

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: Apollo Block I Spacesuit Development and Apollo Block II Spacesuit Competition

Date: January 29, 2013 **Time:** 11:30-1:00 pm **Location:** JSC/B5S/R3102

DAA 1676 Form #: 29277

This is a link to all lecture material and video: <\\js-ea-fs-01\pd01\EC\Knowledge-Capture\FY13 Knowledge Capture\20130129 McBarron Apollo Block I SS Dev-Apollo Block II SS Competition\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: Jim McBarron has over 40 years of experience with the U.S. Air Force pressure suit and NASA spacesuit development and operations. As a result of his experience, he shared his significant knowledge about the requirements and modifications made to the Gemini spacesuit, which were necessary to support the Apollo Block I Program. In addition, he provided an overview of the Apollo Block II Spacesuit competition test program conducted by the NASA Manned Spacecraft Center. Topics covered included the program's chronology; competition test program ground rules, scoring details, and final test results; and the implementation of resulting modifications to the Apollo Spacesuit Program. He concluded his 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.

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 SERIES

Apollo Block I Spacesuit Development and Apollo Block II Spacesuit Competition

JAMES W. McBarron II
Retired NASA JSC
January 29, 2013

AGENDA

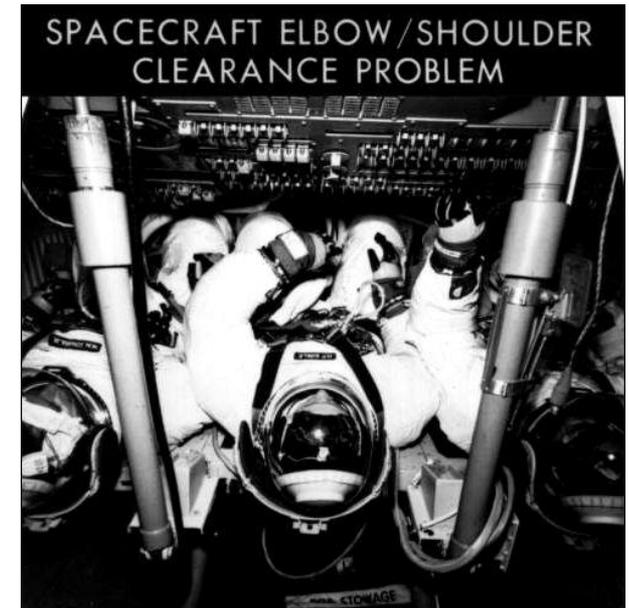
- Apollo Block I Spacesuit Development
 - Chronology
 - Requirements
 - Configuration
 - Procurement Plan
- Apollo Block II Spacesuit Competition
 - Chronology
 - Competition spacesuits
 - Test plan details
 - Test results
 - Program change implementation
- Lessons Learned

APOLLO BLOCK I SPACESUIT CHRONOLOGY

- **January, 1964**—North American Aviation (NAA) presented block change concept to the Manned Spacecraft Center (MSC):
 - Block I spacecraft would carry no rendezvous and docking equipment and would be for Earth-orbital missions only.
 - Block II Command Service Module (CSM) changes were necessary: Lunar Excursion Module (LEM) compatibility; structural changes to reduce weight and improve CSM center of gravity; plus other critical systems changes. Block II CSM would be final design configuration for lunar missions.
- **February - March, 1964**—During this time, Crew Systems Division (CSD) began reviewing the possibility of using Gemini suits during Apollo Earth orbital flights, and during the next several weeks, began testing Gemini suits in Apollo environments.

APOLLO BLOCK I SPACESUIT CHRONOLOGY

- **April, 1964 - MSC and NAA conducted review of Block I CSM mockup.**
 - First time three prototype spacesuits were used in CM couches.
 - Testing of three suited astronauts lying side by side in couches at 3.7 psig showed suit elbows and shoulders overlapped preventing effective operation of CM displays and controls.
 - Previous tests with only one suited subject indicated prototype suit mobility was adequate.
- *“One of the most worrisome items astronauts found in the CM arrangement was an “elbow-shoulder clearance problem,” Four years later, in 1968, this problem still vexed astronauts Walter Schirra, Donn Eisele, and Walter Cunningham, the first crew to fly an Apollo spacecraft.....”*



APOLLO BLOCK I SPACESUIT CHRONOLOGY

- **May, 1964**—Decision made to use Gemini suits for Block I missions.
 - Use of Gemini suits for Apollo Block I Earth orbital missions promised a substantial financial saving.
 - Existing Hamilton Standard (HS)/International Latex Corporation (ILC) Apollo space suit contract was redirected to concentrate on later Apollo Block II flights.
 - Redesign of prototype Apollo suit shoulders and elbows was initiated.
- **June, 1964**—MSC directed NAA to make whatever design changes necessary to make Block I CSM compatible with the Gemini spacesuit.
- **July, 1964**—NASA gave David Clark Company (DCC) program for modifying and testing Gemini suits for use in Apollo program after the decision was made to use Gemini space suits for Apollo Earth-orbital flights. Formal contract award to DCC scheduled for later this year.

APOLLO BLOCK I SPACESUIT CHRONOLOGY

- **October, 1964**—MSC CSD investigated environmental control system (ECS) implications of using Gemini suits in Apollo Block I missions.
 - Results indicated ECS capable of maintaining nominal cabin temperature and carbon dioxide partial pressure levels.
 - This mode of operation had an adverse effect on cabin dew-point temperature and water condensation rate.
- **November, 1964**—MSC determined lights on spacesuit glove fingertips were adequate to supplement CM interior lighting. Exact requirements for fingertip lights to be defined. Astronauts preferred red bulbs, a redesign to the existing Gemini glove system.
- **Sept-Dec, 1964**—CSD approved use of modified Gemini spacesuits in Block I Apollo spacecraft.
 - MSC amended DCC Gemini suit contract for design and fabrication of a prototype Apollo Block I suit.
- **November, 1964**—Apollo Spacesuit Assembly designated Apollo Extravehicular Mobility Unit (EMU) by direction of Max Faget, MSC engineering director.

APOLLO BLOCK I SPACESUIT CHRONOLOGY

- **January, 1965**—Block II CM Preliminary Design Review held at NAA.
Significant problems identified:
 - Wear cycles and requirements for donning and stowage of spacesuits needed to be resolved and incorporated into CSM specifications.
 - NAA interpretation of specifications conflicted with MSC CSD's then current plan that all three crewmen should be able to wear suits without helmets during the first several missions.
- **January, 1965**—Apollo System Program Office (ASPO) Systems Engineering Division (SED) concluded Block I CMs should be outfitted for partial suit wear to build confidence in the pressurization system and recommended ASPO manager direct NAA to incorporate provisions for partial suit wear in Block I.

