3RD SPACE EXPLORATION CONFERENCE & EXHIBIT

Extravehicular Activity – Challenges in Planetary Exploration

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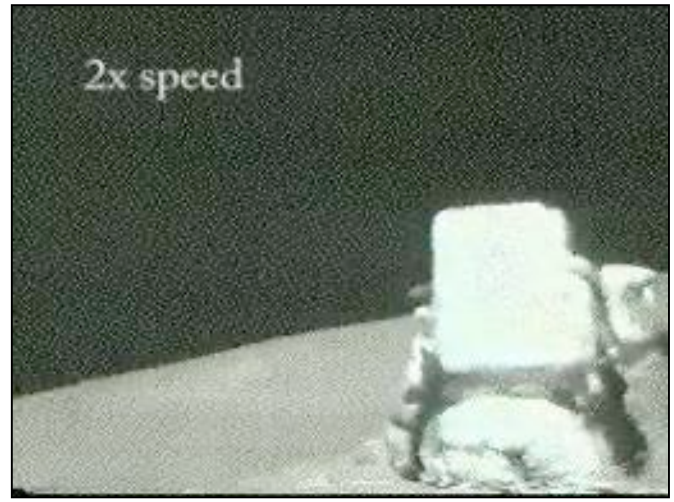
Apollo Accomplishments

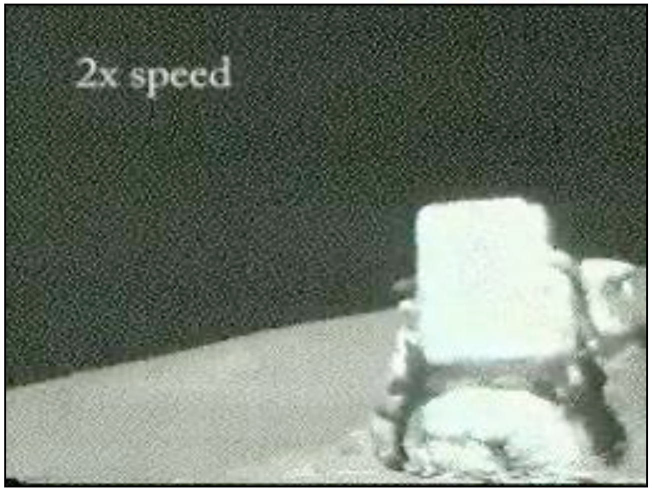
- Apollo was a remarkable human achievement
- Nearly 20 EVAs completed, maximum of 3 per mission
- EVA duration increased from 2.8 hours per EVA to approximately 7 hours per EVA
- Total EVA per landing increased from 2.8 to 22.1 hours per crewmember
- Miles traveled by crews increase from 0.16 miles to 21.9 using unpressurized rover.
- 6 different locations on Moon visited by sending individual landers to each location
- EVAs primarily for science
- Work efficiency index of 2



Current State of Shuttle/Station EVAs

- Routine EVAs being conducted with and without shuttle present
- Three different types of EVA prebreathe have been demonstrated
- Typical shuttle assembly mission involves 3 to 4 EVAs by 1 or 2 EVA teams (no more than 2 persons EVA at a time
- Average EVA length 7 hours per crew member
- EVAs primarily for assembly/maintenance of station
- Work efficiency index of 0.39 to 0.51

  Driven by prebreath requirements
- Distance away from ISS/Shuttle minimized
- Robotic/human interaction common

