

THE VALUE OF PERFORMANCE.
NORTHROP GRUMMAN

PHM for Space Systems

*Where we're going, how we'll get there,
and why PHM is important*

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Where are we going?

What do we need to get there?

- What are the pieces?
- What are the challenges?

How does PHM relate?

Where Are We Going?



Mars Lander



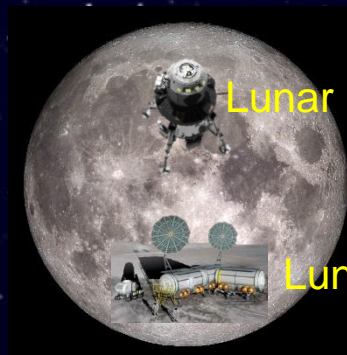
Mars Outpost



Deep Space Transport



Lunar Lander



Lunar Outpost



Lunar Orbital Platform



Orion

ISS



Earth image from: https://www.nasa.gov/multimedia/imagegallery/image_feature_2159.html
Moon image from: <https://moon.nasa.gov/resources/77/the-near-side-of-the-moon/>
ISS image from: <https://www.newscientist.com/article/2205935-nasa-will-let-people-pay-to-stay-on-the-international-space-station/>
Orion image from: https://www.researchgate.net/figure/Orion-spacecraft-Image-credit-Analytical-Mechanics-Associates-Johnson-Space-Center_fig5_269049229
Lander image from: <https://www.lockheedmartin.com/content/dam/lockheed-martin/space/documents/ahead/LM-Crewed-Lunar-Lander-from-Gateway-IAC-2018-Rev1.pdf>
Outpost image from: https://www.nasa.gov/50th_magazine/futureExploration.html
DST image from: https://nvlite.jsc.nasa.gov/presentations/b2/D1_Mars_Conolly.pdf
Mars image from: http://upload.wikimedia.org/wikipedia/commons/b/b8/2005_1103mars-full.jpg
Mars outpost image from: https://www.nasa.gov/sites/default/files/thumbnails/image/mih_fig-3_cloudsac-search_crewarrives.jpg

Comparing Destinations

220 miles
45 minutes to Earth



EARTH FROM ISS

240,000 miles
5 days to Earth



EARTH FROM THE MOON

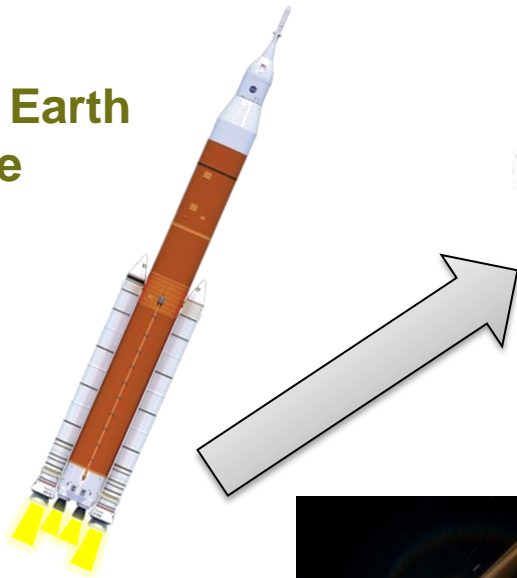
57 - 240 million miles
>180 days to Earth