APOLLO BLOCK I SPACESUIT CHRONOLOGY

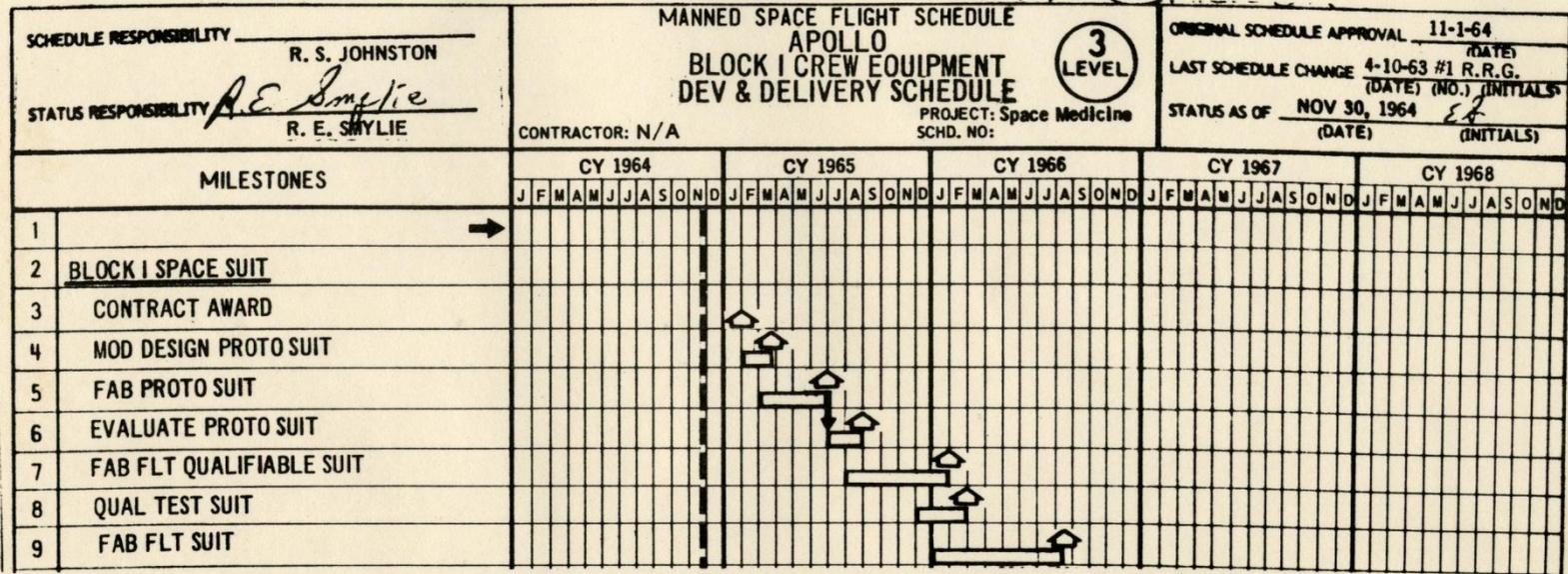
- **February, 1965**—MSC CSD tested the time an astronaut could don and doff a Block I suit assembly while at various stations inside the spacecraft in the Apollo CM mockup.
 - Two subjects average donning times were 9 min 33 sec and 10 min; mean doffing times were 4 min 5 sec, and 5 min 23 sec.
- **February, 1965**—Navy Air Crew Equipment Laboratory (NACL) began subject testing Gemini Block I Apollo spacesuit in a wide range of environmental temperatures to determine comfort and physiological responses.
- **February, 1965**—MSC and DCC reached agreement on a sole source contract for Apollo Block I spacesuits. First delivered suits would go to NAA for CM testing.

APOLLO BLOCK I SPACESUIT CHRONOLOGY

- **March, 1965**—First Project Gemini Flight; GT-3
- **March, 1965**—CSD recommended a "shirtsleeve" environment be kept in the CM:
 - This design was simpler and more reliable, and promised greater personal comfort than wearing a spacesuit during an entire mission.
- **November, 1965**—CSD reviewed and approved majority of Block I spacesuit drawings:
 - Design of Block I spacesuit helmet ear cup and attachment was finalized. Existing Gemini-type "soft" ear cups were deemed adequate for Block I flights based on evaluation of acoustic test data.
 - NAA and DCC specifications were changed to reflect revised requirements.

APOLLO BLOCK I SPACESUIT PROGRAM PLAN

FIGURE 1



APOLLO BLOCK I SPACESUIT PROCUREMENT

Contract NAS 9-1396, Amend. 6, Modification 12–December 15, 1964

- **Program scope:**
 - Review Apollo CM interfaces and incorporate modifications required for spacesuit compatibility.
 - Identify necessary design changes and modify the Gemini G-3C spacesuit configuration for Apollo Block I Earth orbital missions.
 - Employ DCC developed Project Gemini processes and documentation to maximum extent possible.
 - Fabricate and deliver prototype, qualification, program support, and training and flight spacesuits.
 - Provide operations support for Apollo Block I Earth orbital missions.
- **January, 1967**–Contract effort was terminated after SA-204 (Apollo 1) mission pre-launch pad fire in CM resulting in loss of all crewmen.

