### OLI Lunar Irradiance Characterization

#### Background

Lunar acquisitions will be used to complement image quality assessments of the OLI. These will help detect changes in gain, provide a measure of radiometric stability, and reduce absolute radiometric uncertainties.

Changes in relative gains are determined by comparing the measured lunar irradiances with modeled irradiances, which are calculated by the Robotics Lunar Observatory (RoLO), USGS/Flagstaff, using their lunar irradiance model. The interface between IAS and RoLO consists of a set of data interchange files. The IAS provides RoLO with the measured integrated lunar irradiances, image times and spacecraft position vectors. RoLO in turn generates a set of reports containing lunar observation geometrical parameters used by the model and comparisons of suitably scaled measured versus modeled irradiances. These reports will be ingested into the database for trending.

The L1R lunar product will also be used for further geometrical processing and analysis including creation of geometrically corrected image products (resampled) and MTF characterizations.

Operationally, it is expected that the moon will be imaged once a month (at approximate 7 degrees lunar phase angle) on several Sensor Chip Arrays (SCAs) with one “reference” SCA image always acquired. Information regarding which SCAs are illuminated is also expected from mission operations element since they will be programming the lunar maneuver.

#### Input

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  **Descriptions**  | **Symbol** | **Units** | **Level**  | **Source** | **Type** |
| Scene (L1r) |  | W/m2/sr/μm | Nbands x NSCAs x Ndetectors |  | Float |
| ImpNoise  |  |  | Nbands x NSCAs x Ndetectors | LM | Int |
| Sat Pixels |  |  | Nbands x NSCAs x Ndetectors | LM | Int |
| Inop Dets |  |  | Nbands x NSCAs x Ndetectors | CPF | Int |
| Odd/even detector offsets |  |  | Nbands x NSCAs x Ndetectors | CPF |  |
| Median Filter Size |  |  |  | CPF | Int |
| Dropped Frames |  |  | Nbands x NSCAs | LM | Int |
| SCA\_illumination\_flag |  |  | NSCAs | Currently not available in the Ancillary/db. A mechanism to get this information is desired. | Int |
| Data/Imagery start/stop time [UTC] | Tstart,Tend | YYYYDDDhhmmss.sss |  | Ancillary/db  | Text or Date |
| Frame rate | F | Hz |  | Ancillary/db  | Float |
| Integration time | I | Ms |  | Ancillary/db | Float |
| Spacecraft ephemeris/Attitude |  | Km |  | Ancillary/db | Float |
| Moon-SC distance  | Rm-sc | Km |  | Currently not available in Ancillary/db but can be calculated by IAS using existing code. | Float |
| Earth-Sun distance | Re-s | Km |  | Currently not available in Ancillary/db but can be calculated by IAS using existing code. | Float |
| Earth-Moon distance | Re-m | Km |  | Currently not available in Ancillary/db but can be calculated by IAS using existing code. | Float |
| Earth-SC distance | Re-sc | Km |  | Currently not available in Ancillary/db but can be calculated by IAS using existing code.  | Float |
| Radiance Integration Thresholds |  |  | Nbands | CPF | Float |

#### Output

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Descriptions** | **Symbol** | **Units** | **Level**  | **Target** | **Type**  |
| **Interface items to ROLO** |  |  |  |  |  |
| Time at center of lunar image [UTC] | tm | YYYYDDDhhmmss.sss | Nbands x NSCAs | DB and text file | Text or Date  |
| Apparent lunar YSize [mrad] | Ysize | mrad | Nbands x NSCAs | Db and text file | Float |
| Integrated Irradiances  | SumIrr | [microWatts / m^2 / nm] | Nbands x NSCAs | Db and text file | Float |
| SC PositionVector [J2000 GCI] |  | Km |  | Db and text file | Float |
|  |  |  |  |  |  |
| **Interface items from ROLO**  |  |  |  |  |  |
| Modeled Integrated Irradiances |  | microW/m^2/nm | Nbands x NSCAs | Db and text file | Float |
| Scaled Measured Irradiances |  | microW/m^2/nm | Nbands x NSCAs | Db and text file | Float |
| Irradiance percent differences  |  | percent | Nbands x NSCAs | Db and text file | Float |
| Lunar diameter as observed from the SC |  | mrad | Nbands x NSCAs | Db and text file | Float |
| Oversampling Factor |  | dimensionless | Nbands x NSCAs | Db and text file | Float |
| Dynamical barycentric Days |  | Day |  | Db and text file | Float |
| Selenographic longitude of the Sun |  | degrees |  | Db and text file | Float |
| Selenographic latitude of the Sun |  | degrees |  | Db and text file | Float |
| Selenographic longitude of spacecraft |  | degrees |  | Db and text file | Float |
| Selenographic latitude of spacecraft |  | degrees |  | Db and text file | Float |
| Distance of spacecraft from center of Moon |  | km |  | Db and text file | Float |
| Heliocentric range of the Moon |  | Au |  | Db and text file | Float |
| Factor to correct irradiance to standard distances |  | dimensionless |  | Db and text file | Float |
| Lunar phase angle |  | mrad |  | Db and text file | Float |
| Position Angle of lunar axis, ccw from North |  | degrees |  | Db and text file | Float |
| Lunar Mask |  | boolean | Nbands x NSCAs x Ndetectors | Image File | Int |
|  |  |  |  |  |
| **Other algorithm generated parameters** |  |  |  |  |  |
| Frame numbers at top and bottom of lunar image, location moon’s center (frame number, detector location) |  | N/A | Nbands x NSCAs | DB and text file | Int |
| S/C attitude and attitude rates at top, middle and bottom of lunar image  |  | rads,rads/s or arcsec,arcsec/s [as provided in the ancillary db] | Nbands x NSCAs | DB and text file | Float |
| Sun-Earth-Moon ranges [km] |  | km |  | DB and text file | Float |

Note, Ints are 16-bit, Floats are 32-bit.

