Cover Page for Proposal Submitted to the National Aeronautics and Space Administration

NASA Proposal Number

12-APRA12-0049

NASA PROCEDURE FOR HANDLING PROPOSALS

This proposal shall be used and disclosed for evaluation purposes only, and a copy of this Government notice shall be applied to any reproduction or abstract thereof. Any authorized restrictive notices that the submitter places on this proposal shall also be strictly complied with. Disclosure of this proposal for any reason outside the Government evaluation purposes shall be made only to the extent authorized by the Government.

SECTION I - Proposal Information

Principal Investigator	E-mail Address	Phone Number
Christopher Walker	cwalker@as.arizona.edu	520-621-8783

Street Address (1)	Street Address (2)
933 N Cherry Ave	

City	State / Province	Postal Code	Country Code
Tucson	AZ	85721-0009	US

Proposal Title : **Reflight of the Stratospheric TeraHertz Observatory: STO-2**

Proposed Start Date	Proposed End Date	Total Budget	Year 1 Budget	Year 2 Budget	Year 3 Budget	Year 4 Budget	Year 5 Budget
01 / 01 / 2014	12 / 31 / 2016	1,081,269.00	499,876.00	396,165.00	185,228.00	0.00	0.00

SECTION II - Application Information

NASA Program Announcement Number	NASA Program Announcement Title
NNH12ZDA001N-APRA	Astrophysics Research and Analysis

For Consideration By NASA Organization *(the soliciting organization, or the organization to which an unsolicited proposal is submitted)*

Astrophysics

Date Submitted	Submission Method	Grants.gov Application Identifier	Applicant Proposal Identifier
03 / 21 / 2013	Electronic Submission Only		

Type of Application	Predecessor Award Number	Other Federal Agencies to Which Proposal Has Been Submitted
New	NNX08AG39G	

International Participation	Type of International Participation
Yes	Collaborator

SECTION III - Submitting Organization Information

DUNS Number	CAGE Code	Employer Identification Number (EIN or TIN)	Organization Type
806345617	0LJH3	742652689	2A

Organization Name (Standard/Legal Name)	Company Division
University Of Arizona	

Organization DBA Name	Division Number

Street Address (1)	Street Address (2)
888 N EUCLID AVE	

City	State / Province	Postal Code	Country Code
TUCSON	AZ	85719-4824	USA

SECTION IV - Proposal Point of Contact Information

Name	Email Address	Phone Number
Christopher Walker	cwalker@as.arizona.edu	520-621-8783

SECTION V - Certification and Authorization

Certification of Compliance with Applicable Executive Orders and U.S. Code

By submitting the proposal identified in the Cover Sheet/Proposal Summary in response to this Research Announcement, the Authorizing Official of the proposing organization (or the individual proposer if there is no proposing organization) as identified below:

- certifies that the statements made in this proposal are true and complete to the best of his/her knowledge;
- agrees to accept the obligations to comply with NASA award terms and conditions if an award is made as a result of this proposal; and
- confirms compliance with all provisions, rules, and stipulations set forth in the two Certifications and one Assurance contained in this NRA (namely, (i) the Assurance of Compliance with the NASA Regulations Pursuant to Nondiscrimination in Federally Assisted Programs, and (ii) Certifications, Disclosures, and Assurances Regarding Lobbying and Debarment and Suspension.

Willful provision of false information in this proposal and/or its supporting documents, or in reports required under an ensuing award, is a criminal offense (U.S. Code, Title 18, Section 1001).

Authorized Organizational Representative (AOR) Name	AOR E-mail Address	Phone Number
Mary Gerrow	maryg@email.arizona.edu	520-626-6000

AOR Signature *(Must have AOR's original signature. Do not sign "for" AOR.)*	**Date**

PI Name : **Christopher Walker**	NASA Proposal Number
Organization Name : **University Of Arizona**	**12-APRA12-0049**

Proposal Title : **Reflight of the Stratospheric TeraHertz Observatory: STO-2**

SECTION VI - Team Members

Team Member Role	Team Member Name	Contact Phone	E-mail Address
PI	**Christopher Walker**	**520-621-8783**	**cwalker@as.arizona.edu**
Organization/Business Relationship: **University Of Arizona**		Cage Code: **0LJH3**	DUNS#: **806345617**
International Participation: **No**	U.S. Government Agency:		Total Funds Requested: **0.00**
Co-I	**Craig Kulesa**	**520-621-6540**	**ckulesa@as.arizona.edu**
Organization/Business Relationship: **University Of Arizona**		Cage Code: **0LJH3**	DUNS#: **806345617**
International Participation: **No**	U.S. Government Agency:		Total Funds Requested: **0.00**
Co-I	**William Langer**	**818-354-5823**	**William.Langer@jpl.nasa.gov**
Organization/Business Relationship: **Jet Propulsion Laboratory**		Cage Code: **23835**	DUNS#: **095633152**
International Participation: **No**	U.S. Government Agency: **Other**		Total Funds Requested: **14,550.00**
Co-I	**Jorge Pineda**	**626-429-0299**	**Jorge.Pineda@jpl.nasa.gov**
Organization/Business Relationship: **Jet Propulsion Laboratory**		Cage Code: **23835**	DUNS#: **095633152**
International Participation: **No**	U.S. Government Agency: **Other**		Total Funds Requested: **44,810.00**
Co-I	**Brian Stalder**	**617-496-7360**	**bstalder@cfa.harvard.edu**
Organization/Business Relationship: **Smithsonian Institution/Smithsonian Astrophysical Observatory**		Cage Code: **1PPP1**	DUNS#: **003261823**
International Participation: **No**	U.S. Government Agency:		Total Funds Requested: **0.00**
Co-I	**Harold Yorke**	**818-354-5515**	**Harold.Yorke@jpl.nasa.gov**
Organization/Business Relationship: **Jet Propulsion Laboratory**		Cage Code: **23835**	DUNS#: **095633152**
International Participation: **No**	U.S. Government Agency: **Other**		Total Funds Requested: **14,550.00**
Co-I/Institutional PI	**Pietro Bernasconi**	**443-778-8970**	**pietro.bernasconi@jhuapl.edu**
Organization/Business Relationship: **Self**		Cage Code: **N/A**	DUNS#: **N/A**
International Participation: **No**	U.S. Government Agency:		Total Funds Requested: **0.00**

Team Member Role	Team Member Name	Contact Phone	E-mail Address
Co-I/Institutional PI	**Christopher Groppi**	**480-965-6436**	**cgroppi@asu.edu**
Organization/Business Relationship: **Arizona State University**		Cage Code: **4B293**	DUNS#: **943360412**
International Participation: **No**	U.S. Government Agency:		Total Funds Requested: **0.00**
Co-I/Institutional PI	**David Hollenbach**	**559-336-9525**	**dhollenbach@seti.org**
Organization/Business Relationship: **SETI Institute**		Cage Code: **1NVY9**	DUNS#: **137315552**
International Participation: **No**	U.S. Government Agency:		Total Funds Requested: **0.00**
Co-I/Institutional PI	**Jonathan Kawamura**	**818-393-4779**	**jonathan.h.kawamura@jpl.nasa.gov**
Organization/Business Relationship: **Jet Propulsion Laboratory**		Cage Code: **23835**	DUNS#: **095633152**
International Participation: **No**	U.S. Government Agency: **Other**		Total Funds Requested: **940,450.00**
Co-I/Institutional PI	**Antony Stark**	**617-496-7648**	**aas@cfa.harvard.edu**
Organization/Business Relationship: **Smithsonian Institution/Smithsonian Astrophysical Observatory**		Cage Code: **1PPP1**	DUNS#: **003261823**
International Participation: **No**	U.S. Government Agency:		Total Funds Requested: **0.00**
Co-I/Institutional PI	**Mark Wolfire**	**301-405-1538**	**mwolfire@astro.umd.edu**
Organization/Business Relationship: **University of Maryland, College Park**		Cage Code: **0UB92**	DUNS#: **790934285**
International Participation: **No**	U.S. Government Agency:		Total Funds Requested: **0.00**
Co-I/Science PI	**Paul Goldsmith**	**818-393-0518**	**Paul.F.Goldsmith@jpl.nasa.gov**
Organization/Business Relationship: **Jet Propulsion Laboratory**		Cage Code: **23835**	DUNS#: **095633152**
International Participation: **No**	U.S. Government Agency: **Other**		Total Funds Requested: **148,720.00**
Other Professional	**Brian Duffy**	**520-247-5238**	**bduffy@as.arizona.edu**
Organization/Business Relationship: **University Of Arizona**		Cage Code: **0LJH3**	DUNS#: **806345617**
International Participation: **No**	U.S. Government Agency:		Total Funds Requested: **0.00**

PI Name : **Christopher Walker**	NASA Proposal Number
Organization Name : **University Of Arizona**	**12-APRA12-0049**

Proposal Title : **Reflight of the Stratospheric TeraHertz Observatory: STO-2**

SECTION VII - Project Summary

This is the Lead Proposal for the "Reflight of the Stratospheric TeraHertz Observatory: STO-2". STO-2 will address a key problem in modern astrophysics, understanding the Life Cycle of the Interstellar Medium (ISM). STO-2 will survey approximately ¼ of the Southern Galactic plane in the dominant interstellar cooling line [CII] (158 µm) and the important star formation tracer [NII] (205 µm). With ~1 arcminute angular resolution, STO-2 will spatially resolve atomic, ionic and molecular clouds out to 10 kpc. Taking advantage of its enhanced, extended lifetime cryogenic receivers, the STO-2 survey will be conducted at unparalleled sensitivity levels. STO-2 will uniquely probe the pivotal formative and disruptive stages in the life cycle of interstellar clouds and the relationship between global star formation rates and the properties of the ISM. Combined with previous HI and CO surveys, STO-2 will create 3-dimensional maps of the structure, dynamics, turbulence, energy balance, and pressure of the Milky Way's ISM, as well as the star formation rate. Once we gain an understanding of the relationship between ISM properties and star formation in the Milky Way, we can better interpret observations of nearby galaxies and the distant universe.

The mission goals for these surveys are to: 1) Determine the life cycle of Galactic interstellar gas, 2) Study the creation and disruption of star-forming clouds in the Galaxy, 3) Determine the parameters that affect the star formation rate in the galaxy, and 4) Provide templates for star formation and stellar/interstellar feedback in other galaxies.

STO-2 will re-use the 80cm telescope, gondola, and subsystems from STO-1. For the STO-2 flight, STO-1's high spectral resolution (<1 km/s) heterodyne receiver system will be upgraded for extended cryogenic lifetime, enhanced sensitivity, and greater reliability. The flight receiver has eight, cryogenic HEB mixers; four optimized for the [CII] line and four for the [NII] line. STO-2 will also fly an uncooled, Schottky receiver to observe the 609 µm [CI] line at 3 arcminute resolution. The instrument spectrometer has sufficient bandwidth to detect all clouds participating in Galactic rotation in each of its 9 pixels. STO is capable of detecting every giant molecular cloud, every HII region of significance, and every diffuse HI cloud with (AV # 0.4) within its survey region.

The STO-1 launch was on 15 January 2012. Before achieving float altitude a frozen absolute pressure regulator vented approximately half of the liquid helium supply to the atmosphere. This event reduced the cryogenic (THz) portion of the mission to ~5 days. The efficacy of the observations conducted during this period was hindered by several technical issues experienced early in the flight. The causes of these issues were identified and corrected in flight. STO then transitioned into its `Warm Mission' science program and continued observations using an uncooled 492 GHz [CI] receiver until the end of its flight on 29 January 2012. Here we propose to re-fly STO with an upgraded, more robust cryogenic/receiver system that will allow THz observations to continue until stratospheric conditions or recovery constraints require terminating the mission (up to ~60 days). STO-2 will benefit tremendously from the heritage and experience gained during the STO-1 campaign.

PI Name : **Christopher Walker**	NASA Proposal Number
Organization Name : **University Of Arizona**	**12-APRA12-0049**

Proposal Title : **Reflight of the Stratospheric TeraHertz Observatory: STO-2**

SECTION VIII - Other Project Information

Proprietary Information

Is proprietary/privileged information included in this application?

Yes

International Collaboration

Does this project involve activities outside the U.S. or partnership with International Collaborators?

Yes

Principal Investigator	Co-Investigator	Collaborator	Equipment	Facilities
No	**No**	**Yes**	**No**	**No**

Explanation :

University of Cologne scientist (Juergen Stutzki) will be a Science Team affiliate. University of New South Wales scientist (Michael Burton) will be a Science Team affiliate.

NASA Civil Servant Project Personnel

Are NASA civil servant personnel participating as team members on this project (include funded and unfunded)?

No

Fiscal Year	Fiscal Year	Fiscal Year	Fiscal Year	Fiscal Year	Fiscal Year
Number of FTEs	Number of FTEs	Number of FTEs	Number of FTEs	Number of FTEs	Number of FTEs

PI Name : **Christopher Walker**	NASA Proposal Number
Organization Name : **University Of Arizona**	**12-APRA12-0049**

Proposal Title : **Reflight of the Stratospheric TeraHertz Observatory: STO-2**

SECTION VIII - Other Project Information

Environmental Impact

Does this project have an actual or potential impact on the environment?	Has an exemption been authorized or an environmental assessment (EA) or an environmental impact statement (EIS) been performed?
No	**No**

Environmental Impact Explanation:

Exemption/EA/EIS Explanation:

PI Name : **Christopher Walker**	NASA Proposal Number
Organization Name : **University Of Arizona**	**12-APRA12-0049**

Proposal Title : **Reflight of the Stratospheric TeraHertz Observatory: STO-2**

SECTION VIII - Other Project Information

Historical Site/Object Impact

Does this project have the potential to affect historic, archeological, or traditional cultural sites (such as Native American burial or ceremonial grounds) or historic objects (such as an historic aircraft or spacecraft)?

Explanation:

PI Name : **Christopher Walker**	NASA Proposal Number
Organization Name : **University Of Arizona**	**12-APRA12-0049**

Proposal Title : **Reflight of the Stratospheric TeraHertz Observatory: STO-2**

SECTION IX - Program Specific Data

Question 1 : Short Title:

Answer: Reflight of the Stratospheric TeraHertz Observatory: STO-2

Question 2 : Type of institution:

Answer: Educational Organization

Question 3 : Will any funding be provided to a federal government organization including NASA Centers, JPL, other Federal agencies, government laboratories, or Federally Funded Research and Development Centers (FFRDCs)?

Answer: Yes

Question 4 : Is this Federal government organization a different organization from the proposing (PI) organization?

Answer: Yes

Question 5 : Does this proposal include the use of NASA-provided high end computing?

Answer: No

Question 6 : Research Category:

Answer: 7) Suborbital rocket/balloon/airplane investigation

Question 7 : Team Members Missing From Cover Page:

Answer:

Juergen Stutzki, University of Cologne, Cologne, Germany, Science Team affiliateGordon Stacey, Cornell University, Ithaca, NY, Science Team affiliateMichael Burton, University of New South Wales, Australia, Science Team affiliate

Question 8 : This proposal contains information and/or data that are subject to U.S. export control laws and regulations including Export Administration Regulations (EAR) and International Traffic in Arms Regulations (ITAR).

Answer: Yes

Question 9 : I have identified the export-controlled material in this proposal.

Answer: Yes

Question 10 : I acknowledge that the inclusion of such material in this proposal may complicate the government's ability to evaluate the proposal.

Answer: Yes

Question 11 : Does the proposed work include any involvement with collaborators in China or with Chinese organizations, or does the proposed work include activities in China?

Answer: No

Question 12 : Are you planning for undergraduate students to be involved in the conduct of the proposed investigation?

Answer: Yes

Question 13 : If Yes: How many different undergraduate students?

Answer: 2

Question 14 : What is the total number of student-months of involvement for all undergraduate students over the life of the proposed investigation?

Answer: Assuming $10/hr and 10 hrs a week, the total comes to ~46 months of funded undergraduate involvement.

Question 15 : Provide the names and current year (1,2,3,4) for any undergraduate students that have already been identified.

Answer:

Casey Honniball, SophomoreBrent Tayah, Freshman

Question 16 : Are you planning for graduate students to be involved in the conduct of the proposed investigation?

Answer: Yes

Question 17 : If Yes: How many different graduate students?

Answer: 2

Question 18 : What is the total number of student-months of involvement for all graduate students over the life of the proposed investigation?

Answer: 36 months of funded graduate student involvement.

Question 19 : Provide the names and current year (1,2,3,4, etc.) for any graduate students that have already been identified.

Answer:

David Lesser, 3rd year

Question 20 : Proposal Category:

Answer: Suborbital Investigation: Balloon

Question 21 : If Detector Development, Supporting Technology, or Suborbital Investigation, select proposal type:

Answer: Sub-mm

Question 22 : If this is a Balloon payload, please select a category.

Answer: Science Investigations

Question 23 : Is this a suborbital proposal?

Answer: Yes

Question 24 : Proposal Type:

Answer: PI

Question 25 : If a Co-I proposal, identify the Lead PI (name and institution) and the title on the Lead proposal.

Answer:

Question 26 : Requested Launch Vehicle:

Answer:

Question 27 : Launch Site:

Answer:

Question 28 : Launch date and window:

Answer:

Question 29 : Apogee and/or observation time:

Answer:

Question 30 : Special launch considerations:

Answer:

Question 31 : Pointing Accuracy:

Answer:

Question 32 : Telemetry rates, number of links:

Answer:

Question 33 : Special systems:

Answer:

Question 34 : Recovery:

Answer:

Question 35 : Hardware to be built by NSROC:

Answer:

Question 36 : Experiment section diameter:

Answer:

Question 37 : Approximate experiment section weight:

Answer:

Question 38 : Approximate experiment section length:

Answer:

Question 39 : Experiment section CG estimate:

Answer:

Question 40 : Approximate experiment section power:

Answer:

Question 41 : Experiment section contamination sensitivity:

Answer:

Question 42 : Experiment section cleanliness:

Answer:

Question 43 : Experiment section purge requirements:

Answer:

Question 44 : Experiment section deployments:

Answer:

PI Name : **Christopher Walker**	NASA Proposal Number
Organization Name : **University Of Arizona**	**12-APRA12-0049**

Proposal Title : **Reflight of the Stratospheric TeraHertz Observatory: STO-2**

SECTION X - Budget

Cumulative Budget

Budget Cost Category	Funds Requested ($)					
	Year 1 ($)	Year 2 ($)	Year 3 ($)	Year 4 ($)	Year 5 ($)	Total Project ($)
A. Direct Labor - Key Personnel	75,660.00	78,161.00	57,569.00	0.00	0.00	211,390.00
B. Direct Labor - Other Personnel	75,232.00	77,723.00	53,135.00	0.00	0.00	206,090.00
Total Number Other Personnel	3	3	1	0	0	7
Total Direct Labor Costs (A+B)	150,892.00	155,884.00	110,704.00	0.00	0.00	417,480.00
C. Direct Costs - Equipment	47,000.00	0.00	0.00	0.00	0.00	47,000.00
D. Direct Costs - Travel	4,032.00	38,940.00	0.00	0.00	0.00	42,972.00
Domestic Travel	4,032.00	34,364.00	0.00	0.00	0.00	38,396.00
Foreign Travel	0.00	4,576.00	0.00	0.00	0.00	4,576.00
E. Direct Costs - Participant/Trainee Support Costs	0.00	0.00	0.00	0.00	0.00	0.00
Tuition/Fees/Health Insurance	0.00	0.00	0.00	0.00	0.00	0.00
Stipends	0.00	0.00	0.00	0.00	0.00	0.00
Travel	0.00	0.00	0.00	0.00	0.00	0.00
Subsistence	0.00	0.00	0.00	0.00	0.00	0.00
Other	0.00	0.00	0.00	0.00	0.00	0.00
Number of Participants/Trainees						0
F. Other Direct Costs	158,216.00	89,732.00	21,240.00	0.00	0.00	269,188.00
Materials and Supplies	44,000.00	12,066.00	2,134.00	0.00	0.00	58,200.00
Publication Costs	0.00	0.00	4,400.00	0.00	0.00	4,400.00
Consultant Services	0.00	0.00	0.00	0.00	0.00	0.00
ADP/Computer Services	0.00	0.00	0.00	0.00	0.00	0.00
Subawards/Consortium/Contractual Costs	49,216.00	49,666.00	9,706.00	0.00	0.00	108,588.00
Equipment or Facility Rental/User Fees	0.00	0.00	0.00	0.00	0.00	0.00
Alterations and Renovations	0.00	0.00	0.00	0.00	0.00	0.00
Other	65,000.00	28,000.00	5,000.00	0.00	0.00	98,000.00
G. Total Direct Costs (A+B+C+D+E+F)	360,140.00	284,556.00	131,944.00	0.00	0.00	776,640.00
H. Indirect Costs	139,736.00	111,609.00	53,284.00	0.00	0.00	304,629.00
I. Total Direct and Indirect Costs (G+H)	499,876.00	396,165.00	185,228.00	0.00	0.00	1,081,269.00
J. Fee	0.00	0.00	0.00	0.00	0.00	0.00
K. Total Cost (I+J)	499,876.00	396,165.00	185,228.00	0.00	0.00	1,081,269.00
Total Cumulative Budget						1,081,269.00

PI Name : **Christopher Walker**	**NASA Proposal Number**
Organization Name : **University Of Arizona**	**12-APRA12-0049**

Proposal Title : **Reflight of the Stratospheric TeraHertz Observatory: STO-2**

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
01 / 01 / 2014	12 / 31 / 2014	Project	1

A. Direct Labor - Key Personnel

Name	Project Role	Base Salary ($)	Cal. Months	Acad. Months	Summ. Months	Requested Salary ($)	Fringe Benefits ($)	Funds Requested ($)
Kulesa, Craig	CO-I	57,554.00	3			14,444.00	4,506.00	18,950.00
Duffy, Brian	Other_Professional_TYPE	65,936.00	6			33,095.00	10,326.00	43,421.00
Walker, Christopher	PI_TYPE	90,763.00			1	10,129.00	3,160.00	13,289.00
							Total Key Personnel Costs	75,660.00

B. Direct Labor - Other Personnel

Number of Personnel	Project Role	Cal. Months	Acad. Months	Summ. Months	Requested Salary ($)	Fringe Benefits ($)	Funds Requested ($)
1	Graduate Students		4.5	3	30,175.00	19,614.00	49,789.00
1	Undergraduate Students	4			9,000.00	1,080.00	10,080.00
1	Principal Engineer	2			11,710.00	3,653.00	15,363.00
3	Total Number Other Personnel					Total Other Personnel Costs	75,232.00

Total Direct Labor Costs (Salary, Wages, Fringe Benefits) (A+B)	150,892.00

PI Name : **Christopher Walker**	NASA Proposal Number
Organization Name : **University Of Arizona**	**12-APRA12-0049**

Proposal Title : **Reflight of the Stratospheric TeraHertz Observatory: STO-2**

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
01 / 01 / 2014	**12 / 31 / 2014**	**Project**	**1**

C. Direct Costs - Equipment

Item No.	Equipment Item Description	Funds Requested ($)
1	Traveling Helium leak checker	13,000.00
2	Spectrometer Card (space)	10,000.00
3	Sunpower CT cryocooler & spare	24,000.00
	Total Equipment Costs	47,000.00

D. Direct Costs - Travel

	Funds Requested ($)
1. Domestic Travel (Including Canada, Mexico, and U.S. Possessions)	4,032.00
2. Foreign Travel	0.00
Total Travel Costs	4,032.00

E. Direct Costs - Participant/Trainee Support Costs

		Funds Requested ($)
1. Tuition/Fees/Health Insurance		0.00
2. Stipends		0.00
3. Travel		0.00
4. Subsistence		0.00
Number of Participants/Trainees:	Total Participant/Trainee Support Costs	0.00

PI Name : **Christopher Walker**	NASA Proposal Number
Organization Name : **University Of Arizona**	**12-APRA12-0049**

Proposal Title : **Reflight of the Stratospheric TeraHertz Observatory: STO-2**

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
01 / 01 / 2014	**12 / 31 / 2014**	**Project**	**1**

F. Other Direct Costs

	Funds Requested ($)
1. Materials and Supplies	**44,000.00**
2. Publication Costs	**0.00**
3. Consultant Services	**0.00**
4. ADP/Computer Services	**0.00**
5. Subawards/Consortium/Contractual Costs	**49,216.00**
6. Equipment or Facility Rental/User Fees	**0.00**
7. Alterations and Renovations	**0.00**
8 . Other: **Shipping**	**4,000.00**
9 . Other: **Fabricated Equipment**	**61,000.00**
Total Other Direct Costs	**158,216.00**

G. Total Direct Costs

	Funds Requested ($)
Total Direct Costs (A+B+C+D+E+F)	**360,140.00**

H. Indirect Costs

	Indirect Cost Rate (%)	Indirect Cost Base ($)	Funds Requested ($)
MTDC (TDC less graduate tuition remission, capital equipment, and subcontracts)	**51.50**	**246,333.00**	**126,861.00**
First $25K of subcontract	**51.50**	**25,000.00**	**12,875.00**
Cognizant Federal Agency: **DHHS Audit Agency, Regional Inspector for Audit (415) 437-8360**		**Total Indirect Costs**	**139,736.00**

I. Direct and Indirect Costs

	Funds Requested ($)
Total Direct and Indirect Costs (G+H)	**499,876.00**

J. Fee

	Funds Requested ($)
Fee	**0.00**

K. Total Cost

	Funds Requested ($)
Total Cost with Fee (I+J)	**499,876.00**

PI Name : **Christopher Walker**	NASA Proposal Number
Organization Name : **University Of Arizona**	**12-APRA12-0049**
Proposal Title : **Reflight of the Stratospheric TeraHertz Observatory: STO-2**	

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
01 / 01 / 2015	**12 / 31 / 2015**	**Project**	**2**

A. Direct Labor - Key Personnel

Name	Project Role	Base Salary ($)	Cal. Months	Acad. Months	Summ. Months	Requested Salary ($)	Fringe Benefits ($)	Funds Requested ($)
Kulesa, Craig	CO-I	59,446.00	3			14,919.00	4,655.00	19,574.00
Duffy, Brian	Other_Professional_TYPE	68,120.00	6			34,191.00	10,667.00	44,858.00
Walker, Christopher	PI_TYPE	93,764.00			1	10,464.00	3,265.00	13,729.00
							Total Key Personnel Costs	78,161.00

B. Direct Labor - Other Personnel

Number of Personnel	Project Role	Cal. Months	Acad. Months	Summ. Months	Requested Salary ($)	Fringe Benefits ($)	Funds Requested ($)
1	Graduate Students		4.5	3	31,174.00	20,263.00	51,437.00
1	Undergraduate Students	4			9,300.00	1,116.00	10,416.00
1	Principal Engineer	2			12,096.00	3,774.00	15,870.00
3	Total Number Other Personnel					Total Other Personnel Costs	77,723.00
						Total Direct Labor Costs (Salary, Wages, Fringe Benefits) (A+B)	155,884.00

PI Name : **Christopher Walker**	NASA Proposal Number
Organization Name : **University Of Arizona**	**12-APRA12-0049**

Proposal Title : **Reflight of the Stratospheric TeraHertz Observatory: STO-2**

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
01 / 01 / 2015	**12 / 31 / 2015**	**Project**	**2**

C. Direct Costs - Equipment

Item No.	Equipment Item Description	Funds Requested ($)
	Total Equipment Costs	**0.00**

D. Direct Costs - Travel

	Funds Requested ($)
1. Domestic Travel (Including Canada, Mexico, and U.S. Possessions)	**34,364.00**
2. Foreign Travel	**4,576.00**
Total Travel Costs	**38,940.00**

E. Direct Costs - Participant/Trainee Support Costs

		Funds Requested ($)
1. Tuition/Fees/Health Insurance		**0.00**
2. Stipends		**0.00**
3. Travel		**0.00**
4. Subsistence		**0.00**
Number of Participants/Trainees:	**Total Participant/Trainee Support Costs**	**0.00**

PI Name : **Christopher Walker**	NASA Proposal Number
Organization Name : **University Of Arizona**	**12-APRA12-0049**

Proposal Title : **Reflight of the Stratospheric TeraHertz Observatory: STO-2**

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
01 / 01 / 2015	**12 / 31 / 2015**	**Project**	**2**

F. Other Direct Costs

	Funds Requested ($)
1. Materials and Supplies	**12,066.00**
2. Publication Costs	**0.00**
3. Consultant Services	**0.00**
4. ADP/Computer Services	**0.00**
5. Subawards/Consortium/Contractual Costs	**49,666.00**
6. Equipment or Facility Rental/User Fees	**0.00**
7. Alterations and Renovations	**0.00**
8 . Other: **Shipping**	**12,000.00**
9 . Other: **Thermal Vac Test**	**16,000.00**
Total Other Direct Costs	**89,732.00**

G. Total Direct Costs

	Funds Requested ($)
Total Direct Costs (A+B+C+D+E+F)	**284,556.00**

H. Indirect Costs

	Indirect Cost Rate (%)	Indirect Cost Base ($)	Funds Requested ($)
MTDC (TDC less graduate tuition remission, capital equipment, and subcontracts)	**51.50**	**216,716.00**	**111,609.00**
Cognizant Federal Agency: **DHHS Audit Agency, Regional Inspector for Audit (415) 437-8360**		**Total Indirect Costs**	**111,609.00**

I. Direct and Indirect Costs

	Funds Requested ($)
Total Direct and Indirect Costs (G+H)	**396,165.00**

J. Fee

	Funds Requested ($)
Fee	**0.00**

K. Total Cost

	Funds Requested ($)
Total Cost with Fee (I+J)	**396,165.00**

PI Name : **Christopher Walker**	NASA Proposal Number
Organization Name : **University Of Arizona**	**12-APRA12-0049**

Proposal Title : **Reflight of the Stratospheric TeraHertz Observatory: STO-2**

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
01 / 01 / 2016	**12 / 31 / 2016**	**Project**	**3**

A. Direct Labor - Key Personnel

Name	Project Role	Base Salary ($)	Cal. Months	Acad. Months	Summ. Months	Requested Salary ($)	Fringe Benefits ($)	Funds Requested ($)
Walker, Christopher	PI_TYPE	96,861.00			1	10,810.00	3,373.00	14,183.00
Kulesa, Craig	CO-I	61,402.00	3			15,409.00	4,808.00	20,217.00
Duffy, Brian	Other_Professional_TYPE	70,366.00	3			17,659.00	5,510.00	23,169.00
							Total Key Personnel Costs	57,569.00

B. Direct Labor - Other Personnel

Number of Personnel	Project Role	Cal. Months	Acad. Months	Summ. Months	Requested Salary ($)	Fringe Benefits ($)	Funds Requested ($)
1	Graduate Students		4.5	3	32,203.00	20,932.00	53,135.00
1	Total Number Other Personnel					Total Other Personnel Costs	53,135.00
						Total Direct Labor Costs (Salary, Wages, Fringe Benefits) (A+B)	110,704.00

PI Name : **Christopher Walker**	NASA Proposal Number
Organization Name : **University Of Arizona**	**12-APRA12-0049**

Proposal Title : **Reflight of the Stratospheric TeraHertz Observatory: STO-2**

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
01 / 01 / 2016	**12 / 31 / 2016**	**Project**	**3**

C. Direct Costs - Equipment

Item No.	Equipment Item Description	Funds Requested ($)
	Total Equipment Costs	**0.00**

D. Direct Costs - Travel

	Funds Requested ($)
1. Domestic Travel (Including Canada, Mexico, and U.S. Possessions)	**0.00**
2. Foreign Travel	**0.00**
Total Travel Costs	**0.00**

E. Direct Costs - Participant/Trainee Support Costs

		Funds Requested ($)
1. Tuition/Fees/Health Insurance		**0.00**
2. Stipends		**0.00**
3. Travel		**0.00**
4. Subsistence		**0.00**
Number of Participants/Trainees:	**Total Participant/Trainee Support Costs**	**0.00**

PI Name : **Christopher Walker**	**NASA Proposal Number**
Organization Name : **University Of Arizona**	**12-APRA12-0049**

Proposal Title : **Reflight of the Stratospheric TeraHertz Observatory: STO-2**

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
01 / 01 / 2016	**12 / 31 / 2016**	**Project**	**3**

F. Other Direct Costs

	Funds Requested ($)
1. Materials and Supplies	**2,134.00**
2. Publication Costs	**4,400.00**
3. Consultant Services	**0.00**
4. ADP/Computer Services	**0.00**
5. Subawards/Consortium/Contractual Costs	**9,706.00**
6. Equipment or Facility Rental/User Fees	**0.00**
7. Alterations and Renovations	**0.00**
8 . Other: **Shipping**	**5,000.00**
Total Other Direct Costs	**21,240.00**

G. Total Direct Costs

	Funds Requested ($)
Total Direct Costs (A+B+C+D+E+F)	**131,944.00**

H. Indirect Costs

	Indirect Cost Rate (%)	**Indirect Cost Base ($)**	**Funds Requested ($)**
MTDC (TDC less graduate tuition remission, capital equipment, and subcontracts)	**51.50**	**103,463.00**	**53,284.00**
Cognizant Federal Agency: **DHHS Audit Agency, Regional Inspector for Audit (415) 437-8360**		**Total Indirect Costs**	**53,284.00**

I. Direct and Indirect Costs

	Funds Requested ($)
Total Direct and Indirect Costs (G+H)	**185,228.00**

J. Fee

	Funds Requested ($)
Fee	**0.00**

K. Total Cost

	Funds Requested ($)
Total Cost with Fee (I+J)	**185,228.00**

PI Name : **Christopher Walker**	NASA Proposal Number
Organization Name : **University Of Arizona**	**12-APRA12-0049**

Proposal Title : **Reflight of the Stratospheric TeraHertz Observatory: STO-2**

SECTION X - Budget

Start Date :	End Date :	Budget Type : **Project**	Budget Period : **4**

A. Direct Labor - Key Personnel

Name	Project Role	Base Salary ($)	Cal. Months	Acad. Months	Summ. Months	Requested Salary ($)	Fringe Benefits ($)	Funds Requested ($)
Walker, Christopher	**PI_TYPE**	**0.00**				**0.00**	**0.00**	**0.00**
							Total Key Personnel Costs	**0.00**

B. Direct Labor - Other Personnel

Number of Personnel	Project Role	Cal. Months	Acad. Months	Summ. Months	Requested Salary ($)	Fringe Benefits ($)	Funds Requested ($)
0	Total Number Other Personnel					Total Other Personnel Costs	**0.00**

Total Direct Labor Costs (Salary, Wages, Fringe Benefits) (A+B)	**0.00**

PI Name : **Christopher Walker**	NASA Proposal Number
Organization Name : **University Of Arizona**	**12-APRA12-0049**

Proposal Title : **Reflight of the Stratospheric TeraHertz Observatory: STO-2**

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
		Project	**4**

C. Direct Costs - Equipment

Item No.	Equipment Item Description	Funds Requested ($)
	Total Equipment Costs	0.00

D. Direct Costs - Travel

	Funds Requested ($)
1. Domestic Travel (Including Canada, Mexico, and U.S. Possessions)	0.00
2. Foreign Travel	0.00
Total Travel Costs	0.00

E. Direct Costs - Participant/Trainee Support Costs

		Funds Requested ($)
1. Tuition/Fees/Health Insurance		0.00
2. Stipends		0.00
3. Travel		0.00
4. Subsistence		0.00
Number of Participants/Trainees:	**Total Participant/Trainee Support Costs**	0.00

PI Name : **Christopher Walker**	NASA Proposal Number
Organization Name : **University Of Arizona**	**12-APRA12-0049**

Proposal Title : **Reflight of the Stratospheric TeraHertz Observatory: STO-2**

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
		Project	**4**

F. Other Direct Costs

	Funds Requested ($)
1. Materials and Supplies	0.00
2. Publication Costs	0.00
3. Consultant Services	0.00
4. ADP/Computer Services	0.00
5. Subawards/Consortium/Contractual Costs	0.00
6. Equipment or Facility Rental/User Fees	0.00
7. Alterations and Renovations	0.00
Total Other Direct Costs	0.00

G. Total Direct Costs

	Funds Requested ($)
Total Direct Costs (A+B+C+D+E+F)	0.00

H. Indirect Costs

	Indirect Cost Rate (%)	Indirect Cost Base ($)	Funds Requested ($)
	0.00	0.00	0.00
	0.00	0.00	0.00
	0.00	0.00	0.00
	0.00	0.00	0.00
	0.00	0.00	0.00
	0.00	0.00	0.00
	0.00	0.00	0.00
	0.00	0.00	0.00
	0.00	0.00	0.00
	0.00	0.00	0.00
Cognizant Federal Agency:		**Total Indirect Costs**	0.00

I. Direct and Indirect Costs

	Funds Requested ($)
Total Direct and Indirect Costs (G+H)	0.00

J. Fee

	Funds Requested ($)
Fee	0.00

K. Total Cost

	Funds Requested ($)
Total Cost with Fee (I+J)	0.00

PI Name : **Christopher Walker**	NASA Proposal Number
Organization Name : **University Of Arizona**	**12-APRA12-0049**

Proposal Title : **Reflight of the Stratospheric TeraHertz Observatory: STO-2**

SECTION X - Budget

Start Date :	End Date :	Budget Type : **Project**	Budget Period : **5**

A. Direct Labor - Key Personnel

Name	Project Role	Base Salary ($)	Cal. Months	Acad. Months	Summ. Months	Requested Salary ($)	Fringe Benefits ($)	Funds Requested ($)
Walker，Christopher	PI_TYPE	0.00				0.00	0.00	0.00
							Total Key Personnel Costs	0.00

B. Direct Labor - Other Personnel

Number of Personnel	Project Role	Cal. Months	Acad. Months	Summ. Months	Requested Salary ($)	Fringe Benefits ($)	Funds Requested ($)
0	Total Number Other Personnel					Total Other Personnel Costs	0.00
						Total Direct Labor Costs (Salary, Wages, Fringe Benefits) (A+B)	0.00

PI Name : **Christopher Walker**	NASA Proposal Number
Organization Name : **University Of Arizona**	**12-APRA12-0049**

Proposal Title : **Reflight of the Stratospheric TeraHertz Observatory: STO-2**

SECTION X - Budget

Start Date :	End Date :	Budget Type : **Project**	Budget Period : **5**

C. Direct Costs - Equipment

Item No.	Equipment Item Description	Funds Requested ($)
	Total Equipment Costs	**0.00**

D. Direct Costs - Travel

	Funds Requested ($)
1. Domestic Travel (Including Canada, Mexico, and U.S. Possessions)	**0.00**
2. Foreign Travel	**0.00**
Total Travel Costs	**0.00**

E. Direct Costs - Participant/Trainee Support Costs

		Funds Requested ($)
1. Tuition/Fees/Health Insurance		**0.00**
2. Stipends		**0.00**
3. Travel		**0.00**
4. Subsistence		**0.00**
Number of Participants/Trainees:	**Total Participant/Trainee Support Costs**	**0.00**

PI Name : **Christopher Walker**	**NASA Proposal Number**
Organization Name : **University Of Arizona**	**12-APRA12-0049**

Proposal Title : **Reflight of the Stratospheric TeraHertz Observatory: STO-2**

SECTION X - Budget

Start Date :	End Date :	Budget Type :	Budget Period :
		Project	**5**

F. Other Direct Costs

	Funds Requested ($)
1. Materials and Supplies	0.00
2. Publication Costs	0.00
3. Consultant Services	0.00
4. ADP/Computer Services	0.00
5. Subawards/Consortium/Contractual Costs	0.00
6. Equipment or Facility Rental/User Fees	0.00
7. Alterations and Renovations	0.00
Total Other Direct Costs	0.00

G. Total Direct Costs

	Funds Requested ($)
Total Direct Costs (A+B+C+D+E+F)	0.00

H. Indirect Costs

	Indirect Cost Rate (%)	Indirect Cost Base ($)	Funds Requested ($)
	0.00	0.00	0.00
	0.00	0.00	0.00
	0.00	0.00	0.00
	0.00	0.00	0.00
	0.00	0.00	0.00
	0.00	0.00	0.00
	0.00	0.00	0.00
	0.00	0.00	0.00
	0.00	0.00	0.00
	0.00	0.00	0.00
Cognizant Federal Agency:	**Total Indirect Costs**		0.00

I. Direct and Indirect Costs

	Funds Requested ($)
Total Direct and Indirect Costs (G+H)	0.00

J. Fee

	Funds Requested ($)
Fee	0.00

K. Total Cost

	Funds Requested ($)
Total Cost with Fee (I+J)	0.00

The information (data) contained in pages 17 and 18 of this proposal is subject to U.S. export control laws and regulations. It is furnished to the Government with the understanding that it will not be exported without the prior approval of the Proposer under the terms of an applicable export license or technical assistance agreement.

