

## **JSC/EC5 Spacesuit Knowledge Capture (KC) Series Synopsis**

**All KC events will be approved for public using NASA Form 1676.**

*This synopsis provides information about the Knowledge Capture event below.*

**Topic:** Intra-Extra Vehicular Activity Russian & Gemini

**Date:** August 3, 2016    **Time:** 11:30 p.m. – 12:15 p.m.    **Location:** JSC/B5S/R3102

**DAA 1676 Form #:** 36646

This is a link to all lecture material <\\js-ea-fs-03\pd01\EC\Knowledge-Capture\FY16 Knowledge Capture\20160000 Thomas IEVA Russian & Gemini Suits\1676 - Charts>

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*For 1676 review use Synopsis Thomas IEVA Russian & Gemini.docx*

**Presenter:** Kenneth S. Thomas

**Synopsis:** Kenneth Thomas will discuss the Intra-Extra Vehicular Activity Russian & Gemini spacesuits. While the United States and Russia adapted to existing launch- and reentry-type suits to allow the first human ventures into the vacuum of space, there were differences in execution and capabilities. Mr. Thomas will discuss the advantages and disadvantages of this approach compared to exclusively intra-vehicular or extra-vehicular suit systems.

**Biography:** Kenneth S. Thomas is a second-generation space engineer who was graduated cum laude with a bachelor's degree from Central Connecticut State University, and worked over four decades in industry. In 1989, he became a contractor project engineer (task manger and team leader) on the Shuttle Extravehicular Mobility Unit Program. To develop his expertise in this area, he conducted hundreds of hours of unpaid research interviewing scores of early spacesuit designers and engineers from many organizations who were directly involved from the beginning of U.S. developments to what was then current. Mr. Thomas also reviewed documents from the early NASA period to provide further insight and validate interview results. In 1993, he became a consultant to the National Air and Space Museum's Space History Division where he gained access to even greater documentation, interview information, and insights. He was a suit-system project engineer for over 20 years and served as principal investigator or key technical support engineer on Lunar-Mars suit efforts for over 15 years, being an inventor or the sole inventor on four international spacesuit patents. He is currently teaching engineering part-time at Central Connecticut State University.

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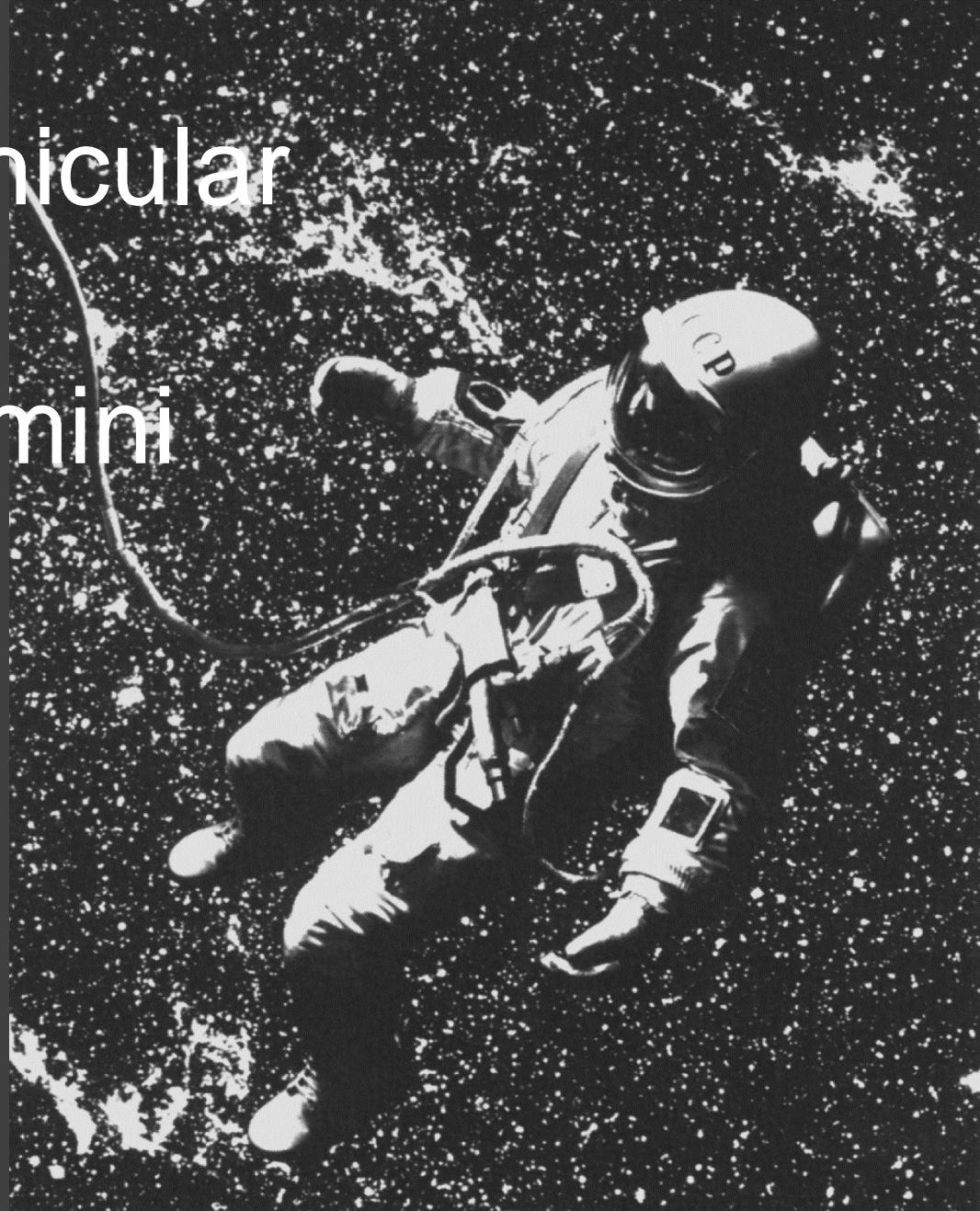
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# Intra-Extra Vehicular Activity (IEVA) Russian & Gemini Spacesuits

Presented by  
Kenneth S. Thomas  
July ??, 2016



# IEVA Spacesuit Programs:

- Voskhod Berkut Suit (1964) & World's First "Space Walk"
- Soyuz 4/5 Yastreb Spacesuit (1969)
- Oriol Lunar Soft-Suit (1964-69 Terminated By Soviet Decision To Use Dedicated EVA Suit)
- Gemini IV To XII Suit Systems (1964-66)
- The Other Gemini Capsule (USAF) Program, The Manned Orbiting Laboratory

# BEFORE SOVIET IEVA SUITS



Fig. 1 Yuri Gagarin In His SK-1 Launch Suit

During the Cold War, Factory 53 of Tomilino Russia (now RD&PE Zvezda) produced high altitude pressure suits and fighter ejection seat and parachute systems. When the Soviet Union started its space program, Factory 53 (Zvezda) became the exclusive creator of Soviet spacesuits systems (both pressure suit and life support).

The first Factory 53 design to see space use was the Vostok Model SK-1 spacesuit was for male cosmonauts. This was an exclusively intra-vehicular design. A SK-2 variant was produced for females. The entire suit-system was designed and manufactured by The pressure spacesuit was a soft garment with a purge-type ventilation system. The enclosure incorporated two layers: the outer restraint layer was made of Laysan and the inner pressure bladder of sheet rubber. A protective coverall was put over the enclosure. The helmet was rigid and irremovable, with a double visor and a system for emergency visor slide-down.

Development of the SK-1 started in 1960. The suit was first used on 12 April 1961 by Yuri Gagarin. The SK-2 began in 1962. The SK-1 and SK-2 suits were used in conjunction with the Vostok spacecraft until 1963).

The suit in conjunction with on-board ventilation system, on-board and parachute oxygen supply systems provided a cosmonaut with:

- Operating pressure of 3.9-4.4 psid (27.0-30.0 kPa)
- Spacesuit mass of 44 lbs (20 kg)