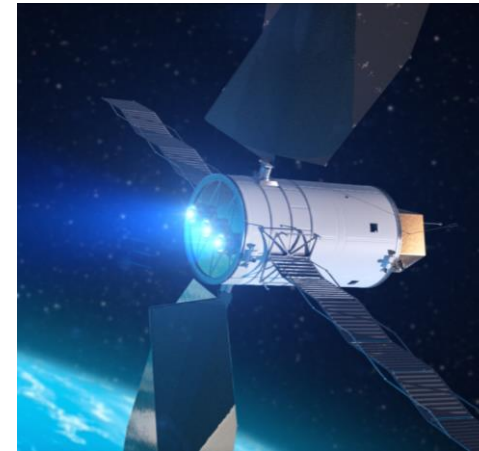
EARTH FROM MARS

Six Major Pieces for Crewed Flight

1. From Earth to Space

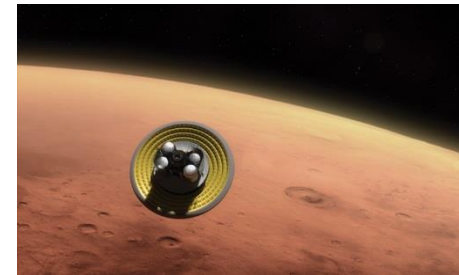


2. Living in Space

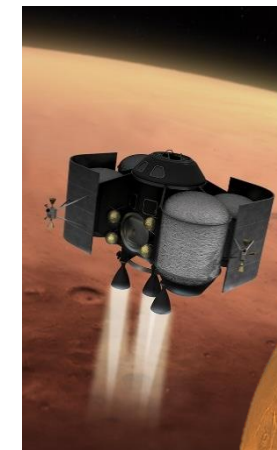


3. Moving Around in Space

4. Down to Other Surface from Space



5. Up from Other Surface to Space



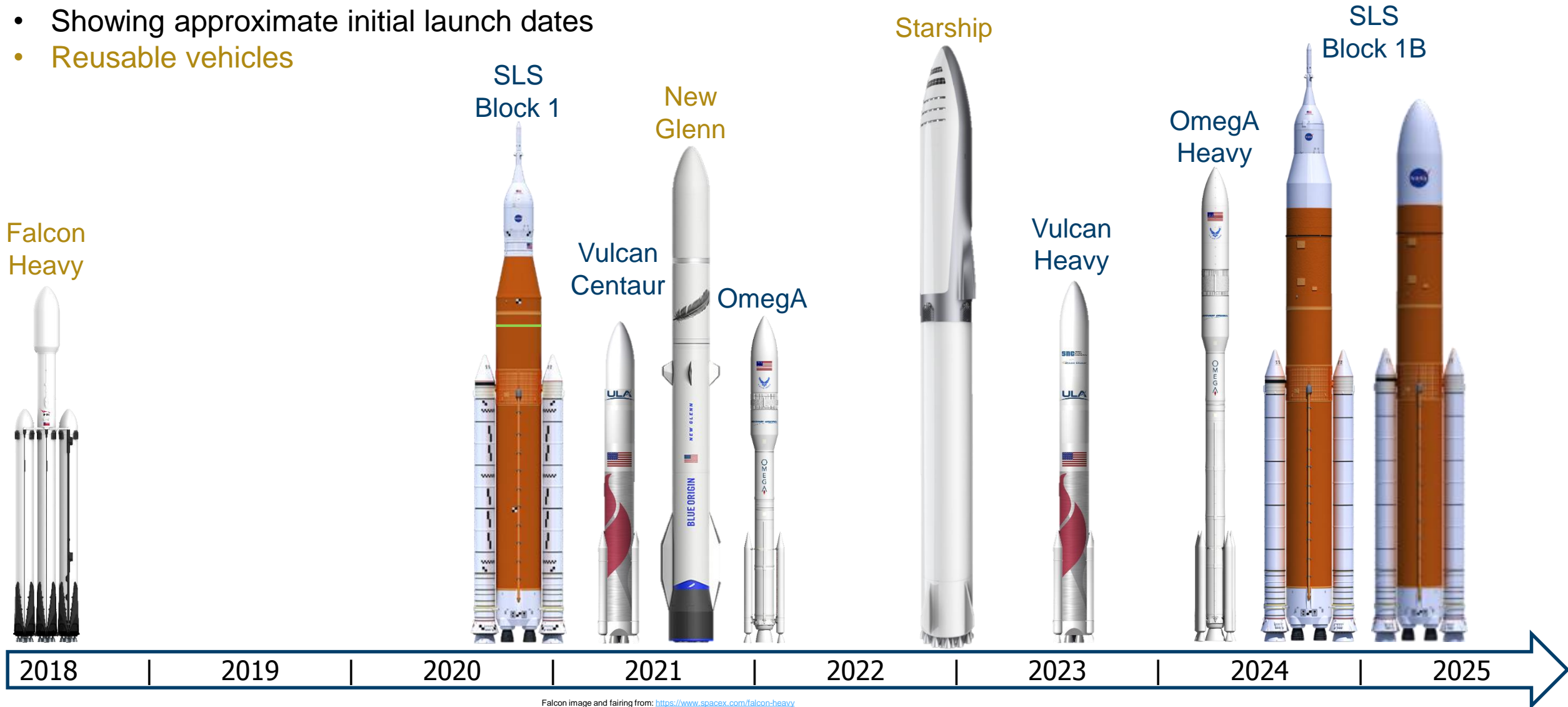
6. Down to Earth from Space



Sources:
Image of Earth from: http://upload.wikimedia.org/wikipedia/commons/7/7e/The_Earth_seen_from_Apollo_17_with_white_background.jpg
Image of Mars: <https://www.jpl.nasa.gov/news/news.php?feature=6267>
Orion re-entry image from: https://planetary.s3.amazonaws.com/assets/images/spacecraft/2014/20141106_eft-1-orion-reentry.jpg
SEP spacecraft image from: <https://www1.grc.nasa.gov/space/sep/#lightbox-gallery-1-4>
Mars lander image from: https://aviationweek.com/site-files/aviationweek.com/files/uploads/2015/05/DF-MARSASCENT_3_NASA.jpg
MAV image from: https://aviationweek.com/site-files/aviationweek.com/files/uploads/2015/05/DF-MARSASCENT_1_NASA.jpg

Launch Vehicles – Heavy and Super Heavy Classes

- Showing approximate initial launch dates
- Reusable vehicles

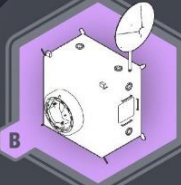
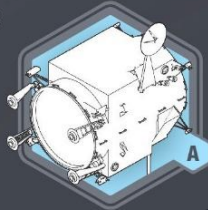


Falcon image and fairing from: <https://www.spacex.com/falcon-heavy>
