National Aeronautics and Space Administration

Artemis Program Heliophysics Science and Instruments on Gateway

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for the Gateway Heliophysics Discipline Working Group

COPUOS meeting
August 31, 2021

Heliophysics Discipline Working Group

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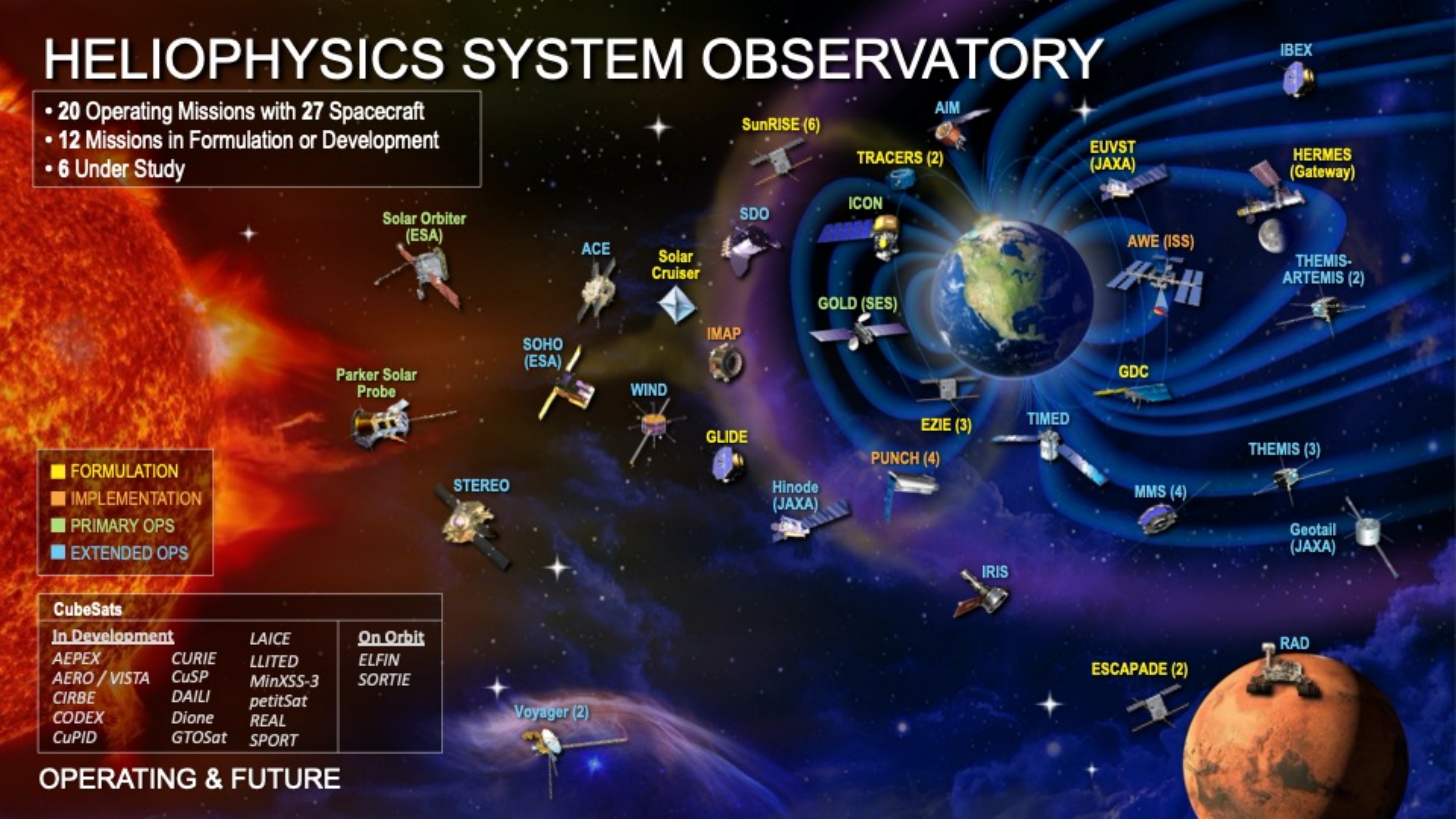
Matt Taylor - ESA
Leonardo Surdo – ESA
Petteri Nieminen – ESA
Juha-Pekka Luntama - ESA
Melanie Heil – ESA
Piers Jiggens – ESA
John Manuel – CSA
Eric Gloutnay –CSA
Perry Johnson-Green – CSA
Aiko Nagamatsu – JAXA
Akira Higashibata – JAXA
Takefumi Sakaguchi – JAXA
Nakamura Masato – JAXA
Sabrina Savage – NASA
Debra Needham – NASA
Brad Bailey – NASA
Jamie Favors – NASA
Bill Paterson - NASA
Jim Spann – NASA
Gary Brown – NASA
Lisa Carnell – NASA
Tim Horvath - NASA

Heliophysics is the study of the Sun, its extended atmosphere, its connectivity with and impact on solar system bodies, and its interaction with interstellar space. It is referred to as Solar and Space Physics.

