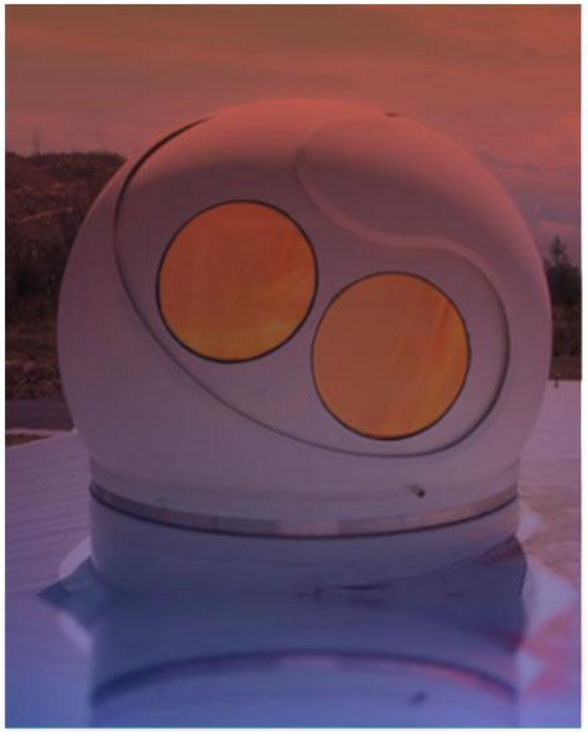
National Aeronautics and Space Administration

ILLUMA-T (Integrated LCRD LEO User Modem and Amplifier Terminal) Payload

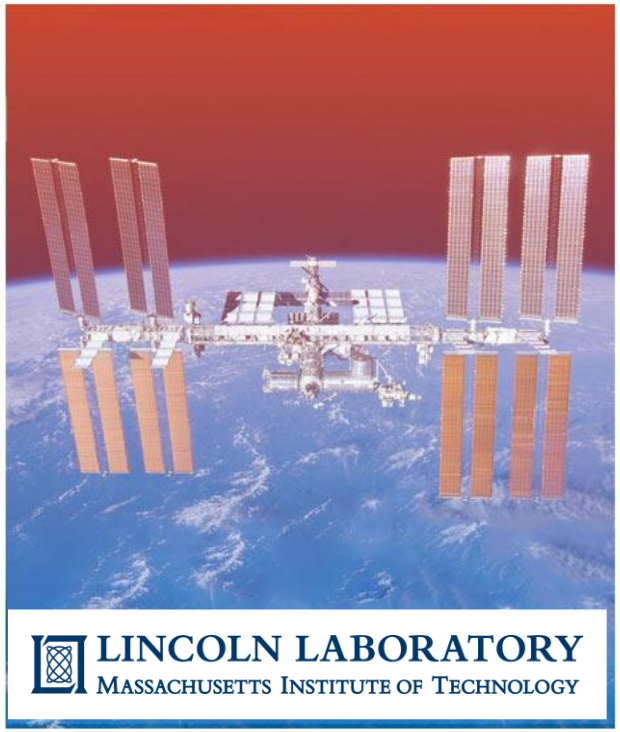
Antonios Seas, Zachary Gonnsen, Timothy Yarnall

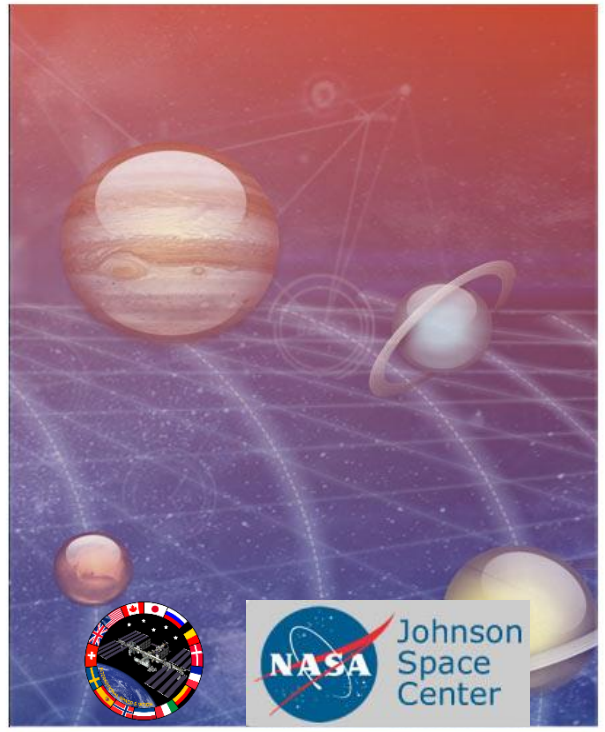
LEM NOS

Laser-Enhanced Mission Communications Navigation and Operational Services



Exploration & SPACE Communications





Agenda

- Introduction
- Objectives & L1 Requirements
- High Level System Architecture
- Operational Characteristics
- Schedule
- Conclusion

ILLUMA-T: Integrated LCRD LEO User Modem and Amplifier Terminal

LEMNOS Overview

LEMNOS: Laser-Enhanced Mission Communications Navigation and Operational Services

LEMNOS Project:

Implement Optical Communications on NASA spaceflight missions starting with demonstrations of operational utility on Orion EM-2 (O2O) and ISS (ILLUMA-T).

Orion EM2 Optical Communications Terminal (O2O)

Objective:

O2O provides the first optical communications payload on a human exploration mission

Partners:

HQ/HEO, GSFC, MIT-LL, JSC/Orion, Orion/Lockheed Martin, GSFC Space Network, JPL

Funding Source: HEO

Integrated LCRD LEO (Low-Earth Orbit) User Modem and Amplifier – Terminal (ILLUMA-T)

Objective:

First LEO user terminal of LCRD relaying data using GEO satellite

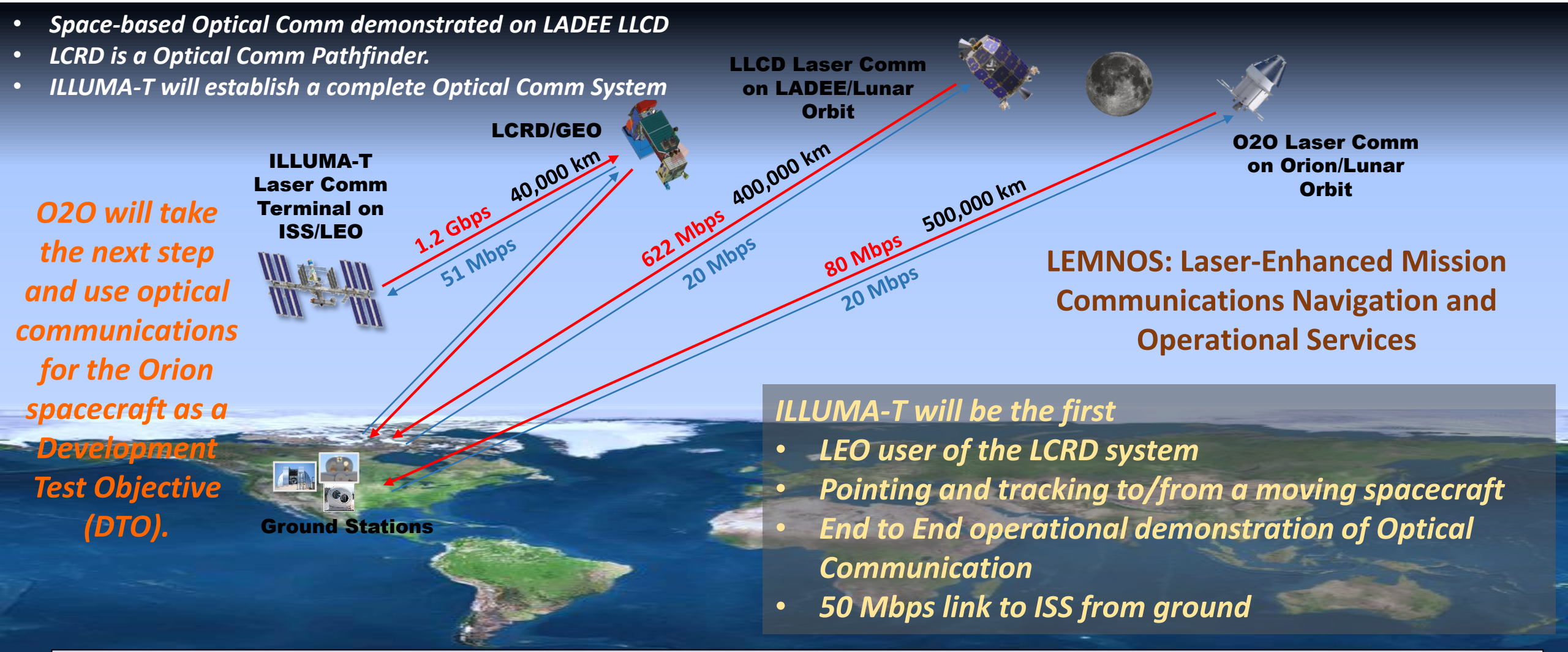
Partners:

HQ/SCaN, GSFC, LCRD, MIT-LL, JSC/ISS, JAXA,

Funding Source: SCaN

ILLUMA-T Introduction

- *Space-based Optical Comm demonstrated on LADEE LLCD*
- *LCRD is a 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).

