A simplified three dimensional model of the VIIRS on-board calibration system for visualization and anomaly investigation

Dave Pogorzala[1] and Changyong Cao[2]

[1] Integrity Applications Incorporated
[2] NOAA/NESDIS/STAR
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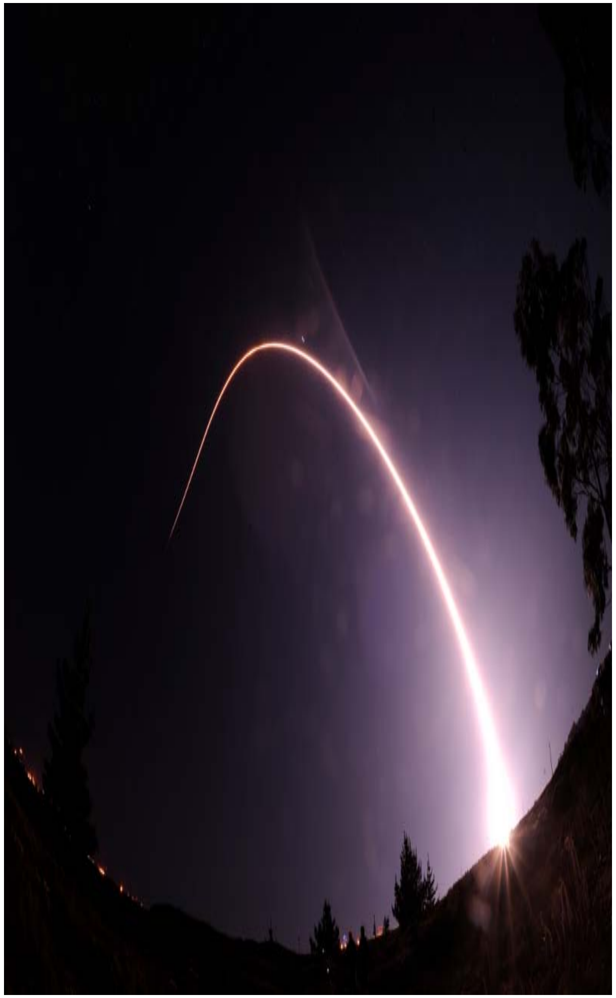
Outline

- Motivation
- Information sources
- Constructing the model
- Significance and benefits
- Going forward

Motivation

- Post-launch testing of VIIRS began late 2011.
- Sensor Data Record (SDR) Team was tasked with validating the on-orbit calibration of VIIRS.
- Radiometric calibration is very dependant on geometry.
- Source documents define this geometry in various conventions, all of which are difficult to visualize as a unified system.
  - azimuth/elevation/declination angles
  - angles about x/y/z axes
  - matrix transformations

