

Five Phases of Lunar Development

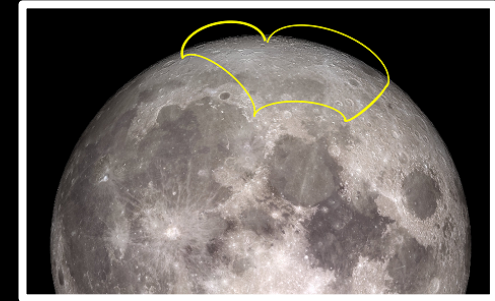
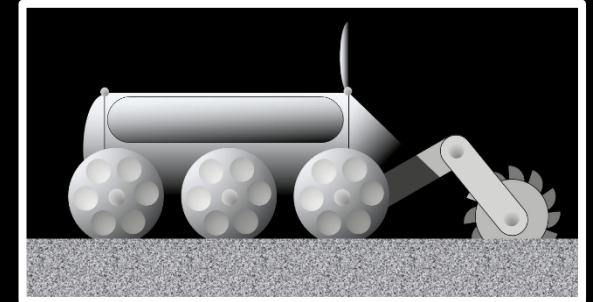
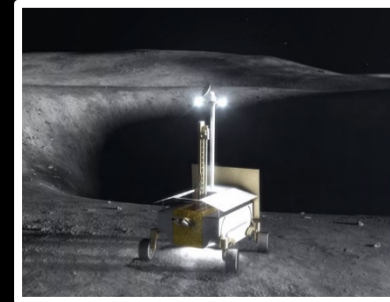


DOUG PLATA MD, MPH

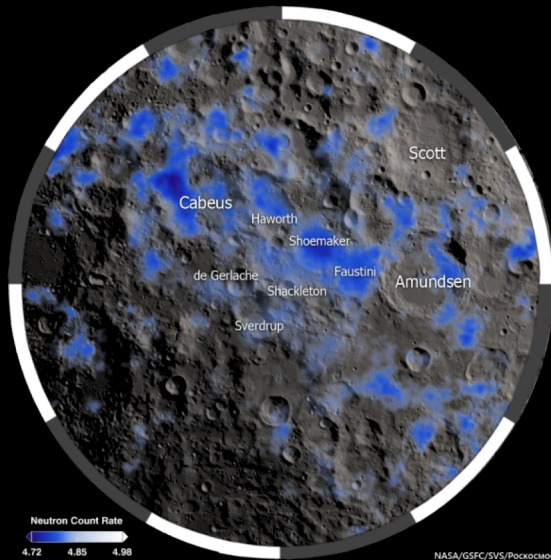
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Five Phases of Lunar Development

1. Prospecting
2. Telerobotic
3. Initial crewed
4. International, suborbital, lunar exploration
5. Private settlement



Lunar Polar Ice



Hydrogen concentration (NASA)

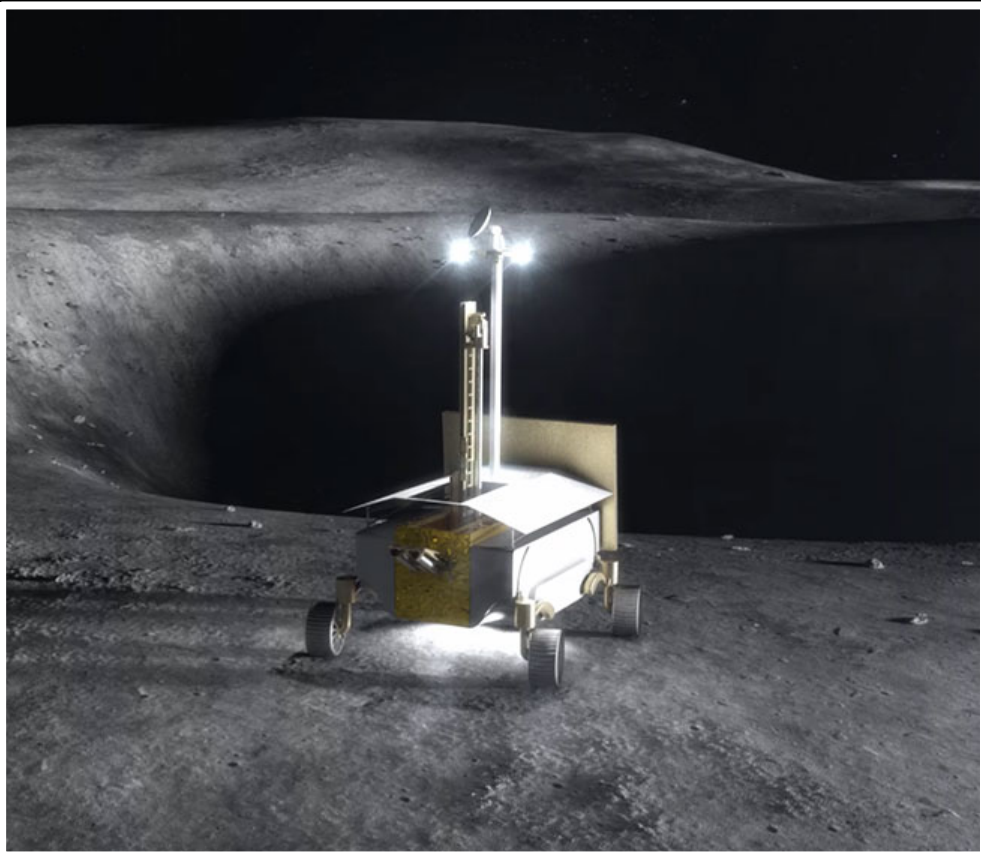


From LCROSS animation (NASA)

“Given the estimated total excavated mass of regolith that reached sunlight, and hence was observable, the concentration of water ice in the regolith at the LCROSS impact site is estimated to be $5.6 \pm 2.9\%$ by mass”.

A. Colaprete, et al. "Detection of Water in the LCROSS Ejecta Plume", Science 22 Oct 2010: Vol. 330, Issue 6003, pp. 463-468.

1. Prospecting Phase

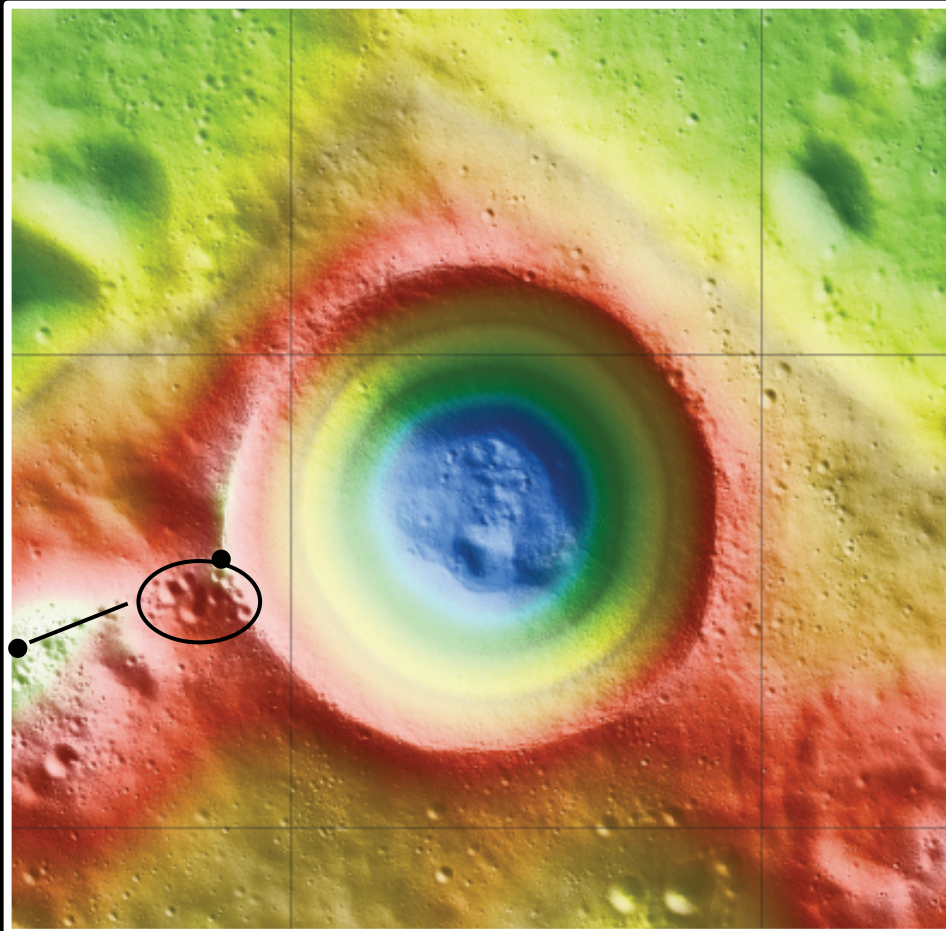


Resource Prospector mission (NASA)

