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: Early Apollo Spacesuit Development, A-7L Suit Requirements, and Design Details

Date: January 21, 2015 **Time:** 11:00a.m. - noon **Location:** JSC/B5S/R3102

DAA 1676 Form #: 33168

This is a link to all lecture material and video \\js-ea-fs-01\pd01\EC\Knowledge-Capture\FY15 Knowledge Capture\20150121 McBarron_Apollo A-7L for Apollo 7-14\For 1676 Review & Public Release

*A copy of the video will be provided to the NASA Technical Library and STI Program's YouTube 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 STI 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.

* This file is also attached to this 1676 and will be used for distribution.

For 1676 review use_Synopsis_McBarron_Early Apollo SS Dev_1-21-2015.docx

Presenter: Jim McBarron

Synopsis: Jim McBarron has over 50 years of experience with NASA spacesuit development and operations as well as the U.S. Air Force pressure suit. As a result of his experience and research, he shared his significant knowledge about early Apollo spacesuit development, A-7L suit requirements, and design details.

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.

EC5 Spacesuit Knowledge Capture POCs:

Cinda Chullen, Manager
cinda.chullen-1@nasa.gov
(281) 483-8384

Vladenka Oliva, Technical Editor (Jacobs)
vladenka.r.oliva@nasa.gov
(281) 461-5681

U.S. SPACESUIT KNOWLEDGE CAPTURE SESSIONS

- **“Apollo A-7L Spacesuit Development for Apollo 7 Through 14 Missions”**

Previous Spacesuit Sessions

- “Spacesuit Development and Qualification for Project Mercury,” November 2012
- “Spacesuit Development and Qualification for Project Gemini,” December 2012
- “Apollo Block I Spacesuit Development and Apollo Block II Spacesuit Competition,” January 2013

James W. McBarron II
January 21, 2015
Retired NASA JSC

AGENDA

- **EARLY APOLLO SPACESUIT DEVELOPMENT**
  - Initial EMU contract
  - Contract Change for Apollo Block II Spacesuit
  - A-5L PGA and A-6L Spacesuit CEI's contracts development

- **APOLLO BLOCK II SPACESUIT REQUIREMENTS**
  - Delivery
  - Lunar Landing Mission
  - Environmental
  - Design
  - Interface

APOLLO 1 ACCIDENT IMPACT

APOLLO BLOCK II SPACESUIT CEI'S REDESIGN

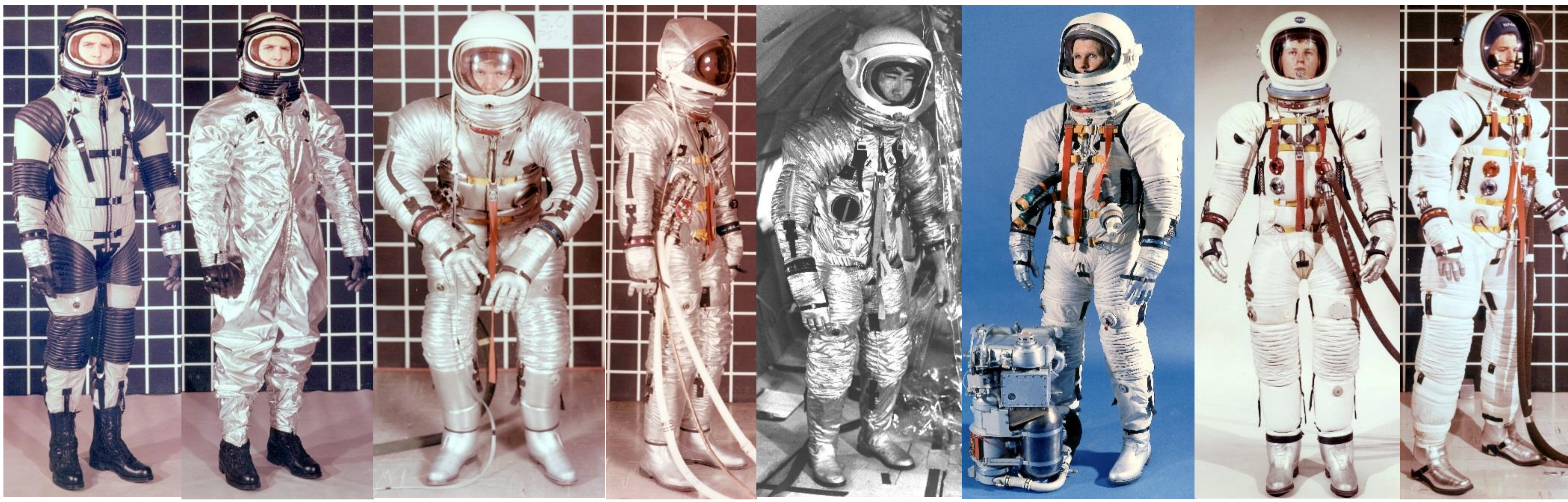
EARLY APOLLO EMU SPACESUIT DEVELOPMENT
1962-1965

- **Initial Apollo Extravehicular Mobility Unit (EMU) contract**
  - NASA competitive procurement.
  - Hamilton Standard (HS) selected as prime EMU contractor.
  - International Latex Corp. (ILC) selected as spacesuit subcontractor.
  - ILC selection based on NASA proposal evaluation results.
  - HS and ILC were not on same proposal teams.

- **Joint HS and ILC spacesuit development effort results found unsatisfactory by NASA**
  - Multiple spacesuit prototypes technical performance issues.
  - Unresolved management issues between HS and ILC.
  - Resulted in serious NASA Management concerns regarding HS/ILC. capability to meet Apollo Program schedule requirements.

EARLY APOLLO EMU SPACESUIT DEVELOPMENT
1962-1965

- **NASA found prototype model spacesuits developed under EMU contract unsatisfactory based on astronauts evaluation and MSC testing.**



SPD-143 AX-1L AX-1H AX-2H AX3H AX-3HR1 A-4H

APOLLO SPACESUIT SELECTION

JUNE 1965

NASA MSC ESTABLISHED AN IN-HOUSE COMPETITIVE TEST PROGRAM TO SELECT A SPACESUIT CONFIGURATION FOR CONTINUED CONTRACTOR DEVELOPMENT.

- Test program included evaluation of suit design, function, operation, and man/suit interfaces.
- Test conditions controlled to present identical test situations for each contractors submitted prototype spacesuit configuration. Test procedures structured to maximize objectivity.
- Evaluation rational emphasized mission requirements. Sixty-five separate test and evaluation situations conducted and scored.
- Test details and results reported previously in “Apollo Block I Spacesuit Development and Apollo Block II Spacesuit Competition” knowledge capture briefing conducted in January 2013.

RESULTS OF NASA SPACESUIT COMPETITION

Conducted March through June 1965

- **AX-5L** company funded prototype spacesuit submitted by ILC scored highest and was selected for Apollo Block II spacesuit development.
- Lower scoring prototype spacesuits not selected:

  AX-1C suit developed by David Clark (DCC) under (NAS 9-3642}.

  AX-6H suit developed by HSD, DCC, and BFG under (NAS 9-723).

