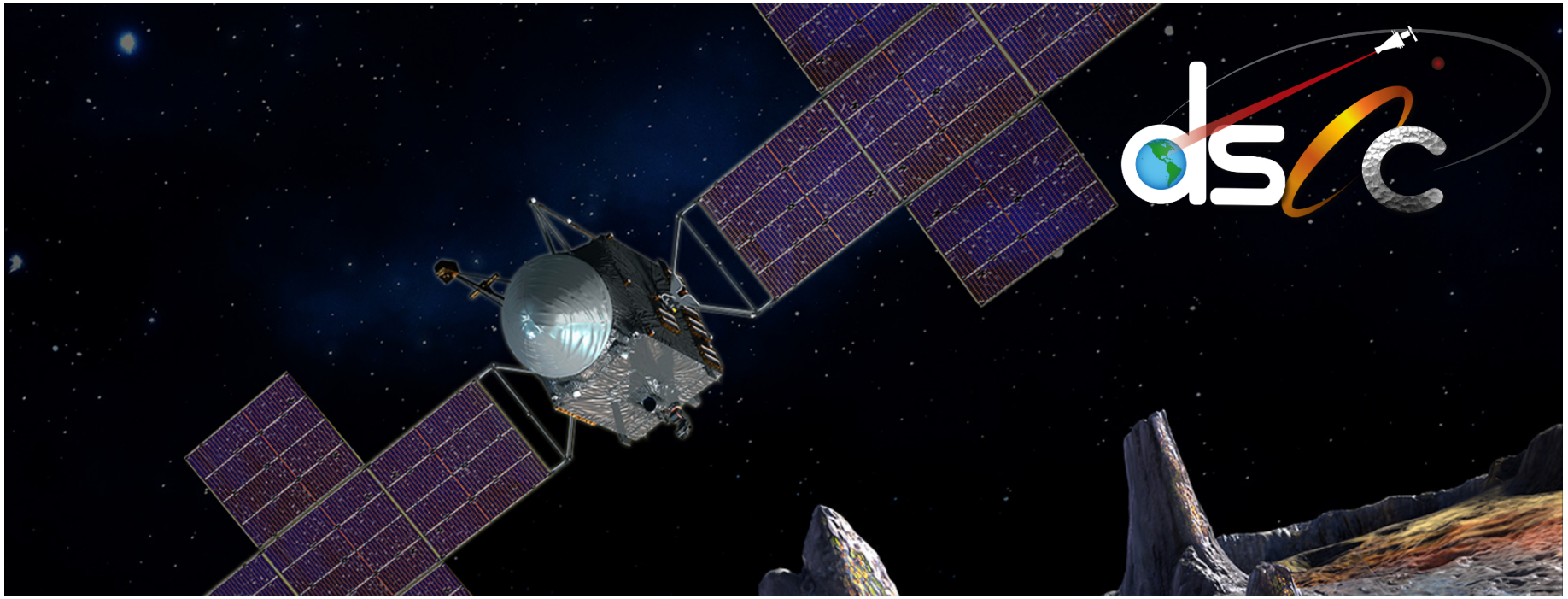


Deep Space Optical Communications (DSOC) Status

Steve Townes
Chief Technologist
Interplanetary Network Directorate
NASA-JPL/Caltech

Abhijit Biswas
DSOC Project Technologist
Supervisor, Optical Communications Systems Group
NASA-JPL/Caltech

CCSDS Spring Meeting 2019

JPL

L3

MIT Lincoln Laboratory

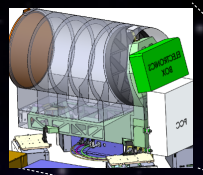
NASA

Controlled Dynamics Inc.
Precision Navigation & Targeting Systems

LGS INNOVATIONS

Deep-Space Optical Communications (DSOC)

Flight Laser Transceiver (FLT)
22 cm
4 W avg.



