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SIRTF FOCAL PLANE SURVEY
A PRE-FLIGHT ERROR ANALYSIS

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1 EXECUTIVE SUMMARY

This report contains a pre-flight error analysis of the calibration accuracies expected from implementing the currently planned SIRTF focal plane survey strategy. The main purpose of this study is to verify that the planned strategy will meet focal plane survey calibration requirements (as put forth in the SIRTF IOC-SV Mission Plan [4]), and to quantify the actual accuracies expected. The error analysis was performed by running the Instrument Pointing Frame (IPF) Kalman filter on a complete set of simulated IOC-SV survey data, and studying the resulting propagated covariances.

The main conclusion of this study is that the all focal plane calibration requirements can be met with the currently planned survey strategy. The associated margins range from 3 to 95 percent, and tend to be smallest for frames having a 0.14" requirement, and largest for frames having a more generous 0.28" (or larger) requirement. The smallest margin of 3 percent is associated with the IRAC 3.6 and 5.8 um array centers (frames 068 and 069), and the largest margin of 95 percent is associated with the MIPS 160 um array center (frame 087).

For pointing purposes, the most critical calibrations are for the IRS Peakup sweet spots and short wavelength slit centers (frames 019, 023, 052, 028, 034). Results show that these frames are meeting their 0.14" requirements with an expected accuracy of approximately 0.1", which corresponds to a 28 percent margin.

2 INTRODUCTION

2.1 Overview

This report summarizes a pre-flight error analysis of the planned SIRTF focal plane survey strategy. The focal plane survey is expected to be implemented during the first 3 months of the mission, corresponding to the In-Orbit Checkout (IOC) and Science Validation (SV) period. The main purpose of this study is to:

(1) Verify that the planned in-flight experiments are sufficiently informative about the desired calibration parameters

(2) Verify that the in-flight experiments are repeated a sufficient number of times to reduce errors and ensure that calibration requirements will be met.

(3) Analyze the expected focal plane survey accuracies associated with the calibration of all Prime and Inferred frames

The full-up covariance analysis performed here replaces the simple spreadsheet analysis (cf., [4]), used earlier by the Science Teams to roughly gauge the number of times needed to repeat their calibration exeriments. The current study uses the full fidelity of the 37 state IPF Kalman filter to provide a more reliable and accurate error analysis.

This study is intentionally restricted to cover the Fine Surveys, since they must meet the most stringent calibration requirements. The Fine Survey calibrations are expected to be implemented during the latter part of the IOC-SV period, after the telescope has sufficiently cooled and the final focus adjustments have been made.

2.2 Error Analysis Procedure

This study represents a linearized covariance analysis. While not as general as a full-up Monte Carlo study, the results provide useful first-order information about parameter accuracies, and confidence levels to expect in meeting requirements.

The error analysis was performed by running the Instrument Pointing Frame (IPF) Kalman filter on a complete set of simulated IOC-SV survey data, and studying the resulting propagated covariances. For this purpose, each of the science instrument teams provided a detailed description of their planned survey manuevers, and the number of repeats used for their Fine survey calibration strategy. The cognizant science team leads for this effort were:

- Jocelyn Keene - MIPS arrays

- Peter Eisenhardt - IRAC arrays

- Carl Grillmair - IRS slits

- Keven Uchida - IRS peakup arrays

For each of the Prime Frames, the following procedure was followed:

- A FLUTE simulation was developed consistent with the IOC-SV experiment design sequences for Fine calibration of the specified Prime frame. FLUTE (cf., [3]), is the unit test facility used for testing and validating the IPF filter , and is used here to generate all simulation data.

- The Instrument Pointing Frame (IPF) Kalman filter [1][2] was exercised on the FLUTE run data, and used to generate covariance analysis results.

Since the IPF filter is a fully operational Kalman filter, it generates both mean and covariance information. The mean information is realization-dependent and not relevant to the present covariance study (although it may be viewed in the Appendices). In contrast, the covariance propagation is realization-independent (at least to first-order), and is meaningful for providing a generic characterization of the expected calibration accuracy.

Top level calibration performance is summarized in Section 3. More complete information associated with each of the Prime frame runs is given in the Run Summaries of Section 4, and in the Appendices (see Appendix A for IRS, Appendix B for IRAC, and Appendix C for MIPS). The Appendices include FLUTE simulation parameters, centroid plots, estimated vs. true parameters, and expected parameter accuracies (optical distortions, scan mirror parameters, systematic pointing errors, etc.). The Appendices also include some Pre-Coarse survey data runs (IRAC only) that might be of peripheral interest.

To avoid confusion when interpreting results in the Appendices, it is emphasized that an artificially large 10 percent plate scale error was injected into all simulation runs. Actual plate scale errors are not expected to be this large. However, this stresses the estimator for testing purposes and helps visualize the errors when plotting. The large plate scale error has little effect on the covariance analysis above, but makes realized errors appear artificially large. For example, the WAS to IS Brown angles on the Inferred Frames are particularly sensitive to this assumption of large a-priori plate scale errors.

3 TOP LEVEL SUMMARY

The expected calibration accuracy for each of the Prime frames is summarized in Table 3.1, in units of arcseconds, 1-sigma, radial. (P) in the frame column denotes Prime frames (in contrast to Inferred frames, Derived frames, etc.). The last column, denoted as "REQ", lists the requirements by Prime frame as provided in reference [4]. The second column from the right, denoted as "TOTAL", lists the total end-to-end error in localizing the Prime Frame in the telescope focal plane. By comparing these last two columns, it is seen that all of the main focal plane survey requirements are met. Accordingly, it is expected that the Prime frames will be calibrated sufficiently accurately to meet all relevant SIRTF pointing requirements.

FRAME	DESCRIPTION	ANALYSIS	TOTAL	REQ
018(P)	IRS_Red_PeakUp_FOV_Center	Covariance Analysis	0.1279	0.25
019(P)	IRS_Red_PeakUp_FOV_Sweet_Spot	Covariance Analysis	0.1009	0.14
022(P)	IRS_Blue_PeakUp_FOV_Center	Covariance Analysis	0.1285	0.25
023(P)	IRS_Blue_PeakUp_FOV_Sweet_Spot	Covariance Analysis	0.1014	0.14
028(P)	IRS_ShortLo_1st_Ord_Center_Pos	Covariance Analysis	0.1056	0.14
034(P)	IRS_ShortLo_2nd_Ord_Center_Pos	Covariance Analysis	0.1061	0.14
040(P)	IRS_LongLo_1st_Ord_Center_Pos	Covariance Analysis	0.2571	0.28
046(P)	IRS_LongLo_2nd_Ord_Center_Pos	Covariance Analysis	0.2587	0.28
052(P)	IRS_ShortHi_Center_Position	Covariance Analysis	0.1037	0.14
058(P)	IRS_LongHi_Center_Position	Covariance Analysis	0.1864	0.28
068(P)	IRAC_Center_of_3.6umArray	Covariance Analysis	0.1358	0.14
069(P)	IRAC_Center_of_5.8umArray	Covariance Analysis	0.1359	0.14
075(P)	IRAC_Center_of_4.5umArray	Covariance Analysis	0.1103	0.14
076(P)	IRAC_Center_of_8.0umArray	Covariance Analysis	0.1103	0.14
087(P)	MIPS_160um_center_large_FOV	Covariance Analysis	0.2413	3.70
087(P)	MIPS_160um_center_large_FOV	Covariance Analysis	0.2449	3.70
087(P)	MIPS_160um_center_large_FOV	Covariance Analysis	0.2504	3.70
087(P)	MIPS_160um_center_large_FOV	IOC Multi-Run	0.1601	3.70
095(P)	MIPS_24um_center	Covariance Analysis	0.1235	0.14
095(P)	MIPS_24um_center	Covariance Analysis	0.1233	0.14
095(P)	MIPS_24um_center	IOC Multi-Run	0.1172	0.14
107(P)	MIPS_70um_center	Covariance Analysis	0.2957	2.60
107(P)	MIPS_70um_center	Covariance Analysis	0.2936	2.60
107(P)	MIPS_70um_center	IOC Multi-Run	0.2219	2.60
118(P)	MIPS_70um_fine_center	Covariance Analysis	0.2117	1.10
118(P)	MIPS_70um_fine_center	Covariance Analysis	0.2110	1.10
118(P)	MIPS_70um_fine_center	IOC Multi-Run	0.1661	1.10
121(P)	MIPS_SED_center	Covariance Analysis	0.6551	1.10
121(P)	MIPS_SED_center	Covariance Analysis	0.6501	1.10
121(P)	MIPS_SED_center	IOC Multi-Run	0.4116	1.10

Table 3.1: Top Level Performance Summary ([arcsec], 1-sigma, radial)

Some Prime frames have more margin than others. As might be expected, frames having a 0.14" accuracy requirement are tighter on margin than those with a more relaxed 0.28" and larger requirement. The least margin is associated with the 068 Prime Frame for the Center of the 3.6 um array, which is meeting its .14" as requirement with an expected 0.1358" accuracy (3 percent margin). The most margin is associated with the 087 MIPS Prime Frame for the Center of the 160 um array, which is meeting its generous 3.7" requirement with an expected 0.16" accuracy (96 percent margin).

Arguably, the most critical focal plane calibrations are associated with the IRS Peakup Array Sweet Spots (frames 019, 023), and the Centers of the Short-Hi slit (frame 052) and Short-Lo slit (frames 028, 034) since they are essential for accurate incremental offset pointing (SIRTF's most stringent pointing requirement). Here, the Blue and Red Sweet Spots are meeting their 0.14" requirement with an expected 0.1" accuracy (28 percent margin). The Short-Hi and Short-Lo slit centers (frames 052, 028, 034) are meeting their .14" requirement with an expected 0.1" accuracy (28 percent margin).

It has further been shown that if one defines the Sweet Spot region as a 6x6 pixel area, the calibration accuracy degrades to approximately 0.12" (compared to the 0.2" requirement) which corresponds to a 40 percent margin. See more details in Section 4.2 (Red) and Section 4.2 (Blue) for the Peakup arrays where, for this study, the "corners" of the Sweet Spot region were defined by a square 6x6 pixel region on the Peakup array.

It is also worth reminding the reader that the IRS Peakup arrays use units of centi-pixels, while all other arrays use units of pixels. The entrance apertures associated with the IRS spectroscopy slits do not have physical pixels associated with them, so they are assigned a 1 arcsecond "artificial" pixel for calibration purposes.

Runs associated with MIPS Prime frames are treated a little differently. The MIPS calibrations for a given Prime frame are very long in duration, and are broken into separate shorter calibration data sets typically taken on different days of the mission. For processing purposes, each calibration data set is treated as a stand-alone calibration, and is processed separately by the IPF filter. The results are reported as seperate lines in Table 3.1 which indicate "Covariance Analysis". For improved accuracy, the results from the multiple calibration data sets are then combined into a single estimate using the IPF Multi-Run tool, and reported in Table 3.1 on the row which indicates "IOC Multi-Run". For example, it can be seen from Table 3.1 that the MIPS 160 um (frame 087) is calibrated using three separate "Covariance Analysis" data sets, and then combined into a single "IOC Multi-Run". Since in this example there are three statistically independent and (nearly) identical data sets, the improvement from the Multi-Run analysis is approximately sqrt(3) times better than any single Run (i.e., 0.25/sqrt(3)=0.14, compared to 0.16 in Table 3.1).

4   INDIVIDUAL RUN SUMMARIES

Execution summaries are provided in this section for all individual Prime frames. Each execution summary contains two tables. The first table is a calibration error summary. The second table is a prediction error summary. This latter table is not available for MIPS multi-runs. These two tables are discussed below.

