Evaluation of the ARC Controller for the NASA IRTF

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Our goal is to answer this question:

Does the ARC Gen III array controller satisfy IRTF's needs?

- Noise
- Readout speed
- Reliability
- Mounting and cabling
- Schedule
- Cost
- Risk

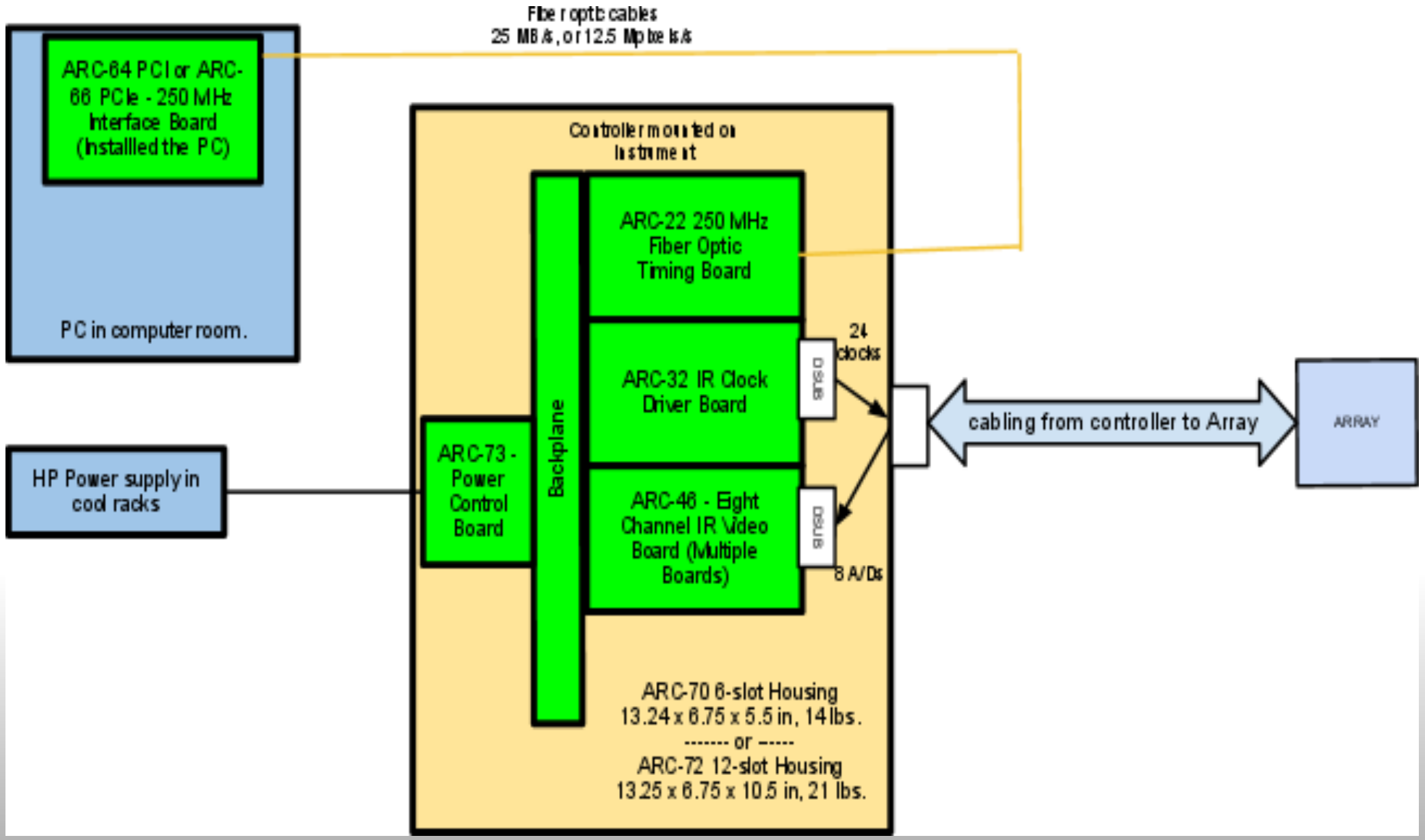
Overview

- Controller Needs for IRTF
- The ARC Controller
- ARC Systems in Use
- Estimated Performance for IRTF Instruments
- Controller Mounting & Cabling Issues
- Tasks, Schedules, & Costs
- Conclusions

Controller Needs

- iSHELL
  - Spectrograph: H2RG, 32 outputs
  - Guider: Aladdin, 8 output
- SpeX
  - Spectrograph: H2RG, 32 output
  - Guider: Aladdin, 8 outputs
- NSFCam2: H2RG, 32 outputs