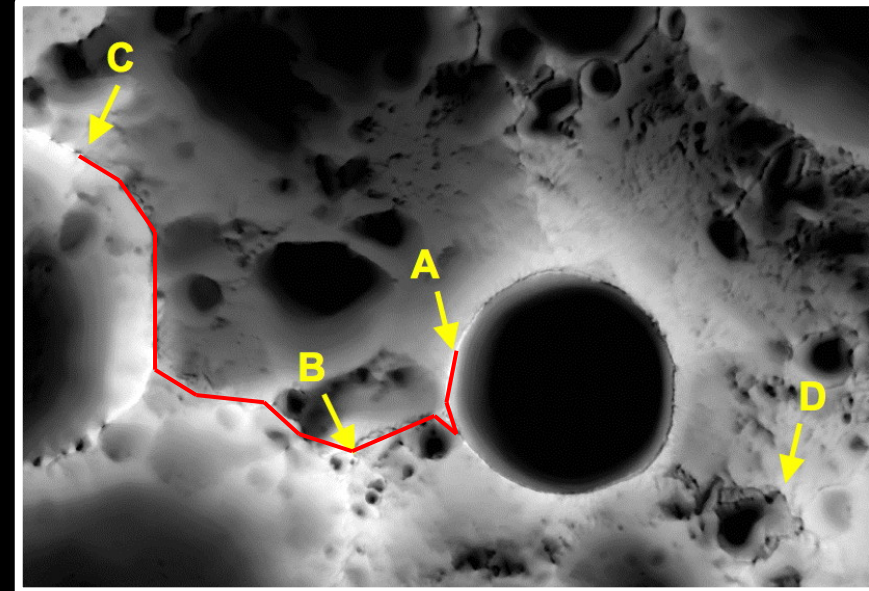
“RP will provide knowledge to inform the selection of future destination, support the development of exploration systems, and reduce the risks associated with human exploration”.

D. R. Andrews, et al. "Introducing the Resource Prospector (RP) Mission", AIAA SPACE 2014 Conference and Exposition, AIAA SPACE Forum, (AIAA 2014-4378).

1. Prospecting Phase



Shackleton Crater (NASA – LRO)



Concept for traverse path between sunlit peaks



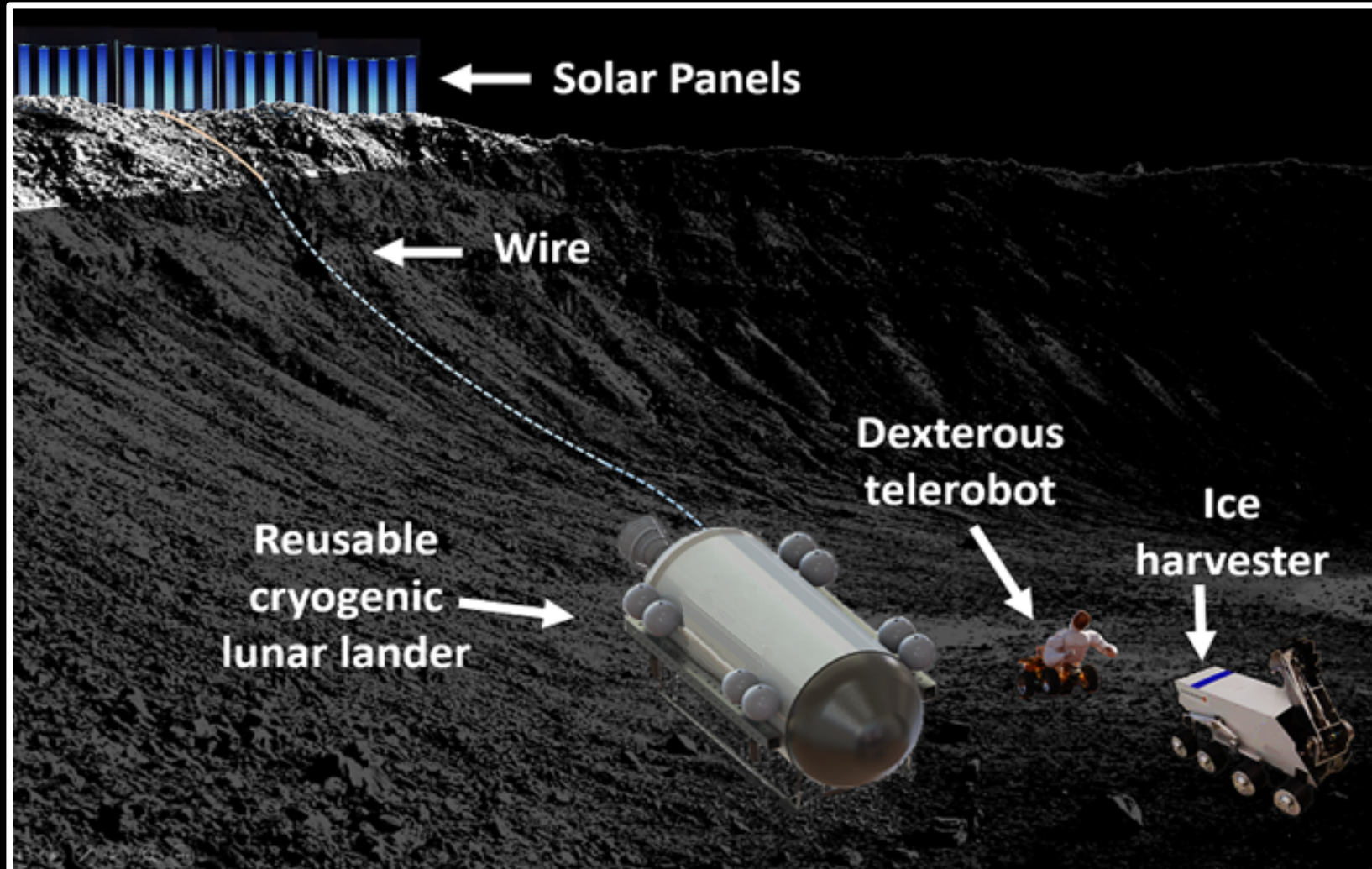
Rim of Shackleton Crater south pole (NASA – LRO)

1. Prospecting Phase

Table 1. Three-Phase Approach to Lunar COTS Missions

Phase 1: Surface Resources and Hazards Assessment	Phase 2: Pilot Lunar ISRU Demonstration	Phase 3: Lunar ISRU Production and Delivery Services
<ul style="list-style-type: none">• Demonstrate capabilities to transport payloads from Earth to lunar surface cost effectively;• Prospect several sites for surface resources and hazards;<ul style="list-style-type: none">• Provide ground truth data of various sites;• Assess potential sites for hazards and accessibility• Demonstrate techniques for resource extraction and future ISRU operations.	<ul style="list-style-type: none">• Demonstrate capabilities for ISRU resource production, such as, H₂O, LOX, LH₂, and storage on a pilot-scale program;• Demonstrate feasibility and economics of scaling up production and capability to store several tons of resources on lunar surface.• Demonstrate capability to transport large payloads from lunar surface to cis-lunar space destinations for long-term storage.	<ul style="list-style-type: none">• NASA awards long-term contracts for Lunar ISRU production of H₂O or LOX/ LH₂ on the order of several metric tons per year;• Awards are also made for delivery services to Cis-Lunar Depot;• Awards are made to multiple commercial providers to reduce risk and enable competition.

