

MVA Special Project: Moon Village Association Roadmap for establishing the Moon Market

Co-chairmen:

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DRAFT WHITE PAPER

RATIONALE

The goal of this special project is to define and characterize different scenarios to jump-start a large cislunar economy on the basis of lunar infrastructures and resources at the 2040+ horizon.

It is a fact that the Moon is back since few years as the main focus of international space programs, public and private. The United States is pursuing the NASA's Artemis program to land astronauts on the Moon in 2024 or slightly later, with international partnership built on the heritage of the International Space Station (the Gateway project), and the goal to establish a sustainable human presence on the Moon from 2030 on.

Russia has never abandoned the idea to land humans on the Moon, possibly as a partner in the Artemis program, and is on the verge to restart automatic lunar exploration.

Japan is very interested in joining international efforts to explore the Moon, with automatic probes and inhabited vehicles.

China is conducting an ambitious automatic lunar exploration program and makes no mystery of aiming to land humans on the Moon around 2030.

India is also very active in automatic lunar exploration.

Large private US actors like SpaceX and Blue Origin pursue their own paths, with very large-scale projects (SpaceX' Starship program for instance), which

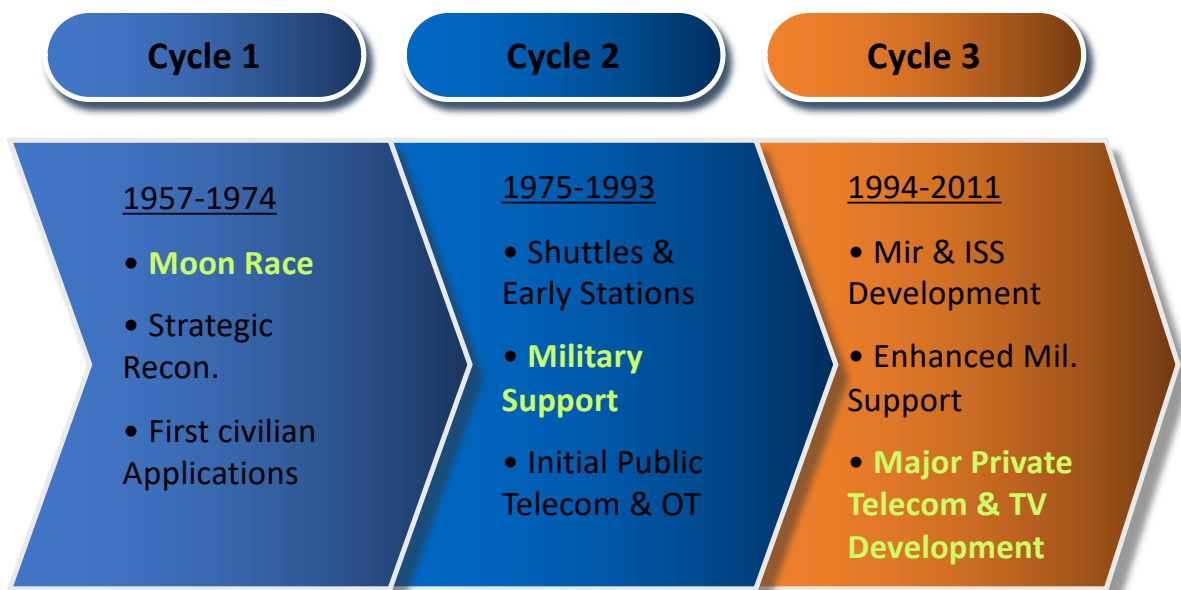
could complement public programs, and even lead to a disruptive acceleration leading to major economic developments in the cislunar sphere.

All these activities raise one question: could they lead not only to spectacular achievements, but more concretely to a change of paradigm for the economic development of space, making the human earth civilization a cislunar civilization as a first step toward a solar system civilization?

In order to structure the MVA Roadmap for establishing the moon market, it makes sense to put this roadmap in historical perspectives, following a method introduced by one of the co-chairmen, Alain Dupas, in the 2000s, analyzing space past and future space developments in cycles of about 17-18 years.

The three first cycles correspond to the “First Space Age” (1957-2011). Each one is characterized by a major driver.

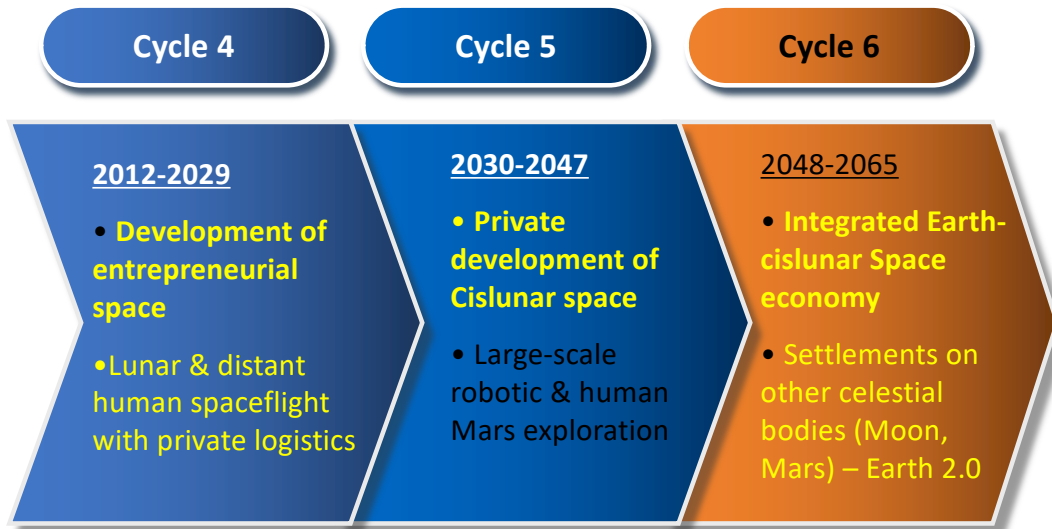
The first space-age - half a century & three Cycles (a model developed by A. Dupas in the 2000s)