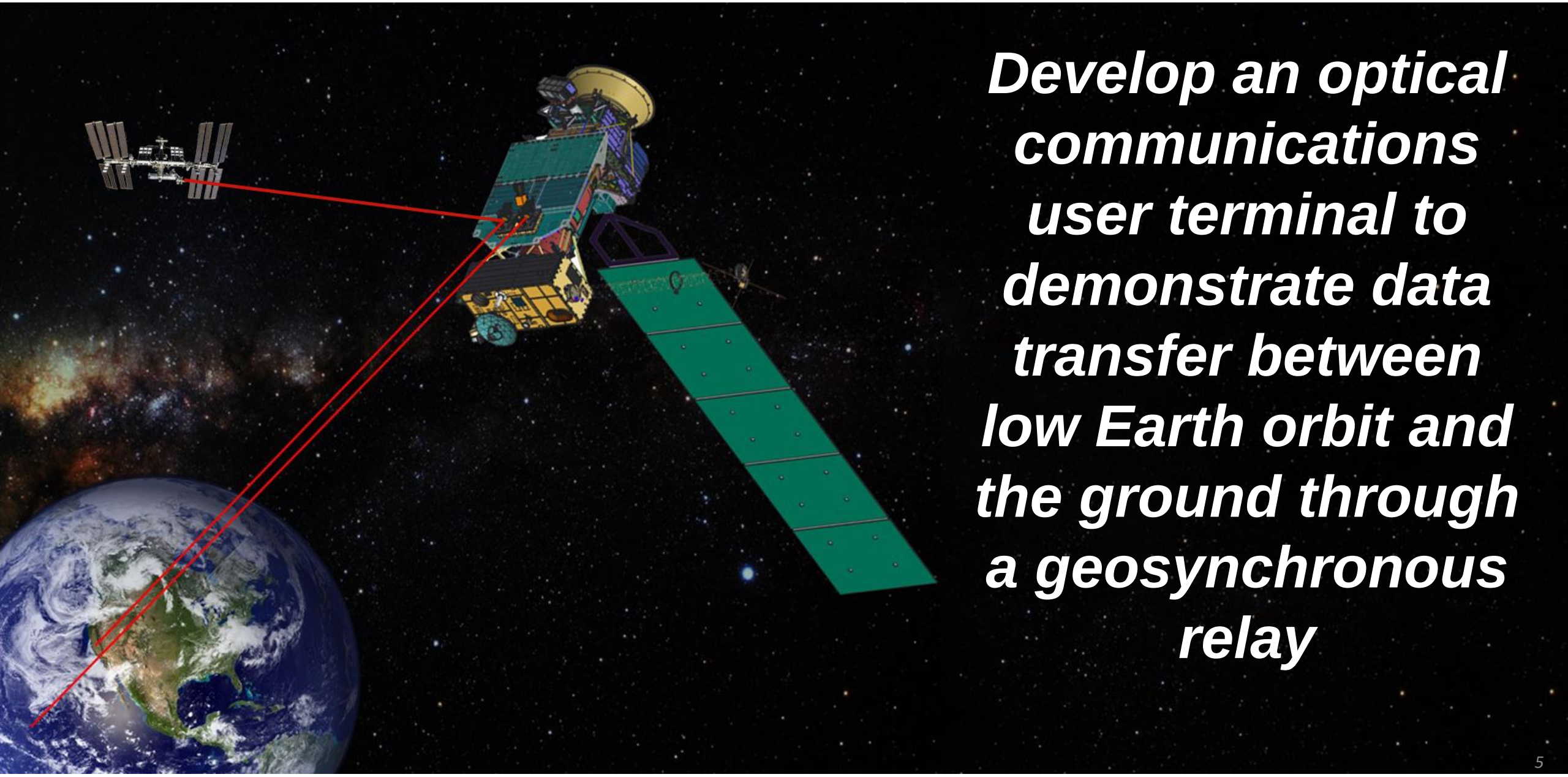
LEMNOS: Laser-Enhanced Mission Communications Navigation and Operational Services

ILLUMA-T will be the first

- *LEO user of the LCRD system*
- *Pointing and tracking to/from a moving spacecraft*
- *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 EM2 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

ILLUMA-T Overarching Objective



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

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ILLUMA-T: Integrated LCRD LEO User Modem and Amplifier Terminal

