National Aeronautics and Space Administration

ISS Pointing Approaches and Best Practices

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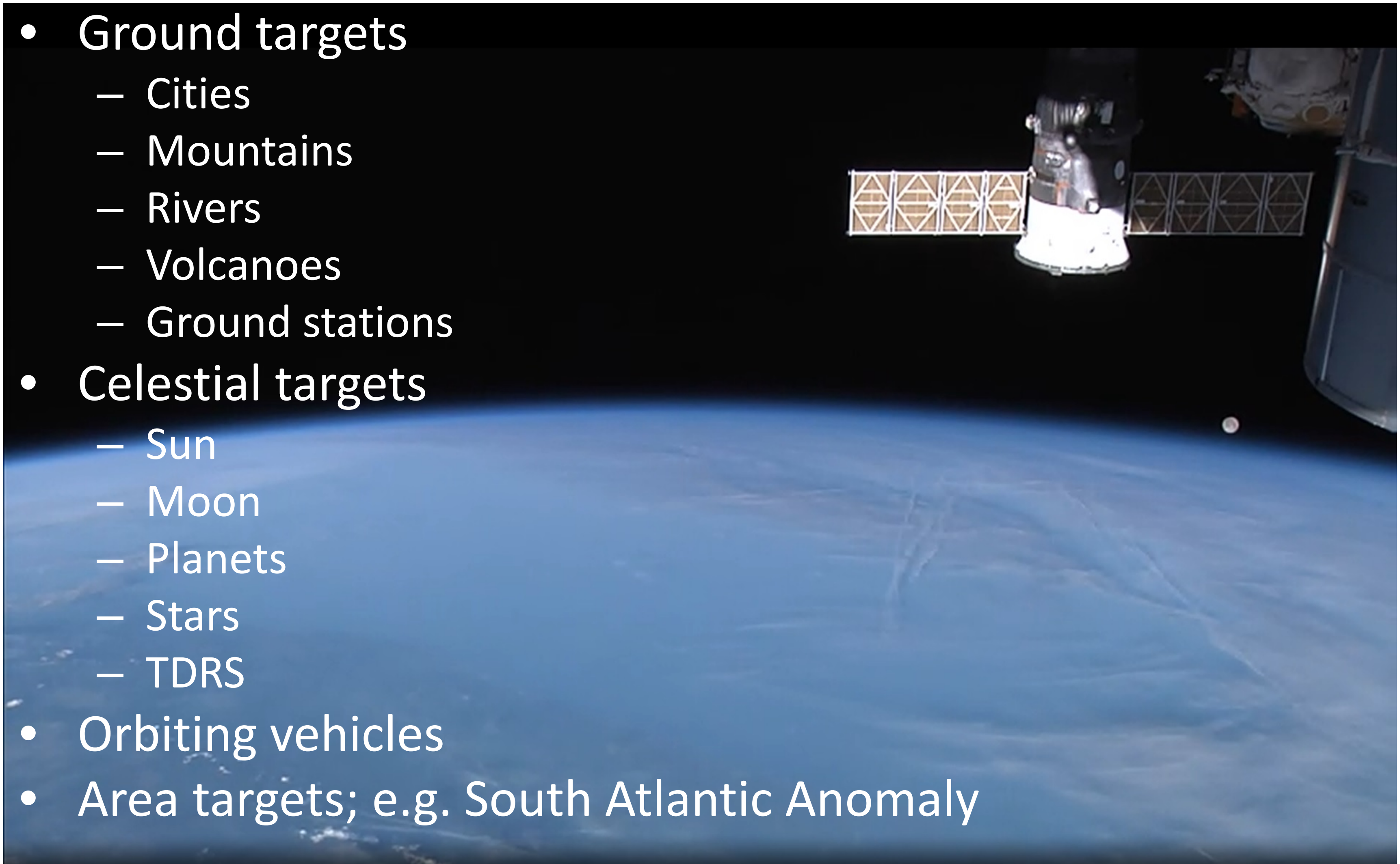
Agenda

- Possible Targets
- Line of Sight Prediction Effects
  - Trajectory
  - Attitude
  - Time
- Best Practices
  - OPALS
  - HICO
  - ISSAC
- Summary

What Can Be Seen From the ISS?



- Ground targets
  - Cities
  - Mountains
  - Rivers
  - Volcanoes
  - Ground stations
- Celestial targets
  - Sun
  - Moon
  - Planets
  - Stars
  - TDRS
- Orbiting vehicles
- Area targets; e.g. South Atlantic Anomaly

What Affects an Observation?

