MITCHELL INSTITUTE
for Aerospace Studies

Securing Cislunar Space and the First Island Off the Coast of Earth

Charles Galbreath

Senior Resident Fellow For Space Studies

Spacepower Advantage Center of Excellence

“The universe is an ocean, the Moon is the Diaoyu Islands, Mars is Huangyan Island. If we don’t go there now even though we’re capable of doing so, then we will be blamed by our descendants. If others go there, then they will take over, and you won’t be able to go even if you want to. This is reason enough.”

Ye Peijian, Lead for the Chinese Lunar Exploration Program, 2015

“We choose to go to the Moon in this decade and do the other things not because they are easy, but because they are hard. Because that goal will serve to organize and measure the best of our energies and skills, because that challenge is one that we’re willing to accept.”

President John F. Kennedy, 1962

Earthrise: Apollo 8, the first manned mission to the Moon, entered lunar orbit on Christmas Eve, Dec. 24, 1968.
https://www.nasa.gov/image-article/earthrise-3/

The Space Force and US Space Command must take steps today to secure cislunar national interests

- The United States and China are in a race to harness the national security, economic, and scientific benefits of the Moon and cislunar regime
- China views this race as a key element to replace the United States as the world leader
- The Chinese territorial approach to the cislunar regime contrasts starkly with the efforts of the U.S. Artemis Accords—a voluntary multinational agreement to establish norms of cooperation and peaceful collaboration space
- To win the new race to the Moon, the U.S. military will need to establish an infrastructure that fosters scientific and economic activities, as well as the means to secure those activities
- Congress must support and fund additive growth in the Space Force and U.S. Space Command to secure the peaceful advance of U.S. national interests in the cislunar environment
- Modest, early investment will simultaneously accelerate U.S. and allied efforts and reduce the future need for larger investments to overcome an advantage ceded to China

"Secure our Nation's interests in, from, and to space"
USSF Mission Statement

New Thinking for a New Domain

Space Doctrine Publication 3.0 defines three orbital regimes based on the dominant gravitational force in the region.

Geocentric Regime. The geocentric regime is where Earth's gravity dominates, and objects follow orbital trajectories relative to the Earth.

Cislunar Regime. The cislunar regime, *characterized by the combined gravitational effects of the Earth and Moon*, includes translunar space between these bodies, the Earth-Moon Lagrange points, and orbits around the Moon.

Solar Regime. The Sun's massive gravitational field defines the solar regime, where planets and other objects in the solar system orbit around the Sun.

- Our thinking on space as a separate and distinct domain continues to mature
- As space capabilities move further from Earth their utility to directly support terrestrial operations and interests decreases—the "high ground" analogy becomes less applicable
- A more appropriate analogy is moving from brown/green water to blue water
- The cislunar regime and the Moon, as the first "island" in blue water, is an early opportunity to exercise this new thinking and establish precedents
- We now see the development of new interests that will require preservation for their own sake

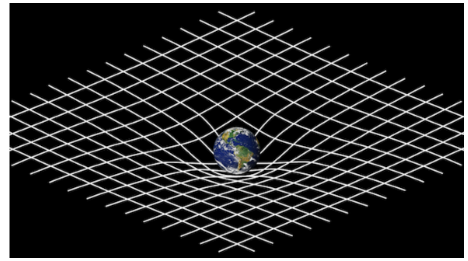
We are entering era where space activities, objectives, and interests are supported by other domains without a direct reciprocal benefit

