National Aeronautics and Space Administration

NASA Centers and Universities collaborate through Smallsat Technology Partnerships

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Chief Technologist

NASA STMD Small Spacecraft Technology Program

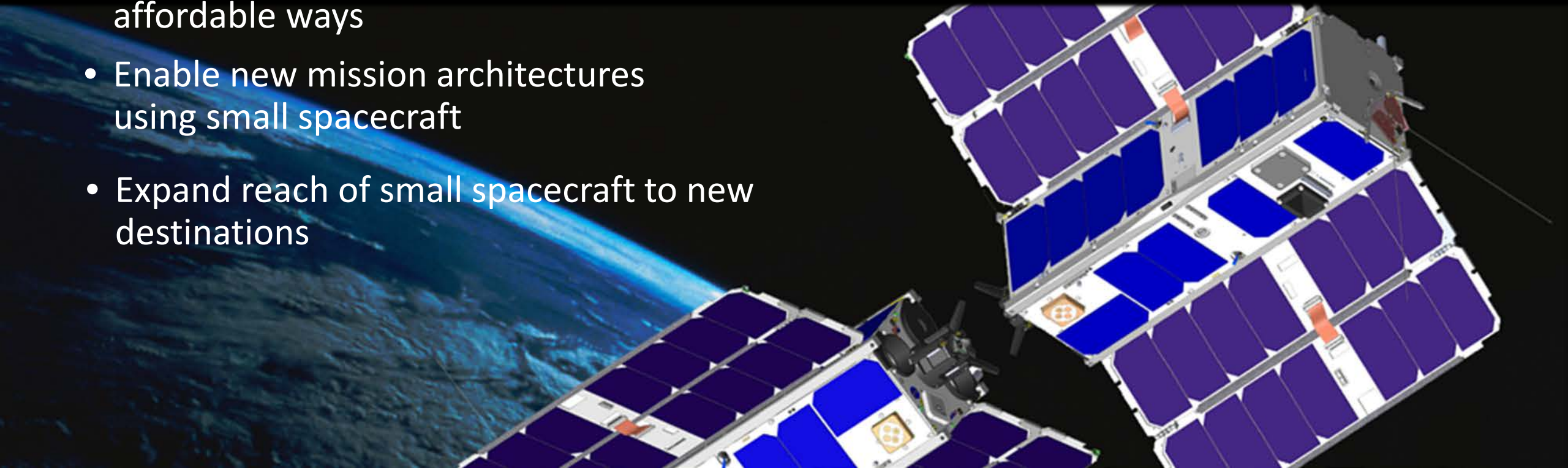
Presentation to AIAA/USU SmallSat Conference