APOLLO BLOCK I SPACE SUIT PERFORMANCE DESIGN REQUIREMENTS

PRESSURE

- PROOF 8.0 PSIG (15 MINUTE DURATION)
- OPERATING NORMAL (0.15 PSIG)
DECOMPRESSED CABIN (3.7 PSIA FOR
A MAXIMUM TIME DURATION OF 4 HOURS)
- 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

VENTILATION DISTRIBUTION SYSTEM

● PRESSURE DROP

NOT TO EXCEED 4.75 INCHES H₂O UNDER FOLLOWING
CONDITIONS

- A. SUITABLY SIZED SUBJECT RESTRAINED IN APOLLO
- B. INLET VENT FLOW RATE 11.5 ACFM
- C. INLET VENT GAS 100% O₂
- 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 Δ P 0 TO 1 INCH H₂O

● HELMET CO₂ REMOVAL

HELMET VENT SYSTEM TO PROVIDE ADEQUATE CO₂
FOR ALL MISSION CONDITIONS

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

APOLLO BLOCK I SPACE SUIT ASSEMBLY PERFORMANCE DESIGN REQUIREMENTS (CONT)

MOBILITY

ADEQUATE MOBILITY UNPRESSURIZED AT 3.7 PSI TO PERFORM ALL REQUIRED MISSION TASKS, BOTH NORMAL AND EMERGENCY

COMFORT

- UNPRESSURIZED

COMFORTABLE (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 HELMENT 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

APOLLO BLOCK I SPACE SUIT ASSEMBLY PERFORMANCE DESIGN REQUIREMENTS (CONT)

SUIT ASSEMBLY LIFE (CONT)

- HELMET AND WRIST BEARING-DIS CONNECTS
CAPABLE OF BEING CONNECTED AND DISCONNECTED FOR 500 CYCLES WITH THE BEARING PORTIONS CAPABLE OF 5,000 CYCLES OF ROTATION THROUGH 180° WITHOUT FAILURE
- VENTILATION INLET, OUTLET, AND BLOOD PRESSURE FITTINGS
CAPABLE OF BEING CONNECTED AND DISCONNECTED FOR 500 CYCLES WITHOUT FAILURE
- INFLIGHT DRINKING PORT
CAPABLE OF 500 PROBE INSERTIONS AT 3.5 PSIG SUIT PRESSURE WITHOUT FAILURE
- ENTRANCE PRESSURE SEALING CLOSURE
CAPABLE 500 OPENINGS AND CLOSURES WITHOUT FAILURE
- FINGERTIP GLOVE LIGHTING
PROVIDE .325 CANDLEPOWER, THRU RED TINTED LENSES, TO PRODUCE 1.3 MILLILAMBERTS AND ILLUMINATES A 2 INCH RADIUS AT A DISTANCE OF 6 FEET

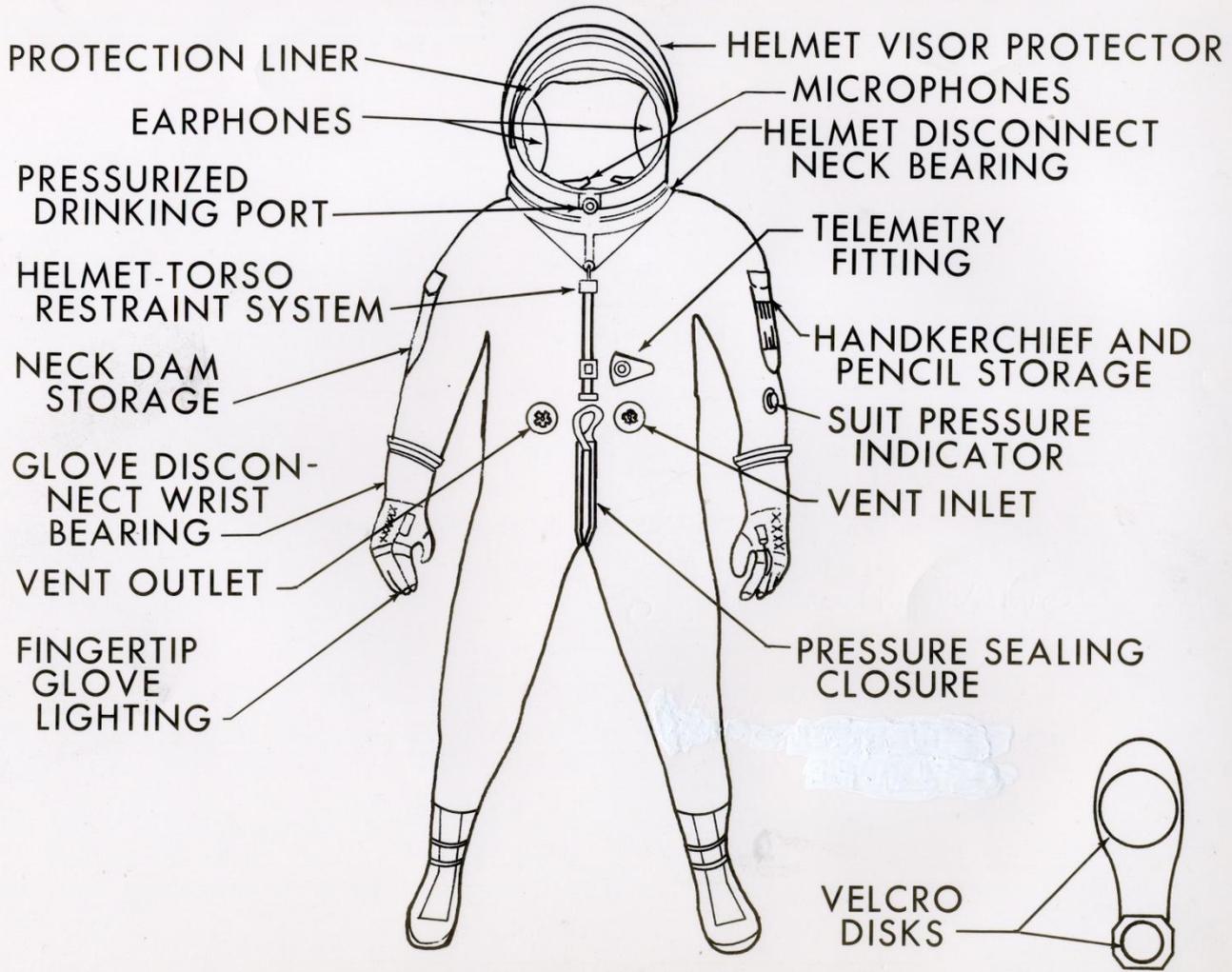
MODIFICATIONS TO GEMINI G-3C SUIT REQUIRED FOR APOLLO C/M INTERFACE

1. VENTILATION GAS CONNECTORS AND HOSE NOZZLES
2. SHROUD CUTTER POCKET (DELETED)
3. RESTRAINT LAYER H+-1
4. GLOVE ASSEMBLY
5. FINGERTIP LIGHTING SYSTEM
6. BOOT ASSEMBLY (VELCRO DISKS ON BOTTOM TO BE ADDED)
7. UNDERGARMENT ASSEMBLY (TO BE COMPATABLE WITH APOLLO BIO-INSTRUMENTATION)
8. VISOR PROTECTOR ON HELMET
9. PRESSURE RELIEF VALVE - TO BE DELETED, EXCEPT FOR CHAMBER SUITS WHICH WILL HAVE ONLY ONE PRESSURE RELIEF VALVE
10. WRIST BEARING DISCONNECTS - G-4C WRIST DISCONNECTS TO BE EMPLOYED IN APOLLO BLOCK I SUIT
11. NECK DISCONNECTS - G-4C NECK DISCONNECTS TO BE EMPLOYED IN APOLLO BLOCK I SUIT

