

University of Wisconsin Department of Astronomy

SOUTHERN AFRICAN LARGE TELESCOPE
ROBERT STOBIE SPECTROGRAPH
NEAR INFRARED INSTRUMENT

STATUS REPORT

SUBMITTED
MAY 5, 2015

PROJECT YEAR 7
JAN – APR 2015

PRINCIPAL INVESTIGATOR: MARSHA WOLF
PRINCIPAL INVESTIGATOR: ANDREW SHEINIS
PROJECT MANAGER: MARK MULLIGAN

EXECUTIVE SUMMARY

Status of Key Tasks (additional information provided in the subsystem sections)

- Detector, Science Grade (SG) Characterization/Optimization: The science grade detector has been installed in the instrument dewar and we have verified that it is functioning. We have started characterization and optimization testing.
- *Detector, Engineering Grade (EG) Characterization/Optimization*: The engineering grade detector characterization and optimization is complete.
- *Dewar Prep:* We received a L7 (final camera field flattener lens) retaining ring from Johns Hopkins University and have readied the dewar for testing.
- *CO_2 Cooling System:* Mike Smith and Doug Adler are working with a South African vendor to develop an alternative cooling system.
- *Integration & Testing:* Jeff Percival has been supporting the testing and characterization of the fold mirror tip / tilt mechanism and continuing his work to mature the control system.
- *Commissioning:* The commissioning plan and budget has been reviewed and updated.

De-scoped Systems

Our current schedule has RSS-NIR ready to ship in April 2016. The de-scoped RSS-NIR modes would require about a year to implement into the instrument before delivery. This would be the most efficient path, since some items would require removal of RSS from the telescope to add at a later time. However, there is now no longer time to implement these de-scoped modes in the current delivery schedule. The two items that would require removal of RSS from the telescope are the cooled slit and the cryogenic long wavelength cutoff filters, both of which would allow sky-limited spectroscopy out to wavelengths longer than 1.55 microns. Appendix B lists the de-scoped items and costs to re-scope them. The estimated cost of commissioning the NIR, the de-scoped items, and the Fabry-Perot etalon system are listed in Table 1. The Astronomy Department team member contributions through Washburn Astronomical Laboratories are listed as well. Appendix B also summarizes the instrument performance gains through the addition of each de-scoped item.

Budget & Schedule

The NIR financial status is summarized in Table 1. Spending through March 2015 is $8.386M and we estimate the cost to ready the instrument for delivery to South Africa at $713k. The sum of spending and what is required to ready the instrument is $9.037M. The funding available to ready the instrument is $8.826M leaving a deficit of $273k, which is an increase of $41k since the end of the last quarter. The reasons for the growth continue to be the same with one exception. Like last quarter, the growth includes the second and final $15k payment to Infinite Optics for the second dichroic. While not in our budget, we chose to accept Infinite Optic's offer to coat the second substrate for $30k as it provided an opportunity for improved optical performance and an assurance of a spare dichroic. To order one later, would easily be three to four times more costly. The decision appears to have been good as the optical performance of

the second dichroic is improved. As before, the project continues to require electrical engineering (detector testing and control system implementation), engineering support of the cooling system design, and project management that was not included in an extremely lean budget to ready the instrument for shipping.

The schedule was updated with the status as of the end of March. The new ready to ship date is April 2016. The critical path is the detail design, fabrication, skin install, and final assembly of the pre-dewar enclosure. Moving forward with the enclosure is on hold while we work to find a solution to the enclosure cooling system. The CO_2 cooling system bids were too expensive to implement. We are working with a South African vendor to find another solution. Should that fail to converge, we may have to return to the fluorinert solution presented at the Mid-Term and Critical Design Reviews.

The dewar development and detector testing continues to make good progress. With the enclosure development stalled, the detector schedule now has ~8 weeks of slack.

Appendix A has an updated schedule risk table.

Table 1. *The table summarizes the financial state of the RSS-NIR. The left column presents the spending-to-date and budget estimate to get ready-to-ship, commission the instrument, add descoped items, and to add the Fabry-Perot mode (which never has been part of the funded scope). On the right, the source and amount of funding contributions are shown with the funds needed to reach development states or to add scope.*

RSS-NIR SPENDING AND BUDGET SUMMARY

March 2015 (figures in thousands of dollars)

Spending-to-date	$8,386
Budget to get ready to ship	
Apr '14 to Ready-to-Ship	$603
Rescoped Items	
Dewar Cooling System	$20
Pre-dewar Enclosure Cooling System	$90
Sum	$713
Commissioning	
Estimate cost of commissioning	$504
Sum	$504
Descoped Items	
Polarizing Beamsplitter	$138
Cooled Slit Hardware	$54 [1]
Order Blocking Filters (12)	$261
Cryogenic Filters (2)	$56 [1]
Gratings (4)	$250
Sum	$760
Fabry-Perot Etalon	
Fabry-Perot Etalon with controller	$305
Sum	$305

RSS-NIR FUNDING SUMMARY

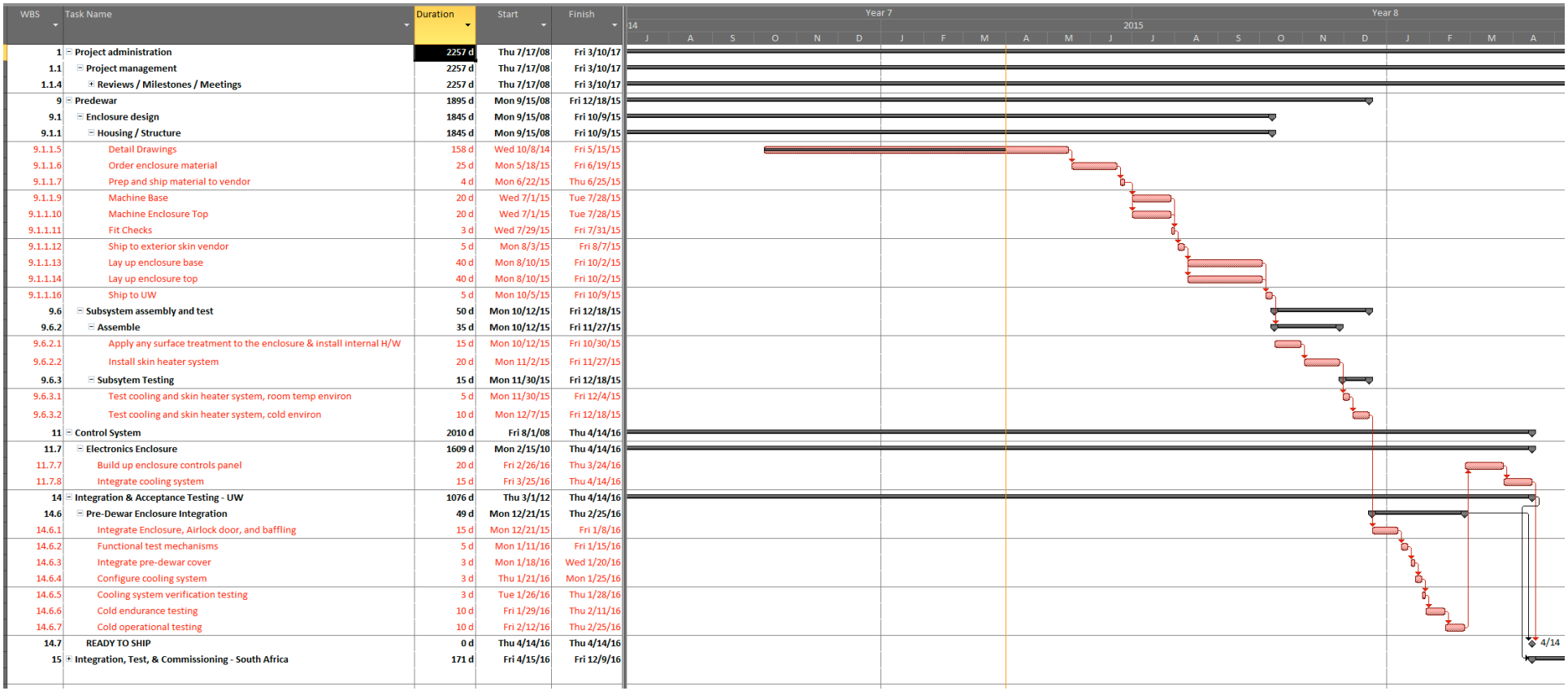
March 2015 (figures in thousands of dollars)

Sources			
Wisconsin Alumni Research Foundation		$3,300	
National Science Foundation		$1,997	
UW-Astronomy		$2,493	
UW-Astronomy	$1,400		
Washburn Astronomy Laboratories: Ready-to-ship	$768		[2]
Washburn Astronomy Laboratories: Commissioning	$249		[2]
Washburn Astronomy Laboratories: De-scope Items	$54		[2]
Washburn Astronomy Laboratories: F-P Etalon	$23		[2]
SALT		$932	
UW-Space Science & Engineering Center		$429	
Sum of Funding to get Ready to Ship		$8,826	
Total Sum of Funding		$9,152	

Funds Needed to be Ready-to-Ship	$273	[3]
Funds needed through Commissioning (cumulative)	$528	
Funds needed to add descoped items (cumulative)	$1,234	
Funds needed to include etalon (cumulative)	$1,516	[4]
Balance of $1.4M UW-Astronomy Funds	$140	

Notes

1. These de-scope items should be installed before the NIR is installed on the telescope. The instrument will function with reduced capability without them, but it will require that the instrument be removed to install them.
2. Estimated figure based on assumed Astronomy support for project activities. The actual figure may be larger or smaller.
3. This figure includes the Dewar and instrument cooling systems as presented at the Nov '12 Board Meeting.
4. The etalon has never been officially added to the scope of work and therefore has not ever been included in previous budget estimates.



WBS	Task Name	Duration	Start	Finish
1	Project administration	2257 d	Thu 7/17/08	Fri 3/10/17
1.1	Project management	2257 d	Thu 7/17/08	Fri 3/10/17
1.1.4	Reviews / Milestones / Meetings	2257 d	Thu 7/17/08	Fri 3/10/17
9	Predewar	1895 d	Mon 9/15/08	Fri 12/18/15
9.1	Enclosure design	1845 d	Mon 9/15/08	Fri 10/9/15
9.1.1	Housing / Structure	1845 d	Mon 9/15/08	Fri 10/9/15
9.1.1.5	Detail Drawings	158 d	Wed 10/8/14	Fri 5/15/15
9.1.1.6	Order enclosure material	25 d	Mon 5/18/15	Fri 6/19/15
9.1.1.7	Prep and ship material to vendor	4 d	Mon 6/22/15	Thu 6/25/15
9.1.1.9	Machine Base	20 d	Wed 7/1/15	Tue 7/28/15
9.1.1.10	Machine Enclosure Top	20 d	Wed 7/1/15	Tue 7/28/15
9.1.1.11	Fit Checks	3 d	Wed 7/29/15	Fri 7/31/15
9.1.1.12	Ship to exterior skin vendor	5 d	Mon 8/3/15	Fri 8/7/15
9.1.1.13	Lay up enclosure base	40 d	Mon 8/10/15	Fri 10/2/15
9.1.1.14	Lay up enclosure top	40 d	Mon 8/10/15	Fri 10/2/15
9.1.1.16	Ship to UW	5 d	Mon 10/5/15	Fri 10/9/15
9.6	Subsystem assembly and test	50 d	Mon 10/12/15	Fri 12/18/15
9.6.2	Assemble	35 d	Mon 10/12/15	Fri 11/27/15
9.6.2.1	Apply any surface treatment to the enclosure & install internal H/W	15 d	Mon 10/12/15	Fri 10/30/15
9.6.2.2	Install skin heater system	20 d	Mon 11/2/15	Fri 11/27/15
9.6.3	Subsytem Testing	15 d	Mon 11/30/15	Fri 12/18/15
9.6.3.1	Test cooling and skin heater system, room temp environ	5 d	Mon 11/30/15	Fri 12/4/15
9.6.3.2	Test cooling and skin heater system, cold environ	10 d	Mon 12/7/15	Fri 12/18/15
11	Control System	2010 d	Fri 8/1/08	Thu 4/14/16
11.7	Electronics Enclosure	1609 d	Mon 2/15/10	Thu 4/14/16
11.7.7	Build up enclosure controls panel	20 d	Fri 2/26/16	Thu 3/24/16
11.7.8	Integrate cooling system	15 d	Fri 3/25/16	Thu 4/14/16
14	Integration & Acceptance Testing - UW	1076 d	Thu 3/1/12	Thu 4/14/16
14.6	Pre-Dewar Enclosure Integration	49 d	Mon 12/21/15	Thu 2/25/16
14.6.1	Integrate Enclosure, Airlock door, and baffling	15 d	Mon 12/21/15	Fri 1/8/16
14.6.2	Functional test mechanisms	5 d	Mon 1/11/16	Fri 1/15/16
14.6.3	Integrate pre-dewar cover	3 d	Mon 1/18/16	Wed 1/20/16
14.6.4	Configure cooling system	3 d	Thu 1/21/16	Mon 1/25/16
14.6.5	Cooling system verification testing	3 d	Tue 1/26/16	Thu 1/28/16
14.6.6	Cold endurance testing	10 d	Fri 1/29/16	Thu 2/11/16
14.6.7	Cold operational testing	10 d	Fri 2/12/16	Thu 2/25/16
14.7	READY TO SHIP	0 d	Thu 4/14/16	Thu 4/14/16
15	Integration, Test, & Commissioning - South Africa	171 d	Fri 4/15/16	Fri 12/9/16

