MONTHY STATUS REPORT FOR OCTOBER 2001

Spartan IR Camera for the SOAR Telescope

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Milestones, Spartan IR Camera

Date	**Event**	
1-Oct-2001	Requisition to Compunetics for flexible circuit board issue	JB
3-Oct-2001	Software specifications written	MD
12-Oct-2001	Sent software specifications to Imaginatics & T. Carter	EL
10-Oct-2001	Picture read with SCA and SUA	EL&
16-Oct-2001	Tom Carter will write software	
17-Oct-2001	Ordered computers for Tom Carter & Rene Laporte	EL
18-Oct-2001	Measured noise of camera card	JB&
18-Oct-2001	Received quotes for window	MD
23-Oct-2001	Requisition to Compunetics for rigid dewar circuit board is	JB
27-Oct-2001	Redesigned posts to eliminate interference	EL
28-Oct-2001	Completed mechanical design of vacuum enclosure	EL
31-Oct-2001	Sent design of vacuum enclosure top to Precision Cryogeni	EL
31-Oct-2001	Nitrogen can 3-d design done; ready for drafting	DK&
5-Nov-2001	Flamant transition done; ready for 3-d design	EL
5-Nov-2001	NOAO delivers project plan	

1 Tasks

1.1 Mechanical layout

Dave Keesaer is working on the master mechanical layout, which define space envelopes for each assembly. We identified two assemblies with interference. (1) The f/11 collimator and mechanism for inserting the f/21 collimator interfere. This is fixed by moving the insertion mechanism to the front of the f/21 collimator. (2) The post for the first fold mirror and the post for the rotation stage for a filter wheel interfere. This is fixed by a redesign, described below, of the posts to save space

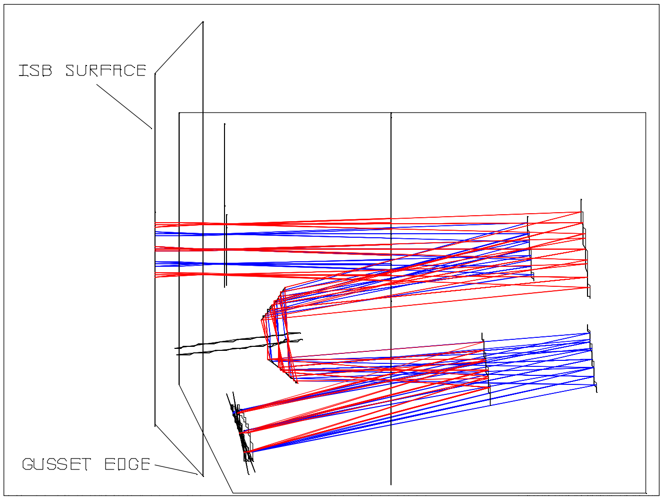

Figure 1 Optical layout. The box is the outline of the cryogenic optical box. The detector assembly is shown without the pyramidal mirror. The optical box is 940×790×400mm.

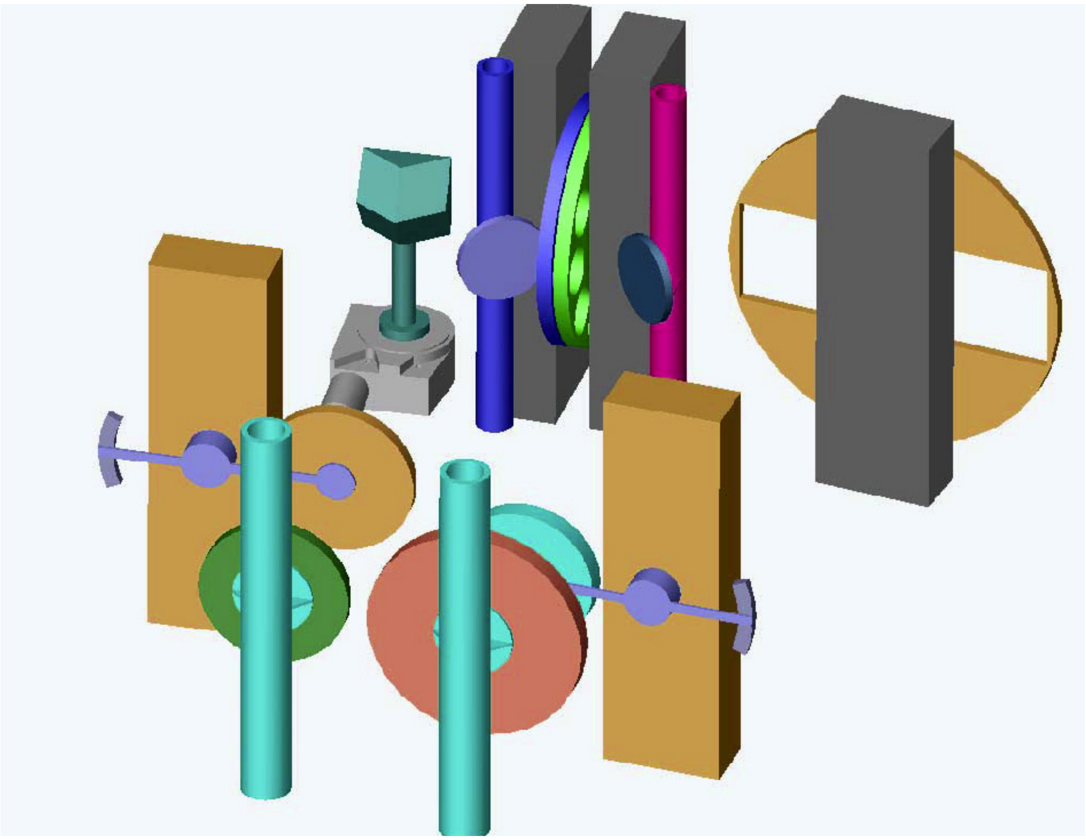

Figure 2 Master layout model, which is used to proof space envelopes of each assembly. Light enters from the upper right, traverses the mask wheel, hits either the f/21 collimator or the f/11 collimator (if the f/21 collimator is rotated out), hits a fold mirror, traverse the filter and Lyot stop, hits a fold mirror, hits either the f/21 or f/11 camera mirror, hits a pyramidal mirror, and then the detector (not shown).

1.2 Mounting posts

A mounting post attaches each optical assembly to the optical box.

1.2.1 Rotation stages

The mounting posts for the assemblies that use a rotation stage have been redesigned to save space. The rotation stages had been attached to two I-beams on the back of the stages. Now they are placed inside an aluminum box with 4-mm walls. There is an opening in the box for the rotating platform.

The box resists torsion.

1.2.2 Fixed optics

The mounting posts for the fixed optics use a tube. For the f/11 collimator and the f/21 camera mirror, the tubes are 50 mm in diameter with 6-mm walls. For the fold mirrors, the tubes are 38 mm in diameter with 6-mm walls.

1.2.3 Flexure

The specifications are that the camera and tip-tilt guider maintain boresight alignment to 0.04 arcsec in the sky and that the focus change is less than 30µ to preserve the image. The safety factors, defined to be the ratio of the specification split evenly between 4 optical elements to the actual error, is comfortably large (Table 1). Rotation of the posts affects boresight, and sag of the posts affects focus. The posts are very stiff under a torsion load.

Table 1 Safety factors for focus and boresight alignment with the tip-tilt sensor.

Assembly	Post	Safety factor	
		Boresight	Focus
Mask wheel	Box	17	10
f/21 collimator	Box	19	4.8
f/11 collimator	Tube	10	2.3
Fold	Tube	110	11
Filter wheel	Box	Large	Large
f/21 camera	Tube	16	4.0
f/11 camera	Box	13	2.9

1.3 Condensation on the window and the heat load of the instrument opening

The window cools because of radiation into the cold instrument, and the instrument accepts a substantial heat load of 3 W. The window warms by radiation and conduction to the edges, which are at ambient temperature. A CaF2 window can operate without condensation at up to 50-60% relative humidity (lowest curve in Figure 3). The center of the window is 7 C cooler than the edge.

