Lunar Discovery and Exploration Updates

National Aeronautics and Space Administration

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Lunar Discovery & Exploration Program Elements

- **Commercial Lunar Payload Services (CLPS)**
  - Two landings per year
  - Enabling community-driven science
  - VIPER Delivery in 11/2024
- **Science Instrument Development for CLPS Delivery**
  - Instruments deployed by CLPS (NPLP, LSITP, PRISM)
  - Maturation of instrument concepts (DALI)
- **VIPER Rover**
  - Project
  - VIPER Review Team (VRT)
- **Lunar Reconnaissance Orbiter (LRO) mission operations**

- **Lunar Trailblazer**
  - Project; IM-2 rideshare launch
- **Lunar International Mission Collaborations**
- **Science Instrument Development for Artemis Human Missions (includes LTV, HLS deployed, Astronaut hand-held instruments)**
- **Lunar Science Research – Competed Geology Teams, Internal Science Team, Curation, Data Infrastructure/Tools, Increased Lunar R&A, Apollo Next Generation Sample Analysis (ANGSA)**
- **Mission Concept Studies for Endurance-A, LGN, LRO successor, etc.**
- **Future Missions/Projects**

Lunar Discovery and Exploration – President's Budget Request 2023

FY 2023 President's Budget Request	FY 2023	FY 2024	FY 2025	FY 2026	FY 2027
Lunar Discovery & Exploration	**486,253**	**458,256**	**458,258**	**458,258**	**468,340**
CLPS	255,278	254,412	254,424	254,437	254,450
Lunar Instruments	31,844	82,921	105,409	102,479	96,453
PRISM-1	21,501	8,471	-	-	-
PRISM-2	25,000	15,000	5,000	-	-
LIMC	500	500	500	500	500
Lunar Science Research	5,666	9,461	12,856	13,089	17,585
VIPER	96,994	30,600	-	-	-
Lunar Trailblazer	1,179	4,328	3,384	1,825	767
DALI	14,346	15,000	15,000	15,000	15,000
LRO	22,000	22,000	22,000	22,000	22,000
Lunar Management	6,033	9,826	4,548	4,476	4,554
Lunar Future	5,912	5,737	35,137	44,452	57,031

Endurance A Decadal Mission Costs

For <u>2030 landing</u> with Mod 1 Next Gen Power System, cost is a significant fraction of LDEP's budget through 2034

