Phase 2 Development for the HEAT Observatory at Ridge A, Antarctica

Based on the results of an NSF-funded design study in 2006 and successful deployment in 2012, we propose the second development phase for the High Elevation Antarctic Terahertz (HEAT) telescope system, a robotic, 0.6-meter THz observatory at the summit of the Antarctic plateau. HEAT observes the brightest and most diagnostic spectral lines from the Galaxy. It is tasked with the dual purpose of performing both site testing and leading-edge terahertz astronomy. The (first) telescope was deployed in 2012 with the University of New South Wales' PLATeau Observatory (PLATO-R) to Ridge A, the driest, calmest and clearest point on the summit. The facility operates with no direct human contact for a year at a time between servicing missions, with commands and data being transfered to and from the experiment via satellite daily. The site is truly exceptional, and HEAT has already made the most sensitive large-scale maps in the 370 micron line of neutral carbon and performed landmark observations at 200 microns, unveiling a population of "CO dark" molecular clouds and new regions where molecular clouds may be forming. With an established facility, we propose here the next level of instrument development, namely the augmentation of a hot electron bolometer (HEB) receiver operating at 4K, whose increased sensitivity will allow the facility to map the Galaxy >10 times faster. This effort is the second phase of development for this novel robotic facility. This proposal requires fieldwork in the Antarctic.

What is the intellectual merit of the proposed activity? The HEAT telescope forges entirely new capabilities for ground based infrared and submillimeter astronomy which otherwise would be unachievable except via expensive airborne or space-based platforms. HEAT and PLATO-R represent a new generation of polar instrumentation that permits the excellent conditions available from remote sites like Ridge A to be harnessed without the costs and hazards associated with manned operations. The unparalleled stability, exceptional dryness, low wind and extreme cold make Ridge A a site without equal for astronomy at infrared and submillimeter wavelengths. HEAT operates in the far-IR atmospheric windows in which the most crucial astrophysical spectral diagnostics of the formation of galaxies, stars, planets, and life are found. HEAT is addressing timely and fundamental questions about the evolution of the interstellar medium and star formation. In particular, through large-scale Galactic surveys, the measurement and impact of the Galactic environment on the life cycles of interstellar clouds and their relation to star formation are gradually being realized. The proposed upgrades of mixer, local oscillator, low-noise amplifier, cryogenic, and DSP technologies will play essential roles in future Terahertz observatories. This pioneering mission paves the way for future astronomical investigations from the high plateau and beyond.

What are the broader impacts of the proposed activity? HEAT's key project is to map, with great sensitivity and precision, portions of the Southern Galactic Plane in the spectral light of the dominant coolants of the interstellar medium. Already, comprehensive science products from the survey and its collaborations are being freely made available to the astronomy & aeronomy community with no proprietary period. These survey products enhance the value of numerous contemporary surveys. Beneficiaries include Legacy programs from the Spitzer Space Telescope, Key Projects from Herschel, the most recent HI and CO surveys of the Galactic Plane, and the 2MASS & UKIDSS infrared sky surveys. The wide-field terahertz surveys provided by HEAT place Herschel, ALMA, SOFIA and balloon-borne observations in a broader, richer context. Thus, HEAT will serve both as a scientific and technological pathfinder for contemporary and future suborbital and space-based missions. As a portable, accessible terahertz observatory, the local copy of the HEAT telescope transforms into an outstanding educational and outreach tool. Furthermore, the HEAT project uniquely captures the kind of high adventure spirit that attracts many to science in the first place, and we aim to provide video and photographic documentation of our experience for everyone via PBS's NOVA program. Finally, the design and fabrication of HEAT has been an interdisciplinary team effort involving students from astronomy, optical sciences, and electrical engineering. Astronomical instrumentation is becoming ever more complex, requiring the talents of many individuals to bring them to fruition. Providing students with both technical training and team-work experience increases their probability of success, both in science and in society.

