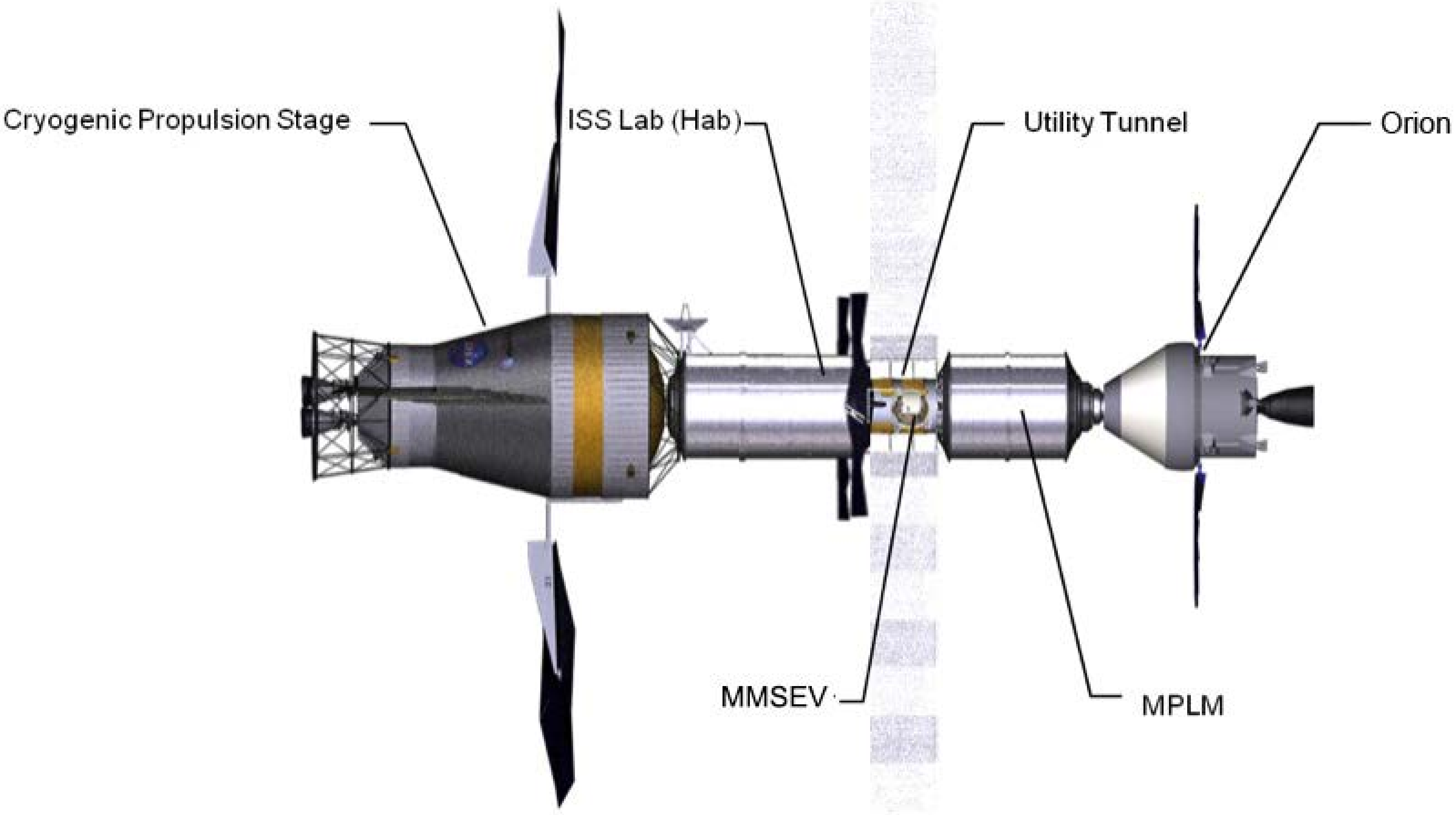
Lunar Lighthouse

Dr. Michael Evans
NASA/Johnson Space Center (JSC)
Astromaterials Reseach and Exploration Science (ARES)
Planetary Scientist

EVOLUTION OF NASA’S LUNAR PLAN
Deep Space Habitat (2012)

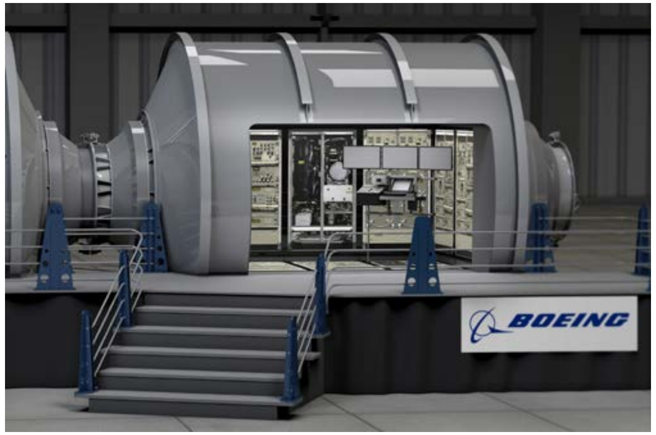


http://www.nasa.gov/exploration/technology/deep_space_habitat/constructing-demonstrators.html https://www.nasa.gov/feature/nextstep-partnerships-develop-ground-prototypes