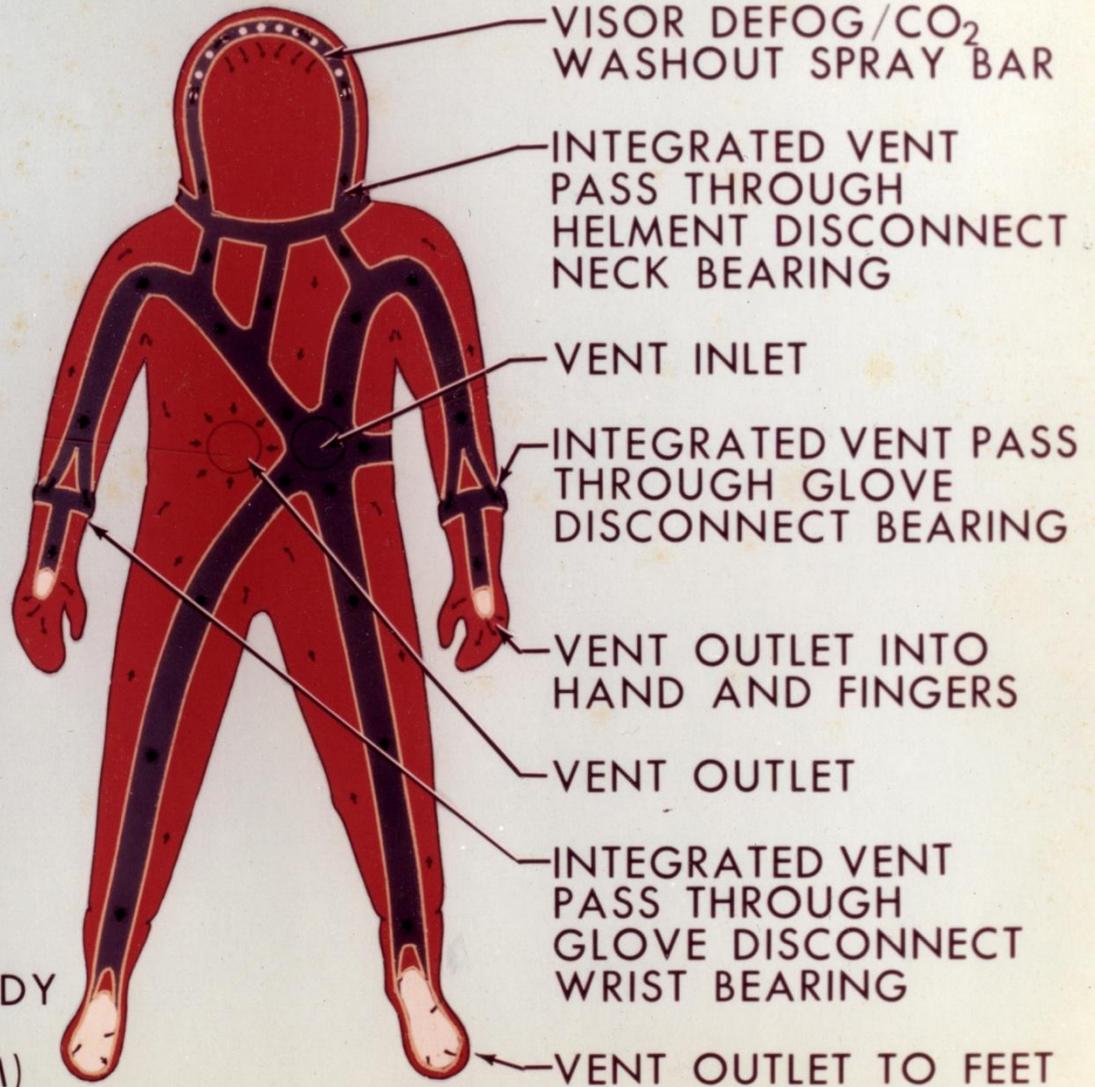
APOLLO BLOCK I CHANGES RESULTING FROM GEMINI G-4C DEVELOPMENT PROGRAM

1. MOBILITY IMPROVEMENT OF SHOULDERS, ARMS,
KNEES, AND WAIST
2. REDESIGN VENTILATION INLET AND OUTLET FITTINGS
TO INCORPORATE AUTOMATIC LOCKING FEATURE
3. REDESIGN GLOVES TO INCORPORATE
 - A MOBILITY IMPROVEMENT
 - B INCORPORATE VENTILATION PROVISIONS
 - C IMPROVE ABRASION, TEAR, PUNCTURE, ETC
STRENGTHS
4. WRIST BEARING DISCONNECT
5. NECK BEARING DISCONNECT
6. RESTRAINT LAYER-HT-1