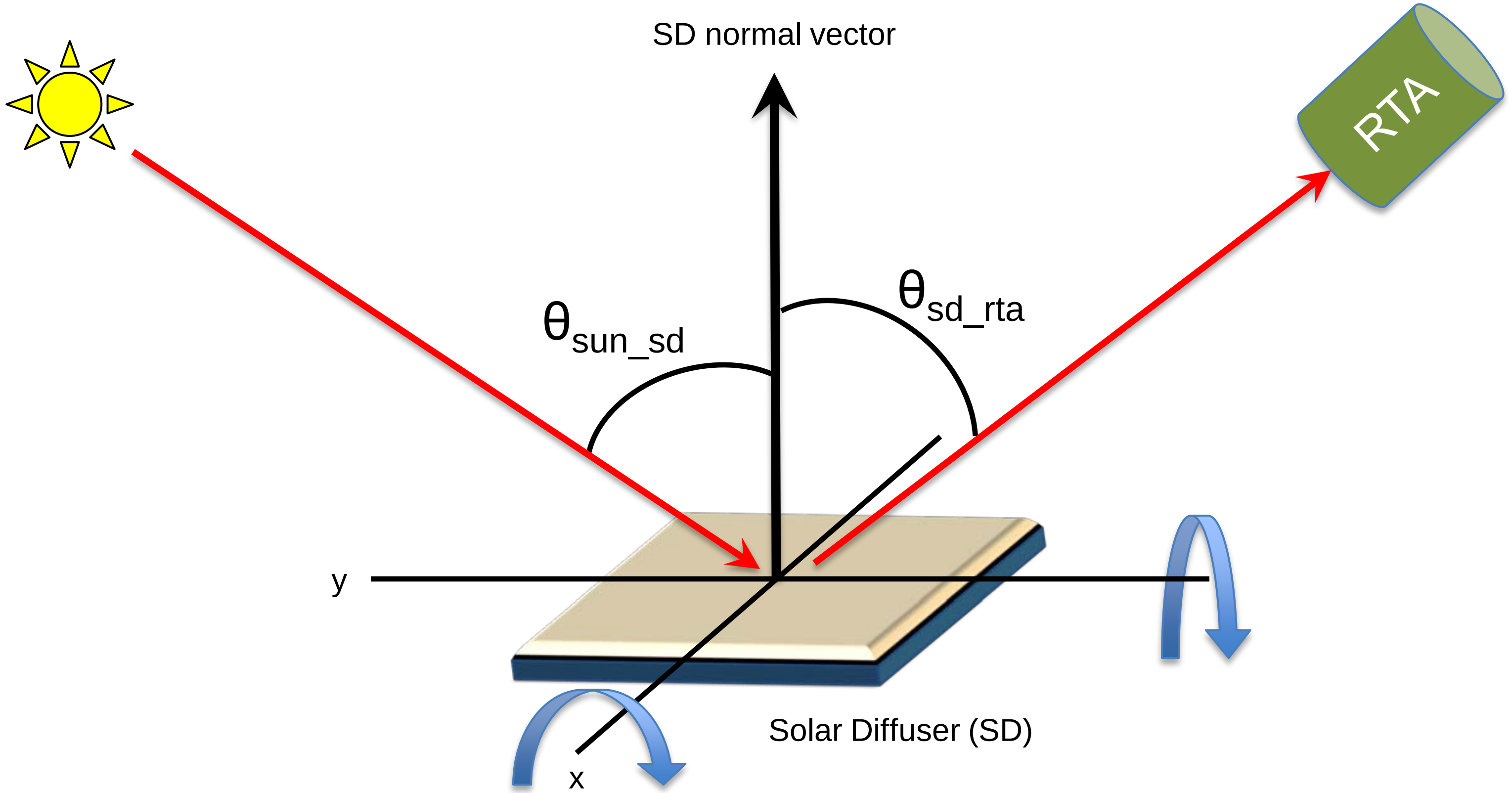


NPP launch

Image credit: NASA/Bill Ingalls Oct. 28, 2011

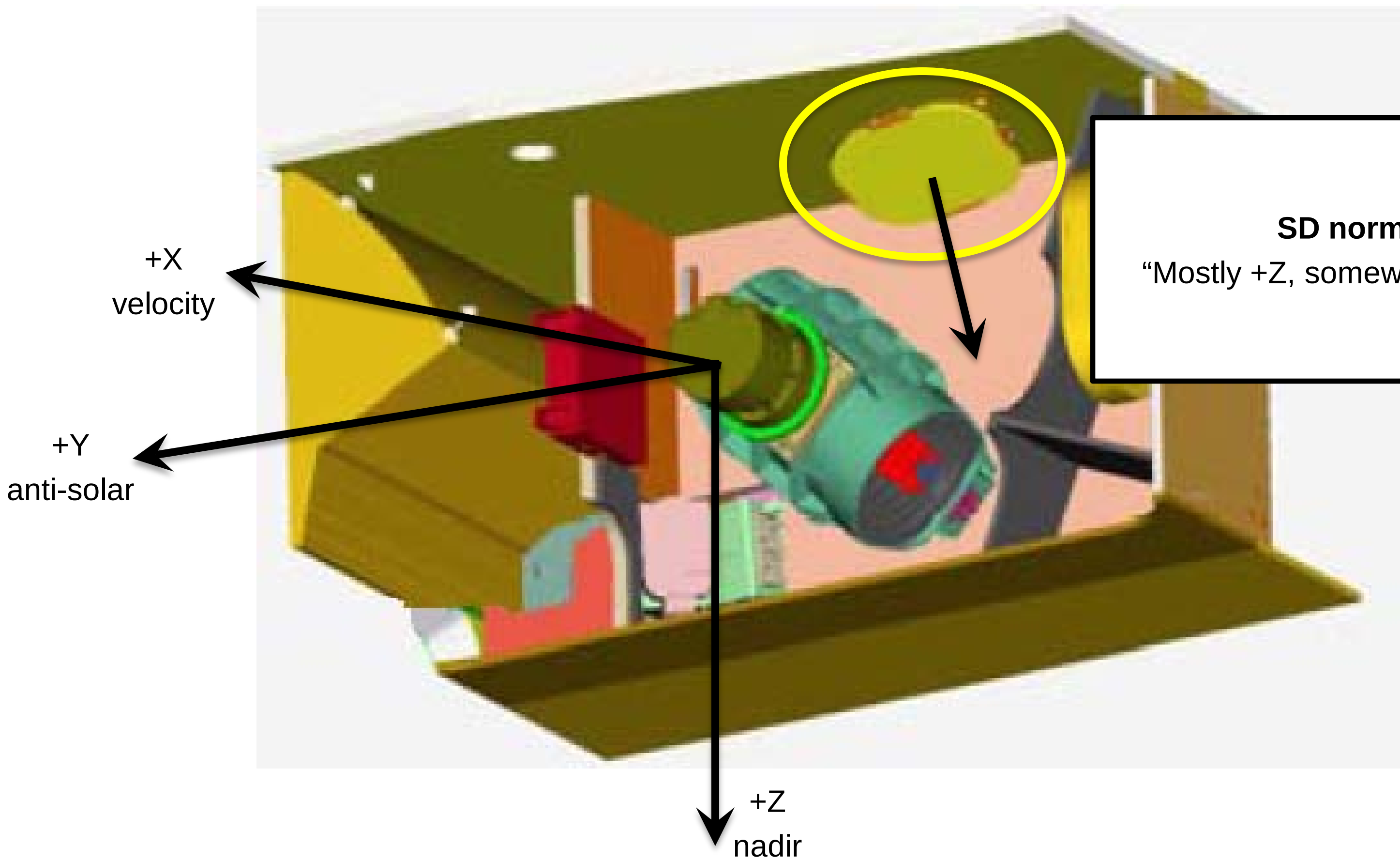
Motivation

- <u>Goal:</u> Unify these into a cohesive knowledge of the instrument.
- SDR Team needed to *intuitively understand* parameters like:



Motivation

SD Orientation (1 of 3)



SD normal vector:

"Mostly +Z, somewhat +X, slightly –Y?"

source: *"VIIRS Radiometric Calibration ATBD" with annotated vectors*

Motivation

SD Orientation (2 of 3)

3.3.1.3.4. Instrument to Solar Diffuser

The transformation matrix that describes the relationship between the instrument coordinate system and the Solar Diffuser assembly is described by the transformation matrix $T_{SD/inst}$:

$$\mathbf{T}_{sd/inst} = R_z(\gamma_{SD})R_y(\beta_{SD})R_z(\alpha_{SD})$$

$$= \begin{bmatrix} \cos\gamma_{SD} & \sin\gamma_{SD} & 0 \\ -\sin\gamma_{SD} & \cos\gamma_{SD} & 0 \\ 0 & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} \cos\beta_{SD} & 0 & -\sin\beta_{SD} \\ 0 & 1 & 0 \\ \sin\beta_{SD} & 0 & \cos\beta_{SD} \end{bmatrix} \cdot \begin{bmatrix} \cos\alpha_{SD} & \sin\alpha_{SD} & 0 \\ -\sin\alpha_{SD} & \cos\alpha_{SD} & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$= \begin{bmatrix} \cos\alpha_{SD}\cos\beta_{SD}\cos\gamma_{SD} - \sin\alpha_{SD}\sin\gamma_{SD} & \sin\alpha_{SD}\cos\beta_{SD}\cos\gamma_{SD} + \cos\alpha_{SD}\sin\gamma_{SD} & -\sin\beta_{SD}\cos\gamma_{SD} \\ -\cos\alpha_{SD}\cos\beta_{SD}\sin\gamma_{SD} - \sin\alpha_{SD}\cos\gamma_{SD} & -\sin\alpha_{SD}\cos\beta_{SD}\sin\gamma_{SD} + \cos\alpha_{SD}\cos\gamma_{SD} & \sin\beta_{SD}\sin\gamma_{SD} \\ \cos\alpha_{SD}\sin\beta_{SD} & \sin\alpha_{SD}\sin\beta_{SD} & \cos\beta_{SD} \end{bmatrix}$$