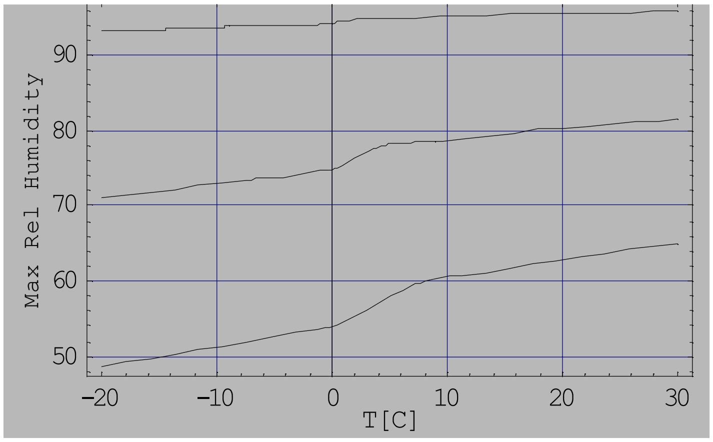

Figure 3 Maximum relative humidity for a CaF2 window with radiation reflector (top), fused silica window with radiation reflector (mid), and a CaF2 window without radiation reflector (bottom).

We have designed a hemispherical-planar reflector, which reflects the warm radiation back. The reflector consists of a hemisphere centered about 20 cm inside the window and a planar cap. There are holes in the hemisphere and plane for light to enter and exit.

Thermal radiation emitted by the center of the mirror reflects back from the hemisphere except that which emitted into the opening of the field stop. Most of the thermal radiation from the edge of the window returns to the window after 4 reflections. Because the plane and hemisphere join at a right angle, the joint acts like a corner reflector. (See Figure 4.)

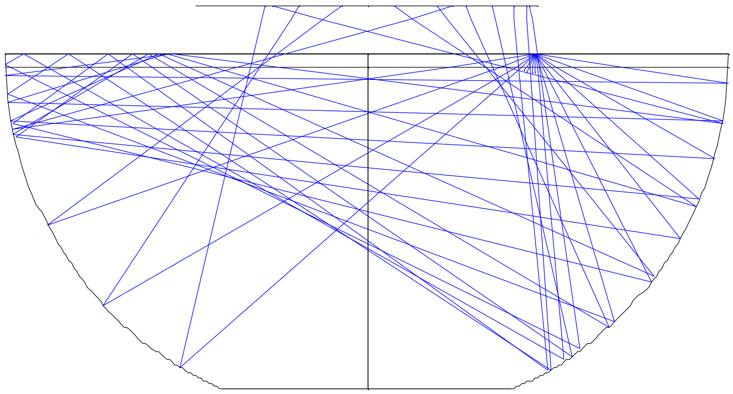

Figure 4. Hemispherical-planar reflector. A fan of rays are emitted from a point on the warm window. The rays heading toward the left return to the window after one reflection. The rays heading to the right hit the plane mirror and return to the window after 4 reflections. The rays that enter the cold instrument (at the bottom) are not shown.

We estimate that the emissivity of the window is reduced by the factor 0.1. The center of a CaF2 window is 0.7 C cooler than the edge, and the maximum relative humidity without condensation is about 95%.

1.4 Vacuum enclosure

The requirements for the vacuum enclosure are these: (1) Stress in the aluminum enclosure is less than 60MPa (ASME Pressure Vessel Code, Section VIII, Division 2 for bending stress). (2) The electrical and nitrogen lines should remain connected when the vacuum cover is removed. (3) Alignment and adjustment must be possible with the cover removed and the telescope simulator attached. (4) Change of filter should be possible without removal of the entire vacuum cover and disassembly of the optical box. (5) The vacuum gauges and valve need to be accessible when the instrument is on the telescope. (6) The nitrogen lines may run out to an accessible location that is not near the exit from the vacuum enclosure.

The vacuum enclosure is made of two pieces, a 900×500×200-mm base and a 900×500×900-mm top. The base has electrical and nitrogen lines and the window. In addition, it serves as the connection between the ISB and the A-struts that hold the cryogenic optical box. The top has a

Conflat port to which gauges, a valve, a Zeolite getter for water, and a pop valve are attached. The large 900×900-mm surfaces support the 9-ton force of the atmosphere, and the maximum stress is 45 MPa, which is safe.

The design of the top is done, and the design of the base is near completion. The design of the top was sent to the Physics-Astronomy shop and to Precision Cryogenics of Indianapolis. Precision Cryogenics submitted a quote, which was within budget.

1.5 A-frame struts

A-frame struts hold the cryogenic optical box and provide thermal resistance. The most stringent requirement is to preserve boresight alignment between the instrument and the tip-tilt guider when the mounting surface of the instrument support box (ISB) is vertical. The primary pair of struts, made of G-10 with 1×½-in cross section, is optimized for that requirement. The secondary pair, made of G-10 with 3/8×3/8-in cross section, prevents a rotation of the instrument. Both pairs keep focus when the mounting plate is horizontal. The distance between the base and apex of the "A" is 130 mm, and the opening angle at the apex is 120°.

The safety factor for buckling is 74 for the primary struts and 8 for the secondary struts. When the cryogenic optical box cools from room temperature to 77 K, the struts bend. The safety factor for stress due to bending is 11 for the primary struts and 5 for the secondary struts.

The heat load is 600 mW.

The worst-case shift of the boresight alignment between the instrument and the tip-tilt guider is 9μ or 0.03 arcsec, which is 3 times better than the shift of the ISB. The worst-case shift in focus is 23μ, whereas the maximum allowance is 30μ.

1.6 Flamant attachment

The aluminum instrument must bolt onto the stainless steel ISB, and the attachment must allow for a 30C change in the ambient temperature between installation and operation.

If the vacuum enclosure were bolted directly to the instrument, the instrument will slip by up to 0.4 arcsec in an unpredictable way when the ambient temperature changes. With a 30-C change in temperature, bolts must resist a 40,000-N force to resist differential expansion. Since that is 3 times the maximum force of the M10-1.5 bolt, the instrument will slip.

We designed an attachment between the instrument and ISB that accommodates changes in temperature. The attachment is a semicircular plate based on the “Flamant solution” (Handbook of Engineering Mechanics, W. Flugge, ed., McGraw-Hill, New York, 1962). The center of the plate is bolted on the ISB, and the periphery is bolted on the instrument. Two attachments on opposite sides prevent boresight errors, and a third, thinner attachment prevents rotation of the instrument.

The maximum boresight error with rotation of the instrument is 2.0μ, which is 1/15th that of the specification of the ISB. The maximum focus error is also 2.0μ. (The equality of the motions in the two directions is Flamant’s solution.) Since the third attachment is not paired (Its mate is made inaccessible by the gusset on the ISB.), it causes an unbalanced force. The resulting boresight error is a negligible 0.009μ/C, which is 1/100th of the diffraction width for a 30-C change.

When the temperature cools 30 C from installation, the bolt to the ISB must hold a 930-N force, which is 1/16th of its maximum.

1.7 Requests for 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, and REOSC of France. The mirrors are to be delivered in the aluminum cells. By ordering this unit from the vendor, we avoid the problem of designing for the thermal contraction between the mirrors and our all-aluminum mounting posts.

1.7.1 Hastings Controls

Hastings Controls submitted a quote on time. Their design of the mirror cell neglected to consider thermal contraction, and it included 6-axis adjustment of the mirror, which was not in the request. We worked with their subcontractor for mechanical design to clarify the requirements, and they submitted a revised quote.

The mechanical design uses Invar mirror cells or a spring to accommodate the glass mirror. The Invar mirror cell will stress the mirror because the cell will cool faster than the mirror. If the contact area between the cell and mirror is less than 1/6th of the area of the side, the mirror will crack. Therefore the contact between the cell and mirror must be carefully controlled. The spring is a better design.

1.7.2 SORL

SORL submitted a quote a month after the due date. The optical prescription was taken from the preliminary RFQ of June 2001 rather the current one. They are reworking the quote.

SORL is not able to meet the specification for the precision of the location of the vertex of the parent. Had that specification been met, the mirrors could be placed mechanically accurately enough to avoid optical alignment.