August 4, 2018

NASA's Space Technology Mission Directorate
Small Spacecraft Technology Program

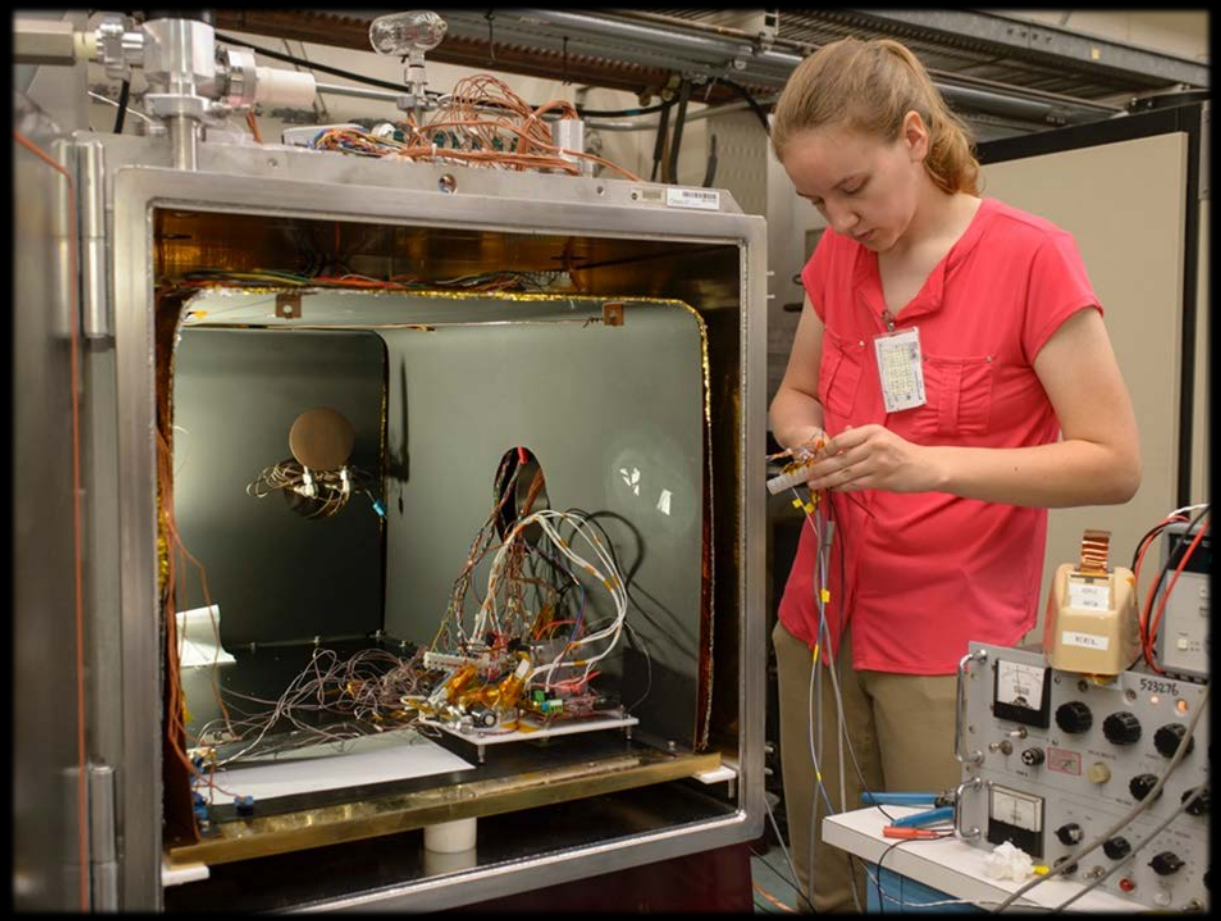
Develops and demonstrates small spacecraft capabilities to:

- Achieve science, exploration missions in unique and more affordable ways
- Enable new mission architectures using small spacecraft
- Expand reach of small spacecraft to new destinations
- Augment existing assets and future missions with small spacecraft support



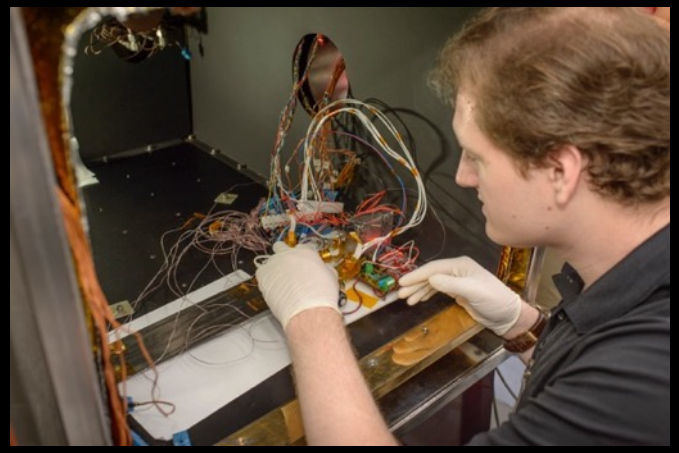
Why University – NASA Partnerships?

- Advance novel technologies for Smallsats useful to NASA and industry
- Leverage unique talents, fresh perspectives of the university community
- Share NASA experience and expertise in relevant university projects
- Engage NASA personnel in rapid, agile and cost-conscious small spacecraft approaches that characterize university teams
- Foster a new generation of innovators for NASA and the nation.



What are Smallsat Technology Partnerships (STPs)?