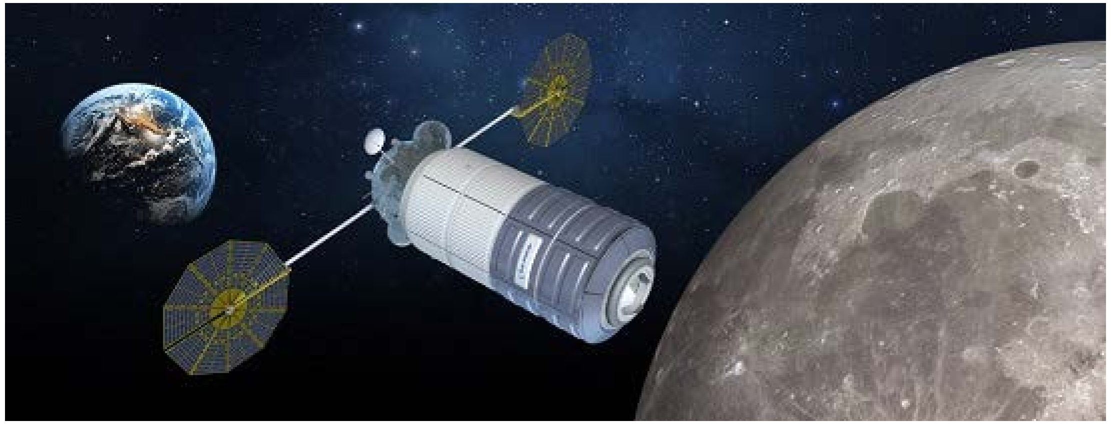
NextSTEP Concepts (2016)