Remark: 54 years is in the duration range (50-60 years) of the famous (Nicolas) Kondratiev long-waves or supercycles of the World economy

The next three ones cover the “Second Space Age” (2012-2065):

The second space-age (tentative!) could last 53 years and include three Cycles



This model forecast the beginning of the development of a cis-lunar economy in Cycle 5 and large-scale economical expansion in Cycle 6.

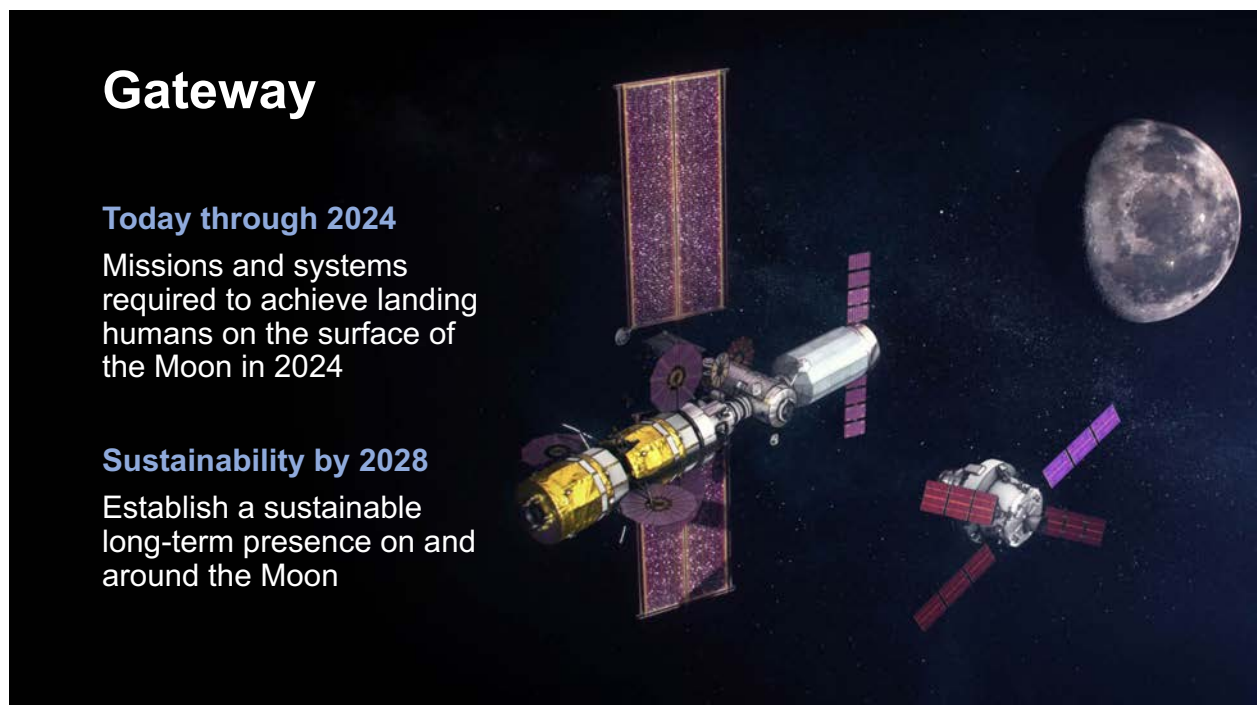
The current Cycle 4 of space development has, according to this analysis, been characterized in its first half by the emergence of NewSpace entrepreneurial companies, and will be focused in its second half (the 2020s) by the restart of Lunar and deep-space spaceflight, probably led by state space agencies, but with logistics provided (at least partly) by private companies, following the model introduced by NASA in the 2010s with the COTS, CRS and Commercial Crew programs to transport cargo and astronauts to and from the International Space Station.

The 2020s, that is the second part of Cycle, cover in this analysis the short-term considerations of the MVA draft roadmap.

SHORT-TERM CONSIDERATIONS

One of the driving forces of the human exploration of the solar system is the collaboration between state space agencies and private companies. NASA and other space agencies consider this journey in stages touching various destinations, namely the Moon, objects close to the Earth (like a selection of asteroids), the moons of Mars and finally Mars itself.

