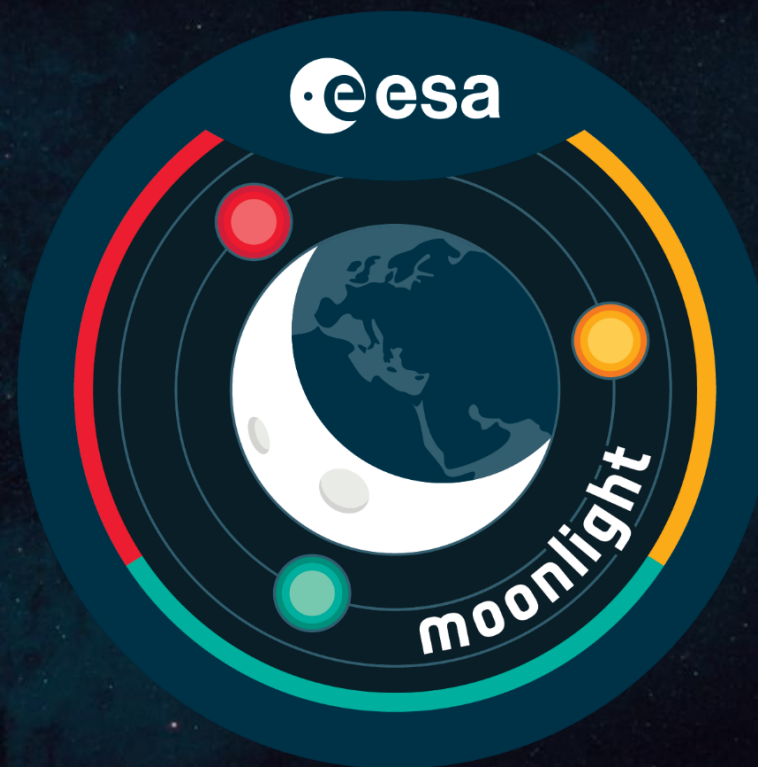


Moonlight

Work Plan 2024 for Advanced Technologies
Activities

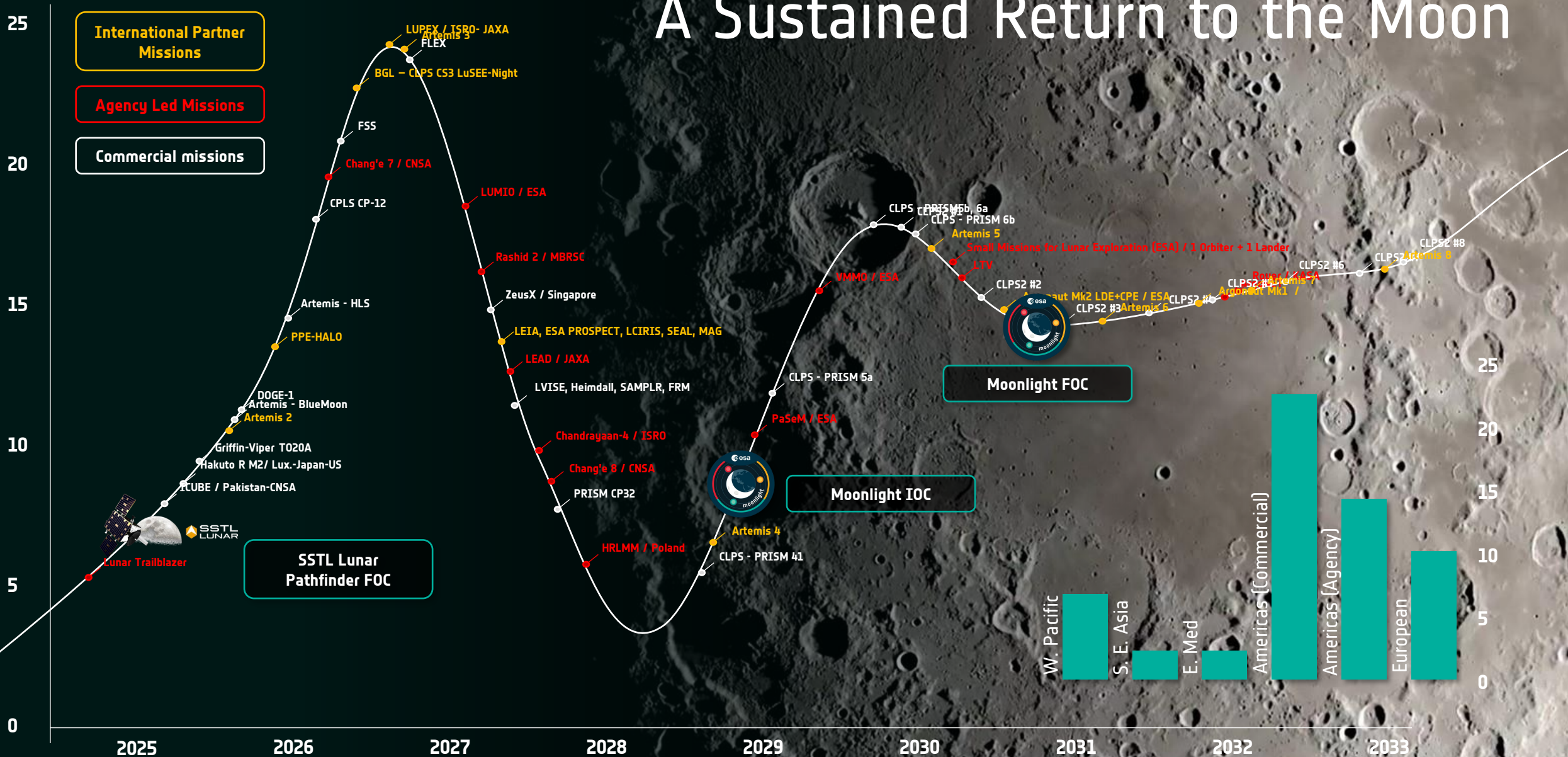


ESA UNCLASSIFIED - For ESA Official Use Only



→ THE EUROPEAN SPACE AGENCY

A Sustained Return to the Moon



400+



Planned missions to the moon in the next 20 years

The ESA Moonlight Ecosystem



Lunar Pathfinder

- COM satellite (S-Band)
3 Hosted Payload Experiments
- Radiation Monitor
 - Laser Retro-Reflect
 - GNSS Weak Signal Detection



Moonlight Lunar COM and NAV System (LCNS)

