STATUS REPORT FOR JANUARY 2002

Spartan IR Camera for the SOAR Telescope

Edwin D. Loh

Department of Physics & Astronomy
Michigan State University, East Lansing, MI 48824

Loh@pa.msu.edu 517 353–4869

12 February 2002

1 Tasks

1.1 Quotes for mirrors

Request for quotes for four off-axis mirrors, two flats, and aluminum cells were sent to Space Optics Research Laboratory (SORL) of Waltham, MA, Hastings Controls of Pittsburgh, PA, REOSC of France, and Axsys Technologies of Rochester Hills, MI. The mirrors are to be delivered in aluminum cells. By ordering both the mirror and cell from the vendor, we avoid the problem of designing for the thermal contraction between the mirrors and our all-aluminum mounting posts.

SORL submitted a quote and a concept drawing on 24 January 2002. They propose aluminum 6061-T6 tangent bars to hold the mirrors. (See Figure 1.) This concept is technically sound. The tangent bars solve the problem of differential thermal contraction between glass and aluminum. They propose to glue the glass mirror to Invar pads, and they have done this successfully for other projects.

SORL is not able to meet the specification for metrology, that the location of the vertex of the parent be located to an accuracy of (0.15, 0.55) mm. This means the instrument must be aligned optically.

Axsys Technologies submitted a quote on 8 January 2002. They propose a one-piece aluminum mirror and mirror cell. The aluminum is turned on a numerical lathe with a diamond bit. A 25-m layer of nickel is deposited on the aluminum, turned, and then polished and tested. A gold film is deposited on the nickel. They meet all specifications.

Axsys has a superior method for metrology. They pin the aluminum mirror to an aluminum jig, which contains alignment references. With this scheme, the mirror position and the position of the vertex of the parent are known to a few μm. We can position the mirror using the same alignment pins.

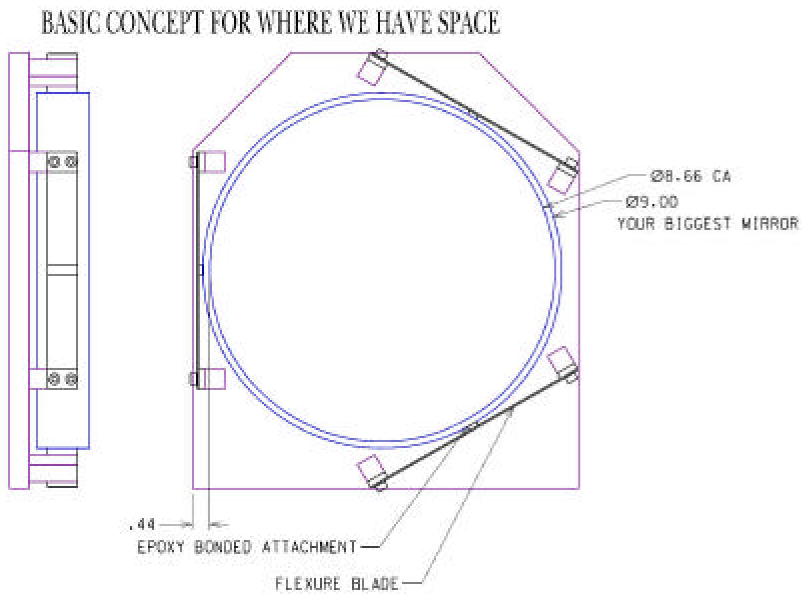


Figure 1 SORL concept for mirror cell from Sterritt, J, 2002, "Cryogenic Mounts for Fused Silica Optics," Space Optics Research Labs.

Hampton Controls submitted a quote and concept design. They were not aware of thermal contraction at 77K. They resubmitted a concept design that is flexible enough to account for thermal contraction.

1.2 Detector circuit card

The detector circuit card holds the detector and connects it to the flexible cables. The detector card was built without a connection between the ground pins and the ground plane. The vendor will fix the problem without cost.

1.3 Mirror support

The mirror support connects the mirror and the rotation stage. We had engineered it analytically by approximating it as a beam. We reengineered the mirror support with a finite-element program VisualNastran and a design program SolidWorks.

