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INSTRUMENT ACCESS, MAINTENANCE, AND SERVICING REQUIREMENTS DOCUMENT

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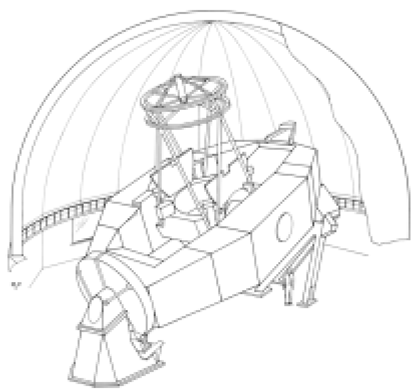

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Revision History

Revision No.	Author & Date	Approval & Date	Description
Revision X	Tim Bond Feb 10/12	Tim Bond Feb 10/12	Preliminary Release.
Revision 1.0	Alan Tokunaga Mar 6/12	Alan Tokunaga Mar 6/12	First Release

Contents

1 Introduction

1.1 Project Background

ISHELL is to be a facility-class infrared cross-dispersed spectrograph developed for the IRTF using silicon immersion grating technology. As a goal, this instrument will provide a resolving power of up to 80,000 at 1.2–2.5 µm and 70,000 at 3–5 µm. No other spectrograph in the Northern Hemisphere presently provides such a high resolving power at near infrared wavelengths.

Silicon immersion gratings are to be incorporated into the design to keep ISHELL manageably small (about the same size as the IRTF facility instrument, SPEX). The immersion grating design will have the advantage of allowing high spectral resolving power without requiring an extremely narrow slit or large collimated beam diameters. This will be the first facility instrument at 1–5 µm to employ an immersion grating, and therefore it will be an important demonstration of this new technology for future instrumentation.

The total instrument budget for ISHELL has been secured from several different sources – NSF, NASA, UH, and through the IRTF operations budget itself. The total budget of the instrument is approximately $4M and it has been estimated to require about 14 man years of effort (distributed over 4 years) to reach completion.

1.2 Document Purpose

This document is the Instrument Access, Maintenance and Servicing Requirements Document. The purpose of this document is to specify and summarize a general overview of how, when, and where the appropriate servicing activities will occur. The document will serve as a basis for the engineers to begin detailed development of the instrument, and should contain all of the relevant information required for the design, fabrication, assembly and testing of the instrument.

1.3 Applicable and Reference Documents

Document Title	**Document Number**
Instrument Specification Document	
Instrument Handling Plan	

1.4 Abbreviations

2 Instrument Reference Design

A general description of the instrument is given here as a basis for discussion. This description can be considered as a pre-conceived instrument concept or "strawman design" from which further refinements and/or developments shall occur. It is presented only to give the reader a general flavor of the instrument, and the description given in this reference design should not be interpreted as any kind of established development or requirement of the instrument.

2.1 Basic Layout

The ISHELL cryostat is mounted on the telescope at the cassegrain focus. At this focus location the beam speed is approximately f/38. Inside the cryostat are three major optical sub-assemblies: the fore-optics, the slit viewer, and the spectrograph. The last major subsystem exists outside the cryostat – the calibration unit.

In the fore-optics the f/38 beam from the telescope enters the cryostat through the entrance window and comes to a focus at the telescope focal plane. A dichroic just inside the entrance window transmits the optical beam out of the cryostat through the exit window and into a wavefront sensor, and the infrared beam is reflected. The telescope focal plane is re-imaged onto the slit wheel by a collimator-camera system. A pupil image is formed following the collimator mirror and the system cold stop is placed here. A k-mirror image rotator is located immediately behind the cold stop.

Reflective slits in the slit wheel send the field surrounding the slit into the slit viewer. Here a refractive collimator-camera re-images the slit field onto a Raytheon 512x512 InSb array. A filter wheel in the slit viewer allows a selection of filters to be used for object acquisition, guiding, and scientific imaging. A lens in the filter wheel is used to image the telescope pupil. This pupil viewer provides a means to align the cryostat on the telescope. The slit viewer will operate independently of the spectrograph.