- COM Satellite (Ka & S-Band)
4x NAV Satellites
High Data Rate



Commercial



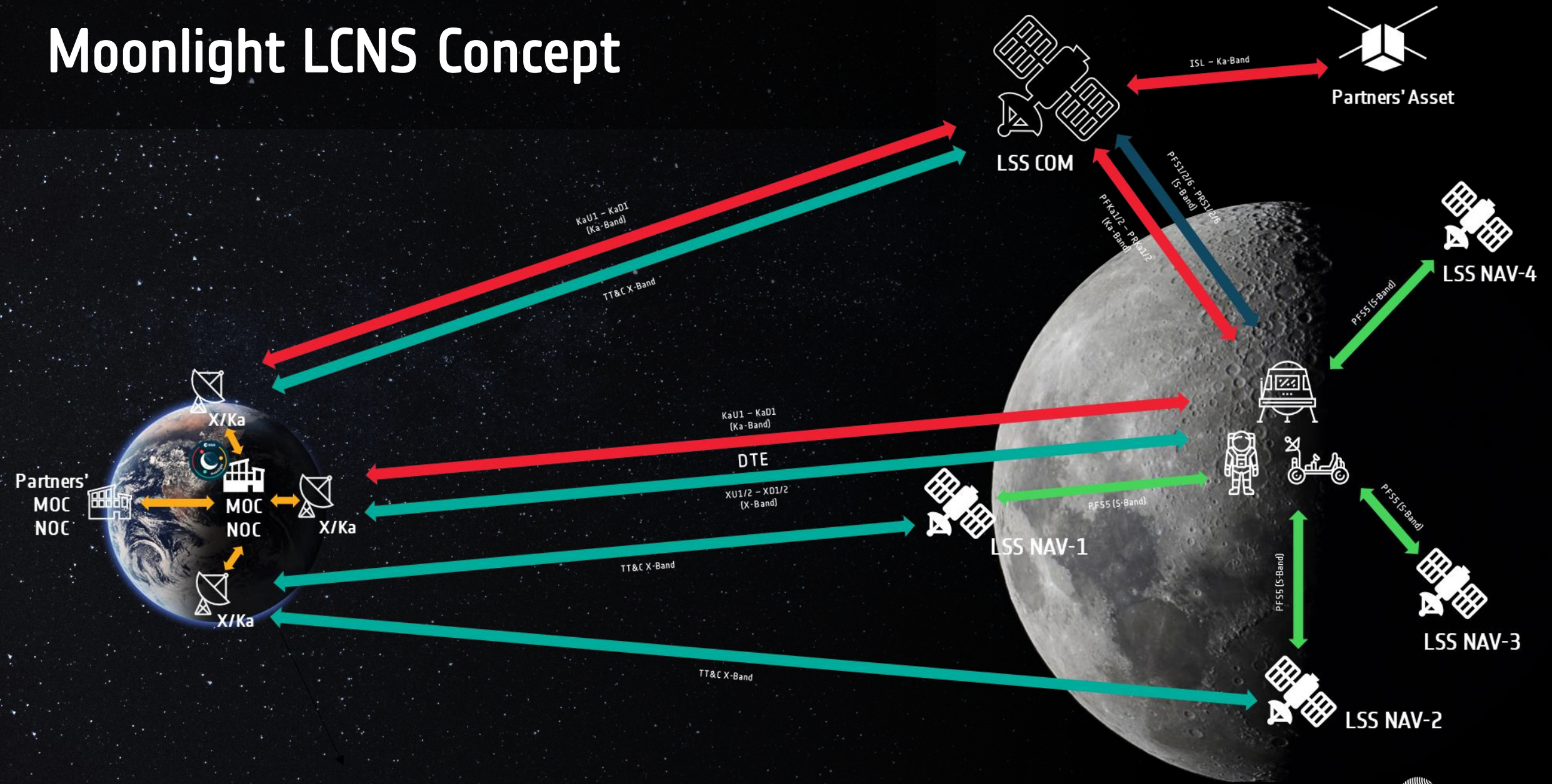
ESA Missions



Gov. Missions



Moonlight LCNS Concept