 Vulcan image from: <https://www.americaspace.com/wp-content/uploads/2019/08/Vulcan-Centaur-DC-Poster-1.jpg>
 New Glenn image and fairing from: <https://www.blueorigin.com/new-glenn>
 Starship/Heavy image from: https://www.spacex.com/sites/spacex/files/making_life_multiplanetary-2017.pdf

These modules must be deployed prior to Orion

Power and Propulsion Element:

Power, communications, attitude control, and orbit control and transfer capabilities for the Gateway.

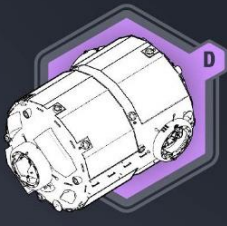


ESPRIT:

Science airlock, additional propellant storage with refueling, and advanced lunar telecommunications capabilities.

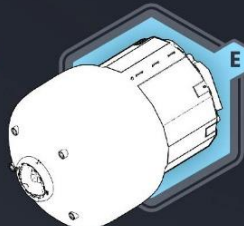
U.S. Utilization Module:

Small pressurized volume for additional habitation capability.



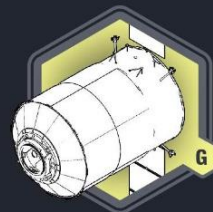
Habitation Modules:

Pressurized volumes with environmental control and life support, fire detection and suppression, water storage and distribution.



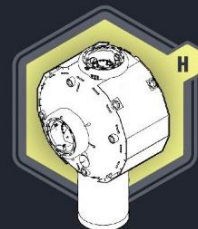
Robotic Arm:

Mechanical arm to berth and inspect vehicles, install science payloads.



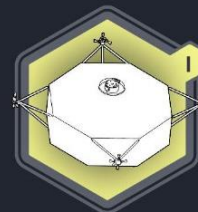
Logistics and Utilization:

Cargo deliveries of consumables and equipment. Modules may double as additional utilization volume.