The f/38 beam enters the spectrograph through the slit and order-sorting filter wheel. It is then folded and collimated at the first off-axis parabola (OAP1). The silicon immersion grating is located at the pupil following OAP1. An in/out mirror close to the pupil is able to select either of two immersion gratings (IG1 covers 1.1-2.5 μm and IG2 covers 2.8-5.3 μm). The immersion grating is tilted slightly so that the emerging beam is reflected at OAP1 to form a dispersed image of the slit at the spectrum mirror. The beam reflected at the spectrum mirror is re-collimated at OAP2 and forms a second "white" pupil image at the cross-disperser mechanism. Gratings in the cross-disperser wheel send the beam into the spectrograph camera lens, which images the resulting spectrum onto a 2048x2048 H2RG array.

A calibration unit is located on top of the cryostat. It contains illuminating optics, an integrating sphere, arc and flat-field lamps, and a gas cell. An in-out mirror above the entrance window is used to project calibration light into the instrument. A gas cell is mounted on a two-position stage between the entrance window and in-out mirror so that it can be placed into the beam for radial velocity science observations. An option for precision wavelength calibration required for radial velocity science is to feed the output of a laser frequency comb into the integrating sphere. Due to its size (≈1m3) and stability required, the laser comb is located in the instrument preparation room and its output fed to the integrating sphere via an optical fiber.

The cryostat is of similar size to the existing IRTF instrument SPEX (≈1m3) and will nominally uses the same cooling scheme. It contains an optical bench to which the optical sub-assemblies are mounted. The optics and bench are cooled to ≈75K using a liquid nitrogen can. The radiation load on the cold structure is minimized by surrounding it with a radiation shield, which is cooled using the first stage of a Cryodyne 1050 CP closed-cycle cooler. The spectrograph and slit viewer arrays are cooled to 38K and 30K respectively, using the second stage of the cooler.