ILLUMA-T Objective and L1 Requirements

<u>Objective:</u> 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 at defined LCRD data rates including 1.244 Gbit/s on the return link (ISS via relay to ground) and 51 Mbps on the forward link (Ground via relay 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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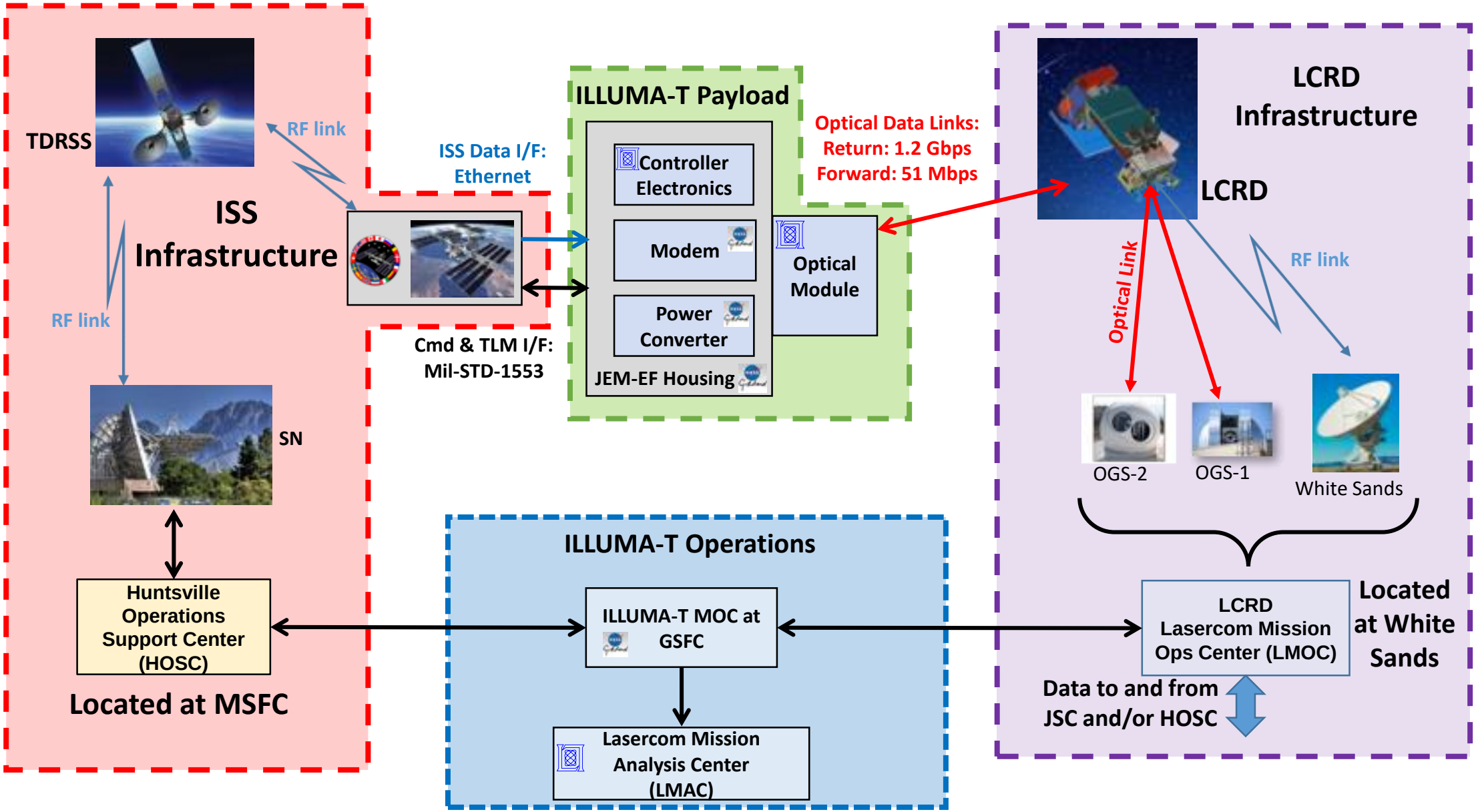
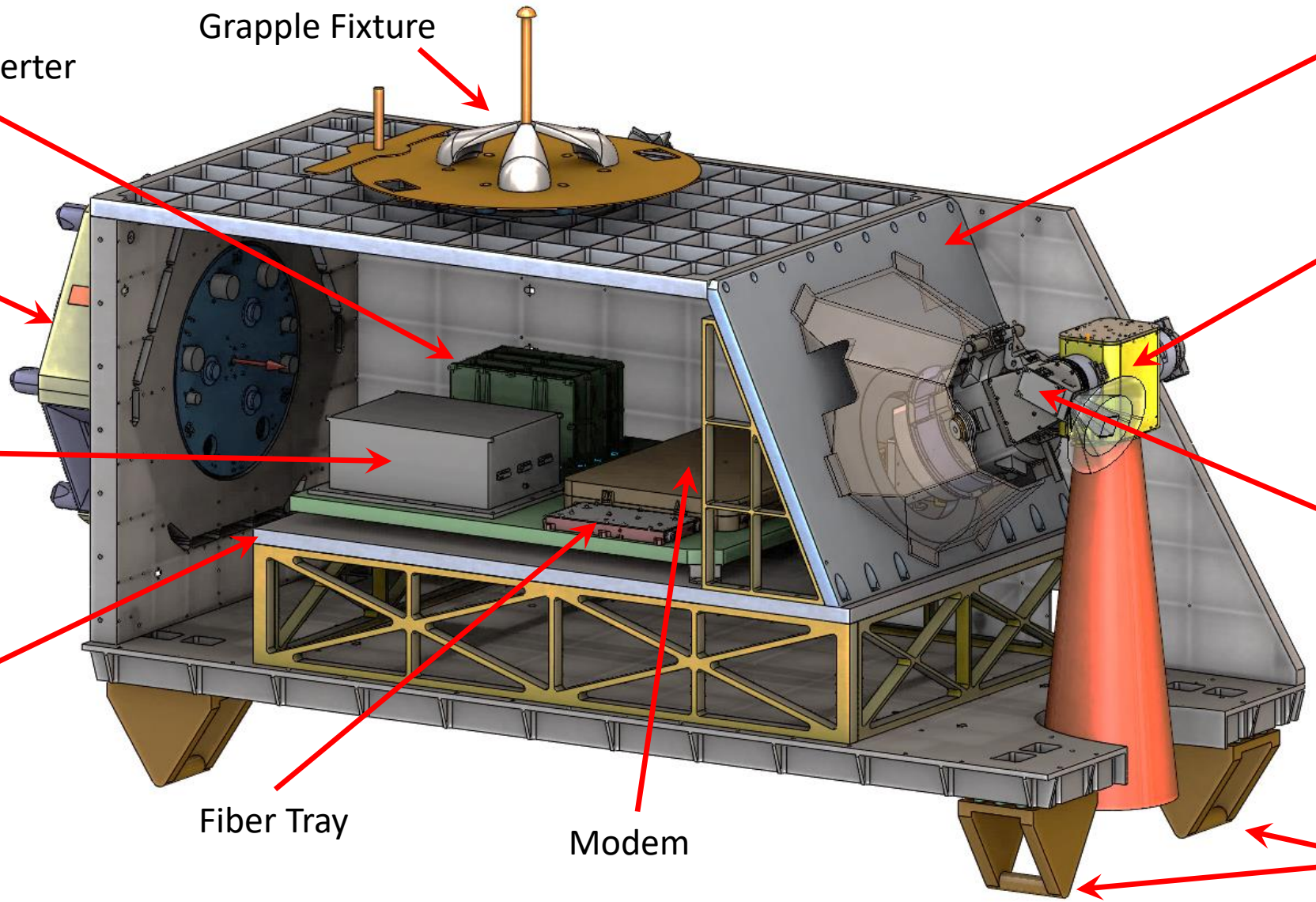
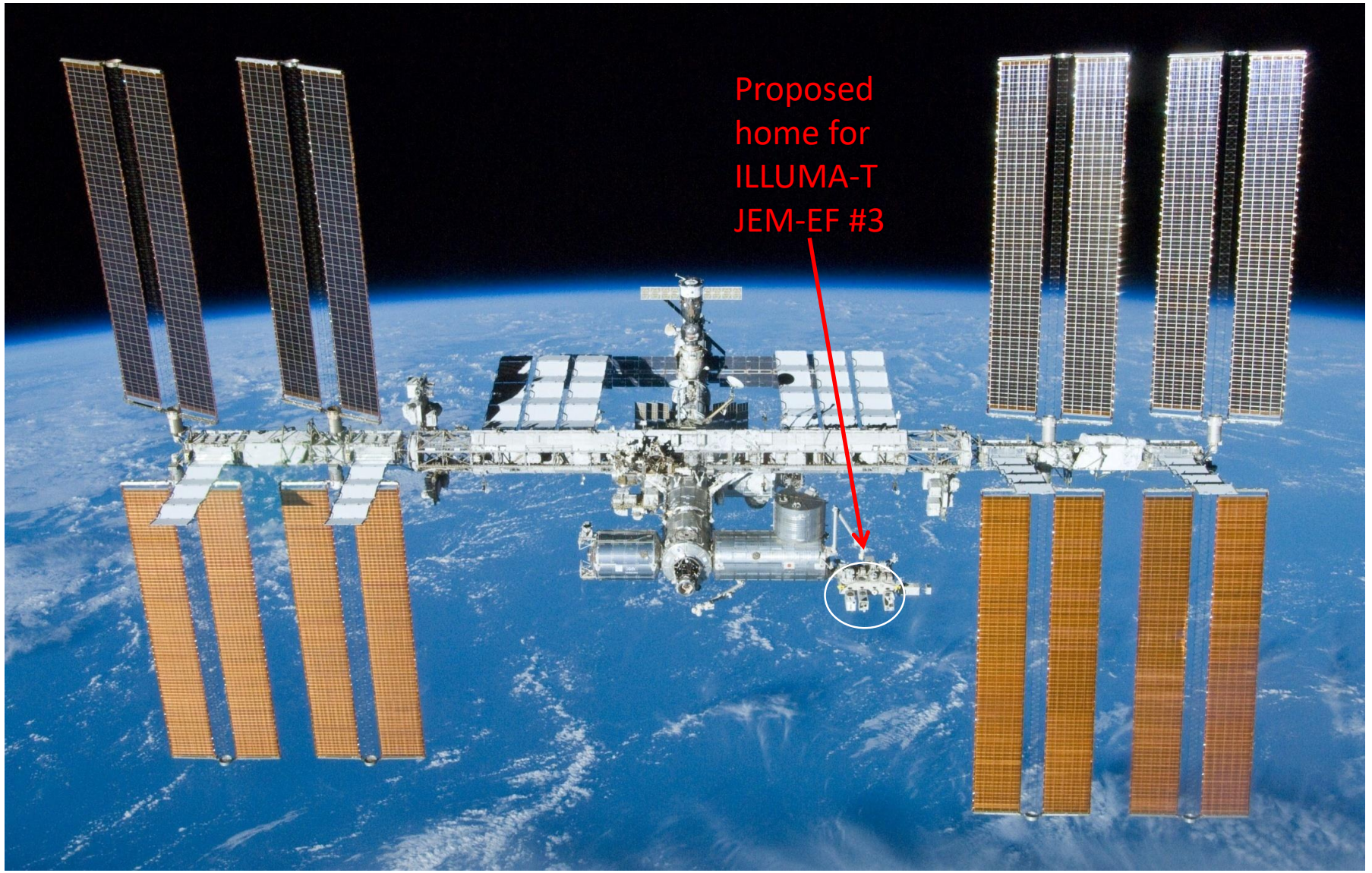
ILLUMA-T Architecture