ARC Hardware



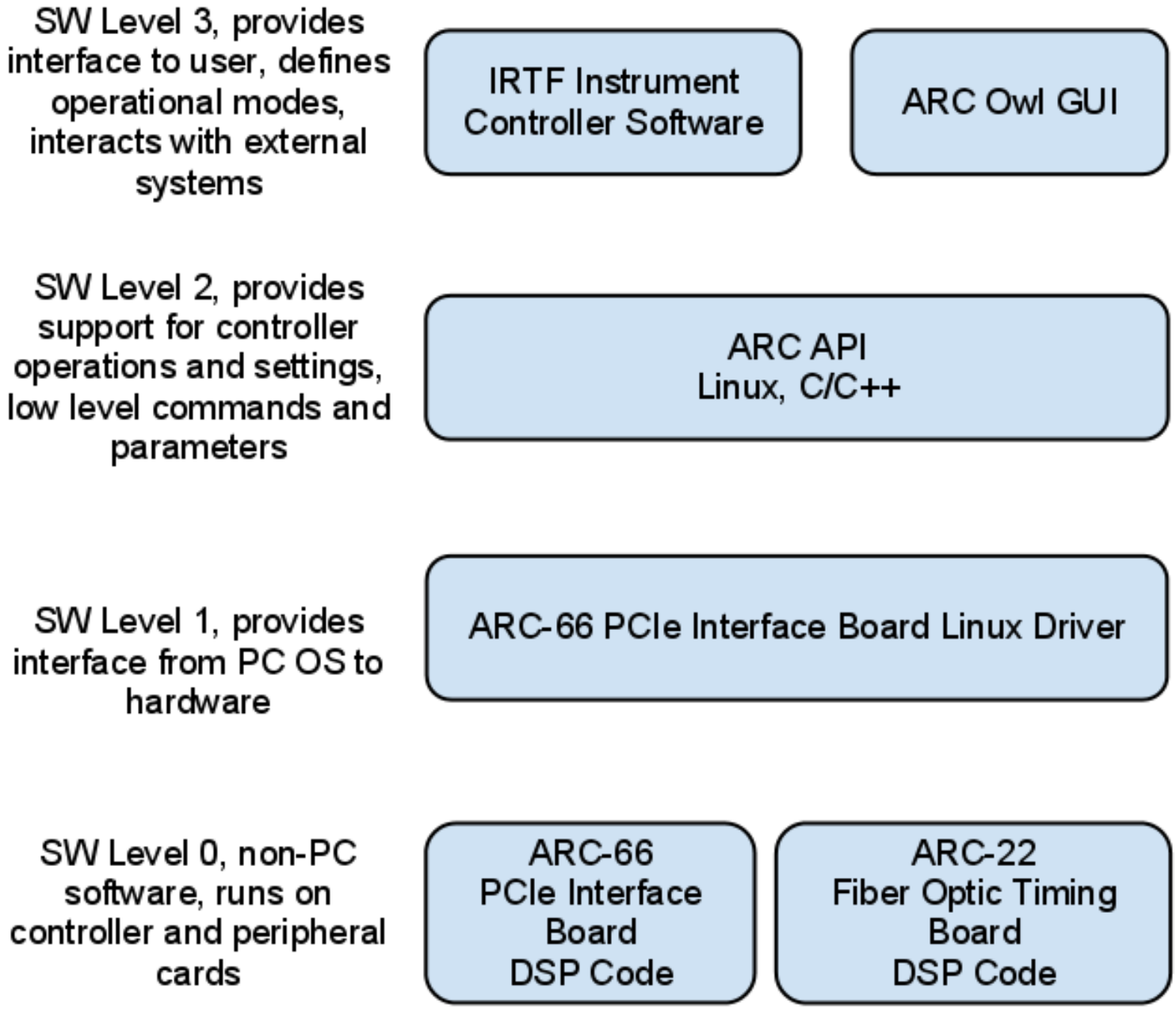
ARC Example Configurations

	Aladdin	H2RG 32ch	H2RG 32ch +8	Component Cost ($)
ARC-70 6-slot housing w/ backplane	1	1		2K
ARC-72 12-slot housing w/ backplane			1	3K
ARC-73 Power Control Board	1	1	1	0.4K
ARC-22 Fiber Optic Timing Board	1	1	1	2.5K
ARC-32 IR Clock Driver Board	1	1	1	2.5K
ARC-46 Eight Channel IR Video Board	1	4	5	6K - Configured with jumpers and components based on IR array.
ARC-66 (PCIe) or ARC-46 (PCI) Interface Board	1	1	1	3K
Approximate Cost	$17K	$35K	$41K	

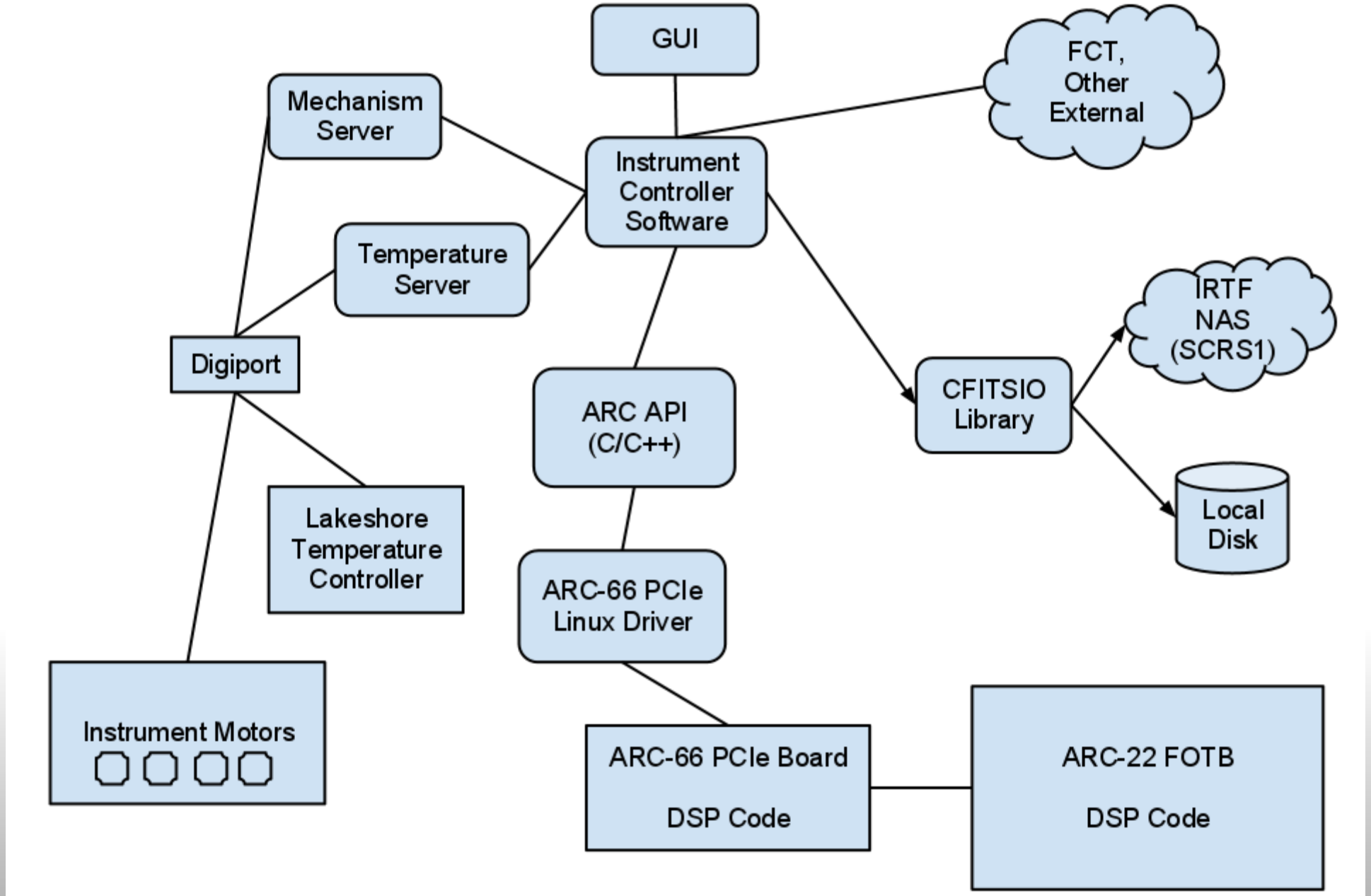
ARC Component Costs

Part Number	Description	Price ($)
ARC-22	Gen III Fiber Optic Timing Board	2,500
ARC-32	IR Clock driver Board	2,500
ARC-46	8 Channel IR Video Board	6,000
ARC-50	Utility Board	2,000
ARC-66	Gen III PCI-Express Interface Board	3,000
ARC-70	6 Slot Controller Housing	2,000
ARC-72	12 Slot Controller Housing	3,000
ARC-80	Large Power Supply	2,000

General ARC Software Description



NSFCAM2 with ARC Controller



ARC Systems in Use

- MIRSI uses Gen II Controller
  - Boards date back to 1997-2000
  - PCI board very problematic
  - Briefly considered for iSHELL, NSFCam2, SpeX
- WIRcam (CFHT)
- Astronircam (MKIR)
  - H2RG w/ ARC Gen III controller
  - 2-3 ADU noise
  - Estimated gain in e-/ADU=6
  - Current fastest pixel time is 3.3 microseconds, rate = 300 kHz

Community Feedback

- H2RG support is well developed for the ARC controller
  - Used in all output modes: 1, 4, & 32
  - Pixel readout rates used > 300 kHz
- Stable Operation
  - Users reported being able to attain stable operation of the controller
- Read Noise
  - Users reported that configurations where system noise is device limited were attained.