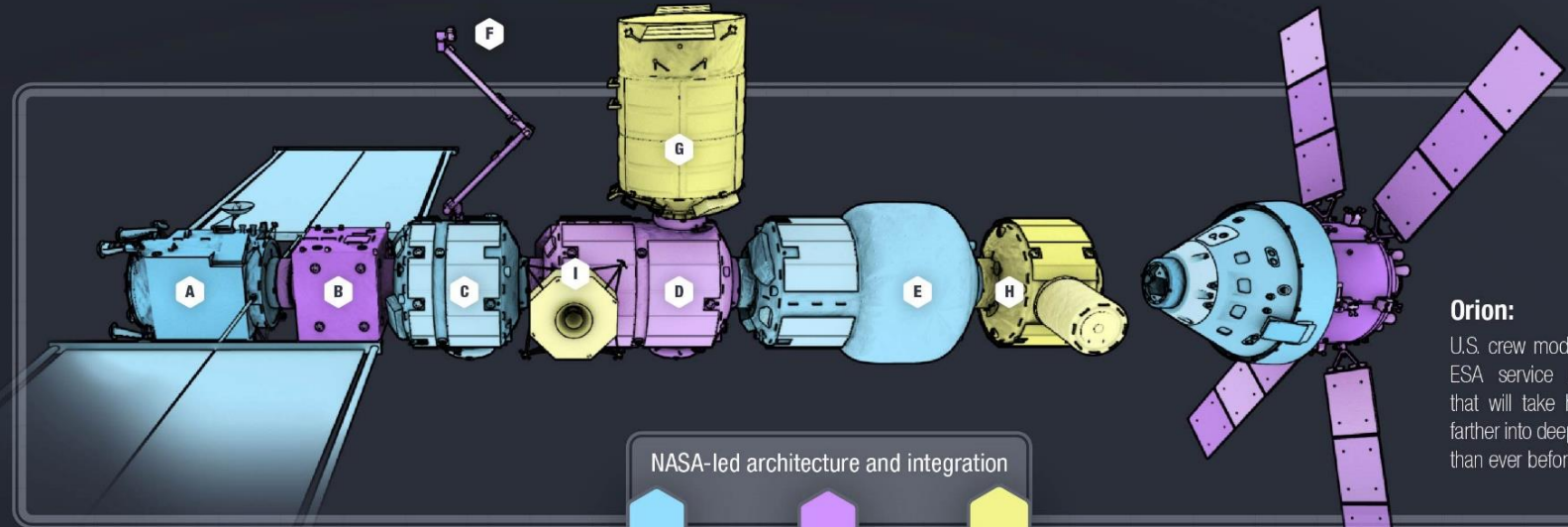
Airlock:

Enables spacewalks, potential to accommodate docking elements.



Sample Return Vehicle:

A robotic vehicle capable of delivering small samples or payloads from the lunar surface to the Gateway.



NASA-led architecture and integration

U.S.

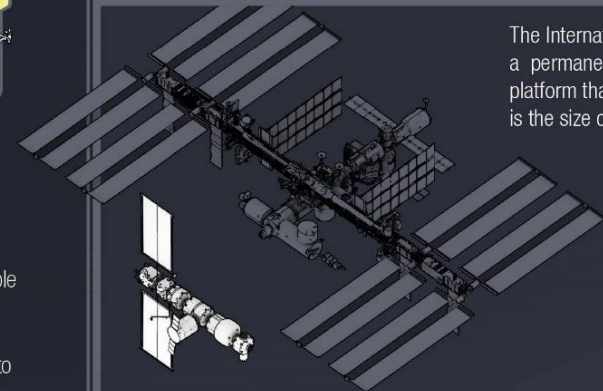
International

TBD: U.S. and/or International

Orion:

U.S. crew module with ESA service module that will take humans farther into deep space than ever before.

Gateway Compared to the International Space Station



The International Space Station is a permanently crewed research platform that has 11 modules and is the size of a football field.

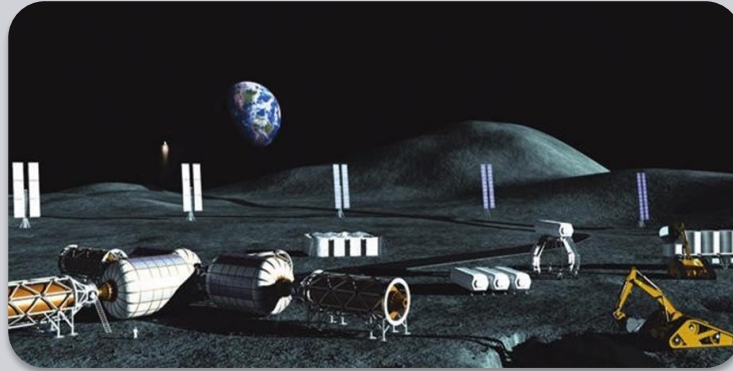
The Gateway is a much smaller, more focused platform for extending initial human activities into the area around the Moon.