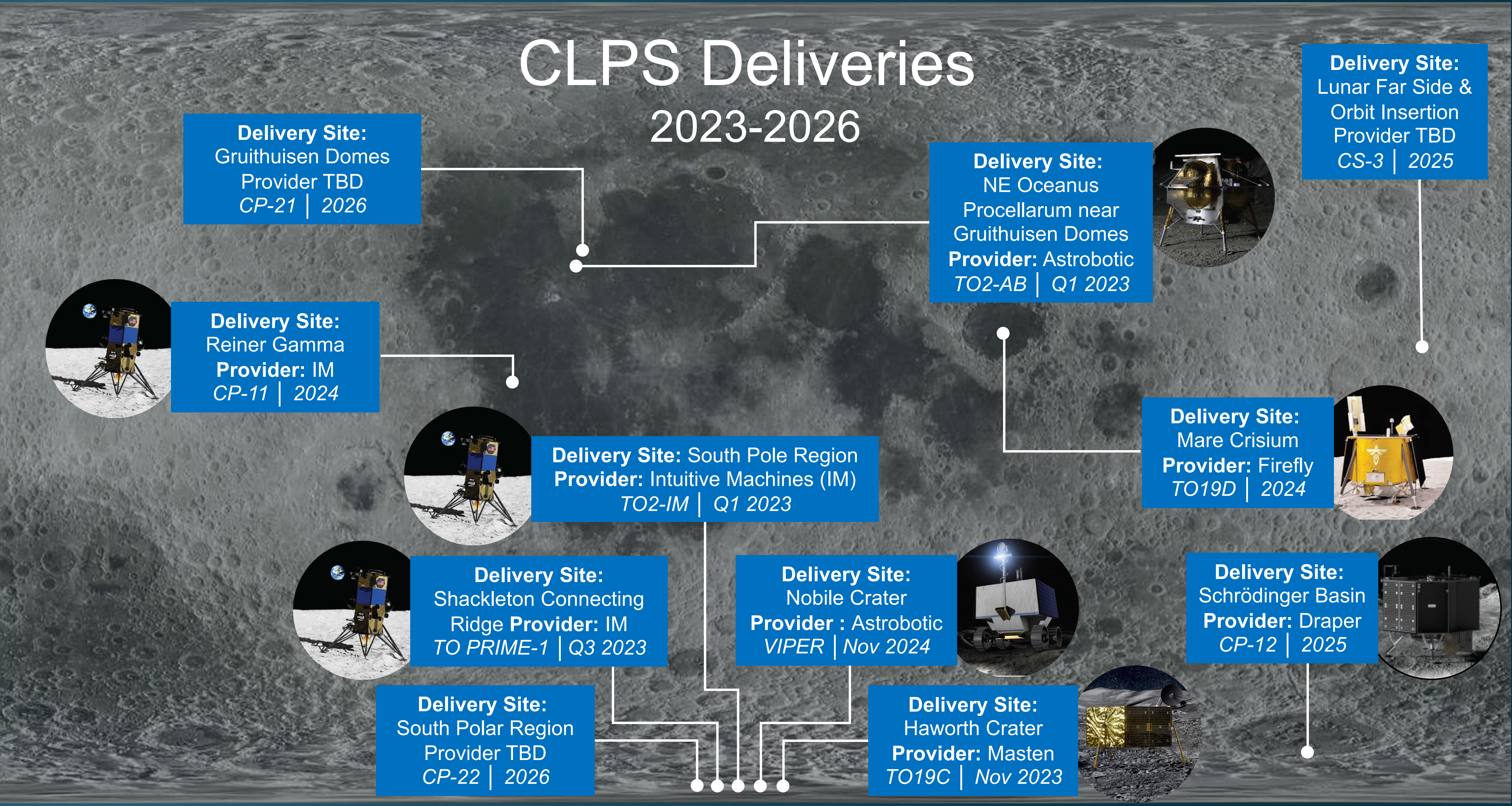
Table 5-3. Endurance A Mission Cost Funding Profile (FY costs[1] in Real Year $, Totals in Real Year and FY25 $).

Item	FY24	FY25	FY26	FY27	FY28	FY29	FY30	FY31	FY32	FY33	FY34	Total (RY$M)	Total (F25$M)
Cost													
Phase A Concept Study	2.1	2.9	-	-	-	-	-	-	-	-	-	4.9	5.0
Technology Development	-	-	-	-	-	-	-	-	-	-	-	-	-
Phase B-D Development[2]	-	59.6	203.4	257.4	157.7	87.3	35.7	-	-	-	-	801.0	755.0
Phase B-D Reserves	-	27.2	92.9	117.6	72.0	39.9	16.3	-	-	-	-	366.0	345.0
Total A-D Development Cost	2.1	89.6	296.3	375.0	229.7	127.2	52.0	-	-	-	-	1,171.9	1,105.0
Launch services	-	-	34.3	35.2	36.2	37.3	38.3	39.4	-	-	-	220.8	200.0
Phase E Science	-	-	-	-	-	-	16.3	18.9	19.5	20.0	20.6	95.3	78.2
Other Phase E Cost	-	-	-	-	-	-	23.0	26.6	27.4	28.2	29.0	134.1	110.0
Phase E Reserves	-	-	-	-	-	-	9.4	10.9	11.2	11.5	11.8	54.7	44.9
Total Phase E Cost	-	-	-	-	-	-	48.7	56.4	58.0	59.7	61.4	284.1	233.1
Education/Outreach													
Other (specify)													
Total Cost	**2.1**	**89.6**	**330.6**	**410.2**	**266.0**	**164.5**	**139.0**	**95.8**	**58.0**	**59.7**	**61.4**	**1,676.8**	**1,538.1**
											Total Mission Cost	**1,676.8**	**1,538.1**