2. Telerobotic Phase

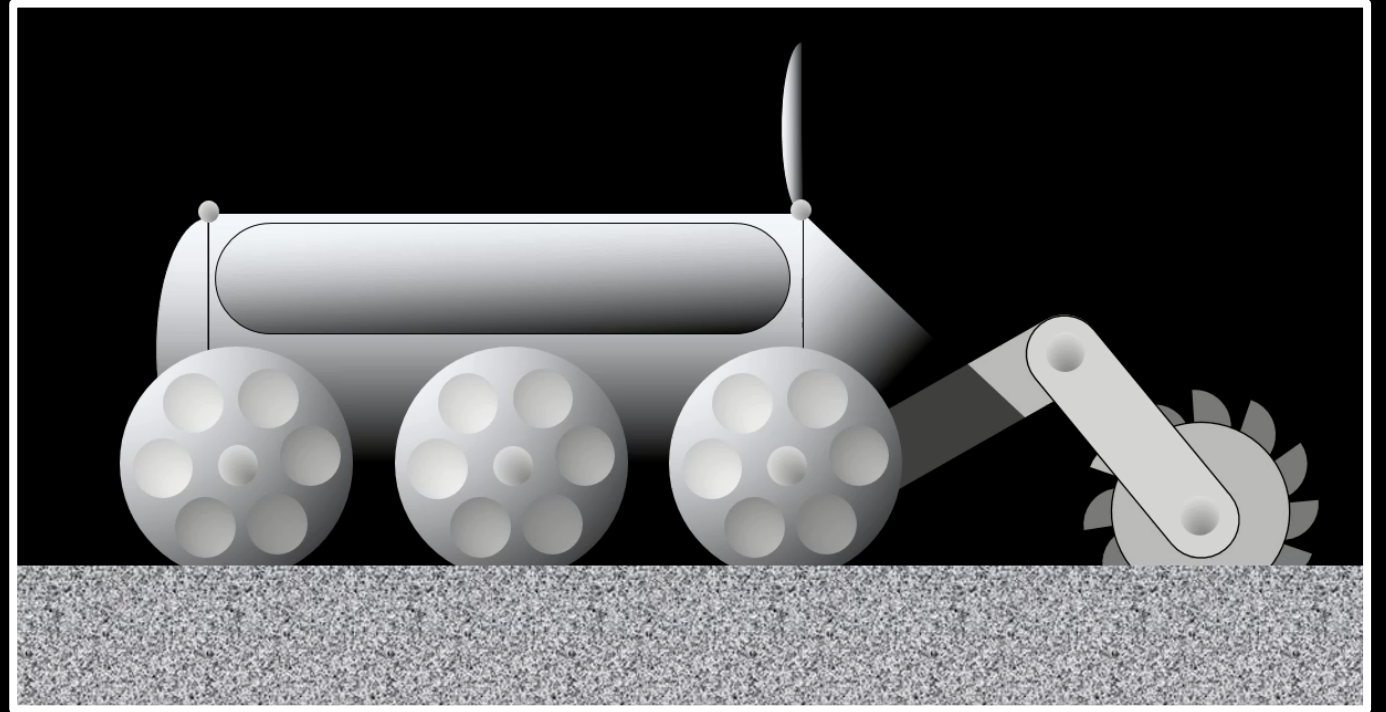


Concept for an initial ice-harvesting operation

2. Telerobotic Phase



XEUS lander – crew (ULA)