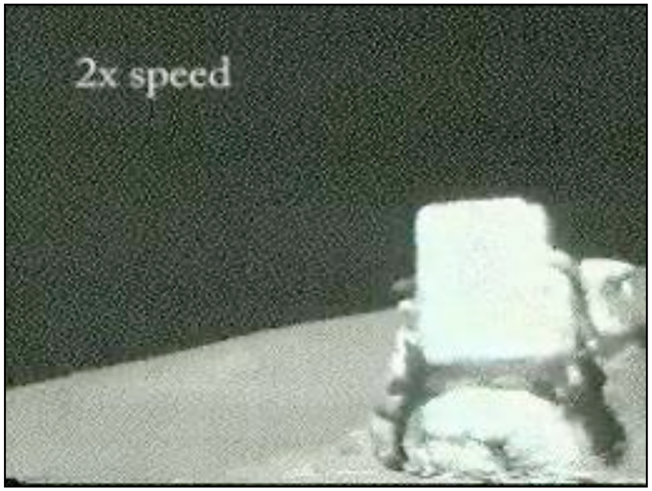


The Challenge of Moving Past Apollo/ISS

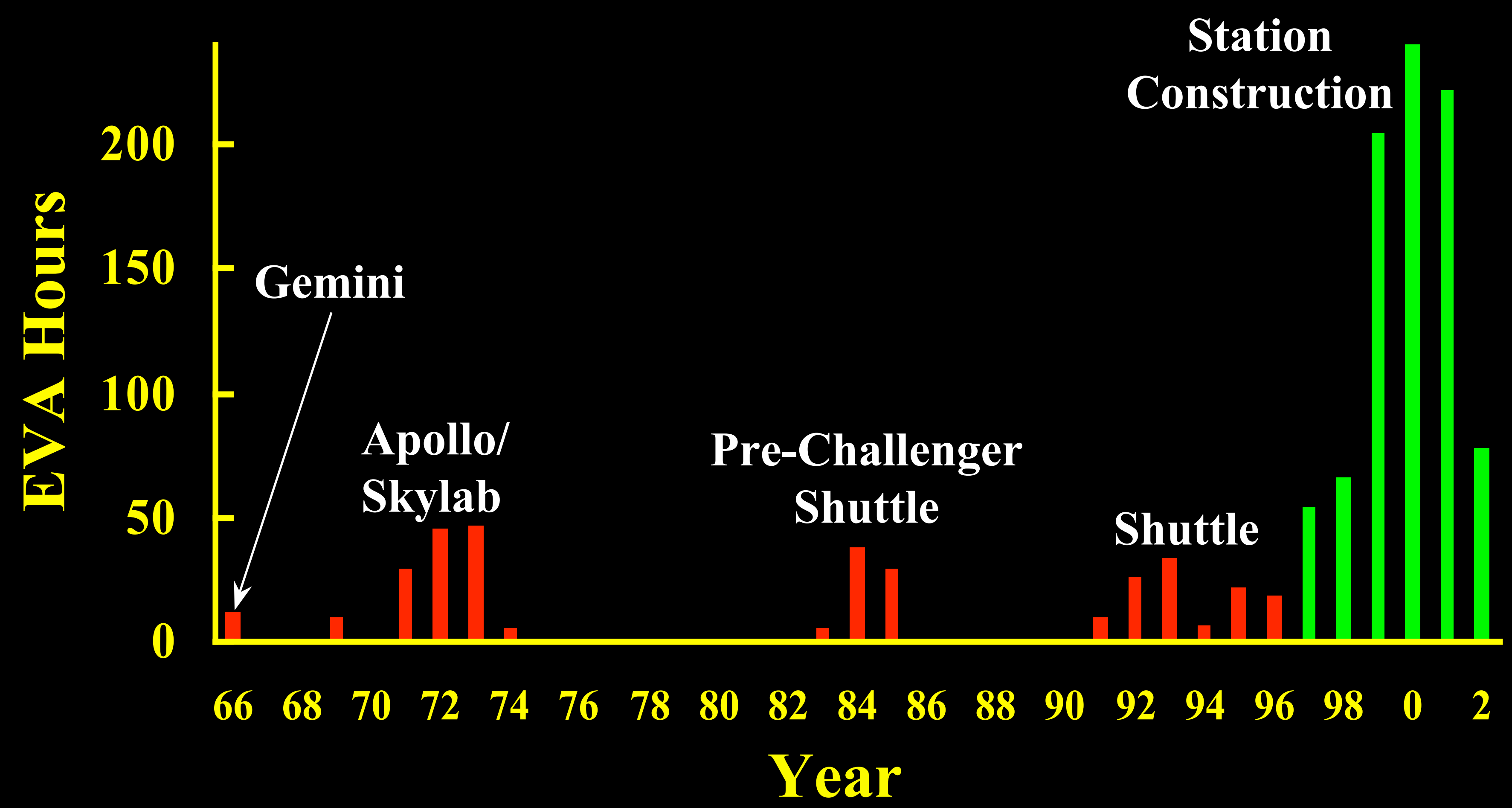
- **Architecture studies estimate up to 2000 EVAs over the 10 year Lunar program**

