

ICES HISTORY PANEL

A photograph of an astronaut on the moon. The astronaut is wearing a white space suit and is standing on the lunar surface. To the right of the astronaut is a large American flag on a pole. Further to the right is the lunar module, which is a complex structure with various instruments and equipment. The background shows the dark, cratered surface of the moon under a black sky.

SPACE SUIT DEVELOPMENT

Mercury – Gemini – Apollo

James McBarron II
July 9, 2007

SPACE SUIT DEVELOPMENT

AGENDA

LITTLE KNOWN DETAILS ABOUT

- SPACE SUIT & CONTRACTOR SELECTION**
- SOME LESSONS LEARNED**

SPACE SUIT SELECTION

PROJECT MERCURY

COMPETITIVE SUITS DOD TESTING

- Conducted by USAF and USN
- Suit NASA selected - 1959
Modified XN20 Navy Mark IV Suit
B. F. Goodrich Co.
- Suits not selected
Modified MC2 USAF X-15 suit
David Clark Co.
SPD-117 Prototype suit
International Latex Co.



SPACE SUIT SELECTION

PROJECT GEMINI

COMPETITIVE SUITS NASA TESTING

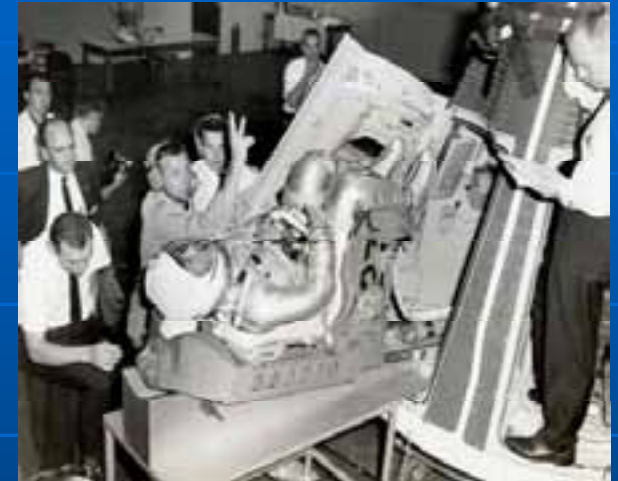
- Astronaut Gus Grissom evaluation

- Suit selected - 1962

Rear Entry GX-1C Suit
David Clark Co.

- Suits not selected

Partial Wear GX-1A Suit
Arrowhead Products Co.
Rear Entry GX-1G suit
B. F. Goodrich Co.



SPACE SUIT SELECTION

APOLLO PROGRAM

COMPETITIVE NASA CONTRACT SOURCE PROCUREMENT

- **Selected in 1962**

 - Hamilton Standard Corp. – Prime Contractor for PLSS and Suit

 - * International Latex Co. – Subcontractor for Suit

- **Not Selected**

 - David Clark Co. - Hamilton Standard Suit Subcontractor

 - Litton Systems Division of Bendix Corp.

 - General Electric & B. F. Goodrich Co.

 - Grumman Aircraft & AiResearch of Garrett Corp

 - * International Latex & Republic Aviation & Westinghouse Corp.

 - North American Aviation

 - Northrop Corporation's Space Laboratory

* NASA Directed Suit Subcontractor For Hamilton Standard Contract

SPACE SUIT SELECTION

NASA FOUND PROTOTYPE APOLLO SUITS INADEQUATE (1962-65)



SPD-143

AX-1L



AX-1H



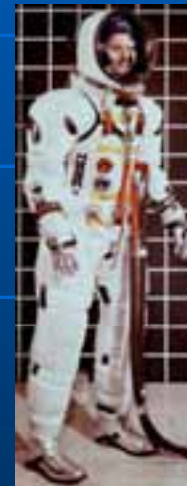
AX-2H



AX-3H



AX-3H R1



A-4H



AX-5H

SPACE SUIT SELECTION

APOLLO PROTOTYPE SUITS INADEQUACIES

- Unfavorable astronaut evaluation findings
- Wide shoulders interference with CSM Couches
- Joints and gloves mobility requirements not met
- Helmet
 - Downward visibility
 - Eye relief distance to G&N optics
- Separate covergarment
 - Difficult don/doffing
 - Mobility encumbrance
- Pressure loss and restraint failures during testing

SPACE SUIT SELECTION

APOLLO PROGRAM (Block I Missions)

- NASA SOLE SOURCE CONTRACTOR PROCUREMENT
- SELECTED IN 1964
Modified Gemini G-3C Suit
David Clark Co.
- CANCELLED AFTER APOLLO 1 FIRE



A-1C

SPACE SUIT SELECTION

APOLLO PROGRAM (Block II Missions)

NASA CONTRACTORS SUITS COMPETITION

- **SELECTED IN 1965**
 - **AX-5L Prototype Suit**
International Latex Corp.
- **SUITS NOT SELECTED:**
 - **AX-1C Prototype Suit**
David Clark Co.
 - **AX-6H Prototype Suit**
Hamilton Standard Corp.,
B.F. Goodrich Co., &
David Clark Co.



