

# System level TVAC functional testing for the Integrated LCRD Low-Earth Orbit User Modem and Amplifier Terminal (ILLUMA-T) payload destined for the International Space Station

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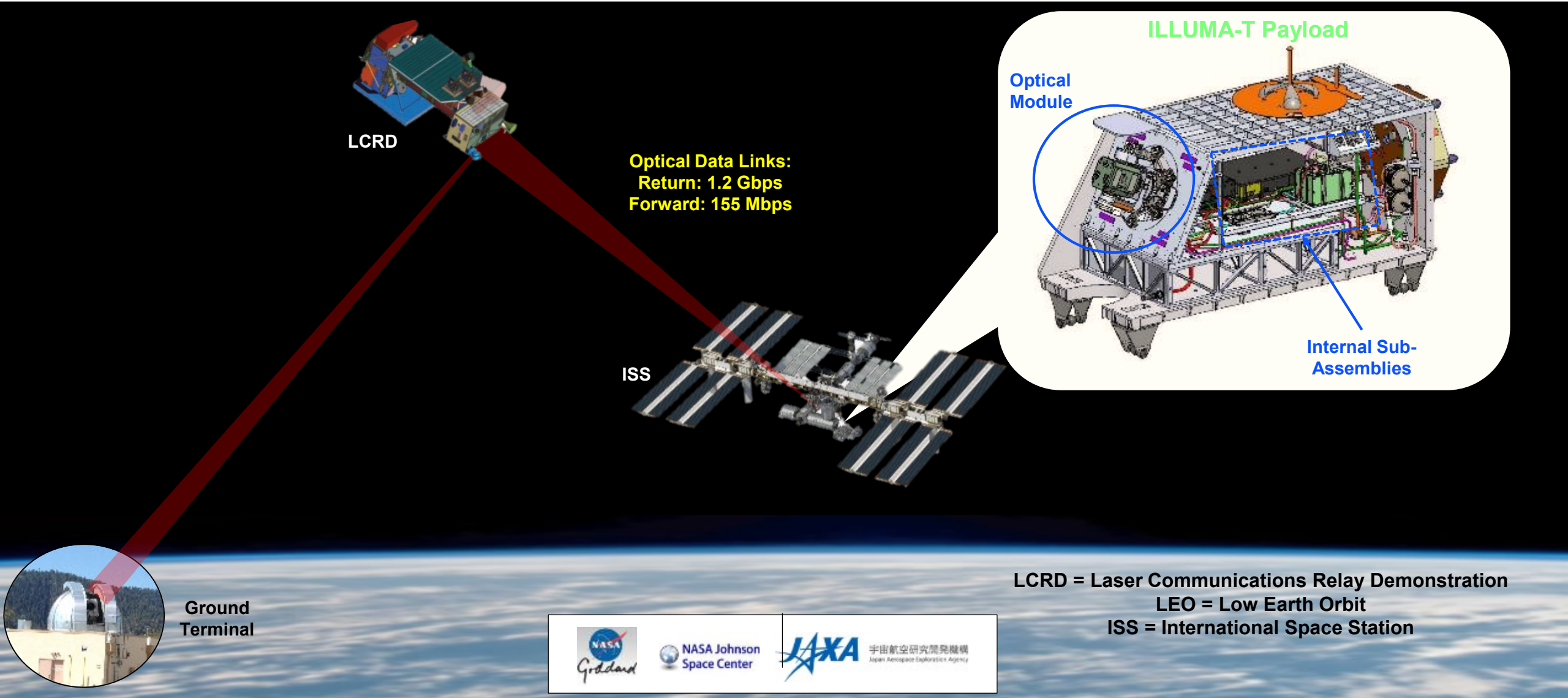
# Outline



- **Background and payload description**
- **Test facilities and test plan**
- **System testing**
- **Results**
- **Summary**



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

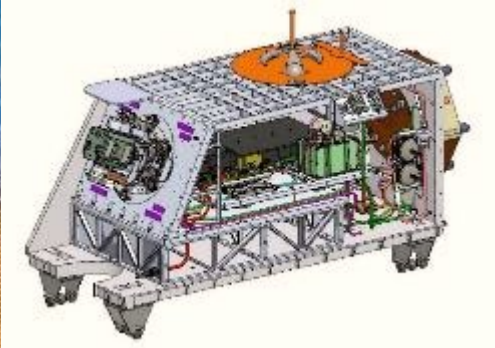
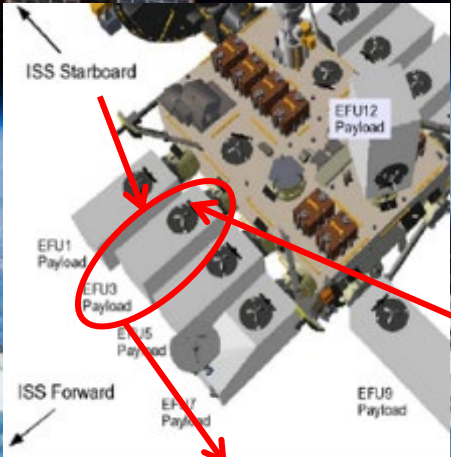
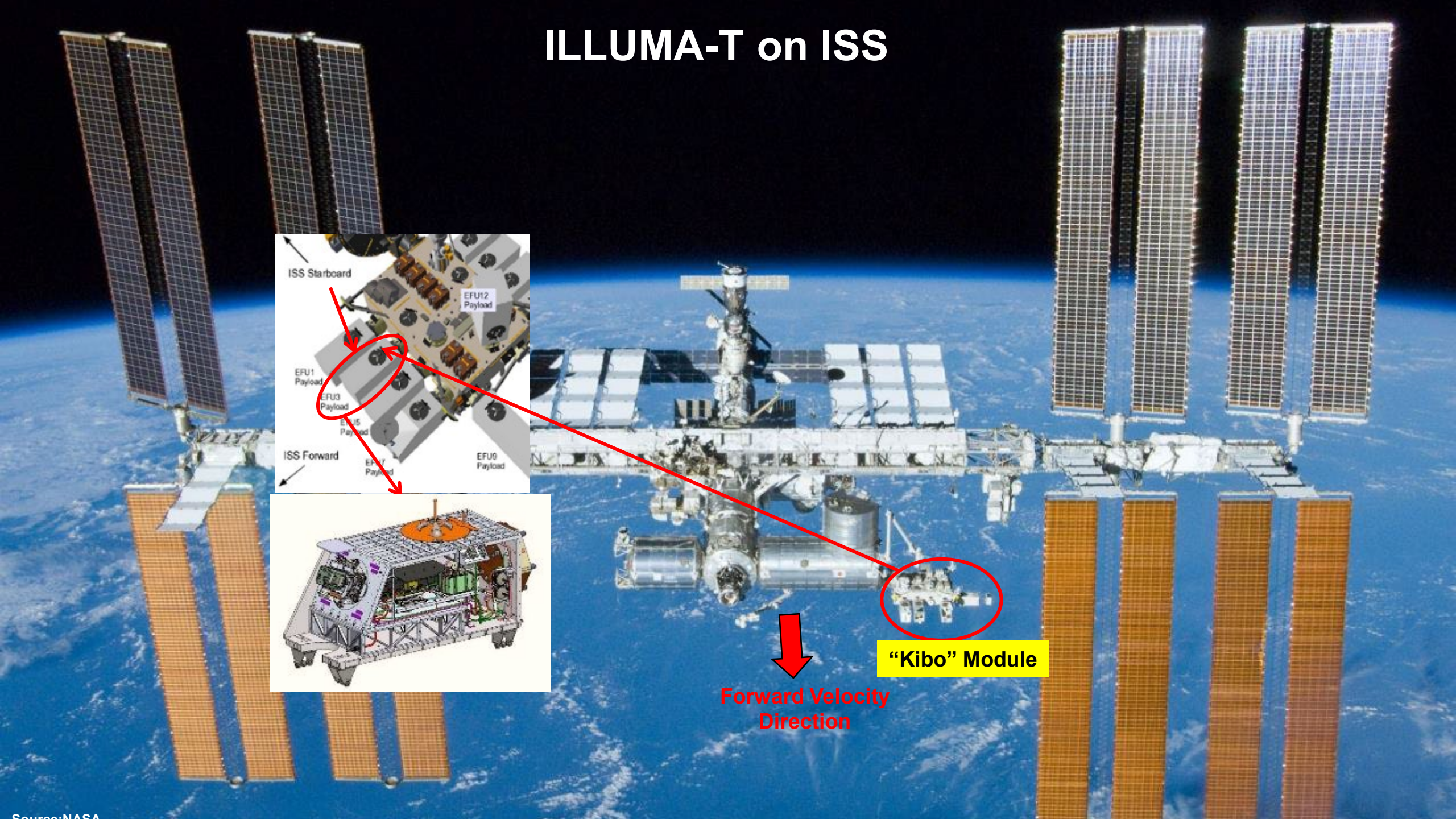