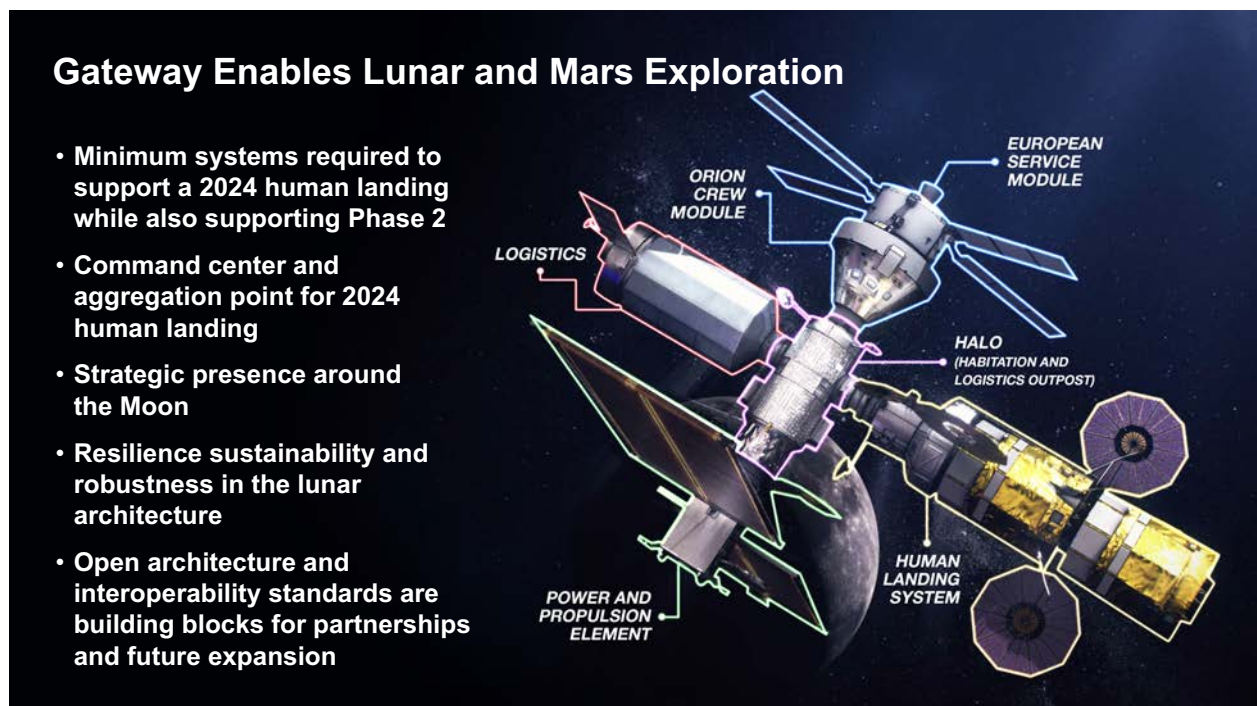
If the final goal is to reach Mars and the other planets of the solar system, the use of space resources will be decisive for the success of these missions. In the short term, space resources would guarantee fuel, oxygen and water derived from the Moon to supply spacecraft in various orbits between Earth and the Moon, as well as to maintain supporting systems for life of a cislunar space station (Gateway project), currently planned to move around the Moon on a very special trajectory called NRHO (Near-Rectilinear Halo Orbit), but which could later be displaced to one of the Lagrangian points of the the Earth-Moon system, or to a Low Lunar Orbit (LLO).



For several years now, NASA engineers and their colleagues from other space agencies have been working on the design of the new space station. If everything goes as planned, the first mission will be launched in 2023 and will

position a robotic spacecraft, the PPE (Power and Propulsion Element), in the NRHO elliptical trajectory.

In the following two years, a couple of modules similar to two barrels (4.5 meters wide, 5 meters long, a little less than 10 tons of weight each) will be sent to the same orbit and assembled with the PPE. The first one is called the Gateway HALO (Habitation and Logistics Outpost) which would be a very small habitat where the crew arriving in a Orion spacecraft would wait and transfer to the Human Landing System (HLS) in which it would travel to the Moon surface before coming back to the Gateway, on its return path to the Earth aboard the Orion Spacecraft.



The Gateway will be able to host four astronauts for periods that can last up to 90 days. In addition, around the middle of the next decade, a "clearing chamber" built by Russia could be added to the station, so that it would be easier for astronauts to leave and re-enter their space home.

At present, there are numerous space agencies' prospecting Moon missions in the pipeline, trying to figure out where the ice is, in what concentrations and with what kind of variability across the lunar surface. ESA is developing a drilling and sample-analysis payload (Prospect), which will fly to the moon aboard Russia's Luna 27 mission in the 2022-2023. NASA's Resource Prospector mission, which has been reconfigured to fly instruments on private

lunar landers (Commercial Lunar Payload Services – CLPS), aims to locate elements from a lunar polar region, particularly volatiles such as hydrogen, oxygen and water. Governments will thus provide initial support in the construction of space infrastructures, exploration, scientific progress, and the necessary technological advances.