$$= \begin{bmatrix} 0.74977311 & -0.54875096 & -0.36974676 \\ 0.59060567 & 0.80696031 & 0 \\ 0.29837096 & -0.21837453 & 0.92913257 \end{bmatrix}$$

(3.3-5a)

Nominal values for the rotation angles α_{SD}, β_{SD}, and γ_{SD} are:

$\alpha_{SD} = -36.2°$
$\beta_{SD} = 21.7°$
$\gamma_{SD} = 0°$

source: *“VIIRS Geolocation ATBD”*

Sequential Euler rotations can be difficult to visualize for some.

What is the starting orientation of the SD?

Motivation

SD Orientation (3 of 3)

Solar Diffuser Normal Vector Components

The normal vector of the Solar Diffuser as mounted was determined from the ProE model of VIIRS. The components of the Solar Diffuser normal vector are:

$$\mathbf{n}_D = (X_D, Y_D, Z_D) = ([redacted]) \quad (5)$$

source: *"VIIRS Solar Diffuser BRF Calibration Orientation"*

Remark. The nominal solar diffuser Spectralon™ panel orientation relative to the Spacecraft Coordinate System (SCC) is defined by sequential rotations. Beginning with the diffuser's normal parallel to the SCC Z-axis (nadir) and the long axis of the diffuser parallel with the SCC Y-axis, define a local coordinate system for the diffuser (X',Y',Z') which is identical to the SCC system. First, rotate the diffuser about the X'-axis. Then rotate the diffuser about the Y'-axis. X'-axis-rotation = [redacted]° ± [redacted] arcsec, Y'-axis-rotation = [redacted]° ± [redacted] arcsec.

source: *"Solar Diffuser and Solar Attenuation Screen, Product Specification - VIIRS"*