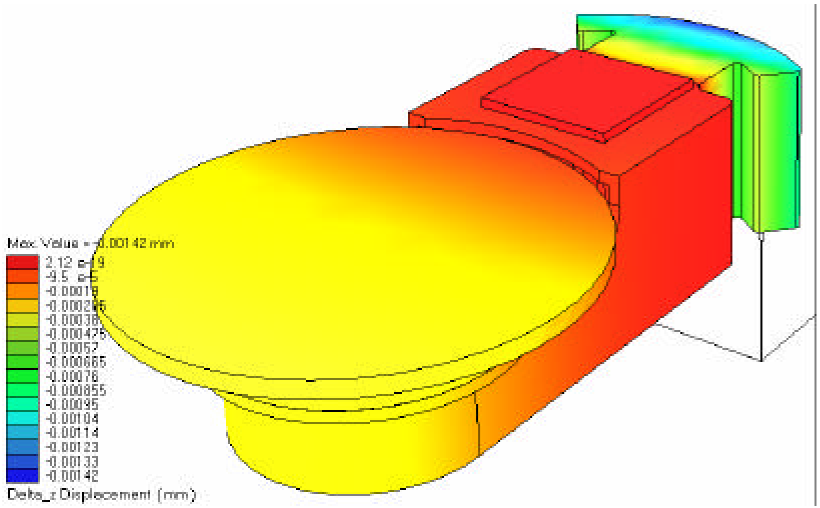


Figure 2 Displacement (mm) of the mirror (mostly yellow), mirror support (mostly red), and counterweight (green and blue) with gravity vertical. The entire assembly is supported by a rotation stage, which bolts to the square pad. The edge of the mirror sags 410nm, and the mirror tilts 1.9µrad.

The mirror support (Figure 2) exceeds the requirement that the tilt of the mirror be less than 6µrad (1/2 pixel at the focal plane). The tilt is 1.9µrad.

1.4 Motor circuit board

The motor circuit board is a thermal resistor between the warm outside and the motors at 77K. The motor current is 1A.

The idea is to use thin traces to achieve thermal resistance and to dissipate the Ohmic heat by radiation. The temperature is kept low by spreading the heat over an area much larger than that of the traces with the circuit board. Figure 3 shows the spreading effect.

We measured the heating of this design with an existing board in vacuum. We found that the temperature rise is a factor of 3 higher in vacuum than at atmospheric pressure. With these measurements on hand, we can design the board.

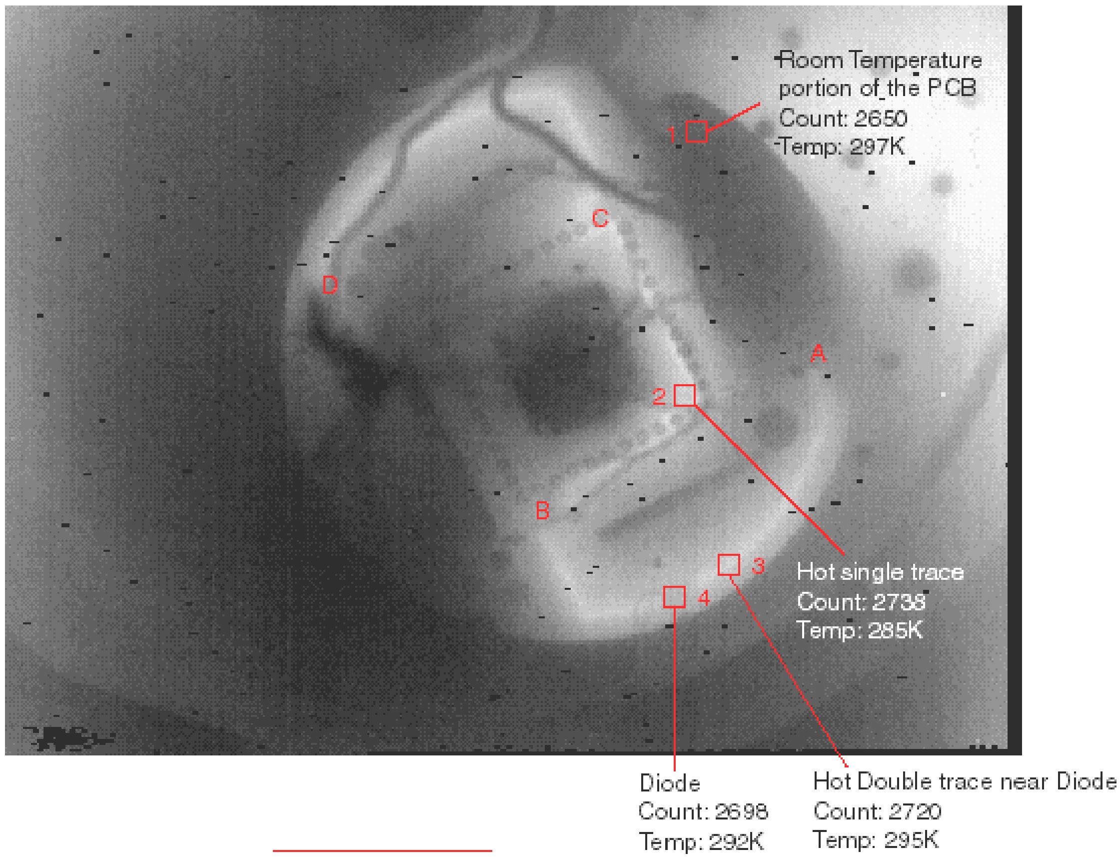


Figure 3 Thermal infrared image of prototype circuit board. Current runs through traces in the shape of a backwards “S”. The heating spreads over an area much larger than that of the trace.