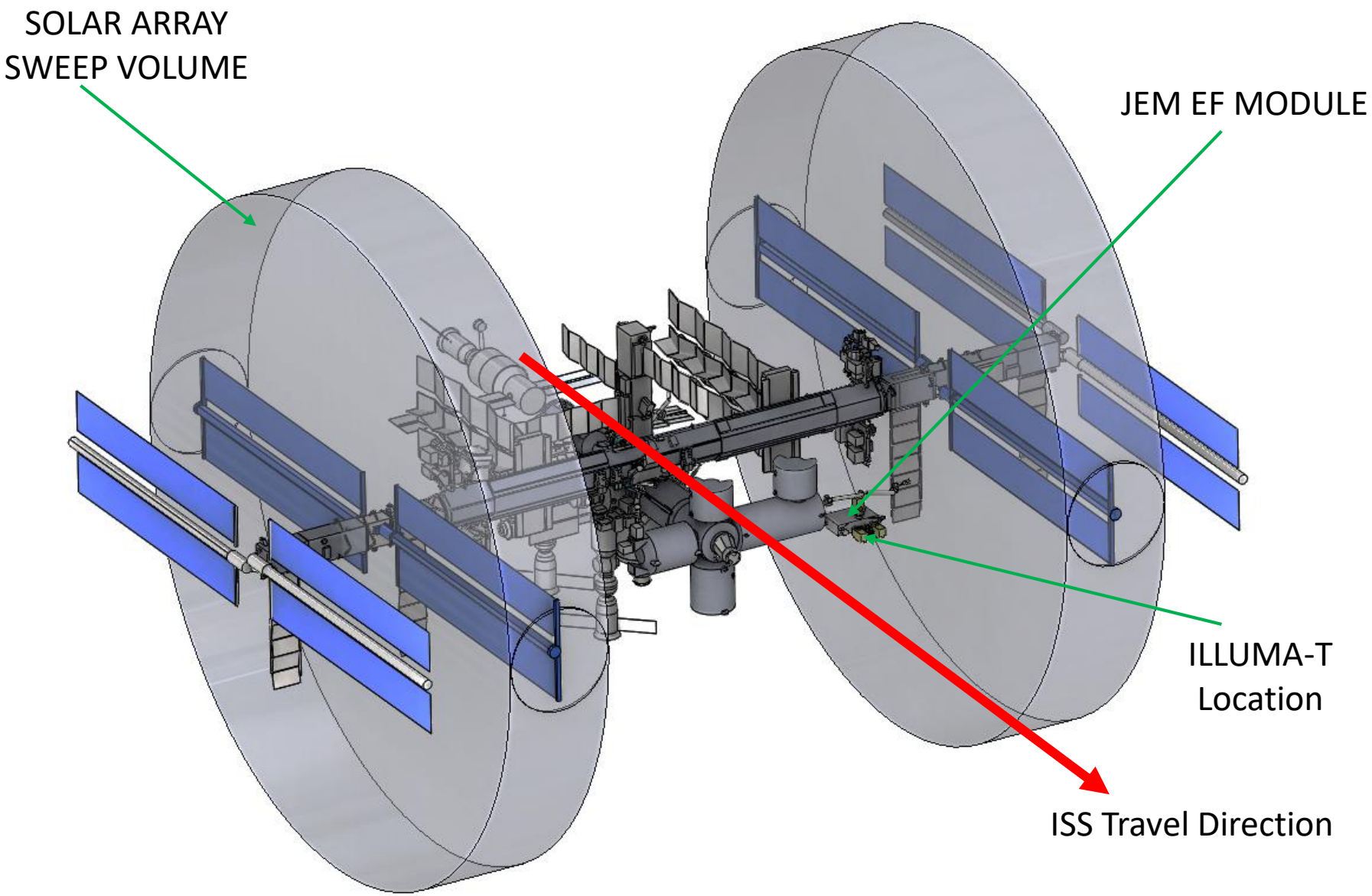
ILLUMA-T Payload



ILLUMA-T Location on ISS



ILLUMA-T Transceiver FOV Blockages



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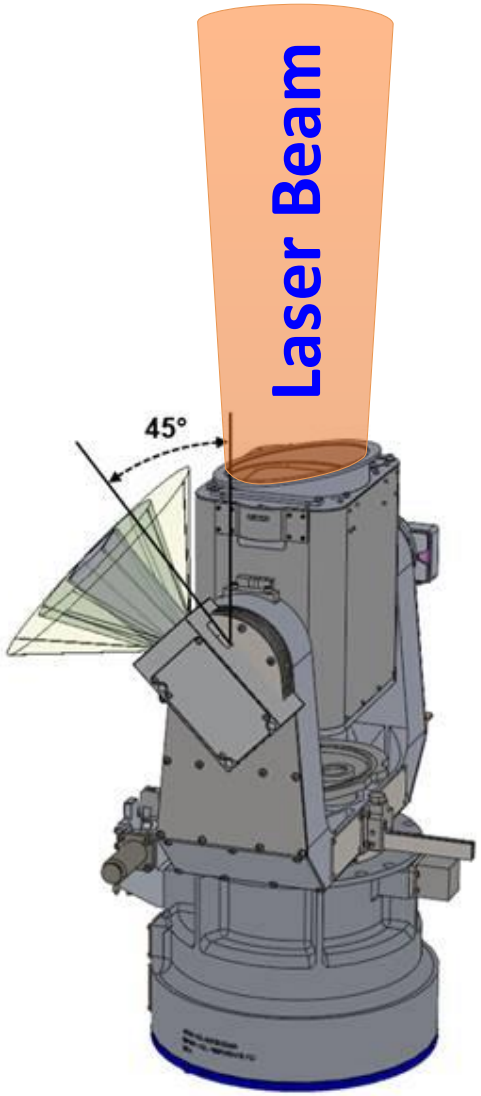
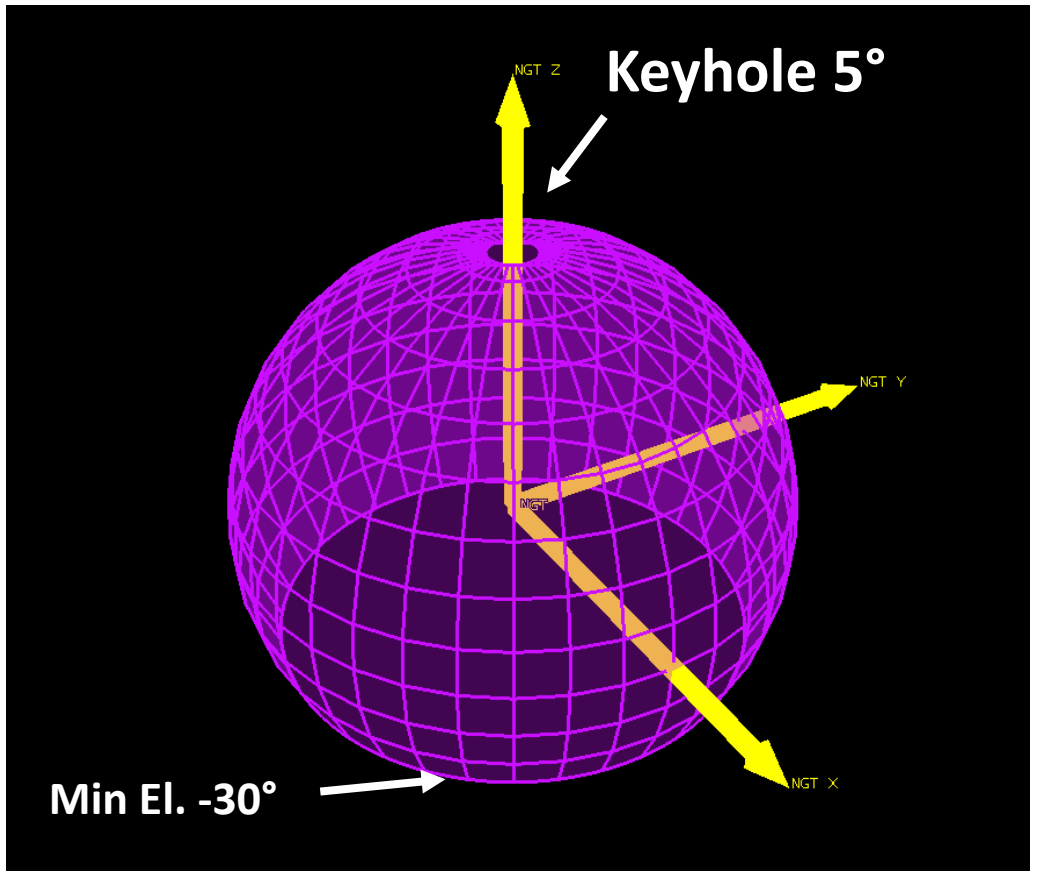
ILLUMA-T Optical Terminal

