Applying the SOFIA Coordinate System to the HIRMES Instrument

Category: Engineering
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Introduction

- The Stratospheric Observatory for Infrared Astronomy (SOFIA) is a telescope observing infrared light

Figure 1: The telescope aboard the SOFIA aircraft

- The High-resolution Mid-infrared Spectrometer (HIRMES) is being built to study the structure and evolution of protoplanetary disks
- HIRMES should be in-flight by late 2019

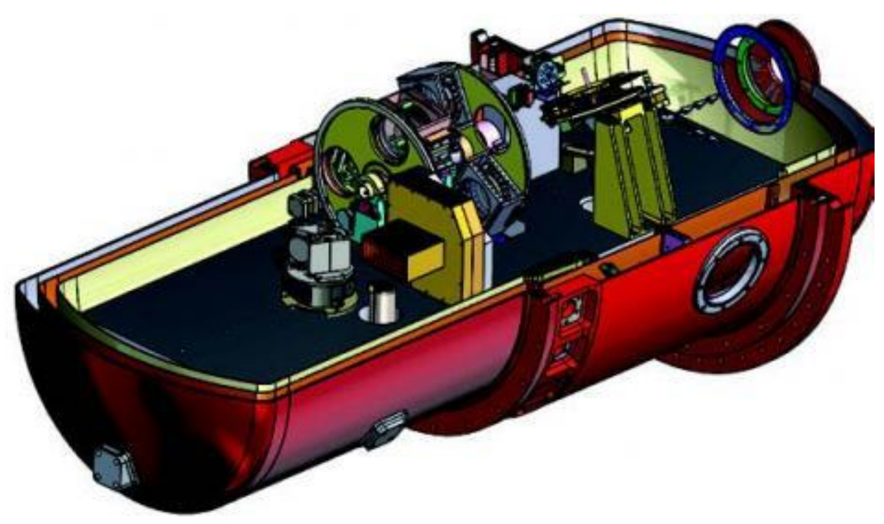

Figure 2: CAD model of HIRMES instrument[1]

Problem Statement

- The SOFIA coordinate system needs to be defined based on the mechanic's schematics
- The first mirror in HIRMES can provide tip and tilt adjustment to align the incoming light onto the slit wheel
- Rotational adjustments cannot be made to the first mirror
- Applying the SOFIA coordinate system will allow the spectrometer and telescope to be aligned

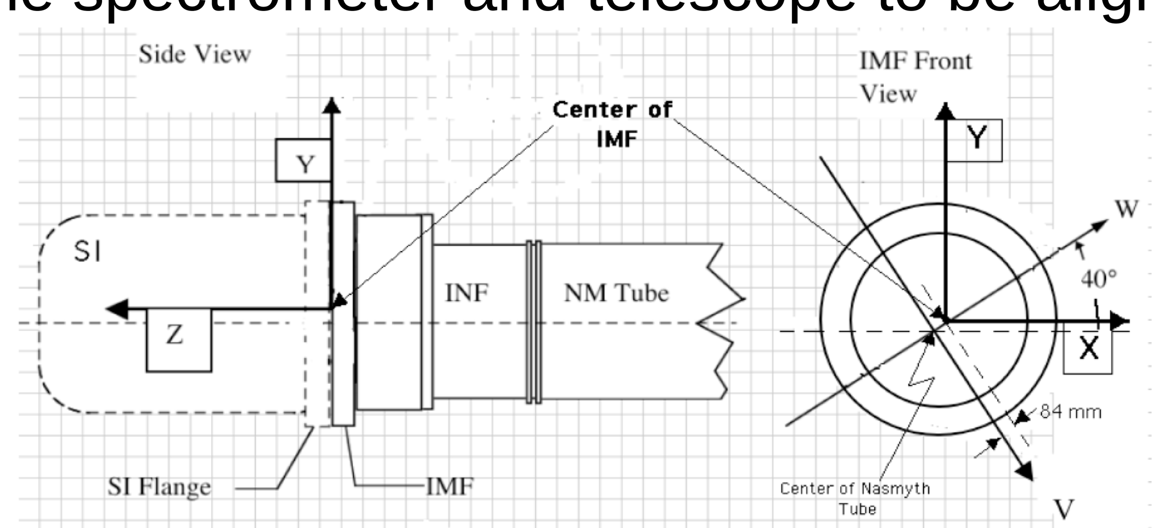

Figure 3: The mechanics schematics the SOFIA and HIRMES reference frames[1]