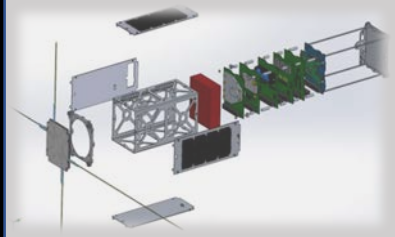
- U.S.-based university and NASA center, PI-lead cooperative agreements
- Competitive solicitations
  - Specific technology topics vary
- Grants for max duration of two years
  - Year-2 option after first annual review
- 4 “classes” to-date: 2013, 2015, 2016, 2018



Grant Award Caps		
STP Proposal Class	**University**	**NASA/JPL FTE**
2013, 2015, 2016	$100k / year 2-year max	• 1.0 FTE for NASA/JPL partner, • $25k procurement to NASA/JPL in second year
2018	$200k / year 2-year max	• 0.5 FTE for NASA/JPL partner • $25k procurement to NASA/JPL in second year

STP Technology Topics

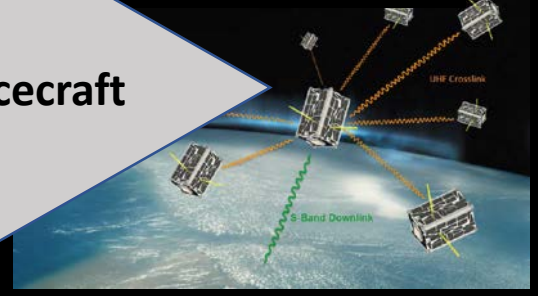
STP Class	2013	2015	2016	2018
Technology Topics	Communications	Avionics/C&DH Subsystem	Enhanced Power Generation and Storage	Instruments for SmallSats incl. Multiple SmallSats
	GN&C	Communication Subsystem	Cross-linking Communications Systems	Technologies That Enable Large Swarms of Small Spacecraft
	Propulsion	Ground Data Systems	Relative Navigation for Multiple Small Spacecraft	Technologies That Enable Deep Space Small Spacecraft Missions
	Power	GN&C/ADCS Subsystem	Instruments and Sensors for Small Spacecraft Science Missions	
	Science Instrument Capabilities	Payloads		
	Advanced Manufacturing	Power Subsystem		
		Propulsion Subsystem		
		Structures and Mechanisms		
# Proposals Submitted	**> 100**	**109**	**80**	**111**
# Grants Awarded	**13**	**8**	**8**	**8**



Subsystem-Oriented, Manufacturing Instruments

System-Oriented LEO Instruments

Mission-Oriented Deep Space, Multi-Spacecraft Instruments

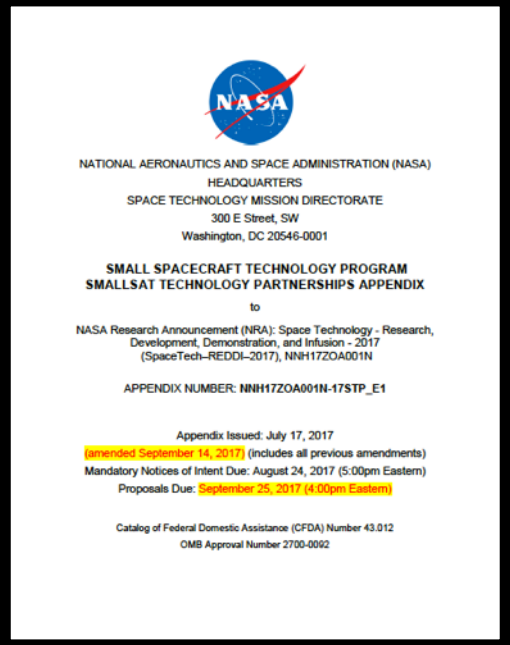


Annual Solicitation Process

Solicited through NASA NSPIRES & grants.gov; reviewed by SME teams

Evaluation Criteria (2018):

Relevance and Impact	45%
Technical & Management Approach	45%
Cost	10%



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA)
HEADQUARTERS
SPACE TECHNOLOGY MISSION DIRECTORATE
300 E Street, SW
Washington, DC 20546-0001

SMALL SPACECRAFT TECHNOLOGY PROGRAM
SMALLSAT TECHNOLOGY PARTNERSHIPS APPENDIX

to

NASA Research Announcement (NRA): Space Technology - Research, Development, Demonstration, and Infusion - 2017 (SpaceTech–REDDI–2017), NNH17ZOA001N