In principle, optical alignment of the collimator requires adjusting 6 parameters. SORL is able to set the rotation about the optic axis. The position in the direction of the optic axis is within mechanical tolerance. We have determined that the tilt of the surface can be set mechanically so that the surface matches the true surface within the accuracy of a coordinate measuring machine (3µ). The surface error (Figure 5) of the f/11 collimator shifted in the direction of the perpendicular to the optical plane of the instrument with a compensating tilt is very small (tens of nm). Therefore alignment requires determination of two parameters by examination of the images.

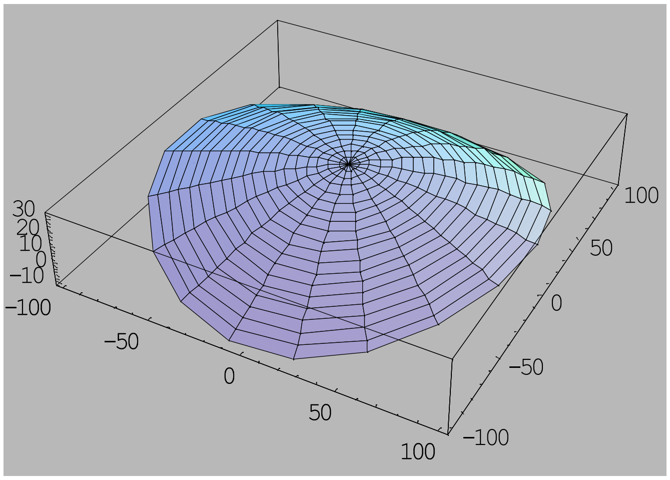

Figure 5 Mirror surface error in nm for a shift in the x-direction equal to the tolerance (0.1mm) for the f/11 collimator. Removed are a translation of 9.6µ along the optic axis and a tilt amounting to 7.4µ at the edge.

1.8 Telescope simulator (SOBER)

CTIO plans to build a telescope simulator to test the Instrument Support Box (ISB), and we are trying to determine whether it can be used to test the IR camera. Tom Ingerson has sent us the optical design.

1.9 Detector cable

The cable between the detector and controller has three parts. (1) The detector mounts on a rigid board. (2) A flexible board connects that board and the detector controller, which is outside of the vacuum enclosure. (3) The flex board is potted in a vacuum bulkhead.

The flex board has just been delivered. We will send the flex board to Pave to pot into the vacuum bulkhead. The detector board is in fabrication.

1.10 Detector controller

We are debugging the detector controller. The detector controller works when the field programmable gate array (FPGA) is made to emulate an existing CCD controller. This proves the digital part of the design. We are working on the analog part of the circuit.

1.10.1 Noise and bandwidth

We measured the bandwidth of the signal chain to be 2.4 MHz, which means the time to settle to a part in 2^{12} is 0.55µs.

We measured the noise of the controller board to be 14.8µV referenced to the input at a bandwidth of 2.4 MHz. The OPA350 op-amp and a 1kΩ resistor contribute equally to the noise. The measured noise is within a few percent of the theoretically predicted noise.

The circuit will probably be run at 1/3 the bandwidth, since the goal is to read at 3 µs/pixel. In that case the board produces a noise of 8.5 µV, which is equivalent to 2.4 electrons. The detector noise is less than 10 electrons (http://www.rsc.rockwell.com/imaging/hawaii2/index.html).

The 1/f noise is a concern, because the signal chain is DC coupled. The root mean power of the rows (middle spectrum in Fig. 6, offset by –2) is independent of spatial frequency. (The picture is read by rows.) The root mean power of the columns (top spectrum in Fig. 6) shows a slight rise at very low frequency. The root power of the average column (bottom spectrum in Fig. 6) shows a large amount of low frequency noise. The white noise is less by a factor of √512, but the low frequency excess is unchanged. This shows the low frequency noise is correlated over rows. The low frequency excess contains 5×10^{-4} of the power.

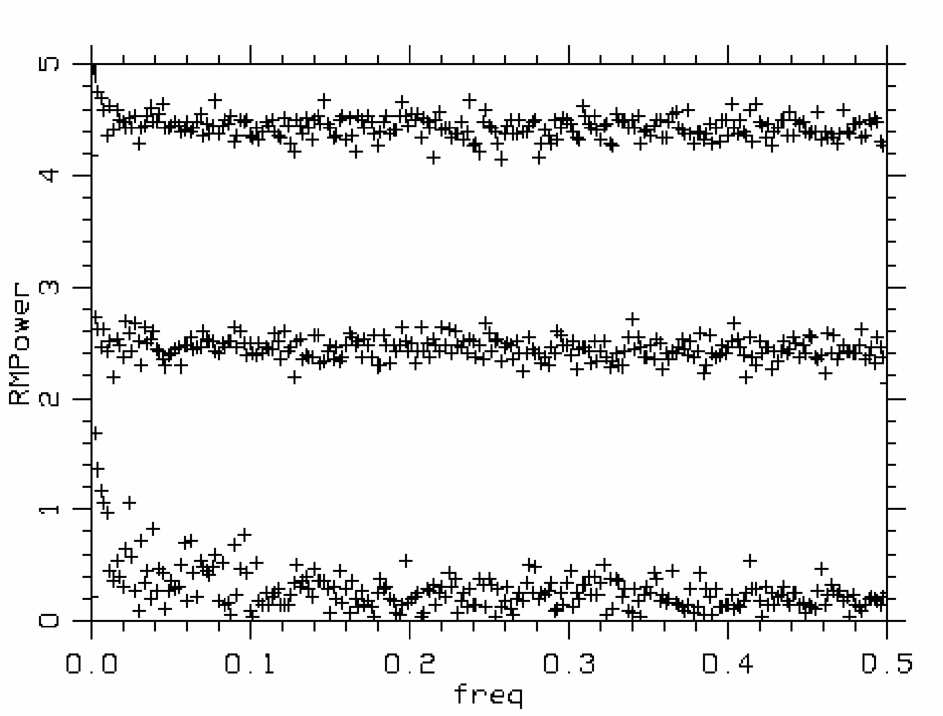

Figure 6 Caption: Root-mean-power of the columns (top) and of the rows (middle offset by 2) and the power of the average column (bottom) vs spatial frequency. For white noise, the standard deviation is RMP/√2. For sinusoidal noise, the amplitude is RMP/16. The picture is 512×512.

1.10.2 High gain analog-to-digital converter

There are two analog-to-digital converters (ADC), one with gain 1 for large signals and one with gain 16 for low signals. The high gain ADC was mistakenly designed to operate for signal levels near saturation. This will be fixed in the next version of the board.

1.10.3 Digital potentiometers

Digital potentiometers set the offset levels for each quadrant, the reset voltage, and bias gate. These are controlled by software. These function properly.

1.10.4 Temperature sensors

Diode temperature sensors are run and read out by a circuit on the card. The sensor that reads the board temperature functions properly. The circuit that reads the sensors that will be placed in the dewar functions properly.

1.10.5 Phase-locked loop

A phase-locked loop generates a clock from the master clock on the umbilical board. With a single master clock, all of the circuits are synchronous and no noise due to beating of different clocks is possible. The phase-locked loop has not been checked.

1.11 Detector assembly

The concept design for the detector assembly is complete. Each detector is held in an aluminum mount. The mount also holds a field-flattening lens. Two sides of the mount are sprung to hold the detector in two directions. A cover is sprung to hold it in the third direction. The springs accommodate the thermal mismatch between aluminum mount and the alumina detector frame.

A detector assembly will be built and tested in a test dewar. This is in progress.

1.12 Software

Mike Davis & EL wrote the software requirements. We sent this document to Mike Ashe of Imaginatics and to Tom Carter of the Chemistry Department. Tom agreed to write the software. Mike is willing to help with questions about ArcView.

2 Brazilian collaboration

René Laporte’s move to East Lansing has been postponed because of personal commitments.

3 Budget

We thank Neil Gaughan NOAO for teaching the PI rudimentary project planning and Dan Elkund of NOAO for making a well organized draft plan in Microsoft Project.