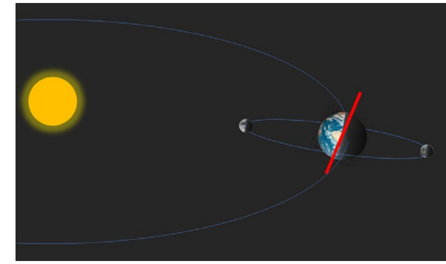
Cislunar 101

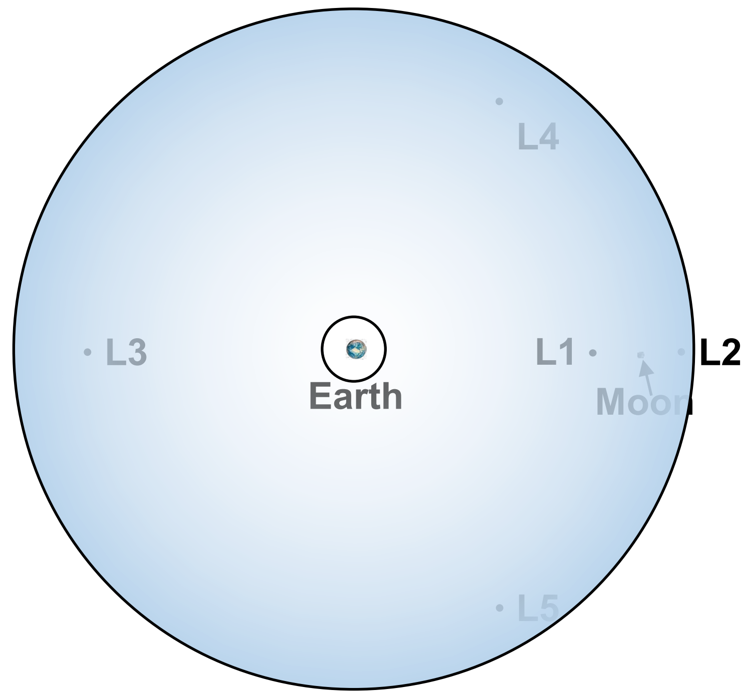
Cislunar Terms of Reference

<u>Gravity Well:</u> The mass of the Earth can be thought of as warping space around it, in the same way a heavy ball placed on a fabric surface creates an indentation. The resulting "gravity well" has a larger influence on objects closer to the center or "deeper" in the well. As an object moves further away, or "up the gravity well," the force exerted on it by the Earth's mass decreases.

<u>2-Body and 3-Body Problems:</u> For satellites orbiting the Earth in the geocentric regime, the forces influencing their path are well established. Known as a two-body problem, the major factors are the masses of the two bodies, in this case the Earth and satellite, and the distance between them. There are solved equations governing the motion of satellites in this regime. **However, in the cislunar regime, the additional gravitational force of the Moon significantly complicates the equations of motion.** Known as a three-body problem, the major factors are the masses of the three bodies, now Earth, satellite, and Moon, and the distances between the Earth and Moon, Earth and satellite, Moon and satellite. There is no general solution for the trajectory of an object in a three-body problem. In the cislunar regime, there are a few special locations where the gravitational pull of the Earth and the Moon balance and an equilibrium is attained. These positions are known as Lagrange points.