# VOSKHOD BERKUT

The Soviet Union Made  
The World's First EVA On  
March 18, 1965

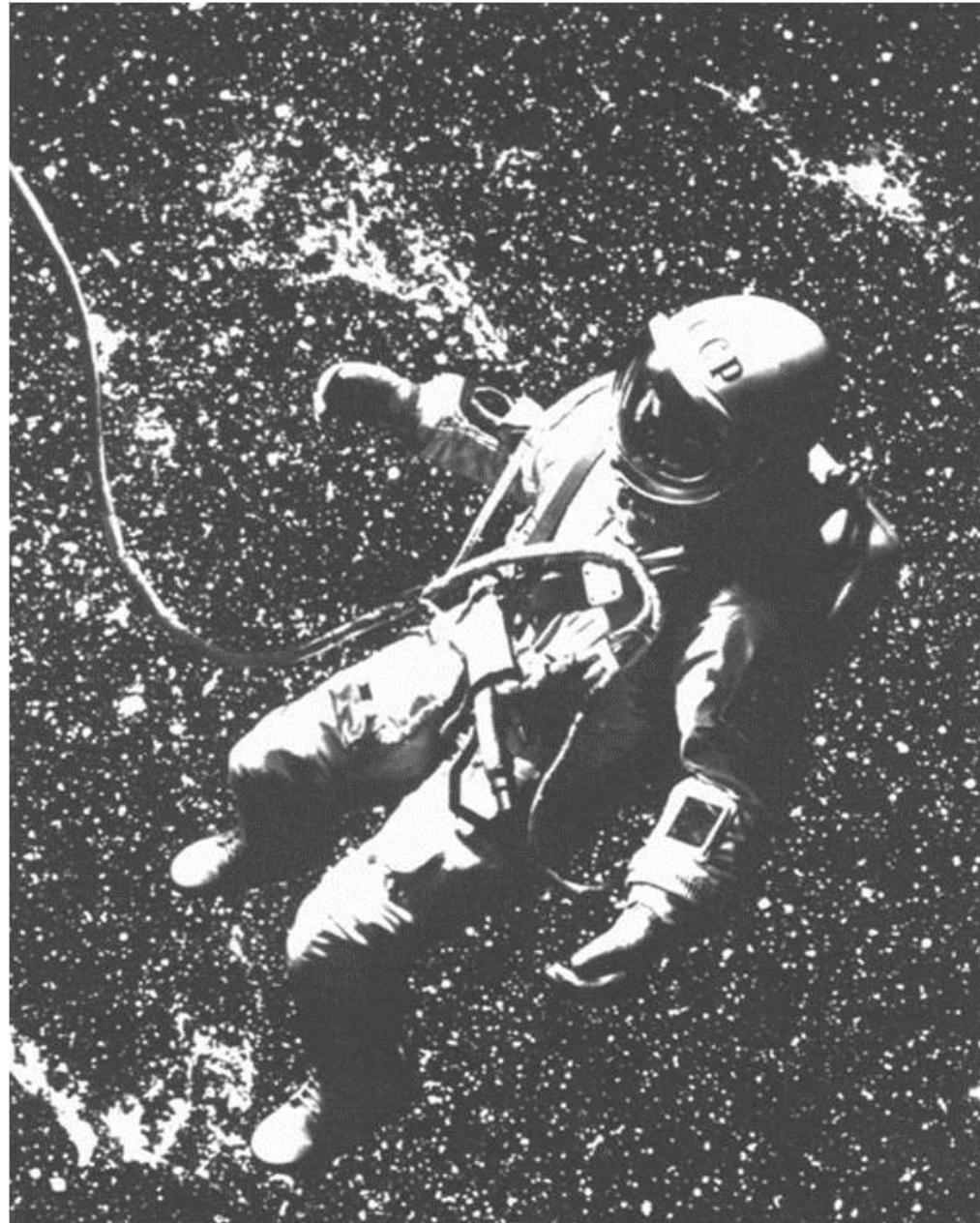


Fig. 2.1 World's First IEVA Suit-System

## VOSKHOD BERKUT, CONT.



The entire Berkut suit-system was designed and manufactured by Factory 53 (Zvezda) of Tomilino Russia. Berkuts were only used by the Voskhod-2 crew members where Aleksey Leonov made the world's first space walk (12 minutes, 9 seconds).

The pressure suit assembly (PSA) of the Berkut had a soft with a removable rigid helmet and a purge-type ventilation system. The PSA incorporated three layers. The inner layer was a double pressure bladder system. The primary bladder was made of sheet rubber and the back-up (internal) bladder was porous rubber. The restraint layer was made of Kapron (visible at far left). A protective coverall (on right of figure) provided vacuum thermal insulation was put over the pressure garment.

The PSA operated in conjunction with a self-contained life support system (LSS) arranged in a removable backpack (KP-55 oxygen unit). This LSS was designed to support an EVA by one of the two Voskhod-2 crew members and rescue of both crew members in case of emergency depressurization of the spacecraft cabin.

Fig. 2.2 Leonev Berkut At Zvezda

## VOSKHOD BERKUT, CONT.



**Fig 2.3 (above) The World's First EVA Life Support System**



**Fig. 2.4 (left) The Inflatable Airlock That Made The EVA Possible**

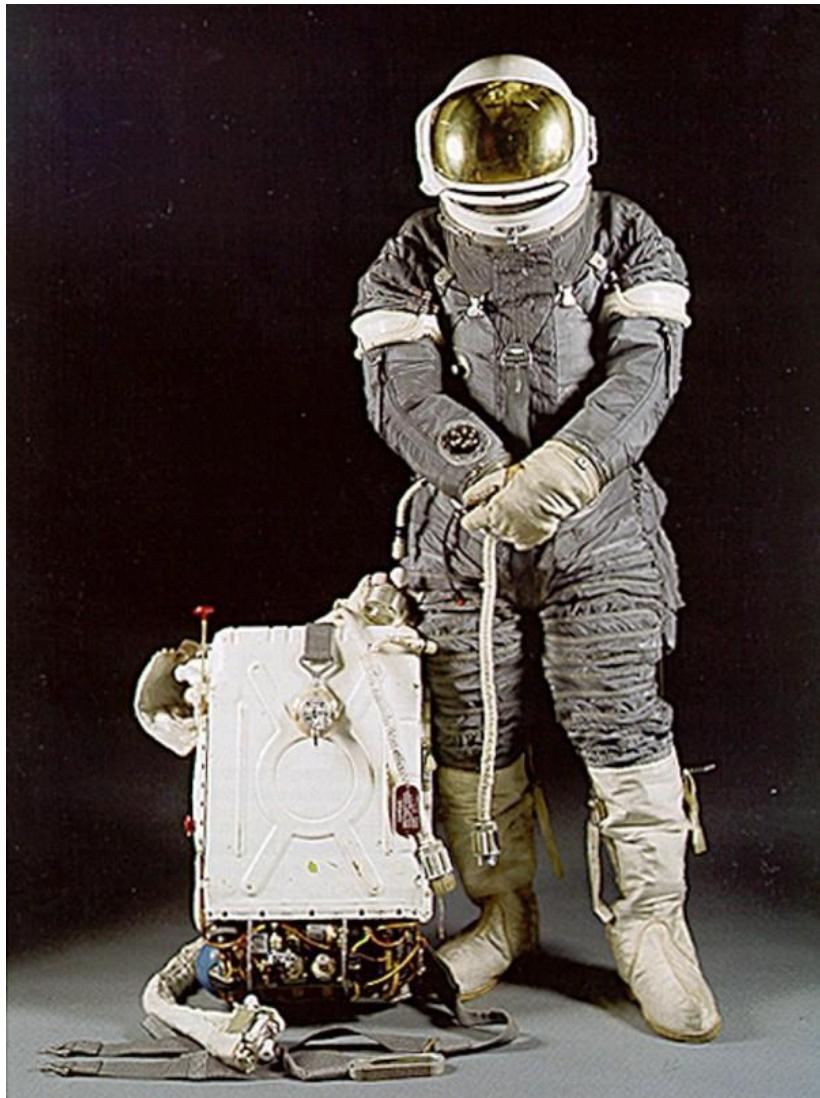
**Development & Operational Dates:** Development started in 1964. Operations were aboard Voskhod 2 in 1965. Leonov used Inflatable Airlock to perform EVA (12 minutes outside airlock, 24 minutes in space vacuum). Mission Commander Pavel Belyayev supported from inside Voskhod 2.

**Technical Characteristics (in conjunction with the on-board ventilation and oxygen supply system):**

Stay in a depressurized cabin:	4 hours
Autonomous LSS duration:	45 minutes
Nominal operating pressure:	5.9 psid (40.0 kPa)
Optional operating pressure:	3.11 psid (27.0 kPa)
Pressure suit mass:	44 lbs (20 kg)
Backpack LSS mass:	47.4 lbs (21.5 kg)

**Quantities Manufactured:** There were 9 test and training models. Flight model production consisted of 4 units.

# SOYUZ 4/5 YASTREB SUIT-SYSTEM



**Fig. 3.1 Yastreb System Without  
Torso Cover Garments**

The entire Yastreb suit-system was designed and manufactured by Factory 53 (now Zvezda). The Yastreb(s) were used by A. Yelisyev and E. Khrunov for tether transfer from Soyuz-5 to Soyuz-4 through free space on January 17, 1969.

The Pressure Suit Assembly (PSA) was of the soft garment with a removable rigid helmet. The enclosure incorporated three layers. The inner layer was a two-bladder system. The main bladder was made of sheet rubber and the backup (internal) bladder of porous rubber. The restraint layer was made of Kapron. An outside protective coverall provided vacuum thermal insulation was put over the pressure enclosure. The suits were manufactured in several standard sizes and featured additional adjustment of shoulder breadth and height. The pressure suit operated in conjunction with a self-contained life support system (SCLSS).

The SCLSS model RVR-1P was a fully autonomous type system that was leg mounted for the Soyuz 4/5 operation.

## 3.8 SOYUZ 4/5 YASTREB, Cont.



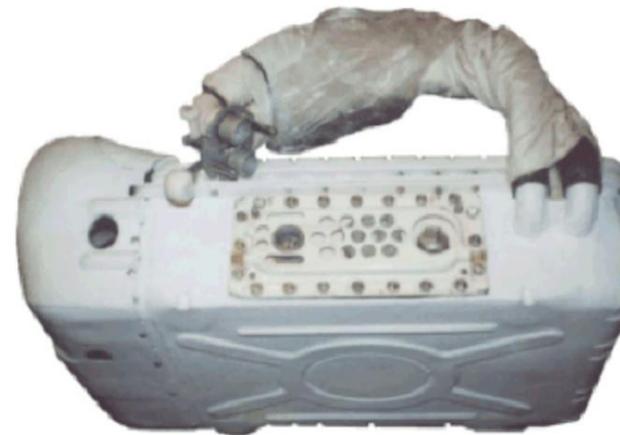
**Fig. 3.2 Yastreb PSA  
With Cover Garments**

Development & Operational Dates: Development and tests: 1965-1967. Operations: 1969.