Table of Contents

Reflight of the Stratospheric Terahertz Observatory: STO-2

An LDB Experiment to Investigate the Life Cycle of the Interstellar Medium

1 Executive Summary

The structure of the interstellar medium, the life cycle of interstellar clouds, and their relationship with star formation are processes crucial to deciphering the evolution of galaxies. High resolution spectral line imaging of key gas tracers not accessible from the ground is needed to supply major missing pieces of Galactic structure and witness the formation and dissipation of interstellar clouds. The reflight of the Stratospheric Terahertz Observatory (STO-2), a balloon-borne 0.8-meter telescope with an 8-beam far-infrared heterodyne spectrometer, will address these issues and significantly advance NASA's Strategic Goal of "discovering how the universe works" by exploring how structures in galaxies evolve and how galactic-scale star formation proceeds, using our Milky Way as a template.

In its long duration flight, STO-2 will survey part of the Galactic plane in [C II] line emission at 158 μm, the brightest spectral line in the Galaxy; and [N II] line emission at 205 μm, a tracer of the formation rate of massive stars. With ~1' angular resolution and <1 km/s velocity resolution, STO-2 will detect every interstellar cloud with $A_V \geq 0.4$ mag (hydrogen column density $\geq 4 \times 10^{20}$ cm^{-2}) in the surveyed region (Figure 1), and, through excitation and kinematic diagnostics provided by [C II] and [N II] line emission, will study how atomic and molecular clouds are formed and dispersed. STO-2 will make 3-dimensional maps of the structure, dynamics, turbulence, energy balance, and pressure of the Milky Way's Interstellar Medium (ISM), as well as the star formation rate.

STO had its first science flight in January 2012. [CII], CO J=12-11, and [CI] observations began within 12 hours of reaching float altitude. Early observations were hindered by several technical issues (Section 5.1) that were resolved in flight. Once the liquid helium supply was exhausted (after ~4 days), STO continued observing using an uncooled 492 GHz [CI] receiver until the end of its 14-day mission. Here, we propose to re-fly STO with an upgraded, robust cryogenic/receiver system that will allow it to fulfill its baseline mission objectives and continue THz observations until stratospheric conditions or recovery constraints require terminating the mission.

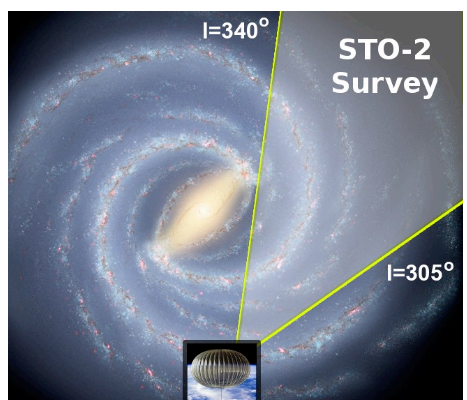

Figure 1*:* Overview of the region to be surveyed by STO-2. This 35° swath through the Galactic Plane includes spiral arm and interarm regions.

1.1 Summary: Science Goals and Objectives

STO-2 will help provide a comprehensive understanding of the inner workings of our Galaxy by exploring the connection between star formation and the life cycle of interstellar clouds. We will study the formation of molecular clouds, the feedback of high mass star formation heating and disrupting clouds, and the effect of these processes upon the global structure and evolution of the Galaxy. The detailed understanding of star formation and evolution of stars and gas in the Galaxy is directly relevant to star formation in other galaxies. The nature of the feedback mechanism of massive star formation is pivotal to the evolution of galaxies. STO-2 thus addresses NASA's goals and research objectives on galaxy evolution and star formation. STO-2 addresses the high priority goals:

1. ***Determine the life cycle of Galactic interstellar gas.***
2. ***Study the creation and disruption of star-forming clouds in the Galaxy.***
3. ***Determine the parameters that affect the star formation rate in a galaxy.***
4. ***Provide templates for star formation and stellar/interstellar feedback in external galaxies.***

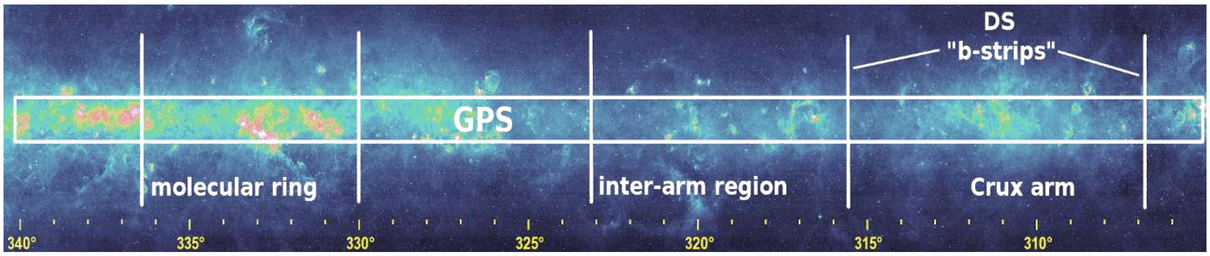

Figure 2: Midcourse Space Experiment (MSX) 8.3 μm map of the Galactic Plane from the Molecular Ring through the Scutum-Crux spiral arm. Annotations highlight regions to be explored by STO-2 in its Galactic Plane Survey (GPS) and the deeper survey *b* strips (DS).

1.2 Summary: Mission Approach

To achieve these timely scientific goals, STO-2 will map the pivotal [C II] 158 μm and [N II] 205 μm lines. **[C II] is extraordinarily versatile**; it probes ionized gas (HII), atomic clouds (HI), and the photo-illuminated surfaces of molecular clouds. **[C II] provides a unique measure of the interstellar medium that is not possible with HI or CO line emission alone**: it directly distinguishes *atomic clouds* from diffuse intercloud HI gas (unlike HI which is not density sensitive), identifies "CO-dark" molecular gas not associated with CO emission, and probes mass flows from molecular cloud surfaces. Thus, in combination with CO, HI and [NII], [C II] identifies and measures the formation and destruction of clouds in ways not possible with HI and CO images. The [N II] line, in addition to providing an extinction-free probe of ionizing radiation and star formation rate in the Galaxy, can be used to isolate the fraction of [C II] line emission that comes from ionized gas.

To map the [C II] and [N II] lines over a large portion of the southern Galactic Plane, STO-2 will utilize two heterodyne receiver arrays to produce a total of eight beams in the focal plane, each with 1024 spectral channels. In the long duration (14 to 55 day) flight STO-2 will map a 35^ox1^o area including the Galactic molecular ring (Figures 1 & 2) as well as 5 deeper strips in Galactic latitude b=±2° in selected arm and interarm regions. STO-2 achieves arcminute angular resolution and 3σ intensity limits of 7×10^{-6} and 1×10^{-6} erg s^{-1} cm^{-2} sr^{-1} in the [C II] and [N II] lines, respectively, sufficient to resolve both spectrally and spatially all Giant Molecular Clouds (GMCs), all significant H II regions, and all cold neutral medium (CNM) clouds with $A_V \geq 0.4$ mag (potential building blocks of GMCs) in the surveyed region. The STO-2 heterodyne receivers provide sufficient velocity resolution and coverage to detect and resolve line emission from all significant Galactic clouds along the line of sight. The deliverable data products include:

1) A high fidelity database of spatially and velocity resolved [C II] 158 μm and [N II] 205 μm fine-structure line emission in the Galaxy.

2) A combination of STO-2's data with existing line and continuum surveys to characterize the structure and dynamics of interstellar clouds and their relation to star formation.

The data are produced in large scale (Galactic Plane Survey) and selective (Deep Survey) modes:

- **GPS: Galactic Plane Survey:** 305° < l < 340°; −0.5° < b < 0.5°. The GPS contains more than 10^5 spatial pixels and has 10^4 times higher sensitivity than FIRAS/COBE when convolved to the same resolution. STO-2 will catalogue all neutral clouds with $A_V \geq 0.4$ mag. and all ionized clouds with emission measure > 50 cm^{-6} pc, detecting all significant interstellar material in the Galaxy.
- **DS: Deep Survey** of arm and interarm regions defined by ancillary observations from AST/RO and Mopra telescopes: b = −2° to +2° strips at l = 315.97°, 323.13°, 330.00°, 336.42° and 342.54°, with Δl=0.05°. Sensitivity will be 3-4 times higher than of **GPS**.

2 Science Goals & Objectives

2.1 Background

Via spatially and spectroscopically resolved [CII] and [NII] line emission, STO-2 probes the formative and disruptive stages in the life cycles of interstellar clouds. It reveals new insight into the relationship between interstellar clouds and the stars that form from them, a central component of galactic evolution.

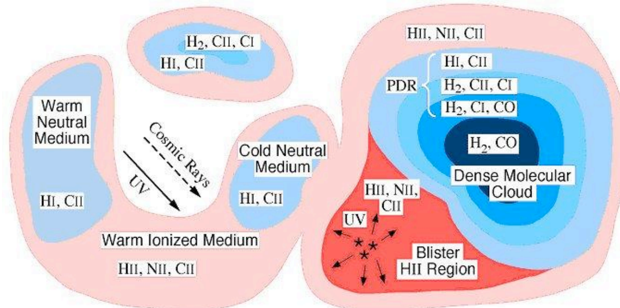

Figure 3: Schematic representation of ISM com-ponents. STO-2 detects and maps in the Galaxy the higher column density CNM component, the H_2/C^+ "CO-dark" component, the photodissociation region (PDR) surfaces of molecular clouds, the H II component, and (with H I) the WNM/CNM ratio.

The current multi-phase model of the interstellar medium (ISM) is shown schematically in Figure 3. Neutral interstellar gas is the dominant mass component of the ISM and tends to exist as two phases in rough thermal pressure equilibrium: a diffuse warm neutral medium (WNM) with hydrogen densities at the solar circle of n~0.3 cm^{-3} and T~8000 K, and denser, colder "diffuse HI clouds" (cold neutral medium: CNM) with n~40 cm^{-3} and T~70 K (Heiles & Troland, 2003; Wolfire et al., 2003). Turbulence provides a broader spectrum of conditions (Mac Low et al., 2005; Gazol et al., 2005; Jenkins & Tripp, 2011; Kim et al. 2011), but thermal balance drives neutral gas toward these phases. With sufficient shielding column, N > 10^{20} − 10^{21} cm^{-2} of hydrogen nuclei, the CNM clouds begin to harbor molecular interiors. These H_2/C^+ clouds are sometimes called "CO-dark clouds" because they cannot be detected in HI, H_2, or CO emission. This component has been indirectly inferred by γ ray (e.g., Grenier et al. 2005), submillimeter dust emission (Planck Collaboration et al. 2011), and IR dust extinction maps (Paradis et al. 2012), but direct observations of it and a determination of how it contributes to the ISM can only be achieved using the sensitive, large-scale [CII] and [NII] survey capabilities of STO-2. The CNM and CO-dark clouds are the building blocks of giant molecular clouds (GMCs).

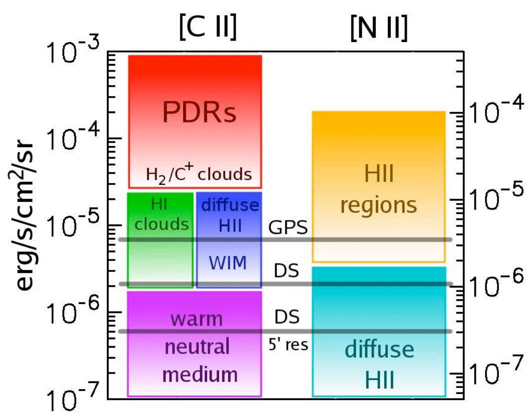

Figure 4: Comparison of STO-2's sensitivity with [C II] and [N II] integrated intensity for various ISM components. HI and H_2/C^+ clouds (CO-dark gas) constitute the building blocks for molecular clouds. HII regions and bright PDRs often include photoevaporating gas from molecular cloud destruction. The 3σ sensitivities of STO-2's two survey modes (see §1.2 for definiti*ons) are indicated by horizontal lines*.

WNM is converted into CNM clouds via thermal instability either if the ultraviolet radiation field (heating) diminishes (Parravano et al., 2003) or if the pressure increases because of the passage of a (e.g., supernova) shock wave (McKee & Ostriker, 1977). GMCs presumably form from a large assemblage of CNM clouds; the leading theoretical models invoke gravitational instabilities in huge regions 0.5-1 kpc in size along spiral arms (Ostriker & Kim, 2004). Other mechanisms have been invoked such as the convergence of flows in a turbulent medium (Hennebelle & Perault, 2000; Heitsch et al., 2006).

Figure 4 shows the [C II] and [N II] intensities of these cloud components with the nominal STO-2 survey mode sensitivities, while Figure 5 shows a Herschel/GOTC+ [C II] observation with complementary CO and H I spectra along a line of sight through the Galaxy. This pointed observation shows that many kinds of clouds are detectable with modern heterodyne receivers at THz frequencies. This single pointing with Herschel foreshadows the large scale mapping of these lines that will be possible with STO-2.

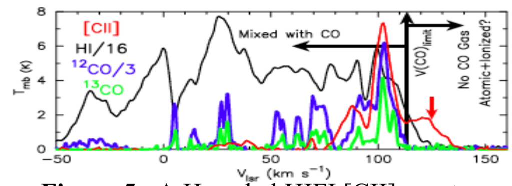

Figure 5: A Herschel HIFI [CII] spectrum from GOT C+ program (Velusamy et al. 2012) of study Scutum-Crux spiral arm tangency.

2.2 Goal 1: Map the Entire Life Cycle of Interstellar Gas

STO-2 will (1) map and catalog the size, mass distribution, and internal velocity dispersion of atomic, molecular and ionized clouds as a function of Galactic position. It will (2) identify the physical origin of [C II] emission, (3) allow construction of the first large-scale thermal pressure map of the ISM, (4) the first map of the gas heating rate, and (5) a more sensitive, detailed map (using [N II]) of the star formation rate.

(1) STO-2 will survey spiral arm/ interarm regions and a large portion of the molecular ring, where much of the star formation occurs in the Galaxy. Galactic rotation causes a distance-dependent velocity separation of the clouds along the line of sight, and STO-2's high spectral resolution allows us to then determine the distance to the clouds using standard methods. Therefore, *STO-2 will provide an unprecedented 3D global map of the distribution of clouds of ionized gas, atomic gas, and molecular clouds (via their [C II]-emitting surfaces) as a function of Galactocentric radius (R) and height (z) in the Galaxy*. We can compute the density of clouds (*i.e.,* the number of clouds per kpc^3) and their size distribution as functions of R and z, and see how clouds are clumped together in spiral arms or supershells. In regions of cloud clustering, the superb velocity resolution of STO-2 will measure the random motions of clouds, and diagnose *large-scale turbulence*.

(2) Because [C II] line emission can come from ionized, atomic clouds, and from atomic and molecular surfaces of Giant molecular clouds (CO-dark H_2 material), its origin can be difficult to disentangle toward complicated lines of sight, particularly in the Inner Galaxy. For example, COBE FIRAS observations show that the ionized component of the ISM radiates strongly in both [C II] 158 μm and [N II] 205 μm (Wright et al., 1991). To distinguish the origin(s) of [C II] emission, velocity-resolved measurements of the distribution of the ionized gas must be made in [N II] and compared to the [C II] distribution, along with comparisons with H I and CO. *STO-2 will conclusively determine the origin of the [C II] emission*, by measuring the portion of the [C II] emission coming from each component.

(3) The ratio of CNM [C II] to H I intensity (which determines their column and mass)

provides a measure of the [C II] emissivity per H atom which rises monotonically with gas density and thermal gas pressure. *The STO-2 survey of a large portion of the Galactic Plane enables the construction of the first barometric maps of the Galactic disk*, determining the ambient thermal pressure in different environments (*e.g.,* spiral arms vs. interarm regions, turbulent vs. quiescent regions). The STO-2 team's theoretical models are vital to determining the density, temperatures, and thermal pressures in the clouds. These can then be correlated with star formation rates to understand stellar/interstellar feedback mechanisms.

(4) The [C II] line dominates the cooling of CNM clouds. From its intensity we directly obtain the gas heating rate of clouds as a function of radius throughout the Galaxy. Besides the fundamental interest in tracing the energy flow in the Galaxy, the observations also can test our theoretical hypothesis that the heating is provided by the grain photoelectric heating mechanism in diffuse clouds.

2.3 Goal 2: Reveal the Formation & Destruction of Clouds

By observing the [C II] line, STO-2 will reveal clouds clustering and forming in spiral arms, super-shells, and filaments, and follow the growth of clouds to shield molecules and eventually to become gravitationally-bound GMCs. STO-2 will observe "CO-dark" clouds that cannot be seen in H I, H_2, or CO emission, and estimate their contribution to GMC formation. STO-2 will also directly measure the subsequent dissolution of GMCs into diffuse gas via stellar feedback.

Formation of diffuse H I clouds (CNM). Turbulence may play an important role in the formation and evolution of interstellar clouds. In a standard scenario where CNM clouds are formed from WNM gas by thermal instability, we can picture the role of turbulence in two ways: large scale instabilities, density waves and supernovae drive compressional motions that increase the thermal pressure and trigger the thermal instability (de Avillez & Breitschwerdt, 2005). Alternatively, regions undergoing thermal instability may generate turbulence, and convert the CNM into a complex network of pancakes and filaments (Kritsuk & Norman, 2002). STO-2 will perform the survey of both the spatial structure and kinematics of diffuse gas in transition between phases necessary to tell us the role of turbulence and dynamic pressure in the life-cycle of the ISM.

Formation of GMCs. The formation of GMCs is a prerequisite for massive star formation, yet the process has not yet been directly observed! STO-2 is designed with the unique combination of sensitivity and resolution needed to observe cold atomic and CO-dark clouds being assembled into GMCs (Figure 6). Four mechanisms have been proposed to consolidate gas into GMC complexes (Elmegreen 1996): (1) self-gravitating instabilities within the diffuse gas component, (2) random collisional agglomeration of clouds, (3) accumulation of

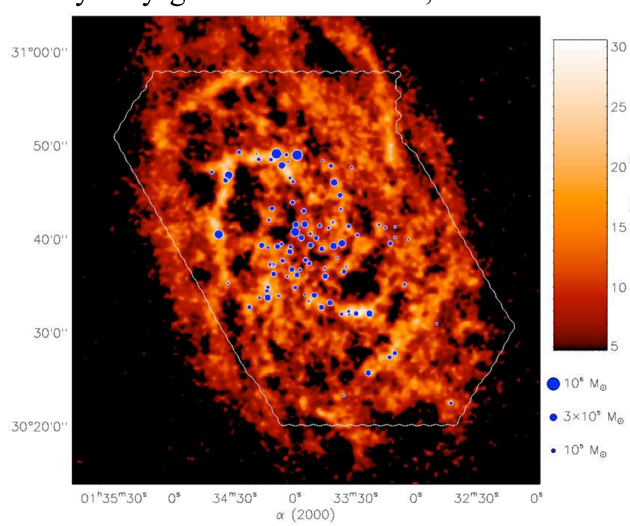

Figure 6: GMCs locations (blue dots) in the nearby spiral galaxy M33 are overlaid upon an integrated intensity map of the HI 21 cm line (Engargiola et al., 2003). These observations show that GMCs in M33 are formed from large structures of atomic gas, and foreshadow the detailed study that STO-2 will provide of GMC formation in the Milky Way.

material within high pressure environments, e.g. shells and rings generated by OB associations, and (4) compression in the randomly converging parts of a turbulent medium. STO-2 can distinguish these processes from each other and consider new cloud formation schemes by:

- Accounting for all the molecular hydrogen mass (the H_2/C^+ CO-dark clouds as well as the H_2/CO clouds) when computing global measures of the interstellar medium.
- Clearly identifying CNM clouds via the density sensitivity of [CII] compared to HI 21 cm.
- Constructing spatial and *kinematic* comparisons with sufficient resolution, spatial coverage and dynamic range to discriminate the above 4 scenarios.

The high spectral resolution of STO-2 enables crucial kinematic studies of the Galaxy. STO-2 will determine the kinematics and thermal pressures of most supershells, fossil superrings, and molecular clouds just condensing via gravitational instability of old superrings. STO-2 will detect many of the CNM clouds formed out of WNM in the shells, and the larger column density clouds, which may harbor H_2. With these detections STO-2 will determine the role of OB association-driven supershells and superrings in the production of molecular clouds and the cycling of gas between the various phases of the ISM.

STO-2 reveals the disruption of clouds. [CII] and [NII] measure the photoevaporating atomic or ionized gas driven from molecular clouds with UV-illuminated surfaces, thereby converting the clouds to WNM, CNM, or to diffuse H II regions. Thus, STO-2 can directly determine the rate of mass loss from catalogued clouds, and their destruction timescales.

2.4 Goal 3: Map the Star Formation Rate in the Galaxy

STO-2 will probe the relation between the gas surface density on kpc scales and the [N II]-derived star formation rate, so that we might be able to better understand the empirical Schmidt-Kennicutt Law used to estimate the star forming properties of external galaxies.

Star formation within galaxies is commonly described by two empirical relationships: the variation of the star formation rate per unit area with the gas surface density (atomic + molecular), Σ_{SFR} (Schmidt, 1959) and a surface density threshold below which star formation is suppressed (Kennicutt, 1989; Martin & Kennicutt, 2001). This empirical relationship is used in most models of galaxy evolution with surprising success given its simplicity. In practice, the relationship is derived by comparing a tracer of star formation to a tracer of interstellar gas; it has been evaluated from the radial profiles of Hα, H I, and molecular emission for tens of galaxies. The mean value of the Schmidt index, n, varies from 2 (Schmidt, 1959) for star formation vs. H I, to ~1 for star formation compared to tracers of high-density H_2 gas (Onodera et al. 2010).

STO-2 will help us understand the origin of the Schmidt Law. The [N II] line is a potentially excellent tracer of the star formation rate, measuring ionizing luminosity with high sensitivity, angular and spectral resolution, unaffected by extinction (Bennett et al. 1994). The [C II] line, in conjunction with H I (21cm) and CO line emission, provides the first coherent map of the neutral interstellar gas surface density and its variation with radius. STO-2 data will correlate the thermal pressures on the surfaces of GMCs (which may relate to the formation of cores inside) with surface densities of H I and CO. Extensive, velocity-resolved studies of our Galactic ISM with STO-2 will provide the detailed, complete picture of star formation that will enable us to understand the Schmidt law.

2.5 Goal 4: Construct a Milky Way Template

[C II] 158 μm, the strongest Galactic cooling line, is the premier diagnostic tool for studying relatively nearby galaxies in the far-infrared (FIR) and more distant galaxies in the submillimeter (*e.g.* with the Atacama Large Millimeter Array). To interpret the measurement of extragalactic [C II] one must turn to the Milky Way for the spatial resolution needed to disentangle the various contributors to the total [C II] emission. At present, there is debate on the dominant origin of the [C II] emission in the Galaxy: diffuse H II regions, CNM clouds, or the surfaces of GMCs. ***STO-2 will solve this mystery.*** The [C II] and [N II] images, combined with ancillary CO and HI observations, identify each component of [C II] emission. The STO-2 mission covers a broad range of density and UV intensity, thus establishing the relationship between physical properties, [C II], [N II], CO, H I, FIR emission, and star formation. This study will provide a ***"Rosetta Stone"*** for translating the global properties of distant galaxies into reliable estimators of star formation rate and state of the ISM.

3 Science Requirements

The science goals outlined in Section 2 define a clear set of measurement requirements which the instrument and mission must be able to perform (Table 1). These requirements define the STO-2 surveys, which will span a maximum of 35 square degrees at moderate sensitivity. STO-2 will fully sample both [CII] and [NII] emission over large regions of sky with ~1' angular resolution and ~1 km/s velocity resolution. STO-2's Deep Survey (DS) will be sensitive to truly diffuse cloud column densities corresponding to A_V = 0.1 mag and spanning the full emission scale height of the Galaxy. The Deep Survey is comprised of five 4-degree linear strips in Galactic latitude, spaced equally in Galactocentric radius, including the Molecular Ring, Scutum-Crux spiral arm, and inter-arm regions. These strips are chosen to match b-strips made both by AST/RO (in [C I] and mid-J CO lines) and Mopra (in CO J=1-0). Deep surveys allow us to detect faint [C II] and [N II] from diffuse ionized clouds, probe the formation of small molecular clouds, and help determine the origin of most of the [C II] emission in the Galaxy.

4 Complementarity to Existing Data Sets and with Other Missions

STO-2 will provide the community with a totally unique [C II] and [N II] survey, enabling quantitative extraction of many physical parameters of the interstellar medium in a 3D data cube.

4.1 Relationship to Existing Data Sets

CO: The Mopra telescope in Australia has been upgraded for the STO project to make rapid carbon monoxide J = 1-0 surveys of the southern sky in three carbon monoxide isotopologues (^{12}CO, ^{13}CO, and C^{18}O). We have already obtained maps in each isotopologue from b = ±0.5° and l = 323° to 340°, at subarcminute angular resolution and 0.1 km/s spectral resolution. Funds have been obtained by our Australian collaborators to support the required telescope time. The CO J=1-0 surveys will complement the STO-2 survey by helping to identify molecular clouds whose surfaces STO-2 detects and whose ionized gas seen in [N II] and warm neutral gas seen in [C II] may be expanding into the diffuse ISM (Onishi et al., 2005).

H I: The STO-2 surveys enhance substantially the interpretation of existing H I surveys McClure-Griffiths, 2005). The H I emission maps are sensitive only to column, whereas [C II] is sensitive to density times column. [C II] therefore picks out the cloud regions with density > 30 cm^{-3}, whereas the H I is often dominated by the WNM emission (see Figure 5).

Table 1: *Flow of Requirements, from Science goals to Instrument Implementation*		
Pertinent Science Goal(s)	**Measurement Requirement**	**Instrument requirement**
Life cycles (1), Formation of clouds (2)	Angular resolution to resolve ~3 pc clouds in the 5kpc Molecular Ring.	1 arcminute resolution requires 0.8m aperture at 1-2 THz.
Life Cycles (1), Formation of clouds (2), Galactic SFR (3), Milky Way template (4)	Spectral resolution to resolve spectral lines and measure cloud, shell and superbubble dynamics (km/s scale).	High-resolution heterodyne spectroscopy with 1 km/s spectral channels.
Life Cycles (1), Galactic SFR (3), Milky Way template (4)	Spectral bandwidth to span the Galactic rotation curve from l=305^o to 340^o .	V_{LSR} = -140 to +20 km/s requires max 1 GHz bandwidth at [CII].
Life Cycles (1), Galactic SFR (3), Milky Way template (4)	Mapping coverage to sample the inner Molecular Ring, interarm regions, and at least one major spiral arm.	Mapping longitudes from l=305^o to 340^o and coverage of the molecular scale height (-0.5^o to 0.5^o) in latitude.
Life cycles (1), Formation of clouds (2)	Sensitivity to sense CNM clouds aggregating into molecular clouds	3σ detectability of 1 K km/s = 7x10^{-6} erg/s/cm^2/sr in [CII].
Life cycles (1), Galactic SFR (3), Milky Way template (4)	Sensitivity to sense HII regions with emission measure of 50 cm^{-6} pc.	3σ detectability of 0.3 K km/s = 1x10^{-6} erg/s/cm^2/sr in [NII] w/ smoothing.
Life Cycles (1), Formation of clouds (2), Galactic SFR (3)	Sensitivity and mapping coverage to cover the full [CII] and [NII] scale heights to A_V = 0.1 mag.	Deep survey spanning -2^o to +2^o in latitude, with 3σ sensitivity 0.3 K km/s =2x10^{-6} erg/s/cm^2/sr in [CII].
Life Cycles (1), Formation of clouds (2), Galactic SFR (3), Milky Way template (4)	Sufficient mapping speed to span 35 square degrees of mapping within one LDB flight from Antarctica.	>1 sq.deg/day requires THz arrays of ~4 pixels per frequency band at current sensitivities (T_{rec} = ~1500K DSB).

[C I]: Moving from the CNM through the surfaces of molecular clouds to their cores, the predominant form of carbon changes from C^+ to CO, with atomic C abundant in the transition region. The STO team has access to guaranteed observing time at the NANTEN2 telescope in Chile to obtain complementary data for the regions covered by STO in the [C I] 370 μm and 609 μm lines with angular resolutions of 25" and 45", respectively. In addition, a southern Galactic Plane survey of the 609 and 370 micron [C I] lines (at ~2' angular and 1 km/s spectral resolution) is currently being performed by the High Elevation Antarctic Terahertz (HEAT) telescope now in operation at 'Ridge A', the summit of the high Antarctic plateau (Kulesa et al. 2011). These data are in the public domain with no proprietary period. Maps from STO-2 coupled with CO and [C I] data, will follow carbon in all its forms in position, velocity, cooling rate, temperature and pressure as the interstellar gas evolves.

Infrared Continuum Surveys: MSX, IRAS, and Spitzer GLIMPSE and MIPSGAL Galactic plane surveys permit locating CO-dark clouds, supershells, and star forming regions in the plane of the sky. With [CII] observations from STO-2, they can be located along the line of sight.

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4.2 Complementarity with Other Missions

STO-2 builds upon the heritage of three pioneering surveys that provided coarse pictures of [C

II] and [N II] emission in the Galaxy: COBE (spatial resolution 7°, velocity resolution >1000 km/s), BICE (spatial resolution 15′, velocity resolution 175 km/s), and the Infrared Telescope in Space (IRTS, spatial resolution 10′, velocity resolution 750 km/s). *STO-2 has sensitivity to accurately measure the [CII] along individual lines of sight, with orders of magnitude improvement in spatial and spectral resolution.* None of these missions had sufficient spectral or spatial resolution to locate clouds, or separate one cloud from another along a given line of sight, and thus could not draw specific conclusions about cloud properties or distributions, or even the origin of the [CII] or [NII] emission (Hollenbach & Tielens, 1999). The Spitzer Space Telescope has no spectroscopic capability at these wavelengths.

The Herschel Space Observatory (HSO) is in its last months of operation and the observing program has been finalized. The high spectral resolution HIFI instrument on HSO has made a number of small maps of [C II] and [N II] emission from active star-forming cores and their adjacent cloud interfaces. The Herschel Galactic Observations of Terahertz C+ (GOT C+) project surveyed the Galactic disk in the [C II] line with HIFI's sub km/s resolution. GOT C+ measured 500 lines-of-sight (with a narrow 15 arcsec beam) separated typically by 0.5 to 1 degree. GOT C+ demonstrated the utility of velocity-resolved [C II] observations (together with complementary HI and CO surveys) to trace the different phases of the ISM. In particular, the GOT C+ survey found a significant number of CO-dark gas components (Langer et al. 2010, Velusamy et al. 2010) and detected CO-dark gas throughout the inner Galaxy (Pineda et al. 2013). STO-2 will map and measure the motions of these dark clouds. Due to its coarse sampling, the GOT C+ survey lacks a picture of the surroundings of individual lines-of-sight, and ***STO-2 will provide the full picture of clouds that are forming and dissipating.***

SOFIA with its present heterodyne instrument GREAT, and in particular with its future array heterodyne receiver upgrades, will be efficient at mapping the detailed distribution and structure of ISM clouds at high spatial resolution over small areas, but ***will not*** have sufficient observing time to conduct large scale mapping. The STO-2 survey in the [C II] and [N II] lines will provide guidance to SOFIA follow-up studies of small-scale structure in confined areas of interest. STO-2 will be unique in providing maps of large areas at moderate spatial but full spectral resolution, thus obtaining an unbiased sample of ISM clouds and their motions across the Milky Way.

The Gal/Xgal Ultra-Long Duration Balloon-borne Spectroscopic/Stratospheric THz Observatory (*GUSSTO*) is a proposed Explorer Mission of Opportunity managed by the University of Arizona in partnership with the Johns Hopkins University Applied Physics Laboratory (APL). *GUSSTO* is a cryogenic balloon-borne, 1.1 m off-axis telescope designed to stay aloft for 100 days or more using a super pressure balloon (SPB) developed by NASA. During its time aloft *GUSSTO* will survey ~150 square degrees of the inner Milky Way and all of the Large Magellanic Cloud (LMC) in three important interstellar lines: [CII], [OI], and [NII] at 158, 63, and 205 μm, respectively. The *GUSSTO* project has just recently completed a Phase A design study and is awaiting a selection decision from NASA. The *GUSSTO* instrument is an expanded version of what is proposed for STO-2. If *GUSSTO* is selected for flight, we will negotiate with NASA to use STO-2 funding to increase the survey range of *GUSSTO* to include the wedge of the Milky Way targeted by STO-2 (Figure 1). Depending on funding schedules, it may be possible to first fly STO-2 and then *GUSSTO*. The additional funds could also permit a northern hemisphere cryogenic test flight of *GUSSTO*, from which several targets only accessible from the northern hemisphere could be surveyed in [CII], [NII], and [OI].

STO-2 benefits tremendously from the experience gained on STO-1 and recent breakthroughs in THz local oscillator (LO) technology by Co-I's at JPL. The STO-2 instrument package will be more sensitive, simple, and robust than on STO-1. The addition of a small, efficient, cryocooler will extend the mission's cryogenic lifetime to ~60 days. The entire instrument package will go through a thermal-vac test before flight.

5 Science Implementation

5.1 The 2012 STO-1 Campaign

Following a successful I&T and Hang Test in Palestine (TX) in August 2011, the gondola was cleared for flight and shipped to Antarctica. At the beginning of November 2011 STO team members deployed to McMurdo Station to participate in the integration, testing, and launch campaign. The field team was supported remotely by other STO team members at UofA, APL, and Oberlin College. APL hosted the MOC, while Oberlin hosted the SOC. In Antarctica the gondola was reassembled and all subsystems reintegrated, tested and calibrated (Sec. 5.2). On December 26 we had the Hang Test with the STO payload in full flight configuration (see Figure 7). Following a successful Hang Test STO was cleared for launch. After 8 unsuccessful launch attempts, mostly due to bad weather, STO was finally launched on January 15, 2012. STO reached 40 km altitude in about 3 hours. For about 30 hours we took advantage of the high rate line-of-sight telemetry and commanding link to check-out all the subsystems and perform instrument commissioning. Following loss of LOS communications, contact with the payload was maintained through TDRSS relay radio link, and operations control was handed over to the

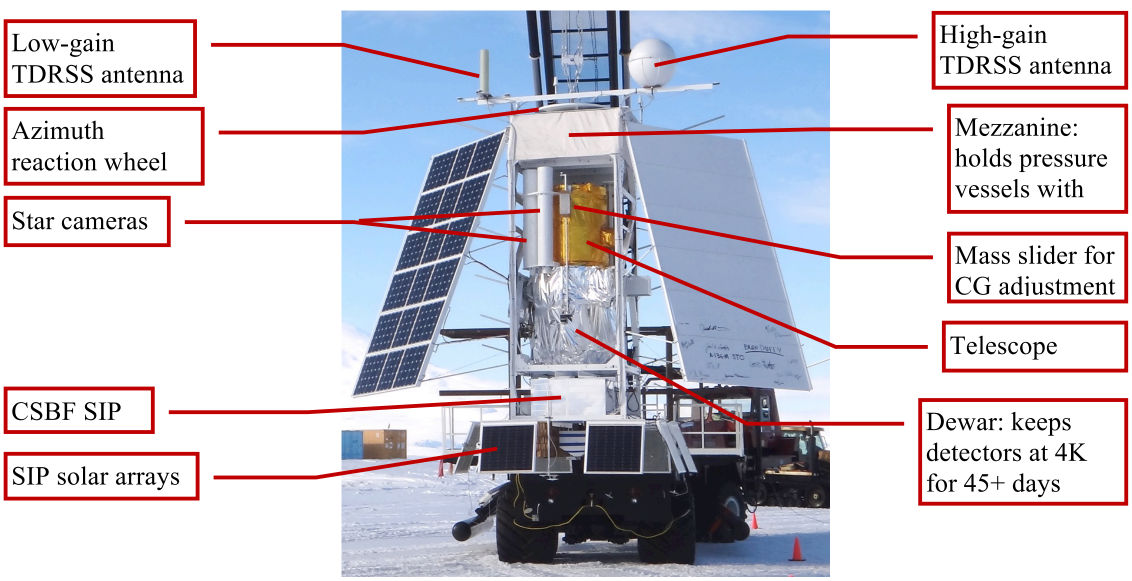


Figure 7: The STO-1 gondola ready for its first scientific flight from Antarctica in January 2012.

Mission Operation Center at APL and the Science Operation Center at Oberlin College, where a staff of three people monitored the payload health and commanded changes in the science operations.

5.1.1 In-Flight Performance

All command & control systems worked flawlessly with the exception of a glitch in part of the software for the star camera, which caused the star recognition software to work only intermittently. The root cause was identified in-flight and the issue was successfully completely resolved with a software patch installed about 5 days into the flight. The power system worked better than expected and we always had large power margins throughout the mission. The command and control software worked nearly perfectly. We only had to perform some small in-flight changes to account for some anomalous behavior that was not predicted by the flight simulations conducted prior to launch.

5.1.2. Pointing System

After fixing an initial error in the star camera software in-flight, STO-1 had excellent pointing stability when in active tracking mode. Compared to the performance exhibited during the 2009 test flight, the overall pointing stability during the 2012 Antarctic flight was improved by a factor of 5: < 2 arcsec RMS Jitter almost indefinitely, < 5 arcsec peak-to-peak almost indefinitely, and < 2 arcsec for up to 10 minutes at a time. Despite these impressive results, not everything worked as predicted. During the flight we noticed a previously unpredicted fast gondola roll at a 0.5 Hz frequency and with amplitudes from 10 up 100 arc seconds. A gondola roll has an effect on the azimuth pointing error depended on the telescope elevation, according to the following relationship: *Azimuth error = sin(telescope elevation) * Roll angle.* Therefore, the higher the telescope elevation is, the higher is the azimuth pointing error on the sky induced by the gondola roll. One way to compensate for this error is to steer the gondola in azimuth accordingly based on the magnitude of the roll and the telescope elevation angle. However, since the frequency of this roll is quite high and the gondola momentum of inertia is also high, this method requires fast and substantial changes in the reaction wheel angular momentum. This causes increased jitter and higher power draw by the azimuth motor. This method was attempted during the STO Antarctic flight with moderate success.

For STO-2 we will mitigate this issue by implementing a roll compensation system with a reaction wheel mounted vertically with its rotation axis pointed in the gondola front-back direction. The reaction wheel will be commanded by the PCS computer using input from the roll gyroscope and will use an algorithm very similar to the one to command the azimuth reaction wheel. As proof of concept we have already developed a computer model simulating the dynamics of the STO gondola and implemented a PID controller system that commands the roll reaction wheel to compensate for the gondola roll pendulation. Dynamical models with the additional reaction wheel indicate the gondola roll is dampened in amplitude by more than a factor of 10 and only a minor residual low frequency roll easily address by the azimuth control system remains. All roll compensation electronics will be thermal-vac tested and the full pointing system tested with the gondola suspended from a crane.