Sierra Nevada concept


Lockheed Martin concept

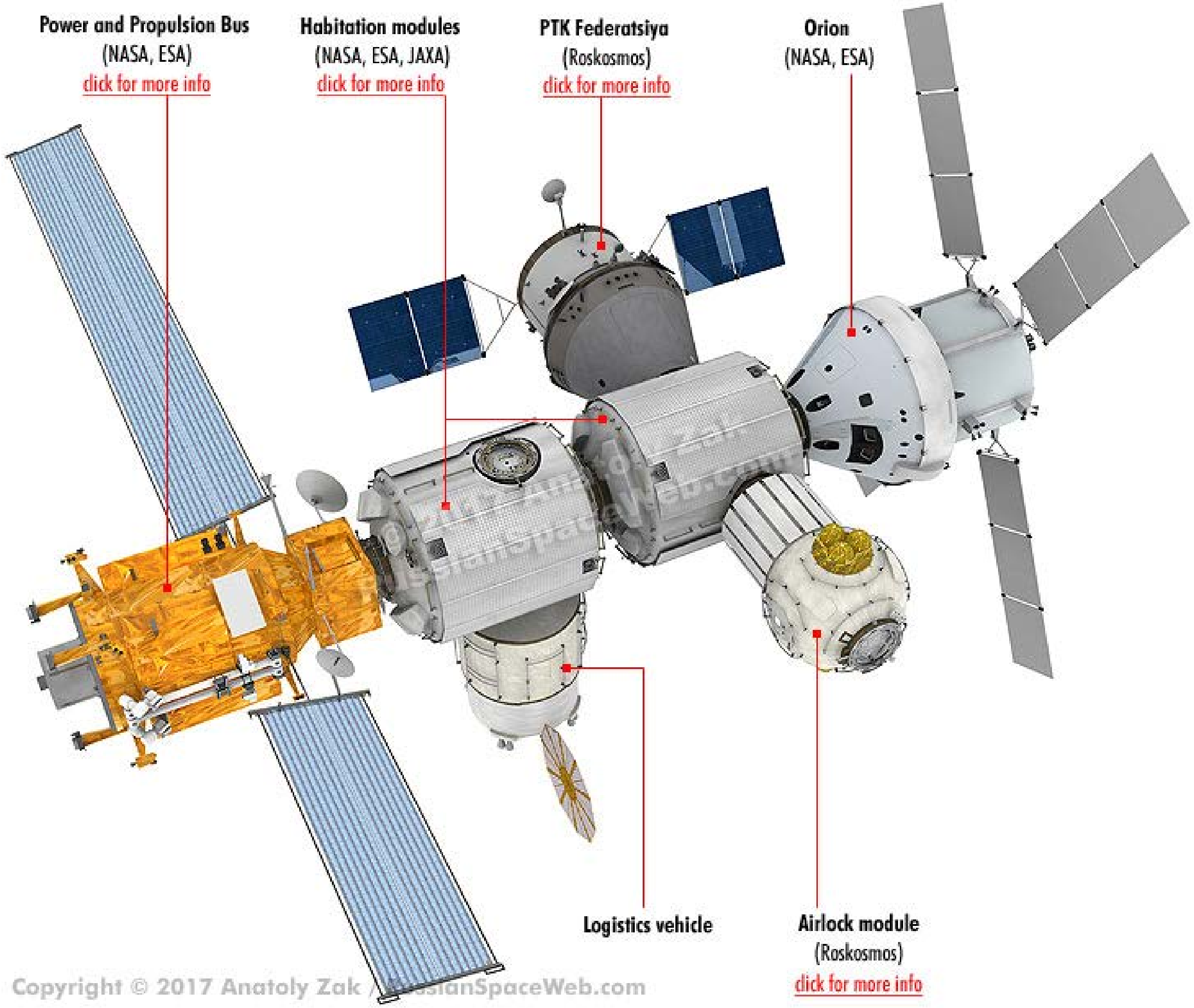


Boeing concept


Orbital ATK (Cygnus) concept

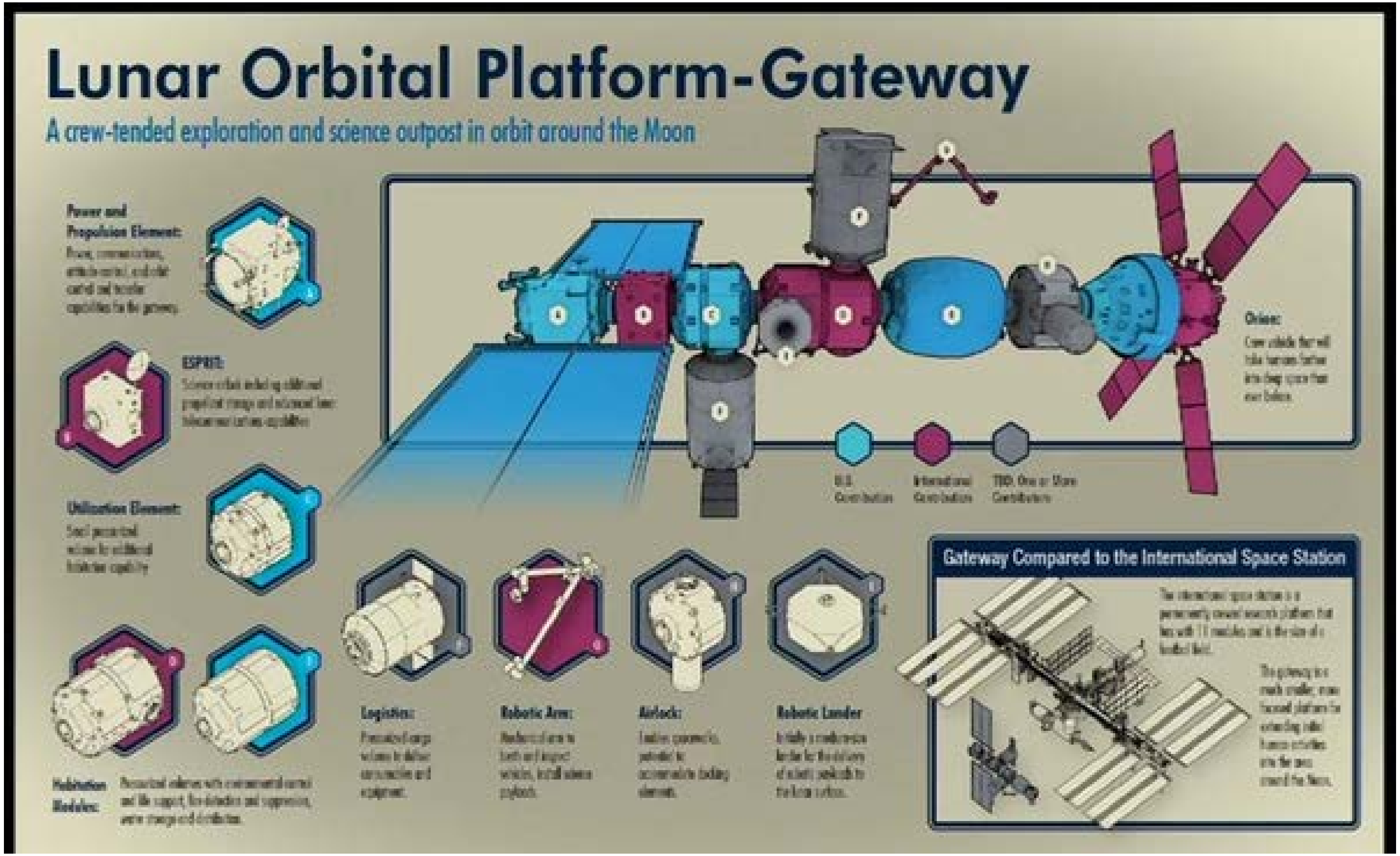

Bigelow concept, https://observer.com/2019/09/nasa-bigelow-b330-space-habitat-lunar-gateway/

Deep Space Gateway (2017)