1.5 Pyramidal mirror

The detector fields cannot abut without some space between, and two separate designs are possible.

The simplest design is four abutting detectors in a plane, which covers a 96-mm square. A 1-mm wide space separates the detector packages. A 20-mm dead space separates the 38-mm light-sensing regions.

A design that enables a tighter field uses a pyramidal mirror to split the field into four facets. (Figure 4.) The dead space between detectors is 8 mm.

We plan to install the two detectors on hand in the planar arrangement, and to decide on the pyramidal mirror when we install a third detector.

MikeDavis put the pyramidal mirror into the Zemax design in order to prove the concept and define the space required.

1.6 Test dewar

A test dewar has been designed. These tests will be performed with it.

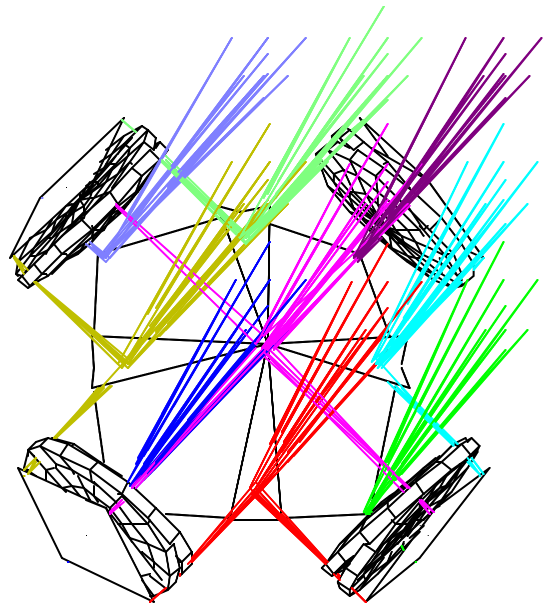


Figure 4 Pyramidal mirror to split focal plane into four facets. (The ridges of the pyramid are not true, since squares instead of diamonds represent the facets of the pyramid.)

- Is the thermal design of the detector PCB, flexible cable, and heat straps sufficient to cool the detector?
- The electronics have been tested extensively without a detector, but will the electronics run the detector? We will measure the noise of the detector, and take a picture in the laboratory.
- Is it possible to expose for a long time?
- We will measure the quantum efficiency of the detector by observing standard star.

The test dewar uses an existing dewar. The detector mount assembly (Figure 5) and modifications of the dewar have been designed and drawings are ready. They will be sent to the shop for fabrication when the shop has moved to the new building during the last week of February.