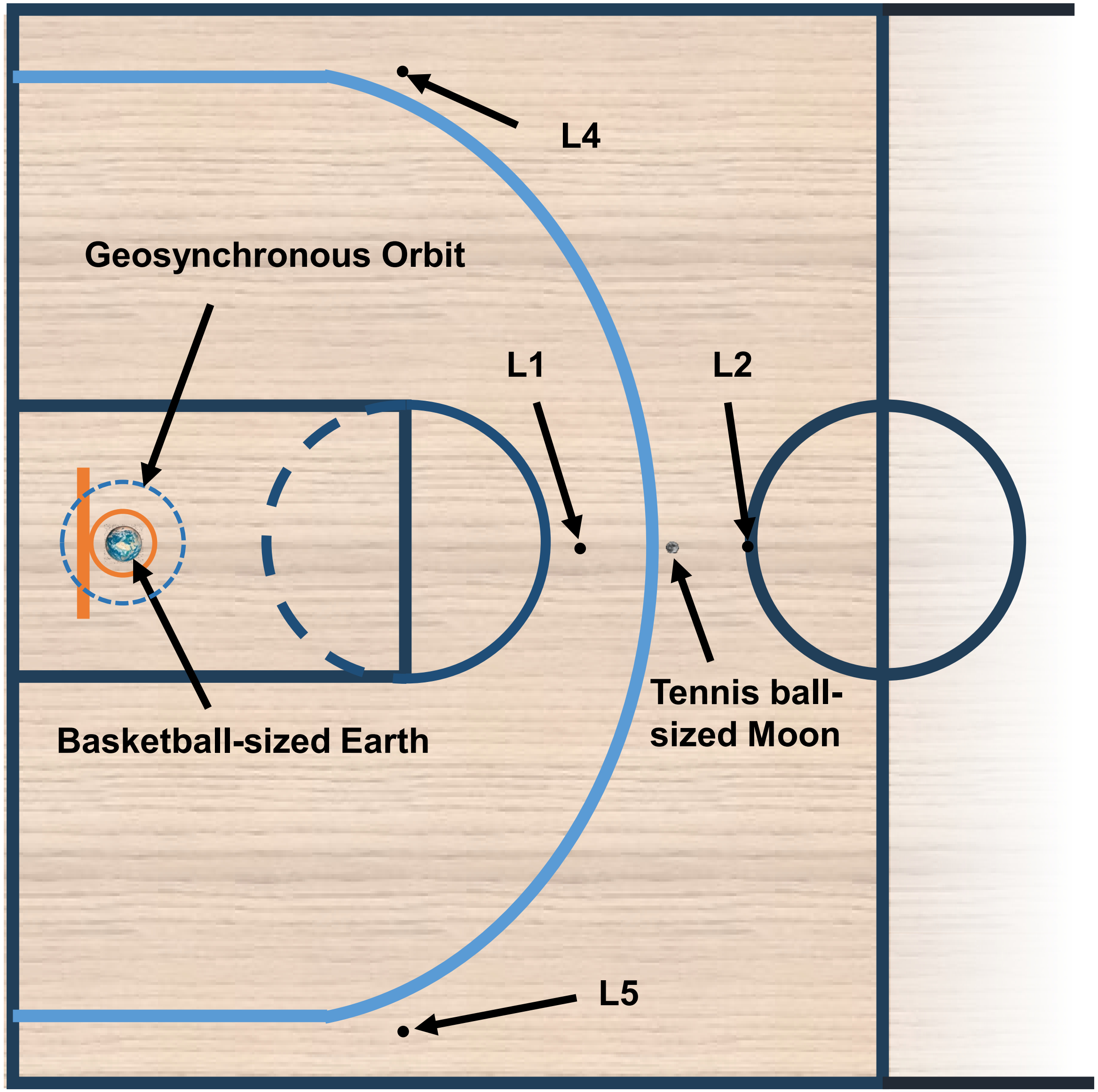






Earth orbit satellite determination models are insufficient for cislunar trajectories

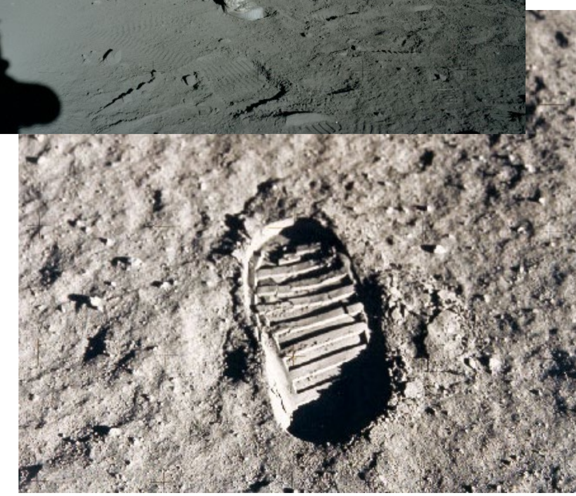
Cislunar Basketball—The Challenge of Scale



- The average distance from the Earth to the Moon is 238,900 miles—over 9 times the circumference of the Earth
- Maintaining domain awareness in such a large volume of space will require new sensors and processing systems
- The Earth/Moon/Sun geometry further complicate cislunar domain awareness and operations

Lunar Surface Challenges

- Solar and cosmic radiation
  - Unblocked by atmosphere or magnetic field, radiation primarily from the Sun bombards the lunar surface
  - Significant risks to human health & electronic systems
- Regolith—lunar dust
  - Jagged, small, electrostatically charged particles formed by heat and force of meteor impacts
  - Unworn by atmospheric or water erosion, and exposed to billions of years of solar radiation and charged plasma from the Sun
  - Easily spreads during landing and launch operations in the low lunar gravity
  - Poses risk to respiration, electric systems, and mechanical systems