APOLLO BLOCK I FLIGHT SPACE SUIT

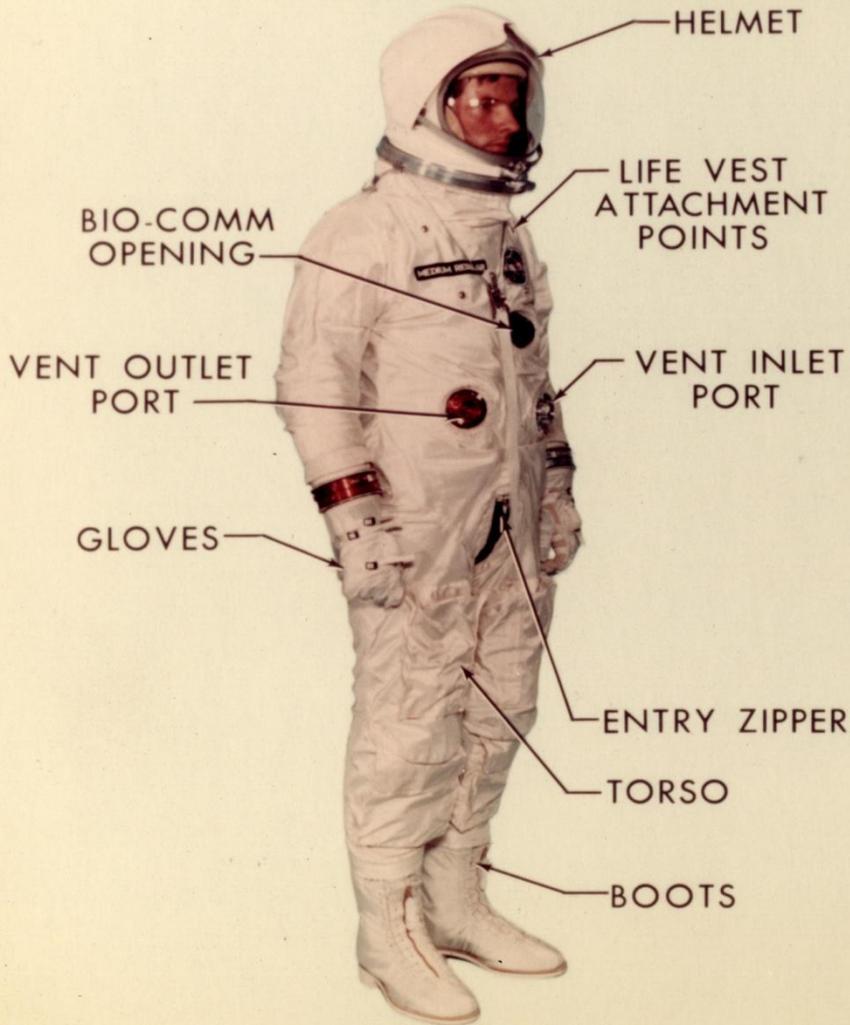


APOLLO BLOCK I
SPACE SUIT
ASSEMBLY
VENTILATION
DISTRIBUTION
SYSTEM



APOLLO BLOCK I A-IC SPACE SUIT

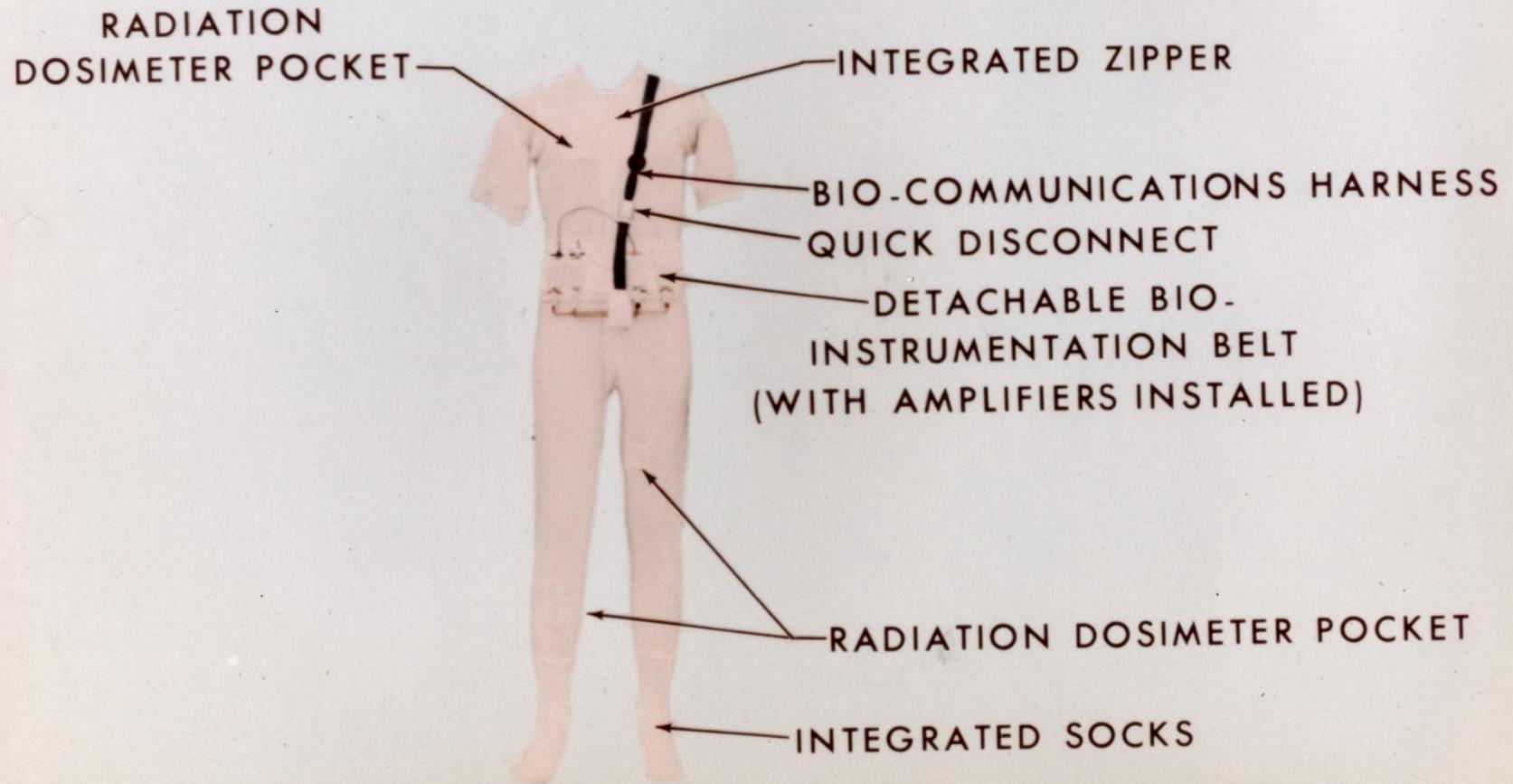
OVERALL VIEW



CUTAWAY VIEW



APOLLO BLOCK I CONSTANT WEAR GARMENT WITH BIO-INSTRUMENTATION AND ELECTRICAL HARNESS INSTALLED



SPACE SUIT INSTALLED ACCESSORIES



PENCIL
DOSIMETER



PEN LIGHT



SUNGLASSES



SCISSORS



WATER INGRESS
NECK SEAL



FLIGHT CHECKLIST
AND DATA BOOKS



URINE COLLECTION DEVICE



LIFE VEST ASSEMBLY



MARKING PENS



MECHANICAL
PENCILS



RADIATION DOSIMETER

APOLLO BLOCK I SPACESUIT



Water Ingress Ready



Vent Pressure



3.75 psig

BLOCK II SPACESUIT COMPETITION CHRONOLOGY

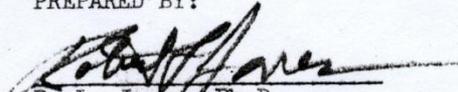
- **January, 1965**—MSC negotiated backup Block II spacesuit development program with DCC, paralleling the HSD spacesuit program:
 - Criteria for selecting spacesuit for ultimate Block II development would be from the EMU and performance specification.
 - MSC to conduct selection test program using CM mockup, lunar simulation facility, and LEM mockup.
- **June, 1965**—MSC conducted comprehensive test program:
 - Evaluation of suit design, function, operation, and man/suit interfaces
 - Test conditions controlled to present identical test situations to each suit
 - Basic evaluation rational emphasized mission requirements