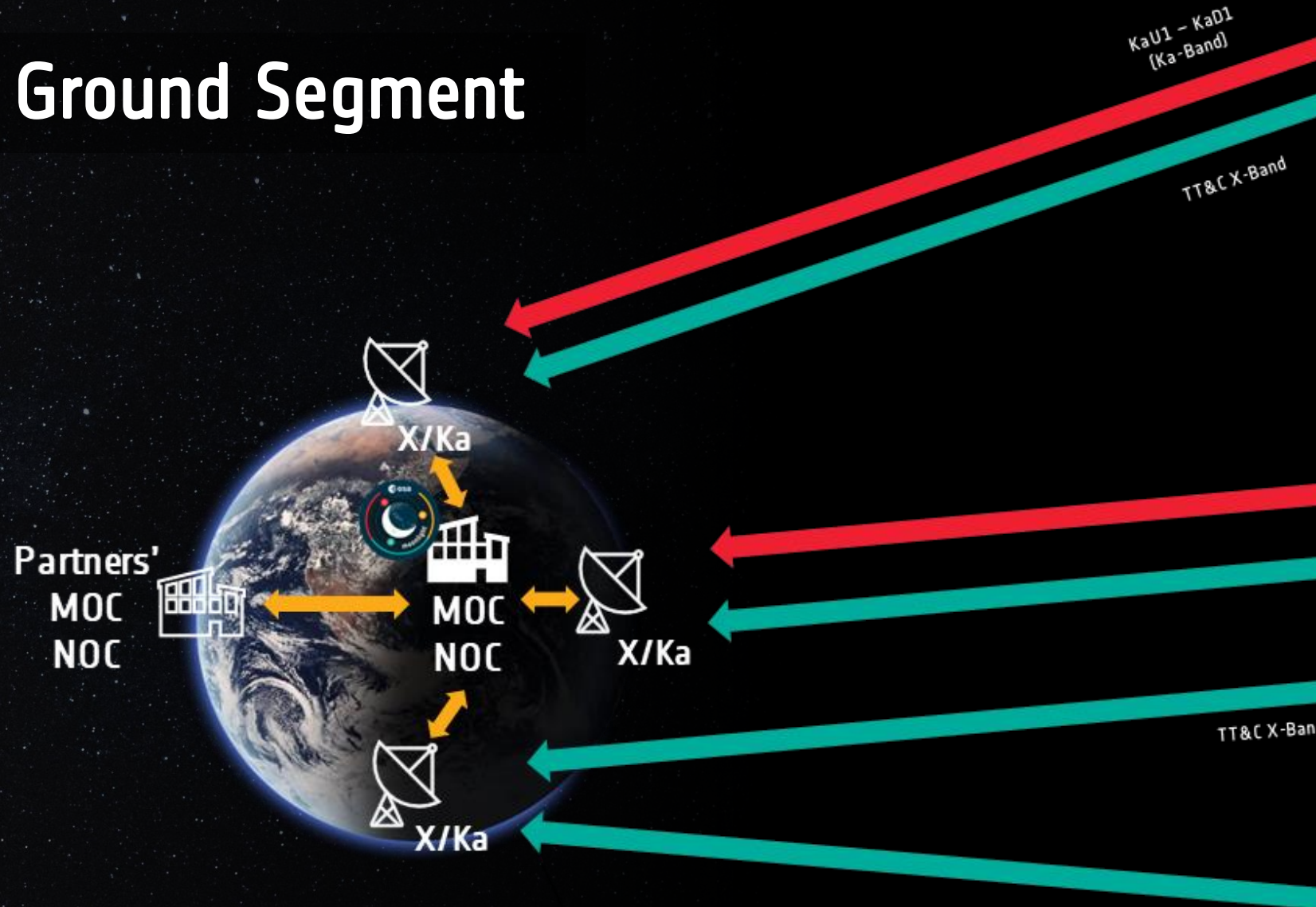


Moonlight LCNS Earth Ground Segment

Moonlight industry owned and operated MOC and NOC

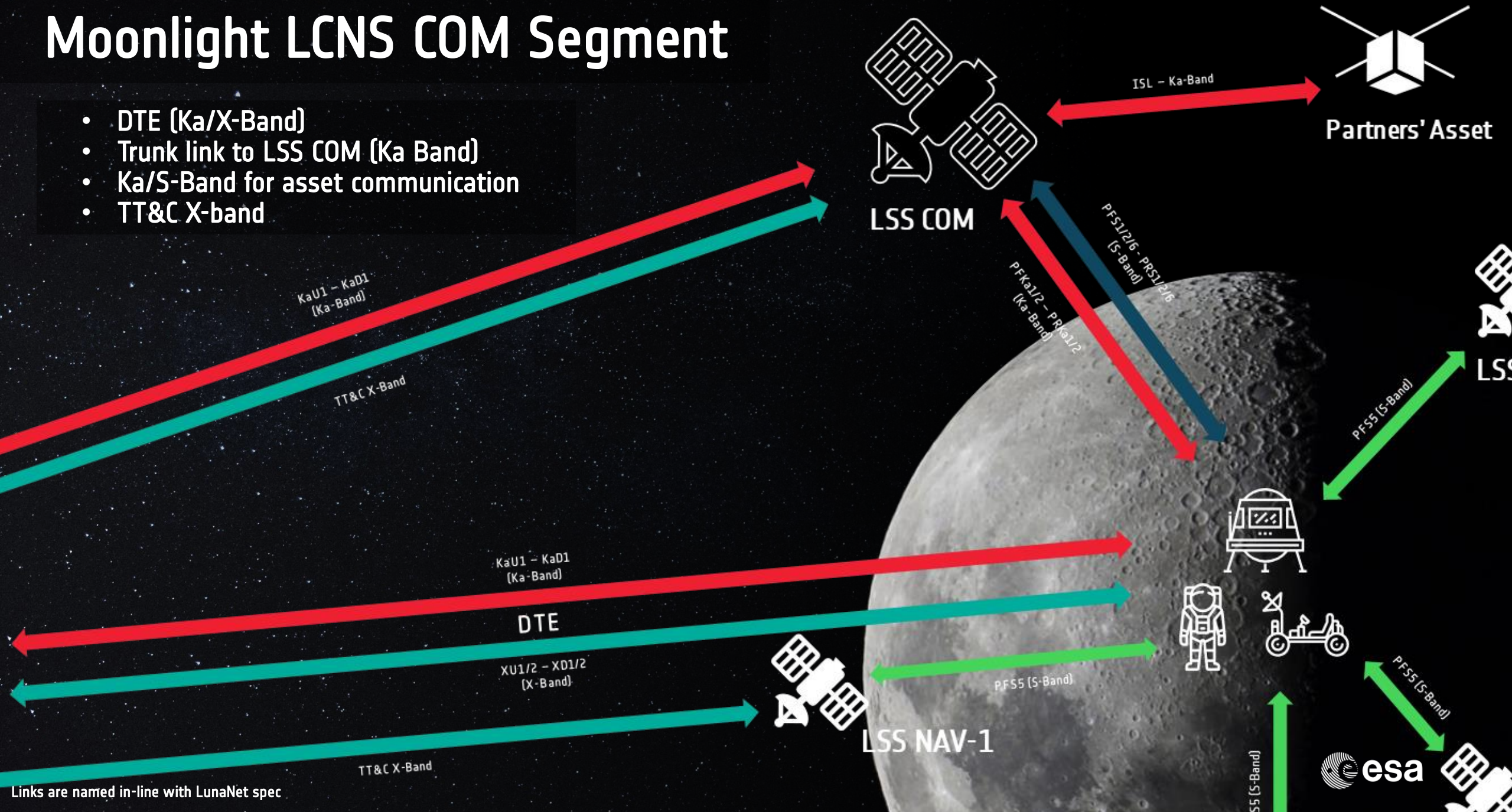
X/Ka Band Ground Stations