  Significantly beyond our current experience base

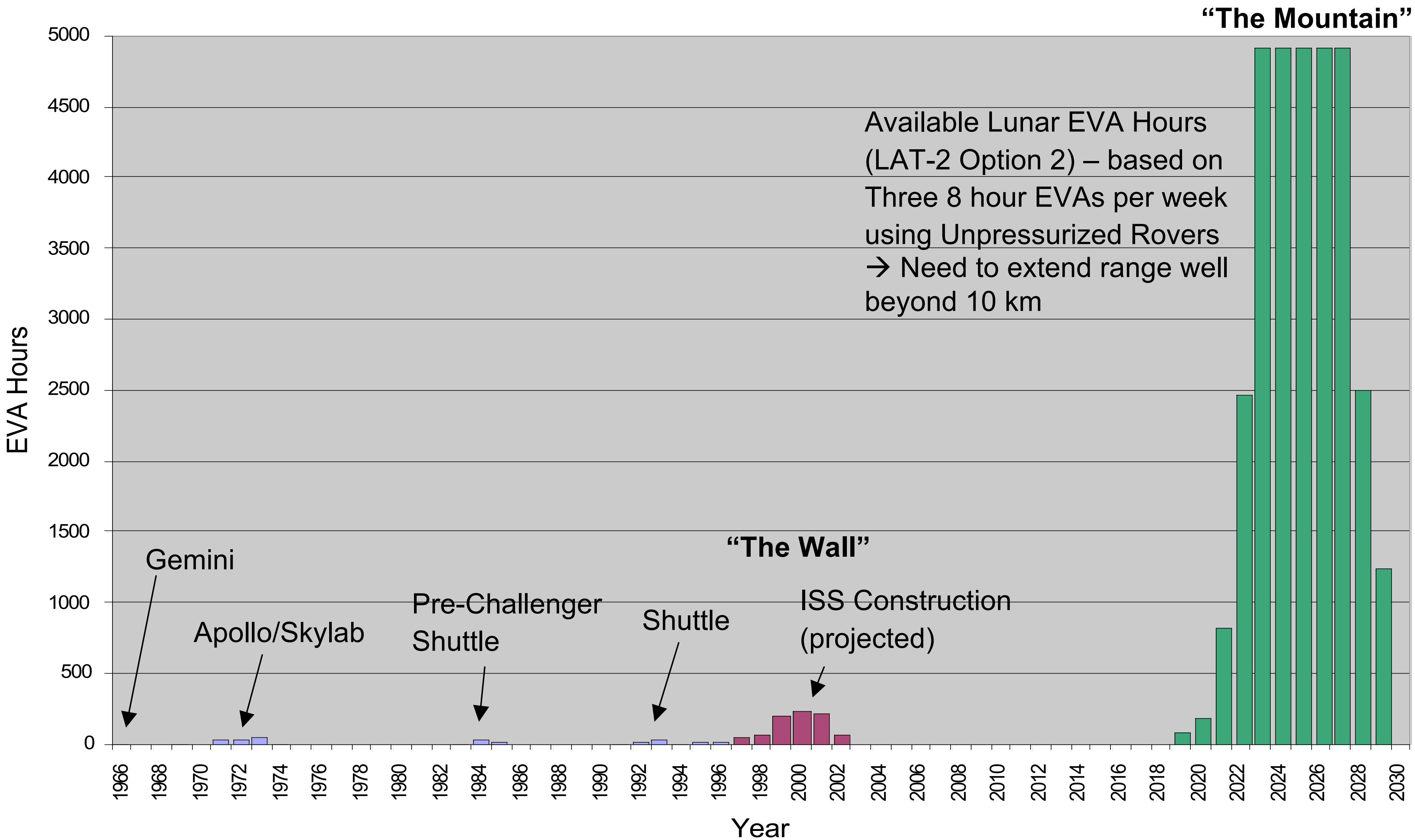
- **With outpost-based architecture, surface mobility is essential for long distance lunar surface missions**
- **Improvements in mobility, dexterity, visibility, center of gravity and other features of the suit are required to maximize crew productivity**
- **The vision is to develop and EVA system that is low overhead and results in close to (or better than) one g shirt sleeve performance**
- **Lunar EVA will be very different from earth orbit EVA – Change in design and operational philosophies will be required to optimize suited human performance in lunar gravity.**



“The Wall of EVA” for ISS Construction



Potential EVA requirements for Lunar Exploration: “The Mountain of EVA”



Medical Challenges for EVA on the Moon

- Risk of excess radiation from a significant Solar Particle Event (SPE)
- Suit induced trauma will can occur even with minimal EVA time
- Thermal issues associated with shadows/craters
- Skin, eye and lung irritation caused by lunar dust in the habitat
- Increased Decompression Sickness (DCS) risk and prebreathe requirements associated with planned 8 psi 32% 02 cabin pressure (versus Apollo with 5 psi 100% 02)

Technological Challenges to Lunar EVA

- Mitigating Effect of Lunar Dust on Bearings and Outer Garments
- Reducing Suit Consumables
- Developing Effective Suit/Tool Interfaces
- Optimally Locating CG for Optimum Task Performance
- Improving Suit Maintainability
- Reducing Preparation and Post EVA Checkout Needs
- Improved Thermal Control Systems
- Minimum Volume Airlocks
- Radiation Monitoring
- Food and Medicine Delivery Systems to Suited Crewmembers
- Interface to Mobility and Robotics Systems
- Data and Navigation Display