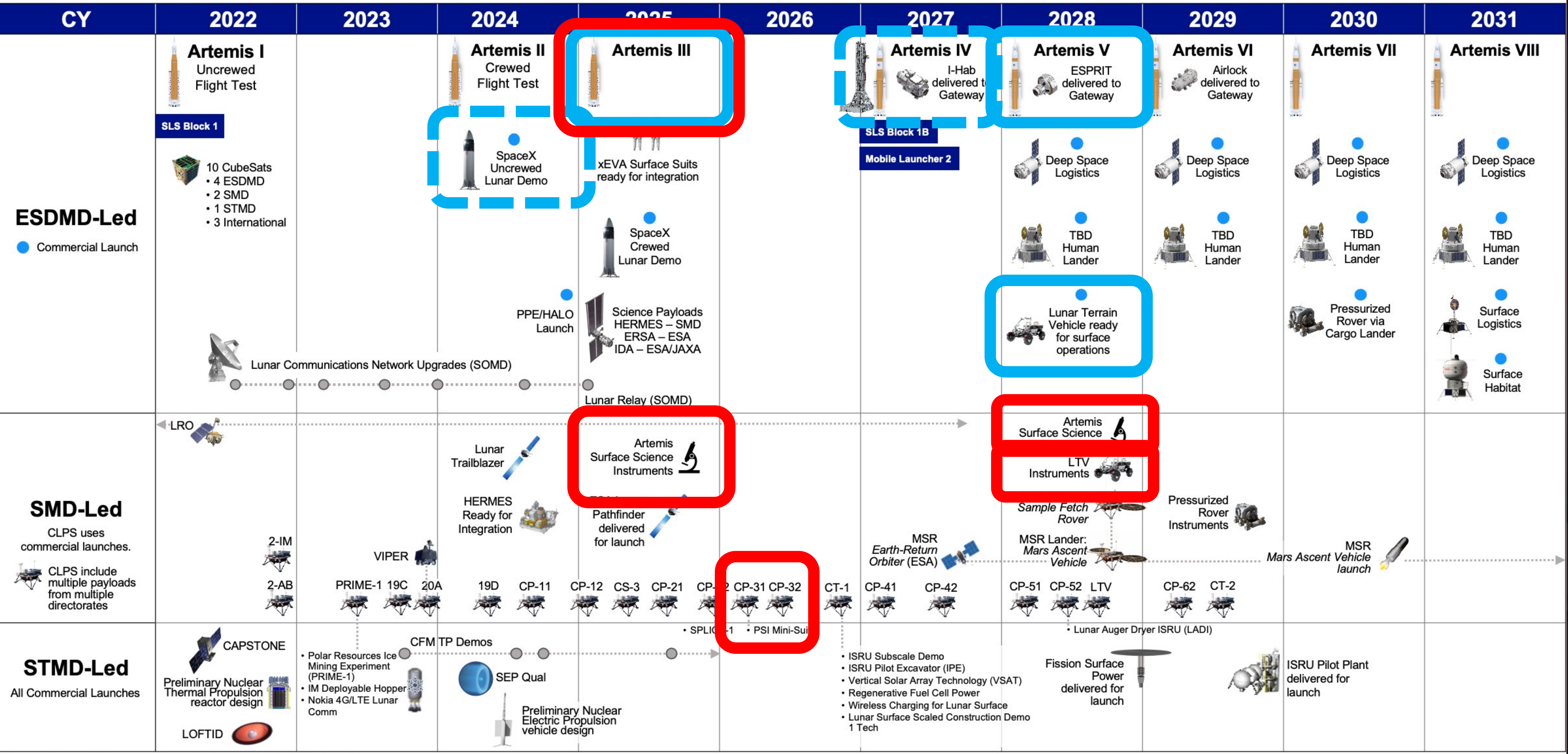
[1] Costs should include all costs including any fee

