ESA LightShip-1 science payloads of opportunity

Study status and intended Announcement of Opportunity

Community briefing

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28 February 2025

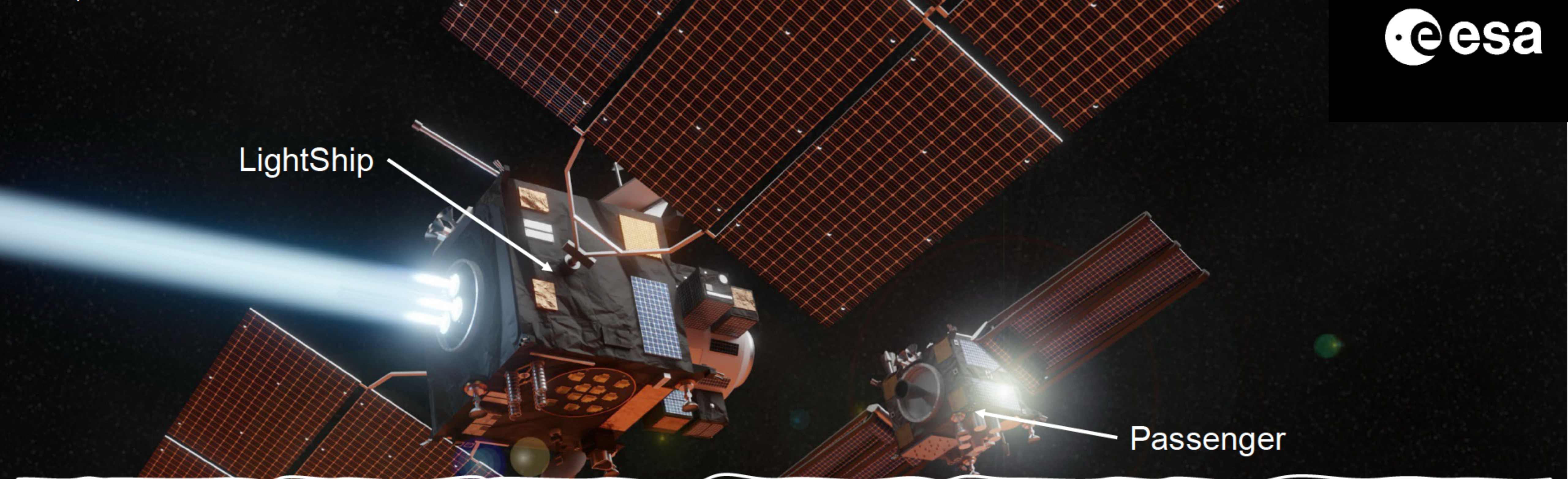
Today's programme

- ESA LightShip-1 mission concept
- Science Definition Team activities in 2024
  - Instrument Definition Team (IDT)
  - Measurement Definition Team (MDT)
- Intended Announcement of Opportunity

