Suited For Space

Joe Kosmo
Johnson Space Center

Hollywood Sci-Fi Space Suits 1950 - 1960

Speaking to Congress and the Nation, President Kennedy said on May 25, 1961:

" I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the Moon and returning him safely to Earth. No single space project in this period will be more impressive to mankind, or more important in the long-range exploration of space; and none will be so difficult or expensive to accomplish."

Why Do You Need A Space Suit?

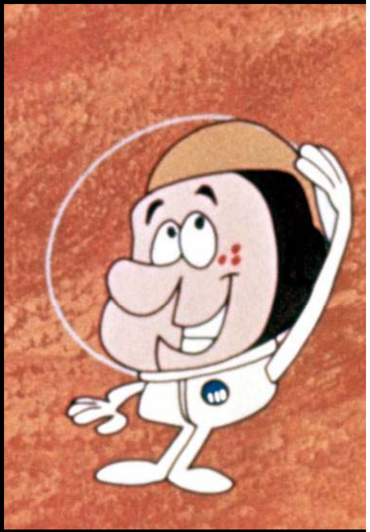
Space Suits Provide 3 Basic Functions For EVA Astronauts:

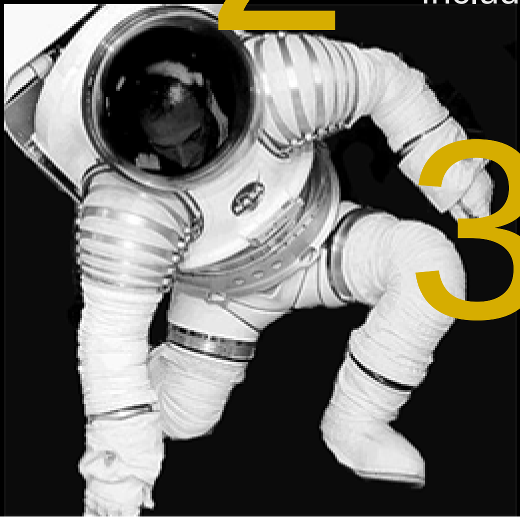
1 **First, in conjunction with a portable life support system, the space suit maintains the physiological well-being of the astronaut**

- Supplying oxygen for pressurization, breathing, and ventilation
- Provide carbon dioxide and metabolic heat removal

2 **Secondly, the space suit incorporates various mobility joint systems to enable the astronaut to perform EVA tasks in the pressurized condition**

- Includes both dual-axis and single axis joints and bearings





3 **Finally, the space suit provides protection against the hazards of the particular EVA environment**

- Thermal extremes
- Meteoroid and orbital debris
- Radiation conditions
- Abrasion and sharp edges
- Sand, dust, and rocks

In essence, the space suit is a small spacecraft in itself

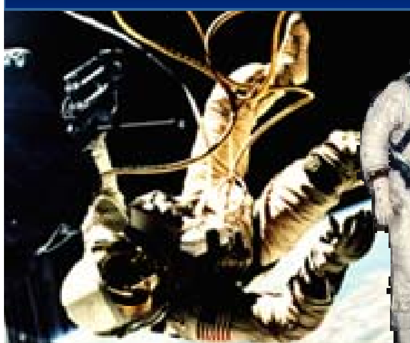
- PAST -

Mercury Program:

- Space suit derived from Navy MK IV High-Altitude aircraft suit:
  - Provided only “loss of cabin” protection

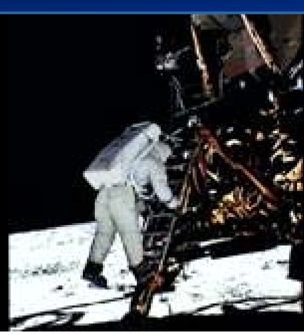
    “GET ME DOWN CAPABILITY”!

Gemini Program:



- Space suit derived from USAF AP/22 High Altitude aircraft suit:
- Protection similar to Mercury suit
- 1st USA use of a true “space suit” in the vacuum of space
  - Gemini IV; Ed White – June 3, 1965

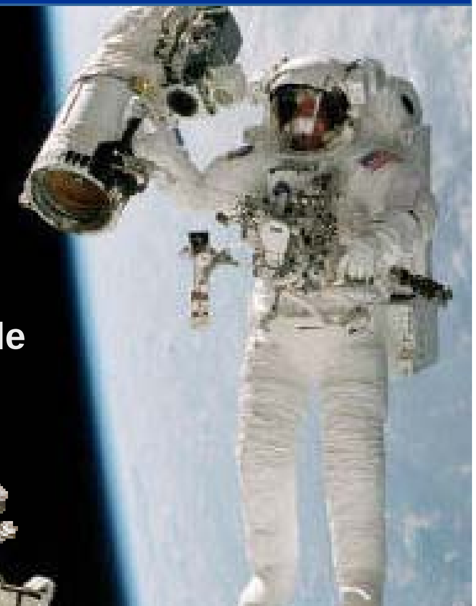
Apollo Program:

