LUnar CubeSats for Exploration (LUCE) mission concept studies

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General SysNova objectives

- To carry out focused and frequent advanced studies of relevance to the exploration of potential technology needs beyond current ESA programmes.
- To facilitate the involvement of both industrial and research teams in ESA concept and technology assessment work recognizing the critical role of joint studies by industry and academia.
- To foster technology R&D efforts with a goal demonstration mission in the mid- to long-timeframe
- To explore the potential for technology spin-in and increase the awareness of non-space industrial and research actors of ESA's activities, programmes and priorities.

LUCE SysNova Objectives

- Within the ESA General Studies Programme the fourth SysNova is focused on LUnar Cubesats for Exploration (LUCE).
- Through competition and technological challenges it aims to generate a number of alternative solutions to support ESA's lunar exploration objectives.
- These solutions could be selected for future flight opportunities as they arise.
- 4 proposals are selected for a further study phase and afterwards evaluated by an ESA panel. The winner will be awarded a CDF study at ESTEC for further advancing their design.

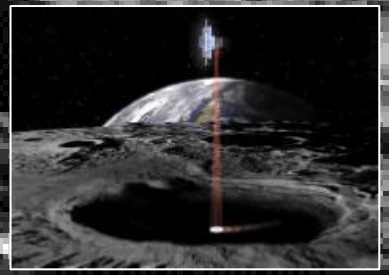
Key technologies to be addressed

For lunar exploration with cube- and nano-sats several key technologies are necessary.

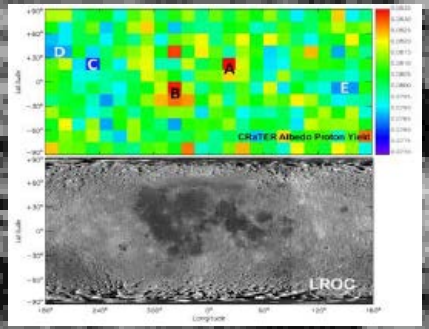
- Deployment and autonomous operation of small satellites in a lunar orbit either as individual elements, or as part of a distributed system;
- Miniaturization of scientific payload instrumentation and associated technology flight demonstration in a lunar orbit;
- Science observations of and from the moon not achievable by past, current or planned lunar missions;
- Inter-satellite communication links to a larger Lunar Communications Orbiter for data relay to users on Earth.
- Technologies directly useful for future exploration missions, and in need of flight demonstration in a representative environment.

Main SysNova LUCE themes and constraints

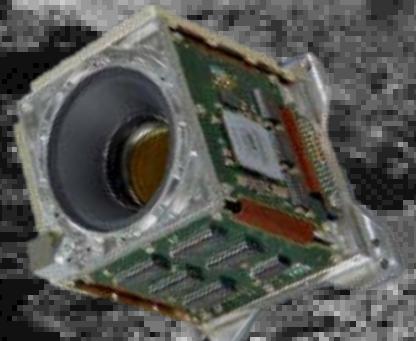
Lunar Prospecting



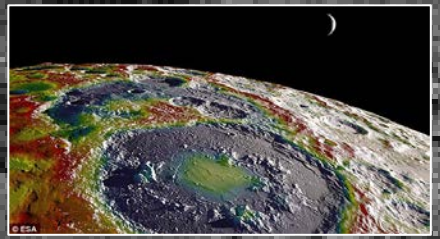
Lunar Environment



Technology demonstration



Science



- Put into a lunar orbit by a larger Lunar Orbiter
- Communication with the Lunar Orbiter
  - No direct to earth
  - 1 hour/day
- One or more NanoSats (<60 kg)
  - <24kg each
  - <12U each
- Orbit: >500 km circular, >50° incl.
- High autonomy (10 days without ground-contact)

LUCE Concept 1

LUMIO: Lunar Meteoroid Impact Observer

Mission concept: Characterize the flux of meteoroids impacting the lunar surface.

- *Monitor* the lunar surface for meteoroid impacts
- *Detect* flashes caused by meteoroid impacts with the lunar surface
- *Characterize* the properties of the impacting meteoroids

Politecnico Di Milano (IT)

TU Delft (NL)

École Polytechnique Fédérale de Lausanne (FR)

S[&]T Norway (NO)

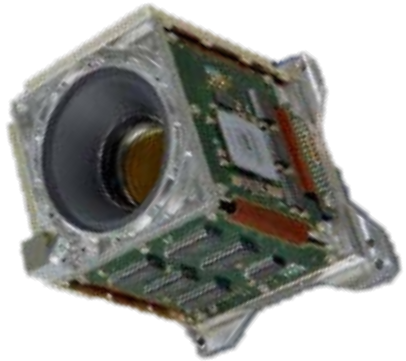
Leonardo S.p.A (IT)