Calibration Error Table

The calibration error summary table shows the specific Prime frame, all of its Inferred frames, and all of the four associated array corners. The table shows the total error from the earlier Table 3.1 in the column denoted as "TOTAL" and how it is broken down into the root-sum-square (RSS) combination of three separate errors: IPF, SF, ARW. Here, the IPF error corresponds to errors which are directly modeled by the IPF filter covariances (systematic pointing errors, alignments, and optical distortions); SF is the error due to gyro scale factor: and the ARW is the error due to Angle Random Walk. These latter two errors are not directly modeled by the IPF filter and must be added in an RSS fashion.

Prediction Error Table

This table shows a summary of prediction errors incurred by the IPF Kalman filter. The errors are shown a-priori (the prediction errors **before** calibration) and a-posteriori (the prediction errors **after** calibration) to demonstrate the improvement due to calibration. The a-posteriori error can be roughly interpreted as the pixel-to-sky pointing reconstruction accuracy that was achieved by the IPF filter after calibration. This includes star tracker errors and tracker-to-telescope alignment errors, so it is expected to be between 1 and 5 arcseconds based on current understanding of the pointing system. The Attitude Corrected error is useful because it can be interpreted as an estimate of the achieved centroiding accuracy associated with science centroids taken on the specified array. Centroiding errors are typically between .05 and .2 pixels, depending on the signal-to-noise of the observation. IRS slits have "artificial" pixels scaled to 1 arcsecond, and do not hold to this convention. Peakup arrays use units of centi-pixels, so one would expect centroiding errors between 5 and 20 centi-pixel units.

4.1 IPF EXECUTION SUMMARY OF ID991018

FOCAL PLANE SURVEY ANALYSIS: Covariance Analysis.
INSTRUMENT NAME: IRS_Red_PeakUp_FOV_Center NF: 18
PIX2RADW: 8.72660000E-008[rad/pixel] = 1.8000E-002[arcsec/pixel]
PIX2RADV: 8.72660000E-008[rad/pixel] = 1.8000E-002[arcsec/pixel]

FRAME	DESCRIPTION	IPF[1]	SF[2]	ARW[3]	TOTAL	REQ
018(P)	IRS_Red_PeakUp_FOV_Center	0.0632	0.0855	0.0710	0.1279	0.25
TR (C)	CORNERS OF INSTRUMENT	0.4089	0.0855	0.0710	0.4237	N/A
BR (C)	CORNERS OF INSTRUMENT	0.5553	0.0855	0.0710	0.5663	N/A
TL (C)	CORNERS OF INSTRUMENT	0.5896	0.0855	0.0710	0.6000	N/A
BL (C)	CORNERS OF INSTRUMENT	0.5512	0.0855	0.0710	0.5623	N/A

Table 4.1: IPF calibration error summary ([arcsec], 1-sigma, radial)

RMS METRIC	A PRIORI[4]	A POSTERIORI[4]	ATT. CORRECTED[5]	UNITS
Radial	2.4216	1.0298	0.1392	arcsec
Radial	134.5356	57.2107	7.7332	pixels
W-Axis	82.2847	39.4798	5.9278	pixels
V-Axis	106.4380	41.4055	4.9662	pixels

Table 4.2: Measurement prediction error summary (1-sigma)

---

[1]IPF filter removes systematic pointing errors due to: thermomechanical alignment drift (Body to TPF), gyro bias and bias drift, centroiding error, attitude error, and optical distortion. IPF SIGMA presented here is "NOT Scaled" by the Least Squares Scale factor. The Least Squares Scale Factor was: 1.109770.

[2]Error due to gyro Scale Factor: assumes 95 ppm error over 0.250 degree maneuver.

[3]Error due to gyro Angle Random Walk: assumes ARW = 100 $\mu deg/\sqrt{hr}$, with 490 second Maneuver time (max), and 7 independent Maneuvers.

[4]This can be interpreted as estimate of "pixel to sky" pointing reconstruction error if no science data is used.

[5]This can be interpreted as estimate of achieved S/I centroiding error

4.2 IPF EXECUTION SUMMARY OF ID991019

FOCAL PLANE SURVEY ANALYSIS: Covariance Analysis.
INSTRUMENT NAME: IRS_Red_PeakUp_FOV_Sweet_Spot NF: 19
```
PIX2RADW: 8.72660000E-008[rad/pixel] = 1.8000E-002[arcsec/pixel]
PIX2RADV: 8.72660000E-008[rad/pixel] = 1.8000E-002[arcsec/pixel]
```

FRAME	DESCRIPTION	IPF[1]	SF[2]	ARW[3]	TOTAL	REQ
019(P)	IRS_Red_PeakUp_FOV_Sweet_Spot	0.0334	0.0855	0.0420	0.1009	0.14
TR (C)	CORNERS OF INSTRUMENT	0.0430	0.0855	0.0420	0.1045	N/A
BR (C)	CORNERS OF INSTRUMENT	0.0472	0.0855	0.0420	0.1063	N/A
TL (C)	CORNERS OF INSTRUMENT	0.0654	0.0855	0.0420	0.1156	N/A
BL (C)	CORNERS OF INSTRUMENT	0.0709	0.0855	0.0420	0.1187	N/A

Table 4.3: IPF calibration error summary ([arcsec], 1-sigma, radial)

RMS METRIC	A PRIORI[4]	A POSTERIORI[4]	ATT. CORRECTED[5]	UNITS
Radial	2.2406	1.3922	0.1487	arcsec
Radial	124.4764	77.3449	8.2629	pixels
W-Axis	68.2405	52.2785	5.8166	pixels
V-Axis	104.1039	57.0017	5.8688	pixels

Table 4.4: Measurement prediction error summary (1-sigma)

---

[1]IPF filter removes systematic pointing errors due to: thermomechanical alignment drift (Body to TPF), gyro bias and bias drift, centroiding error, attitude error, and optical distortion. IPF SIGMA presented here is "NOT Scaled" by the Least Squares Scale factor. The Least Squares Scale Factor was: 1.093741.

[2]Error due to gyro Scale Factor: assumes 95 ppm error over 0.250 degree maneuver.

[3]Error due to gyro Angle Random Walk: assumes ARW = 100 $\mu deg/\sqrt{hr}$, with 490 second Maneuver time (max), and 20 independent Maneuvers.

[4]This can be interpreted as estimate of "pixel to sky" pointing reconstruction error if no science data is used.

[5]This can be interpreted as estimate of achieved S/I centroiding error

4.3 IPF EXECUTION SUMMARY OF ID991022

FOCAL PLANE SURVEY ANALYSIS: Covariance Analysis.
INSTRUMENT NAME: IRS_Blue_PeakUp_FOV_Center NF: 22
```
PIX2RADW: 8.72660000E-008[rad/pixel] = 1.8000E-002[arcsec/pixel]
PIX2RADV: 8.72660000E-008[rad/pixel] = 1.8000E-002[arcsec/pixel]
```

FRAME	DESCRIPTION	IPF[1]	SF[2]	ARW[3]	TOTAL	REQ
022(P)	IRS_Blue_PeakUp_FOV_Center	0.0646	0.0855	0.0710	0.1285	0.25
TR (C)	CORNERS OF INSTRUMENT	0.4553	0.0855	0.0710	0.4687	N/A
BR (C)	CORNERS OF INSTRUMENT	0.5831	0.0855	0.0710	0.5936	N/A
TL (C)	CORNERS OF INSTRUMENT	0.5978	0.0855	0.0710	0.6080	N/A
BL (C)	CORNERS OF INSTRUMENT	0.6226	0.0855	0.0710	0.6324	N/A

Table 4.5: IPF calibration error summary ([arcsec], 1-sigma, radial)

RMS METRIC	A PRIORI[4]	A POSTERIORI[4]	ATT. CORRECTED[5]	UNITS
Radial	1.8245	0.6989	0.1482	arcsec
Radial	101.3591	38.8306	8.2316	pixels
W-Axis	69.9566	14.0138	5.9145	pixels
V-Axis	73.3468	36.2136	5.7252	pixels

Table 4.6: Measurement prediction error summary (1-sigma)

---

[1]IPF filter removes systematic pointing errors due to: thermomechanical alignment drift (Body to TPF), gyro bias and bias drift, centroiding error, attitude error, and optical distortion. IPF SIGMA presented here is "NOT Scaled" by the Least Squares Scale factor. The Least Squares Scale Factor was: 1.190793.

[2]Error due to gyro Scale Factor: assumes 95 ppm error over 0.250 degree maneuver.

[3]Error due to gyro Angle Random Walk: assumes ARW = 100 $\mu deg/\sqrt{hr}$, with 490 second Maneuver time (max), and 7 independent Maneuvers.

[4]This can be interpreted as estimate of "pixel to sky" pointing reconstruction error if no science data is used.

[5]This can be interpreted as estimate of achieved S/I centroiding error

4.4 IPF EXECUTION SUMMARY OF ID991023

FOCAL PLANE SURVEY ANALYSIS: Covariance Analysis.
INSTRUMENT NAME: IRS_Blue_PeakUp_FOV_Sweet_Spot NF: 23
```
PIX2RADW: 8.72660000E-008[rad/pixel] = 1.8000E-002[arcsec/pixel]
PIX2RADV: 8.72660000E-008[rad/pixel] = 1.8000E-002[arcsec/pixel]
```

FRAME	DESCRIPTION	IPF[1]	SF[2]	ARW[3]	TOTAL	REQ
023(P)	IRS_Blue_PeakUp_FOV_Sweet_Spot	0.0346	0.0855	0.0420	0.1014	0.14
TR (C)	CORNERS OF INSTRUMENT	0.0427	0.0855	0.0420	0.1044	N/A
BR (C)	CORNERS OF INSTRUMENT	0.0529	0.0855	0.0420	0.1090	N/A
TL (C)	CORNERS OF INSTRUMENT	0.0645	0.0855	0.0420	0.1150	N/A
BL (C)	CORNERS OF INSTRUMENT	0.0720	0.0855	0.0420	0.1194	N/A

Table 4.7: IPF calibration error summary ([arcsec], 1-sigma, radial)

RMS METRIC	A PRIORI[4]	A POSTERIORI[4]	ATT. CORRECTED[5]	UNITS
Radial	2.0538	1.3430	0.1486	arcsec
Radial	114.1022	74.6103	8.2540	pixels
W-Axis	66.0626	60.8339	5.8371	pixels
V-Axis	93.0325	43.1964	5.8358	pixels

Table 4.8: Measurement prediction error summary (1-sigma)

---

[1]IPF filter removes systematic pointing errors due to: thermomechanical alignment drift (Body to TPF), gyro bias and bias drift, centroiding error, attitude error, and optical distortion. IPF SIGMA presented here is "NOT Scaled" by the Least Squares Scale factor. The Least Squares Scale Factor was: 1.128829.

[2]Error due to gyro Scale Factor: assumes 95 ppm error over 0.250 degree maneuver.

[3]Error due to gyro Angle Random Walk: assumes ARW = 100 $\mu deg/\sqrt{hr}$, with 490 second Maneuver time (max), and 20 independent Maneuvers.

[4]This can be interpreted as estimate of "pixel to sky" pointing reconstruction error if no science data is used.