5.1.3 Helium Loss on STO

Approximately four days into the flight, temperatures within the focal plane unit began to rise slowly, indicating a premature loss of liquid within the dewar. Figure 8 shows the temperatures of the various stages of the STO cryostat during ascent. The cold plate, NII, and CII mixer temperatures are seen to decrease during ascent, indicating the absolute

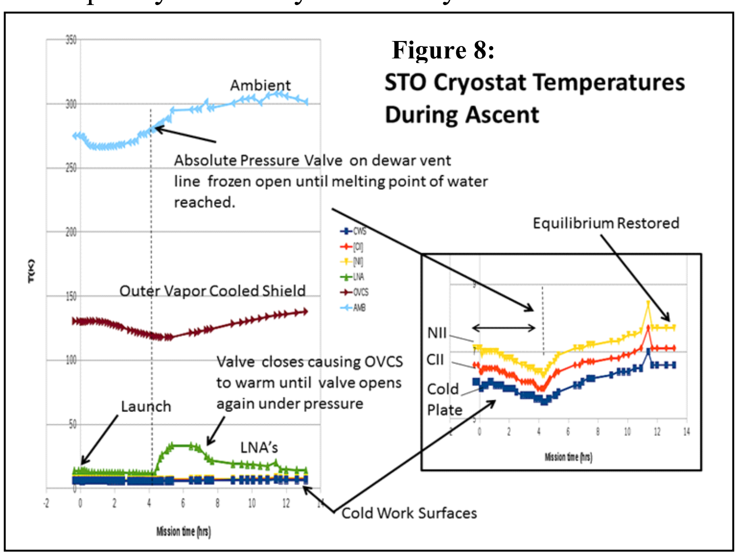


Figure 8: STO Cryostat Temperatures During Ascent

pressure valve on the dewar's helium vent line was stuck open, presumably by ice. With the vent line open the pressure above the helium reservoir was at ambient, corresponding to ~3 millibar by the time float altitude was achieved. This low pressure resulted in ~50% of the liquid helium boiling off prematurely. Once the gondola reached an ambient temperature > 273K, the ice melted and the valve snapped shut, preventing gas flow through the vent line. This in turn caused the LNA's (which are cooled by the helium gas flowing through the vent line) to warm up until the pressure in the line increased to the valve's rated value (14 psi). Once the valve opened a regulated flow of helium gas through the vent line was established and equilibrium operation was restored. On STO-2 we will use a simple heater (*e.g.* ~3 watt power resistor) to keep the pressure regulator assembly safely above freezing during ascent. Such heaters were used on other pieces of hardware flown on STO. Once the liquid helium was exhausted, STO then entered its Warm Mission Phase, where it continued observations using an uncooled [CI] receiver until termination. While running much warmer than expected, all instrument electronics worked well throughout the flight and suffered no harm from the landing. The flight dewar was also recovered unharmed. Example [CII] and [CI] observations made during the STO flight are shown in Figures 9 and 10. Sadly, a *cold cryostat and fully functioning pointing system were mutually exclusive* during the STO-1 flight, and only a handful of [CII] detections were made, far from the uniformly sampled 35 square degrees baselined in the STO proposal (and again here).

5.1.4 Flight Termination

The flight lasted almost 14 days performing a nearly perfect circle around Antarctica at an average altitude of about 37 km. The STO flight was terminated on January 29, 2012 while the balloon was flying above the Ross Ice Shelf. STO landed safely and relatively undamaged on the Ross Ice Shelf about 155 miles away from McMurdo Station.

In summary, the STO-1 flight represented a technical success; nearly every aspect of the system was validated and most issues were successfully solved in-flight. However, the baseline science mission objectives were not met, mostly due to the initial loss of liquid helium. To meet these objectives, we are proposing this re-flight, STO-2, with an improved, <u>simplified instrument package</u> and <u>augmented system testing plan</u> based on lessons learned from STO-1, below.

5.2 Lessons Learned from the STO Antarctic Flight

- **Ship the flight cryostat in a steel-reinforced container and have a team member travel with it.** During shipment from the US to Antarctica the container carrying the flight dewar was struck and damaged by a forklift. One vacuum seal was compromised and had to be repaired on-site. This accident resulted in a ~2 week launch readiness delay.
- **Heat the absolute pressure regulator.** As discussed above (Sec. 5.2.2), the absolute pressure regulator on STO-1's dewar vent line temporarily froze open during ascent, resulting in a loss of liquid helium. The same pressure regulator was successfully used during the STO Ft. Sumner test flight. In future flights the regulator will be heated to keep it above freezing.
- **Carry back-ups of as many mission critical components as possible**. Within a few days of our first launch attempt one of the instrument's three local oscillators (LO's) died, making it necessary to use a back-up unit with a different tuning range (1380-1460 GHz). The low LO power at the [NII] end of its tuning range made [N II] observations untenable.

- **Design flight hardware to be as simple and modular as possible.** This is especially true for balloon payloads that are assembled and disassembled in the field. For STO, the complexity of instrument assembly was driven by the tight mechanical tolerances required by the THz optics. These tolerances also impacted instrument performance, reducing available mapping speed. Fortunately, for STO-2, new high-power LO's have been developed that make the assembly and performance optimization *much* easier. For example, STO adopted a *Fabry-Perot Interferometer* to diplex the weak LO beam into the cryostat, which proved nearly impossible to align optically for all elements of STO's 4-beam mixer array. In contrast, STO-2's LO diplexing will be performed with a simple 90/10 beamsplitter.
- **Maximize TDRSS link availability.** During the STO flight over Antarctica, it was only possible to achieve the desired higher data rates through TDRSS about half the time. This was partly due to occasional obstructions in the field of view of the high gain TRDSS antenna and performing gondola azimuths slews that outpaced the ability of the high gain antenna to keep up. On STO-2 telecommunication antennas will be located to provide an unobstructed view of TDRSS when it is available. In addition, gondola slews will be coordinated between the MOC and CSBF.
- **System level testing cannot be overdone.** During flight several software anomalies arose that were not detected during ground testing. One of these impacted pointing early in the mission, making closed loop pointing intermittent. Fortunately, we were able to resolve these issues in flight. For STO-2 we have scheduled extensive and repeated I&T periods to validate and verify the performance of 1) components, 2) subsystems and 3) the integrated flight payload.
- **Implement roll compensation system** to dampen fast side-to-side gondola pendulation that affects azimuth pointing (see Sec. 5.1.2).
- **Design system to allow pointing at low elevation and develop a pointing model to establish alignment offset between star cameras and THz beam.** The location of the helium vent line on the STO-1 dewar prevented the telescope from being pointed to sufficiently low elevations to observe planets. On STO-2 a valve will be added that allows the vent line to be temporarily closed when pointing the telescope at low elevations. A pressure regulator (heated) will be placed in parallel with the valve to insure the helium tank is operated well within design margins.
- **Implement a focusing mechanism for the narrow field star camera.** The narrow field star

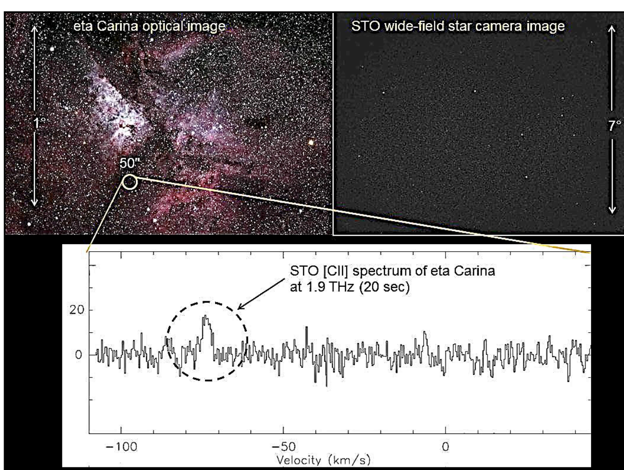


Figure 9: [CII] line observed toward Eta Carina during STO flight.

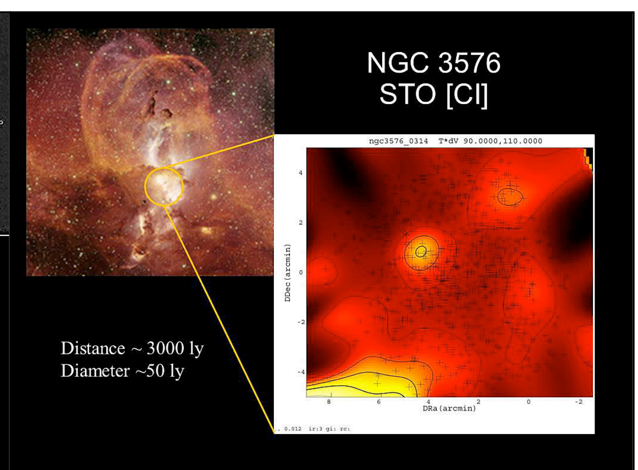


Figure 10: [CI] map of star forming region NGC3576 made during STO flight.

camera had a manual focus mechanism that could only be operated from the ground. During ground calibrations the focus was manually adjusted to produce sharp star images. However, once we reach float altitude, we noticed that the narrow field star camera images were blurry. We could still see stars down to about magnitude 6 but could not see stars at the magnitude 10 level that we expected preflight. For STO-2, we will implement a simple focusing mechanism, based on high TRL hardware, which will allow adjustment of the narrow field star camera focus in flight.

- **Thermal-Vac Test full instrument.** The full STO-2 flight cryostat will be tested wet (i.e. with liquid helium) in a thermal vac chamber (either at APL or CSBF) before shipment to Antarctica. This will allow the team to identify and solve potential problems (e.g. with pressure regulators) before flight.

5.3 Instrument Summary

A cross sectional view of the full science payload is shown in Figure 11. The observational goal of STO is to make high spectral (<1 km/s) and angular resolution (50") maps of the Galactic plane in [C II] (1.9 THz) and [N II] (1.46 THz). During the flight complementary maps in [C I] (492 GHz) will also be made. A summary of key instrument parameters is provided in Table 2. To achieve the angular resolution requirement STO utilizes a telescope with an 80cm aperture. To achieve the target spectral resolution and sensitivity, STO utilizes a leading-edge, THz heterodyne receiver system. Our observing strategy for the main survey is to make adjacent On-the-Fly (OTF) strip maps of the Galactic plane. An ambient load/cold-sky calibration (CAL) is used at the beginning and end of each strip map. During each strip map (lasting as long as ~20 minutes) the calibration load will be regularly observed. With this mode of operation, secondary chopping is not required.

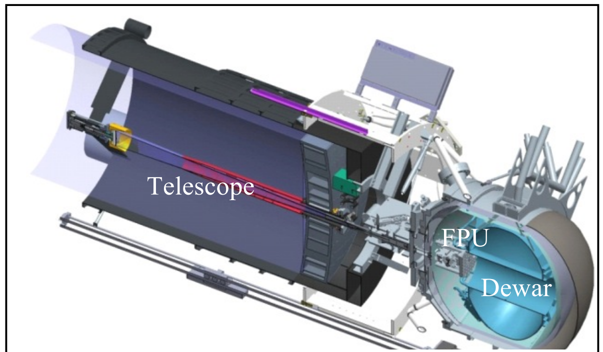


Figure 11: STO Science Payload

5.3.1 System Description

A block diagram of the STO-2 instrument is shown in Figure 12. The STO instrument properties are summarized in Table 2. The STO-2 optical system consists of an f/17.5 Cassegrain telescope, Calibration (Cal) Box, Local Oscillator (LO) Box, and simple reimaging optics. The converging light from the telescope's secondary passes through its focus just above the Cal Box. Just inside the box is a flip mirror. When in the beam path the mirror redirects the light to a room temperature, Schottky receiver tuned to the

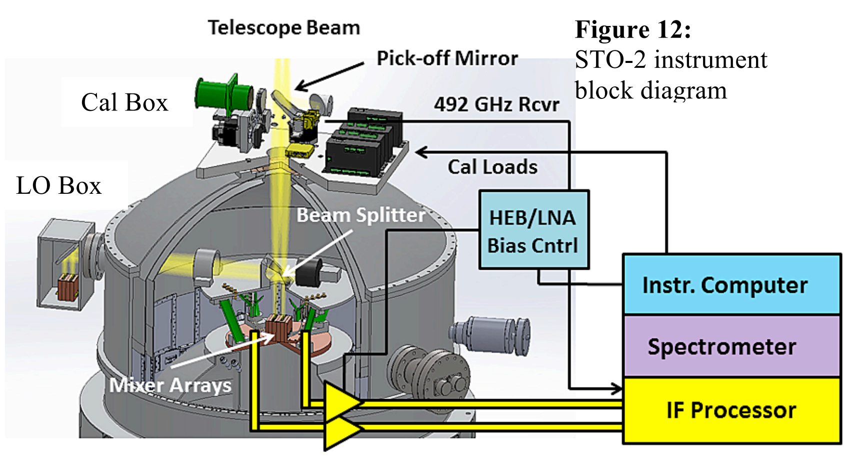


Figure 12: STO-2 instrument block diagram

492 GHz [CI] line **(the same unit that was flown in STO-1)**. While on the ground this receiver is used to perform end-to-end testing of STO's electronics. It also provides ancillary science data while in flight. Once the on-board liquid helium supply is exhausted, the 492 GHz receiver continues to operate, allowing the possibility of a warm mission. While the pick-off mirror is in the beam path the mirror's back-side directs the light from a blackbody calibration load down into the cryostat. The calibration load can be heated or kept at ambient temperature. With the flip mirror out of the way, the telescope beam is reimaged onto two, 1x4 mixer arrays by a lens which also serves as the dewar's vacuum window. A 10% reflective dielectric beam splitter mounted above the mixer arrays is used to inject the THz LO beams into the telescope beam.

STO-2 utilizes recently developed LO sources with ~10 times the power of those available at the time of the STO-1 flight. The ability to use a simple beamsplitter in STO-2 instead of the Fabry-Perot ring diplexer required by STO-1 dramatically reduces the complexity of the system, making assembly and optical alignment far simpler.

The new LO sources were designed by our Co-I's at JPL specifically for STO-2. Each 1.9 and 1.46 THz 1x4 mixer array is directly machined into a single metal block and are mounted back-to-back with a pixel spacing that projects 2x4, 50" beams onto the sky. The Hot Electron Bolometer (HEB) mixers to be used on STO-2 are repackaged versions of the type flown on STO-1 and are bolted to the dewar's 4 K plate. The HEB mixers downconvert the high frequency sky signals to much lower, microwave frequencies. From the mixer output coax conveys the downconverted sky signal to a series of low-noise cryogenic and room temperature microwave amplifiers. The amplifiers boost signal levels to where they can be digitized. The first stage IF low-noise amplifiers (LNAs) will utilize the same high-performance, low-power technology developed for STO-1. The IF signal will have a center frequency of 1.65 GHz and a 1 GHz bandwidth. At our highest observing frequency, 1.9THz, a 1GHz IF bandwidth will provide 160 km/s of velocity coverage. Each STO-2 pixel will have its own 1024 channel FFT spectrometer to produce a power spectrum of the input signal. The power spectra from all pixels are read by the instrument computer and passed on to the gondola via ethernet link. All instrument electronics & subsystems flew on STO-1.

Table 2: STO-2 Instrument Properties

Property	**Description**
Telescope	0.8m Cassegrain
Target Frequencies	[CI]: 1.9THz [NII]: 1.46THz [CI]: 0.49THz
Angular Resolution	50"
Receiver Type	1x4 HEB Mixer Arrays
System Noise Temp	~3000K (SSB)
Spectrometer	Digital FFT
Bandwidths	1 GHz - Corresponds to 158 km/s for [CII]
Spectral Resolution	2 channel resolution = 0.3 km/s at [CII]
Cryogenic System	Hybrid He-4 Cryostat
LHe Hold-time	~60 days

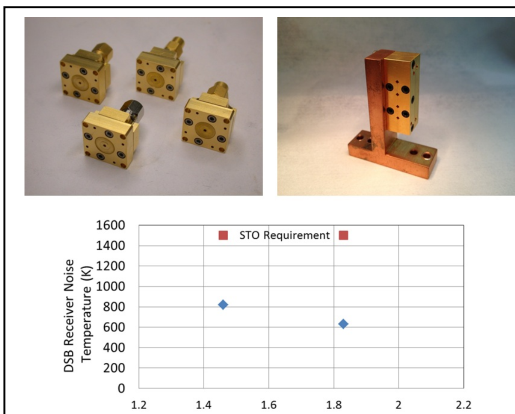


Figure 13: STO-2 mixers & performance.

5.3.2 Component Selection

Recent lab measurements of STO-2 mixers developed at JPL have yielded receiver noise temperatures at 1.46 and 1.9 THz of 820 and 650 K, respectively (Figure 13). The high performance, cryogenic LNAs successfully flown on STO were developed specifically for this program by Sander Weinreb at Caltech/JPL. For our sensitivity calculations we have assumed a conservative end-to-end DSB receiver noise temperature of 1500K and single-sideband (SSB) system noise temperature, T_{sys} = 3000K. With a 15 second integration time per Nyquist-sampled resolution element (characteristic of the unbiased, Galactic Plane survey (GPS) mode), we will be able to achieve *rms* noise levels of 0.3 K at a 1 km/s velocity resolution.

JPL has developed and delivered flight-qualified solid state local oscillator (LO) chains for HIFI that cover the 1400-1600 and 1600-1900 GHz bands. These LO chains consist of GaAs MMIC power amplifier modules and JPL designed and fabricated waveguide GaAs planar multiplier Schottky diode circuits. Since the development of HIFI, a number of improvements, including the high output power capability, have been demonstrated by JPL and will be used for STO-2. Both LO chains employ a x2x3x3 architecture (see Figure 14). The first two stages will be built in a common housing. A row of diagonal horns will be integrated into the last stage tripler. Even with a 10% beam splitter being used for LO injection, each HEB pixel will receive ~1 microwatt of LO power, an ample amount for efficient mixing. **A lower power version of these LO chains was successfully flown on STO-1.**

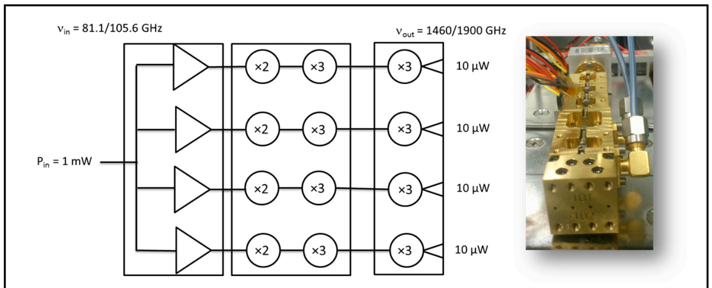


Figure 14: Block diagram and prototype of 1.9 THz, 4-pixel local oscillator unit under development at JPL.

STO-2 will utilize the same spectrometer system successfully flown on STO-1. Developed originally for the PI's 64-beam, 345~GHz heterodyne array ("SuperCam") project by Omnisys, each spectrometer board has four, 1Gs, 8-bit digitizers and a Xilinx Virtex4 FPGA which together perform a real time FFT of the IF signal. Four Omnisys boards are used in the flight system, providing 8 IF inputs with 1 GHz of bandwidth each. One spectrometer input will be RF-switched with the 492 GHz Schottky receiver's IF for the warm mission phase.

Gray Text is Subject to Export Control Restrictions

5.3.3 Cryostat

STO-2 will use the same high efficiency, liquid helium cryostat from Ball Aerospace flown on STO, with the following enhancements: (1) A small, robust cryocooler will be added to extend the helium hold time to ~60 days, and (2) a new vacuum collar and lid will be machined to reduce the number of vacuum seals and simplify the optical alignment of the cryostat, afforded by the use of new, high-power LOs. Figure 11 shows a cutaway view of the STO-2 cryostat. The STO mixer arrays and associated optics are mounted on the lower insert stage which bolts to the top of the helium tank. The beamsplitter for LO diplexing is mounted on the upper stage of the insert just above the mixers (see Figure 12). The mixers dissipate approximately one milliwatt of heat and operate at $\leq$ 4.5 K. The IF output of each mixer is connected to an LNA via a short (~6 cm) length of stainless-steel coax. The first stage of each LNA dissipates ~2 mW. The LNAs and IVCS operate at 16 and 30 K, respectively, and are cooled primarily by the helium tank vent gas. A low-loss, AR-coated silicon window passes the desired signals from the telescope through the vacuum shell. There is a THz low-pass filter in the signal path through the OVCS. The 1.46 and 1.9 THz LO signals enter the cryostat through a vacuum window in the side collar and pass through an IR blocking filter on the OVCS. A cryocooler will be mounted on the side collar to provide additional cooling of the OVCS and beamsplitter plate. The cryocooler chosen is the Sunpower Cryotel CT, a low cost, commercial, linear Stirling cycle cooler. This cryocooler has 5 watts of capacity at 65 K, which is a margin of 50%. With all instrumentation on, the cryostat thermal model predicts the dewar will have a hold-time of ~60 days.

The STO-2 cryostat will undergo extensive thermal-vac testing before its hang-test. After the hang-test it will be packed in a padded, steel reinforced shipping container for the trip to Antarctica.

5.4 Gondola & Telescope

5.4.1 STO Telescope

We will reuse the same telescope that was previously used for the first Antarctic flight of STO (Walker et al. 2010), shown in Figure 15, with only minor modifications. The primary mirror is an 80 cm diameter, f/1.5 hyperboloid made of honeycombed Ultra Low Expansion titanium silicate glass and weighing just 50 kg. Its surface is polished to optical quality, and is thus esssentially perfect for operation in the 100-200 μm range. Its support and spider arms are made of graphite-epoxy, which is light weight and has high thermal stability. For STO-2 the secondary mirror will be the same as that flown on STO-1. Before instrument/telescope I&T, the surface of the primary mirror will be re-aluminized.

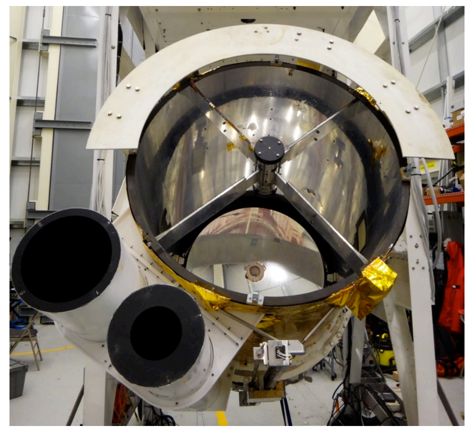


Figure 15: STO's 80-cm aperture telescope successfully flown in January 2012 from Antarctica.

5.4.2 STO Gondola Structure

The STO gondola will be the same one previously used for STO-1. Figure 7 shows the STO gondola in full flight configuration. The gondola carries and protects the telescope and cryostat and houses the command and control systems for both STO-2 and NASA-CSBF. Its basic dimensions (without solar arrays) are: 2 x 1.5 x 4.5 m (WxDxH). The frame is made of standard aluminum angles bolted together and painted with a white thermal coating. The structure is strong enough to support up to 2000 Kg even under the 10 g shock experienced at the end of the flight when the parachute inflates. The total mass of the STO payload, shown in Table 3, is well below the design structural limit. It is rigid enough to allow the required telescope pointing stability of < 15". The gondola can be separated into lighter components for easy post-flight retrieval in the field. NASA-CSBF balloon control electronics (the Support Instrument Package, SIP) is attached on the bottom of the gondola, inside a protective aluminum cage.

Table 3: STO-2 Weights

	Weight	
Item	**lbs**	**kg**
Gondola frame & command & control	2100	953
Telescope:	490	222
Heterodyne spectrometer/He dewar:	360	163
CSBF equipment:	570	259
Total:	**3520**	**1597**

For STO-2 we will repair/replace the gondola structural components that were damaged during the STO-1 landing and recovery. Subsequently we will perform thorough system & subsystems testing with a suspension system at APL's high-bay Balloon Payload Integration Facility, which is comparable to the balloon train. Thermally all STO-1 subsystems behaved as predicted, no major changes in the thermal design will be done for STO-2. We already have detailed thermal and structural analysis of the current gondola configuration. The models will be modified to take into account any small mechanical and electronics changes we plan for the STO-2 program.

5.4.3 Command and Control System

Figure 16 gives an overview of STO-2 command and control system. It is virtually the same used for STO-1. We do not plan any modifications since it performed flawlessly during the STO-1 flight. There are two main computers on-board: the Command and Control Computer (CCC) and the Actuators Control Computer (ACC). Both computers use a commercial system board with a Pentium-based CPU, solid state hard drives, and Linux operating system. They are housed in two vessels that maintain 1 atm pressure throughout the flight, allowing the use of off-the-shelf commercial grade components.

5.4.4 Telecommunications

The telecommunications system for STO-2 will be the same as that used for STO-1. We will rely entirely on the NASA-CSBF provided Support Instrument Package (SIP) for remote link between the gondola and the ground. The SIP has three available channels to/from the ground. For the first ~24 hours the gondola will be in Line-of-Sight (LOS) to the launch station in Antarctica and will use a UHF radio link at a data rate of 1 Mb/s. During LOS operations ample amounts of housekeeping data will be available for analysis of both science and gondola performance. After loss of the LOS radio link, communications will be maintained via a 92-Kb/s TDRSS satellite relay and a lower rate IRIDIUM relay (one 255 byte packet every 15 minutes). A 6-Kb/s TDRSS link is also available and is used as backup. TDRSS and IRIDIUM signals will be received at CSBF's Operations Control Center (OCC) in Palestine (TX) and sent to a local STO ground support computer that will redistribute the data packets to other STO ground stations at APL, the University of Arizona and to the team in Antarctica. About 90% of the science data acquired during the flight will be downlinked using the TDRSS link and will be sufficient to meet the scientific goals in the case of payload loss. The ground support computers will use the same software package GSEOS, by GSE Software, Inc., that was previously used for STO-1. During the STO-1 flight the 92-Kb/s TDRSS link would sometimes drop out during observations when the gondola moved in azimuth. Our team will work closely with CSBF to minimize these occurrences.

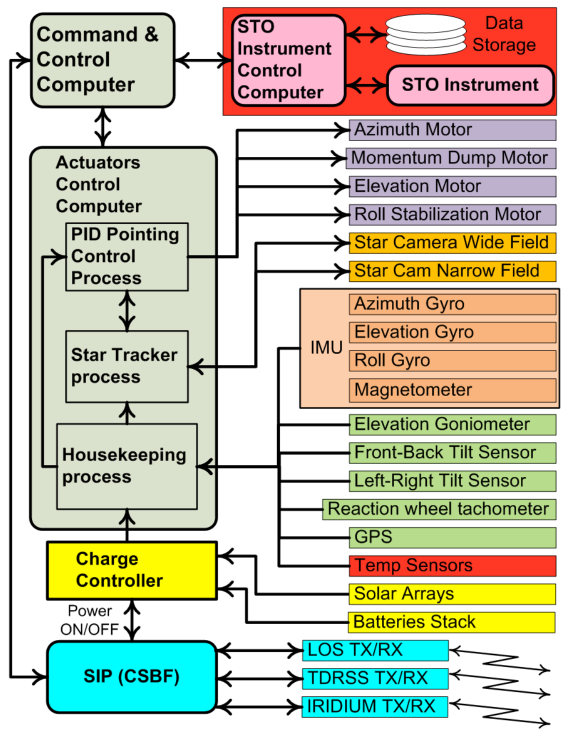


Figure 16: STO Command & Control System

5.4.5 Pointing System

The pointing system will be virtually the same as that used for STO-1, with the addition of a roll compensation system discussed in Sec. 5.1.2. The science pointing requirements are: pointing range of 360° and 0 to 57° in elevation less a half cone of 20° in the direction of the Sun; stability < 15"; knowledge < 15"; source acquisition accuracy < 20". During the STO-1 Antarctic flight we have demonstrated that the current design can exceed those requirements. To aim the telescope at the desired target in the sky we use an elevation/azimuth mount. The telescope is attached to the gondola on its elevation axis and a torque motor attached to it rotates the telescope in elevation by pushing against the gondola frame. It is also equipped with a goniometer that measures the angle with respect to the gondola with a resolution of ~ 10 arc minutes. To point in azimuth the entire gondola rotates on the vertical axis via Momentum Transfer Unit (MTU) which is same as the one flown in STO-1. The fine gondola attitude is determined by an Inertial Measuring Unit (IMU) and two APL built star cameras. The IMU is composed of three high-precision, low-drift fiber optic gyroscopes, the Optolink SRS-2000, already flown on STO-1. Initialization of azimuth and elevation for the IMU is done on the ground before launch.

For precision attitude knowledge to < 5 arcseconds, STO-2 flies the same two star cameras developed and built by APL for the STO-1 program, and successfully used on its Antarctic flight (Figure 15). They are commercial Stardot Netcam SC-5 with APL modified hardware to allow them to operate at float altitude environment. One star camera is configured with a 50mm focal length f/2.4 lens and red filter. It has a ~7° FOV and is capable of detecting magnitude 6.5 (and dimmer for red stars) stars at altitude during daylight conditions. STO's second star camera is identical to the first except that the input optical system is a 500mm mirror lens. It has a ~0.5° FOV and is capable of imaging bright stars (< magnitude 2), and planets during daylight from the ground. The pointing performance achieved during the STO-1 flight demonstrates that the combination of gyroscopes, star cameras and PID controller can deliver a pointing knowledge of about 2 arc-seconds and stability of < 2 arc-seconds in both elevation and azimuth, meeting the requirements of STO-2.

5.4.6 Power System

The STO-2 power system will be the same used for STO-1 with no modifications planned since it performed flawlessly during the Antarctic flight. It consists of the solar arrays, the charge controller, and the battery stack. The solar arrays are composed of 480 cells model A300 from SunPower Corp. The maximum power delivered by the arrays is about 1100 W, while the estimated total STO-2 power requirement will be only about 450 W. This gives a margin of 650 W. Approximately 50% of STO-1's solar arrays were lost during landing and recovery. For STO-2 we plan to replace only the damaged arrays. The new arrays are assembled by SunCat Solar of Arizona who also built the ones for STO-1. The charge controller distributes the load across the panels, ensures that the system's battery stacks are maintained at near full charge, sunlight permitting, and provides on/off power switching capability from ground commands. It will be the same used for STO-1 and will require no modifications. The battery stack is composed of 2 sealed lead-acid ODYSSEY PC1700 rechargeable batteries. With a capacity of 65 Ahr at 24 VDC, the battery charge level never dipped below 60% during the STO-1 flight.

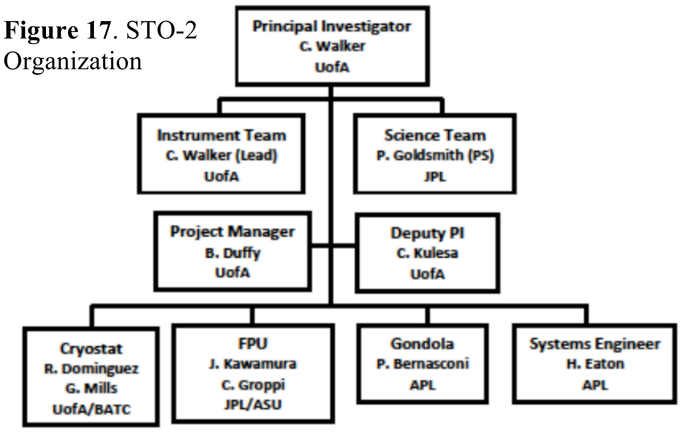
5.5 Data Analysis and Archiving

STO-2 data analysis will make use of the data reduction techniques developed for STO-1. Both missions benefit from the many man-years of effort put into reducing *Herschel*/HIFI HEB receiver data. Indeed, several of our team members are experts in this area and are now applying their skills to the STO-1 data set.

Once the raw data has been accurately tagged and a baseline removed, a wide range of standard data reduction packages and techniques can be employed. The most demanding storage requirement for a 35 sq. degree spectral map is 10 GB. In flight this data volume can be readily handled by embedded computers with nonvolatile Flash memory. The spatially & spectrally re-gridded final data product data volume is <500 MB. There will be two data product releases in the proposal performance period: (1) a preliminary, first light, release after the Antarctic mission in March 2015, and (2) a final release of all data in December 2016. The final release will be fully calibrated and include all science products. All science tools, packaged reduction software, data products and catalog products will be made available from the STO survey web page.

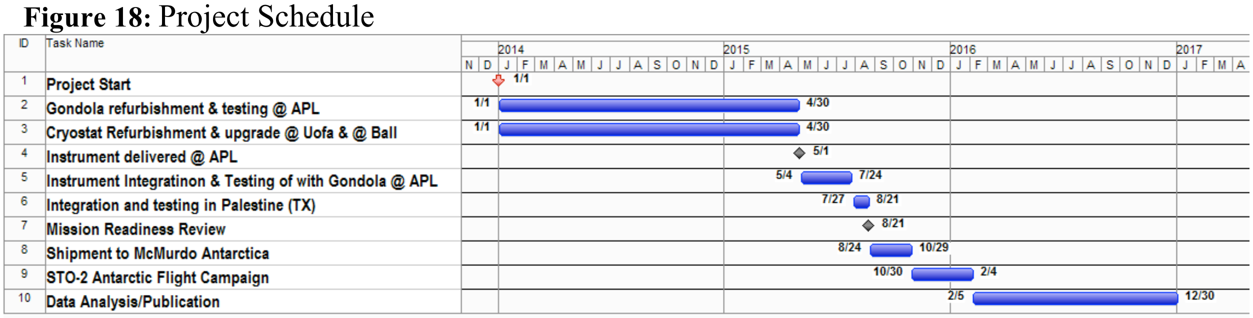
6 Management

Figure 17. STO-2 Organization



The STO-2 organizational structure is shown in Figure 17 and closely follows that of STO-1. Dr. Walker (PI) is responsible for all aspects of the success and scientific integrity of STO-2. He will be assisted at the University of Arizona by Dr. Craig Kulesa, who will serve as Deputy PI and Brian Duffy, Project Manager (PM). The STO science team will be led by Dr. Paul Goldsmith, who will be STO Project Scientist (PS). The Instrument Team will be led by the PI (Walker). Dr. Bernasconi (APL Institutional PI) will oversee the STO gondola efforts at APL and STO-2 flight operations. Dr. Jonathan Kawamura will oversee the FPU integration and testing at JPL. The master schedule shown in Figure 18 identifies the project's major milestones and development activities. We are fortunate in that all flight critical systems were recovered from STO-1 in excellent condition; this allows STO-2 to get off to a running start in January 2014. The STO-2 work breakdown structure is equally divided into a payload development program, which improves and simplifies the flight system as described in Sections 5.2 and 5.3, and an integrated testing program which serves to validate and verify the flight system repeatedly at the individual component, subsystem, and integrated payload levels. The testing program begins immediately, in parallel with payload development, so that issues can be solved early in the program cycle. The testing program culminates in an integrated thermal-vacuum test (Section 5.2) of the science instrument which provides validation that data acquisition will perform optimally in flight. These tests will be coordinated by the Systems Engineer in concert with the PI/DPI and the individual payload subsystem leads (Figure 17). As with STO-1, the instrument and science teams will make extensive use of electronic communication and management tools including e-mail, secure websites, on-line meetings and video communications to expedite accurate information dissemination. All management and control information will be posted on a secure STO website maintained by the UofA.

Figure 18: Project Schedule



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Biographical Sketch: CHRISTOPHER K. WALKER

PROFESSIONAL PREPARATION

Clemson University	Electrical Engineering	B.S. 1980
Ohio State University	Electrical Engineering	M.S. 1981
University of Arizona	Astronomy	Ph.D. 1988

APPOINTMENTS

- Professor of Astronomy and Optical Sciences, Associate Professor of Electrical Engineering, University of Arizona, 2003-
- Associate Professor of Astronomy, Optical Sciences, and Electrical Engineering, University of Arizona, 2002-2003
- Associate Professor of Astronomy & Optical Sciences, University of Arizona, 2000-2002
- Associate Professor, Steward Observatory, University of Arizona, 1997-2000
- Assistant Professor, Steward Observatory, University of Arizona, 1991-1997
- Millikan Research Fellow in Physics, Caltech, 1988-1991
- Graduate Research Assistant, Steward Observatory, 1983-1991
- Research and Development Engineer, Jet Propulsion Laboratory, 1983
- Electrical Engineer, TRW Aerospace Division, 1981-1983

Research and Management Experience

PI Christopher Walker of the University of Arizona (UA), has over 25 years of experience designing, building, and using state-of-the-art receiver systems for THz astronomy. He has advanced degrees in both astronomy and electrical engineering and has worked in industry (TRW Aerospace and JPL) as well as academia. As a Millikan Fellow in Physics at Caltech, he led the effort to develop the first low-noise, SIS waveguide receiver above 400 GHz. At the University of Arizona he began the Steward Observatory Radio Astronomy Lab (SORAL), which has become a world leader in developing leading-edge submillimeter-wave receiver systems. SORAL constructed the world's first 810 and 345 GHz heterodyne array receivers and helped developed one of the first 1.5 THz HEB receiver systems for radio astronomy. These instruments are multi-institutional efforts, with key components coming from JPL, several universities, and a number of industrial partners. Prof. Walker managed and coordinated these efforts. Instruments developed by Prof. Walker's team have served as primary facility instruments at the Heinrich Hertz Telescope and the AST/RO telescope at the South Pole for over a decade. Funded by the NSF, Prof. Walker is leading the effort to design and build the world's largest submillimeter-wave heterodyne array receiver (64 pixels). He is PI of the NASA funded long duration balloon project ``The Stratospheric THz Observatory (STO)''. Prof. Walker has published numerous papers on star formation and protostellar evolution. He has served as dissertation director for 9 Ph.D. students (7-Astronomy and 2-Optical Sciences).

RELATED PUBLICATIONS

Bussmann, R. S., Wong, T. W., Hedden, A., Kulesa, C., and Walker, C. K., 2007, *A CO (J=3-2) Outflow Survey of the Elias 29 Region*, *Ap.J.*, 657, Issue 1, pp. L33-L36.

Hedden, A. S., Walker, C. K., Groppi, C. E., and Butner, H. A., 2006, Star *Formation in the Northern Cloud Complex of NGC 2264*, *Ap.J.*, **645**, p.345.

Kulesa, C., Hungerford, a., Walker, C., Zhang, X., and Lane, A., 2005, *Large-Scale CO and [CI] Emission in the Rho Ohiuchi Molecular Cloud, Ap. J.,* **625**, 194.

Stark, A., Martin, C., Walsh, W., Xiao, K., Lane, A., and Walker, C., 2004, "*Gas Density, Stability, and Starbursts near the Inner Lindblad Resonance of the Milky Way*", *Ap.J.*, **614**, Issue 1, pp. L41-L44.

Martin, C., Walsh, W., Xiao, K., Lane, A., and Stark, A., 2004, *The AST/RO Survey of the Galactic Center Region. I. The Inner 3 Degrees*, *Ap.J.S.*, **150**, 239.

OTHER SIGNIFICANT PUBLICATIONS

Narayanan, D., Kulesa, C., Boss, A., and Walker, C. K., 2006, *Molecular Line Emission from Gravitationally Unstable Protoplanetary Disks, Ap.J.*, **647**, Issue 2, pp. 1426-1436.

Narayanan, D., Cox, T., Robertson, B., Dave', R., Di Matteo, T., Hernquist, L., Hopkins, P., Kulesa, C., and Walker, C. K., 2006, *Molecular Outflows in Galaxy Merger Simulations with Embedded Active Galactic Nuclei*, *Ap.J.*., 642, Issue 2, pp. L107-L110.

Groppi, C., Kulesa, C., Walker, C., and Martin, C., 2004, *Millimeter and Submillimeter Survey of the R Coronae Australis Region, Ap. J.,* **612**, 946.

Narayanan, G., Moriarty-Schieven, G., Walker, C.K., and Butner, H.M. 2002, *Detection of Infall Signatures Towards SMM4*, *Ap.J.*, **565**, 319.

Melia, F., Bromley, B., Liu, S., and Walker, C.K. 2001, *Measuring the Black Hole Spin in Sag A*, Ap. J. Letters*, **554**, 37.

Ph.D. ADVISEES

Grace Wolf (Hansen Planetarium), Jason Glenn (UC Boulder), Gopal Narayanan (U. Mass), Craig Kulesa (UofA-Astronomy), Christian d'Aubigny (UofA-Planetary Sciences), Christopher Groppi (ASU), Desika Narayanan (UofA- Bok Fellow), Abigail Hedden (ARL), Dathon Golish (UofA-ECE)

M.S. ADVISEES

Michael Borden (JPL), Jenna Kloosterman (UofA-ECE)

RECENT COLLABORATORS (48 Months)

Pietro Bernasconi (JHAPL), Paul Goldsmith (JPL), Christopher Groppi (ASU), David Hollenbach (SETI Institute), Karl Jacobs (U. Cologne), John Kawamura (JPL), Craig Kulesa (UofA), William Langer (JPL), Arthur Lichtenberger (UVa), Carey Lisse (JHAPL), Christopher Martin (Oberlin College), David Neufeld (JHU), Gordon Stacey (Cornell), Antony Stark (SAO) Jeffrey Stern (JPL), Juergen Stutzki (U. Cologne), Sander Weinreb (CIT/JPL), Mark Wolfire (U. Maryland), Harold Yorke (JPL), Eric Young (SOFIA)

CURRICULUM VITAE

PIETRO N. BERNASCONI

Current Position

The Johns Hopkins University / Applied Physics Laboratory
Senior Scientist
Space Department, Space Science Group, Solar Physics Section

Education

1992 Diploma (Physics) (equivalent to American Master's Thesis), Swiss Federal Institute of Technology Zürich (ETH-Z)
1997 Ph.D. (Natural Science), Swiss Federal Institute of Technology Zürich (ETH-Z)

Relevant experience

2008 - 2011: Payload PI, Stratospheric TeraHertz Observatory balloon program.
2007 - present: PI, Solar Bolometric Imager balloon/space program.
2001-2007: Project Scientist, Solar Bolometric Imager balloon program.
1997-2004: Project Scientist, Flare Genesis Experiment balloon program.
1992-1997: Research Fellow, Institute for Astronomy of the Swiss Federal Institute of Technology Zürich, Solar Physics Group.