Motivation

Incident Solar Angle Definitions

Sun Angles

The angles at which the Bidirectional Reflectance Factor (BRF) of the VIIRS Solar Diffuser need to be calibrated are determined from the sun direction angles that are obtained during that portion of the orbit when the Solar Diffuser BRF is measured by the Solar Diffuser Stability Monitor (SDSM). The sun angular range for the SDSM is specified in the Solar Diffuser Specifications [redacted] as:

[redacted] deg ≤ azimuth angle ≤ [redacted] deg and [redacted] deg ≤ declination angle ≤ [redacted] deg

source: *"VIIRS Solar Diffuser BRF Calibration Orientation"*

<u>In these four examples:</u>

transformation matrix

Euler angles

normal vector

$x_{VIIRS}/y_{VIIRS}/z_{VIIRS}$ and $x_{SD}/y_{SD}/z_{SD}$ rotations

azimuth/declination angles

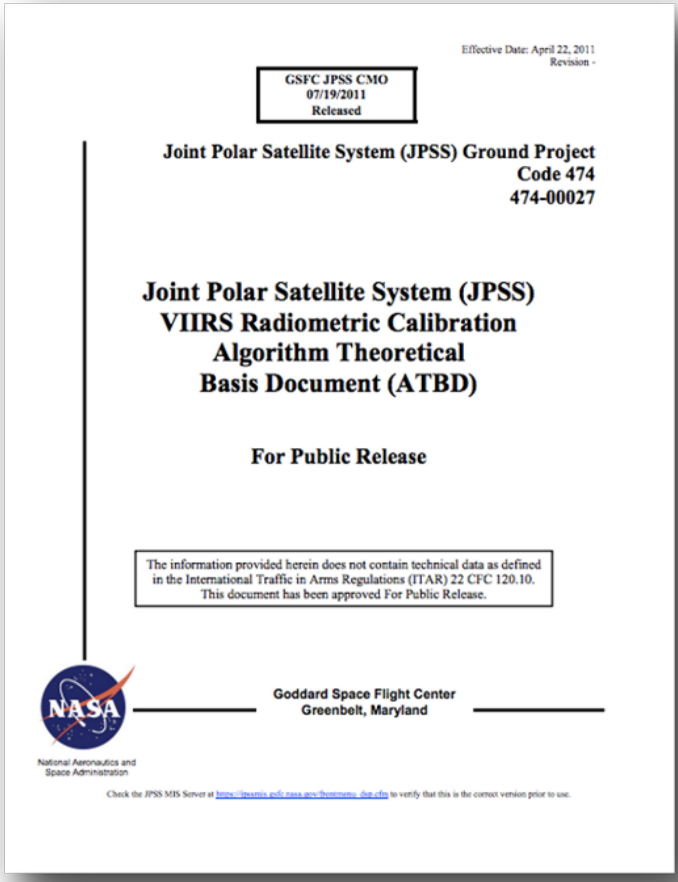
Information Sources

Publicly Released:

- "JPSS VIIRS Radiometric Calibration Algorithm Theoretical Basis Document (ATBD)"
- "NPOESS VIIRS Geolocation ATBD"
- "VIIRS Sensor Data Record User's Guide"

Not Publicly Released:

- Mechanical Interface Control Drawings
- Coordinate Transformations Between Spacecraft and Screen Coordinates
- VIIRS Solar Diffuser BRF Calibration Orientation
- Solar Diffuser and Solar Diffuser Screen Requirements



Effective Date: April 22, 2011
Revision -

GSFC JPSS CMO
07/19/2011
Released

Joint Polar Satellite System (JPSS) Ground Project
Code 474
474-00027

Joint Polar Satellite System (JPSS)
VIIRS Radiometric Calibration
Algorithm Theoretical
Basis Document (ATBD)

For Public Release

The information provided herein does not contain technical data as defined in the International Traffic in Arms Regulations (ITAR) 22 CFC 120.10.
This document has been approved For Public Release.