Figure 1. *RSS-NIR Critical Path updated March 31, 2015.*

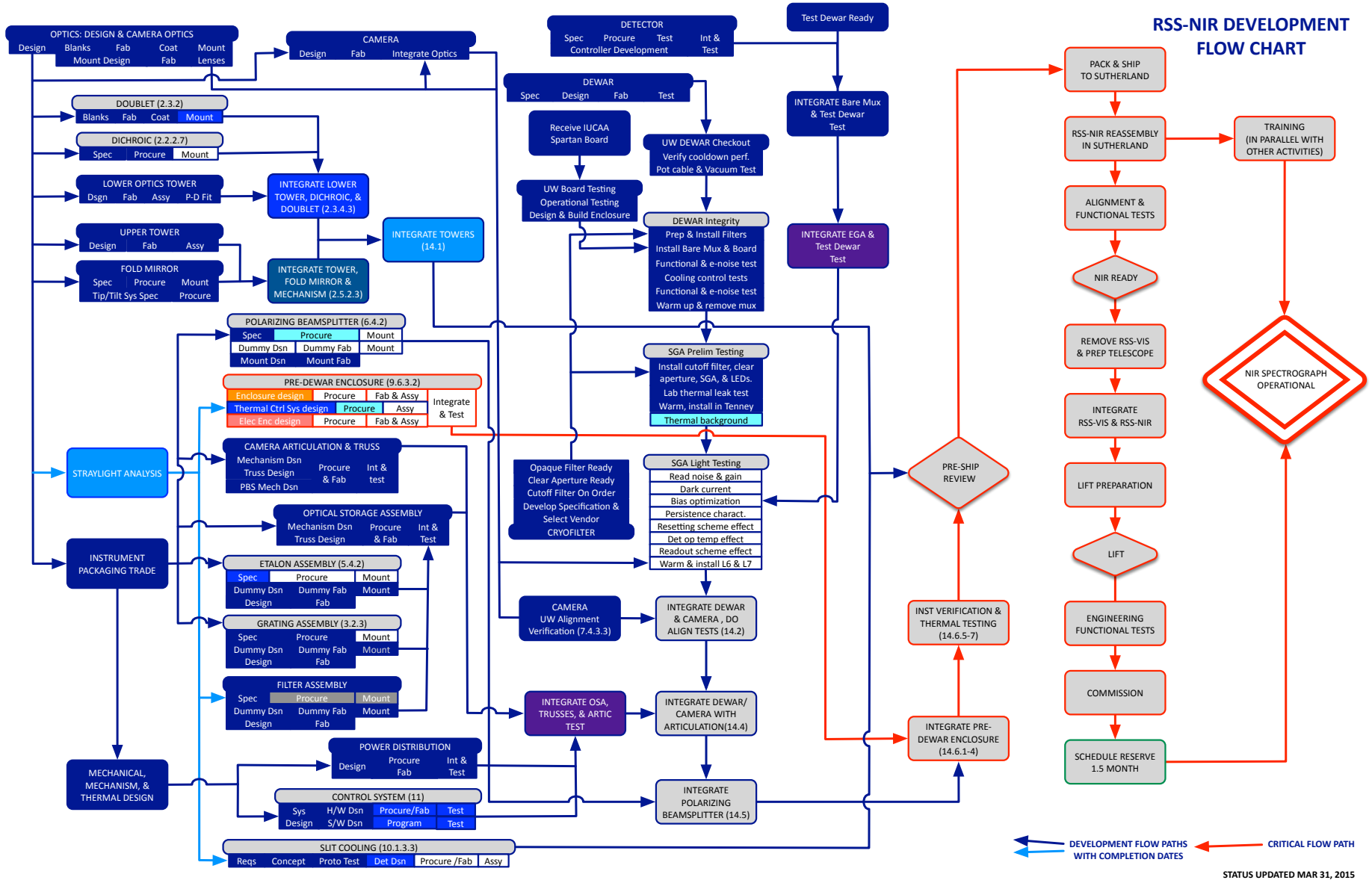
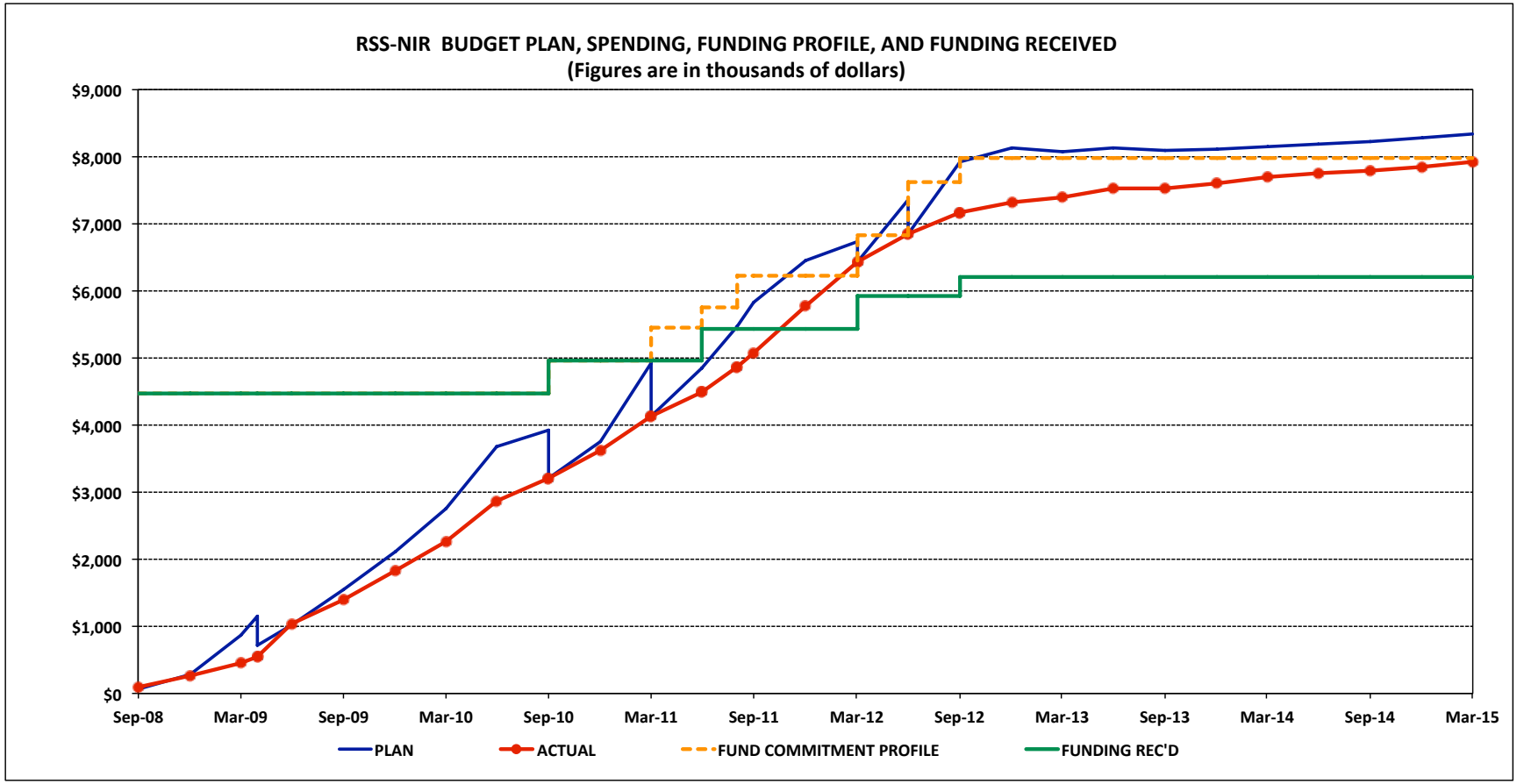


Figure 2. *RSS-NIR Development flow chart, updated March 31, 2015.*



	PROJECT YEAR 1				PROJECT YEAR 2				PROJECT YEAR 3				PROJECT YEAR 4				PROJECT YEAR 5				PROJECT YEAR 6				PROJECT YEAR 7		
	Sep-08	Dec-08	Mar-09	Jun-09	Sep-09	Dec-09	Mar-10	Jun-10	Sep-10	Dec-10	Mar-11	Jun-11	Sep-11	Dec-11	Mar-12	Jun-12	Sep-12	Dec-12	Mar-13	Jun-13	Sep-13	Dec-13	Mar-14	Jun-14	Sep-14	Dec-14	Mar-15
PLAN	$65	$285	$865	$1,027	$1,540	$2,118	$2,757	$3,682	$3,208	$3,755	$4,126	$4,840	$5,828	$6,459	$6,734	$7,357	$7,930	$8,137	$8,075	$8,130	$8,100	$8,113	$8,149	$8,185	$8,220	$8,274	$8,332
ACTUAL	$91	$267	$446	$1,030	$1,402	$1,827	$2,269	$2,874	$3,208	$3,622	$4,126	$4,491	$5,067	$5,765	$6,423	$6,855	$7,175	$7,322	$7,399	$7,520	$7,519	$7,595	$7,691	$7,748	$7,788	$7,850	$7,918

Figure 3. *RSS-NIR financial status since the Preliminary Design Review in July 2008. The adjustments in Sep'10, Mar'11, Mar'12, and Jun '12 are due to re-baselining cost projections. Project accounting is conducted monthly and the cost data updated quarterly. Please note: 1) the actual and planned spending presented does not include the contributions and spending made by the Washburn Astronomy Laboratories and 2) the planned spending does include the "Funds needed to be ready to ship" estimate from Table 1.*

Table 2. *Risk Summary (updates are in blue).*

Risk	Type	Impact Assessment	Mitigation Plan	State
1. *Instrument Mass*: SALT facility currently cannot accommodate the instrument mass, estimated at 405 kg at MTR.	Technical Schedule	Medium High	The mass estimate remains at 448.1 kg as we have not machined new parts nor updated the design. Once the cooling system decision is finalized the enclosure design can be completed. The mass will be updated at that time.	Open
2. *ADC*: Must be corrected to allow simultaneous VIS and NIR observations.	Technical	Medium	Darragh O'Donoghue has been evaluating the effectiveness of the current ADC and options for the telescope looking forward.	Open
3. *Instrument Delivery:* Target delivery for the commissioned instrument is December 2012.	Schedule Cost	Low Significant	Ready to ship is currently projected as Apr 2016. The slip is driven by the pre-dewar enclosure design and build.	Open
4. *Dichroic Thickness*: The dichroic must be sufficiently thick that the coatings do not distort the light beam, but the thickness is limited by the physical space.	Technical	Low	Ken and Marsha have reviewed the data on the dichroic. While it does not perfectly meet the specification, it will be accepted with a slight discount. Infinite Optics will coat the spare substrate and attempt to improve the optical performance. The flatness of the dichroic is acceptable.	Closed
5. Dichroic Cost: JDSU ROM estimate for a dichroic that meets our preliminary specification is $500k. $60k was budgeted based on scaling of costs for a dichroic on another instrument.	Cost	Medium	The dichroic final cost is $98,040, which is well below the $500k ROM.	Closed
6. *Pre-dewar Enclosure Cost*: ROM estimates from outside vendors to support the enclosure design and build the enclosure ranged from $250-600k. The budget provided ~$100k.	Cost	Medium	Mike Smith has updated the model design and has Jeff Wong reviewing it. This is on hold while the cooling system decision is being made.	Open
7. *Pre-dewar Enclosure cooling system:* At CDR, The SALT Ops teams strongly requested that the RSS-NIR team research gas cooling alternatives to the high pressure fluorinert system proposed since PDR.	Schedule Cost	Medium Significant	Mike Smith is continuing to work with Byron Billings of Concept Cooling in South Africa to converge on a cooling system design.	Open
8. *Budget:* The project budget is not sufficient to fund the scope of work agreed to at the board meeting in Ireland.	Cost	Significant	An agreement has been reached between Astronomy and Space Science to continue to work on the project while Astronomy continues to identify sources of funds to ready the instrument for shipping.	Open

Status and Issues by Subsystems

1. ***Project Administration***

- *Mass*: There have been no changes to the mass and the mass estimate in the last quarter as we have not machined new parts nor matured the design of the pre-dewar or electronics enclosures. It remains at 448.1 kg, but will be updated once we select a cooling system and complete the detailed design of the enclosure.

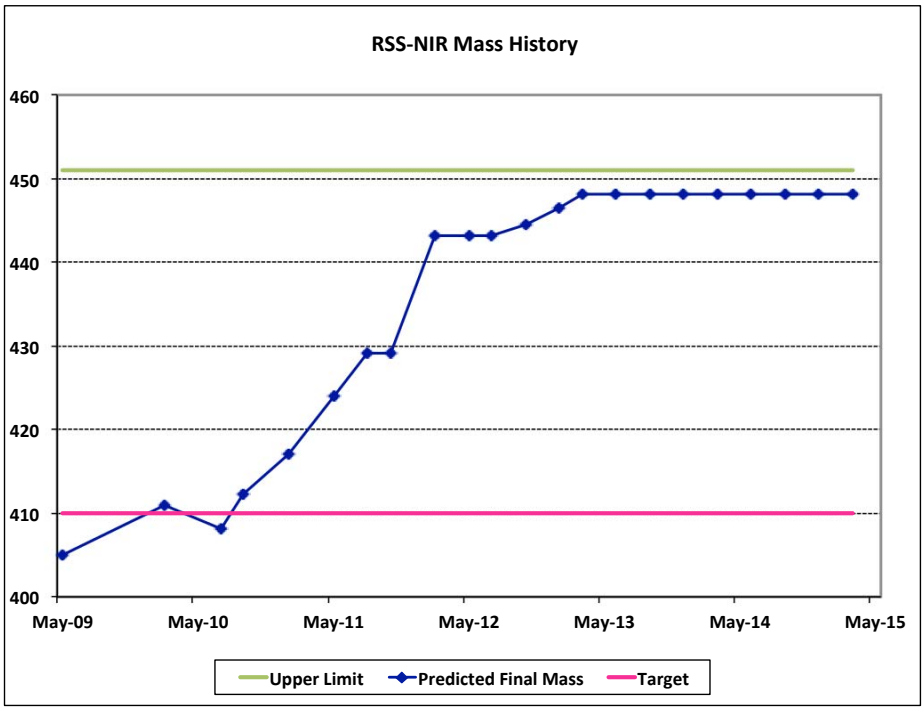


Figure 4. *RSS-NIR mass history with the target mass and upper limit.*

- *Interface Control Document:* There have been no further discussions between SALT staff and the NIR team concerning the ICD since the last quarterly report.

2. ***Optics (doublet, dichroic, and fold mirror)***

- No issues or status update.

3. ***Grating Assembly***

- Chris Clemens has not done the S and P 0-order efficiency measurements with the grating at an angle of 0° (measurements normal to the grating surface).

4. ***Broadband Filters & Optical Storage Assembly***

- No issues or status update.

5. ***Fabry-Perot Assembly***

- No issues or status update.

6. ***Polarizing Beamsplitter***

- No issues or status update.

7. Camera Assembly

- No issues or status update.

8. Detector / Dewar Assembly

- *EG Detector, Full Well Depth Optimization (some information is repeated from the last Quarterly report which covered January as well)*: Greg Mosby, Astronomy graduate student, has continued his work to optimize the full well depth. For a given gain setting, he can set the detector bias (difference between Dsub and Vreset) for a desired well depth and adjust the voltages Vrefmain and Vbiasgate as needed to ensure the detector output voltage is within the limits of the input to the ADC.

  While optimizing, Greg determined that the Vrefmain has a limited range. He observed a nonlinear response when it was set much above or below 1-volt. With the Vrefmain set at approximately 1-volt, he explored finding an optimum detector bias. He also optimized the output common mode voltage, Vcm, to center the amplified detector output voltages on the midpoint of the range of input voltages acceptable to the ADC, at least for this testing. He feels this approach is working to find an optimal full-well depth, as he was able to improve the well depth from 50,000 to 112,000 e-. Not surprisingly, the read noise increased, but Greg was able to reduce the RN (<20 DN) by re-optimizing a series of ASIC currents to operate at the new detector bias.

  Greg was able to increase the fell-well depth to 120,000 e-, which is about what Teledyne reported in their testing. The deeper well was at the expense of high read noise, but the trade in depth for noise may be acceptable for brighter objects.

  During his well depth optimization tests, Greg once again observed the horizontal artifacts, which we had been seeing in the reset by line mode. Greg reviewed the IUCAA software and determined that the clocking mode and resetting schemes could get out of sync and result in the horizontal artifacts. Greg communicated his finding to IUCAA during a videoconference. They found an issue with their software and updated it. Greg was not able to reproduce the horizontal artifacts with the updated software and confirmed that the noise levels did not go up.