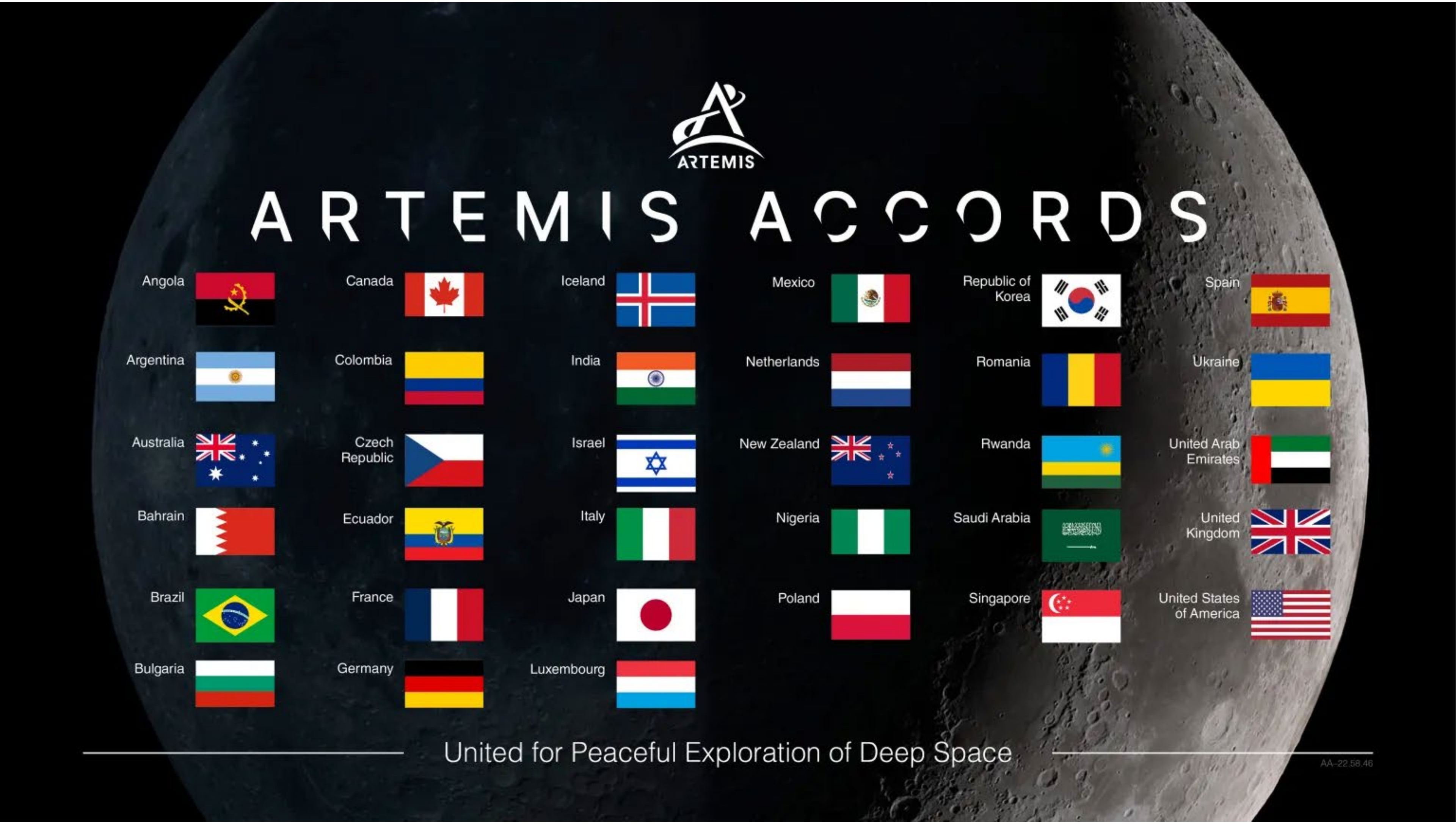
- Extreme temperatures
  - With no atmosphere to regulate it, temperatures range from 250°F to -208°F
  - In craters near the Moon’s poles, NASA has recorded temperatures lower than -410°F
  - Temperature extremes and swings pose a challenge to human presence and material expansion/contraction can make materials brittle and wear out connections

Why Race to the Moon?

- National security implications of cislunar operations affecting geocentric space operations and growing interests in space
- Economic opportunities tied to deposits of potential fuel sources and Rare Earth Minerals
- Scientific interests tied to specific regions of the lunar surface and surrounding space
  - Shielded Zone of the Moon (SZM) for radio astronomy
  - South Pole craters for insight into the formation of the solar system
  - Lunar ice as source of oxygen and hydrogen
  - As a proving ground for further development and exploration
- Illustration of national prestige and power that will shape the geopolitical landscape on Earth

Establish a precedent for future exploration and operations

Growing Partners



https://www.nasa.gov/artemis-accords/ as of December 11, 2023

What Threatens Cislunar Success?