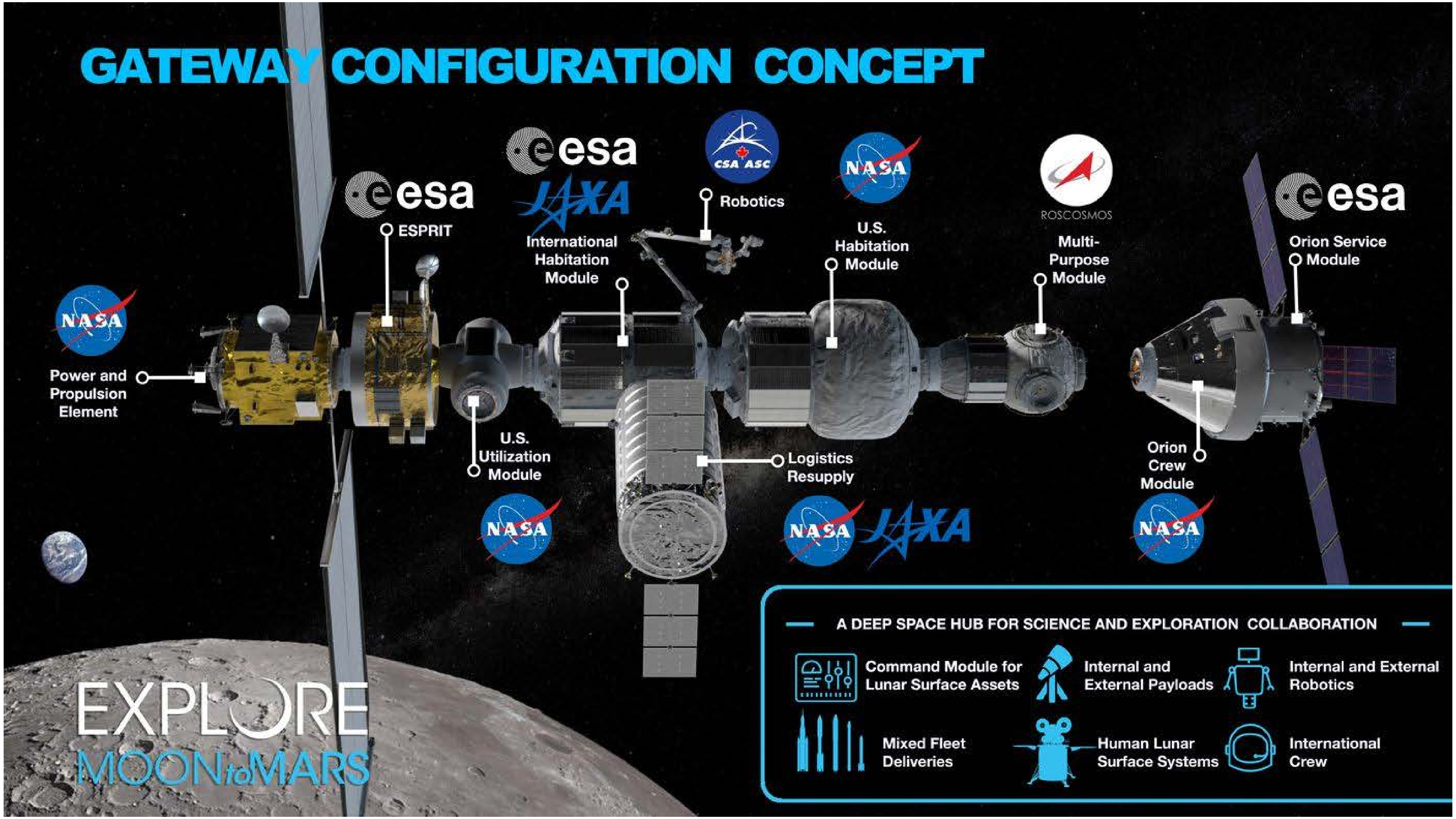
http://www.russianspaceweb.com/imp-2017.html

Lunar Orbital Platform – Gateway (2018)



http://thespacereview.com/article/3529/1

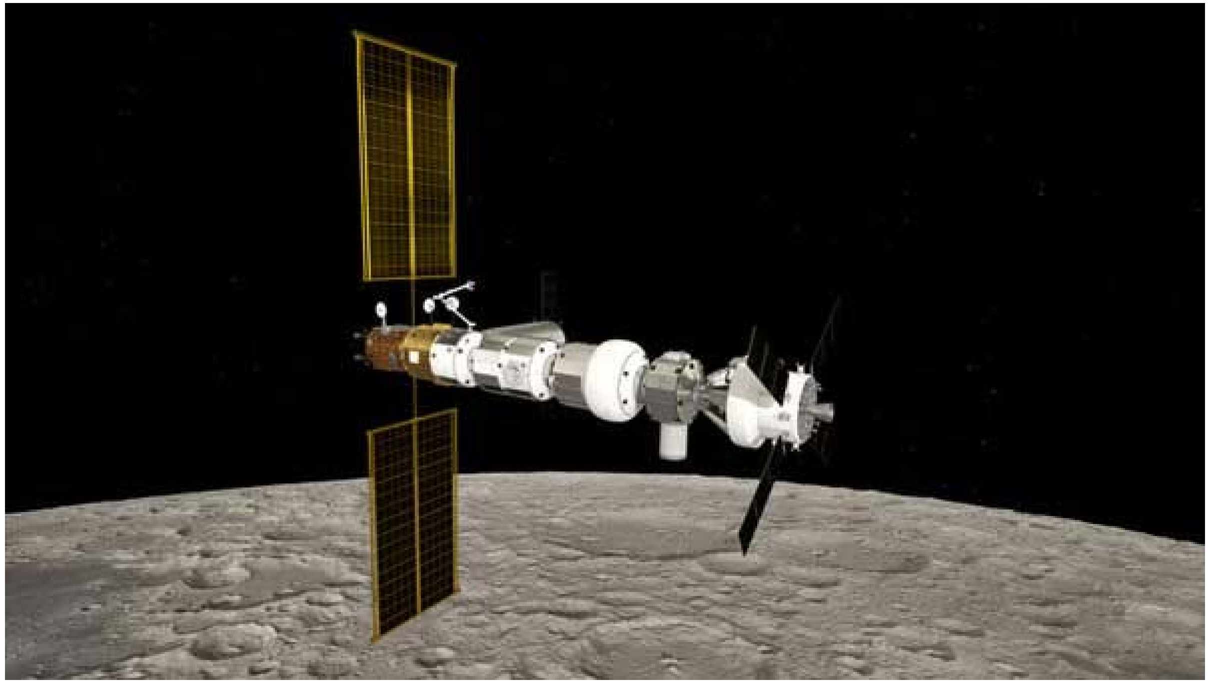
bigger Gateway (2019)



