JSC/EC5 U.S. 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: Spacesuit Development and Qualification for Project Gemini

Date: December 4, 2012 **Time:** 11:30-1:00 pm **Location:** JSC/B5S/R3102

DAA 1676 Form #: 29299

A PDF of the presentation is also attached to the DAA 1676 and this is a link to all lecture material and video: \\js-ea-fs-01\pd01\EC\Knowledge-Capture\FY13 Knowledge Capture\20121204 McBarron_Gemini\For 1676 Review and Public Release

*A copy of the video will be provided to NASA Center for AeroSpace Information (CASI) via the Agency's Large File Transfer (LFT), or by DVD using the USPS when the DAA 1676 review is complete.

Assessment of Export Control Applicability:

This Knowledge Capture event has been reviewed by the EC5 Spacesuit Knowledge Capture Manager in collaboration with the author and is assessed to not contain any technical content that is export controlled. It is requested to be publicly released to the JSC Engineering Academy, as well as to CASI for distribution through NTRS or NA&SD (public or non-public) and with video through DVD request or YouTube viewing with download of any presentation material.

Presenter: Jim McBarron

Synopsis: With the information Jim McBarron has collected as a result of his experience with the U.S. Air Force pressure suit and NASA spacesuit development and operations, he shared significant knowledge about the Advanced Spacesuit Technology Development program that provided early prototype Gemini spacesuits for NASA evaluation and testing. In addition, he provided Gemini spacesuit development, qualification, and flight missions configuration changes. Topics included the various advanced suit configurations developed; suit configuration and contractor selection; and Gemini spacesuit design, performance, and environmental test requirements. McBarron also identified Gemini spacesuit modifications made for each mission. He ended the presentation by identifying noteworthy lessons learned.

Biography: In 1960, James (Jim) William McBarron II earned a bachelor of science in geology at the University of Dayton in Dayton, Ohio, and in 1983, he received a master of business administration from the University of Houston – Clear Lake in Houston, Texas. During his time in college, from 1958 to 1961, he worked part time on a University of Dayton contract with the Wright Patterson Air Force Base Aeromedical Laboratory that provided student test subjects to determine human endurance characteristics during and after exposure to extreme environmental conditions. His work as a student assistant also involved pressure suit design testing including suit hardware evaluation for the NASA Project Mercury. His career at NASA began in 1961 as an aerospace technologist with the Crew

Equipment Branch, Life Sciences Division, Space Task Group, at Langley Field, Virginia. During his time with NASA, McBarron supported the Manned Spacecraft Center at JSC and worked with spacesuits for all NASA flight programs including Mercury, Gemini, Apollo, Apollo-Soyuz Test Project (ASTP), Skylab, Shuttle, and the ISS. Throughout his career he was given several prestigious awards including the American Astronautical Society Victor A. Prather Award for outstanding contribution in the field of EV protection in space in 1979. He is the author and co-author of many spacesuit-related publications. Before he retired in 1999, McBarron was the CTSD chief engineer for EVA projects. In 1999, McBarron took a position with ILC Dover, Inc. as spacesuit systems manager where he reviewed advanced spacesuit technology requirements and design concepts for future manned space flight programs. In 2002, McBarron started his own consulting service to support development of advanced spacesuit technology and inflatable products for current and future manned-space missions.

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U.S. SPACESUIT KNOWLEDGE CAPTURE SERIES

"SPACESUIT DEVELOPMENT AND QUALIFICATION FOR

PROJECT GEMINI"

James McBarron II
Retired NASA JSC
December 4, 2012

GEMINI SPACESUIT DEVELOPMENT AND QUALIFICATION

AGENDA

- Advanced Spacesuit Technology Development
  - GX-1G, GX-2G, G-1G, and G-2G prototype suits – BF Goodrich
  - GX-1A prototype suit - Arrowhead Inc
  - GX-1P prototype suit - Protection Inc
- Spacesuit Selection for Project Gemini
- Gemini Requirements
  - Mission
  - Design features
  - Environmental
- G-1C Development Suits – David Clark Company
- G-2C Training Suits
- G-3C Intravehicular Spacesuit
- G-4C Extravehicular Spacesuit
- GT-III and GT-IV Qualification Tests
- G-5C Intravehicular Spacesuit
- Gemini Fights Supported
- Lessons Learned

SPACE SUIT TYPE NOTATION

- **First letter left of (-) denotes Project**
  M = Mercury
  G = Gemini
  A = Apollo

- **Letter (X) next to first letter denotes experimental prototype**
  GX-

- **Number to left of (-) denotes development sequence number**
  GX-1, G-1, G-2, G-3, G-4

- **Letter following number denotes manufacturer**
  A = Arrowhead Products
  C = David Clark Co.
  G = B. F. Goodrich Co.
  L = International Latex Co.

- **Examples**
  GX-1G = Gemini Prototype Suit mfg. by B.F. Goodrich Co.
  G-3C = Gemini Flight Suit mfg. by David Clark Co.
  AX-1L = Apollo Prototype Suit mfg. by International Latex Co.

Source: NASA memo by C.C. Lutz dated July 9, 1962

ADVANCED FULL PRESSURE SUIT TECHNOLOGY DEVELOPMENT

NASA MSC AWARDED THREE CONTRACTS - APRIL, 1962

- **Contract NAS 9-252**
  B.F. Goodrich Co.
- **Contract NAS 9-253**
  Arrowhead Products, Inc.
- **Contract NAS 9-254**
  Protection Inc..
- **David Clark Company**
  - Declined participation due to USAF DynaSoar Project suit procurement
- **RFP SOW Requirements**
  - Full pressure, anthropomorphic suit for Earth Orbital Missions
  - Compatible with closed circuit environmental control system
  - Provide pressure protection, ventilation, and body restraint during:
    a. Loss of normal cabin environment
    b. Emergency ejection (considered)
  - Unpressurized suit comfort for long-duration missions
  - Use as exposure garment after emergency descent
- **Design Features**
  - Increased mobility: repatterned joints, bearings, bellows, and “slip net” fabric
  - Reliable pressure sealing entry closure
  - Exterior reflective protective layer with restraint and parachute harness
  - Flotation system

ADVANCED SPACE SUIT TECHNOLOGY DEVELOPMENT

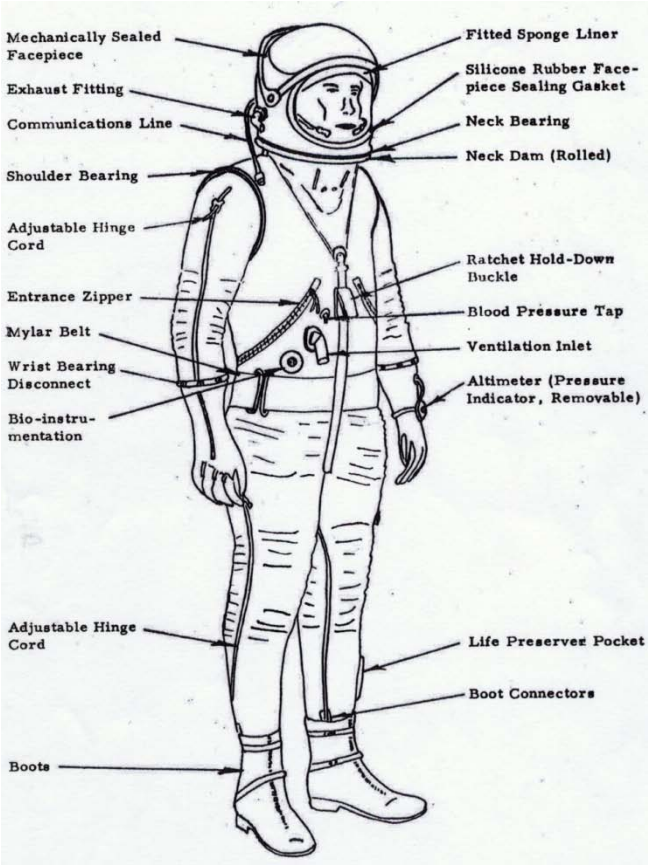
Contract NAS 9-252 - BF Goodrich Company

- Provide successively improved advanced full pressure suit prototypes

Advanced Full Pressure Suit

- Improved Project Mercury suit
  for potential MA-10 and later missions

- Provide maximum mission comfort and mobility:
  - Unpressurized suit 14-day duration
  - Pressurized suit 4-hour duration



ADVANCED SUIT TECHNOLOGY DEVELOPMEN

ADVANCED FULL PRESSURE SUIT PROTOTYPES

GX-1G suit - delivered April 13, 1962

- **Configuration at delivery:**

  Modified Mercury MA-9 helmet
  - Mechanical visor seal
  - Helmet in-flight feeding port
  - Molded crushable foam liner
  - Bone conduction microphones and earphones

  Torso
  - Nylon restraint; Neoprene bladder
  - Criss-cross sliding cable shoulders
  - Mark IV neck bearing; improved seal and connector latch
  - Circumferential pressure sealing closure entry
  - Mercury helmet hold-down; lower attached seat saddle straps
  - Stretch Nylon fabric knees
  - Loose fitting integrated foot, ankle, and in-step covering
  - Inlet vent fitting with spring-loaded water-check valve
  - Improved Mercury suit bioconnector
  - Glove disconnect 1-1/2 in. closer to elbow than Mercury Suit
  - Mercury gloves modified with link-net material wrists

  Coverall – Reflective aluminized fabric

ADVANCED SUIT TECHNOLOGY DEVELOPMENT

ADVANCED FULL PRESSURE SUIT PROTOTYPES – (cont.)