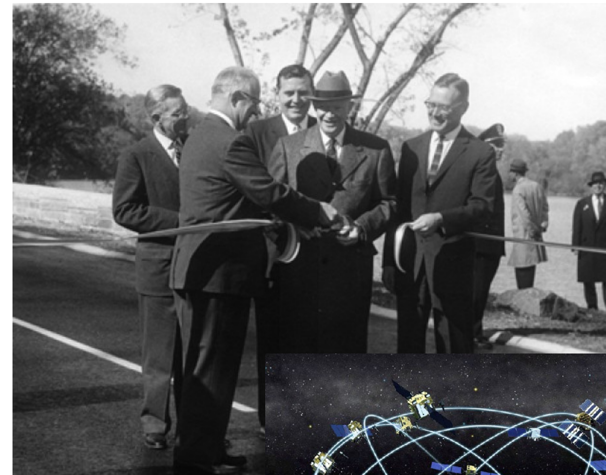
- Mutually reenforcing issues
  - The lack of established international norms for lunar exploration and resource extraction
  - The territorial mindsets of China and Russia
- In the Western Pacific, we have seen repeated and increasingly aggressive behavior to exert territorial control and defy international standards

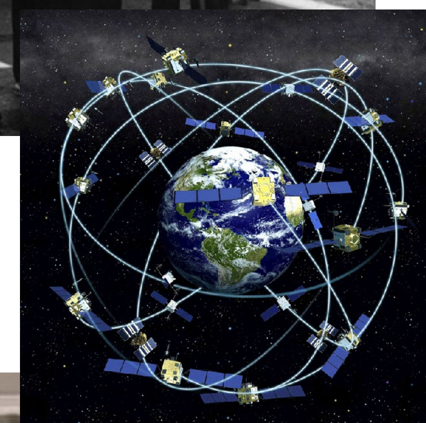
- If China establishes a "scientific" station in or near a region of shared interest, they could require a keep-out zone to not interfere with the research, effectively seizing that region
- Of note, China already has a communication satellite and rover on the far side of the Moon

China seeks to be the preeminent global power and sees leading in cislunar space as vital steps toward that objective

The Case for Military Involvement

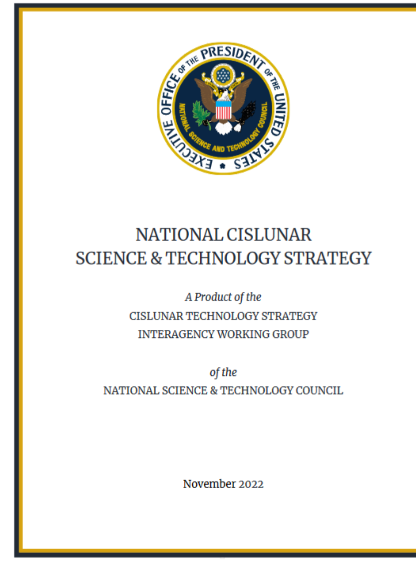
- The US Military has a long history of early exploration and development securing the way for civil and commercial opportunities
  - Capt Lewis and Lt Clark
  - Interstate Highway System
  - ICBMS to rockets and ranges
  - Internet
  - Global Positioning System
- USSF and US Space Command will need to have capabilities to secure growing cislunar interests and assure freedom of cislunar operations
  - Domain Awareness
  - Communication
  - Navigation and Timing
  - Maneuver
  - Power Distribution





Building Success

- Considerations for DOD Involvement
  - DOD is in a supporting role to civil and commercial enterprises
  - DOD support to cislunar activities requires additive resources
  - Incremental investments made early will reduce need for large expenditures later with higher risk
- DOD efforts must start with foundational elements
  - Develop a DOD Cislunar Strategy to identify objectives, activities, and relationships
  - Develop Guardians with cislunar expertise dedicated to addressing unique challenges of cislunar operations
  - Develop cislunar Doctrine, CONOPS, and Requirements
- DOD must invest to mature key technologies and transition them to operations