[5]This can be interpreted as estimate of achieved S/I centroiding error

4.5 IPF EXECUTION SUMMARY OF ID992028

FOCAL PLANE SURVEY ANALYSIS: Covariance Analysis.
INSTRUMENT NAME: IRS_ShortLo_1st_Ord_Center_Pos NF: 28
```
PIX2RADW: 4.84813681E-06[rad/pixel] = 1.0000E+00[arcsec/pixel]
PIX2RADV: 4.84813681E-06[rad/pixel] = 1.0000E+00[arcsec/pixel]
```

FRAME	DESCRIPTION	IPF[1]	SF[2]	ARW[3]	TOTAL	REQ
028(P)	IRS_ShortLo_1st_Ord_Center_Pos	0.0466	0.0855	0.0408	0.1056	0.14
026(I)	IRS_ShortLo_1st_Ord_1st_Pos	0.0519	0.0855	0.0408	0.1080	N/A
027(I)	IRS_ShortLo_1st_Ord_2nd_Pos	0.0492	0.0855	0.0408	0.1067	N/A
029(I)	IRS_ShortLo_Module_Center	0.0943	0.0855	0.0408	0.1336	N/A
TR (C)	CORNERS OF INSTRUMENT	0.0824	0.0855	0.0408	0.1256	N/A
BR (C)	CORNERS OF INSTRUMENT	0.0719	0.0855	0.0408	0.1189	N/A
TL (C)	CORNERS OF INSTRUMENT	0.0868	0.0855	0.0408	0.1285	N/A
BL (C)	CORNERS OF INSTRUMENT	0.0778	0.0855	0.0408	0.1226	N/A

Table 4.9: IPF calibration error summary ([arcsec], 1-sigma, radial)

RMS METRIC	A PRIORI[4]	A POSTERIORI[4]	ATT. CORRECTED[5]	UNITS
Radial	2.0798	0.8361	0.8179	arcsec
Radial	2.0798	0.8361	0.8179	pixels
W-Axis	1.7932	0.4411	0.4331	pixels
V-Axis	1.0535	0.7102	0.6939	pixels

Table 4.10: Measurement prediction error summary (1-sigma)

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[1]IPF filter removes systematic pointing errors due to: thermomechanical alignment drift (Body to TPF), gyro bias and bias drift, centroiding error, attitude error, and optical distortion. IPF SIGMA presented here is "NOT Scaled" by the Least Squares Scale factor. The Least Squares Scale Factor was: 0.947647.

[2]Error due to gyro Scale Factor: assumes 95 ppm error over 0.250 degree maneuver.

[3]Error due to gyro Angle Random Walk: assumes ARW = 100 $\mu deg/\sqrt{hr}$, with 740 second Maneuver time (max), and 32 independent Maneuvers.

[4]This can be interpreted as estimate of "pixel to sky" pointing reconstruction error if no science data is used.

[5]This can be interpreted as estimate of achieved S/I centroiding error

4.6 IPF EXECUTION SUMMARY OF ID992034

FOCAL PLANE SURVEY ANALYSIS: Covariance Analysis.
INSTRUMENT NAME: IRS_ShortLo_2nd_Ord_Center_Pos NF: 34
```
PIX2RADW: 4.84813681E-06[rad/pixel] = 1.0000E+00[arcsec/pixel]
PIX2RADV: 4.84813681E-06[rad/pixel] = 1.0000E+00[arcsec/pixel]
```

FRAME	DESCRIPTION	IPF[1]	SF[2]	ARW[3]	TOTAL	REQ
034(P)	IRS_ShortLo_2nd_Ord_Center_Pos	0.0478	0.0855	0.0408	0.1061	0.14
032(I)	IRS_ShortLo_2nd_Ord_1st_Pos	0.0530	0.0855	0.0408	0.1086	N/A
033(I)	IRS_ShortLo_2nd_Ord_2nd_Pos	0.0505	0.0855	0.0408	0.1074	N/A
TR (C)	CORNERS OF INSTRUMENT	0.0839	0.0855	0.0408	0.1265	N/A
BR (C)	CORNERS OF INSTRUMENT	0.0733	0.0855	0.0408	0.1198	N/A
TL (C)	CORNERS OF INSTRUMENT	0.0889	0.0855	0.0408	0.1299	N/A
BL (C)	CORNERS OF INSTRUMENT	0.0780	0.0855	0.0408	0.1227	N/A

Table 4.11: IPF calibration error summary ([arcsec], 1-sigma, radial)

RMS METRIC	A PRIORI[4]	A POSTERIORI[4]	ATT. CORRECTED[5]	UNITS
Radial	2.9959	0.9409	0.9241	arcsec
Radial	2.9959	0.9409	0.9241	pixels
W-Axis	2.0384	0.4544	0.4421	pixels
V-Axis	2.1955	0.8238	0.8115	pixels

Table 4.12: Measurement prediction error summary (1-sigma)

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[1]IPF filter removes systematic pointing errors due to: thermomechanical alignment drift (Body to TPF), gyro bias and bias drift, centroiding error, attitude error, and optical distortion. IPF SIGMA presented here is "NOT Scaled" by the Least Squares Scale factor. The Least Squares Scale Factor was: 0.982943.

[2]Error due to gyro Scale Factor: assumes 95 ppm error over 0.250 degree maneuver.

[3]Error due to gyro Angle Random Walk: assumes ARW = 100 $\mu deg/\sqrt{hr}$, with 740 second Maneuver time (max), and 32 independent Maneuvers.

[4]This can be interpreted as estimate of "pixel to sky" pointing reconstruction error if no science data is used.

[5]This can be interpreted as estimate of achieved S/I centroiding error

4.7 IPF EXECUTION SUMMARY OF ID992040

FOCAL PLANE SURVEY ANALYSIS: Covariance Analysis.
INSTRUMENT NAME: IRS_LongLo_1st_Ord_Center_Pos NF: 40
```
PIX2RADW: 4.84813681E-06[rad/pixel] = 1.0000E+00[arcsec/pixel]
PIX2RADV: 4.84813681E-06[rad/pixel] = 1.0000E+00[arcsec/pixel]
```

FRAME	DESCRIPTION	IPF[1]	SF[2]	ARW[3]	TOTAL	REQ
040(P)	IRS_LongLo_1st_Ord_Center_Pos	0.2312	0.0855	0.0730	0.2571	0.28
038(I)	IRS_LongLo_1st_Ord_1st_Pos	0.2510	0.0855	0.0730	0.2750	N/A
039(I)	IRS_LongLo_1st_Ord_2nd_Pos	0.2564	0.0855	0.0730	0.2800	N/A
041(I)	IRS_LongLo_Module_Center	0.4766	0.0855	0.0730	0.4897	N/A
TR (C)	CORNERS OF INSTRUMENT	0.4058	0.0855	0.0730	0.4211	N/A
BR (C)	CORNERS OF INSTRUMENT	0.4168	0.0855	0.0730	0.4317	N/A
TL (C)	CORNERS OF INSTRUMENT	0.4234	0.0855	0.0730	0.4380	N/A
BL (C)	CORNERS OF INSTRUMENT	0.4194	0.0855	0.0730	0.4342	N/A

Table 4.13: IPF calibration error summary ([arcsec], 1-sigma, radial)

RMS METRIC	A PRIORI[4]	A POSTERIORI[4]	ATT. CORRECTED[5]	UNITS
Radial	5.0644	2.5467	2.3778	arcsec
Radial	5.0644	2.5467	2.3778	pixels
W-Axis	4.5603	1.4728	1.1774	pixels
V-Axis	2.2028	2.0775	2.0658	pixels

Table 4.14: Measurement prediction error summary (1-sigma)

---

[1]IPF filter removes systematic pointing errors due to: thermomechanical alignment drift (Body to TPF), gyro bias and bias drift, centroiding error, attitude error, and optical distortion. IPF SIGMA presented here is "NOT Scaled" by the Least Squares Scale factor. The Least Squares Scale Factor was: 1.070036.

[2]Error due to gyro Scale Factor: assumes 95 ppm error over 0.250 degree maneuver.

[3]Error due to gyro Angle Random Walk: assumes ARW = 100 $\mu deg/\sqrt{hr}$, with 740 second Maneuver time (max), and 10 independent Maneuvers.

[4]This can be interpreted as estimate of "pixel to sky" pointing reconstruction error if no science data is used.

[5]This can be interpreted as estimate of achieved S/I centroiding error

4.8 IPF EXECUTION SUMMARY OF ID992046

FOCAL PLANE SURVEY ANALYSIS: Covariance Analysis.
INSTRUMENT NAME: IRS_LongLo_2nd_Ord_Center_Pos NF: 46
```
PIX2RADW: 4.84813681E-06[rad/pixel] = 1.0000E+00[arcsec/pixel]
PIX2RADV: 4.84813681E-06[rad/pixel] = 1.0000E+00[arcsec/pixel]
```

FRAME	DESCRIPTION	IPF[1]	SF[2]	ARW[3]	TOTAL	REQ
046(P)	IRS_LongLo_2nd_Ord_Center_Pos	0.2330	0.0855	0.0730	0.2587	0.28
044(I)	IRS_LongLo_2nd_Ord_1st_Pos	0.2563	0.0855	0.0730	0.2798	N/A
045(I)	IRS_LongLo_2nd_Ord_2nd_Pos	0.2494	0.0855	0.0730	0.2735	N/A
TR (C)	CORNERS OF INSTRUMENT	0.4328	0.0855	0.0730	0.4472	N/A
BR (C)	CORNERS OF INSTRUMENT	0.3835	0.0855	0.0730	0.3996	N/A
TL (C)	CORNERS OF INSTRUMENT	0.4161	0.0855	0.0730	0.4310	N/A
BL (C)	CORNERS OF INSTRUMENT	0.3746	0.0855	0.0730	0.3911	N/A

Table 4.15: IPF calibration error summary ([arcsec], 1-sigma, radial)

RMS METRIC	A PRIORI[4]	A POSTERIORI[4]	ATT. CORRECTED[5]	UNITS
Radial	4.5138	2.5817	2.3507	arcsec
Radial	4.5138	2.5817	2.3507	pixels
W-Axis	4.0279	1.2698	1.1567	pixels
V-Axis	2.0372	2.2478	2.0464	pixels

Table 4.16: Measurement prediction error summary (1-sigma)

---

[1]IPF filter removes systematic pointing errors due to: thermomechanical alignment drift (Body to TPF), gyro bias and bias drift, centroiding error, attitude error, and optical distortion. IPF SIGMA presented here is "NOT Scaled" by the Least Squares Scale factor. The Least Squares Scale Factor was: 0.999059.

[2]Error due to gyro Scale Factor: assumes 95 ppm error over 0.250 degree maneuver.

[3]Error due to gyro Angle Random Walk: assumes ARW = 100 $\mu deg/\sqrt{hr}$, with 740 second Maneuver time (max), and 10 independent Maneuvers.

[4]This can be interpreted as estimate of "pixel to sky" pointing reconstruction error if no science data is used.