The budget (summary in Table 2) includes the upgrade for the second focal ratio. It does not include the pyramidal mirror that is needed if more than two detectors are installed. Fixed costs are vendor purchases and fixed cost labor of J Biel, M Davis, and E Loh. Hourly costs, those that are charged by the hour, include the Physics-Astronomy machine shop, external shops, a part-time mechanical designer, and part-time mechanical drafting.

Table 2 Budget summary.

WBS	**Description**	**Cost [$]**				**Labor [hr]**				
		Fixed	**Hourly**	**Contingenc**	**Total**	**FixedC**	**Design**	**Draftir**	**Shop**	**Total**
1	Spartan IR Camera	1,013,331	107,156	34,350	1,154,837	4785	666	855	2092	8498
1.1	Project Management	161,611	0	0	161,611	887	0	0	0	887
1.2	System Engineering	0	720	0	720	415	24	0	0	439
1.3	Mechanical	273,280	92,956	24,004	390,240	1072	518	791	1724	4105
1.4	Electronics	5,366	6,080	2,986	14,432	777	44	24	208	1053
1.5	Software	10,000	800	0	10,800	0	0	0	0	100
1.6	Integration	0	3,800	0	3,800	1098	40	40	80	1258
1.7	Deliverables	18,000	2,800	0	20,800	331	40	0	80	451
1.8	Procurement	122,408	0	7,360	129,768	205	0	0	0	205
1.9	Preplan Spending	422,666	0	0	422,666	0	0	0	0	0

Project Management (Table 3) includes creation and maintenance of the schedule and budget, meetings, reviews, reports, consultants, travel in support of purchases, and fixed cost labor.

System Engineering includes writing plans, writing requirements, and analysis.

Mechanical (Table 4) includes the construction of the vacuum enclosure, cryogenic optical box, and optics.

Electronics includes the detector electronics and detector assembly.

Software is modification of ArcView.

Integration includes installation of each assembly in the instrument and testing of the completed instrument.

Deliverables includes writing manuals, the acceptance test, and installation at the telescope. It does not include commissioning.

Procurement (Table 5) includes most of the purchased items.

Preplan Spending means funds that we spent or encumbered before 1 Sept 2001. The major item here is the cost of the detector, $250,000.

This budget includes the quote for the mirrors from SORL. This was a substantial uncertainty in the preliminary budget of 23 August 2001.

Contingency is done in this way: (1) For purchased item with a written vendor quote, the contingency is 5%. For purchased items without a formal quote, the contingency is 25% or greater. (2) For fixed-cost labor (Biel, Davis (1/2 time), and Loh), the number of hours in 22 months is 6600. With 4607 hours budgeted, the contingency is 43%. The addition of Laporte adds to the contingency. (3) For hourly labor, Gaughan and Loh tried to estimate times so that the task can be done comfortably.

Table 3 Summary budget for WBS 1.1, Project Management

WBS	**Description**	**Cost [$]**				**Labor [hr]**				
		Fixed	**Hourly**	**Contingen**	**Total**	**FixedC**	**Design**	**Draftir**	**Shop**	**Total**
1.1	Project Management	161,611	0	0	161,611	887.2	0	0	0	887.2
1.1.1	Schedule & Budget	6,611	0	0	6,611	86.2	0	0	0	86.2
1.1.2	Weekly Meetings	0	0	0	0	273	0	0	0	273
1.1.3	Reviews	0	0	0	0	176	0	0	0	176
1.1.4	Reports	0	0	0	0	352	0	0	0	352
1.1.5	Consultants	10,000	0	0	10,000	0	0	0	0	0
1.1.6	Fixed Costs	140,000	0	0	140,000	0	0	0	0	0
1.1.7	Travel to vendors	5,000	0	0	5,000	0	0	0	0	0

Table 4 Budget summary for WBS 1.3, Mechanical

WBS	Description	Cost [$]				Labor [hr]				
		Fixed	Hourly	Contingen	Total	FixedC	Design	Draftir	Shop	Total
1.3	Mechanical	$273,280	$92,956	$24,004	$390,240	1072	518	791	1724	4105
1.3.1	Cryo-Optical Box	$6,000	$33,364	$750	$40,114	248	216	431	536	1430
1.3.1.1	MLI Blanket	$3,000	$1,047	$750	$4,797	33	16	23	0	71
1.3.1.2	CryoBox	$1,000	$18,880	$0	$19,880	184	136	160	270	750
1.3.1.3	Mask Plate	$1,000	$600	$0	$1,600	8	8	8	8	32
1.3.1.4	A-Frame	$0	$5,600	$0	$5,600	6	40	80	120	246
1.3.1.5	N2 Can	$1,000	$7,237	$0	$8,237	16	16	160	138	330
1.3.2	Thermal Reflector	$3,000	$880	$0	$3,880	31	16	16	0	63
1.3.3	Vacuum Enclosure	$0	$27,380	$0	$27,380	50	40	100	296	486
1.3.4	Filter Wheel	$1,000	$11,400	$0	$12,400	174	80	136	280	670
1.3.5	Rotational Stage	$47,850	$1,600	$2,393	$51,843	46	0	0	80	126
1.3.6	Mirrors & Mounts	$96,175	$2,400	$4,799	$103,374	191	20	8	80	299
1.3.7	Filters	$51,000	$0	$12,750	$63,750	8	0	0	0	8
1.3.8	Upgrades	$68,255	$15,931	$3,313	$87,499	324	146	100	452	1023

Table 5. Summary budget for WBS 1.8, Procurement

WBS	Description	Cost [$]				Labor [hr]				
		Fixed	Hourly	Contingen	Total	FixedC	Design	Draftir	Shop	Total
1.8	Procurement	$122,408	$0	$7,360	$129,768	205	0	0	0	205
1.8.1	Procure Computer for Laborat	$2,400	$0	$0	$2,400	0	0	0	0	0
1.8.2	Procure Solidworks License	$1,645	$0	$0	$1,645	0	0	0	0	0
1.8.3	Procure Dust-Free Hood	$3,000	$0	$150	$3,150	26	0	0	0	26
1.8.4	Procure Parts for Test Dewar	$2,000	$0	$500	$2,500	9	0	0	0	9
1.8.5	Procure Diode Sensors - 12 E	$1,860	$0	$0	$1,860	4	0	0	0	4
1.8.6	Procure Field Flattener Lens (	$2,000	$0	$0	$2,000	21	0	0	0	21
1.8.7	Procure Bulkhead	$4,300	$0	$0	$4,300	32	0	0	0	32
1.8.8	Procure 4 Additional Rotation	$62,040	$0	$3,102	$62,040	4	0	0	0	4
1.8.9	Procure Parts for Vacuum En	$7,163	$0	$358	$7,521	40	0	0	0	40
1.8.10	Procure Parts for Telescope Si	$500	$0	$125	$625	18	0	0	0	18
1.8.11	Procure Window	$8,000	$0	$2,000	$10,000	36	0	0	0	36
1.8.12	Procure Coordinate Measurin	$22,500	$0	$1,125	$23,625	15	0	0	0	15
1.8.13	Misc Supplies	$5,000	$0	$0	$5,000	0	0	0	0	0

4 Schedule

The Gantt chart is attached.

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5 Problems

Too much work is assigned to the designer and the drafting person at the beginning of the project. (See Figures 7 and 8.) René Laporte will help relieve this problem. A possible solution is to hire additional help for a short period. We are addressing this problem.