  The testing on the engineering grade detector has been judged complete. It will be left configured in the test dewar in the event that we need to run further tests while optimizing the science grade detector.

- *Science Grade Detector Installation Prep*: A number of tasks were completed to ready the dewar and science grade detector for installation. These included:
  - *Review and update the SG installation procedure.* ***Done***.
  - *Prep the clean room*. ***Done***.
  - *Install the diffuser (for lab testing), long wavelength cutoff filter, and the glass blank in the filter wheel*. ***Done***.

- *Prepare new indium straps*. ***Done***.
- *Install the field flattener*. ***Done***.
- *Install the detector cup position adjusters*. ***Done***.
- *Inspect the long cable*. ***Done***.
- *Install LEDs (for lab testing)*. ***Done***.
- *Additional Temperature Sensors*. We decided to add two additional temperatures into the Lakeshore monitor; one on the dewar external surface and one in the air near it. Ron Koch has reconfigured the cable to accommodate these sensors. ***Done***.
- *Power cabling to the ISDEC Card*. Ron has completed the re-configuration to power the ISDEC card so that it is in its final configuration. ***Done***.
- *Interlocks*. Kurt Jaehnig developed a series of interlocks to safe the system in the event of different failures. Work on this was started in late September. The system includes an over/under temperature monitoring of the Tenney environmental chamber (which houses the instrument dewar), a power relay box between the Tenney and the single phase 208-volt power, and an "uber" interlock box that monitors the state of the system and cuts off power if needed. ***Done***.
- *L7 Retaining Ring*. Previously, we reported that we observed debris in the detector cup. The source of the debris was the L7 retaining ring. Painted surfaces had been incorrectly coated with a Teflon anodize. Steve Smee agreed to remake the part for us and we received the new ring during the first week of March. ***Done.***

- *Science Grade Detector Installation:* The science grade detector was installed in the dewar during the second week of March and we verified the detector was alive very shortly thereafter. This was a very big milestone for the project! Pictures of the installation are shown in Figure 5.

  Before testing, we completed some additional work on the instrument dewar configuration.

  - Kurt Jaehnig configured a filtered purge line to back fill the dewar.
  - We verified the ion pump was functioning properly.
  - We confirmed the filter wheel was operating to select the positions of the cutoff filter, opaque disk, clear window, and the two open slots.
  - Kurt installed and implemented the safety interlock system.
  - We closely monitored the first cool down of the dewar with the science grade detector. The operation went as smoothly as the test cool downs before the detector was installed.
  - We are in the process of configuring the detector power so that it is the same as it will be on the instrument.

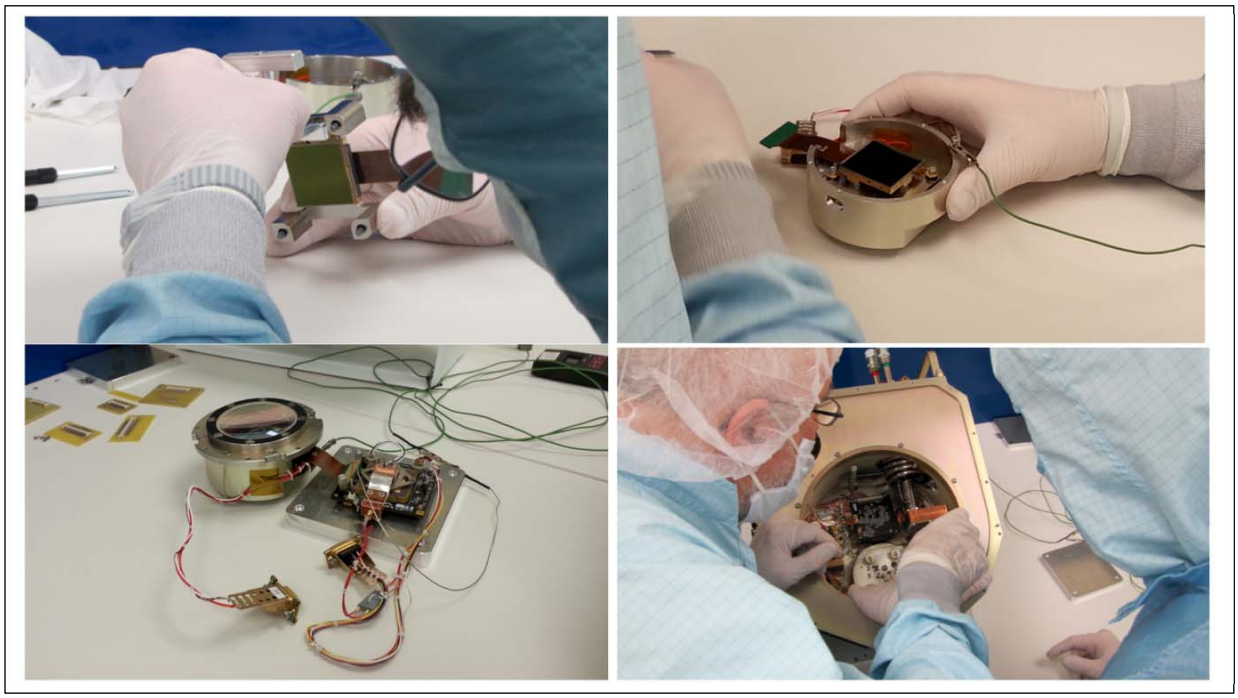


Figure 5. *Installation of the science grade detector.* ***Top left****: SG detector with short flex cable attached.* ***Top right****: SG detector in its mounting cup.* ***Bottom left****. Field flattener lens (L7) mounted on top of the detector cup and the SIDECAR ASIC board is attached to the short flex cable.* ***Bottom right****: Detector cup mounted in the dewar with its back side facing outward. The SIDECAR ASIC board is above the detector cup and the cryotiger cold head is to the right of the SIDECAR.*

With the Tenney chamber cold or at instrument operating temperature (-40 °C) Greg collected read noise and background measurements. The background measurements, taken with the filter wheel in each position, changed as expected. The results are presented in Table 3. For reference, the dark current of the detector is 0.002 e-/sec. The good news is that we have no large thermal leaks in the dewar. Marsha will model the laboratory instrument setup to further evaluate the performance of the dewar and cutoff filter.

Table 3. *Science Grade Detector background noise measurements in the instrument dewar in lab (20°C) and operating (-40°C) environments.*

Aperture	Tenney @ -40 °C (e^-/s)	Tenney @ ~20 °C (e^-/s)
Opaque Disk	0.1	0.1
Cutoff Filter	0.1	6
Clear Filter	0.25	200
Open	0.25	270

Greg has started to test increasing the full well depth in a lab temperature environment. He was able to increase the depth from 60,000 to 90,000 e-, but the

read noise increased from 16 e- to 26 e-. We would like to keep the read noise at 20 e- or less. For comparison, Teledyne was able to set the full well depth at 85,000 e- with a read noise of 22 e-. Greg's optimization is close but requires some additional testing.

With the detector set to 120 K and the cold plate at 108 K, their temperature control heaters are running at 92% and 75% heater power respectively. Greg's testing of the engineering model detector found a 120 K operating temperature to be a balance between acceptable noise levels and manageable persistence. However, if we could lower the detector heater power by decreasing its operating temperature a degree or two, this would provide some additional control margin. The cold plate temperature may be reduced as well, reducing the load on its heater. Greg will evaluate this once he is conducting persistence tests.

9. Pre-dewar Enclosure

- *Enclosure cooling system:* Mike Smith and Doug Adler are continuing to work with Bryone Billings at Concept Cooling, a South African vendor, to develop a cooling system that meets the RSS-NIR requirements and is compliant with the SALT facility. Byrone is working to complete the design and develop a cost estimate.
- *Enclosure Design*: This is again on hold while we finalize the cooling system.
- *Skin Heater System Design:* No significant progress to report, Mark Werner is planning to complete the final build of all of the skin heater controller boards. The boards are built up with the exception of installing one component, a connector, and the control software.

10. RSS Common Optics Environmental Control

- *Slit Cooling Test:* No significant progress.

11. Control System

- *Documentation:* With the exception of the Analog Input Board, all of the board drawings have been organized, signed off, and added to the NIR documentation server.
- *General*: Ron continues to address other minor hardware issues as they arise.

12. Power Distribution

- No issues or status update.

13. Support and Test Equipment

- No issues or status update.

14. Integration, Verification and Testing (@ UW)

- *Camera / Dewar Integration*: Mike Smith has reviewed the interface between the camera and the dewar with the objective of adding the capability to adjust the spacing and the alignment of the camera barrel (containing L1-L5) to the dewar (containing L6 & L7). Due to the space constraints the flexibility could not be added. We will proceed

with a more traditional static interface, which may require some shimming to properly align and space. Mike is in the process of machining parts to measure the run out of the L6 mount.

- *Fold Mirror Tip/Tilt Mechanism*: Jeff Percival was able to find a LabView program that Dustin Mason can use to conduct the centroid analysis. The program allows Dustin to collect enough test data to reduce the noise to an acceptable level. Jeff was also able to import python code into LabView for the control of the tip/tilt piezo actuators. Jeff has verified that it is working.
- *Absolute Encoders*: Jeff has revisited a couple of issues with the absolute encoders.
  - The control system uses both absolute and quadrature encoders that may or may not agree on where a particular position is. Jeff has implemented Newton's Method to initially find a position and then save that information. That information is then used to get back to that position. He found that it only took 2-4 iterations to find a position. He cannot use his knowledge of this position to tell him where other positions are on this axis. He must find each position. There is an initial time cost to find the positions, but after that it works well.
  - The other issue is mechanical. A mechanism can be sitting at a certain position, Jeff can rotate a cam, and the absolute position reading may change even though there has been no actual movement of the mechanism along that axis. Jeff is still struggling with this issue.

Open Punch List Items:

- *OSA Mechanism Readiness*
  - *Light-tight enclosure for the relative encoder*: Curtis Bartocz, a graduate student, has tested the new encoder enclosures for light tightness. With the encoder powered on and mounted in the new housing we were not able to see any light with a VIS or NIR camera; however, the tests were equally good with the factory housing. The lab camera used for the tests did not have sufficient sensitivity to verify the effectiveness of the encoder enclosure, so it will be retested once the SG detector and dewar are integrated into RSS-NIR.
- *Grating & Filter Insertion Mechanism:*
  - *Cable tie-down bracket*: Mike Smith is planning to have a student simulate the cable tie down that will be used once the instrument is in the enclosure.
  - *Adjust limit switches:* Not yet done.
  - *Calibrate the home switch on the absolute encoder:* Ron has developed a scheme to calibrate the home switch. He has provided this to Jeff.
  - *Light tight enclosure for the relative encoder:* See the OSA mechanism.
- *RFID*
  - *Protect antennas*: We are planning to coat the antennas in a thin layer of RTV. Kurt Jaehnig will be evaluating the best approach to apply the RTV without damaging

the antennas.

- *Camera Focus*
  - Set the hardware limit switches
  - Add software limit switches
  - Swap out the hall sensor

15. RSS-NIR Commissioning

We made progress on developing the RSS-NIR commissioning plan. The rough estimate of commissioning cost that has been carried for some time is $630k. We revised this estimate through a more detailed analysis of required tasks, the staff traveling to South Africa, and realistic travel costs. This exercise decreased the total number to $504k, which includes labor for UW Astronomy staff. Washburn Astronomical Laboratories has covered the Astronomy staff labor on the RSS-NIR project for the past 3 years and it has not been included in the total instrument cost. SSEC staff are paid by the project, so those labor expenditures continue. However, if UW is able to continue the practice of donating the Astronomy labor to the project (e.g. Washburn Labs receives continued funding from the UW College of Letters & Science), then the total commissioning cost estimate decreases further to $255k.

The commissioning activities are divided into “Engineering Commissioning” that includes packing, shipping, reassembly, checkout, integration with RSS-VIS, installation on the telescope, and functionality testing (all of which require involvement of UW staff who know the instrument well) and “Science Commissioning” that includes on-sky instrument performance verification and characterization tests. A draft of the integration and commissioning plan is summarized in Table 4, which lists the WBS tasks, duration, location, staff involvement, and cost estimate for each phase. Cost estimates are further broken down into UW Astronomy labor, UW SSEC labor, materials and equipment, and travel in Table 5.

The total duration of commissioning is 34 weeks, which includes 6 weeks of contingency (3 for engineering and 3 for science). During this time RSS-VIS will be unavailable for 10 weeks + 3 weeks contingency. The major activity phases listed in Table 4 are described below.

1) Packing and shipping. This activity will be carried out in Madison by much of the instrument team after passing a Pre-Ship Acceptance Test. It includes the procurement and/or construction of shipping containers and pallets, fabrication of lifting equipment, finalizing documentation, arranging all test and alignment equipment required in South Africa, and shipping to Sutherland. We have allocated a total of 7 weeks, which includes a shipping time of 3 weeks.
2) Reassembly. Once the instrument arrives in Sutherland, a reduced team from UW will travel to SALT. This team will include Marsha Wolf, Mike Smith, Kurt Jaehnig, and Ron Koch. Others from the instrument team will be on call back in Madison: Jeff Percival for software, Doug Adler for cooling system, Don Thielman for detector system, and Mark Mulligan for

purchasing, shipping, and admin support. Reassembly will occur in the SALT spectrometer room on a temporary structure. Once the mechanical structure and mechanisms are in place, the optics and detector system will be integrated and aligned. After full functionality is verified, the cooling system will be integrated. Depending on what this system is (currently still under development), this could be the first time it is integrated with RSS-NIR. It could be that part of the cooling system has been previously shipped to Madison for lab testing and then shipped to Sutherland, but this in not yet determined. The telescope installation and commissioning plan will be finalized while the team is on site. A total of 4 weeks are allocated for this phase. The UW team will then return to Madison, leaving RSS-NIR assembled in the spectrometer room.

3) Preparation of telescope and RSS-VIS for integration. This is a period of 4 weeks during which the UW team is in Madison documenting any engineering changes encountered during the reassembly phase and finalizing any further preparations for integrating with RSS-VIS and the telescope. Meanwhile, the SALT staff works with the cooling system vendor to install the RSS-NIR cooling system on the telescope, performs any remaining tracker upgrades, removes RSS-VIS from the telescope, relocates the RSS-VIS electronics boxes that currently protrude into NIR space, and makes any required small structure modifications to RSS-VIS. ***Tasks during which RSS-VIS will be unavailable are marked by red text in Table 4***.
4) Integrate RSS-NIR and RSS-VIS. Once RSS-VIS is ready for integration with RSS-NIR, the same UW team will travel back to SALT. In the spectrometer room RSS will be integrated, aligned, and tested. New baffling around RSS=VIS will be installed. Full up optical tests will be performed. We have allocated a total of 4 weeks for this phase.
5) Install RSS on telescope. With the UW team still at SALT, the combined RSS will be lifted onto the telescope. Due to crane weight restrictions, all optical cartridges (grating magazines, etalons, filter magazines) will be removed for the lift. The RSS-NIR electrical enclosure will also be removed and lifted after RSS is installed at prime focus. The lifting plan details are currently being jointly developed by UW and SALT staff. Once all components are installed and cables and hoses are connected, full functionality tests will be performed. We have allocated a total of 3 weeks for this phase. After successful completion, the UW team returns to Madison.
6) Science commissioning. This phase includes 6 weeks of commissioning tasks. We have budgeted travel for 3 UW staff to SALT, which will likely include Marsha Wolf, Ralf Kotulla, and another TBD astronomer. Much of this work could also be carried out by SALT Astronomers or astronomers from partner institutions, with remote support from the instrument team in Madison. Appendix C contains a detailed list of science commissioning tasks.