[5]This can be interpreted as estimate of achieved S/I centroiding error

4.9 IPF EXECUTION SUMMARY OF ID995052

FOCAL PLANE SURVEY ANALYSIS: Covariance Analysis.
INSTRUMENT NAME: IRS_ShortHi_Center_Position NF: 52
```
PIX2RADW: 4.84813681E-06[rad/pixel] = 1.0000E+00[arcsec/pixel]
PIX2RADV: 4.84813681E-06[rad/pixel] = 1.0000E+00[arcsec/pixel]
```

FRAME	DESCRIPTION	IPF[1]	SF[2]	ARW[3]	TOTAL	REQ
052(P)	IRS_ShortHi_Center_Position	0.0383	0.0855	0.0445	0.1037	0.14
050(I)	IRS_ShortHi_1st_Position	0.0417	0.0855	0.0445	0.1050	N/A
051(I)	IRS_ShortHi_2nd_Position	0.0378	0.0855	0.0445	0.1035	N/A
TR (C)	CORNERS OF INSTRUMENT	0.0557	0.0855	0.0445	0.1113	N/A
BR (C)	CORNERS OF INSTRUMENT	0.0448	0.0855	0.0445	0.1063	N/A
TL (C)	CORNERS OF INSTRUMENT	0.0606	0.0855	0.0445	0.1138	N/A
BL (C)	CORNERS OF INSTRUMENT	0.0573	0.0855	0.0445	0.1121	N/A

Table 4.17: IPF calibration error summary ([arcsec], 1-sigma, radial)

RMS METRIC	A PRIORI[4]	A POSTERIORI[4]	ATT. CORRECTED[5]	UNITS
Radial	1.8495	1.0968	1.0763	arcsec
Radial	1.8495	1.0968	1.0763	pixels
W-Axis	0.8534	0.5961	0.5785	pixels
V-Axis	1.6409	0.9207	0.9077	pixels

Table 4.18: Measurement prediction error summary (1-sigma)

---

[1]IPF filter removes systematic pointing errors due to: thermomechanical alignment drift (Body to TPF), gyro bias and bias drift, centroiding error, attitude error, and optical distortion. IPF SIGMA presented here is "NOT Scaled" by the Least Squares Scale factor. The Least Squares Scale Factor was: 0.970098.

[2]Error due to gyro Scale Factor: assumes 95 ppm error over 0.250 degree maneuver.

[3]Error due to gyro Angle Random Walk: assumes ARW = 100 $\mu deg/\sqrt{hr}$, with 880 second Maneuver time (max), and 32 independent Maneuvers.

[4]This can be interpreted as estimate of "pixel to sky" pointing reconstruction error if no science data is used.

[5]This can be interpreted as estimate of achieved S/I centroiding error

4.10 IPF EXECUTION SUMMARY OF ID992058

FOCAL PLANE SURVEY ANALYSIS: Covariance Analysis.
INSTRUMENT NAME: IRS_LongHi_Center_Position NF: 58
```
PIX2RADW: 4.84813681E-06[rad/pixel] = 1.0000E+00[arcsec/pixel]
PIX2RADV: 4.84813681E-06[rad/pixel] = 1.0000E+00[arcsec/pixel]
```

FRAME	DESCRIPTION	IPF[1]	SF[2]	ARW[3]	TOTAL	REQ
058(P)	IRS_LongHi_Center_Position	0.1407	0.0855	0.0872	0.1864	0.28
056(I)	IRS_LongHi_1st_Position	0.1466	0.0855	0.0872	0.1908	N/A
057(I)	IRS_LongHi_2nd_Position	0.1544	0.0855	0.0872	0.1969	N/A
TR (C)	CORNERS OF INSTRUMENT	0.2568	0.0855	0.0872	0.2844	N/A
BR (C)	CORNERS OF INSTRUMENT	0.2624	0.0855	0.0872	0.2894	N/A
TL (C)	CORNERS OF INSTRUMENT	0.2500	0.0855	0.0872	0.2782	N/A
BL (C)	CORNERS OF INSTRUMENT	0.2414	0.0855	0.0872	0.2705	N/A

Table 4.19: IPF calibration error summary ([arcsec], 1-sigma, radial)

RMS METRIC	A PRIORI[4]	A POSTERIORI[4]	ATT. CORRECTED[5]	UNITS
Radial	2.9122	2.2034	1.8477	arcsec
Radial	2.9122	2.2034	1.8477	pixels
W-Axis	2.1321	1.4224	1.2601	pixels
V-Axis	1.9837	1.6827	1.3514	pixels

Table 4.20: Measurement prediction error summary (1-sigma)

---

[1]IPF filter removes systematic pointing errors due to: thermomechanical alignment drift (Body to TPF), gyro bias and bias drift, centroiding error, attitude error, and optical distortion. IPF SIGMA presented here is "NOT Scaled" by the Least Squares Scale factor. The Least Squares Scale Factor was: 1.007471.

[2]Error due to gyro Scale Factor: assumes 95 ppm error over 0.250 degree maneuver.

[3]Error due to gyro Angle Random Walk: assumes ARW = 100 $\mu deg/\sqrt{hr}$, with 740 second Maneuver time (max), and 7 independent Maneuvers.

[4]This can be interpreted as estimate of "pixel to sky" pointing reconstruction error if no science data is used.

[5]This can be interpreted as estimate of achieved S/I centroiding error

4.11 IPF EXECUTION SUMMARY OF ID991068

FOCAL PLANE SURVEY ANALYSIS: Covariance Analysis.
INSTRUMENT NAME: IRAC_Center_of_3.6umArray NF: 68
PIX2RADW: 5.86625000E-006[rad/pixel] = 1.2100E+000[arcsec/pixel]
PIX2RADV: 5.86625000E-006[rad/pixel] = 1.2100E+000[arcsec/pixel]

FRAME	DESCRIPTION	IPF[1]	SF[2]	ARW[3]	TOTAL	REQ
068(P)	IRAC_Center_of_3.6umArray	0.0883	0.0855	0.0576	0.1358	0.14
070(I)	IRAC_Center_of_3.6umSub-array	0.1012	0.0855	0.0576	0.1445	N/A
TR (C)	CORNERS OF INSTRUMENT	0.0846	0.0855	0.0576	0.1334	N/A
BR (C)	CORNERS OF INSTRUMENT	0.0941	0.0855	0.0576	0.1396	N/A
TL (C)	CORNERS OF INSTRUMENT	0.0972	0.0855	0.0576	0.1417	N/A
BL (C)	CORNERS OF INSTRUMENT	0.1051	0.0855	0.0576	0.1472	N/A

Table 4.21: IPF calibration error summary ([arcsec], 1-sigma, radial)

RMS METRIC	A PRIORI[4]	A POSTERIORI[4]	ATT. CORRECTED[5]	UNITS
Radial	16.2650	1.1312	0.2203	arcsec
Radial	13.4421	0.9349	0.1821	pixels
W-Axis	9.3995	0.5690	0.1289	pixels
V-Axis	9.6093	0.7418	0.1286	pixels

Table 4.22: Measurement prediction error summary (1-sigma)

---

[1]IPF filter removes systematic pointing errors due to: thermomechanical alignment drift (Body to TPF), gyro bias and bias drift, centroiding error, attitude error, and optical distortion. IPF SIGMA presented here is "NOT Scaled" by the Least Squares Scale factor. The Least Squares Scale Factor was: 1.300400.

[2]Error due to gyro Scale Factor: assumes 95 ppm error over 0.250 degree maneuver.

[3]Error due to gyro Angle Random Walk: assumes ARW $= 100 \ \mu deg/\sqrt{hr}$, with 600 second Maneuver time (max), and 13 independent Maneuvers.

[4]This can be interpreted as estimate of "pixel to sky" pointing reconstruction error if no science data is used.

[5]This can be interpreted as estimate of achieved S/I centroiding error

4.12 IPF EXECUTION SUMMARY OF ID991069

FOCAL PLANE SURVEY ANALYSIS: Covariance Analysis.
INSTRUMENT NAME: IRAC_Center_of_5.8umArray NF: 69
```
PIX2RADW: 5.86625000E-006[rad/pixel] = 1.2100E+000[arcsec/pixel]
PIX2RADV: 5.86625000E-006[rad/pixel] = 1.2100E+000[arcsec/pixel]
```

FRAME	DESCRIPTION	IPF[1]	SF[2]	ARW[3]	TOTAL	REQ
069(P)	IRAC_Center_of_5.8umArray	0.0885	0.0855	0.0576	0.1359	0.14
070(I)	IRAC_Center_of_3.6umSub-array	0.1013	0.0855	0.0576	0.1446	N/A
TR (C)	CORNERS OF INSTRUMENT	0.0848	0.0855	0.0576	0.1335	N/A
BR (C)	CORNERS OF INSTRUMENT	0.0943	0.0855	0.0576	0.1397	N/A
TL (C)	CORNERS OF INSTRUMENT	0.0973	0.0855	0.0576	0.1418	N/A
BL (C)	CORNERS OF INSTRUMENT	0.1052	0.0855	0.0576	0.1473	N/A

Table 4.23: IPF calibration error summary ([arcsec], 1-sigma, radial)

RMS METRIC	A PRIORI[4]	A POSTERIORI[4]	ATT. CORRECTED[5]	UNITS
Radial	15.1482	1.1060	0.2170	arcsec
Radial	12.5191	0.9140	0.1794	pixels
W-Axis	9.7684	0.7176	0.1232	pixels
V-Axis	7.8299	0.5662	0.1304	pixels

Table 4.24: Measurement prediction error summary (1-sigma)

---

[1]IPF filter removes systematic pointing errors due to: thermomechanical alignment drift (Body to TPF), gyro bias and bias drift, centroiding error, attitude error, and optical distortion. IPF SIGMA presented here is "NOT Scaled" by the Least Squares Scale factor. The Least Squares Scale Factor was: 1.267990.

[2]Error due to gyro Scale Factor: assumes 95 ppm error over 0.250 degree maneuver.

[3]Error due to gyro Angle Random Walk: assumes ARW = 100 $\mu deg/\sqrt{hr}$, with 600 second Maneuver time (max), and 13 independent Maneuvers.

[4]This can be interpreted as estimate of "pixel to sky" pointing reconstruction error if no science data is used.

[5]This can be interpreted as estimate of achieved S/I centroiding error

4.13 IPF EXECUTION SUMMARY OF ID991075

FOCAL PLANE SURVEY ANALYSIS: Covariance Analysis.
INSTRUMENT NAME: IRAC_Center_of_4.5umArray NF: 75
```
PIX2RADW: 5.85170000E-006[rad/pixel] = 1.2070E+000[arcsec/pixel]
PIX2RADV: 5.85170000E-006[rad/pixel] = 1.2070E+000[arcsec/pixel]
```

FRAME	DESCRIPTION	IPF[1]	SF[2]	ARW[3]	TOTAL	REQ
075(P)	IRAC_Center_of_4.5umArray	0.0392	0.0855	0.0576	0.1103	0.14
077(I)	IRAC_Center_of_4.5umSub-Array	0.0495	0.0855	0.0576	0.1144	N/A
TR (C)	CORNERS OF INSTRUMENT	0.0507	0.0855	0.0576	0.1149	N/A
BR (C)	CORNERS OF INSTRUMENT	0.0501	0.0855	0.0576	0.1146	N/A
TL (C)	CORNERS OF INSTRUMENT	0.0530	0.0855	0.0576	0.1159	N/A
BL (C)	CORNERS OF INSTRUMENT	0.0537	0.0855	0.0576	0.1163	N/A

Table 4.25: IPF calibration error summary ([arcsec], 1-sigma, radial)

RMS METRIC	A PRIORI[4]	A POSTERIORI[4]	ATT. CORRECTED[5]	UNITS
Radial	16.1895	1.1310	0.2196	arcsec
Radial	13.4130	0.9371	0.1819	pixels
W-Axis	9.3363	0.5703	0.1287	pixels
V-Axis	9.6303	0.7435	0.1285	pixels

Table 4.26: Measurement prediction error summary (1-sigma)

---

[1]IPF filter removes systematic pointing errors due to: thermomechanical alignment drift (Body to TPF), gyro bias and bias drift, centroiding error, attitude error, and optical distortion. IPF SIGMA presented here is "NOT Scaled" by the Least Squares Scale factor. The Least Squares Scale Factor was: 1.297251.