Total Suit and Airlock Overhead – the WEI

Work Efficiency Index

Total EVA time

Total EVA Overhead

PREBREATHE PROTOCOL	Shuttle 10.2 Staged Decompression (12 hrs at 10.2)	ISS: 4 hour In Suit	ISS CEVIS Exercise (Using ISS O2)
EVA Overhead Activities	**TIME IN MINUTES**	**TIME IN MINUTES**	**TIME IN MINUTES**
Suit checkout	115	185	185
REBA powered hardware checkout	25	25	25
SAFER checkout	30	30	30
Airlock config	95	90	90
Consumables Prep	60	120	120
EVA prep - prebreathe related	60	0	80
EVA prep - EMU related	30	30	30
Suit donning & leak check	60	60	60
SAFER donning	Completed during Prebreathe	Completed during Prebreathe	Completed during Prebreathe
Purge	8	12	12
Prebreathe	75	240	60
Airlock depress	15	30	40
Airlock egress	15	15	15
Airlock ingress	15	15	15
Airlock repress	15	15	15
Suit doffing	25	25	25
SAFER doffing & stow	10	10	10
Post EVA processing	105	90	90
TOTAL	**758**	**992**	**902**
EVA WORK EFFICIENCY INDEX	**0.51**	**0.39**	**0.43**

Current Concept for EVA Surface Mobility

Small Pressurized Rover

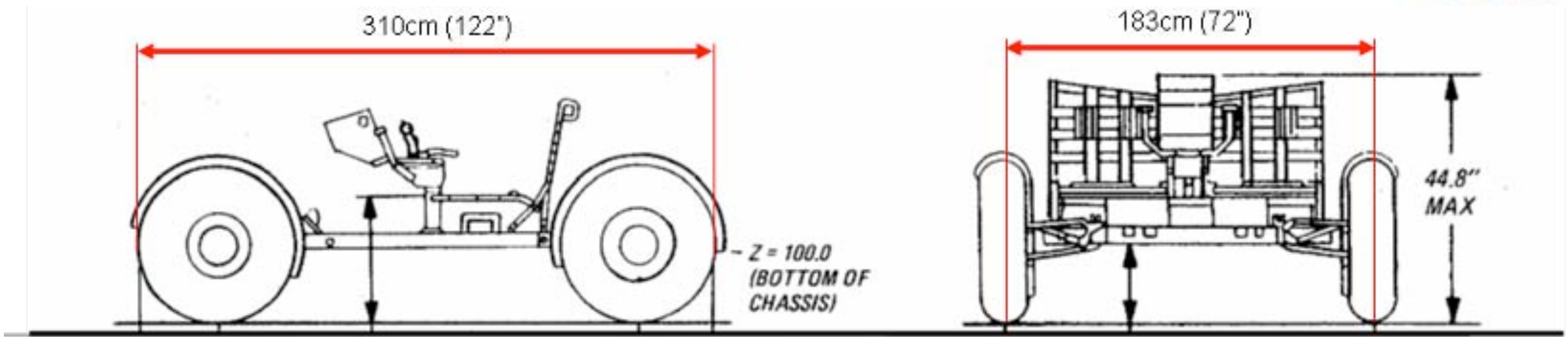
- Provide a rapidly accessible pressurized, rad-hard safe haven with life support of at least 72 hours to protect against
  - Significant Solar Particle Events (SPE)
  - Acute suit malfunctions
  - Other medical emergencies (e.g. decompression sickness treatment)