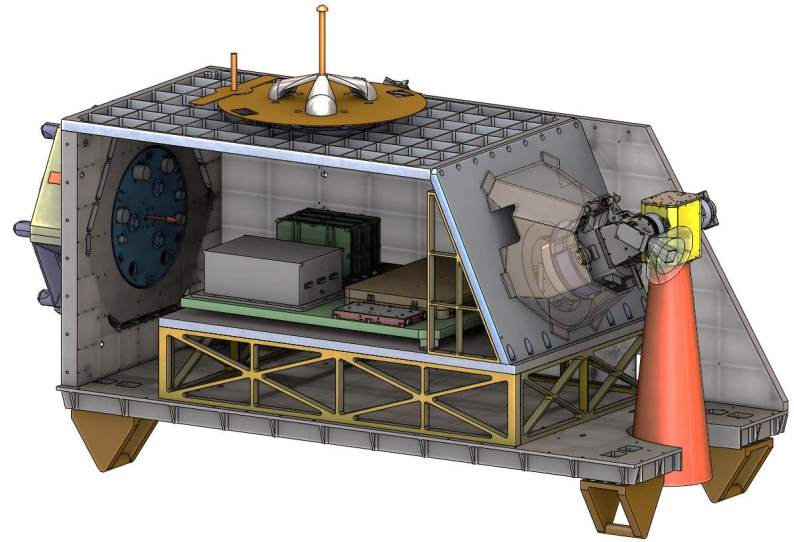


ILLUMA-T Optical Terminal



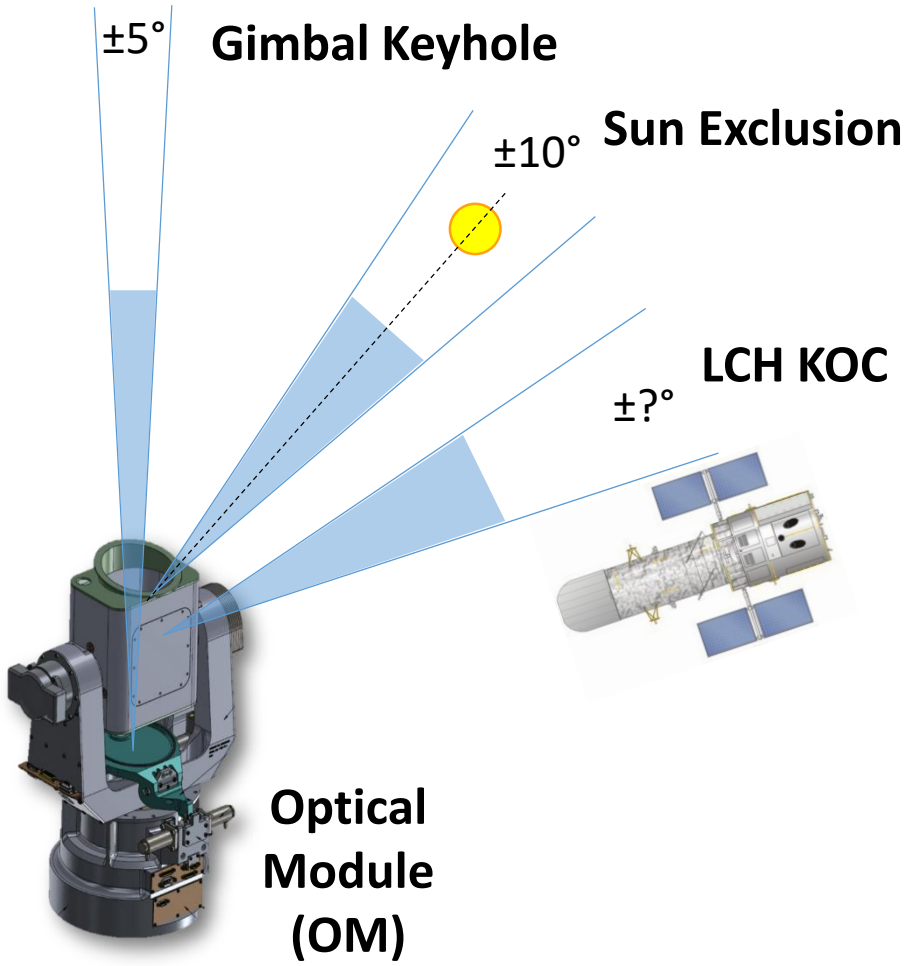
Gimbal Field Of Regard (FOR), 90° to -30° by 360°

- NGT has two mechanical angular pointing restrictions:
  - Keyhole, within 5 degrees of NGT +Z
  - Low elevation, 30 degrees below the XY-plane



Factors Impacting Link Access*

- Orbit
- Sun in Field Of View (FOV) of the acquisition/track sensor
  - ➢ OM will not operate when the sun is within 10° of the Line Of Sight (LOS) to LCRD
- Keyhole at gimbal mount zenith (±5°)
  Very small fraction of passes (TBD)
- Gimbal Field Of Regard (FOR)
  (90° to -30° by 360°)
- ISS Body Mask
- Laser Clearing House (LCH) Keep Out Cone (KOC)



*Access := A time period during which all conditions for the establishment and operation of a link are satisfied