[2]Error due to gyro Scale Factor: assumes 95 ppm error over 0.250 degree maneuver.

[3]Error due to gyro Angle Random Walk: assumes ARW = 100 $\mu deg/\sqrt{hr}$, with 600 second Maneuver time (max), and 13 independent Maneuvers.

[4]This can be interpreted as estimate of "pixel to sky" pointing reconstruction error if no science data is used.

[5]This can be interpreted as estimate of achieved S/I centroiding error

4.14 IPF EXECUTION SUMMARY OF ID991076

FOCAL PLANE SURVEY ANALYSIS: Covariance Analysis.
INSTRUMENT NAME: IRAC_Center_of_8.0umArray NF: 76
```
PIX2RADW: 5.86140000E-006[rad/pixel] = 1.2090E+000[arcsec/pixel]
PIX2RADV: 5.86140000E-006[rad/pixel] = 1.2090E+000[arcsec/pixel]
```

FRAME	DESCRIPTION	IPF[1]	SF[2]	ARW[3]	TOTAL	REQ
076(P)	IRAC_Center_of_8.0umArray	0.0392	0.0855	0.0576	0.1103	0.14
079(I)	IRAC_Center_of_8.0umSub-Array	0.0465	0.0855	0.0576	0.1131	N/A
TR (C)	CORNERS OF INSTRUMENT	0.0508	0.0855	0.0576	0.1149	N/A
BR (C)	CORNERS OF INSTRUMENT	0.0501	0.0855	0.0576	0.1147	N/A
TL (C)	CORNERS OF INSTRUMENT	0.0531	0.0855	0.0576	0.1160	N/A
BL (C)	CORNERS OF INSTRUMENT	0.0537	0.0855	0.0576	0.1163	N/A

Table 4.27: IPF calibration error summary ([arcsec], 1-sigma, radial)

RMS METRIC	A PRIORI[4]	A POSTERIORI[4]	ATT. CORRECTED[5]	UNITS
Radial	17.1566	1.2882	0.2177	arcsec
Radial	14.1908	1.0655	0.1801	pixels
W-Axis	9.8126	0.6232	0.1227	pixels
V-Axis	10.2514	0.8642	0.1317	pixels

Table 4.28: Measurement prediction error summary (1-sigma)

---

[1]IPF filter removes systematic pointing errors due to: thermomechanical alignment drift (Body to TPF), gyro bias and bias drift, centroiding error, attitude error, and optical distortion. IPF SIGMA presented here is "NOT Scaled" by the Least Squares Scale factor. The Least Squares Scale Factor was: 1.273899.

[2]Error due to gyro Scale Factor: assumes 95 ppm error over 0.250 degree maneuver.

[3]Error due to gyro Angle Random Walk: assumes ARW = 100 $\mu deg/\sqrt{hr}$, with 600 second Maneuver time (max), and 13 independent Maneuvers.

[4]This can be interpreted as estimate of "pixel to sky" pointing reconstruction error if no science data is used.

[5]This can be interpreted as estimate of achieved S/I centroiding error

4.15   IPF EXECUTION SUMMARY OF ID991087

FOCAL PLANE SURVEY ANALYSIS: Covariance Analysis.
INSTRUMENT NAME: MIPS_160um_center_large_FOV NF: 87
```
PIX2RADW: 7.73998982E-005[rad/pixel] = 1.5965E+001[arcsec/pixel]
PIX2RADV: 7.73998982E-005[rad/pixel] = 1.5965E+001[arcsec/pixel]
```

FRAME	DESCRIPTION	IPF[1]	SF[2]	ARW[3]	TOTAL	REQ
087(P)	MIPS_160um_center_large_FOV	0.2224	0.0855	0.0384	0.2413	3.70
088(I)	MIPS_160um_plusY_edge	0.3130	0.0855	0.0384	0.3268	N/A
089(I)	MIPS_160um_large_only	0.2224	0.0855	0.0384	0.2413	N/A
091(I)	MIPS_160um_small_FOV1	0.2521	0.0855	0.0384	0.2690	N/A
092(I)	MIPS_160um_small_FOV2	0.2550	0.0855	0.0384	0.2717	N/A
TR (C)	CORNERS OF INSTRUMENT	0.4719	0.0855	0.0384	0.4811	N/A
BR (C)	CORNERS OF INSTRUMENT	0.4549	0.0855	0.0384	0.4644	N/A
TL (C)	CORNERS OF INSTRUMENT	0.4592	0.0855	0.0384	0.4686	N/A
BL (C)	CORNERS OF INSTRUMENT	0.4660	0.0855	0.0384	0.4753	N/A

Table 4.29: IPF calibration error summary ([arcsec], 1-sigma, radial)

RMS METRIC	A PRIORI[4]	A POSTERIORI[4]	ATT. CORRECTED[5]	UNITS
Radial	8.4111	2.9188	2.6882	arcsec
Radial	0.5268	0.1828	0.1684	pixels
W-Axis	0.4327	0.1172	0.1073	pixels
V-Axis	0.3006	0.1404	0.1298	pixels

Table 4.30: Measurement prediction error summary (1-sigma)

---

[1]IPF filter removes systematic pointing errors due to: thermomechanical alignment drift (Body to TPF), gyro bias and bias drift, centroiding error, attitude error, and optical distortion. IPF SIGMA presented here is "NOT Scaled" by the Least Squares Scale factor. The Least Squares Scale Factor was: 1.105367.

[2]Error due to gyro Scale Factor: assumes 95 ppm error over 0.250 degree maneuver.

[3]Error due to gyro Angle Random Walk: assumes ARW = 100 $\mu deg/\sqrt{hr}$, with 615 second Maneuver time (max), and 30 independent Maneuvers.

[4]This can be interpreted as estimate of "pixel to sky" pointing reconstruction error if no science data is used.

[5]This can be interpreted as estimate of achieved S/I centroiding error

4.16 IPF EXECUTION SUMMARY OF ID992087

FOCAL PLANE SURVEY ANALYSIS: Covariance Analysis.
INSTRUMENT NAME: MIPS_160um_center_large_FOV NF: 87
```
PIX2RADW: 7.73998982E-005[rad/pixel] = 1.5965E+001[arcsec/pixel]
PIX2RADV: 7.73998982E-005[rad/pixel] = 1.5965E+001[arcsec/pixel]
```

FRAME	DESCRIPTION	IPF[1]	SF[2]	ARW[3]	TOTAL	REQ
087(P)	MIPS_160um_center_large_FOV	0.2262	0.0855	0.0384	0.2449	3.70
088(I)	MIPS_160um_plusY_edge	0.3085	0.0855	0.0384	0.3225	N/A
089(I)	MIPS_160um_large_only	0.2262	0.0855	0.0384	0.2449	N/A
091(I)	MIPS_160um_small_FOV1	0.2508	0.0855	0.0384	0.2678	N/A
092(I)	MIPS_160um_small_FOV2	0.2619	0.0855	0.0384	0.2782	N/A
TR (C)	CORNERS OF INSTRUMENT	0.4584	0.0855	0.0384	0.4679	N/A
BR (C)	CORNERS OF INSTRUMENT	0.4430	0.0855	0.0384	0.4528	N/A
TL (C)	CORNERS OF INSTRUMENT	0.4583	0.0855	0.0384	0.4678	N/A
BL (C)	CORNERS OF INSTRUMENT	0.4702	0.0855	0.0384	0.4795	N/A

Table 4.31: IPF calibration error summary ([arcsec], 1-sigma, radial)

RMS METRIC	A PRIORI[4]	A POSTERIORI[4]	ATT. CORRECTED[5]	UNITS
Radial	23.4028	2.9739	2.5673	arcsec
Radial	1.4659	0.1863	0.1608	pixels
W-Axis	1.1563	0.1355	0.1116	pixels
V-Axis	0.9011	0.1278	0.1158	pixels

Table 4.32: Measurement prediction error summary (1-sigma)

---

[1]IPF filter removes systematic pointing errors due to: thermomechanical alignment drift (Body to TPF), gyro bias and bias drift, centroiding error, attitude error, and optical distortion. IPF SIGMA presented here is "NOT Scaled" by the Least Squares Scale factor. The Least Squares Scale Factor was: 1.097370.

[2]Error due to gyro Scale Factor: assumes 95 ppm error over 0.250 degree maneuver.

[3]Error due to gyro Angle Random Walk: assumes ARW = 100 $\mu deg/\sqrt{hr}$, with 615 second Maneuver time (max), and 30 independent Maneuvers.

[4]This can be interpreted as estimate of "pixel to sky" pointing reconstruction error if no science data is used.

[5]This can be interpreted as estimate of achieved S/I centroiding error

4.17   IPF EXECUTION SUMMARY OF ID993087

FOCAL PLANE SURVEY ANALYSIS: Covariance Analysis.
INSTRUMENT NAME: MIPS_160um_center_large_FOV NF: 87
```
PIX2RADW: 7.73998982E-005[rad/pixel] = 1.5965E+001[arcsec/pixel]
PIX2RADV: 7.73998982E-005[rad/pixel] = 1.5965E+001[arcsec/pixel]
```

FRAME	DESCRIPTION	IPF[1]	SF[2]	ARW[3]	TOTAL	REQ
087(P)	MIPS_160um_center_large_FOV	0.2322	0.0855	0.0384	0.2504	3.70
088(I)	MIPS_160um_plusY_edge	0.3289	0.0855	0.0384	0.3420	N/A
089(I)	MIPS_160um_large_only	0.2322	0.0855	0.0384	0.2504	N/A
091(I)	MIPS_160um_small_FOV1	0.2647	0.0855	0.0384	0.2808	N/A
092(I)	MIPS_160um_small_FOV2	0.2916	0.0855	0.0384	0.3062	N/A
TR (C)	CORNERS OF INSTRUMENT	0.5227	0.0855	0.0384	0.5310	N/A
BR (C)	CORNERS OF INSTRUMENT	0.5194	0.0855	0.0384	0.5277	N/A
TL (C)	CORNERS OF INSTRUMENT	0.5466	0.0855	0.0384	0.5545	N/A
BL (C)	CORNERS OF INSTRUMENT	0.5699	0.0855	0.0384	0.5775	N/A

Table 4.33: IPF calibration error summary ([arcsec], 1-sigma, radial)

RMS METRIC	A PRIORI[4]	A POSTERIORI[4]	ATT. CORRECTED[5]	UNITS
Radial	7.4107	2.6825	2.3851	arcsec
Radial	0.4642	0.1680	0.1494	pixels
W-Axis	0.3570	0.1202	0.1032	pixels
V-Axis	0.2967	0.1174	0.1080	pixels

Table 4.34: Measurement prediction error summary (1-sigma)

---

[1]IPF filter removes systematic pointing errors due to: thermomechanical alignment drift (Body to TPF), gyro bias and bias drift, centroiding error, attitude error, and optical distortion. IPF SIGMA presented here is "NOT Scaled" by the Least Squares Scale factor. The Least Squares Scale Factor was: 1.028017.

[2]Error due to gyro Scale Factor: assumes 95 ppm error over 0.250 degree maneuver.

[3]Error due to gyro Angle Random Walk: assumes ARW = 100 $\mu deg/\sqrt{hr}$, with 615 second Maneuver time (max), and 30 independent Maneuvers.

[4]This can be interpreted as estimate of "pixel to sky" pointing reconstruction error if no science data is used.