APPENDIX NUMBER: **NNH17ZOA001N-17STP_E1**

Appendix Issued: July 17, 2017
(amended September 14, 2017) (includes all previous amendments)
Mandatory Notices of Intent Due: August 24, 2017 (5:00pm Eastern)
Proposals Due: September 25, 2017 (4:00pm Eastern)

Catalog of Federal Domestic Assistance (CFDA) Number 43.012
OMB Approval Number 2700-0092

NRA Appendix

2013 STP

- 100+ Proposals submitted
- 13 proposals selected
- 2 spaceflight demonstrations
  - CSUN, CSUNSat1, OA-7, (May 2015)
  - MSU, RadSat, ISS, (May 2018)
- 1 patent applied for
  - Space Optical Communications Using Modulating Retro-Reflectors (MRR) with Vertical Cavity Semiconductor Optical Amplifiers (VCSOA)
- 6 Technical Topics:
  - Communications
  - GN&C
  - Propulsion
  - Power
  - Science Instrument Capabilities
  - Advanced Manufacturing

Project	Topic	PI	University	NASA/JPL	NASA/JPL
High Rate CubeSat X-band/S-band Communication System	Comm	Scott Palo	University of Colorado, Boulder	Sarah Melssen, Gary Crum, ALTUNC, SERHAT, Scott Schaire, Steven Bundick,	GSFC/ MSFC
Space Optical Communications Using Laser Beam Amplification	Comm	Govind Agrawal	University of Rochester	Peter Goorjian	ARC
Development of Novel Integrated Antennas for CubeSats	GN&C	David Jackson	University of Houston	Patrick Fink	JSC
SmallSat Precision Navigation with Low-Cost MEMS IMU Swarms	GN&C	John Christian	West Virginia University	Darryl Mary	JSC
CubeSat Autonomous Rendezvous & Docking Software (CARDS)	Science Instrument Capabilities	Glenn Lightsey	University of Texas, Austin	Christopher D'Souza, Darryl Mary, James Casey	JSC
Radiation Tolerant, FPGA-based SmallSat Computer System		Brock LaMeres	Montana State University, Bozeman	Tom Flatley	GSFC/ MSFC
An Integrated Precision Attitude Determination and Control System	GN&C	Norman FitzCoy	University of Florida, Gainsville	Zhiqiang Zhou, Carlos Roithmayr, Natalie Clark	LaRC
Propulsion System and Orbit Maneuver Integration in CubeSats	Propulsion	Jennifer Hudson	Wester Michigan University, Kalamazoo	Damon Landau, Charles Vanelli, Eric Gustafson, Richard Hfofer, Sara Spangelo	JPL
Film-Evaporation MEMS Tunable Array for PicoSat Propulsion and Thermal Control	Propulsion	Alina Alexeenko	Purdue University	Eric Cardiff	GSFC
SmallSat Low Mass, Extreme Low Temperature Energy Storage	Power	Sharlene Katz	California State University, Northridge	Naomi Palmer, William West,	JPL
Compressive Sensing for Advanced Imaging and Navigation	GN&C	Richard Kurtwitz	Texas Engineering Experiment Station	Paul Manhart, Glenn Hines,	LaRC
Mini Fourier-Transform Spectrometer for CubeSat-Based Remote Sensing	Science Instrument Capabilities	John Allen	Appalachian State University	Shahid Aslam, Patrick Roman, Qian Gong	GSFC
Printing the Complete CubeSat	Advanced Manufacturing	Craig Kief	University of New Mexico	Kyla Sorensen, Brian Zufelt, Susan De Los Sanots	GRC

2015 STP

- 109 proposals submitted
- 8 grants awarded
- 2 Spaceflight demonstrations:
  - UofA, ARKSAT-1, CSLI (in dev)
  - UofIllinois, CAPSat, CSLI (fall 2018)
- 2 NTRs/Patents Applied for:
  - Film-Evaporation MEMS Tunable Array thruster
  - Method for Inflating In-space Gossamer Structures with Solid-State Gas Generator Arrays
- 4 Technical Topics
  - Precise attitude control and pointing systems for CubeSats (33)
  - Power generation, energy storage, and thermal management systems (30)
  - Simple low cost deorbit systems (14)
  - Communications and tracking systems and networks (32)