Lunar Landing → Lunar Outpost



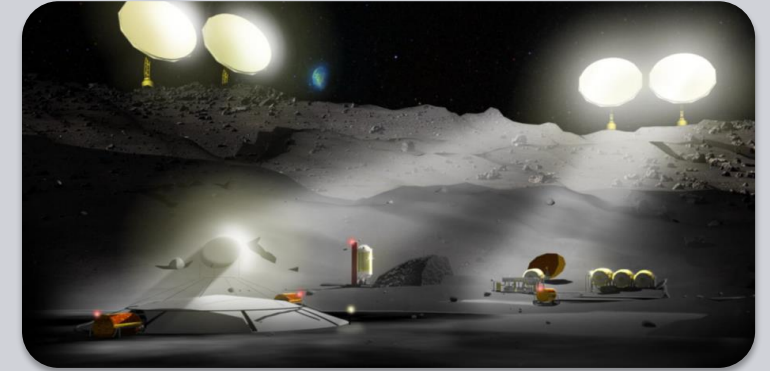
Lunar Lander

- Planned for 2024
- Stage from/to Gateway



Lunar Outpost

- Build Up Over Time
 - Habitats
 - Rovers
 - Power
- Crewed Only Sporadically



Lunar Mining

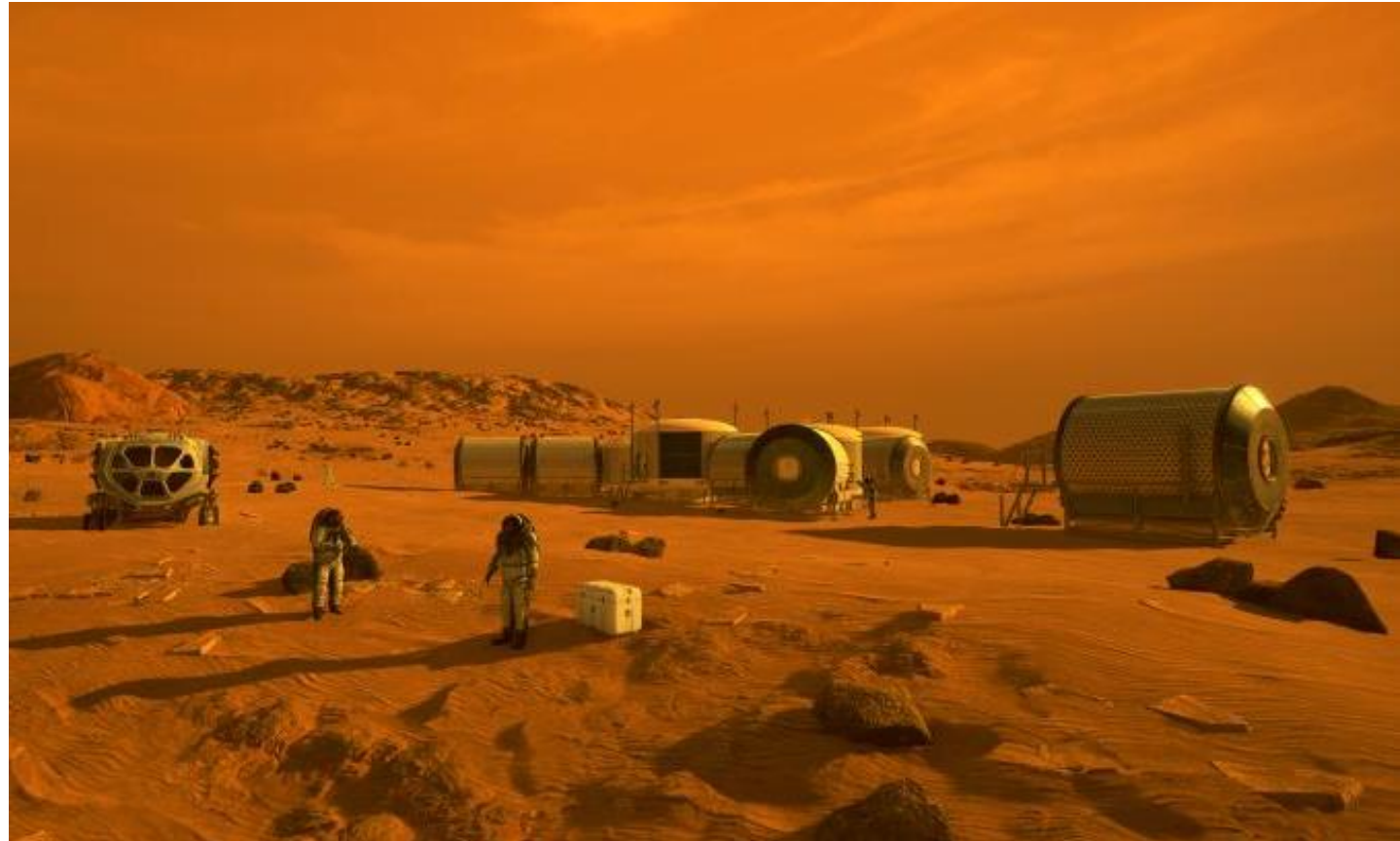
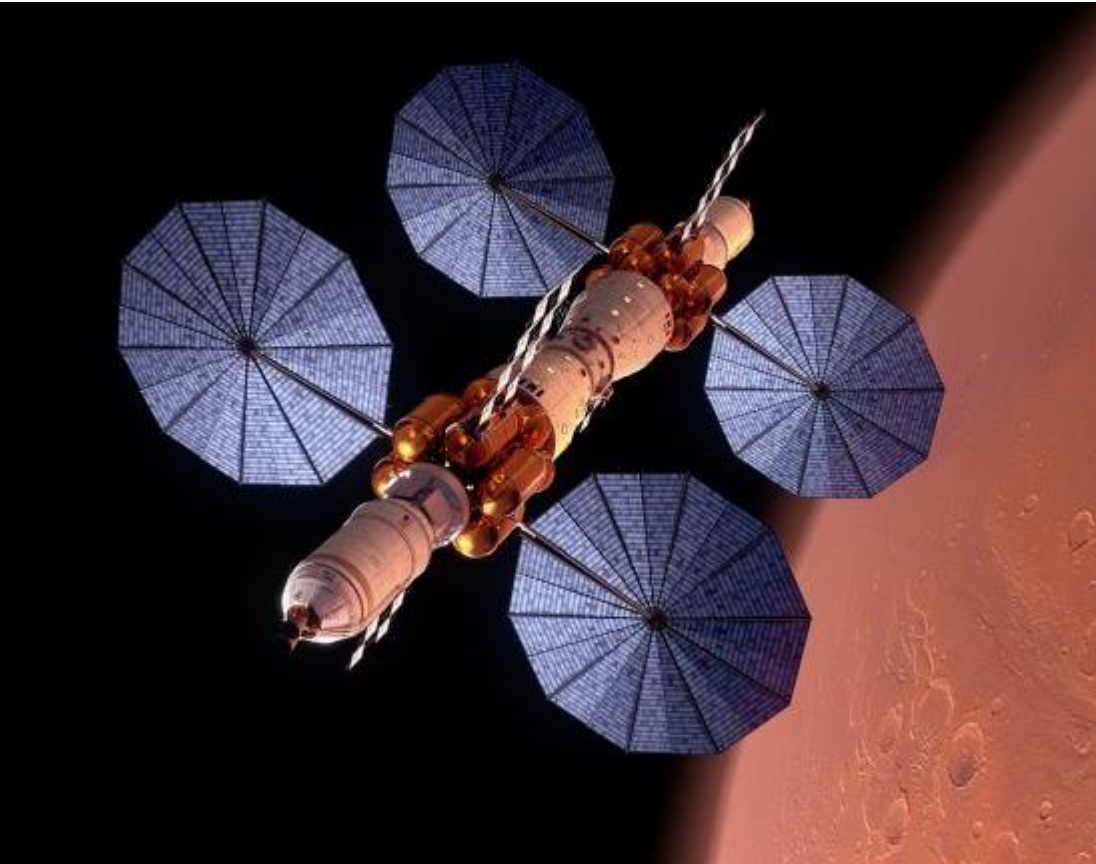
- Remote / Un-crewed Operations
- Mining Lunar Water for Propellant
 - Harvest
 - Separate
 - Transfer
 - Store
- Mining Rare Metals

