The extravehicular mobility unit space suit assembly is shown in figure 13. A water-cooled garment is the first layer of the space suit assembly, as it was found early in the development program that conventional pressure suit cooling and ventilation systems which relied upon evaporative cooling were inadequate for the high metabolic expenditures required for pressurized space suit operation. Laboratory tests showed that man expended approximately two times his normal energy level while performing various tasks in a pressurized space suit. A water-cooled undergarment pioneered by the British Royal Aircraft Establishment at Farnborough, England, has been developed and refined to accommodate the anticipated metabolic loads and to maintain the crewman in thermal balance. The pressure garment is made up of an impermeable gas-retention layer and a structural layer which prevents suit ballooning. An

NASA-S-65-4987

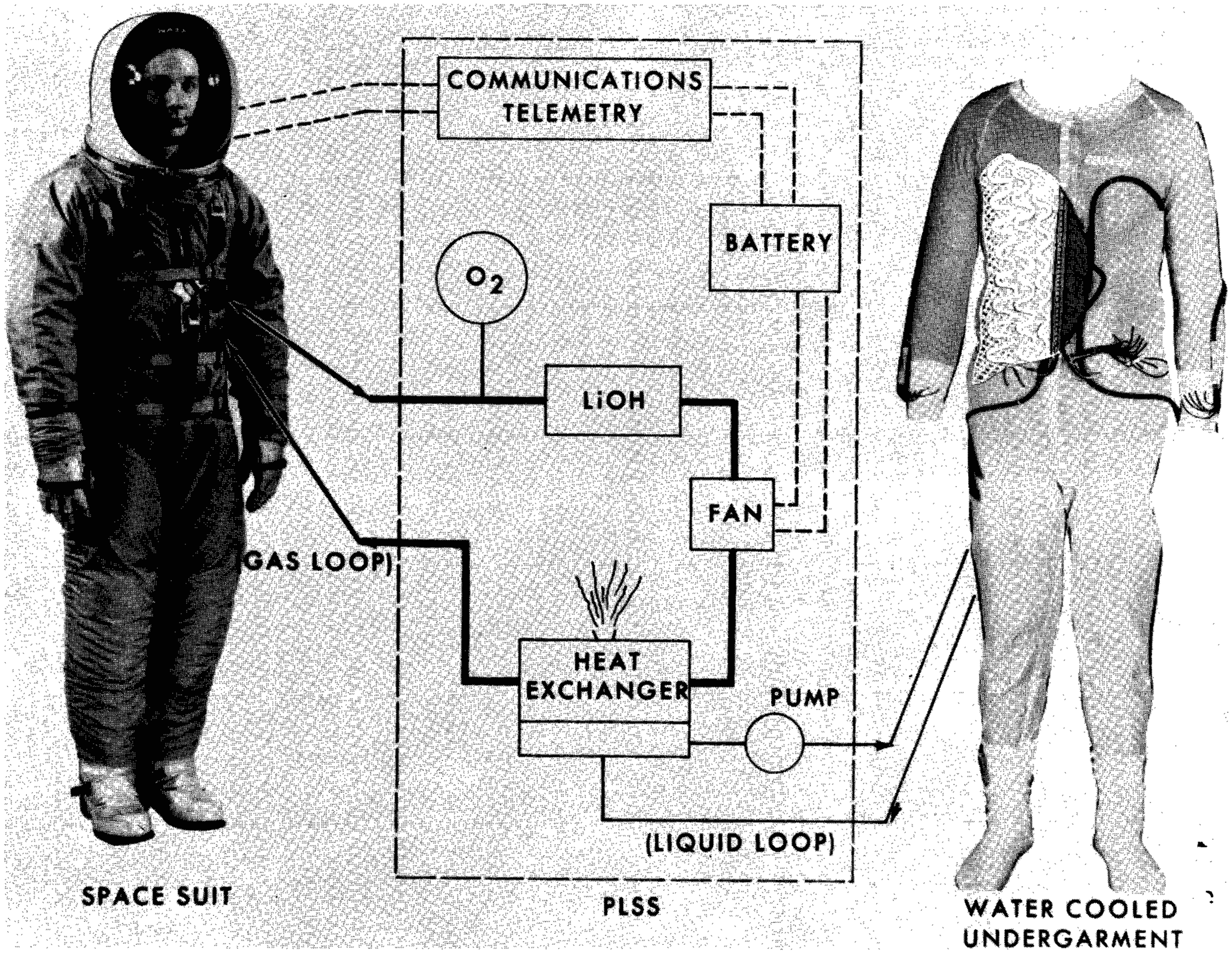

Figure 13. - Apollo portable life support system.

outer layer is provided as a protective cover while the suit is worn within the spacecraft. The space suit assembly is completed for lunar operation by a combined thermal-meteoroid-protective garment which is worn over the pressure garment.