Direct links to Partners' MOC and NOC



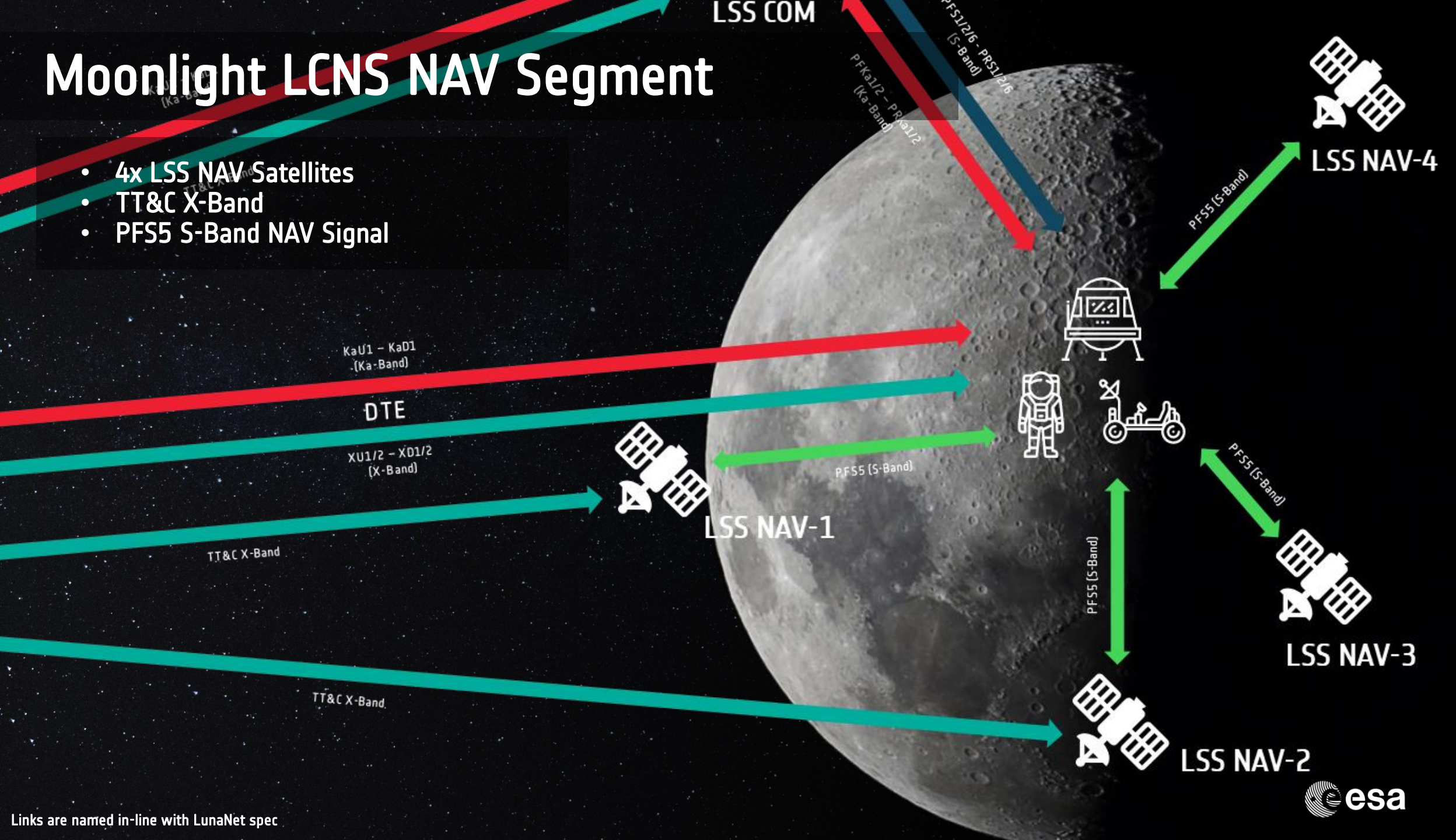
Moonlight LCNS COM Segment

- DTE (Ka/X-Band)
- Trunk link to LSS COM (Ka Band)
- Ka/S-Band for asset communication
- TT&C X-band