AX-5L

AX-1C

AX-6H

APOLLO EMU PROGRAM CHANGE
September 1965

- **Robert R. Gilruth provided details for continued development of Apollo EMU to Dr. George B. Mueller, NASA Hdqrs:**
  - Recommended three changes **<u>not</u>** consistent with the previous EMU procurement plan approved by NASA Hdqrs:
    1. Amend **existing** HSD EMU contract to provide for development, qualification, and fabrication of **<u>only</u>** PLSS and associated equipment. for the Apollo Block II program.
    2. Award a new **<u>separate contract</u>** to ILC for development, fabrication, test and delivery of Apollo Block II flight spacesuits and associated equipment.
    3. Assign NASA MSC Crew Systems Division responsibility for Apollo Block II EMU Program implementation:
       - Management
       - Systems integration
       - Spacesuit qualification

APOLLO BLOCK II EMU PROGRAM

SEPTEMBER 1965

- **Basis for decision and recommendation:**
  - Results of the MSC comparative suit evaluation.
  - Reassessment of capabilities of ILC.
  - Previous lack of success of HSD in effecting an adequate total system development effort.
  - Recognize HSD competence in their portable life support systems (PLSS) work.
- **NASA announced it would negotiate with ILC for a contract to develop and provide Apollo Block II spacesuits.**

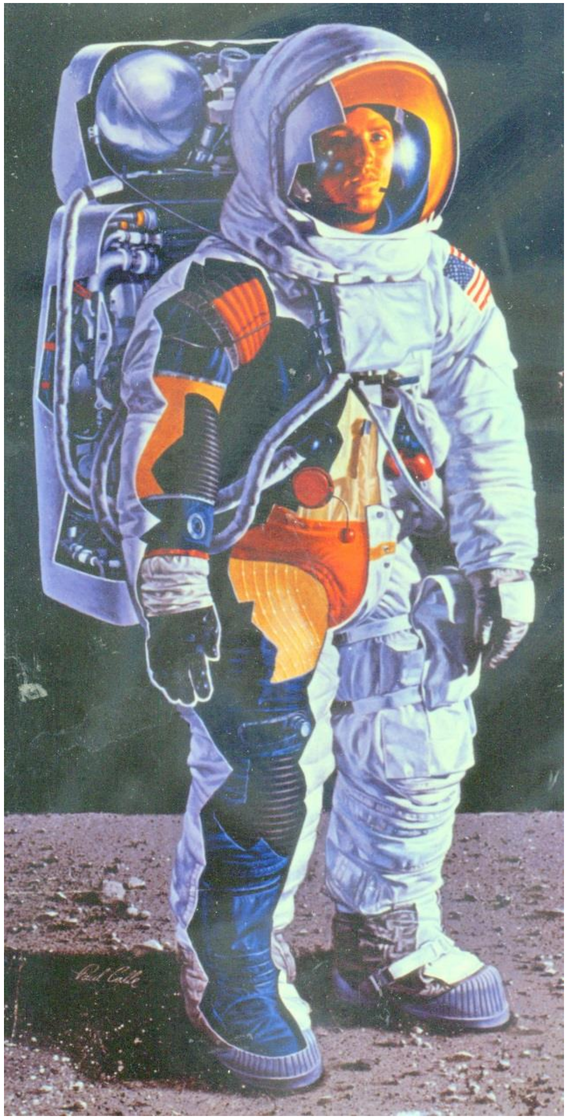
APOLLO BLOCK II EMU CONTRACT END ITEMS

HS Contract

- **PLSS**
  - **Controls and Displays**
- **Emergency Oxygen System (EOS)**

ILC Contract

- **Pressure Garment Assembly (PGA)**
  - **Torso limb suit (TLS)**
  - **Helmet**
  - **IV and EV Gloves**
- **Constant Wear Garment (CWG)**
- **Liquid Cooling Garment (LCG)**
- **Thermal Meteoroid Garment (TMG)**
- **Extravehicular Visor Assembly (EVVA)**
- **Waste Management System (WMS)**
  - **Urine collection device (UCD)**
  - **Fecal Containment System (FCS)**



APOLLO BLOCK II ILC SPACESUIT PROGRAM

TWO CONTRACTS IMPLEMENTED WITH ILC

- **NAS-9-5332:** A-5L engineering model PGA’s incorporating identified configuration changes necessary to support immediate Apollo Program needs for suits.
  - Letter Cost plus Fixed Fee contract.
- **NAS-9-6100:** A-6L spacesuit Contract End Item's development and production of qualification, training, and flight units.
  - Implement Apollo Program Configuration Management, Quality Assurance, and Reliability requirements.
  - Provide field support and spares.
  - Incentive award fee contract based on Schedule, Cost, and Technical Performance.

A-5L PGA ENGINEERING MODEL DEVELOPMENT
1965-1966

NAS 9-5332 CONTRACT CONTENT

- Incorporated modifications to the AX-5L prototype competition suit to establish A-5L PGA's design. (See Appendix A)
- 10 A-5L PGA's were built and delivered to support immediate Apollo Block II Program requirements:
  - Command Module (CM) mockup interface testing at NAA.
  - Lunar Module (LM) mockup interface testing at GAEC.
  - CEI's development support and design verification testing at ILC
  - PLSS/OPS development support at HS.
  - Pressure seal closure reliability testing by U.S. Army Natick Labs.
  - Astronaut simulators development support at NASA MSC.
  - Development testing and interfaces verification at MSC CSD.
- A-5L PGA's were fabricated under Class III engineering control to support immediate Apollo Program interfaces definition and test requirements.

A-6L FLIGHT SPACESUIT DEVELOPMENT
June 1966 to March 1970

NAS 9-6100 CONTRACT CONTENT

- Training and Flight CEI's development, production, and certification.
  - Implement Configuration, Quality Assurance, and Reliability controls for production and certification testing.
  - Incorporate A-5L PGA modifications to establish A-6L training and flight CEI's design configuration. (See Appendix B)
- Contract included:
  - CEI's manufacture, delivery, and design verification and qualification endurance cycle testing at ILC.
  - Spare parts, repair materials, and Familiarization and Illustrated parts manuals.
  - ILC Field support personnel located at NASA MSC and KSC, NAA, GAEC, and HS.

APOLLO BLOCK II SPACESUIT DEVELOPMENT

CONTRACT DELIVERY REQUIREMENTS

- Provide custom-sized suits for mission assigned astronauts.
- 1 training, flight, and flight backup suit provided for prime crewmembers.
- 1 training and flight suit provided for backup crewmembers.
  - Training suits delivered 12 months before flight.
  - Flight suits delivered 6 months before flight.
  - Prime crew flight backup suits delivered 3 months before flight.
  - Star code identification during manufacture to protect identity of mission assigned astronauts before official NASA release of names.
- 3 certification test suits:
  - Design Limit Cycle endurance testing at ILC.
  - Environmental exposure testing at NASA MSC.
  - PLSS/OPS interface testing at HS.
- Support manned 2TV1 & LTA-8 modules T/V tests at NASA MSC.
- Support CM and LM preflight vacuum and interface tests at NASA KSC.
- Support launch at NASA KSC and NASA MSC in-flight analysis.

APOLLO BLOCK II EMU SPACESUIT DEVELOPMENT

LUNAR LANDING MISSION REQUIREMENTS

- Perform crewmen oxygen pre-breathe before launch.
- Suit worn unpressurized during all mission phases except during depressurized CM/LM cabin conditions:
  - Capability to exit CM or LM in free space.
  - Capability to exit LM upon lunar landing to perform exploratory examinations of lunar surface and return safely to the LM.
  - Provide backup short-term emergency protection within or external to the CM/LM modules in event of spacecraft failures.
  - Support 30-minute contingency return time to module pressurization.
- Operate spacecraft during unscheduled cabin pressure loss:
  - Included a 115-hour transit period from lunar surface to a safe earth atmosphere in decompressed LM/CM modules.
- Perform task activities on lunar surface.

