METROLOGY OF THE CRYO-OPTICAL BOX

Spartan IR Camera for the SOAR Telescope

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This reports the measurements of the locations of the features on the cryo-optical box (COB) to which the optics mount. The features are pin holes and pads. The top and of the COB is shifted with respect to the bottom by (0.038, 0.079) mm, where the coordinates are in the short and long dimensions of the COB. The standard deviation of the location of the pin holes is (0.007, 0.017) mm. The pads on the top and bottom plates deviate from a plane by 0.063 mm (standard deviation); with a twist removed, the standard deviation is 0.037 mm. These errors will be removed with shims. We developed a procedure for assembling the COB reproducibly.

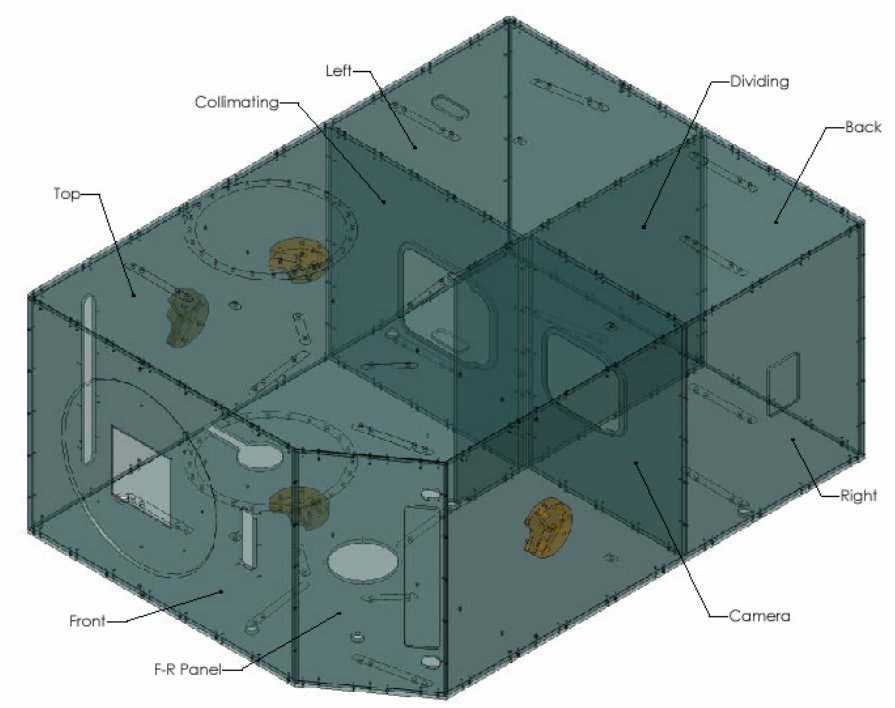


Figure 1 The cryo-optical box

1 Preliminaries

Figures 1 and 2 define features on the COB.