https://www.nasa.gov/feature/multilateral-coordination-board-joint-statement

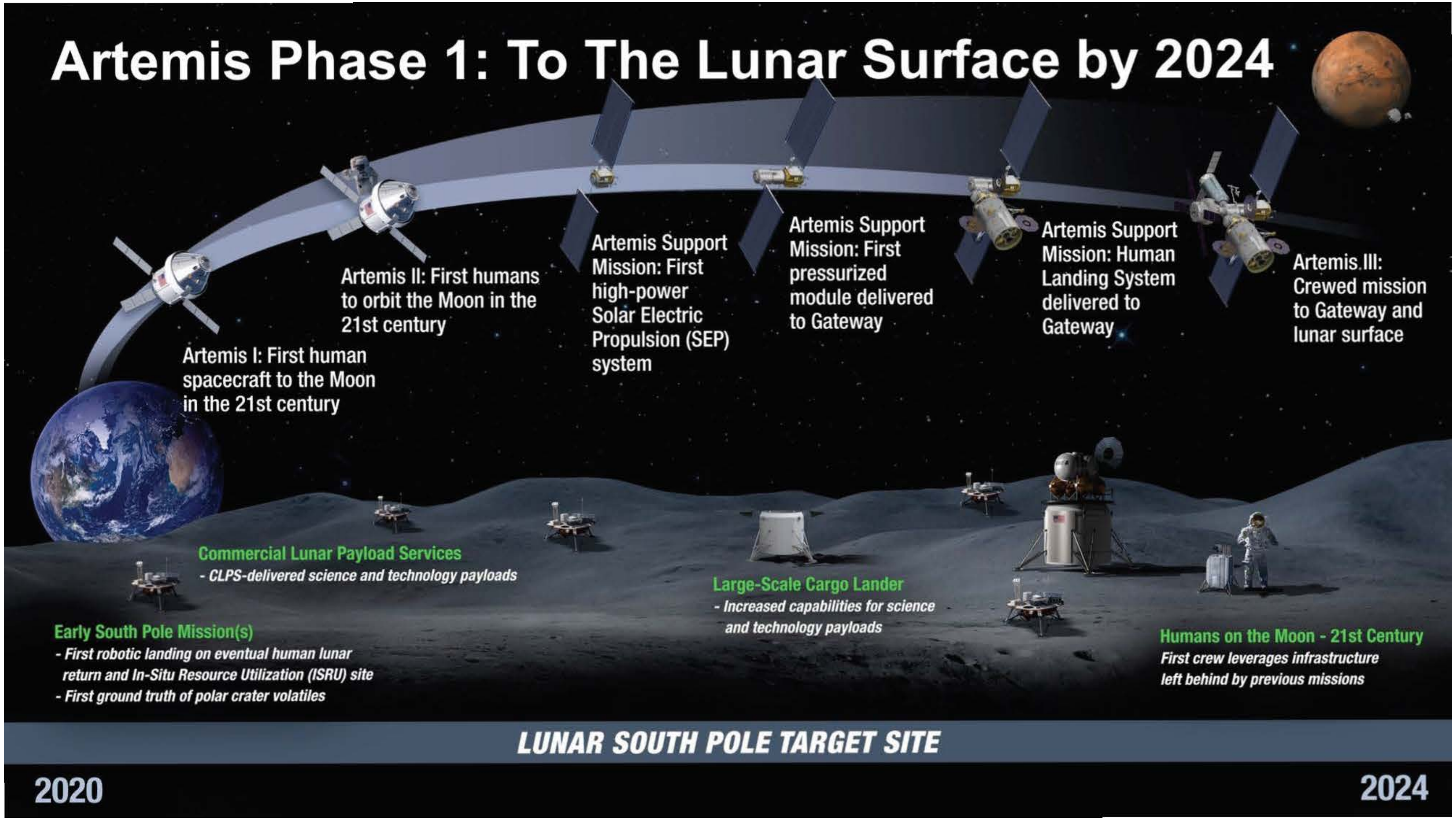
smaller Gateway (2019)

https://spacenews.com/industry-wants-nasa-to-move-ahead-quickly-on-gateway-module/



http://www.parabolicarc.com/tag/lunar-gateway/

NASA Artemis Program (2019)



https://www.nasa.gov/press-release/nasa-administrator-to-make-artemis-moon-program-announcement-media-teleconference-set

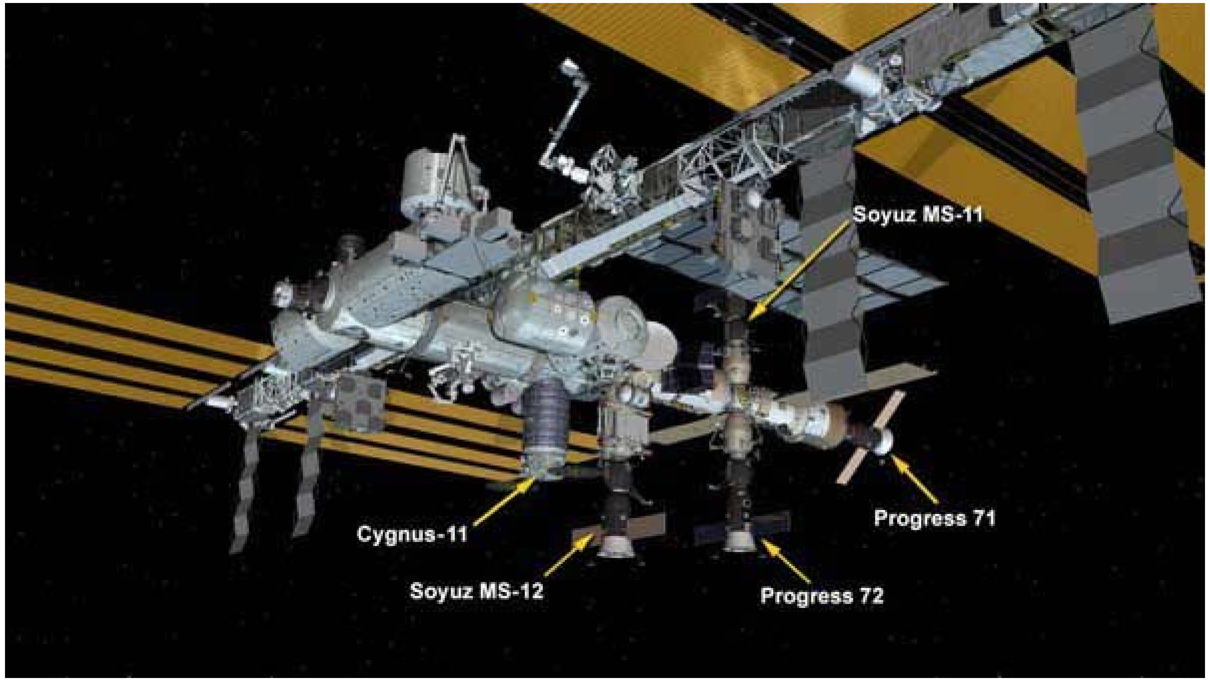
Power and Propulsion Element (PPE) by MAXAR