- ***OBJECTIVES***

Advance NASA's enhanced communication goals by:

- *Demonstrating optical communications from deep space (0.1 – 2.6 AU) to validate:*
  - ***Link acquisition, laser pointing control***
  - ***High photon efficiency signaling***

1550 nm downlink

1064 nm uplink beacon 1.6 kb/s

Ground Laser Transmitter (GLT)
Table Mtn., CA
5 kW avg. power

Ground Laser Receiver (GLR)
Palomar Mtn., CA
5m. dia. photo-counting rcvr

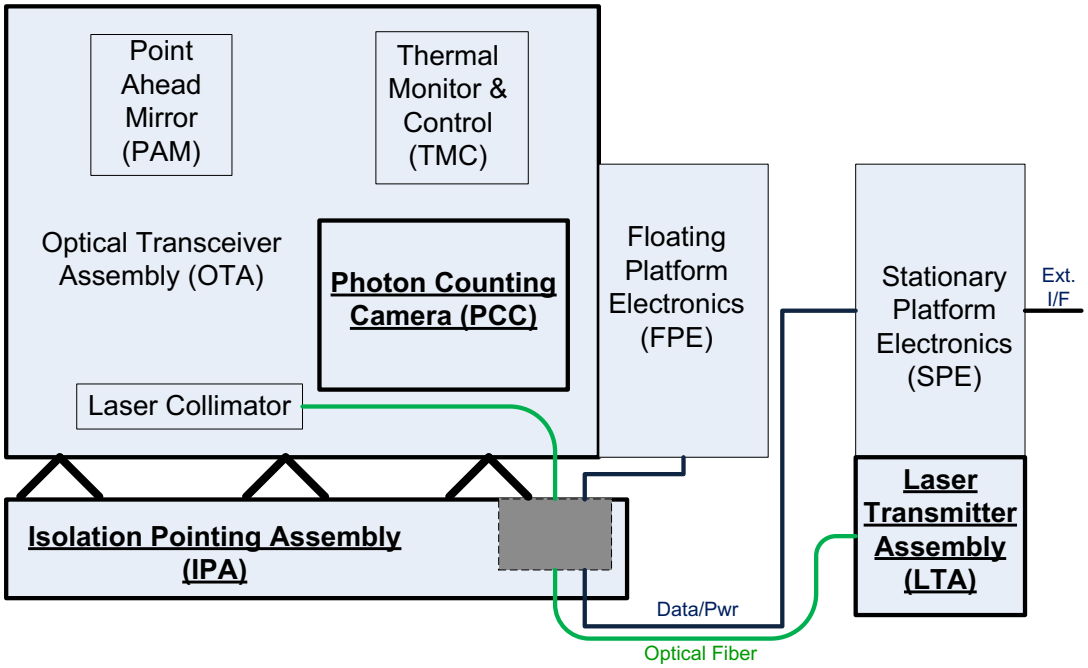
Psyche Ops Center

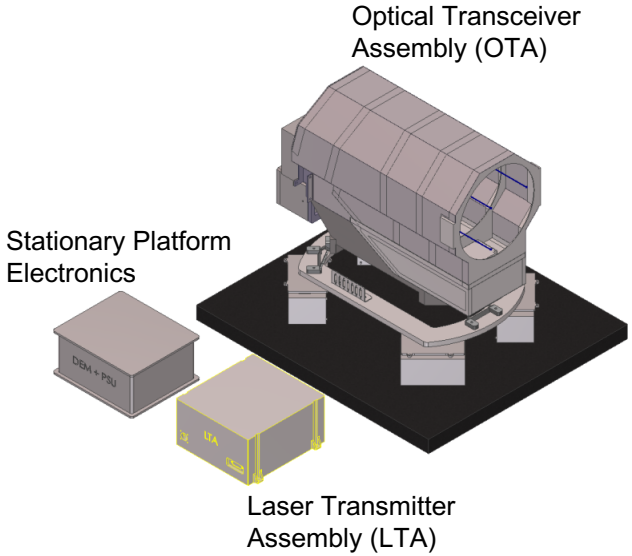
DSOC MOS

DSOC Flight Laser Transceiver (FLT)