GX-1G suit prototype delivered, evaluated, modified

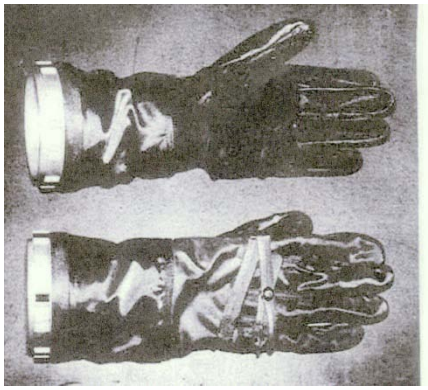
- **Configuration changes:**

Torso

- Bleeder channel added to Estane neck dam
- Improved shoulder cable construction
- Left arm reworked to normal relaxed 45-deg position
- Arms lengthened by 1 in.
- Waist band added to waist section
- Thumb loop added to arm vent tubes
- Boots provided greater foot mobility and foot ventilation
- Block and tackle front pulley added to helmet tie-down

Gloves

- Length shortened by 1 in.
- Lacing added on back of hands
- Snaps added to palm restraint take-up webbing



ADVANCED SUIT TECHNOLOGY DEVELOPMENT

ADVANCED FULL PRESSURE SUIT PROTOTYPES - (cont.)

Second GX-2G suit – delivered October 7, 1962

- **Configuration at delivery**

Helmet

- Aluminized Mylar-coated Nylon cover layer
- Integral soft helmet (smaller than G-IG) with fixed clear visor
- Pressure sealing closure opening crossed head from side to side
- In-flight feeding port located lower front center of visor
- Snap on light attentuation visor with sealing gasket against clear visor to prevent windblast removal
- Fabric attached to neck disconnect ring and latch by a rigid fiberglass base ring
- Crash padding and ear cups deleted
- Separately wired microphones and earphones with breakaway torso disconnect
- Dyna Magentics maxial mounted bone conduction microphones
- Beltone custom molded earplugs supported by earphones

Torso

- Aluminized Mylar-coated Nylon cover layer
- Pressure sealing entry closure down the back, through crotch, and up to navel
- Integrated boots; ankle-instep constriction by lacing and zipper front
- Mobility provided by convolutes in elbows and knees

ADVANCED SUIT TECHNOLOGY DEVELOPMENT

ADVANCED FULL PRESSURE SUIT PROTOTYPE - (cont.)

Second GX-2G suit delivered - (cont.)

- **Configuration at delivery**

Torso - (cont.)

- Criss-cross shoulder Nylon cord with Teflon tubes suspension no cables
- Combination sliding water check inlet and exhaust fitting; 1-1/2 in. higher than GX-1G
- Mechanical waist take-up with Teflon lined tubes on sides of entry closure for waist hold down cables to assist waist bending
- 32-pin electrical comm and biomed connector located on left side opposite combination inlet and exhaust fitting
- Plenum-type manifold ventilation system with soft distribution tubes
- Pressure relief valve installed in left leg - 5.5-6.0 psig
- Suit pressure indicator installed on left arm
- Permanently attached gloves with wrist bearings – no disconnects
- Pressure sealing closure to extend hands and arms outside of arms
- Lower leg pocket for GFE flotation vest stowage
- Ventilation spray bar supported on head harness strap
- Internal drawstring actuated neck dam

Gloves – similar to G-1G suit gloves

Underwear – similar to Mercury suit underwear

- Trilock vent spacer patches eliminated from arms and lower legs

ADVANCED SUIT TECHNOLOGY DEVELOPMENT

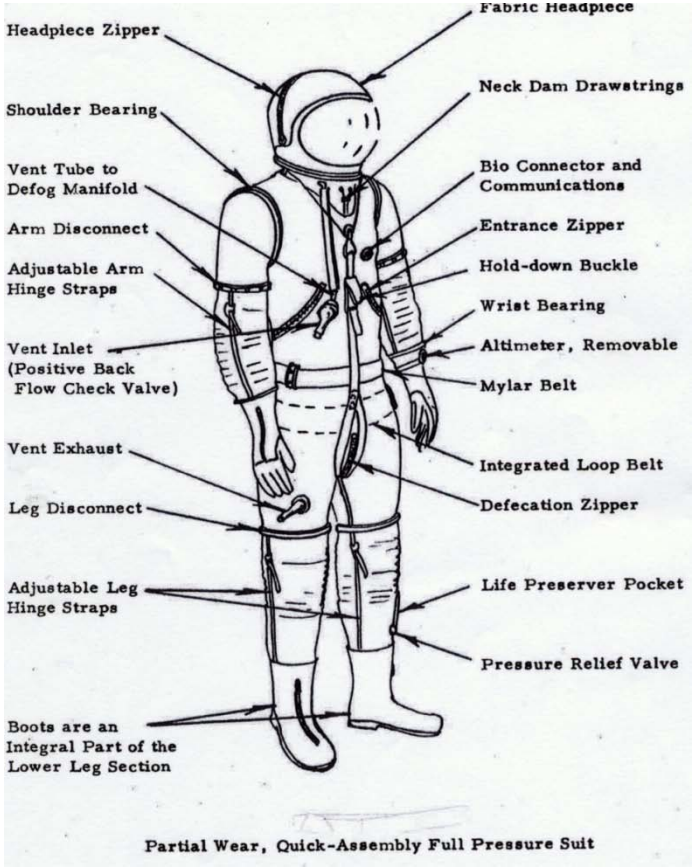
Contract NAS 9-252 - BF Goodrich Company

- Provide successfully improved partial-wear and quick-assembly suit prototypes

Partial-wear Quick-Assembly Suit

- Maximum long term continuous intravehicular wear capability

- Provide maximum mission comfort and mobility:
  - Unpressurized suit 14-day duration
  - Pressurized suit 4-hour duration



Partial Wear, Quick-Assembly Full Pressure Suit

ADVANCED SUIT TECHNOLOGY DEVELOPMENT

PARTIAL-WEAR QUICK-ASSEMBLY PRESSURE SUIT PROTOTYPES

G-1G suit - Delivered June 12, 1962

- **Configuration at delivery:**

  Helmet

  - Soft 2-ply construction head cover layer
  - Aluminized Nylon outer layer
  - Neoprene gas retention inner layer
  - Fixed Plexiglas visor with in-flight feeding port
  - Pressure sealing closure parallel to visor bottom edge
  - Visor held open by Velcro strap
  - Light attenuation visor held with Velcro

  Cloth cap – Fabric cloth support for communications

  - Dyna Magnetic microphones on top of head - bone conduction receivers behind ears
  - Electrical leads connected inside torso

  Foam crash liner

  - Worn over cloth cap

  Crash protective outer helmet shell

  - 2 fiberglass hard-shells outside of soft helmet held in place with Velcro tape

ADVANCED SUIT TECHNOLOGY DEVELOPMENT

PARTIAL WEAR QUICK-ASSEMBLY PRESSURE SUIT PROTOTYPES

G-1G suit prototype modified, and re-delivered - July 7, 1962

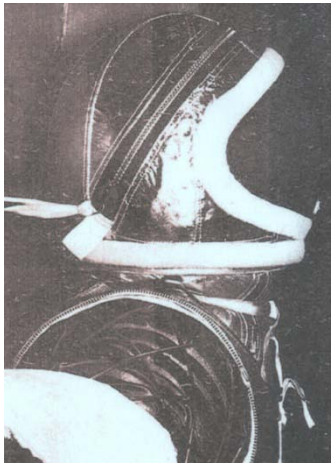
- **Configuration changes:**

  Helmet

  - Smaller size 2-ply soft helmet

  Torso

  - Shoulder bearings replaced with criss-cross sliding shoulder cables
  - Circumferential pressure sealing closure entry
  - Internal neck dam deleted
  - Fiberglass vent sleeves replaced with metal sleeves
  - Inlet and exhaust fittings raised upwards 3 in.



ADVANCED SUIT TECHNOLOGY DEVELOPMENT

PARTIAL-WEAR QUICK-ASSEMBLY PRESSURE SUIT PROTOTYPES

- **G-2G-1 suit prototype configuration at delivery**

TORSO

- Aluminized Mylar-coated nylon fabric restraint layer
- Pressure sealing entry closure from nape of neck down back, and up to navel area
- Helmet attached by neck ring bearing disconnect with self-donning features
- Snap-together arm bearing disconnects and leg disconnects
- Convolute elbows and knees with aluminized Mylar covers
- Criss-cross cable suspension shoulders and hips with aluminized covers
- Waist take-up block and tackle front length take-up. Cables inside Teflon tubing along the torso running beside both sides of entry closure across shoulders to front length take-up system
- Fabric boots with lacings down front with zipper center closure
- Separate donned ventilation garment with plug-in connection to vent inlet connector
- Inlet vent connector with sliding water-check valve on right front of torso; outlet vent connector on left front torso with water-check valve

ADVANCED SUIT TECHNOLOGY DEVELOPMENT

PARTIAL WEAR QUICK-ASSEMBLY PRESSURE SUIT PROTOTYPES

- **G-2G-1 suit prototype configuration at Delivery**

  TORSO – (cont.)

  - 32-pin electrical biomed connector on right side of inlet fitting
  - Pressure relief valve located on left leg – 5.5-6.0 psig
  - Dyna Magnetics suit pressure gage on left lower arm

ADVANCED SUIT TECHNOLOGY DEVELOPMENT

CONTRACT NAS 9-253 – ARROWHEAD PRODUCTS COMPANY

- Provide a prototype partial-wear quick-assembly full pressure suit

- **Partial-wear and quick-assembly full pressure suit**




- **Comparative evaluation shortcomings resulted in no further contract effort**
  - Shortcomings: bulk, comfort, component failures, and workmanship

ADVANCED FULL PRESSURE SUIT TECHNOLOGY DEVELOPMENT

Contract NAS 9-254 – Protection Inc.