Concept for an Ice Harvester

2. Telerobotic Phase

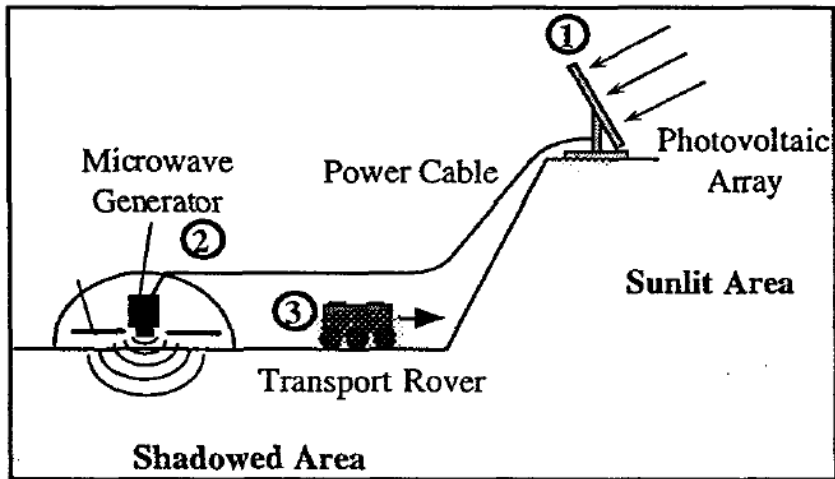


Figure 2. Schematic Diagram of Extraction System #1

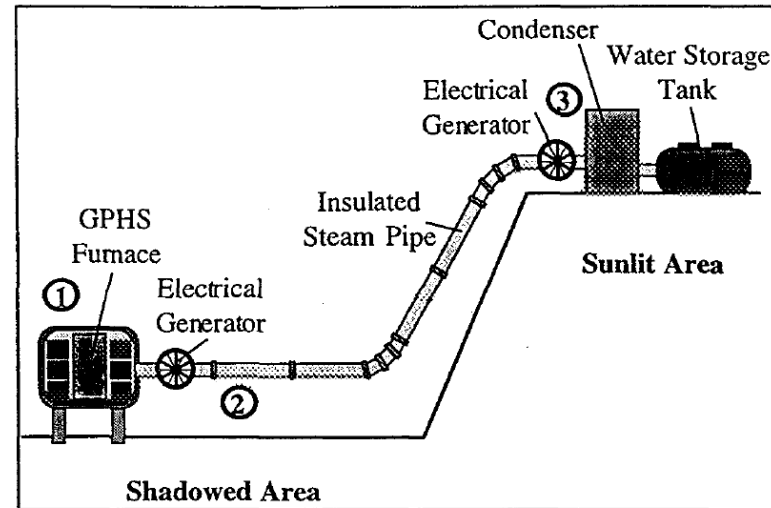


Figure 3. Schematic Diagram of Extraction System #2

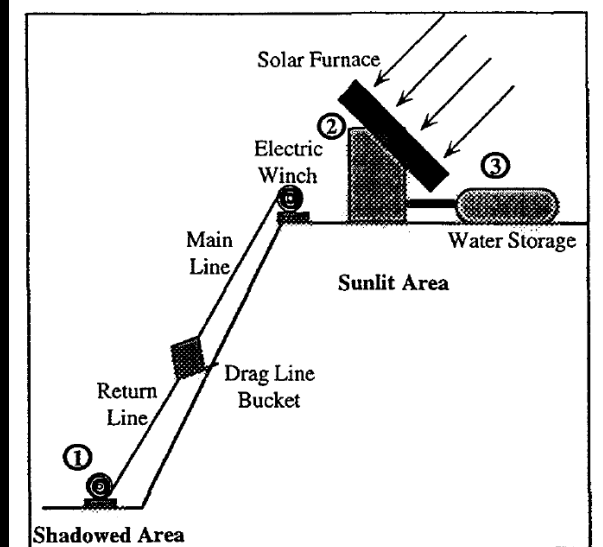
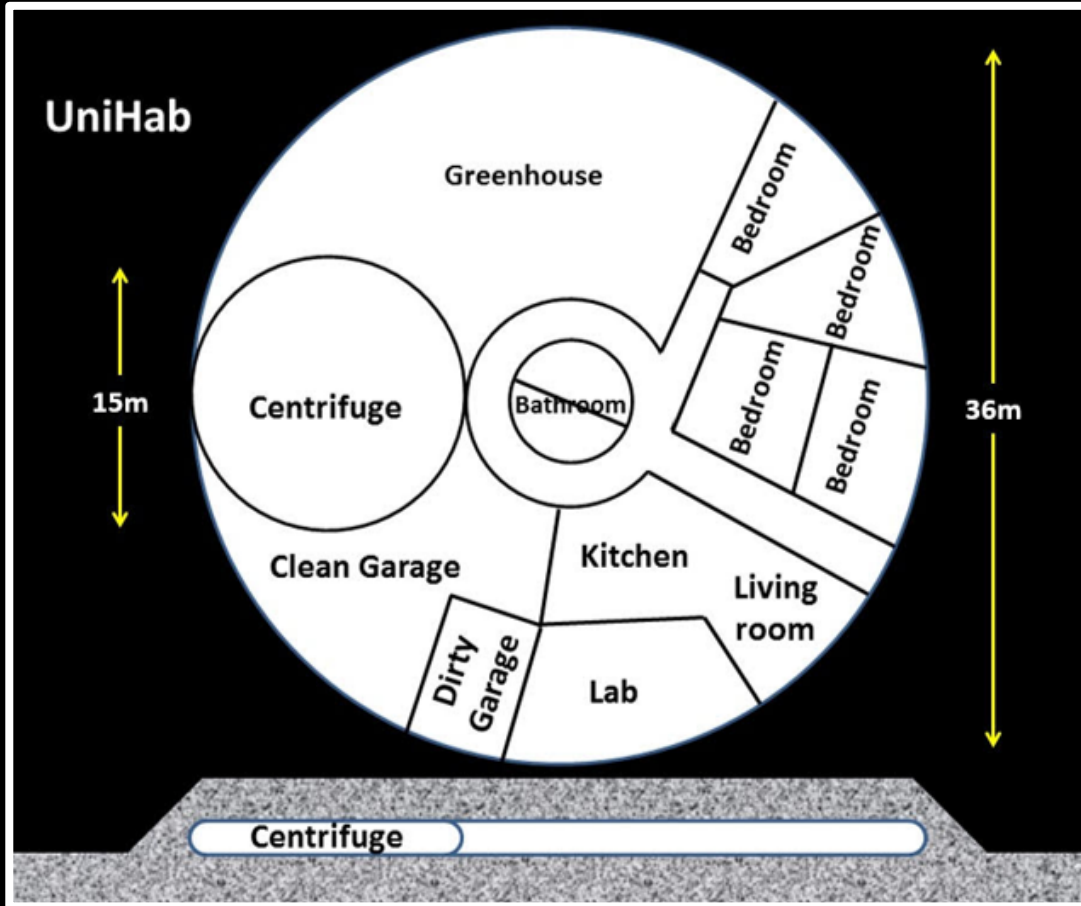


Figure 4. Schematic Diagram of System #3

Duke, et al, AIAA 1998

3. Initial Crew Phase

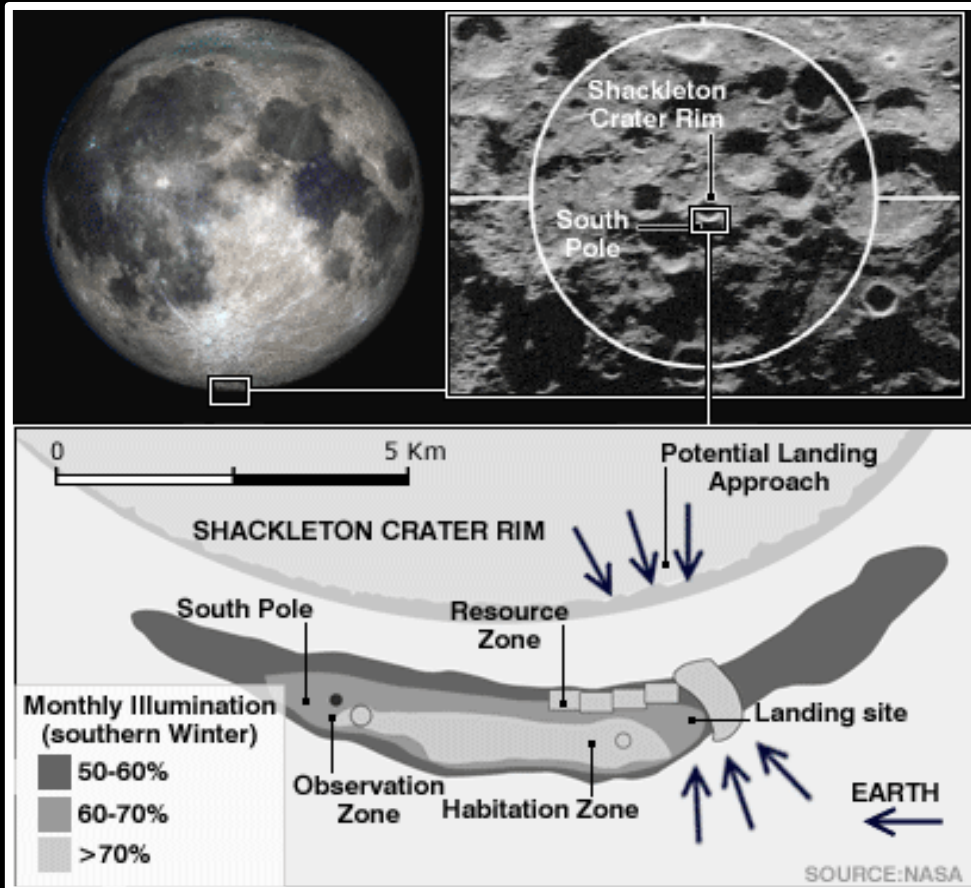


UniHab concept (Plata)

