National Aeronautics and Space Administration

Optical Communications Systems for NASA's Human Space Flight Missions

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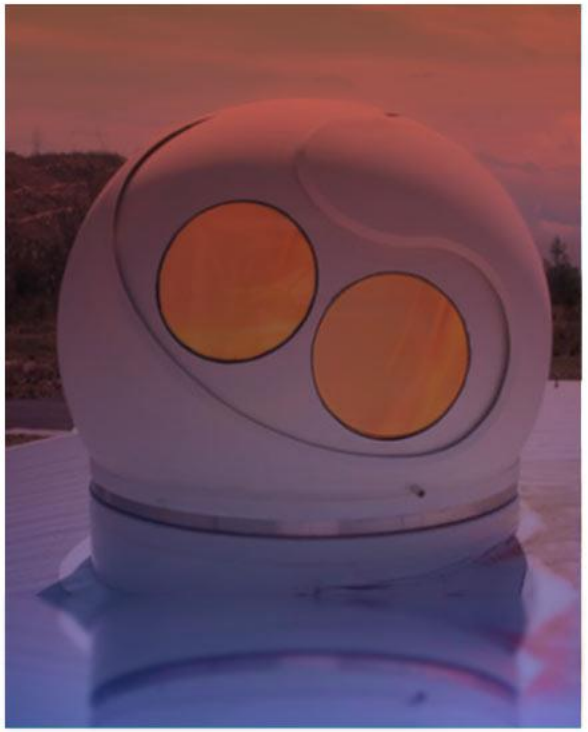
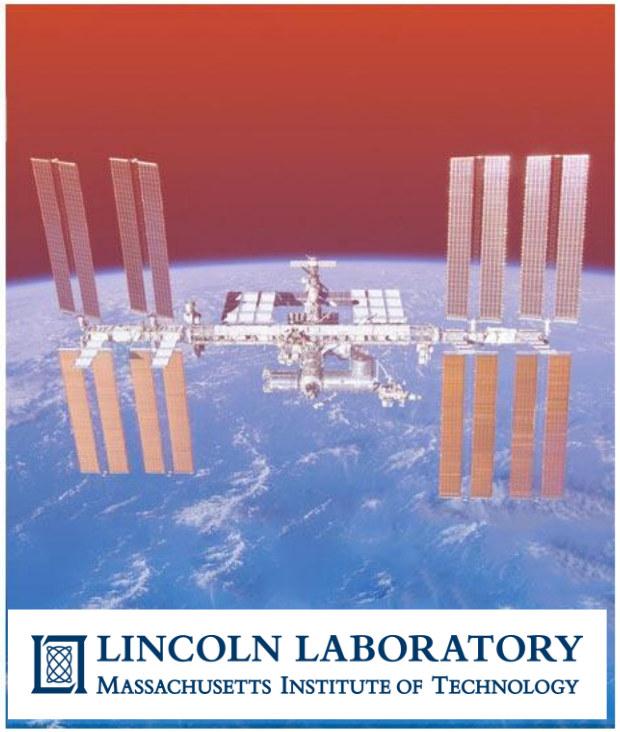
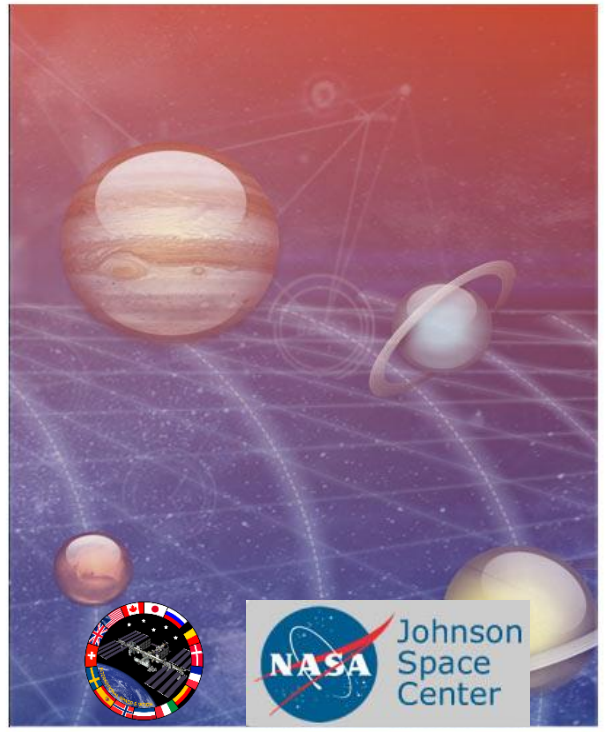
LEMNOS

Laser-Enhanced Mission Communications Navigation and Operational Services







Exploration & SPACE Communications

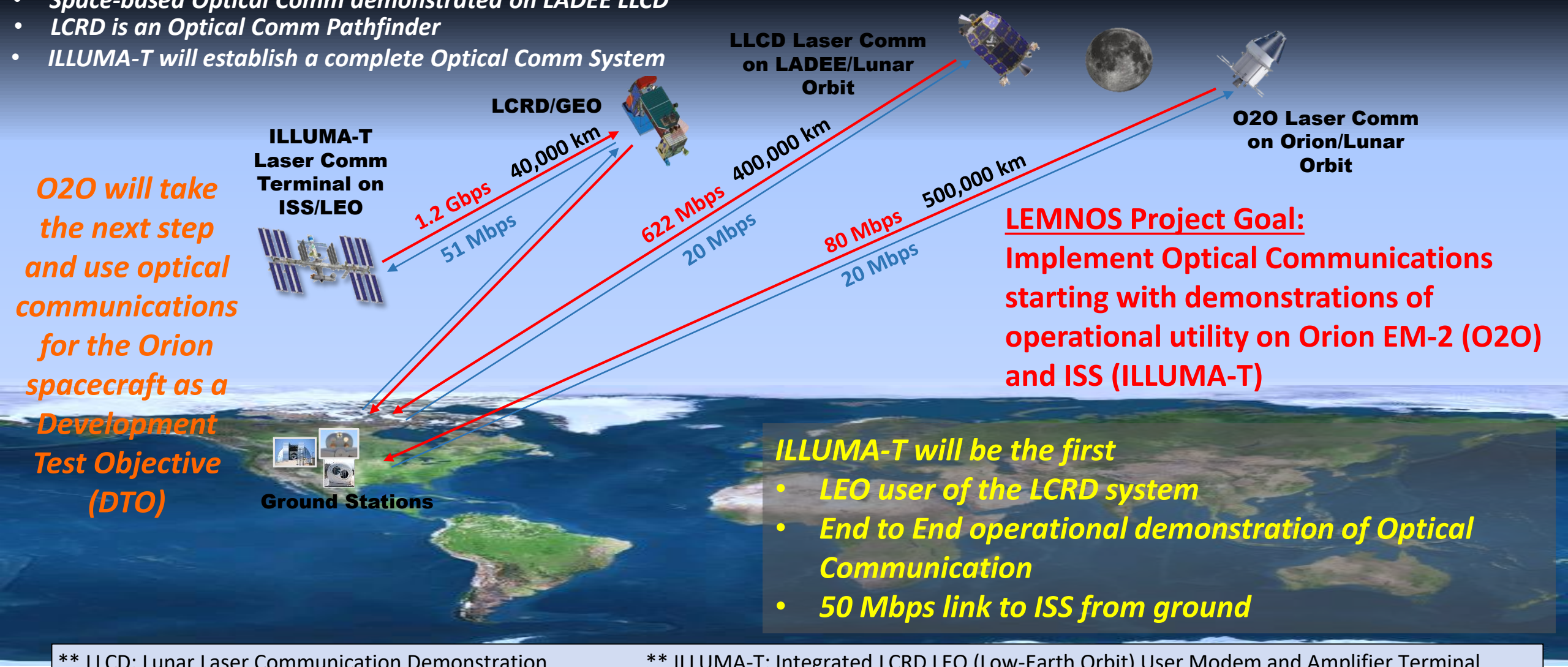
Agenda

- Introduction
- Objectives & L1 Requirements
- High Level System Architecture/Operational Characteristics
- Modular, Agile, Scalable Optical Terminal (MAScOT)
- Conclusion