- Provide one prototype partial-wear quick-assembly full pressure suit

- **Contract effort discontinued after comparative evaluation**
  - Mobility, function, and comfort inferior to capabilities of other sources

- **All photographs destroyed**
  - Direction by NASA Crew Systems division manager

PROJECT GEMINI SUIT DEVELOPMENT

BF Goodrich NAS 9-252 Contract amended - September 1962

- Changed to support Gemini space suit development
- “Confidential” security classification assigned for portions of work
- Gemini project effort in state of flux during fall of 1962
- Delivered prototype suits and hardware redesigned, tested, modified, and retested

BF Goodrich NAS 9-252 Contract again amended – December 1962

- 14 G-2G suits added to contract
  5 G-2G-1 to G-2G-5 suits were completed at design freeze to incorporate test results:
  - Removable boots with disconnects deleted
  - Removable gloves and wrist disconnects incorporated
- G-2G-6 suit delivered incorporated design changes – January 3, 1963
  - Suits production again halted to incorporate evaluation results
- G-2G-8 suit delivered incorporating additional design changes – January 21, 1963
  - Suit configuration used for NASA competitive suit evaluation
- G-2G-9 to G-2G-14 suits production were completed and delivered
  - Delivered suit inventory supported early Gemini project needs:
    - 2 for Air Research ECS testing
    - 2 for McDonnell Douglas capsule mockup evaluations
    - 4 for El Centro, CA parachute-harness qualification testing
    - 2 for simulated off-the-pad testing
- Contract final report delivered – February 1965

GEMINI SPACE SUIT COMPETITIVE SELECTION

- David Clark Co. requested evaluation and submitted modified S-951 suit
- BF Goodrich Co. G-2G prototype suit delivered to NASA for evaluation
- Mockup review conducted at McDonnell Aircraft Co. – 1962
  - Astronauts Gus Grissom, John Young, and Elliot See performed evaluation
- Gemini Program Office approved astronauts recommendation to use G-1C suit

Suit selected

David Clark Company
G-1C-1

MDA Gemini Mockup

Suit not selected

B F Goodrich Company
G-2G-8

SYSTEM DEVELOPMENT PHASE

GEMINI SPACESUIT REQUIREMENTS

- **Mission Requirements**
  - Anthropomorphic full pressure suit
  - Long-duration flight – 14 days
  - High system reliability
  - Astronaut mobility and comfort
  - Ejection system compatibility

- **Design Features**
  - Self donning helmet and gloves
  - Low torque and low leakage helmet and glove-bearing disconnects
  - Helmet and glove disconnects have integrated ventilation channels
  - Combined comm and biomed electrical connector
  - Low ventilation flow resistance
  - Self-sealing, torso located Inlet and exhaust ECS disconnects
  - Boots heel plate compatible with ejection seat foot stirrup
  - Hardware flange mounted
  - Removable outer cover layer and comfort liner to simplify cleaning and structural inspection of inner restraint layer and gas bladder

GEMINI SPACESUIT DEVELOPMENT

Contract NAS 9-1396 - David Clark Company

- **G-1C Production Configuration** – 14 suits delivered

  Modifications To G-1C-1 suit

  - BFG helmet, neck ring bearing disconnect, helmet liner, and comm wiring system
  - BFG neck ring modified for two-point helmet tie-down with single pull strap on front torso
  - International Latex Co. glove to torso bearing disconnect
  - BFG pressure suit gloves
  - Communication connector with positive lock
  - 32-pin biomed connector on upper torso – red color
  - Blood pressure system fitting on front torso
  - Ejection seat restraint system heel plates on boot soles
  - Antenna electrical fitting on front torso on five suits to support ejection seat development tests

GEMINI SPACESUIT DEVELOPMENT

Contract NAS 9-1396 - David Clark Company

- **G-2C Configuration -** 16 suits delivered

  Helmet:
  - Permanently installed ventilation distribution duct
  - Visual field equal to G-1C-1 suit helmet
  - Torso neck ring with integral vent system and positive lock
  - Bearing provided in torso neck attachment ring
  - Drinking and eating provision provided
  - International Latex-type thin ear cups
  - GFE microphones and earphones

  Torso:
  - Improved shoulder, hip-waist, and knee mobility
  - Improved single-front helmet tie-down
  - Blue vent inlet and red outlet disconnect fittings
  - Arm-glove disconnect-bearings match vent fittings colors
  - Modified legs to pull-in knees at 3.75 psig
  - Blood pressure cuff fitting on upper left chest
  - Combined 31-pin biomed and comm connector on upper right chest

GEMINI SPACESUIT DEVELOPMENT

Contract NAS 9-1396 - David Clark Company

- **G-2C Configuration**

TORSO: – (cont.)

- 2 in. length sizing adjustment added to arms and legs
- Aluminized HT-1nfabric cover layer laced to torso for easy removal
- Ejection foot retention heel plates installed on both boots
- 2-10 psig pressure indicator installed on left lower arm
- Handkerchief pockets on left and right coverall arms
- Accessory pockets on left and right coverall legs
- NASA emblem attached on upper left torso cover layer
- Name tag attached on upper right torso cover layer

Investigations conducted:

- Teflon coated bladder cloth and Teflon link-net restraint cord – no benefit
- Elimination of helmet tie down system – not possible
- Integration of Gemini parachute restraint into outer suit layer – no benefit

G-3C GEMINI SPACE SUIT ASSEMBLY
PERFORMANCE DESIGN REQUIREMENTS

PRESSURE

- PROOF — 7.0 psig (15 MINUTE DURATION)
- OPERATING — NORMAL (0.15 psig)
  DECOMPRESSED CABIN (3.7 psia FOR A MAXIMUM TIME DURATION OF 4 HOURS)
- RELIEF VALVES (2) — OPERATING PRESSURE 4.5 ± 0.2 psig WITH A MINIMUM TOTAL FLOW PER EACH OF 40 STANDARD LPM
- SUIT PRESSURE INDICATOR — ABSOLUTE TYPE WITH SCALE RANGE 2-10 psia

LEAKAGE

- TOTAL SUIT ASSEMBLY — 200 SCC/MIN AT 3.7 psig
  200 SCC/MIN AT 0.15 psig
  250 SCC/MIN AT 3.7 psig WITH DRINKING PROBE INSERTED
- COMPONENTS —
  A. 3.7 psig
  GLOVES (EACH) ____ 20 SCC/MIN
  HELMET ____ 30 SCC/MIN
  TORSO ____ 130 SCC/MIN
  B. 0.15 psig
  GLOVES (EACH) ____ 20 SCC/MIN
  HELMET ____ 30 SCC/MIN
  TORSO ____ 130 SCC/MIN

G-3C GEMINI SPACE SUIT ASSEMBLY
PERFORMANCE DESIGN REQUIREMENTS (CONT.)

VENTILATION DISTRIBUTION SYSTEM

- PRESSURE DROP ——— NOT TO EXCEED 4.75 INCHES H_2O UNDER FOLLOWING CONDITIONS

  A. SUITABLY SIZED SUBJECT RESTRAINED IN GEMINI SEAT AND PARACHUTE HARNESS
  B. INLET VENT FLOW RATE 11.5 ACFM
  C. INLET VENT GAS 100% O_2
  D. INLET TEMPERATURE 55° F
  E. INLET RELATIVE HUMIDITY 65% TO 100%
  F. AMBIENT PRESSURE 5.5 ± 0.4 psia
  G. SUIT OUTLET TO AMBIENT ΔP 0 TO 1 INCH H_2O

- HELMET CO_2 REMOVAL —— HELMET VENT SYSTEM TO PROVIDE ADEQUATE CO_2 REMOVAL FOR ALL MISSION CONDITIONS

  A. NORMAL - 3.8 mm Hg
  B. MAXIMUM - 7.6 mm Hg
  C. EMERGENCY - 15 mm Hg

G-3C GEMINI SPACE SUIT ASSEMBLY PERFORMANCE DESIGN REQUIREMENTS (CONT.)

MOBILITY	ADEQUATE MOBILITY UNPRESSURIZED AND PRESSURIZED AT 3.7psi TO PERFORM ALL REQUIRED MISSION TASKS, BOTH NORMAL AND EMERGENCY
COMFORT	
• UNPRESSURIZED	COMFORATABLE(EASILY TOLERATED) FOR A PERIOD OF UP TO AND INCLUDING 14 DAYS
• PRESSURIZED	TOLERABLE (WITH SUBJECTIVE STRESSING) FOR A PERIOD OF UP TO AND INCLUDING 4 HOURS
DONNING	FROM PARTIAL DON CONDITION, GLOVES AND HELMET DONNING TIME 3 MINUTES TOTAL
SUIT ASSEMBLY LIFE	
• ASSEMBLY	CAPABLE OF BEING DONNED AND DOFFED FOR 200 CONSECUTIVE CYCLES WITHOUT MAJOR OVERHAUL OR UNSATISFACTORY PERFORMANCE
• HELMET VISOR	CAPABLE OF 5,000 CYCLES OF OPERATION WITHOUT FAILURE