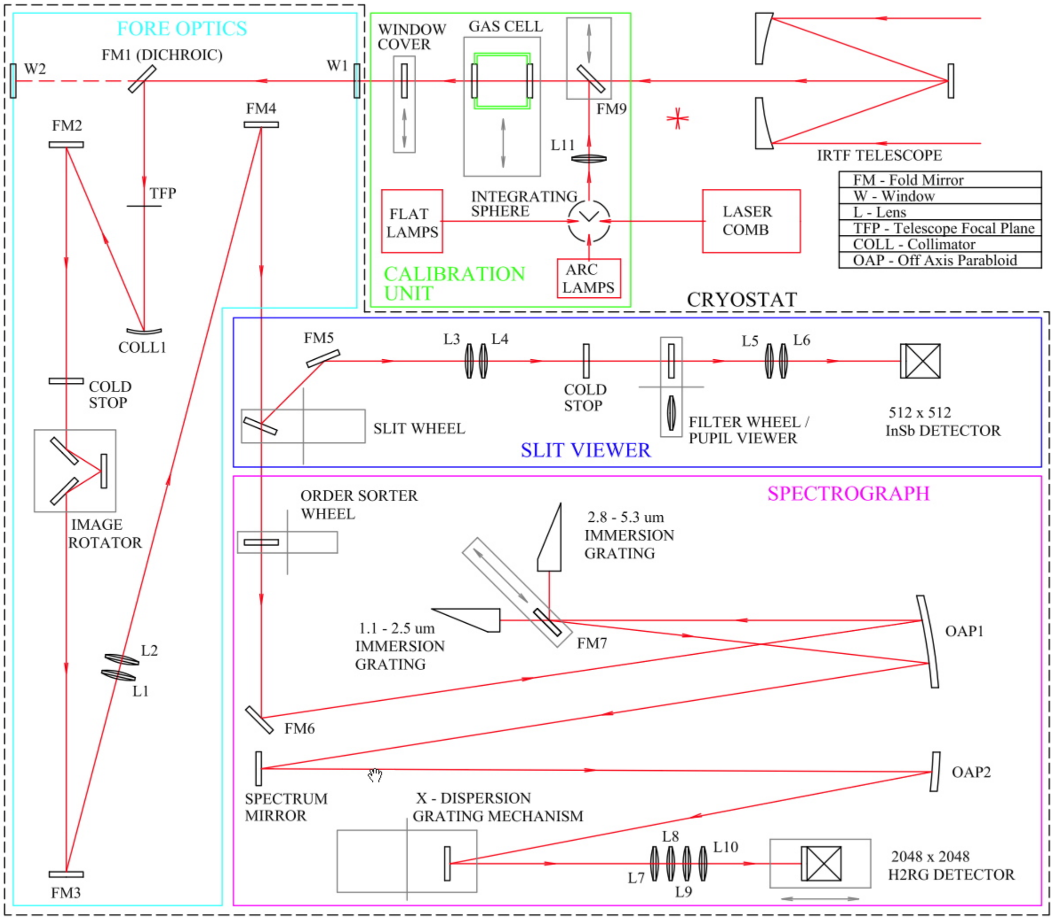

Figure #1: ISHELL schematic layout

2.2 Observing Modes and Calibration

ISHELL has three basic spectroscopy modes. Short cross-dispersed mode covers observations done at ~1-2.5 µm. Radial velocity mode is a subset of sort cross-dispersed mode in which observations are made through a gas cell. Long cross-dispersed mode covers observations done at ~2.8-5.3 µm. In addition, the infrared slit viewer that is used for acquisition and guiding, can also be used for scientific imaging.

2.3 Acquisition and Guiding

Target acquisition and guiding is executed with the infrared slit viewer. Due to the high background at wavelengths longer than ~2.5 µm this is usually done in the *J, H, K*, or similar wavelength narrow-band filters. Once the target is acquired it is placed in the slit by offsetting the telescope and guiding is started. Since guiding is implemented by offsetting the telescope, guiding is necessarily slow and corrects telescope tracking at rates of <0.3 Hz. In most cases guiding will be done on spill-over from the target star in the slit. Alternatively, a guide star in the field of view of the slit viewer can be used. The centroid of extended objects can be guided on by increasing the size of the guide box.

3 Instrument Maintenance and Servicing

Ideally, ISHELL would require no maintenance or servicing during the life of the instrument. But putting such a requirement on the design would not only be impractical, but virtually impossible to achieve. Still, due to the nature of the telescope scheduling, an extremely high degree of reliability is required for the instrument as a whole. In general, the impact of servicing and maintenance on the telescope schedule needs to be carefully considered, and disruptions to scheduled observations minimized.

3.1 Anticipated Maintenance and Servicing Events

	Maintenance Activity	Urgency	Required Downtime	Complexity (Location)	Frequency
3.1.1	Instrument reboot	Immediate	None (< 1 hr)	On telescope	Common (days or weeks)
3.1.2a	Minor electronics issues board replacement	Immediate	None (<1 hr)	On telescope	Common (days or weeks)
3.1.2b	Major electronics issues box replacement	Immediate	None (<1 d)	On telescope	Common (days or weeks)
3.1.3	Calibration box lamp replacement	Short term (no schedule impact)	Very Little (<1 day)	Summit (inst prep room)	Unknown 1 – 10 yrs?
3.1.4	Re-establishment of vacuum	Short term (possible schedule impact)	Substantial (~1 week)	Summit (inst prep room)	Occasionally (6 months - 2 years)
3.1.5	Instrument warm up / cool down	Short term (possible schedule impact)	Substantial (~1 week)	Summit (inst prep room)	Occasionally (6 months - 2 years)
3.1.6	Add / remove Filters	Long term (no schedule impact)	Substantial (~1 week)	Summit (inst prep room)	Infrequently (3 - 5 years)
3.1.7	Change / service cooling head	Long term (no schedule impact)	Substantial (~1 week)	Summit (inst prep room)	Infrequently (2 - 3 years)
3.1.8	Add / remove order sorting element	Long term (no schedule impact)	Substantial (1 - 2 weeks)	TBD (on case by case basis)	Anticipate possibly once per lifetime
3.1.9	Add / remove a X-disperser	Long term (no schedule impact)	Substantial (1 - 2 weeks)	TBD (on case by case basis)	Anticipate possibly once per lifetime
3.1.10	Add / remove / adjust a slit	Long term (no schedule impact)	Substantial (1 - 2 weeks)	TBD (on case by case basis)	Integration and Testing Phase
3.1.11	Alignment of the cold stop	Long term (no schedule impact)	Substantial (1 - 2 weeks)	Hilo Labs	Integration and Testing Phase
3.1.12	Alignment of optical elements	Long term (no schedule impact)	Substantial (1 - 2 weeks)	Hilo Labs	Integration and Testing Phase
3.1.13	Replace failed motor	Short or Long (may impact schedule)	Substantial (1 - 2 weeks)	TBD (on case by case basis)	Unknown 5– 10 yrs?
3.1.14	Replace failed encoder	Short or Long (may impact schedule)	Substantial (1 - 2 weeks)	TBD (on case by case basis)	Unknown 5 – 10 yrs?
3.1.15	Service failed mechanism or stage	Short or Long (may impact schedule)	Substantial (1 - 2 weeks)	TBD (on case by case basis)	Unknown 5 – 10 yrs?
3.1.16	Service to the arrays	Short or Long (may impact schedule)	Substantial (1 - 2 weeks)	TBD (on case by case basis)	Unknown 5 – 10 yrs?