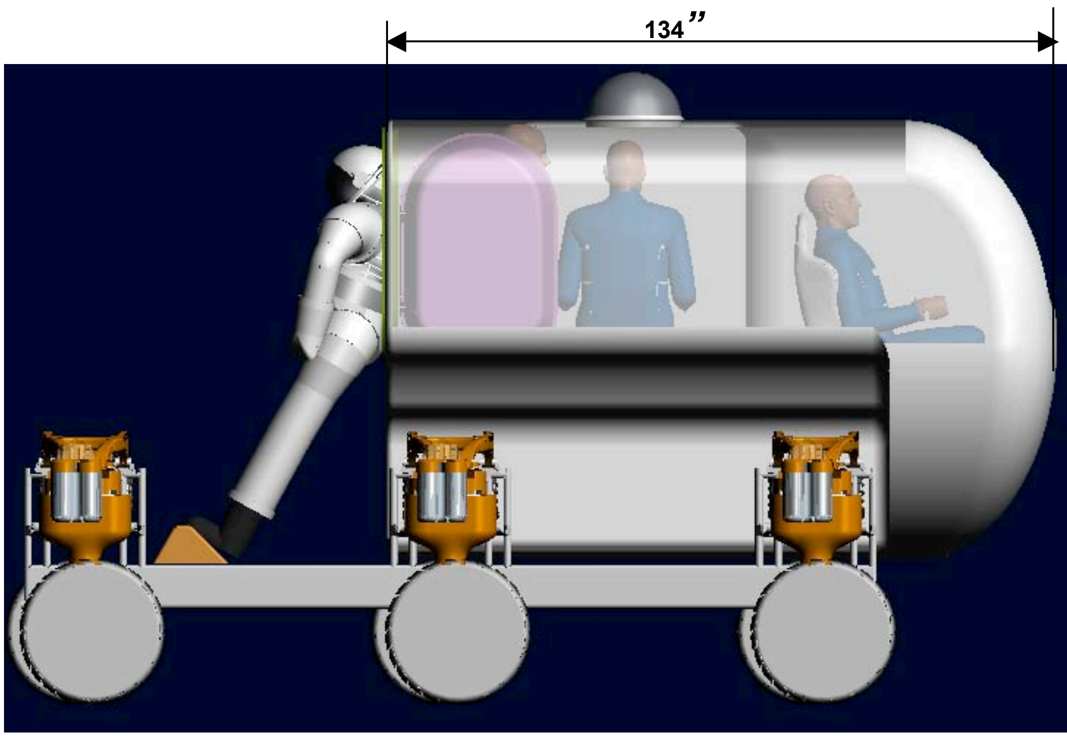
- Rapid ingress/egress provided through the use of a suit lock

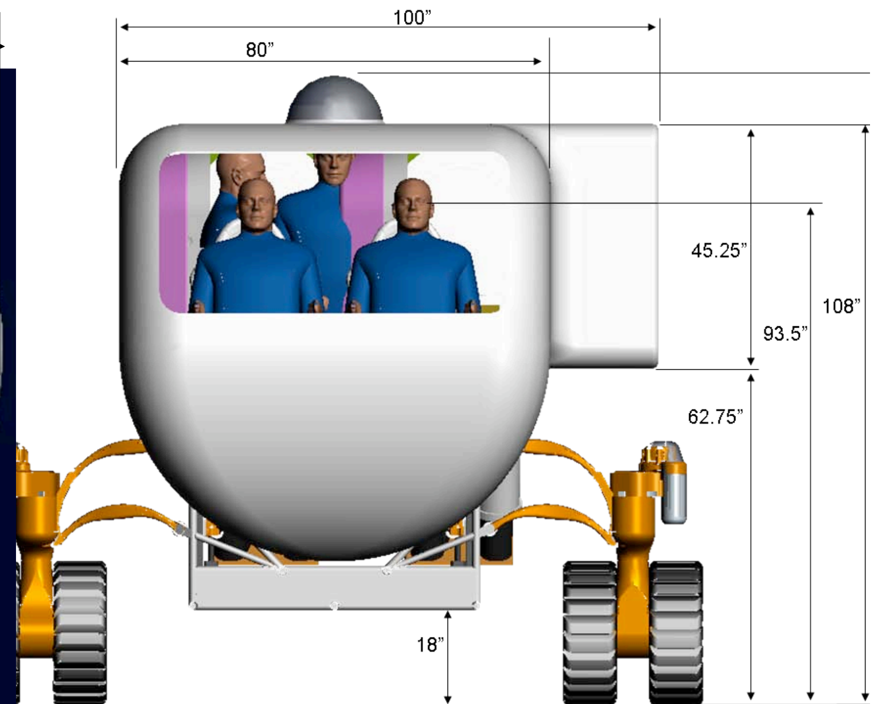
- Extend the exploration range by at least an order of magnitude beyond the Apollo 10 km range
  - Provide redundant methods for return to the outpost or Lander by known path at all times.