LCRD = Laser Communications Relay Demonstration  
LEO = Low Earth Orbit  
ISS = International Space Station





# ILLUMA-T on ISS



**"Kibo" Module**

**Forward Velocity Direction**

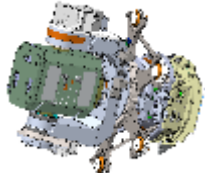




# ILLUMA-T Space Terminal Elements




MAScOT (OM)



L3HARRIS™

ATA Applied Technology Associates




Controller Electronics (CE)




SE SEAKR Engineering, Inc.

Modem Module (MM)


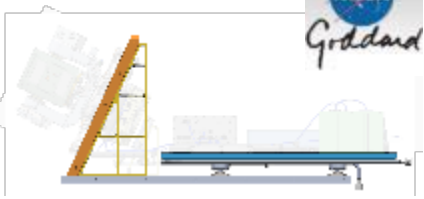


CACI EVER VIGILANT

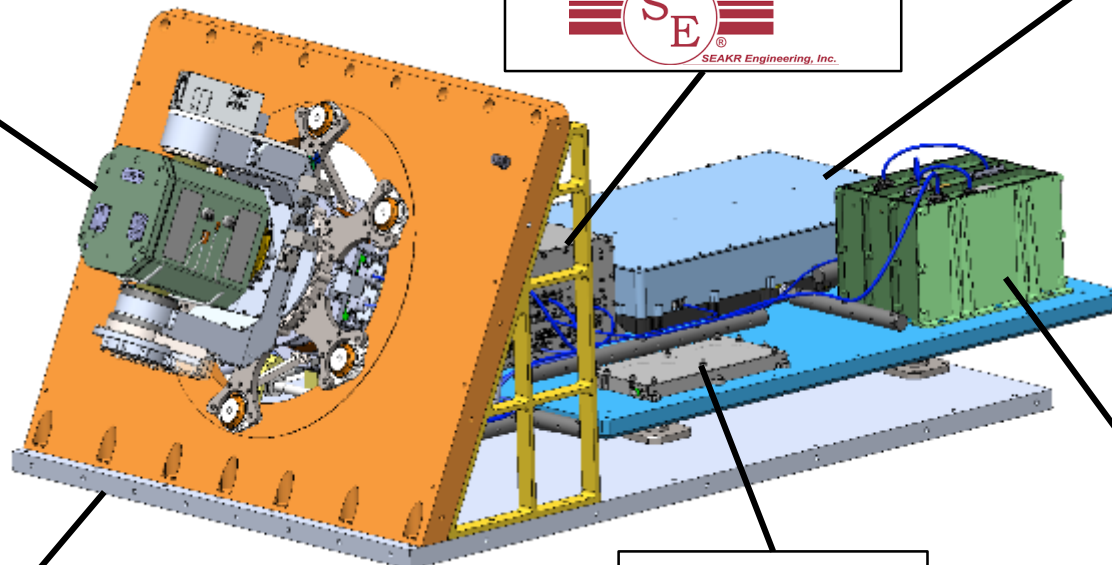


Goddard



Instrument Sled & ATCS Cold Plates





Goddard



Fiber Spool Assembly (FSA)



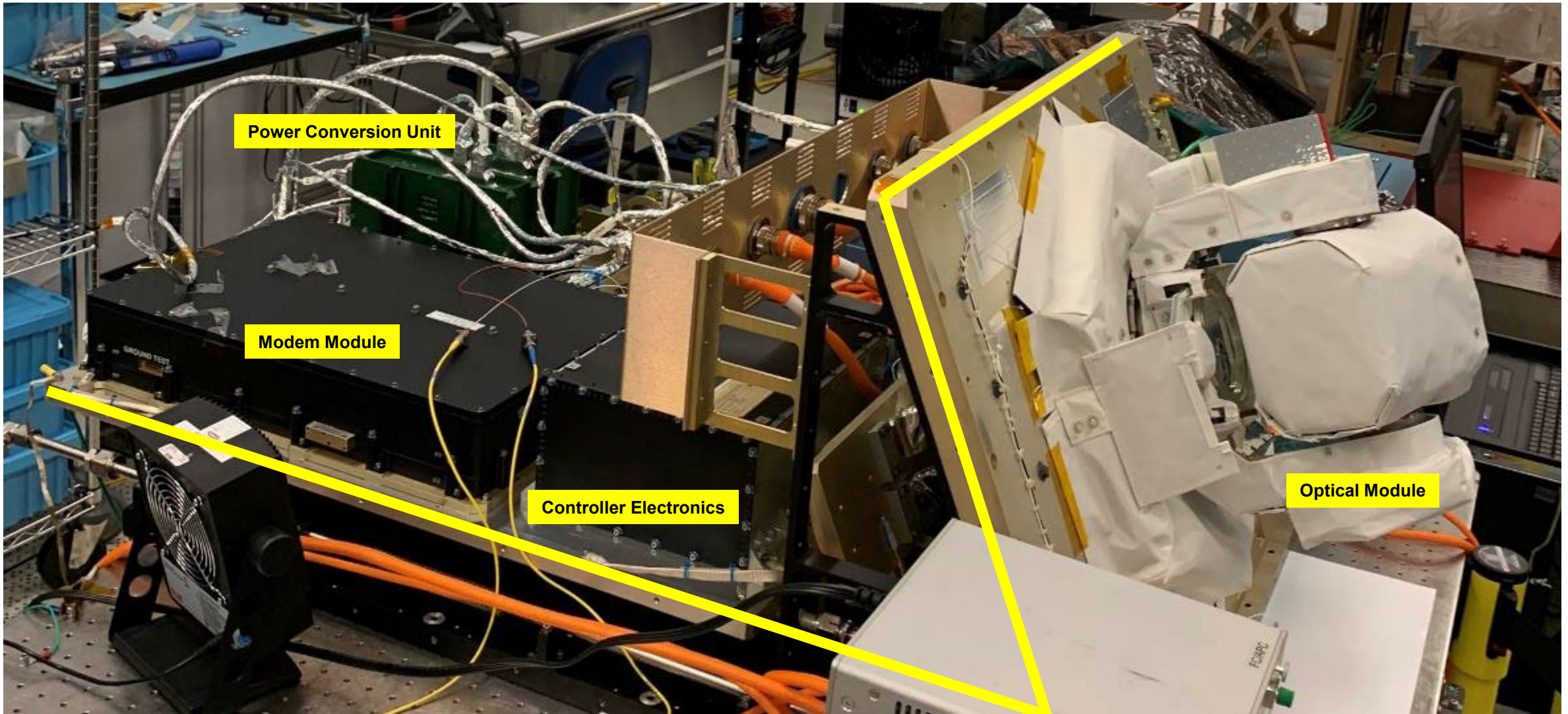
Power Converter Unit (PCU)