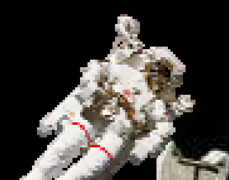


- Space suit (A7L & A7LB Configurations)
  - Designed to support and perform both intravehicular (survival) operations and extravehicular lunar surface (mobility) operations

- PRESENT -

Space Shuttle Program:

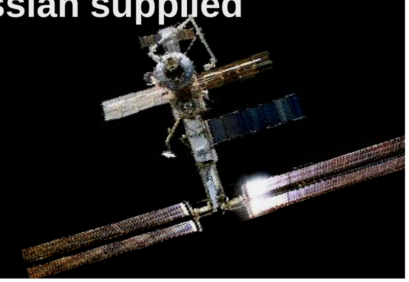




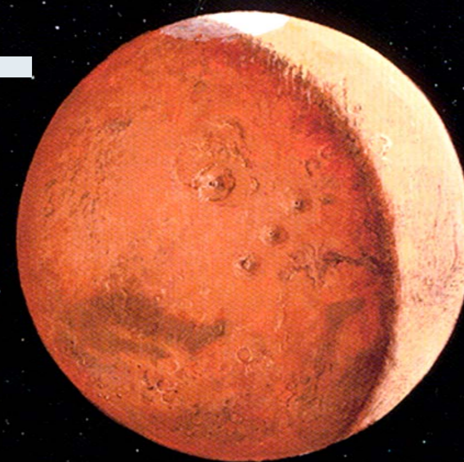
- **First truly designed "EVA Space Suit"**
  - Design emphasis on space operations external to spacecraft
  - No requirement for intravehicular cabin operations
- **Enabled maximum use of mobility joint systems for free-space, pressurized, space suit performance capabilities**
- **Incorporates modular-element suit design to fit wide range of male and female astronaut sizes**
- **Designed for multi-use long-service life**
  - 25-EVA Operations
  - Apollo space suit designed for limited use (3-EVA operations)

International Space Station Program (ISS):

- **Advanced space suit development cancelled due to lack of funding**
- **Currently utilizes both enhanced Shuttle space suit and Russian supplied ORLAN-M space suit assemblies**



- FUTURE -

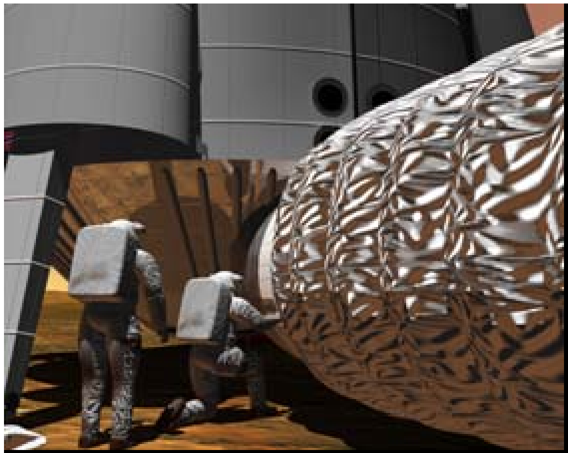


BACK TO THE MOON - - - -

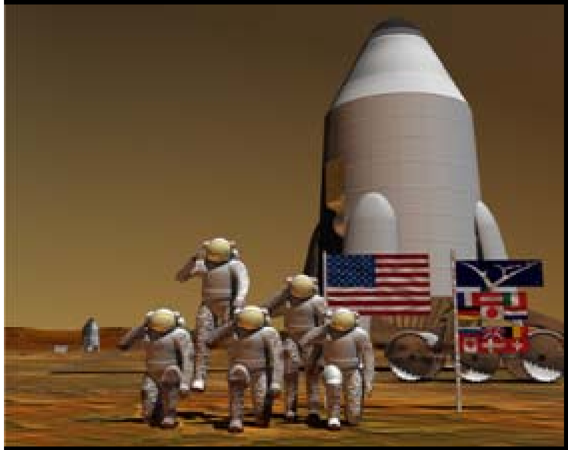
- - - - - - - and ON TO MARS !