FLT Block Diagram

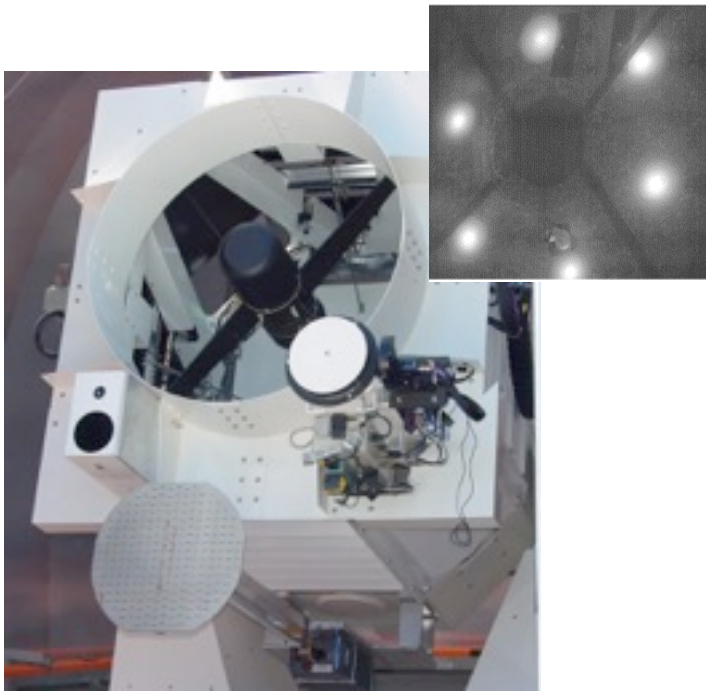
- Simplified block diagram showing functional assemblies of the FLT





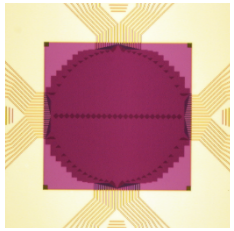
Note: launch locks, motion cage and docking mechanism not shown

DSOC Ground Network

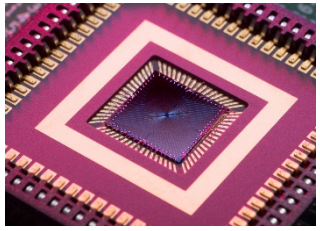


Ground Laser Transmitter (GLT)
Optical Communication Telescope Laboratory (OCTL) - JPL managed facility – Table Mountain, California

- 1m aperture (multi-beaming sub aperture)
- 5 kW uplink lasers at 1064 nm



Optical microscope image
JPL fabricated array.