University of Arizona (US)

Proposed Payloads

LUMIO Camera

- Mass <4.5 kg
- Volume <10x10x30cm
- Power <10W
- Spatial resolution: 3.4 km/Pixel
- Temporal resolution: 3 Hz
- FOV 3.5x3.5 deg



LUCE Concept 1

LUMIO: Lunar Meteoroid Impact Observer

Cubesat mission design:

- 12U CubeSat
- 24 kg
- Deployable solar arrays
- 41 W generated power
- EML2 Halo orbit
- Propulsion >200 m/s Δv
- Pointing stability 40 arcsec/s
- Pointing knowledge 30 arcsec/s

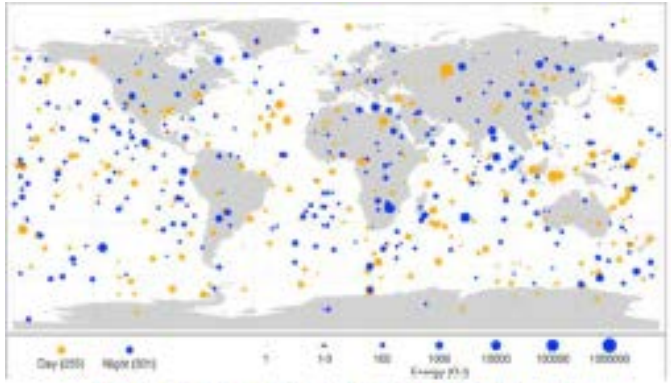
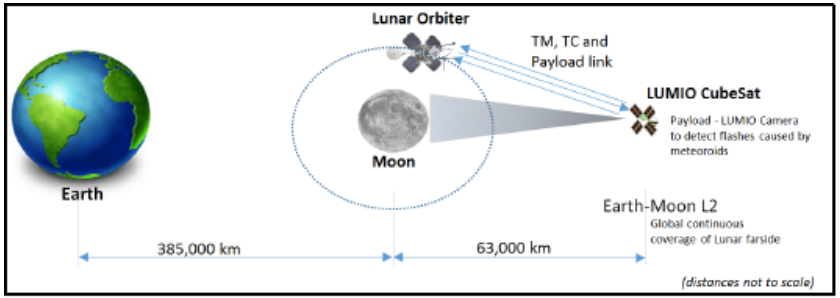


Figure 1: Bolide events (1994-2013).



LUCE Concept 2

MoonCARE: CubeSat for the Analysis of the Radiation Environment on the Moon

Mission concept: Understand the physiological and biological effects of the lunar environment on non-human life forms.

- *Characterize* the lunar radiation environment with unprecedented spatial and temporal resolution
- *Study* the survival and active metabolism of specific micro-organisms in the extreme lunar radiation environment

von Karman Institute (BE)
German Aerospace Centre (DE)
Tyvak International (IT)
Politecnico di Torino (IT)

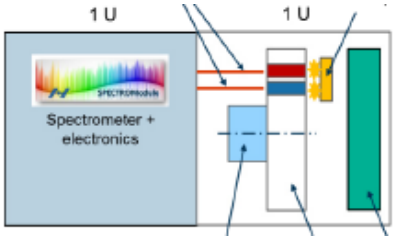
Proposed Payloads

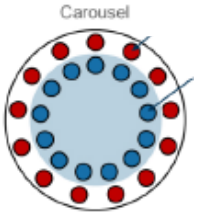
Radiation Detector (MoonRAD)

- 0.06 MeV to 200 MeV

Astrobiology experiment (MoonBIO)

- 4 different micro-organisms
- Measuring growth of cultures via absorbance measurement



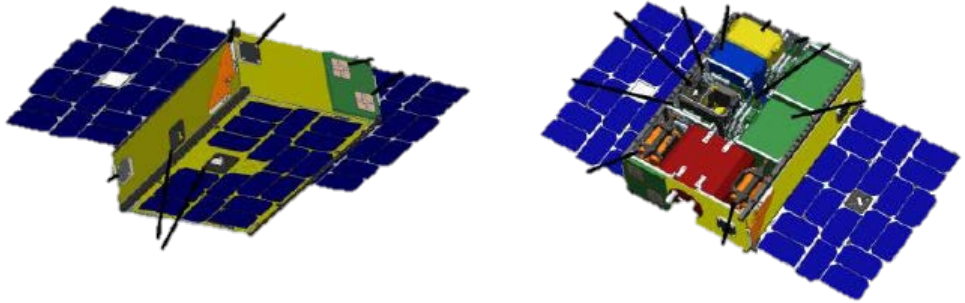


LUCE Concept 2

MoonCARE: CubeSat for the Analysis of the Radiation Environment on the Moon

CubeSat mission design:

- 4 or more 6U CubeSats
- 10 kg each
- Deployable solar arrays
- 80W max power
- Propulsion >150 m/s Δv
- Single orbit constellation
- Pointing accuracy: 10 deg



LUCE Concept 3

CLE: CubeSat Low frequency Explorer

Mission concept: Provide a stepping stone to distributed low frequency radio telescopes in lunar orbit.