[2] MSI&T - Mission System Integration and Test and preparation for operations included

	Endurance A Concept Study											
	FY24	FY25	FY26	FY27	FY28	FY29	FY30	FY31	FY32	FY33	FY34	Total
Endurance A report	2.1	89.6	330.6	410.2	266	164.5	139	95.8	58	59.7	61.4	1676.9
LDEP in-guide, with 2% inflation	458.3	458.3	458.3	468.3	475.3	484.8	494.5	504.4	514.5	524.8	535.3	5376.7


CLPS Deliveries
2023-2026
Delivery Site: Gruithuisen Domes
Provider TBD
CP-21 | 2026
Delivery Site: NE Oceanus Procellarum near Gruithuisen Domes
Provider: Astrobotic
TO2-AB | Q1 2023
Delivery Site: Lunar Far Side & Orbit Insertion
Provider TBD
CS-3 | 2025
Delivery Site: Reiner Gamma
Provider: IM
CP-11 | 2024
Delivery Site: South Pole Region
Provider: Intuitive Machines (IM)
TO2-IM | Q1 2023
Delivery Site: Mare Crisium
Provider: Firefly
TO19D | 2024
Delivery Site: Shackleton Connecting Ridge Provider: IM
TO PRIME-1 | Q3 2023
Delivery Site: Nobile Crater
Provider : Astrobotic
VIPER | Nov 2024
Delivery Site: Schrödinger Basin
Provider: Draper
CP-12 | 2025
Delivery Site: South Polar Region
Provider TBD
CP-22 | 2026
Delivery Site: Haworth Crater
Provider: Masten
TO19C | Nov 2023

FY23 PBR Moon to Mars Planning Manifest



Imagery is meant to represent the calendar year in which the launch occurs.
Does not include impact from FY22 appropriations.

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Integrated Lunar Science Strategy

From the Decadal Recommendations:

- "PSD should develop a strategic lunar program that includes human exploration as an additional option to robotic missions to achieve decadal-level science goals at the Moon."
- "Conducting decadal-level science should be a central requirement of the human exploration program."

What is an “Integrated Lunar Science Strategy”?

- An opportunity to think strategically about the tools available to us, within budget constraints, and how they map to the high priority science we want to accomplish at the Moon
- A path forward that is flexible enough to react to the changing landscape as our capabilities grow and priorities evolve

What is it not?

- A document, carved in stone, that will come down from the proverbial mountain top and be handed to the community

What’s our approach?

- We will present a path for developing a strategy to meet the biggest challenges for lunar science, as defined by the community

How long will this take?

- We plan to start several mission studies and Science Definition Teams over the next couple of years to make informed decisions about our strategic direction

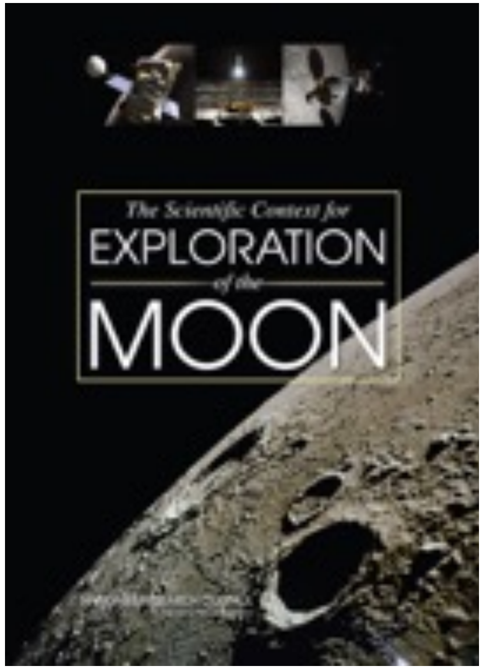
Who is developing it?