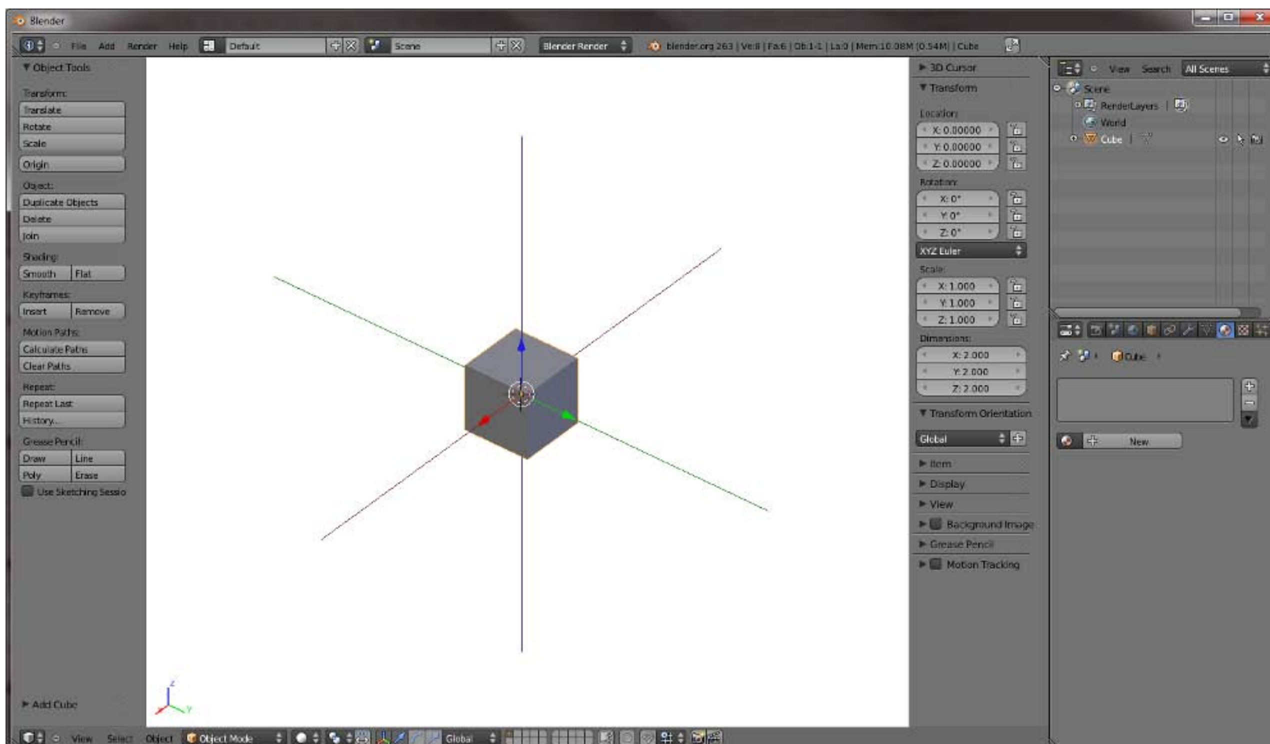
National Aeronautics and Space Administration

Goddard Space Flight Center
Greenbelt, Maryland

Check the JPSS MIS Server at https://jpssmis.gsfc.nasa.gov/frontmenu_dsp.cfm to verify that this is the correct version prior to use.

The 3D Model

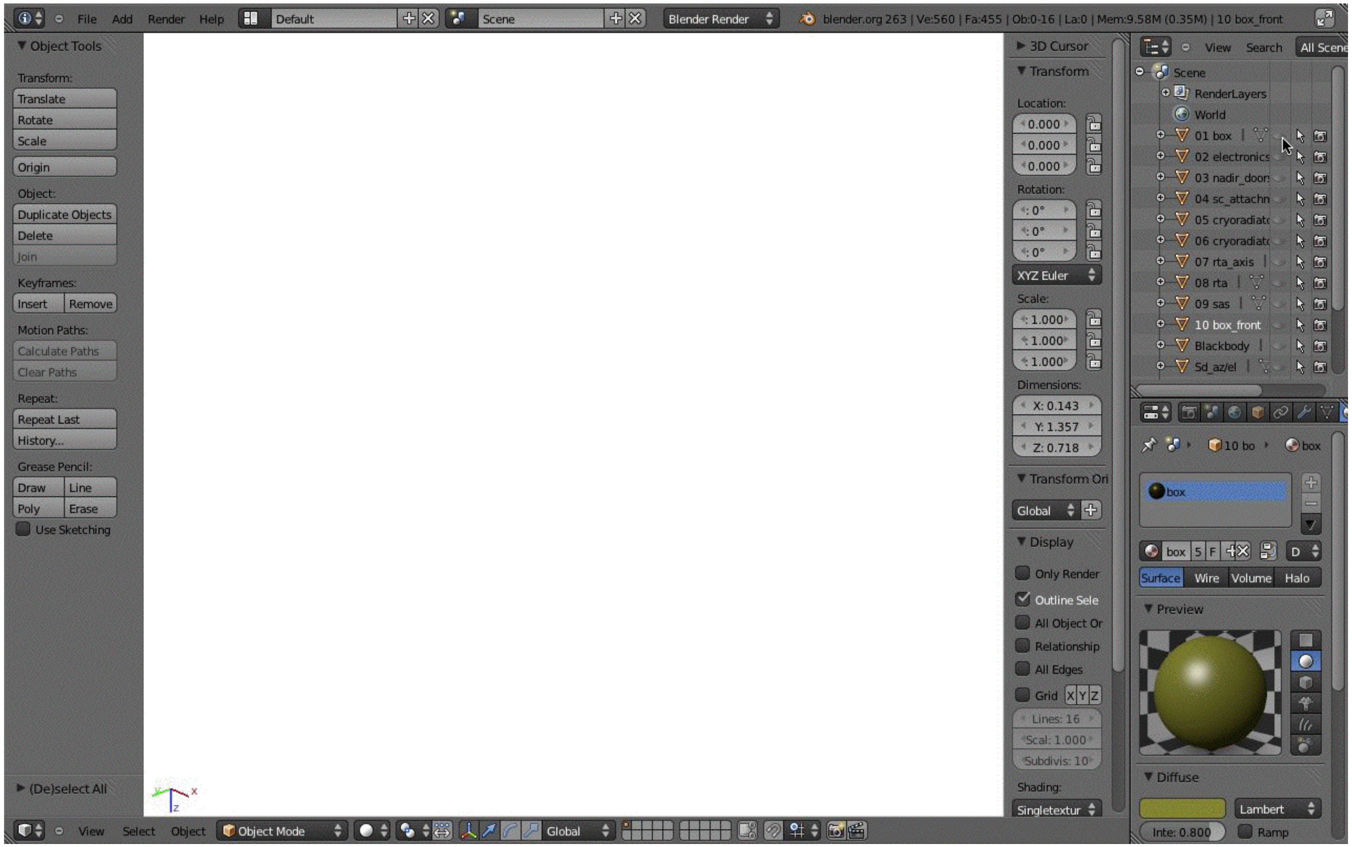
- In order to resolve these various definitions and schematics, we created our own *simplified* 3D model of VIIRS using Blender.
- Absolute size and location of all objects *are not* exact.
- Angular orientations of key objects *are* exact.