Disclaimer

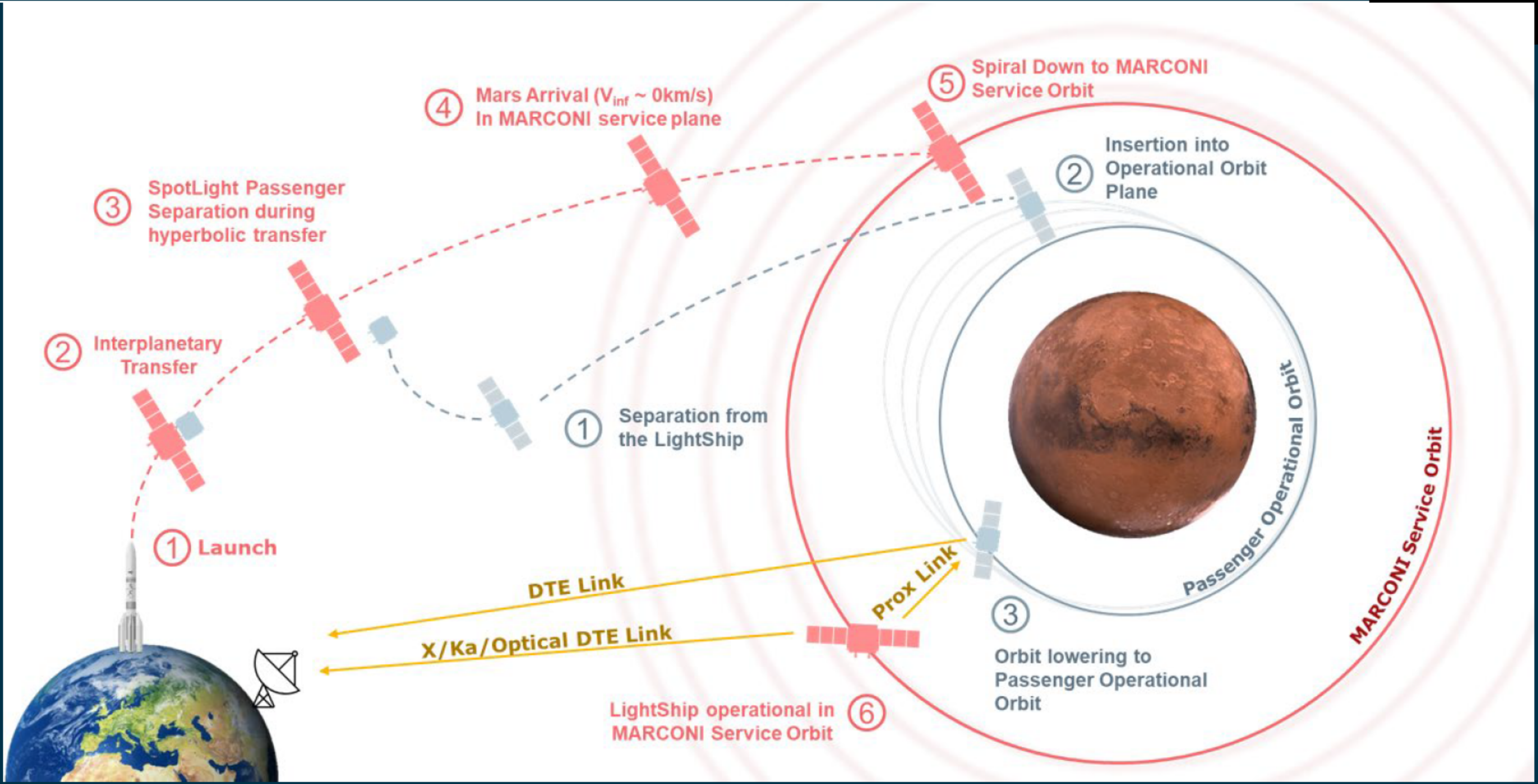
Implementation of LightShip-1 missions and related activities are pending outcome of Council of Ministers in Nov 2025.