January 14, 2004, President George W. Bush announced

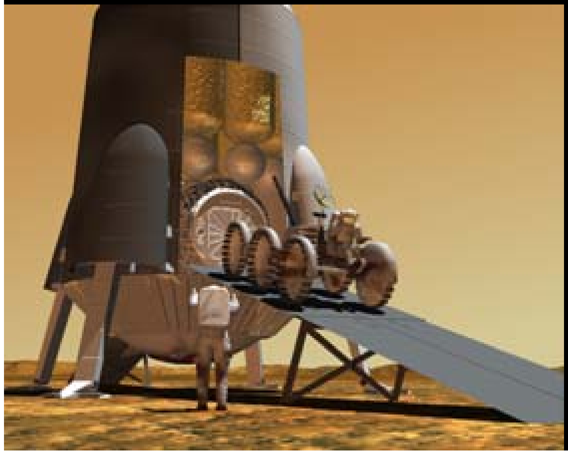
"A Renewed Spirit of Discovery: The President's Vision for U.S. Space Exploration"

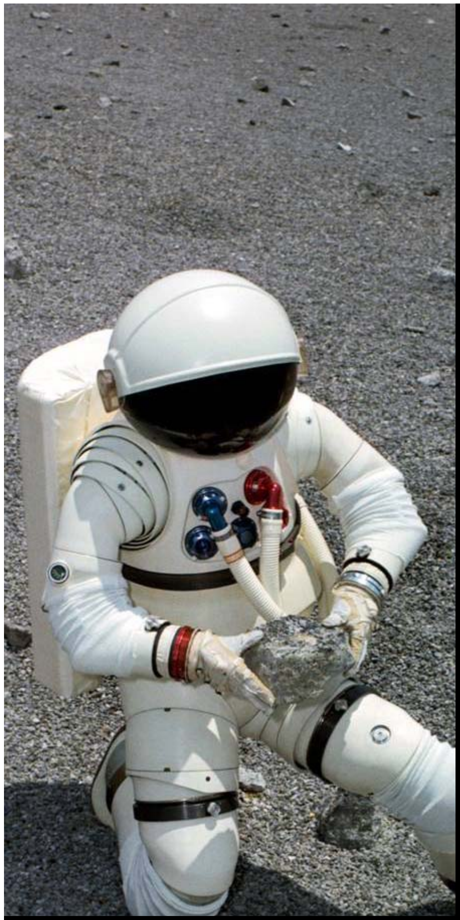


Next-Generation EVA Operations Require:



- EVA's MUST be Routine, Weekly Activities
- EVA Hardware MUST Minimize Mission Time Overhead
- EVA Hardware MUST be Rugged and Lightweight
- EVA Hardware MUST be Easy to Use
- EVA Hardware MUST be Un-encumbering
- EVA Hardware MUST be Serviceable In-place
- EVA Hardware MUST be Repairable & Maintainable In-place
- EVA Life Support System MUST Limit Consumable Usage





Cardinal Elements Of A Planetary Surface Space Suit

Mobility:

- Required for negotiating rough terrain (EVA traverses)
- Required for EVA deployment, maintenance & repair tasks
- Mandatory for center-of-gravity control and walking
- Required for ingress/egress airlocks and rovers (seated position)
- Near shirtsleeve range with low force required to reduce fatigue

Robustness:

- Durability
  - High mission cycle life capability for multiple EVA’s (daily operations)
  - Abrasion/dust resistance
  - Impact/tear resistance
  - Incorporate long-term shelf-life/operational-life materials
- Wearability
  - Don/doff use (daily operations over long mission periods)
  - Handling capability (cleaning/storage)

Lightweight:

- Reduce crewmember fatigue (assisted by low Lunar & Mars gravity)
- Mass handling control (primarily “on-back” carry weight - - PLSS)
- Reduce mission launch cost impact

Simplicity:

- Reduce system element complexity (incorporate modularity)
- Ease of maintenance & repair

Generic EVA System Requirements

Space Suit

- Long-term durability and reliability
- Minimal mass and volume
- Anthropometric re-sizing capability
- Interface with vehicle and ancillary support elements (cooling garment, bio sensors, communications, PLSS)
- Appropriate pressure to eliminate “bends” risk and pre-breathe requirements
- Environmental hazards protection