Laser-Enhanced Mission Communications Navigation and Operational Services (LEMNOS)

LEMNOS Introduction

- *Space-based Optical Comm demonstrated on LADEE LLCD*
- *LCRD is an Optical Comm Pathfinder*
- *ILLUMA-T will establish a complete Optical Comm System*



O2O will take the next step and use optical communications for the Orion spacecraft as a Development Test Objective (DTO)

LEMNOS Project Goal:
Implement Optical Communications starting with demonstrations of operational utility on Orion EM-2 (O2O) and ISS (ILLUMA-T)

ILLUMA-T will be the first
- *LEO user of the LCRD system*
- *End to End operational demonstration of Optical Communication*
- *50 Mbps link to ISS from ground*

** LLCD: Lunar Laser Communication Demonstration
** LCRD: Laser Communication Relay Demonstration
** O2O: Orion EM-2 Optical Communications Terminal
** ILLUMA-T: Integrated LCRD LEO (Low-Earth Orbit) User Modem and Amplifier Terminal
** LEMNOS: Laser-Enhanced Mission Communications Navigation and Operational Services

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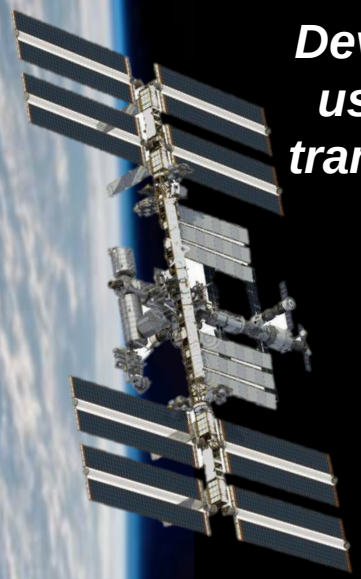
LEMNOS Projects

ILLUMA-T

(Integrated LCRD LEO User Modem and Amplifier Terminal)



Develop an optical communications user terminal to demonstrate data transfer between low Earth orbit and the ground through a geosynchronous relay

1.2 Gbps return
51 Mbps forward
To Ground via LCRD relay

Feb 2021 delivery to GSFC

Mar 2022 Launch on SpaceX Dragon (TBR)

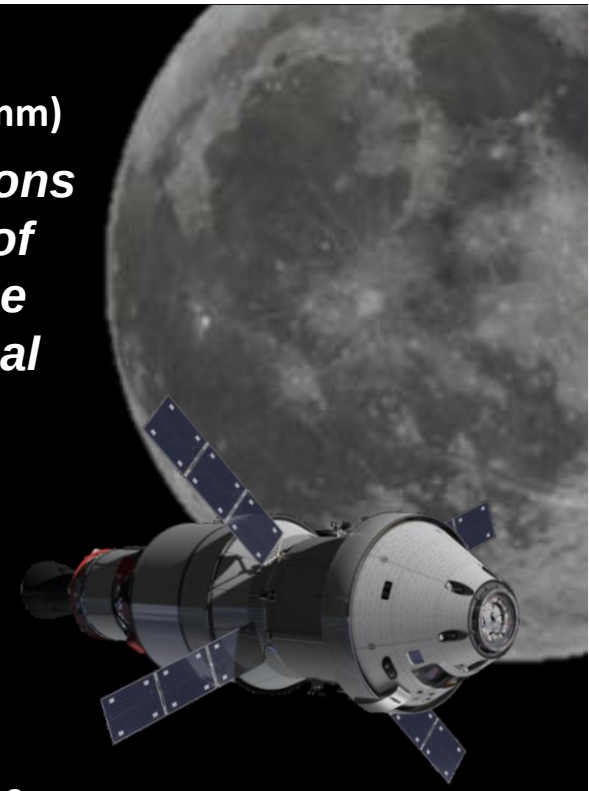
~ 6 months mission

NASA Goddard | LINCOLN LABORATORY, Massachusetts Institute of Technology | NASA Johnson Space Center | JAXA 宇宙航空研究開発機構 Japan Aerospace Exploration Agency

O2O

(Orion EM-2 Optical Comm)

Employ optical communications capability for Orion series of spacecraft, starting with the demonstration of operational utility on EM-2.



80 Mbps return
20 Mbps forward
Direct to ground (WSC, TMF)

Nov 2020 delivery to KSC

June 2022 Launch on Orion/SLS

8-21 day mission

NASA Goddard | LINCOLN LABORATORY, Massachusetts Institute of Technology | NASA Johnson Space Center | LOCKHEED MARTIN | JPL | NASA Marshall Space Flight Center

O2O Objective and L1 Requirements

Objective: Implement optical communications capability for Orion series of spacecraft, starting with a demonstration of operational utility on EM-2	
1.0	Develop an Optical Comm System to plan and demonstrate an operational optical comm link for Orion EM-2
2.0	Maintain a development path to a fully operational Optical Comm System
3.0	Flow data from Orion through the Optical Comm Fight Terminal to the Optical Comm Ground Terminal
4.0	Flow data from Optical Comm Ground Terminal to Optical Comm Fight Terminal and forward to Orion
5.0	Distribute data to/from Orion MCC real time or store and distribute later
6.0	Flight terminal conforms to the Orion accommodations, mission objectives, and environments
7.0	Ground terminal and data system developed with operational interfaces

ILLUMA-T Objective and L1 Requirements

Objective: The ILLUMA-T project shall develop an optical communications user terminal to demonstrate data transfer between low Earth orbit and the ground through a geosynchronous relay	
1.1	The ILLUMA-T project shall demonstrate a duplex optical communications link from the ILLUMA-T terminal located on the ISS to a ground station via the LCRD satellite
1.2	The ILLUMA-T user terminal shall operate up to 1.244 Gbit/s on the return link (ISS to Ground) and up to 51 Mbps on the forward link (Ground to ISS)
1.3	The ILLUMA-T protoflight terminal shall be developed using an approach that includes participation of commercial companies and enables the transfer of optical communications technology to industry
1.4	The ILLUMA-T terminal orientation shall support line of sight to a ground station
1.5	The ILLUMA-T terminal shall support a bi-directional data connection of at least 1.0 Gbit/s (i.e. 100/1000 Mbps Ethernet connection)

