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

Dave Pogorzala\textsuperscript{1} and Changyong Cao\textsuperscript{2}

\textsuperscript{1} Integrity Applications Incorporated
\textsuperscript{2} NOAA/NESDIS/STAR
08/27/2012
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
Motivation

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

![Diagram showing solar diffuser (SD) and RTA with angles $\theta_{\text{sun}_\text{sd}}$, $\theta_{\text{sd}_\text{rta}}$]
Motivation
SD Orientation (1 of 3)

source: “VIIRS Radiometric Calibration ATBD” with annotated vectors

SD normal vector:
“Mostly +Z, somewhat +X, slightly –Y?”
Sequential Euler rotations can be difficult to visualize for some.

**What is the starting orientation of the SD?**

---

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 $T_{SD/inst}$:

$$T_{SD/inst} = R_z(\gamma_{SD})R_y(\beta_{SD})R_x(\alpha_{SD})$$

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

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

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

(3.3-5a)

Nominal values for the rotation angles $\alpha_{SD}$, $\beta_{SD}$, and $\gamma_{SD}$ are:

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

source: “VIIRS Geolocation ATBD”
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:

\[ \mathbf{n}_D = (X_D, Y_D, Z_D) \]  \hspace{1cm} (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 = ___° ± ___ arcsec, Y’-axis-rotation = ___° ± ___ arcsec.

**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 as:

\[
\text{deg} \leq \text{azimuth angle} \leq \text{deg} \quad \text{and} \quad \text{deg} \leq \text{declination angle} \leq \text{deg}
\]

source: “VIIRS Solar Diffuser BRF Calibration Orientation”

---

**In these four examples:**

- transformation matrix
- Euler angles
- normal vector
- \(x_{\text{VIIRS}}/y_{\text{VIIRS}}/z_{\text{VIIRS}}\) and \(x_{\text{SD}}/y_{\text{SD}}/z_{\text{SD}}\) 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
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.

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.