Space Weather is the applied expression of Heliophysics

Above: *Space weather can interfere with satellite electronics, radio communications and GPS signals, spacecraft orbits, and even power grids on Earth.*



HELIOPHYSICS SYSTEM OBSERVATORY
• 20 Operating Missions with 27 Spacecraft
• 12 Missions in Formulation or Development
• 6 Under Study
Solar Orbiter (ESA)
ACE
Solar Cruiser
SunRISE (6)
SDO
AIM
TRACERS (2)
ICON
EUVST (JAXA)
HERMES (Gateway)
IBEX
AWE (ISS)
THEMIS-ARTEMIS (2)
GOLD (SES)
IMAP
SOHO (ESA)
Parker Solar Probe
WIND
GLIDE
EZIE (3)
TIMED
GDC
PUNCH (4)
THEMIS (3)
MMS (4)
Geotail (JAXA)
Hinode (JAXA)
STEREO
IRIS
RAD
ESCAPADE (2)
Voyager (2)
FORMULATION
IMPLEMENTATION
PRIMARY OPS
EXTENDED OPS
CubeSats
In Development
AEPEX
AERO / VISTA
CIRBE
CODEX
CuPID
CURIE
CuSP
DAILI
Dione
GTOSat
LAICE
LLITED
MinXSS-3
petitSat
REAL
SPORT
On Orbit
ELFIN
SORTIE
OPERATING & FUTURE

National Aeronautics and Space Administration

Artemis Science Objectives

Objective 1: Understanding Planetary Processes

Objective 2: Understanding Volatiles Cycles

Objective 3: Interpreting the Impact History of the Earth-Moon system

Objective 4: Revealing the Record of the Ancient Sun

Objective 5: Observing the Universe from a Unique Location

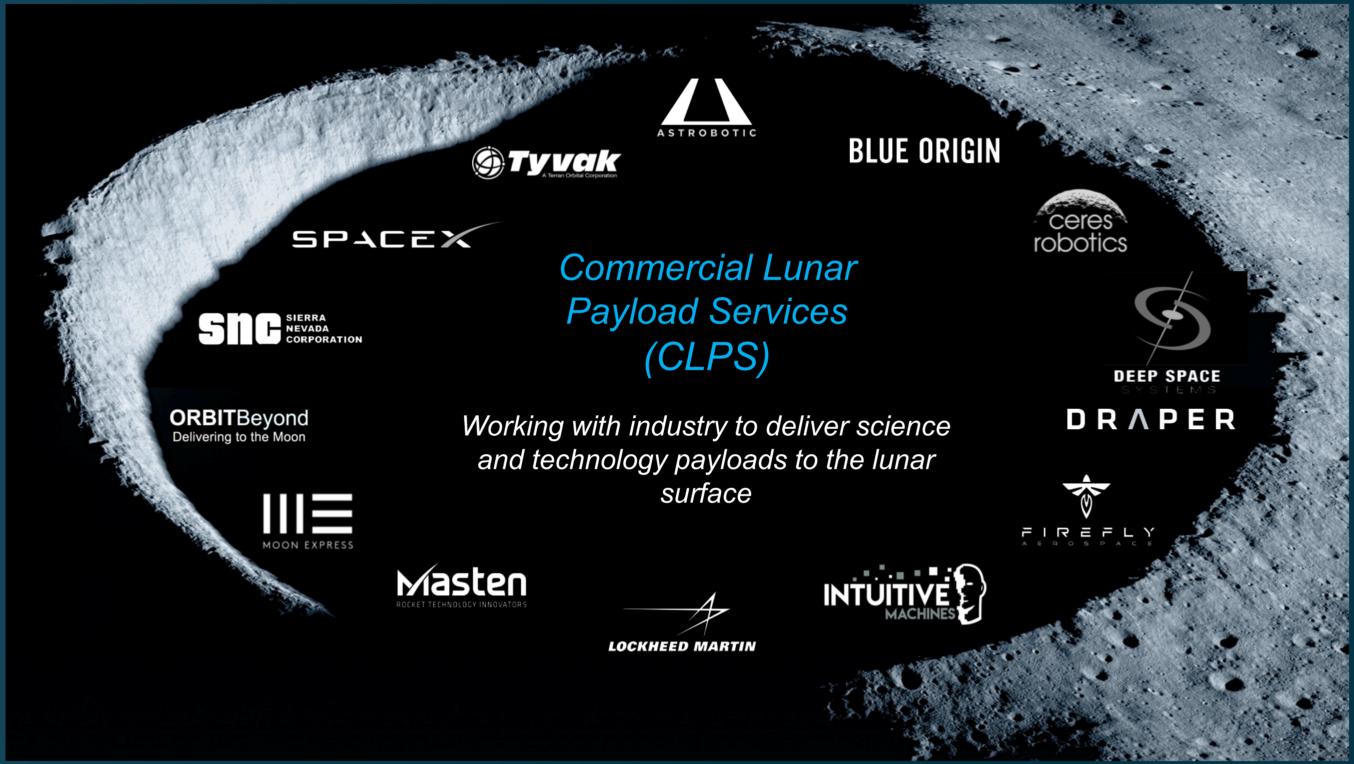
Objective 6: Conducting Experimental Science in the Lunar Environment