The space suit helmet is attached to the pressure garment by a pressure-sealing ring. Currently, a bubble-type helmet is being evaluated. This type of helmet is being considered because of the increased reliability afforded through the elimination of a movable visor, the increase in visual field, the decrease in helmet weight, and the simplicity in operational use. For lunar operation, a series of light-attenuating visors will be attached to the helmet. The crewmen will wear a "bump hat" under the helmet. This "bump hat" will contain communications equipment and will be worn by the crewmen during both suited and unsuited operation within the spacecraft.

During lunar operations, the astronauts will be equipped with a backpack which contains the life support and communications system. A schematic diagram of this system is shown in figure 13. A gas circulation system provides pressurization, breathing oxygen, and removal of carbon dioxide and other gaseous products. Oxygen is circulated by an electrically powered centrifugal fan into the suit through a gas disconnect. This oxygen passes to the helmet at a rate of 6 cfm to provide breathing oxygen. The resulting gas mixture passes out of the suit through a gas disconnect into the backpack return hose. Carbon dioxide is removed by lithium hydroxide. Other contaminating gases are collected by a layer of activated charcoal. The gas stream is then cooled by a porous-plate, water-evaporative heat exchanger. Oxygen pressure is maintained in the space suit by a demand regulator which meters oxygen into the system from a 900-psi gaseous oxygen supply. This oxygen supply quantity is 1.1 pounds, which is sufficient for 3 to 4 hours of lunar operation. The oxygen tank may be recharged from the lunar excursion module supplies.

A liquid loop is provided to service the water-cooled garment. Water is circulated by a small electrical pump into the water-cooled undergarment. In the undergarment, this water is distributed over the body by capillary tubes to remove the metabolic heat by conduction. This warmed water is then passed through the system heat exchange where the water is cooled. The astronaut will be provided a selector valve which will permit selection of three water inlet temperatures - 45° F, 65° F, or 77° F.

The backpack communications system will permit the extravehicular astronaut to communicate with the lunar excursion module and the lunar orbiting command module. Biomedical data will also be telemetered during lunar exploration periods. Electrical power is provided by replaceable batteries.

POST-APOLLO SPACE SUITS

Space suits for post-Apollo missions such as long-term space stations, extended lunar base operation, or interplanetary travel will require new approaches in design and operation. Space suits for long-term intravehicular operation cannot be used indefinitely. The crewmen must therefore be provided a true shirt-sleeve environment for normal operation. However, lightweight emergency-type pressure suits may be required to permit the crew to make internal repairs on a section of the spacecraft which is decompressed. Spacecraft designers should provide emergency donning areas in the spacecraft in which this lightweight pressure suit could be donned. Sections of the spacecraft should be designed such that they can be sealed off like a compartment within a submarine. Through a design and operational approach, as outlined, spacecraft travel can be made safe, comfortable, and more acceptable to the operating crews.

NASA-S-65-4964

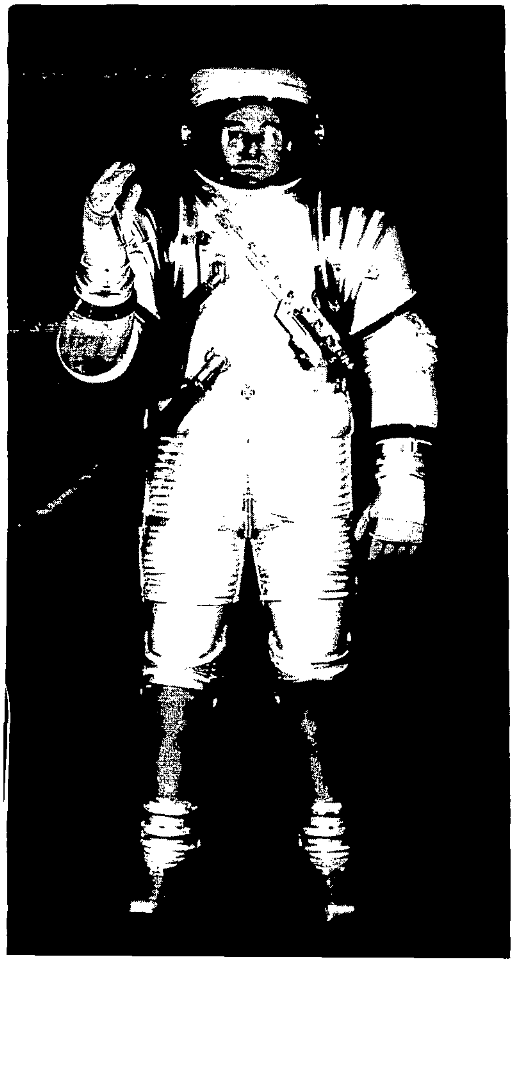

Figure 14. - Early "hard" suit.