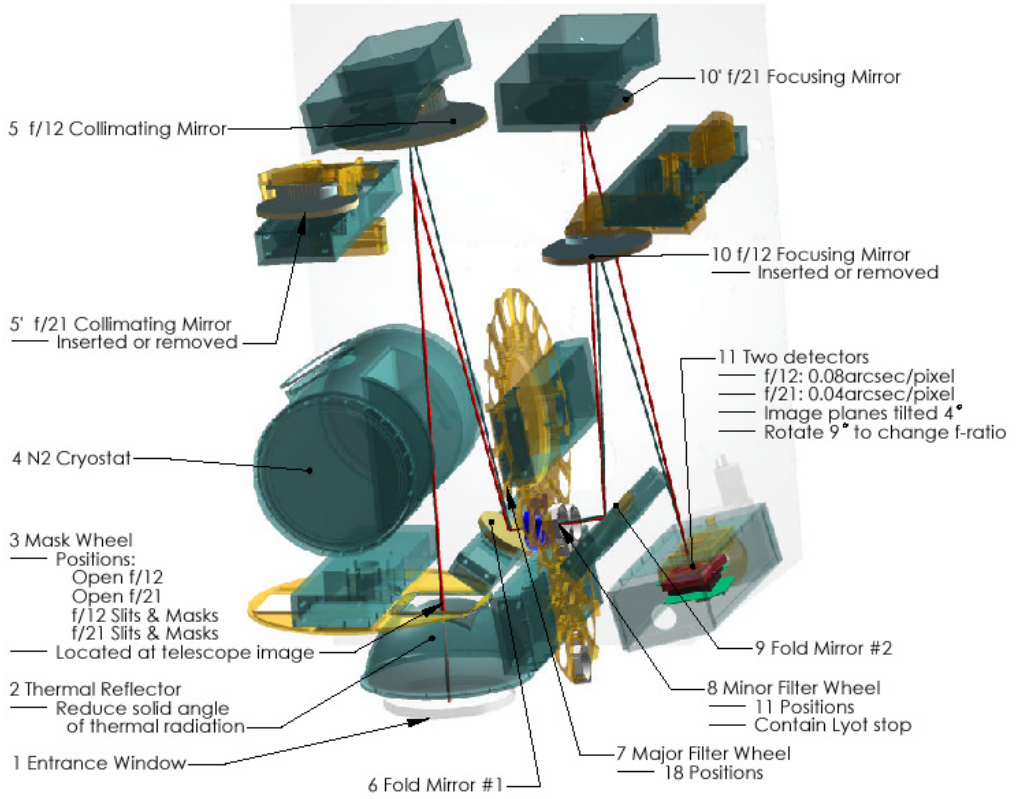


Figure 2 Optics

A coordinate measuring machine (CMM) (DEA Diamond 01.02) was used for all measurements. Its greatest error over the 1020×660×460-mm volume is 0.006 mm. Over short distances, the error is smaller.

The tightest requirements for positioning the optics are in Table 1 (O Loh & E Loh, June 2001, "Mechanical Design, Spartan IR Camera."

Table 1 Tightest tolerances for image quality. The x-direction is perpendicular to the large plates of the cryo-optical box. The z-direction is the local optical axis.

	x	y	z
Translation [mm]	0.36	0.14	0.03
Translation [mil]	14.2	5.5	1.2
Rotation [mrad]	0.1	0.2	2.7
Rotation [µm per 3in]	11	15	206
Rotation [mil per 3in]	0.4	0.6	8.1

2 Measurements of the Cryo-optical Box

2.1 Assembly Procedure

We now have a procedure for assembling the COB with a reproducible twist. Using a new procedure, Elissa assembled the COB with a twist of 0.10 mm with the screws loose. When she tightened the screws, the twist changed to 0.12 mm. The twist is measured at the bottom edge of the

front and back walls through the access holes in the bottom. The twist is adjusted by moving the 1-2-3 blocks on which the COB rests. On two previous assemblies where the twist is uncontrolled, the twist was 0.22 and 0.29 mm, which is a factor of 2 larger.

1. Assemble all—top and bottom plates and walls. Tighten the internal screws. Leave the rest snug but not tight.

2. Attach rails near the top surface.

3. Put the COB on three 1-2-3 blocks on the CMM with the top down. The front is resting on two blocks, and the back is on one. The back is near the front of the CMM.

4. The front should be level within 0.03 mm. (Use the holes in the bottom plate to access the bottom edge of the front wall.)

5. Measure the bottom edge of the back wall. The edge at the left access hole should be 0.10 mm lower than the edge at the right access hole. Move the 1-2-3 block on the back until that is so.

