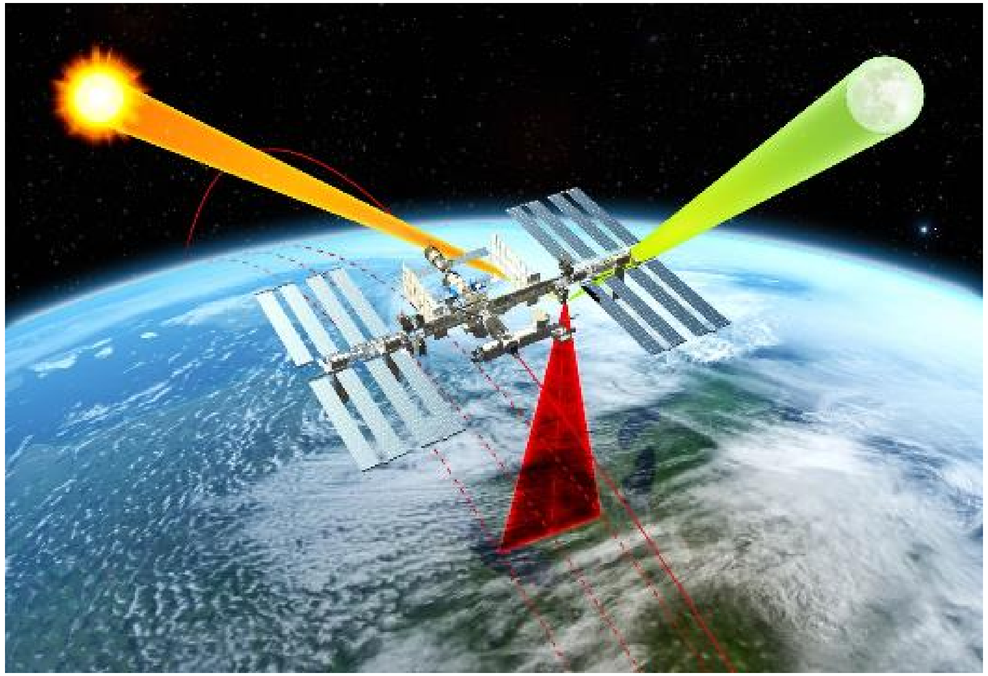
# Lunar Calibration Applications for CLARREO Pathfinder

Tom Stone — USGS Flagstaff

CLARREO Pathfinder Science Workshop
03 November 2021

# CLARREO Pathfinder will observe the Moon as a secondary mission objective



Potential applications of CPF lunar measurements:

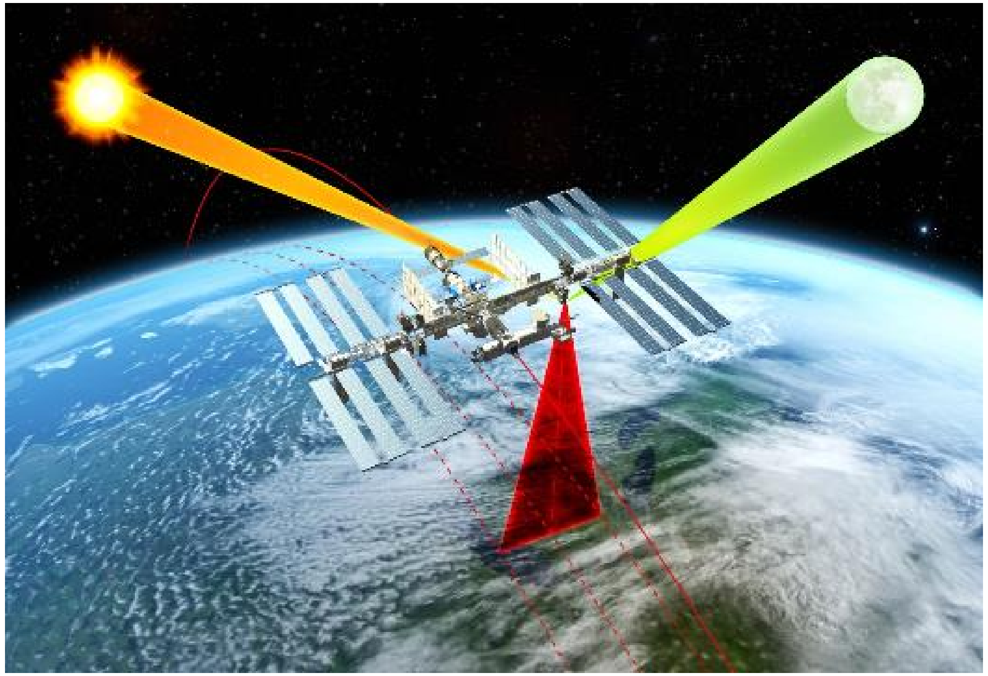
- lunar inter-calibration
  - using the Moon as a common target
- improved knowledge of lunar reflectance
  - for advancing development of lunar models