Table 4. *RSS-NIR Draft Integration and Commissioning Plan. WBS tasks are given in columns 1 & 2, the duration in weeks in column 3, the location of the task in column 4, staff involved in columns 5-27, and the cost of the high level task in column 28 (in thousands of U.S. dollars). Tasks for which RSS-VIS, and possibly the telescope, will be unavailable are marked with red text.*

				UW Astronomy Staff											UW SSEC Staff						SALT Staff					
WBS	TASKS	DURATION (WEEKS)	LOCATION	M Wolf	M Smith	K Jaehnig	S Gabelt	S Buckley	Machinist	J Percival	R Kotula	G Mosby	Astronomer	Grad Student	Undergrad	M Mulligan	D Adler	B Mason	J Wong	R Koch	D Thielman	Mechanical	Electrical	Software	Machinist	Astronomer	Cost
20.0	RSS NIR COMMISSIONING	34																									$504
20.1	PREPARE TO SHIP	4		X	X	X				X				X	X				X	X							$58
20.1.1	Arrange Shipping	0.25		x											x												
20.1.2	Order Crates, pallets and shipping material	0.25			x																						
20.1.3	Reserve Travel to South Africa	0.25	MADISON, WI	x											x												
20.1.4	Disassemble and Pack Instrument	3.00		x	x	x				x				x					x	x							
20.1.5	Finalize fabrication of lifting equipment	0.25			x																						
20.2	SHIPPING	3		X	X										X				X	X							$24
20.2.1	Ship instrument	3.00	TRANSIT												x												
20.2.2	Wisconsin team finalize all documentation	2.00		x	x														x	x							
20.2.3	Send documentation to SALT for review and training	0.00	MADISON, WI		x																						
20.2.4	Arrange equipment required in South Africa	1.00		x	x																						
20.3	REASSEMBLY	4		X	X	X				X					X	X			X		X	X	X	X			$86
20.3.1	Travel to South Africa	0.40		x	x	x									x				x								
20.3.2	Unpack Instrument	0.25		x	x	x													x		x	x	x				
20.3.3	Assemble instrument on temporary structure	0.75		x	x	x													x		x	x	x	x			
20.3.4	Integrate optics and electronics	0.50		x	x	x													x		x	x	x	x			
20.3.5	Alignment	0.50		x	x	x													x		x	x	x	x			
20.3.6	Functional test	0.50	SUTHERLAND, SOUTH AFRICA	x	x	x			x										x		x	x	x	x			
20.3.7	Install cooling system	0.25		x	x	x										x			x		x	x	x	x			
20.3.8	Test cooling system	0.50		x	x	x			x							x			x		x	x	x	x			
20.3.9	Remove cooling system for telescope integration	0.20		x	x	x													x		x	x	x				
20.3.10	Finilize installation and commisioning plan	0.15		x	x	x													x		x	x	x				
20.4	PREPARE TELESCOPE AND RSS-VIS FOR INTEGRATION	4		X	X	X									X				X		X	X	X	X			$10
20.4.1	Return to Madison	0.40	TRANSIT	x	x	x													x								
20.4.2	Documentation and engineering changes	3.60	MADISON, WI	x	x										x				x								
20.4.3	SALT prepare telescope for RSS removal	0.60																			x	x	x	x			
20.4.4	RSS removal	0.20																			x	x	x	x			
20.4.5	Cooling system telescope installation	0.60		x	x																x	x	x	x			
20.4.6	Telescope (tracker) upgrades as required	0.80	SUTHERLAND, SOUTH AFRICA																		x	x	x	x			
20.4.7	Prepare RSS-VIS	0.60		x	x																x	x	x	x			
20.4.8	Relocate RSS-VIS Electronics	0.60		x	x																x	x	x	x			
20.4.9	Small Structure Mods to RSS-VIS	0.60		x	x																x	x	x	x			
20.5	INTEGRATE RSS-NIR AND RSS-VIS	4		X	X	X									X	X			X	X	X	X	X	X	X		$90
20.5.1	Travel to South Africa	0.40	TRANSIT	x	x	x									x				x								
20.5.2	Integrate and Align Instrument	0.80		x	x	x													x		x	x	x	x			
20.5.3	Integrate Cooling system	0.60		x	x	x										x			x		x	x	x	x			
20.5.4	Cold Test	0.80	SUTHERLAND, SOUTH AFRICA	x	x	x										x			x		x	x	x	x			
20.5.5	Integrate new baffling around RSS-Vis	0.60		x	x	x										x			x		x	x	x	x			
20.5.6	Fullup Optical Tests	0.80		x	x	x													x	x	x	x	x	x	x		
20.6	INSTALL RSS ON TELESCOPE	3		X	X	X									X				X		X	X	X	X	X		$144
20.6.1	Pepare for lift	0.40		x	x	x									x				x		x	x	x	x			
20.6.2	Lift	0.20	SUTHERLAND, SOUTH AFRICA	x	x	x													x		x	x	x	x			
20.6.3	Connect cables and hoses	0.50		x	x	x													x		x	x	x	x			
20.6.4	Run functional tests	1.50		x	x	x													x		x	x	x	x	x		
20.6.5	Return to Madison	0.40	TRANSIT	x	x	x													x								
20.7	SCIENCE COMMISSIONING (details next sheet)	6		X						X		X			X	X			X	X	X	X	X	X	X		$102
20.7.1	Travel to South Africa	0.40	TRANSIT	x						x		x			x												
20.7.2	On-site support	5.20	SUTHERLAND	x						x		x									x	x	x	x	x		
20.7.3	Return to Madison	0.40	TRANSIT	x						x		x															
20.7.4	Support from UW	6.00	MADISON, WI		x				x							x			x	x							
20.8	CONTINGENCY	6		X	X	X					X		X		X	X			X	X	X	X	X	X	X		$92
20.8.1	Instrument assembly, integration, and checkout	3.00	SUTHERLAND, SOUTH AFRICA	x	x	x									x	x			x		x	x	x	x			
20.8.2	Science Commissioning	3.00		x						x		x			x						x	x	x	x	x		
	Time RSS-VIS will be down (weeks):	10																			TOTAL					$504
	Contingency (additional weeks):	3																			Without WL Labor					$255

Table 5. *Commissioning cost breakdown by category, in thousands of U.S. dollars.*

	RSS-NIR Commissioning	Duration (wks)	Astro Labor	SSEC Labor	Mtrl, Equip	Travel	SUM *No Astro*
20.1	**PREPARE TO SHIP**	4	$29	$10	$20	$0	$30
20.2	**SHIPPING**	3	$4	$4	$15	$0	$19
20.3	**REASSEMBLY**	4	$38	$18	$12	$18	$48
20.4	**PREPARE TELESCOPE AND RSS-VIS FOR INTEGRATION**	4	$7	$3	$0	$0	$3
20.5	**INTEGRATE RSS-NIR AND RSS-VIS**	4	$34	$20	$9	$26	$56
20.6	**INSTALL RSS ON TELESCOPE**	3	$26	$13	$3	$0	$16
	Subtotal Engineering Commissioning	**22**	**$138**	**$69**	**$59**	**$44**	**$172**
20.7	**SCIENCE COMMISSIONING**	6	$62	$12	$10	$18	$40
20.8	**CONTINGENCY**	6	$49	$17	$0	$26	$43
	TOTAL	**34**	**$249**	**$98**	**$69**	**$88**	**$255**

Budget and Spending Detail

Table 6: *RSS-NIR planned versus actual spending since the Preliminary Design Review in July 2008. Only the last four years of spending is presented. The adjustments in Sep'10, Mar'11, Mar'12, and Jun '12 are due to re-baselining cost projections. Project accounting is conducted monthly and the cost data updated quarterly.*

RSS-NIR SUMMARY	2011			2012		2013				2014				2015			PROJECT TOTAL
	ROJECT YEAR	PROJECT YEAR 4				PROJECT YEAR 5				PROJECT YEAR 6				PROJECT YEAR 7			
QUARTERLY SPENDING	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	
LABOR	$196,636	$210,544	$232,976	$231,359	$209,190	$77,307	$30,663	$21,459	$17,900	($3,899)	$16,147	$9,377	$15,206	$10,524	$13,025	$15,201	$3,243,467
MATERIAL	$46,680	$27,277	$27,127	$32,330	$20,137	$11,535	($2,755)	$9,742	$2,850	$11,734	$4,422	$8,402	$2,161	$6,081	$2,610	$13,138	$472,748
CAPITAL EQUIPMENT	$23,069	$140,304	$144,011	$111,847	$33,948	$6,457	$3,403	$0	$49,878	$0	$24,255	$42,419	$6,195	$0	$15,000	$14,700	$1,383,050
TRAVEL	$5,210	$8,407	$13	$870	$6,144	$6,746	$0	$0	$0	$0	$3,243	$0	$0	$0	$0	$0	$112,959
SUBCONTRACTS	$71,763	$124,229	$121,029	$110,393	$156,407	$92,600	$46,874	$25,081	$25,744	$45,623	$14,138	$19,657	$17,266	$11,345	$16,690	$8,170	$1,722,823
TUITION REMISSION	$0	$0	$889	$2,889	$1,778	$6,408	$0	$0	$0	($4,000)	$0	$0	$0	$0	$0	$0	$42,331
OVERHEAD	$21,570	$65,181	$172,027	$168,409	$4,391	$118,837	$68,247	$21,257	$24,484	($50,714)	$13,800	$16,789	$15,585	$12,577	$14,547	$16,429	$940,498
QUARTERLY TOTAL	$364,928	$575,941	$698,071	$658,096	$431,994	$319,889	$146,431	$77,539	$120,857	($1,256)	$76,005	$96,645	$56,414	$40,527	$61,872	$67,639	$7,917,876
QUARTERLY BUDGET																	
LABOR	$293,234	$346,776	$242,188	$185,906	$216,498	$82,664	$197,888	$182,180	$172,018	$0	$0	$0	$0	$0	$0	$0	$3,649,949
MATERIAL	$28,112	$86,883	$41,812	$18,850	$70,889	$5,542	$7,542	$24,542	$21,875	$0	$0	$0	$0	$0	$0	$0	$468,320
CAPITAL EQUIPMENT	$129,124	$270,131	$151,290	$20,000	$251,440	$10,000	$165,100	$97,750	$68,750	$0	$0	$0	$0	$0	$0	$0	$1,558,800
TRAVEL	$4,350	$32,282	$3,397	$0	$12,764	$0	$31,000	$1,500	$1,500	$0	$0	$0	$0	$0	$0	$0	$143,715
SUBCONTRACTS	$257,051	$193,980	$79,050	$50,250	$189,918	$12,500	$32,500	$0	$20,000	$0	$0	$0	$0	$0	$0	$0	$1,544,734
TUITION REMISSION	$1,800	$900	$2,700	$0	$1,600	$1,000	$3,000	$0	$0	$0	$0	$0	$0	$0	$0	$0	$49,331
OVERHEAD	$0	$57,297	$110,223	$0	$190,765	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$787,497
QUARTERLY TOTAL	$713,670	$988,249	$630,659	$275,006	$933,873	$111,706	$437,029	$305,972	$284,143	$0	$0	$0	$0	$0	$0	$0	$8,202,347
NET (BUDGET - SPEND)																	
LABOR	$96,598	$136,232	$9,212	($45,453)	$7,308	$5,358	$167,225	$160,721	$154,118	$3,899	($16,147)	($9,377)	($15,206)	($10,524)	($13,025)	($15,201)	$406,482
MATERIAL	($18,568)	$59,607	$14,685	($13,480)	$50,752	($5,993)	$10,297	$14,799	$19,025	($11,734)	($4,422)	($8,402)	($2,161)	($6,081)	($2,610)	($13,138)	($4,428)
CAPITAL EQUIPMENT	$106,055	$129,827	$7,279	($91,847)	$217,492	$3,543	$161,697	$97,750	$18,872	$0	($24,255)	($42,419)	($6,195)	$0	($15,000)	($14,700)	$175,750
TRAVEL	($860)	$23,875	$3,384	($870)	$6,620	($6,746)	$31,000	$1,500	$1,500	$0	($3,243)	$0	$0	$0	$0	$0	$30,757
SUBCONTRACTS	$185,288	$69,751	($41,979)	($60,143)	$33,511	($80,100)	($14,374)	($25,081)	($5,744)	($45,623)	($14,138)	($19,657)	($17,266)	($11,345)	($16,690)	($8,170)	($178,088)
TUITION REMISSION	$1,800	$900	$1,811	($2,889)	($178)	($5,408)	$3,000	$0	$0	$4,000	$0	$0	$0	$0	$0	$0	$7,000
OVERHEAD	($21,570)	($7,884)	($61,804)	($168,409)	$186,374	($118,837)	($68,247)	($21,257)	($24,484)	$50,714	($13,800)	($16,789)	($15,585)	($12,577)	($14,547)	($16,429)	($153,001)
QUARTERLY NET	$348,742	$412,308	($67,411)	($383,090)	$501,880	($208,183)	$290,598	$228,432	$163,286	$1,256	($76,005)	($96,645)	($56,414)	($40,527)	($61,872)	($67,639)	$284,470