PLSS

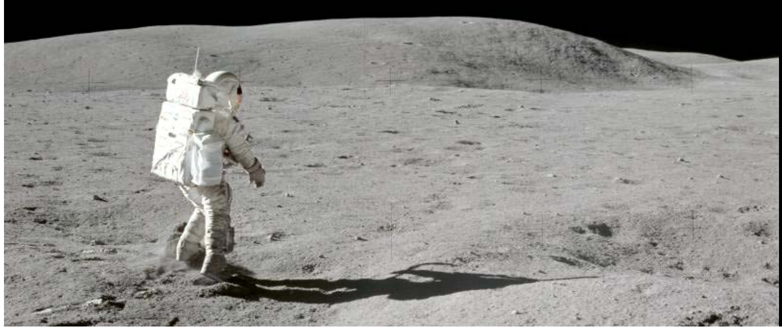
- High reliability and safety
- Minimal mass and volume
- Maintain normal range of (physiological) aspects during various activities (O_2, CO_2, ventilation rates, temperatures)
- Interface with suit
- Minimize expendables (H_2O, O_2, power)
- Protect components from fall and environmental hazards

Apollo Lunar Surface Cycling Certification

Scope:

- Conduct 24 hours of walking at a rate of 0.5 – 0.75 mph on simulated lunar surface while being supported by 1/6-G counterbalance simulator
- Testing was performed in 6-each, 4-hour "excursions"
  - Each "excursion" was followed by a suit leak check and visual inspection
  - 5 of the 24 hours spent on an inclined plane
    - varied from 5-degrees to 25-degrees at 5-degree increments with 1 hour at each setting
- During each "excursion", one lunar module ladder climb was performed
  - 20ft climb with 10-in rung spacing

Goal:

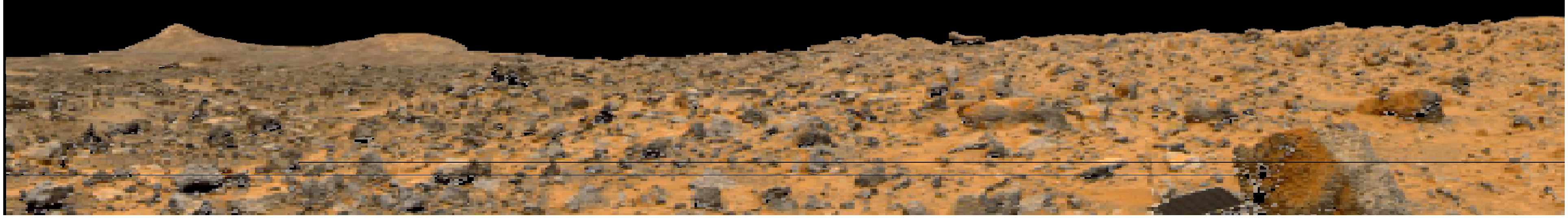


- For the Apollo space suit lunar EV excursion (including an emergency 115-hour return) an estimated 22,780 steps were required for design certification
- With a safety factor of 2; 45,560 steps were required for final mission certification

EVA Operating Cycles for Mars Surface Missions

Assumptions:

1) **Maximum surface stay – 18 months @ ~ 500 days on surface**
2) **Assume routine human EVA's over a 7-day period:**
   - **3 EVA's per week; one every other day allows 1-day rest in between each EVA**
3) **Resulting "Nominal EVA Operating Cycles":**
   - **500 divided by 7 = ~72 EVA weekly cycles X 3 EVA's/week = 216 EVA Operations to be conducted over planned surface stay period**
4) **For EVA system Certification Cycle Life (Suit & PLSS):**
   - **216 EVA Operations X 2 Factor = 432 EVA Operating Cycles**
5) **The 432 EVA Operating Cycles represents:**
   - **432 EVA Operating Cycles X 8-hour EVA events = 3456 hours of use per system**



Mars Surface EVA Mission Cycle Requirements

Assume 432 EVA Operating Cycles as goal for EVA system certification:

- 432 EVA Operating Cycles X 8-hour EVA events = 3456 hours of use
- Assume that Mars surface EVA operations will be supported by rovers (based on Apollo 15, 16 & 17 w/rovers)

"Off Rover" Suited Activities:

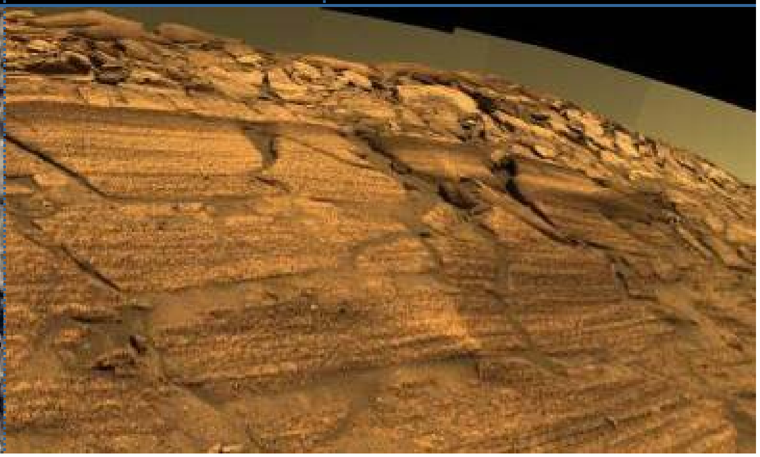
(80 % of EVA Timeline)