NATIONAL CISLUNAR
SCIENCE & TECHNOLOGY STRATEGY

A Product of the
CISLUNAR TECHNOLOGY STRATEGY
INTERAGENCY WORKING GROUP

of the
NATIONAL SCIENCE & TECHNOLOGY COUNCIL

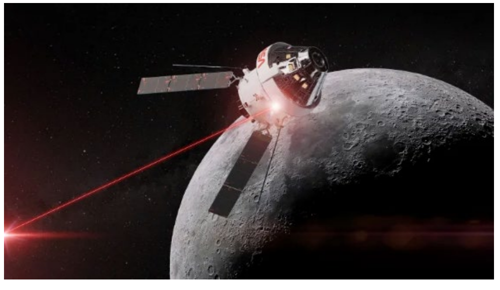
November 2022

DOD Cislunar Strategy

?

Develop the Technology for Mission Success

- **Domain Awareness**
  - AFRL's Oracle program provides an initial starting point
  - Could employ a combination of optical and radio frequency sensors
  - Consider fielding spacecraft with beacons and transponders to reduce demands on "search and detect"
  - Requires new construct to catalog trajectories of cislunar objects



https://www.nasa.gov/communicating-with-missions/lasercomms/

- **High Speed Communication**
  - Laser communication is an ideal choice due to high data rates, low mass, and absence of atmospheric issues
  - NASA has already demonstrated utility and feasibility of laser communication for Artemis

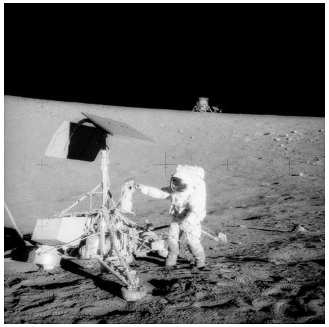
- **Position, Navigation, and Timing**
  - Similar to the deployment of GPS, a USSF provide PNT capability will unlock civil and commercial opportunities
  - May not require a stand-alone system, but could be imbedded with the communication and domain awareness architecture

Support Overcoming Technical Challenges

- **Propulsion and Maneuverability**
  - Given large distances, nuclear propulsion has great potential for cislunar operations
  - DARPA's Demonstration Rocket for Agile Cislunar Operations (DRACO) is a great example of this research
  - The criticality of assured propulsion and maneuver may require additional options

https://www.darpa.mil/program/demonstration-rocket-for-agile-cislunar-operations

- **Power Generation and Distribution**
  - Generation, storage, and transfer of power to spacecraft payloads and lunar surface operations is critical and must overcome extreme temperatures and long nights
  - AFRL's Joint Emergent Technology Supplying On-orbit Nuclear Power (JETSON) is a good example of efforts exploring alternative spacecraft power generation
  - Beaming power is also an option being pursued by the Space Solar Power Incremental Demonstrations and Research (SSPIDR) effort at AFRL
- **Lunar Surface Launch and Landing**
  - To reduce the spread of regolith, alternate launch and landing capabilities may be required
  - Electromagnetic rail launch, space elevators, and pad construction should be explored