The radiometric quantity used for lunar calibration is spatially integrated irradiance

- requires observing the complete Moon disk
  - to be accomplished with CPF RS by scanning
- adds complexity to deriving measurements from line-scanning sensors

USGS

# CLARREO Pathfinder will observe the Moon as a secondary mission objective



Potential applications of CPF lunar measurements:

- lunar inter-calibration
  - using the Moon as a common target
- improved knowledge of lunar reflectance
  - for advancing development of lunar models

The radiometric quantity used for lunar calibration is spatially integrated irradiance

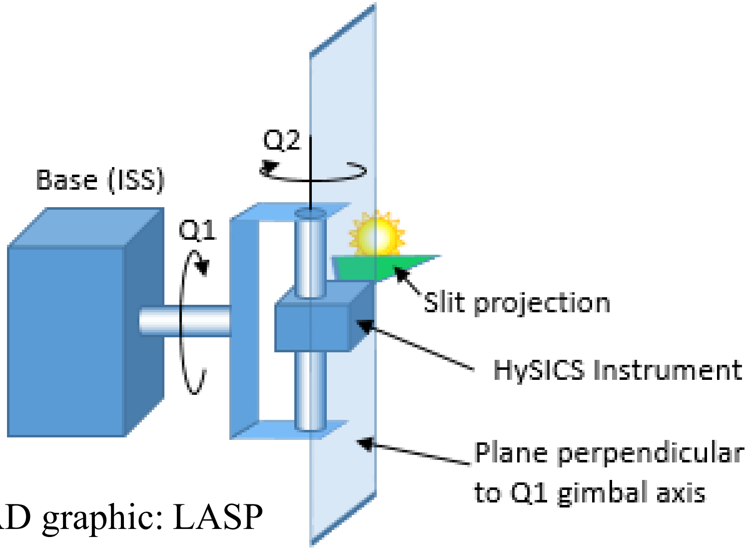
- requires observing the complete Moon disk
  - to be accomplished with CPF RS by scanning
- adds complexity to deriving measurements from line-scanning sensors

*The accuracy achievable for lunar irradiance measurements by CPF remains to be demonstrated*

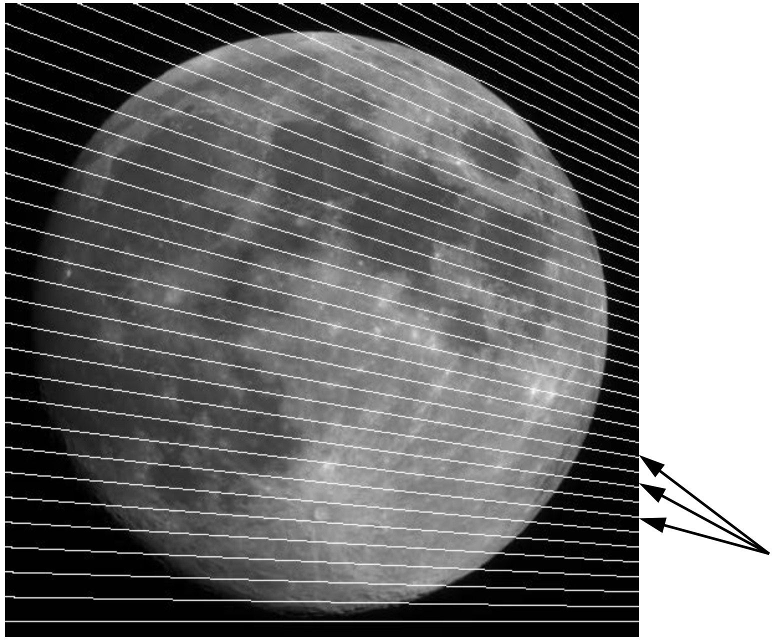
USGS

# Technical issue — scan oversampling

- CPF Moon images will be composed of concatenated scan lines
- The 2-axis gimbal CPF pointing system means Moon scans will trace a curved path over the lunar disk