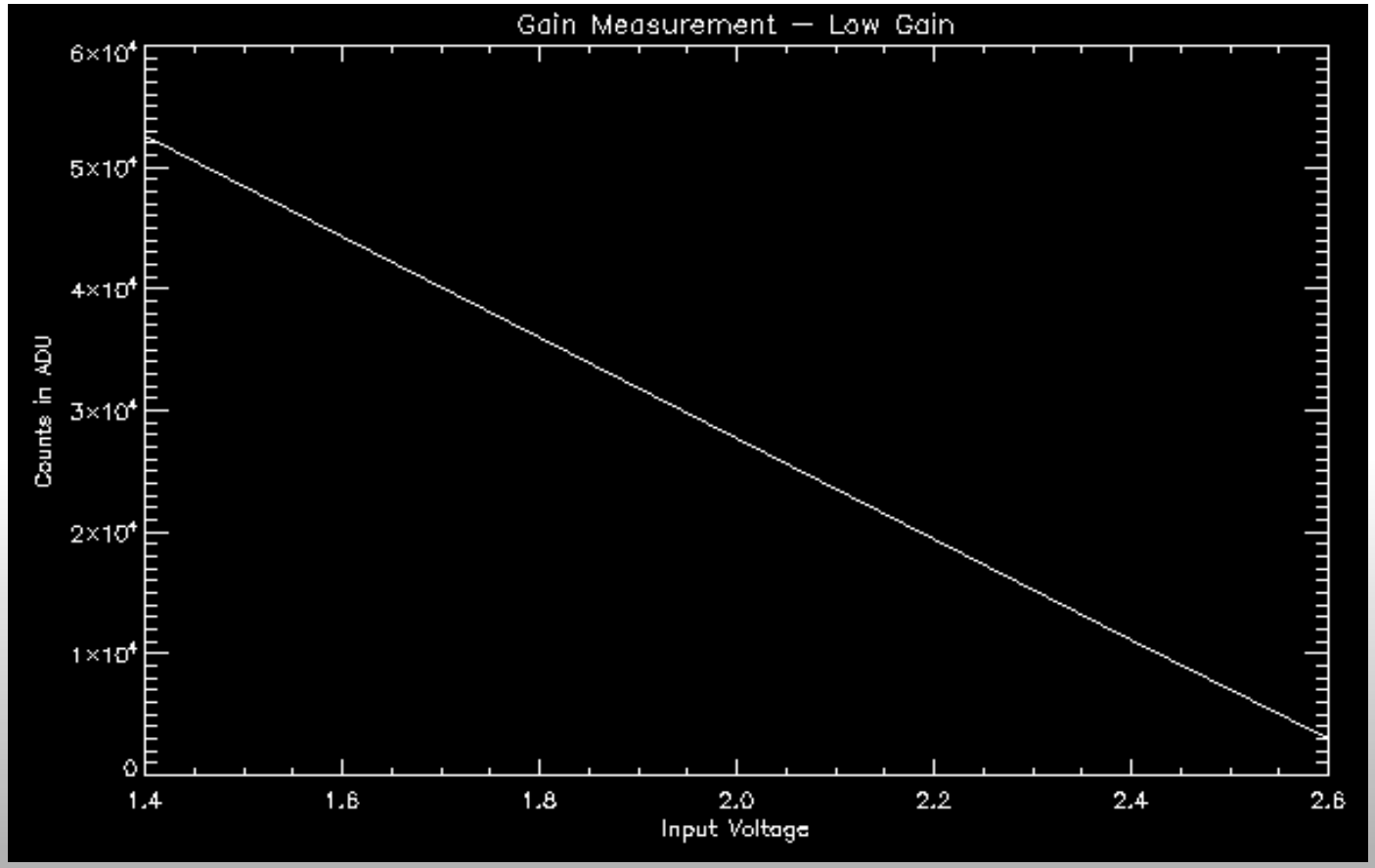
Measured Performance of the ARC

Gain & Noise Testing

Gain Testing: Low Gain

Voltage	1.4V	1.6V	1.8V	2.0V	2.2V	2.4V	2.6V
Mean (ADU)	52,529	44,305	36,024	27,751	19,470	11,202	2,919
Noise (ADU)	5.91	5.94	5.89	5.91	5.92	5.94	5.96