### Technical Characteristics:

Autonomous LSS duration:	2.5 hours
Operating pressure, main mode:	5.9 psi (40.0 kPa)
Operating pressure, back-up:	3.11 psi (27.0 kPa)
Pressure suit mass:	44 lbs (20 kg)
LSS mass:	69.4 lbs (31.5 kg)

Quantities Manufactured: Test and training models: 18. Flight models: 6.



**Fig 3.3 SCLSS model RVR-1P  
Control Panel**

# ORIOL IEVA LUNAR SUIT DESIGN

While the Yastreb was the last Soviet IEVA suit to see flight use, it was not the end of Russian “soft” suit-system IEVA development. In parallel to the Yastreb and the hybrid hard/soft Krechet/Olan suits, Factory 53 also developed a multi-purpose spacesuit to support launch/reentry, rescues and lunar EVA under the code name Oriol (Fig. 4).

The time needed to fold/tie the bladder, lace up the restraint garment and don outer garments was the probably greatest influence in the Soviets selecting the Kretchet lunar lander and Orlan command module designs.

The hybrid hard/soft command module design with periodic changes became the Russian space station Orlan series still in use today.



**Fig. 4 An Oriol Prototype**

## ORIOL LUNAR SOFT-SUIT, CONT.

PSA - The Oriol featured a “soft” type pressure garment. The outer protective enclosure had vacuum thermal insulation and within limitations shielded from radiation and micro-meteoroids. The Oriol incorporated the restraint layer made of Kapron and Orthofabric, a knitted fabric supported natural rubber bladder (no back-up, or standby bladder was used), a water-cooled garment, a ventilation suit and a removable rigid helmet. In the final phase of the suit’s development program, Oriol development was used as an opportunity to evaluate mobility system options.

LSS - The Oriol lunar spacesuit was to have a closed-loop type Baikal LSS arranged in a “backpack” that was designed to support cosmonaut EVA on the Moon.

Development ranged from 1966 to 1970 before the Oriol effort was terminated.

Technical characteristics included:

Operating pressure, main mode:

5.9 psi (40.0 kPa)

Operating pressure, back-up:

3.11 psi (27.0 kPa)

Duration of LSS operation

4 hrs

Pressure suit assembly mass

Aprox. 44 lbs (20 kg)

Baikal LSS mass

Aprox. 79 lbs (36 kg)

Quantity of manufactured space suits

Pressure suits:

3 test suits in various configurations

Baikal LSS:

1 mock-up of the Baikal backpack.

# GEMINI IV EVA SYSTEM

- Gemini spacecraft full-opening hatch made EVA feasible (Fig. 5.1, right)
- EVA started as a Gemini secondary objective

- Leonov's March 18, 1965 EVA (Fig. 5.2, right) accelerated US plans for an American EVA



## GEMINI IV EVA SYSTEM, CONT.

- 69 days from concept inception to orbit
- Open-loop system; relief valve controlled suit pressure
  - Cooling from dry gas + sweating
- 25 foot gold-coated umbilical fed O2 from Spacecraft
- Oxygen flow to helmet purged CO2
- 9 minute manually initiated emergency purge
- Nitrogen-powered hand-held maneuvering unit
- 36 minute EVA



**Fig. 5.3 (right) Ed White Performing America's First EVA on 6/3/65**

## GEMINI IV EVA SYSTEM, CONT.

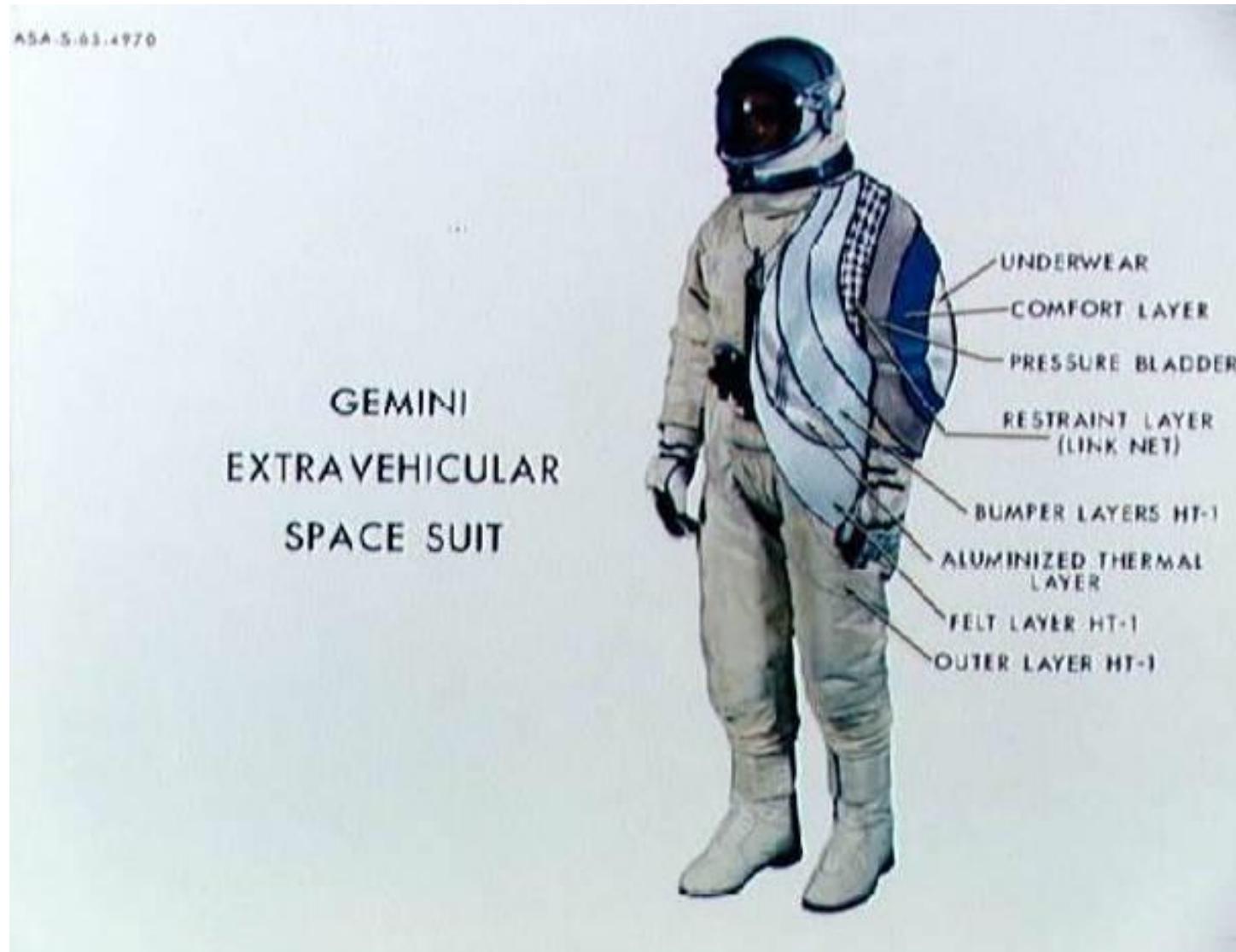


Fig. 5.4 Gemini IV Pressure Suit Features

## GEMINI IV EVA SYSTEM, CONT.

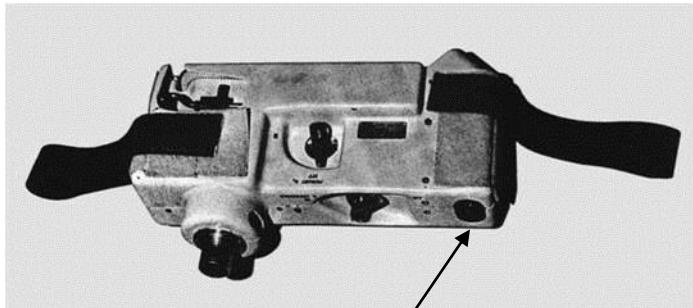


Fig. 5.5 (above)  
Ventilation Control  
Module (VCM)

Fig. 5.6 (right) Hand-  
Held Maneuvering Unit  
(HHMU)