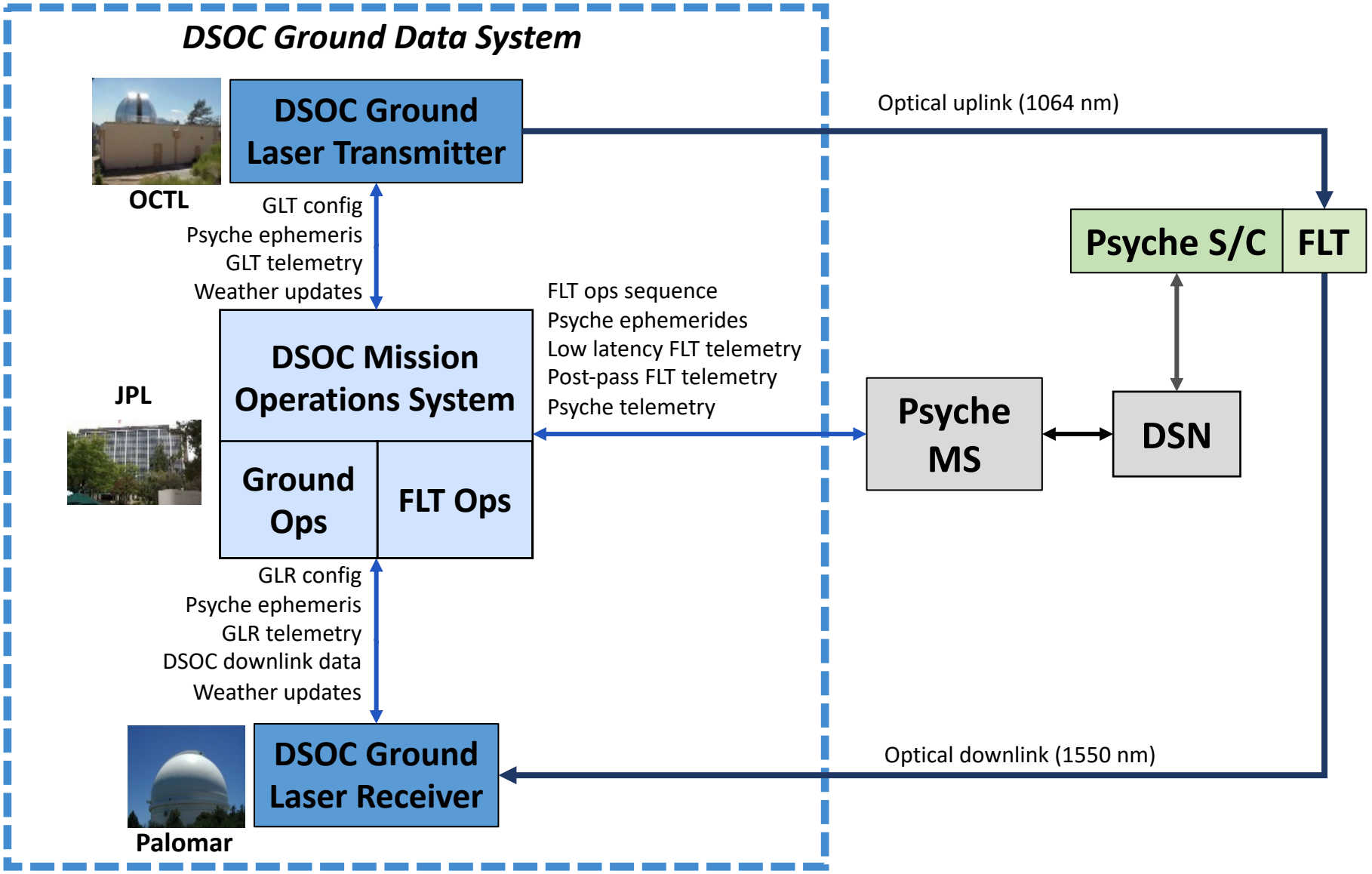


Packaged SNSPD Array

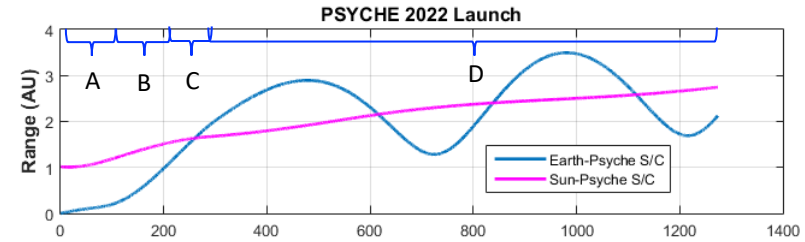
Ground Laser Receiver (GLR)
Palomar Mountain, California – in coordination with Caltech Optical Observatories

- Photon-counting ground detectors
- >50% Eff. WSi nanowire arrays
- Real time Time-to-Digital converter for PPM demodulation

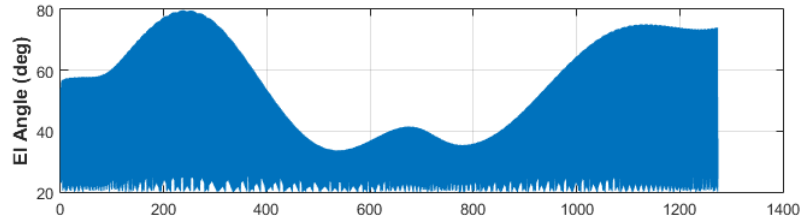
High Level Block Diagram of DSOC Ground System