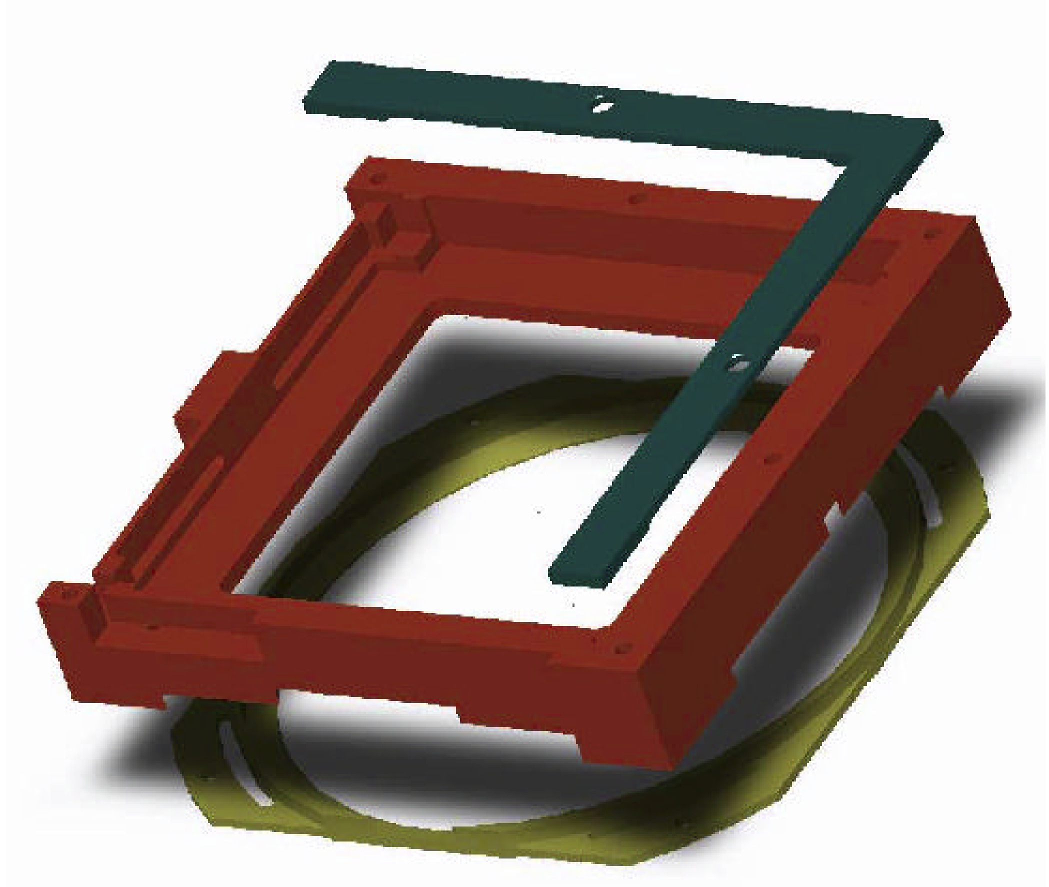


Figure 5 Detector assembly, the parts of which are the detector mount (red), axial spring (green), and lens mount (yellow). The detector is held in addition to the axial springs with three lateral springs that are integral to the mount (lower left and upper lef).

2 Personnel

Four new members join the team of Jason Biel, technician, Tom Carter, programmer, Mike Davis, graduate student, and Ed Loh.

René Laporte will reside in East Lansing during the period March 2002–February 2003. He will work on mechanical design. While in Brazil, he has designed the filter wheels.

Dale Circle, a designer formerly of NOAO, has been hired as a part-time mechanical designer. He remains in Tucson.

Anton Ponischil, an intern from Capital Area Career Center, has started doing drafting.

Owen Loh, a student in the Biomedical Department at Johns Hopkins, worked 3 weeks on finite-element analysis of the mirror mount and mirror posts.

Project Management

The project summary is in Table 1.

Table 1 Project summary

Status date	2/13/2002		
Dates			
Start:	Tue 9/4/01	Finish:	Tue 6/10/03
Baseline Start:	Mon 9/3/01	Baseline Finish:	Tue 6/10/03
Actual Start:	Tue 9/4/01	Actual Finish:	NA
Start Variance:	0 d	Finish Variance:	-1 d
Duration			
Scheduled:	460 d?	Remaining:	360.36 d?
Baseline:	461 d?	Actual:	99.64 d
Variance:	-1 d?	Percent Complete:	22%
Work			
Scheduled:	9,079.87 h	Remaining:	6,901.57 h
Baseline:	8,733.15 h	Actual:	2,178.3 h
Variance:	346.72 h	Percent Complete:	24%
Costs			
Scheduled:	$1,118,827	Remaining:	$575,172
Baseline:	$1,131,372	Actual:	$543,655
Variance:	($12,545)		
Task Status		**Resource Status**	
Tasks not yet started:	404	Work Resources:	6
Tasks in progress:	43	Overallocated Work Resources:	7
Tasks completed:	166	Material Resources:	0
Total Tasks:	613	Total Resources:	13

2.1 Earned value analysis

Earned value analysis does not apply here to work done by Biel, Davis, and Loh; therefore it cannot show problems in work done by them. It can show problems with purchased parts and labor that is charged by the hour.

The earned value analysis of the schedule shows several tasks are behind schedule. (See columns BCWS, BCWP, and SV of Table 2.) The "schedule variance," SV, shows $128k of work should have been performed but has not. The greatest part is in WBS 1.3, "Mechanical," and the major problem is that the mirrors have not been ordered.

What can we do to reduce the schedule variance by the end of February? The task with the greatest schedule variance per month is Mirrors. The requisition is almost done. The other tasks with schedule variances/month larger than $1000/mo are shown in Table 3.

The earned value analysis of the cost shows small variances. (See columns BCWP, ACWP, CV, and VAC of Table 2.) The "cost variance," CV, and "variance at completion," VAC, are small. The task with the largest cost variance is WBS 1.3.1.4, "A-Frame Struts," where the budgeted and actual costs are $5600 and $445.