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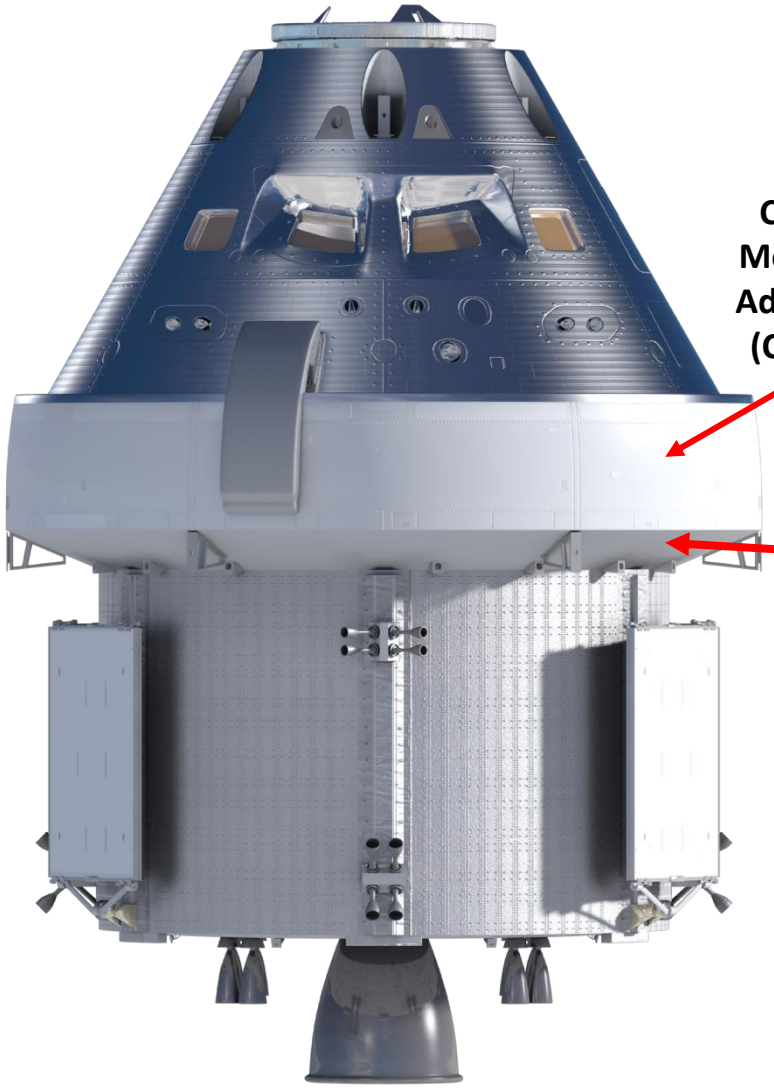
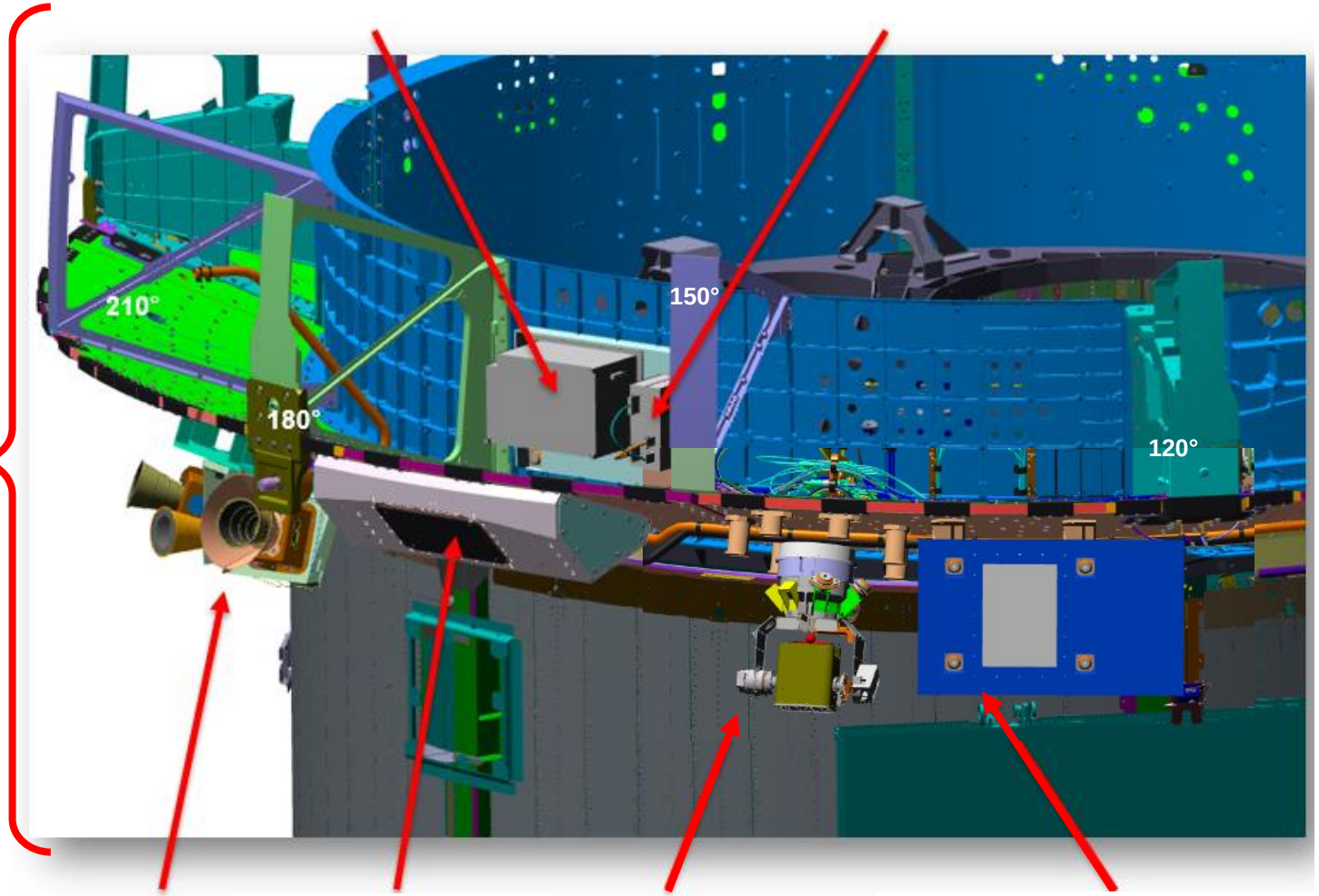
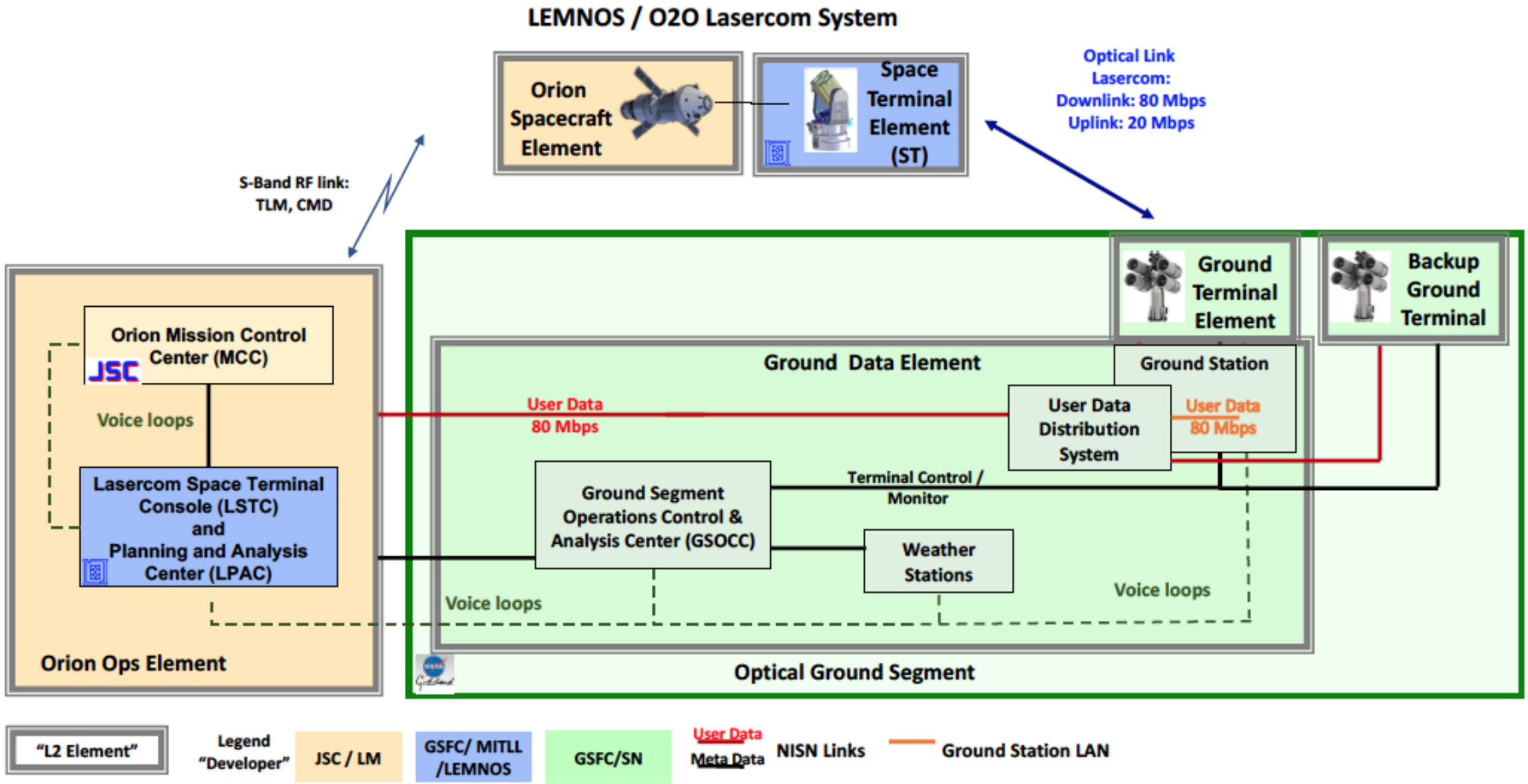
O2O Implementation