 - Test procedures structured to maximize objectivity
 - Sixty-five separate evaluation situations conducted and scored
 - Astronaut Mike Collins was primary test subject, and an experienced CSD suit subject served as second test subject
 - Each test conductor and test subject scored each test and sublevel test results using pre-established weighting factors
 - Weighting factors were established by a committee representing responsible MSC branch managers and suit engineers, astronaut Mike Collins, and overall test program manager.

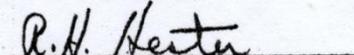
APOLLO BLOCK II SPACESUITS COMPETITION TEST PLAN

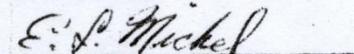
THE EVALUATION AND COMPARISON OF THREE PROTOTYPE APOLLO SPACE SUIT ASSEMBLIES

CPS-65-14

PREPARED BY:


R. L. Jones, Ph.D.
Test Conductor

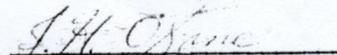

R. H. Hester

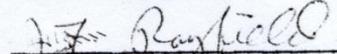

E. L. Michel


G. M. Burnett

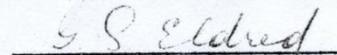

J. B. Slight

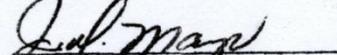

W. D. Salyer


J. H. O'Kane


V. F. Rayfield

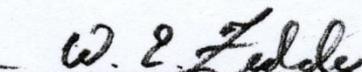

D. E. Kirkpatrick


G. A. Eldred


J. D. Mays

APPROVED BY:


W. E. Fadderson, Ph.D.
Head, Crew Performance Sec.


L. F. Dietrich, M.D.
Chief, Space Medicine Br.

jmcarron

APOLLO BLOCK II SPACESUITS COMPETITION TEST PLAN

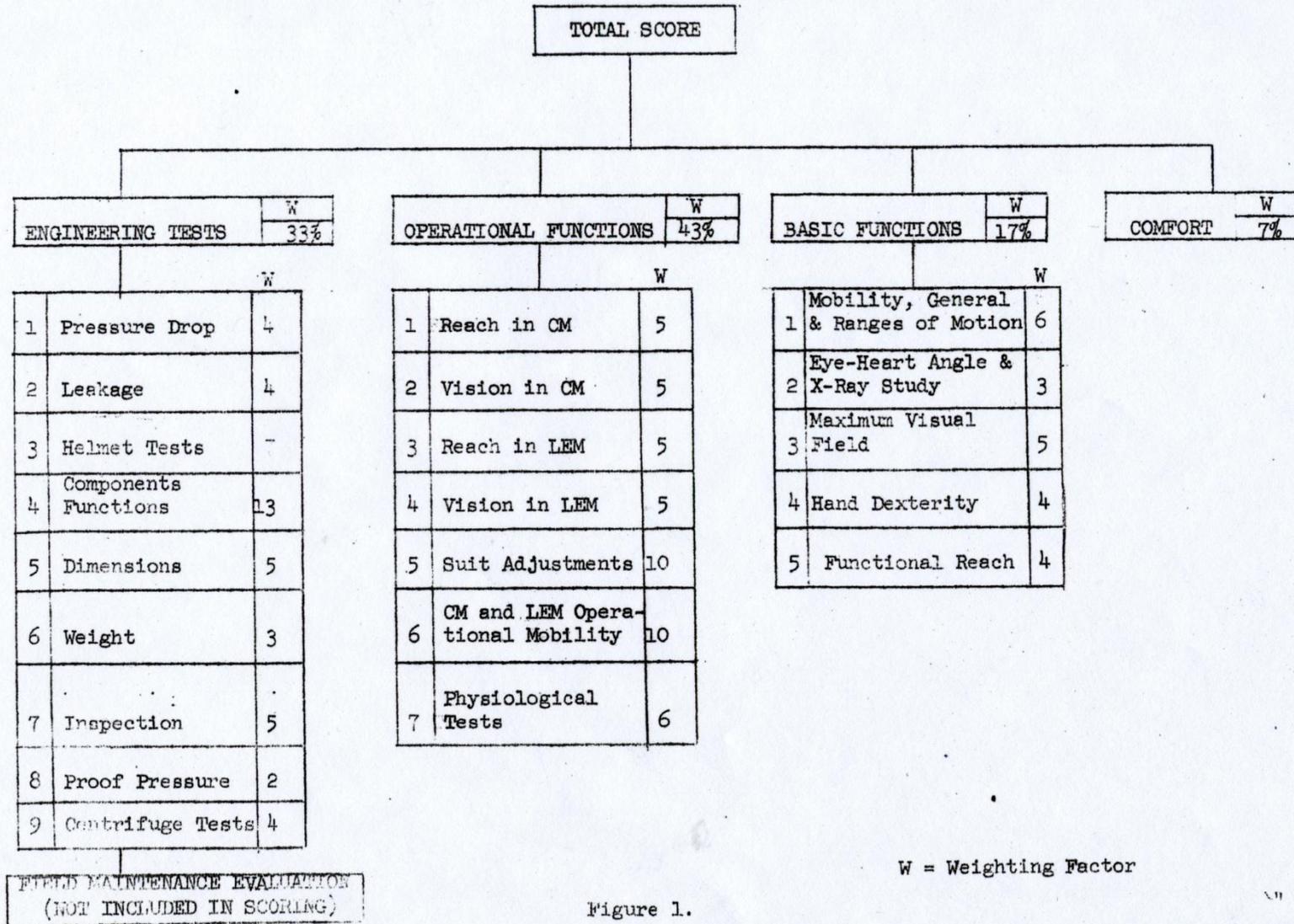


Figure 1.