- Walking & general functional mobility tasks - (3456 X 80% = 2765 hours)
- Assume 1-each habitat ingress/egress per each 8-hour EVA:
  - Supported by either a ladder or ramp and each ingress/egress takes 1-minute
- Walking Cycle Requirement would be:
  - Assume speed of 0.75 mph (3960 feet/hr) & a 29-inch stride = 1639 steps/hour
  - Therefore, Walking Cycle Requirement = 1639 X 2765 = 4,531,835 steps

Based on 100% success and an 8-hour test day, this cycle test would take approximately 1 year to complete!

Robustness – Durability Requirements Comparison

	Apollo	Mars	Factor Difference
EVA Operations per Mission	3	216	72 x
EVA Hours Use Certification	24	3,456	144 x
Walking Cycle Requirements	45,560	4,531,835	~100 x



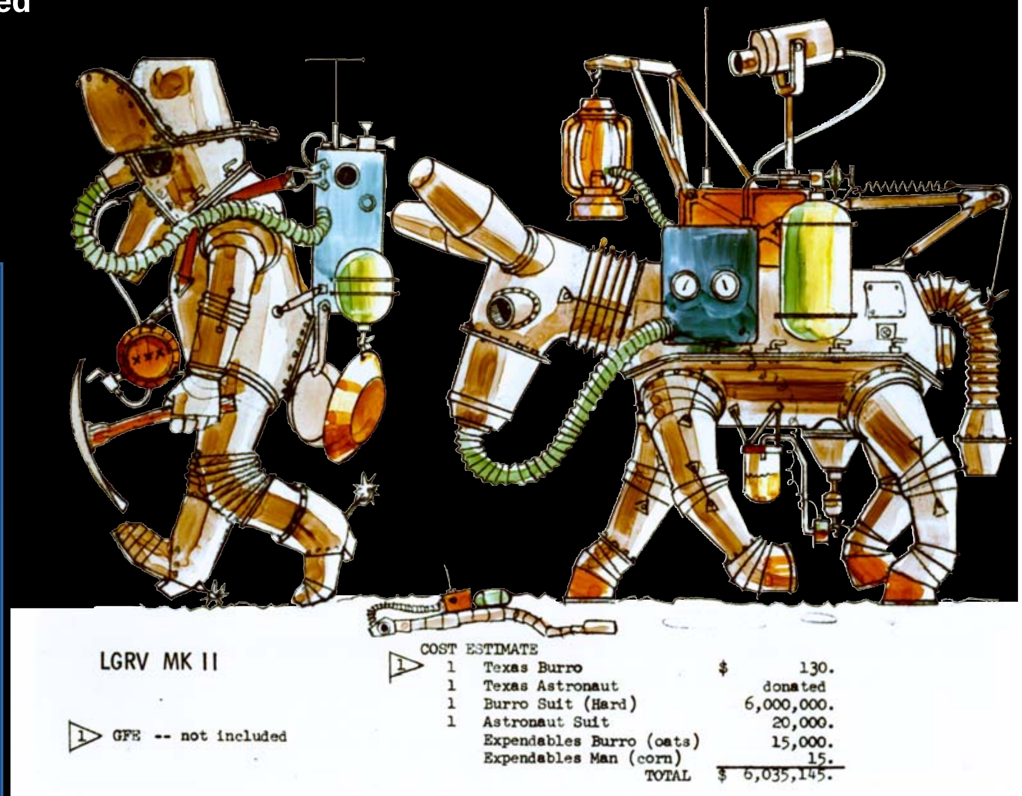
Carry-Weight Capabilities

Earth Based Requirements::

- **MILITARY:** On-back carry 1/3 of body mass
  - Assume 180 lb subject can carry 60 lb for extended periods of time (~8 hrs.)
- **OSHA:** Recommended lifting limit is 45 lb
  - No OSHA identification of "carry weight" limit as such; possibly assume 45 lb.

Comparative Space Suit + PLSS System Earth Weights

	APOLLO	SHUTTLE	ADV. EVA SYSTEM
Suit	60 LBS.	110 LBS.	80 LBS.
PLSS	140 LBS.	165 LBS.	110 LBS.
Combined	200 LBS.	275 LBS.	190 LBS.
Moon	32 lbs.	44 lbs.	30 lbs
Mars	74 lbs.	102 lbs.	70 lbs.