6. Tighten the screws near the pins on the top and bottom plates.

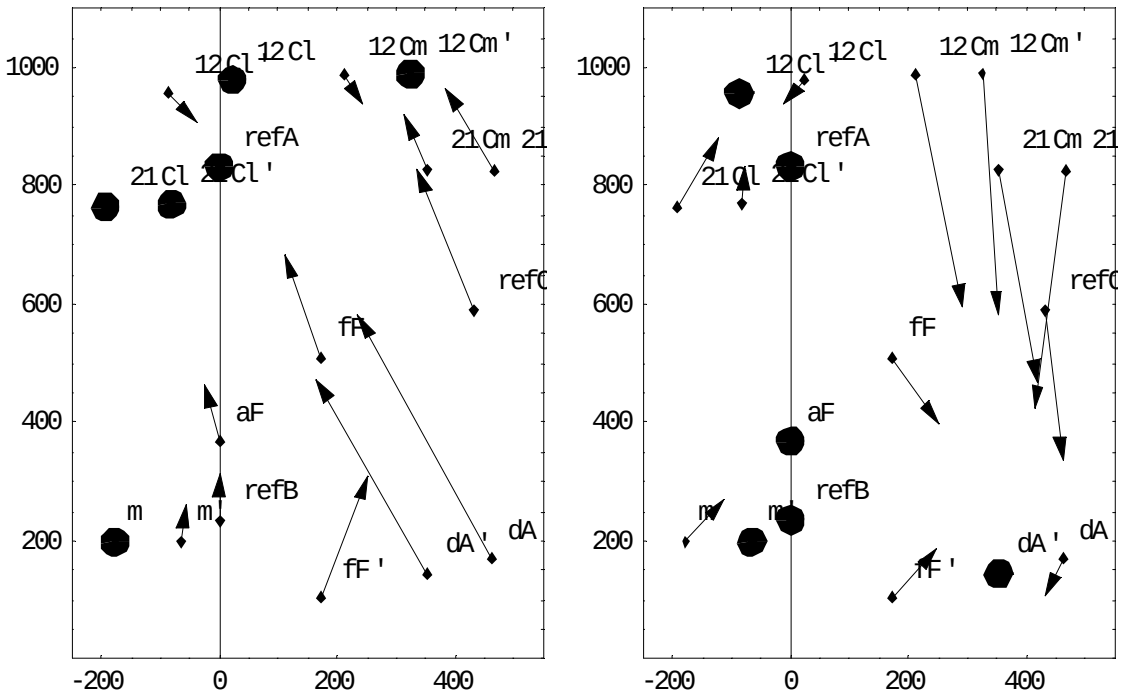
7. Tighten the remaining screws that are accessible on the top and bottom plates. The screws between the top plate and interior wall are mostly inaccessible.

8. Tighten the screws between the external walls.

9. Remove the COB from the CMM and tighten the remaining screws on the internal walls.

2.2 Pin Locations

Pin holes locate the optics, and the table in Figure 3 lists their positions with respect to reference holes A and B. Apparently machining the two halves of the plates occurred on two days. The temperature was cooler by 2.2 C on the day on which the right half was done.



Pin		Nominal Location		Error Bot		Error Top	
		x	y	x	y	x	y
Detector Assy - Right	dA-R	461.954	169.731	-0.023	0.041	-0.003	-0.006
Detector Assy - Left	dA-L	352.998	144.853	-0.019	0.033	0.003	-0.003
Fold-Filter - Back	fF-B	173.236	509.686	-0.006	0.017	0.008	-0.011
Fold-Filter - Front	fF-F	174.002	103.915	0.008	0.021	0.008	0.008
Mask - Left	m-L	-176.768	198.222	0.002	0.003	0.007	0.007
Mask - Right	m-R	-65.008	198.222	0.001	0.006	0.001	0.003
f/12 Collimator - Right	12Cl-R	22.485	978.487	0.002	0.002	-0.003	-0.004
f/12 Collimator - Left	12Cl-L	-87.090	956.492	0.005	-0.005	0.001	0.000
f/12 Camera - Left	21Cm-L	354.156	827.397	-0.004	0.009	0.006	-0.036
f/12 Camera - Right	21Cm-R	465.909	826.129	-0.008	0.014	-0.005	-0.040
f/21 Collimator - Left	21Cl-L	-192.759	764.050	0.002	-0.002	0.007	0.012
f/21 Collimator - Right	21Cl-R	-81.123	769.314	0.001	0.004	0.000	0.006
f/21 Camera - Left	12Cm-L	212.779	987.489	0.003	-0.005	0.008	-0.039
f/21 Camera - Right	12Cm-R	324.539	988.757	0.003	-0.001	0.003	-0.041
aFrame	aF	0.000	367.774	-0.002	0.010	-0.003	-0.001
refC		431.800	590.550	-0.010	0.024	0.003	-0.025
refB		0.000	234.950	0	0.008	0	-0.001
refA		0.000	831.850	0	0	0	0
Top with respect to bottom						0.038	0.079