Goddard

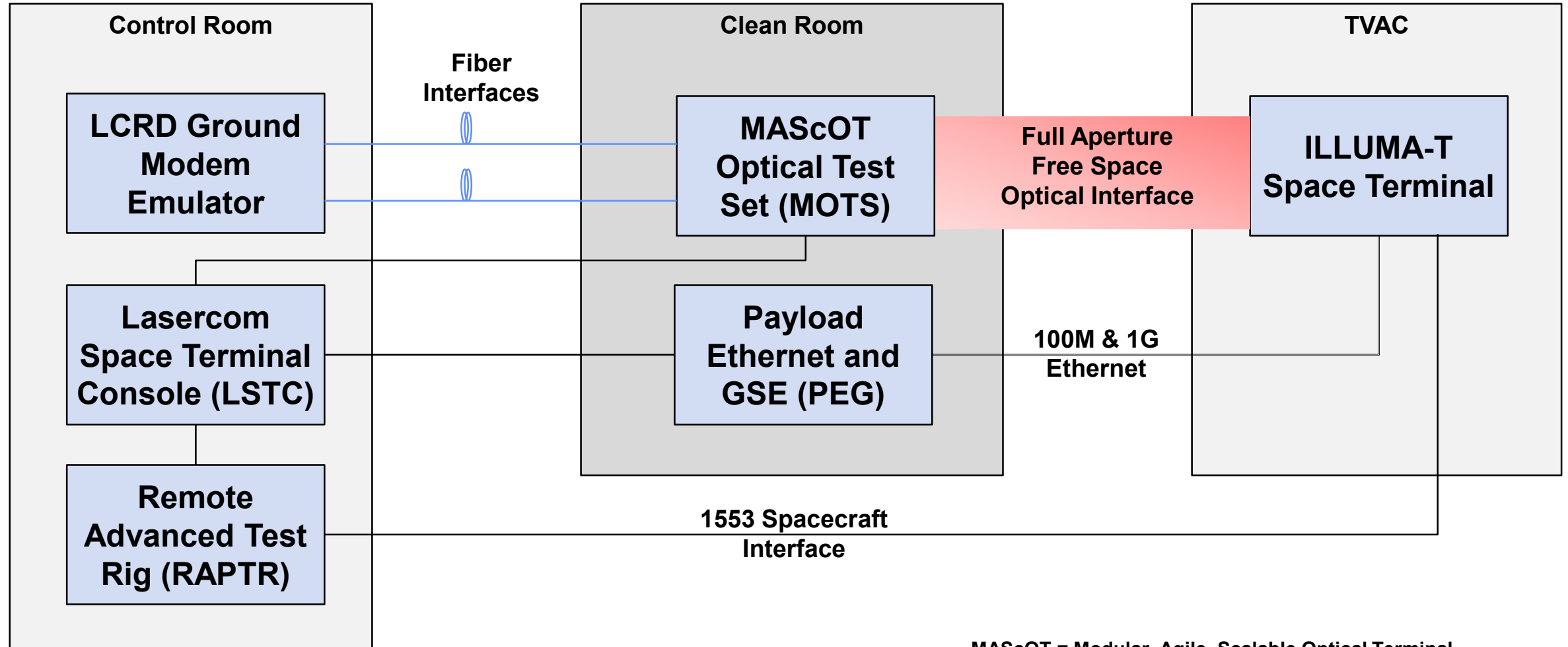


# Assembled ILLUMA-T Payload Sled Assembly





# Test Setup Block Diagram



MAScOT = Modular, Agile, Scalable Optical Terminal

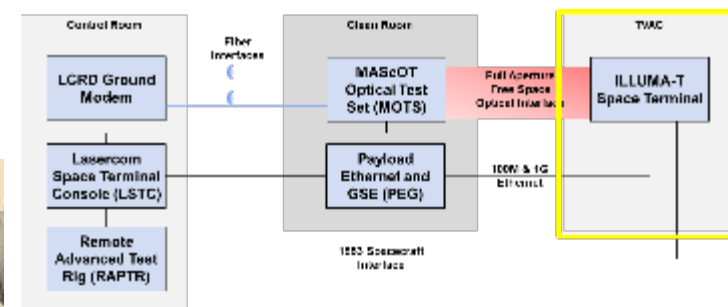
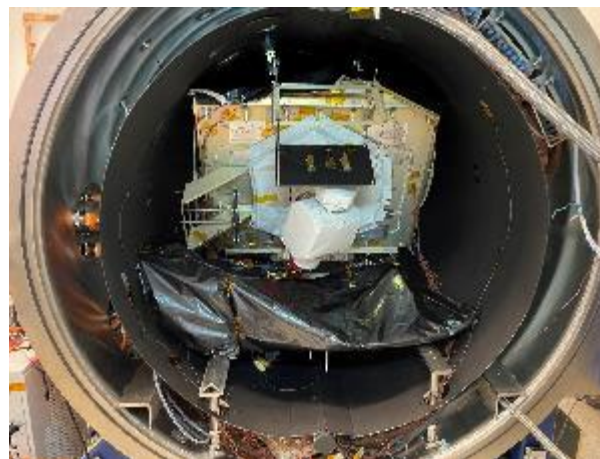
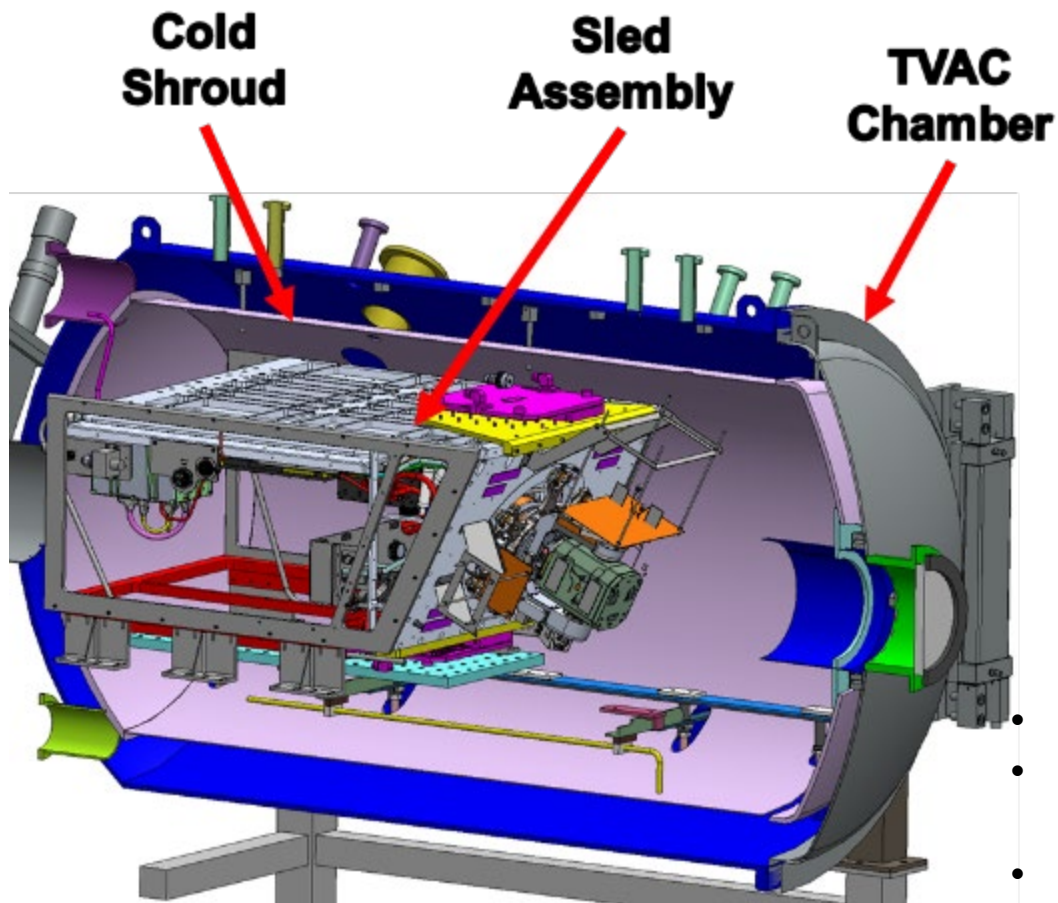
LCRD = Laser Communications Relay Demonstration