the Blender modeling environment
(www.blender.org)

The 3D Model
Instrument Body

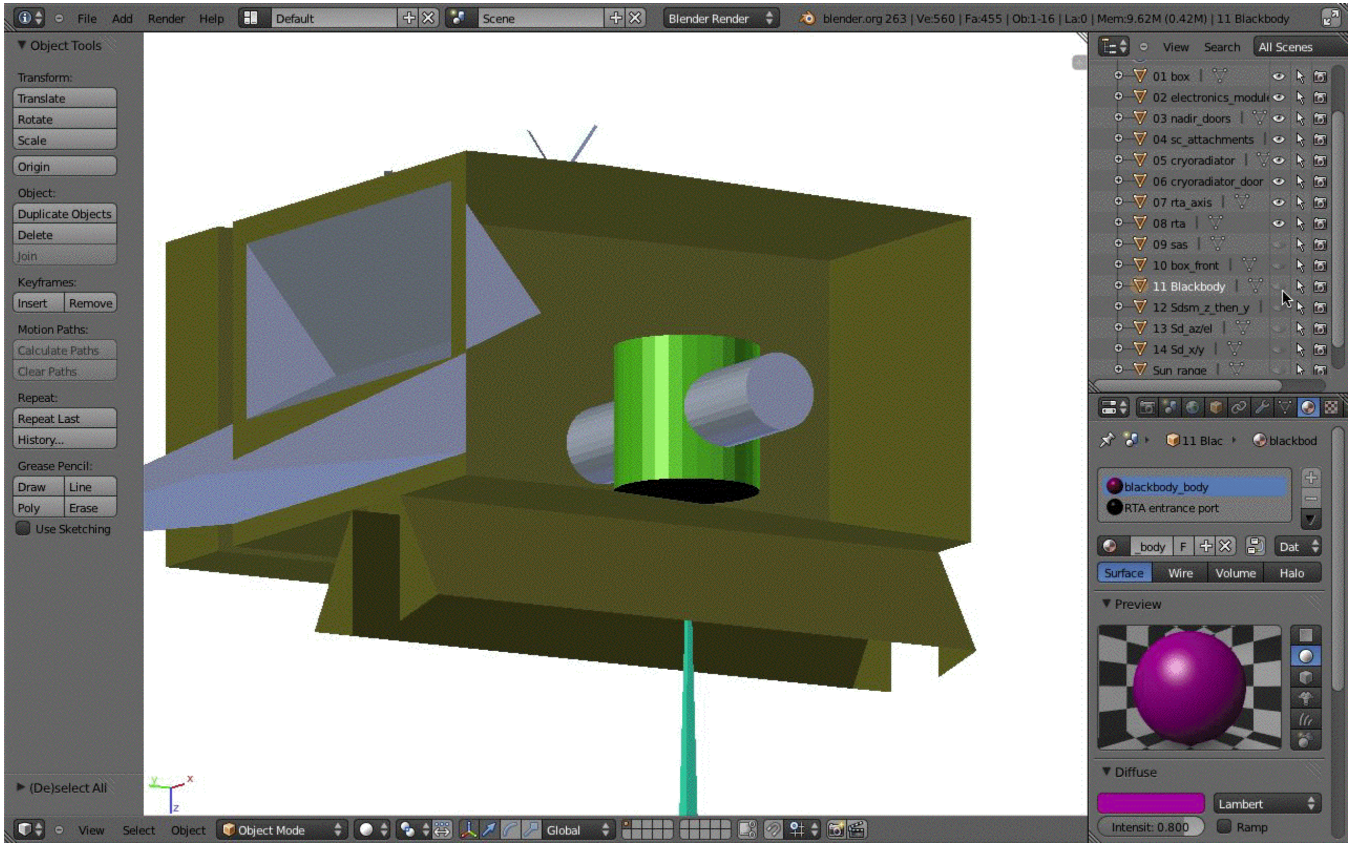
- Started with instrument body, RTA, glint shield, etc.
- No cables, hoses, nuts or bolts