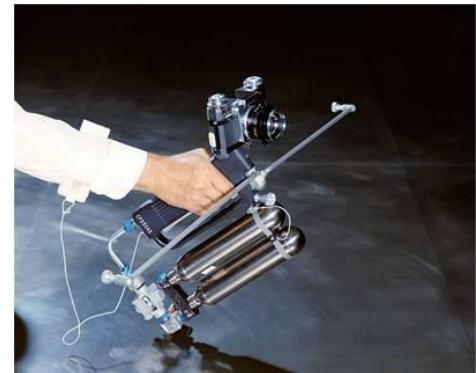
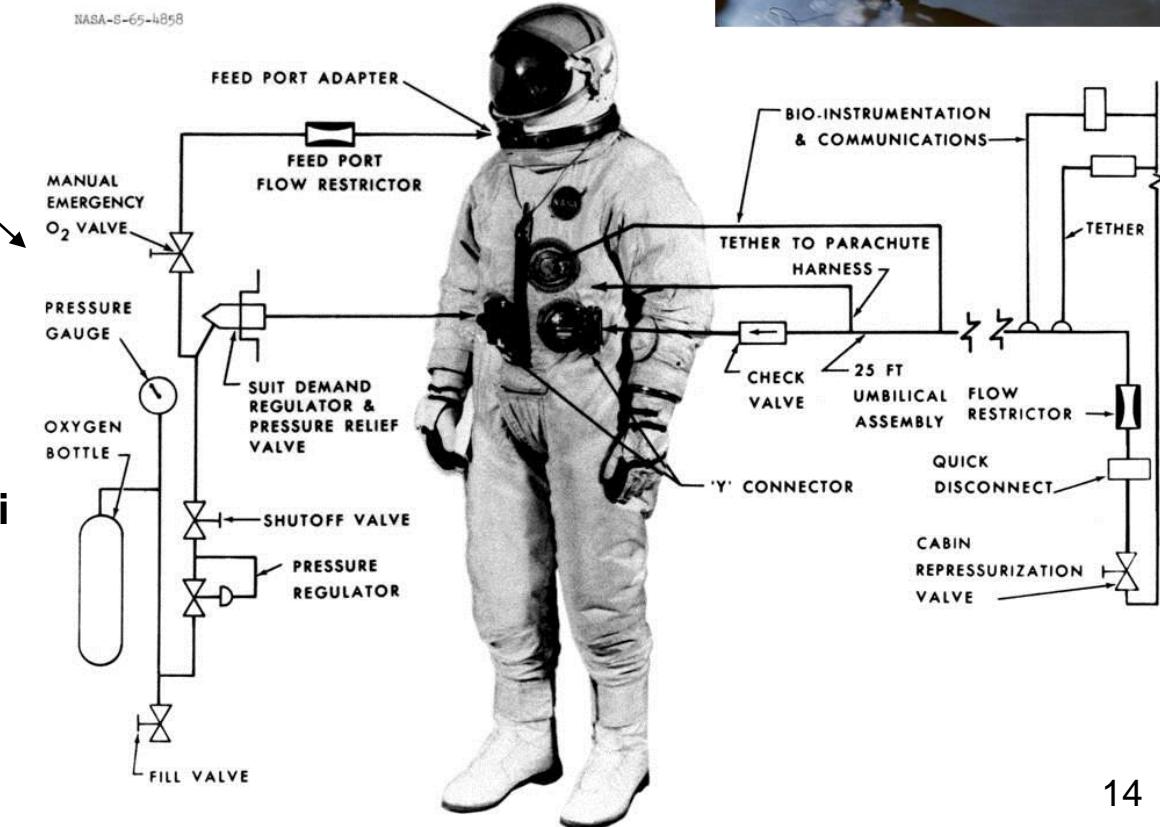


Fig. 5.7 (right) Gemini  
IV Suit-System  
Schematic



## GEMINI IV EVA SYSTEM, CONT.

- Visor fogging and overheating of CM while closing hatch
- Early indications of the need for restraints
- Difficulty, energy cost of working in the suit



**Fig. 5.8 (right) White Re-entering Spacecraft Demonstrates Encumbrance Of Gemini IV Umbilical**

## GEMINI IV EVA SYSTEM, CONT.

### Summary:

Description: The Gemini IV suit-system consisted of G4C spacesuits and a NASA/AiResearch Ventilation Control Module (VCM). The particular configuration of G4C and the VCM life support system were unique to the Gemini IV mission.

Development & Operational Dates: Development of this suit-system started in March 1965 using existing designs and hardware wherever possible. The Gemini G4C Intra/Extra-Vehicular Activity (IEVA) spacesuit was designed and manufactured by the David Clark Company of Worcester Massachusetts, USA to be able to support extra-vehicular activity (EVA) and also launch/reentry/rescue functions. NASA was the system level integrator and developed the VCM using existing design and (where possible) made hardware with an AiResearch-supplied umbilical in response to the Soviet Union's/world's first EVA performed by Aleksey Leonov. The VCM and umbilical provided Astronaut Ed White with life support on the first U.S. EVA mission. The system flew and supported a successful 20-minute EVA in June 1965.

### Technical Characteristics:

Function:	Both IVA & EVA
Operating Pressure (Nominal):	3.7 psi (25.5 kPa)
PGA Weight @ 1-G:	34 lbs (15.4 kg)
EVA Life Support System, Primary:	VCM Umbilical, not time limited
EVA Life Support System, Backup:	VCM 9 minutes
VCM Weight @ 1-G:	7.75 lbs (3.52 kg)

Quantities Manufactured: As G4C suits were used on all the later missions (except Gemini VII) and the non-flown suits associated with Gemini IV were rolled into other program functions, determining "Gemini IV" quantities is not possible. Therefore, the quantities are included in "Gemini V, VI, & VIII To XII IEVA Spacesuit System" summary later in this Appendix. It is believed that only three VCM units were made.

# GEMINI VIII TO XII SYSTEM OVERVIEW



Umbilical (above) providing:

- Oxygen
- Electrical Power
- Communications

Extra-vehicular Supply Pack (right) autonomously providing:

- Oxygen
- Electrical Power
- Communications
- Gas for Propulsion



Astronaut Maneuvering Unit (above) autonomously providing:

- Oxygen
- Electrical Power
- Communications
- Propulsion

**Fig. 6.1 Gemini Extra-vehicular Life Support System (ELSS) Features**

# GEMINI VIII TO XII SYSTEM OVERVIEW, CONT.

NASA-S-67-242

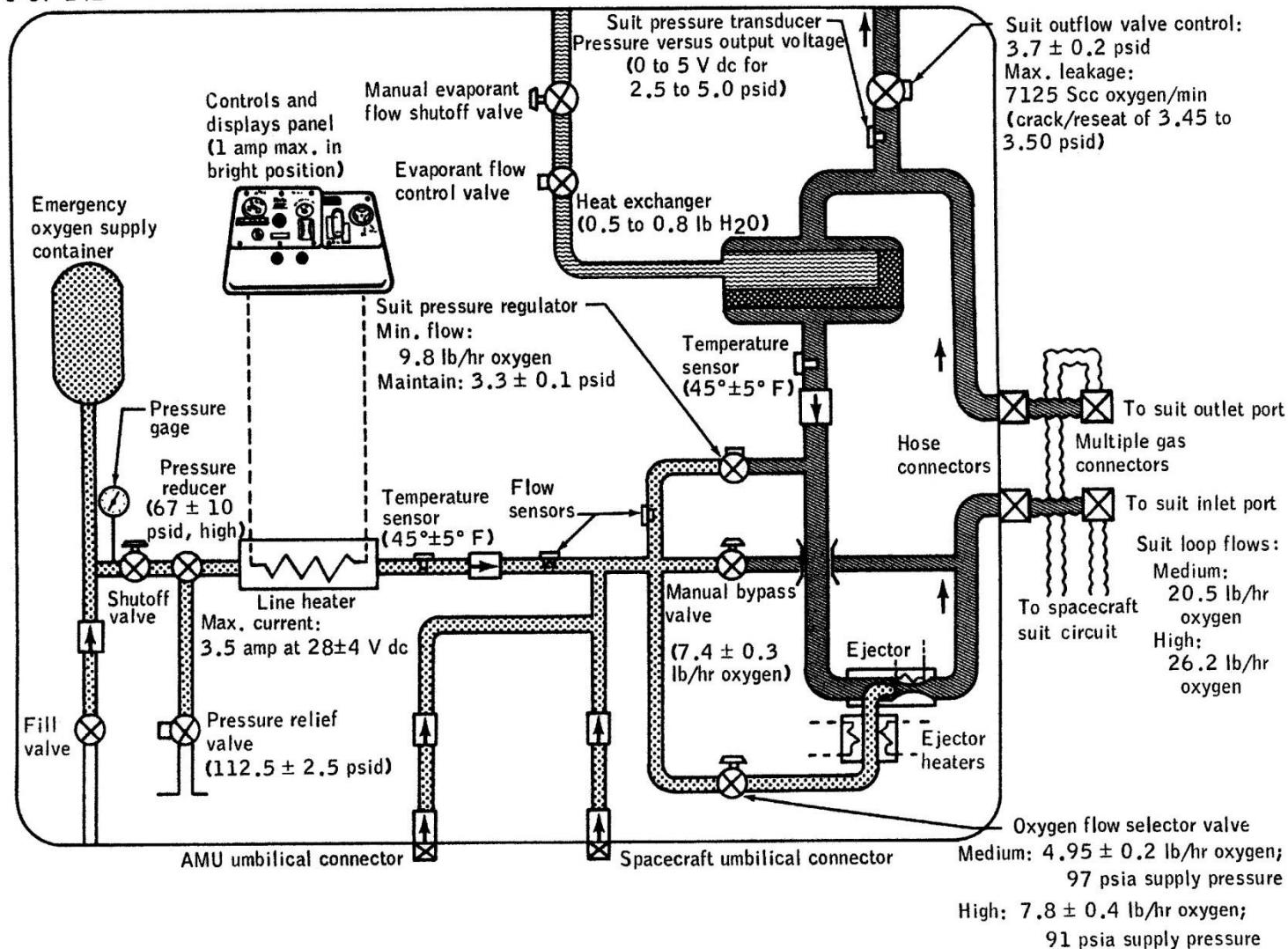


Fig. 6.2 Gemini Extra-vehicular Life Support System Schematic

## GEMINI VIII TO XII SYSTEM OVERVIEW, CONT.

### Summary:

Description: NASA was integrator. The G4C spacesuit was a product of the David Clark Company of Worcester Massachusetts, USA. The ELSS was developed and manufactured by AiResearch (now Honeywell) of Torrence California, USA.