Objective 7: Investigating and Mitigating Exploration Risks to Humans

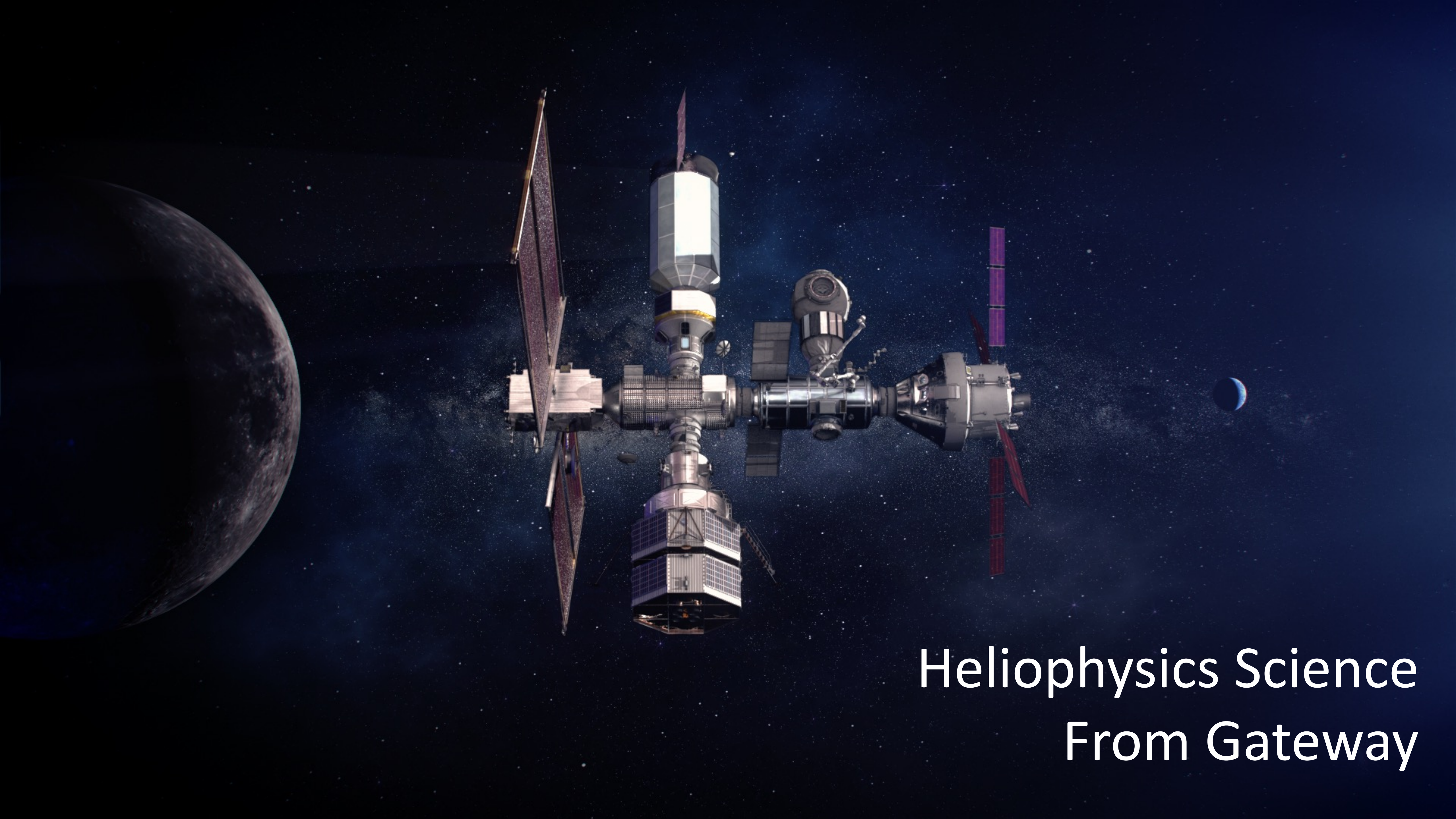
Commercial Lunar Payload Services (CLPS)