TASK ACTIVITIES ON LUNAR SURFACE

- EGRESS THRU LEM HATCH AT 1/6 G
- CLIMB DOWN LADDER OR POLE TO LUNAR SURFACE
- INSPECT LUNAR SURFACE WALKING 0.3-1.6 MPH: RANGE ≤1 MILE
- VISUALLY INSPECT LEM EXTERIOR
- REMOVE EQUIP & SET UP BASE OF EXPERIMENTS
- ADJUST AND OPERATE INSTRUMENTS
    - MANIPULATE PHOTO EQUIP
    - USE CONTAINER TO COLLECT ATMOSPHERIC SAMPLE
    - USE GEOLOGIC HAMMER
    - MAKE FINE INSTRUMENT READINGS
    - USE HAND TOOLS
- BEND OR KNEEL DOWN TO COLLECT SAMPLES FROM LUNAR SURFACE
- WALK OR CLIMB OVER LUNAR OBSTACLES
- CARRY HEAVY OBJECTS

APOLLO BLOCK II EMU SPACESUIT DEVELOPMENT

ENVIRONMENTAL REQUIREMENTS

- Cabin Atmosphere Compatibility:
  - Odor and toxicity
  - Oxygen and humidity
  - Salt fog
  - Stowage low temperature
- Vibration
- Acceleration
- Shock
- Impact
- Sand and dust
- Body wastes
- Acoustic noise
- Thermal vacuum
- Micrometeorite impact
- Lunar environmental conditions

SUMMARY OF LUNAR ENVIRONMENTAL CONDITIONS

AMBIENT PRESSURE	-	10^{-10} TORR
GRAVITY	-	1/6 EARTH GRAVITY
THERMAL	-	SURFACE TEMPERATURE ±250° 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

APOLLO BLOCK II EMU SPACESUIT DEVELOPMENT

INTERFACE REQUIREMENTS

- CM/LM atmosphere ~100% oxygen gas at 5.0 psi pressure.
- CM couch restraint, and LM landing and launch restraint system.
- CM/LM navigation and control optical systems.
- CM/LM functional transfer and stowage.
- CM, LM, PLSS, and ground communication and instrumentation.
- PLSS restraint straps for LM egress, lunar surface activity and LM return ingress.
- Crew vacuum transfer capability between CM and LM ECS, and LM ECS and PLSS/OPS without loss of suit pressure.
- Capability for self connect-disconnect-reconnect of all PGA connectors (gas, water, urine, and electrical).
- Self-operation of necessary CM, LM, and PLSS/OPS controls.
- Visibility of necessary CM, LM, and PLSS displays.
- Urine transfer to CM and LM waste storage.
- Medical injector application.
- Post-landing water survival equipment.

APOLLO BLOCK II EMU SPACESUIT DEVELOPMENT

CEI'S DESIGN REQUIREMENTS

- **PGA:**
  - 3.7 +/- 0.25 psi operating pressure to maximize suit mobility.
  - 6.0 psig proof, 8.0 psig structural, and 10.0 psig burst pressures.
  - 4.7 inches water pressure max from PGA inlet to outlet gas connectors at 12 cfm oxygen gas flow rate (diverter valve open).
  - 1.953 inches water pressure drop max from PGA inlet to outlet gas connectors at 6 cfm oxygen gas flow rate (diverter valve closed).
  - Leakage rate less than 180 scc/minute at either 0.2 or 3.7 psi.
  - Relief valve open at 4.10 psig with max flow at 5.5 psig.
  - Helmet C02 level less than16 mm/Hg at 1600 BTU/Hour.
  - Helmet-mounted feed port for insuit nourishment.
  - Hands dexitary and fingers tactility to operate controls and tools.
  - Adequate crewman helmet vision for mission interfaces and phases.
  - Post-landing ocean water immersion.
  - Four-year shelf age life from pre-delivery acceptance test.

APOLLO BLOCK II EMU SPACESUIT DEVELOPMENT

CEI'S DESIGN REQUIREMENTS

- **TMG**
  - Self-donned and doffed jacket and pants separately worn over TLSA.
  - Provide PGA TLSA thermal and micrometeoroid protection.

- **EVA Gloves**
  - Hands dexitary and fingers tactility to operate controls and tools.
  - Provide +/- 250 deg F grasp capability for EVA tools, lunar surface scientific experiments, and surface materials.
  - Provide abrasion, scuff, and cut protection for pressure glove bladder.

- **Lunar Boots**
  - Self-donned and doffed boots worn over PGA TLSA boots for Lunar surface activity.
  - Provide +/- 250 deg F lunar surface thermal protection to TLSA boots/feet.
  - Provide abrasion, scuff, and cut protection for PGA TLSA boots.

APOLLO BLOCK II EMU SPACESUIT DEVELOPMENT

CEI'S DESIGN REQUIREMENTS

- **LCG**
  - 9.3 to19.0 psig operating pressure.
  - Proof pressure 28.5 psig and burst pressure 47.5 psig.
  - Pressure drop 2.65 psi from 4 to 10 psi and 45 deg F inlet temp.
  - Water tubing over arms, torso, and legs; - socks only over feet
  - 0.10 cc/hr leak rate at 19.5 psig and 45 deg F.
  - Provide water cooling during suited LM and lunar surface activity.
  - Attachment provision for biomedical instrumentation.

- **EVVA**
  - Self-donned and doffed shell/thermal collar worn over helmet during EVA.
  - Provide visual, solar, thermal, micrometeoroid, and supplemental helmet defog and impact protection.
  - Provide adequate field of vision in either sunlight or darkness.
  - Provide supplemental helmet defogging capability.

APOLLO BLOCK II EMU SPACESUIT DEVELOPMENT

CEI'S DESIGN REQUIREMENTS

- **CWG**
  - Worn comfort during launch and CM suited mission phases.
  - Cover arms, torso, and legs.
  - Attachment provision for biomedical instrumentation.

- **GFE Communications Carrier Assembly (CCA)**
  - Self-donning and doffing and attachment to EEH.
  - Redundant microphones and earphones.

- **Electrical Harness (EEH)**
  - Connectors attachment for PGA TLSA, CCA, and Biomed instrument sensors.

APOLLO BLOCK II EMU SPACESUIT DEVELOPMENT

CEI'S DESIGN REQUIREMENTS

- **WMS**
  - UCD
    - Provide in-suit storage of urine with 950 scc of fluid capacity.
    - Capability to transfer fluid from inside suit to CM/LM stowage containers.
  - FCS
    - Absorb body fluids and contain feces during unpressurized and pressurized suited conditions having capacity of 1000 cc.
    - Provide 114-hour continuous pressurized suit wear capability.

APOLLO 1 (AS-204) ACCIDENT

Occurred January 27, 1967

- **THREE NASA ASTRONAUTS LOST THEIR LIVES DURING A FLASH FIRE INSIDE THE CM ON THE LAUNCH PAD AT KSC.**
- **CREWMEN WERE WEARING APOLLO BLOCK I SPACESUITS MANUFACTURED BY DCC.**

GUS GRISSOM, ED WHITE, ROGER CHAFFE

APOLLO PROGRAM MANAGEMENT RESPONSE

- Immediately cease all oxygen enriched atmosphere operations and testing.
- No manned testing conducted in an oxygen enriched atmosphere by contractors.
- All manned testing in an oxygen-enriched atmosphere will be performed at NASA facilities – only after successful completion of an Operational Readiness Inspection (ORI).
- Identify and eliminate all ignition sources in enriched oxygen atmospheres.
- Remove all flammable materials from oxygen enriched atmospheres.
- Exception only when no suitable material replacement is available.
  - Materials use exceptions documented by Material Use Agreement (MUA) approved by the Apollo Program Change Board.