Figure 3 Errors (magnified by 10,000) of the pin holes in the bottom (left panel) and top (right panel) plates. Points with errors less than 0.005mm are shown as dots. The points are shifted so that refA has zero error and rotated so that refB has minimal error. The largest errors are 0.041mm [1.6mil] and 0.047mm [1.9mil] for the top and bottom respectively.

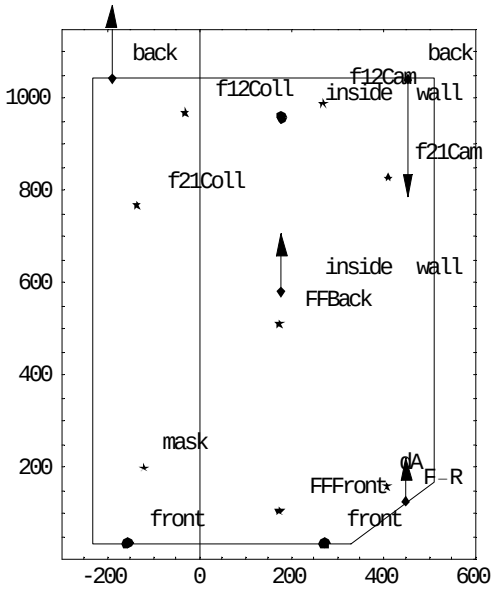
2.3 Deviation of the Bottom Plate from a Plane

Since the top and bottom plates of the COB are thin (6 mm) and flexible, the walls fix the form of the plates. We measured the edges of the defining walls through access holes in the bottom plate. See Figure 4.

Three points, “frontL” and “frontR” in the front and “insideFar” in dividing wall, define the reference plane. All of the optics are centered on this plane.

The deviation of the bottom plate from the reference plane is shown in Figure 4. The standard deviation is 0.063 mm. To first order, the back of the COB is twisted, and the standard deviation is 0.037 mm with the twist removed.

It is probably unlikely that optics can be placed much more accurately than the deviation with the twist removed, since some of that is due to repeatability of assembly. The deviation is acceptable, since the tightest tolerance is 0.14 mm, which is a factor of 4 larger.



Location	x [mm]	y [mm]	zBot [mm]
backL	-191	1041	0.079
backR	453	1040	-0.126
insideFar	178	957	0.000
insideNear	178	579	0.062
front-right	450	126	0.046
frontR	271	34	0.000
frontL	-157	35	0.000

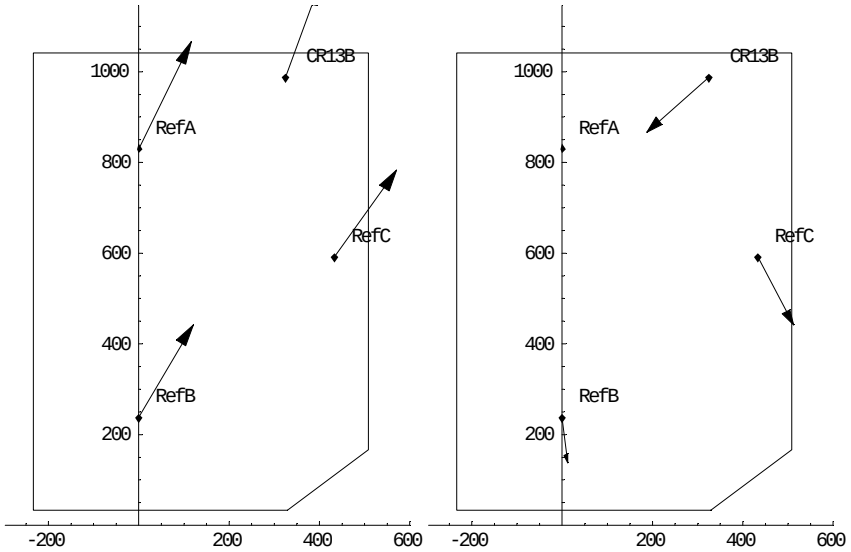
Figure 4 Deviation, magnified by 2000, of the bottom edge of the walls from a plane. The right edge of the back wall is low (shifted away from the top) by 0.13 mm.