Goal: Utilize commercial end-to-end delivery services to enable access to the lunar surface

- 2021: Non-polar delivery (Astrobotic and Intuitive
  Machines) – TO 2A & 2B
- 2022: Polar delivery (Masten) – TO 19C
- 2022: PRIME-1 (Intuitive Machines)
- 2023: Crisium delivery (Firefly Aerospace) – 19D
- 2023: VIPER to Moon's south polar region (Astrobotic) – TO 20A



- 9 of 29 payloads for 21/22 deliveries have relevance to heliophysics and space weathe



Heliophysics Science From Gateway

Gateway Utilization Program Strategic Goals

1. Enable Lunar related science
2. Prepare for Mars and Deep Space Exploration
3. **Conduct Science/Research unique to Gateway's Deep Space Location**
4. Engage with the Public and Inspire Future Generations

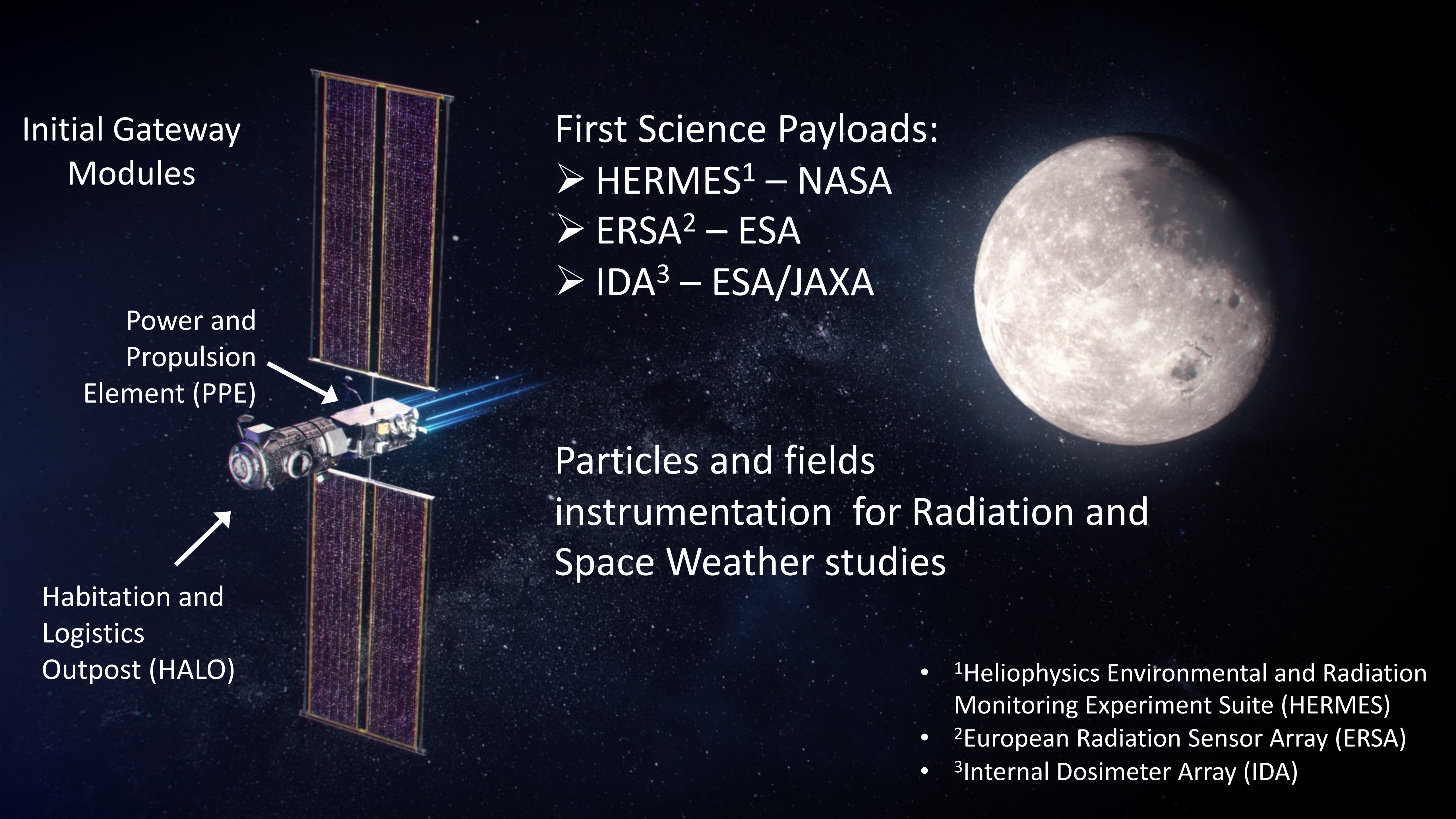
Heliophysics and the Gateway

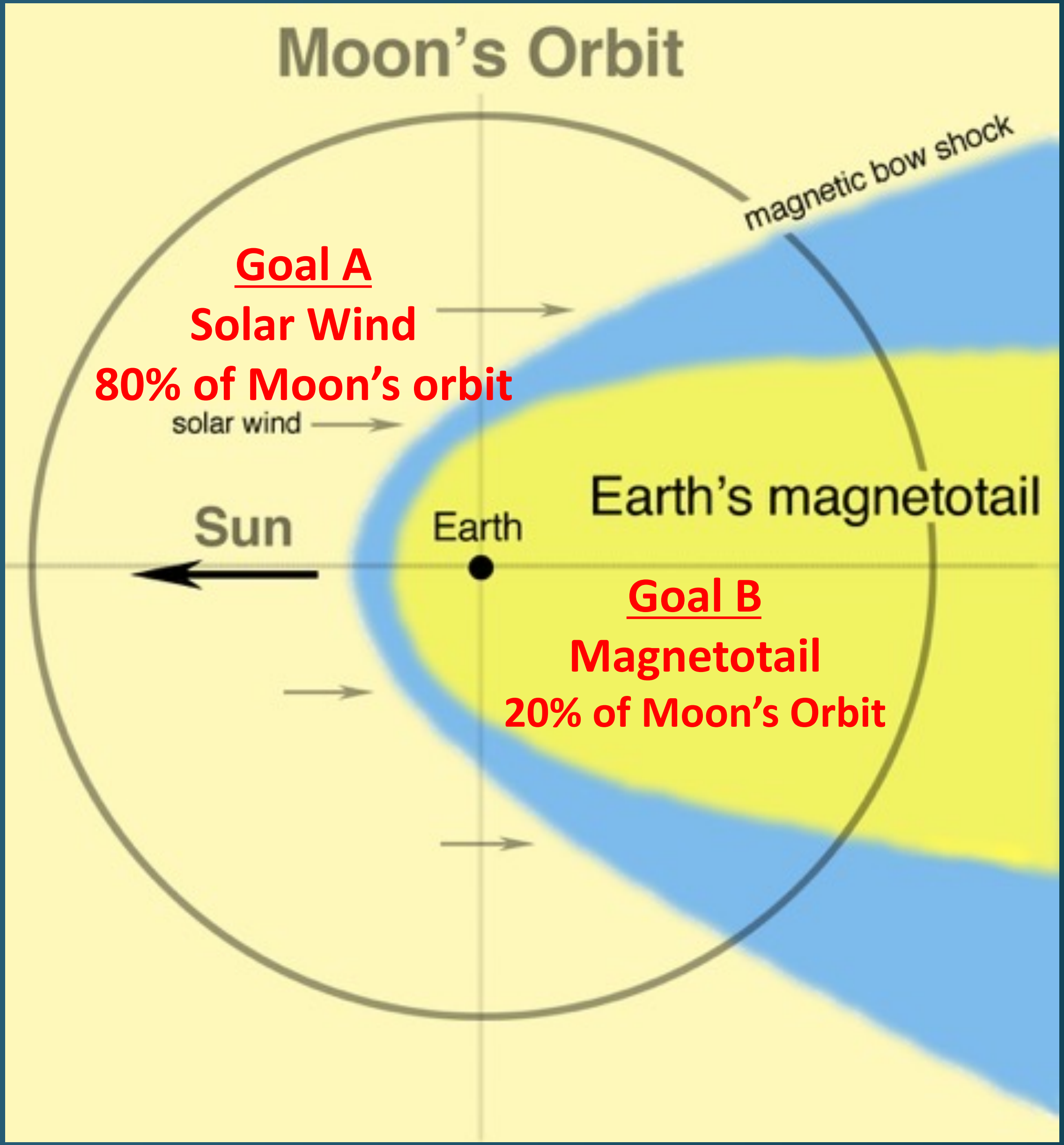
3. Conduct Science/Research unique to Gateway's Deep Space Location

- **3.1 Study Natural Environment at Gateway**
  - Study the ambient plasma environment outside of the Earth's magnetosphere as a proxy for deep space
  - Study and characterize SEPs & GCRs environment at the gateway
  - Study and characterize the ambient plasma environment resulting from the vicinity of the moon
  - Study and Characterize the local ambient plasma and radiation environment to support human exploration
  - Provide operational Space Weather measurements at gateway (real time)
  - Study the local dust environment
- **3.2 Characterize Induced Environment at Gateway**
  - Study and Characterize the local plasma environment induced by the gateway
  - Study local dust environment and contrast result of LEO and Lunar orbit related to cosmic dust flux and impact of anthropogenic activity.