Artist impression: Credit ESA

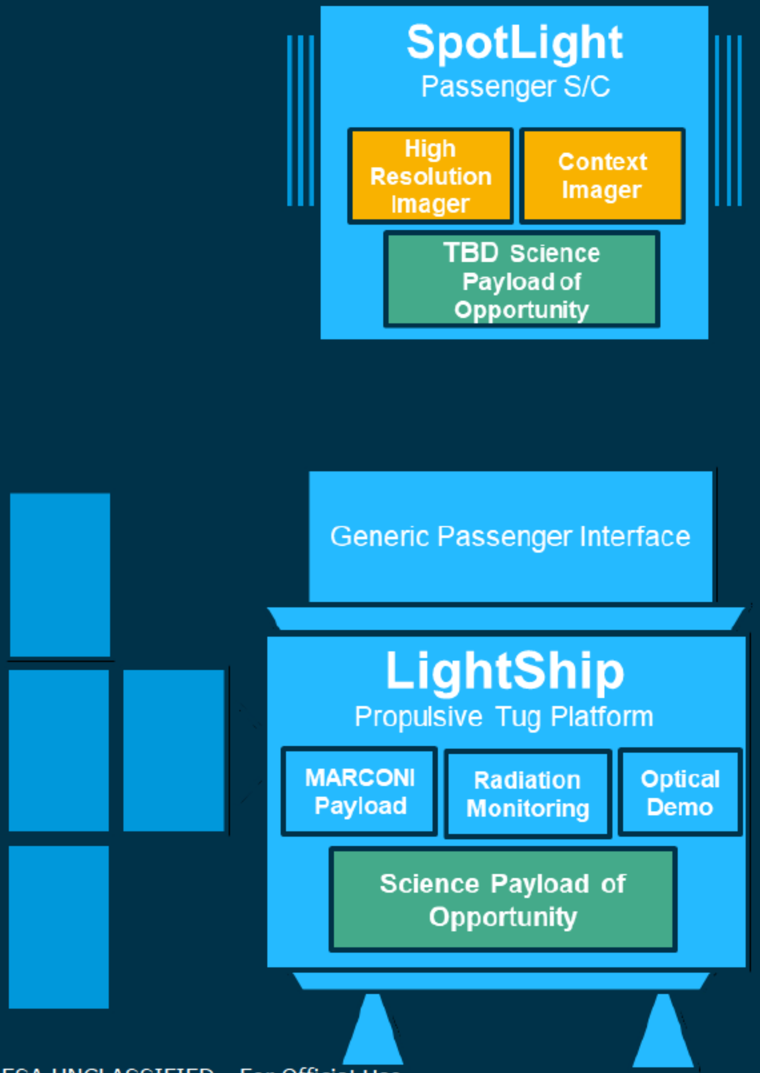


- ESA's LightShip is a **generic electric propulsive tug** that can deliver a single large passenger spacecraft or multiple smaller, low-cost spacecraft to a variety of Mars orbits.
- Once LightShip has released its passenger(s) it will then transfer to an operational service orbit where it will remain as a node that provides a **Mars Communication and Navigation Infrastructure** (MARCONI) service, and **exploration science** opportunities.
- Over the course of multiple missions, the coverage and bandwidth of this service would increase, providing redundancy and higher return of scientific data and opportunities for networked science.
- LightShip parallel industrial Phase A spacecraft studies were kicked off in Dec 2024.
- Mission development schedule aims for a launch readiness date in 2032.

LightShip-1 Mission Context Diagram



LightShip-1 Mission Space Elements



KEY

Exploration Focused and Infrastructure Payloads

- Prime Contractor Responsibility
- Funded by ESA through Prime Contract
- ESA owned requirements

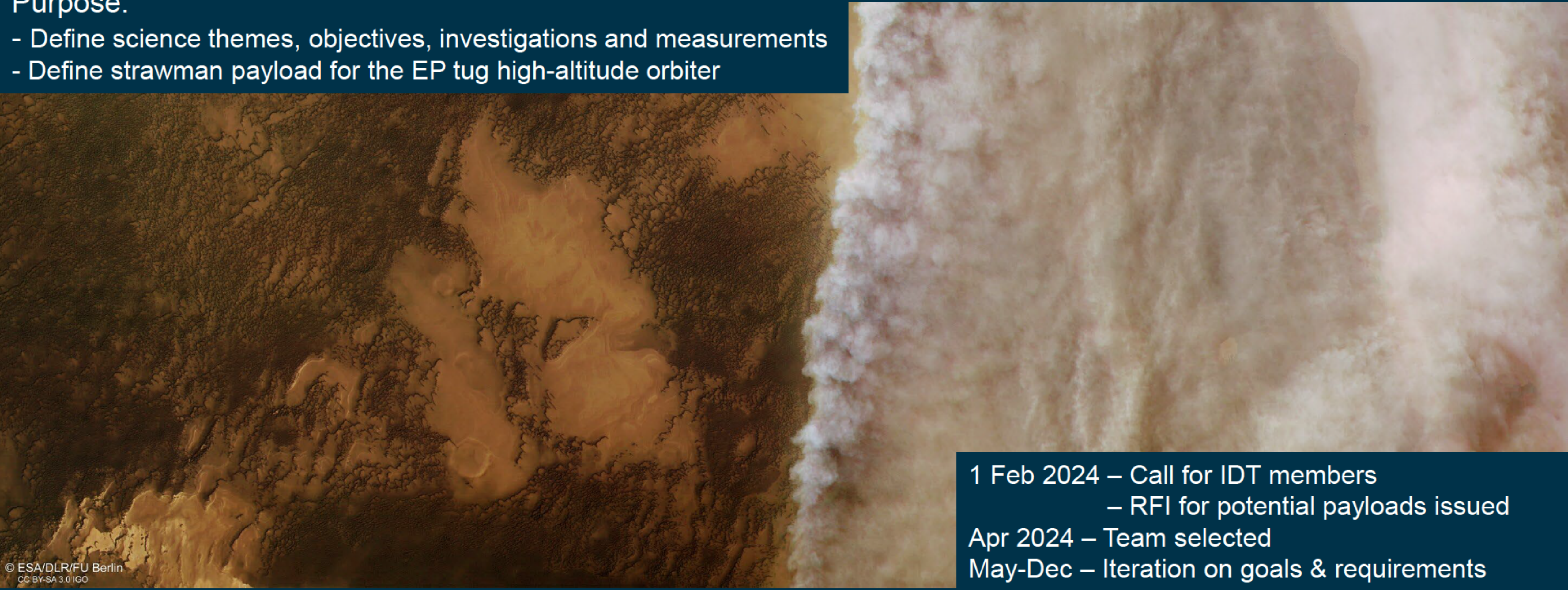
- Dedicated ESA funded payload development due to criticality to Explore2040 strategy