The above table is an initial estimate of a large number of the activities that may need to be undertaken under the guise of servicing and maintenance. Discussion of the individual entries can be found in the following subsections.

3.1.1 Instrument Reboot

It is highly probable that many software or computer related issues will arise (particularly during the initial commissioning of the instrument). Past experience has shown that a simple reboot of the associated computer can in many cases eliminate the problems encountered and allow resumed use of the instrument. Such reboots are fairly common on the current suite of IRTF instruments, and expectations are the same for ISHELL.

The time required to perform such a reboot is relatively short (4 minutes as spelled out in the Instrument Specification Document) and the operation should be performed easily with the instrument still mounted on the telescope.

3.1.2 Electronics Board / Box Replacement

In past experiences of the IRTF it has been found that problems associated with the instrument electronics can generally be mitigated by having a large and easily available compliment of spare electronics boards available for swapping in and out of the instrument. However, here have been incidents recently in which spare boards were swapped into service only to suffer the same fate as the board being replaced. These incidents have highlighted the need to have a more comprehensive plan in place in this regard, and details of such a plan are outlined in Section XXX.

A thorough evaluation will be done to determine what boards (and in what quantities) will be made available at the summit as well as evaluating the feasibility of having an entire "spare" subsystems available for swapping into the instrument.

For individual boards, the time required to perform such a switch would be minimal (anticipated to be less than an hour) and the operation would be performed with the instrument on the telescope. In the case of the larger subsystem replacement, the operation would be performed in less than 1 day (also performed with the instrument still on the telescope).

3.1.3 Calibration Box Lamp Replacement

In the event that a calibration box lamp needs to be replaced, the process would be relatively simple. There is no need to break the vacuum or to warm/cool the instrument. The instrument will be lowered from the telescope and moved to instrument preparation room and the procedure performed.

It is unknown as to what the frequency of such an event will be (in the case of SPEX, there has not been a failure of this kind for the entire life of the instrument). But even if this event were to occur at a frequency of 1-2 years, the impact would be negligible due to the fact that such a simple procedure and can be performed quite quickly.

3.1.4 Re-establishment of Vacuum

There most definitely will be cases where the instrument vacuum will have degraded and will need to be re-established. This procedure would be carried out in the instrument preparation room and it would most likely be the case that a complete instrument warm up and cool down would also be required. All of the vacuum pumps, associated plumbing, and tools required for such a procedure would be made available in the instrument preparation room.

It is anticipated that this process may be undertaken quite often and plans should be made considering such an event occurring periodically every 1 to 2 years.

3.1.5 Instrument Warm Up or Cool Down

There will be many cases where it will be necessary for the instrument to be warmed up to room temperature and then cooled back down to cryogenic temperatures (i.e. typically this is done to ensure removal of all moisture from the interior of the vacuum jacket). The instrument specification required that such an event can occur in less than 6 days (3 days for warm up and 3 days for cool down).