Within the last decade, several private initiatives have surfaced promoting the expansion of the space economy beyond earth orbit. These companies are seeking the best path to commercial success and aggressively leading the way beyond Earth orbit. Private companies in the United States, such as Astrobotic, indicate their willingness to launch exploratory missions to the Moon in view of future mining operations.

Astrobotic is developing a lunar lander called Peregrine, which the company says will be able to deliver up to 265 kilograms of payload to the surface of the Moon.

The Japanese iSpace startup has a vision which involves mapping lunar resources with swarms of rovers, which the company will deliver to the Moon.

Blue Origin, the entrepreneurial company created and owned by Jeff Bezos, laid out the basic vision for the company's lander, the Blue Moon, which will be capable of putting up to 4,500 kg of payload down on the lunar surface.

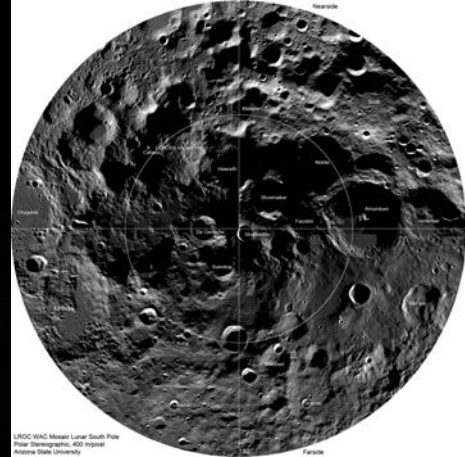
Blue Origin, as leader of an industrial team comprising also two major US space companies, has proposed the Blue Moon as one of the elements of the Human Landing System of the Artemis program.



A recent report "*Commercial Lunar Propellant Architecture: A Collaborative Study of Lunar Propellant Production*" has cut to the chase, detailing what is needed and what happens next. This appraisal by industry writers, NASA, lunar scientists and space lawyers focused on extracting water from the moon's permanently shadowed regions for use as rocket fuel.

A commercial lunar propellant system will be a vast undertaking. It will require an analysis of propellant demand, price, and location of use as customer base; improved space law to facilitate commercial use of lunar resources; and investment for technology development and maturity, which in turn require innovative financing.

**The
discovery
of water ice
in the
Moon's
polar crater
is a game
changer for
expansion
in space
during
Cycle 5
(2030-2047)
and Cycle 6
(2048-2065)**



These developments will substantially reinforce the medium and long-term prospects of the Moon Village project. Refueling, in low earth orbit spaceship, directed to geostationary orbit and to the Moon, and, in cislunar orbit, the ones directed beyond the Moon will contribute to a reduction of costs of these ventures. Development of technologies for an automated plant for extracting oxygen and hydrogen from Moon ice and its implementation will certainly help later stages of the Moon Village realization.

MEDIUM-TERM CONSIDERATIONS

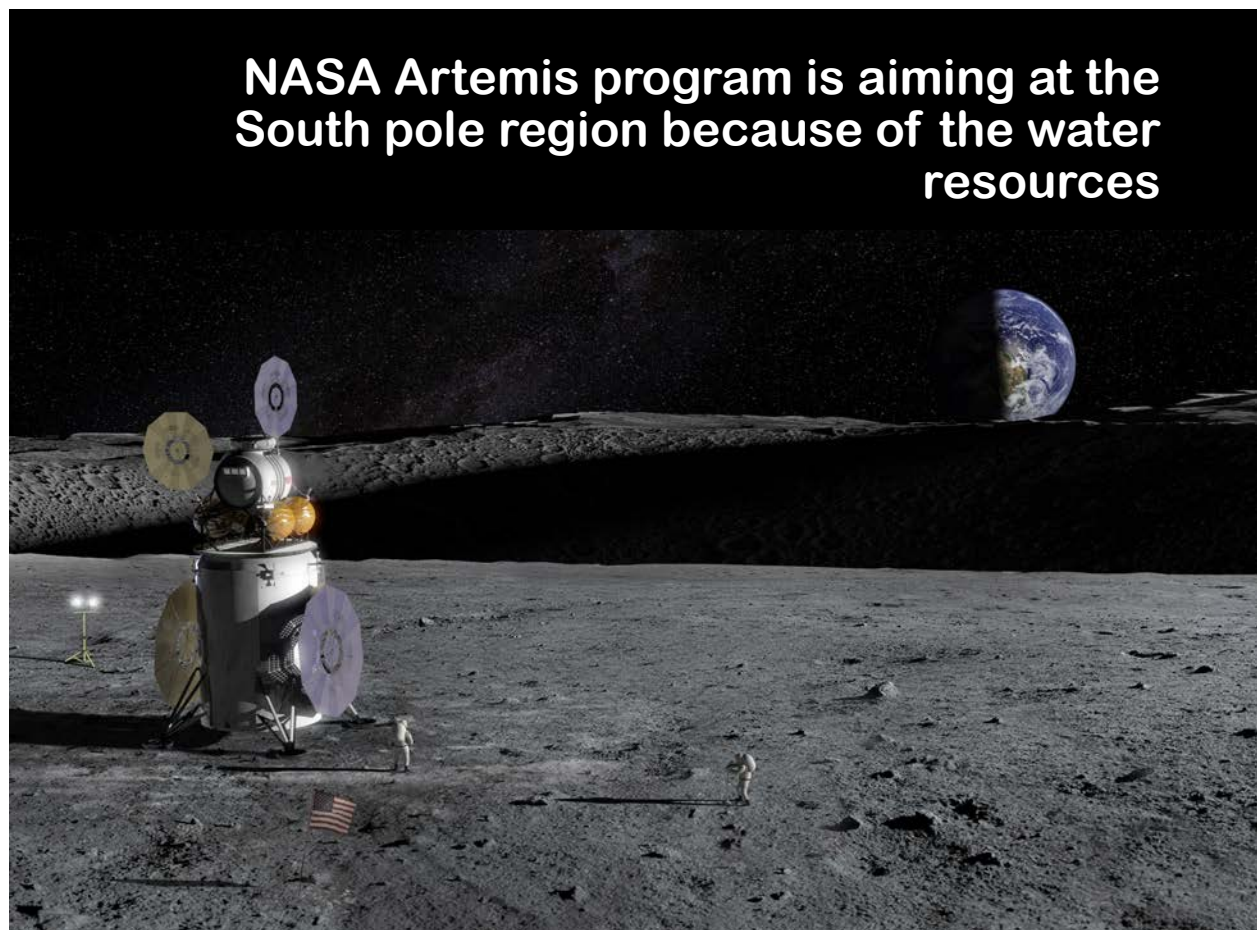
The problematics of the medium-term part of the considered roadmap is dominated by two questions:

1. Will the model of the 2020s (second part of Cycle 4), based on state space agencies leadership using private logistics to decrease programs cost and

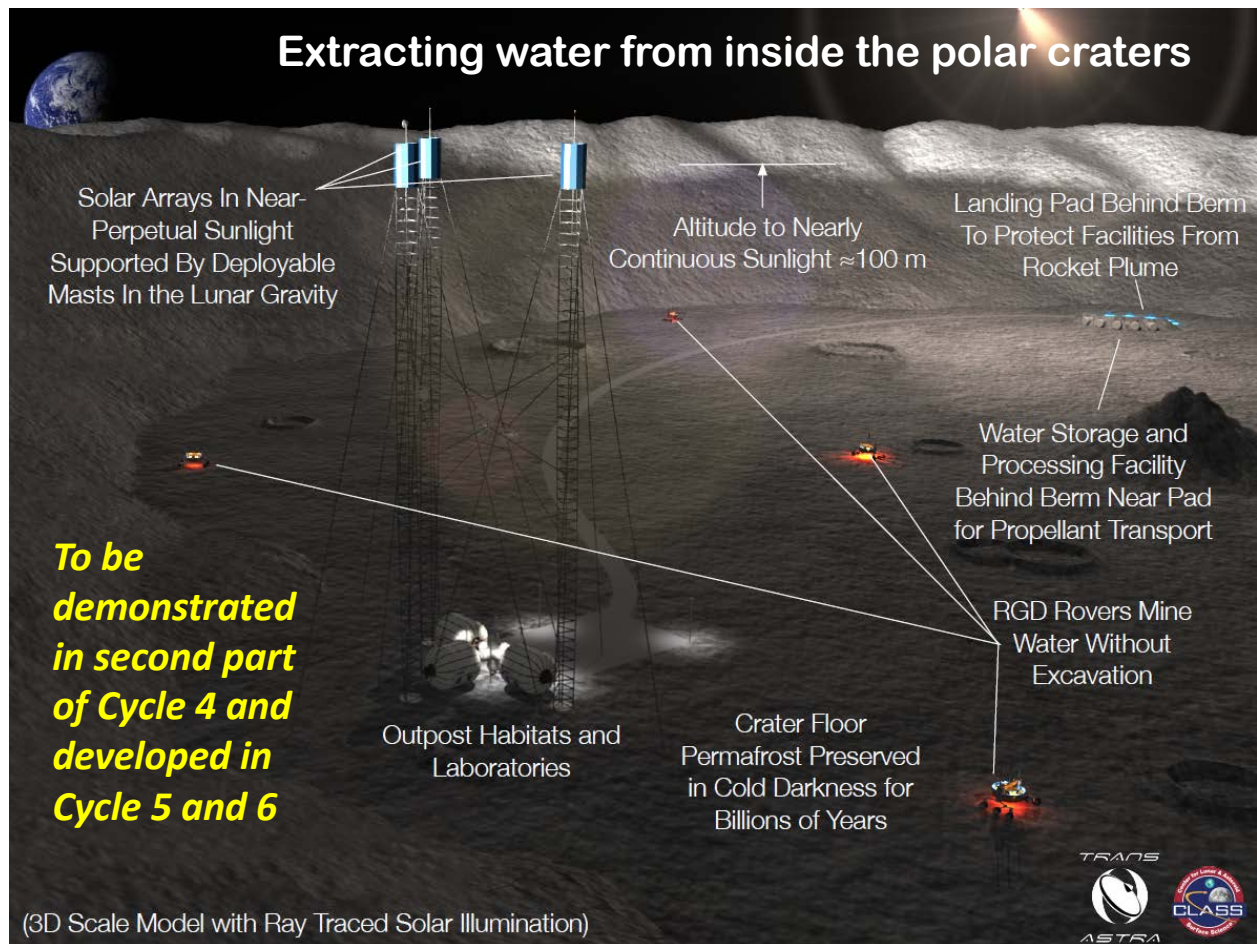
increase efficiency, stay the dominant model in the 2030s (first part of Cycle 5)? Or will private actors take the lead with the creation of value becoming the main driver, taking (at least partly) over strategic and scientific considerations?