[5]This can be interpreted as estimate of achieved S/I centroiding error

4.18   IPF EXECUTION SUMMARY OF ID91M087

FOCAL PLANE SURVEY ANALYSIS: MULTI-RUN
INSTRUMENT NAME: MIPS_160um_center_large_FOV NF: 87
```
PIX2RADW: 7.73998982E-005[rad/pixel] = 1.5965E+001[arcsec/pixel]
PIX2RADV: 7.73998982E-005[rad/pixel] = 1.5965E+001[arcsec/pixel]
```

FRAME	DESCRIPTION	IPF[1]	SF[2]	ARW[3]	TOTAL	REQ
087(P)	MIPS_160um_center_large_FOV	0.1298	0.0855	0.0384	0.1601	3.70
088(I)	MIPS_160um_plusY_edge	0.1961	0.0855	0.0384	0.2173	N/A
089(I)	MIPS_160um_large_only	0.1406	0.0855	0.0384	0.1689	N/A
091(I)	MIPS_160um_small_FOV1	0.1584	0.0855	0.0384	0.1841	N/A
092(I)	MIPS_160um_small_FOV2	0.1658	0.0855	0.0384	0.1904	N/A
TR (C)	CORNERS OF INSTRUMENT	0.2978	0.0855	0.0384	0.3122	N/A
BR (C)	CORNERS OF INSTRUMENT	0.2911	0.0855	0.0384	0.3058	N/A
TL (C)	CORNERS OF INSTRUMENT	0.2992	0.0855	0.0384	0.3135	N/A
BL (C)	CORNERS OF INSTRUMENT	0.3071	0.0855	0.0384	0.3211	N/A

Table 4.35: IPF calibration error summary ([arcsec], 1-sigma, radial)

---

[1]IPF filter removes systematic pointing errors due to: thermomechanical alignment drift (Body to TPF), gyro bias and bias drift, centroiding error, attitude error, and optical distortion. IPF SIGMA presented here is "NOT Scaled" by the Least Squares Scale factor. The Least Squares Scale Factor was: 1.082902.

[2]Error due to gyro Scale Factor: assumes 95 ppm error over 0.250 degree maneuver.

[3]Error due to gyro Angle Random Walk: assumes ARW = 100 $\mu deg/\sqrt{hr}$, with 615 second Maneuver time (max), and 30 independent Maneuvers.

4.19 IPF EXECUTION SUMMARY OF ID991095

FOCAL PLANE SURVEY ANALYSIS: Covariance Analysis.
INSTRUMENT NAME: MIPS_24um_center NF: 95
```
PIX2RADW: 1.20874169E-005[rad/pixel] = 2.4932E+000[arcsec/pixel]
PIX2RADV: 1.20874169E-005[rad/pixel] = 2.4932E+000[arcsec/pixel]
```

FRAME	DESCRIPTION	IPF[1]	SF[2]	ARW[3]	TOTAL	REQ
095(P)	MIPS_24um_center	0.0548	0.0855	0.0703	0.1235	0.14
096(I)	MIPS_24um_plusY_edge	0.0973	0.0855	0.0703	0.1473	N/A
099(I)	MIPS_24um_small_FOV1	0.0547	0.0855	0.0703	0.1234	N/A
100(I)	MIPS_24um_small_FOV2	0.0525	0.0855	0.0703	0.1225	N/A
103(I)	MIPS_24um_large_FOV1	0.0549	0.0855	0.0703	0.1235	N/A
104(I)	MIPS_24um_large_FOV2	0.0547	0.0855	0.0703	0.1234	N/A
TR (C)	CORNERS OF INSTRUMENT	0.1210	0.0855	0.0703	0.1640	N/A
BR (C)	CORNERS OF INSTRUMENT	0.1166	0.0855	0.0703	0.1608	N/A
TL (C)	CORNERS OF INSTRUMENT	0.1127	0.0855	0.0703	0.1579	N/A
BL (C)	CORNERS OF INSTRUMENT	0.1193	0.0855	0.0703	0.1627	N/A

Table 4.36: IPF calibration error summary ([arcsec], 1-sigma, radial)

RMS METRIC	A PRIORI[4]	A POSTERIORI[4]	ATT. CORRECTED[5]	UNITS
Radial	13.7662	1.2918	0.3992	arcsec
Radial	5.5215	0.5181	0.1601	pixels
W-Axis	3.9682	0.3399	0.1131	pixels
V-Axis	3.8393	0.3911	0.1133	pixels

Table 4.37: Measurement prediction error summary (1-sigma)

---

[1]IPF filter removes systematic pointing errors due to: thermomechanical alignment drift (Body to TPF), gyro bias and bias drift, centroiding error, attitude error, and optical distortion. IPF SIGMA presented here is "NOT Scaled" by the Least Squares Scale factor. The Least Squares Scale Factor was: 1.125028.

[2]Error due to gyro Scale Factor: assumes 95 ppm error over 0.250 degree maneuver.

[3]Error due to gyro Angle Random Walk: assumes ARW = 100 $\mu deg/\sqrt{hr}$, with 960 second Maneuver time (max), and 14 independent Maneuvers.

[4]This can be interpreted as estimate of "pixel to sky" pointing reconstruction error if no science data is used.

[5]This can be interpreted as estimate of achieved S/I centroiding error

4.20 IPF EXECUTION SUMMARY OF ID992095

FOCAL PLANE SURVEY ANALYSIS: Covariance Analysis.
INSTRUMENT NAME: MIPS_24um_center NF: 95
```
PIX2RADW: 1.20874169E-005[rad/pixel] = 2.4932E+000[arcsec/pixel]
PIX2RADV: 1.20874169E-005[rad/pixel] = 2.4932E+000[arcsec/pixel]
```

FRAME	DESCRIPTION	IPF[1]	SF[2]	ARW[3]	TOTAL	REQ
095(P)	MIPS_24um_center	0.0544	0.0855	0.0703	0.1233	0.14
096(I)	MIPS_24um_plusY_edge	0.0926	0.0855	0.0703	0.1443	N/A
099(I)	MIPS_24um_small_FOV1	0.0555	0.0855	0.0703	0.1238	N/A
100(I)	MIPS_24um_small_FOV2	0.0512	0.0855	0.0703	0.1219	N/A
103(I)	MIPS_24um_large_FOV1	0.0547	0.0855	0.0703	0.1234	N/A
104(I)	MIPS_24um_large_FOV2	0.0542	0.0855	0.0703	0.1232	N/A
TR (C)	CORNERS OF INSTRUMENT	0.1275	0.0855	0.0703	0.1688	N/A
BR (C)	CORNERS OF INSTRUMENT	0.1091	0.0855	0.0703	0.1554	N/A
TL (C)	CORNERS OF INSTRUMENT	0.1259	0.0855	0.0703	0.1676	N/A
BL (C)	CORNERS OF INSTRUMENT	0.1165	0.0855	0.0703	0.1607	N/A

Table 4.38: IPF calibration error summary ([arcsec], 1-sigma, radial)

RMS METRIC	A PRIORI[4]	A POSTERIORI[4]	ATT. CORRECTED[5]	UNITS
Radial	24.5101	1.9672	0.3985	arcsec
Radial	9.8307	0.7890	0.1598	pixels
W-Axis	6.6821	0.3457	0.1110	pixels
V-Axis	7.2106	0.7093	0.1150	pixels

Table 4.39: Measurement prediction error summary (1-sigma)

---

[1]IPF filter removes systematic pointing errors due to: thermomechanical alignment drift (Body to TPF), gyro bias and bias drift, centroiding error, attitude error, and optical distortion. IPF SIGMA presented here is "NOT Scaled" by the Least Squares Scale factor. The Least Squares Scale Factor was: 1.134791.

[2]Error due to gyro Scale Factor: assumes 95 ppm error over 0.250 degree maneuver.

[3]Error due to gyro Angle Random Walk: assumes ARW = 100 $\mu deg/\sqrt{hr}$, with 960 second Maneuver time (max), and 14 independent Maneuvers.

[4]This can be interpreted as estimate of "pixel to sky" pointing reconstruction error if no science data is used.

[5]This can be interpreted as estimate of achieved S/I centroiding error

4.21 IPF EXECUTION SUMMARY OF ID91M095

FOCAL PLANE SURVEY ANALYSIS: MULTI-RUN
INSTRUMENT NAME: MIPS_24um_center NF: 95
```
PIX2RADW: 1.20874169E-005[rad/pixel] = 2.4932E+000[arcsec/pixel]
PIX2RADV: 1.20874169E-005[rad/pixel] = 2.4932E+000[arcsec/pixel]
```

FRAME	DESCRIPTION	IPF[1]	SF[2]	ARW[3]	TOTAL	REQ
095(P)	MIPS_24um_center	0.0385	0.0855	0.0703	0.1172	0.14
096(I)	MIPS_24um_plusY_edge	0.0755	0.0855	0.0703	0.1340	N/A
099(I)	MIPS_24um_small_FOV1	0.0439	0.0855	0.0703	0.1190	N/A
100(I)	MIPS_24um_small_FOV2	0.0413	0.0855	0.0703	0.1181	N/A
103(I)	MIPS_24um_large_FOV1	0.0436	0.0855	0.0703	0.1189	N/A
104(I)	MIPS_24um_large_FOV2	0.0433	0.0855	0.0703	0.1188	N/A
TR (C)	CORNERS OF INSTRUMENT	0.0988	0.0855	0.0703	0.1484	N/A
BR (C)	CORNERS OF INSTRUMENT	0.0897	0.0855	0.0703	0.1424	N/A
TL (C)	CORNERS OF INSTRUMENT	0.0945	0.0855	0.0703	0.1455	N/A
BL (C)	CORNERS OF INSTRUMENT	0.0940	0.0855	0.0703	0.1452	N/A

Table 4.40: IPF calibration error summary ([arcsec], 1-sigma, radial)

---

[1]IPF filter removes systematic pointing errors due to: thermomechanical alignment drift (Body to TPF), gyro bias and bias drift, centroiding error, attitude error, and optical distortion. IPF SIGMA presented here is "NOT Scaled" by the Least Squares Scale factor. The Least Squares Scale Factor was: 1.129920.

[2]Error due to gyro Scale Factor: assumes 95 ppm error over 0.250 degree maneuver.

[3]Error due to gyro Angle Random Walk: assumes ARW = 100 $\mu deg/\sqrt{hr}$, with 960 second Maneuver time (max), and 14 independent Maneuvers.

4.22 IPF EXECUTION SUMMARY OF ID991107

FOCAL PLANE SURVEY ANALYSIS: Covariance Analysis.
INSTRUMENT NAME: MIPS_70um_center NF: 107
PIX2RADW: 4.79044679E-005[rad/pixel] = 9.8810E+000[arcsec/pixel]
PIX2RADV: 4.79044679E-005[rad/pixel] = 9.8810E+000[arcsec/pixel]

FRAME	DESCRIPTION	IPF[1]	SF[2]	ARW[3]	TOTAL	REQ
107(P)	MIPS_70um_center	0.2741	0.0855	0.0708	0.2957	2.60
108(I)	MIPS_70um_minusY_edge	0.4370	0.0855	0.0708	0.4509	N/A
111(I)	MIPS_70um_default_small_FOV1	0.3241	0.0855	0.0708	0.3426	N/A
112(I)	MIPS_70um_default_small_FOV2	0.2266	0.0855	0.0708	0.2523	N/A
115(I)	MIPS_70um_default_large_FOV1	0.2741	0.0855	0.0708	0.2957	N/A
TR (C)	CORNERS OF INSTRUMENT	0.6322	0.0855	0.0708	0.6418	N/A
BR (C)	CORNERS OF INSTRUMENT	0.5906	0.0855	0.0708	0.6010	N/A
TL (C)	CORNERS OF INSTRUMENT	0.5123	0.0855	0.0708	0.5242	N/A
BL (C)	CORNERS OF INSTRUMENT	0.5148	0.0855	0.0708	0.5266	N/A

Table 4.41: IPF calibration error summary ([arcsec], 1-sigma, radial)

RMS METRIC	A PRIORI[4]	A POSTERIORI[4]	ATT. CORRECTED[5]	UNITS
Radial	12.4171	1.9197	1.4950	arcsec
Radial	1.2567	0.1943	0.1513	pixels
W-Axis	0.8909	0.1323	0.1053	pixels
V-Axis	0.8863	0.1423	0.1087	pixels

Table 4.42: Measurement prediction error summary (1-sigma)

---

[1]IPF filter removes systematic pointing errors due to: thermomechanical alignment drift (Body to TPF), gyro bias and bias drift, centroiding error, attitude error, and optical distortion. IPF SIGMA presented here is "NOT Scaled" by the Least Squares Scale factor. The Least Squares Scale Factor was: 1.073640.