Project	Topic	PI	University	NASA/JPL	Center
Solid State Inflation Balloon Active Deorbiter	Prop	Adam Huang	University of Arkansas, Fayetteville	David Mayer Robin Beck Kimberly Hines	ARC
Miniaturized Phonon Trap Timing Units for PNT of Cubesats	GN&C	Mina Rais-Zadeh, Associate	University Of Michigan, Ann Arbor	Serhat Altunc	GSFC
Design and Validation of High Date Rate Ka-Band Software Defined Radio of Small Satellite	Comm	Tian Xia Xinming Huang	University of Vermont Worcester Polytechnic Institute	Wai fong, Wing Lee	GSFC
Propellantless attitude control of solar sail technology utilizing reflective control devices	GN&C	Jeremy Munday	University of Maryland, College Park	Tiffany Russell	MSFC
Integrated Solar-Panel Antenna Array for CubeSats (ISAAC)	Power	Reyhan Baktur	Utah State University	Serhat Altunc	GSFC
Small Spacecraft Integrated Power System with Active Thermal Control	Power Thermal	Alexander Ghosh	University Of Illinois, Urbana-Champaign	David Mayer	ARC
MEMS Reaction Control and Maneuvering for Picosat beyond LEO	GN&C	Alina Alexeenko	Purdue University	Eric Cardiff	GSFC
Active CryoCubeSat	Thermal	Charles Swenson	Utah State University	Douglas Hofmann Jose Rodriguez A J Mastropietro	JPL

2016 STP

- 80 Proposals Submitted
- 8 Grants Awarded
- 1 New Technology Report
  - Solid-State Structural Battery Composite Materials
- 6 Balloon / Spaceflight Demos Planned
  - Highly-integrated THz Rx, GUSTO balloon
  - Low-resource magnetometer, M-BARC (planned)
  - Miniature Tether Electrodynamics Experiment, MITEE-1, ELaNa 2018
  - MOCT, CLICK, 2020? (plan)
  - Ominidirectional Optical Comm (intent to fly)
  - Smoothing-Based Relative Nav, ISS exp
- 4 Technical Topics
  - Enhanced Power Generation and Storage (18)
  - Cross-linking Communications Systems (24)
  - Relative Navigation for Multiple Small Spacecraft (13)
  - Instruments and Sensors for Small Spacecraft Science Missions (25)

Project	Topic	Speaker/PI	Univ.	NASA/JPL	Center
Highly Integrated THz Receiver Systems for Small Satellite Remote Sensing Applications	Instrument	Christopher Groppi	Arizona Sate University	Jose Siles	JPL
Development of New Low-Resource Magnetometers for Small Satellites	Instrument	Mark Moldwin	Univ. of Mich. Ann Arbor	Eftyhia Zesta	GSFC
Precision GNSS-Based Navigation and Timekeeping for Miniaturized Distributed Space Systems	Navigation	Simone D'Amico	Stanford University	Neerav Shah	GSFC
Smoothing Based Relative Navigation & Coded Aperature Imaging	Navigation	Alvar Saenz Otero	Massachusetts Institute of Technology	Carl Liebe, Norbert Sigrist	JPL
Fast, power efficient pulsed modulators and receivers for space-to-space optical communications	Comm	John Conklin	Univ. of Florida, Gainsville	Belgacem Jaroux	ARC
Development of Lightweight Cubesat with Multifuncitonal Structural Battery Systems	Power	Ryan Karkkainen	Univ. of Miami, Coral Gables	Luke Roberson	GRC KSC
Omnidirectional Inter-satellite Optical Communicator	Cross	Ozdal Boyraz	UC Irvine	Jose Velazco	JPL
Demonstration of a Nano-Enabled Space Power System	Enhanced Power Gen/ Storage	Ryne Raffaelle	Rochester Institute of Technology	Geoffrey Landis	GRC

2018 STP

- 111 proposals submitted
- 8 grants awarded
- 4 Technology Topics:
  - Instrument Technologies for Small Spacecraft

    Incl. multipoint measurements from multiple SmallSats
  - Technologies that Enable Large Swarms of Small Spacecraft
  - Technologies that Enable Deep Space Small Spacecraft Missions