CAD graphic: LASP




This leads to different oversampling for each lunar image pixel

– oversampling correction is a matrix operation

– the algorithm for generating the oversampling matrices is still in development

# Technical issue — scan oversampling

- The oversampling factor is a critical component of lunar irradiance measurements from images:

$$\boldsymbol{E}_{\mathrm{meas}} = \Omega_{\mathrm{p}} \sum_{i}^{N} \frac{1}{\eta_i} \boldsymbol{L}_i$$

$\Omega_{\mathrm{p}}$ = pixel IFOV (solid angle)
$\eta_i$ = pixel oversampling factor
$L_i$ = pixel radiance
$N$ = # of pixels on Moon

- Each term on the right carries an uncertainty
  - radiometric calibration applies only to the pixel radiances $\boldsymbol{L}_i$
  - combination of terms means lunar irradiance measurements cannot reach the same level of accuracy as the sensor radiometric calibration
- TBD: the level of uncertainty in CPF oversampling factors $\eta_i$
- Potential to develop cutting-edge techniques for measuring lunar irradiance

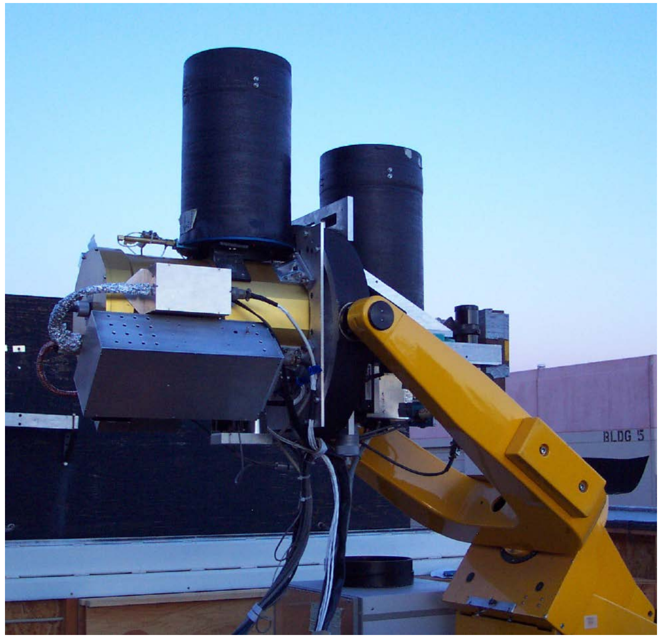
USGS

# Application: lunar inter–calibration

- The Moon can be observed as a common target for multiple sensors
  - the lunar surface reflectance has exceptional photometric stability, better than $10^{-8}$ $yr^{-1}$
- Lunar inter-cal requires using a lunar model
  - the apparent lunar brightness changes continuously
    - relatively rapidly when viewed from orbit
  - all Moon observations have different geometries, thus different irradiances
- Inter-calibration of sensors to CPF using the Moon is technically feasible
  - CPF Science Planning System (SPS) can predict opportune observation events
  - uncertainties in lunar model predictions are reduced for closely matched view geometries

# Application: lunar reference database

- The lunar calibration reference is a predictive model
  - to accommodate the continuously changing lunar brightness
- Lunar model development follows from extensive radiometric characterization measurements
  - minimum 3 years required to sample geometry variations
  - USGS ROLO observations spanned more than 8 years
    - dedicated observatory in Flagstaff, AZ →



ROLO telescopes zenith-pointed at dusk

- Advances in lunar modeling need a new collection of high-accuracy measurements
  - to achieve absolute lunar calibration with sub-percent uncertainty
- Numerous opportunities for CPF to view the Moon are anticipated
  - potential to build up a substantial database of lunar irradiance measurements

# Thank You!