Development & Operational Dates: Development of the G4C started in March 1965 and saw flight in June 1965 aboard Gemini IV. Gemini V and VI G4C lacked EVA sun visors, over-jackets and over gloves. The Gemini VIII through XII G4C suits all had mission-specific cover garments. Development of the ELSS was a planned Gemini program activity that started in 1963, but was extensively revised during development. The ELSS first flight was Gemini VIII and first EVA was Gemini IX-A. This system was used by 4 astronauts to log 11 hours, 49 minutes of total EVA time in 4 EVAs.

### Technical Characteristics:

Function:	IVA (without ELSS) & EVA (with Accessories)
Operating Pressure (Nominal):	3.7 psi (25.5 kPa)
PGA Weight @ 1-G:	34 lbs (15.4 kg)
EVA Life Support System, Primary:	ELSS Umbilical, not time limited
EVA Life Support System, Backup:	ELSS EOS 30 minutes
ELSS Weight @ 1-G:	47 lbs (21.3 kg)

Quantities Manufactured: At least 42 G4C suits were made supporting Gemini IV through VI and VIII through XII, of which 16 saw flight. Eight chestpacks were built; of which, four were used during EVA. All chestpacks used during EVA were jettisoned into space before re-entry.

# GEMINI VIII SUIT SYSTEM (1966)

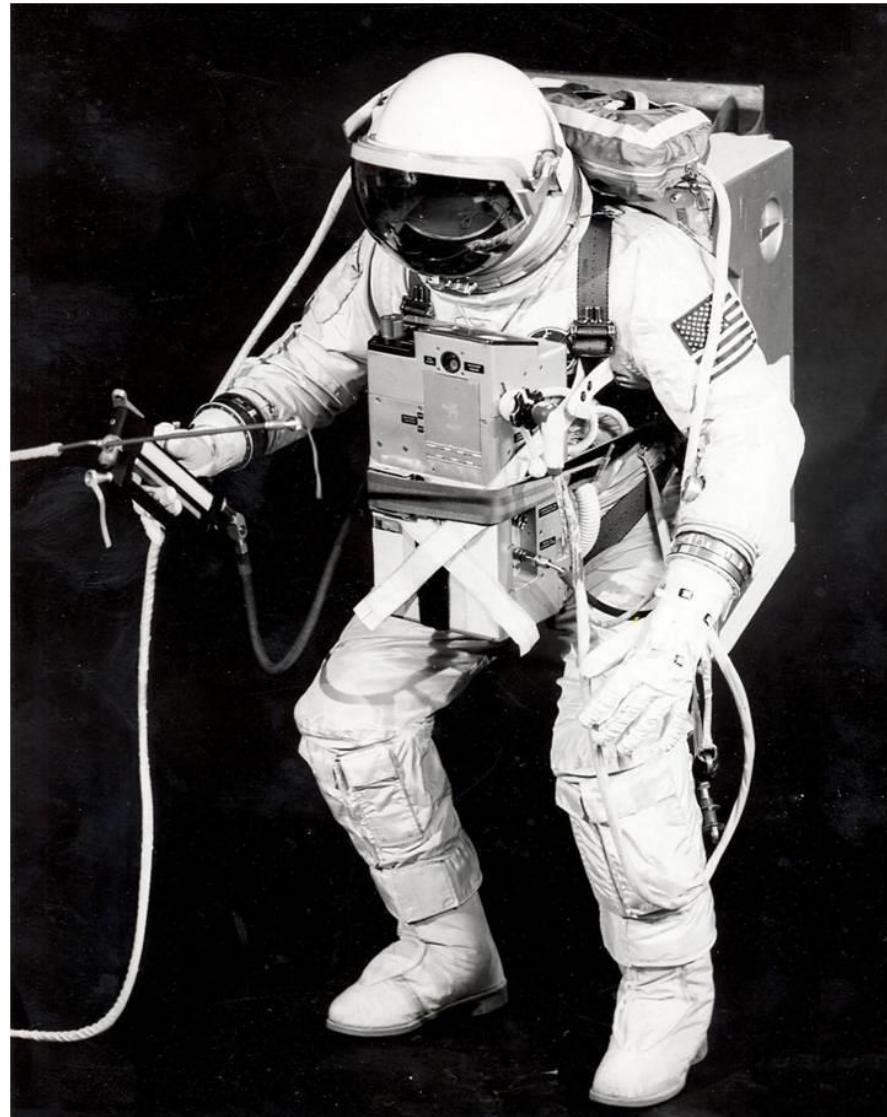
PSA – minor change from GT-4:

- 2 layers neoprene-coated nylon vs nylon felt and nylon fabric
- Integral glove TMG vs overglove

Life support and maneuvering system modular approach

- Chest-mounted Extravehicular Life Support System (ELSS)
- Back-mounted Oxygen/Nitrogen-Freon Extravehicular Support Pack (ESP)

Fig. 7.1 GT-8 Suit System (right)