#### Options

1. Output lunar mask for verification.
2. Text output of Integrated Irradiance, apparent lunar y-sizes, start and stop frame numbers of lunar images, and location of the middle of the lunar images for each band and in every illuminated SCA.
3. Alternate median filter size.

#### Procedure

1. Obtain illuminated SCA flag from ancillary database or other methods/sources.
2. For each illuminated SCA calculate inputs to Rolo
	1. Read L1R metadata
		1. Image dimensions
		2. Image start time
		3. Frame rate
		4. Integration time
	2. For each BAND
		1. Read image data, L1Riband,isca
		2. If the input L1R data implemented any odd even offsets, then remove odd/even detector offsets from L1Riband,isca → L1Ciband,isca. Otherwise, L1Ciband,isca = L1Riband,isca
		3. Create Lunar Mask, LMiband,isca:
			1. By thresholding.
			2. Remove artifacts (bright stars, etc.) from image, e.g.,: Filter each column with median filter, size = . (default=5).
			3. Obtain maximum radiance value, MaxRad iband,isca = max(L1Ciband,isca)
			4. Set irradiance Threshold = MaxRad iband,isca \*, where  is the radiance integration threshold factor (current default value = 0.8)
			5. LM = 1 where L1Ciband,isca ≥ Threshold, else LM = 0
		4. Calculate Irradiance, SumIrriband,isca
			1. Sum radiance over lunar images, SumRadiband,isca = ∑ LRad\*LM.
			2. Convert SumRAD iband,isca to Irradiance in µW/(m2.nm), SumIrr:
			3. For MS bands, SumIrr(1-7,9),isca=SumRAD(1-7,9),isca\* 1.81077e-13
			4. For Pan band, SummIrr8,isca=SumRAD8,isca\*4.52694e-14
			5. These constant may be added to the CPF.
		5. Calculate apparent lunar y-size:
			1. For each detector locate start/end frame number where LM = 1, startidet, endidet
			2. Number of mask pixels in each column: Nidet=endidet-startidet
			3. Ysize iband,isca = Maximum(Nidet), at column location Dmax iband,isca. .I.e. Y-size is the maximum number of pixels set to 1 in the lunar mask and Dmax is the detector number where that maximum occurs.
			4. Ysize in mrads,:
			5. For MS bands, mYsize(1-7,9),isca =Ysize(1-7,9),isca \* Ωms
				1. where detector solid angle is Ωms=4.2553e-5
			6. For Pan band, mYsize8,isca =Ysize8,isca\*Ωpan
				1. where detector solid angle is Ωpan=2.1277e-5
		6. Calculate UTC time at center of moon, UTC\_Moon(Band,SCA):
			1. Center of moon in image, FrameNumberMoonCenter = (start(Dmax)+end(Dmax)/)/2
			2. UTC\_moon=(Image start time)+FrameNumberMoonCenter/(Frame rate)
			3. Alternatively, query image data time code at FrameNumberMoonCenter.
		7. Read spacecraft ephemeris at UTC\_moon: J2000 Position Vector(X,Y,Z).
3. Outputs
	1. Obtain and populate database with integrated irradiance results and ancillary data. These include the following:
		1. Sun-moon-Earth ranges,
		2. Lunar Irradiance,
		3. Lunar Y-sizes (in mrads and frame count),
		4. Frame numbers at top and bottom of lunar edges.
		5. UTC time, spacecraft position vectors at center of lunar image.
4. Rolo interface:
	* 1. Query database, format and transmit results to Rolo.
		2. Receive lunar model results from Rolo and populate database.

**Known/Potential Issues:**

One input specification is a flag to denote which SCA is being illuminated. Currently, such information is not available to IAS. An alternate, but less preferred, method is for IAS to use the imagery itself to determine which SCA is illuminated.

The Moon-SC, Earth-Sun, Earth-Moon, and Earth-SC distances are also not currently available in the ancillary databases. The IAS can alternatively calculate this information using existing software.

#### Maturity

Level2 (reuse from ALIAS)

1. Enable usage of L1G as input.
2. Develop alternate methods for obtaining lunar masks.
	1. Image classification to separate moon image from dark space.
	2. Lunar edge/limb determination as implemented for the RoLO model.
3. Estimate apparent lunar y-size using spacecraft attitude information. This requires spacecraft attitude and attitude rates(Roll, Pitch, Yaw), and moon size from the spacecraft’s position.