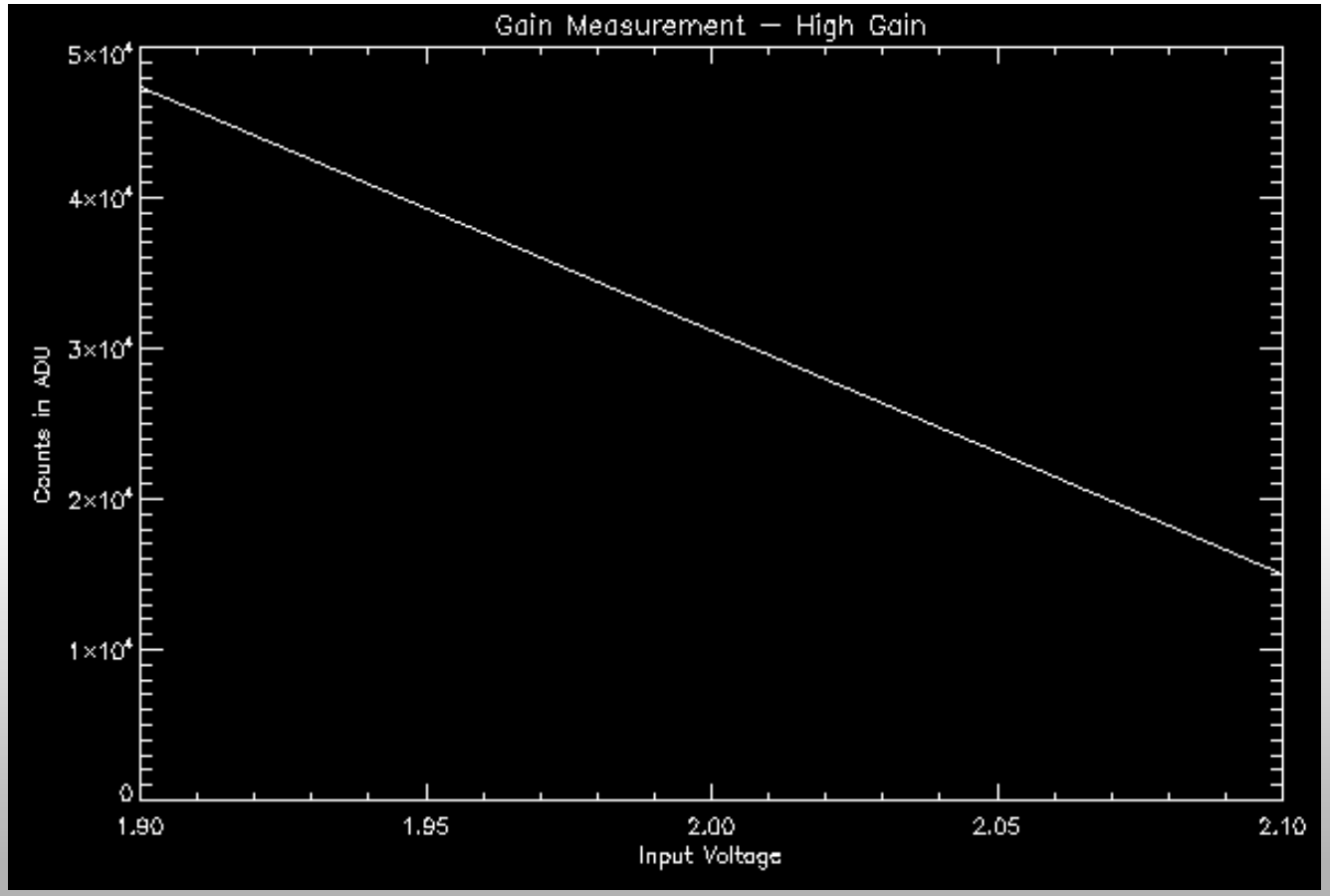
- Measured system gain: -24uV/ADU



Gain Testing: High Gain

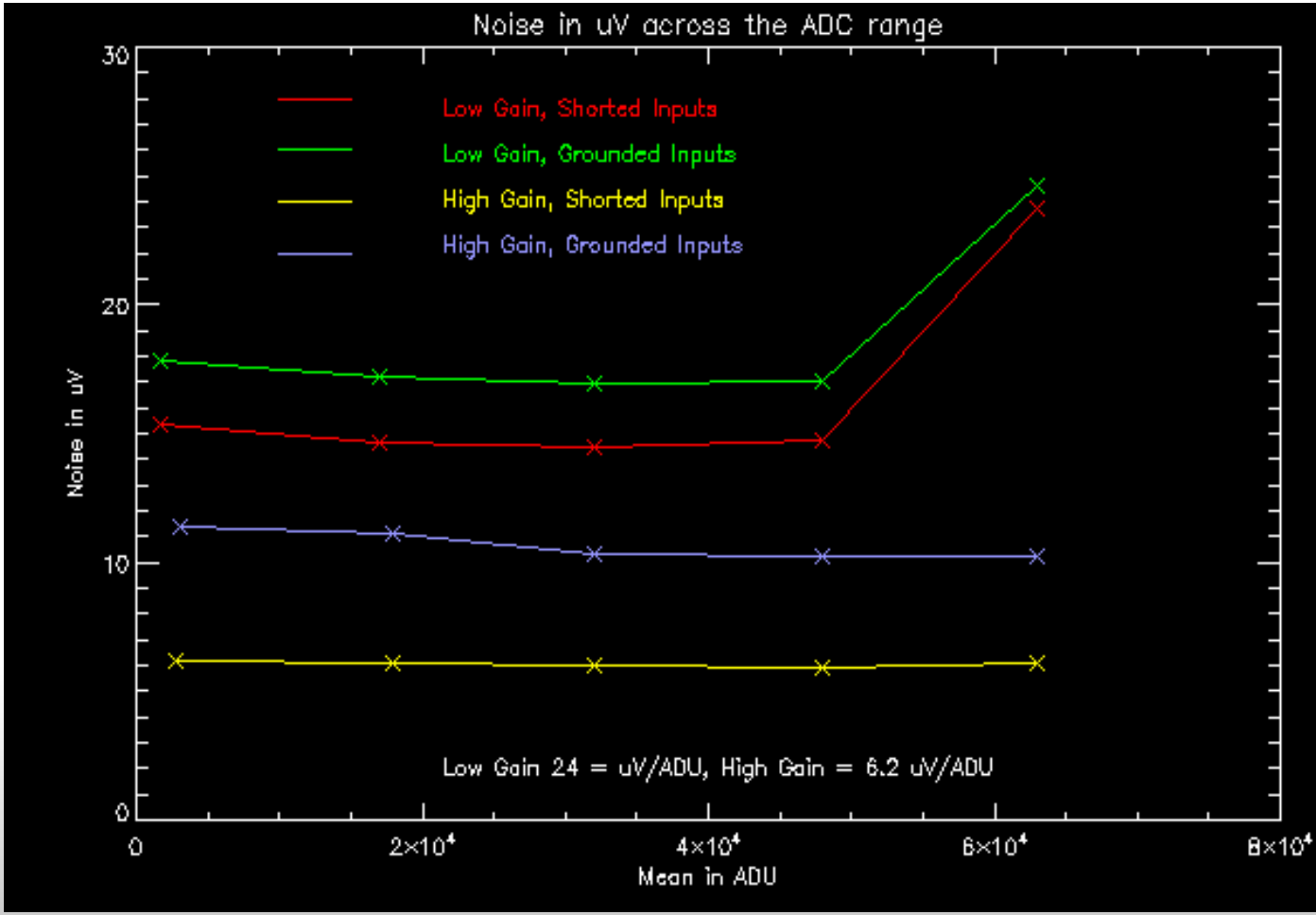
Voltage	1.90V	1.95V	2.0V	2.05V	2.10V
Mean (ADU)	47,288	39,326	31,176	23,149	14,994
Noise (ADU)	22.63	22.81	22.80	22.88	23.09

- Measured system gain: -6.2uV/ADU



Noise Testing: Shorted & Grounded Inputs

- Inputs grounded through 10K resistor
- Inputs grounded directly
- Low gain noise: 0.65-0.8 ADU
- High gain noise: 0.9-2.0 ADU



Measured Performance with Astronircam

Test Conditions

- Cold H2RG @ 85K
- 4 output mode
- 3.33 microseconds/pixel
- Total readout in 3.6s
- Detector cold blanked off
- High gain mode

Region	Noise in ADU	Noise in uV
Top 4 rows (RR)	2.18 ADU	52.3 uV
Left 4 Columns (RR)	2.44 ADU	58.6 uV
Right 4 Columns (RR)	2.11 ADU	50.6 uV
Bottom 4 Rows (RR)	2.24 ADU	53.8 uV
Full Array	6.39 ADU	153 uV
20x20 Pixel Subarray [58:77,9:28]	2.46 ADU	59.0 uV

Estimated Performance for IRTF Instruments

IRTF Array Controller Requirements: H2RG

Category	Requirement	Can Meet?
Controller must fit on instrument		yes
Read noise for slow readout (with NDRs)	<5e- RMS req'd, <2e- RMS goal	yes
Slow readout overhead	<30s	yes
Read noise for standard readout	<15e- RMS req'd	yes
Standard readout overhead	<1s	yes
Read noise for fast readout (<0.1s)	<100e- RMS req'd, <30e- RMS goal	no: minimum readout speed 0.45s
Fast readout overhead	<0.1s	no: minimum readout speed 0.45s
Subarray	>=3 boxes	yes
Cadence (Strictest mode)	~6 frames per minute	yes

IRTF Array Controller Requirements: Aladdin II/III

Category	Requirement	Can Meet?
Controller must fit on instrument		yes
Read noise for slow readout (<5.0s)	<30e- RMS req'd, <20e- RMS goal	yes
Slow readout overhead	<5s	yes
Read noise for standard readout (<1. 0s)	<70e- RMS req'd, <20e- RMS goal	yes
Standard readout overhead	<1s	yes
Read noise for fast readout (<0.1s)	<100e- RMS req'd, <30e- RMS goal	no: minimum readout speed 0.11s
Fast readout overhead	<0.1s	no: minimum readout speed 0.11s
Subarray	>=3 boxes	yes
Cadence (Strictest mode)	~30 frames per minute	yes

Throughput Rate Limitation

Data transfer rate	Time for full readout	Full readouts per second	Time for 33 channel readout**	33 channel readouts per second**
9 Mpix/s	0.467 sec	2.14 Hz	0.481 sec	2.08 Hz
10 Mpix/s	0.419 sec	2.38 Hz	0.432 sec	2.31 Hz
12.5 Mpix/s	0.336 sec	2.98 Hz	0.346 sec	2.89 Hz