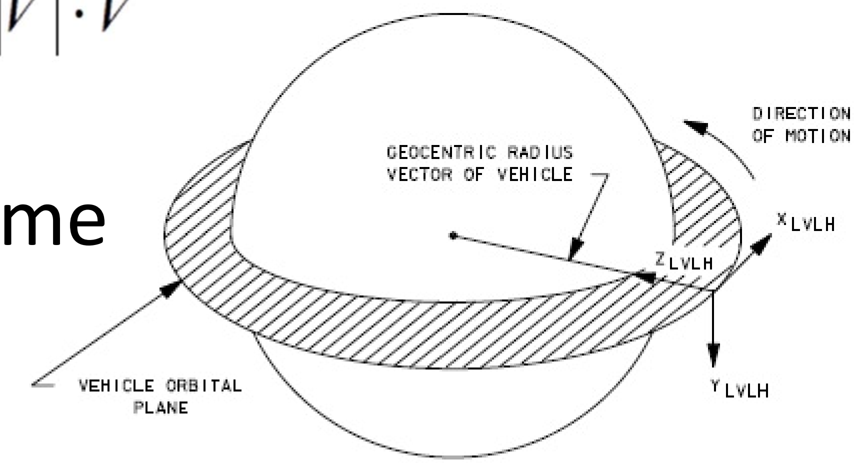
- Line of Sight Predictions
  - Trajectory
  - Attitude
  - Time

Trajectory

- ISS orbit determination performed by processing Global Positioning System (GPS) telemetry
- Atmospheric Drag

$$a_d = -\frac{1}{2}\frac{C_d \cdot A_f}{M} \cdot \rho \cdot \left|V\right| \cdot \overline{V}$$