Table 7. *RSS-NIR key schedule milestones by WBS.*

RSS-NIR KEY MILESTONES

CRITCAL PATH | TASKS COMPLTED IN THE LAST QUARTER

WBS	DESCRIPTION	TARGET DATE	SLACK (WORKDAYS) FREE	SLACK (WORKDAYS) TOTAL	MUST HAVE BY DATE	RESPONSIBLE TEAM MEMBER
1.3.2	**Documentation**					
1.3.2.2	FPRD	6/26/15			-	Wolf
1.3.2.5	OCDD	6/4/15			-	Wolf
1.3.2.4	ICD	7/21/15			-	Mulligan
1.3.2.6	Verification & Test Plan	6/16/15			-	Wolf
1.3.2.7	Commissioning Plan	8/21/15			-	Wolf
2.2	**Dichroic**					
2.2.1.6	Receive Spare Dichroic	1/30/15	-	-		Nordsieck
2.2.2.7	Dichroic Mounted in holder	7/21/15	0	0	7/21/15	Smith
2.3	**Doublet**					
2.3.2.9	Doublet lens mounted in holder, delivered to UW	3/20/15	*87*	87	7/19/15	Smith
2.2.4	**Lower Tower**					
2.3.4	Assemble dichroic, doublet, & lower tower	8/18/15	0	0	8/18/15	Smith
2.4.4	**Upper Tower**					
2.5.2.2	Assemble fold mirror & mechanism, pupil baffle, grating rotation stage mechanism and upper tower	7/14/15	25	25	8/18/15	Smith
3.1	**Gratings**					
3.2.1.6.1	Grating mounted in holder	5/29/15	81	125	11/20/15	Smith
6.2	**Polarizing Beamsplitter Mechanism**					
6.2.8	Dummy Polarizing Beamsplitter assembled in housing	8/18/15	19	83	12/12/15	Smith
8.4	**Engineering Grade Array**					
8.4.6.3	Test Dewar: Cold temperature testing of engineering grade array complete	2/28/15	-	-	-	Wolf / Mobsy
8.5	**Science Grade Array**					
8.5.2.2	LEDs installed in Dewar	2/6/15	-	-	-	Wolf
8.5.2.6	SGA integrated in Dewar. Thermal light leak testing complete @ room temp	3/20/15	-	-	-	Wolf
8.5.2.8	Dewar installed in Tenney Chamber and the chamber is cooled down	3/24/15	-	-	-	Wolf
8.5.2.9	Thermal background characterized at cold temperature	5/1/15	0	44	7/1/15	Wolf
8.5.3	SGA Dark Dewar characterization complete (bias opt., read noise, dark current)	6/12/15	0	44	8/12/15	Wolf
8.5.5.4	SGA Persistence Characterization and Testing Complete	7/31/15	0	44	9/30/15	Wolf/Smith
8.5.5.6	Dewar configured with L6 & L7	8/10/15	0	44	10/10/15	Wolf/Smith
8.5.6	Data reduction sofware complete	8/14/15	26	70	11/20/15	Babler
9.1	**Pre-dewar Enclosure**					
9.1.1.5	**Pre-dewar enclosure detail design complete**	**5/15/15**	**0**	**0**	**5/15/15**	**Wong**
9.1.1.6	**Order remaining enclosure material**	**6/19/15**	**0**	**0**	**6/19/15**	**Wong/Mulligan**
9.1.1.7	**Prep material for machining vendor**	**6/25/15**	**0**	**0**	**6/25/15**	**Smith/Wong**
9.1.1.8	Award pre-dewar enclosure machining and skin layup RFP	6/26/15	2	2	6/28/15	Wong
9.1.1.12	**Machining Complete, delivered to skin layup Vendor**	**8/7/15**	**0**	**0**	**8/7/15**	**Wong**
9.1.1.16	**Layup complete, enclosure delivered to UW**	**10/9/15**	**0**	**0**	**10/9/15**	**Wong**
9.6.2.1	**Inspect and surface treat enclosure**	**10/30/15**	**0**	**0**	**10/30/15**	**Smith**
9.6.2.2	**Skin heaters installed**	**11/27/15**	**0**	**0**	**11/27/15**	**Werner**
9.6.3.2	**Enclosure functionally tested (TBD)**	**12/18/15**	**0**	**0**	**12/18/15**	**Smith**
9.5	**Pre-Dewar & Electronic Enclosures Cooling System Design**					
9.5.2.2	Place order for components	6/30/15	0	12	7/16/15	Adler/Smith
9.5.2.3	Receive components	10/19/15	0	12	11/4/15	Adler/Smith
10	**Slit Cooling**					
10.1.2.1	Detail design complete (shop ready drawings & all components specified)	7/10/15	0	435	-	Smith
11	**Control System**					
11.4.4	Detailed design of cables complete	7/21/15	73	73	10/31/15	Koch
11.4.5	**Wire Harnesses and cables**					
11.4.5.6	PBS mechanism (power, hall)	8/18/15	0	73	11/28/15	Koch
11.4.5.11	Pre-dewar enclosure cooling system wire harness	7/21/15	0	93	11/28/15	Koch
11.4.5.12	Pre-dewar skin heater wire harness	7/28/15	0	48	10/3/15	Koch
11.4.5.13	Airlock cooling system/interlocks	8/4/15	0	73	11/14/15	Koch
11.4.5.15	Housekeeping wire harness	9/1/15	9	73	12/12/15	Koch
11.5	**Thermal control systems**					
11.5.3	Pre-dewar enclosure skin heater system ready to be installed on the enclosure	9/22/15	28	28	10/31/15	Werner
11.5.4	Airlock control system ready to be configured to support enclosure thermal testing	8/14/15	75	75	11/27/15	Koch
11.5.5	Pre-dewar enclosure thermal control system configured to support enclosure thermal testing	7/31/15	85	85	11/27/15	Koch
11.5.6	Electronics enclosure thermal control system ready to cool enclosure	8/5/15	181	181	4/14/16	Koch

Table 7 (continued). *RSS-NIR key schedule milestones by WBS.*

RSS-NIR KEY MILESTONES

					CRITCAL PATH	TASKS COMPLTED IN THE LAST QUARTER
WBS	DESCRIPTION	TARGET DATE	SLACK (WORKDAYS) FREE	TOTAL	MUST HAVE BY DATE	RESPONSIBLE TEAM MEMBER
11.7	**Electronics Enclosure**					
11.7.3	Detail design complete (enclosure and panel layout)	10/20/15	0	57	1/7/16	Koch/Smith
11.7.6	Enclosure Ready	1/5/16	57	57	3/24/16	Smith
11.7.7	**Panel built up**	**3/24/16**	**0**	**0**	**3/24/16**	**Koch**
11.7.8	**Enclosure, with cooling system, assembled**	**4/14/16**	**0**	**0**	**4/14/16**	**Koch**
11.8	**Additional PC Boards (includes mounting bracket fabrication if required)**					
11.8.8	One-wire: Airlock Bulkhead & Exhange Filter Boards	11/13/15	10	10	11/27/15	Koch
11.9.3 Real-time instrument control software (cRIO)						
11.9.3.1	Fold Mirror Tip/Tilt & Nodding	7/24/15	42	42	9/20/15	Percival
11.9.3.7	Polarzing beamsplitter insertion and removal	10/22/15	56	56	1/8/16	Percival
11.9.3.12	Airlock door lock	10/2/15	55	55	12/18/15	Percival
11.9.3.13	Dewar thermal control system	3/6/15	-	-	-	Percival
11.9.3.14	Pre-dewar thermal control system	11/26/15	1	1	11/27/15	Percival
11.9.3.15	Airlock thermal control system	11/26/15	1	1	11/27/15	Percival
11.9.3.16	Skin heater control system	6/12/15	80	80	10/2/15	Percival
13	**Support Equipment**					
13.3.2.6	Dummy polarizing beamsplitter fabricated	8/4/15	0	83	11/28/15	Smith
14	**Integration, Verification, & Testing at UW**					
14.1	**Towers**					
14.1.1	Commence integration of the upper and lower towers	8/19/15	0	0	8/19/15	Smith
14.1.3	Upper and lower towers integrated and tested. Ready to ship	10/13/15	0	0	10/13/15	Wolf
14.2	**Detector/Dewar/Camera**					
14.2.1	Commence integration of the Detector/Dewar with the Camera	8/11/15	0	44	10/11/15	Smith
14.2.3	Detector/Dewar/Camera integration and testing complete	9/21/15	0	44	11/21/15	Wolf
14.3	**Trusses and Mechanisms**					
14.3.3	Electronic integration and testing complete	5/22/15	5	105	10/16/15	Koch
14.3.4	Alignment and functional testing complete	5/29/15	0	100	10/16/15	Smith/Koch
14.3.5	Verification and endurance testing complete - Room Temperature	7/24/15	36	100	12/11/15	Smith/Koch
14.4	**Dewar/Camera & Articulation Mechanism**					
14.4.1	Completed integration of the Dewar/Camera into the articulation truss	9/28/15	0	44	11/28/15	Smith
14.4.2	Functional testing complete	10/5/15	0	44	12/5/15	Wolf / Smith
14.4.3	Detector / Grating testing	10/12/15	0	44	12/12/15	Wolf / Smith
14.5	**Polarizing Beamsplitter Mechanism**					
14.5.1	PBS integrated and tested	10/19/15	0	44	12/19/15	Smith
14.5	**Pre-Dewar Enclosure Integration**					
14.6.1	**Integrate enclosure, air-lock door, and baffling**	**1/8/16**	**0**	**0**	**1/8/16**	**Smith**
14.6.2	**Functional test mechansims complete**	**1/15/16**	**0**	**0**	**1/15/16**	**Smith**
14.6.3	**Integrate pre-dewar cover complete**	**1/20/16**	**0**	**0**	**1/20/16**	**Smith**
14.6.4	**Configure cooling system complete**	**1/25/16**	**0**	**0**	**1/25/16**	**Smith**
14.6.5	**Verify functionality of the cooling system**	**1/28/16**	**0**	**0**	**1/28/16**	**Smith**
14.6.6	**Cold endurance testing**	**2/11/16**	**0**	**0**	**2/11/16**	**Smith**
14.6.7	**Cold operational testing**	**2/25/16**	**0**	**0**	**2/25/16**	**Smith**

APPENDIX A.

Table A1. RSS-NIR Schedule Risk Assessment (see next page for explanation)

SUBSYSTEM	RESPONSIBLE ORG.	SCHEDULED COMPLETE	CURRENT SCHEDULE	ISSUS/CONCERNS/DETAILS	R_P	R_S	Score	Risk	ESTIMATED SCHEDULE SLIP
1. Pre-Dewar Enclosure	UW, Gartner Refrigration, Paradigm Design, and TBD vendors	May 27, 2013	**Dec 18, 2015**	1. Need to find a vendor to complete detail design. 2. Completing the detail design. 3. Lead-times to machine the structure and apply the skin. 4. Installation of skin heaters may be tedious and slow. 5. Relies heavily on Mike Smith.	**6.0**	**12.0**	**72.0**	**MAJOR**	Possibly as much as 3-4 months late.
2. Skin Heaters	UW	Mar 23, 2013	**Sep 22, 2015**	1. Testing and verification of the skin heaters may be time consuming.	**5.3**	**1.0**	**5.3**	**MINOR**	3-4 weeks, but no effect on the overall schedule.
3. Slit Cooling	UW	Feb 11, 2013	**Jul 10, 2015**	1. Installation on the telescope is the primary concern.	1	1	1	**MINOR**	-
4. Electronics Enclosure	UW and TBD Vendor	Aug 31, 2013	**Apr 14, 2016**	1. Fitting all of the electronics into the enclosure in a servicable manner.	**5.0**	**7.6**	**38.0**	**MAJOR**	- Enclosure could be up to a month late, but that would not delay the schedule. - The electrical migration could take an extra 2 weeks, but that seems unlikely. That would slip the ship readiness of the instrument.
5A. Control System - Hardware	UW	Apr 10, 2013	Nov 10, 2014	1. Just need to address some minor issues with the RFID system. 2. Continue to follow up on control system issues as they arise.	-	-	-	-	1-2 weeks, but these tasks are well off the critical path.
5B. Control System - Software	UW	Jun 30, 2013	**Nov 26, 2015**	1. The software development itself should be straightforward. No significant design concerns. 2. Development is all done my Jeff Percival at ~half-time. May slip some if troubleshooting becomes extensive. 3. Cold burn in tests will likely result in some mechanical troubleshooting. Schedule is very success orientated.	**5.5**	**1.7**	**9.1**	**MINOR**	4-6 weeks. Many tasks may slip with no impact on the schedule. The concern is the functional state system and the burn-in tests.
6. Mechanical Assemblies (Doublet)	UW, Physics Machine Shop, & The Pilot Group	Nov 30, 2012	**Mar 20, 2015**	1. Amount of time required by The Pilot Group to mount the lenses	6.0	1.0	6.0	**MINOR**	2 months to allow more time for the doublet to be mounted. Would still not impact schedule.
7. Camera	The Pilot Group & UW	Jan 4, 2013	Nov 26, 2015	1. While the schedule is comfortable for the UW test of the camera, this was a task that Andy was to lead. Marsha and Mike have experience, but have not been the lead for camera testing. 2. Marsha and Mike have many project responsibilities.	-	-	-	-	4- 6 weeks. Testing at Pilot Group is currently slow and we may need a little more time for interferometer tests at UW.
8. Dichroic	Infinite Optics & UW	Jan 18, 2013	**Jul 21, 2015**	1. Infinite Optics has consistently made very slwo progress.	6.0	1.0	6.0	**MINOR**	1 month - would not impact overall schedule
9. Grating	UW	Dec 21, 2012	**May 31, 2015**	1. Grating received. UW needs to mount the grating.	2.0	1.0	2.0	**MINOR**	1 month. Unlikely to effect schedule.
10. Cryofilter	UW & TBD Vendor	Jan 11, 2013	**Dec 19, 2015**	1. No significent issues. Simply need to mount the filters at the appropriate opportunity.	-	-	-	-	4-5 weeks. This would have a direct impact on the overall schedule.
11. Dewar	UW	Nov 16, 2012	**Nov 26, 2015**	1. Conducting the light leak testing may be time consuming due to cooling-testing-warming-modifying-cooling-retesting cycles.	-	-	-	-	4-6 months
12. Detector	UW	Mar 12, 2013	**Aug 14, 2015**	1. The learning curve on the detector has been very challenging and issues seem to come up fequently. 2. Schedule is likely optimistic.	**1.0**	4.9	4.9	**MINOR**	2 months. We are very likely to run into issues with the detector.
13. Integration & Instrument Testing	UW	Aug 5, 2013	**Feb 25, 2016**	1. Final testing always takes longer than you plan. 2. Expected unknown problems.	6.0	7.6	45.6	**MAJOR**	2-3 months

The schedule was reviewed to assess the level of risk associated with each subsystem being completed on time and its risk to delaying the overall schedule. The table presents the scheduled completion date and a list of issues, concerns or additional information for each subsystem. The tasks (not shown) for each subsystem were scored for the probability it will be

late (Risk Probability, R_P) and its risk to the overall schedule (R_S). A weighted average of the task scores were multiplied together to arrive at an overall risk score that were scaled to assign a minor, moderate, or major level of risk to the subsystem.

The two risk factors balance one another. For example, a subsystem may have a high probability of slipping, but is not a risk to the overall schedule (9. Grating), or it may be unlikely to slip, but if it does it will delay the schedule (4. Electronics Enclosure - migration of the electronics). The tasks were weighted 1, 2, or 3 to keep the subsystem score from being skewed by a series of simple tasks, which diluted the risk associated with one significantly difficult task.

The last column presents an estimated schedule slip assessment. This is an educated guess at an amount of time, if added to the schedule would, presumably, reduce the schedule risk to zero. Under ideal circumstances (infinite amount of time and money) the project would add this time to the schedule to increase the probability of meeting the ship readiness date to 100%.