** Includes H2RG reference output, essentially a 2048x2112 pixel image

Transfer rate using 10 Mpix/s

Subarray size	Transfer time (seconds)
H2RG 2048x2112	0.432
H2RG 1500x2112	0.317
H2RG 1024x2112	0.216
H2RG 512x2112	0.108
Aladdin 512x512	0.026

Summary of H2RG Recommened Readout Rates

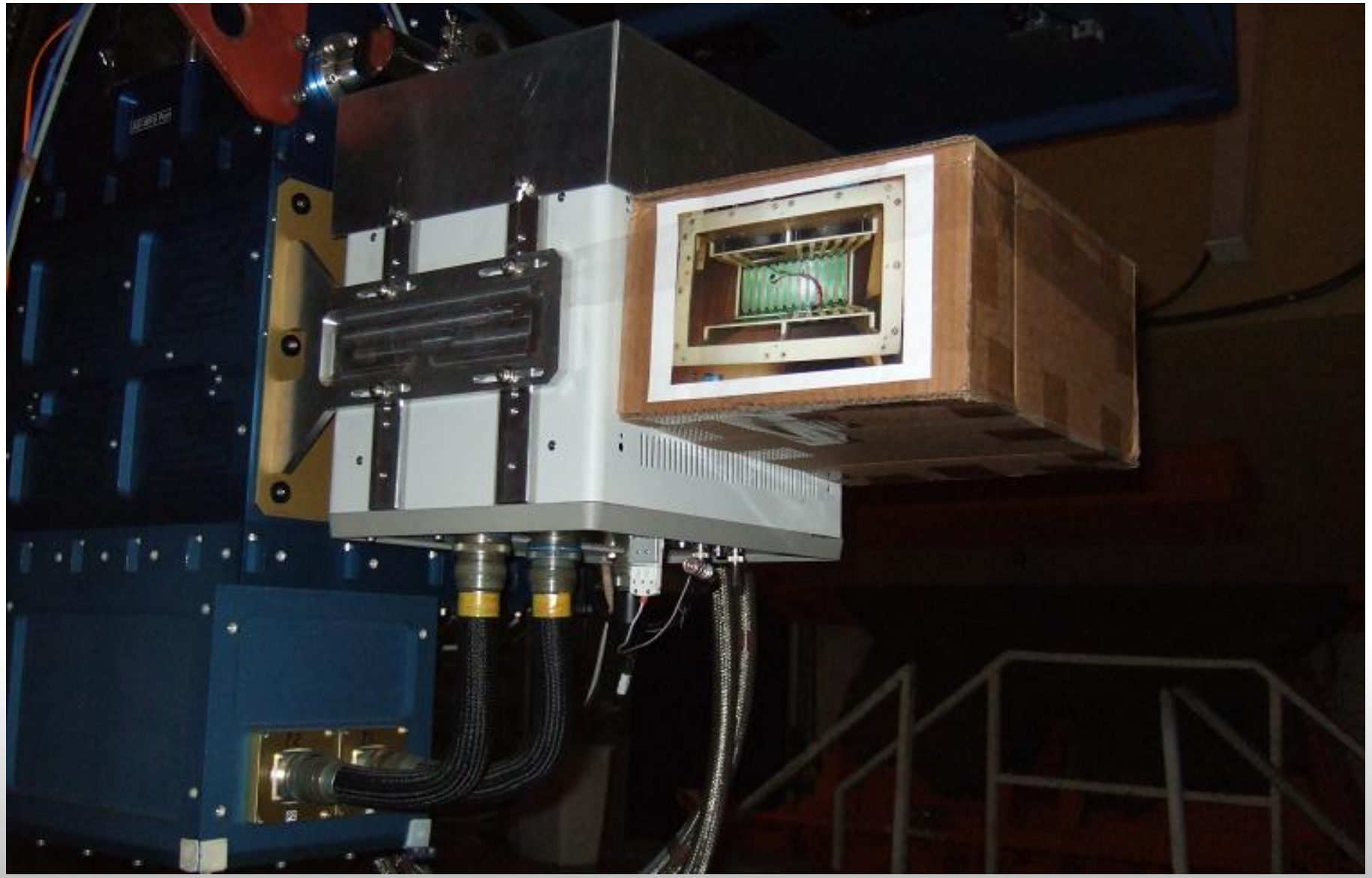
Pixel Rate	Single Pixel Time	Time for full readout in 32 output mode	Time for readout of 512x1024 subarray in 32 output mode
100 kHz	10 usec	1.31 sec	0.328 sec
200 kHz	5 usec	0.66 sec	0.164 sec
300 kHz	3.33 usec	0.436 sec	0.109 sec

Other Gen III ARC Controller Issues

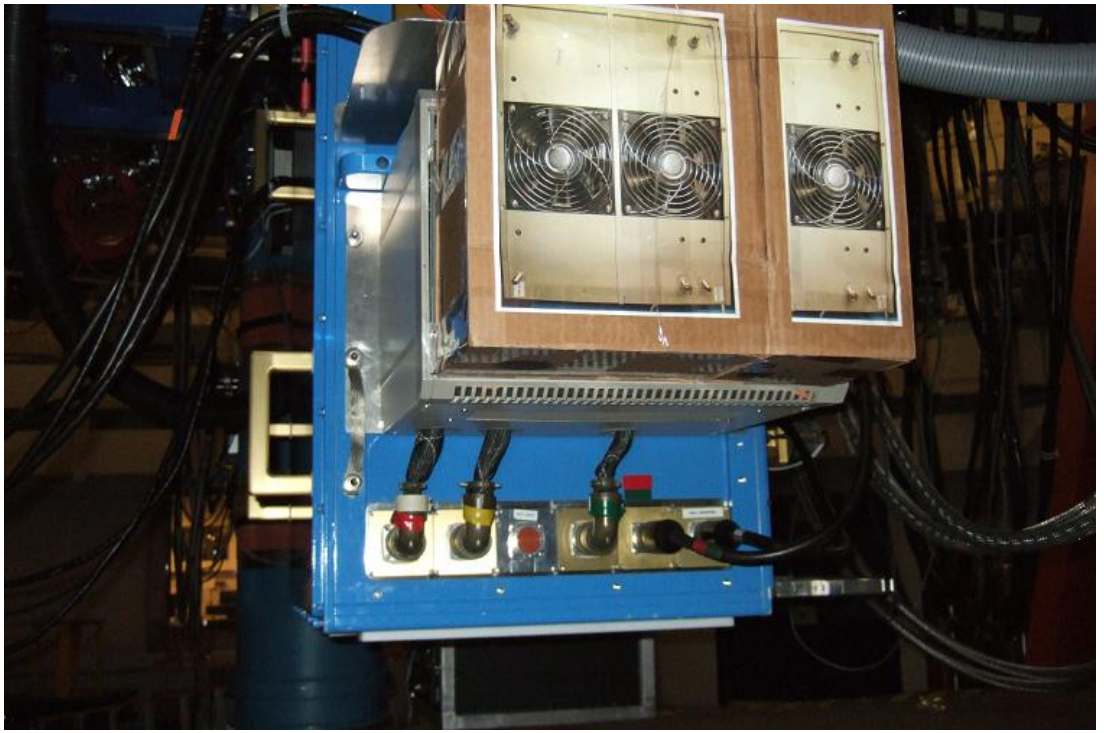
- Software/system crashes
  - Occasional failures with Astronircam
  - After reboot, PCI card needs to be reset
  - Made fixes to MIRSI PCI driver code to reduce impact of crashes
- Impact of software/system crash
  - 3-4 minutes to reboot and restart electronics
  - Potential problem for occultation programs
- Long term support
  - Anticipate vendor support from ARC based on MIRSI experience
  - Maintain working spares
  - Use vendor schematics to build replacements if necessary
  - Status review after 5 years, expect to replace within 10 years