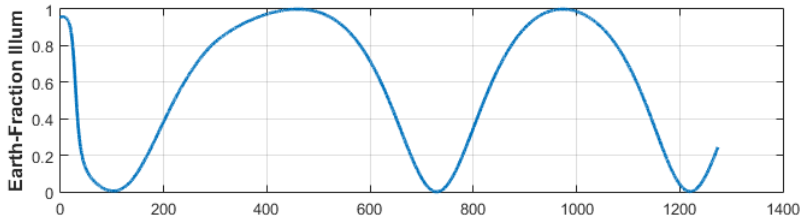
Psyche Trajectory Summary



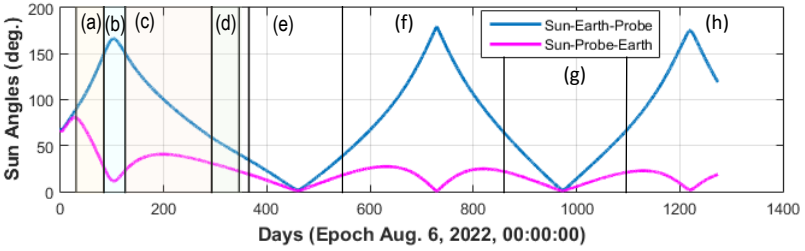
A - ICO
[20220806 – 20221105]
B – Cruise 1
[20221106 – 20230315]
C - MGA
[20230215 – 20230525]
D – Cruise 2
[20230525 – 20260131]