Professional Societies

Member American Astronomical Society, Solar Physics Division (SPD)
Member American Geophysical Union (AGU)
Member Society of Photo-Optical Instrumentation Engineers (SPIE)

Relevant Publications

Bernasconi P.N., Keller C.U., Solanki S.K., and Stenflo J.O., Complex magnetic fields in an active region, A&A 329, 704-720 (1998)
Bernasconi P.N., Rust D.M., Eaton H.A.C., Murphy G.A., A Balloon-borne Telescope for high resolution solar imaging and polarimetry, in Airborne Telescope Systems, eds. R.K. Melugin, H.P. Röser, Proc. of SPIE Vol. 4014, 214 (2000)
Bernasconi P.N., Rust D.M., Eaton H.A.C., High resolution vector magnetograms with the Flare Genesis vector polarimeter, in Advanced Solar Polarimetry - Theory, Observation, and Instrumentation, M. Sigwarth (Ed.), Astron. Soc. Pacific Conf. Series Vol. 236, 399-406 (2001)
Bernasconi P. N., Rust D. M., Georgoulis M. K., LaBonte B. J. 2002, Moving Dipolar Features in an Emerging Flux Region, Sol. Phys. 209, 119-139 (2002)
Bernasconi P.N., Eaton H.A.C., Foukal, P., Rust D.M., The Solar Bolometic Imager, in Advances in Space Research Vol. 33 1746 (2004)
Foukal, P., Bernasconi, P. N., Eaton, H. A. C., and Rust, D. M., Broad-band Measurements of Facular Photometric Contrast with the Solar Bolometric Imager, Astrophysical Journal 611, L57, (2004)
C. Walker, C. Kulesa, P. Bernasconi, et al., 2010, The Stratospheric THz Observatory (STO), in Ground-based and Airborne Telescopes III, eds. Larry M. Stepp, Roberto Gilmozzi, Helen J. Hall, Proc. of SPIE Vol. 7733, 77330N (2010)

PAUL F. GOLDSMITH, STO-2 Project Scientist

Paul.F.Goldsmith@jpl.nasa.gov

Curriculum Vitae

Citizenship: USA

EDUCATION

American School of Paris, France	High School Diploma 1965
University of California, Berkeley	A.B. (Physics) 1969
University of California, Berkeley	Ph.D. (Physics) 1975

POSITIONS HELD

2009 -	Adjunct Professor of Astronomy, University of Arizona, Tucson
2008 -	Chief Technologist, Astronomy and Physics Directorate, Jet Propulstion Laboratory
2006 -	Senior Research Scientist, Jet Propulsion Laboratory
	NASA Project Scientist, Herschel Space Observatory
	Visiting Associate, Department of Astronomy, Calif. Inst. Technology, Pasadena
2006 - 2008	Supervisor, Group 3266, Evolution of Galaxies
2005 - 2006	Principal Scientist, Jet Propulsion Laboratory, Calif. Inst. Technology, Pasadena
2005 -	Professor Emeritus of Astronomy, Cornell University
2000, 2001, 2004, 2012	Professeur Invité, Ecole Normale Supérieure, Paris, France
1999 - 2005	James Weeks Professor in the Physical Sciences, Department of Astronomy, Cornell University
1993 - 2002	Director, National Astronomy and Ionosphere Center
1993 - 2005	Professor, Department of Astronomy, Cornell University
1986 - 1992	Professor, Dept. of Physics & Astronomy, University of Massachusetts, Amherst
1982 - 1992	Vice President of Research and Development, Millitech Corporation
1981 - 1986	Associate Professor, Dept. of Physics & Astronomy, Univ. of Massachusetts, Amherst
1980 - 1992	Associate Director, Five College Radio Astronomy Observatory
1977 - 1980	Consultant, Lincoln Laboratory, Lexington, Massachusetts
1977 - 1979	Resident Visitor, Bell Laboratories, Holmdel, New Jersey
1977 - 1981	Assistant Professor, Dept. of Physics & Astronomy, Univ. of Massachusetts, Amherst
1975 - 1977	Member Technical Staff, Bell Laboratories, Crawford Hill Laboratory, New Jersey
1971 - 1975	Research Assistant, Dept. of Physics, University of California, Berkeley
1969 - 1970	Research Physicist, Lawrence Radiation Laboratory, Berkeley, California

HONORS AND AWARDS

Fellow, Insitute of Electrical and Electronics Engineers, 1991
IEEE Microwave Theory & Techniques Society - Distinguished Lecturer, 1992
NASA Group Achievement Award, 2004 (SWAS)
James Weeks Professor in the Physical Sciences, Cornell University, 1999
NASA Group Achievement Award, 2010 (Herschel)
NASA Exceptional Achievement Medal, 2010
Edward Stone Award for Outstanding Research Publication, 2012
NASA Exceptional Scientific Achievement Medal, 2012

NATIONAL & INTERNATIONAL COMMITTEE SERVICE

Joseph Weber Award for Astronomical Instrumentation Committee, American Astronomical Society, 2003-2005

Chair, Scientific and Technical Advisory Committee for Large Millimeter Telescope (LMT) University of Massachusetts, Amherst, and INAOE (Mexico), 1994 -

SELECTED RELEVANT RECENT ARTICLES

"The Transition from Atomic to Molecular Hydrogen in Interstellar Clouds: 21cm Signature of the Evolution of Cold Atomic Hydrogen in Dense Clouds," Goldsmith, P.F., Li, D., & Krčo, M. 2007, ApJ, 654, 273.

"C^+ Detection of Warm Dark Gas in Diffuse Clouds," Langer, W.D., Velusamy, T., Pineda, J.L., Goldsmith, P.F., Li, D., &Yorke, H.W. 2010, Astronomy & Astrophysics, 521, L17.

"[CII] observations of H_2 Molecular Layers in Transition Clouds," Velusamy, T., Langer, W.D., Pineda, J. L., Goldsmith, P.F., Li, D., &Yorke, H.W. 2010, Astronomy & Astrophysics, 521, L18.

"A Sample of [C II] Clouds Tracing Dense Clouds in Weak FUV Fields Observed by Herschel," Pineda, J.L., Velusamy, T., Langer, W.D., Goldsmith, P.F., Li, D., & Yorke, H.W. 2010, Astronomy & Astrophysics, 521, L19.

"Herschel Measurements of Molecular Oxygen in Orion," Goldsmith, P.F., Liseau, R., Bell, t., et al. 2011, ApJ, 737, 96.

"[CII] 158 μm Line Detection of the Warm Ionized Medium in the Scutum-Crux Spiral Arm Tangency," Velusamy, T., Langer, W.D., Pineda, J.L., & Goldsmith, P.F. 2012, Astron. Astrophys., 541, L10.

"Early Science Results from the Heterodyne Instrument for the Far Infrared (HIFI) on the Herschel Space Observatory,", Goldsmith, P.F. & Lis, D.C. 2012, IEEE Trans. Terahertz Science and Technology, 2, 383.

"Is the Taurus B213 Region a True Filament?: Observations of Multiple Cyanoacetylene Transitions," Li, D. & Goldsmith, P.F. 2012, ApJ, 756, 12.

"Collisional Excitation of the [CII] Fine Structure Transition in Interstellar Clouds," Goldsmith, P.F. 2012, ApJS 203, 13.

"^{13}CO Cores in the Taurus Molecular Cloud," Qian, L., Li, D., & Goldsmith, P.F. 2012, ApJ, 760, 147.

"Water Absorption in Galactic Translucent clouds: Conditions and History of the Gas Derived from *Herschel*/HIFI PRISMAS Observations," Flagey, N., Goldsmith, P.F., Lis, D.C., et al. 2012, ApJ, 762, 11.

CURRICULUM VITAE

Christopher Emil Groppi
School of Earth and Space Exploration, Arizona State University
PO Box 871404, Tempe, AZ 85287-1404
Tel: 480-965-6436, Fax: 480-965-8102
Email: cgroppi@asu.edu   http://thz.asu.edu/cgroppi/

Professional Preparation:

B.A. with Honor in Astronomy, Cornell University, 1997
Ph.D. in Astronomy with minor in Electrical and Computer Engineering, University of Arizona, 2003
Director's Postdoctoral Research Associate, National Radio Astronomy Observatory, 2003-2005
National Science Foundation Astronomy and Astrophysics Postdoctoral Fellow: 2006-2009

Appointments:

Assistant Professor, Arizona State University School of Earth and Space Exploration: 2009-present
Assistant Staff Astronomer, Steward Observatory, 2004-2009

Selected Publications:

Groppi, C.E., Kawamura, J.H., Coherent Detector Arrays for Terahertz Astrophysics Applications, IEEE Trans. on Terahertz Science and Technology, v. 1, no. 1, pp. 85-96, 2011.

Groppi, C.E., Walker, C., Kulesa, C., Golish, D., Kloosterman, J., Weinreb, S., Jones, G., Barden, J., Mani, H., Kuiper, T., Kooi, J., Lichtenberger, A., Cecil, T., Puetz, P., Narayanan, G., Hedden, H., *Testing and Integration of Supercam, a 64-Pixel Array Receive for the 350 GHz Atmospheric Window*, Millimeter and Submillimeter Detectors and Instrumentation for Astronomy V, Edited by Duncan, William, Holland, Wayne, Withingtonm Stafford, Zmuidzinas, Jonas, Proc. SPIE 7741, 774110X, pp. 1-11, 2010.

Walker, C.,Kulesa, C., Bernasconi, P., Eaton, H., Rolander, N., **Groppi, C.**, Kloosterman, J., Cottam, T., Lesser, D., Martin, C., Stark, A., Neufeld, D., Lisse, C., Hollenbach, D., Kawamura, J., Goldsmith, P., Langer, W., Yorke, H., Stern, J., Skalare, A., Mehdi, I., Weinreb, S., Kooi, J., Stutzki, J., Graf, U., Brasse, M., Honingh, C., Simon, R., Akyilmaz, M., Puetz, P., Wolfire, M., *The Stratospheric Terahertz Observatory (STO),* Ground-based and Airborne Telescopes III, Edited by Larry M. Stepp; Roberto Gilmozzi; Helen J. Hall, Proc. SPIE 7733, 773330N, pp. 1-9, 2010.

Narayanan, D., Walker, C., **Groppi, C.** *Warm-Dense Molecular Gas in the ISM of Starbursts, LIRGs and ULIRGs* Ap.J., v. 630, pp. 269-279, 2005.

Groppi, C.E., Walker, C.K., Kulesa, C., Golish, D., Hedden, A., Narayanan, G., Lichtenberger, A.W., Kooi, J.W., Graf, U.U., Heyminck, S. *First results from DesertSTAR: a 7-pixel 345-GHz heterodyne array receiver for the Heinrich Hertz Telescope*, Proc. SPIE, v. 5498, pp. 290-299, 2004.

Synergistic Activities:

- Involvement in all facets of the design, construction, test and integration of five heterodyne array receivers (PoleSTAR, DesertSTAR, SuperCam, Stratospheric Terahertz Observatory, Kilopixel Array Pathfinder Project).
- Development of CNC micromachining techniques for THz circuit fabrication.
- Study of molecular gas content and star formation in nearby galaxies.
- Galactic star formation research using mm-wave and sub-mm wave telescopes, concentrating on the interaction of protostellar sources with the surrounding ISM, and the dynamics of protostellar accretion disks.

INSTITUTIONAL PI: DAVID HOLLENBACH (PROJECT SCIENTIST)

BIOGRAPHICAL DATA: PhD. (Theoretical Physics), Cornell University, 1969; Principal Investigator of the Center for Star Formation Studies 1985-2002; Member of the core IR panel of the Bahcall Committee, 1989-1990; Member of the SOFIA Science Working Group, 1990-1996; Member of the Submillimeter Science Working Group, 1990-1996; Member of the Submillimeter Wave Astronomy Satellite Team, 1988-2005, Associate Member of SWS Team of ISO, 1989-1998; Executive Council of AAS, 1992-1995; Member of the National Academy of Sciences Task Group for Space Astronomy and Astrophysics 1995-1997; Executive Officer of the Astronomy and Astrophysics Survey Committee (National Research Council for the National Academy of Sciences) (1998-2000); Member of the National Academy of Sciences Committee on Astronomy and Astrophysics (2003-2005); Member of the ALMA North American Science Advisory Committee (2003-2005); CoI on 2 Spitzer Legacy Teams (team leader on one), a Key ISO Project team, and a Herschel key project team (HOP). Project Scientist for STO-1.

SELECTED AWARDS: Exceptional Scientist Award (NASA 1995), Outstanding Leadership Medal NASA 2002), NASA Exceptional Achievement Medal (NASA 2005)

CURRENT POSITION: Senior Research Scientist, Carl Sagan Center, SETI Institute

RELEVANT PUBLICATIONS:

Wolfire, M., Hollenbach, D.J., McKee, C., Tielens, A., “The Neutral Atomic Phases of the Interstellar Medium”, Ap. J., 443, 152, 1995.

Hollenbach, D. and Tielens, A., "Photodissociation Regions (PDRs) in the Interstellar Medium of Galaxies", Rev. Mod. Phys., 71, 173, 1999.

Kaufman, M., Wolfire, M., Hollenbach, D., Luhman, M., "Far Infrared and Sub-millimeter Emission from Galactic and Extragalactic Photodissociation Regions", ApJ, 527, 795, 1999.

Wolfire, M., McKee, C., Hollenbach, D., Tielens, A. "Neutral Atomic Phases of the Interstellar Medium in the Galaxy", ApJ, 587, 278, 2003

Kaufman, M.J., Wolfire, M.G., & Hollenbach, D.J. “Si II], [Fe II], [C II], and H_2 Emission from Massive Star-forming Regions”, ApJ, 644, 283, 2006

Wolfire, M.G., Hollenbach, D., & McKee, C.F. “The Dark Molecular Gas”, ApJ, 716, 1191, 2010

Steiman-Cameron, T.Y., Wolfire, M., & Hollenbach, D. “COBE and the Galactic Interstellar Medium: Geometry of the Spiral Arms from FIR Cooling Lines”, 2010, ApJ, 722, 1460, 2010

Jonathan H. Kawamura

Jet Propulsion Laboratory 168-314 tel: 818-393-4779
California Institute of Technology email: kawamura@jpl.nasa.gov
Pasadena CA 91109

Employment:

Senior Electronics Engineer, 2000–; Affiliate, 1998–2000, Jet Propulsion Laboratory
Postdoctoral Scholar in Physics, 1997–2000. California Institute of Technology.
Research Assistant, 1992–1997. Harvard College Observatory.

Education:

Ph. D., Astronomy, Harvard University, 1997; A. M., 1994.
B. S., Astronomy, California Institute of Technology, 1992.

Upon receiving his doctorate in 1997, Dr. Kawamura joined Caltech as a Postdoctoral Scholar in the Submillimeter Astronomy Group. He also became a JPL affiliate. Teaming with the JPL Microdevices Laboratory, he and his colleagues demonstrated a near-quantum noise limited SIS mixer above the gap frequency of Nb. Operating an SIS mixer at such a high-frequency was considered a serious barrier at the time for low-noise mixer operation above 0.7 THz. With colleagues from the Smithsonian Astrophysical Observatory, he built, deployed and performed observations with a HEB receiver. These were the first astronomical observations with this kind of receiver, and a detection of a celestial emission-line above 1 THz was made. These critical technologies were inserted into the HIFI instrument on the Herschel Space Observatory. Dr. Kawamura joined JPL in 2000. He has worked on Herschel HIFI and has been a PI on several research and development efforts to advance THz receiver technology and utilize them for astronomical research. For STO-2 he will be the Institutional PI for JPL. He will lead the mixer development effort as well as testing of the focal plane unit.

Selected relevant publications:

F. Boussaha, J. Kawamura, J. Stern, C. Jung, A. Skalare and V. White, "Terahertz-frequency waveguide HEB mixers for spectral lines astronomy," *Proc. SPIE* 845211 (2012)

F. Boussaha, J. Kawamura, J. Stern, A. Skalare, and V. White, "A low-noise 2.7 TH waveguide-based superconducting mixer," *IEEE Trans. Terahertz Sci. Tech*., 2, 284 (2012)

H.-B. Li, R. Blundell, A. Hedden, J. Kawamura, S. Paine, and E. Tong, "Evidence for dynamically important magnetic fields in molecular clouds," *Monthly Notices of the Royal Astronomical Society*, 411, 2067 (2011)

Th. de Graauw, et al., "The Herschel-Heterodyne Instrument for the Far-Infrared (HIFI)," *Astronomy and Astrophysics*, 518, 6D (2010)

C.-Y. E. Tong, J. Kawamura, D. Marrone, D. Loudkov, S. Paine, R. Blundell, C. Barrientos, and D. Luhr, "A 1.5 THz hot electron bolometer receiver for ground-based terahertz astronomy in northern Chile," *Proc. SPIE* 6373, 6373U (2006)

J. Kawamura, T. R. Hunter, C.-Y. E. Tong, R. Blundell, D. C. Papa, F. Patt, W. Peters, T. L. Wilson, C. Henkel, G. Gol'tsman, & E. M. Gershenzon, "Ground-based Terahertz CO Spectroscopy towards Orion," *Astronomy & Astrophysics*, **394**, 271-274 (2002)

Craig A. Kulesa

Steward Observatory
University of Arizona
Tucson, AZ 85721

Telephone: (520) 621-6540
FAX: (520) 621-1532
Email: ckulesa@email.arizona.edu

Professional Preparation

Ph.D., Astronomy	December 2002	The University of Arizona
B.S., Physics	June 1993	Miami University (Ohio)

Appointments

2006-	Assistant Astronomer Steward Observatory / University of Arizona
2003-2006	Assistant Staff Scientist Steward Observatory / University of Arizona
1994-2002	Research Assistant (Science and Instrumentation) University of Arizona

Selected Papers Relevant to This Proposal

1. "Large Scale CO and [CI] Emission in the Rho Ophiuchi Molecular Cloud", Kulesa, C.A., Hungerford, A.L., Walker, C.K., Zhang X., & Lane, A., 2005, ApJ, 625, 194
2. "Pre-HEAT: submillimeter site testing and astronomical spectra from Dome A, Antarctica", Kulesa, C. A. et al., 2008, Proc. SPIE, 7012, 145.
3. "Exceptional Terahertz Transparency and Stability above Dome A, Antarctica", Yang, H., Kulesa, C. A., Walker, C. K., Tothill, N. F. H., Yang, J., Ashley, M. C. B., Cui, X., Feng, L., Lawrence, J. S., Luong-van, D. M., McCaughrean, M. J., Storey, J. W. V., Wang, L., Zhou, X., Zhu, Z., 2010, PASP, 122, 490.
4. "Abundances of H_2, H_3^+ & CO in Molecular Clouds and Pre-planetary Disks", Kulesa, C. A. & Black, J. H. 2002, Chemistry as a Diagnostic of Star Formation, 60
5. "SuperCam: a 64-pixel heterodyne imaging array for the 870-micron atmospheric window", Groppi, C., Walker, C., Kulesa, C., Puetz, P., Golish, D., Gensheimer, P., Hedden, A., Bussmann, S., Weinreb, S., Kuiper, T., Kooi, J., Jones, G., Bardin, J., Mani, H., Lichtenberger, A., Narayanan, G., 2006, Proc. SPIE, vol 6275, 62750O.

Instrumentation Experience Relevant to this Proposal:

1. Deputy-PI of the *Stratospheric Terahertz Observatory* (STO), a balloon-borne telescope with heterodyne spectrometer. As D-PI, responsible for the overall system engineering and integration of the flight instrument.
2. Deputy-PI of *Supercam*, a 64-beam, 345 GHz heterodyne receiver to be deployed at the 10-meter HHT telescope in Arizona. Responsibilities focus on the I&T of IF processor and spectrometer, system level testing, telescope integration, data system.
3. Constructed *Pre-HEAT*, an automated 0.2-meter terahertz telescope with heterodyne receiver deployed in January 2008 to the isolated summit of the Antarctic ice plateau. As PI, currently deploying *HEAT*, a follow-on THz instrument to South Pole and Ridge A, with a 0.65 cm aperture and 800-1900 GHz heterodyne receivers.

William D. Langer

Jet Propulsion Laboratory 183-600 tel: 818-354-5823
California Institute of Technology email: William.Langer@jpl.nasa.gov
Pasadena CA 91109

Current Position: Senior Research Scientist

Education: Ph.D., Physics, Yale University

Dr. William Langer is a Senior Research Scientist at the Jet Propulsion Laboratory. He has over thirty years experience in astrophysics and is author, or co-author, on over 160 research papers, the majority of them on topics related to the interstellar medium, star formation, and protostellar disks. Dr. Langer has been studying interstellar clouds and star formation both observationally and theoretically. His contributions include various time dependent chemical - dynamical codes for chemistry of clouds and protostellar cores and disks. He is involved in research on the thermal, chemical, and structural properties of the ISM. Currently he is the PI on a Herschel Open Time Key Program, "State of the Diffuse ISM: Galactic Observations of Terahertz CII Line" which will detect dark gas throughout the Galaxy. In addition, he is a member of two Herschel Guaranteed Time Programs and several Herschel Open Time 1 and 2 programs.

Representative Publications:

Molecular Cooling & Thermal Balance of Dense Interstellar Clouds, Goldsmith, P. F. & **Langer, W. D**., 1978, ApJ, 222, 881.

Stability of Interstellar Clouds Containing Magnetic Fields, 1978, Langer, W., ApJ, 225, 95.
Isotope Selective Photodestruction of CO, 1982, Bally, J. & **Langer, W. D**., ApJ, 255, 143.

The Relationship Between Carbon Monoxide Abundance and Visual Extinction in Interstellar Clouds, 1982, Frerking, M. A., **Langer, W. D**., & Wilson, R. W., ApJ, 262, 590.

Structure Function Scaling of a 2MASS Extinction Map of Taurus, Padoan, P., Cambresy, L., and **Langer, W. D**., 2002, ApJ Letters, 580, L57.
Molecular Hydrogen Emission from the Boundaries of the Taurus Molecular Cloud
P. F. Goldsmith, T. Velusamy, D. Li, **W. D. Langer**, 2010, Ap J., 715, 137.
C^+ Detection of Warm Dark Gas in Diffuse Clouds, **W. D. Langer,** T. Velusamy, J. L. Pineda, P. F. Goldsmith, D. Li, & H. W. Yorke, 2010, A&A, 521, L17.

[CII] Observations of H_2 Molecular Layers in Transition Clouds, T. Velusamy, **W. D. Langer,** J. L. Pineda, P. F. Goldsmith, D. Li, & H. W. Yorke, 2010, A&A, 521, L18.

A Sample of [CII] Clouds Tracing Dense Clouds in Weak FUV Fields Observed by Herschel, J. L. Pineda, T. Velusamy, **W. D. Langer,** P. F. Goldsmith, D. Li, & H. W. Yorke, 2010, A&A, 521, L19.

Jorge L. Pineda

Scientist
Jet Propulsion Laboratory
4800 Oak Grove Drive • MS 169-237
Pasadena, CA 91109
(818) 354-3347

RELEVANT EXPERIENCE

Dr. Jorge L. Pineda has extensive experience in observations and interpretation of mm and sub-mm line and continuum emission in the galaxy and extra-galactic sources. He is a member of the Herschel Galactic Observations of Teraherz C+ (GOT C+) project devoted to study the [CII] 1.9 THz line in the Milky Way. In this project, he is responsible for the data analysis and interpretation. He also specializes in mm and submm observations of the Magellanic Clouds. He is the PI of an OT1 Herschel proposal devoted to study ionized and neutral carbon over a wide range of environments on the Large and Small Magellanic clouds.

EDUCATION:

Ph. D., Astronomy, University of Bonn, Germany, 2007.
M.S., Astronomy, University of Chile, Chile, 2003.
B.S., Physics and Astronomy, University of Chile, 2002

PROFESSIONAL EXPERIENCE:

CURRENT POSITIONS:

2011–present: Scientist, Jet Propulsion Laboratory, California Institute of Technology

PREVIOUS POSITIONS:

2008–2011: Postdoc, Jet Propulsion Laboratory, California Institute of Technology
2007–2008: Postdoc, Angelander Institut fuer Astronomie, University of Bonn

SELECTED RELEVANT REFEREED PUBLICATIONS

1. **Pineda**, **J. L.**, Langer, W. D., Velusamy,T., Goldsmith. 2013, GOTC+ [CII] Galactic Plane Survey I: The Global Distribution of ISM Gas Components *A&A*, submitted.
2. **Pineda, J.L.**, Mizuno, N., Röllig, M., et al., Submillimeter line emission from LMC 30 Doradus: The impact of a starburst on a low-metallicity environment, 2012, *A&A*, 544, A84.
3. **Pineda**, **J. L.** Velusamy,T., Langer, W. D., Goldsmith, P. F., Li. D. & Yorke, H.W. 2010. A Sample of [CII] Clouds Tracing Dense Clouds in Weak FUV Fields. *A&A*, 521, L19.
4. **Pineda, J.L.**, Goldsmith, P.F., Chapman, N.L., Li, D., Snell, R., Cambr´esy, L. & Brunt, C. 2010. The Relation Between Dust and Gas in the Taurus Molecular Cloud. *ApJ*, 721, 686

Brian A. Stalder

Harvard University
Department of Physics
17 Oxford Street
Cambridge, MA 02138

Phone: (617) 496-7360
Fax: (617) 495-0416
Email: bstalder@cfa.harvard.edu
http://www.fas.harvard.edu/~stalder

Personal Information

Curent Position: Postdoctoral Fellow, Smithsonian Astrophysical Observatory
Citizenship: United States

Education

University of Hawai'i, Manoa	Ph.D. Astronomy, December 2007
University of Hawai'i, Manoa	M.S. Astronomy, December 2003
California Institute of Technology	B.S. Astronomy, June 2001

Recent Research History

Stratospheric Terahertz Observatory (STO), Department of Physics, Harvard/SAO, 2011 –
STO is a NASA Long Duration Balloon (LDB) experiment designed to address a key problem in modern astrophysics: understanding the Life Cycle of the Interstellar Medium (ISM). Personal responsibilities included developing software for data analysis, and optical alignment of the telescope with instrument package during pre-launch in Antarctica.

Parallel Imager for Southern Cosmological Observations (PISCO), Department of Physics, Harvard/SAO, 2007 –
Participated in design and building of project PISCO, an upcoming imaging instrument for the 6.5 meter Magellan telescope. Designed and built apparatus for quickly testing throughput and noise performance of astronomical detectors. Performed tests of new CCDs and other detectors for future instruments. Programmed software interface for CCD readout and automatic real-time data analysis pipeline.

South Pole Telescope (SPT) Optical/IR Follow-up Team, Department of Physics, Harvard/SAO, 2008 –
Member of optical follow-up team for SPT, particularly for targeted imaging for photometric redshift and richness estimates of galaxy clusters and multi-slit spectroscopy for measuring velocity dispersions.

SPT Data Analysis Team, Harvard/SAO, 2008 –
Developed analysis modules for data pipeline for 10-meter telescope with high frequency bolometer array. Executed studies of stability and performance of pipeline modules using real data.

Pan-STARRS Telescope Group, Institute for Astronomy, Univ. of Hawai'i, 2008 – 2010
Processed and analyzed image quality data from commissioning observing runs on prototype Pan-STARRS1 telescope with 1.4 Gigapixel Camera. Modeled and diagnosed focus, decenter and tilt of focal plane and optical elements from out-of-focus images and sweeps through focus.

Pan-STARRS Camera Group, Institute for Astronomy, Univ. of Hawai'i, 2004 – 2007
Designed and executed lab experiments relating to large focal plane mosaic CCD cameras; evaluated individual CCDs, verifying performance (QE, noise, image quality, thermal conductivity, surface metrology); participated in test camera design, testing, and integration engineering runs with prototype Pan-STARRS1 telescope.

Professional Service

UH 2.2-m Volunteer Instrument Support (OPTIC imager) 2002 – 2007
IfA/UH Telescope Allocation Committee, 2006
IfA Library Committee, 2004 – 2005

Teaching/Mentoring Experience

Mentored Graduate Student Lindsey Bleem, University of Chicago (2011-present)
Mentored Graduate Student Jonathan Ruel, Harvard University (2010-present)
Mentored Graduate Student F. William High, Harvard University (2008-2010)
Instructor in Introductory Astronomy, UH, Summer 2006
Teaching Assistant in Introductory Astronomy, UH, 2001 – 2002
Teaching Assistant in Introductory Astronomy, Caltech, Spring Term 2000, 2001

References

Prof. Chrisopher Stubbs	Dept of Physics, Harvard University (stubbs@physics.harvard.edu)
Dr. Antony Stark	Smithsonian Astrophysical Observatory (aas@cfa.harvard.edu)
Prof. Kenneth Chambers	Institute for Astronomy, UH (chambers@jansky.ifa.hawaii.edu)
Prof. John Tonry	Institute for Astronomy, UH (jt@ifa.hawaii.edu)

Antony A. Stark
Harvard-Smithsonian Center for Astrophysics
60 Garden Street, MS-78
Cambridge, MA 02138

Academic and employment history:

1975	B.S., with honors, Astronomy and Physics, California Institute of Technology
1977	M.A., Astrophysical Sciences, Princeton University
1979	Ph.D., Astrophysical Sciences, Princeton University
1972–1973	*Research Assistant*, Kellogg Radiation Laboratory, California Institute of Technology
1973	*Observing Assistant*, Owens Valley Radio Observatory, Big Pine, CA
1974–1975	*Programmer*, Space Radiation Laboratory, California Institute of Technology
1975, 1976	*Physicist*, Lawrence Livermore National Laboratory
1975–1976	*William Charles Peyton Fellow*, Princeton University
1976–1979	*NSF Fellow in Astronomy*, Princeton University
1979–1991	*Member of Technical Staff*, Radio Physics Research Department, Bell Laboratories, Holmdel, NJ
1979–1992	*Visiting Lecturer*, Department of Astrophysical Sciences, Princeton University
1989–	*Principal Investigator*, Antarctic Submillimeter Telescope and Remote Observatory (AST/RO)
1991–	*Astronomer*, Harvard-Smithsonian Center for Astrophysics

Professional Society Membership:

1977–	American Astronomical Society
1980–	International Astronomical Union

Advisory Committee Membership:

1994–	South Pole User's Committee, (1997–1999 Committee *Chairman*)
1996–	Science and Technology Working Group, SETI Institute

Graduate Students and Postdoctoral Scholars: recent graduate students: none; recent postdoctoral scholars: Richard A. Chamberlin, Simon P. Balm.

Graduate Advisor: Arno A. Penzias

Curriculum Vitae

Mark G. Wolfire (Co-I)

Senior Research Scientist

Current Address: University of Maryland
Astronomy Department
College Park, MD 20742
e-mail: mwolfire@astro.umd.edu

Education

Ph. D. Astronomy, University of Wisconsin-Madison, Madison, Wisconsin - 1985.
M. S. Astronomy, University of Wisconsin-Madison, Madison, Wisconsin - 1982.
B. S. Astronomy, Case Western Reserve University, Cleveland, Ohio - 1980.

Employment

2011 - present: Senior Research Scientist, Astronomy Department University of Maryland
2002 - 2011: Associate Research Scientist, Astronomy Department University of Maryland
2005: Senior National Research Council Associate, NASA Ames Research Center
1996 - 2002: Assistant Research Scientist (promoted 1999), Research Associate, Astronomy Department University of Maryland, College Park
1995 - 1996: Smithsonian Fellow, Air & Space Museum Laboratory for Astrophysics
1994 - 1995: Visiting Assistant Researcher, University of California, Berkeley
1992 - 1994: Senior National Research Council Associate, NASA Ames Research Center
1990 - 1992: Postdoctoral Fellowship, Harvard Smithsonian Center for Astrophysics
1998 - 1990: Postdoctoral Research Assistant: Department of Astronomy and Astrophysics, University of Chicago

Research Interests

Wolfire has been a leader in modeling the chemistry and thermal structure of PDRs. His models have been used extensively to interpret infrared absorption line observations of the diffuse interstellar medium (Herschel) and infrared line emission from Galactic photodissociation regions (KAO, ISO, Spitzer) and from the ISM of normal and starburst galaxies (KAO,ISO, Spitzer, Herschel). He will provide theoretical modeling support for the STO-2 team and will assist in the analysis of the [CII] and [NII] line data.

Selected Publications

M. G. Wolfire, D. Hollenbach, & C. F. McKee "The Dark Molecular Gas" 2010, ApJ, 716, 1191
M. J. Kaufman, M. G. Wolfire, & D.J. Hollenbach, "[Si II], [Fe II] and H_2 Emission from Massive Star Forming Regions",2006, ApJ, 644, 283.
D. A. Neufeld, M. G. Wolfire, & P. Schilke "The Chemistry of Fluorine-bearing Molecules in Diffuse and Dense Interstellar Gas Clouds", 2005, ApJ, 628, 260
M. G. Wolfire, C. F. McKee, D. J. Hollenbach, & A. G. G. M. Tielens "Neutral Atomic Phases of the ISM in the Galaxy", 2003, ApJ, 587, 278.
M. J. Kaufman, M. G. Wolfire, D. J. Hollenbach, & M. L. Luhman "Far Infrared Submillimeter Emission from Galactic and Extragalactic Photo-Dissociation Regions: Models" 1999, ApJ, 527, 795.

Harold W. Yorke

Jet Propulsion Laboratory, California Institute of Technology
MS 169-506, 4800 Oak Grove Drive, Pasadena, CA 91109-8099
Harold.Yorke@jpl.nasa.gov
Tel: 818-354-5515 Fax: 818-393-6546

Dr. Yorke's scientific research has been oriented towards numerical simulations of astrophysical phenomena, but his interests in astronomy are broad and varied. He has observing experience at X-ray, optical, UV, IR, and mm-radio wavelengths. As PI or Co-I on observing proposals he has contributed to the direct modeling and interpretation of astrophysical data from modern instruments. Prior to August 2006 he was the NASA Project Scientist for the Herschel Space Observatory and Section Manager for JPL's Astrophysics and Space Sciences Section. For the following six years he was the Division Manager of JPL's Science Division.

In recent years Dr. Yorke has focused his research efforts in the study of early phases of star formation and the associated impact on the surrounding ISM. His emphasis has been on the radiation hydrodynamic behavior of the dusty gas including the influence of UV irradiation on the protostellar disk by both the central (proto-)star and by external sources. Having made significant contributions to the theory of formation of population I massive stars and their effect on their local environment, he is currently studying the formation of zero-metallicity stars in the early universe and the chemical evolution of the local ISM.

Education:	University Göttingen (1971-74; 1968-69); Caltech (1970-71); UCLA (1966-1970)
Academic Degrees:	B.S. (UCLA, 1970), Physik-Diplom (1972, Göttingen), Dr. rer.nat. (1974, Göttingen), Habilitation (1979, Göttingen)
Scientific Positions:	Senior Research Scientist (Jet Propulsion Laboratory, 1998-present), C3-Prof. (Univ. Würzburg: 1988-98), Prof. (Göttingen: 1983-88), tenured Research Scientist (Göttingen: 1978-83); Scientist (MPI for Astrophysics Munich: 1975-78; Göttingen: 1973-75), R.A. (Caltech, 1970-71)
Selected Awards:	NASA Exceptional Achievement Medal (2003, 2010); Fulbright Fellow (1972-73); Fulbright Scholar (1971-72)
Memberships:	AAS, IAU, AGU; Science Advisory Council of MPI Astronomy (Heidelberg), Editorial Board of *Astronomy Notes* (founded 1821)

Selected Publications and Recent Preprints:

Kuiper R, **Yorke HW**, 2013, *On the Effects of optically thick Gas (Disks) around massive Stars*, **ApJ** 763, 104K 2012arXiv:1211.6432K

Hosokawa T, Yoshida N, Omukai K, **Yorke HW**, 2012, *Protostellar Feedback and Final Mass of the Second-Generation Primordial Stars,* **ApJ**, 760, L37; 2012arXiv1210.3035H

Hosokawa T, Omukai K, **Yorke HW**, 2012, *Rapidly Accreting Supergiant Protostars: Embryos of Supermassive Black Holes?* **ApJ** , 756, 93; 2012arXiv1203.2613H

Tassis K, Willacy K, **Yorke HW**, Turner N, 2012, *Non-Equilibrium Chemistry of Dynamically Evolving Prestellar Cores: II. Ionization and Magnetic Field*, **ApJ**, 754, 6; 2011arXiv1111.4218T

Tassis K, **Yorke HW**, 2011, *A New Recipe for Obtaining Central Volume Densities of Prestellar Cores from Size Measurements*, **ApJ**, 735L

Langer WD, Velusamy T, Pineda JL, Goldsmith PF, Li D, **Yorke HW**, 2010, *C+ detection of warm dark gas in diffuse clouds*, **A&A**, 521, 17L

+32 additional recent letters in two **A&A** Special Issues (Herschel Science & Herschel HIFI Science)

Zinnecker H, **Yorke HW**, 2007, *Toward Understanding Massive Star Formation*, **ARAA**, 45, 481

Christopher K. Walker, PI
The University of Arizona, Steward Observatory

CURRENT AWARDS as Principal Investigator

Project Title:	GUSSTO: Phase A
Sponsoring Agency	NASA Explorer Program (NNG12PK37C)
POC Name, Phone #, email	Gustavo Malagon; (301) 286-6993; Gustavo.A.Malagon@nasa.gov
Total Award Amount:	$250,000
Start and End Date: (MM/DD/YY)	12/01/11 – 05/17/13
Commitment to the Project:	1 summer month

Project Title:	HIGGS: The Herschel Inner Galaxy Gas Survey
Sponsoring Agency	JPL (1369561)
POC Name, Phone #, email	Susan Scrivner; (818) 393-0930; Susan.G.Scrivner@jpl.nasa.gov
Total Award Amount:	$264,000
Start and End Date: (MM/DD/YY)	03/06/2009 – 09/30/2013
Commitment to the Project:	0

CURRENT AWARDS as Co-Investigator

Project Title:	High Elevation Antarctic Terahertz (HEAT) Telescopes for Dome A and Ridge A (PI: C. Kulesa)
Sponsoring Agency	NSF - ANT (0944335)
POC Name, Phone #, email	Vladimir O. Papitashvili; (703) 292-7425; vpapita@nsf.gov
Total Award Amount:	$1,511,020
Start and End Date: (MM/DD/YY)	10/01/2010 – 09/30/2014
Commitment to the Project:	1 summer month per year

Project Title:	Augmentation to Ensure a Successful ATOMMS Demonstration and Evaluation (PI: E. Kursinkski)
Sponsoring Agency	NSF – AGS (0946411)
POC Name, Phone #, email	Eric T. DeWeaver; (703) 292-8527; edeweave@nsf.gov
Total Award Amount:	$1,952,495
Start and End Date: (MM/DD/YY)	10/01/2010 – 9/30/2013
Commitment to the Project:	0

PENDING AWARDS as Principal Investigator

Project Title:	GUSSTO: Phase B, C, D, E, F
Sponsoring Agency	NASA Explorer Program
POC Name, Phone #, email	Gustavo Malagon; (301) 286-6993; Gustavo.A.Malagon@nasa.gov
Total Award Amount:	$53.8M
Start and End Date: (MM/DD/YY)	03/15/2012 – 9/30/2020
Commitment to the Project:	1 summer month per year

Project Title:	Reflight of the Stratospheric TeraHertz Observatory: STO-2 (This proposal)
Sponsoring Agency	NASA – APRA
POC Name, Phone #, email	Michael Garcia; (202) 358-1053; Michael. R.Garcia@nasa.gov
Total Award Amount:	$4,180,531
Start and End Date: (MM/DD/YY)	01/01/14 – 12/31/16
Commitment to the Project:	1 summer month per year

Project Title:	Collaborative Research: SWiFFTS: The Supercam Wideband Fast Fourier Transform Spectrometer
Sponsoring Agency	NSF – ATI
POC Name, Phone #, email	Eric Bloemhof; (703) 292-5302; ebloemho@nsf.gov
Total Award Amount:	$107,587
Start and End Date: (MM/DD/YY)	06/01/2013 – 05/31/2016
Commitment to the Project:	.11 AY month in Y2 and Y3

PENDING AWARDS as Co-Investigator

Project Title:	A Submillimeter-Wave Spectroscopic Galactic Plane Survey using Supercam at the HHT (PI: Craig Kulesa)
Sponsoring Agency	NSF – AAG
POC Name, Phone #, email	Glen Langston; (703) 292-4937; glangsto@nsf.gov
Total Award Amount:	$641,291
Start and End Date: (MM/DD/YY)	09/01/13 – 08/31/16
Commitment to the Project:	1 summer month per year

CURRENT AND PENDING SUPPORT

PIETRO N. BERNASCONI

Current Support

Project title	PI Name	Program Name & Point of contact	Total Budget	PofP	Mm/yr
Solar Probe Plus (SPP)	PM: Andrew Driesman (APL) PS: Nicola Fox (APL)	NASA, Solar Probe Plus Nicola Fox 443 778 3529 Nicola.Fox@jhuapl.edu	$1,200M	2012 – 2025	2
Balloon Rapid Response ISON (BRRISON)	Andy Cheng (APL)	Tibor Kremic NASA Glenn Research Center 216 977 7433	~ $10 M	3/2013 – 02/2014	~ 10

Pending Support

Project title	PI Name	Program Name & Point of contact	Total	PofP	Mm/yr
GUSSTO! Gal/Xgal U/LDB Spectroscopic/Stratospheric TeraHertz Observatory	Christopher Walker	NASA EXPLORER/Mission of Opportunity 2011 NNH08ZDA009O-EXPMO11 Jefferey Newmark 202 358 1762 hq-shp-ps@nasa.gov	$54,965 K	4/2013 – 09/2019	~ 6

Dr. Paul Goldsmith

Pending Awards

Name of Principal Investigator on Award	Award/Project Title	Program Name/ Sponsoring Agency/ Point of Contact telephone and email	Period of Performance/Total Budget	Commitment (Person-Months per Year)
Christopher Walker	Galactic/extragalactic Ultra-long duration Spectroscopic Stratospheric Terahertz Observatory (GUSSTO) Phase B	NASA SMD/Paul Hertz (202) 358-0986 Paul.Hertz@nasa.gov	3/1/2013-4/2020 $55M	1
Jonathan Kawamura	A Local Oscillator sources at 2.7 THz for suborbital astronomy	NASA APRA/Larry Petro (202) 358-4424 Larry.D.Petro@nasa.gov0	1/1/2014-12/2017 $1.75M	1

Current and Pending Research Grants

Christopher Groppi

Current Research Grants:

1. NASA, Explorer 11 Mission of Opportunity, GUSSTO!: The Gal/Xgal U/LDB Spectroscopic/Stratospheric Terahertz Observatory, Proposal 08-EXPMO11-0021, PI: Christopher Walker (University of Arizona), Co-Is: Pietro Bernasconi (Johns Hopkins University), Paul Goldsmith (NASA JPL), Christopher Groppi (ASU), David Hollenbach (NASA Ames), Jonathan Kawamura (NASA JPL), Jacob Kooi (California Institute of Technology), Craig Kulesa (University of Arizona), David Neufeld (Johns Hopkins University), Sander Weinreb (California Institute of Technology), Mark Wolfire (University of Maryland), Erick Young (University of Arizona), J.R. Gao (SRON), Frank Helmich (SRON), Qing Hu (MIT), Gary Melnick (SAO), Antony Stark (SAO), Jorge Pineda (JPL), John Reno (Sandia National Lab), Gordon Stacey (Cornell), Xander Tielens (Leiden), Proposal Total: $60,470,971. ASU : $998,961, SELECTED FOR PHASE A CONCEPT STUDY (ASU Phase A Award $16,003)

   Period of Performance: 9/16/2011-9/15/2012
   Months committed: 1.0 per year
   Point of contact: Christopher J Davis, Infrared, Submillimeter, and Radio Astrophysics, (202) 358-1237, christopher.j.davis@nasa.gov

2. National Science Foundation, Division of Astronomical Sciences Advanced Technology and Instrumentation, A Pathfinder Instrument for Kilopixel Heterodyne Array Receivers, Award 1006148, PI: Christopher Groppi (ASU), Co-Is: Christopher Walker (University of Arizona). Award Total: $773,280 (ASU: $650,267, UofA: $123,013).