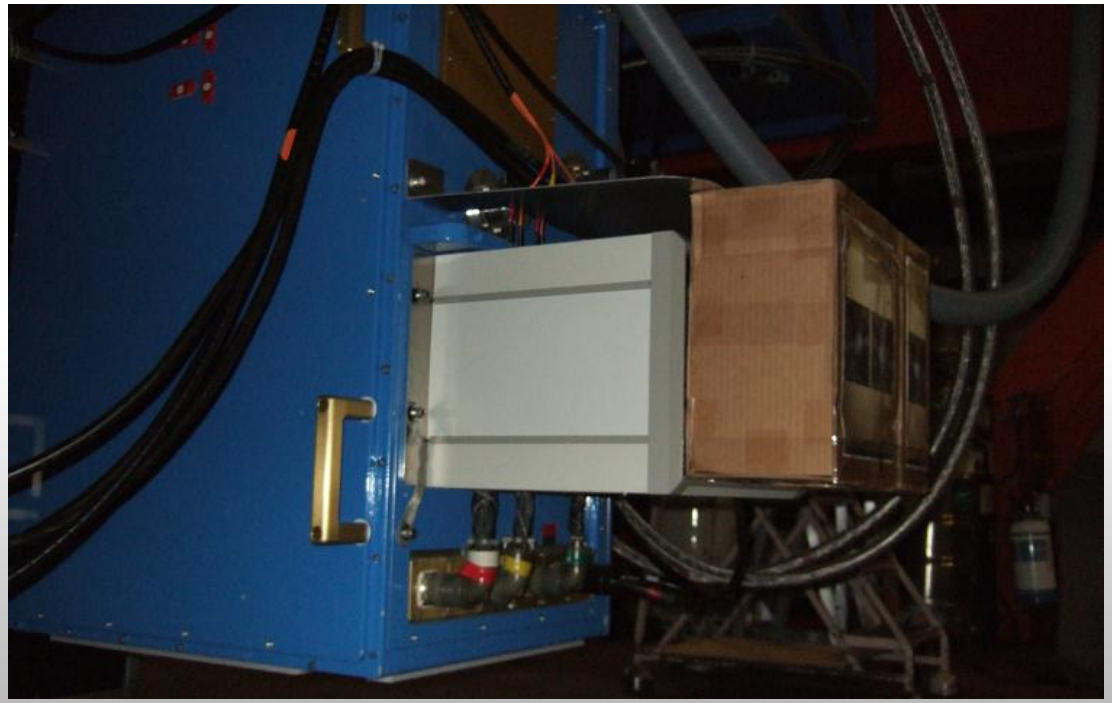
ARC Controller Mounting & Cabling

NSFCam2

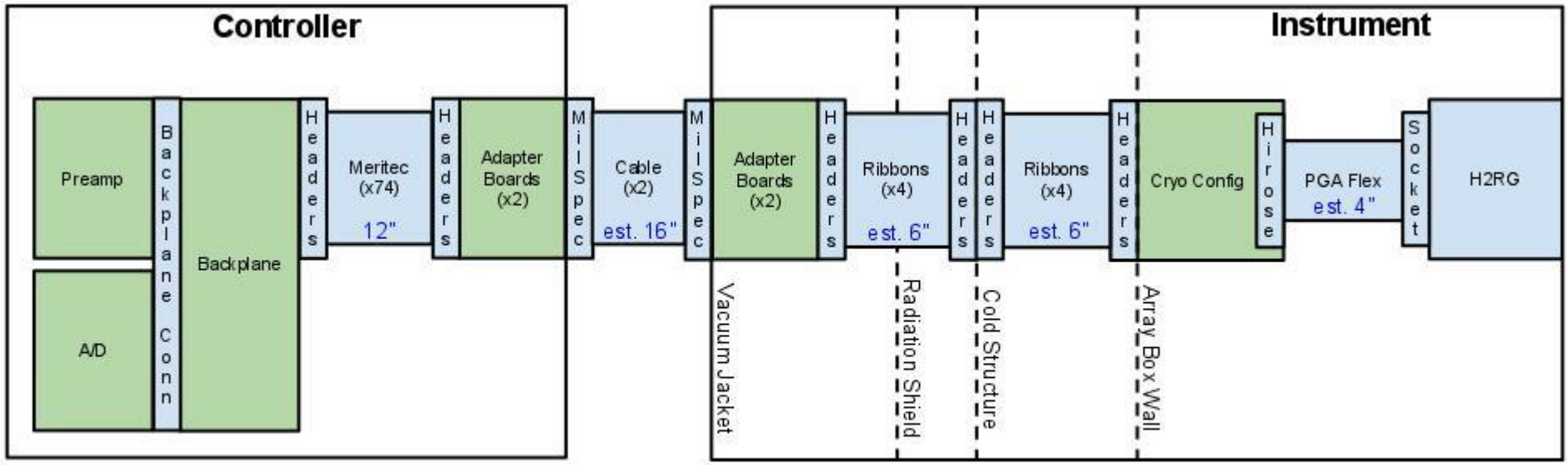


SpeX



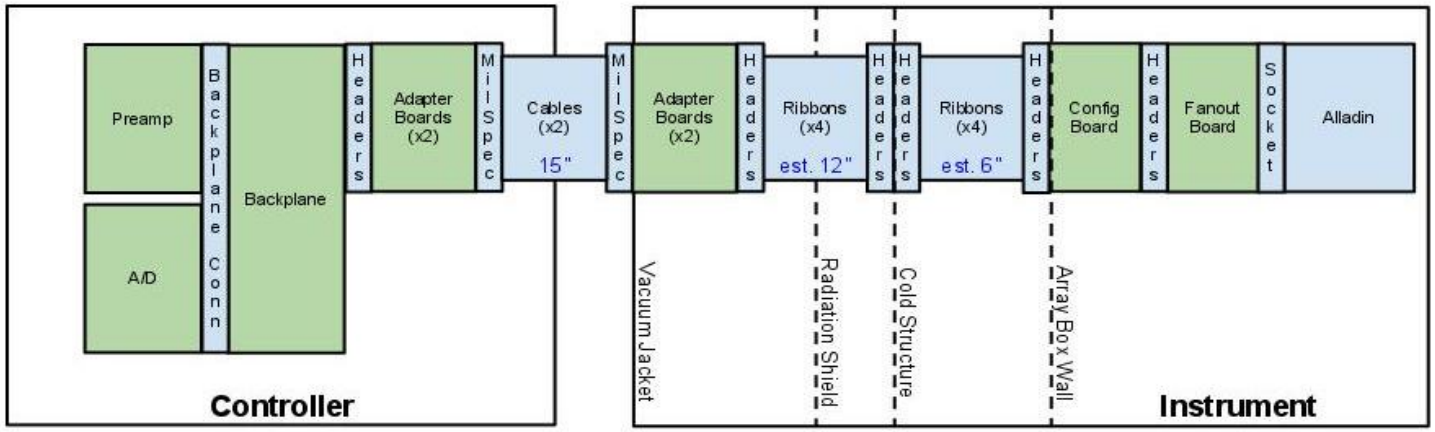


Current Cabling: NSFCam2

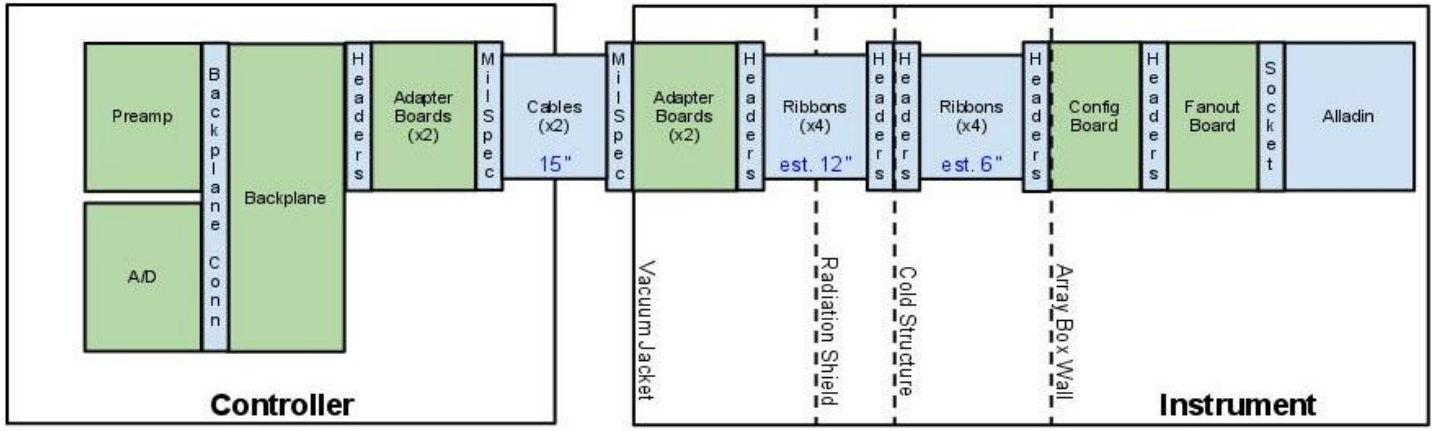


NSFCAM2

Current Cabling: SpeX



SpeX Spectrograph Array



SpeX Guider Array

Cabling Questions

- Cable length
  - Shorter is better, but how short?
- ARC Controller Placement Limitations
  - Cannot mount under NSFCam2 or SpeX
  - Probably mounted in current locations
- Cabling Design & Material
- Connectors
  - Physically rugged
  - Minimize number of connectors
- Forming Cables
- Cable Exit from ARC Controller