- We have assembled a joint PSD/ESSIO working group
  - Sarah Noble, Amanda Nahm (PSD/ESSIO)
  - Shoshana Weider, Bobby Fogel, Jeff Grossman, Kathleen Vander Kaaden, Bo Trieu (PSD)
  - Brad Bailey, Debra Needham, Ryan Watkins (ESSIO)
- Community participation through SDTs, workshops, LEAG SATs, townhalls

Agency Priorities at the Moon

- Why NASA explores – Three Pillars of Exploration:
  - Science
  - National Posture
  - Inspiration
- Safe transport and return of Astronaut crew
- Human Landings at Lunar South Pole (SPD-1)
- Promote a lunar economy to produce rapid, frequent, and affordable access to the lunar surface and cislunar space
- Prepare for human exploration of Mars and beyond

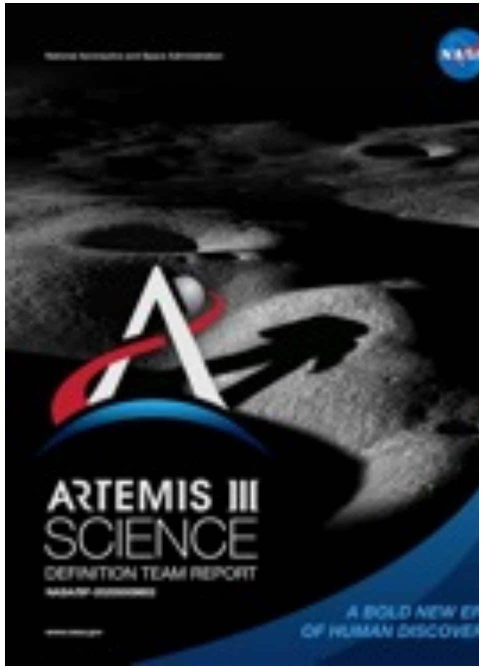
Planetary Community Science Priorities



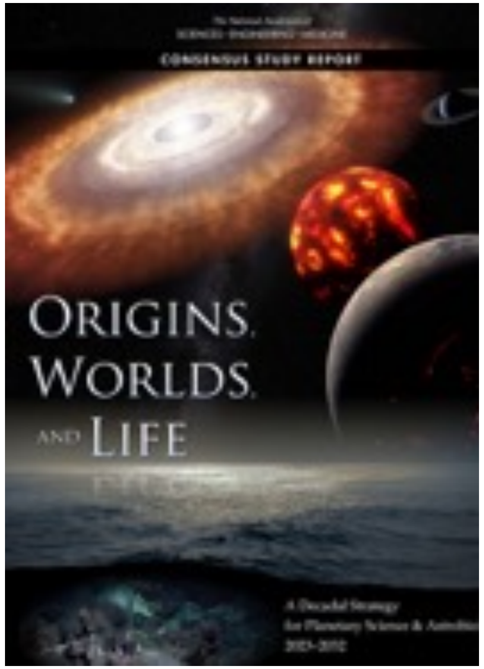
[2007](#)

[2016](#)

[2017](#)



[2020](#)



[2022](#)

The Big Challenges
(i.e., science that requires a strategy to accomplish)

Specific missions that can be achieved through multiple architecture options:

- SPA Sample Return
- Lunar Geophysical Network
- Cryogenic Volatile Sample Return

Objectives that require a build up of knowledge and global access to samples to achieve:

- Lunar Chronology
- Lunar Formation/Evolution

These implement Strategic Research defined for Decadal Science Questions

Implementation Strategy: SPA Sample Return

Options for achieving this:

- New Frontiers
- Endurance-A (or other rover design)
- Human sortie to interior of basin (will not get all the science of a 1000+ km traverse)
  - Two (or more) human sorties
- CLPS sample return w/mobility (CLPS is not currently capable of this)
- Some combination of the above

Path to a decision:

- Mission Studies to look at different approaches for a long-duration sample-collecting rover:
  - SMD-developed rover
  - LTV-derivative rover
- SDT or National Academy study on non-polar sorties for human exploration
- Alternative mobility options also under consideration:
  - Mobility as a CLPS Service

Implementation Strategy: Lunar Geophysical Network

Options for achieving this:

- New Frontiers
- Multiple CLPS deliveries of a self-contained long-duration payload
- Polar and non-polar human sorties
- Some combination of the above

Path to a decision:

- SDT or National Academy study on non-polar sorties for human exploration
- Payload design study
- CLPS capability assessment

Implementation Strategy: Cryogenic Volatile Sample Return

Although this is still a big challenge, architecturally, this is the simplest of the tall poles because we have a viable path to achieve this through Artemis. Still, we should not underestimate the difficulty of collecting, transporting, and curating a cryogenic sample.

Path forward for Sample Return:

- Develop requirements for freezer/sample containers – 3 phase plan:
    - Sealed container (unconditioned)
    - -85C freezer
    - Cryo-freezer
- Current JSC/ESDMD studies:
    - Laboratory studies
    - Roadmap for cold sample return
    - Non-Orion return options
    - What does a freezer look like?
- Working to get new Artemis Curation Lead, a Contamination Control Scientist (Andy Needham – started yesterday) and a Contamination Control Engineer into place asap

Implementation Strategy: Lunar Chronology

Options for achieving this:

- CLPS sample return (not currently within CLPS capabilities)
- In situ dating
- Artemis non-polar sorties
- Some combination of above

Path to achieving this:

- Work towards CLPS sample return
- Development of in-situ dating tools
- SDT or National Academy study on non-polar sorties for human exploration

Implementation Strategy: Lunar Formation/Evolution

By achieving other goals, we will also make progress on this one:

- SPA sample return
- Lunar Geophysical Network
- Many of the same locations for sample return as Lunar Chronology

Path to achieving this:

- SDT or National Academy study on non-polar sorties for human exploration
- Make decisions on SPA and LGN

Orbital Strategy

As much as we would like it to, LRO isn’t going to last forever. However, an orbiting asset is critical for achieving high priority science objectives and to enhance science return from human exploration.

- GSFC has begun a pre-phase A study, based on community needs as delineated in the CLOC SAT report
  - The CLOC SAT report was clear that a large “LRO-class” orbiter is required due to pointing and duration requirements.

CLPS Strategy

The capabilities of our CLPS vendors continues to evolve and they are eager for input on where to put their future development efforts. Neither we, nor they, can afford to go down all the paths simultaneously, so we need to make choices and develop a strategy that will maximize science while maintaining the establishment of a sustainable lunar economy

- Survive the night
  - 1-2 nights
  - 6+ years (needed for LGN?)
- Increased mobility
- Complex instrument deployments
- Sample return

Path to decision:

- Regular surveys of vendor pool
- PRISM is giving us a better sense of cost for capability
- Decision on using CLPS for LGN, and whether lander needs to survive or just payload