2.4 Shift between the Top and Bottom Plates

We measured the shift between the top and bottom plates by measuring the three reference holes. With the top of the COB facing down and the bottom removed, the holes in the top were measured. Then the top was attached, and we measured the holes in the top. See Figure 5.

To determine the shift, the hole on the bottom plate is projected perpendicular to the reference plane of §2.3 to the top plate, which is 406 mm distant.

The location of reference hole A in the top is (0.038, 0.079) mm from the hole in the bottom.

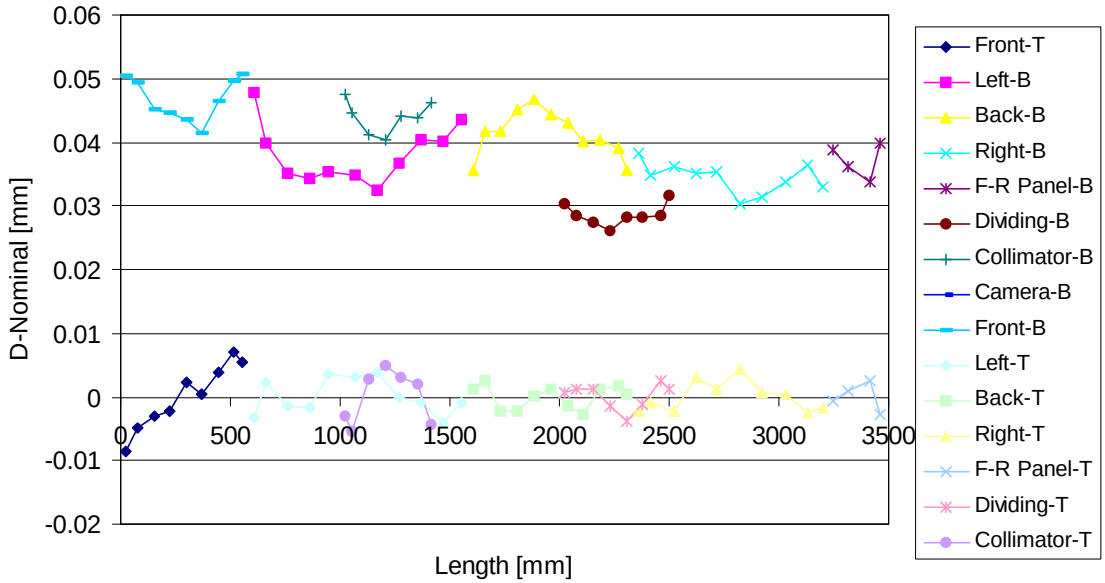


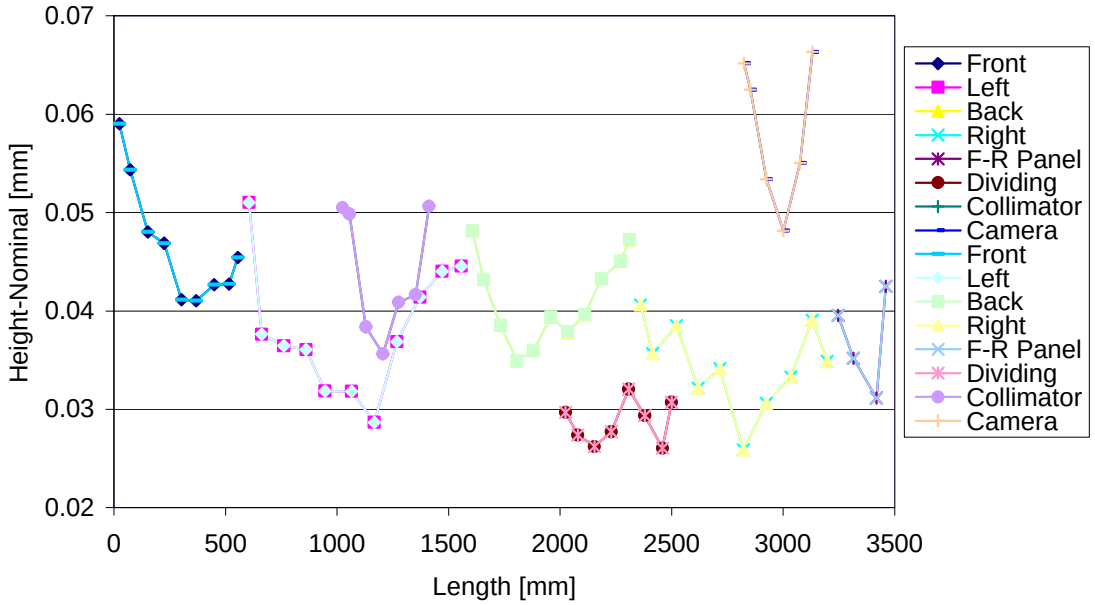
Name	top-bot
CR13B	(-0.014, -0.012)
refA	(0.000, 0.000)
refB	(0.001, -0.010)
refC	(0.008, -0.015)

Figure 5 Shift (left), magnified by 3000, of the pins in the top plate with respect to those in the bottom. Shift (right), magnified by 10,000, after offsetting by the shift of refA (0.038, 0.079). Residuals (in Table) after offsetting.

2.5 Height of the Walls

The walls define the separation between the top and bottom plates. Measurements are in Table 4 and Figure 6. The walls are generally 0.010 mm lower in the middle. The walls were fabricated to be 419.10 mm in height, but the actual mean is 419.141. We adopt 419.141 to be the target separation between the top and bottom plates.





Wall	Mean	Stdev	P-V	M-Nom	M-Mean
Front	419.147	0.006	0.018	0.047	0.006
Left	419.138	0.007	0.022	0.038	-0.003
Back	419.141	0.004	0.013	0.041	0.000
Right	419.134	0.004	0.015	0.034	-0.007
F-R panel	419.137	0.005	0.011	0.037	-0.004