For long-term lunar explorations, during which repeated lunar surface excursions will be made from an operating base, new approaches to space suit designs must also be undertaken. The objectives of these developments must be long-term reliability, improved mobility, low suit leakage, high durability to repeated wear, and lightweight construction. Such a suit is currently under development. Figure 14 shows a photograph of an early "hard" space suit. The suit as depicted was in its early developmental phase. A later suit design, shown in figure 15, has many promising design features. It has an extremely low leak rate

NASA-S-65-57049

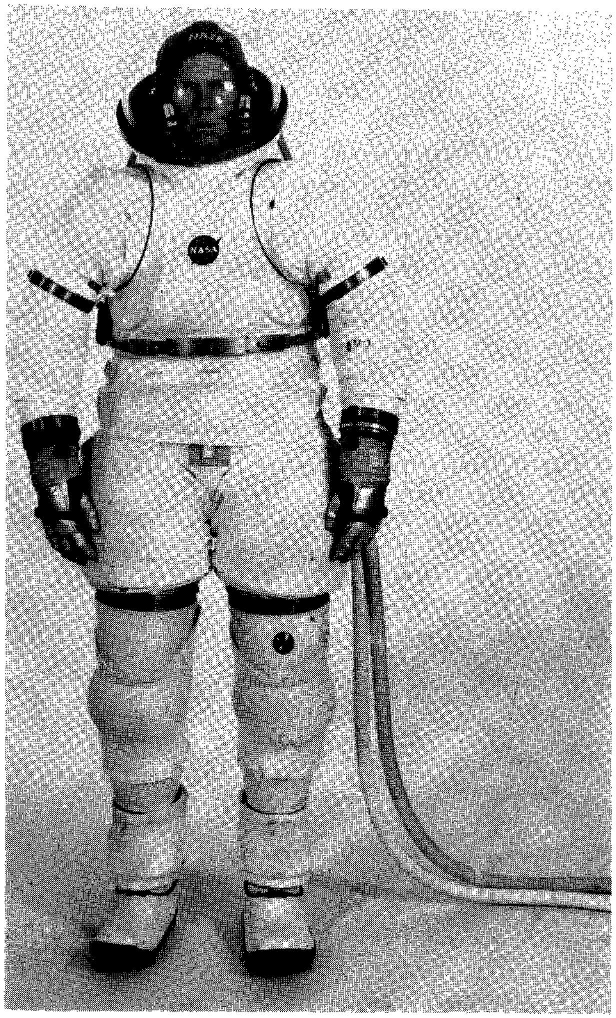

Figure 15. - Latest "hard" suit.

(less than 100 cc/min). Being all metal and plastic, it is durable and is not as vulnerable to abrasion and puncture as are fabric suits. It is comparatively light in weight, can be operated at pressures up to 7 psia, has good shoulder and arm mobility, and the operating forces, even at 7 psia, are extremely low. The suit's main disadvantage is the high volumetric storage requirements. Refinement of this basic suit design is being pursued for future manned space flight use.

RESUME

The present status of space suit development has been reached basically because of the changing goals of each manned spacecraft mission. Duration of flight, duration and type of extravehicular activity, and expected environmental conditions are all factors which have been reflected in any space suit design objectives and requirements. These same factors, in addition to design and operation of future spacecraft, will be considerations in the development of post-Apollo space suits.

Manned Spacecraft Center
National Aeronautics and Space Administration
Houston, Texas, December 20, 1965

"The aeronautical and space activities of the United States shall be conducted so as to contribute . . . to the expansion of human knowledge of phenomena in the atmosphere and space. The Administration shall provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof."

—NATIONAL AERONAUTICS AND SPACE ACT OF 1958

NASA SCIENTIFIC AND TECHNICAL PUBLICATIONS

TECHNICAL REPORTS: Scientific and technical information considered important, complete, and a lasting contribution to existing knowledge.

TECHNICAL NOTES: Information less broad in scope but nevertheless of importance as a contribution to existing knowledge.

TECHNICAL MEMORANDUMS: Information receiving limited distribution because of preliminary data, security classification, or other reasons.

CONTRACTOR REPORTS: Technical information generated in connection with a NASA contract or grant and released under NASA auspices.

TECHNICAL TRANSLATIONS: Information published in a foreign language considered to merit NASA distribution in English.

TECHNICAL REPRINTS: Information derived from NASA activities and initially published in the form of journal articles.

SPECIAL PUBLICATIONS: Information derived from or of value to NASA activities but not necessarily reporting the results of individual NASA-programmed scientific efforts. Publications include conference proceedings, monographs, data compilations, handbooks, sourcebooks, and special bibliographies.

Details on the availability of these publications may be obtained from:

SCIENTIFIC AND TECHNICAL INFORMATION DIVISION

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Washington, D.C. 20546