PROBABILITY TO DELAY, R_P

1	Negligible	5 of 5 are true: Task is understood, experienced staff, resources available, resouces under project control, schedule is good
2	Remote	4 of 5 are true: Task is understood, experienced staff, resources available, resouces under project control, schedule is good
3	Possible	3 of 5 are true: Task is understood, experienced staff, resources available, resouces under project control, schedule is good
4	Likely	2 of 5 are true: Task is understood, experienced staff, resources available, resouces under project control, schedule is good
5	Very Likely	1 of 5 are true: Task is understood, experienced staff, resources available, resouces under project control, schedule is good
6	Extremely Likely	0 of 5 are true: Task is understood, experienced staff, resources available, resouces under project control, schedule is good

SCHEDULE IMPACT, R_S

1	Remote	Has less than 10 weeks slack before the tasks becomes the critcal path
2	Possible	Has less than 8 weeks slack before the tasks becomes the critcal path
3	Likely	Has less than 6 weeks slack before the tasks becomes the critcal path
5	Very Likely	Has less than 4 weeks slack before the tasks becomes the critcal path
8	Sub-critical	Has less than 2 week slack before the tasks becomes the critcal path
12	Critical	Task is on the critical path and any delay will delay the schedule

SCHEUDLE RISK ASSESSMENT

≤ 12	MINOR	Unlikely to be a schedule risk
13 -35	MODERATE	May end up impacting schedule
≥ 36	MAJOR	Very likely to impact schedule and should be monitored closely.

APPENDIX B.
RSS-NIR Capabilities and De-Scoped Options

This appendix serves as a reminder of the capabilities of RSS-NIR at different levels of re-scope. Our hope is that this will make it clearer for SALT partners to consider how additional funding contributions would increase the capabilities of the instrument.

B1. As delivered with current budget

Although the envisioned RSS-NIR would provide all the operating modes of RSS-VIS, the delivered RSS-NIR will be a de-scoped version of its original concept, due to the current level of funding. The delivered RSS-NIR will be an articulated imaging spectrograph with one volume phase holographic grating that operates over 0.9 – 1.55 microns for faint sky-limited objects and 0.9 – 1.7 microns for bright objects. None of the other instrument modes have been precluded by the RSS-NIR design. All mechanisms are in place to support the full suite of gratings for spectroscopy, filters for broadband imaging, Fabry-Perot tunable narrow band imaging, and polarimetry in imaging and spectroscopy modes.

Spectroscopy will initially be limited by the single grating. The predicted performance of the full grating suite is shown in Figure B1. Initially, only the 950 l/mm grating will be installed. It will allow spectroscopy over the full range of 0.9 – 1.7 microns with spectral resolution that varies with wavelength from R ~ 3000 at 0.9 microns to R ~ 7000 at 1.7 microns for a 1 arcsec slit.

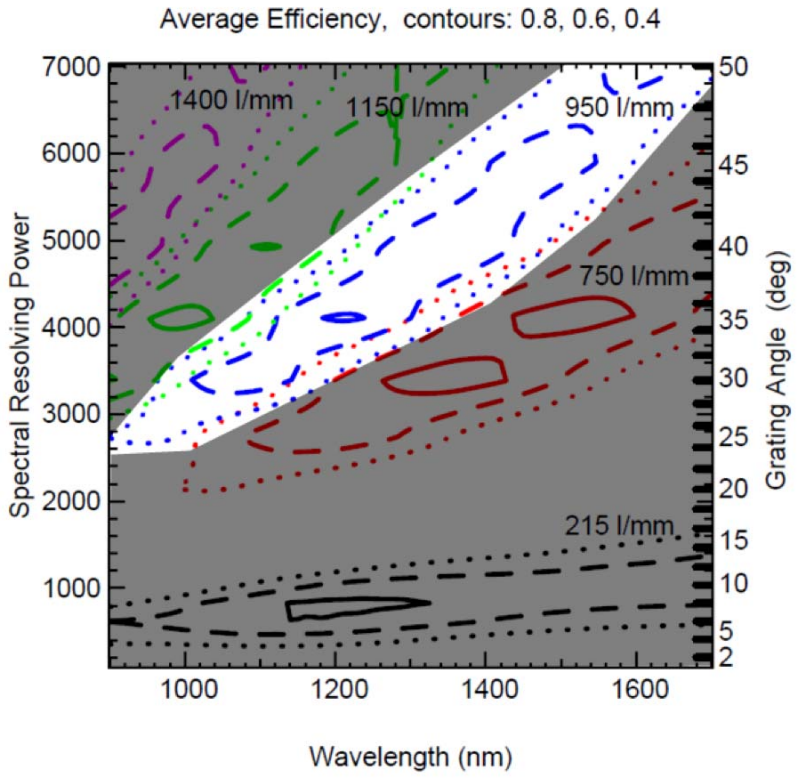


Figure B1. *Predicted performance of the full RSS-NIR grating suite. The spectral resolving power is for a 1 arcsec slit. Initially, only the 950 l/mm grating will be installed. The gray areas mark parameter space that will not be accessible without more gratings.*

No slit cooling will be provided, so the resulting instrument thermal background of an ambient temperature slit limits the longest observed wavelength for faint sky-limited objects to 1.55 microns. This will be achieved with a selectable cryogenic long wavelength cutoff filter in the dewar filter wheel. A clear filter will also be provided to allow observations out to 1.73 microns, the detector cutoff, for bright objects.

RSS-NIR can also be used for imaging, but no broadband or narrowband filters will initially be provided.

B2. De-scoped items

Table B1. *De-scoped items and their estimated costs. The cost estimates include the associated labor to develop specifications, review specifications with vendors, produce purchasing documentation, and, ultimately, the integration and testing. The component prices have been based on actual orders on hold, similar purchases, or discussions with vendors. Please note the descoped grating cost assumes a fused silica substrate. The low OH infrasil adds about $20k/grating or $80k.*

De-Scoped Item	Cost (thousands of US dollars)
Gratings (4)	$250
Cooled slit hardware	$54
Cryogenic long wavelength cutoff filters (2)	$56
Broadband filters (3)	$66
Fabry-Perot order blocking filters (9)	$196
Fabry-Perot etalon system	$305
Polarizing beamsplitter	$138

B3. Full grating suite

The additional 4 gratings in Figure B1 would provide the full range of spectral resolution at each wavelength. However, the long wavelength limitation of 1.55 microns would still apply to faint sky-limited observations without slit cooling.

These gratings could be added with RSS-NIR on the telescope. The instrument would have to be warmed and the pre-dewar enclosure top would have to be removed.

B4. Slit cooling and cryogenic long wavelength cutoff filters

Without slit cooling, sky-limited spectroscopy will only be possible out to a maximum wavelength of 1.55 microns. This is the only long wavelength cutoff filter that has been purchased.

The design includes long wavelength cutoff filters at 1.55, 1.6, 1.67, and 1.73 microns (the latter is a clear filter that relies on the detector cutoff). Using past SALT temperature statistics, we predict that slit cooling to 20 °C below the ambient temperature would allow faint sky-limited observations out to 1.67 microns at R = 4000 for 85% of the time and at R = 7000 for 70% of the time. Performance statistics of the amount of time sky-limited spectroscopy would be possible, based on SALT weather archives, at different cutoff wavelengths are shown in Figure B2.

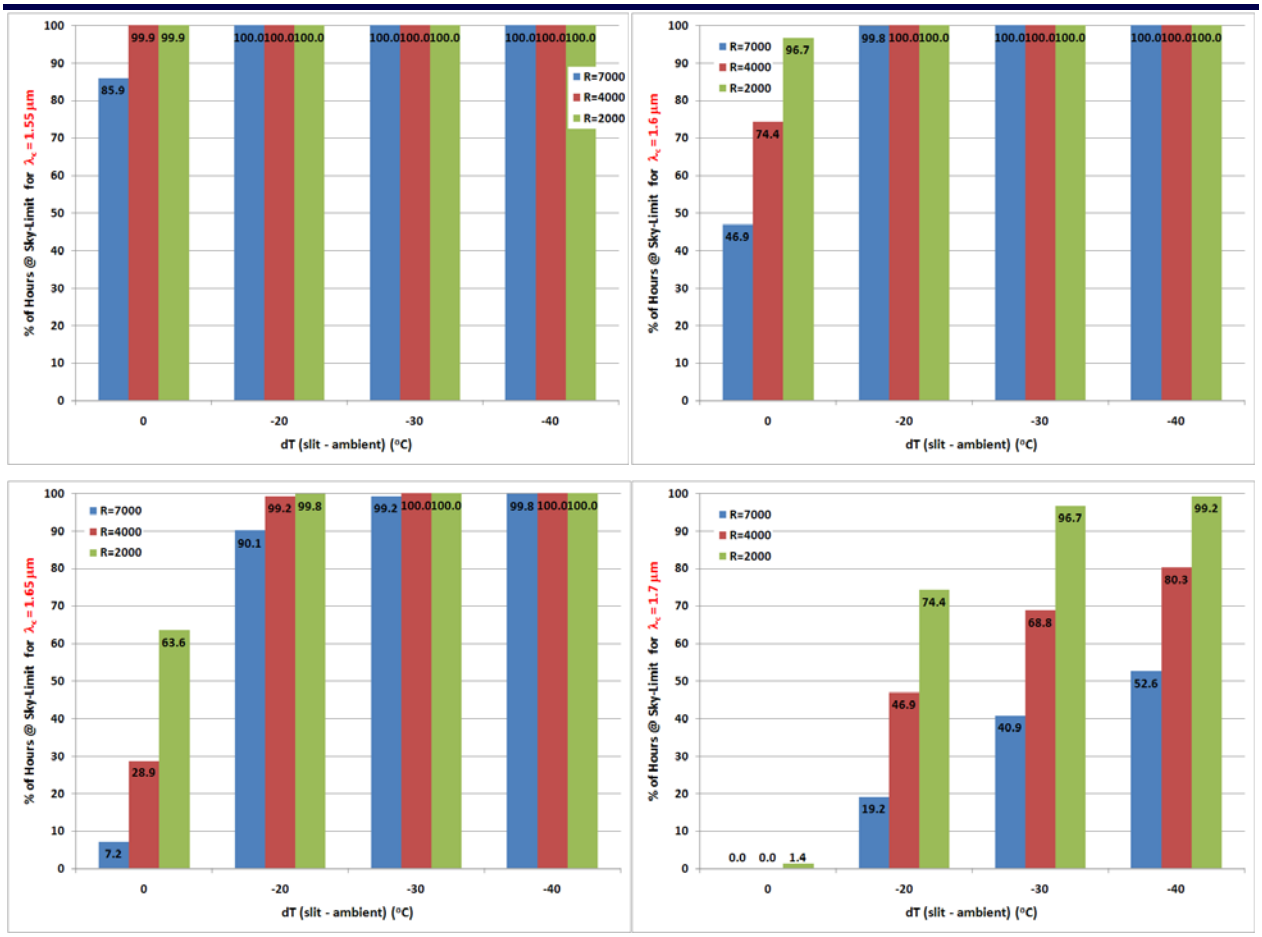


Figure B2. *Based on past SALT temperature statistics, this shows the predicted percentage of dark hours per year during which observations with a cooled slit would be possible at different cutoff wavelengths. We expect to be able to cool the slit to 20 °C below ambient temperature. This would mean, for example, at R = 7000 sky-limited observations out to 1.7 microns would only be possible 19% of the time (during winter nights when the slit is coolest). At 1.65 microns this jumps up to 90% of the time. The longest cutoff wavelength filter at 1.67 microns was chosen by extrapolating between 1.65 and 1.7 microns.*

The addition of slit cooling or extra cutoff filters (for the cryogenic dewar filter wheel) would require removal of RSS-NIR from the telescope.

B5. Broadband imaging

We plan to utilize the Maunea Kea set of Y, J, and H filters. Note that H will be an H_{short} filter, defined by the detector cutoff of 1.73 microns.

These filters could be added with RSS-NIR on the telescope. The instrument would have to be warmed and the pre-dewar enclosure top would have to be removed.

B6. Fabry-Perot tunable narrowband imaging

The addition of the Fabry-Perot mode would require both the etalon system (includes controller) and the set of order blocking filters. The Fabry-Perot system for RSS-NIR will consist of a single etalon operating at R ~ 2500. A series of narrow order blocking filters will be designed to operate with the etalon in specific atmospheric windows between bright OH emission lines in the night sky. Approximately 20 such windows have been identified (Figure B3). However, only 9 filters (the number that would fit in the instrument at once, along with 3

broadband filters) were included in the original RSS-NIR budget and subsequently de-scoped. A filter exchange airlock is part of the baseline instrument. If more than 9 filters are procured, this mechanism would allow the exchange of 3 filters during the day. This mechanism will be checked out as part of the overall integration and testing in Madison.

As long as the cabling (not currently in the budget) for the Fabry-Perot system is installed before RSS-NIR is initially put on the telescope, the etalon and filters could be added with RSS-NIR on the telescope. The instrument would have to be warmed and the pre-dewar enclosure top would have to be removed.

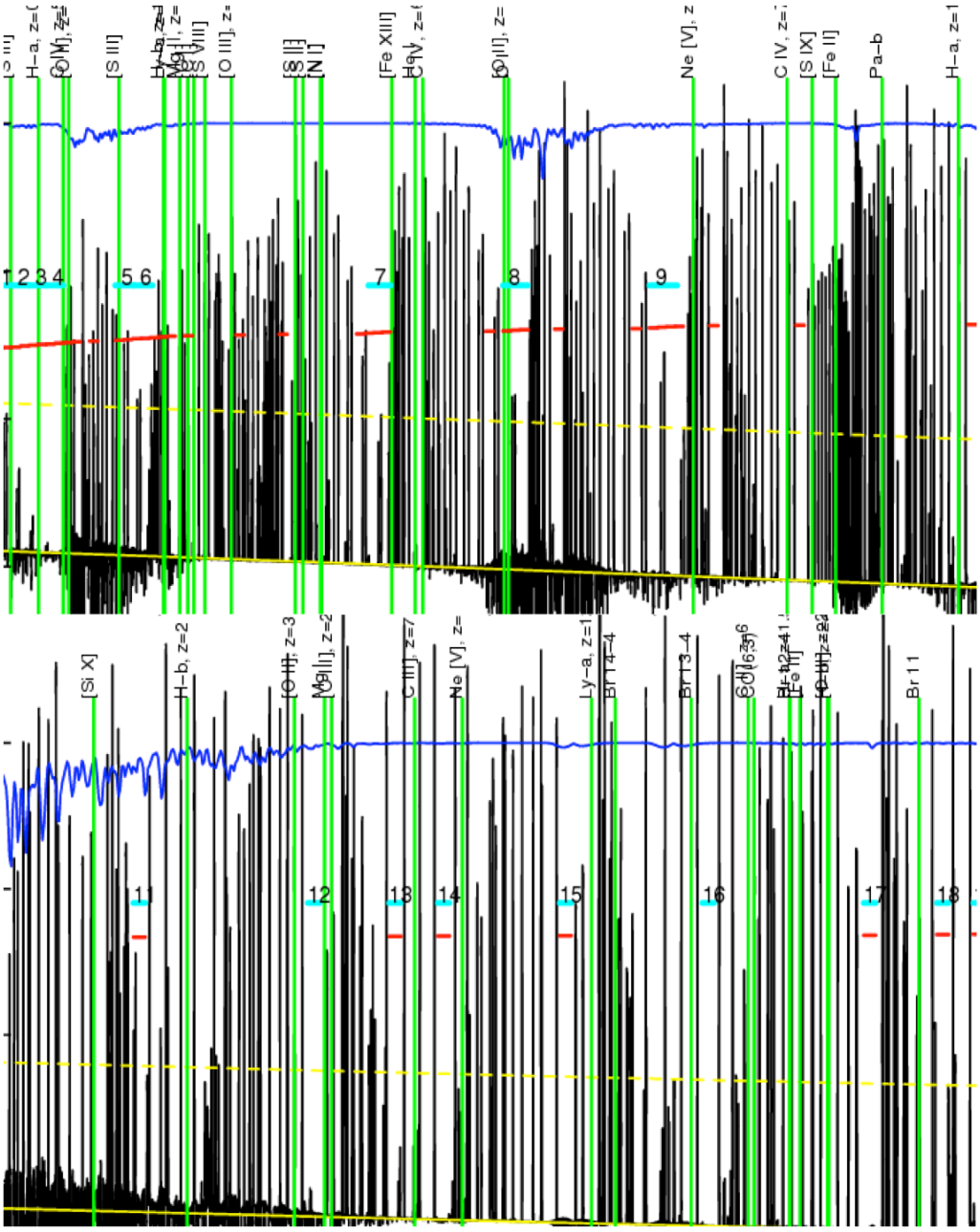


Figure B3. *In black is a night sky spectrum from Maunea Kea in Hawaii. Atmospheric transmission is shown in blue (with arbitrary scaling). The solid yellow line is a fit to the sky continuum and the dashed yellow line marks 10 times the continuum level. Possible Fabry-Perot filter locations are marked by the thick cyan dashes. Their width in*

the J band is matched to the etalon free spectral range, while the H band is approximately 7x the etalon FWHM. Wavelengths of astronomical lines of interest are marked by the vertical green lines.