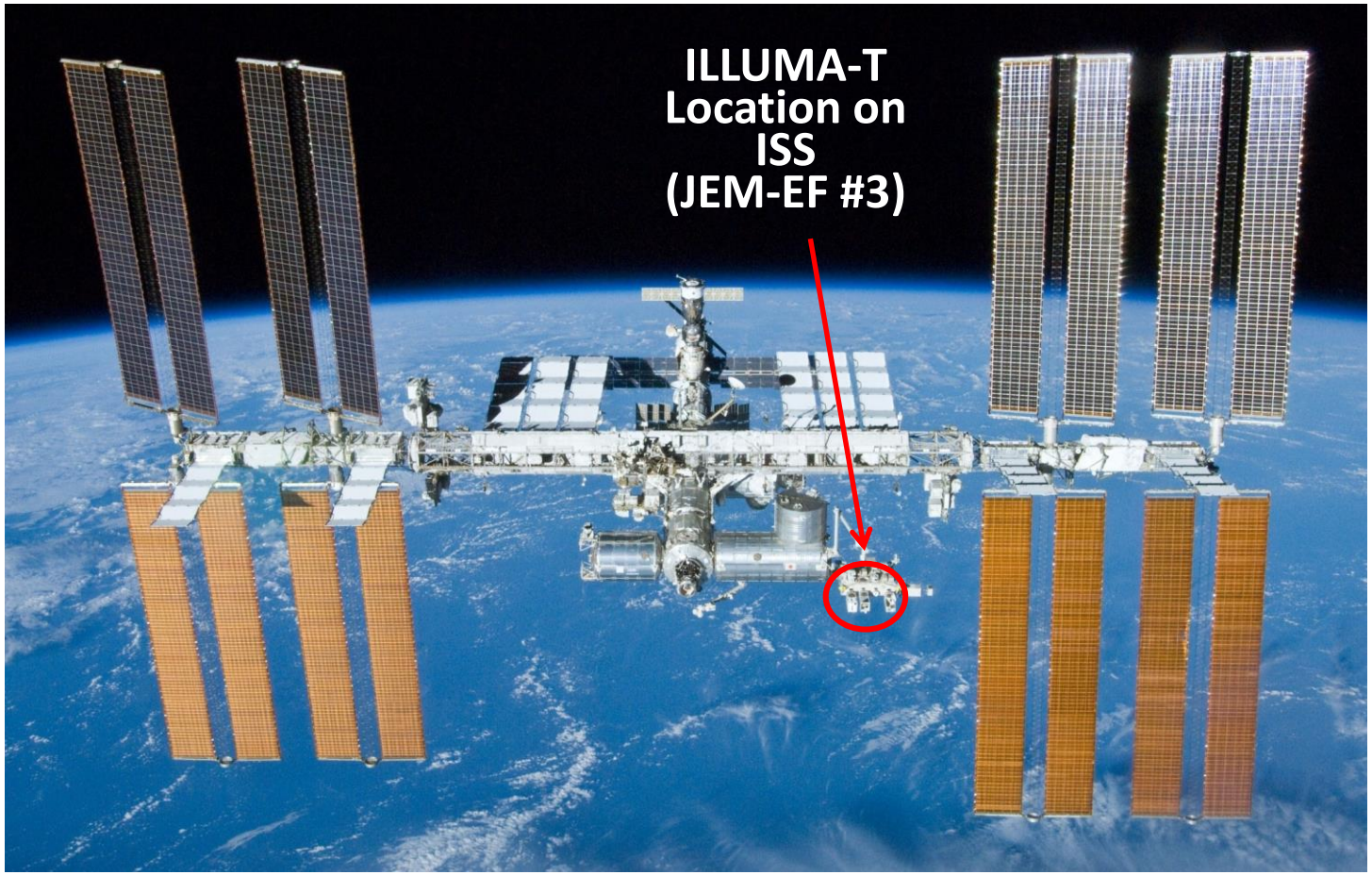
Crew Module Adaptor (CMA)