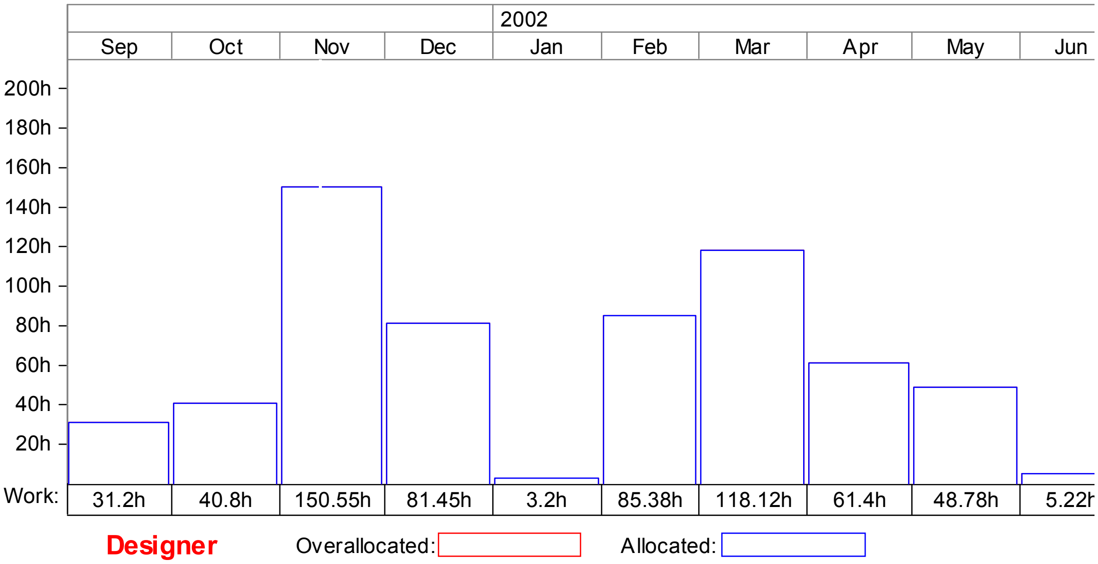


Figure 7 Requirements for designer by month.