ILLUMA-T Field Of View

ILLUMA-T Gimbal Up/Down 180° FOV Hemispheres Definition

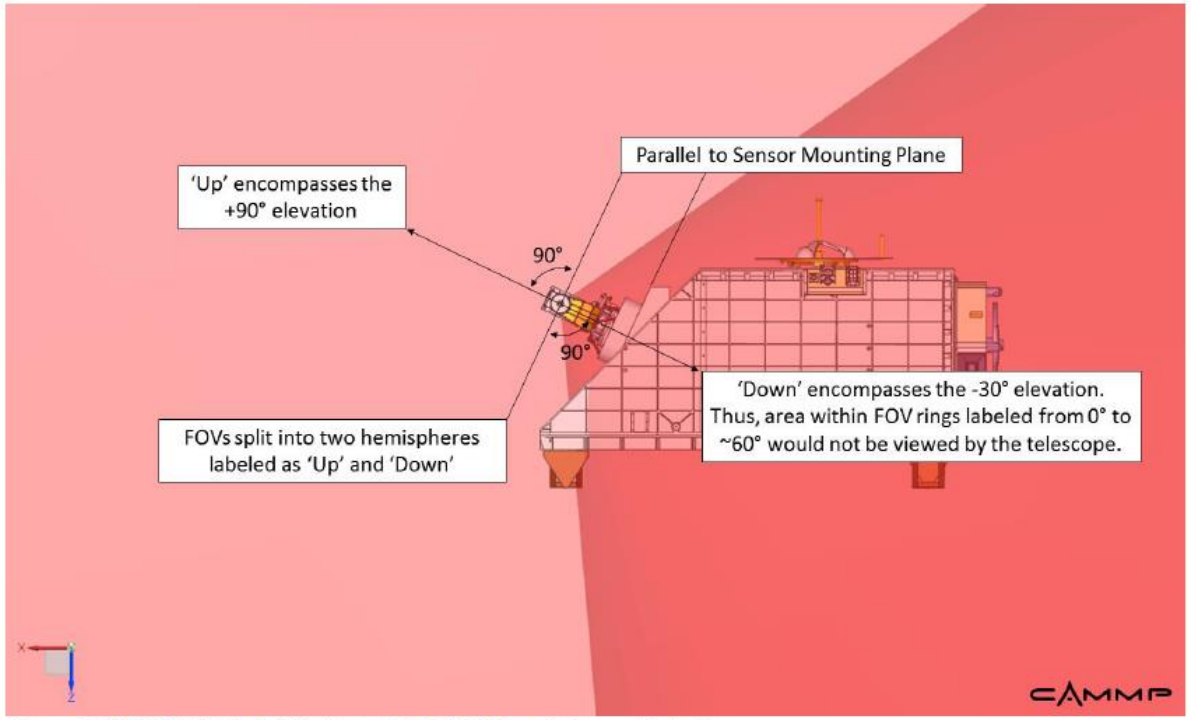
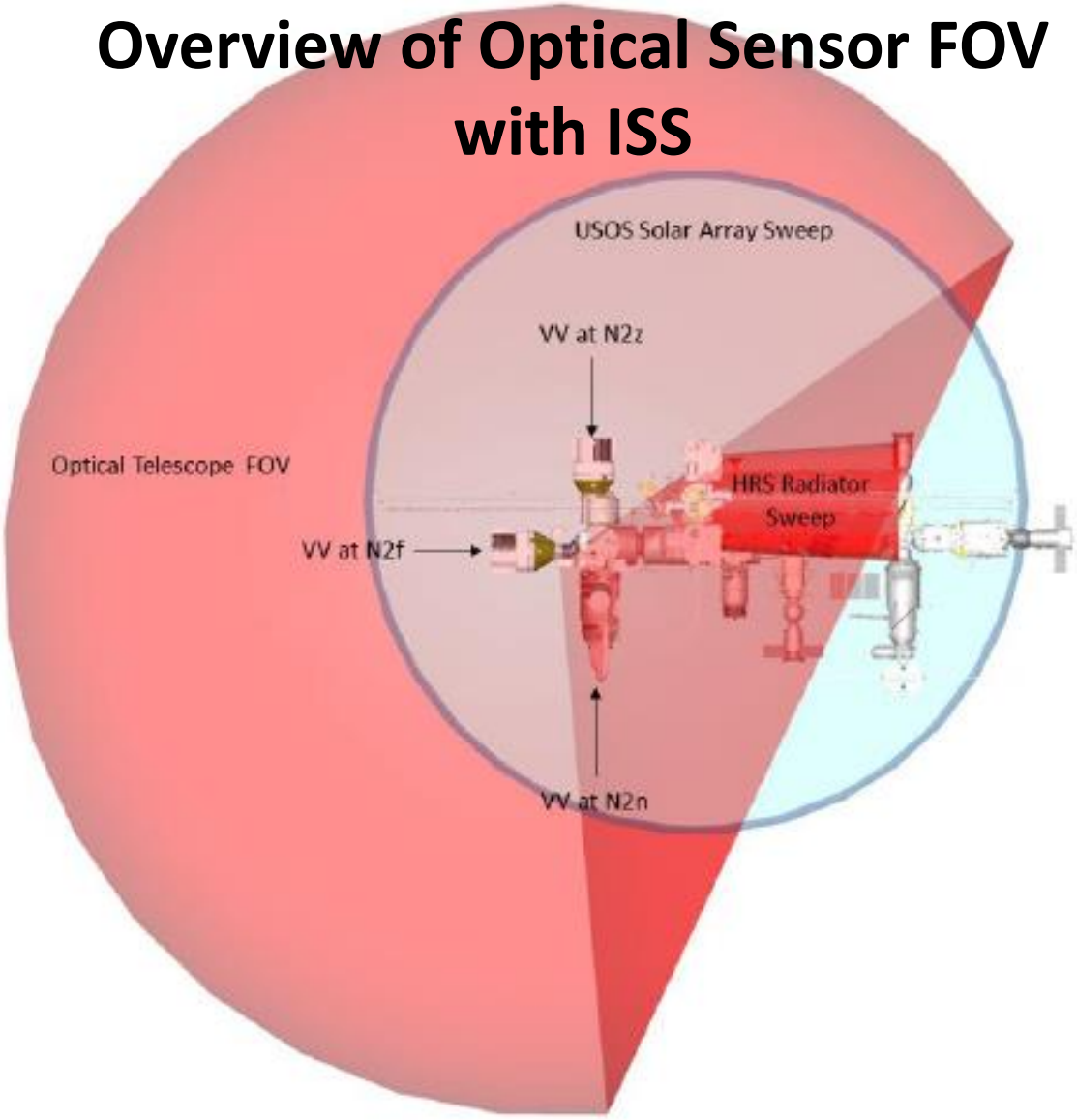
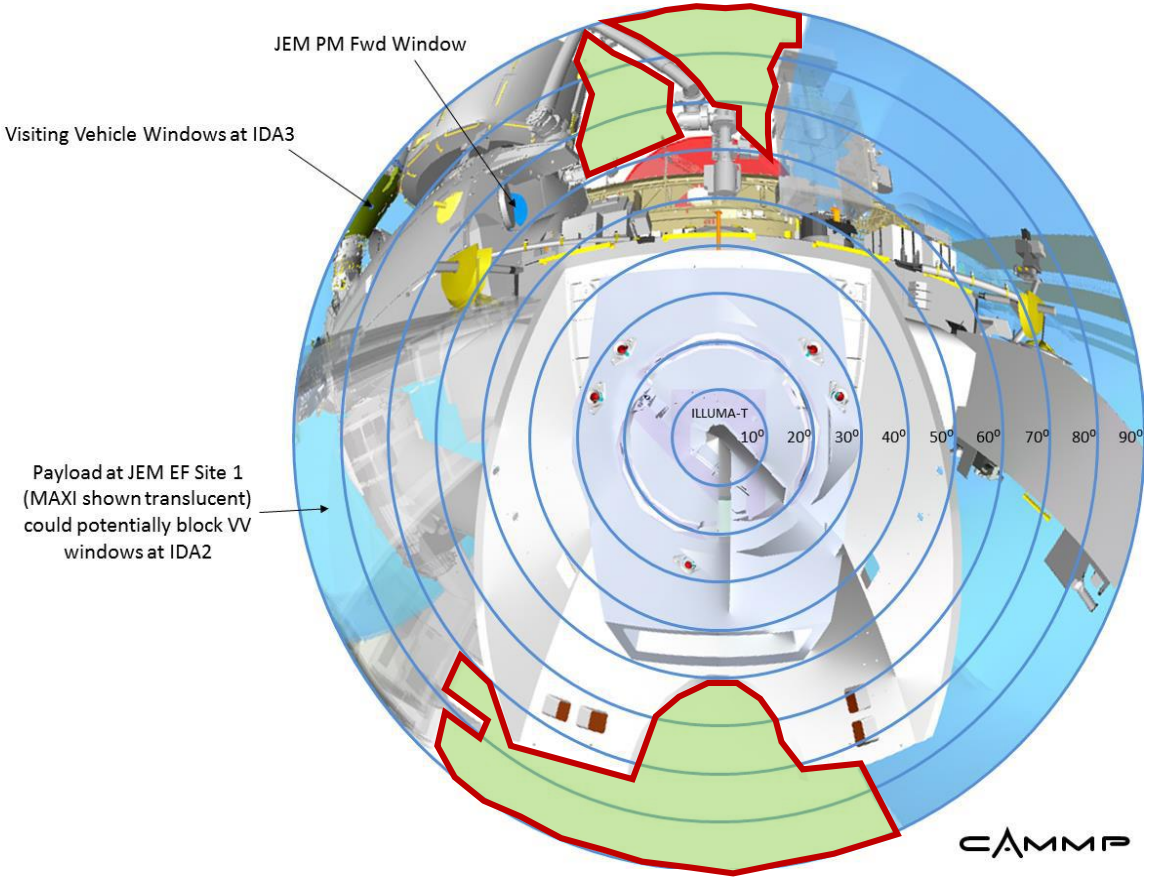


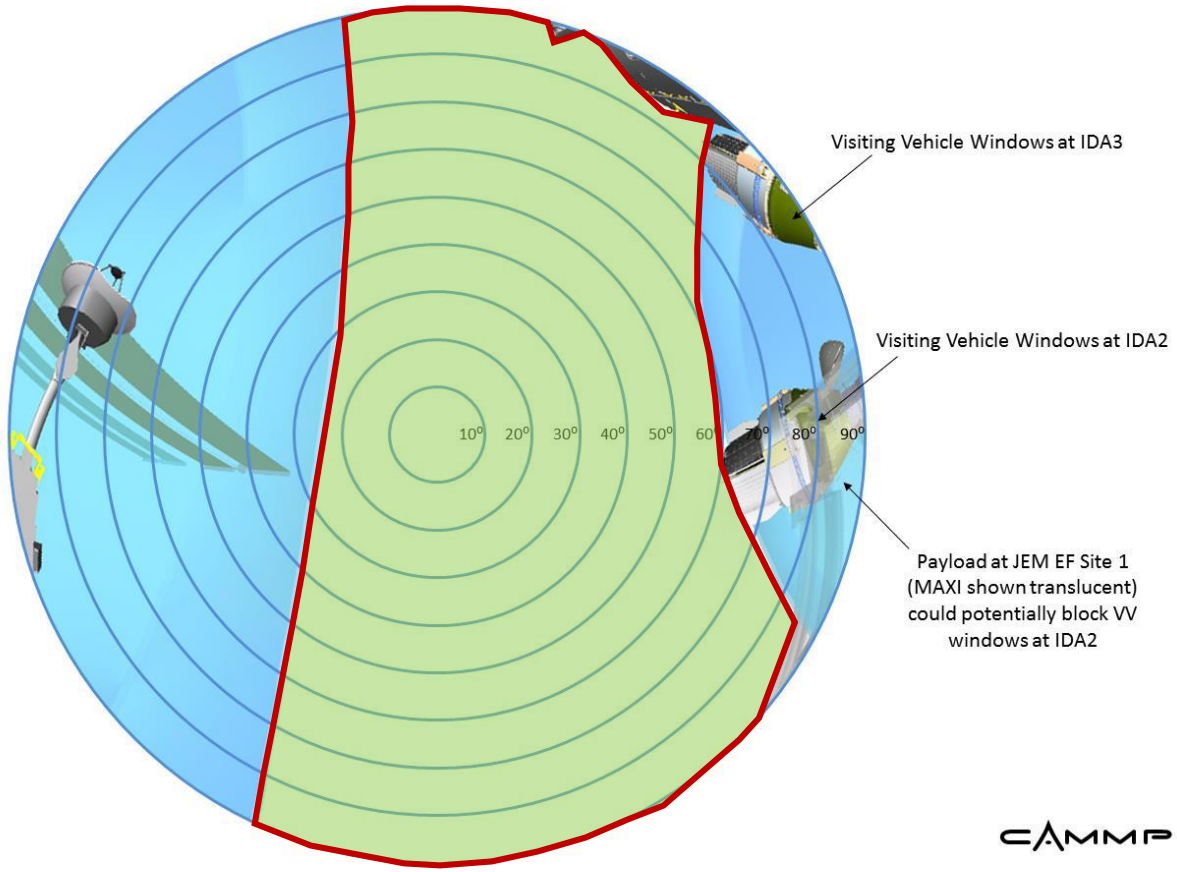
Figure 3. ILLUMA-T Gimbal Up/Down 180° FOV Hemispheres Definition