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





# Test Setup Block Diagram: ILLUMA-T Payload in TVAC

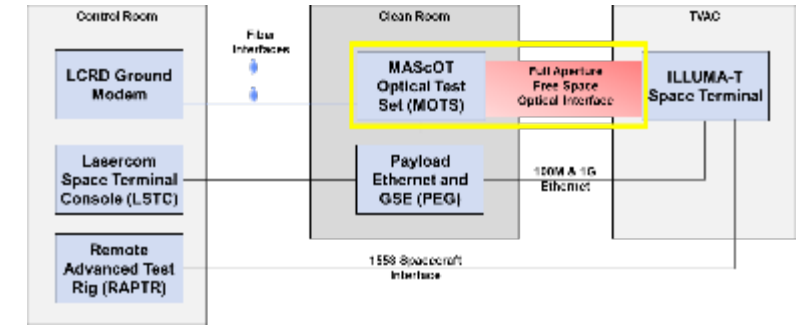
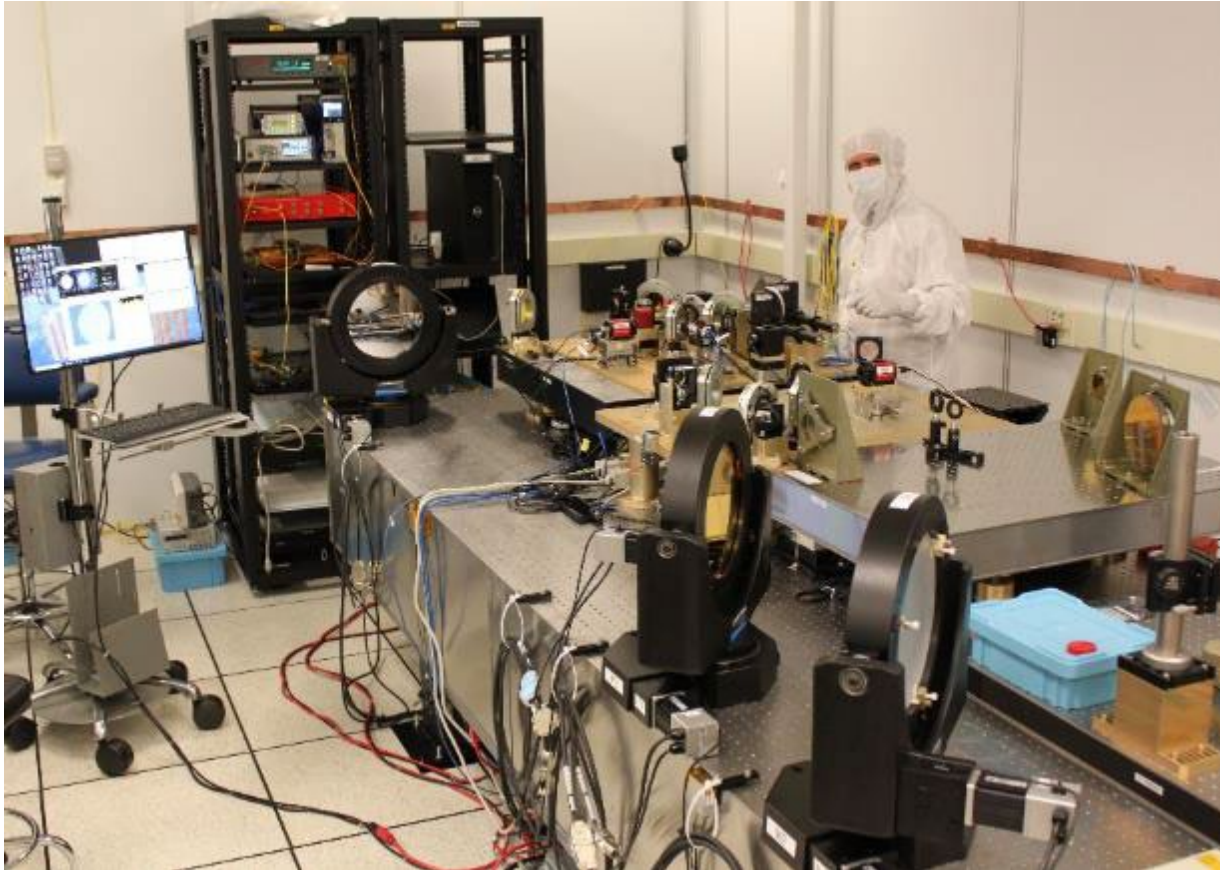


- Payload sled assembly is inside thermal vacuum chamber
- TVAC chamber is pumped down to  $< 1.E-5$  Torr and monitored continuously
- Cold wall shroud and IR heater plates regulate the temperature
- Thermocouples are located throughout the hardware