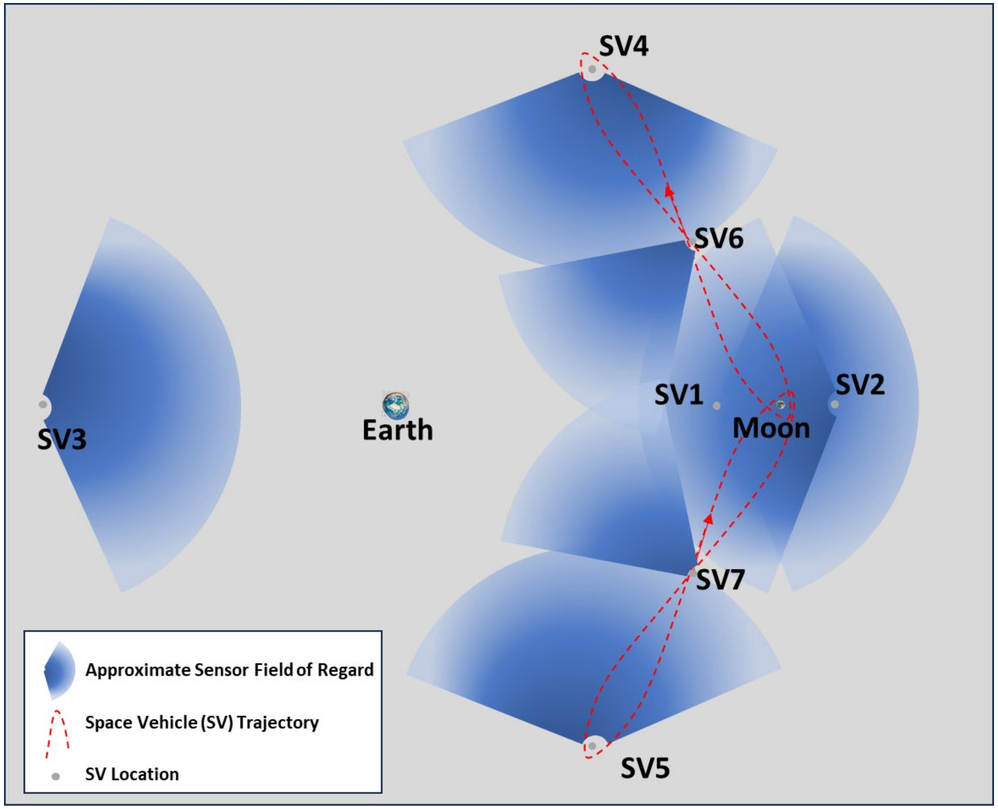


https://www.nasa.gov/image-article/astronauts-pay-visit-surveyor-3/

Determine & Field an Operational Architecture

Solid architectures will drive mission success

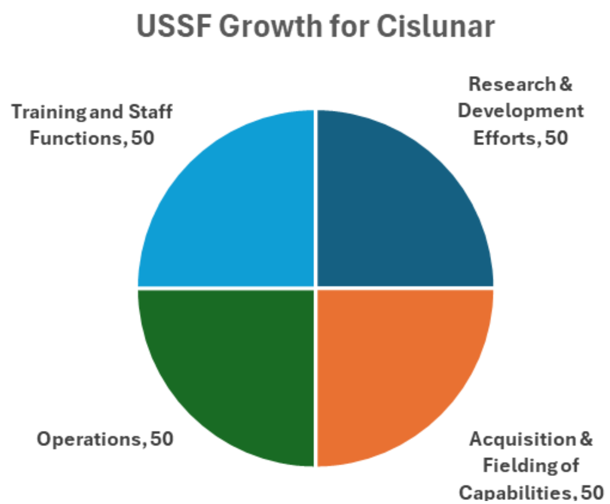
- USSF must have the resources, personnel, and authorities to transition mature technologies to operational capabilities
- Architecture decisions must be made early to best align resources and key personnel
- As an example, deploying an architecture of 7 Oracle spacecraft could establish needed domain awareness of key regions in the cislunar regime--similar decisions for communication and PNT can also accelerate fielding

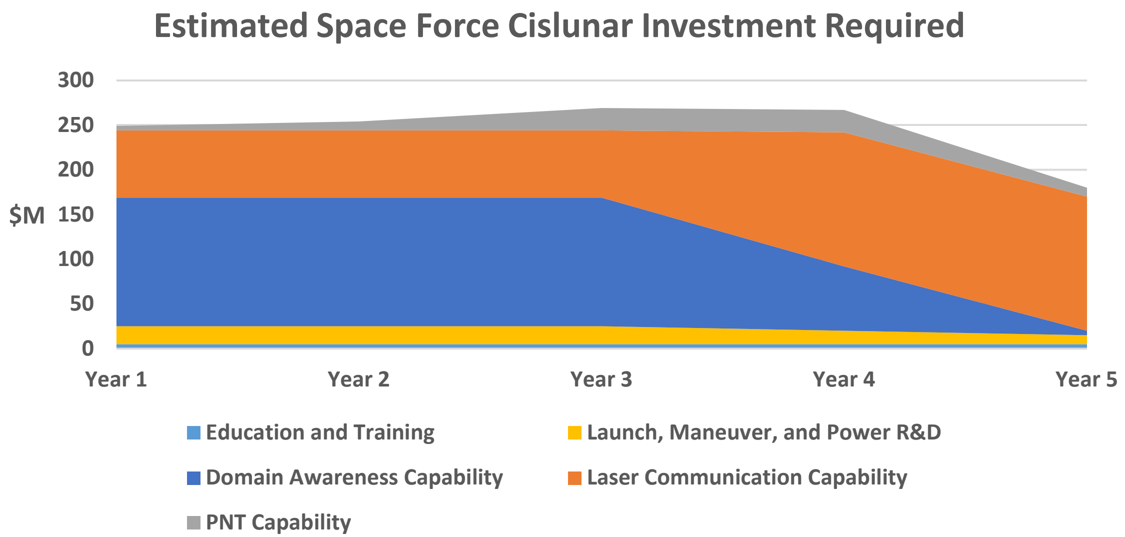


Proposed operational cislunar domain awareness architecture

Recommendations (1/2)