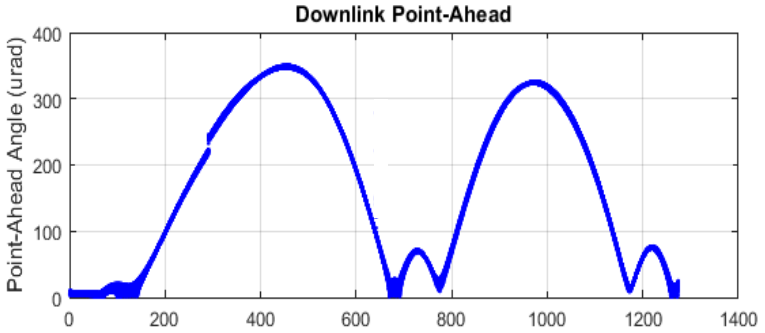


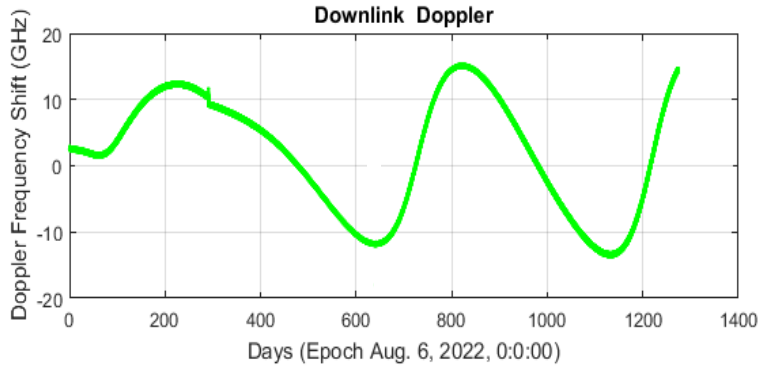
20-deg. elevation Cutoff



Fract. Illum. Earth affects additive noise with beacon





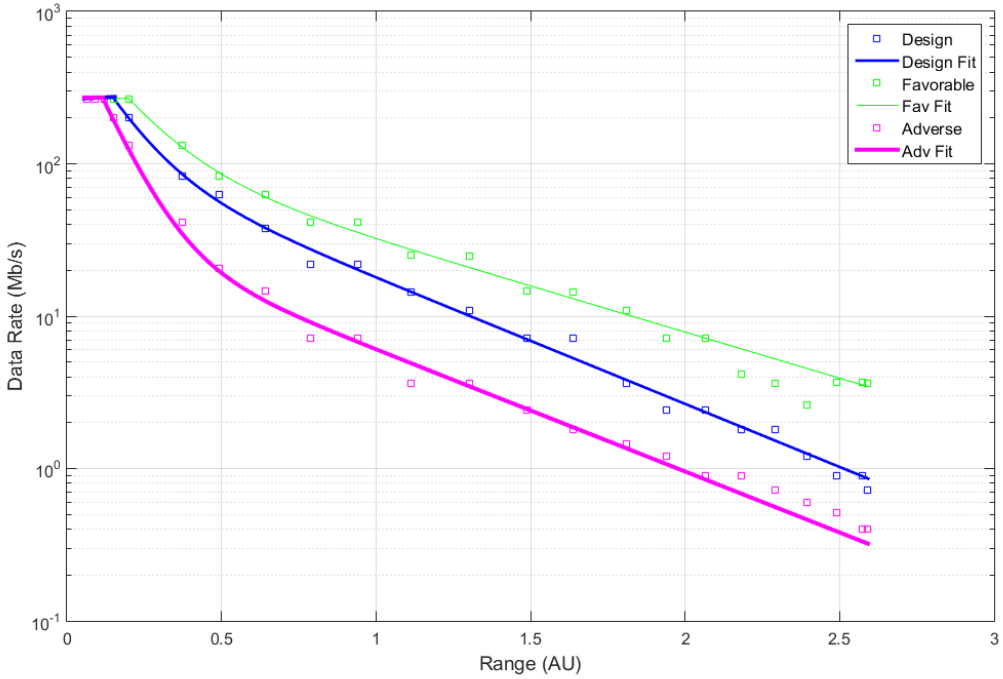


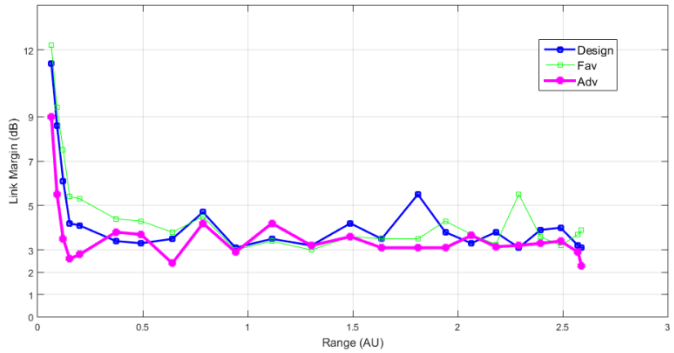
(a) Rise after sunset sets after sunrise
[20220906 - 20231115]
(b) Rise and set at night
[20221115 - 20221125]
(c) Rise before sunset set before sunrise
[20221125 – 20230615]
(d) < 2 hour of night contact
[20230615 – 20230726]
(e) All day contacts *[Uplink only]*

DSOC Predicted Downlink Performance

DSOC Predicted Performance

- **Summary of initial downlink analysis**
  - Assumes 4 W average laser power @ 1550 nm transmitted through 22 cm aperture transceiver
  - Received by 5 m diameter ground aperture and detected using photon-counting detector assembly
  - Pulse position modulation (M-ary PPM) orders with M=16, 32, 64, 128 with discrete slot-widths of [0.5, 1,2,4, 8] ns
  - Discrete code rates of 0.33, 0.5 and 0.6667
  - Inter-symbol guard times (ISGT) used to assist temporal synchronization
  - Results show represent fits to data obtained after initial analysis
  - Atmospheric model derived transmission, sky radiance and "seeing" (*models have been authenticated with site statistics gathered at Table Mtn., CA and Goldstone, CA*)





DSOC Development Status

Flight Development

Laser Transmitter Assembly (LTA developed by LGS Inc.)

- Engineering model assembled under performance and environmental test, delivered to JPL in mid-June 2019

Optical Transceiver Assembly (OTA, SiC primary, secondary and metering, Aluminum bench, developed by L3-SSG)

- In critical design phase, hardware development of SiC optics started, delivery to JPL in June 2020

Photon Counting Camera (PCC, developed by MIT-Lincoln Laboratory)

- Critical Design Review scheduled on May 7, 2019; Engineering model delivery to JPL in Fall'2019 with Flight Model delivery 2020; compatibility testing of camera readout with prototype JPL flight electronics completed in April 2019

Isolation Pointing Assembly Struts (IPA-S, developed by Control Dynamics Inc.)