   Period of Performance: 7/1/2010-6/30/2013
   Months committed: 1.0 per year
   Point of Contact: Jeffrey R. Pier (703) 292-2977 jpier@nsf.gov

Pending Proposals:

1. National Science Foundation, Division of Astronomical Sciences Advanced Technology and Instrumentation, SWiFFTS: The Supercam Wideband Fast Fourier Transform Spectrometer, PI: Christopher Groppi (ASU), Proposal Total: $670,248 (ASU: $670,248).

   Period of Performance: 7/1/2013-6/30/2016
   Months committed: 1.0 per year
   Point of Contact: Jeffrey R. Pier (703) 292-2977 jpier@nsf.gov

2. NASA, Explorer 11 Mission of Opportunity, GUSSTO!: The Gal/Xgal U/LDB Spectroscopic/Stratospheric Terahertz Observatory, Proposal 08-EXPMO11-0021, PI:

Christopher Walker (University of Arizona), Co-Is: Pietro Bernasconi (Johns Hopkins University), Paul Goldsmith (NASA JPL), Christopher Groppi (ASU), David Hollenbach (NASA Ames), Jonathan Kawamura (NASA JPL), Jacob Kooi (California Institute of Technology), Craig Kulesa (University of Arizona), David Neufeld (Johns Hopkins University), Sander Weinreb (California Institute of Technology), Mark Wolfire (University of Maryland), Erick Young (University of Arizona), J.R. Gao (SRON), Frank Helmich (SRON), Qing Hu (MIT), Gary Melnick (SAO), Antony Stark (SAO), Jorge Pineda (JPL), John Reno (Sandia National Lab), Gordon Stacey (Cornell), Xander Tielens (Leiden), Proposal Total: $60,470,971. ASU : $998,961, SELECTED FOR PHASE A CONCEPT STUDY (ASU Phase A Award $16,003)

Period of Performance: 9/16/2011-9/15/2012
Months committed: 1.0 per year
Point of contact: Christopher J Davis, Infrared, Submillimeter, and Radio Astrophysics, (202) 358-1237, christopher.j.davis@nasa.gov

Current and Pending Grants for David Hollenbach (Institutional Principal Investigator, SETI Institute)

Current Awards

1. Project title: The Role of Photoevaporation in Clearing Protoplanetary Disks: Mapping Flows and Determining Mass Flow Rates

Name of PI on award: Ilaria Pascucci (U. Arizona)
Program name: HST
Sponsoring agency: Space Telescope Science Institute (NASA)
Sponsor POC: Paula Sessa
Performance period: May 1, 2011 to April 30, 2014
Total budget: $13,006 to CoI Hollenbach
Person-months/yr: Year 3: .24 months

2. Project title: Herschel Oxygen Project

Name of PI on award: Paul Goldsmith (JPL)
Program name: Herschel
Sponsoring agency: Jet Propulsion Laboratory (NASA)
Sponsor POC: Linda Nenadovic-Cantuna
Performance period: March 4, 2009 to September 30, 2013
Total budget: $67,325 to CoI Hollenbach
Person-months/yr: Year 1: .415 months, Years 2-4: .83 months, Year 5: .208 months

3. Project title: A Herschel Study of Star Formation Feedback on Cloud Scales, Molecular Oxygen in Orion, The Origin of H_2O^+ in Dense Clouds

Name of PI on award: V. Ossenkopf
Program name: Herschel
Sponsoring agency: Jet Propulsion Laboratory (NASA)
Sponsor POC: Linda Nenadovic-Cantuna
Performance period: February 8, 2011 to September 30, 2013
Total budget: $43,683 to CoI Hollenbach
Person-months/yr: .5 months/year

4. Project title: Photoevaporation and Viscous Evolution in Protoplanetary Disks

Name of PI on award: Uma Gorti (SETI)
Program name: ATP
Sponsoring agency: NASA
Sponsor POC: Thierry Marc Lanz

Performance period: September 1, 2009 through August 31, 2012 (extended through Sept 1, 20113 on a no cost extension).
Total budget: $90,000 to CoI Hollenbach
Person-months/yr: 1.5 months/year

Pending Awards

1. Project title: GUSSTO: Gal/Xgal U/LDB Spectroscopic/Stratospheric THz Observatory

Name of PI on award: Chris Walker (U. Arizona)
Program name: Suborbital Program, NASA
Sponsoring agency: NASA
Sponsor POC: Christopher J. Davis
Performance period: September 16, 2012 through June 30, 2020
Total budget requested: $110,000 for CoI Hollenbach
Person-months/yr: Years 1-3: .5 months/year, Years 4-8: 1 month/year

2. This proposal

Dr. Jonathan Kawamura

Current Awards

Name of Principal Investigator on Award	Award/Project Title	Program Name/ Sponsoring Agency/ Point of Contact telephone and email	Period of Performance/Total Budget	Commitment (Person-Months per Year)
Paul Goldsmith	Technology development for a SOFIA Next Generation Heterodyne Instrument	NASA SMD/Mario Perez (202) 358-1535 mario.perez@nasa.gov	5/1/11-5/1/13 $1.1M	4
Jonathan Kawamura	100 pixel 350 micron heterodyne array camera (HAC) for CCAT	JPL R&TD/Daniel McCleese (818) 354-2317 daniel.j.mccleese@jpl.nasa.gov	10/1/12-9/30/13 $100k	5
Christopher Walker	Galactic/extragalactic Ultra-long duration Spectroscopic Stratospheric Terahertz Observatory (GUSSTO!) (CSR)	NASA SMD/Paul Hertz (202) 358-0986 Paul.Hertz@nasa.gov	10/1/11-9/30/12 $250k	1
Boris Karasik	Ultra-wideband MgB2 mixer for high-resolution terahertz spectroscopy	NASA APRA/Larry Petro (202_ 358-4424 Larry.d.petro@nasa.gov	1/1/2013-12/31/2016	1

Pending Awards

Name of Principal Investigator on Award	Award/Project Title	Program Name/ Sponsoring Agency/ Point of Contact telephone and email	Period of Performance/Total Budget	Commitment (Person-Months per Year)
Christopher Walker	Galactic/extragalactic Ultra-long duration Spectroscopic Stratospheric Terahertz Observatory (GUSSTO) Phase B	NASA SMD/Paul Hertz (202) 358-0986 Paul.Hertz@nasa.gov	3/1/2013-4/2020 $55M	5
Jonathan Kawamura	Terahertz Heterodyne Array Receivers for Spectral Line Imaging	NASA APRA/Larry Petro (202 358-4424 Larry.D.Petro@nasa.gov	1/1/2014-12/31/2016/$1.1M	5
Jonathan Kawamura	A Local Oscillator sources at 2.7 THz for suborbital astronomy	NASA APRA/Larry Petro (202) 358-4424 Larry.D.Petro@nasa.gov0	1/1/2014-12/2017 $1.75M	1
Adrian Tang	Instrument Signal Processor on Chip	NASA APRA/Larry Petro (202) 358-4424 Larry.D.Petro@nasa.gov	1/1/2014-12/31/2016 $1.25M	1

Craig Kulesa

Current & Pending Support

Title ***Program Name***	***Agency*** ***Solicitation***	***Performance Period*** ***Budget***	**Commitment** (calendar months/yr)
High Elevation Antarctic Terahertz (HEAT) telescopes for South Pole and Ridge A	NSF/OPP	07/2010 – 6/2014 $1.5M	6
PENDING: Galactic ULDB Spectroscopic Stratospheric Terahertz Observatory (GUSSTO)	NASA NNH08ZDA009O-EXPMO	1/2014 – 12/2018 $0.25M (Phases B-E)	3
PENDING (this proposal): Reflight of the Stratospheric Terahertz Observatory: STO-2	NASA NNH12ZDA001N	01/2014 – 12/2016 $4.1M est'd	3

Dr. Jorge Pineda

Current Awards

Name of Principal Investigator on Award	Award/Project Title	Program Name/ Sponsoring Agency/ Point of Contact telephone and email	Period of Performance/Total Budget	Commitment (Person-Months per Year)
Jorge Pineda	Probing Galactic Spiral Arm Tangencies with [CII] – A Herschel Open Time 2	NASA SMD/ William Danchi (301) 286 4586 william.c.danchi@nasa.gov	6/1/12-6/30/14 $43K	1
Jorge Pineda	Characterizing the life cycle of interstellar matter in the Magellanic Clouds with CII and CI] – A Herschel Open Time 1 Program	NASA SMD/Paul Hertz (202) 358-0986 Paul.Hertz@nasa.gov	10/1/11-9/30/13 $276K	6

Pending Awards

Name of Principal Investigator on Award	Award/Project Title	Program Name/ Sponsoring Agency/ Point of Contact telephone and email	Period of Performance/Total Budget	Commitment (Person-Months per Year)
Christopher Walker	Galactic/extragalactic Ultra-long duration Spectroscopic Stratospheric Terahertz Observatory (GUSSTO) Phase B	NASA SMD/Paul Hertz (202) 358-0986 Paul.Hertz@nasa.gov	3/1/2013-4/2020 $55M	1

CURRENT AND PENDING SUPPORT
Brian A. Stalder

CURRENT AWARDS

Project title: **Optical Confirmation, Redshifts, and Richness for Galaxy Clusters Discovered with the South Pole Telescope**
Name of PI on Award: Antony A. Stark, Smithsonian Astrophysical Observatory
Sponsoring agency or organization: NSF/AST
Performance period: 09/01/10 – 08/31/14
Total budget: $930,881
Commitment: 9 months

PENDING PROPOSALS

Project title: **OCAM: An Oxygen Heterodyne Camera for SOFIA**
Name of PI on Proposal: Antony A. Stark, Smithsonian Astrophysical Observatory
Sponsoring agency or organization: NASA
Performance period: 6/1/12 – 5/31/16
Total budget: $220,775
Commitment: .50 month

Project title: **GUSSTO!: GAL/XGAL U/LDB Spectroscopic/Stratospheric THz Observatory**
Name of PI on Proposal: Gary Melnick, Smithsonian Astrophysical Observatory
Sponsoring agency or organization: NASA
Performance period: 2/1/13 – 8/31/20
Total budget: $757,773
Commitment: .75 month

Project title: (This Proposal) **Reflight of the Stratospheric TeraHertz Observatory: STO-2**
Name of PI on Proposal: Antony A. Stark, Smithsonian Astrophysical Observatory
Sponsoring agency or organization: NASA
Performance period: 1/1/14 – 12/31/16
Total budget: $212,137
Commitment: 2 months

CURRENT AND PENDING SUPPORT
ANTONY A. STARK

CURRENT AWARDS

Project title: **SAO/Cosmological Observations with the 10 Meter South Pole Telescope**
Name of PI on Award: Antony A. Stark, Smithsonian Astrophysical Observatory
Sponsoring agency or organization: NSF/OPP (via University of Chicago)
Performance period: 10/01/07 – 09/30/13
Total budget: $654,693
Commitment by PI: 4 months

Project title: **SAO Component of Herschel Legacy Observations of Inner Galaxy Gas**
Name of PI on Award: Antony A. Stark, Smithsonian Astrophysical Observatory
Sponsoring agency or organization: NASA/Herschel Science Center
Performance period: 03/04/09 – 09/30/13
Total budget: $350,523
Commitment by PI: 2 months

Project title: **Analysis of ISO Galactic Center Observations: Far Infrared Grating Line Maps and Fabry-Perot Spectra**
Name of PI: Antony A. Stark, Smithsonian Astrophysical Observatory
Sponsoring agency or organization: NASA
Performance period: 05/01/10 – 04/30/13
Total budget: $273,562
Commitment by PI: 1 month

Project title: **Optical Confirmation, Redshifts, and Richness for Galaxy Clusters Discovered with the South Pole Telescope**
Name of PI on Award: Antony A. Stark, Smithsonian Astrophysical Observatory
Sponsoring agency or organization: NSF/AST
Performance period: 09/01/10 – 08/31/14
Total budget: $930,881
Commitment by PI: 4 months

Continued, next page

PENDING PROPOSALS

Project title: **OCAM: An Oxygen Heterodyne Camera for SOFIA**

Name of PI on Proposal: Antony A. Stark, Smithsonian Astrophysical Observatory
Sponsoring agency or organization: NASA
Performance period: 6/1/12 – 5/31/16
Total budget: $220,775
Commitment by PI: .75 month

Project title: **Cosmological Observations with the 10-meter South Pole Telescope (June 2012)**

Name of PI on Proposal: Antony A. Stark, Smithsonian Astrophysical Observatory
Sponsoring agency or organization: NSF
Performance period: 11/1/12 – 10/31/17
Total budget: $511,150
Commitment by PI: 4 months

Project title: **GUSSTO!: GAL/XGAL U/LDB Spectroscopic/Stratospheric THz Observatory**

Name of PI on Proposal: Gary Melnick, Smithsonian Astrophysical Observatory
Sponsoring agency or organization: NASA
Performance period: 2/1/13 – 8/31/20
Total budget: $757,773
Commitment by Co-PI: 1 month

Project title: (This Proposal) **Reflight of the Stratospheric TeraHertz Observatory: STO-2**

Name of PI on Proposal: Antony A. Stark, Smithsonian Astrophysical Observatory
Sponsoring agency or organization: NASA
Performance period: 1/1/14 – 12/31/16
Total budget: $212,137
Commitment by PI: 2 months

Co-I: Mark Wolfire

Current and Pending Awards
Project title: "Physical Conditions in PDRs"
Name of PI on Award: Alexander Tielens (Leiden Observatory)
Agency: NASA Herschel, Dr. Lisa Storrie-Lombardi, 626-395-8665, lisa@ipac.caltech.edu
Performance period: 02/14/2011-12/31/13
Total budget: $6 K for UMD
Commitment by Co-I: 0.1 months/yr.

Project title: "Beyond the Peak: Resolved Far-Infrared Spectral Mapping of Nearby Galaxies with SPIRE/FTS"
Name of PI on Award: J. D. Smith (University of Toledo)
Agency: NASA Herschel, Dr. Lisa Storrie-Lombardi, 626-395-8665, lisa@ipac.caltech.edu
Performance period: 02/14/2011-12/31/13
Total budget: $25 K for UMD
Commitment by Co-I: 0.6 months/yr.

Project title: "Hydrogen Fluoride Absorption Toward Luminous Infrared Galaxies"
Name of PI on Award: Steven Lord (IPAC)
Agency: NASA Herschel, Dr. Lisa Storrie-Lombardi, 626-395-8665, lisa@ipac.caltech.edu
Performance period: 03/14/2012-3/13/15
Total budget: $11 K for UMD
Commitment by Co-I: 0.3 months/yr.

Project title: "[CII] Observations of the Perseus Molecular Cloud""
Name of PI on Award: Snezana Stanimirovic (UW, Madison)
Agency: NASA Herschel, Dr. Lisa Storrie-Lombardi, 626-395-8665, lisa@ipac.caltech.edu
Performance period: 03/14/2012-3/13/15
Total budget: $30 K for UMD
Commitment by Co-I: 0.8 months/yr.

Project title: "Scaled Eagle Nebula Experiments on NIF"
Name of PI on Award: Marc Pound (University of Maryland)
Agency: DOE HEDLP, Ms. Ann Satsangi, 301-903-9707, Ann.Satangi@Science.Doe.gov
Performance period: 07/01/2012-6/20/15
Total budget: $82 K for Wolfire, UMD

Commitment by Co-I: 1.6 months/yr

Pending Awards

Project title: "Gal/Xgal U/LDB Spectroscopic/Stratospheric THz Observatory"
Name of PI on Award: Christopher Walker (Steward Observatory)
Agency: NASA APRA, Dr. David L. Pierce, 757-824-1453, david.l.pierce@nasa.gov
Performance period: 9/17/12-8/31/20 pending
Total budget: $276 K for UMD pending
Commitment by Co-I: 1.8 months/yr pending

Project title: "Carbon in the Interstellar Medium"
Name of PI on Award: Mark Wolfire (University of Maryland)
Agency: NSF AAG, Katharina Lodders, 703-292-4895, klodders@nsf.gov
Performance period: 9/01/13-8/31/16 pending
Total budget: $395 K for UMD pending
Commitment by Co-I: 4.0 months/yr pending

Project title: "Providing a New Theoretical Framework for the Interpretation of High-Redshift Galaxy Observations"
Name of PI on Award: Philip Maloney (University of Colorado)
Agency: NSF TCAN, Thomas S. Statler, 703-292-4910, tstatler@nsf.gov
Performance period: 9/01/13-8/31/16 pending
Total budget: $155 K for UMD pending
Commitment by Co-I: 3.0 months/yr pending

Project title: "Reflight of the Stratospheric TeraHertz Observatory: STO-2"
Name of PI on Award: Christopher Walker (Steward Observatory)
Agency: NASA ARPA, Michael Garcia, (202) 358-1053, Michael.R.Garcia@nasa.gov
Performance period: 1/01/14-12/31/16 pending
Total budget: $80 K for UMD pending
Commitment by Co-I: 1.5 months/yr pending

Jet Propulsion Laboratory
California Institute of Technology
4800 Oak Grove Drive
Pasadena, California 91109-8099
(818) 354-4321

JPL

March 19, 2013

Refer to: 710-RAL:kp

Professor Christopher Walker
Department of Astronomy and Steward Observatory
University of Arizona
933 North Cherry Avenue, Room N204
Tucson, AZ 85721-0065

Dear Professor Walker,

Subject: Proposal entitled, "Reflight of the Stratospheric TeraHertz Observatory: STO-2"

Reference: NASA Research Element Announcement entitled, "Astrophysics Research and Analysis," dated February 14, 2012 (NNH12ZDA001N-APRA)

The Jet Propulsion Laboratory is pleased to be your partner on the subject proposal and endorses the participation of Drs. Jonathan Kawamura, Paul Goldsmith, William Langer, Imran Mehdi, Jorge Pineda, and Harold Yorke as co-investigators.

The Jet Propulsion Laboratory is committed to providing the support described in the proposal on cost and schedule assuming NASA funds the proposal.

Please refer to Proposal Number 19005 on all written correspondence to JPL pertaining to this proposal.

If you have any questions regarding JPL's participation on this proposal, please feel free to contact me at (818) 354-5082.

Sincerely,

Roger A. Lee

Roger A. Lee
Deputy Manager, Astrophysics and Heliophysics Formulation Office
Astronomy, Physics, and Space Technology Directorate

STATEMENTS OF COMMITMENT

APL
The Johns Hopkins University
APPLIED PHYSICS LABORATORY

3/5/2013

Prof. Christopher K. Walker
Steward Observatory
933 N. Cherry St.
Tucson, AZ 85721

Dear Chris,

I acknowledge that I am identified by name as a Co-Investigator to the investigation, entitled **Reflight of the Stratospheric TeraHertz Observatory: STO-2**, that is submitted by Prof. Christopher Walker to the NASA Research Announcement, NNH12ZDA001N, and that I intend to carry out all responsibilities identified for me in this proposal. I understand that the extent and justification of my participation as stated in this proposal will be considered during peer review in determining in part the merits of this proposal. I have read the entire proposal, including the management plan and budget, and I agree that the proposal correctly describes my commitment to the proposed investigation. For the purposes of conducting work for this investigation, my participating organization is the JHU/Applied Physics Laboratory.

Sincerely,

Pietro Bernasconi

Ball Aerospace & Technologies Corp.
1600 Commerce Street, Boulder, CO 80301 (303) 939-4000 FAX (303) 939-5100

March 18, 2013

In reply, please refer to CSS.13.JLS.003

Prof. Christopher K. Walker
Steward Observatory
933 N. Cherry St.
Tucson, AZ 85721

Subject: Letter of Commitment for the *STO-2* Proposal
Reference: NASA Research Opportunities in Space and Earth Sciences – 2012: Astrophysics Research and Analysis (NNH12ZDA001N-APRA)

Dear Prof. Walker:

Ball Aerospace & Technologies Corp. (BATC) is pleased to support your proposal entitled "*Reflight of the Stratospheric TeraHertz Observatory: STO-2*" that you are submitting to the NASA Research Announcement NNH12ZDA001N-APRA. We were very pleased with the performance of the *STO* dewar during the January 2012 balloon flight, and look forward to providing you with consulting and engineering support to perform additional thermal analysis of the cryostat and recommendations on dewar redesign to best meet the *STO-2* performance requirements. The *STO-2* reflight, which will continue to use the BATC-provided Lightweight Low Cost (LLC) dewar that was flown on the *STO* flight, represents a low risk and cost effective way for NASA to achieve exciting scientific results by leveraging the technologies and team experience demonstrated on the *STO* balloon flight.

for Dr. Carl Gelderloos
Director, Business Development
Civil Space and Technology
Ball Aerospace & Technologies Corp.

Participant	Team	Affiliation	Participation Activity	% Effort per year		
				1	2	3
Walker, Christopher	I,S	Arizona	Project PI, Star Formation	8.3	8.3	8.3
Bernasconi, Pietro	I,S	JHU/APL	Gondola & Telescope Systems	33.3	42	8
Duffy, Brian	I	Arizona	Program Manager	50	50	25
Goldsmith, Paul	I,S	JPL	Heterodyne Systems, ISM Physics	14	20	25
Groppi, Christopher	I,S	ASU	Heterodyne Systems, Star Formation	8.3	8.3	8.3
Hollenbach, David	S	SETI	Project Scientist, ISM Physics	10	15	15
Kawamura, Jonathan	I,S	JPL	Focal Plane Unit Lead, ISM Physics	40	54	5
Kulesa,Craig	I,S	Arizona	Deputy PI, ISM physics	25	25	25
Mehdi, Imran	I,S	JPL	THz Local Oscillators	1	1	0
Langer, William	S	JPL	ISM Physics, Star Formation	0	2	4
Pineda, Jorge	S	JPL	ISM Physics, Data Analysis	0	11	16
Stadler, Brian	I,S	SAO	Telescope/Instrument Optics, Analysis	10.3	16	10.3
Stark, Antony	I,S	SAO	Submm Surveys, Analysis Software	10.3	15.7	10
Wolfire, Mark	S	Maryland	ISM Physics	4.3	16.6	16.6
Yorke, Harold	S	JPL	Synergy with Herschel	0	2	4

Table 1: Activities of the Science (S) and Instrument (I) Teams

Facilities and Equipment

University of Arizona, Steward Observatory

In 1992 the PI established a laboratory (the Steward Observatory Radio Astronomy Laboratory, SORAL) for the development of state-of-the-art submillimeter-wave receiver systems. SORAL served as the central I&T facility for the STO-1 flight instrument. SORAL will continue working closely with JPL and Ball Aerospace on the planned upgrades of the STO-2 receiver system. SORAL possesses all the equipment (spectrum analyzers, network analyzer's, vacuum pumps, cryogenic support facilities, etc.) needed for the development and characterization of receivers. We have 4He, 3He, and closed-cycle cryostats, a full receiver test-bed, local oscillator sources (including a Coherent/DEOS FIR laser), and an antenna test range which allow us to characterize a wide range of receiver systems. SORAL has licenses for CST Microwave Studio, Zemax, and Code V. These programs are used to accurately model the electrical and optical performance of instrument components. SolidWorks is used to accurately portray the instrument in 3-D. The 3-D models are exchanged between Instrument Team members to insure mechanical interface compatibility.

Using these facilities, SORAL has designed and built a number of receiver systems; including single pixel 230, 490, and 810 GHz receivers and the world's first 345 and 810 GHz arrays. SORAL has been a primary facility instrument builder for both the 10m Heinrich Hertz Telescope on Mt. Graham, Arizona and the AST/RO telescope at the South Pole. Based upon the success of these instruments, the PI was awarded a NSF Major Research Instrumentation (MRI) grant to design and construct the world's largest submillimeter wave heterodyne instrument; a 64 pixel, 345 GHz array receiver. The instrument (known as *SuperCam*, short for Superheterodyne Camera) is a multi-institutional project, much like STO, with many of the same team members. SuperCam will begin its survey of the Milky Way in CO J=3-2 later this year. Much of the instrument control electronics/software flown on STO-1 was originally developed for SuperCam.

STO-1 Dewar Integration:

The UofA has the facilities, personnel, and support equipment needed to assemble, operate, and test leading-edge THz instrumentation for balloon-borne astronomy.

BUDGET NARRATIVE INTRODUCTION

Here we propose to re-fly STO with an upgraded, more robust cryogenic/receiver system that will permit THz observations to continue for up to 46 days. STO-2 will benefit tremendously from the heritage and experience gained during the STO-1 campaign.

This Budget Element explains the total cost the University of Arizona (UA) is expected to incur during the 3 year period of performance of this project (January 1, 2014 – December 31, 2016). The estimates include all labor costs, materials, capital expenses, travel, and indirect (F&A) charges.

The UA budget will be one element in a larger budget to be submitted to the NASA ROSES-2012 Announcement of Opportunity (AO). The total project cost is $4.145million. This proposal is being submitted as a *Multiple-Institution* proposal with the University of Arizona acting as the lead institution.

As instructed by the ROSES AO, each of the Co-Investigator institutions will be requesting separate awards by independently submitting their institutional budgets and task statements through NSPIRES. As directed, they are included in this submission for completeness. The Principal Investigator, Dr. Christopher Walker, is a UA faculty member.

2013 DOLLAR AND SALARY INCREASES

The budget was calculated using 2013 dollars. A salary increase of 3.3% annually (each January) was used for all staff listed.

DIRECT LABOR

Summary

The labor hours applied to the research in the period specified is 10,329 labor hours. This is averages out to an average of 1.65 FTE per year for the period of performance (based on 2088 hr work year).

The labor FTEs are broken down by calendar year in Table B:
Table B1: Annual Labor Breakdown

Year	2014	2015	2016	All Years FTE
Faculty & Science	0.33	0.33	0.33	0.99
Technical Personnel	0.17	0.17	0	0.34
Management	0.5	0.5	0.25	1.25
Graduate Student	0.61	0.61	0.61	1.83

Layout

The UA budget uses calendar years (Jan-Dec) as the time ordinance and has been divided into the basic categories of: 1) Labor; 2) Capital Equipment; 3) Travel; 4) Operations; 5) Indirect costs (F&A). The budget details start with the direct labor calculations for all participants that are to be directly compensated. The direct labor is calculated using the base hourly wages and the level of effort (number of hours) of each individual. The detailed budget includes the starting hourly wages (based upon April 2012 values). Year 1 direct labor is calculated using this wage. For each subsequent year the hourly wage is increased by a 3.3% (inflationary increase) factor to arrive at the adjusted labor cost. The grand total of the direct labor is the sum of all wages with the benefits.

Annual Wages = Rate2012 * Effort * 1.03n-1
where n=1,2, or 3.

UA Academic and Summer Terms

The Faculty and Student employee year is broken into the academic and the summer terms.

The academic term is 9 months, or 39 weeks in duration. The summer term is 3 months or 13 weeks in duration.

UA Faculty and Student Academic and Summer Hours and Rates

Faculty members are allowed a total of 464 hours of compensation during the summer term and 1600 hours during the Academic term. The faculty summer rate is calculated using 155 hours per month. The faculty hourly rate is calculated using the following formula: *Rate = (Academic Salary)*.00072*.

Graduate students are allowed to work a total of 800 hours (89 hrs/month) during the academic term and 464 hours (155 hrs/month) during the summer term. The hourly rate is calculated using the formula: *Rate = (Academic Salary)*.00072*.

UA Appointed Personnel and Classified Staff Hours

Appointed and Classified staff hourly rates are calculated using a 2088-hour work year or approximately a 174-hour work month.

Project Management

The project management effort will include detailed financial tracking as well as project requirements and goal tracking. The effort for these duties are over and above the typical departmental duties provided.

Fringe Benefits Rates

The benefits rates are listed in Table B2. The dollar value is calculated by multiplying the benefits rate to the wages earnings for the specified period.

Table B2: Benefits Schedule

Employee Type	Benefit Rate
Faculty	31.2%
Appointed Staff	31.2%
Classified Staff	48.7%
Graduate Students	
Tuition Remission	58.3% IDC exempt
Fringe Benefits	6.7%

Benefits $ = Hours x Hourly Rate x Benefit rate

SUBCONTRACTS

Subcontracts are used to manage the flow of creative effort between the PI Institution and collaborators.

DIRECT FUNDING

As instructed by the ROSES AO each of the Co-Investigator institutions will be requesting separate awards by independently submitting their institutional budgets and task statements.

EQUIPMENT

Capital equipment purchases of $47,000 are budgeted in this UofA proposal. The following table (Table B3) describes the capital elements and their function. There is an element of fabricated equipment to be required for the success of the project. Fabricated Equipment is defined as elements that are assembled or fabricated within the University from elements that are non-capital acquisitions. (Table B4). The leak checker cost estimate is from an internet quote. The cryocooler estimate comes from the manufacturer. All other estimates are based on the cost incurred in the fabrication and/or procurement of the same or very similar items for STO-1.

Table B3: Capital Acquisitions

Capital item	Description	Cost	Method of Estimate
Helium leak Checker	Leak Checker is essential to ensuring tyhe integrity of vacumm seals and that they are fully functional and not damaged in transit to launch site	$13,000	Internet Search

Omnysis Spectrometer Card (spare)	Flight spectrometer requires 4 cards. this will be a spare in the event that one of the flight cards malfunctions	$10,000	Recent Purchase of similar item
Sun power Cryotel CT linear Stirling cycle cooler	The Cryotel CT Cryocooler is used to extend the lifetime of the cryogens required to cool the STO instrument. These funds also provide a spare	$24,000	Email quote from vendor

Table B4:Fabrication

Item	Description	Cost	Notes
Cryostat Lid	Needed to accommodate new window/FPU placement.	18,000	Cost's derived from STO Project
Cryostat Collar	Needed to accommodate cryocooler upgrade and improved placement of connectors and feed throughs.	15,000	Cost's derived from STO Project
Cryostat radiation shields	Needed to accommodate new window/FPU placement.	18,000	Cost's derived from STO Project
Optics Box	Needed to accommodate simpler, more efficient optical system.	5000	Cost's derived from STO Project
Radiator	Liquid Cooled radiator required to dissipate excess heat from cryocooler	5000	Based on cost's from similarly fabricated equipment

TRAVEL

The STO 2 team leverages the cohesive team spirit and working relationships built during the work-up and participation in the STO-1 Antarctic Campaign of 2011-2012. Weekly telecom’s are used to promote and facilitate inter-organizational communication. Funds are budgeted in year one for two trips of three days length for two people to the Applied Physics Laboratory for kick off and coordination meetings. In year two funds are budgeted for one trip of three days duration and one trip of fourteen days duration is planned for the integration for two people each trip. Travel funds will be chiefly used in the second year of the project for the thermal vac test in Palestine, TX and during the instrument integration phase as well as for preparations leading to the hang test. Two additional trips are planned, 1) for the thermal-vac testing for three people for two weeks and the second for four people for four weeks is budgeted for the hangtest. The baseline trips includes airfare, per diem, rental cars, lodging,. The cost estimate for the basic trip is described in detail in Table B5. The Travel model 2014 is based on the travel costs for a similar effort as experienced in preparation for the STO Antarctic Campaign 2011-2012.

Table B5: Annual Travel

Travel	2014	2015	2016	2016
Destination	Columbia, MD (APL)	Columbia, MD (APL)	Palestine, TX (Hang Test)	Christchurch, NZ
Airfare	1800	1859	514	NA
Lodging	1260	3688	1694	760
Per diem	672	1967	902	384
Rental Car	300	878	600	NA
Per person totals	$1008	$2098	$3646	$1144

SUPPLIES, MATERIALS, & OPS

Operations

Shipping

The delicate nature of the STO II instrument requires special handling and shipping procedures. Various components will be shipped back and forth to locations in Maryland, Colorado and Arizona. Ultimately the entire instrument and support equipment must be shipped to both APL and Palestine, TX for the Hangtest. Considerable money is budgeted for these shipments based upon similar shipping requirements form STOI.

Thermal Vac Testing

Testing the instrument in a thermal vacuum chamber will simulate the atmospheric conditions in which the instrument will operate. A suitable chamber is available in Palestine, Tx. Shipment of the entire instrument and its support equipment back and forth from Arizona is required for this test. Funds for travel and lodging are covered in the travel section

Research Supplies and Services

All supplies described in this budget are charged at the indirect rates described below. All estimates of cost of supplies are based on a history of usage within Steward Observatory. A description of supplies includes research supplies small parts, laboratory supplies (unless notes elsewhere), graphic/photo, and other expendable materials, cost of technical and user documentation, production,
to be used specifically on this project.

Publication Fees
The main product of the scientific investigation is the publication of journal papers. Estimates for publication fees have been included within the budget. The calculations are based upon the following assumptions: 1) Publication of four UA authored journal paper is expected (these papers are independent of Co-Institutions publications efforts); 2) Journal papers will be approximately 10 pages in length; 4)

Journal page fees were estimated from the *Astrophysical Journal Letters* charges ($110 per page, 2013dollars).

INDIRECT COSTS

University indirect costs (Facilities & Administrative) apply to the subtotal of: 1) Direct Labor (including benefits); 2) Travel; 3) Supplies and materials (including equipment items costing under $5000). The University of Arizona defines capital equipment as equipment items costing $5000 or above.

Indirect Cost Rates
The following table describes the University's Indirect rates for the period of performance of this proposal.
Table B6: UA Indirect Cost Schedule
7/1/10 - 6/30/13 Indirect Rate 51.50%

The total estimated indirect charges for this period of the program is $304,629.

BUDGET PREPARATION
The UA Cost Element summary was
The Stratospheric TeraHertz Observatory: STO
NNH06ZDA001N-APRA2

Prepared by:
Program Manager
Steward Observatory
933 North Cherry Ave.
Tucson, AZ 85721
(520) 621-6916
(520) 621-9843 (FAX)

Reviewed by:
Director, Sponsored Projects
University of Arizona
PO Box 210158
(520) 626-6000
(520) 626-4130 (FAX)

Organization *Arizona Board of Regents, University of Arizona*
PI *Christopher Walker*
PM *Brian Duffy*
Sponsor *NASA*
Performance Period *1/1/2014 - 12/31/2016*

	YEAR 1 TOTAL YEAR 1	YEAR 2 TOTAL YEAR 2	YEAR 3 TOTAL YEAR 3	3 YEAR TOTALS
PERSONNEL				
Personnel Labor + ERE Totals	**$ 150,893**	**$ 155,884**	**$ 110,703**	**$ 417,480**
OTHER DIRECT COSTS				
OPERATIONS	**$ 109,000**	**$ 40,066**	**$ 11,534**	**$ 160,600**
TRAVEL	**$ 4,032**	**$ 38,940**	**$ -**	**$ 42,972**
CAPITAL EQUIPMENT	**$ 47,000**	**$ -**	**$ -**	**$ 47,000**
SUBCONTRACTS	**$ 49,216**	**$ 49,666**	**$ 9,706**	**$ 108,588**
Total Other Direct Costs	**$ 209,248**	**$ 128,672**	**$ 21,240**	**$ 359,160**
TOTAL DIRECT COSTS	**$ 360,141**	**$ 284,556**	**$ 131,943**	**$ 776,640**
INDIRECT COSTS - 51.5%, effective 7/1/10				
Total Indirect Costs	**$ 139,736**	**$ 111,609**	**$ 53,284**	**$ 304,629**
TOTAL UA PROJECT COSTS	**$ 499,877**	**$ 396,165**	**$ 185,227**	**$ 1,081,269**
COLLABORATING ORGANIZATION BUDGETS				
JPL (2013)	$ 620,000	$ 368,000	$ 197,000	$ 1,185,000
ASU (2013)	$ 124,949	$ 99,885	$ 102,259	$ 327,093
SAO(Stark- 2013)	$ 62,170	$ 91,056	$ 58,910	$ 212,136
UMaryland (Wolfire- 2013)	$ 11,359	$ 34,033	$ 34,630	$ 80,022
SETI Institute (2013)	$ 23,108	$ 35,201	$ 55,702	$ 114,011
APL (2013)	$ 517,000	$ 618,000	$ 46,000	$ 1,181,000
Total Project Costs	**$ 1,858,463**	**$ 1,642,340**	**$ 679,728**	**$ 4,180,531**

1 Task Statement

This task statement describes the Jet Propulsion Laboratory's contribution to the proposal entitled, "Re-flight of the Stratospheric Terahertz Observatory: STO-2," being submitted to the NASA 2011 ROSES APRA solicitation. The principal investigator of the project is Dr. Christopher Walker of the University of Arizona. After a brief summary of the scientific motivation, we will describe the tasks to be carried out by JPL.