EVA Crewmember Skeletal & Muscular System Supports Basically A "Distributed Load"

- **NOT a "POINT Load" in the Reduced Gravity Environments:**

How weight is carried is as important as how *much* is carried:

- **Pressurized space suit (lower torso) supports majority of overall system weight**
- **Internal suit harness interface w/crewmember provides upper torso & PLSS weight & center-of-gravity (C.G.) control**
- **Actual weight "carried" by the crewmember is only a fraction of the total system weight**

EVA System Challenges
(Mars)

Environmental Issues:

- **Radiation**
  - Exposure time constraints and potential health risks
- **Temperature Extremes**
  - Mars day/night and seasonal variations
- **Pressure Conditions**
  - Mars ambient CO_2 environment (8mb. pressure)
- **Dust**
  - Potential affects to seals, visors and solar arrays
- **Gravity**
  - Mars 1/3 –G influences space suit mobility/weight
- **Wind**
  - Entrained dust damages hardware and obscures vision

Strategic Issues:

- **Existing NASA EVA**
  - Current capability/technology based on low Earth orbit
- **Operations**
  - Need to develop robust EVA surface suits
  - Need good surface model of Mars radiation levels
  - Need better understanding of chemical nature of Mars dust
- **Need to develop realistic planetary exploration experience base**

Human Planetary Surface Exploration Experience

Apollo 11 thru Apollo 17

When Last Accomplished: 34 Years Ago!

Total number of 2-man EVAs	**14**
Total Duration of EVAs	**81 hrs (3.4 days)**
Average EVA duration	**6 hrs**
Total EVA traverse distance	**59.6 miles**
Shortest EVA distance	**.16 miles Apollo 11**
Longest EVA distance	**21.9 miles Apollo 17**

Apollo Mission	11	12	14	15	16	17
Number of EVAs conducted	1	2	2	3	3	3
Duration of EVAs (hrs.) per crewmember	2.8	7.8	9.4	18.6	20.2	22.1
Total traverse distance (miles)	0.16	1.25	2.1	17.4	16.8	21.9

NASA – Johnson Space Center Planetary Analog Activities

DESERT "RATS"
(Research &Technology Studies)

In Support of the Exploration Initiative

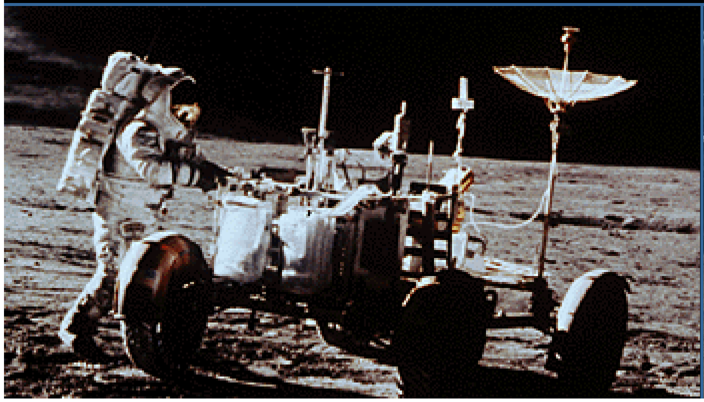
Why Perform Remote Field Tests ?

Testing in a representative environment is essential for proper development of specific technologies & integrated operations :

- **Field work will be the basic method of exploration on planetary surfaces**
  - Terrestrial analogs are required to develop technology & operational techniques
- **Field sites have more realistic terrain than can be achieved in a laboratory**
  - Hills, valleys, canyons, sand, obstructions; astrogeology/astrobiological areas
- **Field sites have larger operations areas than can be achieved in a laboratory**
  - Range of vehicle, EVA traverse mapping, long-range navigation/communications
- **Field tests demonstrate hardware/software & operations requirements for surface science mission activities**
  - Realistic "in-situ" execution of science missions cannot be performed in a laboratory
- **Historically acknowledged wide choice of remote sites for Lunar/Mars analogs**
  - Mojave Desert, Arizona, Utah, Devon Island, Iceland, Antarctica