APOLLO A-6L CEI'S STATUS

February 1967

- **CDR'S COMPLETED 1966**
  - Parts and Material Lists submitted and reviewed.
  - Type 1 CEI's design drawings approved.
  - Interface control documents identified and reviewed.
  - DVT completed with results and problems reports reviewed.

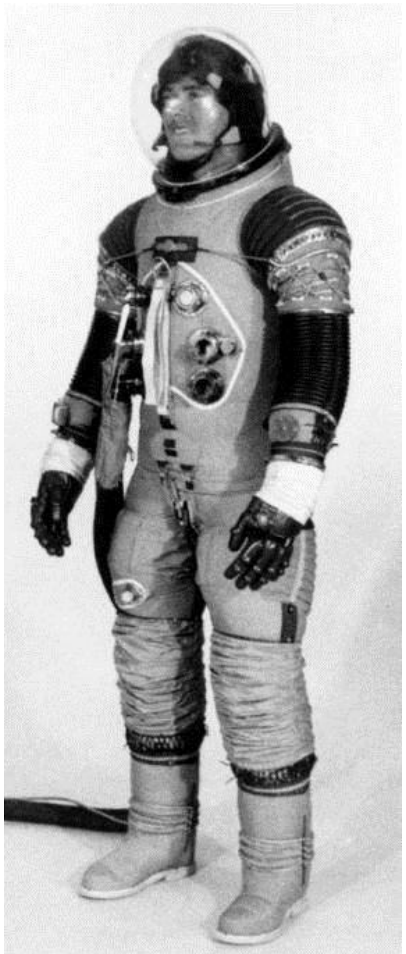
- **FACI COMPLETED FEBRUARY 1967**
  - Documents and Specifications approved.
  - CEI's hardware design configuration approved.
  - Manned demonstration of PGA, TMG, LCG, and FCS.

APOLLO A-6L CEI'S STATUS

February 1967

- **PRODUCTION, DELIVERY, AND CERTIFICATION OF A-6L SUIT CEI'S IN WORK**
  - Certification suits CEI's delivered.
  - Manned certification endurance cycle testing underway at ILC.
  - Manned testing at vacuum being conducted at MSC.
  - Unmanned environments exposure testing underway at MSC.
  - Training suit CEI's in production.