GEMINI SPACE SUIT ENVIRONMENTAL DESIGN REQUIREMENTS

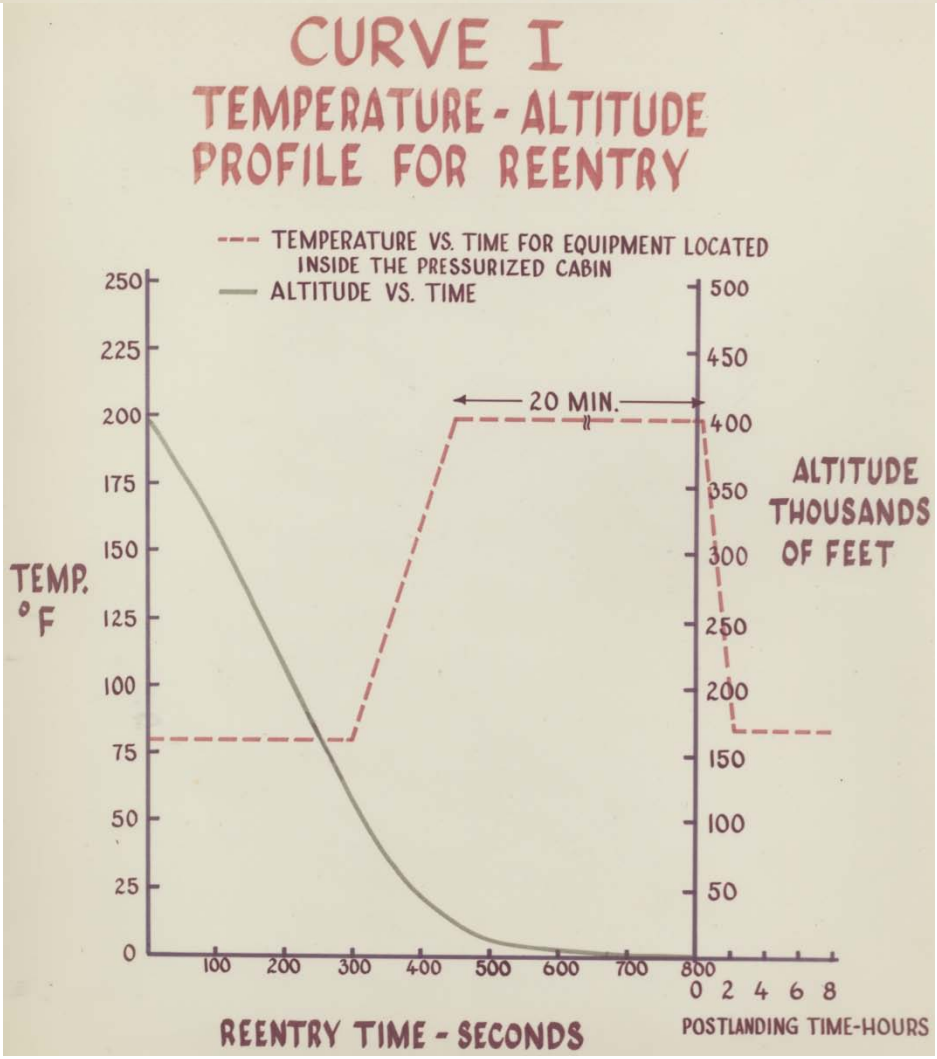
ENVIRONMENT	PRELAUNCH	LAUNCH	ORBIT	REENTRY	POSTLANDING	EJECTION
AMBIENT PRESSURE	14.7 TO 15.5 PSIA	14.7 TO 10^{-7} PSIA	5.1 TO 10^{-7} PSIA	5.1 TO 10^{-7} TO 15.5 PSIA	15.5 PSIA	14.7 PSIA TO 12.9 MM HG
AMBIENT TEMPERATURE	-15° TO +110° F.	0° TO 160°F	0° TO 160°F.	CURVE I	-15° TO +160° F.	-69° TO +250°F CURVE II
SUIT INLET TEMPERATURE	40° TO 80°F.	50° TO 80°F.	50° TO 80° F.	50° TO 90°F.	65° TO 105°F.	TO BE DETERMINED
SUIT INLET FLOW	0 TO 12 SCFM	7.25 SCFM	11.5 CFM @ 5 PSIA, 88°F	TO BE DETERMINED	7.25 SCFM	.036 LB/MIN.
SUIT OUTLET PRESSURE	0 TO 3.7 PSIG	.2 PSIG OR 3.7 PSIA	.2 PSIG OR 3.7 PSIA	.2 PSIG OR 3.7 PSIA	.2 PSIG	.2 PSIG TO 3.7 PSIA
VIBRATION	PROTECTED (SHIPPING)	MAC REPORT 8610	(N/A)	MAC REPORT 8610	(N/A)	(N/A)
SHOCK	PROTECTED (SHIPPING)	MAC REPORT 8610	(N/A)	MAC REPORT 8610	(N/A)	(N/A)

GEMINI SPACE SUIT ENVIRONMENTAL DESIGN REQUIREMENTS

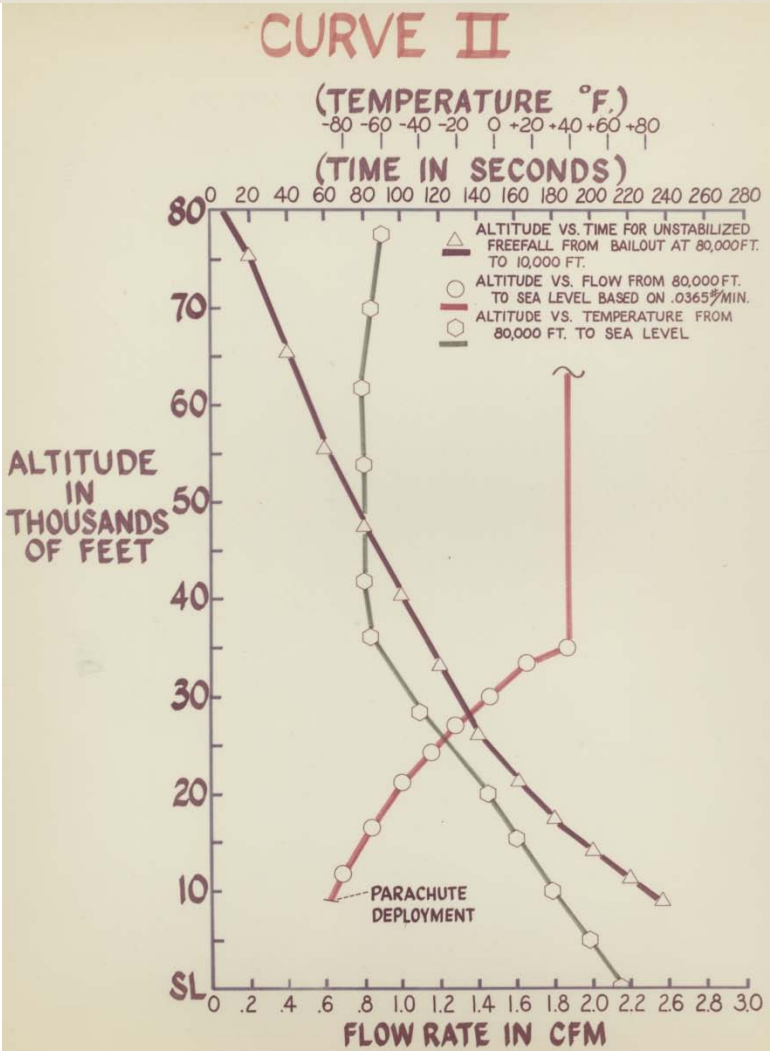
ENVIRONMENT	PRELAUNCH	LAUNCH	ORBIT	REENTRY	POSTLANDING	EJECTION
O_2 EXPOSURE	0-100%	0-100%	0-100%	0-100%	(N/A)	0-100%
RELATIVE HUMIDITY	0-100%	0-100%	0-100%	0-100%	15-100%	0-100%
ACOUSTIC NOISE	PROTECTED (SHIPPING)	MAC REPORT 8610	(N/A)	MAC REPORT 8610	(N/A)	(N/A)
ACCELERATION	1 G	MAC REPORT 8610	0	MAC REPORT 8610	1 G	40G FOR 1 SEC ALL AXES
DYNAMIC LOADING	(N/A)	(N/A)	(N/A)	(N/A)	(N/A)	820 LB/FT^2
TIME SUIT PRESSURIZED TO 3.5 PSI	10 HRS	8 MIN.	4 HR@60-90°F 90 MIN@160°F	CURVE I	(N/A)	15 MIN CURVE II
TIME SUIT PRESSURIZED TO 0.2 PSIG	100 HRS	10 MIN.	360 HOURS	20 MIN	10 MIN @+160°F 36 HR@-15° TO +110°F	5 MIN@+250° F, 14.7 PSIA 10 MIN@-69°F, 33.6 MM HG. CURVE II
TOTAL TIME	4 MONTHS	10 MIN.	360 HOURS	20 MIN	36 HOURS	20 MIN