If such an operation were required, the instrument will be moved from the telescope to the instrument preparation room. This allows the instrument to be brought to a slightly warmer temperature (room temp) than the dome and also provides an atmosphere more suitable for such a procedure (i.e. not subject to the possible bad weather conditions sometimes experienced in the dome environment).

This event is of some complexity, but can be undertaken with short notice as it is simply a case of removing the instrument from the telescope, and transporting it to the visitors prep room. As stated above, the anticipated warm up time is 3 days, and the cool down time is an additional 3 days.

It is anticipated that (based on past instrument experiences) this process may be undertaken quite often and plans should be made considering such an event occurring on average every 1 to 2 years.

3.1.6 Addition or Removal of a SV Filter

Over the life of the instrument, it is anticipated that there might be cases where a particular observer has a filter that he would like to use for his observations. Thus it is required that replacement of filters be considered during the design of the instrument.

The frequency of such an event is unknown, but could be as high as once every 3-5 years. It is therefore required that such a work could be performed at the summit in the instrument preparation room. With a 3 day warm up, one day for the filter replacement, and a 3 day cool down, the total expected down time is 7 days.

3.1.7 Replacement or Servicing of a Cryogenic Cold Head

Based on experiences with existing instruments at the IRTF, it is anticipated that the cryogenic cold heads on instrument will need to be removed and serviced (or replaced) on a fairly regular and predictable time interval. In general, there are common indicators that the aforementioned service work will soon be required. For example, the head temperatures may start to rise, or in some cases, the head begins to produce a noticeable change in operating noise.

Given the predictability of such an event (on average every 2-3 years) and the probability of advanced warning signs, it may be possible to schedule and perform the maintenance with very little impact to the observing schedule.

Due to the relative regularity of this maintenance (anticipated to occur every 2-3 years), it is required that such maintenance be performed with minimal instrument down time and this can best be achieved if the instrument is designed to have these procedures done in the summit instrument preparation room.

3.1.8 Addition or Removal of a Cross Disperser Element

There is a remote possibility that in the future, it may become necessary to replace a cross dispersing element in the grating turret. The chance of this occurring is quite remote, yet the mechanism needs to be designed to allow for this. Note that if this were to occur, an associated order sorting element would also need to be added. This would be a fairly complicated procedure due to the location of the mechanism.

3.1.9 Addition or Removal of an Order Sorting Element

There is a remote possibility that in the future, it may become necessary to replace an element within the order sorting wheel. The chance of this occurring is quite remote, yet the mechanism needs to be designed to allow for this. Note that if this were to occur, an associated cross disperser element would also need to be added. This would be a fairly complicated procedure due to the location of the mechanism.

3.1.10 Addition, Removal, or Adjustment of a Slit

It may be necessary to add, remove, or adjust a slit from either the slit wheel, or the slit dekker mechanism. In fact it is expected that this will occur once during the life of the instrument, during the initial commissioning, but it is not likely that it will ever need to be done again. Still, there is a remote possibility that this may occur again during the life of the instrument. This would be a fairly complicated procedure due to the internal location of the two mechanisms involved.

3.1.11 Alignment of the Cold Stop

There is a single cold stop prior to the slit and its alignment with respect to the optical path is quite important. It is required to have the ability to adjust the cold stop at least once during the integration and testing of the instrument. And the capacity to do so will be built into the instrument. In fact it is very likely that this will occur only once during the life of the instrument (during the initial commissioning) and it is not likely that it will ever need to be done again.

Due to the difficult location for this work and the complicated procedures required to determine the adjustments needed (refer to Optical Alignment Plan), the work would likely be performed in the lab in Hilo.

3.1.12 Alignment of the Optical Elements

The instrument contains nearly 30 individual optical elements that need to be aligned at some level. Details of the alignment procedures and tolerances can be found in the Optical Alignment Plan and the Optical Error Budget Document.

It is assumed that once the instrument is aligned properly, that the optical elements will not need to be adjusted again. If for some reason, a readjustment is required to an individual element, then the alignment plan would need to be referenced. It is anticipated that this would be such a complicated undertaking, that it would only be performed in Hilo with the appropriate personal involved.