- Requires rotation of 40º from the X-axis and translation of 84 mm in the negative W direction

Methodology

1. Took measurements of 0.5" and 1.5" tooling balls, as they were tie points around the instrument, and scans of the instrument with a laser radar at multiple locations around the instrument
2. Used Spatial Analyzer (SA) software and the Unified Spatial Metrology Network (USMN) to quantify the uncertainty in the measurements

Figure 3: Scan of full cryostat with USMN points and uncertainty fields

3. Used SA to isolate the front flange points and created a plane

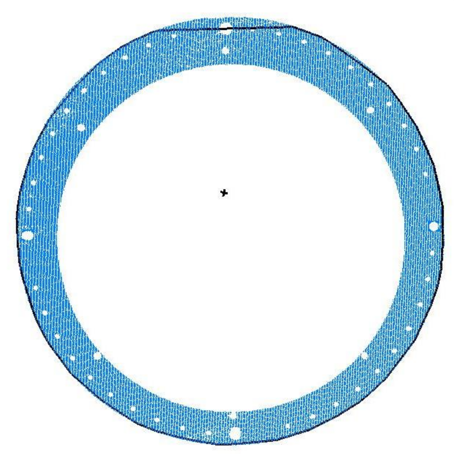

Figure 4: Front flange points with plane (highlighted in black)

4. Used the pin and slot USMN measurements and scan centers that were projected to the front flange plane to determine the center of the front flange and its uncertainty

Table 1: The locations of the pin, slot, and origin and the origin's uncertainty

Name	X (mm)	Y (mm)	Z (mm)
Average Pin	990	7.48	0.176
Average Slot	-0.056	-0.057	0.176
Origin	495	3.74	0.176
Uncert	0.326	0.039	0

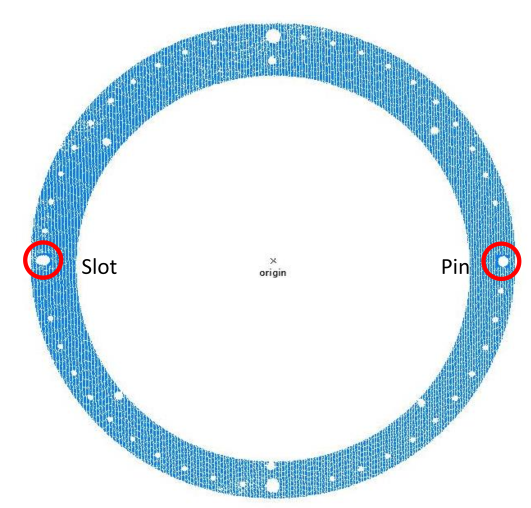

Figure 5: Shows the location of the pin, slot, and origin on the front flange

5. Using SA, the SOFIA reference frame was created

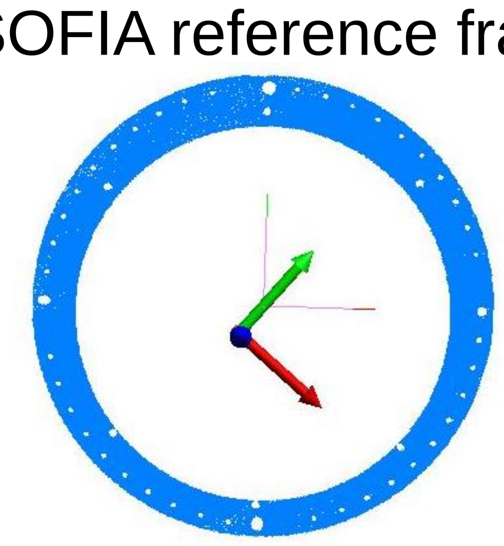

Figure 6: The SOFIA frame (highlighted) and the HIRMES frame on the front flange points