The 3D Model

Calibration Components

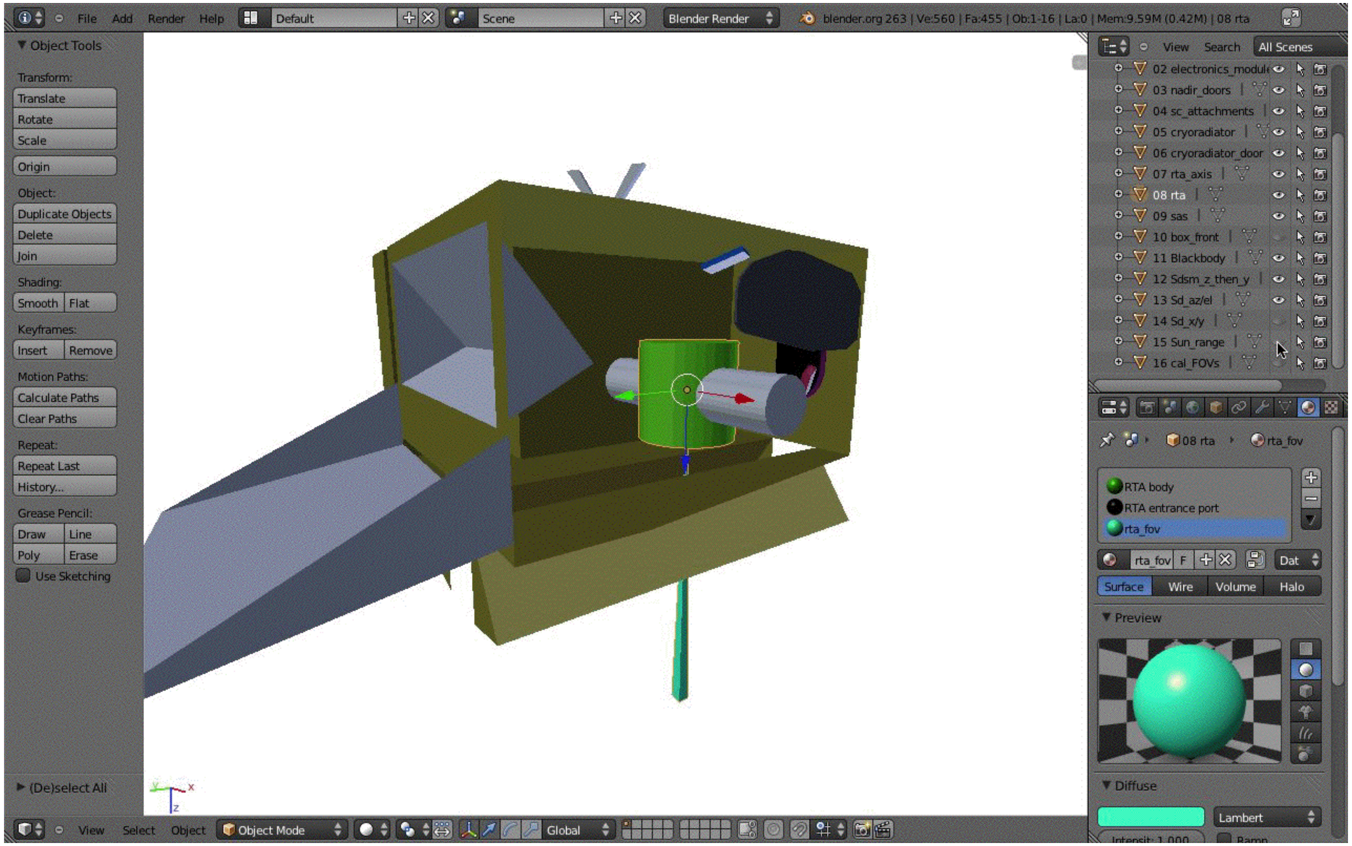
- Added simplified blackbody target and SDSM.
- Added multiple SDs, each aligned according to separate definition.



The 3D Model

Animation and Visualization

- Added incident solar angle envelope.
- Added angular extents of various “looks” throughout RTA scan pattern.