3.1.13 Replacement of a Failed Motor

The instrument contains approximately 8 cold motors that would require access in the event of a failure. Efforts will be made to mount the motors in such a way that access from the exterior of the optical bench would be as simple as possible. Still due to the inherent nature of cold motors (located within the cold cryostat) this will be a relatively complicated operation.

While it is true that a motor failure is something that many people would say is quite common, it is also true that our experience with several instruments (in particular with cryogenic motors) is that they have not had a single motor failure over the entire life of the instrument. MIRSI and IRCS are examples that are referenced in Appendix A.

One could also argue that it is not a typical failure mode for a motor to instantaneously “burn out” on its own. In fact, it would be more typical that the mechanism the motor drives would show signs of failing due to problems within the actual mechanism. Indicators such as increased torques (currents), or dropped steps would likely appear prior to a complete failure, and this could allow some planning time before the repair task is undertaken.

Regardless, in the event of a failed motor, one would really want the ability to investigate and overhaul the entire mechanism if necessary during the repair.

3.1.14 Replacement of a Failed Encoder

There will be a large number of encoders throughout the instrument. Encoder failures are more problematic than motors or mechanisms in that they are more than likely to occur somewhat suddenly and without warning. However some efforts have gone into developing encoder/motor/stage schemes that are somewhat tolerant to an encoder failure - tolerant in a sense that one may still be able to use the instrument albeit in a disabled capacity.

3.1.15 Servicing of a Failed Mechanism or Stage

During the initial design of the instrument, great efforts will be made to ensure that the mechanism will not fail (or require servicing) for the life of the instrument. However, this is not completely ensured, and there can be cases of a mechanism failure preventing the use of the instrument.

One can be optimistic and hope that if a failure were to occur it would be preceded by telltale signs of impending issues. Typical that symptoms might include lost motor counts, torques increases, increased actuation times, etc. And thus in some cases, it may be possible to anticipate that maintenance will be necessary in the near future, and schedule accordingly.

In any case, it will definitely be a complicated undertaking to service mechanisms. Typically the elements that need servicing (the bearings, or any other parts that have contacting surfaces) are not easily accessed without disassembling the entire mechanism.

3.1.16 Servicing of the Arrays

Discussion of the servicing of the arrays.

3.2 Discussion of Maintenance and Servicing Events

3.2.1 Integration and Testing During Initial Commissioning

There will be a period of time as the instrument is being initially assembled, integrated and tested that maintenance and above described service type operations will be quite common. In the case of SPEX, there were 10 cycles where the instrument was cooled down, and warmed up. ISHELL should anticipate as many cases, if not more. These cycles also involve opening of the instrument in order to gain access the all of the mechanisms and optical elements.

Fortunately, these initial cycles will occur in Hilo prior to the instrument being delivered to the summit and will have the benefit of being performed in the highly controlled laboratory space. Also the staff members will be much more effective as they will not be feeling the impact of the high altitude of MK. Regardless, the ease of access issue, to all internals of the instrument, needs to be addressed for this phase of the instruments life.

There are also risks that need to be assessed for such things as work regarding the arrays. These are somewhat mitigated by the fact that most of the integration and testing cycles will be performed with a MUX or “Engineering Grade” array in place. Ideally, one of the last heating/cooling cycles would be used to replace these arrays with the science grade arrays.

3.2.2 Urgency of Maintenance Activities

During the life of the instrument, there are many different types of maintenance activities that will be encountered. Depending on the particular activity, there are several different levels of urgency that may have to be considered. A rough characterization can be given as follows:

1) Immediate maintenance required - There is a problem with the instrument, and corrective actions are required immediately, or there will be a corresponding loss in observing time or impact on the scheduled observers. This type of maintenance event needs to be addressed immediately.

2) Short term with a schedule impact - An unexpected problem has arisen with the instrument, and symptoms indicate that corrective action needs to be taken immediately. The schedule will be examined, and modifications will be done to allow the work to proceed on the instrument as required. Alternative instruments will be scheduled in the short term.

3) Short term with no schedule impact - An unexpected problem has arisen with the instrument, and symptoms indicate that observing may be impacted in the near future if no corrective action is taken. An evaluation is done, and it has been determined that the required maintenance can be performed while another instrument is being used. There is no need to alter the observing schedule.