- Significantly increase the EVA Work Efficiency Index (Apollo WEI was ~ 1.5-2.0, ISS WEI is ~ 0.4) through repeated EVAs

Comparison of SPR with Apollo LRV



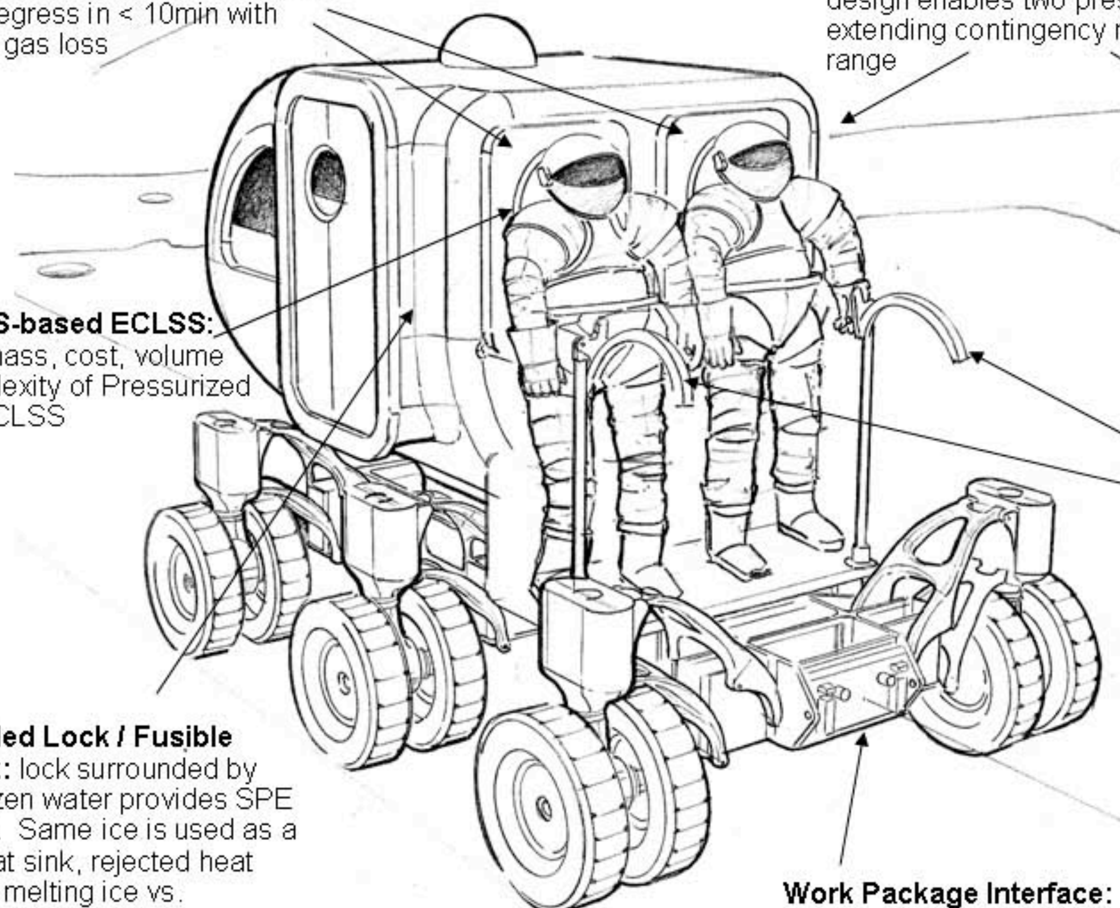


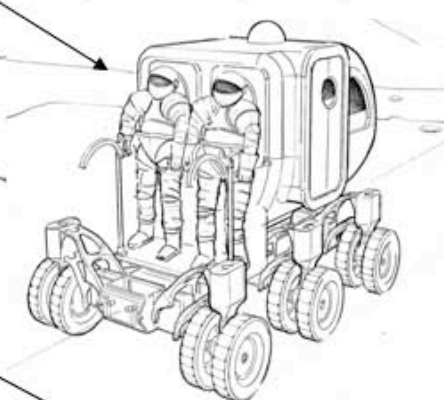


Pressurized Rover Design Features (Slide 1 of 2)

Suitports: allows suit donning and vehicle egress in < 10min with minimal gas loss

Two Pressurized Rovers: Low mass, low volume design enables two pressurized vehicles, greatly extending contingency return (and thus exploration) range



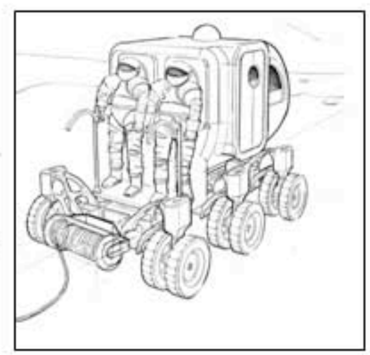


Suit PLSS-based ECLSS: reduces mass, cost, volume and complexity of Pressurized Rovers ECLSS