B7. Polarimetry

Polarimetry could be added with the purchase of the polarizing beamsplitter. Its holder and insertion mechanism are part of the baseline instrument.

This beamsplitter could be added with RSS-NIR on the telescope. The instrument would have to be warmed and the pre-dewar enclosure top would have to be removed.

B8. Requirements of SALT

There are a few requirements of SALT for RSS-NIR to operate on the telescope.

- The tracker must be upgraded to take the extra weight of RSS-NIR.
- The atmospheric dispersion corrector must be redesigned to operate through 1.73 microns.
- The upgraded calibration system must operate through 1.73 microns. We will work with the calibration system upgrade team to specify and meet these requirements.
- The tracker focus interferometer uses a laser that falls within the RSS-NIR wavelength range and will interfere with astronomical observations. If the interferometer will be used again in the future, this needs to be replaced with a laser that operates at > 1.8 microns.

APPENDIX C.
RSS-NIR Science Commissioning Tasks

This commissioning plan is largely drawn from the plan that was developed for RSS-VIS by Eric Hooper and Ken Nordsieck. NIR-specific tasks have been added.

Each task listed in Table C1 has an identifying string which starts with IMG (imaging without the use of any gratings but may employ a mask), LS (long slit), or MOS (multi-object spectroscopy). The italicized short phrases in the object characteristics column of Table 1 refer to entries in Table C2 which give a more detailed description. Closely related observations in different modes are grouped together in the table. Commissioning priority is given in column 2 of Table C1. Several end-to-end tests of measurements of astronomically important parameters (e.g., velocity gradients, redshifts) are denoted by the string "_astro_" in the task identifier. The priority assigned to the "_astro_" tasks is "low," not because they are of scientifically low priority (quite the opposite in fact), but because the initial failure of any single one of them would not necessarily jeopardize the entire corresponding instrument mode and because these are bridge observations between commissioning and routine science operation.

Table C1: On-telescope commissioning tasks for RSS-NIR imaging, long slit, and multi-object instrument modes.

Task Identifier	Priority	Goal	Object characteristics (see table below)	Approx. configuration
IMG_read_noise	Very high	Test read noise after instrument installed on telescope; compare to lab and pre-lift ground tests.	No object.	Any.
IMG_dark	Very high	Test dark current after instrument installed on telescope; compare to lab and pre-lift ground tests.	No object.	Any.
IMG_bkg	Very high	Measure instrument thermal background. Check for any additional sources from telescope.	Dark dome at different ambient temperatures.	Camera articulation at 0 deg. No grating.
LS_bkg	Very high	Measure instrument thermal background with instrument in different LS setup configurations (different viewing angles). Check for any additional sources from telescope.	Dark dome at different ambient temperatures.	Gold and bare long slit masks with and without cooling. Various gratings and angle settings.
MOS_bkg	Very high	Measure instrument thermal background with instrument in different MOS setup configurations (different viewing angles). Check for any additional sources from telescope.	Dark dome at different ambient temperatures.	Gold and bare MOS masks with and without cooling. Various gratings and angle settings.

Task Identifier	Priority	Goal	Object characteristics (see table below)	Approx. configuration
IMG_simul	Very high	Test simultaneous operation of VIS and NIR in imaging mode.	*Standard star.*	Imaging.
LS_simul	Very high	Test simultaneous operation of VIS and NIR in LS mode. • Test stitching together spectra from both instruments.	*Standard star.*	LS mask, any grating.
MOS_simul	Very high	Test simultaneous operation of VIS and NIR in MOS mode. • Test stitching together spectra from both instruments.	*Standard star.*	MOS mask, any grating.
IMG_acq_ img	Very high	Acquire single and multiple targets. Verify basic acquisition with the NIR detector only. Confirm offsets between RSS, acquisition, and guiding ccds. Once basic functionality has been established with one or two filters and basic tracker orientations, tests with remaining filters and orientations can be done as part of other observations.	*Many points.*	No gratings. No slit. All broadband filters. 4 extreme tracker positions + 1 central position @ 2 rotations (90 degrees apart) in one or two filters. 1 tracker position at remaining two 90 degree angles.
IMG_acq_ ls	Very high	Acquire single and multiple targets. Verify acquisition of long-slit targets.	*Points in a line.*	No gratings. Long slit, narrow. 2 tracker pos/rotations (e.g., E&W tracks).
IMG_acq_mos	Very high	Acquire multiple targets, including verification of no measurable distortion at slit plane. End-to-end test of mask design and fabrication. Use target and mask from a different task.	*Many points.*	No gratings. Multislit mask, narrow slits 2 tracker pos/rotations (e.g., E&W tracks).
IMG_mask_ rep_ls	Very high	Check repeatability of position with multiple long slit removals and insertions. Check for any dependence on temperature. Result of interest for repeatability of F-P full aperture mask.	*Points in a line.*	No gratings. Long slit, narrow. 2 tracker pos/rotations (e.g., E&W tracks).

Task Identifier	Priority	Goal	Object characteristics (see table below)	Approx. configuration
IMG_mask_ rep_mos	Very high	Check repeatability of position with multiple slit mask removals and insertions. Check for any dependence on temperature.	*Many points.*	No gratings. Multislit mask, narrow slits. 4 extreme tracker positions + 1 central position @ 2 rotations (e.g., E&W tracks).
LS_persistence	Very high	Check persistence effects and test mitigation strategies. • Effect of sequence of wavelength and resolution (blue to red, low to high R) • Can residual signal from bright sky lines be removed as part of sky subtraction in subsequent observations?	*Bright point source.*	High and low R gratings, blue and red settings. Vary exposure times, cadences, and readout modes. Measure with and without detector-based and schedule-based mitigation strategies.
MOS_persistence	Very high	Check persistence effects and test mitigation strategies. • Effect of sequence of wavelength and resolution (blue to red, low to high R) • What is impact of residual signal of bright line only part way through the 2-D spectrum from slitets in subsequent observations?	*Bright point sources. e.g. star cluster.*	High and low R gratings, blue and red settings. Vary exposure times, cadences, and readout modes. Measure with and without detector-based and schedule-based mitigation strategies.
IMG_iq	Very high	Telescope focus and overall image quality; generate focus plots (psf characteristics vs. focus). Check with image position in f.o.v., temperature, focus encoder repeatability, night to night at same temperature. Measure spatial resolution.	*Many points.*	No gratings. No slit or mask. All filters, order blocking and narrow-band. 4 extreme tracker positions + 1 central position @ 2 rotations (90 degrees apart) in one or two filters. 1 tracker position at remaining two 90 degree angles.
LS_iq	Very high	Verify optimum focus in spatial direction of dispersed light is the same as optimum focus in straight imaging mode. Spatial resolution as fcn. of wavelength. No need to check all params, as in IMG_iq.	*Points in a line.*	Narrow long slit. All gratings, blue & red ends.

Task Identifier	Priority	Goal	Object characteristics (see table below)	Approx. configuration
MOS_iq	Very high	Verify optimum focus in spatial direction of dispersed light is the same as optimum focus in straight imaging mode. Spatial resolution as fcn. of wavelength. No need to check all params, as in IMG_iq.	*Many points.*	Narrow slitlets in mask. All gratings, blue & red ends.
IMG_guide	Very high	Guiding, including reliability of open-loop rotation. Combine with other observations: set up; check positions of targets; do another observation with same target w/o changing pointing or stopping guiding; verify positions in imaging mode after time of typical long single. Of great importance for F-P.	*Many points.*	No gratings. 4 extreme tracker positions + 1 central position @ 2 rotations (90 degrees apart). 1 tracker position at remaining two 90 degree angles.
IMG_ distortion	Very high	Measure RSS-NIR distortion and any other aberrations. Measure internal distortion with pinhole mask plus do an end-to-end test with an astrometric standard field. Especially important for F-P.	Uniform light source. *Many points* in an astrometric standard field.	No gratings. Pinhole mask. Slit mask already available for other purposes. For on-sky target, 4 extreme tracker positions + 1 central position @ 2 rotations (e.g., E&W tracks).
LS_focus	Very high	Verify ground tests of spectrograph focus model.	Calibration line lamp. *Extended emission line.*	Long slit, narrow.
MOS_ focus	Very high	Verify ground tests of spectrograph focus model across field of view.	Calibration line lamp. *Extended emission line.*	Multislit mask, narrow slitlets. 4 extreme tracker positions + 1 central position @ 2 rotations for select gratings. All other gratings, blue and red ends @ 1 tracker position.
LS_tput	Very high	System throughput, including as function of position along slit.	*Standard star.*	All gratings. Burst mode. Appropriate order block filters. No slit.

Task Identifier	Priority	Goal	Object characteristics (see table below)	Approx. configuration
MOS_tput	Very high	System throughput, including as function of slitlet position.	*Standard star.*	All gratings. Burst mode. Appropriate order block filters. Measure with narrow-band filters (MOS_close_pak) as time permits. No slit.
MOS_calib	High	Test slit-to-slit relative calibration strategies and models. Test by tracking globular slowly across the f.o.v. and with an out of focus globular; compare to twilight & lamp flat field. Test for night-to-night stability of relative calibration. Test at extremes of resolution and wavelength range.	Twilight flat field. *Standard star.* *Extended continuum.*	2 tracker pos/rotations (e.g., E&W tracks).
IMG_sky_sub	High	Test efficacy of sky subtraction methods. • "Optical style," in which sky is not subtracted before flat-fielding, and any subtraction is done during analysis (e.g., photometry). • Telescope rastering. • Fold mirror rastering (pattern is narrow in one dimension, long in the other). • Separate sky field observations. • Does readout mode (Fowler, up-the-ramp) affect sky subtraction?	*Many points* plus *Extended* category objects (including possibly extended *many objects* sources) of different sizes. At least one target should be comparable to or larger than the field of view to test the efficacy of separate dedicated sky fields.	All imaging filters. Variety of raster patterns, depending on nature of the target field. Test different individual frame exposure times and the time interval between observations on a large extended target and separate sky pointings.
LS_sky_ sub	High	Test efficacy of sky subtraction methods. • Determine the largest angular extent of an object, plus maximum exposure time, for effective standard 2-D and 1-D sky subtraction algorithms. • Observe dedicated sky images for extended targets and compare the quality of sky subraction both with and without the use of this sky frame. • Nodding along the slit. • Does readout mode (Fowler, up-the-ramp) affect sky subtraction?	Any objects, but including some with low S/N and a variety of angular extents. Use data taken for other purposes whenever possible.	All gratings, as many wavelength settings as possible, especially in the red. Test different number of Fowler reads, different number and rates of up-the-ramp samples.

Task Identifier	Priority	Goal	Object characteristics (see table below)	Approx. configuration
MOS_sky_sub	High	Test efficacy of sky subtraction. • Minimum length of MOS slitlet relative to target size. • Dedicated sky slitlets with the same wavelength coverage as the target object slitlets. • Observe dedicated sky images for some extended targets and compare the quality of sky subraction both with and without the use of this sky frame. • Short nods along slitlets. • Does readout mode (Fowler, up-the-ramp) affect sky subtraction?	Any object, but including some with low S/N and at least one extended object which fills the field of view (i.e., all slitlets). Use data taken for other purposes whenever possible.	All gratings, as many wavelength settings as possible, especially in the red. Test different number of Fowler reads, different number and rates of up-the-ramp samples.
IMG_adc	High	Primary verification of NIR performance of atmospheric dispersion corrector. Check to see that images of stars across the f.o.v. don't move as different filters are inserted.	*Many points.*	No grating. Several narrow band filters that together bracket the entire wavelength range. 2 extreme tracker positions + 1 center position @ 4 position angles, each 45 deg apart.
LS_adc	High	Verify performance of atmospheric dispersion corrector with slit.	*Standard star.*	2 position angles. One tracker position.
LS_flat_ field	High	Test efficacy of flat-fielding, including use of moving baffle.	Quartz lamp and twilight sky. Use flats taken for other observations.	All gratings, as many wavelength settings as possible.
MOS_flat_field	High	Test efficacy of flat-fielding, including use of moving baffle.	Quartz lamp and twilight sky. Use flats taken for other observations as much as possible.	All gratings, as many wavelength settings as possible.
IMG_flat_ field	Low	Test efficacy of flat-fielding, including use of moving baffle.	Quartz lamp, twilight sky, and night sky superflats.	All non-order blocking filters.