## GEMINI VIII SUIT SYSTEM, CONT.

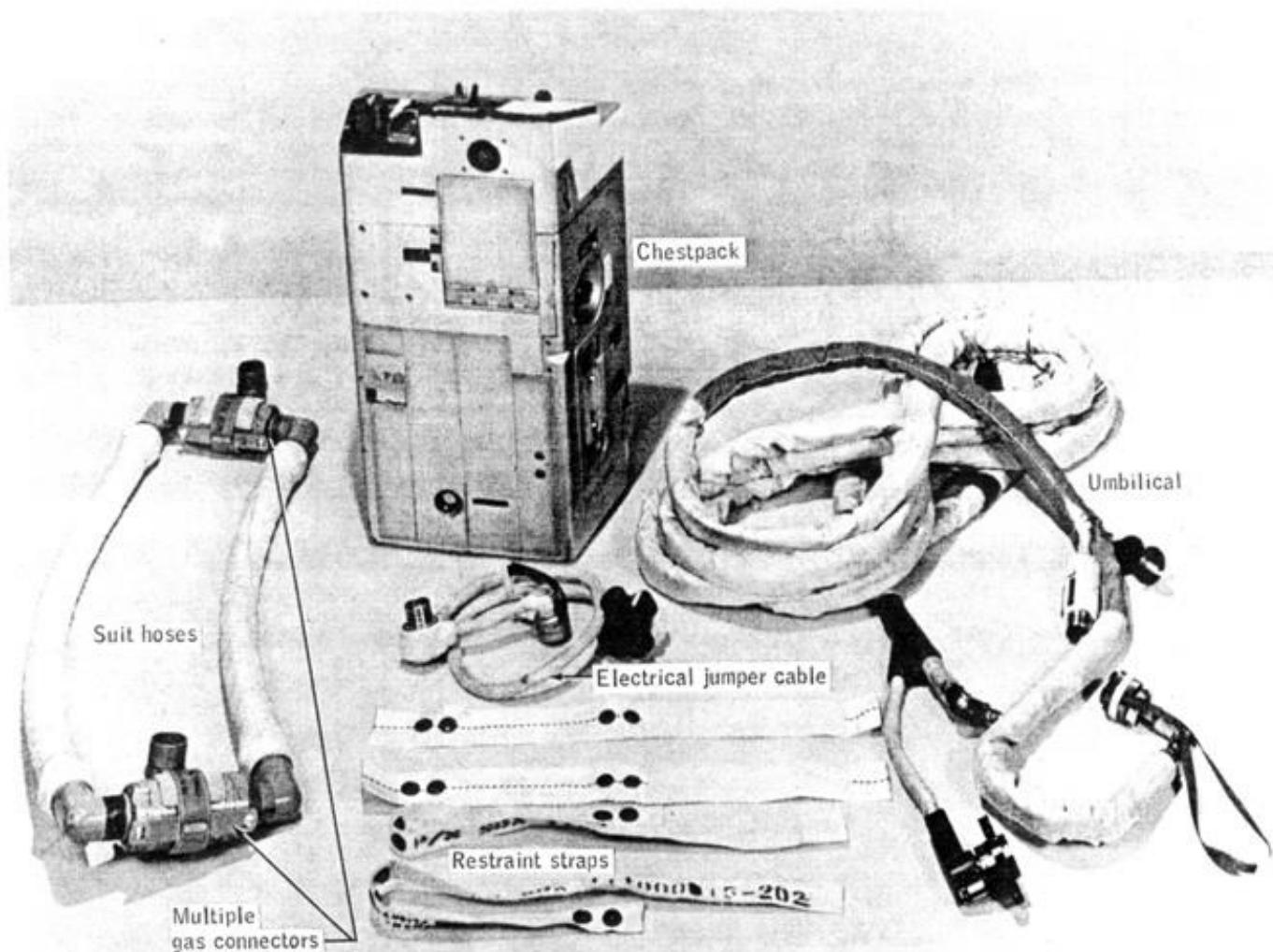


Fig. 7.2 Extravehicular Life Support System (ELSS) Components

## GEMINI VIII SUIT SYSTEM, CONT.

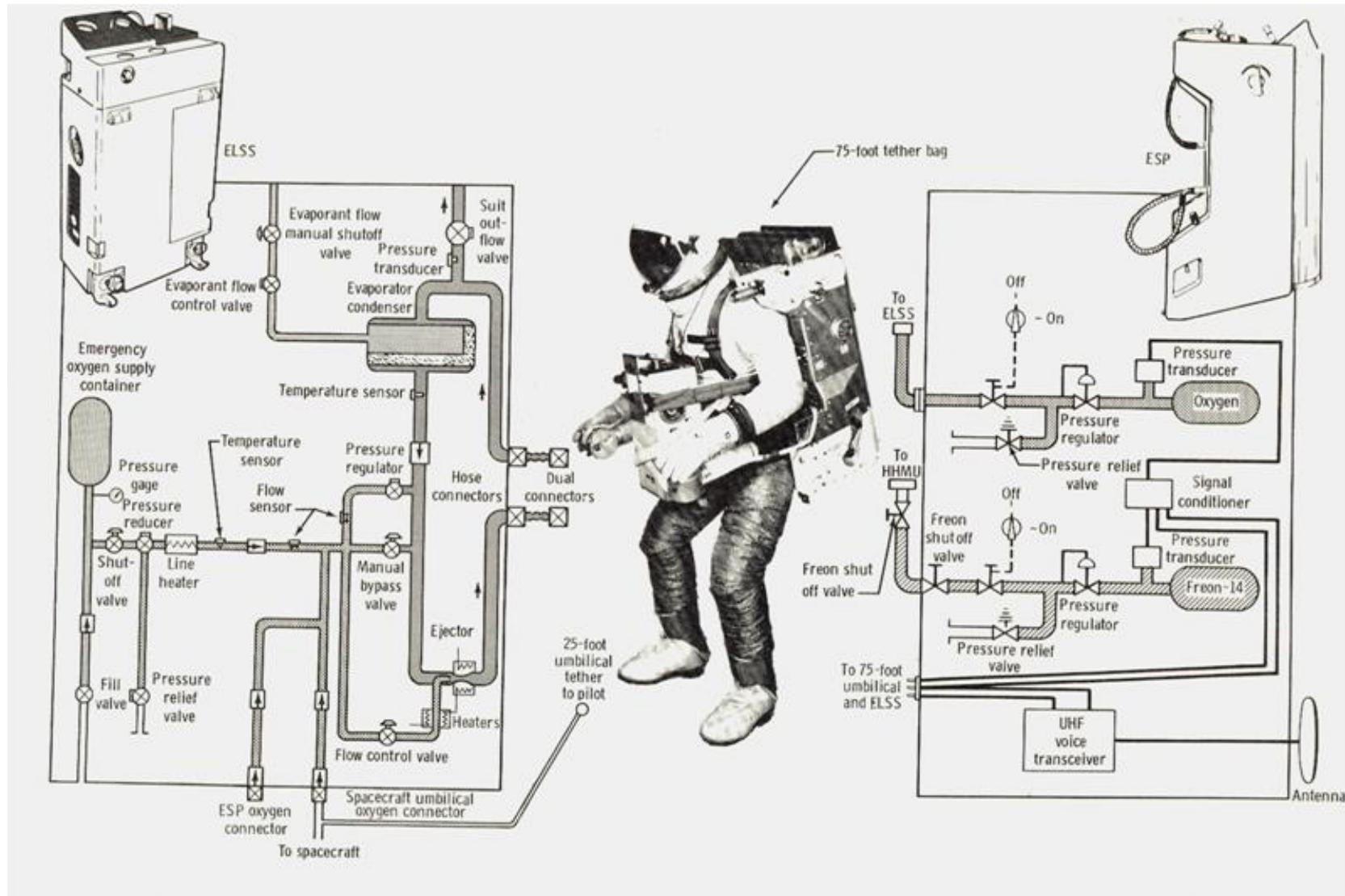


Fig. 7.3 GT-8 Suit System Schematic

## GEMINI VIII SUIT SYSTEM, CONT.

### Back-mounted ESP

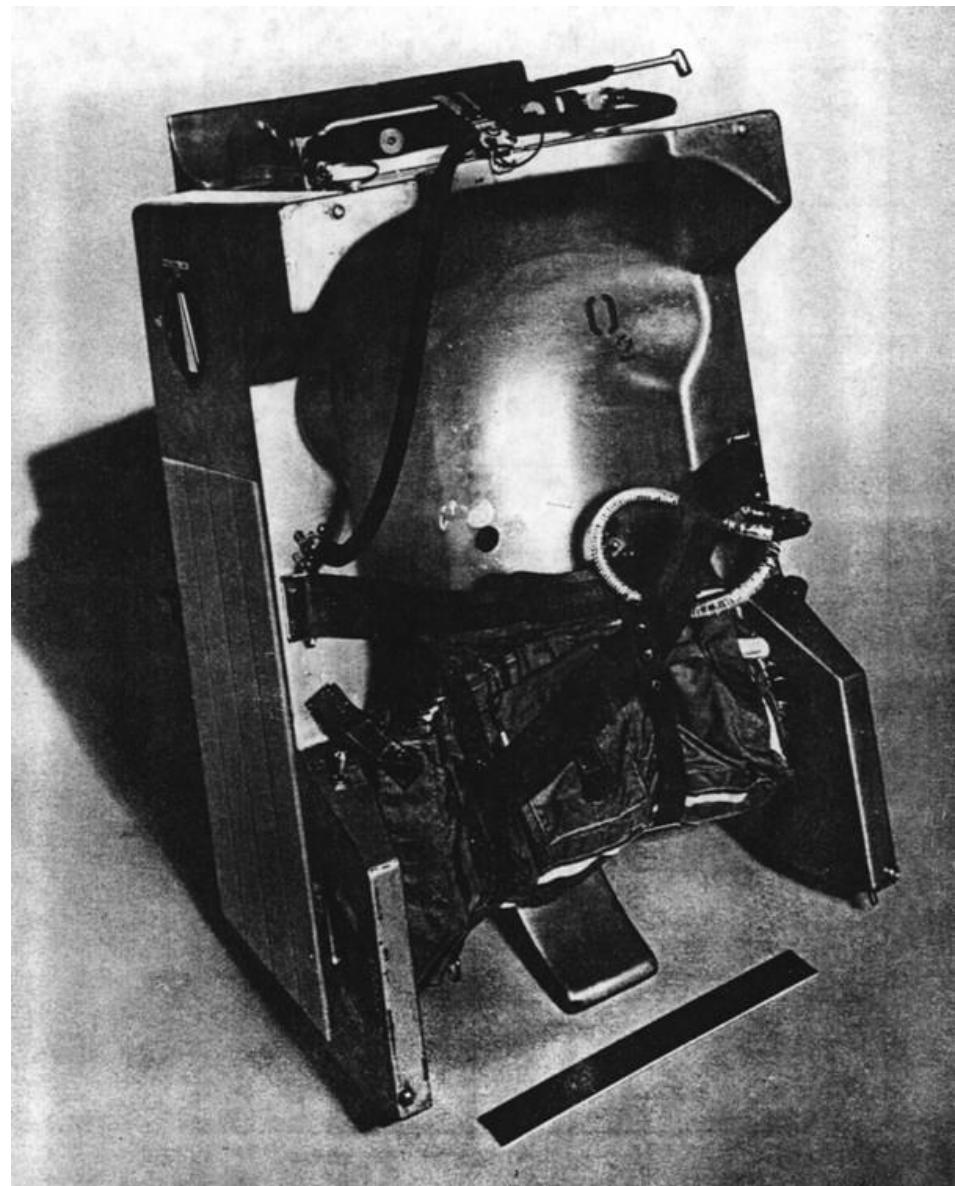
#### Supplying:

- Oxygen for life support; quantity remaining read out on ELSS panel
- Nitrogen/Freon mixture for HHMU propellant
- Radio Communications

#### System Never Used

- Spacecraft thruster failure caused early termination of mission
- ELSS recovered; ESP burned up on entry

**Fig. 7.4 Gemini Extra-vehicular Support Pack (right)**



# GEMINI IX-A SUIT SYSTEM

## Features:

- Cover-layer changed
- Visor changed from Plexiglas to Lexan
- Impact visor eliminated
- Gold-coated acrylic visor added for improved visible and infrared light attenuation