GEMINI SPACE SUIT ENVIRONMENTAL DESIGN REQUIREMENTS

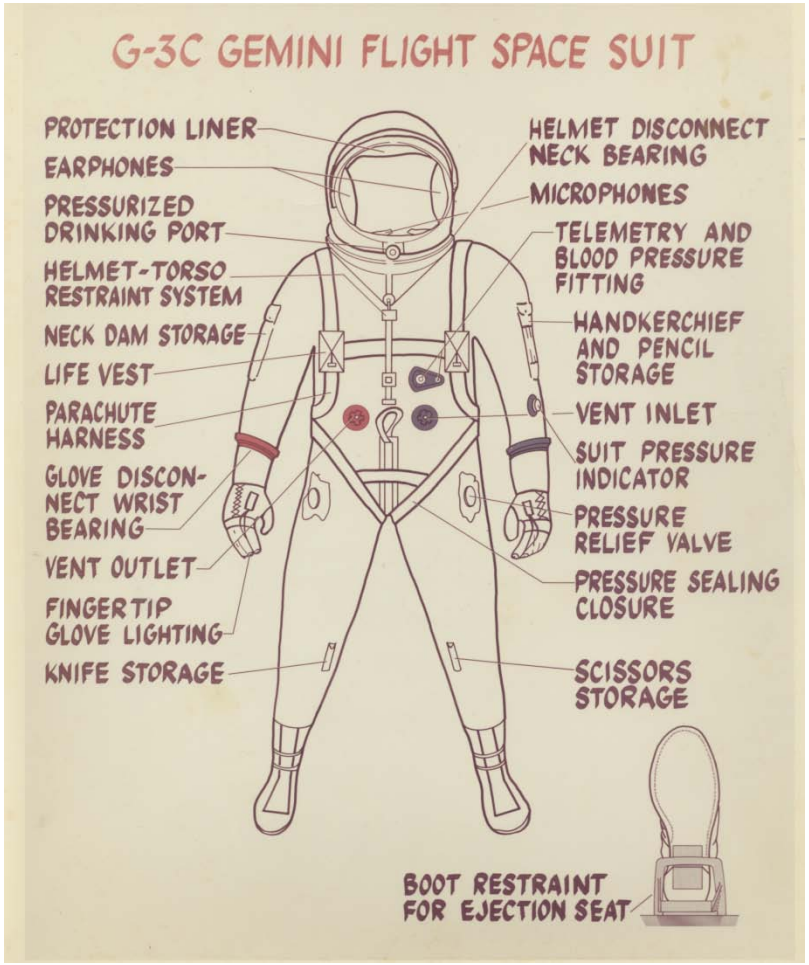
CURVE I
TEMPERATURE - ALTITUDE PROFILE FOR REENTRY

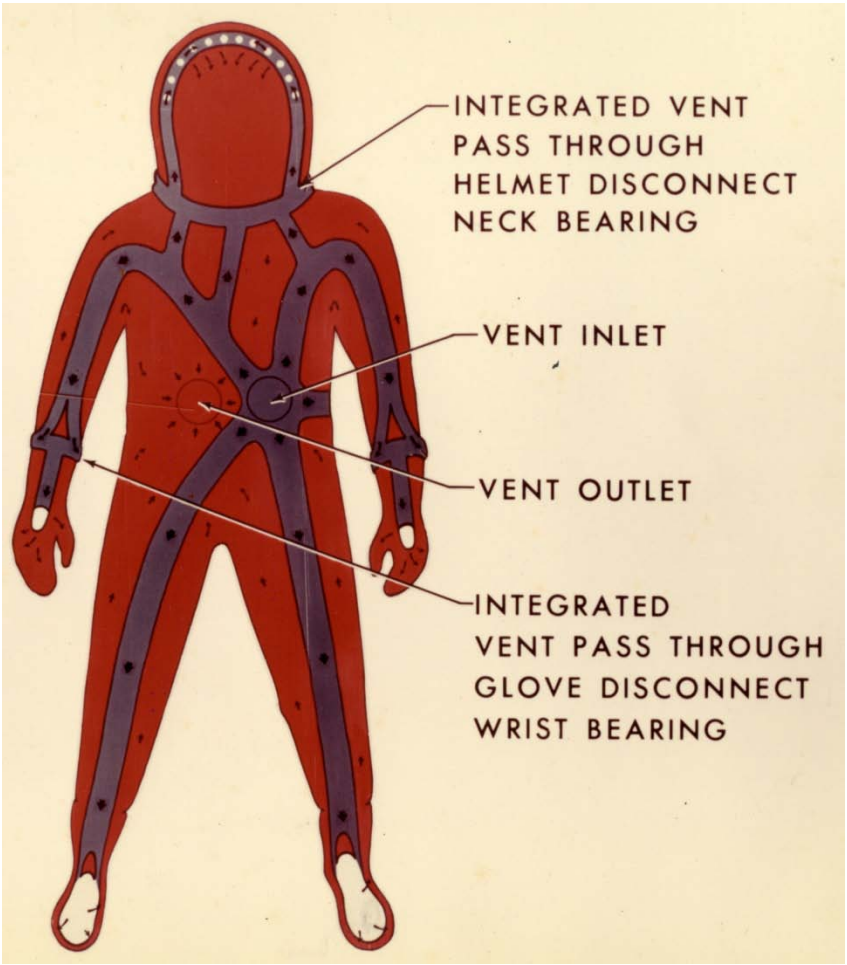


CURVE II

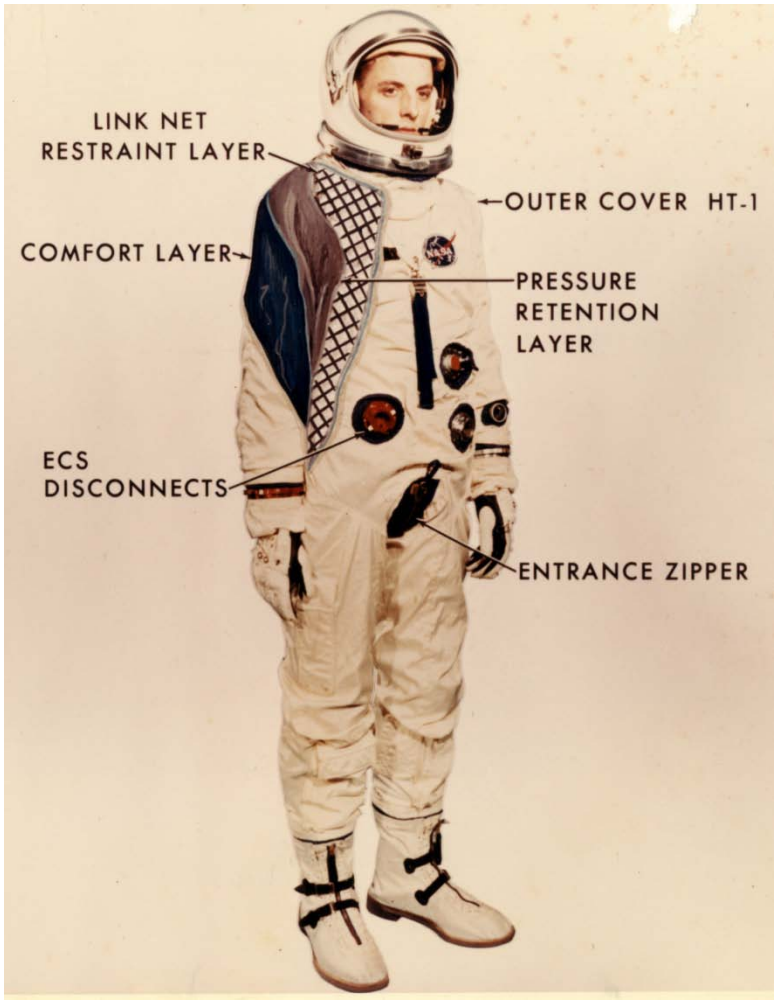


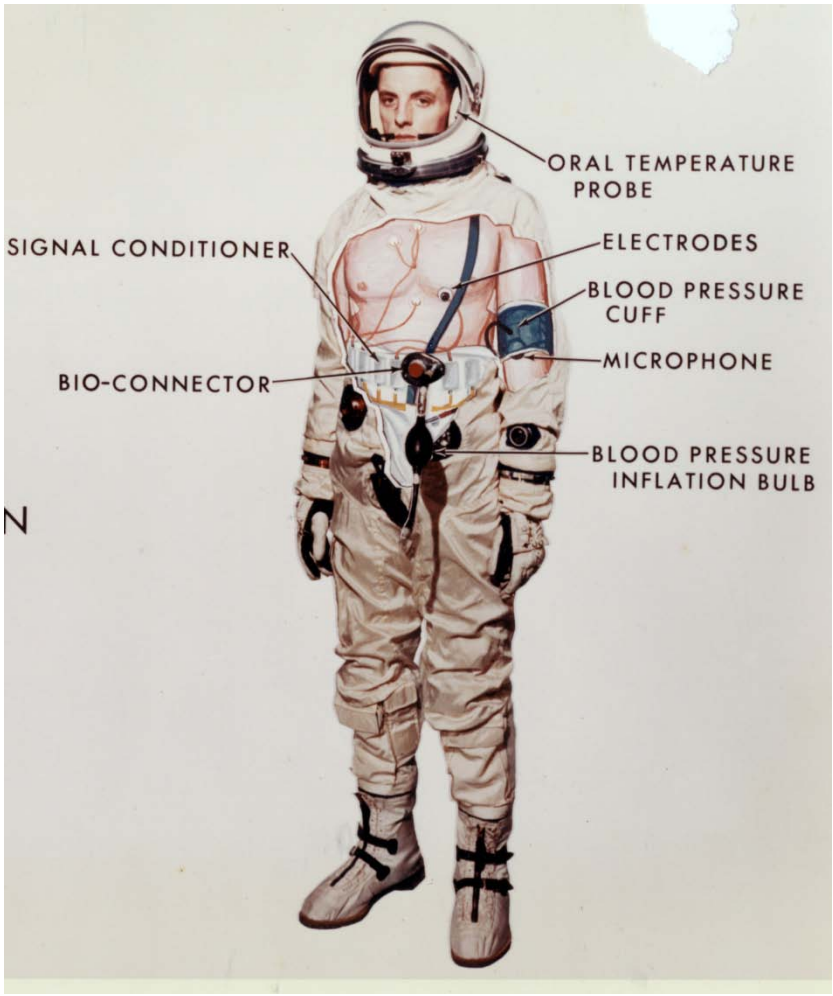
GEMIN G-3C INTRAVEHICULAR SPACESUIT





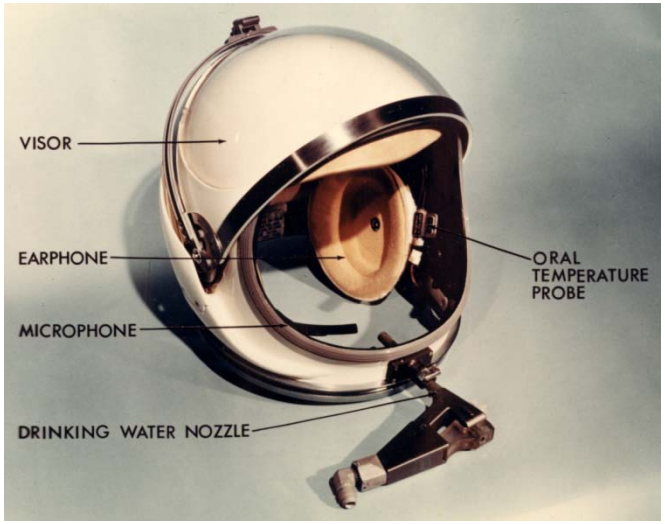
GEMINI G-3C INTRAVEHICULAR SPACESUIT

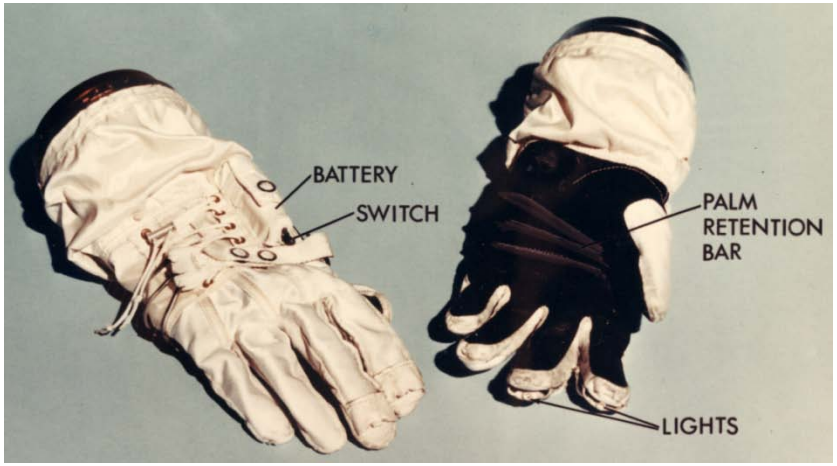


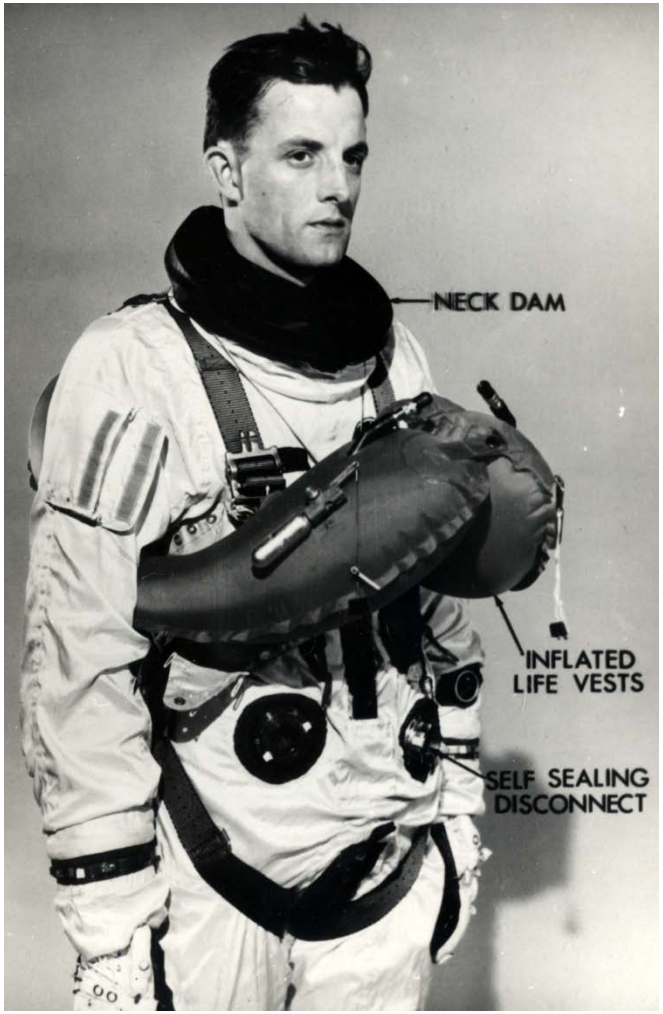


GEMINI G-3C INTRAVEHICULAR SPACESUIT