A-6L PGA and CEI'S DESIGN BASELINE



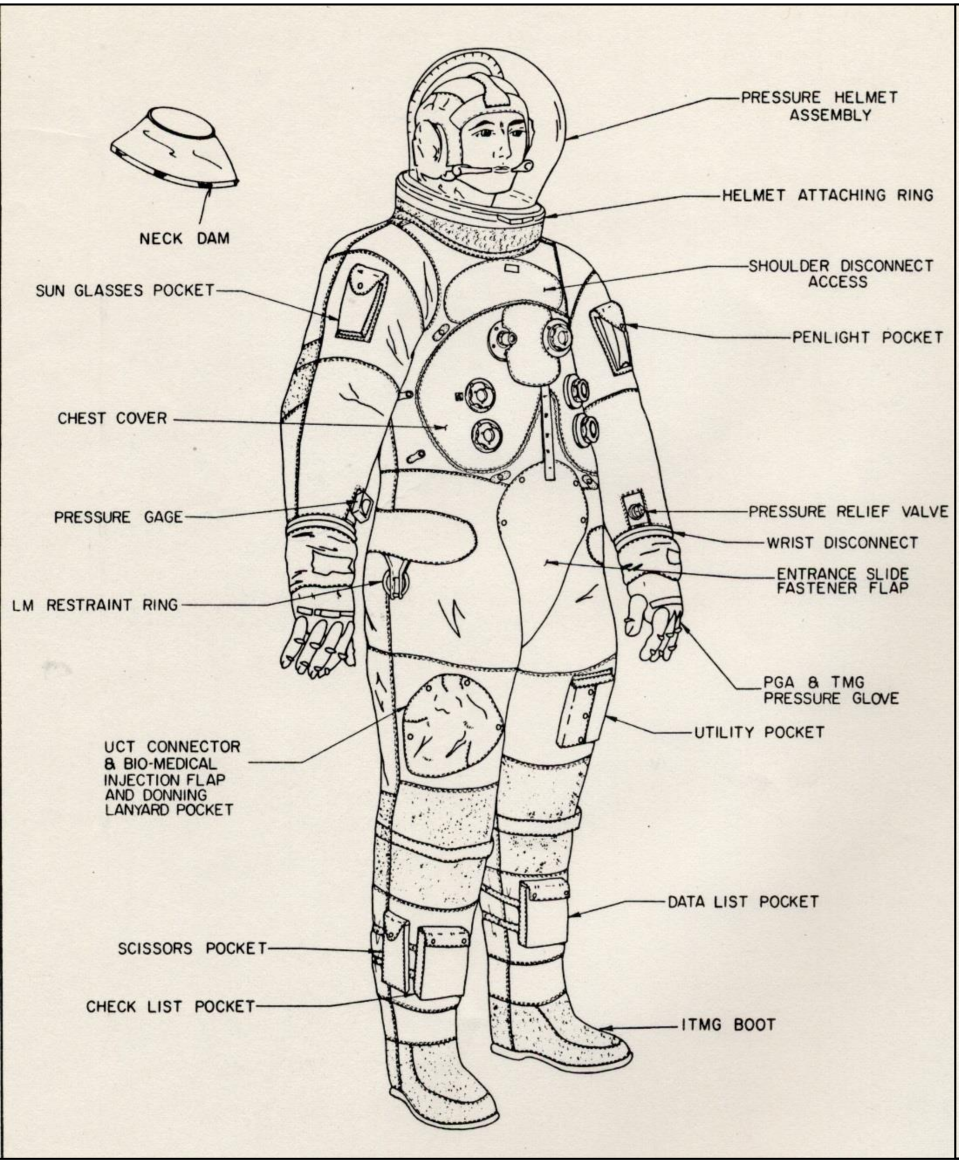
APOLLO 1 ACCIDENT

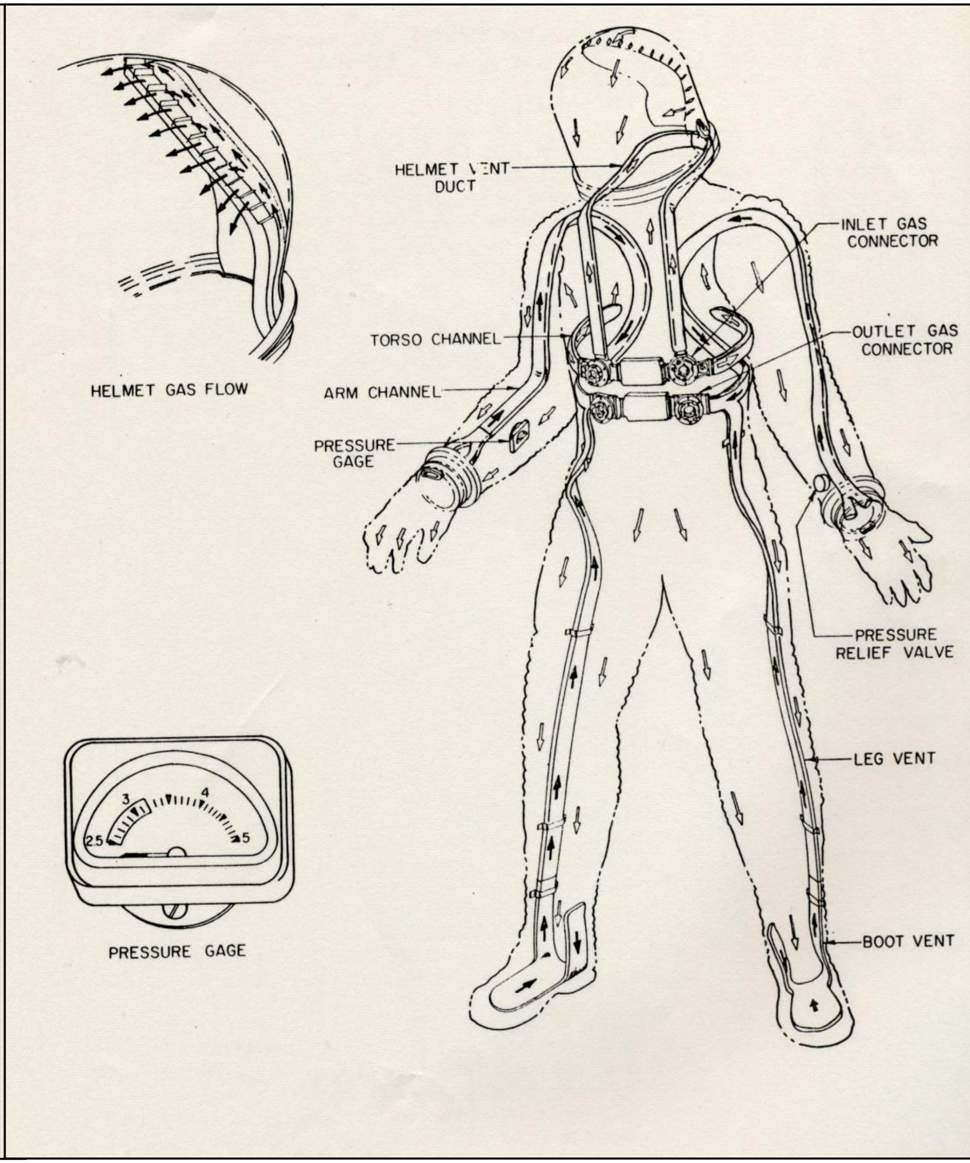
APOLLO BLOCK II CEI’S DESIGN IMPACTS

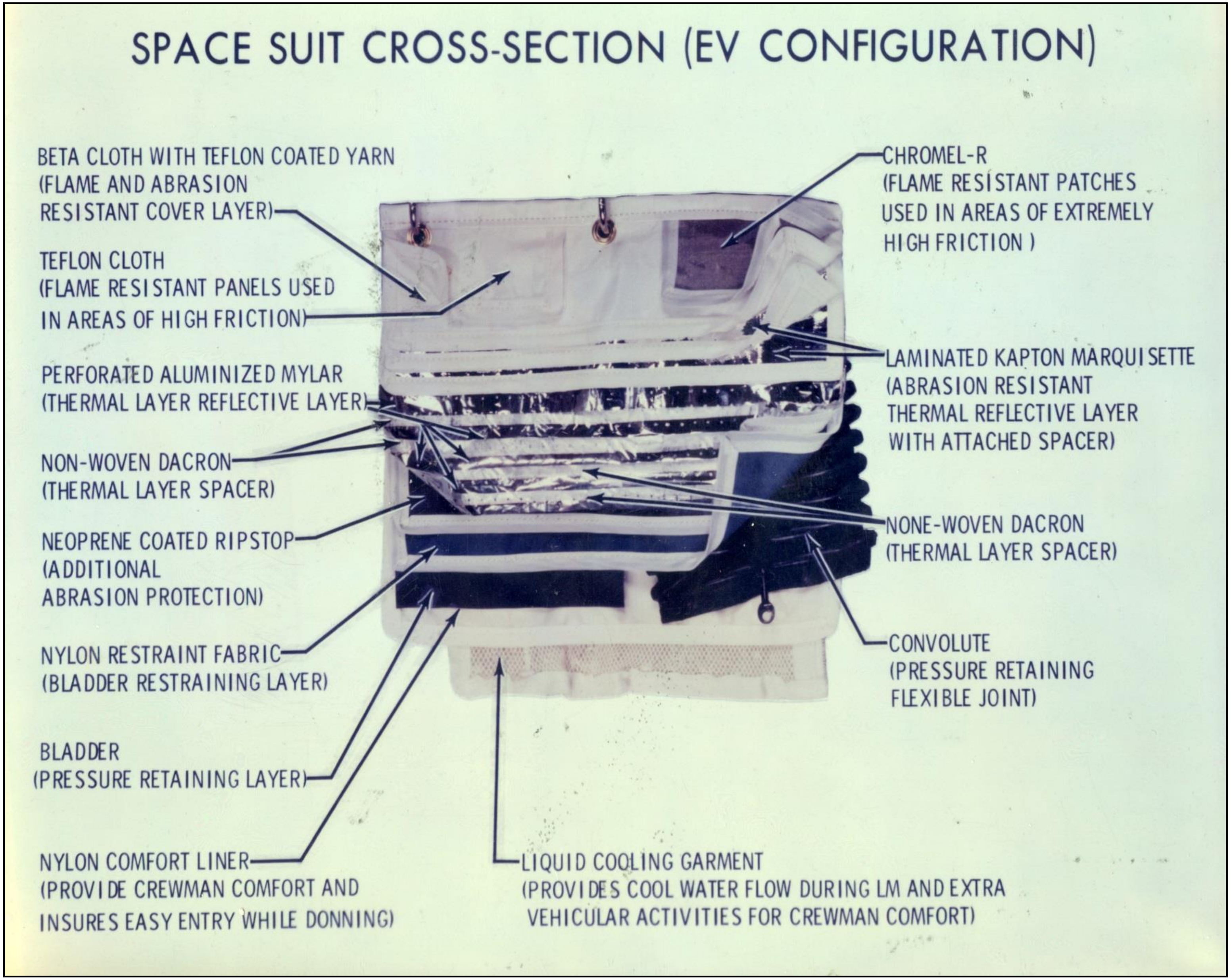
A-6L PGA REDESIGN

- Torso Limb suit assembly (TLSA)
  - Former separately donned and doffed TMG jacket and pants integrated over TLSA arms, torso, legs, and boots.
  - Non-flammable TMG cover-layer materials cross-section incorporated.
  - Boot soles changed to non-flammable Fluorel material.
  - Interior TLSA materials approved by MUA.
    - Rational: No suitable replacement materials.
- Helmet
  - Polyurethane impact vent pad covered with beta cloth material.
  - Exterior polycarbonate material approved by MUA.
    - Rational: No suitable replacement for polycarbonate material.
- IV and EV Gloves
  - Integrated cover-layer changed to non-flammable materials cross-section.
  - Thermal insulation added with Chromyl-R material over EV Glove fingers and palm for abrasion and cut protection.