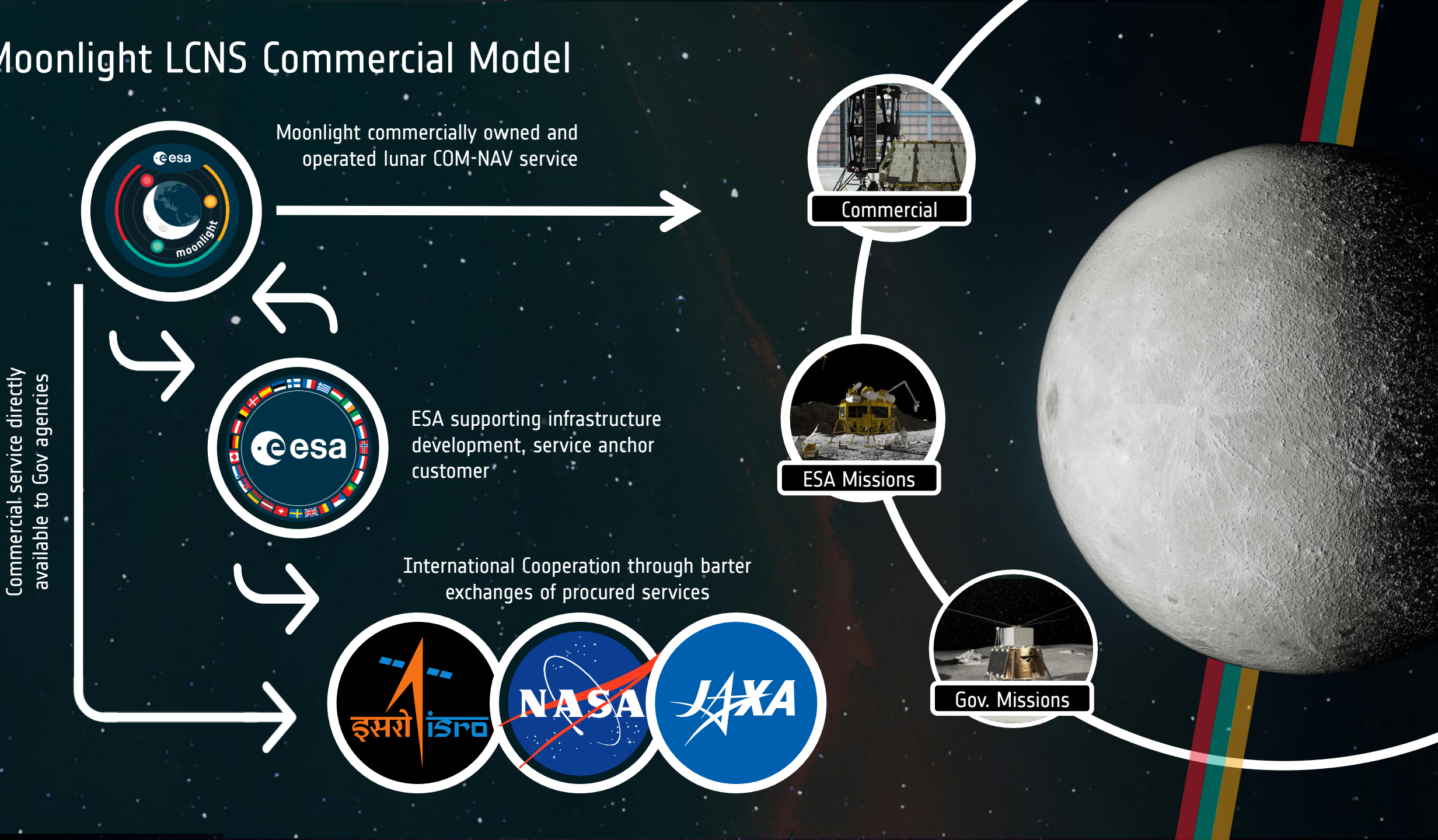


Moonlight LCNS NAV Segment

- 4x LSS NAV Satellites
- TT&C X-Band
- PFS5 S-Band NAV Signal



Moonlight LCNS Commercial Model



The Road to Moonlight

Moonlight LCNS Design and Development

LCNS Moonlight

2024

2026

2028

2030

2032

2034

SSTL Lunar Pathfinder
Launch COM and NAV
Demo, Commercial Service

Moonlight LCNS Manufacture,
Assembly and Test

Moonlight LCNS IOC Launch
(1x COM, 1x NAV)

Moonlight LCNS NAV Satellite
Manufacture, Assembly and Test

Moonlight LCNS FOC Launch
(3x NAV)