Title Phase 2 Development for the HEAT Observatory at Ridge A, Antarctica
Organization *The University of Arizona*
PI, Co-PI *Craig A. Kulesa, Christopher K. Walker*
Sponsor/Program *NSF AST – Advanced Technologies and Instrumentation*
Performance Period *10/1/2016 – 9/30/2019*

	YEAR 1			YEAR 2			YEAR 3			3 YEAR
	Year 1 Rate	Labor Hrs.	TOTAL YEAR 1	Year 2 Rate	Labor Hrs.	TOTAL YEAR 2	Year 3 Rate	Labor Hrs.	TOTAL YEAR 3	TOTALS
PERSONNEL										
Appointed Personnel										
Kulesa, Craig – PI	$ 27.84	696	$ 19,377	$ 28.76	1,044	$ 30,024	$ 29.71	1,044	$ 31,015	$ 80,416
Walker, Christopher – Co-I	$ 72.66	80	$ 5,813	$ 75.06	80	$ 6,005	$ 77.53	80	$ 6,203	$ 18,020
Abram Young – systems lead	$ 34.87	696	$ 24,270	$ 36.02	1,044	$ 37,606	$ 37.21	348	$ 12,949	$ 74,824
Appointed Personnel Subtotal		*1,472*	*$ 49,459*		*2,168*	*$ 73,634*		*1,472*	*$ 50,167*	*$ 173,260*
Classified Staff Subtotal										
Electrical Engineer (1 mo, Y2)	$ 29.93	160	$ 4,789	$ 30.92	160	$ 4,947	$ 31.94	-	$ -	$ 9,736
Mechanical Engineer (1 mo, Y2)	$ 33.52	160	$ 5,363	$ 34.63	160	$ 5,540	$ 35.77	-	$ -	$ 10,903
Classified Staff Subtotal		*320*	*$ 10,152*		*320*	*$ 10,487*		*-*	*$ -*	*$ 20,639*
Undergraduate Student										
Undergrad (summer)	$ 12.00	200	$ 2,400	$ 12.40	200	$ 2,479	$ 12.81	200	$ 2,561	$ 7,440
Undergraduate Student Subtotal		*200*	*$ 2,400*		*200*	*$ 2,479*		*200*	*$ 2,561*	*$ 7,440*
Graduate Students										
Graduate Research Assistant - AY (1 semester) @ 50% FT	$ 22.61	400	$ 9,044	$ 23.36	400	$ 9,343	$ 24.13	400	$ 9,651	$ 28,038
Graduate Research Assistant - summer (1.5-months) @ fu	$ 29.20	207	$ 6,044	$ 30.16	207	$ 6,244	$ 31.16	207	$ 6,450	$ 18,737
Graduate Students Subtotal		*607*	*$ 15,088*		*607*	*$ 15,586*		*607*	*$ 16,101*	*$ 46,775*
Labor Subtotal		**2,599**	**$ 77,099**		**3,295**	**$ 102,187**		**2,279**	**$ 68,828**	**$ 248,114**
FRINGE BENEFITS - Rates effective 7/1/2015 and beyond										
Faculty and Appointed Personnel @ 34.7%		$ 49,459	$ 17,162		$ 73,634	$ 25,551		$ 50,167	$ 17,408	$ 60,121
Classified Staff @ 34.7%		$ 4,789	$ 1,662		$ 4,947	$ 1,717		$ -	$ -	$ 3,378
Undergraduate Student @ 3.5%		$ 2,400	$ 84		$ 2,479	$ 87		$ 2,561	$ 90	$ 260
Graduate Students @ 13.9%		$ 15,088	$ 2,097		$ 15,586	$ 2,166		$ 16,101	$ 2,238	$ 6,502
Fringe Benefits Subtotal			**$ 21,005**			**$ 29,521**			**$ 19,735**	**$ 70,262**