Results

- SOFIA reference frame was successfully created
- USMN points have been translated into the SOFIA frame, creating the coordinate system
- This was process was performed multiple times, creating an uncertainty of 15.5 µm within 1σ

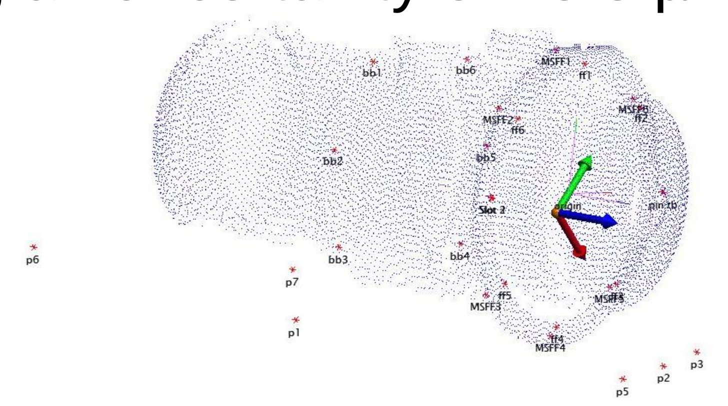

Figure 7: The full scan of the cryostat with the USMN points in the SOFIA frame (highlighted)

Applications

- Allowed the SOFIA coordinate system to be related to the HIRMES coordinate system
- Coordinate systems are necessary for all alignment, integration, and testing (AI&T) of an instrument[2] and will be used throughout AI&T of HIRMES

Example – Hexapod Alignment

- This coordinate system has been used for practicing the alignment of the 60K ring into its nominal position, in the HIRMES hexapod
- This will continue to be used for aligning the flight 60K ring and 5K ring

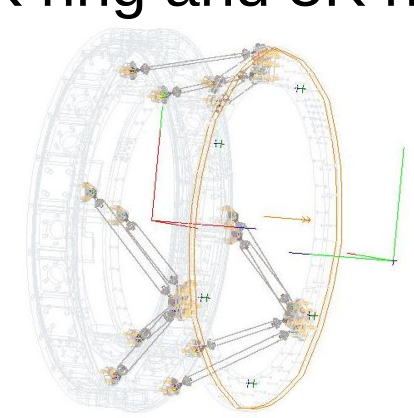

Figure 8: CAD model of hexapod[3]

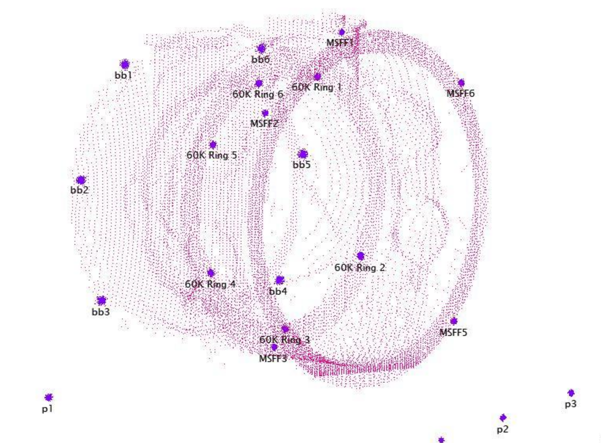

Figure 9: Scan of cryostat with USMN points of 60K ring

Acknowledgements

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References

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[2]Coulter, P., et al. (2016). A Toolbox of Metrology-based Techniques for Optical System Alignment. *The International Society for Optics and Photonics*
[3]Banks, S.