A-7L PGA REDESIGN BASELINE

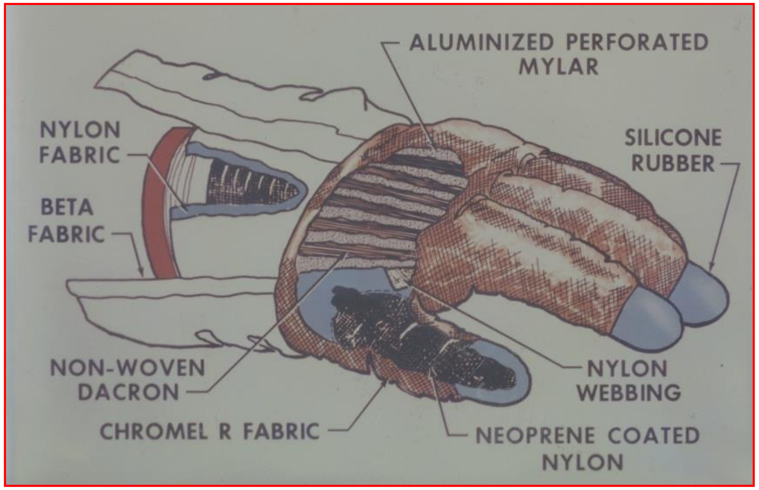


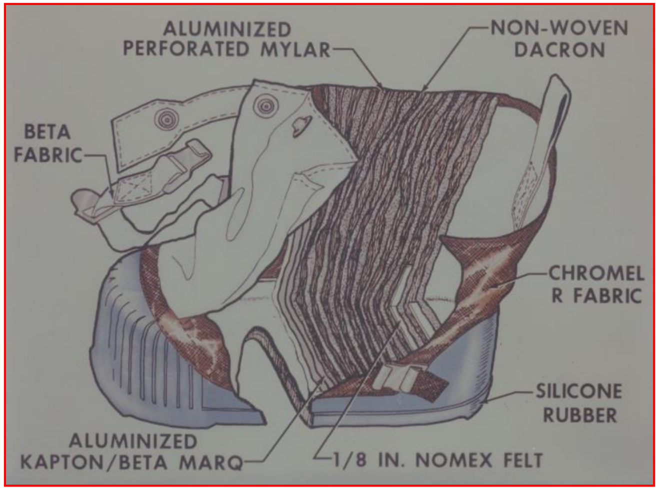



SPACE SUIT CROSS-SECTION (EV CONFIGURATION)
BETA CLOTH WITH TEFLON COATED YARN (FLAME AND ABRASION RESISTANT COVER LAYER)
TEFLON CLOTH (FLAME RESISTANT PANELS USED IN AREAS OF HIGH FRICTION)
PERFORATED ALUMINIZED MYLAR (THERMAL LAYER REFLECTIVE LAYER)
NON-WOVEN DACRON (THERMAL LAYER SPACER)
NEOPRENE COATED RIPSTOP (ADDITIONAL ABRASION PROTECTION)
NYLON RESTRAINT FABRIC (BLADDER RESTRAINING LAYER)
BLADDER (PRESSURE RETAINING LAYER)
NYLON COMFORT LINER (PROVIDE CREWMAN COMFORT AND INSURES EASY ENTRY WHILE DONNING)
CHROMEL-R (FLAME RESISTANT PATCHES USED IN AREAS OF EXTREMELY HIGH FRICTION)
LAMINATED KAPTON MARQUISETTE (ABRASION RESISTANT THERMAL REFLECTIVE LAYER WITH ATTACHED SPACER)
NONE-WOVEN DACRON (THERMAL LAYER SPACER)
CONVOLUTE (PRESSURE RETAINING FLEXIBLE JOINT)
LIQUID COOLING GARMENT (PROVIDES COOL WATER FLOW DURING LM AND EXTRA VEHICULAR ACTIVITIES FOR CREWMAN COMFORT)

APOLLO 1 ACCIDENT

EVA GLOVE and LUNAR BOOT CEI'S REDESIGN BASELINE





APOLLO 1 ACCIDENT

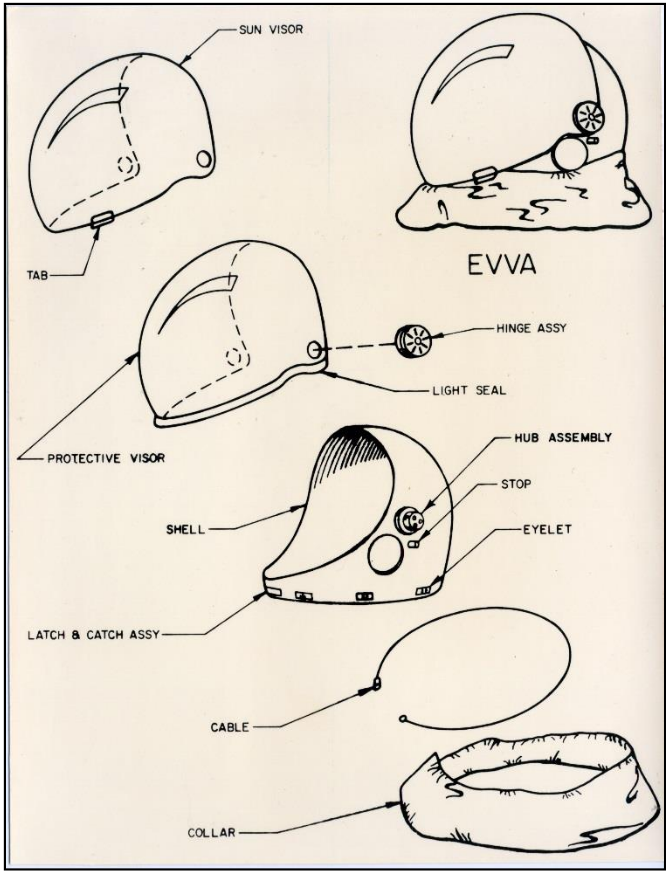
SPACESUIT CEI'S REDESIGN

- **EVVA**
  - Exterior red polycarbonate shell and visors materials approved by MUA.
  - Rational: No suitable materials replacement for polycarbonate material. Stowed in non-flammable container when not worn.

- **GFE CCA and EEH**
  - Current limited into PGA atmosphere to eliminate ignition source.
  - Covering changed to non-flammable Teflon material.
  - Earphones, microphones, and wiring approved by MUA.
  - Rational: No suitable replacement for wiring material and ear phones and microphones. Stowed in non-flammable container when not worn.