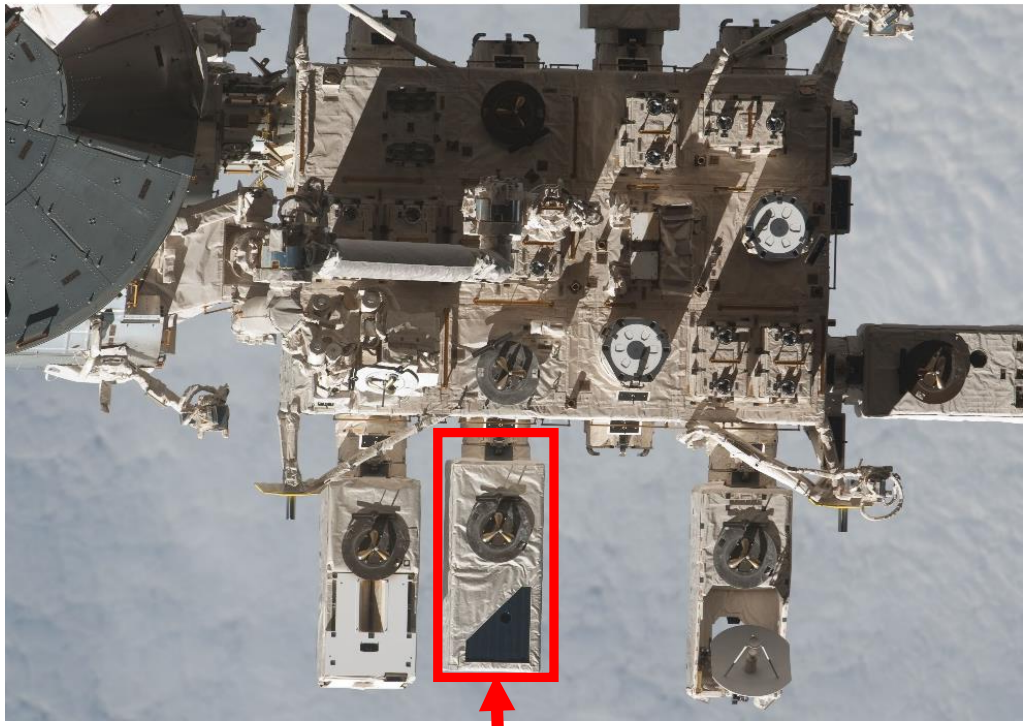


O2O Architecture



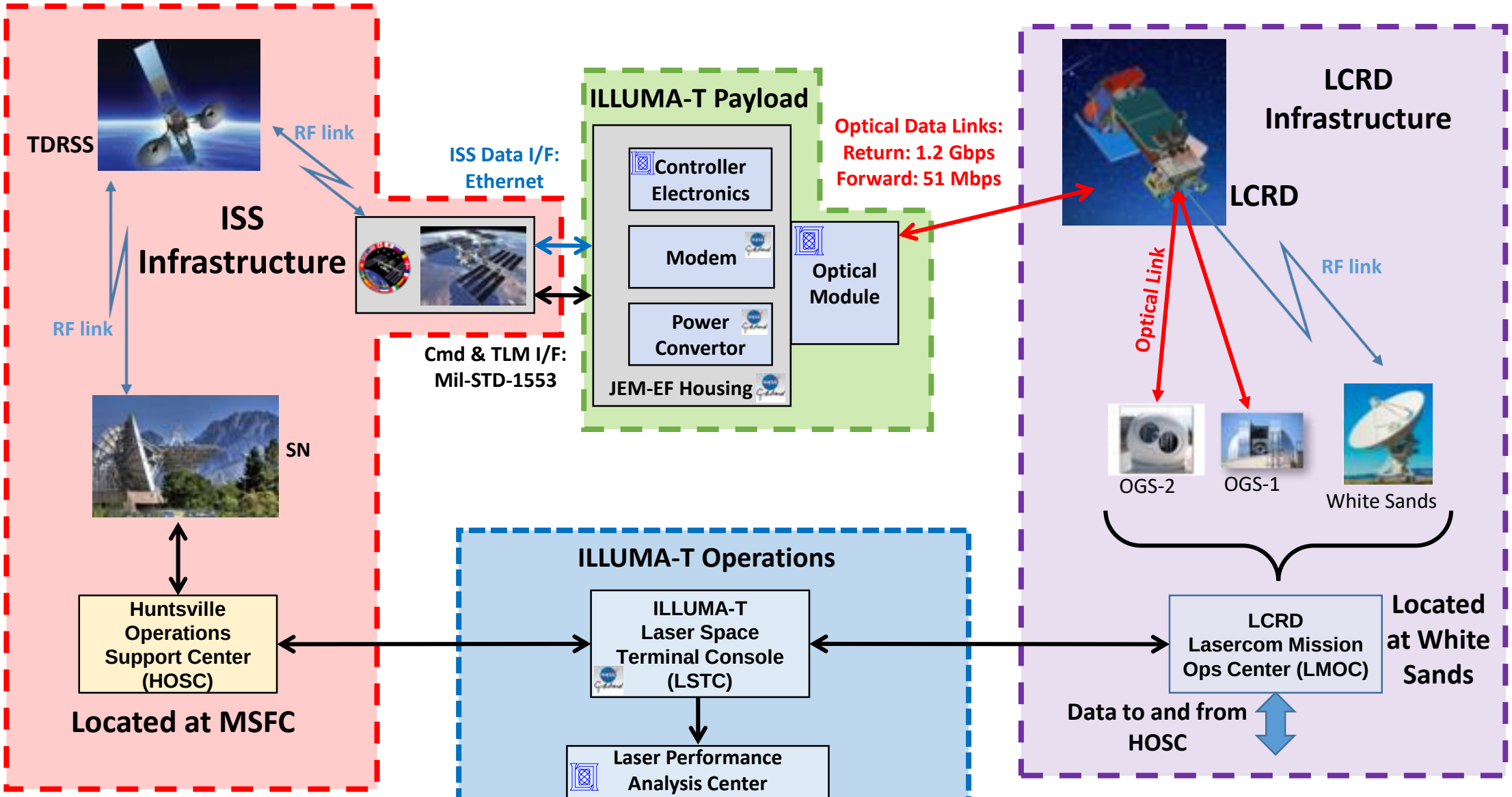
ILLUMA-T Implementation



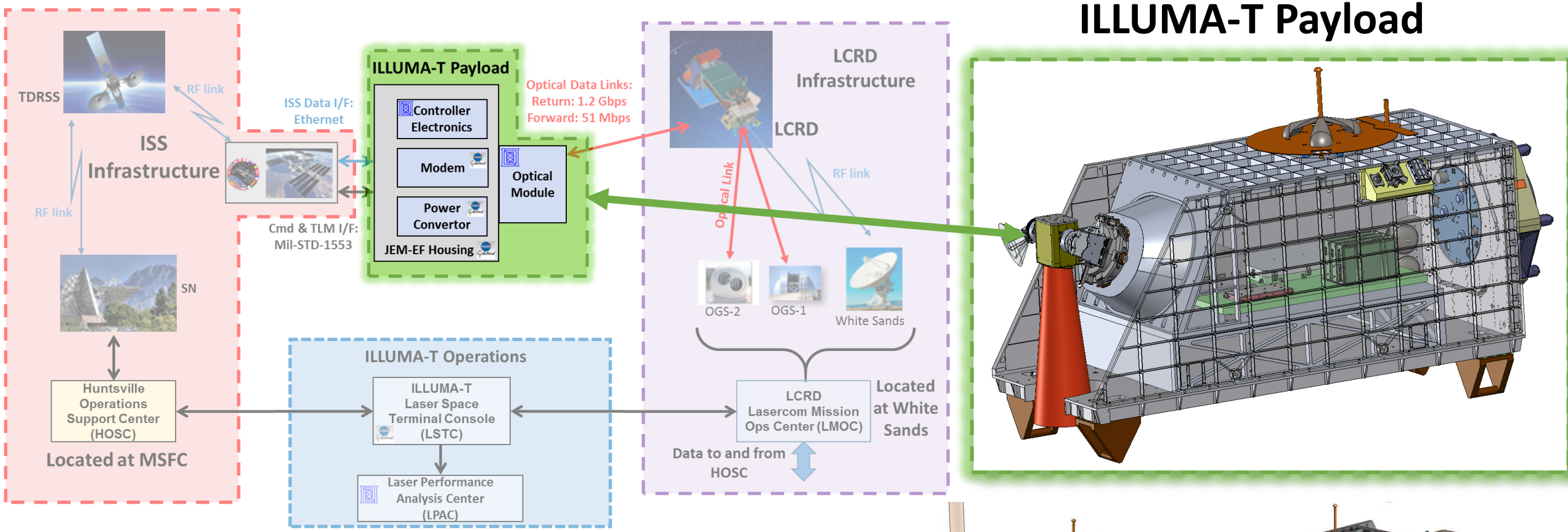


ILLUMA-T
(JEM-EF #3)

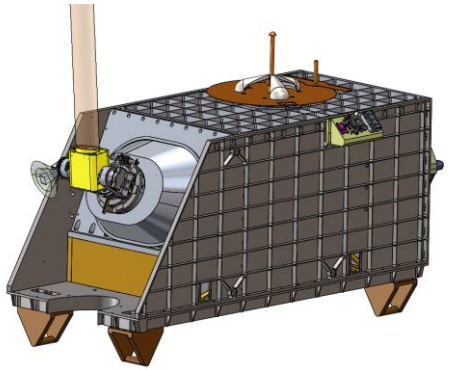
ILLUMA-T Architecture



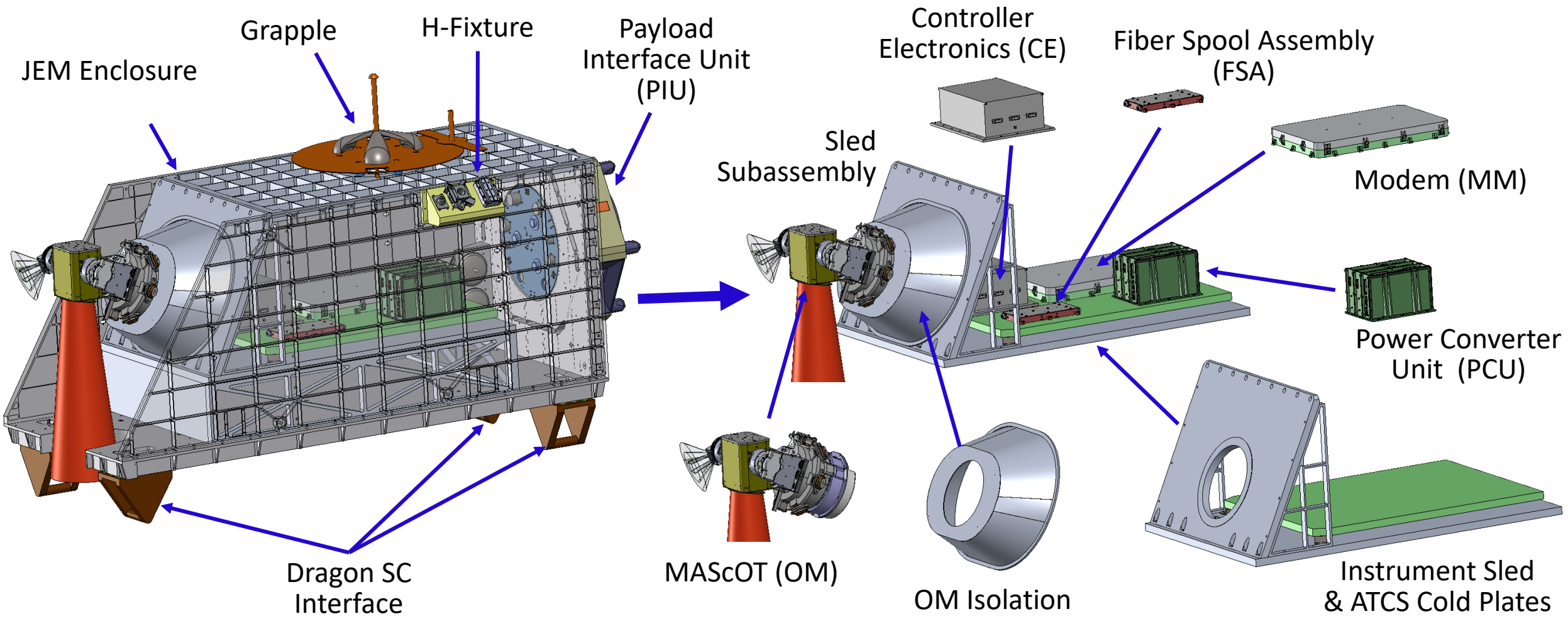
ILLUMA-T Payload Configuration



ILLUMA-T Payload



ILLUMA-T Space Terminal Elements