- LVLH Reference Frame

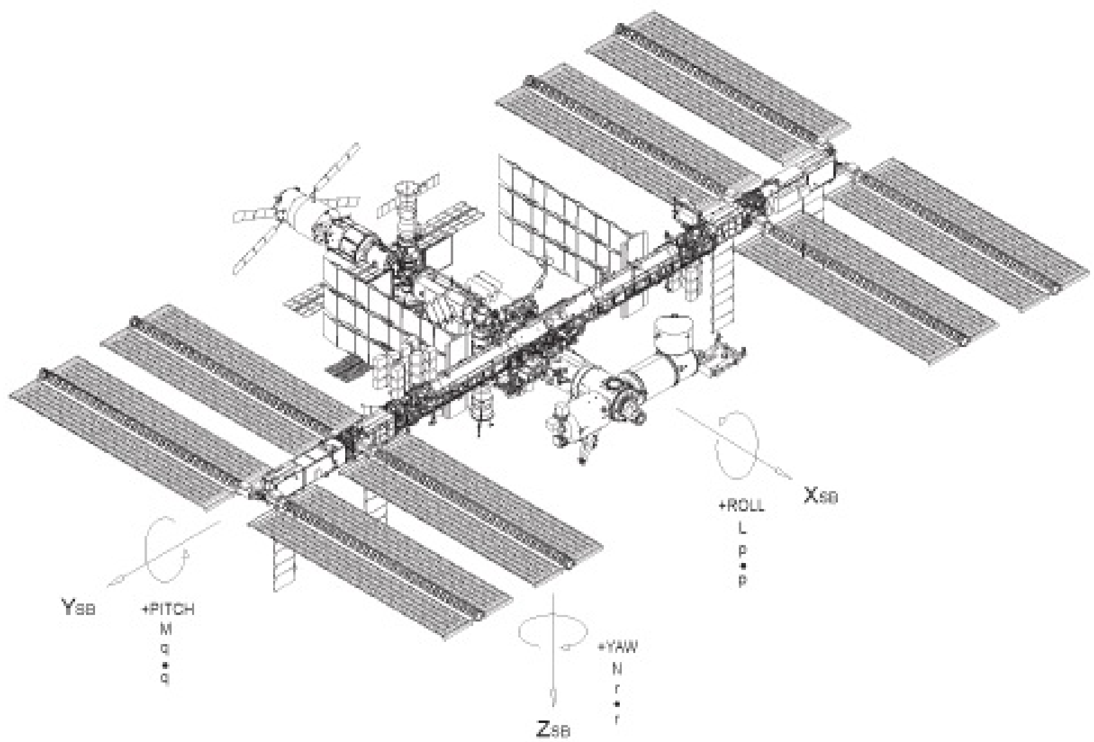


Trajectory

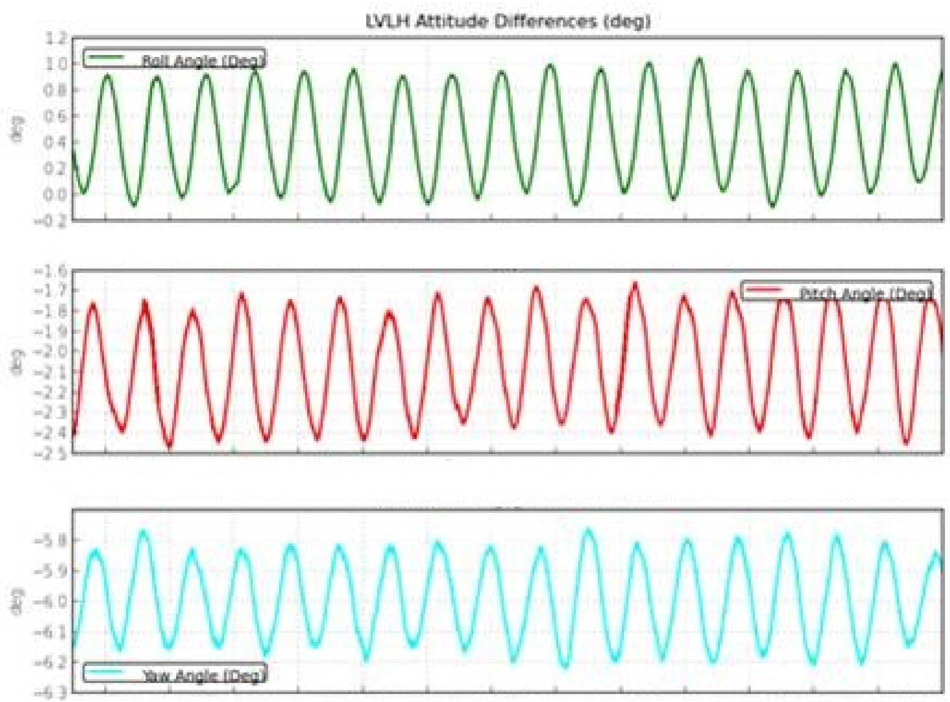
- Downtrack position error grows at largest rate
  - Atmospheric drag uncertainties
    - ISS cross sectional area estimate
    - Atmospheric density estimate
      - Solar Flux
      - Geomagnetic Activity
    - Mass estimate
  - Propagation of a week is off an average of 10 – 30 seconds
    - Trajectory event replanning
    - ISS Debris Avoidance Maneuvers
- Prediction availability (Trajectory Operations Officer)
  - Long term data updated weekly
  - Near term data updated every other day

Attitude

- ISS holds attitude by using CMGs to minimize attitude motion in Yaw, Pitch, and Roll