Heliophysics and the Gateway (cont.)

- **3.3 Heliophysics Investigations**
  - Study and characterize the ambient plasma environment outside of the Earth's magnetosphere as a driver for the dynamics of the terrestrial magnetosphere and associated boundaries
  - Study and characterize the ambient plasma environment outside of the Earth's magnetosphere as a driver for terrestrial & lunar exospheres, lunar surface sputtering & charging
  - Study and characterize SEPs & GCR as lunar surface sputtering sources
  - Study and characterize the global response of the terrestrial magnetosphere to the solar wind
  - Study solar wind interaction with lunar exosphere, regolith & magnetic anomalies
  - Study the global terrestrial plasmasphere, ionosphere, exosphere & lunar exosphere
  - Study and characterize the ambient plasma environment inside the Earth's magnetosphere and its associated boundaries
  - Determine the multiscale plasma and magnetic field properties of CMEs and shocks and how the dynamic inner heliosphere controls the transport of transients to Earth and beyond.
  - Study the fluxes, composition and sources of cometary, asteroidal and intersteller dust particles


Initial Gateway Modules
First Science Payloads:
➢ HERMES1 – NASA
➢ ERSA2 – ESA
➢ IDA3 – ESA/JAXA
Power and Propulsion Element (PPE)
Particles and fields instrumentation for Radiation and Space Weather studies
Habitation and Logistics Outpost (HALO)
• 1Heliophysics Environmental and Radiation Monitoring Experiment Suite (HERMES)
• 2European Radiation Sensor Array (ERSA)
• 3Internal Dosimeter Array (IDA)



HERMES Goals

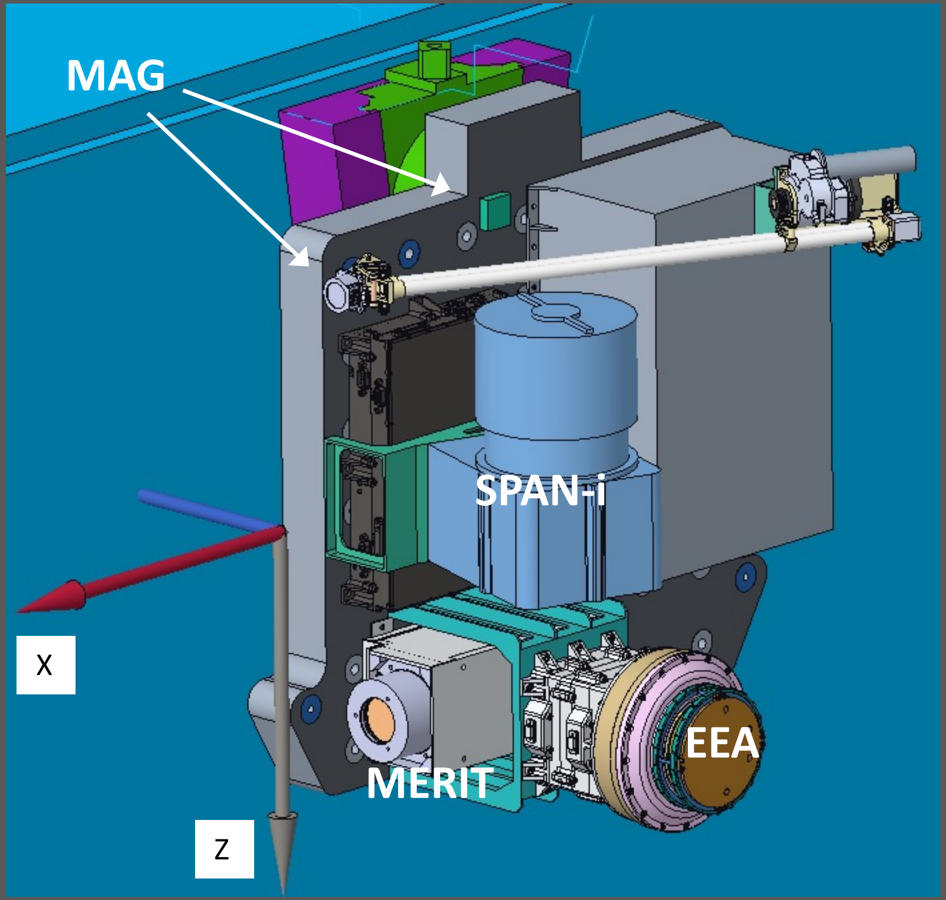
Goal A: Determine mechanisms of ***solar wind*** mass and energy transport