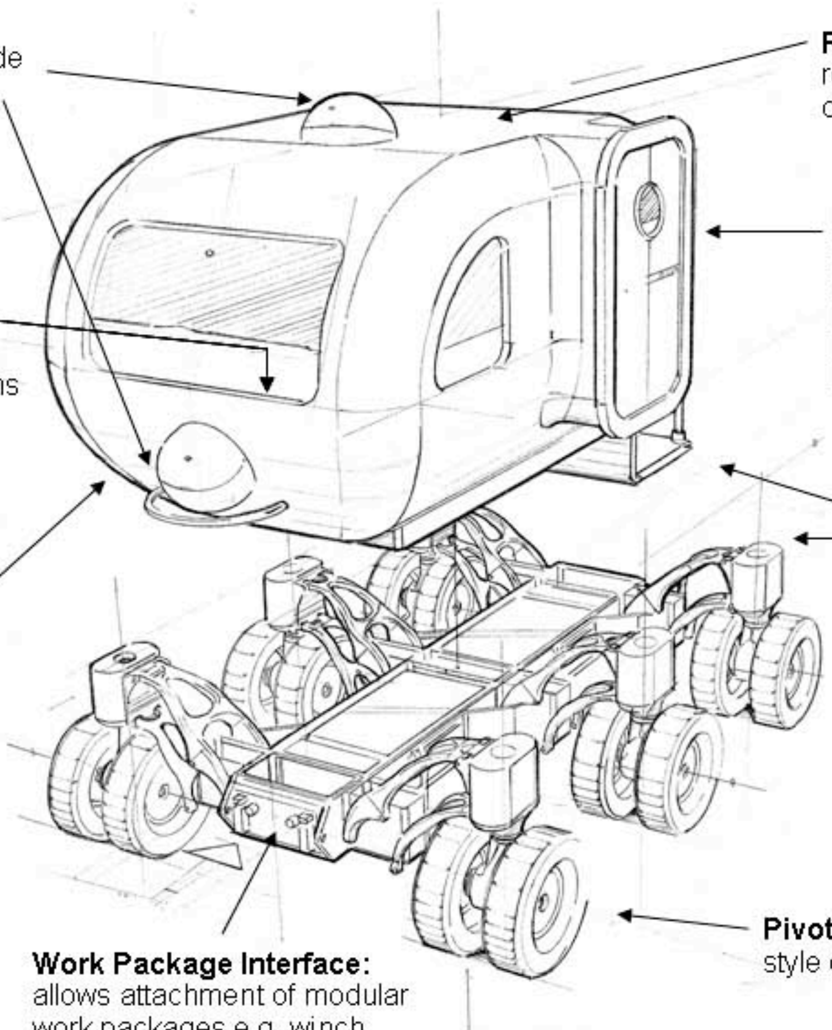
Chariot-Style Aft Driving Station: enables crew to drive rover while EVA, also part of suit port alignment

Ice-shielded Lock / Fusible Heat Sink: lock surrounded by 2.5cm frozen water provides SPE protection. Same ice is used as a fusible heat sink, rejected heat energy by melting ice vs. evaporating water to vacuum.

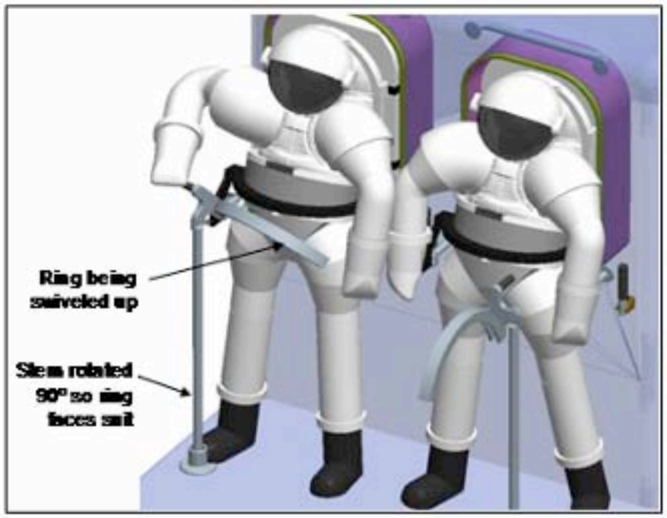
Work Package Interface: allows attachment of modular work packages e.g. winch, cable reel, backhoe, crane