LESSONS LEARNED

PROJECT MERCURY

- **Helmet O2 outlet location caused eye's irritation & distracting noise**
- **Visor seal inflation bottle leakage**
- **Repetitive re-rolling of adhesive seams**
- **Flotation necessary for post landing**
 - **Added on-suit life preserver**
 - **Deployable neck dam**
 - **Automatic closure inlet gas connector**



LESSONS LEARNED

PROJECT GEMINI

- Gas cooling inadequate for EVA metabolic loads
 - Crewmember overheating
 - Helmet visor fogging
- Mobility of pressurized suit joints & gloves lacking
 - Contributed to high metabolic loads
 - Difficulty in donning foot restraints
- Anti-fog solution effectiveness lost over time
 - Apply just before EVA



LESSONS LEARNED

APOLLO PROGRAM (Block II Missions)

- **Bladder & molded components abrasion reinforcement added for J-Missions increased EVA'S duration**
 - Three 7 hour lunar surface EVA's capability
- **Limited don/doff cycle life of pressure sealing closure**
 - Frequent replacements of A7L pressure closure
 - X ray inspection of A-7LB pressure closure
- **Limited flex cycle life of restraint cables at swage fittings**
 - Numerous redesigns due to test failures

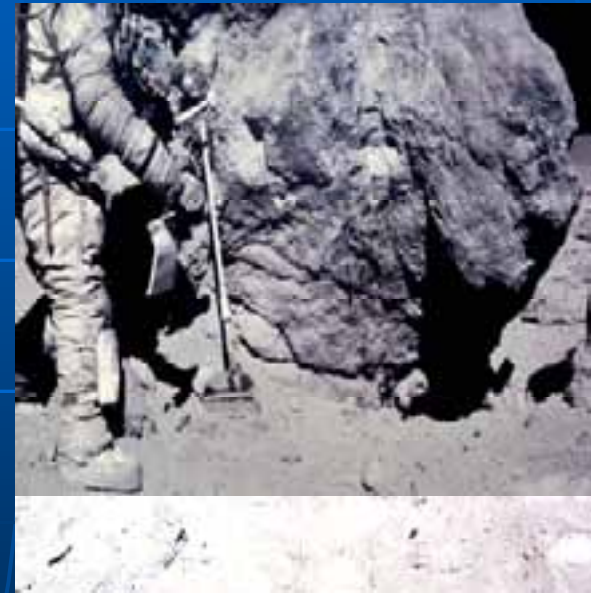


A-7LB

LESSONS LEARNED

APOLLO PROGRAM (Block II Missions)

- Lock-Locks at all pressure integrity connections
- Lunar dust particles contamination
 - Disconnects & connectors difficult to actuate
 - RCU readout lens visually obscured
 - Suit surfaces
 - Lunar Module cabin surfaces & atmosphere
- Materials age life limited reuse of suits & components
 - 4 year materials age life of bladder & molded components



LESSONS LEARNED

APOLLO PROGRAM (Block II Missions)

- **Dipping compound rubber susceptible to reversion to natural state with loss of physical properties**
 - Copper containment caused reversion in convolutes & boot bladders
 - **Replacement of dipped components in Apollo 14-15 flight suits**
 - Anti-oxidant added to rubber compound for Apollo 16-17
- **Significance of crewmember induced loads identified**
 - Redundant axial load restraints added to Apollo 15-17 suit legs

SPACE SUIT DEVELOPMENT

CONCLUSION

- Suit and contractor selection for early NASA Projects was based upon competitive evaluation of prototype suits.
- Lessons learned during early suit developments need to be evaluated for application to future NASA suit programs.
- Lessons learned during current Shuttle Extravehicular Mobility Unit program should also be identified and included in this evaluation.

SPACE SUIT DEVELOPMENT

TO BE CONTINUED

- Shuttle EMU Contractor Selection
- Lessons Learned

1977 - ???

- Constellation Suit & Contractor Selection
- Lessons Learned

200? - ???

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**
 - G-1, G-2, G-3, G-4
- **Letter following number denotes manufacturer**
 - A = Arrowhead Products
 - G = B. F. Goodrich Co.
 - C = David Clark Co.
 - I = International Latex Co.
- **Examples**
 - G-3C = Gemini IV Flight Suit mfg. by David Clark Co.
 - AX-1L = Apollo Prototype Suit mfg. by International Latex Co.

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