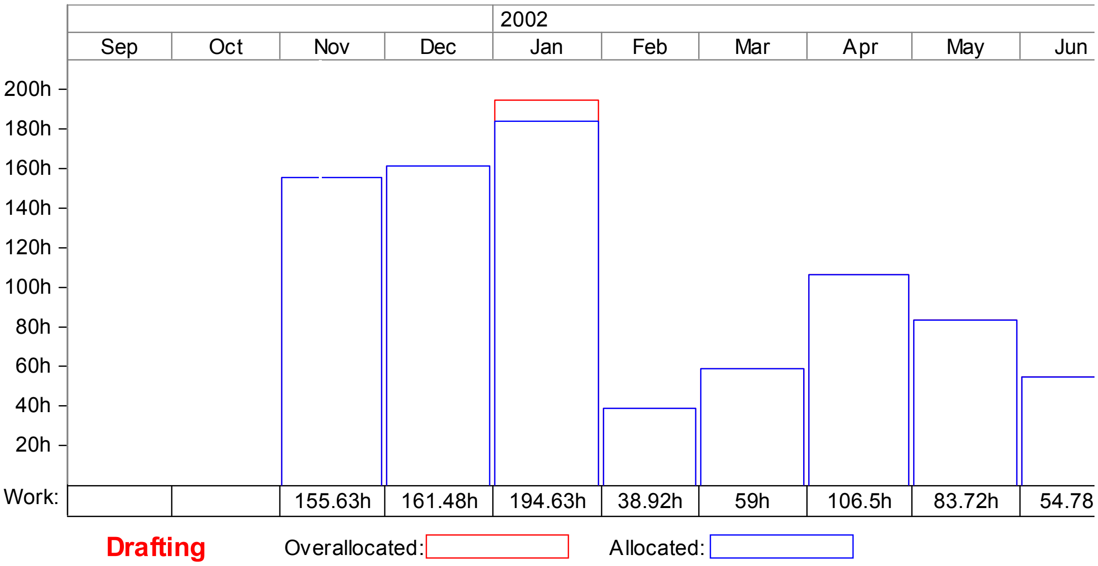
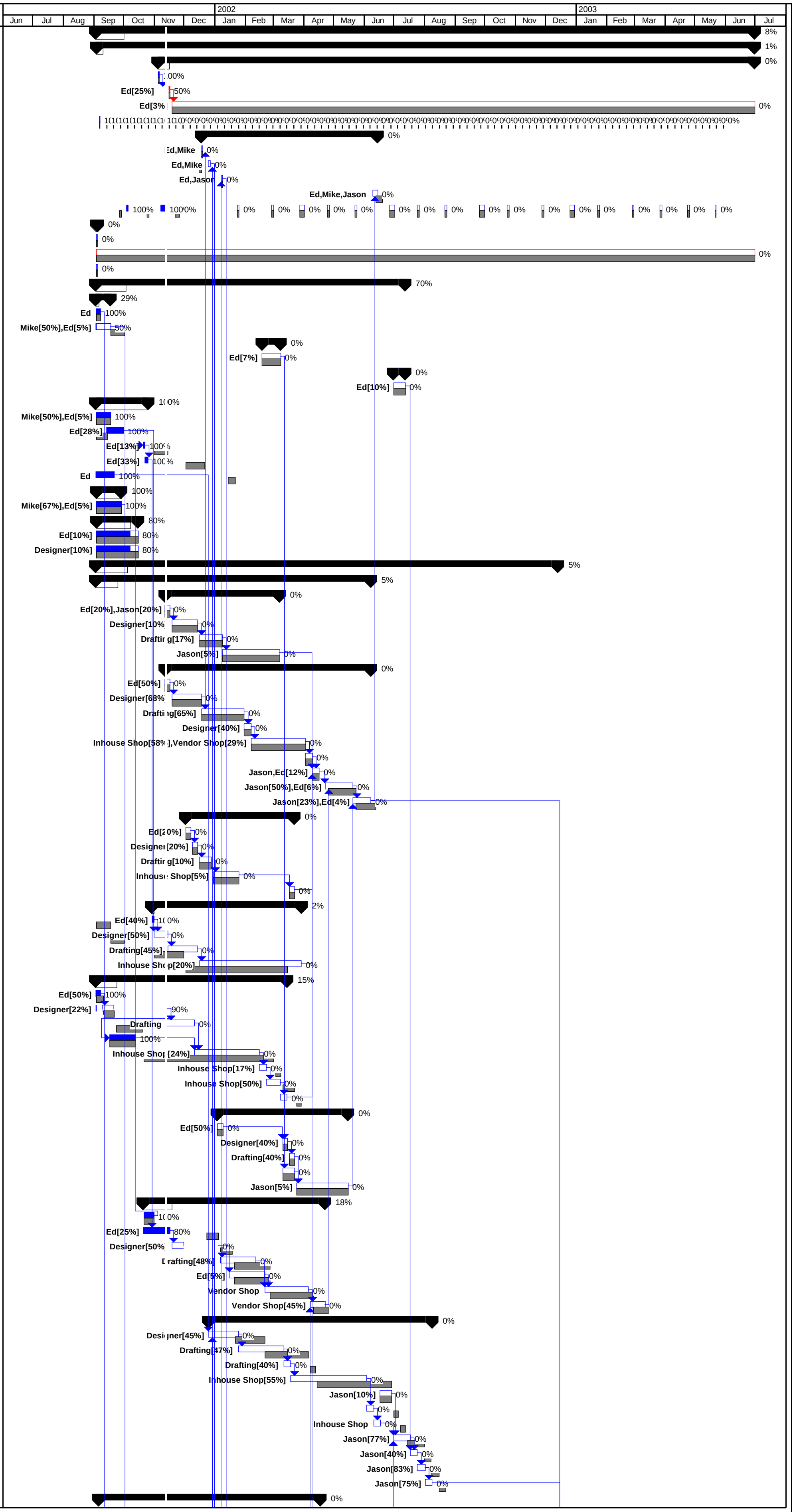
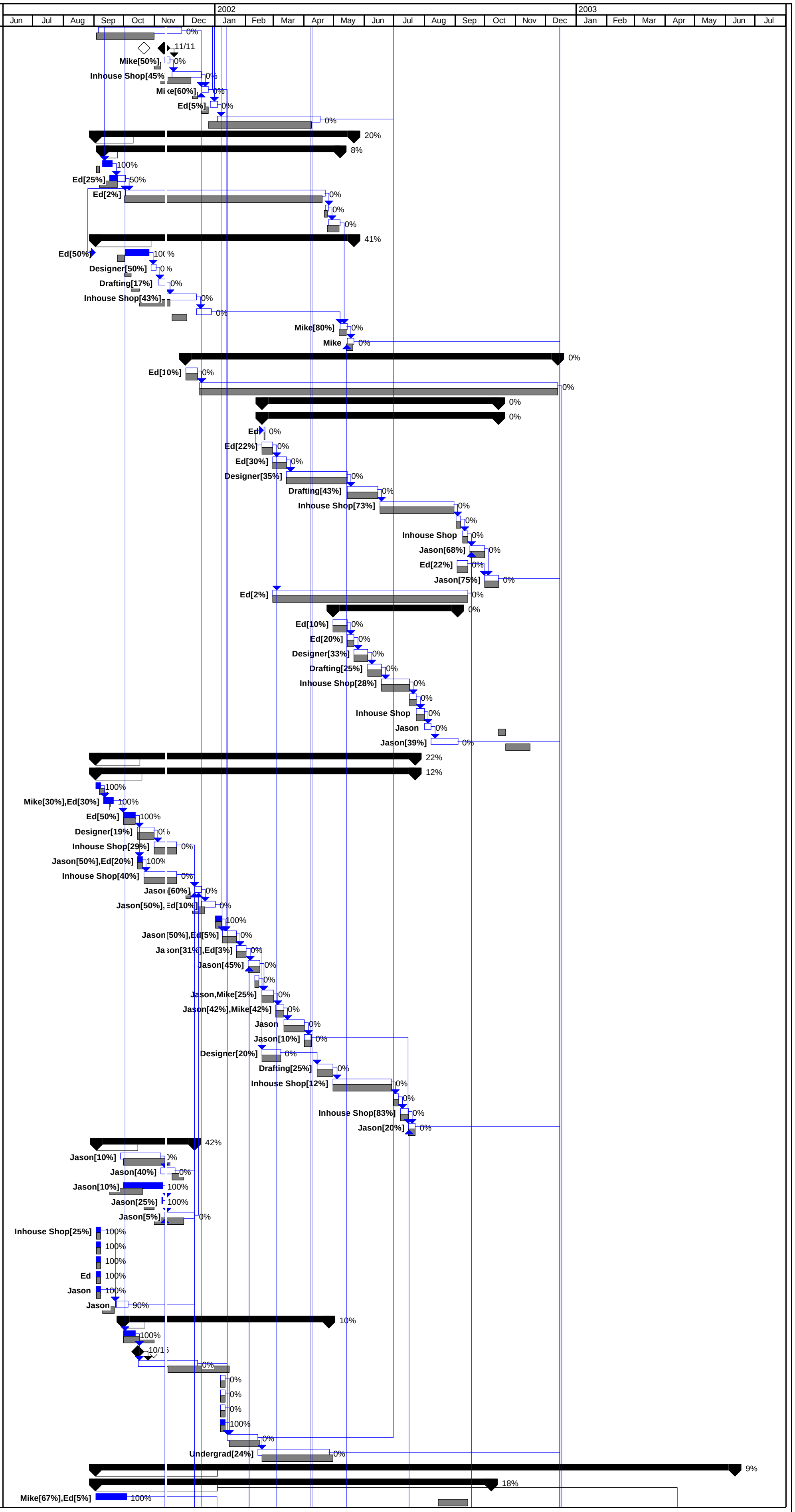