  - No predetermined exit from controller

Other Cable Designs

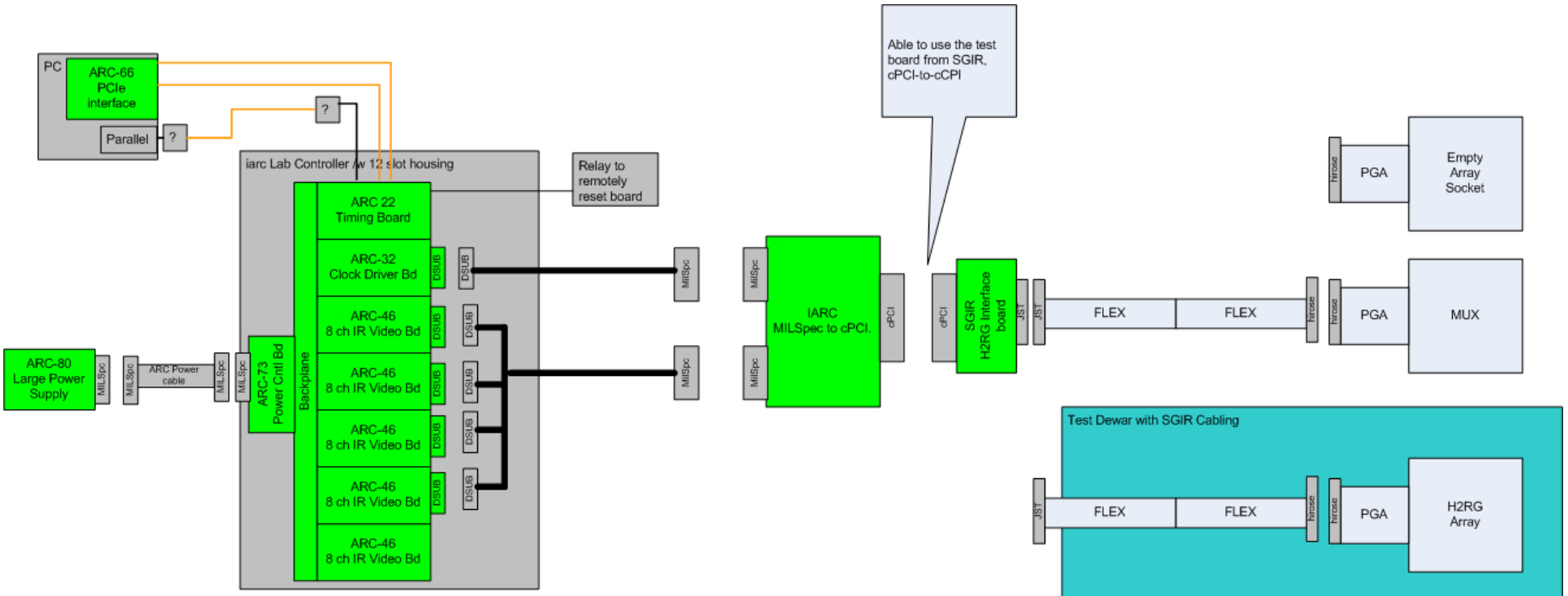
Organization	Instrument	Cable Length	Construction	Comments
MKIR	Astronircam	~42"	Discrete wire and manganin ribbon. Mil-spec round, D-sub, headers	Similar to portions of NSFCam2 design
CFHT	WIRcam	~35"	8" controller unshielded, 19" cable, 8" flex, D-sub, Mil-spec round, other connectors	

Tasks, Schedules, & Costs

Tasks

- **1. Run Mux/H2RG with current SGIR cabling.**
- **2. Test/Select new NSFCAM2 cabling (Ribbon or Flex Design)**
- **3. Testing and Optimization**
- **4. Start NSFCAM2 update.**
- **5. Run Aladdin MUX with ARC Controller.**