1.1 Proposal Summary

The STO is a long-duration balloon experiment, which will uniquely probe the origin and evolution of the interstellar clouds from which all stars and planets form. STO will use high spectral and angular resolution observations of C^+ and N^+ fine-structure lines, two of the most important galactic gas tracers, to probe the physical conditions in atomic and molecular clouds over the central and outer regions of the Milky Way. The mission's goals are to

1) Determine the life cycle of Galactic interstellar gas
2) Study the creation and disruption of star-forming clouds in the Galaxy
3) Determine the parameters that affect the star formation rate in the Galaxy
4) Provide templates for star formation and stellar/interstellar feedback in other galaxies.

The observational goal of STO is to make high spectral (0.1 km/s) and angular resolution (~1' near 2 THz) maps of the Galactic plane in the astrophysically important transitions of C^+ and 1.9 THz and N^+ at 1.46 THz. To make these observations STO has an 80 cm aperture and is equipped with an 8-beam cryogenic heterodyne spectrometer. The first flight of STO in January 2012 provided an initial look at C^+ emission from selected regions and maps in neutral carbon.. The reflight will greatly profit from technical lessons learned from the first flight, and will take advantage of recent advances in local oscillator technology whose use will allow for a much simpler optical design for the receiver. JPL will provide local oscillators and mixer arrays, and I&T and science activity support as described in this plan.

1.2 General plan of work: Tasks at JPL

1.2.1 Mixer development

For STO, JPL delivered to the PI institution four 1.5 THz HEB waveguide mixer units that was flown on the first flight (Figure 1a). These mixers performed as expected on the component level and were assembled into the receiver package for flight. For STO-2 JPL will repackage this mixer design and build 4 pixel arrays operating at 1.5 THz and 1.9 THz. The design of these mixers is very mature and their development entails little risk. Measured sensitivity for the receiver noise temperature is 820 K DSB at 1.46 THz and 630 K DSB at 1.90 THz, and each pixel requires 1 μW of LO power. The housings with be built by STO-2 partner Arizona State University. The activities at JPL include two fabrication runs to yield a sufficient quantity of viable mixers, assembly of 4-pixel arrays, and a testing program to determine the sensitivity of the mixers. Each pixel of a mixer can be tested individually so that an actual four-pixel local oscillator is not required during the development period. The mixers will be tested with a 4-pixel LO once the production of the latter is complete.

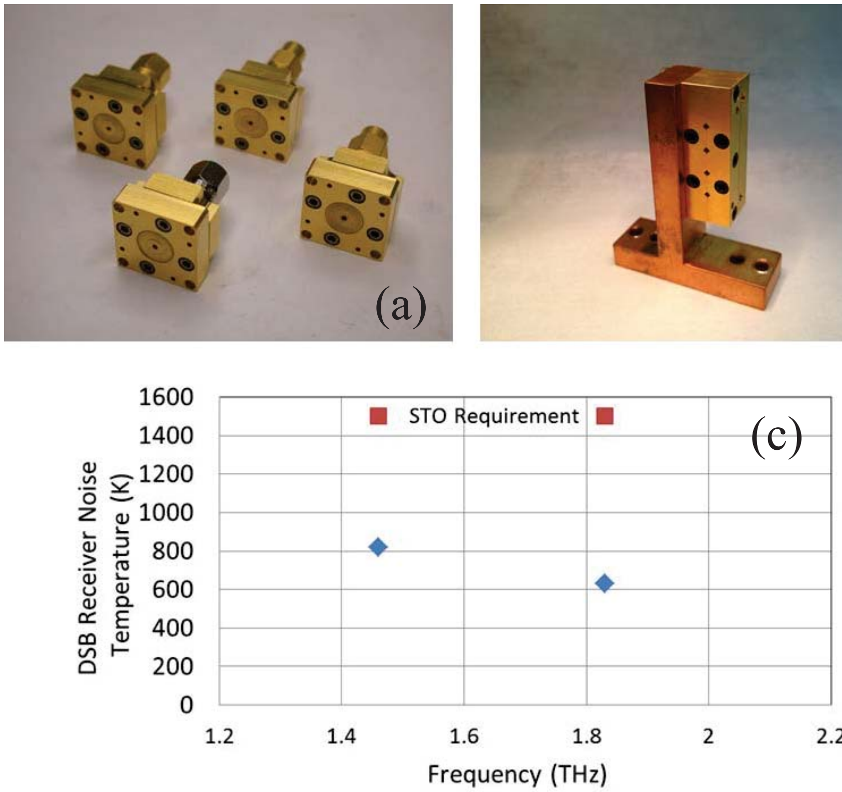


Figure 1. (a) Four 1.46 THz mixers produced for STO-1. (b) Four-pixel 1.9 THz mixer array currently under test. (c) Demonstrated noise performance (blue diamonds) versus STO-2 requirement (red squares) shows there is sufficient performance margin.

1.2.2 Local oscillator development

JPL will provide the PI institution with two local oscillator chains each with four output horns providing power in excess of 10 microwatts at 1.46 THz and 1.90 THz at room temperature. Prototype local oscillators with the required level of performance have been built and demonstrated, as shown below. The only minor change will be to redesign the 1.46 THz chain, which originally targeted a center frequency of 1.37 THz, to shift its response to be centered near the desired frequency. To produce 10 microwatts of output power the 1.46 THz LO chain will require 1 mW input power from 80 GHz to 82 GHz using a WR-10 waveguide flange. The LO chain will consist of 4 parallel cascaded doubler-tripler-tripler diodes as shown in the block diagram (Figure 2). The output will thus be the 18^{th} harmonic of the input frequency. The first two stages will be built in the same housing. A row of diagonal horns will be integrated into the last stage tripler. This level of performance is specified for room temperature operation; cooling the multiplier stages to ~100 K physical temperature will at least double the output power.

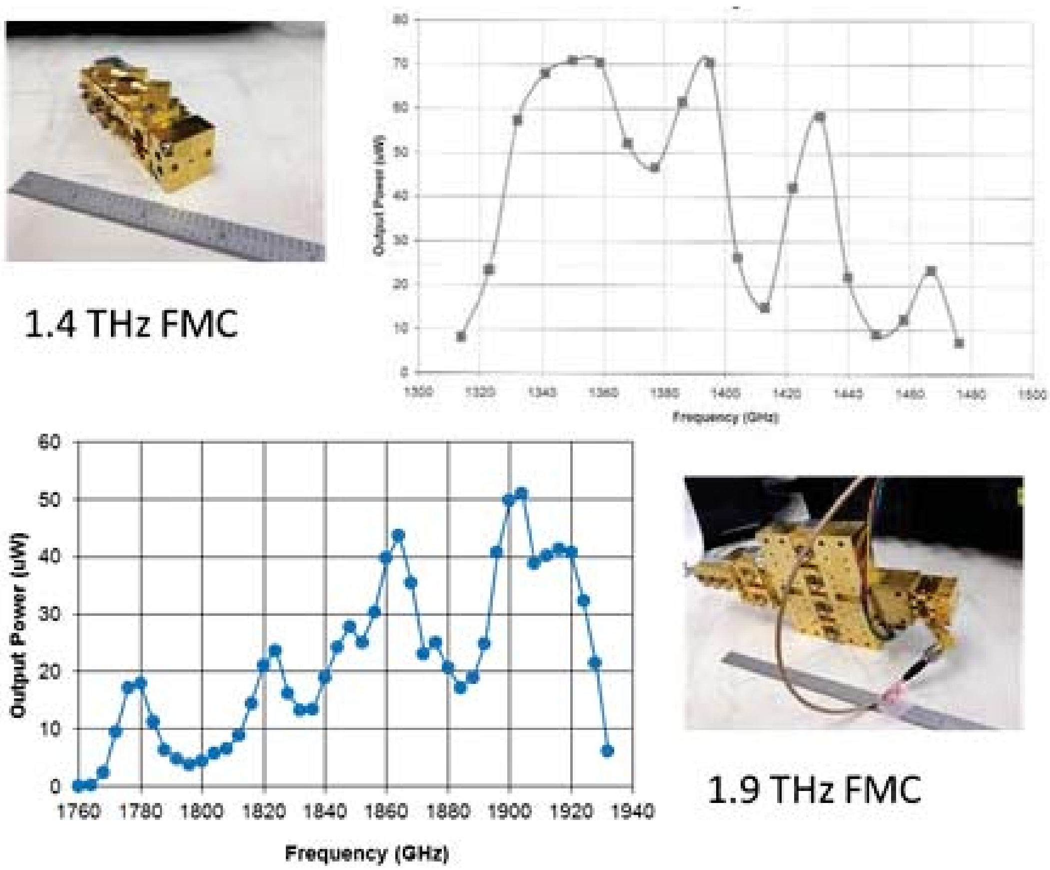


Figure 2. TOP: A local oscillator chain operating near 1.46 THz. This unit produces peak power in excess of 70 µW at room temperature. BOTTOM: A local oscillator chain operating near 1.9 THz produces peak power of 50 µW, also at room temperature. The requirement for STO-2 is output power of 10 µW per pixel, which will comfortably achieved using the approach described here.

The chain will require DC bias for the power amplifier modules and for the three frequency multiplier stages.

The 1.90 THz LO chain will require 1 mW input power from 105 GHz to 107 GHz using a WR-10 waveguide flange. The output will also be the 18^{th} harmonic of the input frequency with a minimum of 10 microwatts centered at 1.90 THz produced at each horn. The construction will be similar to the 1.46 THz LO chain. This level of performance is specified for room temperature operation; cooling the multiplier stages to ~100 K physical temperature will at least double the output power.

The chains will require DC bias for the power amplifier modules and for first two frequency multiplier stages. The bias for the second stage tripler will be used to control the output power from each pixel. Diode devices will be drawn from an existing stock. Machining of the W-band and first stage housing will be performed at ASU; the final tripler stage block will be produced at JPL.

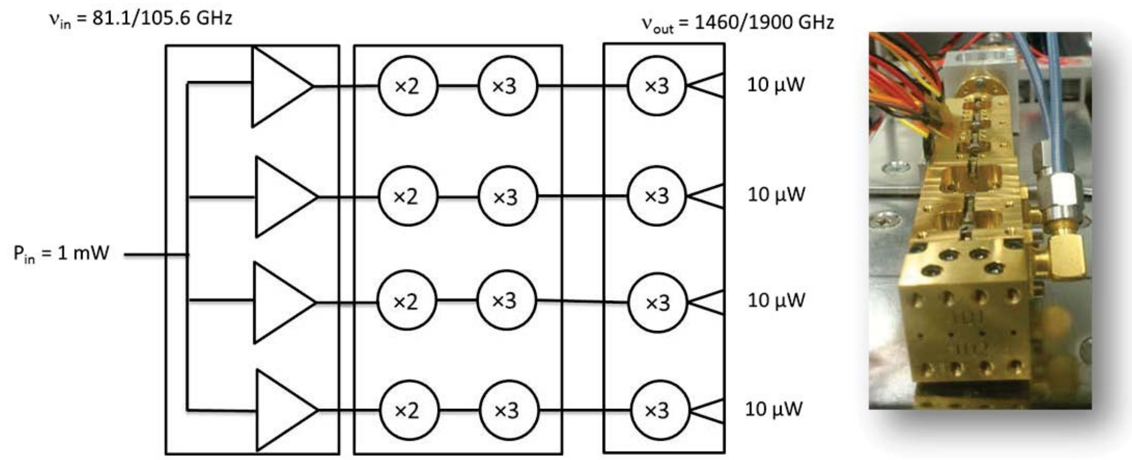


Figure 3. Left: block diagram of the proposed 4-pixel local oscillator unit. It has a single input that accepts power at W-band, a module that divides and amplifies the power into 4 separate channels, a low-frequency module in which the first two stages are housed in the same block, and a block containing the final stage tripler with integrated horns. Right: a 4-pixel 1.9 THz local oscillator under development at JPL.

1.2.3 I&T support

Co-I Kawamura was involved with the integration and testing effort for STO and will bring valuable experience learned from that effort to STO-2. He will participate in the integration and testing of the receiver front-end, during thermo-vac test, the hang-test, and launch operations. This support is provided on a level-of-effort basis.

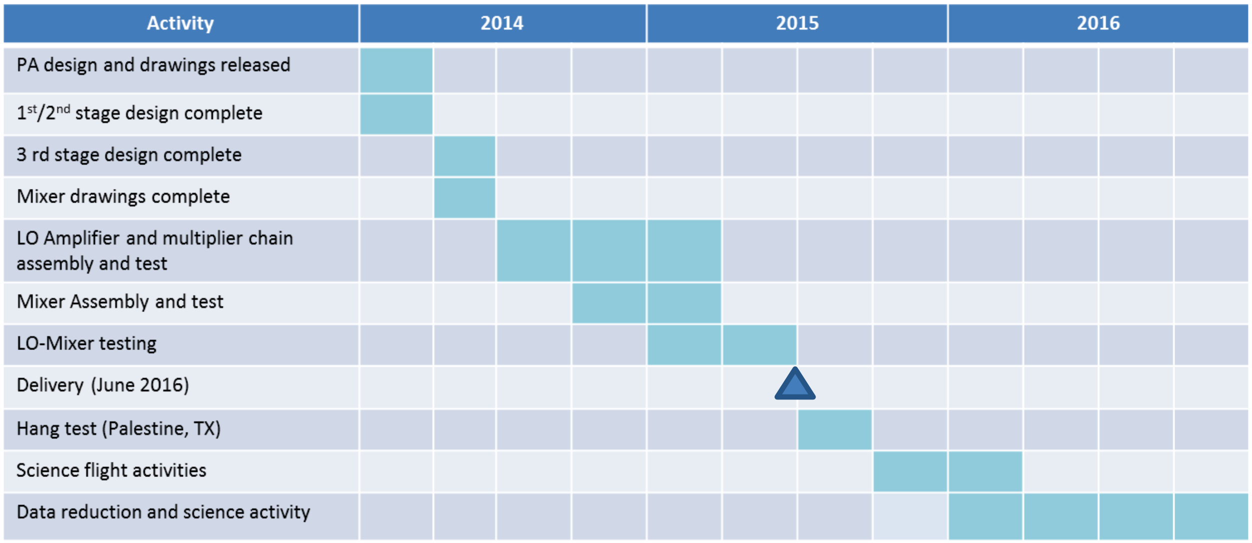
1.2.4 Science support

As this mission bridges the significant gap between current various ground-based terahertz astronomy efforts (e.g., APEX and RLT), and future missions such as Herschel, it is important to plan the science activity so it capitalizes on previous projects and will ensure maximum returns from succeeding missions. JPL is currently involved in a ground-based terahertz astronomy project (Kawamura) and Herschel (Pineda, Goldsmith, Langer and Yorke), so will be able to provide valuable science support to the PI.

1.2.5 Schedule

We assume a January 2014 task start date. The first task is to finalize the design of the power amplifier stage and submit the drawings to ASU. The next two tasks are to complete the drawings for the integrated first/second stage block and the final stage block. The former will be sent to ASU for production. For the latter, a minor design change is necessary for the 1.46 THz final stage block and they will be produced at JPL. The mixer drawings will be completed prior to mid-summer and submitted to ASU for production.

Once the amplifier blocks are returned, they will be populated and tested. Next the first/second stage blocks will be built and tested. Over the next six months the multiplier stages will be built and tested at the component level. Testing the LO with the mixer units will take place during the first half of 2015, with the shipment of the components to the University of Arizona in June 2015. The high level schedule is shown below.



1.2.6 Management structure, expected contribution by co-Is.

Dr. Jonathan Kawamura is the institutional PI and will manage the task at JPL. This will include overseeing the development of the mixer and local oscillator hardware and allocating resources as necessary to ensure timely delivery of the hardware. He will also be involved with the rf testing of the receiver front-end, provide integration and test support on a level-of-effort basis through launch. He will also provide science support, linking the science output from his ground-based project to the STO project. Dr. Imran Mehdi, a co-I, will be responsible for the production of the local oscillator chains.

Drs. Dr. Bill Langer, Paul Goldsmith and Harold Yorke will provide science support, mainly in the third year of the performance period. They are involved in several Herschel projects observing the 1.9 THz C^+ line and will provide a vital link between Herschel's key science objectives and those of STO-2's. Dr. Jorge Pineda will work on analysis of data from the diffuse interstellar medium, in particular cross calibrating STO-2 and Herschel HIFI data. He will work on combining [CII], [NII], CO and HI data in order to separate the different ISM components in the STO-2 survey region and study their properties.

2 References and Citations

None.

5 Budget Justification

5.1 Budget Narrative

5.1.1 Personnel and Work Effort

Name	Organization	Role	Work Commitment		
			Year 1	Year 2	Year 3
Dr. Jonathan Kawamura	JPL	Principal Investigator	0.4	0.5	0.05
Dr. Imran Mehdi	JPL	Co-Investigator	0.1	0.1	-
Dr. Jorge Pineda	JPL	Co-Investigator	-	0.11	0.16
Dr. Paul Goldsmith	JPL	Co-Investigator	0.14	0.2	0.25
Dr. William Langer	JPL	Co-Investigator	-	0.02	0.04
Dr. Harold Yorke	JPL	Co-Investigator	-	0.02	0.04

5.1.2 Facilities and Equipment

1) Microdevices Laboratory, Jet Propulsion Laboratory. This facility houses high-vacuum deposition systems and various pieces of equipment necessary to fabricate terahertz frequency superconductor and semiconductor devices, including optical and electron beam lithography systems, lapping and dicing machines, dry and wet etching capabilities and film deposition systems. No equipment purchases are required for this investigation.

2) Submillimeter-wave Advanced Technology Laboratories. This facility houses extensive collection of hardware required for the manufacturing and characterization of terahertz components and systems. These include a submillimeter-wave network analyzer, extensive collection of coherent sources (frequency-mulitpliers and lasers) and detectors. There is also an extensive collection of instrumented liquid helium-cooled and nitrogen-cooled cryostats and cryo-refrigerators.

5.1.3 Rationale and Basis of Estimate

The STO-2 cost proposal was prepared using JPL’s Pricing System and the current internally published Cost Estimation Rates and Factors dated November 2011.

The derivation of the cost estimate is a grassroots methodology based on the expert judgment from a team of experienced individuals who have performed similar work. The team provides the necessary relevant experience to develop a credible and realistic cost estimate. The cognizant individuals identify and define the products and the schedule needed to complete the tasks for each work element. Then they generate the resource estimates for labor, procurements, travel, and other direct costs for each work element. The resource estimates are aggregated and priced using JPL’s Pricing System. JPL’s process ensures that lower level estimates are developed and reviewed by the performing organizations and their management who will be accountable for successfully completing the proposed work scope within their estimated cost.

5.2 Budget Details – Year 1

Direct Labor – Year 1

- Dr. Jonathan Kawamura is the Institutional PI and will oversee all aspects of the proposed work to occur at JPL. Dr. Kawamura will be involved with the initial designing of the focal plane array, will lead the development of the HEB mixer arrays, and guide the development of the test cryostat. Time Commitment is 0.40 wy. ($44,000 requested salary with $22,740 fringe benefits)
- Dr. Imran Mehdi will serve as a Co-Investigator on this effort. Dr. Mehdi will oversee the production of the local oscillator chains and work with the instrument team to define the interfaces. Time Commitment is .07 wy. ($9,970 requested salary with $5,080 fringe benefits).
- Dr. Paul Goldsmith will serve as co-Investigator on this effort and as Project Scientist. In this role he will be responsible for the overall science program of the STO-2 mission and ensuring publication of results. Time Commitment is 0.14 wy.($22,620 requested salary with $11,550 fringe benefits)
- Dr. Harold Yorke, Dr. William Langer, and Dr. Jorge Pineda will serve as co-Investigators on this effort. For Year 1, they will attend a science planning meeting. ($670 requested salary with $350 fringe benefits, $670 requested salary with $350 fringe benefits, and $440 requested salary with $230 fringe benefits, respectively.
- Semiconductor Device Engineer at the Microdevices Laboratory will produce diodes required for the construction of the local oscillator. Time Commitment is 0.22 wy ($21,180 requested salary with $10,790 fringe benefits.)
- Assembly and test engineer will assemble and test the local oscillator chains. Time commitment is 0.22 wy. ($28,700 requested salary with $14,640 fringe benefits)
- RF designer will complete the local oscillator amplifier design and the first and second stage design and submit the drawings for fabrication. Time commitment is 0.04wy. ($4,210 requested salary with $2,150 fringe benefits)
- THz RF designer will complete the final stage multiplier design including modifying the 1.46 THz multiplier circuit to meet STO-2’s needs. Time commitment is 0.1 wy. ($9,110 requested salary with $4,650 fringe benefits)
- Superconductor Device Enginer at the Microdevices Laboratory will produce superconducting mixers and microplated backpieces. Time commitment is 0.3 wy. ($36,950 requested salary with $18,840 fringe benefits)

Other Direct Costs – Year 1

Subcontracts/Subawards

- Desktop Network Chargebacks (calculated at $5.73/hr.): All JPL computers are subject to a monthly service charge that includes hardware, software, and technical support. ($17,330)

Consultants

- There are no consultants required for this task.

Equipment

- There are no major equipment purchases necessary.

Services

- Machine Shop: Fabrication of final stage multiplier blocks, 2 sets at $20,000 ea.
- Microdevices Laboratory Usage fee: calculated at $25,000 per wy, requesting $17.2k.
- Equipment loanpool: rental of instrumentation required for testing diode devices and mixers $21.8k

- Cryogenics: Access to liquid nitrogen and helium ($0.6k monthly) + liquid helium product cost for 4 months of testing (3 60 liter dewars @ $500 ea). $8.4k total.

Supplies and Publications

- W-band isolators, 2 units at $4k ea ($8k requested)
- GaN MMIC amplifier devices (Northrup Grumman Corporation), 8 units at $1.5k ea ($12k requested)
- General cleanroom laboratory supplies, based on actuals of running laboratory $20k requested.
- Photolithography mask set $3k requested;
- SOI wafers for mixer production $5k lot charge.
- Publication and Documentation: None.

Travel

- 5 team members will go attend project meetings in Tucson, AZ. $400 airfare, 3 days with $130 per diem $4k; PI and LO team member will make two additional trips to Tucson to participate in week-long testing activity, $400 airfare, 8 days with $130 per diem $2.9k. $7k total requested.

Other

- Multiple Program Support (MPS) $38.7K.

Facilities and Administrative (F&A) Costs – Year 1

- Allocated Direct Costs (ADC) $88.2K.
- Applied General ADC $61.8K.

Other Applicable Costs – Year 1

- none

Total Estimated Costs for Year 1: $618,770

5.3 Budget Details – Year 2

Direct Labor – Year 2

- Dr. Jonathan Kawamura is the Institutional PI and will oversee all aspects of the proposed work to occur at JPL. Dr. Kawamura will be involved with the integration and testing activities of the instrument in Year 2, including supporting the I&T effort in Tucson, the hang-test in Palestine, Texas, and the balloon launch activities in Williams Field, Antarctica. Time Commitment is 0.54 wy. ($65,490 requested salary with $33,400 fringe benefits)
- Dr. Imran Mehdi will serve as a Co-Investigator on this effort. Dr. Mehdi will oversee the delivery of the local oscillator chains. Time Commitment is .03 wy. ($4,020 requested salary with $2,050 fringe benefits).
- Dr. Paul Goldsmith will serve as co-Investigator on this effort and as Project Scientist. In this role he will be responsible for the overall science program of the STO-2 mission and ensuring publication of results. Time Commitment is 0.20 wy.($32,910 requested salary with $16,770 fringe benefits)
- Dr. Harold Yorke, Dr. William Langer, and Dr. Jorge Pineda will serve as co-Investigators on this effort. For Year 2, they will begin planning science activities and attend a science planning meeting. Time commitment is 0.02 wy for Drs. Yorke and Langer and 0.11 wy for Dr. Pineda ($2830 requested salary with $1450 fringe benefits, $2830 requested salary with $1450 fringe benefits, and $11,410 requested salary with $5,810 fringe benefits, respectively.
- Assembly and test engineer will assemble and test the local oscillator chains. Time commitment is 0.18 wy. ($13,030 requested salary with $6,640 fringe benefits)

Other Direct Costs – Year 2

Subcontracts/Subawards

- Desktop Network Chargebacks (calculated at $5.73/hr.): All JPL computers are subject to a monthly service charge that includes hardware, software, and technical support. ($11.4K)

Consultants

- There are no consultants required for this task.

Equipment

- There are no major equipment purchases necessary.

Services

- Equipment loanpool: rental of instrumentation required testing multiplier assemblies, including spectrum analyzer and microwave synthesizer. $5k per month for 4 months. $20k.
- Cryogenics: Access to liquid nitrogen and helium ($0.6k monthly) + liquid helium product cost for 1 month of testing (1 60 liter dewars @ $500 ea). $1.1k total.

Supplies and Publications

- Publication and Documentation: None.

Travel

- 5 team members will go attend project meetings in Tucson, AZ. $400 airfare, 3 days with $130 per diem $4k; I&T support engineers will make a total of six trips to Tucson (3), Baltimore, MD, and Palestine, TX to participate in week-long testing activity, $400 airfare, 8 days with $130 per diem $9K. $13K total requested.

Other

- Multiple Program Support (MPS) $27.6K.

Facilities and Administrative (F&A) Costs – Year 2

- Allocated Direct Costs (ADC) $58.1K.

- Applied General ADC $36.6K.

Other Applicable Costs – Year 2

- none

Total Estimated Costs for Year 2: $367,890

5.4 Budget Details – Year 3

Direct Labor – Year 3

- Dr. Jonathan Kawamura is the Institutional PI and will oversee all aspects of the proposed work to occur at JPL. In Year 3 Dr. Kawamura will be involved data reduction from the instrument and science activities. Time Commitment is 0.05 wy. ($6,750 requested salary with $3,440 fringe benefits)
- Dr. Paul Goldsmith will serve as a Co-Investigator on this effort. He will participate in science activities. Time Commitment is 0.25 wy ($42,960 request salary with $21,910 fringe benefits).
- Dr. Harold Yorke will serve as a Co-Investigator on this effort. He will participate in science activities. Time Commitment is 0.04 wy ($6,130 request salary with $3,120 fringe benefits).
- Dr. William Langer will serve as a Co-Investigator on this effort. He will participate in science activities. Time Commitment is 0.04 wy ($6,130 request salary with $3,120 fringe benefits).
- Dr. Jorge Pineda will serve as a Co-Investigator on this effort. He will participate in science activities. Time Commitment is 0.16 wy ($17,820 request salary with $9,100 fringe benefits).

Other Direct Costs – Year 3

Subcontracts/Subawards

- Desktop Network Chargebacks (calculated at $5.73/hr.): All JPL computers are subject to a monthly service charge that includes hardware, software, and technical support. ($5.8K)

Consultants

- There are no consultants required for this task.

Equipment

- There are no major equipment purchases necessary.

Services

- No services required.

Supplies and Publications

- Publication and Documentation: None.

Travel

- 5 team members will go attend project meetings in Tucson, AZ. $400 airfare, 3 days with $130 per diem $4k; PI and LO team member will make two additional trips to Tucson to participate in week-long payload recovery activity (removing components from payload), $400 airfare, 8 days with $130 per diem $2.9k. $7k total requested.

Other

- Multiple Program Support (MPS) $14.4K.

Facilities and Administrative (F&A) Costs – Year 3

- Allocated Direct Costs (ADC) $29.3K.
- Applied General ADC $19.5K.

Other Applicable Costs – Year 3

- none

Total Estimated Costs for Year 3: $196,540

STO-2

Timephased Cost Estimate Sheet
Dollars (Does not include Gov't Co-I's)

	Jan 2014 - Dec 2014		Jan 2015 - Dec 2015		Jan 2016 - Dec 2016		Total Program		
Hours / (FTEs)									
Dr. Jonathan Kawamura	671	(0.40 FTE)	955	(0.54 FTE)	95	(0.05 FTE)	1,720	(0.99 FTE)	Hours / (FTEs)
Dr. Imran Mehdi	116	(0.07 FTE)	45	(0.03 FTE)	0	(0.00 FTE)	162	(0.10 FTE)	Hours / (FTEs)
Dr. Paul Goldsmith	251	(0.14 FTE)	353	(0.20 FTE)	443	(0.25 FTE)	1,047	(0.59 FTE)	Hours / (FTEs)
Dr. Harold Yorke	8	(0.00 FTE)	31	(0.02 FTE)	64	(0.04 FTE)	103	(0.06 FTE)	Hours / (FTEs)
Dr. William Langer	8	(0.00 FTE)	31	(0.02 FTE)	64	(0.04 FTE)	103	(0.06 FTE)	Hours / (FTEs)
Dr. Jorge Pineda	8	(0.00 FTE)	189	(0.11 FTE)	285	(0.16 FTE)	481	(0.27 FTE)	Hours / (FTEs)
Semiconductor Dev Engr	390	(0.22 FTE)	0	(0.00 FTE)	0	(0.00 FTE)	390	(0.22 FTE)	Hours / (FTEs)
Assembly and test engr	639	(0.36 FTE)	283	(0.18 FTE)	0	(0.00 FTE)	922	(0.54 FTE)	Hours / (FTEs)
RF designer	64	(0.04 FTE)	0	(0.00 FTE)	0	(0.00 FTE)	64	(0.04 FTE)	Hours / (FTEs)
THz RF designer	139	(0.09 FTE)	0	(0.00 FTE)	0	(0.00 FTE)	139	(0.09 FTE)	Hours / (FTEs)
Superconductor Dev Engr	563	(0.31 FTE)	0	(0.00 FTE)	0	(0.00 FTE)	563	(0.31 FTE)	Hours / (FTEs)
Total Hours:	2,856	(1.63 FTE)	1,888	(1.10 FTE)	950	(0.54 FTE)	5,694	(3.27 FTE)	Subtotal
Amount		$179,120		$132,520		$79,790		$391,430	JPL Direct Labor Cost w/
Fringe		$91,370		$67,570		$40,690		$199,630	Fringe
Category A		$0		$0		$0		$0	Cat A Direct Labor Cost
Total Direct Compensation (includes Employee Benefits)		$270,490		$200,090		$120,480		$591,060	Subtotal
Travel		$7,000		$13,000		$7,000		$27,000	Direct Travel Cost
JPL Services		$88,300		$21,100		$0		$109,400	Direct Services Cost
Procurements									
Chargebacks		$17,330		$11,420		$5,750		$34,500	Direct Chargebacks cost
Subcontracts		$0		$0		$0		$0	Direct PS cost
Procurement RSA		$0		$0		$0		$0	Direct RSA cost
Purchase Orders		$48,000		$0		$0		$48,000	Direct PM cost
Caltech Transfers		$0		$0		$0		$0	Direct CT cost
Multi-Program Support		$38,740		$27,570		$14,420		$80,730	Direct MPS cost
Total Direct Costs		**$469,860**		**$273,180**		**$147,650**		**$890,690**	Subtotal
Allocated Direct Charge		$88,160		$58,130		$29,340		$175,630	Total ADC
General & Admin		$61,750		$36,580		$19,550		$117,880	Total G&A
Reserves (Burdened)		$0		$0		$0		$0	
Total JPL Costs		**$619,770**		**$367,890**		**$196,540**		**$1,184,200**	Subtotal
Government Co-I's Not in JPL's Costs		**$0**		**$0**		**$0**		**$0**	Bypass
Total Costs		**$619,770**		**$367,890**		**$196,540**		**$1,184,200**	Subtotal

JPL Cost Accumulation System

Introduction

All costs incurred at the Laboratory, including JPL applied burdens, are billed to the Government as direct charges at the rates in effect at the time the work is accomplished.

Allocated Direct Costs

Allocated Direct Cost (ADC) rates contain cost elements benefiting multiple work efforts, including Project Direct, MPS, and Support and Services activities. Rate applications for cost estimates are specific to the given category as stated below:

1) Engineering and Science (E&S)
2) Procurement: Purchase Order, Subcontract, Research Support Agreement (RSA)
3) General and Administrative (G&A): Basic, RSA
4) Specialized G&A applications: Remote Site

The accounting process fully distributes these costs to the respective project/task(s).

Multiple Program Support

The Multiple Program Support (MPS) rate applies costs for program management and technical infrastructure. Cost estimates and system application tools will apply the composite rate to all project direct hours charged to projects managed by JPL.

Employee Benefits

All costs of employee benefits are collected in a single intermediate cost pool, which is then redistributed to all cost objectives as a percentage of JPL labor costs, including both straight-time and overtime. Functions and activities covered by this rate include paid leave, vacations, and other benefits including retirement plans, group insurance plans, and tuition reimbursements.

For this proposal the estimated costs have been derived in the same manner as stated above. However, presentation of the estimated costs in the required tables has been adapted in the following ways:

1. The costs for Employee Benefits are included in the Direct Labor costs stated in this proposal.
2. Engineering and Science ADC and Procurement ADC along with MPS costs are displayed in the “Other” category in the Other Direct Costs section.
3. G&A is shown in the Facilities and Administrative Costs section.
4. JPL’s forecasted labor rates equal an hourly laboratory-wide average for each job family and are further broken down by career level within the job family. Labor cost estimates apply the family average or family average career level rate to the estimated work hours. An actual individual’s labor is considered discrete and confidential information and is only released on an exception basis and only if a statement of work identifies that specific individual as the only one able to perform a task. The use of family average or family average career level rates in consistent with the JPL CAS disclosure statement and the Cost Estimating Rates and Factors CDRL published in response to a requirement in NASA prime contract NAS7-03001 I-10 (d) (1).

The proposed budget of the NRA proposal also covers labor costs for serving on NASA peer-review panels and advisory committee at the request of NASA discipline scientists or program managers.

Task Statement

Arizona State University

Introduction

As a participant in the STO-2 mission, ASU will participate in instrument design and construction, mission I&T, flight operations and data analysis. ASU has unique capabilities in the field of direct metal micromachining, which it will bring to bear on the STO-2 cold optical assembly, flight mixers and LO hardware. In addition, our extensive experience with receiver integration and test will supplement the capabilities of the PI institution during the I&T phase at the University of Arizona, CSBF (Palestine, TX) and in Antarctica. Both the ASU PI and student will also participate in data analysis and publication after the flight.

ASU Deliverables

ASU will provide the following hardware and services for the STO-2 mission:

1. Design and fabrication of an updated cold optics assembly, optimized for maximum fabrication precision and cryogenic performance.
2. Micromachining services for Terahertz waveguide components
    a. 1.4 THz and 1.9 THz waveguide mixer units.
    b. Waveguide multiplier blocks, fabricated for the JPL LO modules. ASU will fabricate all waveguide blocks for the LO with the exception of the final multiplier stages.
3. Instrument Integration and Test support
    a. Initial instrument integration and test at the University of Arizona
    b. Instrument and observatory I&T at the Palestine, TX CSBF facility.
4. STO-2 Flight support in Antarctica
5. Data analysis and dissemination in the post-flight phase.

Cold Optics Assembly

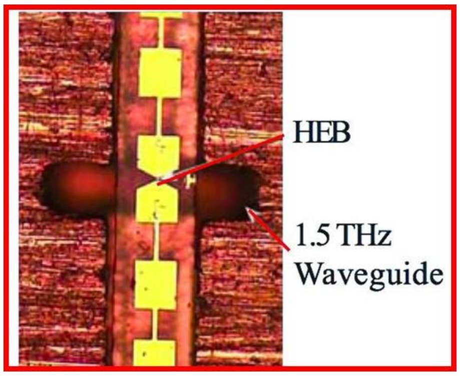
ASU has extensive experience with the design and fabrication of precision machined components. ASU will take the basic designs produced by the University of Arizona and JPL and optimize them for precision fabrication and cryogenic performance. This hardware will then be fabricated with ASU's Kern Model 44 3-axis CNC micromilling system (Figure 1). This machine has a 200mm x 200mm x 200mm work cube (sufficiently large for all STO-2 optical components), with a machining precision of ~1 micron. This system will be used to manufacture the cold optics components to very high precision, using cryogenically optimal materials (high purity copper or

Figure 1: The Kern Model 44 located in the ASU THz lab, with machinist and engineer Matthew Underhill.

aluminum), ensuring optical and cryogenic performance.

Micromachining for Waveguide Components

In addition to the fabrication of the cold optical assembly, ASU will also participate in the design and fabrication of the next generation of STO-2 mixers and LO components. ASU fabricated the STO-1 1.4 THz waveguide mixers (using corrugated horns from Radiometer Physics), and fabricated several waveguide multiplier blocks for JPL provided LO chains (figure 2). These components demonstrated state of the art performance, equal to hardware produced in JPL's own flight hardware shop. For STO-2, ASU will also fabricate required waveguide mixers (1.4 and 1.9 THz), with the added capability of producing direct drilled Pickett-Potter waveguide feeds with a tapered cone circular to rectangular waveguide transformers. Since STO-2 mixers are fixed tuned to the 1.4 and 1.9 THz lines of [NII] and [CII], the ~10% bandwidth of this horn type is not an issue. Direct drilling with custom tools will allow fast and inexpensive fabrication of any necessary feeds. Transition to oval cross-section waveguide will be by means of a tapered cone transformer, 3-D machined with an endmill from the horn side. The oval waveguide will be machined from the back side, using the Kern Model 44's integrated touch-probe system and ultra-high accuracy positioning performance to align the waveguide with the transformer.



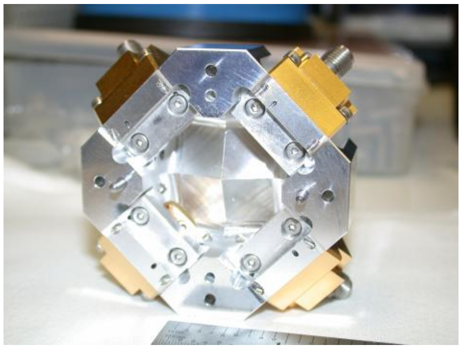


Figure 2: A close up of a STO-1 1.4 THz waveguide mixer produced at ASU (top), and the 4-pixel STO-1 FPU (bottom).

ASU also fabricated several multiplier blocks, at frequencies from 100 GHz to 900 GHz for the STO-1 mission. For STO-2, ASU will work with JPL to design and fabricate additional multiplier blocks for the next generation high power LO sources needed for STO-2. ASU has extensive experience producing complicated, high frequency waveguide blocks for LO sources, and has worked with the JPL group extensively on other projects.

Instrument Integration and Test Support

ASU will assist the PI institution at all phases of instrument I&T. ASU has extensive experience with the construction, test and deployment of THz receiver systems. The ASU PI and a student assisted with the STO-1 test flight in Ft. Sumner, NM in 2009, and the hang test in Palestine, TX in 2011. In addition, ASU designed and built the IF processor module for STO-1. This module worked perfectly during the STO-1 flight, and will be re-used for STO-2. The ASU PI and graduate student will travel to the University of Arizona for instrument I&T activities for STO-2. We will also travel to Palestine, TX for observatory I&T.

STO-2 Flight Support

The ASU PI and graduate student spent 6 weeks in Antarctica in 2011 supporting the STO-1 launch. We will also send personnel to the STO-2 launch, supporting pre-launch observatory I&T in Antarctica. Our extensive experience with both THz receiver systems and the STO payload will provide valuable support in the time up to launch.

Data Analysis and Dissemination

The ASU PI is a member of the STO-1 and STO-2 science teams, and will participate directly in data analysis and dissemination through refereed journal publications. The STO-2 graduate student at ASU is funded for the entire project, and will participate in both engineering and science activities. It is expected that the data provided by the STO-2 flight will become a major part of the thesis for the ASU graduate student funded by this proposed work.

ASU Task Timeline

Year 1:

- Design Cold Optics Assembly
- Design and fabricate LO waveguide components.
- Design and fabricate waveguide mixers and feeds.

Year 2:

- Fabricate and deliver cold optical assembly
- Fabricate additional waveguide components as needed
- Participate in instrument I&T at the University of Arizona

Year 3:

- Participate in instrument I&T at the University of Arizona
- Participate in observatory I&T at CSBF in Palestine, TX
- Participate in STO-2 launch operations in Antarctica
- Participate in data analysis and dissemination post-launch.