Personnel: Labor + ERE Totals			**$ 98,105**			**$ 131,708**			**$ 88,564**	**$ 318,376**
Graduate Student Tuition Remission			**$ 5,520**			**$ 5,962**			**$ 6,439**	**$ 17,920**
Tuition remission, 1 student, 1 semester/yr			$ 5,520			$ 5,962			$ 6,439	$ 17,920
OTHER DIRECT COSTS										
OPERATIONS			**$ 21,090**			**$ 18,692**			**$ 5,297**	**$ 45,079**
Instrument/facility/data archive maintenance and repairs			$ 10,000			$ 10,000			$ 500	
Electronics upgrades to accommodate new receivers			$ 5,000			$ 2,500			-	
Conference Registration (2/year)			$ 450			$ 465			$ 480	
Publication costs charges (3 papers x 8 pages x $110 in each year)			$ 2,640			$ 2,727			$ 2,817	
Shipping costs to Antarctica and back			$ 3,000			$ 3,000			$ 1,500	
TRAVEL			**$ 3,400**			**$ 3,512**			**$ 3,628**	**$ 10,540**
2 persons: domestic conference, annual Antarctic deployment	Domestic	International		Domestic	International		Domestic	International		
Airfare ($400 roundtrip)	$ 800			$ 826			$ 854	$ -		
Lodging ($100/night x 4 nights)	$ 800	$ 800		$ 826	$ 826		$ 854	$ 854		
Per diem ($50/day x 5 days)	$ 500	$ 500		$ 517	$ 517		$ 534	$ 534		
Total per trip	$ 2,100	$ 1,300		$ 2,169	$ 1,343		$ 2,241	$ 1,387		
CAPITAL EQUIPMENT			**$ 146,460**			**$ 155,000**			**$ -**	**$ 301,460**
4K dual closed-cycle cryostat, 1 per telescope			$ 45,000			$ 45,000			-	
1.5 THz LO source, Virginia Diodes Inc			-			$ 80,000			-	
Two HEB mixers, SRON (25k EUR to USD)			$ 30,000							
ROACH2 FFT spectrometer plus 10Gbit ethernet & ADC boards			$ 7,460			-			-	
PLATO-R annual replacement modules			$ 30,000			$ 30,000				
Diamond-turned THz mirrors for existing 2nd telescope			$ 34,000			-			-	
Total Other Direct Costs			**$ 170,950**			**$ 177,204**			**$ 8,925**	**$ 357,080**
TOTAL DIRECT COSTS			**$ 274,575**			**$ 314,874**			**$ 103,927**	**$ 693,376**
INDIRECT COSTS – 53.5%, effective 7/1/16										
MTDC BASE = Total Direct Costs (TDC) less graduate student remission, capital equipment and first $25K of EACH subcontract (N/A here)										
	MTDC Base	IDC		MTDC Base	IDC		MTDC Base	IDC		
Base (on salaries, operations, travel)	$ 122,595	$ 65,588		$ 153,912	$ 82,343		$ 97,489	$ 52,157		
Total Indirect Costs		**$ 65,588**			**$ 82,343**			**$ 52,157**		**$ 200,088**
TOTAL PROJECT COSTS		**$ 340,163**			**$ 397,216**			**$ 156,084**		**$ 893,463**