Figure 8 Requirements for drafting by month.

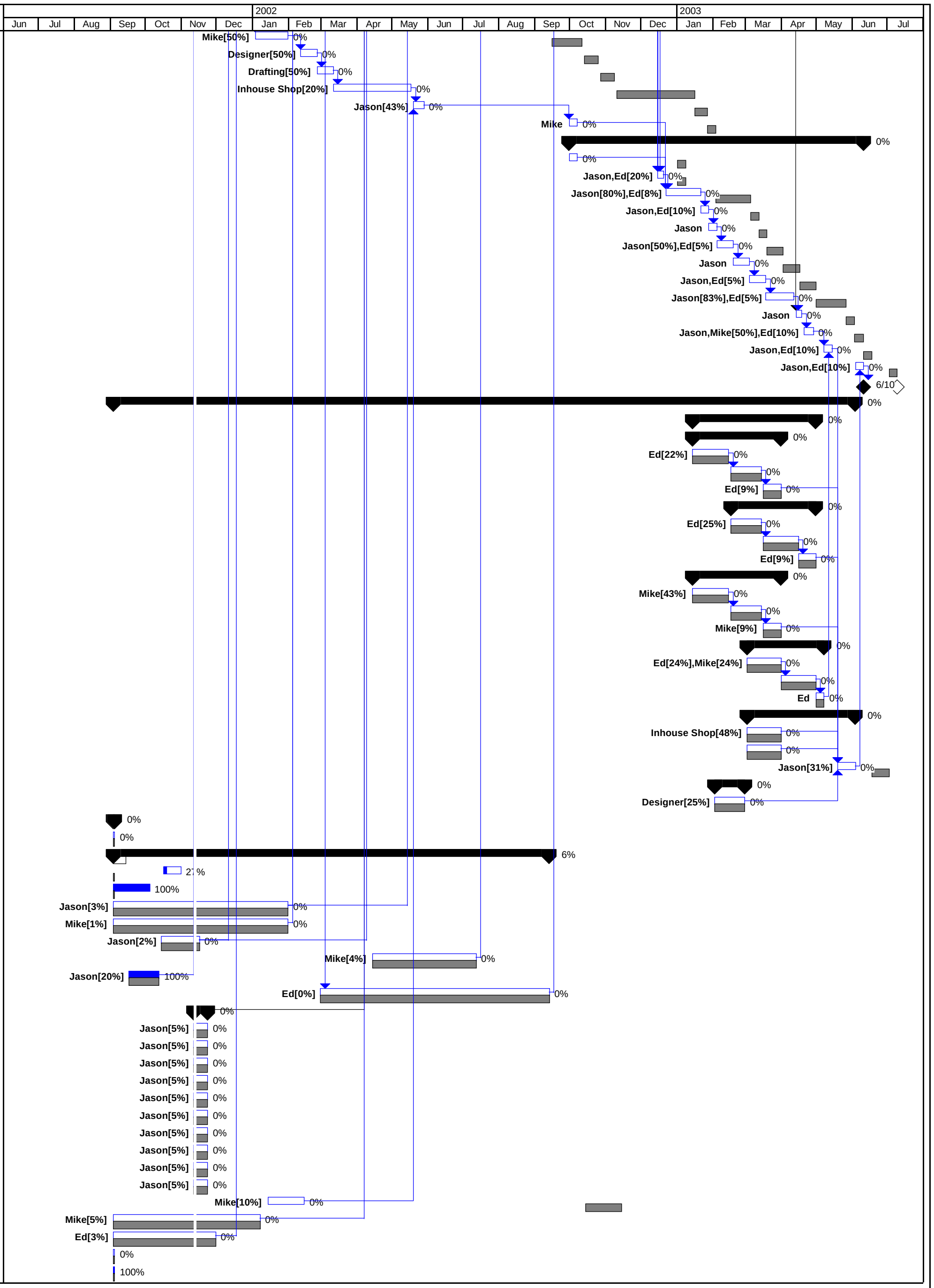
ID	ℹ	WBS	Name
1		**1**	**Spartan IR Camera**
2		**1.1**	**Project Management**
3		**1.1.1**	**Schedule & Budget**
4	✓	1.1.1.1	Create Project Plan [Gaughan & Eklund]
5	▦	1.1.1.2	Modify Project Plan
6	▦	1.1.1.3	Maintain Schedule & Budget
7	⟳	**1.1.2**	**Weekly Meetings**
99		**1.1.3**	**Reviews**
100	▦	1.1.3.1	Cryo-Optical Box Review
101	▦	1.1.3.2	Rotational Stage Review
102	▦	1.1.3.3	Detector Assembly Prototype Review
103	▦	1.1.3.4	Progress Review
104	⟳	**1.1.4**	**Reports**
125		**1.1.5**	**Consultants**
126		1.1.5.1	Engineering
127	▦	1.1.6	Fixed Costs
128		1.1.7	Travel to vendors
129		**1.2**	**System Engineering**
130		**1.2.1**	**Optics**
131	✓	1.2.1.1	Iterate Optical Design
132		1.2.1.2	Create Method for Optical Alignment
133		**1.2.2**	**Analysis**
134	▦	1.2.2.1	Analyze Thermal Reflector Concept
135		**1.2.3**	**Plans**
136	▦	1.2.3.1	Write Test Plan for Filter Wheel
137	✓	**1.2.4**	**Requirements/ICDs/Review Designs**
138	✓	1.2.4.1	Write Requirements for Optical Alignment
139	✓	1.2.4.2	Write Vacuum Enclosure & Cryo Box ICD
140	✓	1.2.4.3	Review Vacuum Enclosure Design
141	✓ 🗒	1.2.4.4	Write Specifications for Vacuum Enclosure
142	✓	1.2.4.5	Specify Filter Wheel Mounting Block
143	✓	**1.2.5**	**Software Requirements**
144	✓ 🗒	1.2.5.1	Write Software Requirements
145		**1.2.6**	**Master Layout**
146	▦	1.2.6.1	Engineer Master Layout
147	▦	1.2.6.2	Design Master Layout
148		**1.3**	**Mechanical**
149		**1.3.1**	**Cryo-Optical Box**
150		**1.3.1.1**	**MLI Blanket**
151	▦	1.3.1.1.1	MLI Blanket Engineering
152	▦	1.3.1.1.2	MLI Blanket 3D Design
153		1.3.1.1.3	MLI 2D Drafting
154	▦	1.3.1.1.4	Vendor Fab MLI Blanket
155		**1.3.1.2**	**CryoBox**
156	▦	1.3.1.2.1	Cryo-Optical Box Engineering
157	▦	1.3.1.2.2	Cryo-Optical Box 3D Design
158		1.3.1.2.3	Cryo-Optical Box 2D Drafting - 15 Dwgs
159		1.3.1.2.4	Drawing Check and Modifications
160		1.3.1.2.5	Fab Cryo-Optical Box
161		1.3.1.2.6	Annodize or Paint
162		1.3.1.2.7	Assemble Cryo-Optical Box
163		1.3.1.2.8	Cryo-Optical Box Thermal Test
164		1.3.1.2.9	Assemble Thermal Reflector into Cryo-Opti
165		**1.3.1.3**	**Mask Plate**
166	▦	1.3.1.3.1	Mask Plate Engineering
167	▦	1.3.1.3.2	Design Mask Plate
168		1.3.1.3.3	2D Detail
169		1.3.1.3.4	Fab Mask Plate
170	▦	1.3.1.3.5	Annodize Plate
171		**1.3.1.4**	**A-Frame**
172	✓	1.3.1.4.1	A-Frame Strut Engineering
173		1.3.1.4.2	A-Frame Strut 3D Design
174	▦	1.3.1.4.3	A-Frame Strut 2D Drafting
175		1.3.1.4.4	Fab A-Fram Struts - 3 pc.
176		**1.3.1.5**	**N2 Can**
177	✓	1.3.1.5.1	N2 Can Engineering
178		1.3.1.5.2	N2 Can 3D Design
179		1.3.1.5.3	N2 Can 2D Drafting (12 Dwgs)
180	✓	1.3.1.5.4	Make / Buy Decision for N2 Can
181		1.3.1.5.5	N2 Can Fab
182		1.3.1.5.6	Vacuum Test of N2 Can
183		1.3.1.5.7	Rework
184		1.3.1.5.8	Annodize or Paint
185		**1.3.2**	**Thermal Reflector**
186	▦	1.3.2.1	Thermal Reflector Engineering
187		1.3.2.2	Thermal Reflector 3D Design
188		1.3.2.3	Thermal Reflector 2D Detail
189		1.3.2.4	Select Vendor for Thermal Reflector
190		1.3.2.5	Vendor Fab Thermal Reflector
191		**1.3.3**	**Vacuum Enclosure**
192	✓	1.3.3.1	Obtain AutoCad Vacuum Enclosure Design
193	▦ ✓	1.3.3.2	Vacuum Enclosure Engineering
194		1.3.3.3	Modify Vacuum Enclosure Design
195		1.3.3.4	Vacuum Enclosure Detail Drafting - 12 Drwgs
196	▦	1.3.3.5	Make-Buy Decision
197		1.3.3.6	Fab Vacuum Enclosure and Plates
198		1.3.3.7	Vacuum Test
199		**1.3.4**	**Filter Wheel**
200		1.3.4.1	Filter Wheel 3D Design
201		1.3.4.2	Filter Wheel 2D Drafting - 16 Dwgs
202		1.3.4.3	Check and Revise Drawings
203		1.3.4.4	Fab Filter Wheel and Blank
204	▦	1.3.4.5	Prepare Filter Wheel Wiring Diagram
205		1.3.4.6	Anodize Filter Wheel
206		1.3.4.7	Fit Check and Re-Work
207		1.3.4.8	Assembly Filter Wheel and Wire
208		1.3.4.9	Warm Test Filter Wheel #1
209		1.3.4.10	Cold Test Filter Wheel #1
210		1.3.4.11	Test Filter Wheel #2
211		**1.3.5**	**Rotational Stage**