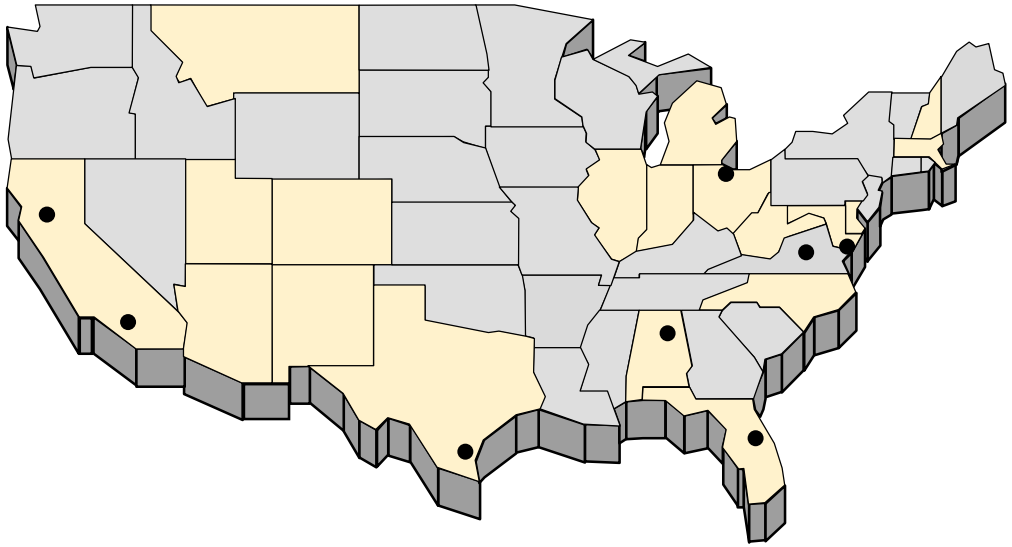
Project	Topic	PI	University	NASA	Center
Autonomous Nanosatellite Swarming using Radio Frequency and Optical Navigation	Swarms	Simone D'Amico	Stanford	Charles "Scott" Richey	ARC
SPRINT: Scheduling Planning Routing Intersatellite Network Tool	Swarms	Kerri Cahoy	MIT	Jeremy Frank	ARC/ GSFC
Application of Machine-learning Algorithms for On-board Asteroid Shape Model Determination and Spacecraft Navigation	Deep Space	Dante Lauretta	University of Arizona	William Cutlip	GSFC
Milli-Arcsecond (MAS) Imaging with Smallsat-Enabled Super-resolution	Instruments	Farzad Kamalabadi	University Of Illinois, Urbana-Champaign	Joseph Davila	GSFC
Distributed Attitude Control and Maneuvering for Deep Space SmallSats	Deep Space	Alina Alexeenko	Purdue University	Khary Parker, Andy Heaton (MSFC)	GSFC/ MSFC
Active Thermal Architecture for Cryogenic Optical Instruments	Instruments	Charles Swenson	Utah State	Ian McKinley	JPL
High Specific-impulse Electrospray Explorer for Deep-space (HiSPEED)	Instruments	Paulo Lozano	MIT	Swati Mohan	JPL
Move to Talk, Talk to Move: Tightly Integrated Communication and Controls for Coordinated Swarms of Small Spacecraft	Swarms	Qi Han	Colorado School of Mines	Jean-Pierre de la Croix	JPL

STP Summary

- Investments:
  - Over $20,569,000 awarded
  - 8 of 10 NASA Centers partnered
  - 24 Universities in 19 states
  - 37 partnerships in 4 class years
- Results:
  - 4 New Technology Reports / Patents
  - 10 flight demonstrations planned
  - 27+ Conference presentations
  - 46+ Papers published
  - 100+ Students involved
  - Many TRLs raised

24 Universities in 19 States

- **8 NASA Centers**



2013 $6,500,000 17 awards; 13 Y2 option
2015 $3,590,150 8 awards; 8 Y2 option
2016 $4,676,693 8 awards; 8 Y2 option
2018 $5,802,500 8 awards; TBD Y2 option

Feedback from STP Investigators

Sent 90 questionnaires to both the NASA and the university participants of the 2013-2017 STP classes.