STO2

ORGANIZATION ARIZONA STATE UNIVERSITY				DURATION (MONTHS) Proposed 36									
PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR Chris Groppi													
A. SENIOR PERSONNEL:	NSF- Funded Person-months CAL	ACA	SUMR	YEAR ONE 2014	YEAR TWO 2015	YEAR THREE 2016	CUMULATIVE	Rate		ERE 2014	2015	2016	
1. PI: Groppi			1.000	$9,763	$10,056	$10,358	$30,176	87863					
2. Co-PI:			1.000	$0	$0	$0	$0	0					
3. Co-PI:			1.000	$0	$0	$0	$0	0					
4.				$0	$0	$0	$0						
5.													
6. ( ) OTHERS													
7. ( ) TOTAL SENIOR PERSONNEL (1-6)				$9,763	$10,056	$10,358	$30,176			30.70%	31.62%	32.57%	
B. OTHER PERSONNEL													
1. ( ) POST DOCTORAL ASSOCIATES				$0	$0	$0	$0			40.70%	41.92%	43.18%	
2. (1) OTHER PROFESSIONAL	4.00			$21,667	$5,579	$5,746	$32,992			40.70%	41.92%	43.18%	
3. (1) GRADUATE STUDENTS				$23,795	$24,509	$25,244	$73,548	23795		8.80%	9.06%	9.34%	
4. (0) UNDERGRADUATE STUDENTS				$0	$0	$0	$0			1.90%	1.90%	1.90%	
5. ( ) SECRETARIAL - CLERICAL				$0	$0	$0	$0			40.70%	41.92%	43.18%	
6. ( ) OTHER				$0	$0	$0	$0			40.70%	41.92%	43.18%	
TOTAL SALARIES AND WAGES (A+B)				$55,225	$40,144	$41,348	$136,717						
C. FRINGE BENEFITS				$13,910	$7,740	$8,211	$29,861						
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A+B+C)				$69,135	$47,884	$49,559	$166,578						
D. EQUIPMENT			0										
TOTAL EQUIPMENT				$0	$0	$0	$0						
E. TRAVEL 1. DOMESTIC				$1,000	$1,000	$2,500	$4,500						
2. FOREIGN				$0	$0	$0	$0						
				$1,000	$1,000	$2,500	$4,500						
F. PARTICIPANT SUPPORT CO:													
1. STIPENDS													
2. TRAVEL	$0												
3. SUBSISTENCE	$0												
4. OTHER	$0												
( ) TOTAL PARTICIPANT COSTS				$0	$0	$0	$0						
G. OTHER DIRECT COSTS													
1. MATERIALS AND SUPPLIES				$1,000	$5,000	$2,500	$8,500						
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				$0	$0	$0	$0						
3. CONSULTANT SERVICES				$0	$0	$0	$0						
4. Facility Use Fees				$0	$0	$0	$0						
5. SUBAWARDS				$0	$0	$0	$0			adj idc to exclude subaward over 25K; will r			
6. OTHER **Tuition**				$15,402	$16,634	$17,965	$50,001			excluded from idc base			
TOTAL OTHER DIRECT COSTS				$16,402	$21,634	$20,465	$58,501						
H. TOTAL DIRECT COSTS (A THROUGH G)				$86,537	$70,518	$72,524	$229,579						
I. INDIRECT COSTS (F&A) (SPECIFY RATE AND BASE)													
54% FY 15 54.5% MTDC				$71,135	$53,884	$54,559	$179,578			**DHHS agreement dated 05/03/12**			
TOTAL INDIRECT COSTS (F&A)				$38,413	$29,367	$29,735	$97,514			FY 14 = 54%			
J. TOTAL DIRECT AND INDIRECT COSTS (H+I)				$124,949	$99,885	$102,259	$327,093			FY 15-out = 54.5%			
K. RESIDUAL FUNDS													
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)							$327,093						
M. COST SHARING: Proposed Level													

NSF Form 1030 (10/98) *Supersedes All Previous Editions*

Tuition Rates -8% escalation eff 8/20/12

	FY2014	FY2015	FY2016
AY	$14,461	$15,618	$16,868
Sumr	$941	$1,016	$1,097
Total	$15,402	$16,634	$17,965

ERE Rates	FY2014	FY2015	FY2016
Faculty	30.70%	31.62%	32.57%
Staff	40.70%	41.92%	43.18%
Part-time	7.70%	7.70%	7.70%
RA/TA	8.80%	9.06%	9.34%
Hourly Students	1.90%	1.90%	1.90%

Budget Narrative

The proposed work is performed over a 3-year period. An itemized budget listing expenditures over this period is provided.

Employee-Related Expenses (ERE)
ASU has negotiated ERE rates with DHHS that are effective 05/03/12 and have been used in the proposal for budget planning:

ERE Rates	FY2014	FY2015	FY2016
Faculty	30.70%	31.62%	32.57%
Staff	40.70%	41.92%	43.18%
Part-time	7.70%	7.70%	7.70%
RA/TA	8.80%	9.06%	9.34%
Hourly Students	1.90%	1.90%	1.90%

Tuition and Fees
Tuition for graduate students is included as a benefit for graduate students and is charged to projects in proportion to the amount of effort the graduate student will work on the project. The tuition charge for graduate students is $15,402 for FY14, $16,634 for FY15 and $17,965 for FY16. Tuition charges are exempt from the Facilities and Administrative (F&A) costs.

Personnel: In each of the 3 years, funds are requested for 1 month of summer salary for the PI (C. Groppi). PI Groppi is responsible for overseeing all aspects of the project. A graduate student is funded full time (including summer salary) for each year. The graduate student will be responsible for system design and testing, assistance in instrument I&T, launch support and analysis and publication of data. A mechanical engineer and machinist is funded for 4 months in year 1, and one month in years 2 and 3. The engineer will be responsible for micromachining of the mixer waveguide blocks and the majority of the local oscillator waveguide blocks (everything but the final multiplier stages). The engineer will also participate in the design of the cold opto-mechanical assembly and fabricate all the precision opto-mechanical components and direct machined optics.

Travel: One trip per year is requested in years 1 and 2 for the PI to attend project meetings. In year 3, funding is requested for the PI and graduate student to prepare in instrument I&T at Palestine, TX and deployment to Antarctica.

Materials and Supplies: Funding is requested to support fabrication of the optical and micromachined components for STO-2. Funds will pay for materials, tools, gold plating and other miscellaneous supplies for fabrication of the cold optics assemblies, mixer blocks and LO hardware.

Facilities & Administrative Costs

Facilities & Administrative costs are calculated on Modified Total Direct Costs (MTDC) using F&A rates approved by Department of Health and Human Services. The most current rate agreement is dated 3 May 2012 and the rate is 54% for FY14 and 54.5% for all out years for Organized Research. Items excluded from F&A calculation include: capital equipment, subcontracts over the first $25,000, student support, participant support, rental/maintenance of off-campus space, and patient care fees.

I. SAO PROPOSAL SUMMARY

This is a collaboration Co-I Institution proposal for the proposal "Reflight of the Stratospheric TeraHertz Observatory: STO-2" whose lead proposal is submitted by the University of Arizona with Christopher Walker as PI. The Smithsonian Astrophysical Observatory (SAO) is pleased to submit this subsidiary proposal for engineering and scientific collaboration on the Reflight of the Stratospheric TeraHertz Observatory (STO-2). The Institutional Principal Investigator for the SAO effort is Antony A. Stark, and scientific Co-Investigator is Brian Stalder. The work at SAO includes consultation on the refurbishment of the gondola, provision and modification of data acquisition and reduction software, and scientific collaboration on the STO Galactic Plane Survey. SAO will provide support for the refurbishment and testing of the STO at Johns Hopkins University Applied Physics Laboratory (JHU/APL). The STO proposal also requests support for participation in the second Long Duration Flight (LDF) from McMurdo Sound in Antarctica, and for subsequent data analysis, scientific interpretation, and publication of results.

II. SAO TASK STATEMENT

A. Statement of Work

Tasks to be accomplished at SAO are:

1. Consultation in the refurbishment of the recovered STO gondola in consultation with collaborators at JHU/APL. Gondola refurbishment and upgrade considerations are described in the Lead Proposal from U. Arizona.
2. Participation in the second LDF from McMurdo Sound, Antarctica.
3. Contributions to data reduction software development in collaboration with project personnel at University of Arizona and Oberlin College.
4. Data analysis and publication of science results.

B. Roles and Responsibilities

The Institutional P.I., Antony Stark, will be responsible for technical and scientific oversight of the project at SAO. As the P.I. of the successful AST/RO (Antarctic Submillimeter Telescope and Remote Observatory) project from 1989 through 2006, and as a Co-Investigator for the on-going, NSF-funded South Pole Telescope project (P.I.: Dr. John Carlstrom, University of Chicago), Dr. Stark has extensive, directly-related experience in design, fabrication, and use of submillimeter telescopes in extreme environments such as Antarctica, and extensive experience in the acquisition, reduction, and analysis of data from such instruments. Dr. Stark has collaborated on the STO project from the beginning, and has designed and developed some of its hardware and software.

STO Co-Investigator Dr. Brian Stalder will participate in the planning of STO scientific observations and in the data analysis and publication of results. Dr. Stalder has extensive experience in the acquisition and reduction of astronomical data. He contributed to the testing of STO at JHU/APL and to the pre-flight integration and software development for STO at the McMurdo Sound Balloon Launch Facility in November and December 2011. Dr. Stalder will transition from a Post-Doctoral Fellow to an SAO Astronomer in 2013.

C. Schedule

The plan is to prepare the STO for reflight in the first year. The second LDB flight will take place late in the second year, in December 2015 or January 2016. Science results will be analyzed and written up for publication in the third year.

D. Facilities

Both A. Stark and B. Stalder have fully-equipped offices and computers, and access to support staff in the Radio and Geoastronomy division of SAO. The computers, computer peripherals, software, internal and external internet interface, data storage and backup are professionally maintained by the SAO Computation Facility.

In December 2005, SAO relocated its engineering organization to a newly constructed facility that contains sophisticated engineering laboratories that were built to the specifications developed by senior engineers to meet the requirements for fabrication and assembly of advanced instrumentation for both space-borne and ground-based scientific research. These laboratories include a large assembly area with the ceiling height and crane capacity required for the complete assembly and test of the gondola and telescope, and integration of the science instrument. Additional facilities include an electronics assembly area; a materials/environmental test laboratory that supports thermal vacuum and temperature test, and contamination bakeout; and product assurance capabilities including a coordinate measurement machine (CMM) and optical comparator for fabricated parts inspection.

The Harvard College Observatory (HCO) Model Shop was also relocated with SAO-CE, to permit closer coordination of parts fabrication. The integration of CNC (Computer Numerically Controlled) machinery into the shop has increased the machinists' ability to work to very tight tolerances (+/- .000 1 "), as well as reducing production time.

VI. BUDGET JUSTIFICATION

We request **$212,137** for a three-year research and development program beginning 1 January 2014 and ending 31 December 2016. Yearly requests are: Year 1 - $62,170, Year 2 - $91,056, and Year 3 - $58,910.

This budget would support science, and the engineering consultation required to prepare the STO gondola. Other funds requested are for travel to technical meetings and field support for flight. Specific budget categories are as follows:

Direct Labor:
Salary and benefits are included for SAO Institutional P.I. (Stark) at 216 hours and SAO Astronomer Brian Stalder at 216 hours for the first year, Stark at 328 hours and Stalder at 336 hours in Year 2, and Stark at 210 hours and Stalder at 216 hours in Year 3.

Summary of Proposal Personnel & Work Efforts (hours)

	Yr 1	Yr 2	Yr 3
Antony Stark, SAO PI	216	328	210
Brian Stalder	216	336	216

Travel:

The projected travel requirements are: Year 1 - $3,840, Year 2 - $9332, and Year 3 - $3,840. Costs are estimated based upon current government air fares and GSA per diem rates.

Domestic travel costs in each of the three years involve a trip for A. Stark and B.Stalder to the University of Arizona for technical meetings with the Project Principal Investigator and science instrument development team to coordinate the project's technical requirements and progress. Expenses include a rental car in Tucson and taxis to/from the airport in Boston.

Foreign travel costs in year 2 for A. Stark and B. Stalder to travel to Antarctica include only the costs of a stopover in Christchurch, NZ, en route to and from McMurdo base. The U.S. Antarctic Program provides air tickets and covers all costs of lodging and meals in Antarctica. New Zealand expenses are budgeted for 2 travelers spending up to 8 days in

Christchurch en route to and from McMurdo, estimated at $2746 per person. Expenses include taxis to/from the airports and in Christchurch, and miscellaneous expenses for polar travel.

Other Direct Costs:

Supplies

Supplies are included in the budget for year one ($2500), year two ($500), and year 3 ($2000). This covers the renewal cost of engineering software (Zemax, SolidWorks), computer and miscellaneous field supplies. An additional $3500 is requested in year one for a data reduction computer and disks.

Fee:

A Management Fee of 3% of the total direct and indirect costs is included here at $1,811 in Year 1, $2,652 Year 2, and $1,716 Year 3, totaling $6,179 over the course of the project.

In order to achieve full cost recovery on contract and grant work efforts, the Smithsonian Astrophysical Observatory [SAO] applies a 3.0% Management Fee to the total estimated direct and indirect costs of its projects. This calculated fixed-fee provides support to SAO for current and future investments in research, for investments in infrastructure and intellectual capital, for the risk assumed in performing requested work, and to cover ordinary and necessary business expenses that are nonreimbursable as a direct or indirect cost under the award. The requested fee will help SAO to quickly address future opportunities and needs, with expert staff, state-of-the-art analytical instruments, and special use equipment. It should be noted that SAO does not receive Facilities Capital Cost of Money. In general, Management Fee will be invoiced incrementally throughout the period-of-performance, based on the funding allotment that has been received.

ESTIMATE OF COST

Period of Performance: 01-JAN-2014 through 31-DEC-2016

Business Unit: SI400
Proposal ID: 000000000001145
Version ID: V101

	01-JAN-2014 thru	31-DEC-2014	01-JAN-2015 thru	31-DEC-2015	01-JAN-2016 thru	31-DEC-2016		
Productive Labor	**Hours**	**Dollars**	**Hours**	**Dollars**	**Hours**	**Dollars**	**Total Hours**	**Total Dollars**
SAO PI	216.00	$16,094	328.00	$24,439	210.00	$15,647	754.00	$56,181
SAO ASTRONOMER	216.00	$6,747	336.00	$11,227	216.00	$7,692	768.00	$25,666
	432	**$22,842**	**664**	**$35,666**	**426**	**$23,339**	**1,522**	**$81,847**
Leave @ 16.4%		$3,746		$5,849		$3,828		$13,423
Fringe Benefits @ 26.8%		$7,125		$11,126		$7,281		$25,532
SAO Direct Operating Overhead Base		$33,713		$52,642		$34,447		$120,802
SAO Direct Operating Overhead @Rate 26.8%		$9,035		$14,108		$9,232		$32,375
Travel - Domestic (STO-2 Team Mtg, Tucson)		$3,840		$3,840		$3,840		$11,520
Travel - International (Christchurch NZ /McMurdo)				$5,492				$5,492
Services - (CAD Software Licenses)		$2,000				$2,000		$4,000
SAO Materials Burden @Rate 5.2%		$208		$26				$234
SAO General & Administrative		$48,796		$76,107		$49,519		$174,423
SAO General & Administrative @Rate 15.5%		$7,563		$11,797		$7,675		$27,036
Equipment Less Than 5K (Desktop Computer, Disks)	$3,500							$3,500
Supplies & Materials	$500		$500					$1,000
Material Base		$4,000		$500				$4,500
Sub-Total		**$60,360**		**$88,404**		**$57,195**		**$205,958**
SAO Management Fee		**$1,811**		**$2,652**		**$1,716**		**$6,179**
TOTAL ESTIMATED COST		**$62,170**		**$91,056**		**$58,910**		**$212,137**

TRAVEL SCHEDULE

Budget Period : 1

01-JAN-2014 Thru 31-DEC-2014

Destination	Purpose	# Trips	# Travellers	Days/Trip	Per Diem	Total Per Diem	Airfare	Total Airfare	Auto Rate	Total Auto	Misc.	Total
Tucson AZ	STO-2 Project team meeting	1.00	2.00	7.00	$160	$2,240	$550	$1,100	$250	$250	$250	$3,840

TOTAL TRAVEL for Budget Period : 1 $3,840

Budget Period : 2

01-JAN-2015 Thru 31-DEC-2015

Destination	Purpose	# Trips	# Travellers	Days/Trip	Per Diem	Total Per Diem	Airfare	Total Airfare	Auto Rate	Total Auto	Misc.	Total
Tucson AZ	STO-2 Project team meeting	1.00	2.00	7.00	$160	$2,240	$550	$1,100	$250	$250	$250	$3,840
Christchurch, New Zealand	to McMurdo for STO-2 launch	1.00	2.00	8.00	$312	$4,992	$0	$0	$0	$0	$500	$5,492

TOTAL TRAVEL for Budget Period : 2 $9,332

Budget Period : 3

01-JAN-2016 Thru 31-DEC-2016

Destination	Purpose	# Trips	# Travellers	Days/Trip	Per Diem	Total Per Diem	Airfare	Total Airfare	Auto Rate	Total Auto	Misc.	Total
Tucson AZ	STO-2 Project team meeting	1.00	2.00	7.00	$160	$2,240	$550	$1,100	$250	$250	$250	$3,840

TOTAL TRAVEL for Budget Period : 3 $3,840

OTHER SERVICES SCHEDULE

Budget Period : 1
01-JAN-2014 Thru 31-DEC-2014

COST BASIS	DESCRIPTION	VENDOR	COST
Estimate	Software Licenses		$2,000

TOTAL OTHER SERVICES for Budget Period : 1 **$2,000**

Budget Period : 2
01-JAN-2015 Thru 31-DEC-2015

COST BASIS	DESCRIPTION	VENDOR	COST

No Data Found

Budget Period : 3
01-JAN-2016 Thru 31-DEC-2016

COST BASIS	DESCRIPTION	VENDOR	COST
Estimate	Software Licenses		$2,000

TOTAL OTHER SERVICES for Budget Period : 3 **$2,000**

MATERIALS SCHEDULE

Budget Period : 1
01-JAN-2014 Thru 31-DEC-2014

COST BASIS	DESCRIPTION	VENDOR	COST
Estimate	Misc. Supplies and Materials		$500

TOTAL MATERIALS for Budget Period : 1 **$500**

Budget Period : 2
01-JAN-2015 Thru 31-DEC-2015

COST BASIS	DESCRIPTION	VENDOR	COST
Estimate	Misc. Supplies and Materials		$500

TOTAL MATERIALS for Budget Period : 2 **$500**

Budget Period : 3
01-JAN-2016 Thru 31-DEC-2016

COST BASIS	DESCRIPTION	VENDOR	COST

No Data Found

EQUIPMENT Less Than 5K Schedule

Budget Period : 1
01-JAN-2014 Thru 31-DEC-2014

COST BASIS	DESCRIPTION	VENDOR	COST
Estimate	Desktop Computer		$3,500

TOTAL EQUIPMENT Less 5k for Budget Period - 1 **$3,500**

Budget Period : 2
01-JAN-2015 Thru 31-DEC-2015

COST BASIS	DESCRIPTION	VENDOR	COST
No Data Found			

Budget Period : 3
01-JAN-2016 Thru 31-DEC-2016

COST BASIS	DESCRIPTION	VENDOR	COST
No Data Found			

CONTRACTUAL AND COST INFORMATION INCLUDING CERTIFICATIONS

The Smithsonian Institution, an independent trust establishment was created by an act of the Congress of 1846 to carry out the terms of the will of James Smithson of England, who had bequeathed his entire estate to the United States of America "to found at Washington, under the name of the Smithsonian Institution, an establishment for the increase and diffusion of knowledge." After accepting the trust property for the United States, Congress vested responsibility for administering the trust in a Smithsonian Board of Regents.

The Smithsonian performs research, educational and other special projects supported by grants and contracts awarded under the cost principles of Title 2 of the Code of Federal Regulations (CFR) Part 230 [formerly the Office of Management and Budget (OMB) Circular A-122: *Cost Principles for Non-Profit Organizations*. It is audited by the Defense Contract Audit Agency, Landover, Maryland.

The Charter of the Smithsonian Institution carries a mandate for the "increase and diffusion of knowledge." Therefore, any grant or contract that may be awarded as a result of this proposal must be unclassified, in order not to abridge the Institution's right to publish, without restriction, findings that result from this research project.

Considering the nature of the proposed effort, it is requested that a Research Grant with reimbursement via electronic funds transfer be awarded to cover the proposed project in accordance with Subpart C, Section 215.22(e) of Title 2 CFR Part 215 [formerly OMB Circular A-110: *Uniform Administrative Requirements for Grants and Agreements with Institutions of Higher Education, Hospitals and Other Non-Profit Organizations].*

Pursuant to Subpart C, Section 215.33 and 215.34 of Title 2 CFR Part 215 [formerly OMB Circular A-110], it is requested that title to all exempt property and equipment purchased or fabricated under the proposed contract be vested irrevocably in the Institution upon acquisition.

In accordance with an agreement between the Office of Naval Research and the Smithsonian, the Institution operates with predetermined fixed overhead rates with carry-forward provisions. The Indirect Cost and Fringe Benefits Rates are developed in accordance with Title 2 CFR Part 230 [formerly OMB Circular A-122]. The following approved rates, provided by ONR Negotiation Agreement dated 17 May 2012, shall be used for forward pricing and billing purposes for Fiscal Year 2012. The Fringe Benefits Rate will be applied to the Total Direct Labor Costs. The Material Overhead Rate will be applied to the cost of materials, equipment and subcontracts. The Direct Operating Overhead Rate will be applied to the Direct Labor and Benefits costs. The G&A Rate will be applied to the base consisting of total costs except the costs associated with the materials, equipment and subcontracts.

The following Approved Rates shall be used for forward pricing and billing purposes for Fiscal Year 2012:

Material Burden Rate (Cost of Materials, equipment and subcontracts)	5.2%
Personnel Leave Rate (Total Direct Labor Costs less paid leave and training {Productive Labor})	16.4%
Fringe Benefits Rate (Full/Part Time Employees) (Total Direct Labor Costs)	26.8%
Fringe Benefits Rate (Intermittent Employees) (Total Direct Labor Costs)	8.4%
Direct Operating Overhead Rate (Total Direct Labor and Fringe Benefits Costs)	26.8%
General and Administrative Rate (G&A) (Base consists of Direct Operating Activities less Net Costs Associated with materials, subcontracts and equipment)	15.5%
Central Engineering Overhead Rate (Central Engineering Direct Labor and Benefits Costs)	26.4%

Rate verification can be made by contacting Mr. Owen Nicholson, Office of Naval Research, Indirect Cost Branch (BD0242, Rm. 371), 875 N. Randolph Street Arlington, Virginia 22203, telephone (703) 696-7742, or e-mail owen.nicholson@navy.mil.

Engineering services are provided by the Central Engineering Department as a Cost Center. Charges by the department to research projects are inclusive of Direct Labor, Fringe Benefits, and Central Engineering Overhead.

In order to achieve full cost recovery on contract and grant work efforts, the Smithsonian Astrophysical Observatory [SAO] applies a 3.0% Management Fee to the total estimated direct and indirect costs of its projects. This calculated fixed-fee provides support to SAO for current and future investments in research, for investments in infrastructure and intellectual capital, for the risk assumed in performing requested work, and to cover ordinary and necessary business expenses that are nonreimbursable as a direct or indirect cost under the award. The requested fee will help SAO to quickly address future opportunities and needs, with expert staff, state-of-the-art analytical instruments, and special use equipment. It should be noted that SAO does not receive Facilities Capital Cost of Money. In general, Management Fee will be invoiced incrementally throughout the period-of-performance, based on the funding allotment that has been received.

CERTIFICATIONS

Pursuant to FAR 52.204-8, ANNUAL REPRESENTATIONS AND CERTIFICATIONS (MAY 2011), for federally funded awards, the Smithsonian Astrophysical Observatory (SAO) is registered with the Online Representations and Certifications Application (ORCA). ORCA can be viewed at http://orca.bpn.gov, using SAO DUNS # 003261823.

Statement of Work for Mark Wolfire: University of Maryland

Reflight of the Stratospheric TeraHertz Observatory STO-2

Dr. Wolfire is an expert at modeling the thermal processes and line emission in the dense molecular and diffuse atomic gas in the interstellar medium. He will be providing analysis tools to interpret the observations from STO-2.

Years 1-2: Co-I Wolfire along with Co-I Hollenbach will develop line emission models for the [C II] emission from the diffuse neutral atomic gas, the [C II] and [C I] emission from molecular cloud surfaces, and the [N II] emission from diffuse and dense ionized gas.

The models will include a merged H II region code (Mappings III) with our PDR code. The important effects of stellar winds and radiation pressure will be included in the H II region. A sufficient range in parameters will be studied to include stellar associations of various luminosities and ages, and to properly analyze the important effects of the Galactic metallicity and UV radiation field gradients. These will be fully self-consistent thermal and chemical equilibrium models. In addition, previous models for the "dark gas" (Wolfire et al. 2010) will be extended to include low mass ($\ll 10^5\ M_\odot$) clouds. Results will be used to help further define the STO-2 instrument characteristics.

Year 3: The models and analysis tools will be applied to the STO-2 data sets. Models will be revised as guided by the new data. Wolfire will assist in the analysis of the data and in writing papers. In particular he will take a leading role in the paper on the diffuse ISM thermal pressure and the origin of the [C II] emission.

University of Maryland, College Park
Dr. Mark Wolfire
Title: Reflight of the Stratospheric TeraHertz Observatory: STO-2 University of Maryland College Park, Co-I

Sponsor:

Duration: January 1, 2014 - December 31, 2016

		Effort Yr-1	Effort Yr 2-3	Year 1	Year 2	Year 3	TOTAL
PERSONNEL							
Mark Wolfire	95993	0.5	2	$ 4,000	$ 15,999	$ 16,319	$ 36,318
FRINGES							
Mark Wolfire		23%		$ 920	$ 3,680	$ 3,753	$ 8,353
Subtotal Salaries & Fringes				**$ 4,920**	**$ 19,679**	**$ 20,072**	**$ 44,671**
TRAVEL							
Domestic				$ 2,500	$ 2,500	$ 2,500	$ 7,500
Foreign				$ -	$ -	$ -	$ -
OTHER DIRECT COSTS							
Publications							$ -
Computer Services				$ 53	$ 211	$ 211	$ 475
TOTAL DIRECT COSTS				**$ 7,473**	**$ 22,390**	**$ 22,783**	**$ 52,646**
FACILITIES & ADMINISTRATION							
Modified Total Direct Costs Base				$ 7,473	$ 22,390	$ 22,783	$52,646
On Campus Rate		**52%**		**$ 3,886**	**$ 11,643**	**$ 11,847**	**$ 27,376**
TOTAL ON-CAMPUS BUDGET				**$ 11,359**	**$ 34,033**	**$ 34,630**	**$ 80,022**

University of Maryland, College Park
PI, Mark Wolfire
Title: Reflight of the Stratospheric TeraHertz Observatory: STO-2, University of Maryland College Park Co-I

BUDGET JUSTIFICATION

Table of Personnel and Work Effort

	Year 1	Year 2	Year 3
Mark Wolfire - Senior Research Scientist	0.5 months	2 months	2 months

PERSONNEL
The PI, Dr. Wolfire, will be responsible for directing, overseeing, and conducting the proposed research. Salary support is budgeted for 0.5 month(s) in the first year and 2 month(s) in years 2 and 3. There is an annual 2% salary increase for costs of living adjustments and merit raises.

FRINGES
In accordance with University of Maryland policies and procedures, fringes are actual costs including FICA, retirement plan contributions and all health insurance subsidies. For budget purposes, fringes have been estimated at 23% for the PI.

TRAVEL
Domestic travel funds are budgeted for the PI to attend 1 domestic conference/workshop per year. Exact costs are unknown at this time, but the following estimates have been used for a four day trip:

$700	Airfare
$800	Lodging
$252	Per Diem
$400	Registration fee
$348	Ground Transportation & Misc Costs
$2500	Total Costs for one traveler/one trip

FACILITIES & ADMINISTRATION
FACITLITIES & ADMINISTRATIVE COSTS (F&A) costs have been applied at the fully negotiated on-campus rate of 52%. The current F&A rate was negotiated with DHHS; The POC is Stephen Virbitsky at (202) 401-2762

FACILITIES and EQUIPMENT

The proposed theoretical modeling can be carried out on in-house and currently available workstations and computer clusters at the University of Maryland. It is anticipated that no additional processors will be needed. The PI at UMD has access to a personal Intel Core i5 3.6 GHz Dell desktop. In addition, models can be run on a computer cluster (currently 17 nodes) maintained by the UMD Astronomy Department. A typical node consists of a dual 12 core, Intel Xeon 2.93 GHz processor with 48 GB memory. The PI also has a personal MacBookPro notebook on which he prepares professional presentations and manuscripts for publication.

STATEMENT OF WORK

1. SUMMARY

This is a collaboration Co-I Institution proposal for the proposal "Reflight of the Stratospheric TeraHertz Observatory: STO2" whose lead proposal is submitted by the University of Arizona with Christopher Walker as PI.

For the STO2 program APL will provide the telescope, observing platform (gondola), pointing system, power system, command and control system, and the ground support equipment to interface with NASA-CSBF telemetry system. Most of the hardware is already on hand. APL personnel will also be responsible for commanding and controlling the STO payload for a 30-day scientific flight in December 2015 from Antarctica. Following the Antarctic flight we will participate in the data analysis and in publication of the results.

2. APL GONDOLA FOR STO

Telescope

We will reuse the same telescope that APL previously used for the first Antarctic flight of STO, shown in Figure 1, with only minor modifications. The primary mirror is an f/1.5 hyperboloid, 80-cm in diameter, made of honeycombed Ultra Low Expansion titanium silicate glass and weighing just 50 Kg. Its support and spider arms are made of graphite-epoxy, which is light weight and has high thermal stability.

Gondola

The STO gondola will be the same one previously used by APL for the STO1 program (Walker et al. 2010). It can be separated into lighter components for easy post-flight retrieval in the field. NASA-CSBF balloon control electronics (the Support Instrument Package, SIP) will be attached below the telescope, inside a protective aluminum cage the same way it was for STO1. Figure 1 shows the STO1 gondola in full flight configuration.

For STO2 we will repair/replace the gondola structural components that were damaged during STO's Antarctic flight in January 2012. Subsequently we will perform thorough system and subsystem testing with a suspension system comparable to the balloon train at APL's high-bay Balloon Payload Integration Facility.

APL already has done detailed thermal and structural analysis for the current configuration of the gondola. The models will be modified to take into account new thermal data from the STO1 flight, and any small mechanical and electronics changes we plan for the STO2 program.

Pointing System

The pointing system will be the same used for STO1 with the addition of a roll compensation system. The science pointing requirements are: pointing range of 360° in azimuth in the direction of the Sun and 0 to 57° in elevation less a half cone of 20° in the direction of the Sun; stability < 15"; knowledge < 15"; source acquisition accuracy < 20". During the Antarctic flight of STO in January 2012 we have demonstrated that the current design exceeds those requirements.

To aim the telescope at the desired target in the sky we use an elevation/azimuth mount: the telescope is attached to the gondola on its elevation axis and a motor attached to it rotates the telescope in elevation by torquing against the gondola frame. To point in azimuth the entire gondola will rotate on the vertical axis.

To achieve position knowledge to < 15arc-secs we will use the same two star cameras developed and built at APL for the STO1 program. The star cameras have a field of view of 7.5

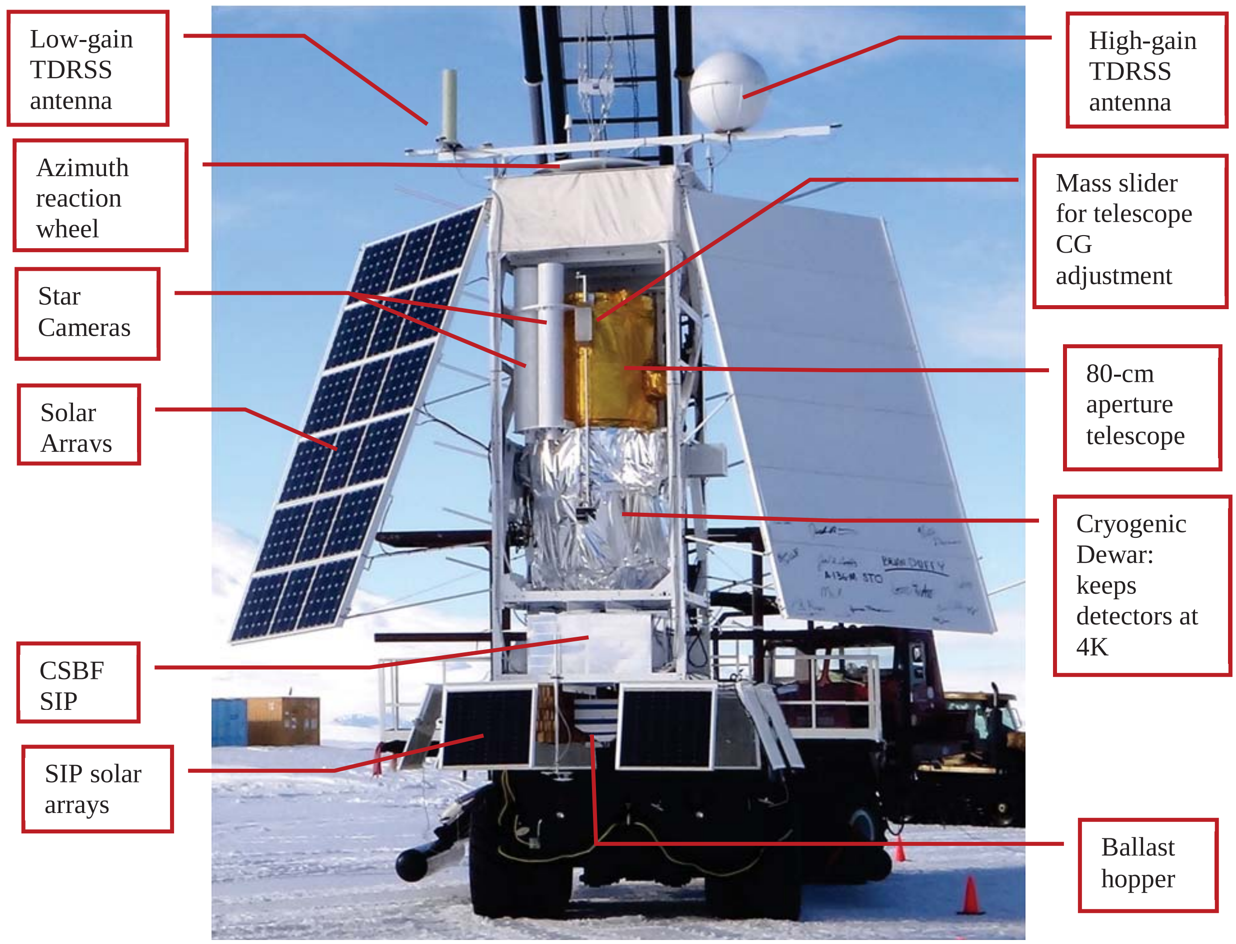


Figure 1: The STO1 gondola ready for its first scientific flight from Antarctica in January 2012.

degrees; can detect stars down to magnitude 6.5 in day-time from a float altitude of 120,000 ft. They run at a rate of up to 1/sec and need at least 4 stars to obtain a bore-sight pointing knowledge of about 5 arc-seconds.

Pointing stability and fine pointing knowledge is maintained using position information from 3 high-precision and low-drift fiber optic gyroscopes, the Optolink SRS-2000 which we have already on-hand from the STO1 program. The gyroscopes provide azimuth, pitch and roll information at a rate of 200Hz and an accuracy of a fraction of an arc-sec.

The digital control system will be the same successfully used for STO1. It uses a Proportional-Integral-Derivative (PID) controller to determine motor drive current entirely from position error sensors. Each pointing mode has four control coefficients per axis that can be adjusted in flight for optimum performance.

STO1 flight has demonstrated that the combination of star trackers, gyroscopes and PID controller delivers a pointing knowledge of about 2 arc-seconds and a pointing stability of < 2 arc-seconds in both elevation and azimuth, fully meeting the requirements for STO2.

Power System

The STO power system will be the same used for STO1 with no modifications planned. It consists of the solar arrays, the charge controller, and the battery stack.

The solar arrays are composed of 480 cells model C60 from SunPower Corp. The maximum power delivered by the arrays is about 1200 W, while the estimated total STO power requirement will be only about 450 W. This gives a margin of 750 W. In the first flight of STO we lost about 50% of the arrays during landing and recovery. For STO2 we plan to replace only the damaged arrays. The new arrays are assembled by SunCat Solar of Arizona who also built the arrays for STO1. The charge controller distributes the load across the panels, ensures that the system's battery stacks are maintained at near full charge, sunlight permitting, and provides on/off power switching capability from ground commands. It will be the same used for STO1 and will require no modifications.

The battery stack is composed of 2 sealed lead-acid ODISSEY PC1700 batteries connected in series. The stack has a capacity of 65 amp-hours with a nominal bus voltage of 24 V.

Command and Control System

The command and control system will also be the same used for STO1 and we do not plan any modifications. Figure 2 gives an overview of the command and control system. There are two main computers on-board: the Command and Control Computer (CCC) and the Actuators Control Computer (ACC). Both computers use a commercial ATX motherboard with a Pentium-based CPU, solid state hard drives, and Linux as the operating system. They are housed in two vessels that maintain 1 atm pressure throughout the flight. The CCC is responsible to schedule all the operations performed by the gondola and handles the communications between the gondola subsystems and the ground. It also communicates to the science computer via an RS232 serial channel. It can operate fully autonomously or execute commands received from the ground. The ACC acts as interface between the CCC computer and all the other gondola subsystems. It gathers all the housekeeping data (temperatures, pressures, voltages, …) and sends them to the CCC for delivery to the ground. The ACC also handles the attitude control system.

Telecommunications

The telecommunications system for STO2 will be exactly the same successfully used for STO1. STO relies entirely on the NASA-CSBF provided Support Instrument Package (SIP) for the remote link between the gondola and the ground. The SIP has three available channels to/from the ground. For the first ~24 hours the gondola will be in Line-of-Sight (LOS) to the launch station in Antarctica and will use a UHF radio link at a data rate of 1 Mb/s. During LOS operations ample amounts of housekeeping data will be available for analysis of both science and gondola performance. After loss of the LOS radio link, communications will be maintained via a 92-Kb/s TDRSS satellite relay and a lower rate IRIDIUM relay at 2-Kb/s. TDRSS and IRIDIUM signals will be received at CSBF's Operations Control Center (OCC) in Palestine (TX) and sent to a local STO ground support computer that will redistribute the data

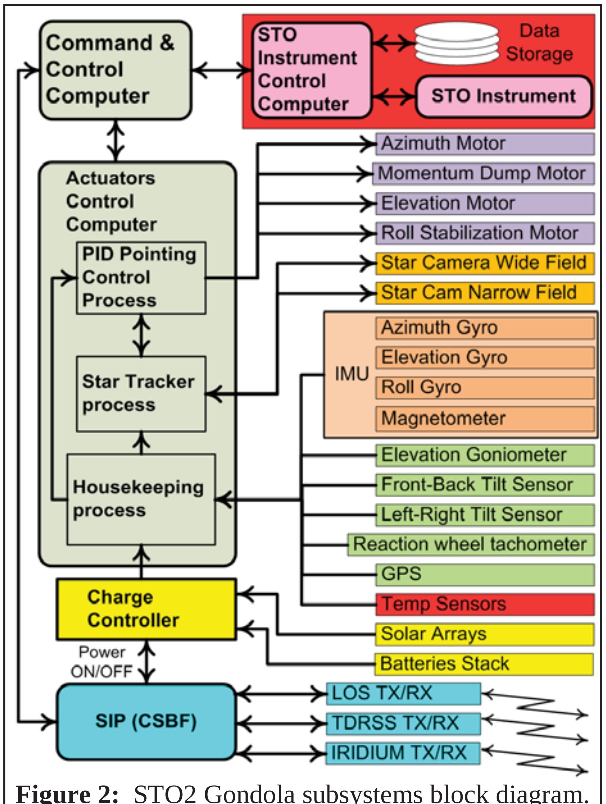


Figure 2: STO2 Gondola subsystems block diagram.