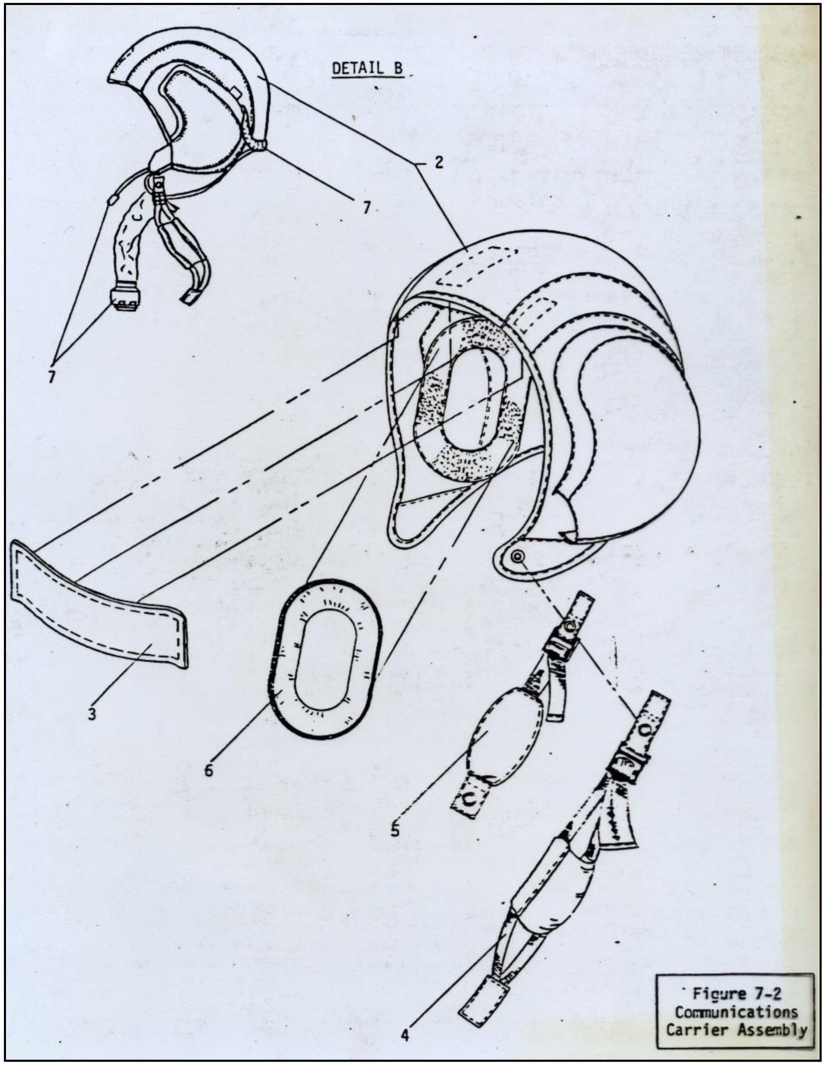
APOLLO 1 ACCIDENT

EVVA REDESIGN BASELINE



APOLLO 1 ACCIDENT

GFE CCA DESIGN BASELINE



APOLLO 1 ACCIDENT

A-6L SUIT CEI's DESIGN IMPACTS

CWG

- Materials approved by MUA.
  - Rational: No suitable replacement materials and worn inside PGA.
    When not worn, stowed in non-flammable container.

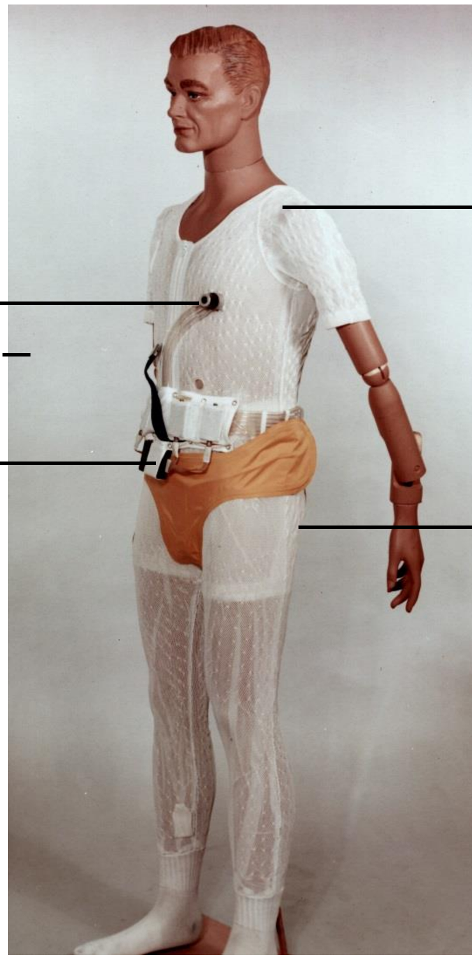
LCG

- Materials approved by MUA.
  - Rational: No suitable materials replacement and worn inside PGA.
    When not worn, stowed in non-flammable container.

WMS

- UCD and FCS materials approved by MUA.
  - Rational: No suitable replacement materials and worn inside PGA.
    When not worn, stowed in non-flammable container.

APOLLO 1 ACCIDENT
CEI'S Design Baseline

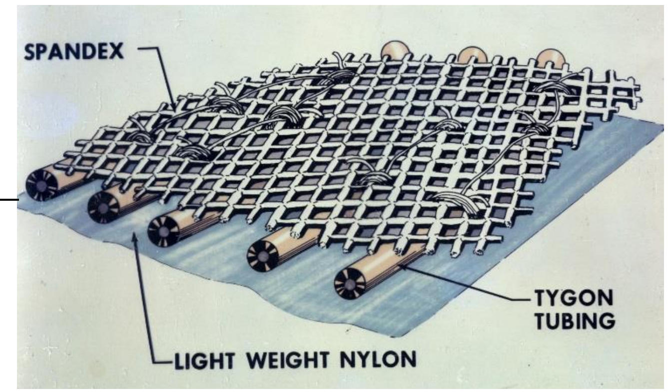


BIOMEDICAL HARNESS

URINE COLLECTION DEVICE

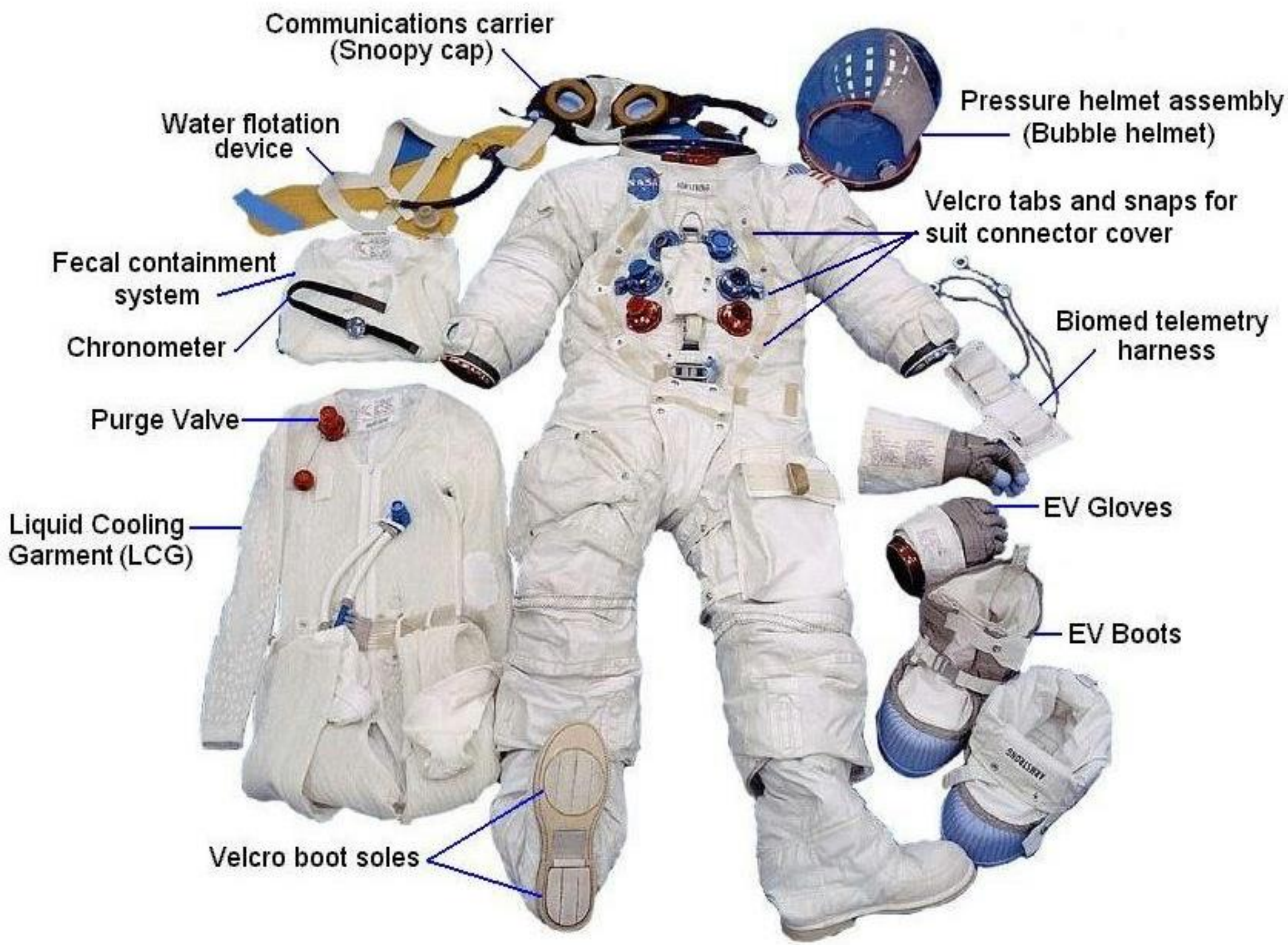
LIQUID COOLING GARMENT

FECAL CONTAINMENT SYSTEM



A-7L PGA AND CEI's BASELINE

(EVVA not shown)