- Engineering models initiating testing; delivery to JPL in June 2019, Flight model manufacturing review completed, delivery to JPL early 2020

Flight electronics (developed at JPL, some legacy from Universal Space Transponder)

- Engineering models of general processor and digital board in summer of 2019 with FM in June 2020; Floating Electronics Module (FEM) prototype boards developed and in test; EM Jan 2020 and FM in May 2020

Ground Development

Ground Signal Processing Receiver (GSPA, developed at JPL with procured Time to Digital Converter, TDC)

- TDC procured, FPGA programming underway, completion by April 2020

Ground Uplink Laser Assembly

- Prototype demonstrated in Dec. 2018, Uplink data formatter development complete; Laser delivery start in Feb. 2020

Flight-Ground Compatibility Testing

- Planned for August 2020

DSOC Testbed Activity Summary

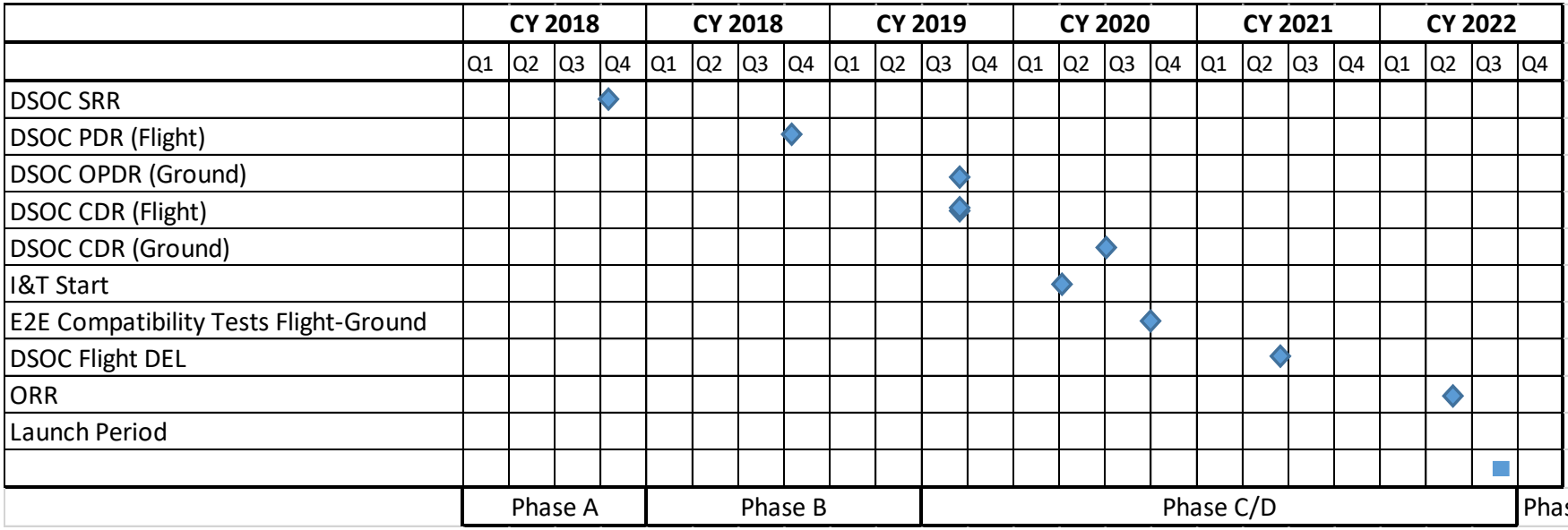
• DSOC maintains two testbeds

- An acquisition tracking testbed used to verify acquisition, tracking and pointing performance
  - Constrained by laboratory noise, gravity (*even though gravity off-load is used, it's difficult to emulate microgravity in the lab)*
  - In the presence of laboratory constraints initial tests with prototype hardware indicate that pointing requirements can be met
  - Plan to repeat with flight hardware

- End-to-end signaling testbed
  - Pulse-position modulated, encoded and interleaved data representative of the CCSDS HPE signaling scheme is received by the photon-counting receiver
  - Currently the detector output is time-stamped with a time-to-digital converter and stored to disc
  - The stored time stamps are processed with software to evaluate synchronization, demodulation, de-interleaving and decoding
  - Favorable comparisons with predicted link budget have been achieve – this work is ongoing

Status of Development

Key Milestones for DSOC Project



Summary

- DSOC development toward meeting the Psyche Mission launch schedule continues
- The Psyche Mission provides an excellent opportunity for demonstration deep space optical communications
- Daytime downlink is currently not baselined due to non-availability of assets with adequate aperture diameter
- JPL's RF-Optical Hybrid Receive Terminal may become available late in the demo, flight hardware health and status permitting over the cruise phase of the Psyche mission