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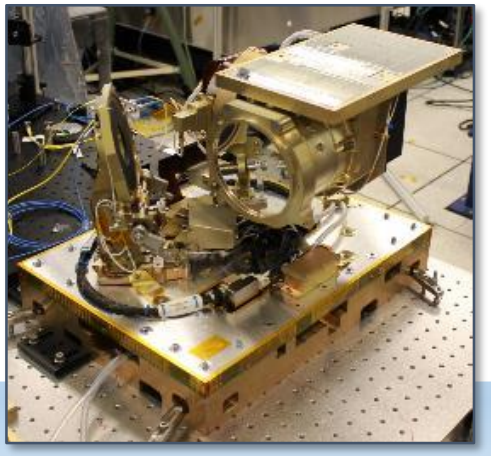
Lasercom Terminal Evolution

LLCD Optical Module on LADEE

2009-2014

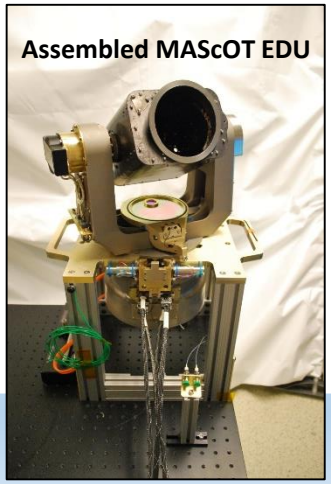
NASA/MITLL developed and demonstrated during Lunar Laser Comm Demo (LLCD)

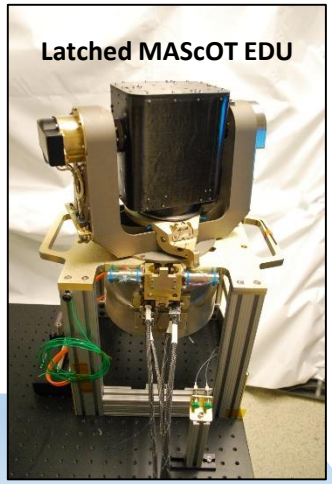


LCRD Optical Module

2011-Present

Industry "build to print" of LLCD-based terminal; to be used for Laser Comm Relay Demo (LCRD)