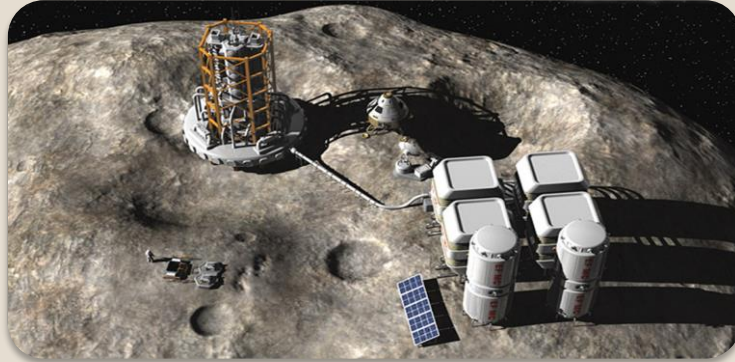
In-Space Transport

- Habitat
- Power
- Propulsion
- Propellant Storage

Mars Outpost

- Habitat
- Rovers
- Power
- ISRU (In-Situ Resource Utilization)
- Ascent





Mining

- Asteroids
- Water
- Rare Metals

Tourism

- Hotels
- Trips

Science

- Earth Observation
- Deep Space Observation
- Low Gravity Studies

Space is Hard!

Launch Vehicle

- Able to Lift Payload (mass)
- Able to Fit Payload (volume)
- Cost / Schedule

Crew Capsule

- Deliver Crew

Lunar Lander

- Deceleration/Retropropulsion
- Targeting
- Having Propellant
- Storing Propellant at Temp
- Engine Ignition
- Stages
- Crew Habitat
- Not Impacting Existing Hardware
- Rendezvous



On Moon

- Supplies
- Health
- Dust
- Temperature
- Very Low Gravity
- ISRU – H2O for ECLSS and Prop
- EVA
- Science
- Sample Return

Deep Space Habitat

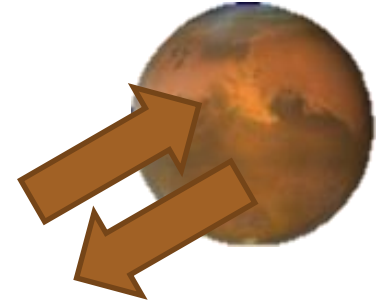
- Radiation Protection
- Micrometeorite Protection
- Microgravity
- ECLSS
- Supplies
- Health – Physiological
- Health – Psychological
- Communication
- Airlock / EVA
- Dormancy / Robotic Ops
- Rendezvous and Docking
- Trajectory / Mission Planning

In-space Propulsion

- Power
- Time of Flight
- Mass Fraction
- Fuel Storage
- Refueling
- Thrust and Isp

Mars Lander

- Aerocapture
- Supersonic Deceleration
- Supersonic Retropropulsion
- Targeting
- Not Impacting Existing Hardware



Mars Ascent Vehicle

- Having Propellant
- Storing Propellant at Temp
- Engine Ignition
- Stages
- Crew Habitat
- Not Impacting Existing Hardware
- Rendezvous

On Mars

- Temperature
- Supplies
- Health
- Dust
- Low Gravity
- Planetary Protection
- ISRU – LOX for ECLSS and MAV
- EVA
- Science
- Sample Return

Earth Re-entry Vehicle

- Supersonic Deceleration
- Landing



Sources:
 Image of Earth from: http://upload.wikimedia.org/wikipedia/commons/7/7e/The_Earth_seen_from_Apollo_17_with_white_background.jpg
 Moon image from: https://www.nasa.gov/centers/langley/images/content/528691main_Super_Moon.jpg
 Image of Mars: <http://upload.wikimedia.org/wikipedia/commons/b/b8/2005-1103mars-full.jpg>

Prognostics and Health Management

• Examples Using Lunar Orbiting Platform

ECLSS (Environmental Controls / Life Support System)

- O₂ Levels
- CO₂ Levels / Removals
- Humidity Levels
- Temperature Controls
- Water Recycling
- Waste Management
- Fire Detection and Suppression

GN&C (Guidance, Navigation, and Control)

- Location Detection
- Navigation
- EDAC (Error Detection and Correction)