Task Identifier	Priority	Goal	Object characteristics (see table below)	Approx. configuration
LS_ wavelength	High	Test wavelength calibration over entire wavelength range, f.o.v., tracker position, and at different times. Compare against night sky lines.	*Points in a line* or any extended object, as long as some sky is visible. Use data taken for other purposes.	All gratings, as many wavelength settings as possible. Conduct a subset at multiple tracker positions.
MOS_ wavelength	High	Test wavelength calibration over entire wavelength range, f.o.v., tracker position, and at different times. Compare against night sky lines.	*Many points* or any extended object, as long as some sky is visible. Use data taken for other purposes.	All gratings, as many wavelength settings as possible. Conduct a subset at multiple tracker positions.
LS_ resolution	High	Test on-sky resolution vs. resolution observed with arc lamps.	Bright *extended emission line* source.	Conduct a subset at 2 tracker pos/rotations (e.g., E&W tracks).
MOS_ resolution	High	Test on-sky resolution vs. resolution observed with arc lamps.	Bright *extended emission line* source.	Conduct a subset at 2 tracker pos/rotations (e.g., E&W tracks)
LS_stray_ light	High	Determine level of stray light from bright stars, the moon, laser to keep tracker aligned with primary mirror (if it's NIR). Look for ghosts.	Bright *extended continuum* source and bright star at various positions on and off slitlets. Moon close/far.	Use uncoated and gold coated long slit with full moon and dark skies (lights on and off during daytime testing) to verify earlier tests of scattered light impact on visible side.
MOS_stray_light	High	Determine level of stray light from bright stars, the moon, laser to keep tracker aligned with primary mirror (if it's NIR). Look for ghosts.	Bright *extended continuum* source and bright star at various positions on and off slitlets. Moon close/far.	Use uncoated and gold coated pinhole mask with full moon and dark skies (lights on and off during daytime testing) to verify earlier tests of scattered light impact on visible side.
IMG_stray_light	Medium	Determine level of stray light from bright stars, the moon, laser to keep tracker aligned with primary mirror (if it's NIR). Look for ghosts.	Bright *extended continuum* source out of field. Bright star in and out of field. Moon close/far.	No gratings. No slit.
LS_psf	Medium	Measure stellar psf, including extended low-level pedestal. Explore accuracy of psf subtraction from underlying extended sources.	*Bright point,* one that is isolated and another embedded in underlying extended emission.	2 tracker pos/rotations (e.g., E&W tracks).

Task Identifier	Priority	Goal	Object characteristics (see table below)	Approx. configuration
MOS_psf	Medium	Measure stellar psf, including extended low-level pedestal. Move a bright point source to a few slitlet positions. Explore accuracy of psf subtraction from underlying extended sources.	*Bright point*, one that is isolated and another embedded in underlying extended emission.	2 tracker pos/rotations (e.g., E&W tracks).
LS_radial_vel	Medium	Radial velocity stability.	*Radial velocity standard*.	Higher resolution gratings. Specific settings depend on line observed.
MOS_ radial_vel	Medium	Radial velocity stability.	*Radial velocity standard*.	Higher resolution gratings. Specific settings depend on line observed. Place standard on several slitlets to cover the f.o.v. 2 tracker pos/rotations (e.g., E&W tracks).
IMG_ls_ slit	Medium	Measure edge uniformity and smoothness.	Any evenly illuminated extended object, such as twilight or line lamps.	All standard slits.
IMG_mos_slit	Medium	Measure edge uniformity and smoothness for slitlets.	Any evenly illuminated extended object, such as twilight or line lamps.	Slit masks made for other purposes.
LS_ stability	Medium	Measure repeatability of an observation with the same instrument configuration over time. This includes more factors and may be over a longer time scale than the _mask_ rep_ family of tasks.	Non-variable *points in a line*.	Check at both high and low resolution, red and blue.
MOS_ stability	Medium	Measure repeatability of an observation with the same instrument configuration over time. This includes more factors and may be over a longer time scale than the _mask_ rep_ family of tasks.	Non-variable *many objects*.	Check at both high and low resolution, red and blue.

Task Identifier	Priority	Goal	Object characteristics (see table below)	Approx. configuration
IMG_ distortion	Low	Measure RSS-NIR distortion and any other aberrations.	Uniform light source. *Many points.*	No gratings. Pinhole mask. Slit mask already available for other purposes. For on-sky target, 4 extreme tracker positions + 1 central position @ 2 rotations (e.g., E&W tracks).
LS_astro_ red	Low	Demonstrate fundamental astronomical capability: performance in the extreme red end of the spectrum available to RSS. Measure throughput and minimum resolution needed for adequate sky line subtraction or avoidance (will likely depend on brightness and scientific purpose).	Any moderately faint to faint source (sky lines are less of a problem for bright sources) detectable to the red wavelength cutoff.	
MOS_astro_red	Low	Demonstrate fundamental astronomical capability: performance in the extreme red end of the spectrum available to RSS. Measure throughput and minimum resolution needed for adequate sky line subtraction or avoidance (will likely depend on brightness and scientific purpose).	Any moderately faint to faint MOS source (sky lines are less of a problem for bright sources) detectable to the red wavelength cutoff.	
LS_astro_ res	Low	Demonstrate fundamental astronomical capability: highest possible spectral resolution.	Any source bright enough to be detected at highest resolution. Should have identifiable features to verify resolution.	0.6 arcsec slit.
MOS_astro_res	Low	Demonstrate fundamental astronomical capability: highest possible spectral resolution.	Any MOS source bright enough to be detected at highest resolution. Should have identifiable features to verify resolution.	

Task Identifier	Priority	Goal	Object characteristics (see table below)	Approx. configuration
LS_astro_ full_calib	Low	Demonstrate fundamental astronomical capability: wavelength & spectrophotometric calibration over full field of view.	*Points on a line, extended continuum, extended emission line*, any other extended source which requires full calibration. *Standard star.*	
MOS_astro_full_calib	Low	Demonstrate fundamental astronomical capability: wavelength & spectrophotometric calibration over full field of view. Test at high and low extremes of resolution and wavelength coverage. Test at multiple tracker orientations.	*Many points, extended continuum, extended emission line*, any other extended source which requires full calibration. *Standard star.* *Extended continuum* for slitlet to slitlet relative calibration.	
LS_astro_ faint_limit	Low	Demonstrate fundamental astronomical capability: faintest achievable magnitude in a reasonable total exposure time (1 – a few hr.)	*Points on a line, extended continuum, extended emission line*, or other very faint source.	Configuration depends on target and scientific goal. Should have both low and high resolution examples, blue and red if possible.
MOS_astro_faint_limit	Low	Demonstrate fundamental astronomical capability: faintest achievable magnitude in a reasonable total exposure time (1 – a few hr.)	*Many points, many objects, extended continuum, extended emission line*, or other very faint source.	Configuration depends on target and scientific goal. Should have both low and high resolution examples, blue and red if possible.
LS_astro_ hiSN	Low	Demonstrate fundamental astronomical capability: evaluate quality of data for S/N > 1000/spectral resolution element. Does the noise match what's expected? Are systematic effects revealed? What is the achievable relative and absolute photometric precision?	Bright to very bright object.	Low resolution for bright objects, higher for very bright.
MOS_astro_hiSN	Low	Demonstrate fundamental astronomical capability: evaluate quality of data for S/N > 1000/spectral resolution element. Does the noise match what's expected? Are systematic effects revealed? What is the achievable relative and absolute photometric precision?	Bright to very bright object.	Low resolution for bright objects, higher for very bright.

Task Identifier	Priority	Goal	Object characteristics (see table below)	Approx. configuration
LS_astro_crowded	Low	Demonstrate fundamental astronomical capability: derive useful data for objects in a very crowded field.	*Many points*, with a range of source densities around targets from moderate to extremely crowded.	Depends on object, feature desired, and science sought.
MOS_astro_crowded	Low	Demonstrate fundamental astronomical capability: derive useful data for objects in a very crowded field.	*Many points*, with a range of source densities around targets from moderate to extremely crowded.	Depends on object, feature desired, and science sought.
LS_astro_ synoptic	Low	Demonstrate fundamental astronomical capability: execute a successful synoptic program.	Any variable object(s).	Depends on object, spectral feature that is variable, and science sought.
MOS_astro_synoptic	Low	Demonstrate fundamental astronomical capability: execute a successful synoptic program.	Any variable objects.	Depends on object, spectral feature that is variable, and science sought.
LS_astro_ vel	Low	Measure fundamental astronomical parameter: velocity and/or velocity gradient. Produce galaxy rotation map.	*Extended with coherent motion.*	Low to high resolution, as needed to produce required accuracy of velocity measurement. Medium to high resolution, as needed to resolve velocity gradient.
MOS_astro_vel	Low	Measure fundamental astronomical parameter: velocity and/or velocity gradient.	*Extended with coherent motion. Many objects* with measurable velocity gradient across field.	Low to high resolution, as needed to produce required accuracy of velocity measurement. Medium to high resolution, as needed to resolve velocity gradient.
LS_astro_ vel_stabil	Low	Demonstrate fundamental astronomical capability: velocity stability. How accurately can time variable velocities be measured? What is the systematic error in a velocity measurement?	Any source, preferably *points in a line*, which requires velocity stability.	High resolution. Which grating and which settings depend on the line being measured.
MOS_astro_vel_stabil	Low	Demonstrate fundamental astronomical capability: velocity stability. How accurately can time variable velocities be measured? What is the systematic error in a velocity measurement?	Any extended or *many points source* which requires velocity stability.	High resolution. Which grating and which settings depend on the line being measured.

Task Identifier	Priority	Goal	Object characteristics (see table below)	Approx. configuration
LS_astro_z	Low	Measure fundamental astronomical parameter: redshift.	*Cosmological sources*, both absorption line and emission line.	Low resolution. Specifics depend on redshift of objects and which features are detectable.
MOS_astro_z	Low	Measure fundamental astronomical parameter: redshift. Traditional MOS mode.	*Cosmological sources*, both absorption line and emission line.	Low resolution. Choice of grating and wavelength coverage depend on redshift of objects, which features are detectable, and the accuracy to which the redshift must be determined. Use traditional mask design, in which the slitlets do not overlap in the spatial direction.
LS_astro_ sigma	Low	Measure fundamental astronomical parameter: velocity dispersion.	*Extended with random motion.*	Medium to high resolution, depending on amount of velocity dispersion.
MOS_astro_sigma	Low	Measure fundamental astronomical parameter: velocity dispersion.	*Extended with random motion.*	Medium to high resolution, depending on amount of velocity dispersion.
LS_single_star	Low	Measure fundamental astronomical parameters: properties of single stars, such as classification, metallicity, gravity, etc.	Single or *many points*, as long as it/they are stars.	Configuration depends on parameters desired and faintness of stars.
MOS_single_star	Low	Measure fundamental astronomical parameters: properties of single stars, such as classification, metallicity, gravity, etc.	*Many points*, as long as they're stars.	Configuration depends on parameters desired and faintness of stars.
LS_astro_ stellar_ pops	Low	Measure fundamental astronomical parameter: stellar populations.	Any source with integrated (as opposed to resolved individual stars) stellar populations.	Medium to high resolution, depends in part on S/N of source and need to include several spectral features.
MOS_astro_stella r_ pops	Low	Measure fundamental astronomical parameter: stellar populations.	Any source with integrated (as opposed to resolved individual stars) stellar populations.	Medium to high resolution, depends in part on S/N of source and need to include several spectral features.

Task Identifier	Priority	Goal	Object characteristics (see table below)	Approx. configuration
LS_astro_ profiles	Low	Measure fundamental astronomical parameter: emission/absorption line profies.	Any source for which the line profile is important.	Resolution depends on line width. Ideally explore at a variety of resolutions and S/N.
MOS_astro_ profiles	Low	Measure fundamental astronomical parameter: emission/absorption line profies.	Any source for which the line profile is important.	Resolution depends on line width. Ideally explore at a variety of resolutions and S/N.
LS_astro_ line_ratios	Low	Measure fundamental astronomical parameter: emission line ratios. A point source could be used, but an extended source is preferable to test accuracy of emission line ratios over the f.o.v. Use lines with same upper quantum level and/or compare to other observations of well-studied objects which are large enough so that the emission lines won't vary in time.	*Extended emission line or points in a line,* with at least two detectable lines.	Depends on whether lines are blended and difference in wavelength between the lines. A minimum number of configurations is preferable.
MOS_astro_line_ ratios	Low	Measure fundamental astronomical parameter: emission line ratios. A point source could be used, but an extended source is preferable to test accuracy of emission line ratios over the f.o.v. Use lines with same upper quantum level and/or compare to other observations of well-studied objects which are large enough so that the emission lines won't vary in time.	*Extended emission line, or many points,* with at least two detectable lines.	Depends on whether lines are blended and difference in wavelength between the lines. A minimum number of configurations is preferable.
LS_ew	Low	Measure fundamental astronomical parameter: emission or absorption line equivalent width.	Single object ok, but *points in a line* preferred.	Probably relatively low resolution, but depends on line, blending, etc.
MOS_ew	Low	Measure fundamental astronomical parameter: emission or absorption line equivalent width.	*Many objects* or an extended line source.	Probably relatively low resolution, but depends on line, blending, etc.

Table C2: Desired characteristics and objects which might potentially fulfill those characteristics.

Designation	Desired Object Characteristics	Potentially Useful Object Types	Notes
Standard star	Spectrophotometric standard star.	Standard stars	Need high quality standards. Better if more than one is in a single field.
Radial velocity standard	Radial velocity standard star.	Radial velocity standards.	
Bright point	Bright point source.	Bright star.	
Points in a line	Point sources, likely stars, in a line.	1) Open cluster. 2) Field stars.	At least two, preferably three points in a line that can be centered with a single long-slit position. The point sources should be bright enough to achieve sufficient S/N in a short exposure time and have sufficiently similar brightness that a single exposure can be used without saturating any. The point sources should cover as much of the extent of the long slit as possible. There may be sources in a *many points* object which satisfy these criteria.
Many points	Many bright point sources with accurate (0.25 arcsec) positions over field of view; low confusion.	1) Outer regions of globular cluster. 2) Open cluster.	Non-point objects, such as a galaxies in a cluster, are not suitable.
Many objects	Many sources over field of view; relatively low confusion.	1) Any “many points” object. 2) Galaxy cluster.	Similar to “many points,” but without the restriction that they are point sources.

Designation	Desired Object Characteristics	Potentially Useful Object Types	Notes
Extended continuum	Extended continuum source. Extended object filling the full, or majority of, the field of view; uniform relative continuum spectrum; few, if any emission lines; high surface brightness.	1) Inner regions of globular cluster with large angular extent, spatially uniform stellar population, and very uniform reddening (i.e., reddening ~ 0). 2) Reflection nebula (?). 3) The Moon (too bright even @ highest res & shortest exposure times?).	Ideally the surface brightness would be uniform as well for some tests. We also need several objects around the sky which could be used in routine instrument operations. 1) The globular will be tracked across the f.o.v. and/or put out of focus. 2) Needs to be sufficiently large and free of emission lines. Must be spectroscopically uniform. 3) Pick maria and/or near full moon.
Extended emission line	Extended emission line source. Extended object filling the full, or majority of, the field of view; bright emission lines across its spectrum.	1) Planetary nebula. 2) HII region. 3) Night sky lines, for certain applications.	
Extended with coherent motion.	Must have detectable emission or absorption features. Motion must produce systematic Doppler shifts detectable by chosen instrument configuration. Should be significantly spatially resolved.	1) Spiral galaxy stellar component. 2) Gas outflows from galaxies.	Objects larger than the field of view may make comparison with earlier results using other instruments difficult. 1) Should be significantly inclined.
Extended with random motion	Must have detectable emission or absorption features. Internal random motion must produce Doppler broadening of the lines detectable by chosen instrument configuration.	1) Galaxy bulges. 2) Group of objects close together on the sky, for which one wants to measure internal velocity dispersions.	Objects larger than the field of view may make comparison with earlier results using other instruments difficult.
Cosmological source.	Object sufficiently distant so that observed apparent velocities are dominated by redshift.	1) Distant galaxy. 2) Quasar.	