http://www.russianspaceweb.com/imp-ppb.html

http://www.parabolicarc.com/2019/05/23/maxar-teams-blue-origin-draper-lunar-gateway-power-propulsion-element/

http://www.satnews.com/story.php?number=1232377005

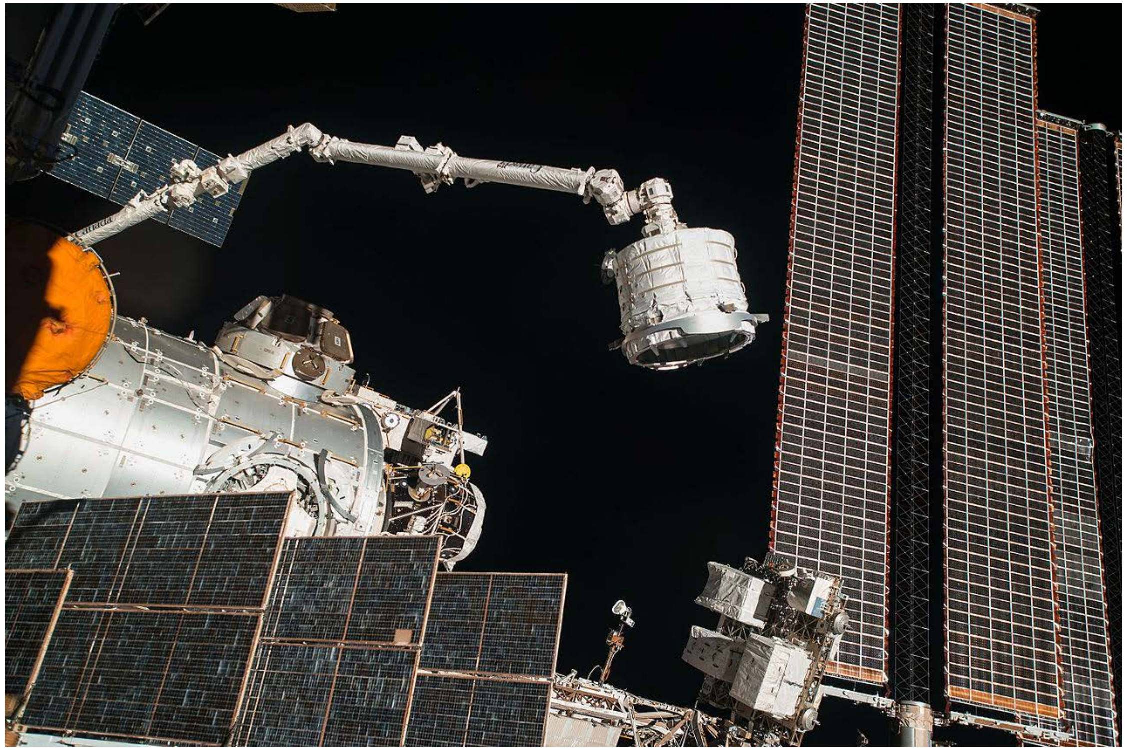
MiniHab (modified Cygnus Module) by Northrop Grumman



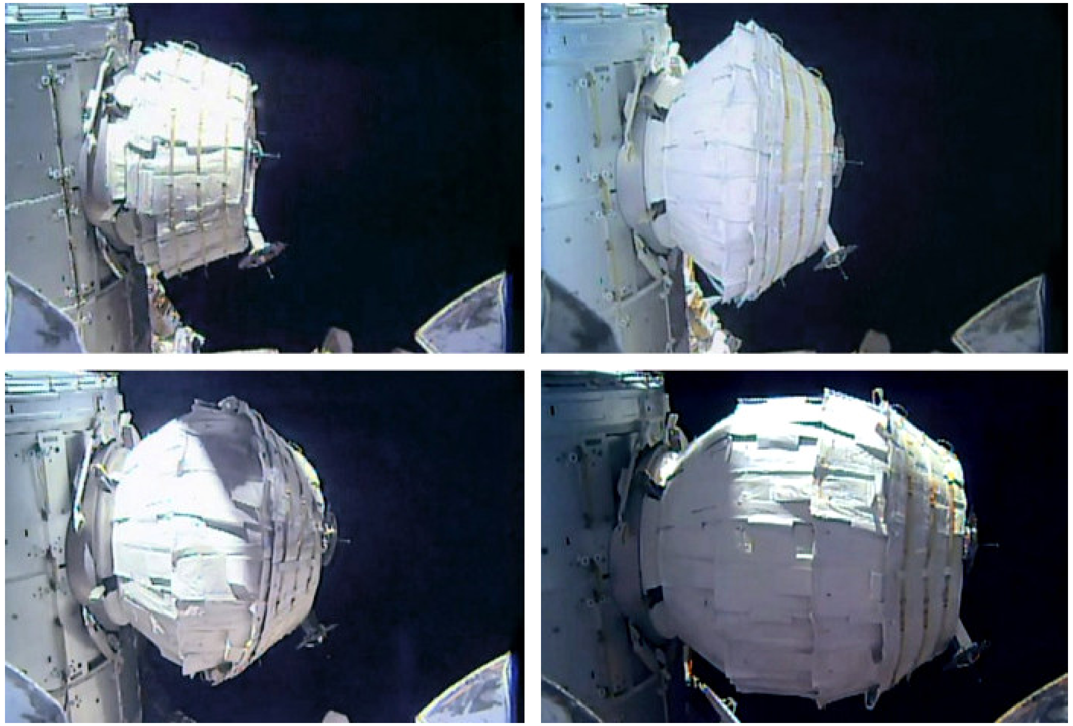
Proposed “MiniHab” for Gateway (without docking ports)
https://spacenews.com/nasa-to-sole-source-gateway-habitation-module-to-northrop-grumman/