Payload of Opportunity

- Open AO process
- Proposed by the science community within provided guidelines
- No impact on primary mission timeline, platform configuration or orbit selection permitted

LightShip Instrument Definition Team (IDT)

Purpose:
- Define science themes, objectives, investigations and measurements
- Define strawman payload for the EP tug high-altitude orbiter



1 Feb 2024 – Call for IDT members
– RFI for potential payloads issued
Apr 2024 – Team selected
May-Dec – Iteration on goals & requirements
Dec 2024 – Final IDT report completed

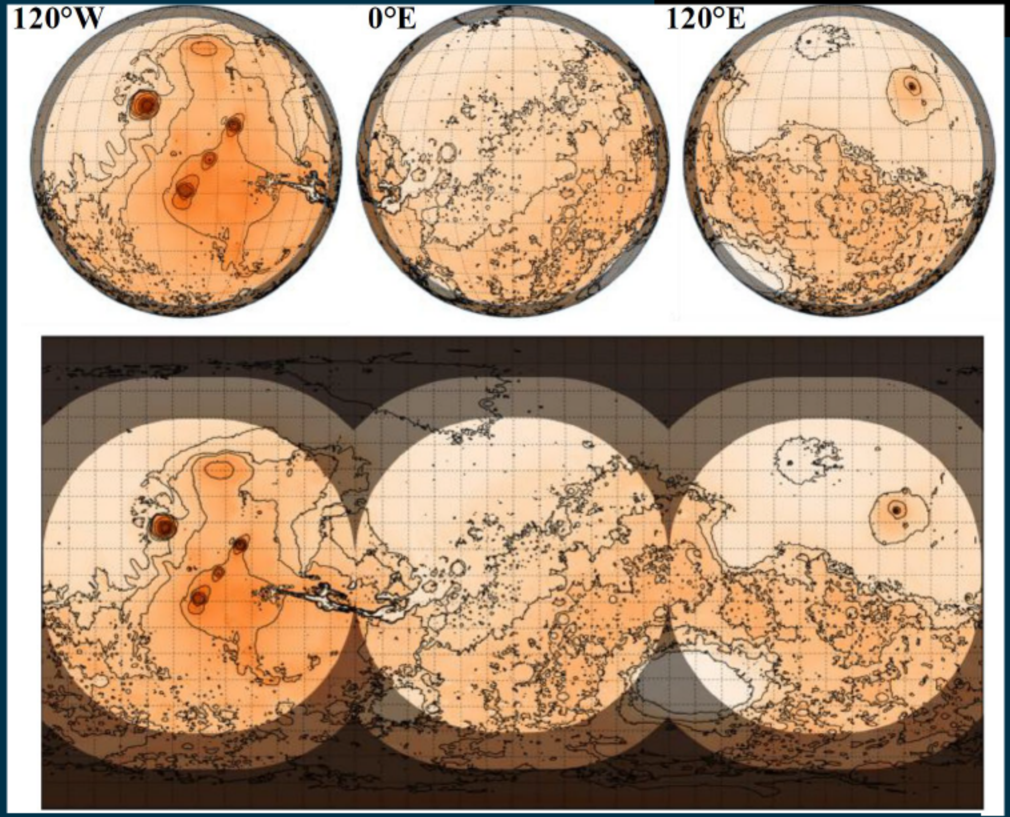
LightShip: towards operational weather monitoring and forecasting

Data relay satellites are ideal for atmospheric monitoring:

- High circular orbit is ideal for synoptic (high-altitude) 'full-disk' mapping of atmospheric temperatures.
- Multiple satellites offer round-the-globe coverage.

Leverages recent developments in Earth Observation:

- Orbital mapping of wind speeds.
- Routine & widespread crosslink radio occultation.
- Large-area multispectral / hyperspectral imaging.
- Advances in data assimilation & numerical weather prediction.



Three high-altitude views of Mars, separated by 120° in longitude. Montabone et al., 2021

LightShip exploration science:

- What governs transport of dust, and water and other volatiles?
- Supports understanding of Mars climate regime through time.
- Improve weather monitoring & prediction.
  - Safer entry, descent and landing.
  - Prediction of thermal & power conditions.
  - Prediction of dust abundances.