4) Long term with no schedule impact – These event are characterized by their long term predictability, and allow the schedule to be made according to a large block of time reserved for the activities required.

3.2.3 Complexity of Maintenance Activities

During the life of the instrument, there are several maintenance complexity levels that may arise. A rough characterization can be given as follows:

1) “On telescope” activities – This includes any type of work that can be done simply and easily while the instrument is mounted on the telescope. Many of these types of activities would typically be performed by a qualified member of the daycrew or telescope operators group.

2) “Instrument preparation room” activities – This category of maintenance activity would require the instrument to be removed from the telescope and transferred to the instrument preparation room. The instrument preparation room provides a warmer working area shielded from the elements that one would be exposed to in the dome (possible foul weather elements such as snow or rain).

3) “Hilo Laboratory” activities – This type of maintenance would require the instrument to be removed from the telescope, packaged into an appropriately designed crate, and transported to the laboratories in Hilo. This presents an ideal environment for working on the instrument where the staff members are no longer working under the duress of high altitude, and the effects of the extremely low humidity are much less pronounced.

3.2.4 Location where Maintenance Work is Executed

In essence, the difficulty of the maintenance work required will dictate where that work will be performed. In looking at the above table, there is no question that events labeled 3.1.1 – 3.1.7 can all be easily accomplished either on the telescope, or within the instrument preparation room at the summit. Also there is little question that the events labeled 3.1.11 – 3.1.12 would best be done at the Hilo laboratories as they require complex optical alignment procedures and equipment.

And so we are left to determine where events 3.1.8 – 3.1.10, and events 3.1.13 – 3.1.16 should be performed. Further examination of these events need to be made taking into consideration the detailed nature of the events, the difficulty of dealing with them, the potential infrequency of them occurring, and the risks associated with performing them.

3.2.5 Frequency of Unanticipated Events

The elements listed in the above table, labeled 3.1.13 – 3.1.16 are somewhat difficult to characterize with respect to the frequency of occurrence or the urgency of the required repair. The nature of the event itself (a failure or symptom of impending failure) would really dictate what type of action is required. And at some level, the exact amount of work required for the fix would not be known until the instrument is opened up and examined.

There are some brief points made in the descriptions of these events (see section 3.1.13 - 3.1.16) that give some insight as to what may be expected, but the bottom line is that we do not really know the answer to this question. Based on experiences with SPEX, one might anticipate 2 failures (in each of 3.1.13 - 3.1.16), yet based on experiences in IRCS and MIRSI (both with cold motors), there has yet to be a failure of these subsystems.

4 Trades that need to be Considered

In any major project there will be conflicting goals or requirements that are driving the design. In order to strike a balance between these opposing desires, trade studies are generally undertaken to help identify the best balance point. In the case of the ISHELL maintenance and service requirements, there are several potentially conflicting goals that can be discussed:

4.1 Mechanical Simplicity vs. Extensive Access Ports

Within the ISHELL instrument, a balance must be struck between the desire to include as many features possible and the need to keep the overall instrument simple and robust. More specifically, the two competing requirements/goals that must be discussed are the desire to make available quick and easy servicing access to all of the internals of the instrument, and the desire to keep the instrument structure simple.

There are many benefits to be realized by keeping the instrument simple. The overall size and weight are reduced, the structural integrity is enhanced (both stiffness and strength to weight ratios), the reliability in maintaining a vacuum is better, and the overall cost will be reduced (less complex machining and fewer components). With the lower weights, the cooling systems will be less taxed, and the ability to meet tight flexural requirements will easier.

These must be balanced with the desire to have the ability to gain quick and easy access to the internals if the instrument if any possible problems are encountered. In some cases (such as with the cooling heads) it is known that regular access will be required. With other cases, the frequency that access will be required is simply not known, and can only be anticipated. Ideally a scheme that is both simple and allows thorough access to the internals of the instrument would be developed. However if this were not the case, then more attention would be needed to individual tasks and the potential frequency that they would need to be performed.