- *Improve* our understanding of the Dark Ages of the universe
- *Determine* the spectral energy distribution of radio galaxies and massive black holes.
- *Establish* an all-sky multi-frequency maps of the galactic interstellar medium
- *Follow* “Type II” bursts and their ensuing CME’s

Innovative Solutions In Space (NL)

ASTRON (NL)

Radboud University Nijmegen (NL)

University of Twente (NL)

TU Delft (NL)

Proposed Payloads

Multi antenna receiver

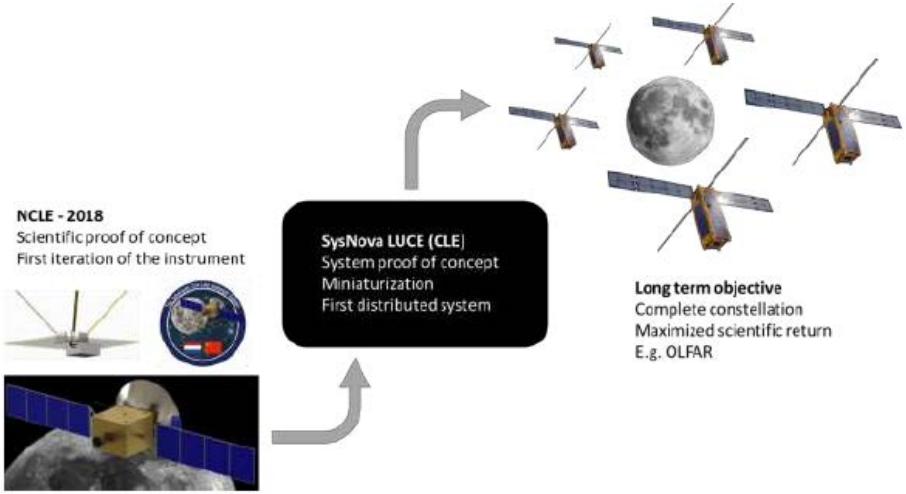
- 3 deployable monopole antennae
- <30 MHz software-defined radio receiver

LUCE Concept 3

CLE: CubeSat Low frequency Explorer

Cubesat mission design:

- 3x 12U CubeSat
- 20 kg each
- Inter-satellite link to enable, ranging, synchronization for interferometry and data transfer
- >500 km circular
- Propulsion to maintain the constellation



LUCE Concept 4

VMMO: Lunar Volatile and Mineralogy Mapping Orbiter

Mission concept: Address key unknowns about the distribution of relevant lunar resources and provide guidance for potential future landed missions.

- *Map* the location of relevant in-situ resources in sufficient quantities to be operationally useful (fuel, life-support).
- *Measure* the local cis-lunar environment (radiation, lofted dust, diurnal temperatures).

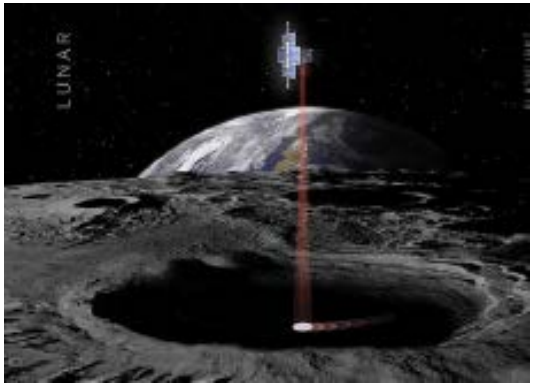
MPB Communications Inc. (CA)
University of Surrey (GB)
Lens R&D (NL)
University of Winnipeg (CA)