LightShip Science Themes & Strawman Objectives

Level 0 (Themes)	Level 1 (Objectives)
Atmospheric circulation and dynamics	a. How are **temperatures, winds and surface weather systems connected** in all seasons and dust conditions?
	b. How **variable is the martian circulation and wave activity** on sub-diurnal to decadal timescales, and what drives this?
	c. Does the spatial and temporal variation of quasi-passive **trace gases** agree with expectations from our understanding of transport and the CO_2 cycle?
Dust cycle and storms	a. What is the **radiative impact of dust** and how does this affect the **circulation**?
	b. How **variable is the martian dust cycle** on sub-diurnal to decadal timescales, and what drives this?
	c. How do **dust storms grow** from local through regional up to global, and how is this related to tides, waves, and the diurnal cycle of solar insolation?
	d. Do **global dust storms decay** due to changes in the circulation, changes in surface dust availability, or something else?
Water cycle, clouds and chemistry	a. What is the **radiative impact of water ice clouds** and how does this affect the **circulation**?
	b. How **variable is the martian water cycle** on sub-diurnal to decadal timescales, and what drives this?
	c. What are the **interactions between the water and dust cycles**?
	d. What chemical, dynamical and dust processes affect **transport of water** towards the **upper atmosphere**?
	e. How **variable is martian atmospheric chemistry** on sub-diurnal to decadal timescales, and what drives this?
Enable Mars exploration (safe arrival & operations)	a. How accurately are **density and wind profiles**, and their variability, represented in atmospheric models?
	b. How well can **weather be predicted** by assimilating temperature, dust, winds, and surface pressure?
	c. How much **warning can be given of dust storms** headed for landing sites?
	*d. What is the **radiation environment** during cruise and in Mars orbit?*
	*e. How many **potential impactors** (dust / micrometeoroids) are present during cruise and in Mars orbit?*
	a. How are **temperatures, winds and surface weather systems connected** in all seasons and dust conditions?
	b. How **variable is the martian circulation and wave activity** on sub-diurnal to decadal timescales, and what drives this?

LightShip Strawman Measurement Requirements

Level 2 (Investigation)	Level 2 (Measurement)	submm	TIR	MIS	NIRSI	Radio occ
Measure **winds**	Measure vertical profiles of line-of-sight wind speeds, accuracy < 10 m/s & vert. res. <8 km	L				
	Measure wind vectors by tracking moving dust & cloud features		N	N		
Measure **temperatures**	Measure vertical profiles of temperature, accuracy 1 K & vert. res. < 8km	L	L			X
	Map thermal emission of atmosphere in spectral bands covering altitudes of 0-60 km, accuracy 1 K & spatial resolution < 10 km	N	N			
	Map surface radiometric temperature to accuracy 1 K, spatial resolution < 10 km	N	N			
Measure **airborne dust**	Measure vertical profiles of dust abundance at 0 - 60 km altitude, vertical resolution < 8 km		L	L		
	Map column abundances across disk of Mars, spatial resolution < 10 km		N	N	N	
	Constrain airborne dust size distribution		N,L	N,L	N,L	
Measure **ice cloud**	Measure vertical profiles of ice abundance at 0 - 60 km altitude, vertical resolution < 8 km		L	L		
	Map column abundances across disk of Mars, spatial resolution < 10 km		N	N	N	
	Constrain ice cloud size distribution & composition		N,L	N,L	N,L	
Measure **water vapour** and related volatiles	Measure profiles of key tracers [H_2O, CO, O_3, ...] at 0 - 100 km altitude, vert. resolution < 8 km	L	L			
	Map column abundances of key tracers [H_2O, CO, O_3, ...] across disk of Mars	N	N		N	
Map **surface-atmosphere exchange**	Map surface changes of dust, H_2O ice, CO_2 ice		N	N	N	
Map **surface pressure**	Map depth of CO2 absorption features to enable pressure to precision of < 10 Pa				N	(X)