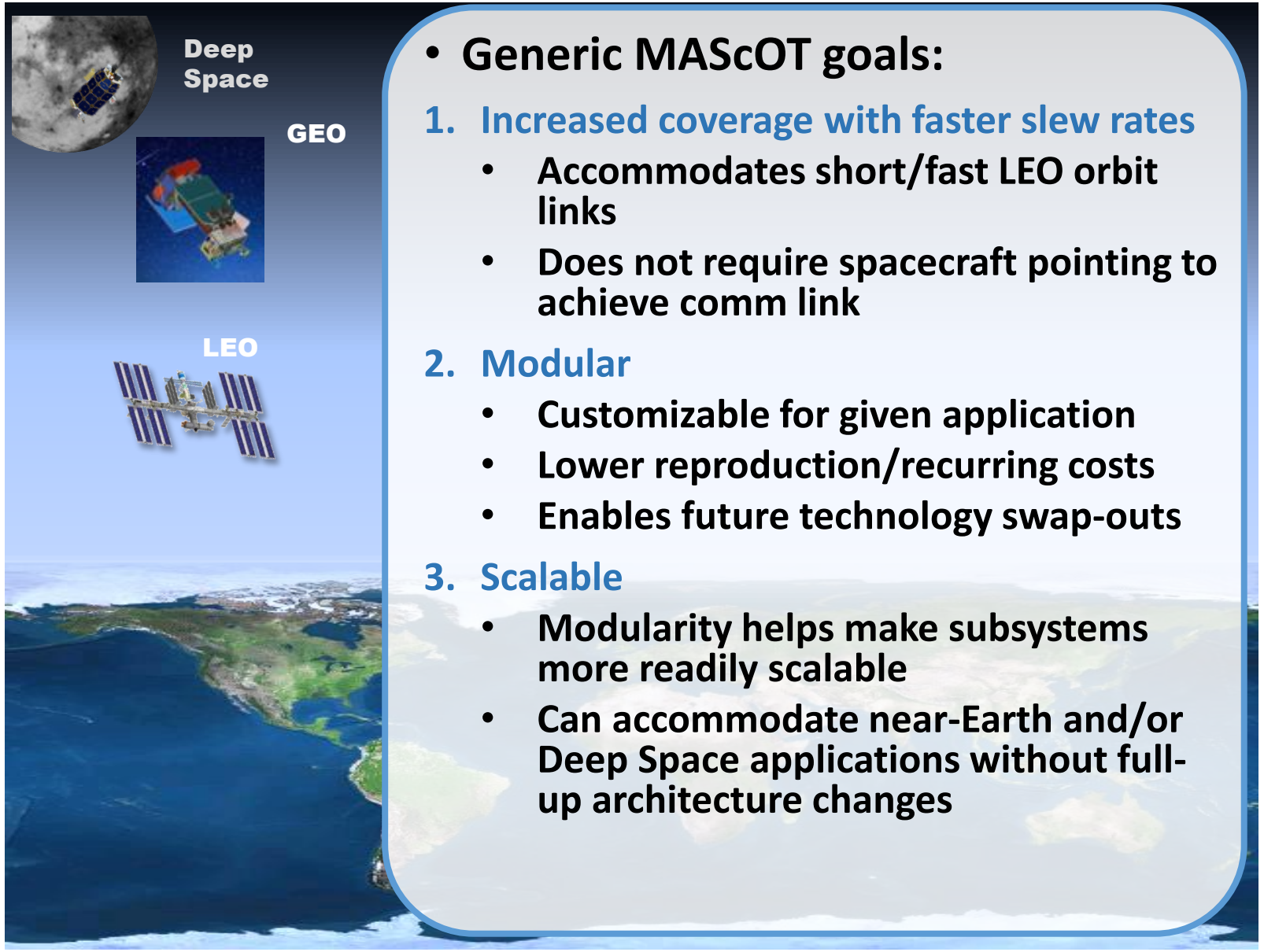
Modular, Agile, Scalable Optical Terminal (MAScOT)*

2013-Present

NASA/MITLL concept, industry-built; to be used in new programs with ISS and Orion; incorporates lessons learned from LLCD/LCRD

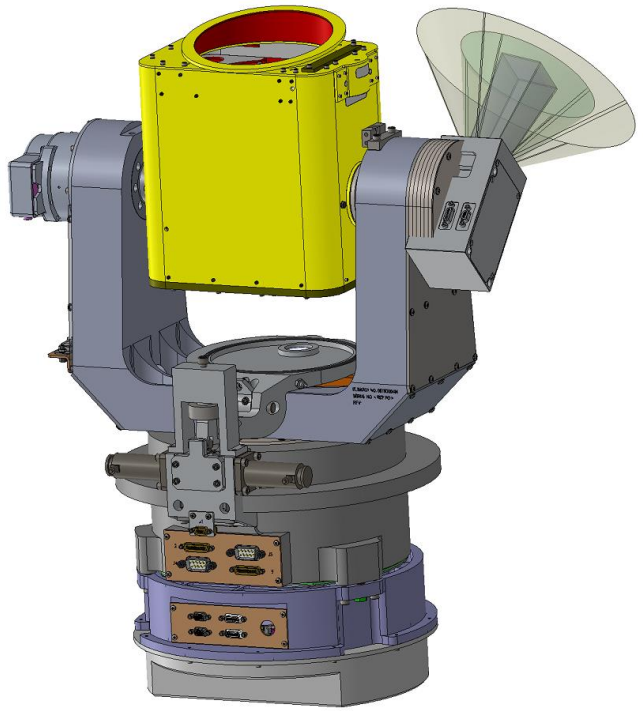
*T. Shih, et al, "A Modular, Agile, Scalable Optical Terminal Architecture for Space Communications", ICSOS 2017.

Modular, Agile, Scalable Optical Terminal(MAScOT)