Other Reasons Why We Perform Remote Field Tests

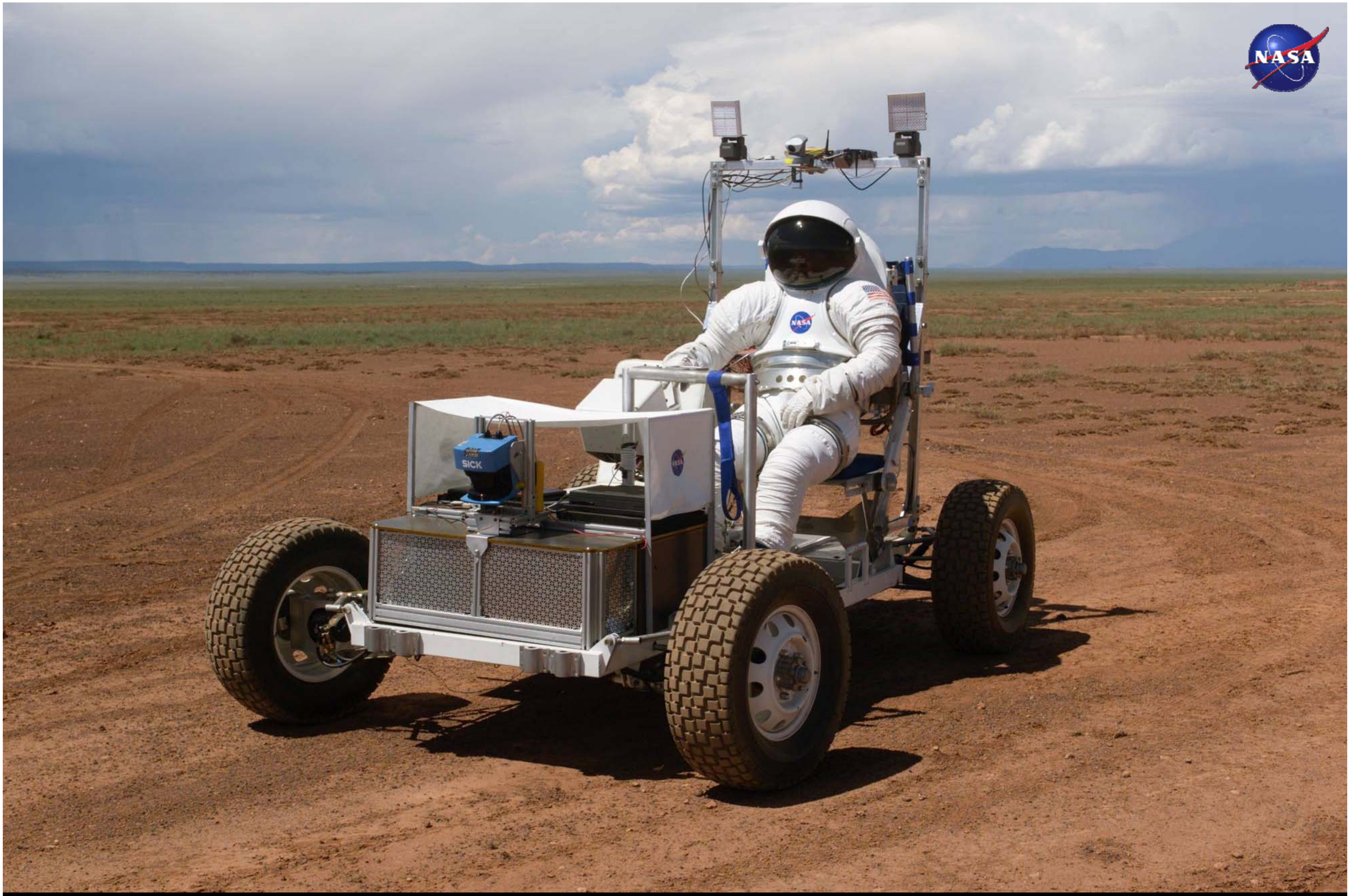
- **To bridge the Apollo-era knowledge gap & help develop the next generation engineering experience base for planetary exploration:**
  - Field testing prepares & provides a high-fidelity experience base for engineers and scientists to enable design & operations of planetary surface systems
- **Integrated field tests with other projects/organizations/centers builds strong interpersonal relationships and networks, along with developing true team spirit:**
  - Provides a common focused goal and inspires technical participation
- **Provides the public with NASA's vision for the future:**
  - Educational outreach to schools
- **Cost is minimal while the return benefits are high**