SSTL Lunar Pathfinder
Decommissioning

Moonlight LCNS
Service Delivery

Phase 1: CM22

Design and development to CDR

- COM
- NAV
- User Terminal
- Ground Segment

LLI Procurement

Phase 2: CM25

Manufacture, Test Launch for IOC

- 1x COM Satellite
- 1x Nav Satellite
- User Terminal for Service Validation

Implement and Test

- Ground Segment

Phase 3: CM28

Manufacture, Test Launch for FOC

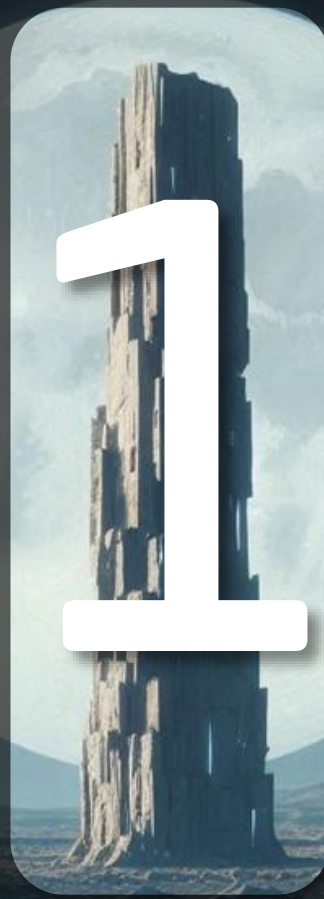
- 3x NAV Satellite

Implement and Test

- Ground Segment Complement



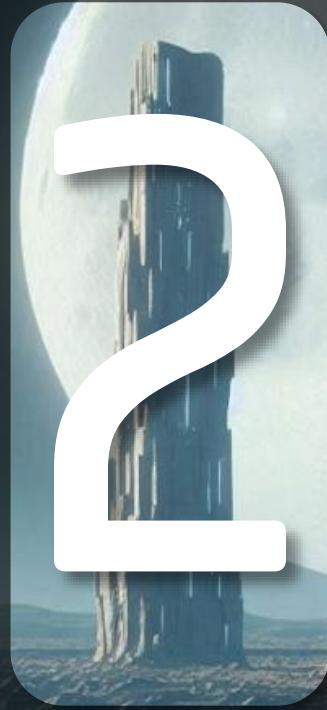
The Moonlight Workplan



LUNAR COMMUNICATIONS AND NAVIGATION SERVICES (LCNS)

Commercial partnership project between ESA and an industrial Partner consortium

All phases of the project, including service provision



PRODUCT ACTIVITIES

Industry development of products for exploitation with commercial and institutional lunar markets.
Activities proposed by industry, or in response to Opportunities announced by ESA or national authorities.



ADVANCED TECHNOLOGIES

Ensure medium to long-term technological readiness of industry to support the cislunar economy.