Significance

Example benefits to SDR Team

- Verified and visualized SD orientation according to multiple sources.
- Visualized appearance of moon in Space View for prediction of lunar calibration opportunities.
- Potential to visualize SD BRDF trends around Summer Solstice.
- Verified outputs from the SD Illumination Predictions table.

ncc.nesdis.noaa.gov/SNO/SNOs//NPP_solar/hist_NPP_SD_illumination_20120225.html

Solar Diffuser Illumination Predictions

Prediction of Solar Diffuser Illumincation for Satellite NPP

Solar zenith angle range: (107.00, 108.50) degree; Solar azimuthal angle range: (13.60, 44.20) degree.

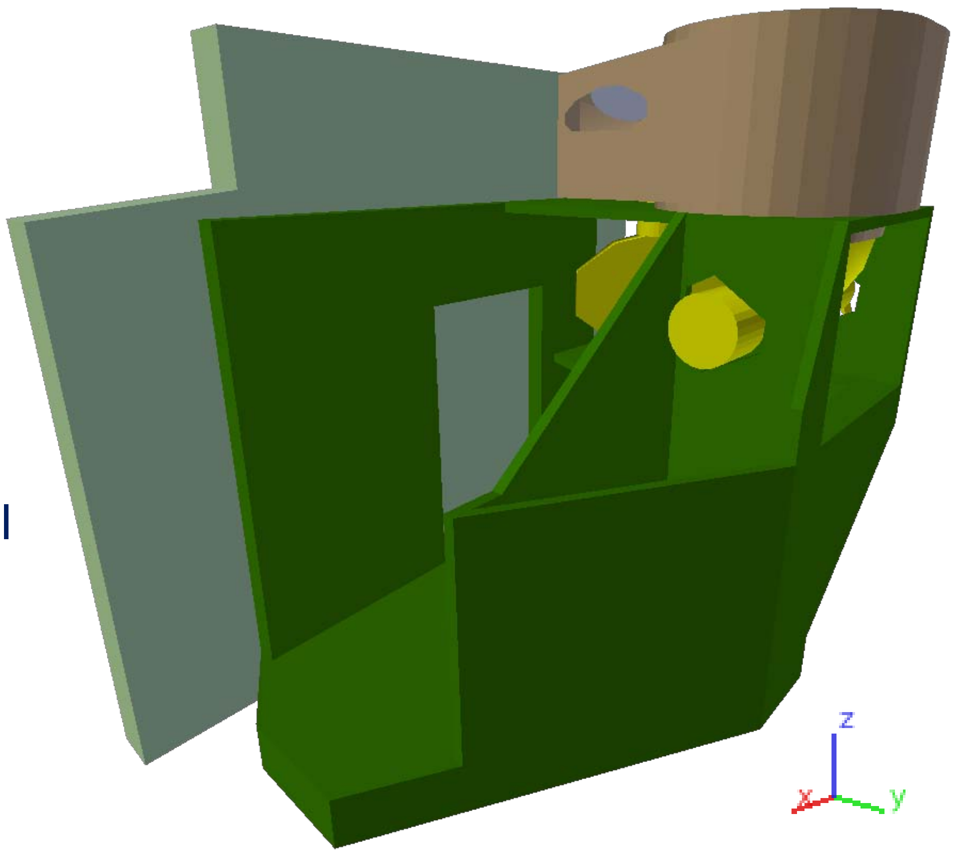
Solar Diffuser Illumination Prediction for Satellite NPP during 10.0 days since TLE Epoch: 2/24/2012

Case	Date (yyyy-mm-dd)	Time	Latitude (degree)	Longitude (degree)	Altitude (km)	Solar Zenith Angle (degree)	Solar Azimuthal Angle (degree)	Solar Declination Angle (degree)	Solar Incident Angle to SD Screen (degree)	Solar Incident Angle to SD (degree)	Sun-Telescope Angle (degree)	SD Elevation Angle (degree)	Incident Azimuthal Angle in Sun-Telescope Plane (degree)
1	2012-2-24	21: 5: 8	-63.7	46.8	851.9	107.00	19.68	18.00	25.79	52.35	80.93	21.55	48.95
2	2012-2-24	22:46:38	-63.7	21.4	851.9	107.02	19.68	18.02	25.80	52.33	80.91	21.55	48.93
3	2012-2-25	0:28: 8	-63.7	356.1	851.9	107.04	19.68	18.04	25.82	52.31	80.90	21.54	48.91
4	2012-2-25	2: 9:38	-63.7	330.7	851.9	107.06	19.69	18.06	25.83	52.29	80.88	21.54	48.89
5	2012-2-25	3:51: 8	-63.7	305.3	851.9	107.08	19.69	18.08	25.84	52.27	80.86	21.53	48.87

SD illumination prediction table, available on the NCC Wiki

Summary and Going Forward

- Recreating VIIRS in Blender has clarified the relative positions and orientations of key OBC objects, helping to validate the offline radiometric calibration procedure.
- This visualization has also enabled us to generate an offline SD illumination and lunar calibration prediction table.
- Enhancements/additions to the model will occur as needed.
- Similar model of GOES-R ABI is under construction.



GOES-R Advanced Baseline Imager as viewed in Blender