Dividing	419.129	0.002	0.006	0.029	-0.012
Camera	419.158	0.007	0.018	0.058	0.017
Collimator	419.144	0.006	0.015	0.044	0.003
Nominal	419.100				
Mean	419.141				

Figure 6 Edges (top panel) and height (middle panel) of the walls. Each wall is positioned where it connects to the previous one. Table at bottom contains the heights of the walls.

3 Measurements Made Before Final Machining

Final machining produces features on the top and bottom plates to which the optics attach. The cryo-optical box is assembled with the top and bottom plates reversed to expose the insides of the plates for machining. The question is whether the top and bottom plates are aligned well enough to proceed with the machining.

Table 2 Error of the corner of plate P with respect to the corner of plate Q and error of edges with respect to the edge of Plate Q near Wall 2

	Along wall 2	Along wall 3
	x	y
Corner of Plate P [mm]	-0.016	0.077
Corner of Plate P [mil]	-0.6	3.0

	[mrad]	[deg]
Edge on Plate Q near Wall 2	0	0
Edge on Plate P near Wall 2	-0.14	-0.0079
Edge on Plate Q near Wall 3	0.03	0.0017
Edge on Plate P near Wall 3	-0.02	-0.0009

We measured the corner at the intersection of walls 3 and 4. The COB is set on three 1-2-3 blocks on the granite surface of the CMM. Plate Q, which will become the top, is on the CMM. We measured a line on the edges of the plates. The intersection defines the corner of the plate.

One corner of the two plates matches to 3 mil (Table 1). If the angle of the edges is used to extrapolate, the other corners would match to 5 mil.

The error of a few mils is sufficient.