L = limb, N = nadir

LightShip Strawman Science Payload

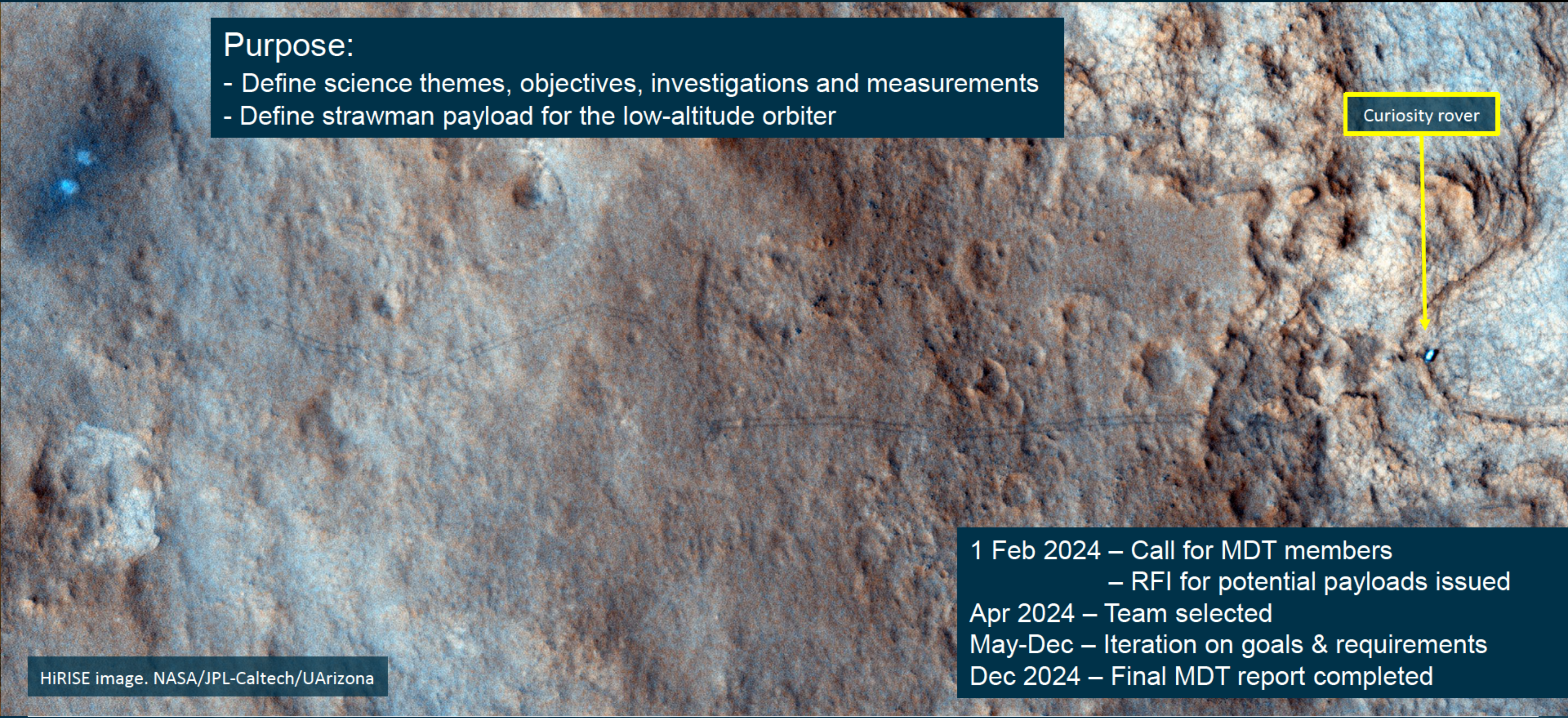
Instrument	mass including maturity margin (kg)	parameters measured
Sub-mm sounder	**18.7**	wind, temperature, volatiles
Thermal IR mapper	**9.6**	temperature, dust, column H_2O vapour
Multiband Imaging Suite	**3.6**	Dust presence, cloud, dust properties
Near-IR Spectral Imaging	**3.6**	dust, H_2O vapour, O_2, surface pressure
Dust / Debris Monitor	**6.2**	Number density & size distribution of particulates in space
Radio Occultation	- (uses relay/nav radios)	T, p, density, ionospheric electrons
	42.7	

Disclaimer:
This is just a strawman!
Actual payload is to be selected by open AO.

Measurement Definition Team (SpotLight)

esa

Purpose:
- Define science themes, objectives, investigations and measurements
- Define strawman payload for the low-altitude orbiter



HiRISE image. NASA/JPL-Caltech/UArizona

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Measurement Definition Team (SpotLight)