Z







GEMINI G-3C SUIT MODIFICATIONS FOR EXTRAVEHICULAR ACTIVITY

HELMET - INCORPORATION OF LENS SHIELD FOR VISUAL, THERMAL, IMPACT AND MICROMETEORITE PROTECTION

TORSO - 1. CHANGE TO NOMEX (HT-1) "LINKNET" IN RESTRAINT LAYER FOR INCREASED STRUCTURAL STRENGTH

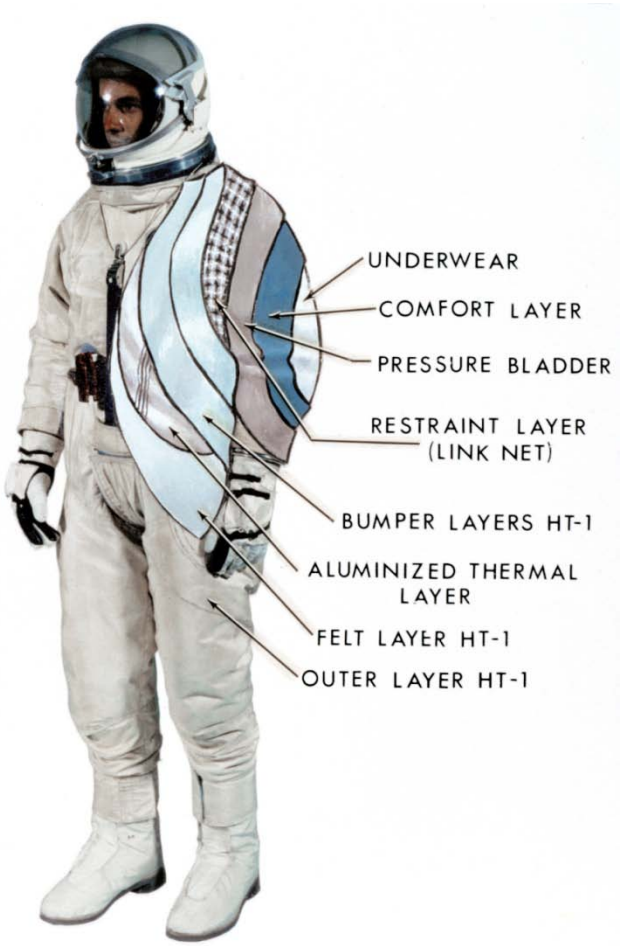
2. INCORPORATION OF REDUNDANT PRESSURE SEALING CLOSURE

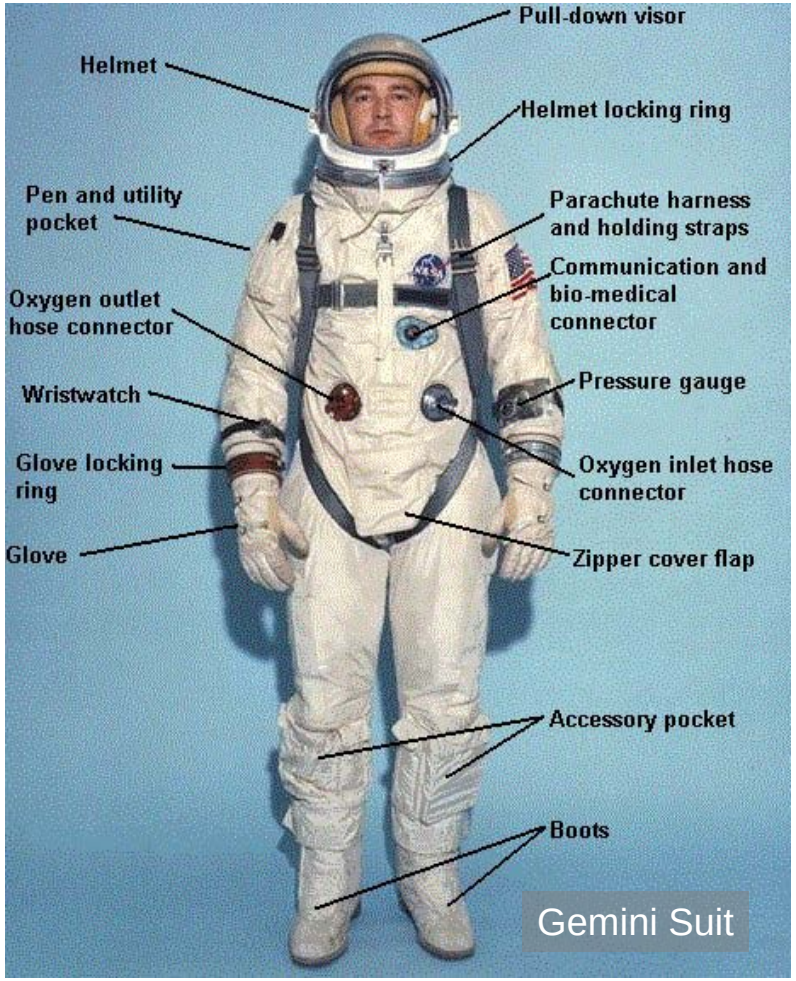
3. INCORPORATION OF REDESIGNED VENTILATION INLET AND OUTLET FITTINGS WITH AUTOMATIC LOCKING AND REDUNDANT SEALING FEATURES