Overview of Optical Sensor FOV with ISS



CAMMP Analysis of Field of Regard (FOR)





- Mounting of ILLUMA-T on 65 degree plate
- FOR modeled by CAMMP
  - Green -> Persistent Line Of Sight (LOS) from ISS
  - Blue -> Solar panel swept solid

ILLUMA-T Performance w/ Solar Panel Swept Solid

Weekly Access Statistics with Solar Panel Swept Solid and 10 degrees solar exclusion

- 91 accesses
- 22 minute mean duration
- 33.5 hrs/week

22 minute contact →

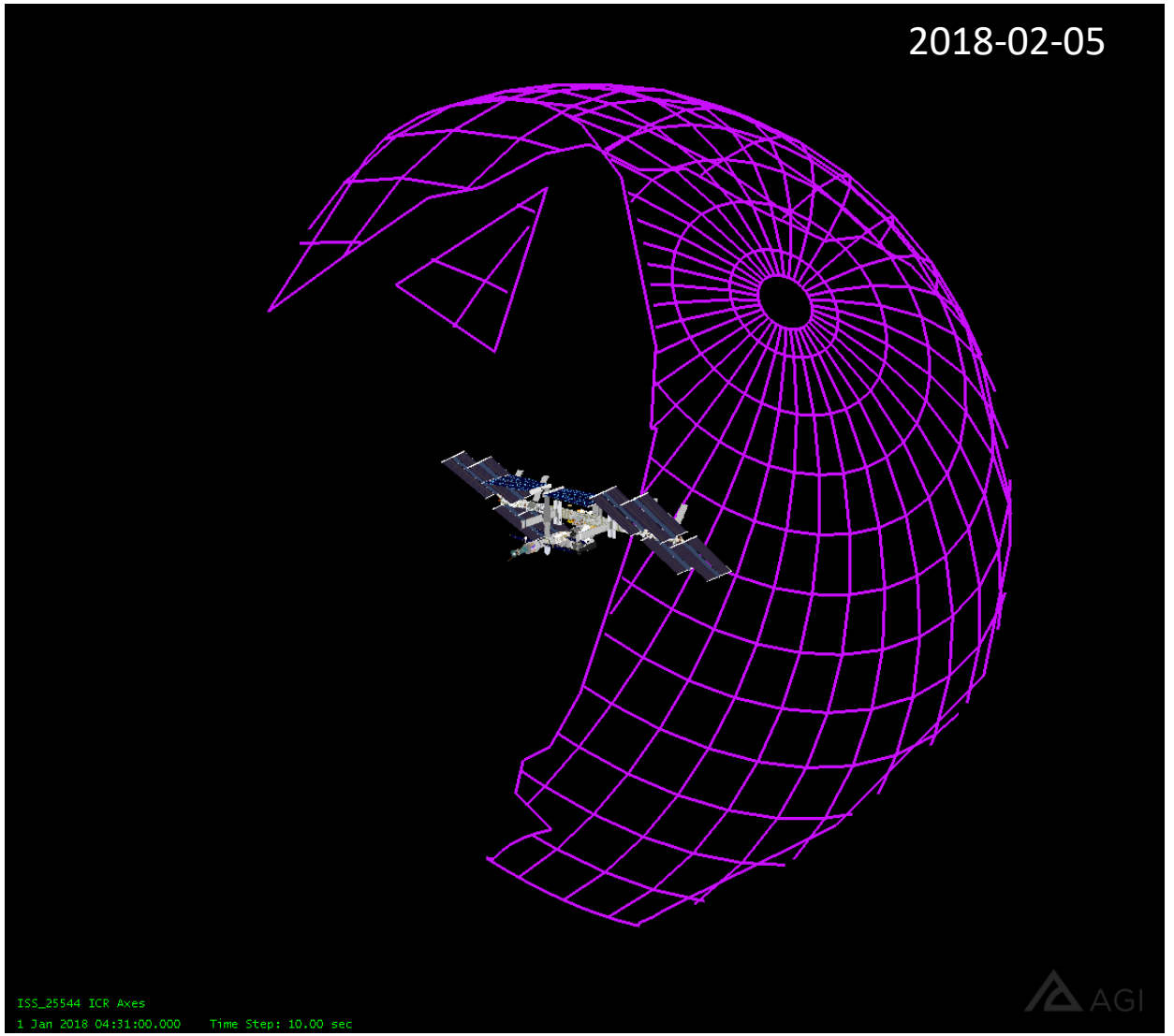
Return: 1.642 Tbits (0.205 TBytes)

Forward: 67 Gbits (8.375 GBytes)

33.5 Hours weekly →

Return: 150.03 Tbits (18.76 TBytes)

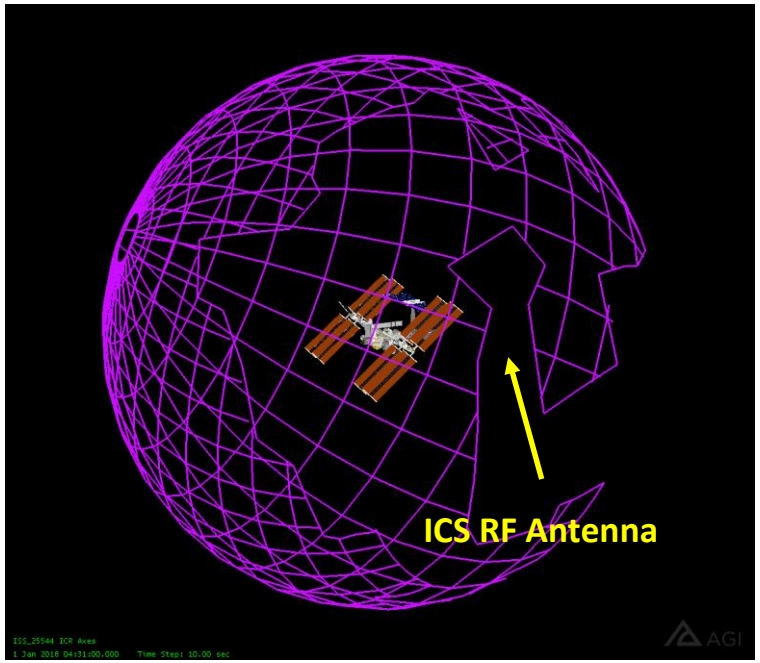
Forward: 6 Tbits (0.75 TBytes)