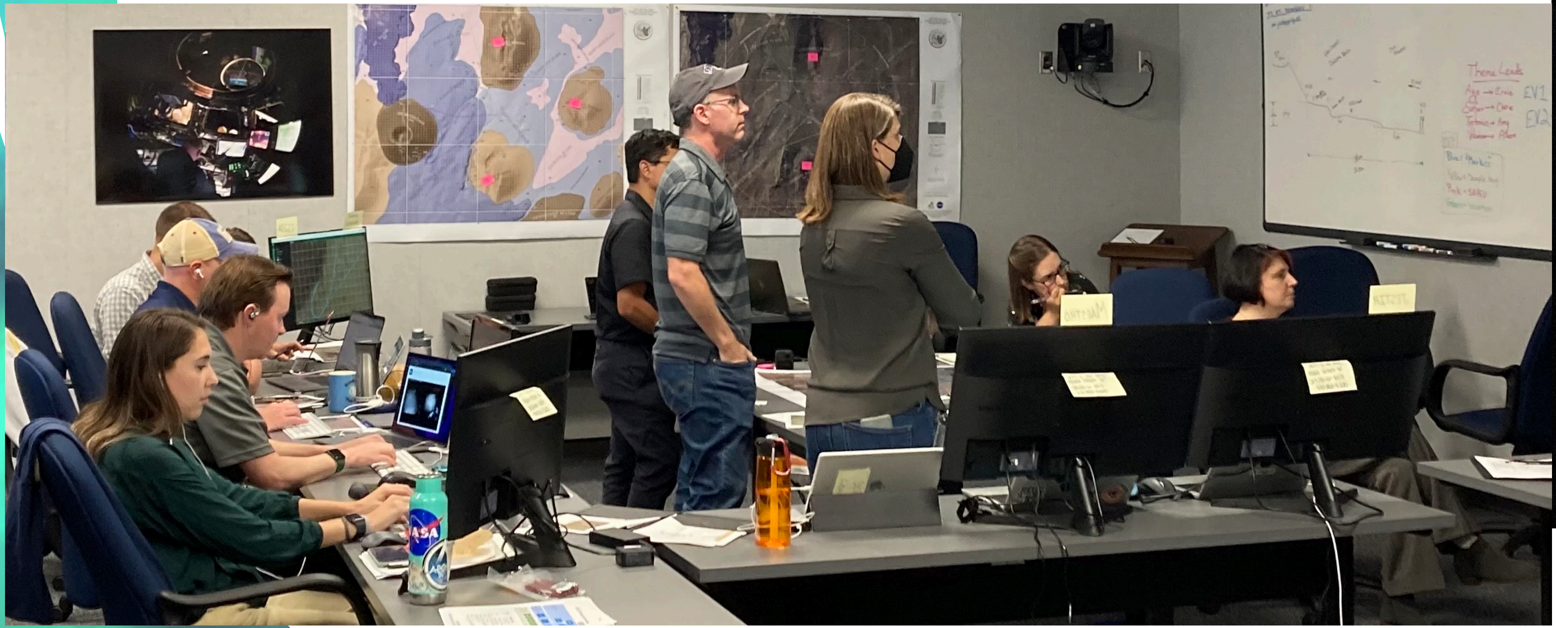
R&A Strategy

In order to be prepared to take full advantage of Artemis, we need to strengthen the sample science community, as well as the field geology community. We also need to ensure that our instrument pipeline is meeting our needs for both Artemis and CLPS.

- We are targeting specific calls to expand the communities and capabilities we need to grow
  - DALI / PRISM
  - ANGSA
  - SSERVI CAN focus on sample science
  - Analog Activities call
- High priority research areas may be called out specifically in LDAP/PDART/LARS and others
- Trying to do this with intention and use the expansion of the community as an opportunity to also diversify the community.
- CLPS data will be incorporated into LDAP, with supplemental budget from ESSIO
- Working with curation/O-REx to develop AstroMat as a repository for sample data and ensure it will meet the needs of Artemis and CLPS sample return
- With help from the USGS, we are developing a Lunar SDI community
- Thinking about laboratory needs, particularly for cold-curated samples

Preparing for Artemis III

- Draft text for C.25 Artemis III Geology Team released for community comment.
  - Comments and questions are due to HQ-ArtemisGeology@mail.nasa.gov by December 23.
  - A townhall will be held on December 9, 2022
- Artemis deployed instruments call – still planned for ROSES22
- Analog Activities call - due today!
- Planetary Science Training Team assembling curriculum
- Landing site workshop in March



JETT-3 - SER and in the field

Questions?