4. REPLACE NOMEX (HT-1) COVERLAYER WITH INTEGRATED THERMAL AND MICROMETORITE COVERLAYER

GLOVES - INCORPORATE NEW DESIGN WITH INCREASED MOBILITY, AND ABRASION RESISTANCE

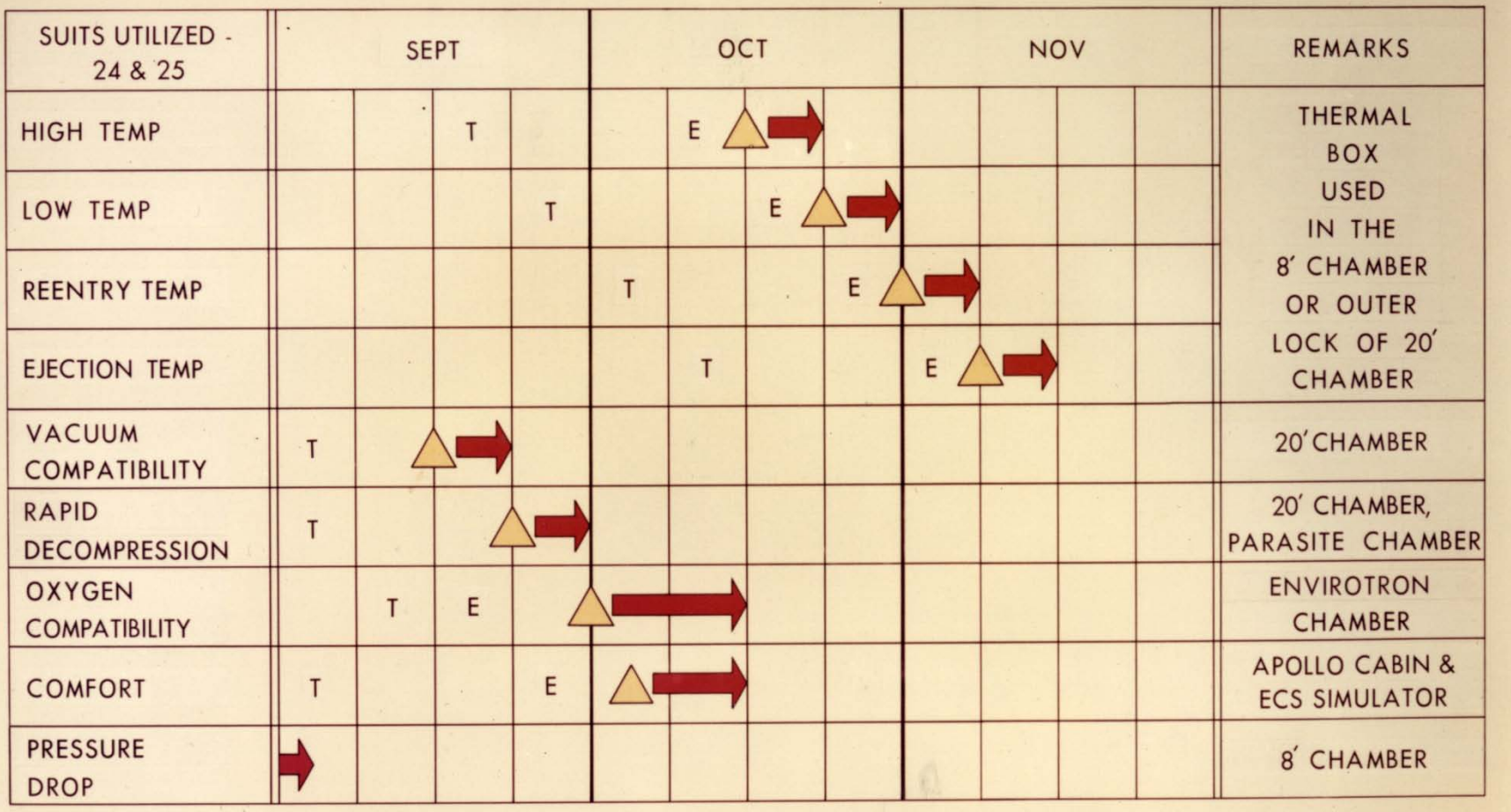
GEMINI G-4C EXTRAVEHICULAR SPACESUIT





NASA-S-64-5433

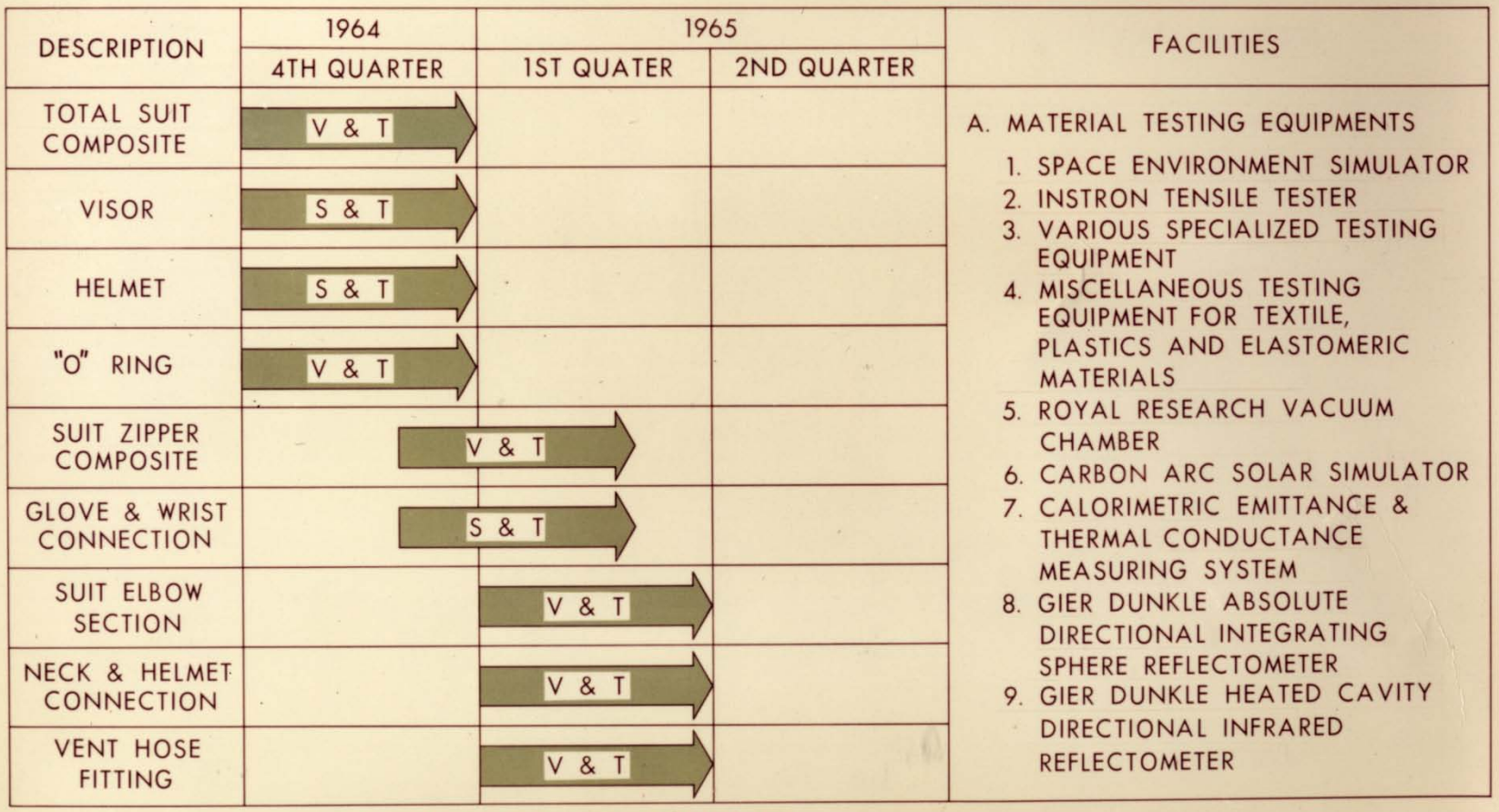
GEMINI SUIT QUALIFICATION TEST SCHEDULE GT-3 & 4



T- TEST PLAN SUBMITTED TO GSO
E- EQUIPMENT READY
△- TEST COMMENCED

NASA-S-64-5435

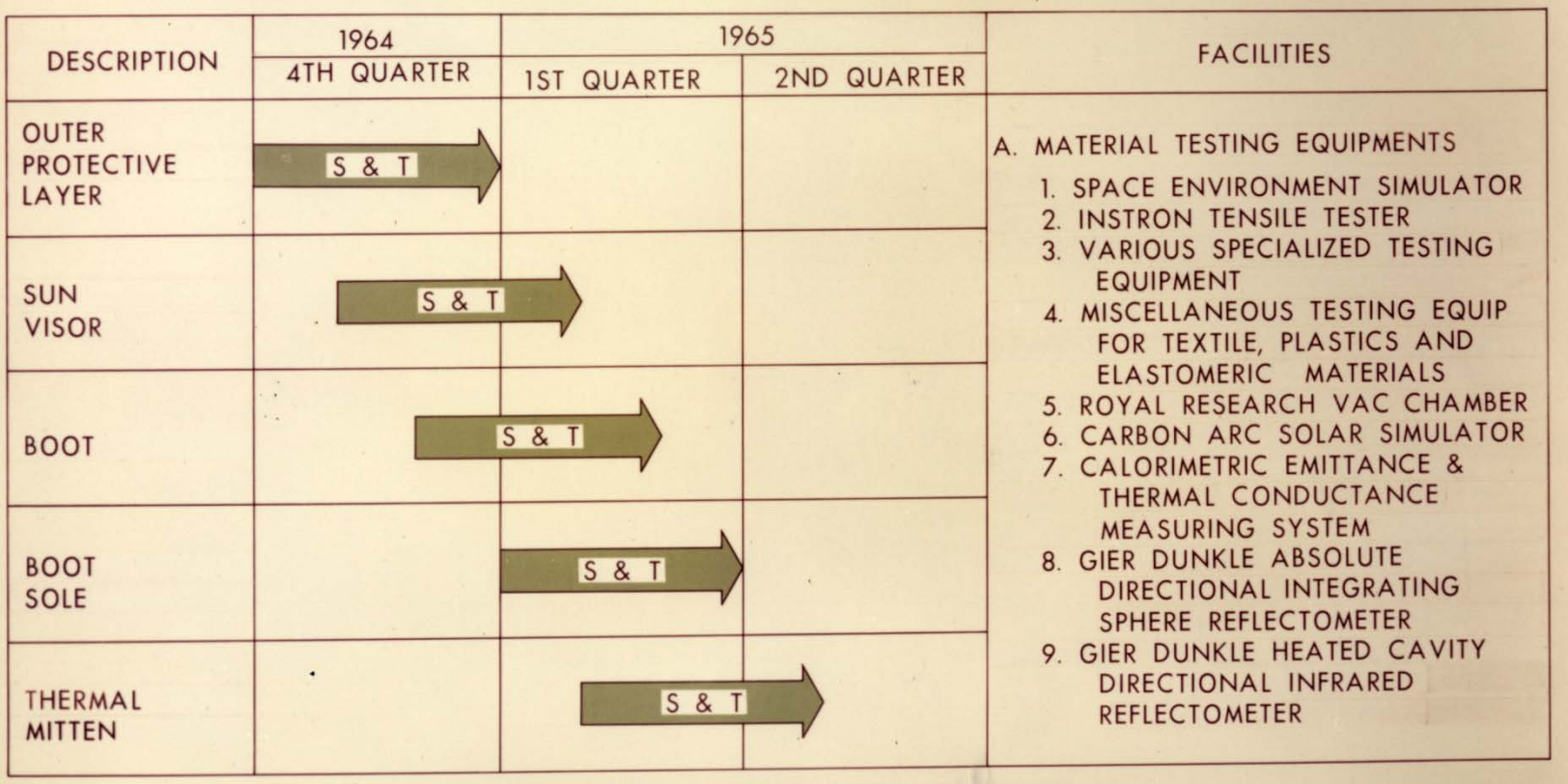
CREW SYSTEMS DIVISION, SYSTEMS TEST BRANCH INTRA-GSSA QUALIFICATION TEST SCHEDULE FOR GEMINI-TITAN FLIGHT NO. III & IV