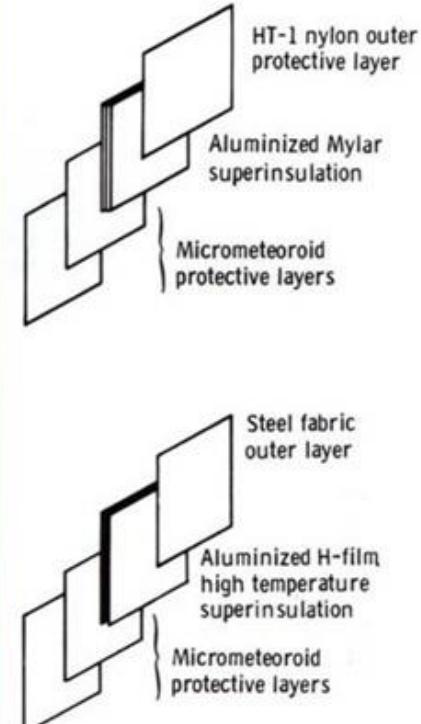


Fig. 8.1 Changes For The IX-A Mission

## GEMINI IX-A SUIT SYSTEM, CONT.

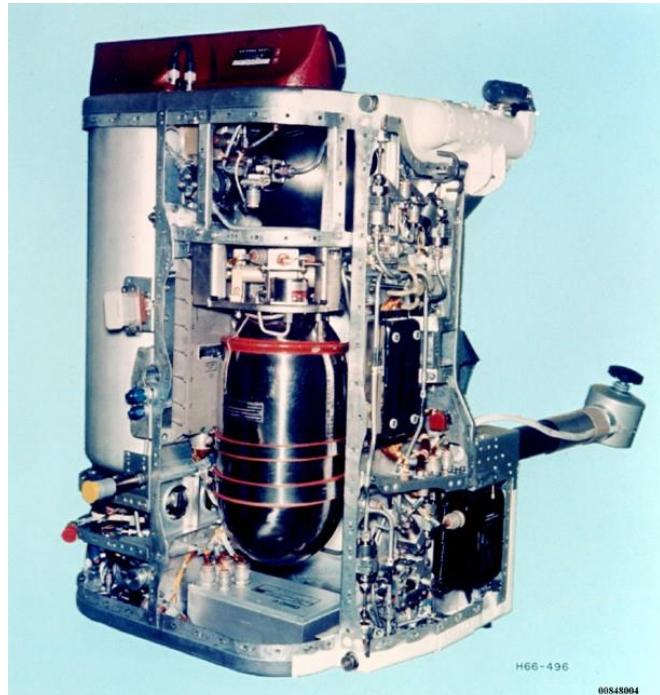
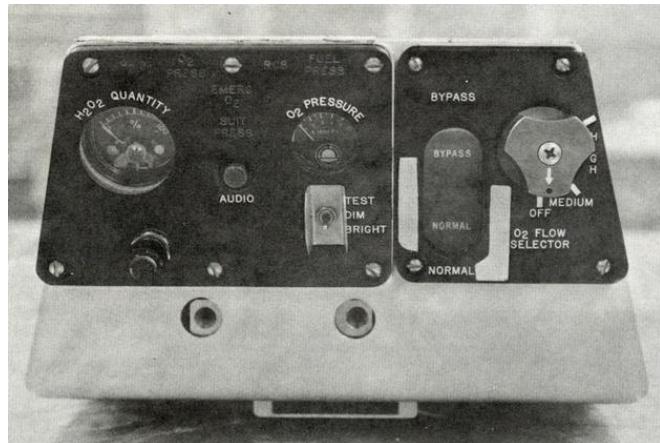
- ELSS – same as GT-VIII

Fig. 8.2 (right) ELSS Console

- Astronaut Maneuvering Unit (AMU) Backpack Providing:

- Oxygen
- Electrical Power
- 125 Foot Safety Tether
- Redundant power; 6 Degrees of Freedom thruster system
- $\text{H}_2\text{O}_2$  propellant (quantity readout on ELSS)
- Radio Communication

Fig. 8.3 (right) AMU Internal View



## GEMINI IX-A SUIT SYSTEM, CONT.

- AMU to be donned in Gemini adapter while EVA
- “Loop”-type foot restraints proved to be inadequate
- Visor fogged due to omission of antifog application and high workload; EVA terminated without AMU evaluation
- AMU suffered same fate as ESP
- Insulation in back of suit noted to be separated – “hot spots”



Fig. 8.4 Gemini IX-A Foot Restraints

# GEMINI X SUIT SYSTEM

## Life Support :

- ELSS had redesigned check valve
- Two instances of internal combustion on old valve
- 50 foot umbilical with oxygen /nitrogen /electrical /tether

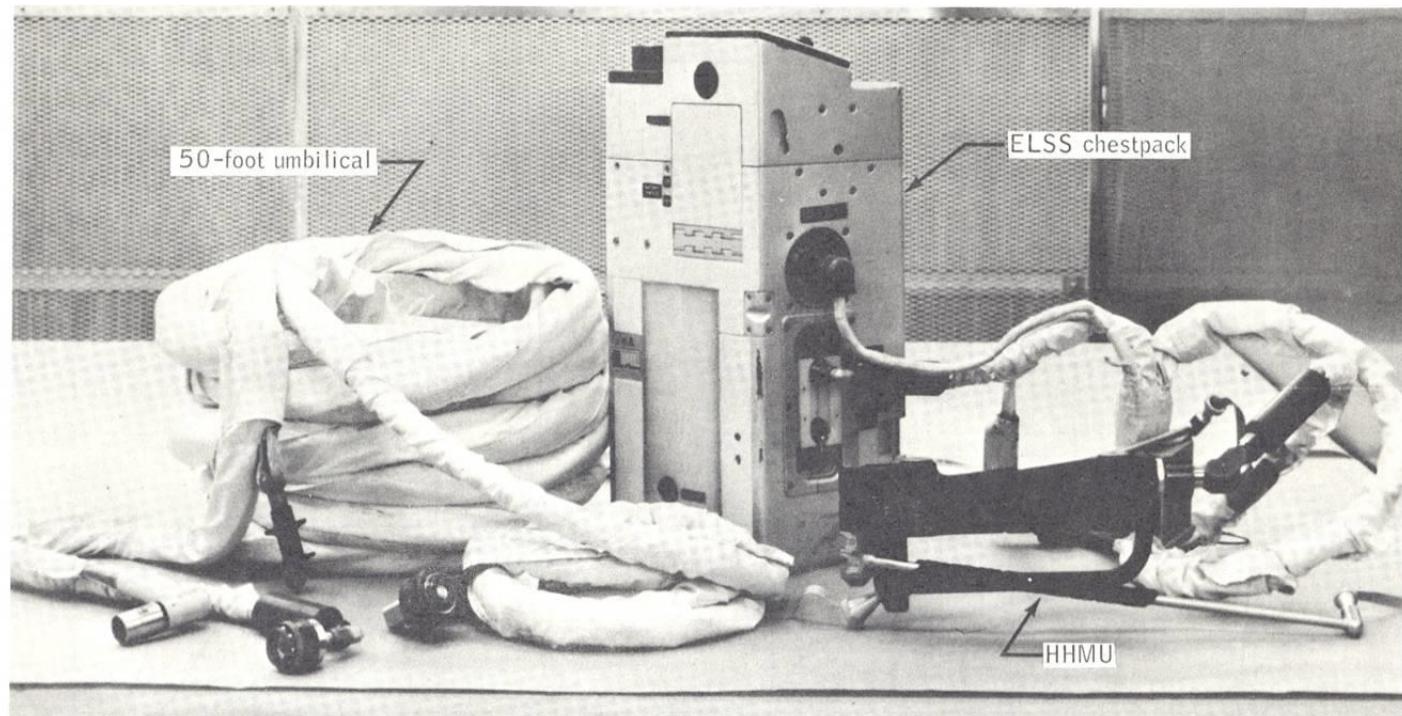


Fig. 9  
(right)  
Gemini X  
ELSS

# GEMINI XI SPACESUIT

## PSA:

- Similar to Gemini X
- Redundant locks added to disconnects

## ELSS:

- Was like Gemini X
- Umbilical length shortened to 35 feet, based on Gemini X experience

## HHMU:

- Quick disconnect replaced previous screw-on coupler



**Fig. 10.1 Gemini XI CM  
Preparing For Flight**

## GEMINI XI SPACESUIT, CONT.



**Fig. 10.2 Traverse Back From Docked Target Spacecraft**



**Fig. 10.3 Gemini XI Ion Wake Experiment**

## **GEMINI XI SPACESUIT, CONT.**

### **Mission Summary:**

- EVA was early in mission
- Overheating experienced during camera mounting; tether attachment to Agena
- Significant sweat in eyes; may have had high CO<sub>2</sub>
- HHMU not evaluated, due to early termination of EVA
- No problems experienced with shorter umbilical
- Limitations of cooling by the ventilation stream demonstrated again

## **GEMINI X SUIT SYSTEM, CONT.**

### **Pressure Suit:**

- Torso Assembly similar to Gemini VIII
- Visor assembly like Gemini IX-A

### **Maneuvering equipment:**

- HHMU similar to Gemini VIII – slight handle mods

### **Mission Summary:**

- S-12 Experiment (micro-meteorite collector) retrieved from docked Agena target vehicle. Later lost; drifted out of cabin. Demonstrated need to secure equipment
- HHMU evaluated, CM commented that “gun” wasn’t extremely accurate, but got him where he needed to go
- 50 foot umbilical bulk a problem in the cabin
- EVA terminated after 39 minutes on umbilical due to HHMU propellant shortage
- CM was cool during EVA

# GEMINI XII SUIT SYSTEM

Suit :