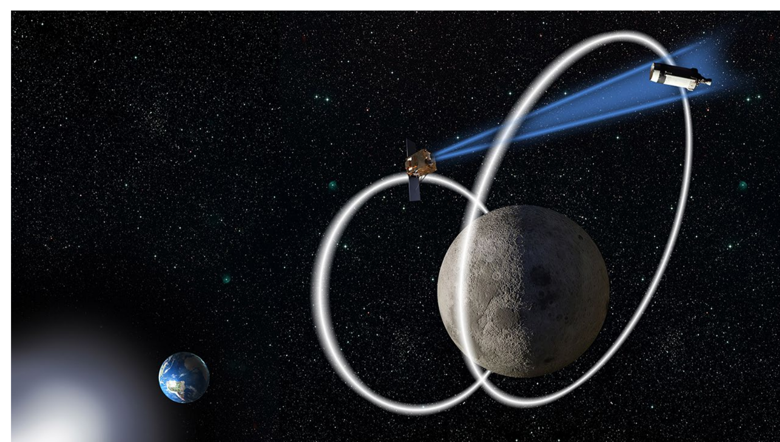
- **The DOD must develop a broad strategy** of how it can support scientific and economic expansion into the cislunar regime. This will identify and prioritize military objectives and describe how they will secure U.S. interests and support civil, commercial, and partner activities
- **Congress must fund additive growth** of about $250M/year to the Space Force budget and increase its end strength by 200 personnel in the next five years for the new responsibilities associated with emerging national interests on the Moon





Recommendations (2/2)

- **The Space Force must develop a cadre of cislunar experts** ready to lead development and operations activities. This cadre will be equipped with the education and training to solve the complex challenges of operations in the cislunar regime
- **U.S. Space Command and the Space Force must establish doctrine, CONOPS, and requirements** to foster the race to the Moon. This will align military efforts and provide a framework for future development and operations
- **The Space Force must invest in cislunar research and development efforts**. Working with organizations like AFRL and DARPA, the Space Force will be able to accelerate R&D activities and streamline their transition to operations
- **The Space Force must rapidly transition R&D activities into operational capabilities** Sustained presence on the Moon will require established programs of record and operational capabilities to support continued civil, commercial, and military activities



Conclusions

- The race to the Moon is an integral facet of the strategic competition with China
- The lack of internationally recognized norms in the cislunar regime creates a sense of urgency for the two sides in the race
    - Artemis Accords parties seeking transparent, cooperative, responsible, and peaceful activities
    - The coalition of China and Russia with a territorial and secretive approach
- The goal of permanent presence and the precedents for future activities adds additional pressure to get it right from the start
- As the military has done multiple times before, it can establish infrastructure to accelerate the civil and commercial advancement while also providing a means to secure emerging interests
- Modest additive growth to the Space Force now will decrease the need for large spending later to overcome an advantage ceded

The challenges and stakes of the race to the Moon demand the Space Force and US Space Command take steps today

MITCHELL INSTITUTE FOR AEROSPACE STUDIES

www.mitchellaerospacepower.org

Basic Framework of 1967 Outer Space Treaty

- The exploration and use of outer space shall be carried out for the benefit and in the interests of all countries and shall be the province of all mankind;
- Outer space shall be free for exploration and use by all States;
- Outer space is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means;
- States shall not place nuclear weapons or other weapons of mass destruction in orbit or on celestial bodies or station them in outer space in any other manner;
- The Moon and other celestial bodies shall be used exclusively for peaceful purposes;
- Astronauts shall be regarded as the envoys of mankind;
- States shall be responsible for national space activities whether carried out by governmental or non-governmental entities;
- States shall be liable for damage caused by their space objects; and
- States shall avoid harmful contamination of space and celestial bodies.

https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/introouterspacetreaty.html