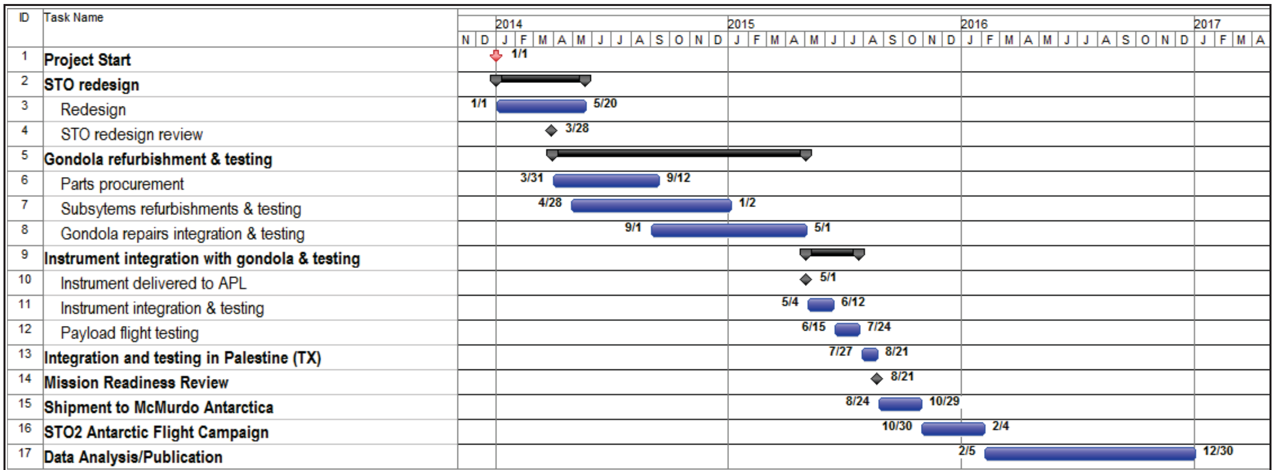


Figure 3: Schedule with milestones for the APL part of the STO2 project.

packets to other STO ground stations at APL, the University of Arizona and to the team in Antarctica. All the STO ground stations will be able to display and store the same telemetry information received at the OCC, and commands can be sent to the gondola computers from any station. The ground support computers will use the same software package that was previously used for STO1: GSEOS by GSE Software Inc.

3. WORK PLAN

The proposed work will be carried out over three years, from January 1, 2014 to December 31, 2016. It will include the following tasks: redesign, modification, refurbishment, and testing of the STO1 gondola for the STO2 program; integrated testing of the entire system; field operations for a long duration flight in Antarctica in 2015; subsequent data analysis and publication of the results. Figure 3 shows a schedule with milestones of the proposed plan of work for the entire period of this investigation.

The STO2 work plan will follow established APL Space Department practice for science instrument development in preparation for balloon-borne flight. The plan features rigorous subsystem testing and then whole payload operation under simulated flight conditions. Following the practice for the first STO program, we will perform functional tests on the pointing system components, optics and other systems and we will document the results. Software tests will be carried out with the actual payload, both in the laboratory and in the open air, to test pointing and data acquisition while tracking a celestial target.

Year 1 (2014)

At the beginning of the first year we will evaluate in detail the condition of the gondola as it returned from the first Antarctic flight and prepare an execute a repair/refurbishment plan.

We will also redesign some aspects of the gondola subsystems to account for lessons learned from the STO1 program. Our main redesign will focus will be on designing, and building a new roll stabilization system that will stop the gondola from oscillating side-to-side. Another subsystem redesign will be the consolidation of the three gyroscopes mounts into one single mount that will attach the three single axis gyroscopes to the STO telescope as a unit. At the end of March 2014 we will have an internal redesign review with the goal to evaluate and certify the redesign effort.

Following the redesign review we will purchase the new gyroscopes mount. We will also initiate a subcontract with SunCat Solar to rebuild the solar arrays that were damaged during the first STO flight. We estimate that we can reuse only about 50% of the existing solar arrays.

By the end of the first year we will have a repaired gondola with installed the refurbished telescope ready for testing

Year 2 (2015)

During the second year we will conduct thorough gondola subsystems testing as well as pointing tests with a dummy instrument attached to the back of the telescope. The pointing tests will be conducted indoors and also outdoors by hanging the gondola to a tall A-frame that we have already on hand.

In June 2015 we will receive the instrument from the University of Arizona and we will conduct I&T with the instrument as well as full flight simulations with the entire payload hanging outdoors from the A-frame.

In late July, 2015 we will transport the payload to NASA-CSBF's balloon facility in Palestine (TX) where we will integrate the STO2 payload with CSBF's balloon control and communication equipment. After a successful integration with CSBF's equipment we will ship the STO2 payload with all its support equipment to Antarctica. At the end of October, we will deploy three members of the APL team to McMurdo Antarctica to re-assemble the instrument, conduct the final preflight tests and to control the payload during flight. We will launch the payload at the first possible opportunity, typically mid-December. After the flight, we will ship the STO payload and support equipment back to APL.

Year 3 (2016)

On the third year of this investigation will be entirely dedicated to data reduction, analysis, archiving, and publication of the results, in collaboration with the rest of the STO science team.

4. PERSONNEL ROLES AND RESPONSIBILITIES

Dr. Pietro Bernasconi will be APL's Institutional PI for the STO2 program at APL. He will be responsible for the overall management and success of the APL part of the project. He will assure that the components provided by APL will allow achievement of the objectives stated in the main proposal submitted by Chris Walker (PI) of University of Arizona. Dr. Bernasconi is responsible for assembling the technical team and for allocating the resources in a reasonable and effective manner to achieve the goals. He will also participate in the instrument refurbishment and testing, and will participate in the I&T field operations in Palestine (TX).

Mr. Harry Eaton of APL will be the STO2 gondola systems engineer. He will also participate in the instrument refurbishment and testing, and will participate in the I&T field operations in Palestine.

Mr. Bliss Carkhuff of APL will be the lead for the power system. He will participate in the instrument refurbishment and testing, and in the I&T operations in Palestine and in Antarctica.

Mr. Steven Hechtman of APL will lead the ground support equipment development and assist Mr. Eaton in testing the pointing system. He will also participate in the instrument refurbishment and testing, and will participate in the I&T field operations in Palestine.

Mr. Matthew Noble of APL will be the lead for optical design and testing.

An APL mechanical engineer will be responsible to conduct design and mechanical analysis of gondola components. He will also participate in the instrument refurbishment and testing at APL.

REFERENCES

C. Walker, C. Kulesa, P. Bernasconi, et al., 2010, The Stratospheric THz Observatory (STO), in Ground-based and Airborne Telescopes III, eds. Larry M. Stepp, Roberto Gilmozzi, Helen J. Hall, Proc. of SPIE Vol. 7733, 77330N (2010)

BUDGET JUSTIFICATION

SUMMARY OF PERSONNEL AND WORK EFFORTS

Personnel	**Role**	**FTEs of efforts for each calendar year**		
		2014	**2015**	**2016**
Pietro N. Bernasconi	PI & Mission Ops Lead	0.33	0.42	0.08
Harry Eaton	Systems Engineer & Pointing System Lead	0.33	0.33	0.04
Bliss Carkhuff	Power System Lead	0.16	0.33	
Steven Hechtman	Avionics Lead & Field Team Lead	0.5	0.5	
Matthew Noble	Optical Lead	0.16	0.08	
Mechanical Engineer		0.33	0.33	
Technical Support Personnel		0.25	0.16	

FACILITIES AND EQUIPMENT

APL is well equipped to carry out the proposed program. It has more than 140 specialized research laboratories, including optical, electrical, mechanical and electromechanical design and associated prototype component test facilities. There are laboratories for environmental testing and integration and test of instrumentation. APL Space Department Environmental Facility has a thermal vacuum chamber large sufficient to accommodate the gondola subsystems for testing the operation of the gondola components at the same altitude and temperature conditions experienced during flight.

For the gondola refurbishment and the I&T effort with the science instrument at APL we will use the Balloon Payload Integration and test facility. This facility has the needed high bay area with easy access to an outdoor test pad where we can hang the gondola from a tall A-frame for functional testing.

For the STO2 program we will use the same gondola and the 80-cm telescope previously used for the STO1 program.

The Laboratory does not need to acquire any new test or handling equipment for this program. By signing this proposal, JHU/APL management commits JHU/APL personnel, facilities and resources, as proposed, to be available to the project.

TA : FG4AY
AD42557

BUDGET SUMMARY

FG4AY-STRATOSPHERIC THZ OBSERVATORY 2

1. Direct Labor

	First Year		Second Year		Third Year	
	Staff Months	$/Staff Months	Staff Months	$/Staff Months	Staff Months	$/Staff Months
Principal Professional Staff	10.00	11,716.70	13.00	12,023.31	1.50	12,486.64
Senior Professional Staff S2	4.00	10,059.00	4.00	10,323.09		-
Senior Professional Staff S1	2.00	8,102.14	1.00	8,314.90		-
Associate Professional Staff A1	6.06	5,776.23	6.06	5,927.47	0.06	6,115.06
Technical Supporting Staff	3.00	4,661.47	2.00	4,783.32		-

2. Other Direct Costs

	First Year	Second Year	Third Year
d. Materials	28,550.00	27,509.00	

Materials are based on an engineering estimate for the electronics and mechanical parts. There will be other materials purchased based on past quotes received from vendors. Please see the attached materials list.

	First Year	Second Year	Third Year
e. Travel		29,134.00	

Travel shall consist of one trip for five people for twenty two days to Palestine, TX to conduct testing with NASA/CSBF. There will also be a trip to Christchurch, New Zealand for three people for eight days in order to participate in the STO integration, testing, and launch. All travel will originate from JHU/APL (Baltimore/Washington). The APL Travel Office quotes fares and the latest government per diem rates are used.

	First Year	Second Year	Third Year
f. Other		3,510.00	3,575.00

MODC is based on PI's past experience with shipping costs to/from Palestine, TX using STI as the shipping vendor. The cost estimate is based on a past quote from the vendor. Please see the attached quotes.

3. Facilities and Administrative (F&A) Costs:

The terms "Facilities and Administrative (F&A) Costs" are not applicable at the Johns Hopkins University Applied Physics Laboratory (JHU/APL). JHU/APL submitted an updated forward pricing rate (FPR) proposal to the Defense Contract Management Agency (DCMA) on 01 August, 2012. The forward pricing rates were revised effective with the new submittal and are reflected in rate memo BSA-FIN-12-L003 as Rate Table ID 074 effective 01 August, 2012. The rates used in this proposal are consistent with this FPR proposal.

Department Overhead on Direct Labor. Per disclosed practices, the Laboratory employs departmental burden rates that are applied as required. Departmental overhead is applied to the sum of JHU/APL direct labor and RSE direct labor. Details of the rates and calculations by department by fiscal year are provided in the proposal

Procurement Burden. Procurement burden is proposed as part of the JHU/APL Forward Pricing submittal and, in accordance with disclosed practices, is applied to the sum of Material and Subcontract costs. Details of the rates and calculations by fiscal year are provided in the proposal documentation.

Administrative and Research Burden. In accordance with JHU/APL disclosed practices, Administrative and Research Burden is applied to the sum of Direct Labor Costs, Procurement Burden, and Other Direct Costs. Details of the rates and calculations by fiscal year are provided in the proposal documentation.

Please be advised that Johns Hopkins University Applied Physics Laboratory (JHU/APL) is governed by the commercial cost principles contained in Federal Acquisition Regulation (FAR) Part 31.2. Accordingly, the work to be performed by JHU/APL under any resulting grant award shall be in accordance with the provisions FAR 31.2.

TA: FG4AY
AD42557

BUDGET SUMMARY

FG4AY-STRATOSPHERIC THZ OBSERVATORY 2

Includes optional Education/Public Outreach Proposal: ____ **YES** __X__ **NO**

Total Period of Performance **From (M/Y/D)** **Jan-2014** **to** **Dec-2016**

			NASA USE ONLY	
1.	Direct Labor (salaries, wages, and fringe benefits)	727,092		
2.	Other Direct Costs:			
	a. Subcontracts			
	b. Consultants			
	c. Equipment			
	d. Supplies	56,059		
	e. Travel	29,134		
	f. Other	7,085		
3.	Facilities and Administrative Costs	362,230		
4.	Other Applicable Costs:			
5.	SUBTOTAL - Estimated Costs	1,181,600		
6.	Less Proposed Cost Sharing (if any)			
7.	Carryover Funds (if any)			
	a. Anticipated amount:			
	b. Amount used to reduce budget			
8.	Total Estimated Costs	1,181,600		XXXXXXXX
9.	APPROVED BUDGET	XXXXXXXX	XXXXXXXX	

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THE JOHNS HOPKINS UNIVERSITY-APPLIED PHYSICS LABORATORY

TA: FG4AY
AD42557

BUDGET SUMMARY

FG4AY-STRATOSPHERIC THZ OBSERVATORY 2

Includes optional Education/Public Outreach Proposal: ____ **YES** __X__ **NO**

For Year 1 of 3 From (M/Y/D) Jan-2014 to Dec-2014

			NASA USE ONLY	
1.	Direct Labor (salaries, wages, and fringe benefits)	327,587		
2.	Other Direct Costs:			
	a. Subcontracts			
	b. Consultants			
	c. Equipment			
	d. Supplies	28,550		
	e. Travel			
	f. Other			
3.	Facilities and Administrative Costs	160,916		
4.	Other Applicable Costs:			
5.	SUBTOTAL - Estimated Costs	517,053		
6.	Less Proposed Cost Sharing (if any)			
7.	Carryover Funds (if any)			
	a. Anticipated amount:			
	b. Amount used to reduce budget			
8.	Total Estimated Costs	517,053		XXXXXXXX
9.	APPROVED BUDGET	XXXXXXXX	XXXXXXXX	

TA: FG4AY
AD42557

BUDGET SUMMARY

FG4AY-STRATOSPHERIC THZ OBSERVATORY 2

Includes optional Education/Public Outreach Proposal: ____ **YES** __X__ **NO**

For Year 2 of 3 From (M/Y/I Jan-2015 to Dec-2015

			NASA USE ONLY	
1.	Direct Labor (salaries, wages, and fringe benefits)	371,299		
2.	Other Direct Costs:			
	a. Subcontracts			
	b. Consultants			
	c. Equipment			
	d. Supplies	27,509		
	e. Travel	29,134		
	f. Other	3,510		
3.	Facilities and Administrative Costs	186,987		
4.	Other Applicable Costs:			
5.	SUBTOTAL - Estimated Costs	618,439		
6.	Less Proposed Cost Sharing (if any)			
7.	Carryover Funds (if any)			
	a. Anticipated amount:			
	b. Amount used to reduce budget			
8.	Total Estimated Costs	618,439		XXXXXXXX
9.	APPROVED BUDGET	XXXXXXXX	XXXXXXXX	

THE JOHNS HOPKINS UNIVERSITY-APPLIED PHYSICS LABORATORY

TA: FG4AY
AD42557

BUDGET SUMMARY

FG4AY-STRATOSPHERIC THZ OBSERVATORY 2

Includes optional Education/Public Outreach Proposal: ____ **YES** __X__ **NO**

For Year 3 of 3 From (M/Y/D) Jan-2016 to Dec-2016

			NASA USE ONLY	
1.	Direct Labor (salaries, wages, and fringe benefits)	28,206		
2.	Other Direct Costs:			
	a. Subcontracts			
	b. Consultants			
	c. Equipment			
	d. Supplies			
	e. Travel			
	f. Other	3,575		
3.	Facilities and Administrative Costs	14,327		
4.	Other Applicable Costs:			
5.	SUBTOTAL - Estimated Costs	46,108		
6.	Less Proposed Cost Sharing (if any)			
7.	Carryover Funds (if any)			
	a. Anticipated amount:			
	b. Amount used to reduce budget			
8.	Total Estimated Costs	46,108		XXXXXXXX
9.	APPROVED BUDGET	XXXXXXXX	XXXXXXXX	

THE JOHNS HOPKINS UNIVERSITY - APPLIED PHYSICS LABORATORY
COST SUMMARY REPORT
Project Summary by Year - Project Period of Performance = Jan 2014 to Dec 2016
(for WBS ID = FG4AY and all Departments)

Project ID: AD42557	**Proposal ID: AD-42557**	**Task ID: FG4AY**	**Cost Model: M8**
	Proposal Title: STRATOSPHERIC THZ OBSERVATORY 2		
WBS ID: FG4AY	**WBS Title:**		

	Total Project: AD42557		
	Staff Hours	**Staff Months**	**Cost**
Direct Labor Cost			
Principal	3,681.4	24.5	292,190
Senior II	1,201.9	8.0	81,520
Senior I	451.1	3.0	24,519
Associate I	1,830.0	12.2	71,291
Technical	751.6	5.0	23,553
Total Direct APL Labor	7,916	52.7	493,074
Employee Fringe			234,017
Direct LW Labor			
Dept. Ovhd on Dir. Labor			221,210
Sub-Total	7,916	52.7	948,301
Direct Procurement Cost			
Material			56,059
Subcontract			
Sub-Total			56,059
Procurement Burden			
Procurement Burden			785
Other Direct Cost			
LW Non-Salary			
LW ODC			
Travel			29,134
Consulting			
Special Test Equipment			
Miscellaneous Other Direct Cost			7,085
Sub-Total			36,219
Total Direct Labor + Procurement Burden + ODC			985,305
Admin & Research Burden			140,236
Total Estimated Cost			1,181,600
Cost of Money			
Total Estimated Cost + COM			1,181,600
Fee			
Total Est. Cost, Fee, COM	**7,916**	**52.7**	**1,181,600**

* Totals and sub-totals may not add due to rounding.

THE JOHNS HOPKINS UNIVERSITY - APPLIED PHYSICS LABORATORY
COST SUMMARY REPORT
Project Summary by Year - Project Period of Performance = Jan 2014 to Dec 2016
(for WBS ID = FG4AY and all Departments)

Project ID: AD42557	**Proposal ID: AD-42557**	**Task ID: FG4AY**	**Cost Model: M8**
	Proposal Title: STRATOSPHERIC THZ OBSERVATORY 2		
WBS ID: FG4AY	**WBS Title:**		

	CY 2014				CY 2015				CY 2016			
	Rates	Staff Hours	Staff Months	Cost	Rates	Staff Hours	Staff Months	Cost	Rates	Staff Hours	Staff Months	Cost
Direct Labor Cost												
Principal		1,505.8	10.0	117,162		1,948.9	13.0	156,298		226.8	1.5	18,730
Senior II		602.3	4.0	40,232		599.6	4.0	41,288				
Senior I		301.2	2.0	16,208		149.9	1.0	8,312				
Associate I		912.5	6.1	35,004		908.5	6.1	35,920		9.0	0.1	367
Technical		451.8	3.0	13,984		299.9	2.0	9,569				
Total Direct APL Labor		3,774	25.1	222,590		3,907	26.1	251,387		236	1.6	19,097
Employee Fringe				104,997				119,912				9,109
Direct LW Labor												
Dept. Ovhd on Dir. Labor				99,492				113,124				8,594
Sub-Total		3,774	25.1	427,079		3,907	26.1	484,423		236	1.6	36,800
Direct Procurement Cost												
Material				28,550				27,509				
Subcontract												
Sub-Total				28,550				27,509				
Procurement Burden												
Procurement Burden				400				385				
Other Direct Cost												
LW Non-Salary												
LW ODC												
Travel								29,134				
Consulting												
Special Test Equipment												
Miscellaneous Other Direct Cost								3,510				3,575
Sub-Total								32,644				3,575
Total Direct Labor + Procurement Burden + ODC				427,478				517,452				40,375
Admin & Research Burden				61,025				73,478				5,733
Total Estimated Cost				517,053				618,439				46,108
Cost of Money												
Total Estimated Cost + COM				517,053				618,439				46,108
Fee												
Total Est. Cost, Fee, COM		**3,774**	**25.1**	**517,053**		**3,907**	**26.1**	**618,439**		**236**	**1.6**	**46,108**

* Totals and sub-totals may not add due to rounding.

FG4AY
AD42557

Material/SUBC Category		Escalation Cost Per	Escalation 1.6% FY14	Escalation 3.3% FY15	Total MODC
Megaflux Torque Motor	Over the phone quote from Vendor	1	1	-	1
		2,400	2,438	-	$ 2,438
Inertial Measurement Unit Mount Cube	Engineering Judgement on with past purchases	1	1	-	1
		15,700	15,951	-	$ 15,951.20
Misc. Mechanical Parts	Engineering Estimate	1	1	-	1
		5,000	5,080	-	$ 5,080.00
Misc. Electronics Parts	Engineering Estimate	1	1	-	1
		5,000	5,080	-	$ 5,080.00
Solar Arrays (SunCat Solar)	Based on attached quote for 9 arrays @ $2070 each in 2012	9	-	9	9
		2,070	-	19,245	$ 19,244.79
Misc. Mechanical Parts	Engineering Estimate	1	-	1	1
		5,000	-	5,165	$ 5,165.00
Misc. Electronics Parts	Engineering Estimate	1	-	1	1
		3,000	-	3,099	$ 3,099.00
TOTAL MODC COSTS			**$ 28,550**	**$ 27,509**	$ 56,058.39

Use or disclosure of data contained on this sheet is subject to the restriction on the title page of this proposal or quotation.

SOURCE: Q1 2008
Global Insight Planner

MODC

FG4AY
AD42557

MODC Category		Escalation Cost Per	Escalation 3.4% FY15	Escalation 5.3% FY16	Total MODC
Shipping Equipment		1	1	-	
APL to Palestine, TX	Based on attached quote	3,395	3,510	-	3,510
Shipping Equipment		1		1	
Palestine, TX to APL	Based on attached quote	3,395	-	3,575	3,575
TOTAL MODC COSTS			**$ 3,510**	**$ 3,575**	**$ 7,085**

Use or disclosure of data contained on this sheet is subject to the restriction on the title page of this proposal or quotation.

SOURCE: Q1 2008
Global Insight Planner

[Contract: ry665300] [ORIGINAL INVOICE] [9/29/2009 Page: 1]

STI

INVOICE

For Payment inquiries or disputes, contact:
Specialized Transportation, Inc.

SPECIALIZED TRANSPORTATION, INC.
ATTN: CHRISTA.SAURBAUGH@STIDELIVERS.C
(260)429-1355

Delv Date: 9/14/2009 09/29/2009

ORIGINAL INVOICE

CONTRACT/PRO NUMBER: RY665300 SHIP DATE: 09/11/2009

BILL TO: APPLIED PHYSICS LAB/JHU
ATTN: BONNIE HIGGS
11100 JOHN HOPKINS RD
LAUREL, MD 20723

REMIT TO: SPECIALIZED TRANSPORTATIO
TAX ID# 77-0638095
NW 5485
P.O. BOX 1450
MINNEAPOLIS, MN 55485-548

SHIPPER: APPLIED PHYSICS L
11100 JOHN HOPKINS RD
LAUREL, MD 20723

CONSIGNEE: CSBF/FORT SUMNER MUN
NORTH 17 STREET
FT SUMNER, NM 88119

CUSTOMER NO: APLAMD03
P.O./GBL NO:

AGENT: 7009-ICAT TRANSPORT INC
YORK, PA 17402

NOAM/TARIFF NO: MRT2004/MRT2004/002
ACTUAL MILES: 1,723
BILLABLE MILES: 1,723

ACTUAL WGT: 10,500
DIM WGT: 19,999
BILLABLE WGT: 19,999

Service Description	Quantity	Rate	Amount
LINEHAUL TRANSPORTATION	19,999		3,506.12
FUEL RELATED INCREASE-LH			70.12
P.O.D. NAME: FRANK CANDELARI			
TARIFF CHARGE IF PAID BY 10/08/2009, REMIT THIS AMOUNT			3,576.24
SURCHARGE PER I.C.C. REGULATIONS			35.76
PAY THIS AMOUNT AFTER 10/08/2009			3,612.00

CREDIT SURCHARGE--A CREDIT SURCHARGE HAS BEEN ADDED TO THE BASE TARIFF PER ICC EX PARTE NO. MC-1, SUB-3 OR EX PARTE NO. MC-73. SERVICE CHARGE IS 1% OF TOTAL --- $10.00 MINIMUM.

PAGE 1

CONTRACT/PRO NUMBER: RY665300 AMOUNT DUE: $ 3,576.24 BY 10/08/2009

CUSTOMER: APLAMD03
APPLIED PHYSICS LAB/JHU
ATTN: BONNIE HIGGS
11100 JOHN HOPKINS RD
LAUREL, MD 20723

REMIT TO: SPECIALIZED TRANSPORTATION, INC
TAX ID# 77-0638095
NW 5485
P.O. BOX 1450
MINNEAPOLIS, MN 55485-5485

Bills of Lading and shipping documents can be obtained on our website at: http://image.spectransinc.com

[Contract: tq430300] [REBILLED INVOICE] [11/12/2009 Page: 1]

INVOICE

For Payment inquiries or disputes, contact:
Specialized Transportation, Inc.

SPECIALIZED TRANSPORTATION, INC.
ATTN: CHRISTA.SAURBAUGH@STIDELIVERS.C
(260)429-1355

Delv Date: 10/27/2009 11/12/2009

REBILLED INVOICE

CONTRACT/PRO NUMBER: TQ430300 SHIP DATE: 10/22/2009

BILL TO: APPLIED PHYSICS LAB/JHU
ATTN: BONNIE HIGGS
11100 JOHN HOPKINS RD
LAUREL, MD 20723

REMIT TO: SPECIALIZED TRANSPORTATIOI
TAX ID# 77-0638095
NW 5485
P.O. BOX 1450
MINNEAPOLIS, MN 55485-548

SHIPPER: CSBF/FORT SUMNER
NORTH 17 STREET
FT SUMNER, NM 88119

CONSIGNEE: APPLIED PHYSICS LABS
11100 JOHN HOPKINS RD
LAUREL, MD 20725

CUSTOMER NO: APLAMD03
P.O./GBL NO:

AGENT: 7009-ICAT TRANSPORT INC
YORK, PA 17402

NOAM/TARIFF NO: MRT2004/MRT2004/002
ACTUAL MILES: 1,723
BILLABLE MILES: 1,723

ACTUAL WGT: 9,040
DIM WGT: 19,999
BILLABLE WGT: 19,999

Service Description	Quantity	Rate	Amount
LINEHAUL TRANSPORTATION	19,999		3,256.12
FUEL RELATED INCREASE-LH			105.18
P.O.D. NAME: SCOTT JACKSON			
TARIFF CHARGE IF PAID BY 11/23/2009, REMIT THIS AMOUNT			3,361.30
SURCHARGE PER I.C.C. REGULATIONS			33.61
PAY THIS AMOUNT AFTER 11/23/2009			3,394.91

CREDIT SURCHARGE--A CREDIT SURCHARGE HAS BEEN ADDED TO THE BASE TARIFF PER ICC EX PARTE NO. MC-1, SUB-3 OR EX PARTE NO. MC-73. SERVICE CHARGE IS 1% OF TOTAL --- $10.00 MINIMUM.

PAGE 1

CONTRACT/PRO NUMBER: TQ430300 AMOUNT DUE: $ 3,361.30 BY 11/23/2009

CUSTOMER: APLAMD03
APPLIED PHYSICS LAB/JHU
ATTN: BONNIE HIGGS
11100 JOHN HOPKINS RD
LAUREL, MD 20723

REMIT TO: SPECIALIZED TRANSPORTATION, INC
TAX ID# 77-0638095
NW 5485
P.O. BOX 1450
MINNEAPOLIS, MN 55485-5485

Bills of Lading and shipping documents can be obtained on our website at: http://image.spectransinc.com

Subject: Re: Quote request for solar panels for STO2 balloon mission
From: "AHMChuzel@aol.com" <AHMChuzel@aol.com>
Date: 3/1/2012 9:40 AM
To: "Bernasconi, Pietro N." <Pietro.Bernasconi@jhuapl.edu>

Pietro,

Thanks for the call yesterday. I misplaced your email.

Please use $18,630.00 for the 9 modules.

FYI, not that it matters for this, the SunPower cells we've been using lately are called "C60" rather than A300. I'm not sure exactly what we used on the previous modules but they likely were either C50s or C60s. SunPower is always improving and I try to always get the latest.

Regards,

Alain
SunCat Solar, LLC
602-710-0477

In a message dated 2/23/2012 8:45:31 A.M. US Mountain Standard Time, pietro.bernasconi@jhuapl.edu writes:

> Hi Alain,
> As I mentioned to you on the phone I would need a ROM quote on solar panels that we will need for the STO2 balloon mission.
>
> We need the following:
> 9 (nine) 6x5 cell solar panel modules
> cells are the SunPowe A300 with a bypass diode within EVA/ETFE based laminates. One bypass diode every 5 cells
> The laminate is to be bonded to bonded to custom aluminum core, RFP faced honeycomb sandwich substrates.
>
> Modules to be delivered by no later than May 1st 2014.
>
> Thank you
> Pietro
>
> --

> ***Dr. Pietro Bernasconi***
> JOHNS HOPKINS UNIVERSITY
> ***Applied Physics Laboratory***
> ***11100 Johns Hopkins Road***
> ***Laurel, MD 20723-6099***
> ***Phone: 443-778-8970   Fax: 443-778-0386***
> ***email:*** pietro.bernasconi@jhuapl.edu
> http://sd-www.jhuapl.edu/FlareGenesis/Team/Pietro/

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Reflight of the Stratospheric TeraHertz Observatory: STO-2

Scientific/Technical Management
(Statement of Work and Roles and Responsibilities)

David Hollenbach, Institutional PI, SETI Institute

The Lead Proposal for this investigation originates from the University of Arizona, Steward Observatory under Principal Investigator Dr. Christopher K. Walker. The SETI Institute is pleased to submit this subsidiary proposal for scientific collaborations on “The Reflight of the Stratospheric Observatory: STO-2.” The Institutional Principal Investigator for the SETI effort is David Hollenbach. The work at SETI includes scientific leadership and the analysis and modeling of the data of the STO-2 mission. Dr. Hollenbach will help the Project Scientist, Paul Goldsmith (JPL) oversee the science for the Observatory including: science requirements on the instruments, theoretical modeling, collection of ancillary data, analysis and modeling of the final data product, and publication of the papers resulting from the STO-2 surveys. Besides his oversight duties, he will also actively participate in these activities.We break down these tasks chronologically into prelaunch activities and postlaunch activities.

Prelaunch activities.

Dr.Hollenbach will work with other members of the team to collect ancillary data which is necessary to interpret the data. We will collect data from pre-existing surveys of CO J=1-0, [CI] fine structure, 5 GHz continuum, hydrogen radio recombination lines and HI 21 cm done at roughly 1 arcminute resolution, comparable to the STO-2 beam. This data will be assembled on a website, for the use of team members, and will later be released to the public once we have taken the STO-2 surveys and added them to this dataset. One of the most time consuming duties (with Dr. Michael Burton, of New South Wales University in Australia) is in obtaining CO J=1-0 observations at similar spectral and spatial resolution as the STO-2 survey.

In addition, the Dr. Hollenbach will collaborate with other members of the team, including M. Wolfire, to prepare models of the interstellar medium

(ISM) of the Milky Way which include cold diffuse clouds, warm neutral medium, diffuse HII regions, and giant molecular clouds (GMCs) with their photodissociation region (PDR) surfaces. These models will be constrained by the current Cosmic Background Explorer (COBE) and Balloon Infrared Carbon Explorer (BICE) observations of [CII] 158um and [NII] 205 um, the CO and HI surveys of the Galaxy, and the radio measurements of the ionized component. It will model the ultraviolet fluxes on these components by observations of the OB stellar content at different galactocentric radii and the ISM dust opacity, and will use these fluxes to determine the thermal structure of the neutral gas and the resultant [CII] and [NII] line fluxes. This work will set in place the modeling tools necessary in order to interpret the STO-2 data, which will have much greater spectral and spatial resolution than COBE or BICE.

Prelaunch activities will also mark a period of intense scrutiny of the observing plan for STO-2. Dr. Hollenbach will aid in tradeoff studies of the science accomplished if the surveyed area were increased at the expense of the deeper surveys (and vice versa), of different lines of sight for the deep surveys, and of contingency plans depending on the length of the flight, the sensitivity of the receivers, the time period of launch, etc.

Finally, as STO-2 is built, Dr. Hollenbach will attend team meetings in order to provide scientific requirements input to the possible discussions of tradeoffs in cost and schedule versus instrument performance.

Postlaunch activities.

The main activity in the postlaunch period is to help the Project Scientist oversee as well as work on the data analysis, comparison with other ancillary data sets, modeling, testing the various hypotheses, and finally the production of published refereed papers.

One aspect of overseeing the data analysis is to organize the science team to review the reduced data, and to perform a reality check against theoretical expectations to ensure that the data make reasonable sense. In addition, Dr.

Hollenbach will help the Project Scientist oversee the production of the survey results with adequate error analysis, and its incorporation into the web based data archive, which will include the ancillary data as well.

Dr. Hollenbach will collaborate with other members of the team in the modeling and the testing of various hypotheses set out in the proposal. He will ensure that the complementary ancillary data is properly used to maximize the scientific return on the STO-2 data. The prelaunch models will now be applied to the STO-2 data in order to attain the 4 main science goals.

1. Determine the life cycle of galactic interstellar gas.
2. Study the creation and disruption of star-forming clouds in the Galaxy.
3. Determine the parameters that affect the star formation rate in a galaxy.
4. Provide templates for star formation and stellar/interstellar feedback in other galaxies.

Dr. Hollenbach, working with the PI and Project Scientist, will organize the subteams of STO-2 team members that will write up publishable papers from the results.

Facilities

D. Hollenbach has a fully-equipped office and computer, and access to support staff at the SETI Institute. The computers, computer peripherals, software, internal and external internet interfaces, data storage and backup are professionally maintained by the SETI Institute.

Reflight of the Stratospheric TeraHertz Observatory: STO-2
Detailed Institutional Budget--SETI Institute

A. Senior/Key Personnel	Salary base	# of Mos.	YEAR 1	Salary base	# of Mos.	YEAR 2	Salary base	# of Mos.	YEAR 3	Total
David Hollenbach, Co-Investigator	135,188	1.2	13,519	141,947	1.8	21,292	149,044	2.4	29,809	64,620
Benefits		13%	1,757		13%	2,768		13%	3,875	8,400
Total Key Personnel			**15,276**			**24,060**			**33,684**	73,020
B. Other Personnel										
None	0	0	0	0	0	0	0	0	0	0
Total Other Personnel			**0**			**0**			**0**	0
Total Direct Labor			**15,276**			**24,060**			**33,684**	73,020
C. Equipment Description										
None			0			0			0	0
Total Equipment			**0**			**0**			**0**	0
D. Travel										
Domestic Travel			1,162			1,196			2,530	4,888
Foreign Travel			0			0			0	0
Total Travel			**1,162**			**1,196**			**2,530**	4,888
E. Participant/Trainee Support Costs			0			0			0	0
F. Other Direct Costs										
F1 Materials and Supplies			**0**			**0**			**0**	0
F2 Publication Costs			**0**			**0**			**4,000**	4,000
F3 Consultant Services			**0**			**0**			**0**	0
F4 ADP/Computer Services			**0**			**0**			**0**	0
F5 Subawards/Consortium/Contractual Costs			**0**			**0**			**0**	0
F6 Equipment or Facility Rental/User Fees			**0**			**0**			**0**	0
F7 Alterations & Renovations			**0**			**0**			**0**	0
F8 Other--**Communcations**			**600**			**618**			**637**	1,855
Total Other			**600**			**618**			**4,637**	5,855
G. Total Direct Costs			**17,038**			**25,874**			**40,851**	83,763
H. Indirect Costs--at 36.93%										
A *Key Personnel IDC*			**5,641**			**8,885**			**12,440**	26,966
B *Other Personnel IDC*			**0**			**0**			**0**	0
C *Equipment (no IDC per definition)*			**0**			**0**			**0**	0
D *Travel IDC*			**429**			**442**			**934**	1,805
E *Participant/Trainee Support Costs IDC*			**0**			**0**			**0**	0
F1 *Materials and Supplies IDC*			**0**			**0**			**0**	0
F2 *Publication Costs IDC*			**0**			**0**			**1,477**	1,477
F3 *Consultant Services IDC*			**0**			**0**			**0**	0
F4 *ADP/Computer Services IDC*			**0**			**0**			**0**	0
F5 *Subs/Consorts/Contracts IDC (first $25K only)*			**0**			**0**			**0**	0
F6 *Equipment or Facility Rental IDC*			**0**			**0**			**0**	0
F7 *Alterations or Renovations IDC*			**0**			**0**			**0**	0
F8 *Other--No IDC applied to Gov't funds*			**0**			**0**			**0**	0
Total IDC @ 36.93%			**6,070**			**9,327**			**14,851**	30,248
I. Total Direct and Indirect Costs (G+H)			**23,108**			**35,201**			**55,702**	114,011

Indirect costs are computed consistent with the SETI Institute's approval from the Office of Naval Research on 4/11/11 for a negotiated FY 2011 Indirect Cost rate. The approved indirect cost rate is 36.93%. Items of equipment with a unit purchase price of $5,000 or more are excluded from indirect cost application. Subcontract amounts above $25,000 are excluded from IDC.

TRAVEL DETAIL --Domestic

Collaboration Meetings				
San Jose to Tucson				
1 Traveler for 3 days				
Airfare	548	564	0	1,112
Per Diem	374	385	0	759
Conference fees	0	0	0	0
Car rental, parking, rental fuel	240	247	0	487
Total	1,162	1,196	0	2,358
Science Conference TBD				
San Jose to Washington, DC				
1 Traveler for 4 days				
Airfare	0	0	751	751
Per Diem	0	0	1,015	1,015
Conference fees	0	0	424	424
Car rental, parking, rental fuel	0	0	340	340
Total	0	0	2,530	2,530
Total Domestic Travel	1,162	1,196	2,530	4,888

TRAVEL DETAIL --Foreign

Airfare	0	0	0	0
Per Diem	0	0	0	0
Conference fees	0	0	0	0
Car rental, parking, rental fuel	0	0	0	0
Total Foreign Travel	0	0	0	0
Total Travel Costs	1,162	1,196	0	2,358

Budget Justification and Narrative

Proposal Title: "The Reflight of the Stratospheric Terahertz Observatory (STO-2): SETI Institute"

Institutional PI: David Hollenbach, SETI Institute (w/PI: Chris Walker, Univ. of Arizona)

Submitted by: The SETI Institute and the University of Arizona in response to NRA Solicitation: NRA NNH12ZDA001N **- APRA**

We are anticipating receiving a grant if this proposal is selected for award.

Summary of Personnel and Work Effort:

Personnel	FY13	FY14	FY15
Principal Investigator Dr. David Hollenbach	0.1	0.15	0.2

Senior Personnel:
The Principal Investigator, Dr. David Hollenbach, is requesting salary and benefits to cover 0.1 year of effort in Year 1, 0.15 year of effort in Year 2, and 0.2 year of effort in Year 3.

Other Personnel: None

Equipment: None

Travel: We are requesting funds to cover one domestic trip per year. In the first two years these trips will be to Tucson for team meetings. The last year includes a trip to a scientific meeting, to present results. We have used Washington, DC as a likely destination for this meeting. Costs are determined by actual airline prices and the GSA per diem tables. Ground transportation and parking is estimated at $75/day. There is a 3% cost of living increase included for Years 2 and 3. There is no anticipated foreign travel.

Other Direct Costs: We are requesting $4,000 for publications in Year 3, based on previous experience of such costs. This estimate is for 2 papers, based on $125 per page.

Indirect Costs:
Indirect costs are computed consistent with the SETI Institute's approval from the Office of Naval Research on 4/11/11 for a negotiated FY 2011 Indirect Cost rate. The approved indirect cost rate is 36.93%.

Facilities and Equipment:
The main facilities required are available at the SETI Institute. These include office space, telephone, access to copying, printing and faxing equipment, and internet access. The equipment needed for the research include high-speed laptop computers, such as the MacBook Pro. Dr. Hollenbach already has such a laptop. The only cost is roughly $600 per year for high speed internet access for Dr. Hollenbach's work office at home. Therefore, there is very little cost other than overhead (indirect costs) for facilities and equipment in this proposal.