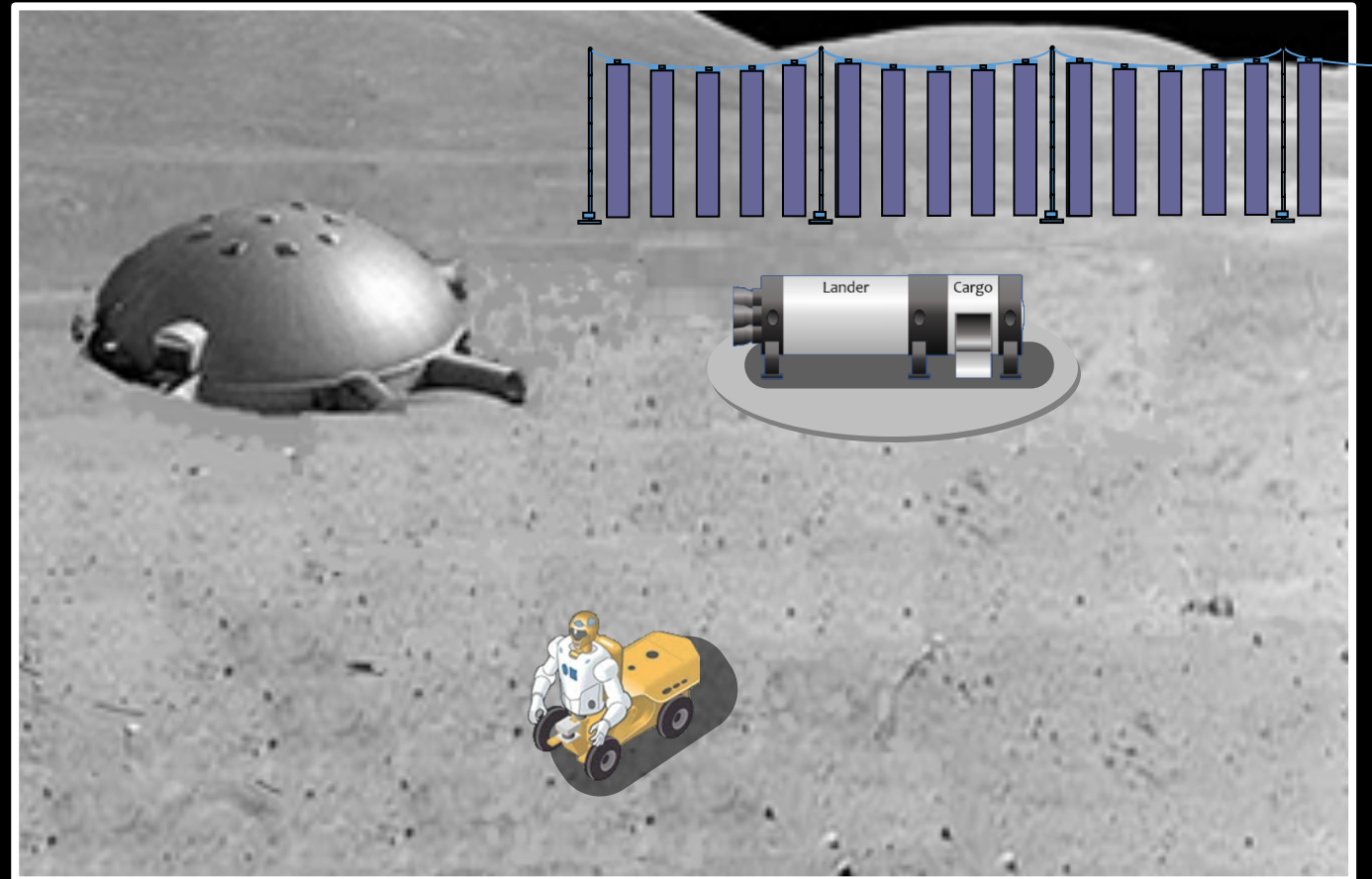


Concept of an initial, permanent, lunar crew and their jobs

3. Initial Crew Phase

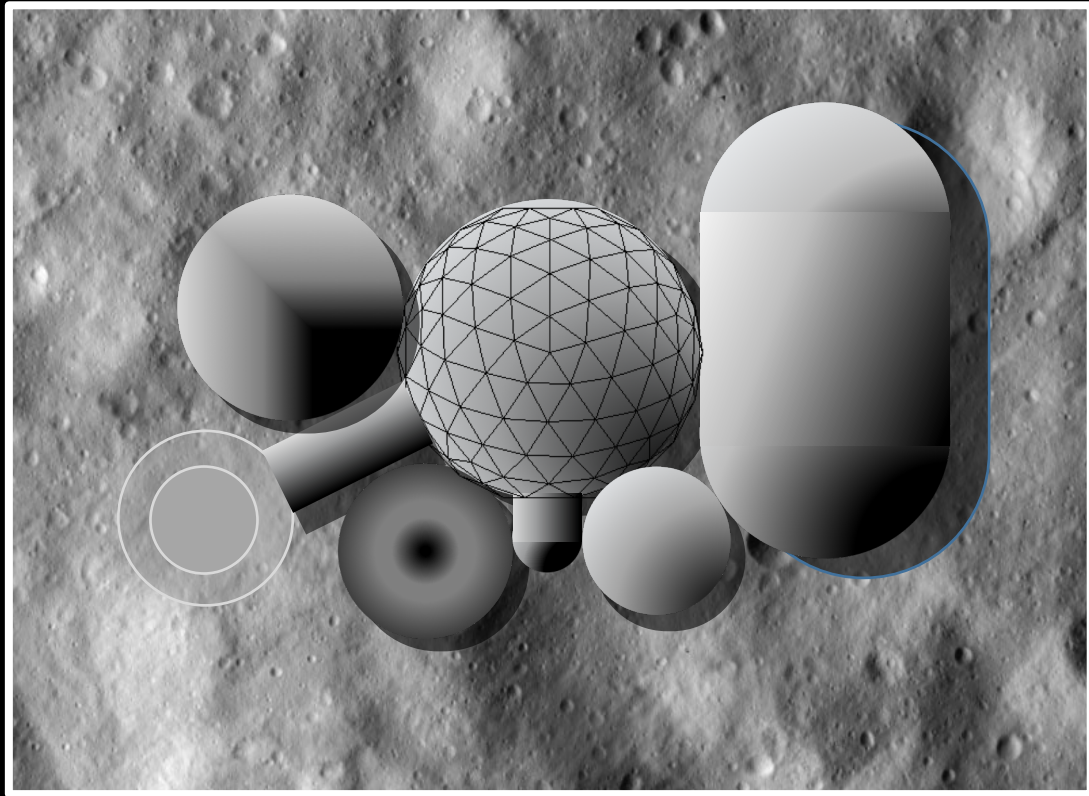


Shackleton base concept (NASA)