Goal B: Characterize energy, topology, and ion composition in the deep ***magnetotail***

Goal C: Establish observational capabilities of an on-board ***pathfinder payload*** measuring local ***space weather*** to support deep-space and long-term human exploration

- HERMES is composed of 3 particle instruments and a set of magnetometers
- Capabilities are typical of in-situ space weather instruments

Instrument	Measurement	PI
EEA, Electron Spectrometer (electrons < 30 keV)	Electron Flux, Density, Speed, Temperature	D. Gershman, GSFC
SPAN-i, Ion Spectrometer (ions < 20 keV)	Ion Flux, Density, Speed, Temperature, M/Q Species	R. Livi, UC Berkeley
MERiT, Ion and Electron Telescope (energetic particles)	0.3 – 9 MeV Electrons, 1 – 190 MeV Ions, Flux	S. Kanekal, GSFC
NEMISIS (MAG) (3 magnetometers)	Magnetic Field Vector	E. Zesta, GSFC M. Moldwin, U Mich



HERMES

MASS < 25 kg

(X,Y,Z) < 0.5 ✕ 0.5 ✕ 0.5 m (Boom Stowed)

Magnetometer Boom Extends ~ 1 m

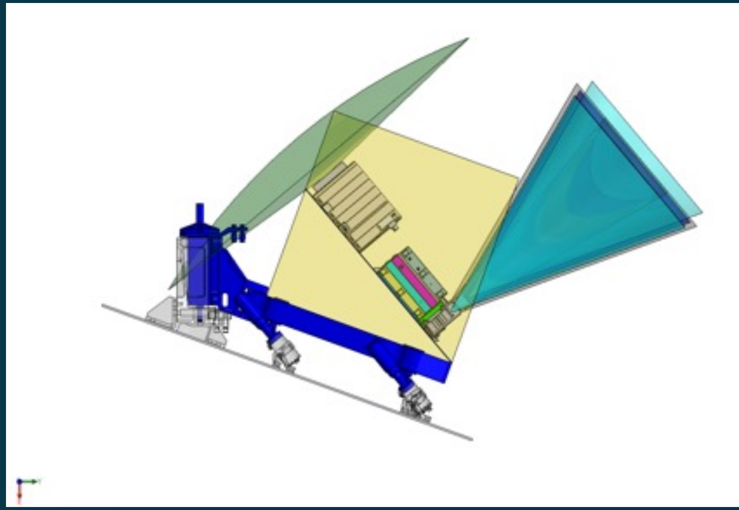
- HERMES concentrates on understanding the causes of space-weather variability as driven by the Sun and modulated by the magnetosphere.
- In coordination with the Heliophysics two-spacecraft mission THEMIS/ARTEMIS already in lunar orbit, the Gateway observations will initiate a heliophysics lunar constellation to conduct science investigations that have never before been possible.
- Six Interdisciplinary Science (IDS) Teams selected

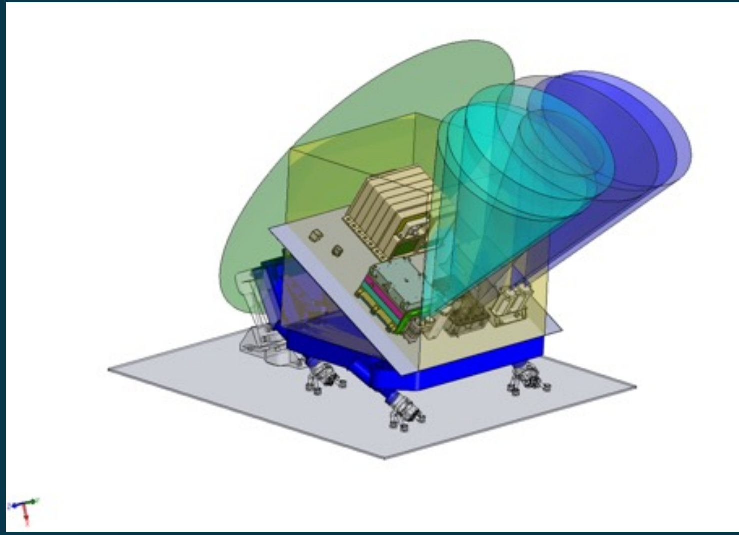
European Radiation Sensor Array (ERSA) Payload

The ESA Radiation Sensor Array (ERSA) consist of several science instruments on a single platform:

- 2 ESA Active Dosimeter (EAD) boards
- Standard Radiation Environment Monitor (SREM)
- Influence of Space Radiation on Advanced Components – New Generation (ICARE-NG)
- Next Generation Radiation Monitor (NGRM)
- 2 MediPix units
- 2 Magnetometer sensors

All instruments have TRL 8 or 9 with readiness to support 1 July 2022 delivery for integration on PPE





ERSA Science Objectives

ERSA will measure Solar Energetic Particles and Galactic Cosmic Rays for space weather forecast and nowcast, near-real time radiation warning on-board the Gateway (crew safety) and for modelling inputs into shielding and radiobiological dose calculations.