NASA BLOCK II SPACESUIT COMPETITION TEST PLAN

(54)

Suit Comparison Test

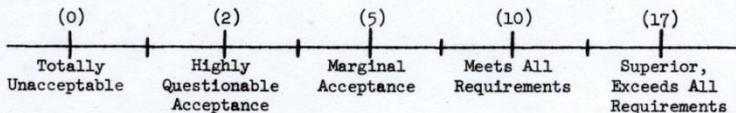
RATING FORM

Rater: _____ Suit: _____

Test: _____ Date: _____ Time: _____

Sub-Test Director: _____

1. Rate the overall performance of the suit on the following scale (circle one point along the scale):



2. If there are several items involved, give each item a rating (circle one point along the scale, using the above scale as a guide):

| <u>TEST ITEM</u> | <u>RATING</u> |
|------------------|-----------------------|
| _____ | (0) (2) (5) (10) (17) |
| _____ | (0) (2) (5) (10) (17) |
| _____ | (0) (2) (5) (10) (17) |
| _____ | (0) (2) (5) (10) (17) |
| _____ | (0) (2) (5) (10) (17) |
| _____ | (0) (2) (5) (10) (17) |
| _____ | (0) (2) (5) (10) (17) |

3. COMMENTS: (Put comments on back of this sheet)

(55)

Suit Comparison Test

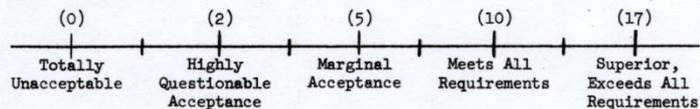
COMFORT RATING

Subject (Rater): _____ Suit: _____

Test: _____ Date: _____

Time: From _____ To _____ Sub-Test Director: _____

- Rate the comfort of the suit for this test on the following items, using this scale:



Circle one point along the scale, using the above guide:

1. Overall Comfort:
 - a. Vent Condition: (0) (2) (5) (10) (17)
 - b. Pressurized: (0) (2) (5) (10) (17)
2. Thermal Comfort:
 - a. Vent Condition: (0) (2) (5) (10) (17)
 - b. Pressurized: (0) (2) (5) (10) (17)
3. Pressure Points:
 - a. Vent Condition: (0) (2) (5) (10) (17)
 - b. Pressurized: (0) (2) (5) (10) (17)
4. Skin Irritation (Abrasions, Rubbing, Pinching):
 - a. Vent Condition: (0) (2) (5) (10) (17)
 - b. Pressurized: (0) (2) (5) (10) (17)

COMMENTS: Describe any problems on the back of this sheet.

APOLLO BLOCK II COMPETITION TEST ARTICLES

- **AX-1C-1 DCC Prototype Spacesuit:**
 - Apollo Block II model developed under NASA contract with DCC
 - Developed from Project Gemini and Apollo Block I spacesuit configurations
 - Design used front single-fold gusset top entry/closure
 - Incorporated multiple composite gas connectors and a water connector developed and provided by Hamilton Standard Division (HSD)
 - ILC-type gloves were provided by HSD
 - Helmet was developed by NASA MSC personnel



APOLLO BLOCK II COMPETITION SPACESUITS

- **AX-6H-037 HSD Prototype Spacesuit:**
 - Sixth prototype model developed under NASA Apollo spacesuit contracts with HSD
 - Suit subcontractor was changed after fifth prototype model from ILC to B. F. Goodrich (BFG) because of contracts performance issues
 - Design incorporated front single-fold gusset top entry/closure
 - Incorporated multiple composite gas connectors and a water connector
 - Helmet was developed and fabricated by HSD
 - ILC-type gloves incorporated
 - Remainder of suit jointly fabricated by HSD and BFG at HSD



APOLLO BLOCK II COMPETITION SPACESUITS

- **AX-5L ILC Prototype Spacesuit**
 - Prototype model developed in-house by ILC and included in the suit competition by ILC request
 - Developed from design concepts used in prior spacesuit development programs
 - Incorporated rear entry Project Gemini-type pressure sealing closure
 - Incorporated Project Gemini-type gas connectors
 - Used sliding cable shoulder/arm and hip/leg mobility systems
 - Incorporated ILC-developed gloves
 - NASA MSC developed, fabricated, and provided helmet



APOLLO BLOCK II SPACESUITS COMPETITION



DCC AX-1C-1



HSD/BFG AX-6H-037

jmcbarron



ILC AX-5L

APOLO BLOCK II SPACESUIT COMPETITION RESULTS

PLACEMENT TABULATION

| | Firsts | Seconds | Thirds |
|-----|--------|---------|--------|
| HSD | 2 | 11 | 9 |
| DC | 8 | 6 | 8 |
| ILC | 12 | 5 | 4 |

The final scores demonstrated the magnitude of the differences among the suits (ILC = 321.4; DC = 290.7; HSD = 270.9) and the ILC suit scored significantly higher than the DC and HSD suits. This is also quite evident in the tabulation of placements on tests. Consequently, the ILC suit was first in the evaluation, the DC suit was second, and the HSD suit last.

APOLLO BLOCK II SPACESUIT COMPETITION RESULTS

172

TABLE 1. APOLLO SUIT EVALUATION PROGRAM: RESULTS SUMMARY

*Not included in final scoring
**Scored as 0 for computation

| Test | DC Suit | | HSD Suit | | ILC Suit | |
|---------------------------------|---------|--------|----------|--------|----------|--------|
| | Place | Rating | Place | Rating | Place | Rating |
| Reach in the CM | 3 | 9 | 2 | 9.5 | 1 | 11 |
| Vision in the CM | 2 | 9 | 3 | 8 | 1 | 11 |
| Reach in the LEM | 3 | 9 | 2 | 10 | 1 | 12.5 |
| Vision in the LEM | 1 | 12 | 3 | 9 | 2 | 11 |
| Suit Adjustments | 3 | 4.9 | 2 | 5.8 | 1 | 6.8 |
| Operational Mobility (LEM & CM) | 3 | 5.9 | 2 | 6.0 | 1 | 10.7 |
| Physiological Tests | 2 | 7 | 3 | 2 | 1 | 8 |
| Pressure Drop | 3 | 0 | 1 | 7 | 2 | 2 |
| Leakage | 1 | 11 | 3 | 0 | 2 | 2 |
| Helmet Tests | 1 | 10.4 | 2 | 9.6 | 3 | 6.1 |
| Component Functions | 1 | 6.5 | 2 | 6.4 | 3 | 5.3 |
| Dimensions | 2 | 9.1 | 3 | 7.9 | 1 | 9.7 |
| Weight | 1 | 10.9 | 2 | 8.8 | 3 | 8.3 |
| Pre-Inspection | 2 | 8.9 | 3 | 7.9 | 1 | 9.1 |
| Post-Inspection* | 2 | | 3 | | 1 | |
| Proof Pressure | 1 | 9.2 | 3 | 7.1 | 2 | 7.9 |
| Centrifuge | 1 | 12.7 | 2 | 7.1 | NA** | NA** |
| General Mobility | 2 | 5.9 | 3 | 4.5 | 1 | 8.2 |
| X-Ray Study | 3 | 1.7 | 1 | 8.3 | 2 | 4.3 |
| Maximum Vision | 2 | 12.4 | 3 | 10 | 1 | 12.8 |
| Hand Dexterity | 3 | 5 | 2 | 9 | 1 | 13 |
| Functional Reach | 3 | 6 | 2 | 7 | 1 | 9 |
| Comfort | 1 | 11 | 2 | 6.9 | 3 | 5.7 |
| Field Maintenance * | 2.5 | 7 | 2.5 | 7 | 1 | 10 |
| Total Score | 290.72 | | 270.85 | | 321.38 | |