S = SIMULATED SPACE ENVIRONMENT EXPOSURE
V = VACUUM EXPOSURE
T = PHYSICAL AND THERMAL TESTING OF UNEXPOSED AND EXPOSED MATERIALS

NASA-S-64-5434

CREW SYSTEMS DIVISION, SYSTEMS TEST BRANCH EXTRA-GSSA QUALIFACTION TEST SCHEDULE FOR GEMINI-TITAN FLIGHT NO. III & IV



S = SIMULATED SPACE ENVIRONMENT EXPOSURE

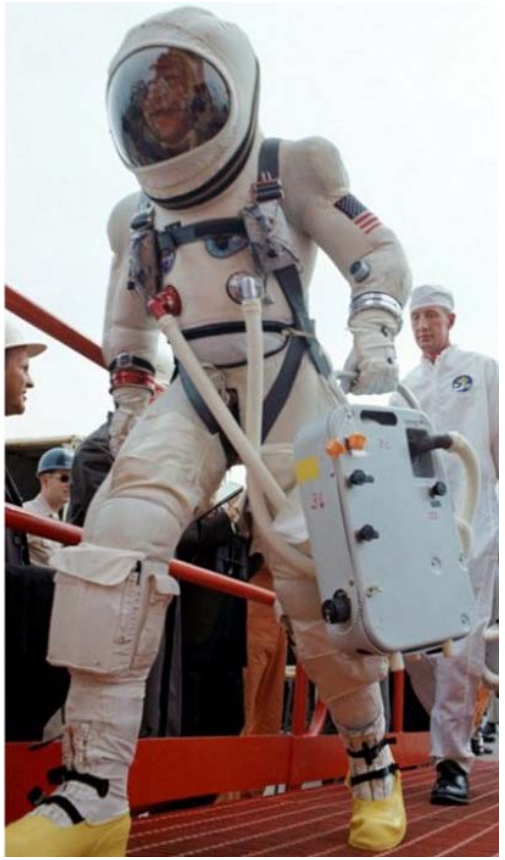
V = VACUUM EXPOSURE

T = PHYSICAL AND THERMAL TESTING OF UNEXPOSED AND EXPOSED MATERIALS

G-5C INTRAVEHICULAR SUIT

- **Mission Requirements**
  - **14-day duration mission**
  - **Cabin decompression protection**
    - **rapid re-entry acceptable**
  - **Ejection escape system compatible**

- **Design Features**
  - **Removable in-flight**
  - **Very light weight – 16 lbs**
  - **Soft cloth hood**
    - **Pressure sealing closure**
  - **G-3C suit interfaces**
  - **1000 scc allowable leakage**



NASA-S-65-9612

GEMINI G-5C SPACESUIT

G-5C INTRAVEHICULAR SUIT

GEMINI FLIGHTS SUPPORTED

- **GT-3**
  - Grissom: G-3C-1
  - Young: G-3C-4
  - March 23, 1965
  - 4 hr 52 min flight

- **GT-4**
  - McDivitt: G-4C-3
  - White: G-4C-8
  - June 3, 1965
  - 97 hr 56 min flight
  - First USA EVA – 23 min duration
  - VCM EVA life support; no suit difficulty

- **GT-5**
  - Cooper: G-4C-10
  - Conrad: G-4C-15
  - August 25, 1965
  - 190 hr 55 min flight

- **GT-6**
  - Schirra: G-3C-3
  - Stafford: G-4C-21
  - December 15, 1965
  - 25 hr 51 min flight

- **GT-7**
  - Borman: G-5C-5
  - Lovell: G-5C-6
  - December 3, 1965
  - 330 hr 35 min flight

- **GT-8**
  - Armstrong: G-4C-24
  - Scott: G-4C-27
  - March 16, 1966
  - 10 hr 41 min flight
  - ELSS and umbilical EVA life support
  - Mission terminated – spacecraft problem

GEMINI FLIGHTS SUPPORTED

- **GT-9**
  - Stafford: G-4C-17
  - Cernan: G-4C-32
    Chromyl-R Leg TMG
  - June 6, 1966
  - 72 hr 20 min flight
  - 2 hr 07 min EVA
  - ELSS and umbilical EVA life support
  - Astronaut Maneuvering Unit (AMU) evaluation terminated due to higher work loads than expected causing visor fogging

- **GT-10**
  - Young: G-4C-19
  - Collins: G-4C-36
  - July 8, 1966
  - 70 hr 46 min flight
  - 1 hr 28 min EVA
  - ELSS and umbilical EVA life support

- **GT-11**
  - Conrad: G-4C-39
  - Gordon: G-4C-40
  - September 12, 1966
  - 71 hr 17 min flight
  - 2 hr 43 min EVA
  - ELSS and umbilical EVA life support

- **GT-12**
  - Lovell: G-4C-41
  - Aldrin: G-4C-42
  - November 11,1966r
  - 94 hr 37 min flight
  - 5 hr 27 min EVA
  - ELSS and umbilical EVA life support

GEMINI FLIGHTS SUPPORTED

GT-4 Ed White G-4C Suit and Life Support System

GT-9 Gene Cernan G-4C Suit with Chromyl-R TMG Legs, Life Support System, and AMU

GEMINI SPACE SUIT LESSONS LEARNED

- Gas cooling inadequate for performing labor intensive EVA tasks that result in high metabolic loads:
  - Crewmember overheating
  - Helmet visor fogging
- Mobility of pressurized suit joints and gloves impacts crewmember capability to perform EVA tasks:
  - Lack of mobility contributed to high metabolic loads
  - Caused difficulty in donning foot restraints
- Helmet anti-fog solution effectiveness lost over time:
  - Apply just before EVA
  - Develop a more permanent anti-fog technique
- Neutral buoyancy procedures development and training contributes significantly to crewmember EVA tasks performance proficiency
- Contractor participation in flight hardware development and qualification testing is highly desirable and beneficial
- Technology development provides newly assigned engineers excellent hands-on (and in) training in suit design, testing, and contract technical management

REFERENCES

1. "Illustrations," from James William McBarron II's records (in private hands) [not dated].
2. "Photographic Images," from NASA Photographic Libraries, and James William McBarron II's records (in private hands) [not dated].
3. "Proposal for a Quick Assembly, Partial Wear Full Pressure Suit," BF Goodrich Aerospace and Defense Company [not dated].
4. "Selection of a Space Suit for Project Gemini," James William McBarron II's records (in private hands) [not dated].
5. "Development of a Quick Assembly, Partial Wear Full Pressure Suit," NASA Manned Spacecraft Center (MSC) RFP, September 1961.
6. "Space Suit Nomenclature," NASA Crew Systems Division (CSD) memo, Charles C. Lutz, July 9, 1962.
7. "Proposal for an Anthropomorphic Capsule, S-951," response to NASA MSC RFP 63-346P, David Clark Company, September 1962.
8. "Gemini Space Suit Program," Contract NAS 9-1396, David Clark Company, March 13, 1964; Amendment 1, June 4, 1964; Amendment 2, June 17, 1964; Amendment 3, July 17, 1964.
9. "Gemini G-3C Intravehicular Space Suit Design Specification," James William McBarron II's records (in private hands), July 9, 1964.
10. "Gemini Flight Space Suit Assemblies," NASA Manned Spacecraft Center RFP, August 19, 1964.
11. "Gemini Space Suit Assembly Program Plan," CSD-G-010 document, September 1, 1964.
12. "Anthropomorphic Capsule, S-951," CSD-G-025 document, September 11, 1964.
13. "Performance Specification for Advanced Full Pressure Suit Assembly," CSD-G-014, James William McBarron II's records (in private hands), September 11, 1964.
14. "Performance Specification for Partial Wear, Quick Assembly Full Pressure Suit," CSD-G-013, James William McBarron II's records (in private hands) September 11, 1964.
15. "Qualification Test Plan for Gemini G-3C Space Suit, P/N S-964A, for GT-3 and GT-4," CSD-G-005 document, September 16, 1964.
16. "Design, Development, and Fabrication of Prototype Pressure Suits," Final Report, Contract NAS 9-252, BF Goodrich Aerospace and Defense Company, February 1, 1965.
17. "Summary of Gemini Extravehicular Activity," NASA SP-149, 1967.
18. "Gemini Summary Conference," NASA SP-138, held at MSC February 1 through 2, 1967.
19. "Gemini Space Suit Program," Final Report, Contract NAS 9-1396, David Clark Company, June 1967.