Table 2 Earned value analysis. A positive "schedule variance," SV, indicates the project is ahead of schedule. A positive "cost variance," CV, or "variance at completion," VAC, indicate the project is less costly than budgeted.

WBS	**Task**	**BCWS**	**BCWP**	**ACWP**	**SV**	**CV**	**EAC**	**BAC**	**VAC**
1	Spartan IR Camera	$684,330	$556,376	$542,841	($127,954)	$13,535	$1,118,827	$1,131,372	$12,545
1.1	Project Management	$49,512	$45,795	$45,925	($3,717)	($130)	$161,619	$161,619	$0
1.2	System Engineering	$720	$720	$2,208	$0	($1,488)	$2,268	$720	($1,548)
1.3	Mechanical	$136,721	$34,310	$25,230	($102,411)	$9,080	$359,625	$368,060	$8,435
1.4	Electronics	$8,785	$6,385	$6,127	($2,400)	$258	$13,447	$12,705	($742)
1.5	Software	$10,000	$0	$0	($10,000)	$0	$10,800	$10,800	$0
1.6	Integration	$0	$0	$0	$0	$0	$3,800	$3,800	$0
1.7	Deliverables	$0	$0	$0	$0	$0	$20,800	$20,800	$0
1.8	Procurement	$46,272	$36,845	$31,031	($9,427)	$5,814	$114,148	$120,548	$6,400
1.9	Preplan Spending	$432,321	$432,321	$432,321	$0	$0	$432,321	$432,321	$0
1	Change from 1/2/02	$60,604	$25,142	$18,905	($35,462)	$6,237	($7,695)	$0	$7,695

BCWS	Budgeted cost of work scheduled
BCWP	Budgeted cost of work performed
ACWP	Actual cost of work performed
SV	Earned value schedule variance; SV=BCWP-BCWS
CV	Earned valve cost variance; CV=BCWP-ACWP.
EAC	Estimate at completion
BAC	Budget at completion

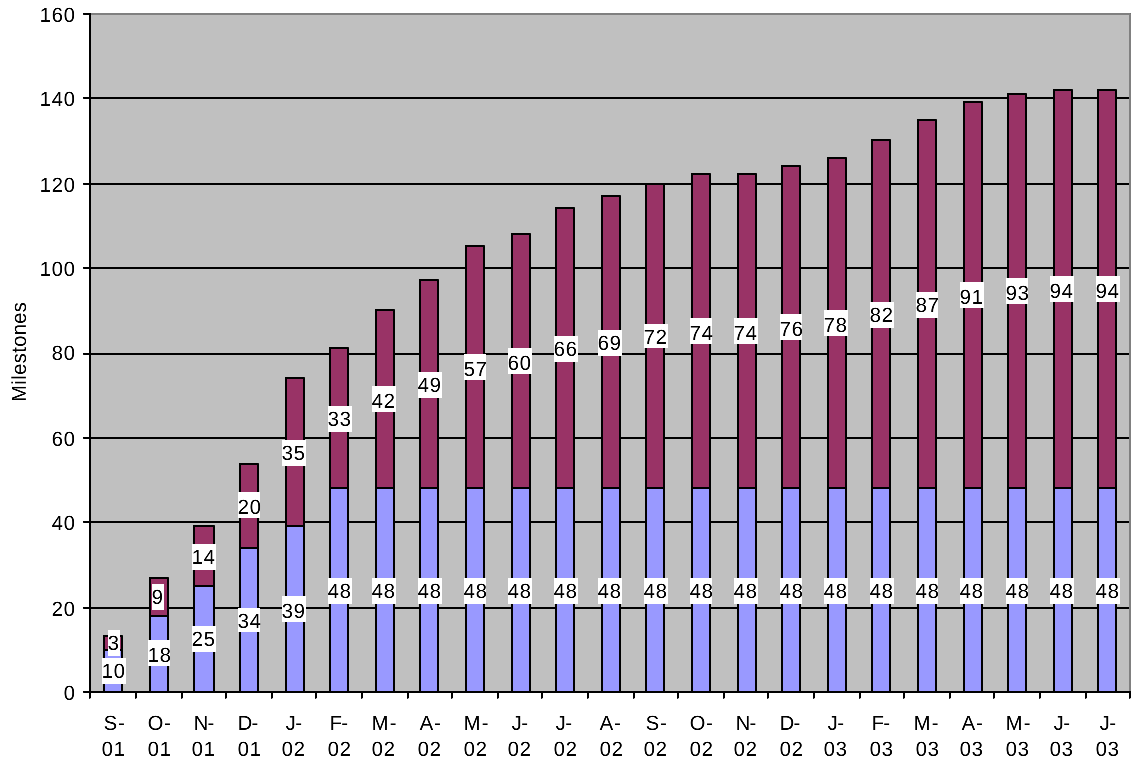
Table 3 Tasks with the greatest schedule variance/month.