ID	ℹ	WBS	Name
212		1.3.5.1	Procure Phytron Rotation Stage with Loaner Co
213	✓	1.3.5.2	Specify LN2 Test Fixture
214		1.3.5.3	Design LN2 Test Fixture
215		1.3.5.4	Fab LN2 Test Fixture
216		1.3.5.5	Test Rotation Stage
217		1.3.5.6	Order Rotation Stage Controller & 2nd Stage
218		1.3.5.7	Procure Rotation Stage & Contoller for Filter Wh
219		**1.3.6**	**Mirrors & Mounts**
220		**1.3.6.1**	**Mirrors**
221	✓	1.3.6.1.1	Produce Mirror Envelope Drawings
222	▦ ✎	1.3.6.1.2	Select Vendor for Mirrors
223	✎	1.3.6.1.3	Vendor Mirror Fab
224		1.3.6.1.4	Inspect Mirrors
225		1.3.6.1.5	Coat Mirrors
226		**1.3.6.2**	**Mounts**
227	✓	1.3.6.2.1	Mounting Blocks Engineering
228		1.3.6.2.2	Design Mounting Blocks
229		1.3.6.2.3	Produce 2D Detail - 2 Dwgs
230		1.3.6.2.4	Fab 4 Mounts - 2 Types
231		1.3.6.2.5	Paint Mounts
232	▦	1.3.6.2.6	Install Mirrors into Mounts
233		1.3.6.2.7	Measure and Set Mirror Angles
234		**1.3.7**	**Filters**
235	▦	1.3.7.1	Join Filter Consortium
236		1.3.7.2	Fab Filters [17]
237		**1.3.8**	**Upgrades**
238		**1.3.8.1**	**2nd Channel Mirrors & Mounts [Upgrade]**
239		1.3.8.1.1	Upgrade Meeting
240	▦	1.3.8.1.2	Make Upgrade Decision for 2nd Channel
241		1.3.8.1.3	Complete 2nd Collimator & Mirror Analysis
242		1.3.8.1.4	Collimator and Camera Mirror 3D Design
243		1.3.8.1.5	Collimator and Mirror 2D Detail
244		1.3.8.1.6	Collimator and Mirror Fab [2 Mirrors]
245		1.3.8.1.7	Anodize
246		1.3.8.1.8	Re-Work
247		1.3.8.1.9	Assemble and Wire
248	▦	1.3.8.1.10	Write Test Plan for Collimator and Mirrors
249		1.3.8.1.11	Warm and Cold Test
250		1.3.8.1.12	Procure F/21 Collimator & Camera Mirrors
251		**1.3.8.2**	**Mask Wheel Upgrade**
252	▦	1.3.8.2.1	Complete Interface Specification
253		1.3.8.2.2	Mask Wheel Engineering
254		1.3.8.2.3	Mask Wheel 3D Design
255		1.3.8.2.4	Mask Wheel 2D Detail
256		1.3.8.2.5	Fab Mask Wheel
257		1.3.8.2.6	Annodize
258		1.3.8.2.7	Re-Work
259		1.3.8.2.8	Assemble Mask Wheel and Wire
260		1.3.8.2.9	Warm and Cold Test
261	✎	**1.4**	**Electronics**
262		**1.4.1**	**Detector Assembly**
263	✓	1.4.1.1	Obtain Measuring Equipment
264	✓	1.4.1.2	Measure Detector Physical Dimensions
265	✓	1.4.1.3	Develop Detector Assembly Concept
266		1.4.1.4	Design Detector Holder Prototype
267		1.4.1.5	Fab Holder Prototype
268	✓	1.4.1.6	Test-Dewar Concept Sketch
269		1.4.1.7	Shop Design / Fab Test-Dewar
270		1.4.1.8	Assemble Electronics into Test-Dewar
271		1.4.1.9	Prototype Thermal Test in Test-Dewar
272	✓	1.4.1.10	Obtain MUX
273		1.4.1.11	Warm MUX Test
274		1.4.1.12	Cold Test
275		1.4.1.13	Install Engineering Grade Detector & J-Band Fil
276	▦	1.4.1.14	Obtain IR Source
277		1.4.1.15	Cold Lab Test
278		1.4.1.16	Sky Field Test
279		1.4.1.17	Re-Work & Re-Test Electronics
280		1.4.1.18	Remove Electronic Boards
281	▦	1.4.1.19	Detector Assembly 3D Design
282	▦	1.4.1.20	Detector Assembly 2D Detail - 6 Dwgs
283		1.4.1.21	Detector Assembly Fab
284		1.4.1.22	Anodize Detector Assembly
285		1.4.1.23	Re-work
286		1.4.1.24	Mechanical Assembly
287		**1.4.2**	**Electronic Hardware**
288	▦ ✎	1.4.2.1	Vendor Fab Detector PCB
289		1.4.2.2	Stuff & Ringout Board
290	✓	1.4.2.3	Vendor Fab Flex Cable PCB
291	✓	1.4.2.4	Ringout & Inpsect
292		1.4.2.5	Vendor Install into Bulkhead
293	✓	1.4.2.6	Design/Fab/Assy Box & Bracket
294	✓	1.4.2.7	Obtain Computer Card
295	✓	1.4.2.8	Obtain CCD Test Fixture
296	✓	1.4.2.9	Obtain Programmed FPGA
297	✓	1.4.2.10	Obtain Controller Card
298		1.4.2.11	Install & Test Controller Card
299		**1.5**	**Software**
300	✓ ✎	1.5.1	Send Req to Vendors for Review/Comment
301	✓	1.5.2	Select SW Vendor
302	✎	1.5.3	Vendor Modify ARC-View SW for SIRC
303	▦	1.5.4	Obtain MUX
304	▦	1.5.5	Obtain Spare Controller Card
305	▦	1.5.6	Obtain Spare Computer Card
306	✓	1.5.7	Obtain 6533 Card
307		1.5.8	Test Hardware & Software
308		1.5.9	Test SIRC Lab View Scripts
309		**1.6**	**Integration**
310		**1.6.1**	**Telescope Simulator**
311	✓	1.6.1.1	Write Specifications for Telescope Simulator



ID	ℹ	WBS	Name
312	▦	1.6.1.2	Telescope Simulator, Engineering
313	▦	1.6.1.3	Design Telescope Simulator
314		1.6.1.4	Drafting for Telescope Simulator
315		1.6.1.5	Fab Telescope Simulator
316		1.6.1.6	Assemble and Wire Telescope Simulator
317	▦	1.6.1.7	Test and Characterize Telescope Simulator
318		**1.6.2**	**Integration**
319	▦	1.6.2.1	Obtain Electronic Motor Controller
320	▦	1.6.2.2	Install Parts into Optical Box - Locate Componer
321	▦	1.6.2.3	Warm Optical Alignment / Mechanical Test
322		1.6.2.4	Flexure Test
323		1.6.2.5	Install Detector
324	✎	1.6.2.6	Cold Test #1
325		1.6.2.7	Warm-Up / Adjust Optics
326	✎	1.6.2.8	Cold Test #2
327	✎	1.6.2.9	Cold Test #3
328		1.6.2.10	Image Test
329		1.6.2.11	Sky Test
330		1.6.2.12	Pre-Ship AT
331		1.6.2.13	Post-Ship AT
332		1.6.3	Project Complete
333		**1.7**	**Deliverables**
334		**1.7.1**	**Manuals**
335		**1.7.1.1**	**Maintenance**
336	▦	1.7.1.1.1	Write
337		1.7.1.1.2	Review
338		1.7.1.1.3	Revise
339		**1.7.1.2**	**Operating**
340	▦	1.7.1.2.1	Write
341		1.7.1.2.2	Review
342		1.7.1.2.3	Revise
343		**1.7.1.3**	**Software**
344	▦	1.7.1.3.1	Write
345		1.7.1.3.2	Review
346		1.7.1.3.3	Revise
347		**1.7.2**	**Acceptance Test**
348	▦	1.7.2.1	Write AT Plan
349		1.7.2.2	SOAR Review
350		1.7.2.3	Revise ATP
351		**1.7.3**	**Pack & Ship**
352	▦	1.7.3.1	Design & Fab Shipping Container
353	▦ ✎	1.7.3.2	Procure Shock Mounts
354	▦	1.7.3.3	Pack & Ship
355		**1.7.4**	**Documentation**
356	▦	1.7.4.1	Assemble As-Built Drawing Package
357		**1.7.5**	**Installation**
358		1.7.5.1	Travel & subsistence (5 trips)
359		**1.8**	**Procurement**
360	▦	1.8.1	Procure Computer for Laboratory (2)
361	✓	1.8.2	Procure Solidworks License
362		1.8.3	Procure Dust-Free Hood
363		1.8.4	Procure Parts for Test Dewar
364	▦	1.8.5	Procure Diode Sensors - 12 Ea
365	▦	1.8.6	Procure Field Flattener Lens (2)
366	✓	1.8.7	Procure Bulkhead
367		1.8.8	Procure 4 Additional Rotational States [Upgrade]
368	✎	**1.8.9**	**Procure Parts for Vacuum Enclosure**
369	▦	1.8.9.1	Vacuum valve SA0050MVCF (Lesker)
370	▦	1.8.9.2	Granville-Phillips 354 Micro-ion gauge 354016-
371	▦	1.8.9.3	Granville-Phillips 275 Convectron gauge 27553
372	▦	1.8.9.4	Devicenet card
373	▦	1.8.9.5	Dual nitrogen feedthroughs
374	▦	1.8.9.6	SS flexible hose MH-TE-Y12 (Lesker)
375	▦	1.8.9.7	4 pc SS flexible hose MEW0500191E (Lesker)
376	▦	1.8.9.8	4 pc Multiwire feedthroughs
377	▦	1.8.9.9	20 Swagelok fittings
378	▦	1.8.9.10	12 pc Diode thermometer DT471 (Lakeshore)
379	▦	1.8.10	Procure Parts for Telescope Simulator
380		1.8.11	Procure Window
381	✎	1.8.12	Procure Coordinate Measuring Machine
382		1.8.13	Misc Supplies
383	✓	1.9	Preplan Spending



Project: Spartan-01-11-11
Date: Mon 11/12/01

Critical	▭	Baseline Split		Rolled Up Critical Progress	🟥	External Tasks	▬
Critical Split		Baseline Milestone	◇	Rolled Up Task	▭	Project Summary	▬
Critical Progress	🟥	Milestone	◆	Rolled Up Split		External Milestone	◆
Task	▭	Summary Progress	▭	Rolled Up Task Progress	🟦	Deadline	⇩
Split		Summary	▬	Rolled Up Baseline	▬		
Task Progress	🟦	Rolled Up Critical	▭	Rolled Up Baseline Milestone	◇		
Baseline	▬	Rolled Up Critical Split		Rolled Up Milestone	◇		