Cygnus Module on ISS:
http://cdn.parabolicarc.com/wp-content/uploads/2019/04/ISS_april192019.jpg

Inflatable Habitation Module (ISS Deployment of Bigelow module)



Installation of stowed Bigelow Expandable Activity Module (BEAM) on ISS
https://www.flickr.com/photos/nasa2explore/26523207085/



Inflation of Bigelow Expandable Activity Module (BEAM) on ISS
http://www.planetary.org/multimedia/space-images/spacecraft/beam-expansion-progress.html

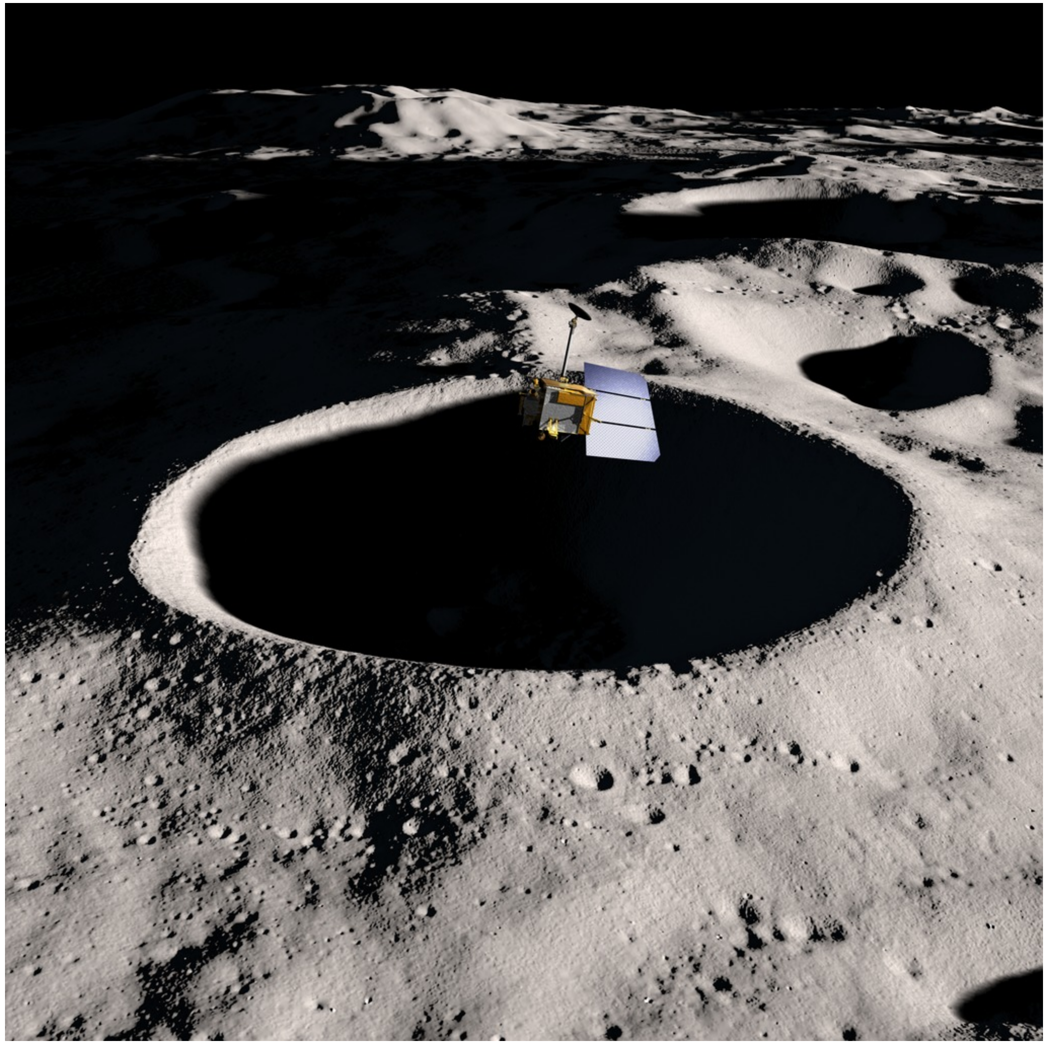
Statement of the Problem

NASA Space Policy Directive 1

"Beginning with missions beyond low-Earth orbit, the United States will lead the return of humans to the Moon for long-term exploration and utilization, followed by human missions to Mars and other destinations" (Trump, 12/11/17)

Exploration of the lunar South Pole region has a number of unique challenges:

- Very steep slopes in large craters (Shackleton Crater at the South Pole)
- Persistently Illuminated Regions (PIRs) provide regions of nearly constant sunlight
- Deep Permanently Shadowed Regions (PSRs) are very cold and never sunlight, and may contain volatiles and water ice (some are very close to the PIRs)



LRO Flies Over Shackleton Crater Near South Pole

Statement of the Problem (cont.)