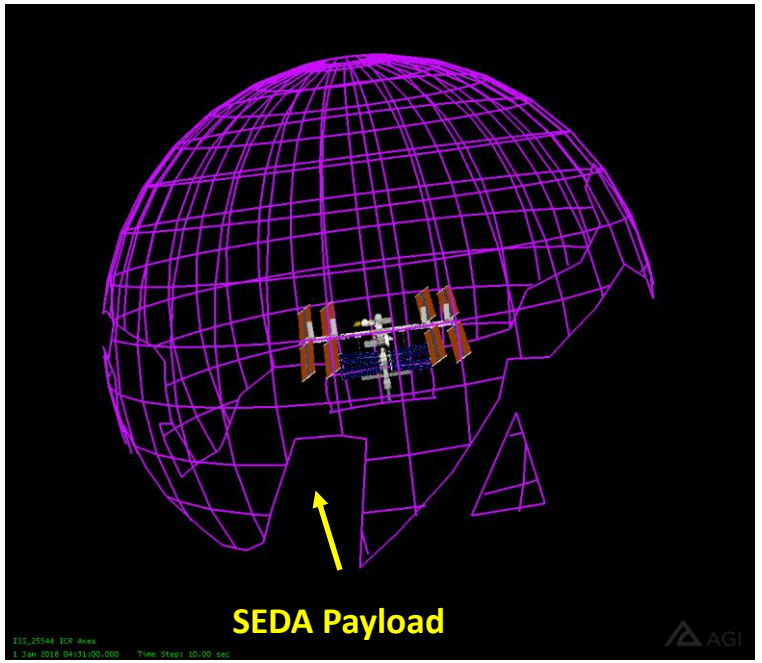


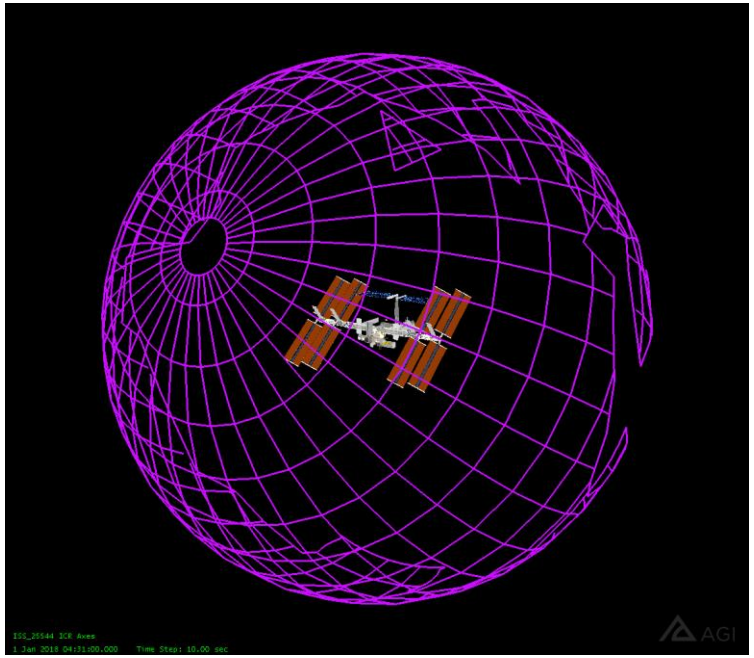
Mask at 65°

ILLUMA-T Performance with w/o Solar Panel Swept Solid

Mask at 65°







LCRD weekly access statistics without solar panel swept solid and 10 degrees solar exclusion angle

- 125 accesses
- 29 minute mean duration
- 61 hours per week

29 minute contact →
Return: 2.164 Tbits (0.27 TBytes)
Forward: 88.74 Gbits (11.1 GBytes)
33.5 Hours weekly →
Return: 273.2 Tbits (34.15 TBytes)
Forward: 11.2 Tbits (1.4 TBytes)

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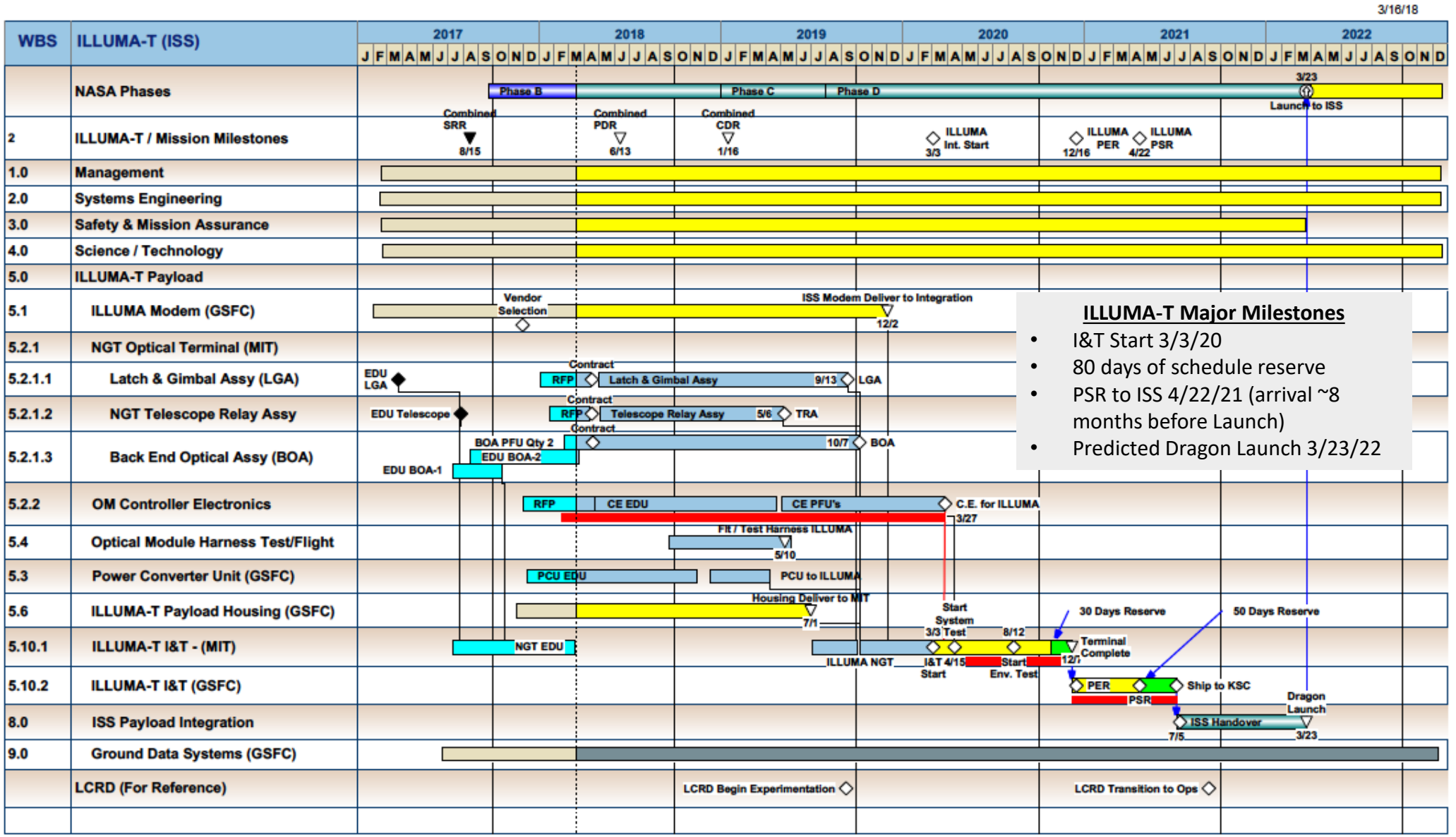
ILLUMA-T Schedule



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Conclusion

- The ILLUMA-T team represents a world recognized group aiming to the demonstration of an end-to-end optical communications system between a LEO terminal and the ground through a GEO relay
- ILLUMA-T is an important opportunity for NASA to further enhance its reputation and skills in high bandwidth optical communications
- The ILLUMA-T project has been established on solid foundation and the ILLUMA-T team is working well together. The team is on track to deliver the optical terminal on schedule
- ILLUMA-T is a great mission that demonstrates key characteristics of optical communications based relay system and is a natural precursor to the planned deployment of the next generation communications relay system

GO ILLUMA-T!

BACKUP SLIDES

Acronyms

ILLUMA-T	Integrated LCRD LEO User Modem and Amplifier Terminal
LLCD	Lunar Laser Communication Demonstration
LCRD	Laser Communication Relay Demonstration
O2O	Orion EM2 Optical Communications Terminal
LEMNOS	Laser-Enhanced Mission Communications Navigation and Operational Services
HOSC	Huntsville Operations Support Center
LMAC	Lasercom Mission Analysis Center
LSTC	Lasercom Space Terminal Console
LMOC	Lasercom Mission Ops Center
ISS	International Space Station
OGS	Optical Ground Station
JEM-EF	Japanese Experiment Module - Exposed Facility
TDRS	Tracking and Data Relay Satellite
CATS	Cloud-Aerosol Transport System
SCaN	Space Communications and Navigation
NGT	New Generation Terminal
LEO	Low-Earth Orbit
MIT-LL	Massachusetts Institute of Technology – Lincoln Laboratory
GEO	Geostationary Earth Orbit
S&MA	Safety and Mission Assurances