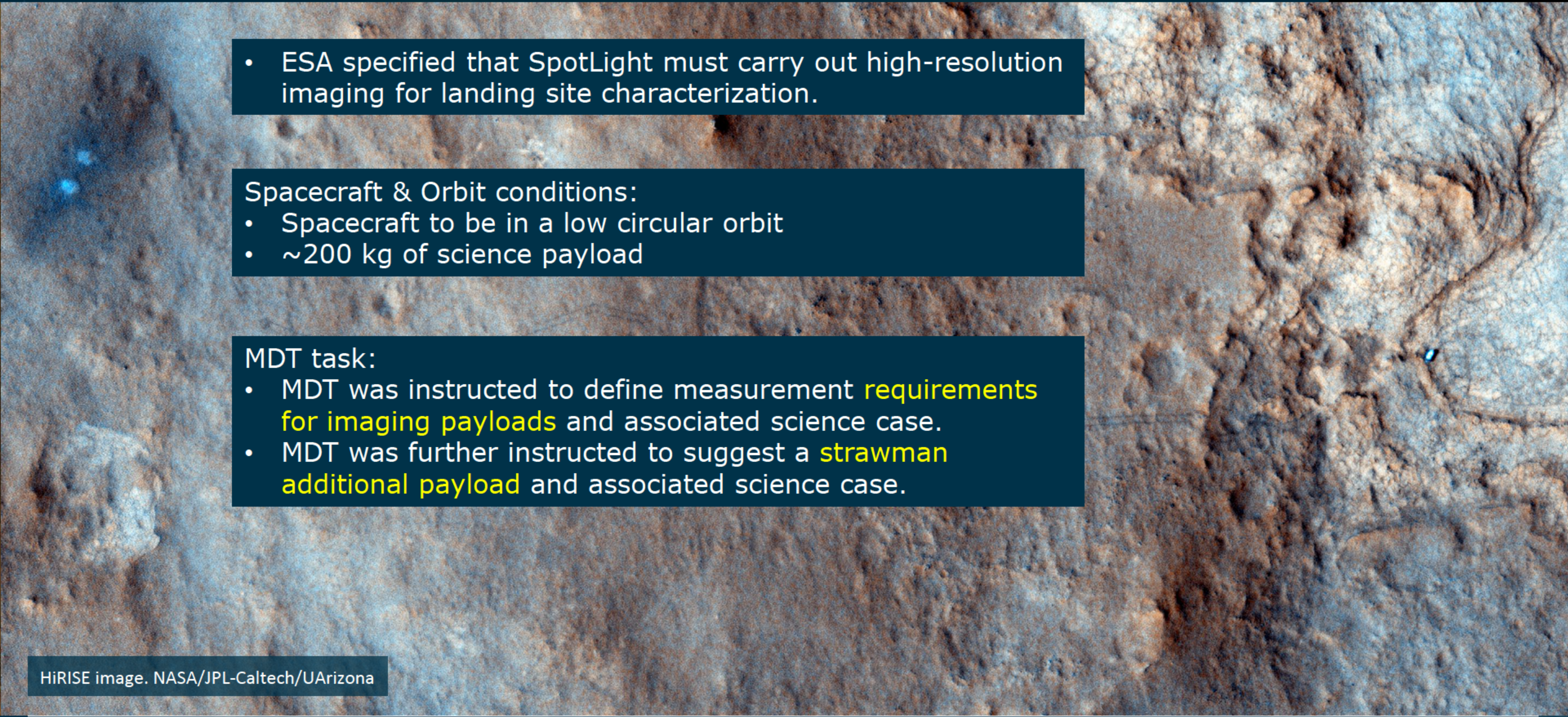
- ESA specified that SpotLight must carry out high-resolution imaging for landing site characterization.

Spacecraft & Orbit conditions:

- Spacecraft to be in a low circular orbit
- ~200 kg of science payload

MDT task:

- MDT was instructed to define measurement requirements for imaging payloads and associated science case.
- MDT was further instructed to suggest a strawman additional payload and associated science case.



HiRISE image. NASA/JPL-Caltech/UArizona

Measurement Definition Team (SpotLight)

esa

Themes	Objectives
Preparing for robotic and human exploration	Assess landing-site characteristics and environment related to **safe landing**.
	Assess landing-site characteristics and environment related to **safe operations** and trafficability within the possible exploration zones to be accessed by rovers or human missions.
	Characterise **potentially extractable water and geological resources** to support in situ resource utilisation.
	Determine the martian environmental niches that meet the definition of **"Special Region" at potential landing sites** and inside of exploration zones for surface missions.
Investigating the evolution of Mars as a geological system.	Identify and characterise **past and present water and other volatile reservoirs**.
	Document the **geologic record** preserved in sediments and sedimentary deposits.
	Constrain the magnitude, nature, timing, and origin of **ancient environmental transitions**.
	Determine the nature, composition and modification history of **the crust**.

Themes	Objectives
Investigating past and present climate and related processes on Mars	Characterise the dynamics, thermal structure, and distributions of dust, water, and carbon dioxide in the **lower atmosphere**.
	Constrain processes by which volatiles and dust **exchange between surface and atmospheric reservoirs**.
	Determine the **climate record of the recent past** that is expressed in geomorphic, geological, glaciological, and mineralogical features of the **polar regions**.
	Determine the record of the **climate of the recent past** that is expressed in geomorphic, geological, glaciological, and mineralogical features of **low- and mid-latitudes**.
	Investigate how the **chemical composition** and mass of the atmosphere have evolved from the ancient past to the present.
	Find and interpret **surface records of past climates** and factors that affect climate.
Investigating past and present habitability on Mars.	Investigate the nature and evolution of **habitable environments** near the surface and in the subsurface, both past and present.
	Assess the **preservation potential of biosignatures** near the surface.
	Constrain the surface, atmosphere, and subsurface **processes through which organic molecules could have formed and evolved** over martian history.