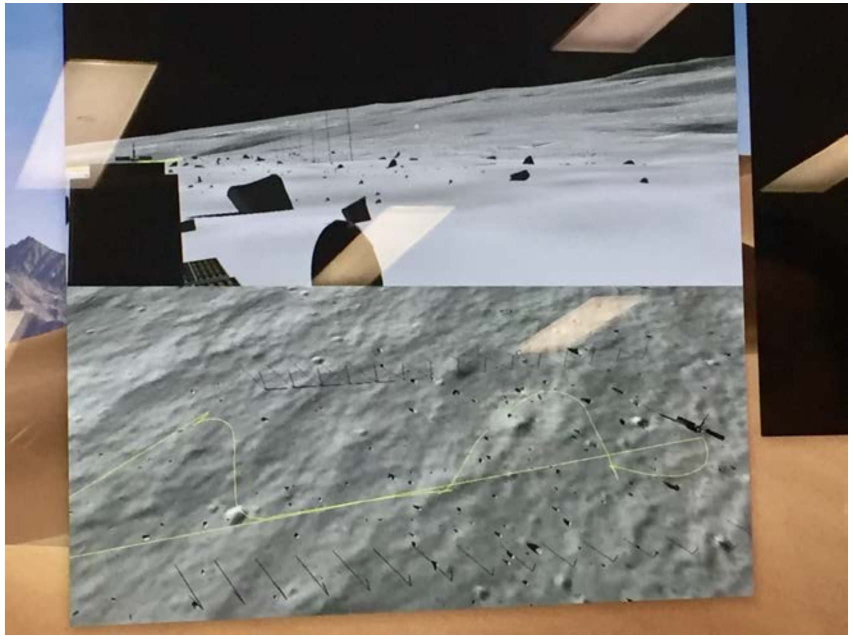
- The bottom of the PSRs have one of the coldest locations in the Solar System
  - Temperatures are from 40-80^{o}K
  - Lunar Crater Observation and Sensing Satellite (LCROSS) Centaur-booster impact showed possible lunar water ice deposits in the ”cold traps” of the PSRs.
  - LCROSS also indicated possible ice contaminants of sulfur, argon and other elements (important for human safety)
  - Lunar Reconnaissance Orbiter (LRO) continues imaging much of the lunar surface, including PSR’s.

1. How can RFID technology provide sensors for accurate environmental measurements and elemental composition in PSRs and other inaccessible planetary regions?


LRO Image of Shackleton Crater Rim

Statement of the Problem (cont.)

- Remote sensing of lunar water ice detection is difficult (e.g. IR use in a PSR would show “solid black”), therefore in-situ measurement is most desirable.
  - Sensors have limited capability due to short battery life.
  - Sensors have limited proximity due to extreme cold
- Telerobotic traverses using rovers on the surface (i.e. <1m elevation) present significant issues for navigation (no “Gods Eye” view, unlike our simulation). On a stark, featureless terrain it is difficult to find/identify specific destinations.



2. How can RFID technology provide easily deployed, accurate, relative navigation sensors for telerobotic traverses on planetary bodies?

Prior Research

"Lunar and NEO Geophysical and Relative Navigation Instrument" (978-1-4577-0557 2012 IEEE), by NASA/JSC Lee Graham & Patrick Fink

- After publication, created the NASA/JSC professional development class for system engineers and project management training
- Analog simulation for science exploration of Near Earth Objects (NEOs)

- 4 drones each deployed 10 pucks (embedded with SAW RFID sensor)
  - Temperature sensors embedded in pucks provided to each team
  - Each team designed and built a puck deployment system for the drone
  - Pucks were dropped onto sand surface, pebble, and asphalt surfaces
- Small rover with transceiver driven in field by each team
  - Transponder pinged each sensor and temperature data was recorded
  - Erroneous data from pucks not firmly grounded on surface material
  - Teams were evaluated on puck deployment design and sensor results

Potential RFID Passive Sensors

- Temperature

  Temperature determination on the floor of the PSR provides partial verification of a lunar surface environments model and conditions for frozen volatiles

- Elemental Detection: Hydrogen (H)

  Provides for detection of lunar water ice (H_2O) or hydrated regolith

- Elemental Detection: Sulfur (S), Argon (Ar), etc.

  Provides for detection of volatile contaminants for development of crew protection from exposure to hazardous material (e.g. H_2S)

- Radiation:

  NASA/KSC/Dr. Jackie Quinn is developing a RFID based radiation sensor in potential collaboration with NASA/JSC/ARES

- Position determination

  Local location precision based upon knowledge of sensor placement

Combinations of any of the above!

Draft Concept of Operations

- Deployment of the RFID chips is planned to be done by rover, human presence is therefore not required.
  - The longer the deployment range the better (>100m)
  - The deployment operation must be able to reach the bottom of the PSR.
- The rover is operated either autonomously or teleoperation.
  - The rover has an inertial measurement unit (IMU) that is tracking movement and location of the rover.
- Once the chip is deployed, the rover will "ping" the chip with a directional antenna to obtain the initial position fix, and obtain the initial science output (e.g. temperature and H_2 concentrations.)

Draft Concept of Operations (cont.)

- The rover will then move on to another location approximately 100-200m further and deploy another RFID chip.
  - Note: What chip type is deployed (i.e. sensing H_2, argon, radiation, etc.) will be dependent on the chip types available in the dispenser and what is needed in the next location. An extremely large PSR, for example, may require multiple chips to provide an accurate assessment of material available.
- Once several chips are deployed, an accurate signal triangulation can be done to determine a precise fix on the rover location.
- This deployment and sensing operation will continue so as to provide a large local “GPS-like” navigation capability.