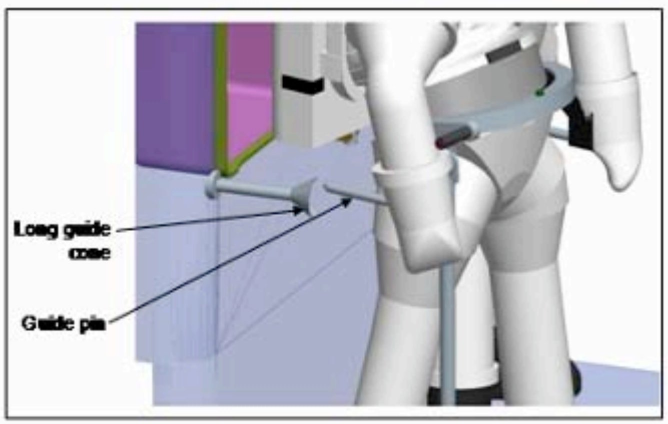


Pressurized Rover Design Features (Slide 2 of 2)

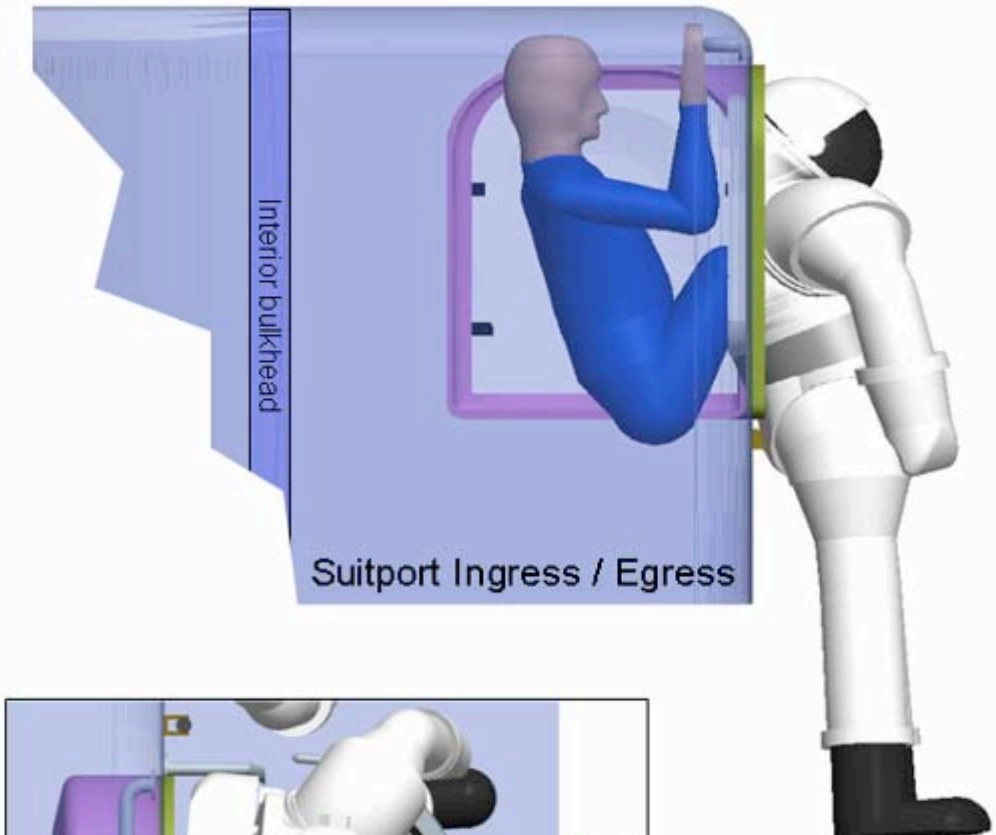


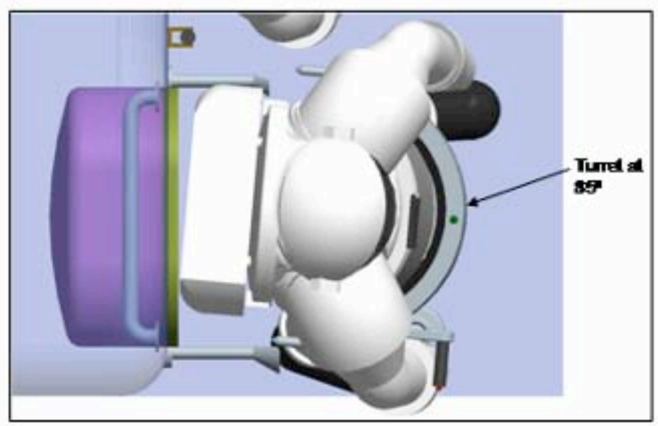
Suitports- “ Step in” suits.





Suit Alignment Guides





Summary

- Human Planetary Exploration Will Be Challenging:
  - Medically
  - Operationally
  - Technologically
- Moon Presents Unique Challenges
  - Dust
  - Thermal
  - Radiation
- Key Challenge is Improving the Work Efficiency Index
- Small Pressurized Rover Could Expand Crew Ability to Work Away from Outpost