U.S. SPACESUIT KNOWLEDGE CAPTURE SESSIONS

Future Spacesuit Sessions In-work:

- **“Apollo A-7L Spacesuit Development for Apollo 7 Through 14 Missions”**
- “Apollo A-7LB Spacesuit Development for Apollo 15 -17 Missions”
- “Apollo Spacesuit Modifications and Development for the Skylab Program”
- “Apollo Spacesuit Modifications and Development for the Apollo Soyuz Test Project”
- “Space Shuttle EMU Spacesuit Development for Initial Space Shuttle Program Flights”
- “Space Shuttle EMU Spacesuit Development for the International Space Station Program”

NASA SPACESUIT TYPE NOTATION

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

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

- **Number to left of (-) denotes development sequence number**
  A-5L, A-6L, A-7L

- **Letter following number denotes manufacturer**
  C = David Clark Co.
  H = Hamilton Standard
  L = International Latex Co.

- **Examples**
  AX-1C = Prototype Suit mfg. by David Clark Co.
  AX-5H = Prototype Suit mfg. by Hamilton Standard
  AX-5L= Apollo Prototype Suit mfg. by International Latex Co.

Source: C. C. Lutz NASA Memo dated July 9, 1962

APPENDIX A

A-5L PGA DEVELOPMENT

A-5L PGA DEVELOPMENT

MODIFICATIONS TO AX-5L COMPETATION SUIT

- Incorporated detachable TLS inner liner to improve donning capability.
  - Velcro fasteners with bar tack indexing marks added to facilitate alignment during installation to pressure retention system.
- TLS boot sizing system design established to accommodate maximum number of crewmen with minimum number of sizes.
  - Boot heel height reduced to improve wearer balance, walking ease, and load distribution.
  - Velcro insole added to facilitate bladder attachment to restraint and to increase donning ease.
  - Donning pull-tab and Velcro strip added vertically up back of boot between bladder and restraint to increase donning ease.

A-5L PGA DEVELOPMENT

MODIFICATIONS TO AX-5L COMPETATION SUIT

- Upper TLS thigh cones stability improved
  - Changed interface angle with knee joints
  - Eliminated hard-shells in cones
  - Position of knee mobility joints sized for different leg lengths
- TLS flange mounted hardware interfaces
  - Gas connectors provided by Airlock Inc. (AL)
  - Water and waste connectors provided by HS
  - Pressure gage provided by Dyna-Magnatics
  - Pressure relief valve provided by AL
  - Electrical fitting provided by Micro-Dot Corp
  - Medical Injection fitting
  - Pressure transducer and low pressure warning switch provided by HS
- Structural adequacy verified by testing in AX-5L suit
  - 500 pressure cycles from 0 to 8 psig and back to 0 psig in 3 seconds

A-5L PGA DEVELOPMENT

MODIFICATIONS TO AX-5L COMPETATION SUIT

- TLS neck section redesigned for compatibility with CM crewman position requirements, comfort, and to increase shoulder mobility.
  - Achieved eye to heart angle of less than 16 deg.
  - Achieved neck ring center line angle of 30 deg. (downward relative to a horizontal plane through mid-point of ring cross-section at back of neck).
  - Reduced bulk of TLS neck section interface.
  - Modified design increased wearer comfort by improving load distribution across shoulders.
  - Modifications Incorporated in AX-5L suit with adequacy verified by testing to assure no compromise to helmet visual field and/or mobility.

A-5L PGA DEVELOPMENT

MODIFICATIONS TO AX-5L COMPETATION SUIT

- Added PLSS pressure transducer and low pressure warning switch attachment to back of TLS neck and EEH.
- Gemini G-4C suit pressure seal/restraint closure integrated in TLS
  - Gussets incorporated at both ends of zipper assembly.
  - Service cycle life adequacy verified by testing four A-5L production PGA’s at U.S. Army Natick Laboratory.
- Nylon fabric protective covers added over TLS knee and elbow convolutes, and lower arm and lower leg lacing size adjustments.
  - Removable covers provided for field inspection and sizing adjustment.
  - Adequacy tested in AX-5L suit to verify lack of joints restriction at 3.7 and 8 psig.

A-5L PGA DEVELOPMENT

MODIFICATIONS TO AX-5L COMPETATION SUIT

- TLS shoulder redesigned to improve wearer comfort in pressurized and unpressurized modes for both CWG and LCG interfaces.
- TLS shoulder sizing developed for minimum number of sizes accommodate a 5^{th} to 95^{th} percentile man.
  - Each developed size incorporated and adequacy verified by testing in the first four A-5L production suits.
- TLS helmet hold-down redundant latch was deleted.

A-5L PGA DEVELOPMENT

MODIFICATIONS TO AX-5L COMPETATION SUIT

- TLS ventilation system development.
  - Design used in previous suits ventilation systems reviewed with regard to vent ducts size and construction.
  - Optimum routing of TLS vent ducts established considering comfort, system efficiency, and performance.
  - Nylon springs tested for use as non-crushable members in vent ducting.
  - Manned and unmanned tests conducted to verify pressure drop and flow split adequate.

A-5L PGA DEVELOPMENT

MODIFICATIONS TO AX-5L COMPETATION SUIT

- A-5L glove components development.
  - Four-point, two-cable restraint system design increased stability, torque uniformity, minimized bulk, and relieved existing AX-5L glove pressure point at base of thumb.
  - Fingerless glove gauntlet and improved glove palm restraint with an abrasion resistant coated nylon fabric.
  - Single restraint cable micrometer adjustment device incorporated to provide wrist joint balance.
  - Static load testing performed to verify adequacy.

APPENDIX B

A-6L SPACESUIT CEI's DEVELOPMENT

A-6L CEI's DEVELOPMENT AND QUALIFICATION

JANUARY 1966

Preliminary Design Review held at ILC for A-6L PGA

- A-5L PGA design configuration baseline plus following changes:
  - Addition of TMG jacket and pants using NASA-provided materials cross-section (outside to inside):
    - One layer of six-ounce Nomex cloth.
    - Seven layers of H.R.C. super-insulation, starting with 0.25 mil aluminized Mylar, and alternating with 1.5-mil unwoven Dacron spacers.
    - Two layers of seven-ounce neoprene rip stop nylon (one side coated with neoprene).
  - Ankle mobility joint incorporated in TLS boot configuration to provide increased walking mobility to perform Lunar surface tasks.

A-6L CEI's DEVELOPMENT AND QUALIFICATION

- **Dust seal incorporated in TLS suit arm bearings to preclude dust particles greater than 50 microns diameter from entering bearing race and pressure seal area.**
  - Leakage demonstrated less than 5-cc per min at 3.7 psig
  - Arm bearing torque verified greater than wrist disconnect torque from 0 to 3.7psi to preclude wrist disconnect from overriding arm bearing.
- **FACI for A-6L PGA and CEI's held at ILC during same month as the Apollo 1 Accident.**