# Test Setup Block Diagram: MOTS



MAScOT = Modular, Agile, Scalable Optical Terminal

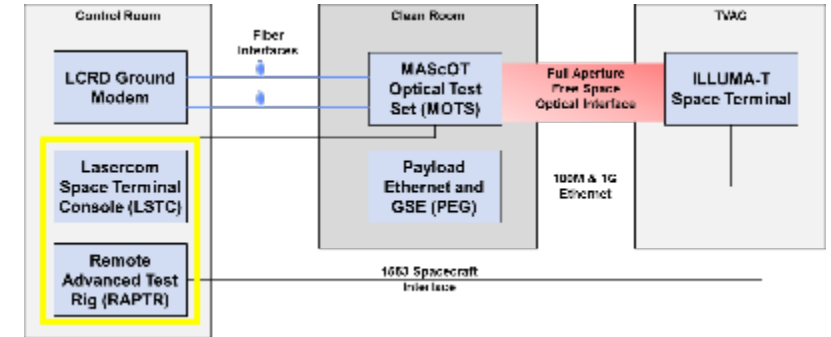
- Provides bi-directional flat-top beams to/from the space terminal's Optical Module (OM)
- Measures boresight and pointing performance using high-speed camera
- Emulates spacecraft jitter using a fast steering mirror
- Contains additional sensors to measure wave front quality and beam profile



# Test Setup Block Diagram: LSTC and RAPTR



- **Remote Advanced Test Rig (RAPTR)** emulates the ISS by providing
  - RS-1553 space craft cmd/tlm interface
  - Broadcast Ancillary Data (BAD)
- **Uses a support interface TREK (not shown)**
- **RAPTR & TREK provided by NASA MSFC**



- **Lasercom Space Terminal Console (LSTC)** provides command and control and telemetry interface for space payload
- **LSTC will be used in the Ops Center during mission**

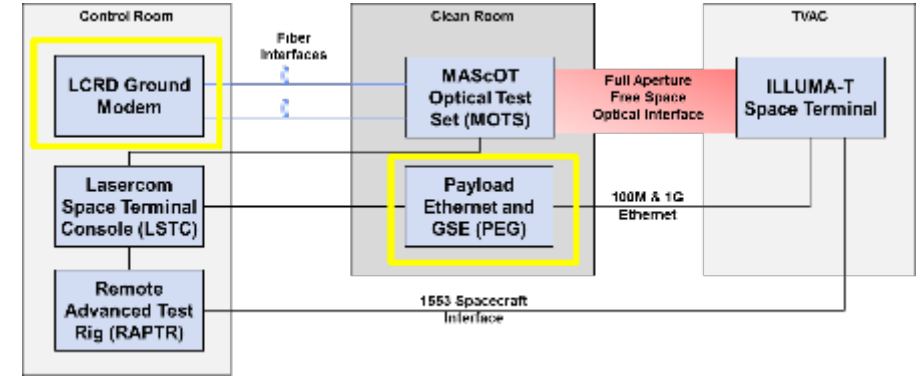




# Test Setup Block Diagram: LCRD Ground Modem & PEG



LCRD Ground Modem Emulator and PEG are provided by NASA GSFC



LCRD = Laser Communications Relay Demonstration

- LCRD ground modem:
  - Transmitter provides forward link signal to ILLUMA-T payload
  - Receiver intakes return link signal from ILLUMA-T payload

- Power Ethernet Ground support equipment (PEG):
  - Provides an ISS-like interface to the payload
  - Ethernet interfaces are 100MbE and 1GbE
  - PEG supplies power to the heaters and the payload