- Initial plans called for AMU evaluation
- Suit to have metal cloth, extra insulation
- AMU deletion from mission resulted in suit modification
- Metal cloth replaced with high-temperature nylon
- Some insulation required for AMU deleted from legs
- Quilting used to prevent tears and separation experienced on Gemini IX-A

ELSS:

- Similar to that used on Gemini XI
- Umbilical – 25 foot version like Gemini IX-A
- No maneuvering equipment flown

## GEMINI XII SUIT SYSTEM, CONT.



Fig. 11.1 First - Aldrin removes micrometeoroid package from Agena

## GEMINI XII SUIT SYSTEM, CONT.

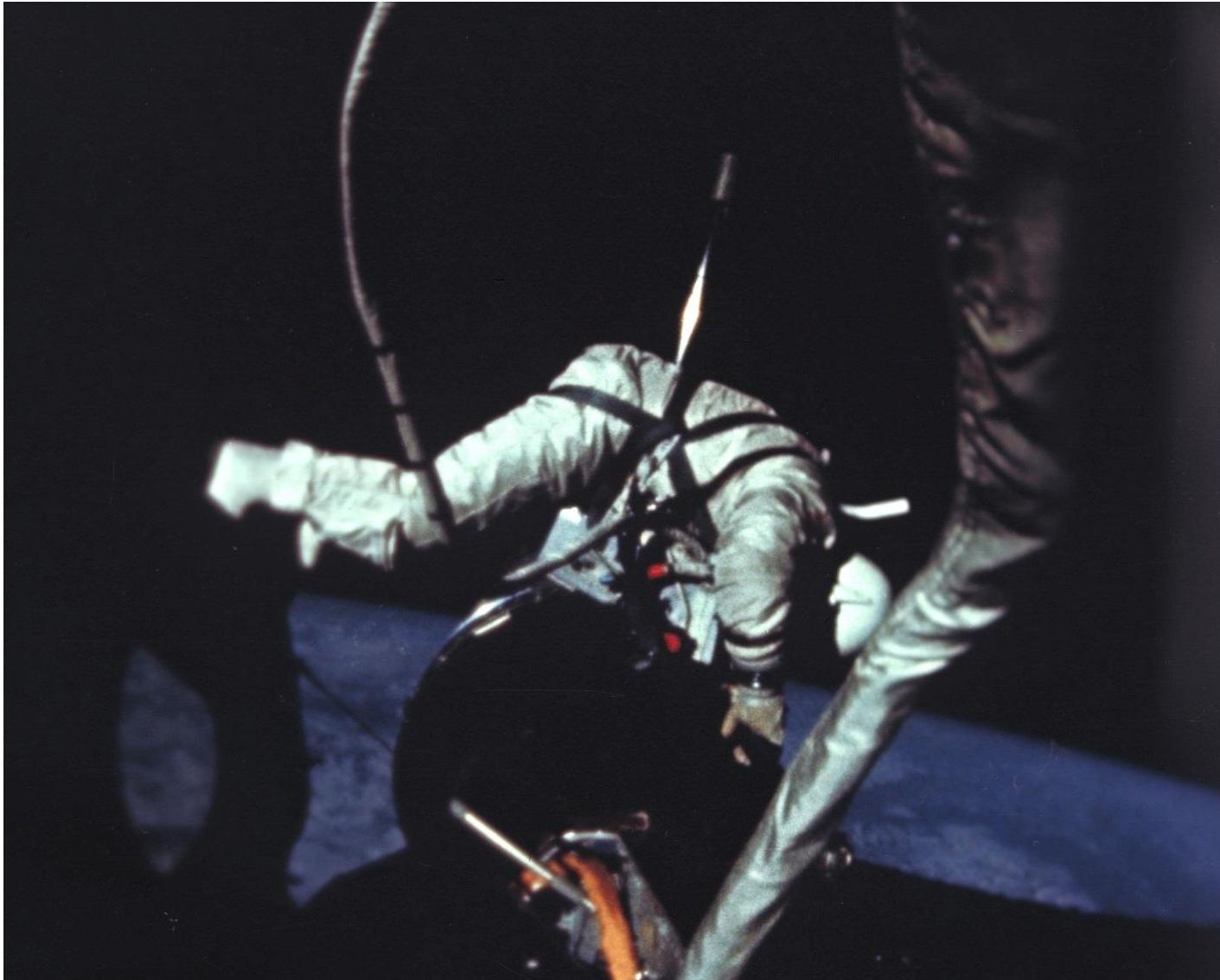


Fig. 11.2 second day - Aldrin Traversing To Docked Agena

## GEMINI XII SUIT SYSTEM, CONT.

Fig. 11.3 Second Day,  
Aldrin Positioned Next  
To Agena Work Station.



## **GEMINI XII SUIT SYSTEM, CONT.**

### **Mission XII Summary:**

- Previous experiences caused mission focus on evaluation of body restraints, handholds, workstations
- Some prototype Apollo tools evaluated
- Astronaut Aldrin was cool – feet were slightly cold – during the 2 hour, 6 minute EVA
- Mission was a success

### **Significance Of Gemini Program EVA:**

- Work in the suit was harder in orbit than anticipated
- Life support system approach (gas cooling) was unequal to the task
- Control of body positioning is essential during EVA
- Pre-flight training using neutral buoyancy is essential for predicting ability to perform tasks in orbit

# MANNED ORBITING LABORATORY



USAF MANNED ORBITING LABORATORY

## MANNED ORBITING LABORATORY, CONT.

The first USAF Manned Orbiting Laboratory (MOL) spacesuit contract was design-to-cost IEVA :

- USAF funded David Clark, International Latex and Litton for development prototypes. Suits were CM cooling by ventilation gas. Hamilton Standard entered under internally funded development and won the 1966 competition.
- The first MOL suit to follow in 1967 was a XM-4A prototype
- Manload-induced suit failures resulted during manned (Lawyer) testing and establishing man-induced suit loads later used on Shuttle EMU



Fig. 12.1 (right) MOL Pilot Dick Lawyer in XM-4A Suit (without cover garments)

## MANNED ORBITING LABORATORY, CONT.

- MH-5 training and MH-6 flight suits followed in 1967. The MH series used the torso configuration and gloves as the XM-4A.
- Revisions in controls and life support connector locations caused model role to MH-7 training and MH-8 flight suits in 1968.
- MH-8 completed certification before program termination in June 1969.



**Fig. 12.2 (right) &  
Fig. 12.3 (left)  
Dick Lawyer Suit  
Subject**



# MANNED ORBITING LABORATORY, CONT.

## Summary:

The flight configuration PSA MH-8. The primary life support was to be provided by the Umbilical Life Support System (ULSS) that anchored to a bracket just below the entry zipper. The ULSS provided communications and a 3.7 psid operating pressure source. The ventilation oxygen was purged by relief-function of the suit's pressure controller located in the lower (as worn) left front of the PSA. The 10 minute backup life support was provided the Emergency Oxygen System (EOS) that was packaged as a strap-on assembly located on the front of the right upper leg.

**Development & Operational Dates:** Development spanned 1965-67. The MH suits were produced from 1967 to 1969, which was the end of the MOL program. There was only one unmanned MOL flight before program termination.

## Technical Characteristics:

Operating Pressure (Nominal):	3.7 psi (25.5 kPa)
LEA PSA Weight @ 1-G:	38.4 lbs (17.4 kg)
EVA PSA Weight @ 1-G:	39.0 lbs (17.7 kg)
Sizing:	10 standardized sizes with leg & arm adjustability
Useful Life:	3 years
EVA Life Support System, Primary:	ULSS Umbilical, not time limited
EVA Life Support System, Backup:	EOS 10 minutes
ULSS/EOS Weight @ 1-G:	13 lbs (5.9 kg)

**Quantities Manufactured:** Development created 9 HS prototype designs, 8 HS funded. Manufacture produced at least 18 training and 4 flight type PSAs. ULSS quantities were limited but are not precisely unknown.

# IEVA Suit Summary:

Model	IVA Mass	EVA Mass	EVA Capability
Gemini IV SSA	34 lbs (15.4 kg)	41.8 lbs (18.9 kg)	Umblical*
Gemini VIII to XII SSA	34 lbs (15.4 kg)	81 lbs (36.7 kg)	Umblical*
Skylab EMU	62 lbs (28 kg)	147 lbs (66.8 kg)	Umblical*
Voskhod Berkut	44 lbs (20 kg)	91.4 lbs (41.5 kg)	Autonomous
Soyuz Yastreb	44 lbs (20 kg)	113.4 lbs (51.5 kg)	Autonomous
Apollo 11-14 EMU	53 lbs (24 kg)	189 lbs (85.7 kg)	Autonomous
Apollo 15-17 EMU	55 lbs (25 kg) **	201 lbs (90.8 kg) **	Autonomous

## Modern Points of Reference:

Sokol-KV-2	22 lbs (10 kg)	N/A	N/A
Shuttle ACES	28 lbs (12.7 kg)***	N/A	N/A
Orlan M	N/A	246 lbs (112 kg)	Autonomous
ISS EMU	N/A	309 lbs (140 kg)****	Autonomous

\*Note: EVA mass is without propulsion or autonomous capability.

\*\*Note: Mass based on nominal suit mass, ILC-Dover provided.

\*\*\*Note: Mass is without parachute and survival harness

\*\*\*\*Note: Maximum mass without SAFER