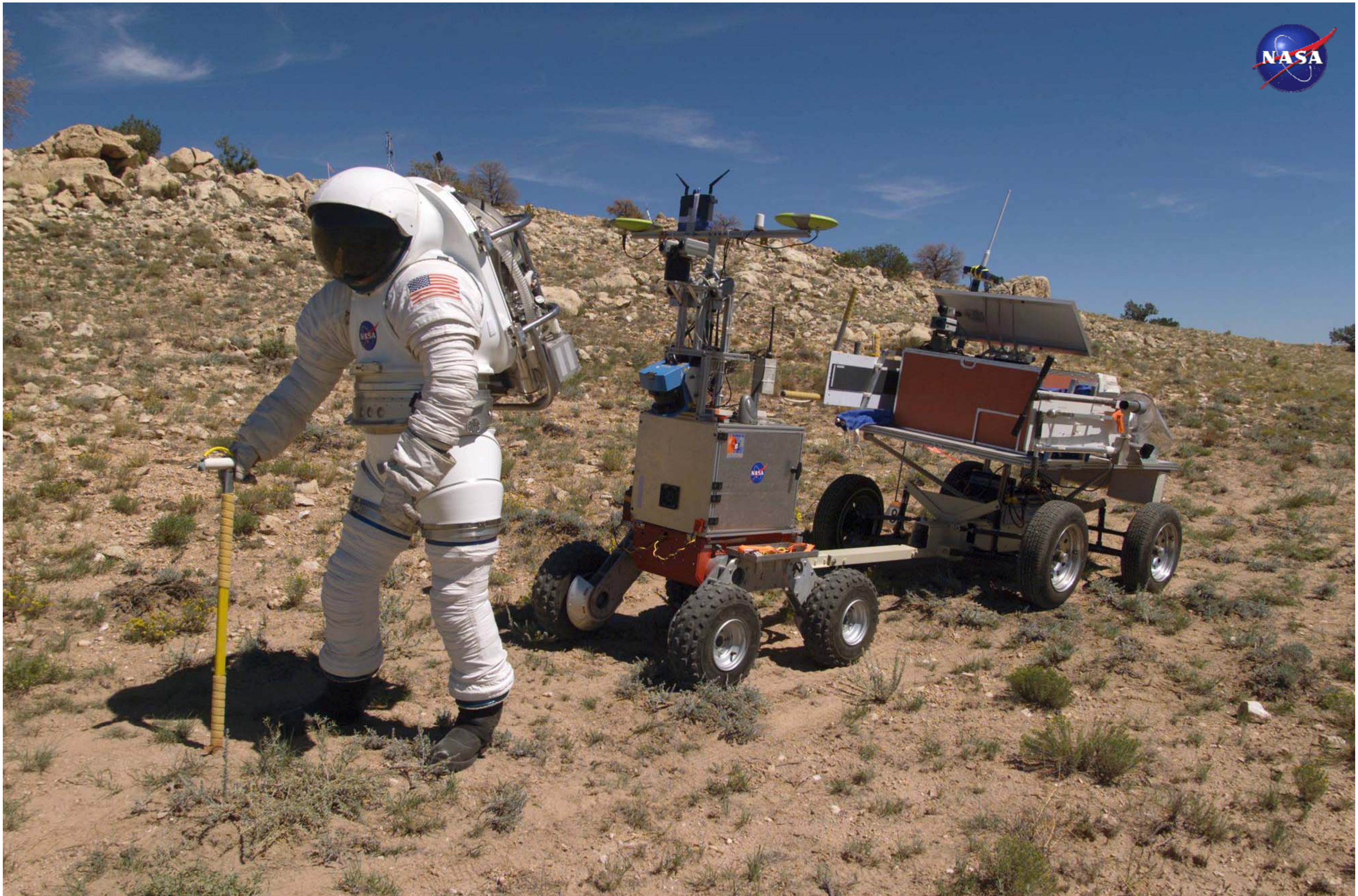

EC5 personnel conducting “dry run” suit mobility & communications testing at JSC prior to remote field activities

Human/robotic interactive task activities being conducted between MK III suit subject and EVA Robotic Assistant (ERA) vehicle

MK III suit subject conducting remote field site task activities with EC5 in-house developed Science Trailer (Mobile Geology Lab)



MK III suit subject driving prototype planetary surface rover vehicle



MK III suit subject conducting EVA exploration traverse assisted by EVA Robotic Assistant (ERA) vehicle and Science Trailer

MK III suit subject prepares for nighttime EVA traverse aided by helmet lights

EVA Beyond The Next Generation?

Bio-engineered adaptation integrating and combining human and robot attributes:

- Anthropomorphic shape with human mobility characteristics
- Augmented strength/vision capabilities
- Programmable and/or autonomous in nature (self-governing; reacting independently)
- Artificial intelligences with computing, reasoning, judgmental and decision making capabilities
- Provide data and visual storage capability and interactive feedback

"ROBO-CYBERNAUT"?

Designed to accommodate the mission profile:

- Environmentally compatible
  - Vacuum and pressure insensitive
- Tolerant of temperature extremes
  - Radiation and UV insensitive
- Accommodate various surface mobility conditions
  - Vehicle interface compatibility
- Long-term mission cycle life endurance

Bio-engineering capability within the next 75 – 100 year timeframe?