WBS	Task	SV/mo	Will SV decrease by next monthly report?	Comment
1.3.6.1	Mirrors	($13,330)	y	Will issue requisition.
1.3.3	Vacuum Enclosure	($8,449)	n	Start of fabrication is not possible because the shop is closed.
1.3.5	Rotational Stage	($7,027)	y	Issue requisition after testing first unit
1.3.1.2	CryoBox	($5,538)	n	Freezing design must wait until mirror interface is fixed
1.3.7	Filters	($3,923)	?	Issue requisition
1.3.8	Upgrades	($3,759)	n	Requisition for mirrors must wait for upgrade decision
1.8.7	Procure 4 Additional Ro	($3,080)	n	Issue requisitions. Must wait for upgrade decision
1.6.1	Telescope Simulator	($2,113)	n	CTIO is making this
1.3.4	Filter Wheel	($1,967)	y	Rene is working on the design
1.8.10	Procure Window	($1,778)	y	Waiting for vendor
1.3.1.1	MLI Blanket	($1,214)	n	Will send RFQ.

2.2 Milestones

The time-phased completion of the milestones is in Figure 6, and a complete list of milestones is in Table 12 in the Appendix. During January and the first part of February, we completed 14 milestones.

Figure 6 Cumulative number of milestones completed (blue) and not completed (magenta) vs. date.



3 Appendix

Three milestones have been removed: "Requisition for Dust-free Hood Issued," "Dust-Free Hood Delivered," and "Requsition for Parts for Test Dewar Issued" We will use the clean room to put the detector into the detector assembly, and we will use an air filter and a tent to protect the instrument from dust. We have found a window and filter from existing parts for the test dewar.

One milestone has been added: "Web site created."

Table 4 Milestones

Milestone		Date			Variance
		Baseline	Completed	Scheduled	
1	Requisition for Flexible Cable Issued	4-Sep-01	1-Oct-01		19 d
2	Requisition for Rotation Stage Issued	6-Sep-01	6-Sep-01		0 d
3	Optical Design Finished	7-Sep-01	7-Sep-01		0 d
4	N2 Can Engineered	7-Sep-01	7-Sep-01		0 d
5	A-Frame Strut Engineered	17-Sep-01	13-Nov-01		42 d
6	Requisition for Vacuum Blukhead Issued	17-Sep-01	7-Sep-01		-6 d
7	Requirements for Optical Alignment Written	17-Sep-01	17-Sep-01		0 d
8	Vacuum Enclosure & Cryo Box ICD Written	18-Sep-01	28-Sep-01		9 d
9	Controller Card SCA Tested (Existing Compute	21-Sep-01	12-Dec-01		58 d
10	Detector Physical Dimensions Measured	24-Sep-01	20-Sep-01		-2 d
11	Requisition for Mirrors Issued	28-Sep-01		6-Feb-02	
12	Requisition for Detector PCB Issued	28-Sep-01	19-Nov-01		36 d
13	Software Requirements Written	28-Sep-01	28-Sep-01		0 d
14	Method for Optical Alignment Created	1-Oct-01	3-Jan-02		68 d
15	Specifications for Telescope Simulator Written	3-Oct-01	3-Oct-01		0 d
16	Requisition for Coordinate-Measuring Machine	5-Oct-01	27-Nov-01		37 d
17	Detector Assembly Concept Developed	8-Oct-01	3-Dec-01		40 d
18	Solidworks License Delivered	11-Oct-01	9-Oct-01		-2 d
19	Mounting Blocks Engineered	12-Oct-01	26-Sep-01		-12 d
20	Select SW Vendor	12-Oct-01	16-Oct-01		1 d
21	Test-Dewar Concept Sketch Finished	15-Oct-01	19-Oct-01		4 d
22	Vacuum Bulkhead Delivered	15-Oct-01	12-Dec-01		42 d
23	N2 Can Designed	18-Oct-01	10-Jan-02		60 d
24	Requisitions for Computer for Laboratory Issued	19-Oct-01	17-Oct-01		-2 d
25	Detector Holder Prototype Designed	25-Oct-01	4-Feb-02		72 d
26	Mounting Blocks Designed	29-Oct-01		29-Oct-01	
27	Rotation Stage Test Fixture Engineered	31-Oct-01	10-Dec-01		28 d
28	Coordinate-Measuring Machine Delivered	2-Nov-01	12-Feb-02		73 d
29	Rotation Stage Test Fixture Designed	7-Nov-01	7-Jan-02		43 d
30	Flex Cable Finished	9-Nov-01	8-Nov-01		-1 d
31	Computers for Laboratory Delivered	9-Nov-01	11-Dec-01		22 d
32	Project Plan Finished	16-Nov-01	19-Dec-01		24 d
33	Cryo-Optical Box Engineering Finished	16-Nov-01	28-Nov-01		8 d
34	Detector Holder Prototype Fabricated	19-Nov-01		19-Nov-01	
35	Test-Dewar Fabricated	19-Nov-01		19-Nov-01	
36	Detector PCB Finished	21-Nov-01		21-Nov-01	
37	Master Layout Designed	26-Nov-01	23-Nov-01		-1 d
38	Rotation Stage Delivered	29-Nov-01	6-Feb-02		50 d