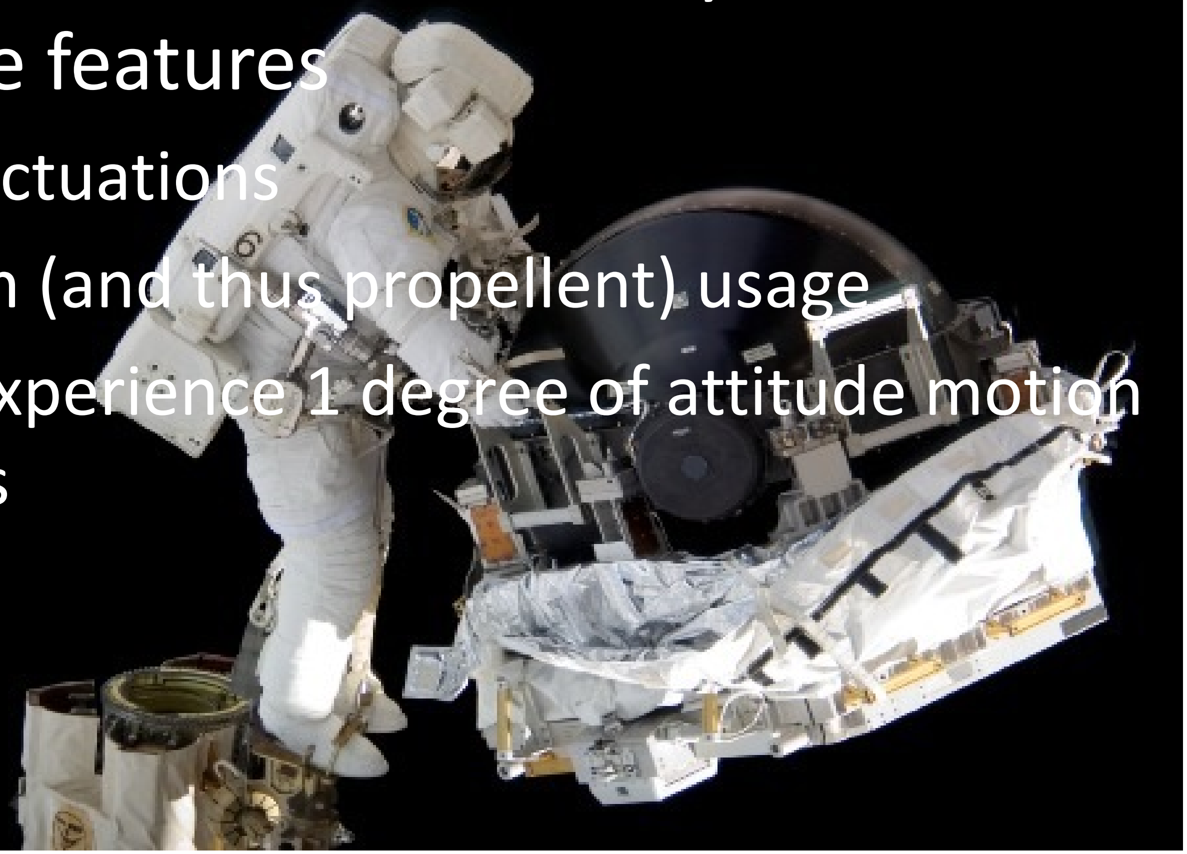


- Fluctuations about each axis occur based on the momentum management controller loaded



Attitude

- Each of seven +XVV MM controllers are designed to have different steady-state performance features
  - attitude fluctuations
  - momentum (and thus propellent) usage
  - generally experience 1 degree of attitude motion in each axis



Attitude

- Prediction Availability (Attitude Determination and Coordination Officer)
  - Attitude Timeline
  - Future maneuvers for next month
- Additional attitude variation to consider is thermal structural flexure
  - Have no info on this

Time

- A significant factor in line of sight predictions for high resolution instruments is knowledge of exact time.
- The ISS is moving at 7 kilometers per second, so depending on your resolution, being off by half a second may mean completely missing a small target