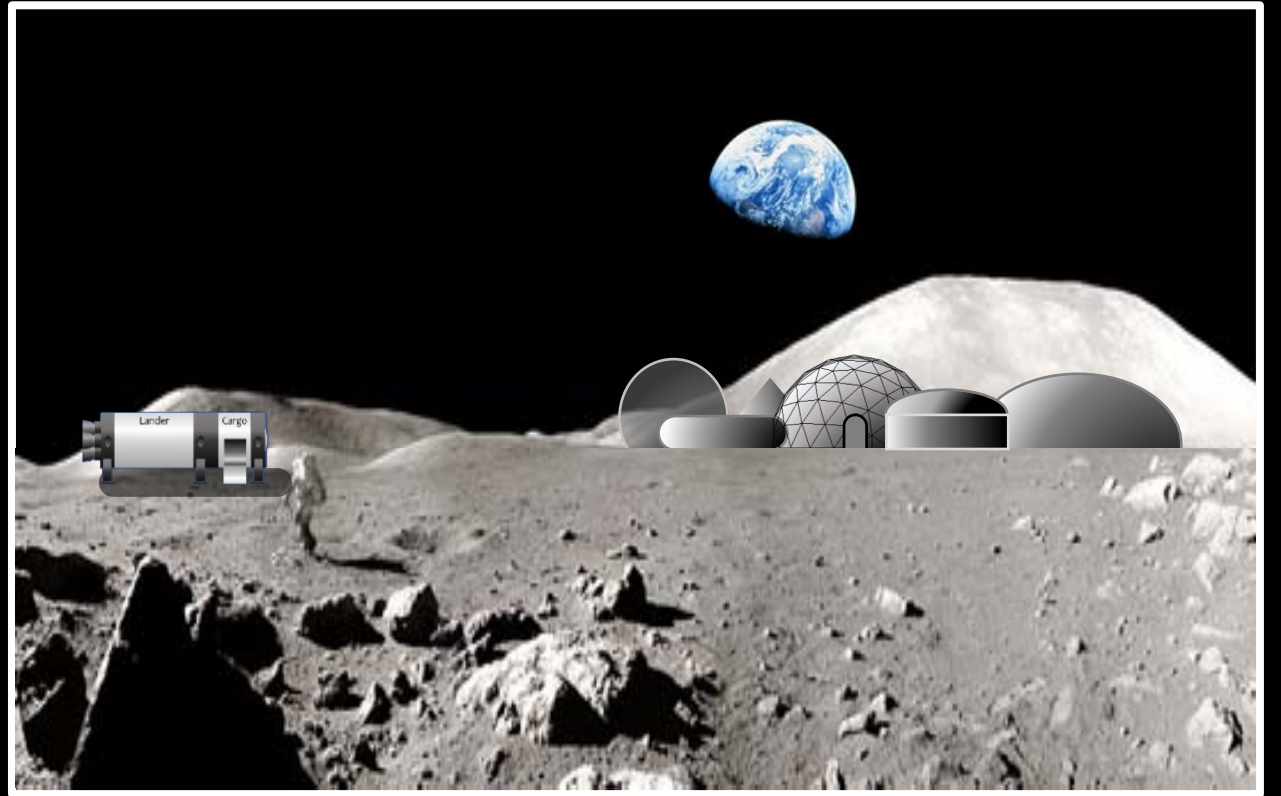


Notion of an initial lunar base

3. Initial Crew Phase

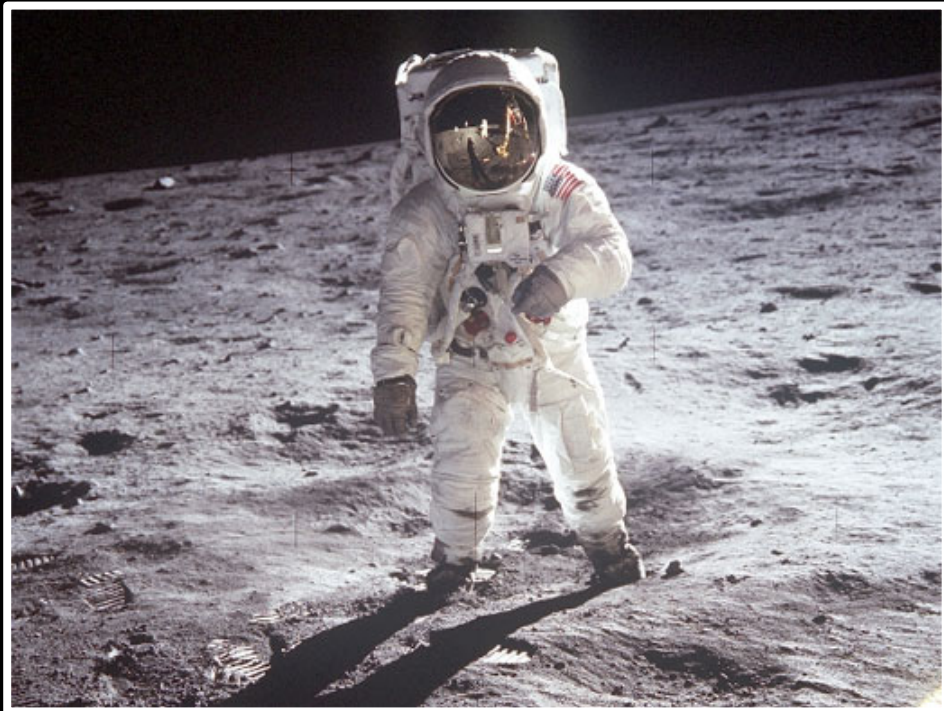


Lunar base concept – Bird's eye view



Lunar base concept – Surface view

4. International, Suborbital, Lunar Exploration Phase



Lunar astronaut (NASA)



Suborbital lunar exploration

5. Private Settlement Phase

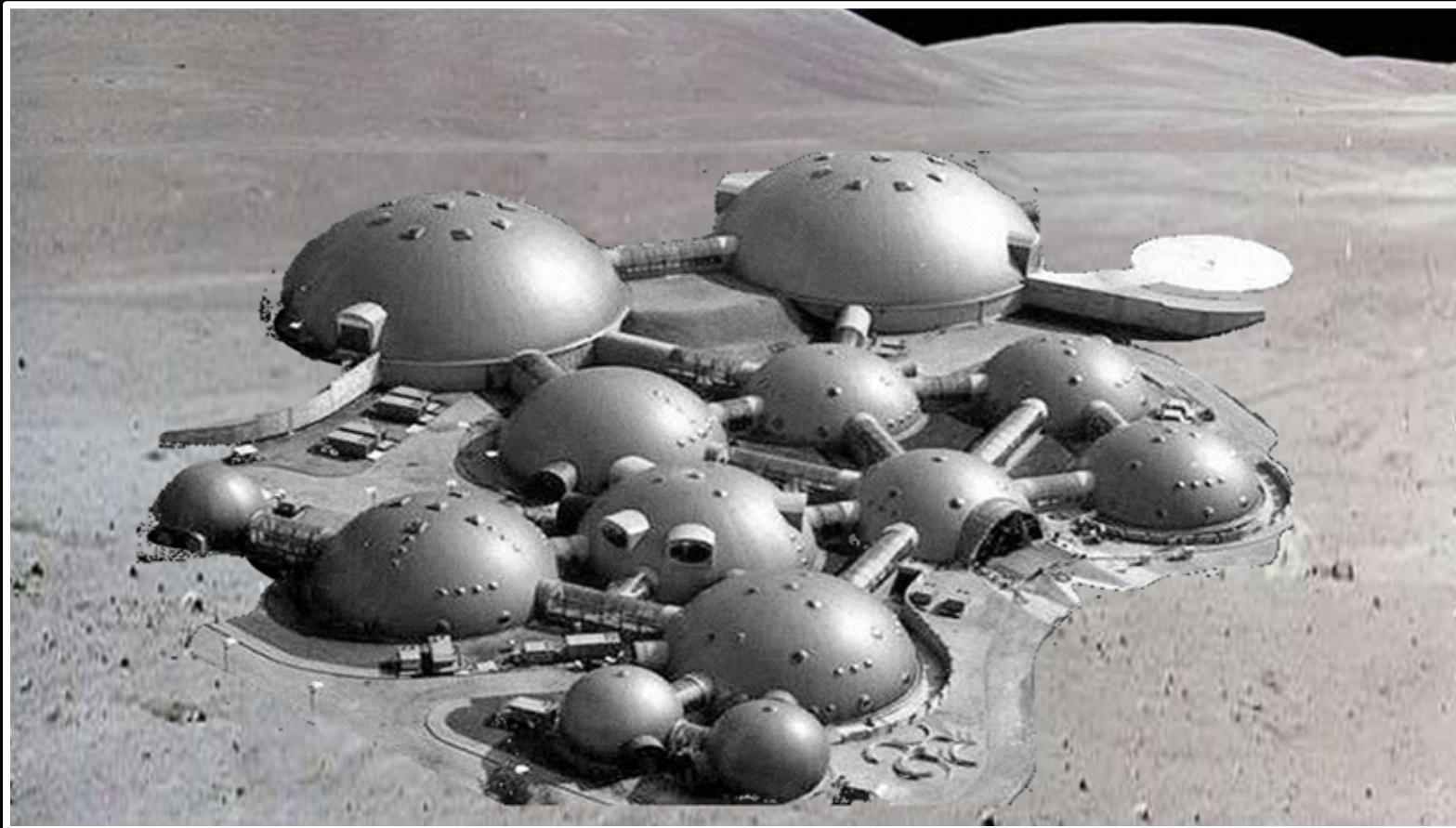


Illustration of a lunar base adapted from Radio Muzyka Fakty (Poland)