Communication

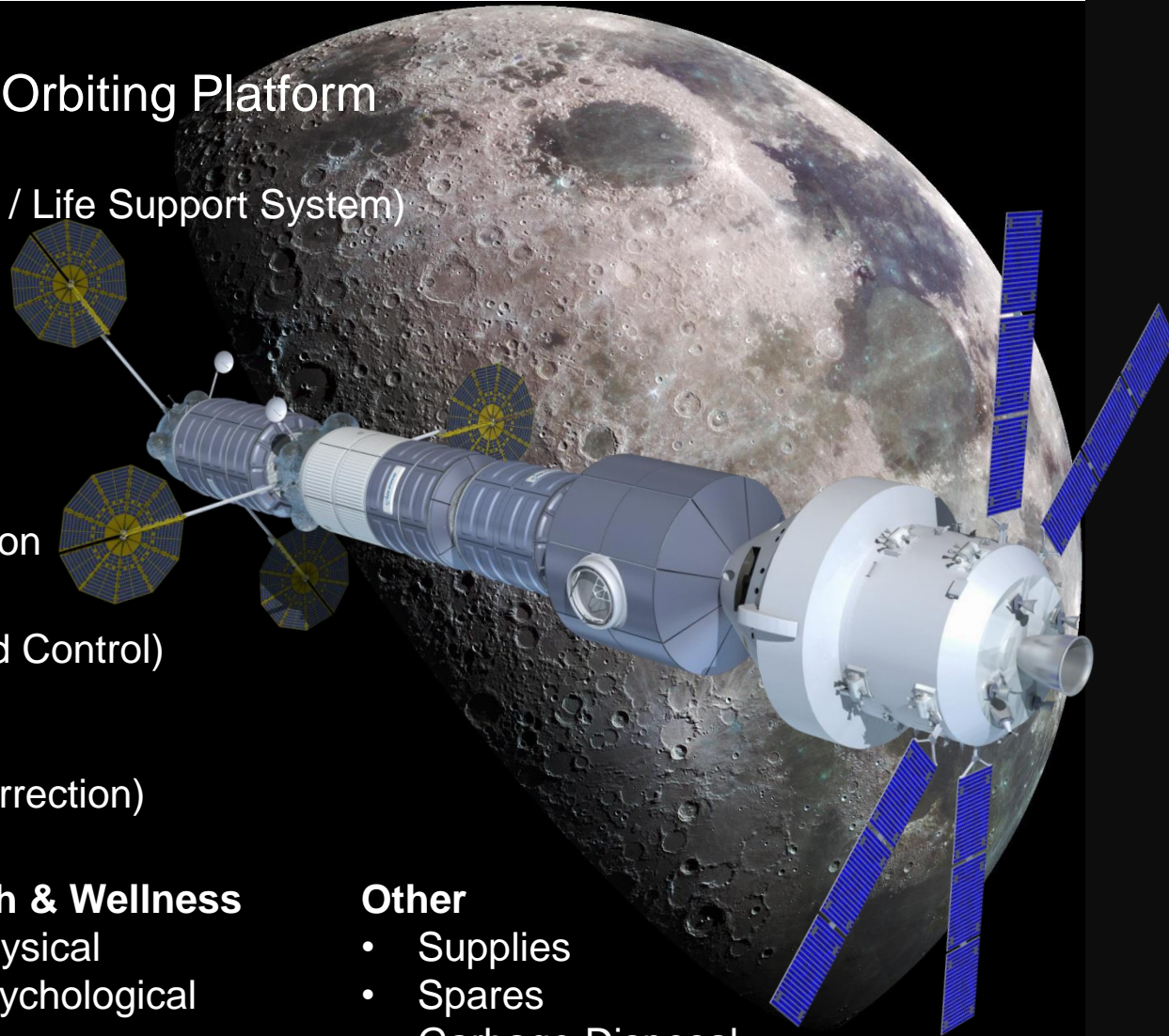
- Downlinks
- Uplinks
- Delay

Health & Wellness

- Physical
- Psychological

Other

- Supplies
- Spares
- Garbage Disposal



Shell

- Habitat Integrity
- Micrometeorite Protection
- Radiation Protection
- Temperature Fluctuations
- Material Degradation

Power

- Solar Array Life
- Solar Array Alignment
- Battery Life
- Distribution

Propulsion

- Ignitions
- Engine Life
- Propellant Storage
- Propellant Transfer

Both crewed and remotely operated

THE VALUE OF PERFORMANCE.

NORTHROP GRUMMAN