BUDGET JUSTIFICATION

A. SENIOR PERSONNEL

4.0 calendar months of salary is requested for PI Craig Kulesa in Year 1, and 6.0 months per year in Years 2 and 3. His base salary is $58,131 per 12-month fiscal year.

0.5 summer months of salary is requested for Co-PI Christopher Walker in Years 1-3. His base salary is $100,914 per 9-month academic year.

4.0, 6.0, and 2.0 calendar months of salary in years 1, 2 and 3 respectively is requested for Systems Engineering Lead, Abram Young. His base salary is $72,800 per 12-month fiscal year.

B. OTHER PERSONNEL

Partial funding for 3 years is requested for one graduate student (base salary $36,177) engaged in Ph.D. thesis research under this project. One semester of academic year support, plus 50% (1.5 months) summer salary is requested. University-designated tuition remission for this student at the level of $5,520 per semester is requested.

During development of the new cryogenic receiver systems in Years 1 and 2, one month of an electrical engineer and one month of a mechanical engineer is requested. The costing is based on the average salary of a departmental electrical and mechanical engineer ($60,000 and 70,000 per 12-month fiscal year, respectively).

200 hours of undergraduate student research support is requested each year (base rate $12/hour).

C. FRINGE BENEFITS

The following university-approved fringe benefit rates were applied to each labor category:

- Faculty/Appointed Personnel and Classified Staff: 34.7%
- Graduate Students: 13.9%
- Undergraduate Students: 3.5%

D. CAPITAL EQUIPMENT

Based on the successful design and construction of the 50-Kelvin HEAT cryostat, Universal Cryogenics will be consigned to construct the two next-generation 4K instrument cryostats. Their quotation for a dual-cryocooler cryostat is $45,000 per system, commensurate with the $26,000 for the current single-stage version. One system will be delivered in year 1, with a second identical system in year 2. They will recycle the Sunpower CT cryocoolers from the prototypes.

A 1.5 THz Local Oscillator source will be purchased in year 2 from Virginia Diodes Inc. to operate the Hot Electron Bolometer mixer receivers. They are the only commercial supplier of such THz systems. Their quotation for a single unit is $80,000.

SRON will provide two quasi-optical Hot Electron Bolometer mixers to the HEAT project for a total of 25,000 EUR, or 30,000 USD at the mean current exchange rate.

A ROACH2-based spectrometer system, identical to one purchased in the prototype system, will be purchased from Digicom in year 1. Their quote is for $7,500 for the ROACH2 FPGA board,

ADC boards, and 10 Gbit ethernet boards. Digicom is the only commercial supplier of the ROACH2 systems.

We will purchase replacement engine modules for PLATO-R from the University of New South Wales (UNSW), the designer and manufacturer of PLATO-R. The total cost for two complete engine modules ready to be installed into PLATO-R is $30,000 and is based on a breakdown of the current actual costs for the individual components. We will purchase one replacement set of 2 engines in each of years 1 and 2.

Finally, only one of the two HEAT telescopes has precision-machined diamond-turned aluminum mirrors. We will task NiPro Optics, the manufacturer of the first precision set for the currently- deployed telescope, to construct a duplicate mirror set for the second telescope. The quoted cost for diamond turning and lightweighting all three mirrors is $34,000.

E. TRAVEL

Domestic

Funds are requested for one domestic conference (typically AAS, SPIE, or SCAR) for two personnel (typ. one graduate student and one mentor) for five days each year. Travel funds requested include roundtrip airfare (@ $400/trip), lodging (@ $100/night), and per diem (@ $50/day). Conference registration fees are detailed under 'Other Direct Costs' in accordance with University of Arizona cost classification practices.

International

To support the annual servicing mission to Antarctica, travel funding support for per diem (@$50 USD/day) and lodging (@$100 USD/day) is requested for 2 personnel for 5 days in Christchurch, New Zealand.

F. OTHER DIRECT COSTS

Funds are requested in each year for research supplies and work-flow/data capture and telecommunications expenses required for the conduction of this investigation. These operational items represent the material costs of creating, replicating, archiving, distributing and presenting all project related data, documentation, reporting, and analysis that are directly related to this project. Such material costs include, but are not limited to, disk drives, poster printer costs, and design and analysis software.

Funds are requested for operational repairs to the HEAT telescope and its cryogenic, receiver, electronics, and optomechanical systems. Costing is based on the replacement costs of repairs during the first two years of operating HEAT at Ridge A, including replacement of instrument control computers, solid state storage, and power supplies.

Funds are requested in years 1 and 2 for augmenting the HEAT electronics control boards used to operate the more advanced receiver system proposed here. The costs listed are based on the actual costs incurred during the previous design and prototyping efforts.

Funds are requested for two domestic conference registrations per year, typically one student and one mentor.

Funds are requested for publication of findings in professional journals each year; estimated at 3 papers of 8 pages per year @ $110/page (Astrophysical Journal).

Shipping charges for equipment to/from Antarctica (commercial surface shipping to Port Hueneme, CA or air freight to Christchurch, New Zealand) is estimated at $3,000 USD annually, based directly on the average shipping cost incurred during the last two years of operation. Shipping costs in year 3 are estimated at $1,500 for the return of the experiment.