39	A-Frame Strut 3D Designed	30-Nov-01	30-Nov-01		0 d
40	Specifications for Vacuum Enclosure Written	6-Dec-01	24-Oct-01		-31 d
41	Rotation Stage Test Fixture Fabricated	7-Dec-01	8-Feb-02		45 d
42	Requisition for Field-flattening Lenses Issued	7-Dec-01		7-Dec-01	
43	Mask Plate Engineering Finished	7-Dec-01		7-Dec-01	
44	Requisition for Window Issued	10-Dec-01	8-Feb-02		44 d
45	MLI Requisition Issued	10-Dec-01		2-Jan-02	
46	Flex Cable/Bulkhead Assemble Finished	11-Dec-01		11-Dec-01	
47	Specification for Filter Wheels Written	14-Dec-01	10-Dec-01		-4 d
48	Rotation Stage Tested	14-Dec-01		14-Dec-01	
49	Mounting Blocks Fabricated	14-Dec-01		14-Dec-01	
50	Joined Filter Consortium	14-Dec-01		14-Dec-01	
51	Requisitions for Vacuum Parts Initiated	20-Dec-01		20-Dec-01	
52	Requisition for Rotation Stage Controller & 2nd	25-Dec-01		25-Dec-01	
53	Cable for Motors Analyzed	28-Dec-01	8-Feb-02		30 d
54	Mask Plate Designed	28-Dec-01		28-Dec-01	
55	Detector Holder Prototype Thermal Test Finishe	1-Jan-02		1-Jan-02	
56	Vacuum Enclosure Engineered	3-Jan-02	31-Oct-01		-46 d
57	MLI Designed	8-Jan-02		8-Jan-02	
58	Thermal Reflector Engineered	9-Jan-02		9-Jan-02	
59	Communications Test Software Delivered	14-Jan-02	30-Jan-02		12 d
60	Requirements for Window Written	15-Jan-02	18-Jan-02		3 d
61	Requirements for Field-Flattening Lens Written	15-Jan-02	8-Feb-02		18 d
62	Requirements for Telescope Simulator Modified	15-Jan-02	10-Dec-01		-26 d
63	Requirements for Pyramidal MirrorWritten	15-Jan-02	8-Feb-02		18 d
64	Motor PCB Designed	18-Jan-02		19-Feb-02	
65	Filter Wheel Mounting Block Specified	21-Jan-02	21-Sep-01		-87 d
66	MUX Tested at Room Temperature	22-Jan-02		22-Jan-02	
67	Parts for Test Dewar Assembled	25-Jan-02	8-Feb-02		10 d
68	Cryo-Optical Box Drawings Finished	30-Jan-02		13-Feb-02	
69	Basic Software Delivered	30-Jan-02		30-Jan-02	
70	Motor Software Delivered	30-Jan-02		30-Jan-02	
71	Complete Software Delivered	30-Jan-02		30-Jan-02	
72	Reworked Software Delivered	30-Jan-02		30-Jan-02	
73	Vacuum Parts Delivered	31-Jan-02		31-Jan-02	
74	Telescope Simulator Engineered	31-Jan-02		31-Jan-02	
75	MUX Tested at Cold Temperature	1-Feb-02		1-Feb-02	
76	Requistions for Parts for Telescope Simulator Is	8-Feb-02		8-Feb-02	
77	Motor PCB Fabricated	8-Feb-02		12-Mar-02	
78	Vacuum Enclosure Designed	22-Feb-02		22-Feb-02	
79	Hardware & Software Tested	26-Feb-02		20-Mar-02	
80	Upgrade Decision for 2nd Channel Made	28-Feb-02		28-Feb-02	
81	Web Site Created	28-Feb-02		28-Feb-02	
82	MLI Blanket Delivered	7-Mar-02		7-Mar-02	
83	Thermal Reflector Concept Analyzed	8-Mar-02		8-Mar-02	
84	Telescope Simulator Designed	11-Mar-02		11-Mar-02	
85	Parts for Telescope Simulator Delivered	13-Mar-02		13-Mar-02	
86	A-Frame Strut Fabricated	15-Mar-02	14-Dec-01		-65 d
87	Mask Plate Finished	22-Mar-02		22-Mar-02	
88	Thermal Reflector Designed	22-Mar-02		22-Mar-02	
89	Vendor for Thermal Reflector Selected	22-Mar-02		22-Mar-02	
90	N2 Can Fabricated	28-Mar-02		20-Jun-02	