2. Will lunar resources (and later possibly asteroid resources) profoundly transform at this horizon space economy, and enable the emergence of a great variety of activities, bound only by human imagination and creativity?

The two questions are linked because the current model, followed notably by the United States and China, are moving quite slowly, with high costs, and limited capabilities in terms of crew size. With this state-led approach, it seems difficult to envision the rapid development of a large NewSpace economy based on extraterrestrial resources during the 2030s, even if the discovery and possible use of water ice in the moon's polar craters is recognized by NASA, and apparently also by the CSA as a major driver for the future of human spaceflight:



Demonstrating the extraction of water from inside the polar craters is a priority, as illustrated by the description of a study supported by NASA:



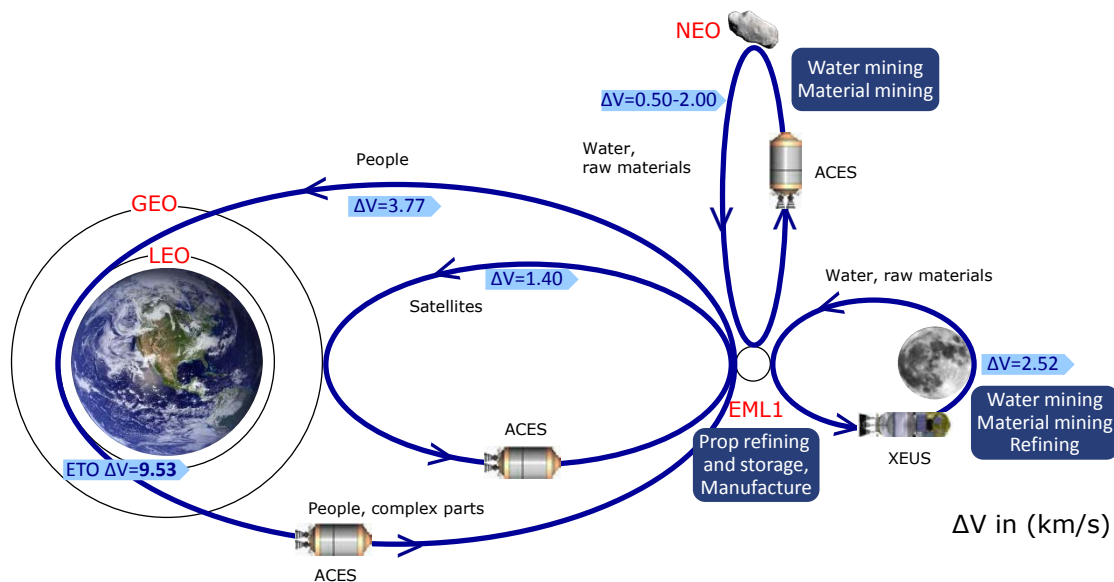
Could such demonstrations lead in the medium-term (2020s) to practical applications, such as the establishment of trade routes (akin to a “silk road” in outer space) considered by George Sowers (currently Professor, Colorado School of Mines) when he worked as Chief Scientist in ULA:

The new "Silk Road" in cis-lunar space?



Transportation System & Trade Routes

- **LO2/LH2 Based System**
 - Water is Ubiquitous
 - Moon, asteroids, Mars...
- **Fully Reusable Transportation**
 - ACES: Shuttle from ELM1/2 to GEO & NEO
 - XEUS: Shuttle from lunar surface to EML1



Fully Reusable Transportation System Serving Robust CisLunar Economy

It is doubtful that such developments could really happen during Cycle 5 first half (the 2030s), if a paradigm shift is not happening in space transportation, with the much lower costs and much larger capacities that would be enabled by fully reusable system, such as the Two-Stages-To-Orbit (TSTO) considered by NASA in early space shuttle studies 50 years ago (1969-1970).

Could such a paradigm shift materialize in the 2030s or even before? In fact such a goal is pursued by SpaceX with the program which is called today Starship (after having been named Interplanetary Transport System – ITS – in 2016 and Big Falcon Rocket – BFR) in 2017):

Could Starship be a game changer for exploitation of the Moon resources?

Two orders of magnitude decrease in transportation cost + huge payload (100 t ? 100 people?)