4.2 Work on Summit vs. Work in Hilo (transporting the instrument)

In general, there are many inherent risks involved with opening up and working on an instrument. And in our particular case, it is relevant to further discuss the risk tradeoffs between working on the instrument at the summit (in the instrument preparation room), verses working on the instrument in the Hilo Laboratory.

Major points to consider are somewhat summarized here:

SUMMIT INSTRUMENT PREP ROOM	HILO LABORATORY
- No need to transport the instrument up or down the summit road	- Better suited facilities (clean room and availability of tools and equipment)
- Potentially less downtime (and impact on observing schedule)	- Staff in better condition (less likely to rush and or make mistakes)
-	- Longer available work days
	- Closer proximity to machine shop
	- Static discharge not as big an issue

Although having a clearly defined plan in regards to when the instrument would be removed from the summit to the Hilo Labs, it is more likely that an evaluation on a case by case basis would better suited. Having said this, the instrument would need to be designed to facilitate working at either location.

4.3 Ease of Performing Repairs vs. Risk of Expediting Repairs

Some thought must be put into the conflicting goals of performing repair quickly, verses the possible risk associated with performing the repair in an expedited manner. There are some methodologies that may be incorporated to help alleviate the risks (such as having extra personnel present during these operations).

Discussion of this topic with recommendations

5 General Maintenance and Servicing Requirements (and Goals)

5.1 General Instrument Development Goals

There are many goals to keep in mind when designing ISHELL, and as alluded to in the previous section, they do not always point the design in the same direction. Some of these goals may seem quite obvious, but are mentioned below as a reminder as what some of the top level drivers are for the design direction of the instrument:

- The instrument needs to be as compact and lightweight as possible.
- The instrument needs to be as simple as possible.
- The instrument needs to be reliable.
- The instrument needs to have quick and easy access for solving problems.
- The instrument needs to be built in a cost effective manner.

Again, these are "goals" in a sense that there is no hard measurement that can be given (unlike the case of a requirement) to evaluate if the goal has been met. But they are useful in a sense that they can help guide the design in the direction needed. Some of the more specific requirements are identified as follows:

5.2 Mechanical Requirements

- The instrument needs quick and easy access ports to the cryogenic cooling heads for servicing.
- The instrument needs quick and easy access ports to the filter mechanism for filter replacement.
- If there is a problem within the instrument, the repair needs to be done as quickly as possible in order to reduce the impact on the observing schedule.
- Additional reqs if proposed scheme is agreed upon
- Additional reqs if proposed scheme is agreed upon

5.3 Electrical / Software Requirements

- At least two people needed to work on instrument at any time??
- The internal cabling to the arrays shall not be disconnected for general servicing activities.
- Additional reqs if proposed scheme is agreed upon
- Additional reqs if proposed scheme is agreed upon

Appendix A: General Summary of Other Instruments

It may be useful in looking at the type and frequency of service events on other IR instruments when trying to anticipate service levels that can be expected for ISHELL.

SPEX (Information from John Rayner)

Thus far in the lifetime of SPEX, the instrument has been cycled (warm up / cool down) 30 times. The breakdown of that is as follows:

Initial Integration and testing (in UH Manoa Lab): 10 times over 1.5 years
General servicing (inst prep room at summit): 20 times over 12 years

The breakdown of the general servicing is as follows:

- 9 times for cooler heads or filters
- 1 time for AR coat on Optic
- 6 mechanism / encoder failures
- 1 array problem (debris)
- 3 due to major cryostat incident

IRCS / NIRI (Information from Alan Tokunaga)

To date, there has not been a single cold motor failure in the IRCS instrument and it has been 12 years since first light. Having said that, as of lately, there has been some unusual noises detected within the slit mechanism. If the mechanism fails, they will likely take the entire instrument down to Hilo to work on it (due to the difficult location within the instrument that the mechanism is located). There are other mechanisms that are more easily accessible, and it is possible they could be repaired at the summit if needed.

IRCS has been very successful in regard to the absence of instrument debilitating failures. NIRI has not been as successful, and has had major mechanism problems.

MIRSI (Information from Lars Bergnut)

During the life of MIRSI there has not been a single cold motor failure. There has been a major problem with the cooling systems and this required moving the instrument down to Hilo for a substantial overhaul.