APOLLO BLOCK II SPACESUIT PROGRAM MODIFICATION

- **September, 1965**—Robert R. Gilruth, MSC director, sent details of actions taken regarding development of the Apollo EMU to NASA Hdqrs. He recommended three changes inconsistent with the overall procurement plan previously approved by NASA Hdqrs:
 1. Amend the existing HSD contract to provide for development, qualification, and fabrication of the Portable Life Support System (PLSS) and associated equipment only. Contract would cover delivery of all flight equipment for the Apollo Block II flight program.
 2. Award a separate contract to ILC for development and fabrication of test and flight spacesuits and associated equipment.
 3. MSC would assume responsibility for total program management, systems integration, and spacesuit qualification.

APOLLO BLOCK II SPACESUIT PROGRAM MODIFICATION

- **September, 1965 (cont)**—Basis for MSC director's recommendations to NASA Hdqrs:
 - Comparative suit evaluation of spacesuits submitted by ILC, HSD, and DCC in June, 1965.
 - Reassessment of ILC's capabilities and the previous difficulties of HSD inadequate total system development, but recognizing their competence in the PLSS work.
 - MSC plan to establish resident engineer at ILC to provide onsite contractor management.
- **November, 1965**—NASA announced that it would negotiate with ILC for a contract to fabricate the Apollo (Block II) spacesuit consisting of the liquid-cooled undergarment, constant wear garment, pressure garment assembly, and thermo-micrometeoroid protective over garment. At the same time, a contract was negotiated with HSD for continued development and manufacture of the PLSS.

LESSONS LEARNED

- Establish and document joint spacecraft module and spacesuit contractor physical and functional interface control documents early in the development process.
- Before module and government furnished equipment (GFE) hardware designs are finalized, provide a module ship set of development model GFE hardware to verify adequacy of the interface design.
- Consider use of the CPS-65-14 test plan procedures and process as an analysis tool for future competitive evaluations and management decision making.

Next Proposed Knowledge Capture Series Briefing

Apollo A-7L Block II Spacesuit Development

for

Apollo 7 Through 14 Missions”

REFERENCES

- "Apollo Monthly Progress Report," SID 62-300-22, pp. 1-2.
- Project Apollo Board Report for NASA Inspection and Review of Block I Mock-Up, April 23-30, 1964," pp. 1-2;
- MSC, "ASPO Weekly Management Report, June 25-July 2, 1964."
- *Rector to Grumman, Attn.: Mullaney, "Stowage volume requirements for Lunar Excursion Module," 27 Nov. 1964; MSC, Consolidated Activity Report, 19 July-22 Aug. 1964, p. 21*
- Memorandum, H. F. Battaglia, MSC, to Chief, MSC Crew Systems Div., "Trip report for visit to David Clark Company, Worcester, Massachusetts concerning Space Suit Program," July 16, 1964.
- Memorandum, Robert E. Smylie, MSC, to Chief, Program Control Division, "Apollo Spacecraft Program Quarterly Status Report No. 10," January 19, 1965, and enclosures.
- Memorandum, Maxime A. Faget, MSC, to Distr., "Change in Designation of the Apollo Space Suit Assembly (SSA)," November 5, 1964.
- Memorandum, William A. Lee, MSC, to Assistant Director for Flight Crew Operations, "Spacesuit Utilization on Block I CSM Earth Orbital Missions," January 6, 1965.
- "Apollo CSM-Block II Preliminary Design Review (PDR), NASA- MSC-ASPO, NAA-S&ID, 6-8 January 1965," pp. 4-40. "Apollo CSM-Block II Preliminary Design Review (PDR), NASA- MSC-ASPO, NAA-S&ID, 6-8 January 1965," pp. 4-40.
- Memorandum, Owen E. Maynard, MSC, to Manager, Apollo Spacecraft Program Office, "Evaluation of space suit wear criteria," January 6, 1965.

REFERENCES (cont)

- "ASPO Weekly Management Report," February 11-18, 1965.
- Memorandum, Matthew I. Radnofsky, MSC, to Gemini and Flight Support Procurement, Attn: Arc F. Lee, "Contract NAS 9-3642, Apollo Block I Suit, David Clark Company," February 25, 1965. MSC, "ASPO Weekly Management Report," November 4-12, 1965.
- Memorandum, Richard S. Johnston, MSC, to Joseph Shea, "Block II Apollo suit program," January 25, 1965.
- Memorandum, Maxime A. Faget, MSC, to Manager, ASPO, "Crew Systems Division recommendation on establishment of suit wear criterion," March 17, 1965.
- "Apollo Block I spacesuit" photographs and documents images, from author's personal records.
- "Evaluation and comparison of three Apollo Spacesuits," Report CPS-65-14, 1965, from author's personal records.
- Letter, Gilruth to NASA Headquarters, Attn: George E. Mueller, "Procurement plan for the Apollo Extravehicular Mobility Unit and EMU ground support equipment development and fabrication," sgd. George M. Low, September 20, 1965.
- NASA News Release 65-346, "NASA to Negotiate for Apollo Suit, Support System," November 5, 1965; "ASPO Weekly Management Report, November 4-12, 1965."
- "Early Spacesuit Dates" personal communication from Jerry Goodman to author, January, 2013.