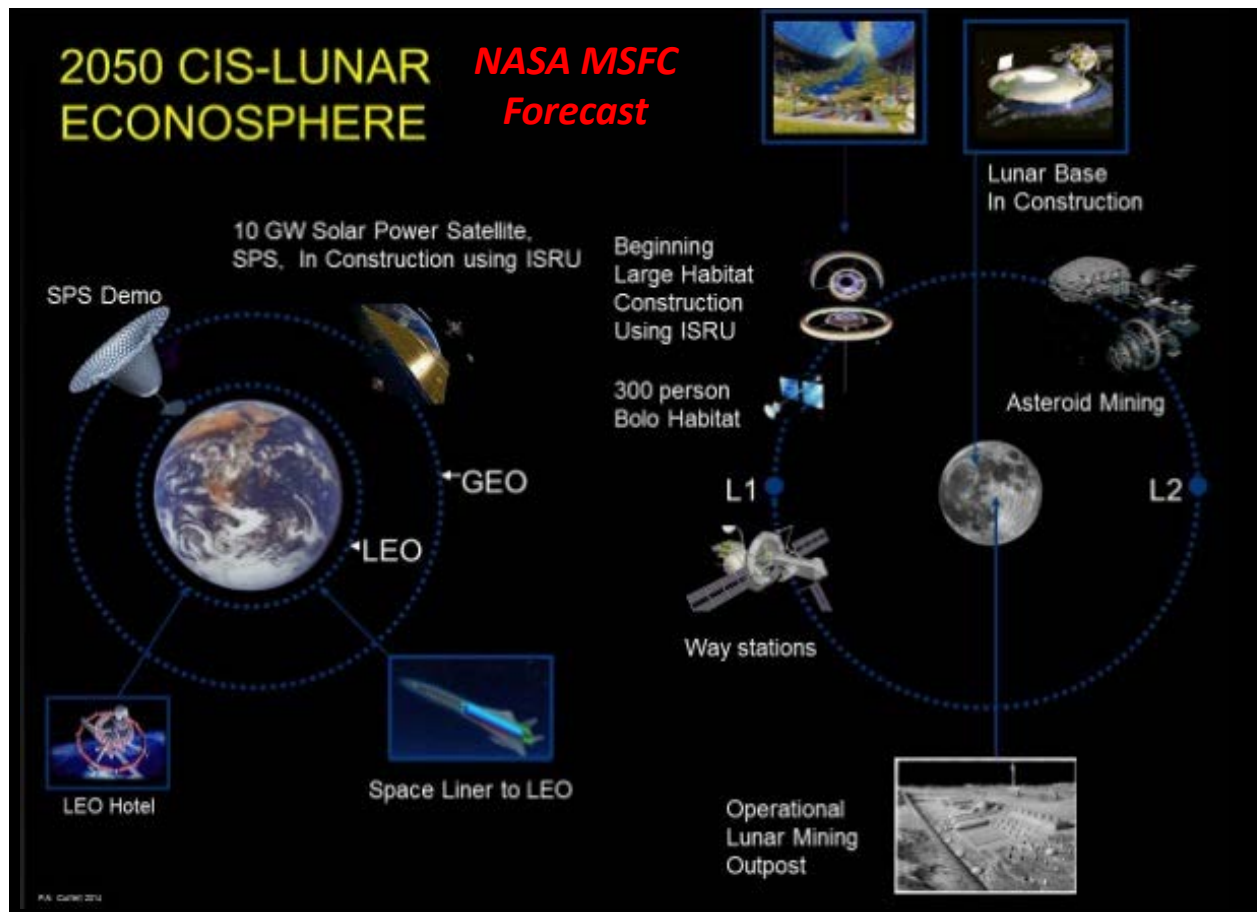
Elon Musk presenting possible Starship role for Moon use at IAC2017

The development of Starship is facing extremely difficult technical challenges but with a decrease in launch cost of two orders of magnitude and an increase in transportation capabilities of one order of magnitude (up to 100 t of payload to the surface of the Moon and potentially a crew of 100 persons), this fully reusable system, conceived to operate not only in Low Earth Orbit (LEO) but also in all cislunar space and even to Mars (the personal goal setup by SpaceX' founder Elon Musk), would revolutionize not only space transportation, but all space activities.

NASA has started to recognize the potential of Starship, even if it continues to rely on its own systems, the giant launcher SLS and the human spacecraft Orion. Up to know the Starship has only been selected for a small NASA commercial cargo transportation program:

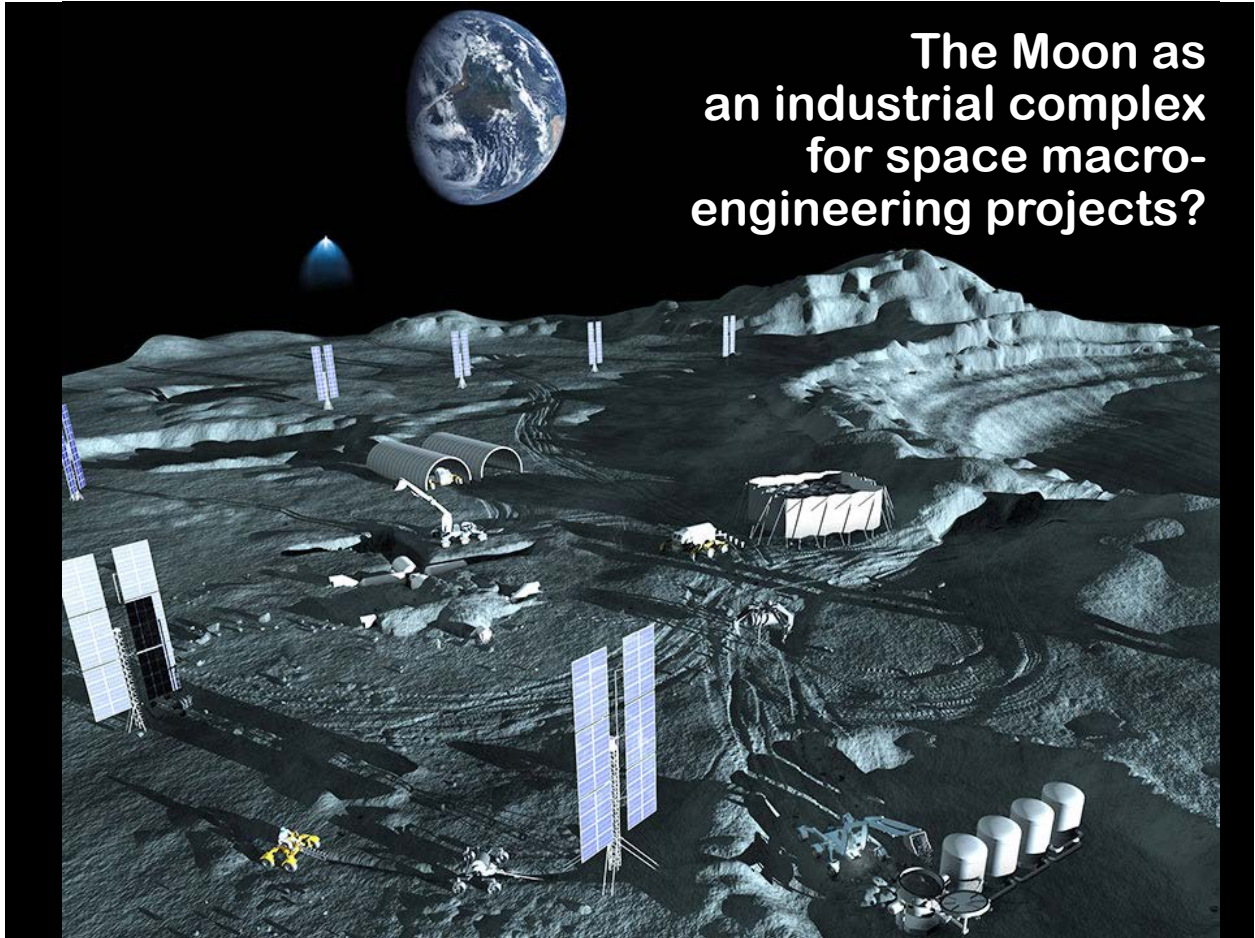


However it could be just a beginning and other NewSpace actors like Blue Origin could join SpaceX in the development of fully-reusable large scale space transportation systems, which could open widely the doors to the emergence of a flourishing cislunar economy during the Cycle 5 timeframe, as illustrated by this NASA MSFC concept for what could be the 2050 (in practice end of Cycle 5 and beginning of Cycle 6) cislunar econosphere:



LONG TERM-TERM CONSIDERATIONS

The introduction of Starship-like systems would be the key for the emergence of the Moon as an industrial complex for space macro-engineering projects:



The Moon as an industrial complex for space macro-engineering projects?

Space macro-engineering could then become the focus of Cycle 6 (2048-2065) and realize the vision expressed by John Marburger in 2006:

John Marburger (1941-2011) has clearly defined in 2006 the economic perspective of future spaceflight



**44th Robert H. Goddard Memorial Symposium
Greenbelt, Maryland
March 15
Keynote Address**

**John Marburger
Director, Office of Science and Technology Policy
Executive Office of the President**

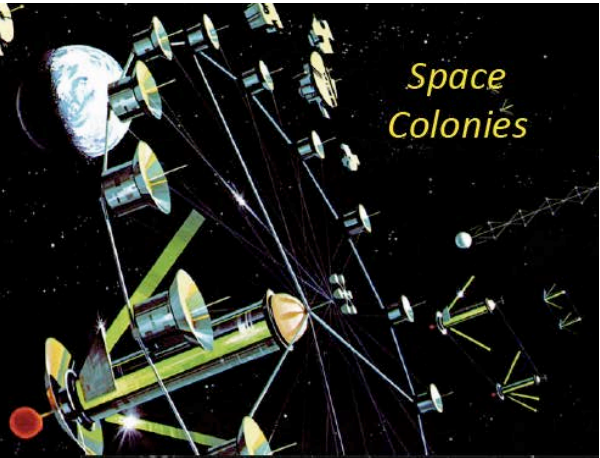
“Phenomena on our side of the interstellar gap, in what we call the Solar System, are potentially amenable to direct investigation and manipulation through physical contact. [...] As I see it, questions [...] boil down to whether we want to incorporate the Solar System in our economic sphere, or not.”

What could be these disruption space macro-projects? Again there, imagination is the only limit:

Space Macroprojects

Could they become reality in the 21st century? And become the basis of human expansion in the solar system and beyond?

*Space
Colonies*



*Solar Power
Satellites*

*Sun Shields against
global Warming*