- **Generic MAScOT goals:**

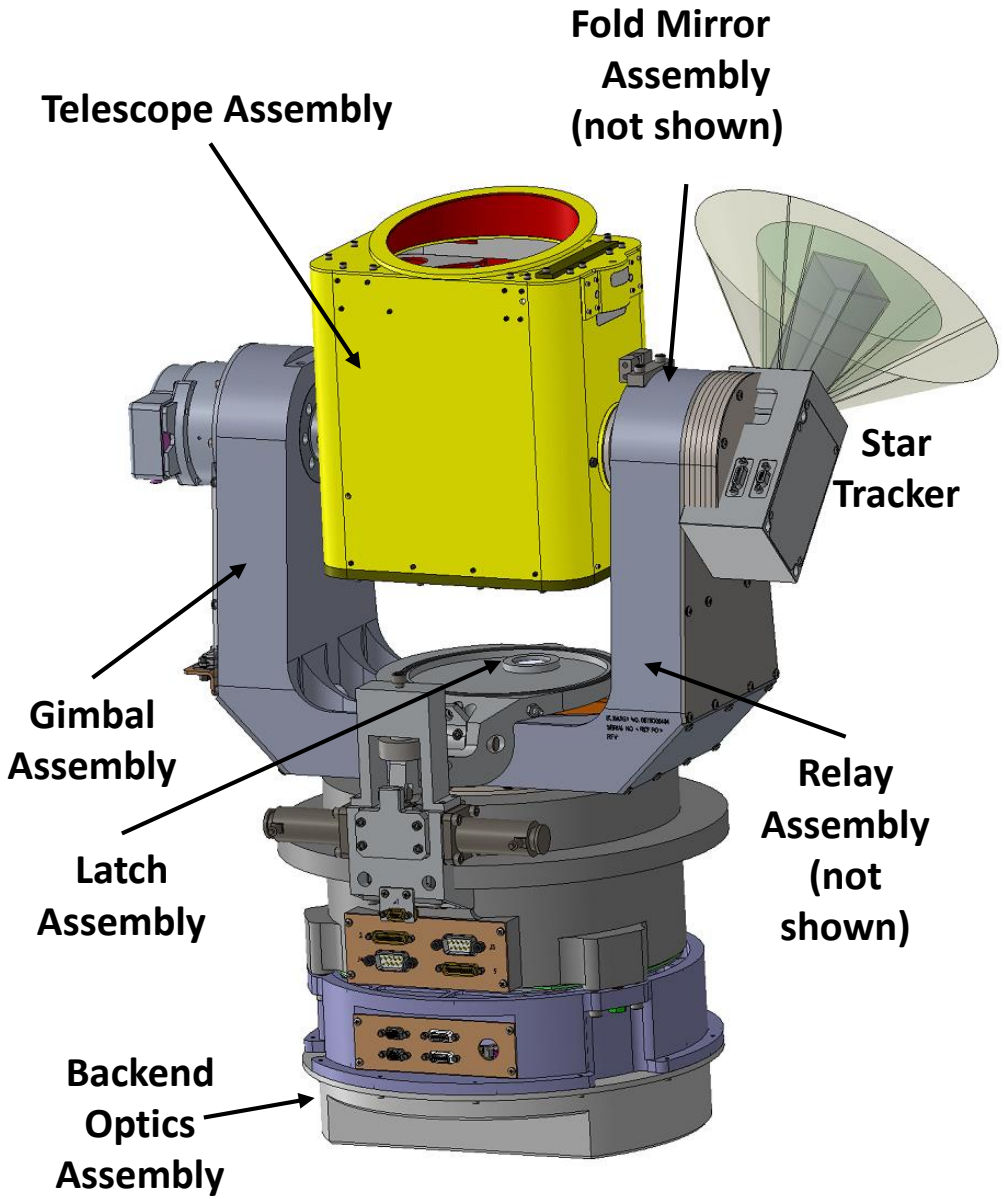
1. **Increased coverage with faster slew rates**
   - Accommodates short/fast LEO orbit links
   - Does not require spacecraft pointing to achieve comm link
2. **Modular**
   - Customizable for given application
   - Lower reproduction/recurring costs
   - Enables future technology swap-outs
3. **Scalable**
   - Modularity helps make subsystems more readily scalable
   - Can accommodate near-Earth and/or Deep Space applications without full-up architecture changes

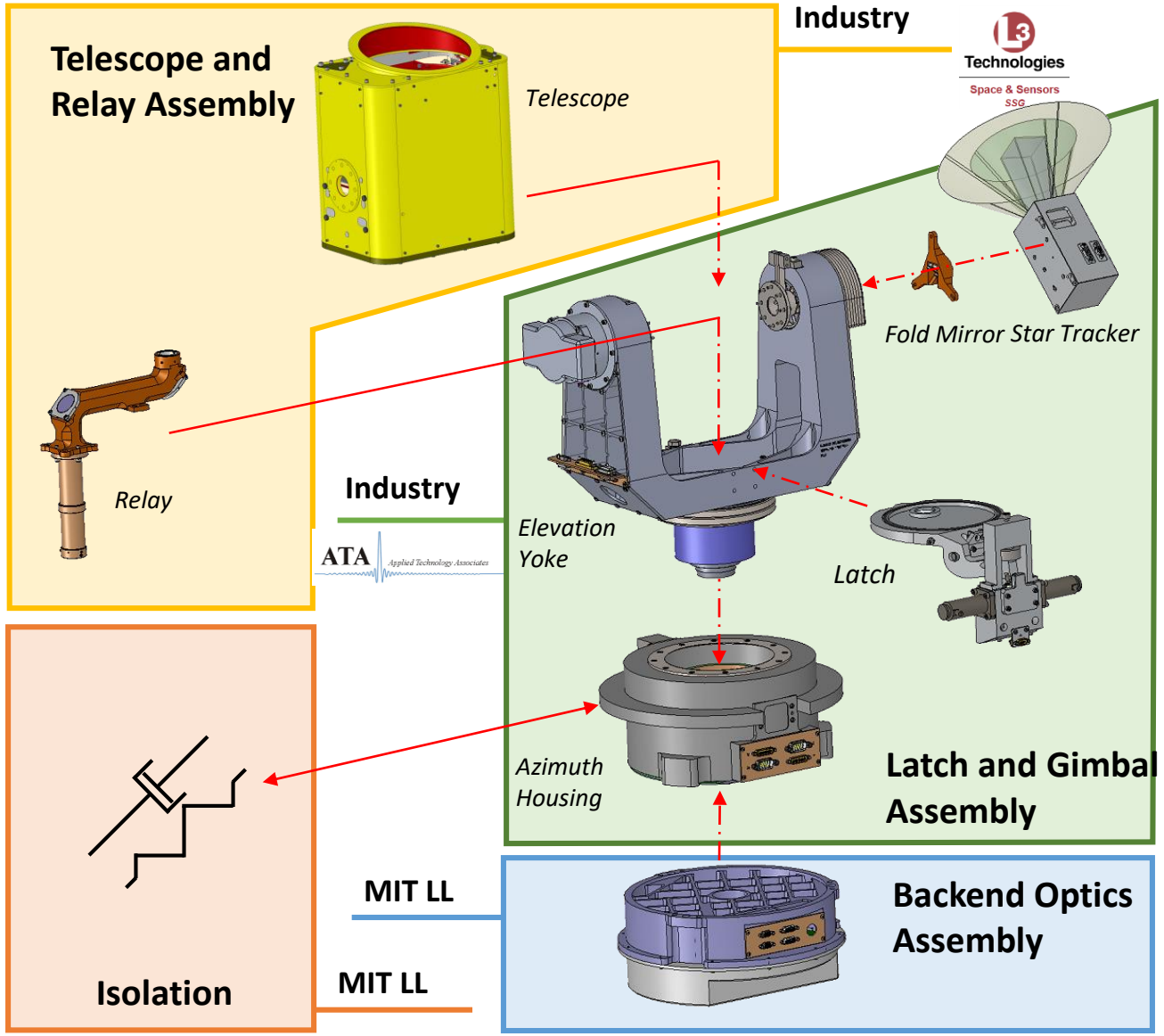


Modular, Agile, Scalable Optical Terminal (MAScOT)

10-cm Terminal Architecture

OM Subassembly Breakdown





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Conclusion

- The LEMNOS team represents a world recognized group aiming to advance the use of optical communications system for space communications
- LEMNOS projects embody important opportunities to demonstrate key characteristics of optical communications based systems and are natural precursors to planned deployment of the next generation communications relay system (Optical TDRS) and Deep Space optical communications
- By 2022 the LEMNOS project will deliver two optical communications terminals demonstrating operational utility of laser communications in both relay and direct to Earth scenarios

GO LEMNOS!

BACKUP SLIDES