Proposed Payloads

Fiber Laser

- 1560 and 530 nm
- 10m GSD

Radiation environment sensor

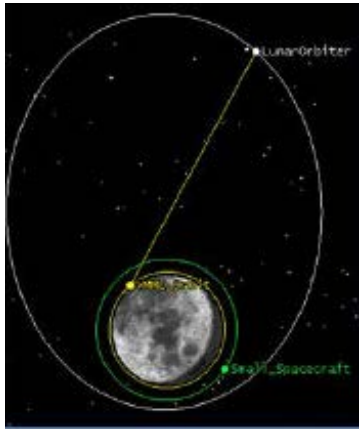


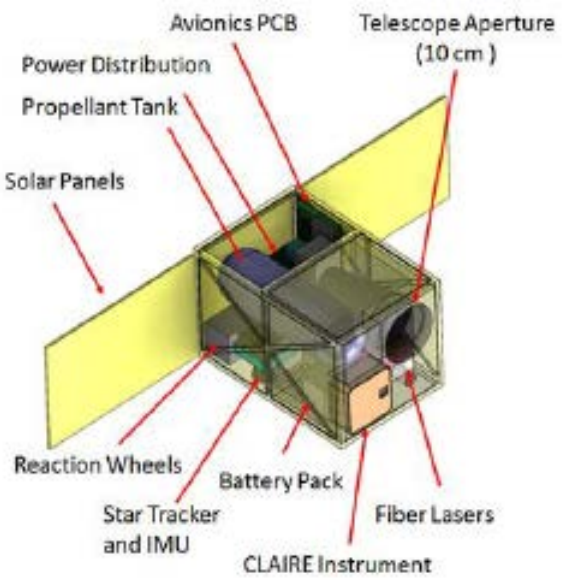
LUCE Concept 4

VMMO: Lunar Volatile and Mineralogy Mapping Orbiter

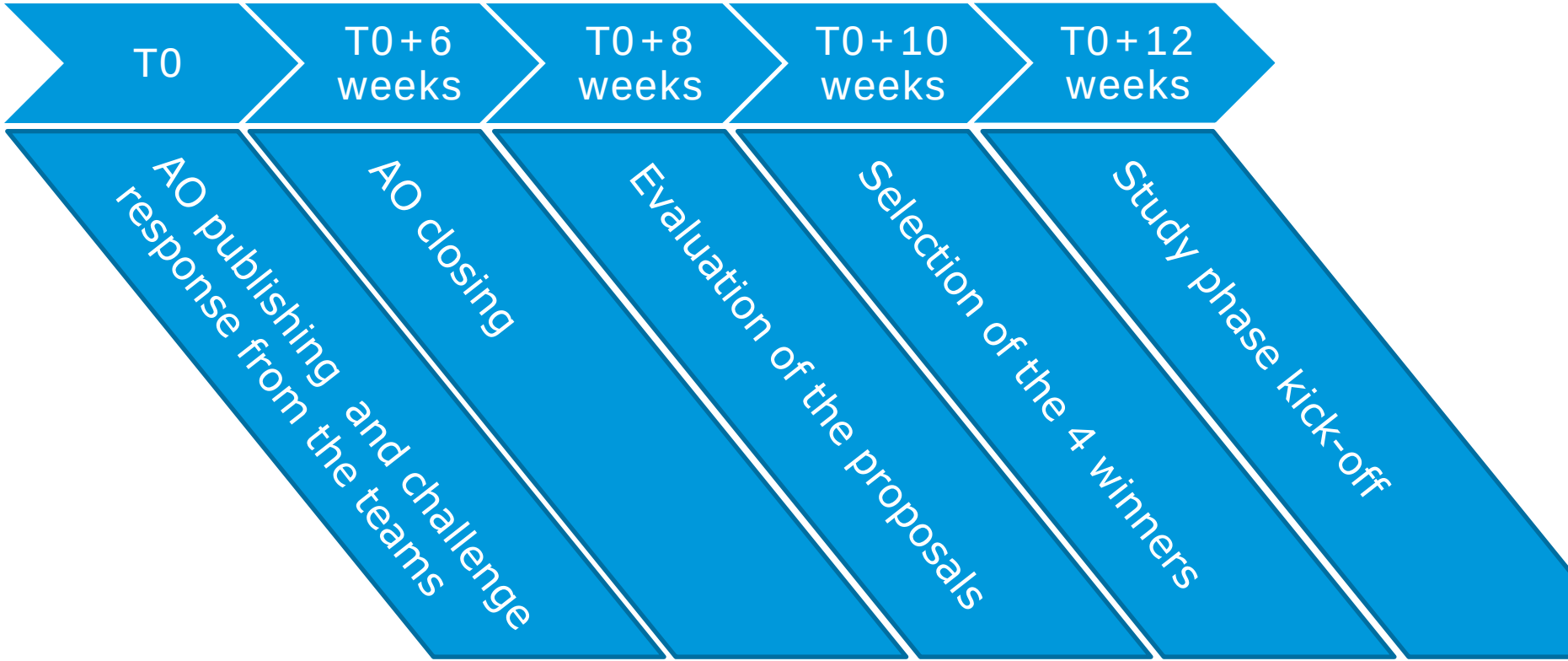
Cubesat mission design:

- 12U CubeSat
- <24 kg
- 100 km circular orbit
- Deployable solar arrays
- Propulsion >300 m/s Δv
- Pointing knowledge: 11 arcsec

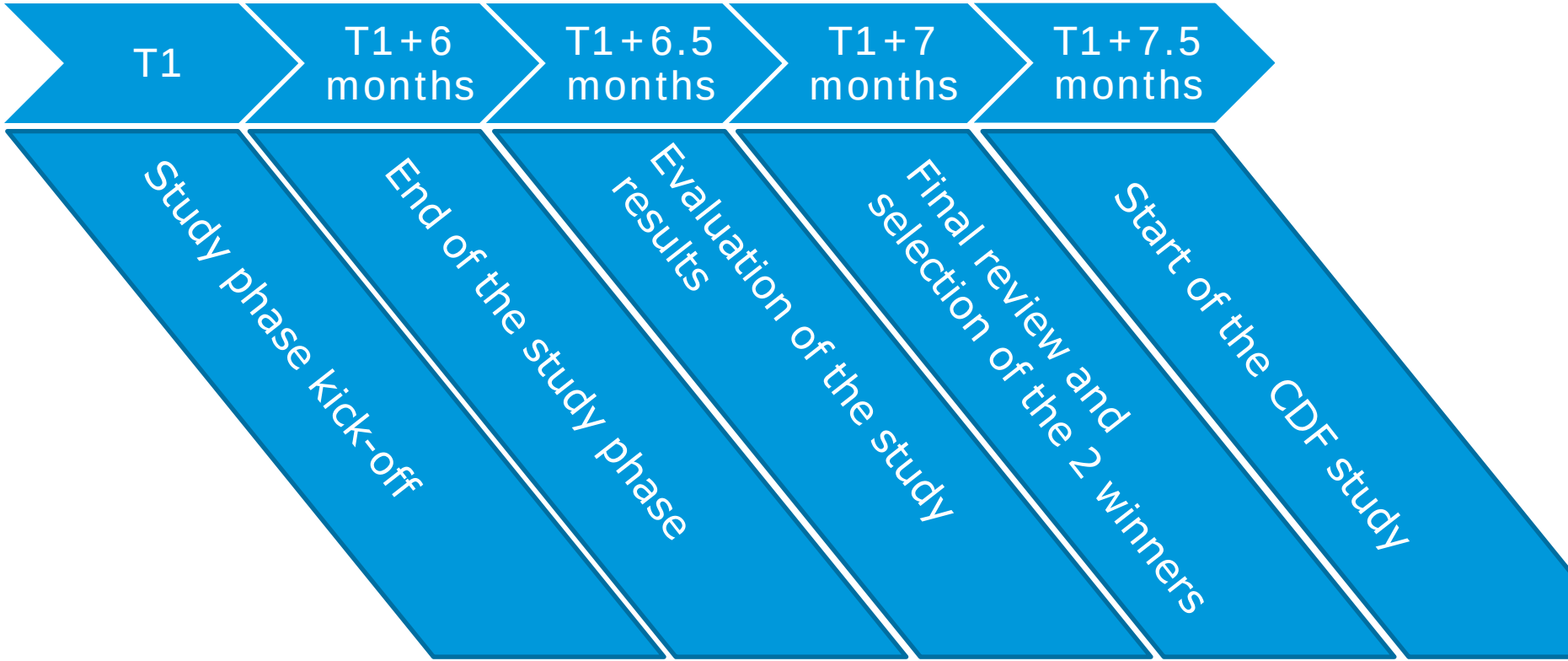




LUCE Schedule



LUCE Schedule



Conclusions

- The LUCE Sysnova challenge received a significant number of high quality proposals
- Difficult to make a selection of only four concepts for further study
- The four selected concepts are innovative and relevant to ESA lunar exploration objectives, covering a broad range of themes:
    - Lunar resource prospecting
    - Lunar environment & effects
    - Novel science in lunar orbit
- One lucky winner to be given a prize of an ESA CDF study on their concept!
- Whichever concept is the winner, the challenge serves to prepare Europe for taking advantages of lunar flight opportunities as the arise in the future
- The mission concepts studied in Sysnova (along with others) may be selected through opportunity-specific AOs depending on the number of slots available
- Enabling scientific/industrial community to contribute to lunar exploration at relatively low entry-level cost