Sled with PEG Rack



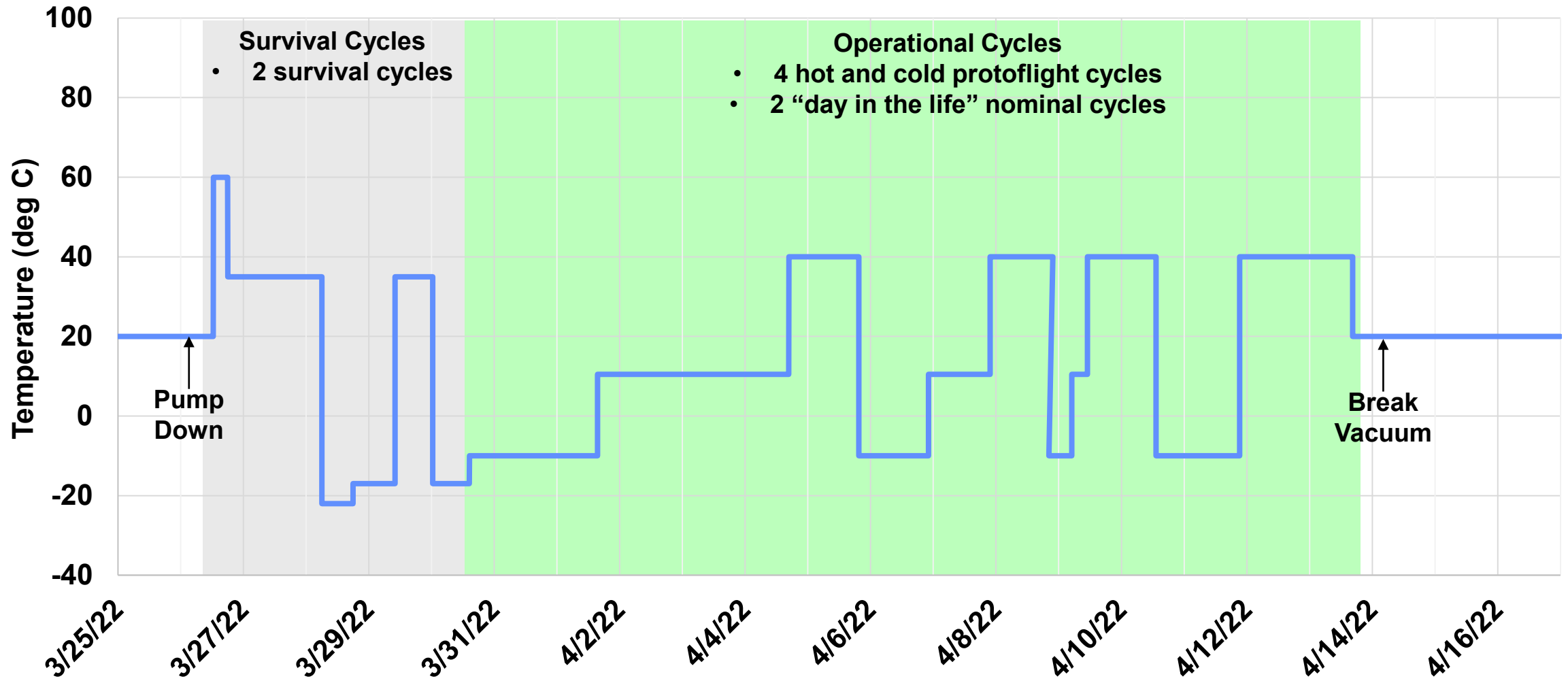
LCRD Ground Modem

Source:NASA

Source:NASA



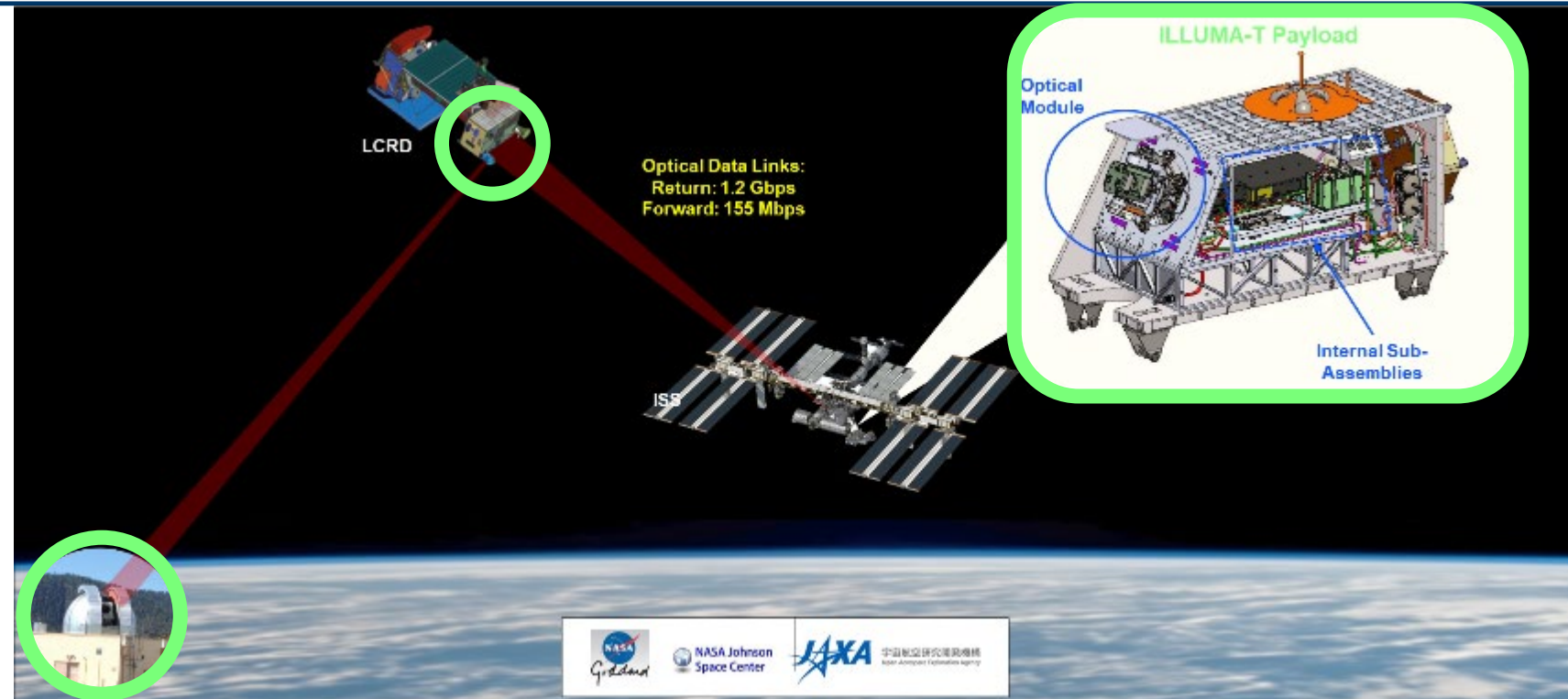
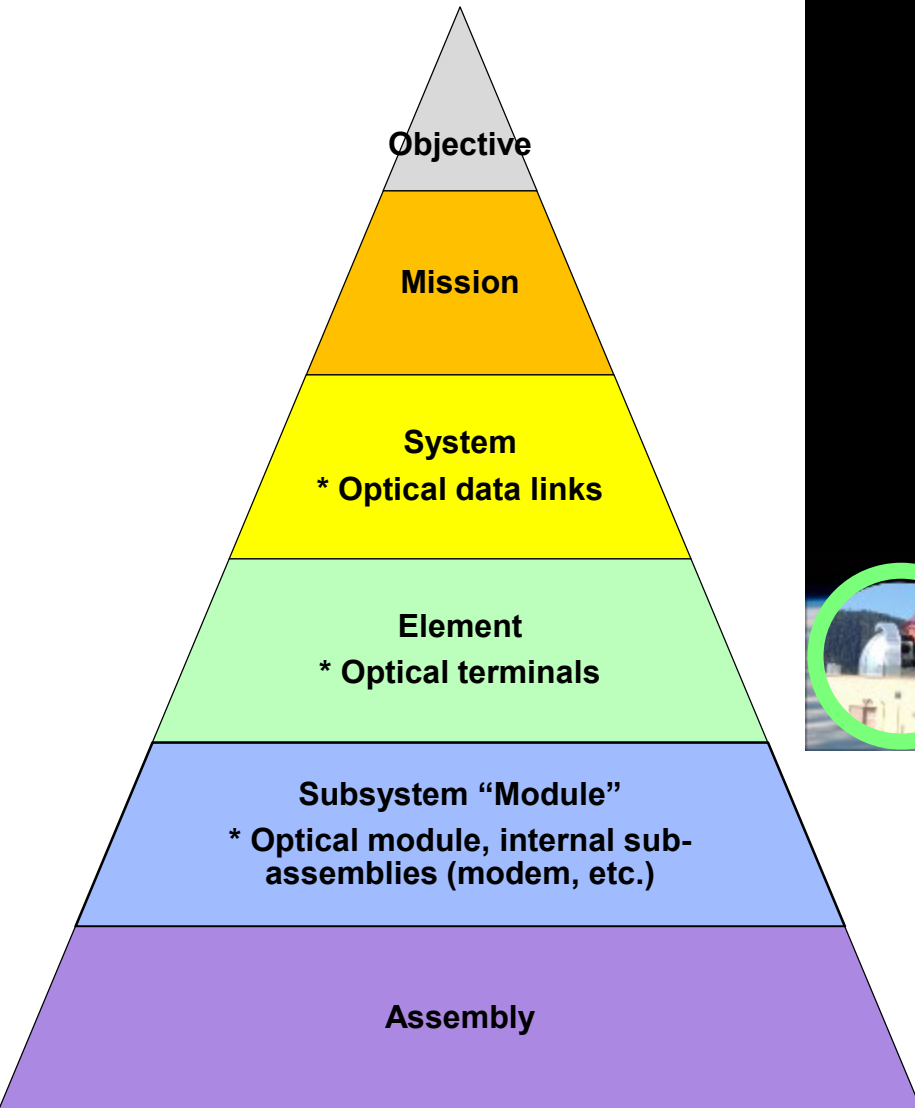
# TVAC Testing Profile







# System Testing and Hierarchy



**System Testing includes characterizing inter-element performance:**

- Optical (e.g. error rate)
- Point, Acq, Track (PAT)
- Plus others... called out in requirements