G. INDIRECT COSTS

The university-mandated indirect cost rate (IDC) was applied to all costs except capital equipment and graduate student tuition remission. This rate is 53.5% effective 7/1/2016.

*A cost inflation rate of 3.3% per year is applied to all eligible costs for years 2 and 3, save graduate student tuition remission which follows the University-recommended 8% annual rate.

QUOTE from Universal Cryogenics

JOB CODE	Date	Quote #
UACL20K	10/2/2015	514

UNIVERSAL CRYOGENICS
1815 W. Gardner Ln.
Tucson, AZ. 85705
520-622-6277 ph
520-623-3167 fx
www.ucryo.com
kirby@ucryo.com

QUOTE VALID FOR 30 DAYS.
SHIPPING WILL BE ADDED TO FINAL INVOICE.
PROGRESS PAYMENTS MAY APPLY WITH PO.

Ship To

The University of Arizona
Central Receiving
1145 South Warren Ave.
Tucson, AZ 85721-0458
Attn Craig Kulesa

Customer Name / Address

The University of Arizona

Customer Contact	Customer Contact Ph	Rep	Project
CRAIG KULESA			

Line	Item	Description	Qty	Rate	Total
1	Dewar	Southpole Dewar based on Closed Cycle System. -12-inch case section -Dewar stand and handles located around cold head for handling. -External case holes TBD for interface with customers system. -Case split at critical location for ease of dewar assembly with array. -Cold plate details to allow install of customers instrument. -System assembly and Stack up.	1	8,500.00	8,500.00
2	Cryo-Cooler	Existing Sunpower CryoTel CT Series cooler. - Sumitomo RDK-101 -Electronics contol box mounted in rack mount enclosure with cooling fan. -KF50 welded bellows interface mount. -SunPower cooling tube with heat exchange fins and high flow cooling fan to allow in lab testing. -Gold plated thermal bus bar interface from cold tip to cold plate. -Thermal radiation shield. -System design and integration.	1	29,000.00	29,000.00
3	Rad-Shield	Radiation shield attached to cold plate. -Allows flange mount at both ends.	1	1,000.00	1,000.00
4	Rigid-Supp-A	Internal Rigid Support System fixed between cold work regions.	1	650.00	650.00

UNIVERSAL CRYOGENICS TERMS AND CONDITIONS 2015 APPLY, THANK YOU FROM UNIVERSAL CRYOGENICS!

Total

QUOTE from Universal Cryogenics

JOB CODE	Date	Quote #
UACL20K	10/2/2015	514

UNIVERSAL CRYOGENICS
1815 W. Gardner Ln.
Tucson, AZ. 85705
520-622-6277 ph
520-623-3167 fx
www.ucryo.com
kirby@ucryo.com

QUOTE VALID FOR 30 DAYS.	Ship To
SHIPPING WILL BE ADDED TO FINAL INVOICE.	The University of Arizona Central Receiving 1145 South Warren Ave. Tucson, AZ 85721-0458 Attn CRAIG KULESA
PROGRESS PAYMENTS MAY APPLY WITH PO.	

Customer Name / Address
The University of Arizona

Customer Contact	Customer Contact Ph	Rep	Project
CRAIG KULESA			

Line	Item	Description	Qty	Rate	Total
13	baffle-filter-hldr	Baffle with filter holding on radiation shield cover.	1	375.00	375.00
14	Blank-Flange-A	Blank mounting Flange mounted to dewar. -Location TBD based on design. -Allows access to array install to match customers instrument design.	1	1,000.00	1,000.00
15	Design	Dewar Mechanical Design of system. -Design meetings and presentation at UofA.	1	1,000.00	1,000.00
16	Dewar-Test-A	Dewar Leak Checking, Vacuum and Cryogenic Testing of Dewar with Documentation.		1,000.00	1,000.00
17	DELIVERY TERMS	DELIVERY OF SYSTEM IS 16 - 18 WEEKS ARO.			