Activities initiated by the Agency based on a work plan

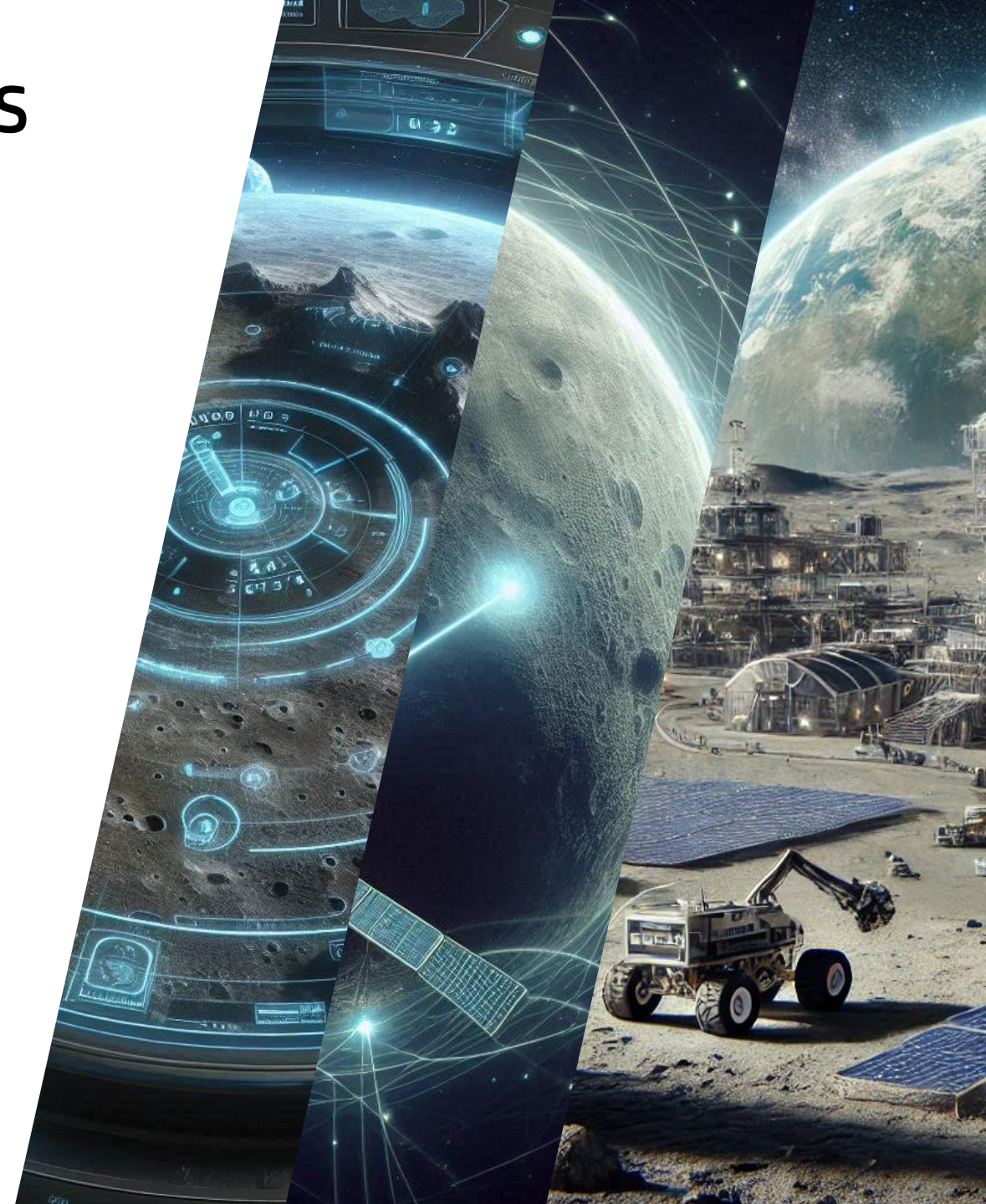


Advanced Technologies Work Plan Rationale



Advanced Technologies Work Plan Rationale

- Scope
 - Second generation of Moonlight system
 - Systems exploiting communication and navigation services for broader purposes
- 2024 Plan
 - Preparing for future Lunar market evolution
 - Enhancing Moonlight services acceptance and user engagement
 - Supporting international cooperation
- Ensuring Europe plays a major role



A detailed illustration of the Lunar Communications Network (LCN) in operation. The Earth and Moon are shown in the background. Several satellites are positioned in various orbits around the Moon, connected by a complex web of glowing blue lines representing communication links. The satellites have solar panels and antennas, and some are emitting bright blue light beams. The scene is set against a dark, starry space background.

Lunar COM Activities

Lunar COM Activities

- Lunar Laser Communication Terminal
- Service orchestration and interoperable Network Management
- Architecture for local proximity communications on the Moon surface
- Multibeam reconfigurable user terminal antenna for continuous connectivity on the Moon
- LunaNet S-band communication user terminal transceiver



Lunar Laser Communication Terminal

- Objective of the Activity
 - Design a Laser Communication Terminal (LCT) concept for Lunar distances
 - Develop an engineering model of a CCSDS compatible transceiver
- Aim
 - Enable a European or Canadian laser optical terminal source for future Lunar LCTs
 - High data rate links of at least 5 Gbps
- Targeted Improvements
 - Enable a European or Canadian Lunar communication terminal
 - Achieve data rate one order of magnitude higher than current designs



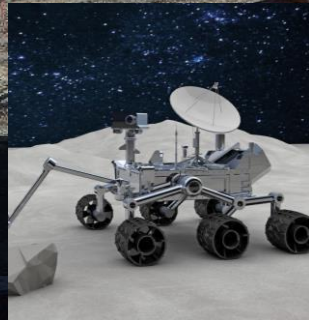
Service Orchestration and Interoperable Network Management

- Objective of the Activity
 - Analyse, develop, and evaluate concepts for coordinating communication services
 - Provisioning services to multiple users and across different providers
- Aim
 - Automation in Planning and Scheduling
 - Coordination Between Providers
- Targeted Improvements
 - Automatic service provisioning for multiple users
 - Coordination between different service providers



Architecture for Local Proximity Communications on the Moon Surface

- Objective of the Activity
 - Define system-level network architecture for Moon surface communications
 - Consider user connection management, authentication, and data traffic routing
 - Ensure interoperability with users from other agencies
- Aim
 - Network Architecture Investigation
 - Investigate usage of surface communication signals to augment PNT functions
 - Breadboard Design
- Targeted Improvements
 - TRL raising of terrestrial wireless networking protocols for usage in Moon scenarios



Multibeam Reconfigurable User Terminal Antenna for Continuous Connectivity on the Moon

- Objective of the Activity
 - Develop and test a multi-beam reconfigurable user terminal antenna for Lunar surface assets
 - Ensure multi-orbit connectivity
- Aim
 - Users can reach several relays simultaneously
 - Reconfigurability requirements on Ka-band terminals
 - Multi-Beam Operation
 - Maintain connectivity while switching satellites
- Targeted Improvements
 - New class of multi-beam reconfigurable ground terminal antenna for Lunar assets



ML-COM-05: LunaNet S-Band Communications User Terminal Transceiver

- Objective
 - LunaNet Framework development
 - Advancing User Technology
- Aims
 - Unit Development
 - Core Radio
 - Emerging Digital Processing Technologies
- Targeted Improvements
 - New capability within ESA Member States to develop LunaNet user terminals
 - Support for ESA and non-ESA missions



Lunar PNT Activities



Lunar PNT Activities

- Earth-based field-testing facility of Moonlight PNT Signals Using Drones
- Miniaturised LunaNet PNT User Terminal Receiver
- Lunar Local Moonlight/LunaNet Augmentation System
- Enhancing the Selenodetic reference frames and Lunar reference time
- Combined communications and navigation user S-band antenna



Earth-based Field-Testing Facility of Moonlight PNT Signals Using Drones

- Objective of the Activity
 - Define, develop, and validate a test facility
 - Generate Lunar PNT-like signals using drones
 - Emulate movement, position, and geometry of Moonlight LCNS satellites
 - Replicate RF signals format, power levels, and characteristics
- Aims
 - Characterise realistic achievable ML-PNT performances
 - Support testing and qualification of Moonlight LCNS receivers, incl. interoperability
 - Assess potential Moonlight PNT system evolutions
- Targeted Improvements
 - Simulate realistic LCNS PNT services signals on Earth