91	Detector Tested in Lab	2-Apr-02	2-Apr-02
92	Rotation Stage Controller & 2nd Stage Delivere	8-Apr-02	8-Apr-02
93	Cryo-Optical Box Fabricated	9-Apr-02	23-Apr-02
94	Detector Tested with Sky	10-Apr-02	10-Apr-02
95	Filter Wheel Designed	12-Apr-02	12-Apr-02
96	Detector Assembly Designed	30-Apr-02	30-Apr-02
97	Scripts Tested	30-Apr-02	30-Apr-02
98	Reworked Electronics Finished	1-May-02	1-May-02
99	Mirrors Delivered	6-May-02	11-Sep-02
100	Window Delivered	9-May-02	9-May-02
101	Thermal Reflector Fabricated	15-May-02	15-May-02
102	Telescope Simulator Fabricated	17-May-02	17-May-02
103	Mirrors Installed in Mounts	20-May-02	25-Sep-02
104	Mask Wheel Engineered	21-May-02	21-May-02
105	Vacuum Enclosure Finished	24-May-02	23-May-02
106	Collimator and Camera Mirror Mount Designed	14-Jun-02	14-Jun-02
107	Mask Wheel Designed	18-Jun-02	18-Jun-02
108	Cryo-Optical Box Thermal Test Finished	21-Jun-02	25-Jul-02
109	Filter Wheels Fabricated	12-Jul-02	12-Jul-02
110	Field-Flattening Lenses Delivered	12-Jul-02	12-Jul-02
111	Test Plan for Filter Wheel Written	12-Jul-02	12-Jul-02
112	Detector Assembly Fabricated	15-Jul-02	15-Jul-02
113	Detector Assembly Finished	22-Jul-02	22-Jul-02
114	Mask Wheel Fabricated	31-Jul-02	31-Jul-02
115	Filter Wheel #1 Tested Warm	7-Aug-02	7-Aug-02
116	Filter Wheel #1 Tested Cold	15-Aug-02	15-Aug-02
117	Filter Wheel #2 Tested	22-Aug-02	22-Aug-02
118	Mask Wheel Tested	3-Sep-02	3-Sep-02
119	Procure F/21 Collimator & Camera Mirrors Del	13-Sep-02	18-Sep-02
120	2nd Collimator and Mirror Mount Fabricated	13-Sep-02	13-Sep-02
121	Telescope Simulator Finished	7-Oct-02	7-Oct-02
122	2nd Collimator and Mirror Mount Tested	17-Oct-02	17-Oct-02
123	Basic Filters Delivered	13-Dec-02	13-Dec-02
124	All Filters Delivered	13-Dec-02	13-Dec-02
125	Instrument Assembled & Aligned at Room Temp	21-Jan-03	21-Jan-03
126	Flexure Tested	28-Jan-03	28-Jan-03
127	Draft Maintenance Manual Written	14-Feb-03	14-Feb-03
128	Draft Software Manual Written	14-Feb-03	14-Feb-03
129	Cold Test #1 Finished	18-Feb-03	18-Feb-03
130	As-Built Drawing Package Assembled	28-Feb-03	28-Feb-03
131	Draft Operating Manual Written	14-Mar-03	14-Mar-03
132	Maintenance Manual Finished	31-Mar-03	31-Mar-03
133	Software Manual Finished	31-Mar-03	31-Mar-03
134	Draft Acceptance Test Written	31-Mar-03	31-Mar-03
135	Shipping Container Finished	31-Mar-03	31-Mar-03
136	Cold Tests Finished	11-Apr-03	11-Apr-03
137	Image Quality Tested in Laboratory	18-Apr-03	18-Apr-03
138	Image Quality Tested on Sky	28-Apr-03	28-Apr-03
139	Operating Manual Finished	30-Apr-03	30-Apr-03
140	Acceptance Test Written	7-May-03	7-May-03
141	Pre-Ship Acceptance Test Finished, Integration	14-May-03	14-May-03
142	Project Complete	10-Jun-03	10-Jun-03