Time

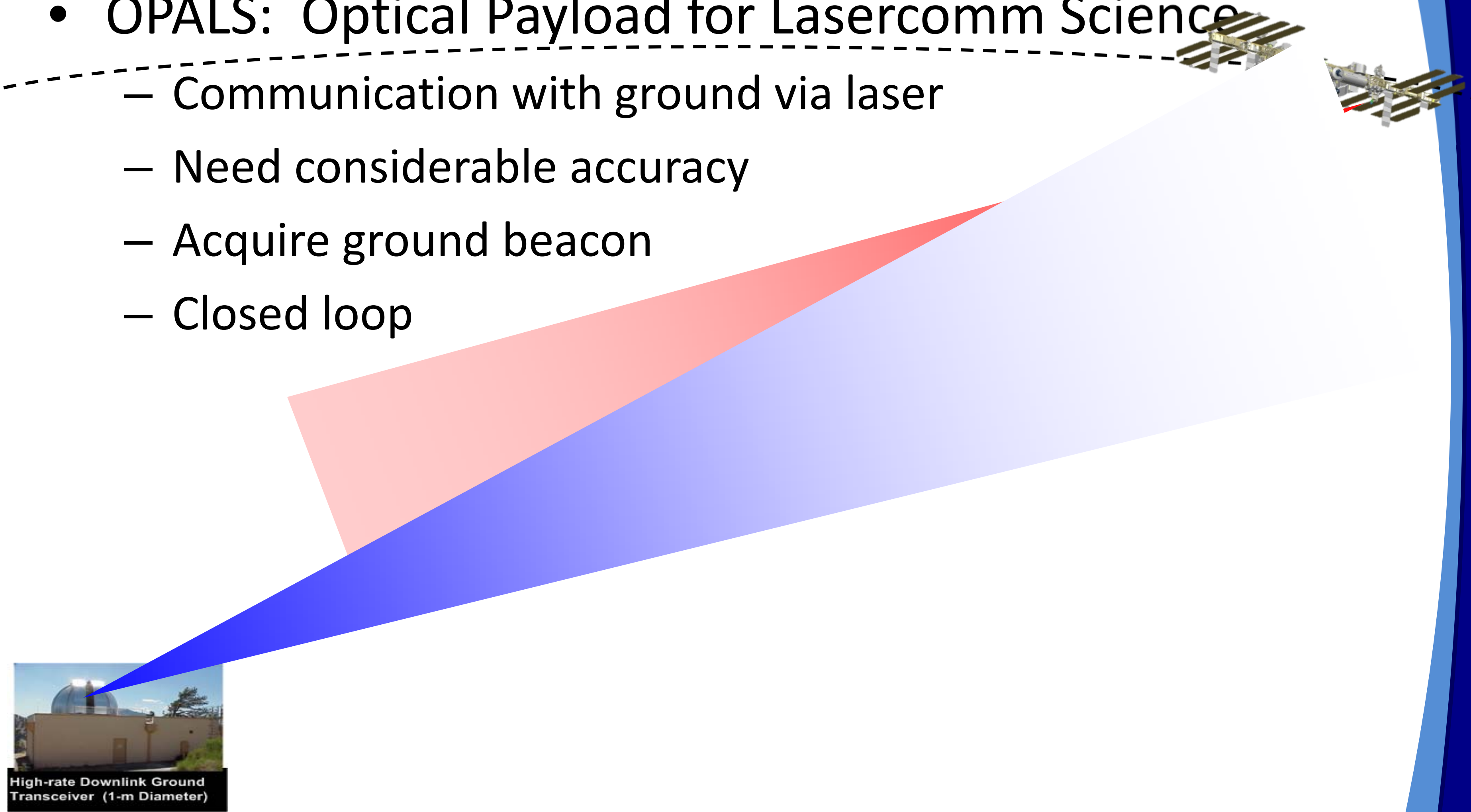
- GPS Time is official time source for ISS
  - Atomic Time System managed by USNO
  - Broadcast by GPS satellites
  - Kept within 1 microsecond of UTC
  - Does not adjust for leap seconds

Time

- Two laptop types onboard ISS
  - Portable Computer System (PCS)
    - Command and control
    - Required to be time synced to within 2 seconds of GPS time
    - Can drift at 1 second / day
    - MCC maintains to within 1 second
  - Station Support Computer (SSC)
    - Most payloads use SSCs
    - Non-command and control
    - Synced to GMT Server
    - Can also drift similarly
    - ISS onboard telemetry time will be in GPS (currently a 16 second difference due to leap seconds)

Best Practices

- OPALS: Optical Payload for Lasercomm Science
  - Communication with ground via laser
  - Need considerable accuracy
  - Acquire ground beacon
  - Closed loop



Best Practices

- HICO: Hyperspectral Imager for the Coastal Ocean
  - Goal is to assign geographic coordinates to each image pixel
  - Sensor tilted and skewed relative to ISS reference frame
  - Boresite calibration necessary
    - Took known images and derived true boresite location
    - Compared to trajectory and attitude telemetry
    - Different correction calculated for each of 7 images
    - Largest correction ~1 degree in X axis, much smaller in other axes
  - Geoposition error reduced by an order of magnitude

Ref: HICO Geolocation Report 09/13

Best Practices

- ISSACS: ISS Agricultural Camera
  - Small camera FOV
  - Regularly missed image due to onboard GPS time conflict with ground GMT
  - Temporary fix was to start recording early

How to Prepare for Operations

- Can your sensor get Sun in the FOV?
  - Does it matter if the sensor is on or off?
  - How long can it look at the Sun?
  - Is there an additional buffer that needs to be protected?
- Does your payload need concurrent ISS communication with the ground?
  - Sband for telemetry?
  - Kuband for video?
- Can ISS elements block your sensor FOV?
  - Solar arrays?
  - Robotic Elements?
  - Thermal radiators?

Summary

- Now is great time to get involved with ISS
  - Assembly Complete
  - Mature Laboratory
  - Lifetime extended until at least 2024 underway
  - There are groups ready to help integrate your payload