Financing

Phase 1 - Prospecting

Phase 2 - Vehicle & telerobotic
development

Phase 2 - Lunar surface transport
& operations

Phase 3 - Commercial crew

Phase 4 - Intl suborbital exploration

Phase 5 - Private settlement

Financing

Phase 1 - NASA - Prospecting

Phase 2 - Vehicle & telerobotic
development

Phase 2 - Lunar surface transport
& operations

Phase 3 - Commercial crew

Phase 4 - Intl suborbital exploration

Phase 5 - Private settlement

Financing

Phase 1 - NASA - Prospecting

Phase 2 - PPP - Vehicle & telerobotic
development

Phase 2 - Lunar surface transport
& operations

Phase 3 - Commercial crew

Phase 4 - Intl suborbital exploration

Phase 5 - Private settlement

Financing

Phase 1 - **NASA** - Prospecting

Phase 2 - **PPP** - Vehicle & telerobotic
development

Phase 2 - **PPP** - Lunar surface transport
& operations

Phase 3 - Commercial crew

Phase 4 - Intl suborbital exploration

Phase 5 - Private settlement

Financing

Phase 1 - **NASA** - Prospecting

Phase 2 - **PPP** - Vehicle & telerobotic
development

Phase 2 - **PPP** - Lunar surface transport
& operations

Phase 3 - **PPP** - Commercial crew

Phase 4 - Intl suborbital exploration

Phase 5 - Private settlement

Financing

Phase 1 - **NASA** - Prospecting

Phase 2 - **PPP** - Vehicle & telerobotic
development

Phase 2 - **PPP** - Lunar surface transport
& operations

Phase 3 - **PPP** - Commercial crew

Phase 4 - **Intl** - Intl suborbital exploration

Phase 5 - Private settlement

Financing

Phase 1 - **NASA** - Prospecting

Phase 2 - **PPP** - Vehicle & telerobotic
development

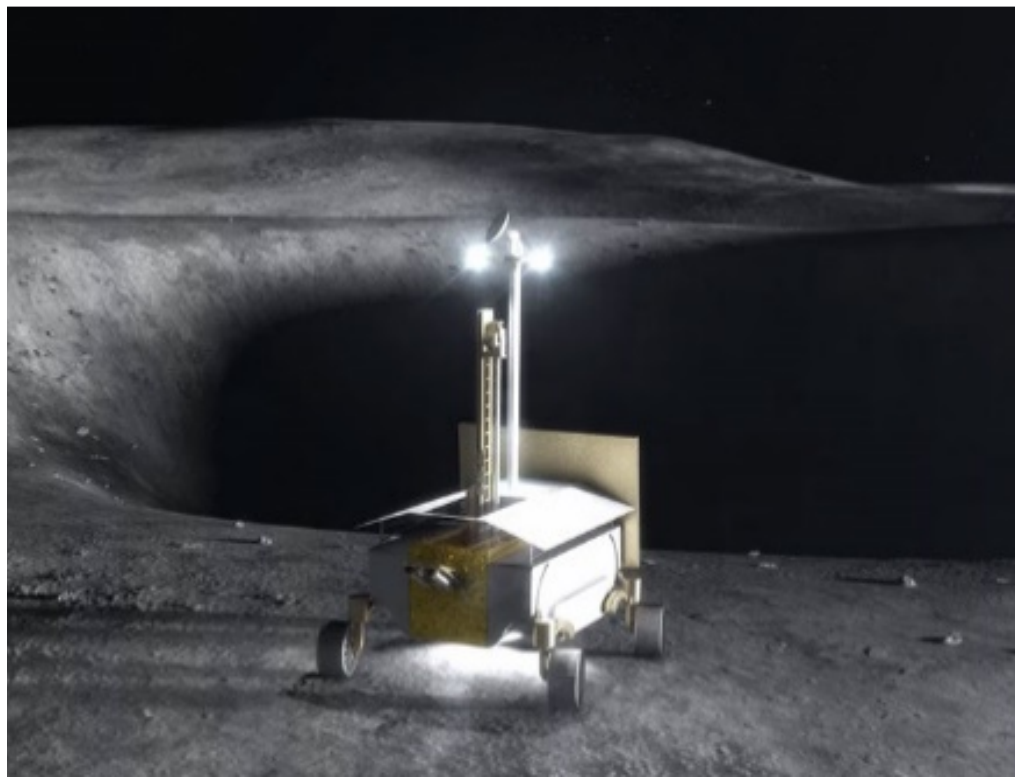
Phase 2 - **PPP** - Lunar surface transport
& operations

Phase 3 - **PPP** - Commercial crew

Phase 4 - **Intl** - Intl suborbital exploration

Phase 5 - **Savings** - Private settlement

Financing: Prospecting Phase

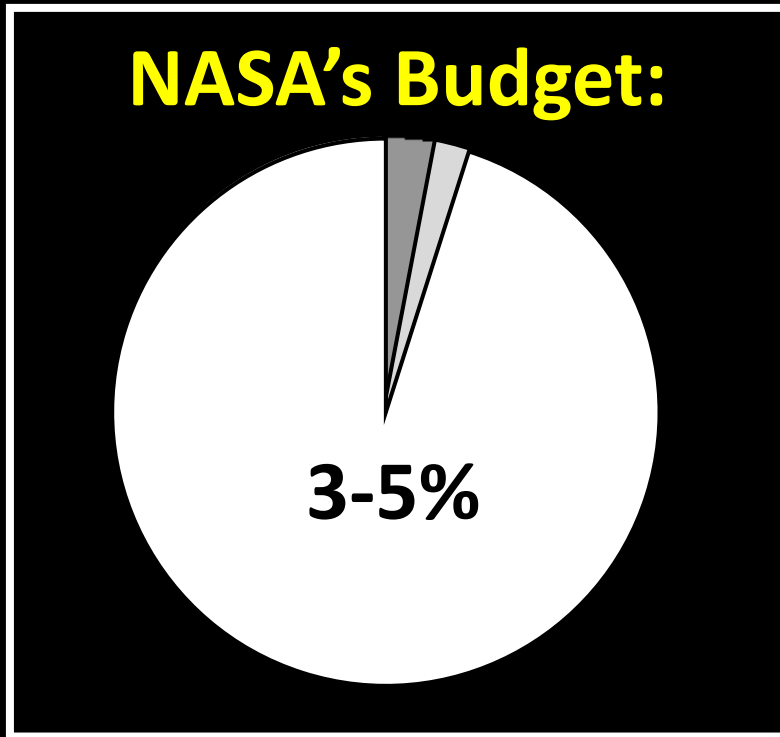


Resource Prospector mission video (NASA)

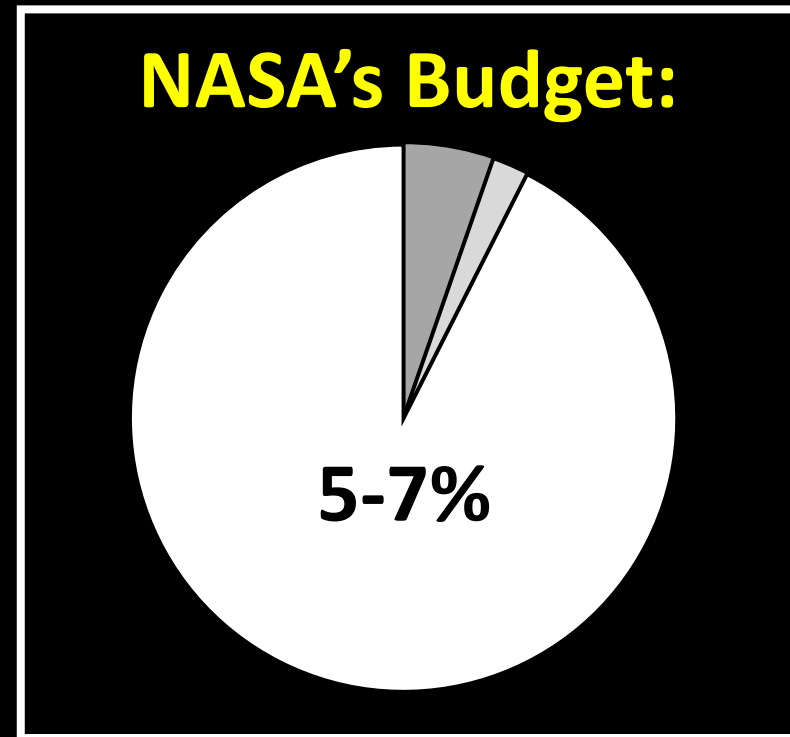


Resource test article (NASA)

Financing: Lunar COTS (LCOTS)



COTS-CC-CC



"Lunar COTS"

Financing: Lunar COTS (LCOTS)



Falcon Heavy (SpaceX)