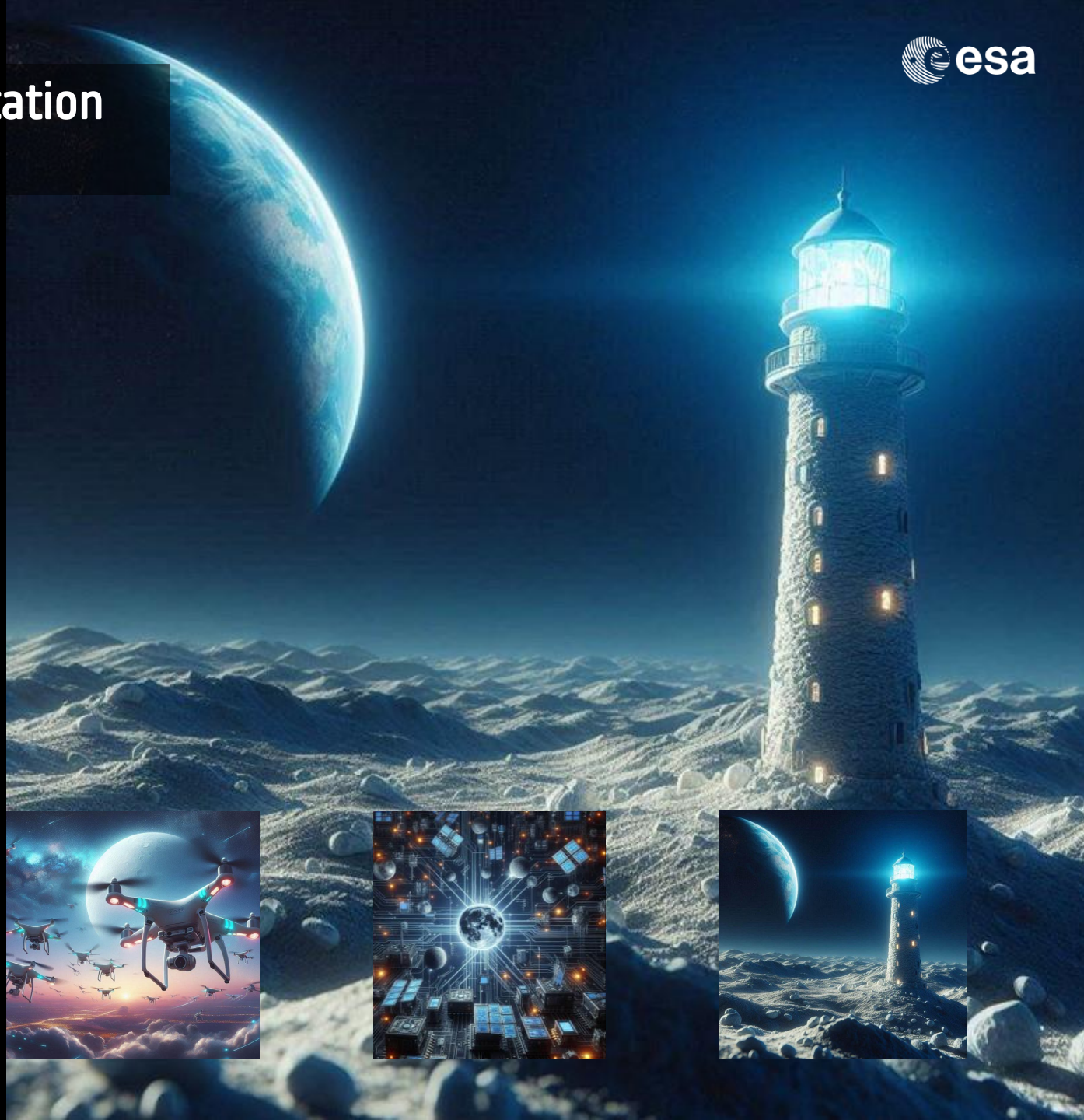
Miniaturised LunaNet PNT User Terminal Receiver

- Objective of the Activity
 - Define, develop, and validate an Engineering Model of a LunaNet PNT user terminal
 - Cover the Lunar Augmented Navigation Service (LANS)
- Aims
 - Ensure necessary user technology is available in Europe
 - Secure market share and spaceborne receiver autonomy for future ESA missions
- Targeted Improvement
 - Reducing Size Weight and Power (SWaP)
 - Navigation Software



Lunar Local Moonlight/LunaNet Augmentation System

- Objective
 - Define, develop, and verify an EM of a Lunar surface element
 - Facilitate robust metre-level user positioning in the local Lunar area
- Aims
 - Use of Differential and Augmentation Techniques
 - Supplement, monitor, and correct satellite-based navigation signals
 - Support for Safety-of-Life Applications
- Targeted Improvements
 - New capability related to high accuracy and robust Lunar PNT
 - Not existing today in ESA Member States



Enhancement of Selenodetic Reference Frames and Lunar Reference Time

- Objective of the Activity
 - Define mid- and long-term strategy for enhancement
 - Potential experimentation and set-up of cislunar infrastructures
- Aims
 - Support to drafting/review of conventions and standardisation documents
 - Understanding links between Lunar and Earth-based reference frames
 - Definition of mid- and long-term strategy for enhancement
 - Provision of concepts for a reference international selenocentric reference station
- Targeted Improvements
 - Achieve a commonly accepted Lunar selenocentric reference system and Lunar reference time



Combined Communication and Navigation User S-band Antenna

- Objective of the Activity
 - Develop a dual band self-diplexing antenna for cislunar space users
 - Support both communication and navigation services simultaneously
- Aims
 - Meet Moonlight Users' Needs by reducing Size, Weight and Power (SWaP)
 - Facilitate applications such as differential augmentation systems using Moonlight
 - High stability in terms of RF performance vs temperature
 - Mitigate multipath effect to minimise impact on performance
- Targeted Improvements
 - New technology development for Moon comms and navigation application