Science Objectives:

- Long-term measurement of radiation environment outside & inside Earth’s magnetosphere
- Explore concepts for real-time radiation alerts
- Operational space weather services
- Magnetosphere and radiation belt modelling

ESA solicitation for International Science Teams released August 23, 2020

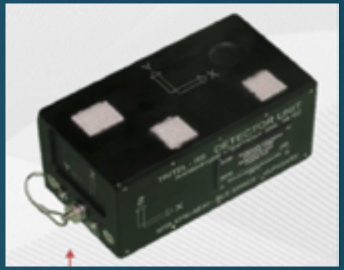
Internal Dosimeter Array (IDA) Payload

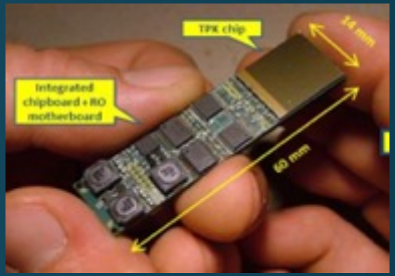
IDA to be integrated in a payload bank enclosure inside HALO (ESA leading payload project)

Payload:

- 1x EAD (active) (ESA, also on ERSA)
- 1x TRITEL Detector Unit (DU) (active) (ESA)
- 1x MediPix (active) (ESA, also on ERSA)
- 1x PADLES (passive) + D-Space dosimeters (active) (JAXA)
- 1x Central electronic unit (CEU) (ESA) providing structural, power & data interfaces between instruments and Gateway

EAD


TRITEL DU


MediPix


PADLES + D-SPACE


CEU

IDA Science Objectives

<u>IDA Provides Scientific Radiation Data that Supports</u>:

- Improve radiation physics models for cancer, cardiovascular and central nervous system effects, informing crew risk assessment for deep space exploration missions
- Refine radiation transport models to evaluate radiation shielding and spallation product generation by the Gateway structure
- Study radiation effects on electronics in deep space

<u>IDA Enables</u>:

- Direct comparison of the external radiation environment (ERSA) to the internal radiation environment (IDA) providing information on the shielding effects; including travel through the Van Allen belts
- Direct comparison between radiation data on ISS and other platforms (same instruments)
- Data acquisition soon after HALO launch and during transit, with operation during uncrewed periods

Questions?

SOLARNET
STATUS: ONLINE
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-210°C
SOLAR FLARE MONITOR
SOLAR FLARE MONITOR
SOLAR X-ray Flux (1- minute da

Backup Slides

Heliophysics Relevant 2021 CLPS Payloads

TO2 Astrobotic Manifest

- PROSPECT Ion-Trap Mass Spectrometer for Lunar Surface Volatiles (PITMS)
  - ➢ Characterize the lunar exosphere after descent and landing, and throughout the lunar day, to understand the release and movement of volatile species.
- Linear Energy Transfer Spectrometer (LETS)
  - ➢ Detect GCRs and SEP precursor particles to acquire knowledge of the lunar radiation environment
- Neutron Measurements at the Lunar Surface (NMLS)
  - ➢ Measure thermal and epithermal neutron flux at the lunar surface, potentially providing radiation environment monitoring, ground truth, and detection of the presence of water or rare Earth Elements.
- Fluxgate Magnetometer (MAG)
  - ➢ Characterize vector magnetic fields to understand energy and particle pathways at the lunar surface.

TO2 IM Manifest

- Low-frequency Radio Observations from the Near Side Lunar Surface (ROLSES)
  - ➢ Determine the photoelectron sheath density and scale height using a low-frequency radio receiver system.

Heliophysics Relevant 2022 CLPS Payloads

Polar Delivery Manifest

- Linear Energy Transfer Spectrometer (LETS)
    - Detect GCRs and SEP precursor particles to acquire knowledge of the lunar radiation environment

Crisium Delivery Manifest

- Lunar Environment [Heliospheric] X-Ray Imager (LEXI)
    - Collect X-ray imagery of Earth's magnetosphere.
- Lunar Magnetotelluric Sounder (LMS)
    - Characterize structure and composition of the Moon's mantle by studying electric and magnetic fields
- Radiation Tolerant Computer System (RadPC)
    - Demonstrate a reconfigurable, radiation tolerant computer technology on the lunar surface that provides increased reliability over the current state-of-the-art in space computers