[2]Error due to gyro Scale Factor: assumes 95 ppm error over 0.250 degree maneuver.

[3]Error due to gyro Angle Random Walk: assumes ARW = 100 $\mu deg/\sqrt{hr}$, with 975 second Maneuver time (max), and 14 independent Maneuvers.

[4]This can be interpreted as estimate of "pixel to sky" pointing reconstruction error if no science data is used.

[5]This can be interpreted as estimate of achieved S/I centroiding error

4.23   IPF EXECUTION SUMMARY OF ID992107

FOCAL PLANE SURVEY ANALYSIS: Covariance Analysis.
INSTRUMENT NAME: MIPS_70um_center NF: 107
```
PIX2RADW: 4.79044679E-005[rad/pixel] = 9.8810E+000[arcsec/pixel]
PIX2RADV: 4.79044679E-005[rad/pixel] = 9.8810E+000[arcsec/pixel]
```

FRAME	DESCRIPTION	IPF[1]	SF[2]	ARW[3]	TOTAL	REQ
107(P)	MIPS_70um_center	0.2718	0.0855	0.0708	0.2936	2.60
108(I)	MIPS_70um_minusY_edge	0.4731	0.0855	0.0708	0.4859	N/A
111(I)	MIPS_70um_default_small_FOV1	0.3249	0.0855	0.0708	0.3433	N/A
112(I)	MIPS_70um_default_small_FOV2	0.2225	0.0855	0.0708	0.2487	N/A
115(I)	MIPS_70um_default_large_FOV1	0.2718	0.0855	0.0708	0.2936	N/A
TR (C)	CORNERS OF INSTRUMENT	0.6472	0.0855	0.0708	0.6567	N/A
BR (C)	CORNERS OF INSTRUMENT	0.5567	0.0855	0.0708	0.5677	N/A
TL (C)	CORNERS OF INSTRUMENT	0.5836	0.0855	0.0708	0.5941	N/A
BL (C)	CORNERS OF INSTRUMENT	0.5083	0.0855	0.0708	0.5203	N/A

Table 4.43: IPF calibration error summary ([arcsec], 1-sigma, radial)

RMS METRIC	A PRIORI[4]	A POSTERIORI[4]	ATT. CORRECTED[5]	UNITS
Radial	22.3440	1.8759	1.4915	arcsec
Radial	2.2613	0.1898	0.1509	pixels
W-Axis	1.5600	0.1322	0.1033	pixels
V-Axis	1.6370	0.1363	0.1101	pixels

Table 4.44: Measurement prediction error summary (1-sigma)

---

[1]IPF filter removes systematic pointing errors due to: thermomechanical alignment drift (Body to TPF), gyro bias and bias drift, centroiding error, attitude error, and optical distortion. IPF SIGMA presented here is "NOT Scaled" by the Least Squares Scale factor. The Least Squares Scale Factor was: 1.070495.

[2]Error due to gyro Scale Factor: assumes 95 ppm error over 0.250 degree maneuver.

[3]Error due to gyro Angle Random Walk: assumes ARW = 100 $\mu deg/\sqrt{hr}$, with 975 second Maneuver time (max), and 14 independent Maneuvers.

[4]This can be interpreted as estimate of "pixel to sky" pointing reconstruction error if no science data is used.

[5]This can be interpreted as estimate of achieved S/I centroiding error

4.24 IPF EXECUTION SUMMARY OF ID91M107

FOCAL PLANE SURVEY ANALYSIS: MULTI-RUN
INSTRUMENT NAME: MIPS_70um_center NF: 107
PIX2RADW: 4.79044679E-005[rad/pixel] = 9.8810E+000[arcsec/pixel]
PIX2RADV: 4.79044679E-005[rad/pixel] = 9.8810E+000[arcsec/pixel]

FRAME	DESCRIPTION	IPF[1]	SF[2]	ARW[3]	TOTAL	REQ
107(P)	MIPS_70um_center	0.1922	0.0855	0.0708	0.2219	2.60
108(I)	MIPS_70um_minusY_edge	0.3417	0.0855	0.0708	0.3593	N/A
111(I)	MIPS_70um_default_small_FOV1	0.2451	0.0855	0.0708	0.2690	N/A
112(I)	MIPS_70um_default_small_FOV2	0.1696	0.0855	0.0708	0.2027	N/A
115(I)	MIPS_70um_default_large_FOV1	0.2060	0.0855	0.0708	0.2340	N/A
TR (C)	CORNERS OF INSTRUMENT	0.4823	0.0855	0.0708	0.4949	N/A
BR (C)	CORNERS OF INSTRUMENT	0.4318	0.0855	0.0708	0.4458	N/A
TL (C)	CORNERS OF INSTRUMENT	0.4097	0.0855	0.0708	0.4244	N/A
BL (C)	CORNERS OF INSTRUMENT	0.3866	0.0855	0.0708	0.4022	N/A

Table 4.45: IPF calibration error summary ([arcsec], 1-sigma, radial)

---

[1]IPF filter removes systematic pointing errors due to: thermomechanical alignment drift (Body to TPF), gyro bias and bias drift, centroiding error, attitude error, and optical distortion. IPF SIGMA presented here is "NOT Scaled" by the Least Squares Scale factor. The Least Squares Scale Factor was: 1.072136.

[2]Error due to gyro Scale Factor: assumes 95 ppm error over 0.250 degree maneuver.

[3]Error due to gyro Angle Random Walk: assumes ARW = 100 $\mu deg/\sqrt{hr}$, with 975 second Maneuver time (max), and 14 independent Maneuvers.

4.25 IPF EXECUTION SUMMARY OF ID991118

FOCAL PLANE SURVEY ANALYSIS: Covariance Analysis.
INSTRUMENT NAME: MIPS_70um_fine_center NF: 118
PIX2RADW: 2.47365083E-005[rad/pixel] = 5.1023E+000[arcsec/pixel]
PIX2RADV: 2.47365083E-005[rad/pixel] = 5.1023E+000[arcsec/pixel]

FRAME	DESCRIPTION	IPF[1]	SF[2]	ARW[3]	TOTAL	REQ
118(P)	MIPS_70um_fine_center	0.1852	0.0855	0.0565	0.2117	1.10
119(I)	MIPS_70um_fine_FOV1	0.1930	0.0855	0.0565	0.2185	N/A
120(I)	MIPS_70um_fine_FOV2	1.6859	0.0855	0.0565	1.6890	N/A
124(I)	MIPS_70um_fine_FOV3	0.1426	0.0855	0.0565	0.1756	N/A
127(I)	MIPS_70um_fine_FOV4	0.1813	0.0855	0.0565	0.2082	N/A
TR (C)	CORNERS OF INSTRUMENT	0.4063	0.0855	0.0565	0.4190	N/A
BR (C)	CORNERS OF INSTRUMENT	0.3893	0.0855	0.0565	0.4026	N/A
TL (C)	CORNERS OF INSTRUMENT	0.2974	0.0855	0.0565	0.3146	N/A
BL (C)	CORNERS OF INSTRUMENT	0.2893	0.0855	0.0565	0.3069	N/A

Table 4.46: IPF calibration error summary ([arcsec], 1-sigma, radial)

RMS METRIC	A PRIORI[4]	A POSTERIORI[4]	ATT. CORRECTED[5]	UNITS
Radial	7.6358	1.5671	0.7963	arcsec
Radial	1.4966	0.3071	0.1561	pixels
W-Axis	0.8157	0.1901	0.1082	pixels
V-Axis	1.2547	0.2412	0.1125	pixels

Table 4.47: Measurement prediction error summary (1-sigma)

---

[1]IPF filter removes systematic pointing errors due to: thermomechanical alignment drift (Body to TPF), gyro bias and bias drift, centroiding error, attitude error, and optical distortion. IPF SIGMA presented here is "NOT Scaled" by the Least Squares Scale factor. The Least Squares Scale Factor was: 1.086063.

[2]Error due to gyro Scale Factor: assumes 95 ppm error over 0.250 degree maneuver.

[3]Error due to gyro Angle Random Walk: assumes ARW = 100 $\mu deg/\sqrt{hr}$, with 975 second Maneuver time (max), and 22 independent Maneuvers.

[4]This can be interpreted as estimate of "pixel to sky" pointing reconstruction error if no science data is used.

[5]This can be interpreted as estimate of achieved S/I centroiding error

4.26 IPF EXECUTION SUMMARY OF ID992118

FOCAL PLANE SURVEY ANALYSIS: Covariance Analysis.
INSTRUMENT NAME: MIPS_70um_fine_center NF: 118
PIX2RADW: 2.47365083E-005[rad/pixel] = 5.1023E+000[arcsec/pixel]
PIX2RADV: 2.47365083E-005[rad/pixel] = 5.1023E+000[arcsec/pixel]

FRAME	DESCRIPTION	IPF[1]	SF[2]	ARW[3]	TOTAL	REQ
118(P)	MIPS_70um_fine_center	0.1845	0.0855	0.0565	0.2110	1.10
119(I)	MIPS_70um_fine_FOV1	0.1922	0.0855	0.0565	0.2178	N/A
120(I)	MIPS_70um_fine_FOV2	1.6669	0.0855	0.0565	1.6700	N/A
124(I)	MIPS_70um_fine_FOV3	0.1420	0.0855	0.0565	0.1751	N/A
127(I)	MIPS_70um_fine_FOV4	0.1806	0.0855	0.0565	0.2076	N/A
TR (C)	CORNERS OF INSTRUMENT	0.4095	0.0855	0.0565	0.4221	N/A
BR (C)	CORNERS OF INSTRUMENT	0.3807	0.0855	0.0565	0.3943	N/A
TL (C)	CORNERS OF INSTRUMENT	0.2936	0.0855	0.0565	0.3110	N/A
BL (C)	CORNERS OF INSTRUMENT	0.2897	0.0855	0.0565	0.3073	N/A

Table 4.48: IPF calibration error summary ([arcsec], 1-sigma, radial)

RMS METRIC	A PRIORI[4]	A POSTERIORI[4]	ATT. CORRECTED[5]	UNITS
Radial	8.1081	1.5610	0.8121	arcsec
Radial	1.5891	0.3059	0.1592	pixels
W-Axis	0.9117	0.2289	0.1133	pixels
V-Axis	1.3016	0.2030	0.1118	pixels

Table 4.49: Measurement prediction error summary (1-sigma)

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[1]IPF filter removes systematic pointing errors due to: thermomechanical alignment drift (Body to TPF), gyro bias and bias drift, centroiding error, attitude error, and optical distortion. IPF SIGMA presented here is "NOT Scaled" by the Least Squares Scale factor. The Least Squares Scale Factor was: 1.100452.