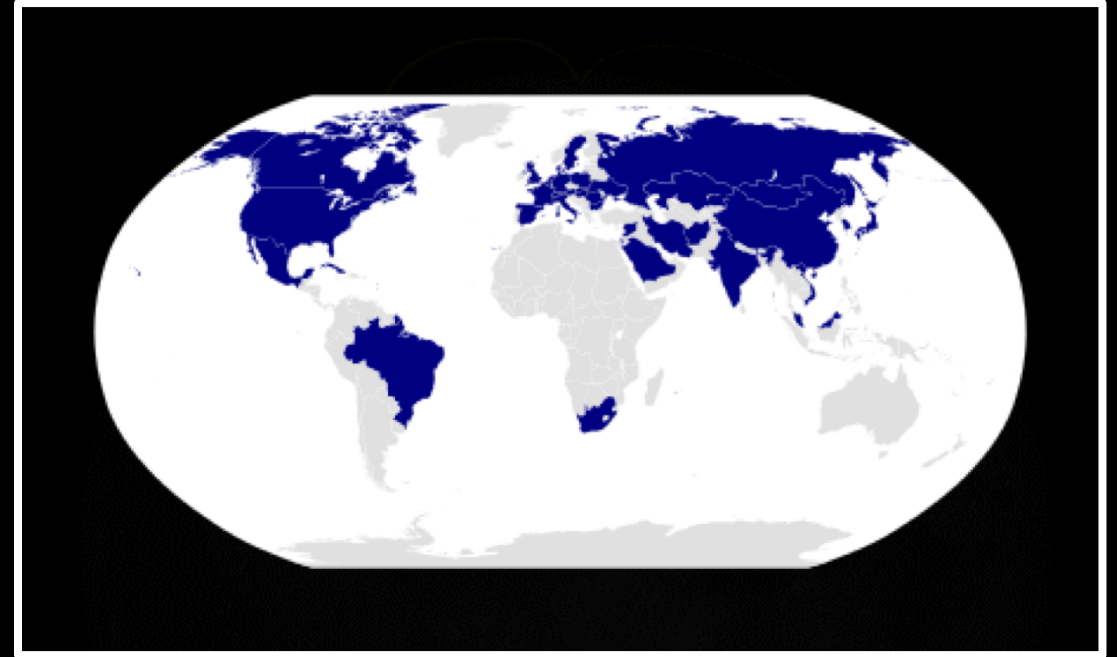


ACES lander (ULA)

Financing: International, Suborbital, Lunar Exploration



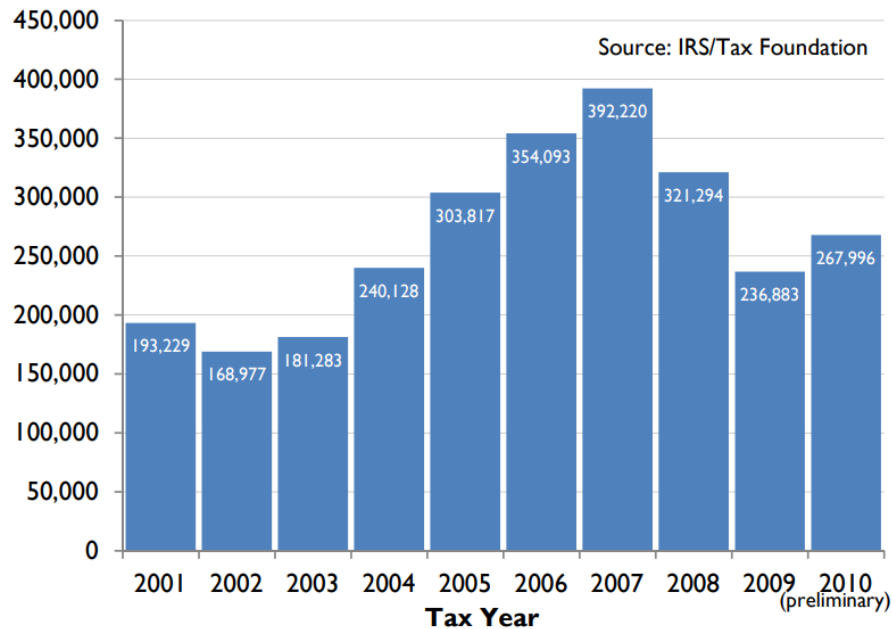
Suborbital lunar hops



Countries of astronauts (Wikipedia – AstroFreak92)

Financing: Private Settlement

**Chart I: The Number of Millionaire Tax Returns
Fluctuates Considerably from Year to Year**



(IRS – Tax Foundation)



Sun City, Phoenix, AZ (Google Maps)

Beyond the Moon

Use of a Lunar Outpost for Developing Space Settlement Technologies

Lloyd R. Purves, NASA Goddard Space Flight Center, Greenbelt, MD, 20771*

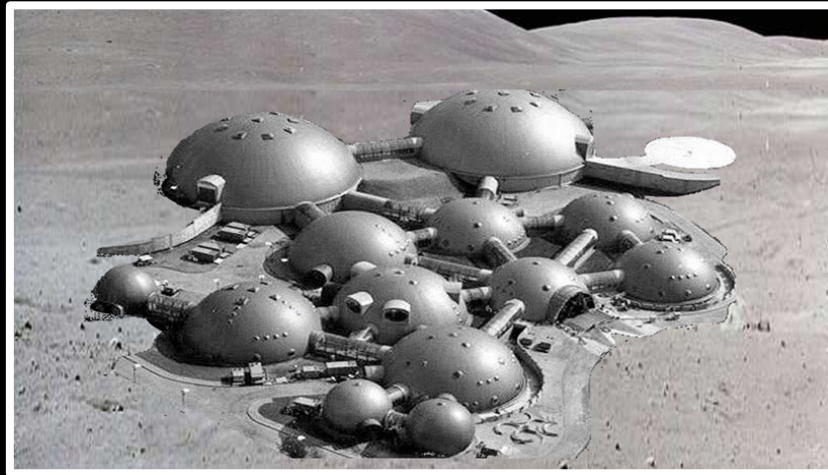
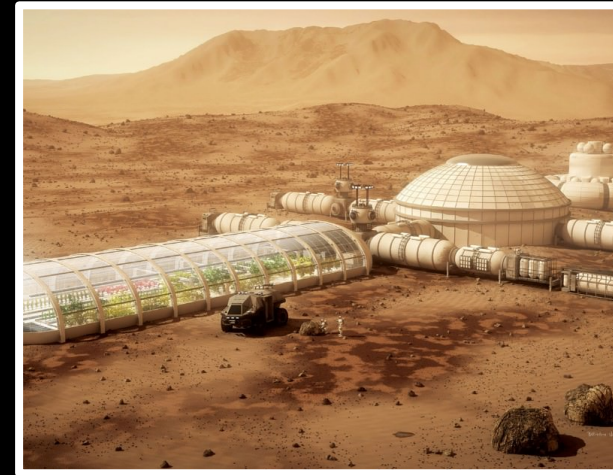


Illustration of a lunar base adapted from Radio Muzyka Fakty (Poland)



Credit: Bryan Versteeg

Summary

Phases

1. Prospecting
2. Telerobotic
3. Initial crewed
4. International, suborbital, lunar exploration
5. Private settlement

Funding

1. NASA
2. Lunar COTS
3. Lunar COTS
4. Sovereign clients
5. Savings

References

A. Colaprete, et al. "Detection of Water in the LCROSS Ejecta Plume", Science 22 Oct 2010: Vol. 330, Issue 6003, pp. 463-468.

A. F. Zuniga, et al. "Kickstarting a New Era of Lunar Industrialization via Campaigns of Lunar COTS Missions", AIAA SPACE 2016, AIAA SPACE Forum, (AIAA 2016-5220)

D. R. Andrews, et al. "Introducing the Resource Prospector (RP) Mission", AIAA SPACE 2014 Conference and Exposition, AIAA SPACE Forum, (AIAA 2014-4378)

M. Duke, et al. "Mining of Lunar polar ice", 36th AIAA Aerospace Sciences Meeting and Exhibit, Aerospace Sciences Meetings, <https://doi.org/10.2514/6.1998-1069>

L. Purves. "Use of Lunar Outpost for Developing Space Settlement Technologies", AIAA SPACE 2008 Conference & Exposition, AIAA SPACE Forum, <https://doi.org/10.2514/6.2008-7680>