UNIVERSAL CRYOGENICS TERMS AND CONDITIONS 2015 APPLY, THANK YOU FROM UNIVERSAL CRYOGENICS!

Total $45,000.00

7 Marconi
Irvine, CA 92618
Phone: (949) 215-1151

QUOTATION NO.: 130917-3

DATE: October 17, 2015
QUOTE VALID THROUGH: **March 17, 2016**

PREPARED BY: Laszlo Tamas
E-mail: Laszlo@NiProOptics.com

Company University of Arizona
Street 1401 E University Blvd Tucson, AZ 85721
City, state,zip Tucson, AZ, 85721
Phone:
Attention: *Craig Kulesa*

CUSTOMER RFQ NO.:

ITEM No.	DESCRIPTION	QUANTITY	UNIT PRICE	EXTENDED PRICE
1	M1 flat mirror, after cutting the first section, tool post will be moved to complete the full surface.	1	$9,500.00	$9,500.00
2	M2 30-degree off axis paraboloid mirror. 610 x 630 elliptical shape, 55 mm thick.	1	$14,000.00	$14,000.00
3	M3 on axis ellipsoidal mirror. OD 230 mm x 55 mm thick	1	$5,500.00	$5,500.00
4	Tooling	1	$5,000.00	$5,000.00
	Total			$34,000.00
	Notes:			
	1 - Mataerial is Al 6061 2 - Surface finish RMS < 10 micron			
	3 - Surface form will not be measured. Best practice will be used for mounting mirrors on fixturing to minimize distortion.			
	Deposit: 50% of total order.			
	Delivery: 8 weeks from receipt of deposit.			

Shipment: UPS ground shipping

FOB: Irvine, Ca.

VIRGINIA Diodes Inc.

QUOTATION: QTC111015UAz

TO: Craig Kulesa
University of Arizona
e-mail: ckulesa@as.arizona.edu

October 10, 2015
Total Pages = 1

We are pleased to offer the following budgetary quotation for Schottky diode multipliers.

Item	Description	Unit	Price	Delivery
1	**1.45 THz Local Oscillator** Output Power: >20 uW from 1.4 to 1.5 THz Expected System Configuration: {PLO} + {Amplifier} + {D60 Doubler} + {D120 Doubler} + {D250 Doubler} + {T750 tripler} + {WR-0.65SHM} RF Input Port: WR-0.65 Diagonal Feedhorn, 25 dB gain typical DC Requirements: 12V @3A		**$80,000**	**16 Weeks**

NOTES:
All VDI components offered use planar diode technology and have no mechanical tuners.
This quote is valid for sixty days beyond date given above.
Delivery: Delivery dates shown are the expected maximum, VDI will add cost of shipping and insurance to invoice. Please include shipping instructions with the PO.
Terms: Net 30 days, VDI Terms and conditions apply.

Authorization:

Thomas W. Crowe, President
Virginia Diodes, Inc.

Roach 2 current status as of Sept. 2014
Updated Aug. 2014

Below are current estimated cost for each of the items that will be available.
The DRAM modules is required for a functional Roach2 board and it is a plug in module. You may also need either a CX4 or the SFP+ cards which are used in pairs to give 8 port output. Even though the power supply is listed separately, for a complete chassis assembly, it is already included. ADC cards suitable for Roach1 are also compatible for Roach2 cards.

Roach2 board assembly, unit price $3,650.00 Xilinx chip to be issued by customer.

DRAM modules Kingston, unit cost $45.00 (one unit per Roach board needed)

ATX power supply, unit cost $65.00, included in complete chassis price.

Complete chassis, power supply, fans, led board, power switch, and associated wiring; $550.0

SFP+ Card Mezzanine, unit cost $450.0
CX-4 card Mezzanine, unit cost $148.0
New ADC card 16 I/P 8 bit . $1500 ea

TOTAL of 1 x ROACH2 + 1 x DRAM + ATX + chassis + 2 x SFP + 2 x ADC5: $7460