[2]Error due to gyro Scale Factor: assumes 95 ppm error over 0.250 degree maneuver.

[3]Error due to gyro Angle Random Walk: assumes ARW = 100 $\mu deg/\sqrt{hr}$, with 975 second Maneuver time (max), and 22 independent Maneuvers.

[4]This can be interpreted as estimate of "pixel to sky" pointing reconstruction error if no science data is used.

[5]This can be interpreted as estimate of achieved S/I centroiding error

4.27 IPF EXECUTION SUMMARY OF ID91M118

FOCAL PLANE SURVEY ANALYSIS: MULTI-RUN
INSTRUMENT NAME: MIPS_70um_fine_center NF: 118
```
PIX2RADW: 2.47365083E-005[rad/pixel] = 5.1023E+000[arcsec/pixel]
PIX2RADV: 2.47365083E-005[rad/pixel] = 5.1023E+000[arcsec/pixel]
```

FRAME	DESCRIPTION	IPF[1]	SF[2]	ARW[3]	TOTAL	REQ
118(P)	MIPS_70um_fine_center	0.1307	0.0855	0.0565	0.1661	1.10
119(I)	MIPS_70um_fine_FOV1	0.1489	0.0855	0.0565	0.1807	N/A
120(I)	MIPS_70um_fine_FOV2	1.2953	0.0855	0.0565	1.2994	N/A
124(I)	MIPS_70um_fine_FOV3	0.1100	0.0855	0.0565	0.1503	N/A
127(I)	MIPS_70um_fine_FOV4	0.1398	0.0855	0.0565	0.1734	N/A
TR (C)	CORNERS OF INSTRUMENT	0.3152	0.0855	0.0565	0.3314	N/A
BR (C)	CORNERS OF INSTRUMENT	0.2974	0.0855	0.0565	0.3146	N/A
TL (C)	CORNERS OF INSTRUMENT	0.2284	0.0855	0.0565	0.2503	N/A
BL (C)	CORNERS OF INSTRUMENT	0.2238	0.0855	0.0565	0.2461	N/A

Table 4.50: IPF calibration error summary ([arcsec], 1-sigma, radial)

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[1]IPF filter removes systematic pointing errors due to: thermomechanical alignment drift (Body to TPF), gyro bias and bias drift, centroiding error, attitude error, and optical distortion. IPF SIGMA presented here is "NOT Scaled" by the Least Squares Scale factor. The Least Squares Scale Factor was: 1.093252.

[2]Error due to gyro Scale Factor: assumes 95 ppm error over 0.250 degree maneuver.

[3]Error due to gyro Angle Random Walk: assumes ARW = 100 $\mu deg/\sqrt{hr}$, with 975 second Maneuver time (max), and 22 independent Maneuvers.

4.28 IPF EXECUTION SUMMARY OF ID995121

FOCAL PLANE SURVEY ANALYSIS: Covariance Analysis.
INSTRUMENT NAME: MIPS_SED_center NF: 121
```
PIX2RADW: 4.79222664E-005[rad/pixel] = 9.8847E+000[arcsec/pixel]
PIX2RADV: 4.79222664E-005[rad/pixel] = 9.8847E+000[arcsec/pixel]
```

FRAME	DESCRIPTION	IPF[1]	SF[2]	ARW[3]	TOTAL	REQ
121(P)	MIPS_SED_center	0.6427	0.0855	0.0936	0.6551	1.10
113(I)	MIPS_SED_5	2.7548	0.0855	0.0936	2.7577	N/A
114(I)	MIPS_SED_6	2.7034	0.0855	0.0936	2.7064	N/A
116(I)	MIPS_SED_7	1.1166	0.0855	0.0936	1.1238	N/A
117(I)	MIPS_SED_8	1.0862	0.0855	0.0936	1.0935	N/A
TR (C)	CORNERS OF INSTRUMENT	1.2580	0.0855	0.0936	1.2644	N/A
BR (C)	CORNERS OF INSTRUMENT	1.2068	0.0855	0.0936	1.2135	N/A
TL (C)	CORNERS OF INSTRUMENT	1.0768	0.0855	0.0936	1.0842	N/A
BL (C)	CORNERS OF INSTRUMENT	1.0703	0.0855	0.0936	1.0777	N/A

Table 4.51: IPF calibration error summary ([arcsec], 1-sigma, radial)

RMS METRIC	A PRIORI[4]	A POSTERIORI[4]	ATT. CORRECTED[5]	UNITS
Radial	5.3188	1.2310	1.2197	arcsec
Radial	0.5381	0.1245	0.1234	pixels
W-Axis	0.4816	0.0970	0.0913	pixels
V-Axis	0.2399	0.0781	0.0830	pixels

Table 4.52: Measurement prediction error summary (1-sigma)

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[1]IPF filter removes systematic pointing errors due to: thermomechanical alignment drift (Body to TPF), gyro bias and bias drift, centroiding error, attitude error, and optical distortion. IPF SIGMA presented here is "NOT Scaled" by the Least Squares Scale factor. The Least Squares Scale Factor was: 0.920167.

[2]Error due to gyro Scale Factor: assumes 95 ppm error over 0.250 degree maneuver.

[3]Error due to gyro Angle Random Walk: assumes ARW = 100 $\mu deg/\sqrt{hr}$, with 730 second Maneuver time (max), and 6 independent Maneuvers.

[4]This can be interpreted as estimate of "pixel to sky" pointing reconstruction error if no science data is used.

[5]This can be interpreted as estimate of achieved S/I centroiding error

4.29 IPF EXECUTION SUMMARY OF ID996121

FOCAL PLANE SURVEY ANALYSIS: Covariance Analysis.
INSTRUMENT NAME: MIPS_SED_center NF: 121
```
PIX2RADW: 4.79222664E-005[rad/pixel] = 9.8847E+000[arcsec/pixel]
PIX2RADV: 4.79222664E-005[rad/pixel] = 9.8847E+000[arcsec/pixel]
```

FRAME	DESCRIPTION	IPF[1]	SF[2]	ARW[3]	TOTAL	REQ
121(P)	MIPS_SED_center	0.6376	0.0855	0.0936	0.6501	1.10
113(I)	MIPS_SED_5	2.5158	0.0855	0.0936	2.5190	N/A
114(I)	MIPS_SED_6	2.5750	0.0855	0.0936	2.5781	N/A
116(I)	MIPS_SED_7	1.0866	0.0855	0.0936	1.0940	N/A
117(I)	MIPS_SED_8	1.0714	0.0855	0.0936	1.0788	N/A
TR (C)	CORNERS OF INSTRUMENT	1.0801	0.0855	0.0936	1.0875	N/A
BR (C)	CORNERS OF INSTRUMENT	1.1063	0.0855	0.0936	1.1135	N/A
TL (C)	CORNERS OF INSTRUMENT	1.1898	0.0855	0.0936	1.1965	N/A
BL (C)	CORNERS OF INSTRUMENT	1.1390	0.0855	0.0936	1.1460	N/A

Table 4.53: IPF calibration error summary ([arcsec], 1-sigma, radial)

RMS METRIC	A PRIORI[4]	A POSTERIORI[4]	ATT. CORRECTED[5]	UNITS
Radial	12.7976	1.8705	1.3913	arcsec
Radial	1.2947	0.1892	0.1408	pixels
W-Axis	0.9117	0.1326	0.0844	pixels
V-Axis	0.9192	0.1350	0.1126	pixels

Table 4.54: Measurement prediction error summary (1-sigma)

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[1] IPF filter removes systematic pointing errors due to: thermomechanical alignment drift (Body to TPF), gyro bias and bias drift, centroiding error, attitude error, and optical distortion. IPF SIGMA presented here is "NOT Scaled" by the Least Squares Scale factor. The Least Squares Scale Factor was: 1.005530.

[2] Error due to gyro Scale Factor: assumes 95 ppm error over 0.250 degree maneuver.

[3] Error due to gyro Angle Random Walk: assumes ARW = 100 $\mu deg/\sqrt{hr}$, with 730 second Maneuver time (max), and 6 independent Maneuvers.

[4] This can be interpreted as estimate of "pixel to sky" pointing reconstruction error if no science data is used.

[5] This can be interpreted as estimate of achieved S/I centroiding error

4.30   IPF EXECUTION SUMMARY OF ID93M121

FOCAL PLANE SURVEY ANALYSIS: MULTI-RUN
INSTRUMENT NAME: MIPS_SED_center NF: 121
PIX2RADW: 4.79222664E-005[rad/pixel] = 9.8847E+000[arcsec/pixel]
PIX2RADV: 4.79222664E-005[rad/pixel] = 9.8847E+000[arcsec/pixel]

FRAME	DESCRIPTION	IPF[1]	SF[2]	ARW[3]	TOTAL	REQ
121(P)	MIPS_SED_center	0.3916	0.0855	0.0936	0.4116	1.10
113(I)	MIPS_SED_5	1.7251	0.0855	0.0936	1.7297	N/A
114(I)	MIPS_SED_6	1.7368	0.0855	0.0936	1.7414	N/A
116(I)	MIPS_SED_7	0.7112	0.0855	0.0936	0.7224	N/A
117(I)	MIPS_SED_8	0.6996	0.0855	0.0936	0.7110	N/A
TR (C)	CORNERS OF INSTRUMENT	0.7381	0.0855	0.0936	0.7489	N/A
BR (C)	CORNERS OF INSTRUMENT	0.7385	0.0855	0.0936	0.7493	N/A
TL (C)	CORNERS OF INSTRUMENT	0.7449	0.0855	0.0936	0.7556	N/A
BL (C)	CORNERS OF INSTRUMENT	0.7250	0.0855	0.0936	0.7360	N/A

Table 4.55: IPF calibration error summary ([arcsec], 1-sigma, radial)

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[1]IPF filter removes systematic pointing errors due to: thermomechanical alignment drift (Body to TPF), gyro bias and bias drift, centroiding error, attitude error, and optical distortion. IPF SIGMA presented here is "NOT Scaled" by the Least Squares Scale factor. The Least Squares Scale Factor was: 0.963396.

[2]Error due to gyro Scale Factor: assumes 95 ppm error over 0.250 degree maneuver.

[3]Error due to gyro Angle Random Walk: assumes ARW = 100 $\mu deg/\sqrt{hr}$, with 730 second Maneuver time (max), and 6 independent Maneuvers.

5   CONCLUSIONS

This report provides a pre-flight error analysis of expected focal plane calibration accuracies. The main conclusion is that all calibration requirements can be met with the currently planned focal plane survey strategy.

The pointing-critical calibrations for the IRS Peakup sweet spots and short wavelength slit centers (frames 019, 023, 052, 028, 034) are meeting their 0.14" requirements with expected accuracies of about 0.1" (28 percent margin).

Margins on other arrays vary from 3 to 95 percent, depending on the requirements. Generally margin is tightest for frames with the 0.14" requirement, and largest for frames which have more generous requirements. The philosophy of holding small margins on frames with tight requirements is consistent with the original intent for focal plane survey activities not to dominate the latter part of IOC-SV (i.e., when the telescope is fully cooled and demand for observing time is highest). However, such small margins on certain frames can potentially increase performance risk and in certain cases may require additional calibrations to be made during an extended SV period or during the normal mission.

The need for such additional testing and calibration efforts should be examined after IOC-SV on a case by case basis.

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