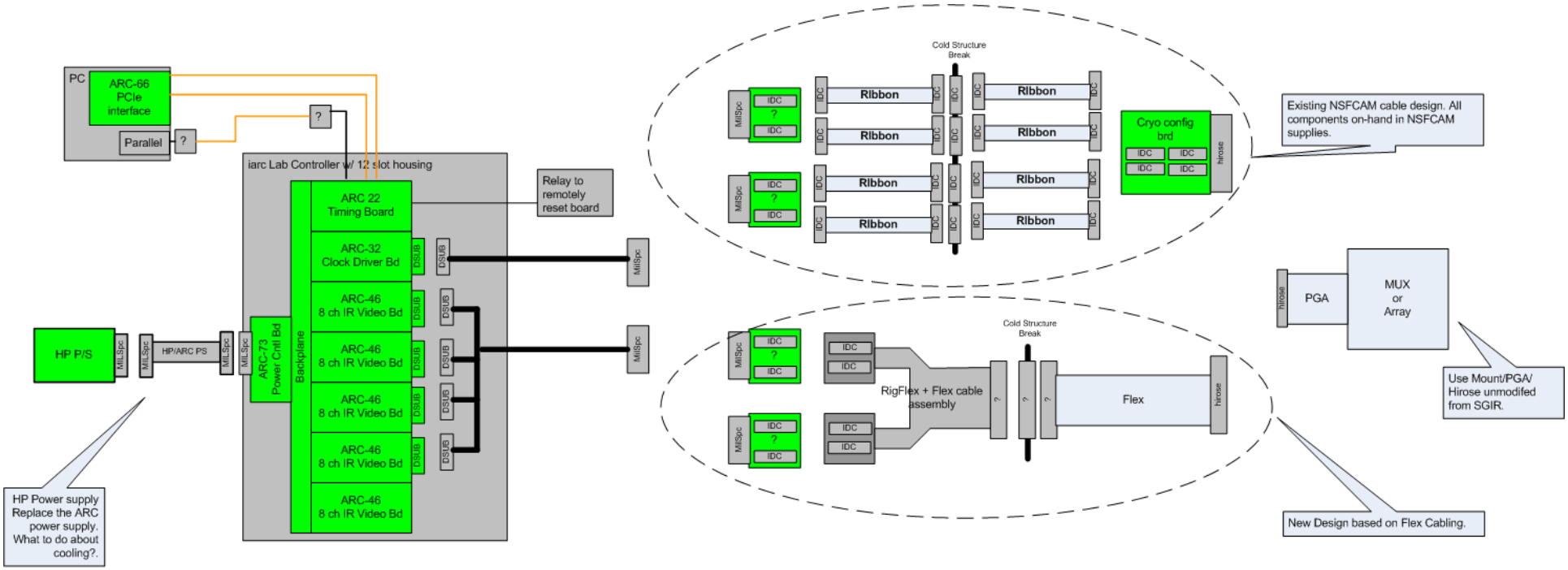
Task 1. Run MUX/H2RG with current SGIR Cabling



Task 1 – Run MUX/H2RG with current cabling.

1. Purchase ARC Controller, setup computers, and software.
2. Build ARC Dsub-MilSpec cable, cPCI interface board.
3. Test operation to Socket. Test to MUX. Then Cold H2RG Device.

Task 2 - Test/Select new NSFCAM2 cabling.



Task 2 – Test/Select NSFCAM Cabling

1. Build NSFCAM2 Ribbon Cabling
2. Build NSFCAM Flex Cabling.
3. Change Power Suppty to HP
4. Select cable design.

Schedule

Estimate time Frame	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
1. Run Mux/H2RG with current cabling									
Purchase ARC & computer/controller	CL								
Design/Build MilSpec Cable, cPCI boards	EW, DW								
Test to Socket, then MUX, then Cold H2RG			CL,EW	*mux, and cold array images.					
Transport test dewar Hilo & Scope any mods	DW								
2. Test/Select NSFCAM Cabling									
Build NSFCAM2 Ribbon cabling	EW/DW			Test ribbon					
Build NSFCAM2 Flex cabling.		EW (design)	EW,DW	and Flex	*evaluate images from Ribbon and flex designs				
HP Power supply			EW,DW						
3. Testing and Optimization									
Select NSFCAM Cable Design					*				
Noise measurement and optimization.					CL,EW	MC			
							* acceptable Images for nsfcam2		
Possible testing of new H2RG									
4. NSFCAM2 Upgrade									
Upgrade to NSFCAM begins								MC, CL	EW ,DW
							*purchase nsfcam2 controller		
5. Run Aladdin Mux with ARC controller									
Purchase ARC controller & computer			TD						
Design Build cabling to mux, test boards					EW,DW				
Image the Aladdin and verify operations							TD,EW		
									*1st aladdin mux image

Equipment Cost									
ARC Controllers	43000	h2rg cntl	25000	aladdin cntl			47000	nsfcam cntl	115000
PC			2000				2000	nsfcam pc	4000
Electronic Fab	3000	cPCI supply	7000	flex cbl, test brds					10000
Machine Shop									0
									0
									0
								Total =	129000

	Month	H2RG	Aladdin	Others
	Jan			Evaluate ARC controller
	Feb	Start Project Order Lab ARC controller Design cPCI interface to SGIR Build NSFCAM2 Ribbon cabling. Test Dewar transported to Hilo		
	Mar	Build test boards, cabling Controller Arrives, test basic software operations. Design NSFCAM2 Flex Cabling		CL vacation 2 wks
	Apr	Test and Image with SGIR Cabling. Build NSFCAM2 Flex cabling. Switch to HP Power Supply.	Purchase lab ARC controller Purchase PC	
	May	Test Ribbon cabling. Take test data. Test Flex cabling. Take test data.	Design/build MUX cables, Aladdin test boards	TD vacation 1.5 wks
	June	Select NFCAM cabling design. Begin Noise test/optimization.		
	July	Noise test/optimization continues.		
	Aug	Noise test/optimization continues. Purchase NSFCAM2 ARC Controller	Verify controller signal logic and voltages	
	Sept	NSFCam2 upgrade begins	MUX imaging	
	Oct			

Executive Summary

Pros	Cons
Cost: ARC controllers are very reasonably priced when compared to other controllers in use, and should fit within IRTF budgetary needs.	**Risk**: As with any controller solution, there is a level of risk that the controller will not meet the needs of IRTF instrumentation, though this risk is very low.
Noise Performance: Noise performance has tested out to be good, and meets instrument requirements.	**Throughput rate is limited**. The throughput rate is faster than the recommended rates for reading the H2RG, but this is still a limitation.
Timely, Available, Responsive. ARC controllers are received within 30 days of order. Bob Leach provides a high level of support for assisting in development and troubleshooting.	
Community Support. The ARC controller, being in wide use, have a large community of users when compared to other options, with groups and individuals willing to provide advice and guidance.	
H2RG Support. The ARC controllers come with H2RG support, and there is a significant amount of developed software available for IRTF to use.	
Aladdin II/III Support. The ARC controllers come with Aladdin II/III support, and there is a significant amount of developed software available for IRTF to use.	
Accessible. The ARC controllers are fairly simple and straightforward, with both software source code and hardware schematics available. It will be easy for IRTF personnel to come up to speed on how the systems work and are built, leading to a high degree of "ownership" by IRTF staff	
Personnel. All personnel required for working on the array controller are available in Hilo: Tony Denault, Eric Warmbier, Darryl Watanabe, and Charles Lockhart.	

Risk Assessment

- Technical Risks
  - Noise Performance
    - Testing indicates ARC controller meets requirements
    - Very low risk
  - Throughput performance
    - ARC controller meets rates specified H2RG controller
    - Flexibility in throughput requirement
    - Very low risk
  - Reliability
    - System hangs rare event
    - Problem is likely solvable
    - Reboot requires 3-5 minutes
- Management Risks
  - Ready for NSFCam2 within 6 months
  - Begin Aladdin customization in 3 months
  - Other IRTF projects have negative impact

Recommendation

We recommend the ARC controller for use at the IRTF for IRTF instruments. Specifically, we recommend using the ARC controller the for building of iShell, and for upgrading SpeX and NSFCam2.