23 Total responses received: 4 NASA partners and 19 University PIs

19 University PIs cited the NASA partner's contributions as critical to project success

2 NASA partners cited university partner's contributions as critical to project success

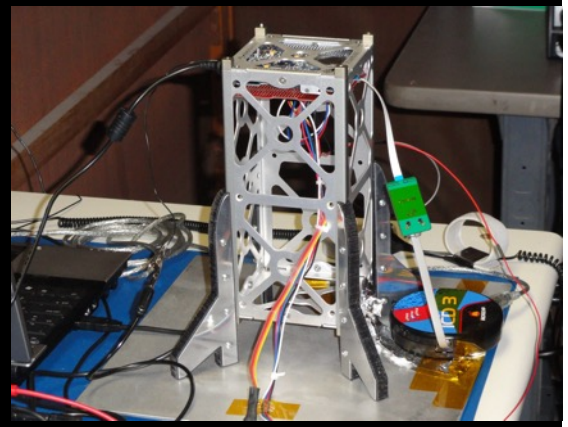
8 University PIs stated the STP effort is likely to result in future business opportunities, technology commercialization, garnered financial contribution from other entities, or likely to result in a future spaceflight mission

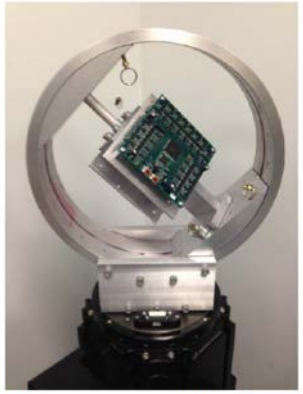
8 University PIs indicated the STP partnership positively influenced students to pursue STEM careers, NASA internship, or resulted in future opportunity in STEM

3 Partners stated that amount of required reporting as too much overhead in proportion to the STP effort

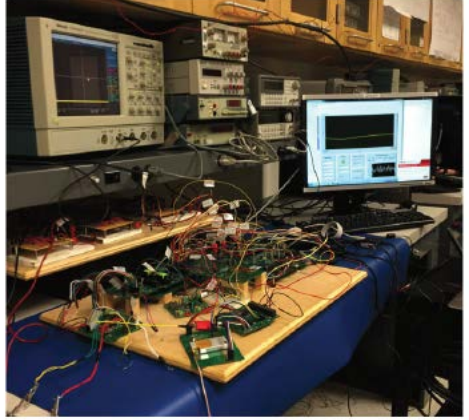
7 Partners cited insufficient funding as a limit to STP effectiveness

STP Successes





The IMU swarm research team developed a new system (patent pending) for calibrating and aligning MEMS IMU clusters on a single-axis rate table.

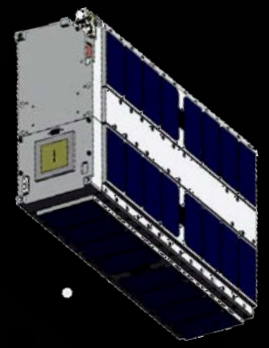


CSUNSat1 Flatsat with Solar Simulator

Goals	Results
Advanced novel technologies for SmallSats useful to NASA and industry	✓ Many patents, licenses, papers, presentations, flight demonstrations, TRLs elevated
Leverage unique talents, fresh perspectives of the university community	✓ Broad range of novel and innovative technologies developed
Share NASA experience and expertise in relevant university projects	✓ Students gained hands-on experience; access to NASA test facilities, processes, expertise and launch opportunities; often students work alongside NASA staff
Engage NASA personnel in rapid, agile and cost-conscious small spacecraft approaches that characterize university teams	✓ NASA benefits from access to broad array of investigations, quick results, validation of low-cost components, and diverse skills and expertise of university teams
Foster a new generation of innovators for NASA and the nation.	✓ More than 100 students participated. Students pursue careers in STEM in industry, academia, NASA internships

Future of Smallsat Technology Partnerships

- NASA will focus on lunar exploration and beyond
- Deep-space-capable Smallsats will contribute
- SST will continue to engage with universities to accelerate Smallsat capabilities
- Stay tuned to NSPIRES and SSSVI



https://www.nasa.gov/directorates/spacetech/small_spacecraft/index.html
https://nspires.nasaprs.com/external