# System Level TVAC Testing Cases



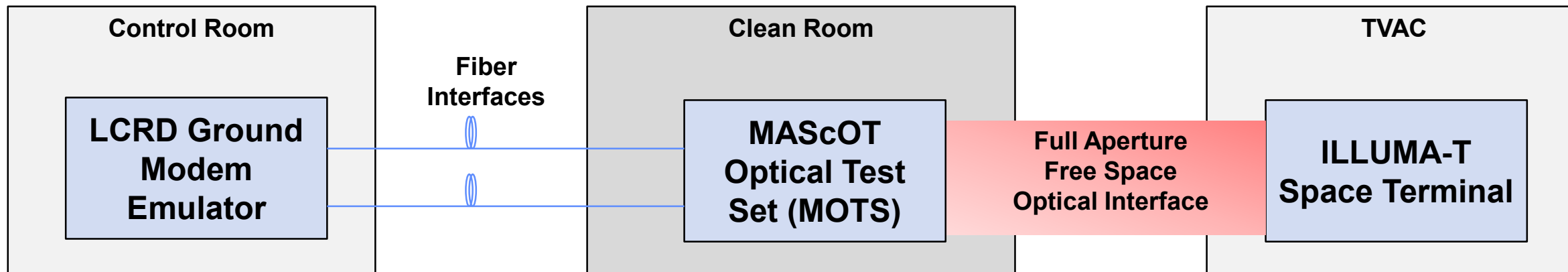
		Return Link Data Rates			
		155 Mbps	311 Mbps	622 Mbps	1244 Mbps
Forward Link Data Rates	51 Mbps	CPT	CPT	Mission Req't CPT, LPT	n/a
	155 Mbps	n/a	n/a	n/a	Mission Req't CPT, LPT

- Mission level required cases
- Cases that are not applicable
- System level Comprehensive Performance Test (CPT)
- System level Limited Performance Test (LPT)





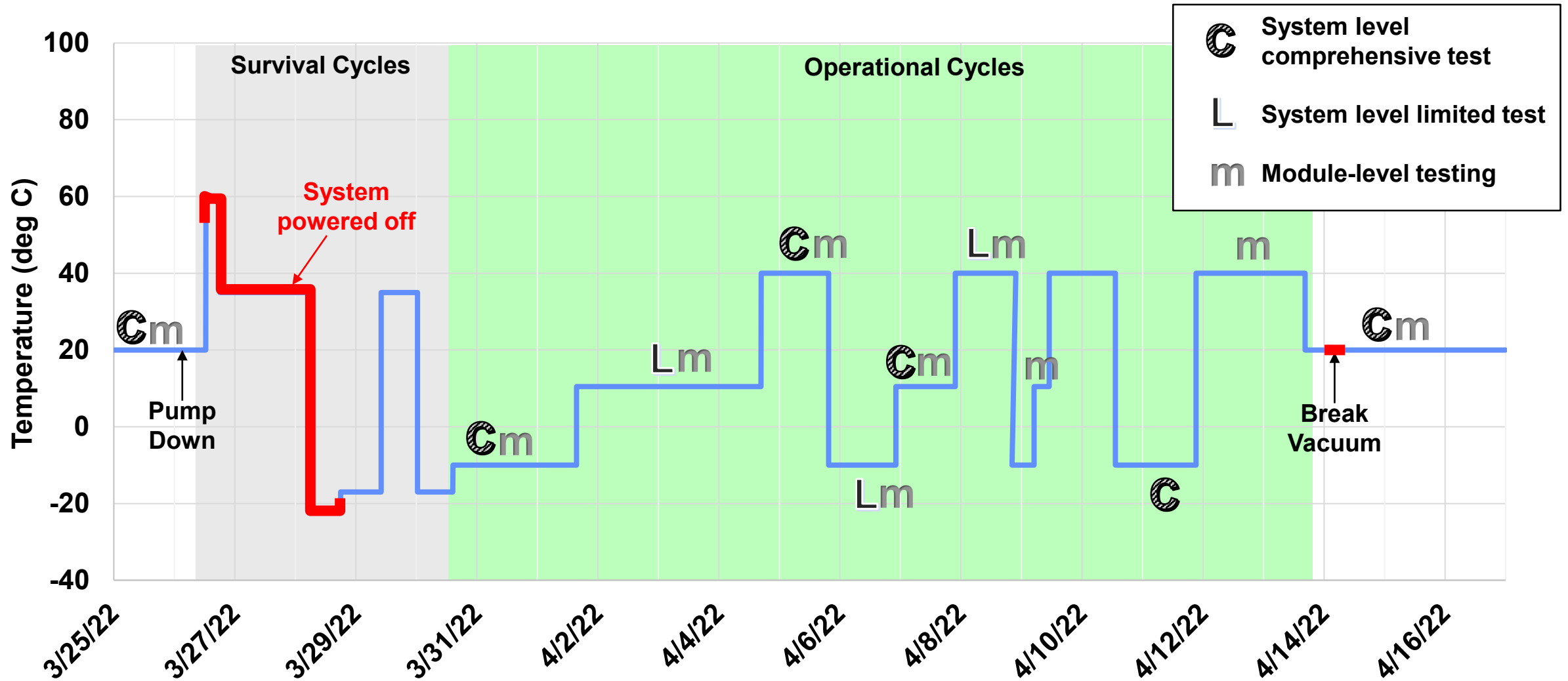
# System Level TVAC Comm Performance Testing



- Comm performance testing is under the following conditions using free space beams to / from the space payload / LCRD ground modem emulator
- The following parameters can be varied
  - Emulated spacecraft jitter
  - Optical module's azimuth and elevation
  - Transmit powers for beacon / comm
  - Beacon modulation frequency
  - Forward and return link data rates (combinations)
  - Ethernet rate
- This ends up being MANY MANY cases!
- Comprehensive performance tests covered most of these cases
- Limited performance tests selected a handful of cases and looked for changes in performance