SpotLight Strawman Science Payload

	Instrument	mass including maturity margin (kg)	parameters measured
ESA-procured	High Resolution Imager	60	Spatial resolution: 25 cm/pixel Swath-width: 7 km Spectral range: 400-1100 nm (at least four spectral filters)
	Colour Context Imager	20	Spatial resolution: 2.5 m/pixel Swath-width: 20 km Spectral range: 400-1100 nm (possibly 2000nm) (at least six spectral filters)
Strawman contributed instruments (payloads of opportunity)	Imaging Spectrometer	48	Spatial resolution ≤ 20m Spectral range 1-6 μm Spectral resolution 10 nm
	Doppler Wind LIDAR	36	Line-of-sight wind velocity profile, 0-30 km altitude dust/cloud vertical profile
		164	

Disclaimer:
This is just a strawman!
Contributed payload is to be selected by open AO.

Intended Science Payload Announcement of Opportunity

Intended Science Payload Announcement of Opportunity

LightShip Science payload

- ~40 kg allocation (combined) for the contributed science instruments
- Payloads should address science themes in the IDT report: atmospheric monitoring & dust/debris monitoring.
- It is intended that investigations using spacecraft subsystems (radio science, radiation monitor science etc) will be conducted; however, such investigations will not be included in the present AO while the hardware systems are in definition.

SpotLight Science payload

- Proposals are not being solicited at this time for High-resolution Imager & Context Imager
  - The intention is that these are being directly procured by ESA.
- The mass availability for additional science payloads for SpotLight is still being determined.
  - At this time, it is not known whether ESA will be in a position to issue an AO for SpotLight payloads of Opportunity.

- Proposals for free-flying passenger spacecraft (smallsats, cubesats) are not being solicited in the present AO.

AO Eligibility

- Proposed instruments should be consistent with a launch date of 2032 and pose no risk to the primary mission operation or schedule. TRL 5 is required by completion of SRR (target early 2027)
- Instrument proposals must be led by institutions in ESA member states, co-operating state or associate member states: Austria, Belgium, Canada, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxemburg, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, United Kingdom.
- No international agreements for contributed instruments are in place at this time, but this is subject to further discussion and approval of ESA member states.

Proposed Science Payload AO timeline

Date	Event
February 2025	Community briefing
end April 2025	Intended release of AO
mid-May 2025	Deadline for Letter of Intent (LoI)
mid-May 2025	Community briefing (only for submitted LoIs)
end June 2025	Deadline for proposals, incl. commitment letter from lead funding agency
July 2025	Review of proposals
September 2025	Instrument selection (preliminary)
Q4 2025	KO for selected **instrument 6-month maturation contracts***
Q1 2026	Payload Readiness Review

*ESA's intention is to provide maturation/derisking contracts to each selected instrument to start work in Q4 2025. Proposals shall include description of what work would be conducted in this period (e.g. TRL-raising activities, interface definition).

Summary

- ESA intends to release an Announcement of Opportunity (AO) for LightShip-1 science payloads (i.e., payloads of opportunity). It is currently planned to release the AO at the end of April 2025.
- A mass allocation for the LightShip Tug science payload of opportunity is already available; a mass allocation for the Spotlight science payload of opportunity is pending feedback from industry.
- Radio science and radiation monitoring are NOT part of the planned AO. It is foreseen that these science investigations will be the subject of future announcements.
- High-resolution surface mapping which is the primary mission of SpotLight, is NOT part of the planned AO.
- The identified strawman payload is a proof of concept and does not represent any pre-selection by ESA of instruments or techniques to accomplish the mission science themes.
- The planned AO will only accept proposals from proposers in ESA member states, cooperating states, and associate members.
- By providing this briefing, ESA is under no obligation to issue the planned AO and solicit proposals. Any costs incurred by prospective investigators in preparing submissions in response to this briefing are incurred completely at the submitter's own risk.
- More information, including the MDT and IDT reports and any schedule updates for the AO, will be provided by on the following web-site: https://scispace.esa.int/news-events/
- Stay informed by signing up to the newsletter: https://esacontact.esa.int/scispace_newsletter_subscribe/
- Questions about this briefing and the planned AO can be addressed to: LightShip_Science@esa.int

Thank you for your attention!

Acknowledgments: thanks to MDT and IDT members, and to all who submitted responses to ESA's RFI, for their extensive inputs.