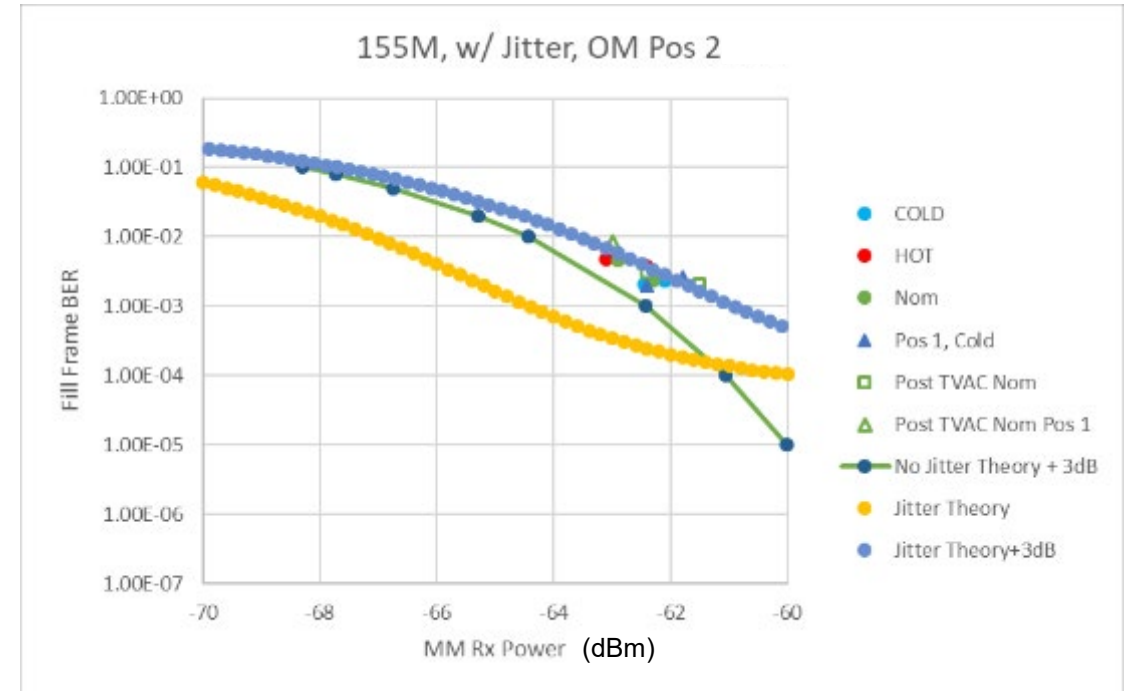
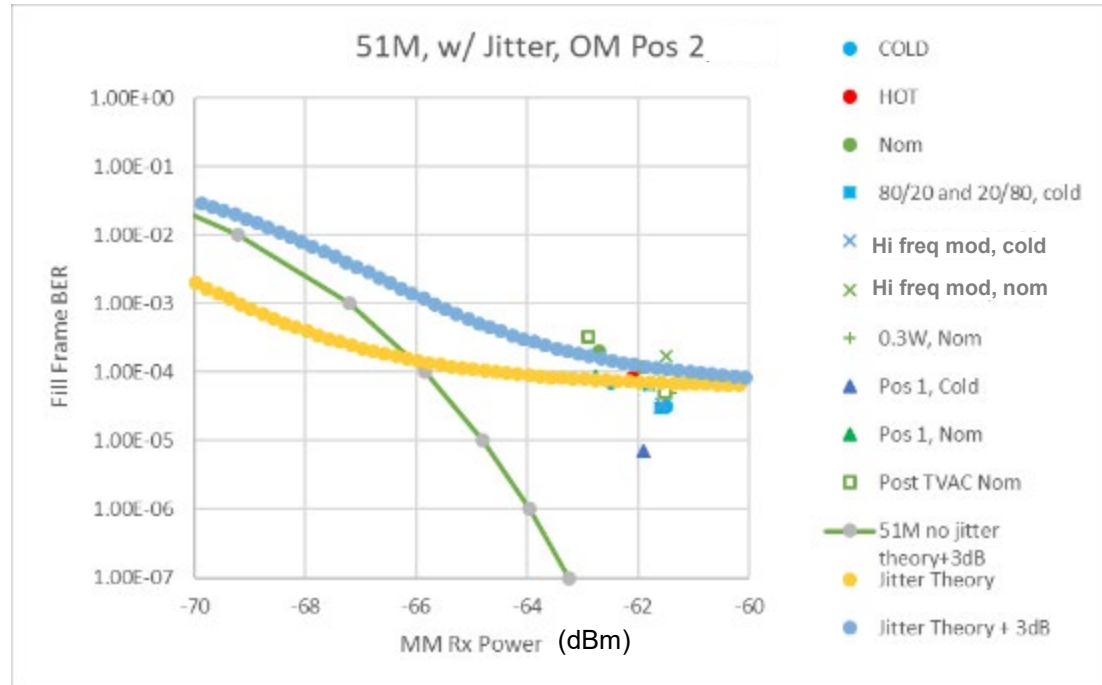


# As-Run TVAC Testing Profile with Tests





# Forward Link Results Example

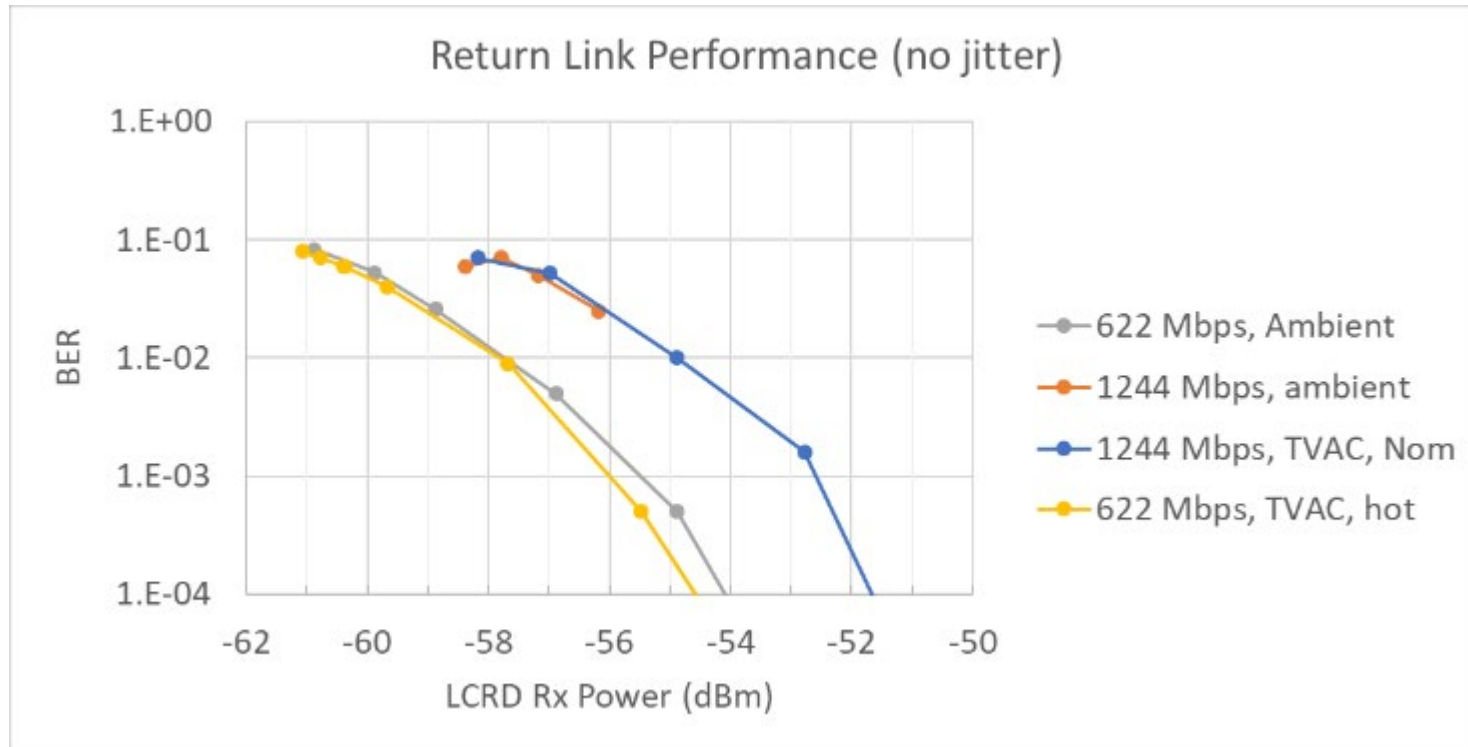


- **Fill frame BER vs. received power shows no apparent dependence on temperature, beacon:comm ratio, beacon modulation frequency, transmit power, and optical module pointing position (elevation)**
- **-70 dBm required power for link at 51 Mbps** ✓
- **-65 dBm required power for link at 155 Mbps** ✓





# Return Link Results Example



- For return link, we test the stability of the payload transmitter only as requirement for payload is to minimize impairment to signal over TVAC and payload configurations
- Results shown for 622 Mbps and 1244 Mbps for hot and nominal as compared to ambient ✓



# Summary



- **System level TVAC testing of the ILLUMA-T Space Terminal has been completed**
- **Communications performance satisfies requirements and is stable over temperature and over various payload settings**
- **ILLUMA-T payload has been shipped to NASA GSFC for further testing and will be manifested on SpaceX Dragon for installation on ISS in 2023**