National Aeronautics and Space Administration

Space Technology Mission Directorate

Flight Opportunities

2015 Annual Report

www.nasa.gov

▷ *March 8, 2015 (from left to right): Paul De Leon (NASA/FO Campaign Manager) and a World View representative prepare the inflation and launch of the first World View balloon flight for the Program at Pinal Airpark near Tuscon, Arizona. (Photo: World View)*

◁ *On the cover: The hopping/tumbling robot called "Hedgehog" was tested by NASA/JPL scientists onboard a parabolic aircraft flight on June 9, 2015 (T0126). More details on pages 85-86. (Photo: NASA/JPL-Caltech)*

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Welcome back

▷ *February 19, 2016: (from left to right) Robert 'Bobby' Roe (NASA/FO Campaign Manager), Ronald Young (NASA/FO Program Manager), Richard Branson (Virgin Galactic), and LK Kubendran (STMD Commercial Partnerships Portfolio) pose in front of the new SpaceShipTwo vehicle unveiled at the Mojave Air & Space Port, CA. (Photo: Virgin Galactic)*

Introduction

Welcome to this third edition of the Flight Opportunities program annual report. In this edition, we continue our story of pathfinding NASA's role in the partnership with the U.S. commercial space and space technology R&D communities to advance national space interests and develop technologies critical to NASA's future missions.

2015 was the year in which a planned change to our payload solicitation strategy saw its first tangible result. As you might remember from our 2014 annual report, in 2015 we set out to facilitate a more direct interaction between flight providers and technology developers by providing fixed funding awards to researchers to directly purchase the flight service(s) that best meet their needs. The selection and award of the first six REDDI-F1 flight grants to non-U.S. government researchers was an important milestone in this regard. From now on, using the REDDI-F1 solicitation appendix, the program will enable non-U.S. government researchers to directly purchase flight services on the emerging suborbital market. The same (or similar) commercial flight services will be available to NASA and other U.S. government agencies (OGA) through commercial contracts that NASA has established through our program. For the latter, our program is available to provide campaign management services, similar to the role we play(ed) for technology payloads remaining in our pool from earlier selections. The full impact of this broader strategic change will likely become more visible in the years ahead as our legacy pool gets depleted and we have implemented a new NASA- and OGA-specific call for proposals. One observation that can already be made after two rounds of REDDI-F1 solicitations is that through this change, the list of commercial flight service providers of interest to non-U.S. government researchers has grown from five in 2014 to nine in 2015.

On the industry development front, our Announcement of Collaborative Opportunities (ACO) solicitation was promoted to an STMD-wide solicitation and released in 2015 in combination with the Tipping Point solicitation. A total of 22 awards was announced in November 2015, 12 of which are ACO awards, and six of these are funded by Flight Opportunities. Through these ACO awards, the program funds NASA technical expertise and NASA test facilities to aid industry partners in maturing key space technologies, in our case focusing on small launch vehicle technology development.

Flight test activity in 2015 saw a steady 13 campaigns with 31 payload-flights (29 unique payloads). Thirteen new payloads were selected into the program in FY2015, and 14 payloads completed flight testing, bringing the total number of completed technology demonstration payloads to 69. Overall, we are pleased with the evolution and growth of the Flight Opportunities program and look forward to continued success in our partnership with the technology R&D community and the commercial space sector.

LK Kubendran
Program Executive
NASA HQ

Ronald Young
Level II Program Manager
NASA/Armstrong Flight Research Center

January 22, 2016: The same New Shepard booster that flew to space and landed vertically in November 2015 takes off from the Blue Origin launch facilities in West Texas where it would fly and land safely again for the second time. (Photo: Blue Origin)

Foundational Activities and Capabilities

To strengthen U.S. leadership in space-related science, technology, and industrial bases, departments and agencies shall: **conduct** basic and applied research that increases capabilities and decreases costs, where this research is best supported by the government; **encourage** an innovative and entrepreneurial commercial space sector; and **help ensure** the availability of space-related industrial capabilities in support of critical government functions.

-- 2010 National Space Policy of the United States of America
https://www.whitehouse.gov/sites/default/files/national_space_policy_6-28-10.pdf

August 30, 2014: Emory Stagmer (left, Co-I for T0130) and FO Campaign Manager Robert 'Bobby' Roe observe the free-floating reaction sphere package during a zero-gravity parabola. Live streaming sensor data confirmed reaction sphere operation in real time. (Photo: NASA/Regan Geeseman)

Through the "Utilizing Public-Private Partnerships to Advance Tipping Point Technologies" solicitation in 2015, STMD selected nine companies to mature technologies beyond their "tipping point" with the goal of enabling private industry to develop and qualify them for market, stimulating the commercial space industry while delivering technologies and capabilities needed for future NASA missions.

One of the awards was the "Tipping Point Proposal for Reaction Sphere" by Northrop Grumman. This project focuses on the advancement of a novel attitude control device. Advantages of the reaction sphere system over reaction wheels and Control Moment Gyroscopes (CMG) include eliminating mechanisms that will wear out due to friction, removing the risks of gimbal lock, and reducing the device mass, power consumption, and volume. Prior to selection in 'Tipping Point', this technology was tested in parabolic flight through Flight Opportunities (T0130, RGO-16, August 2014).

For more information: http://www.nasa.gov/feature/emerging-space-capabilities-and-tipping-point-summaries

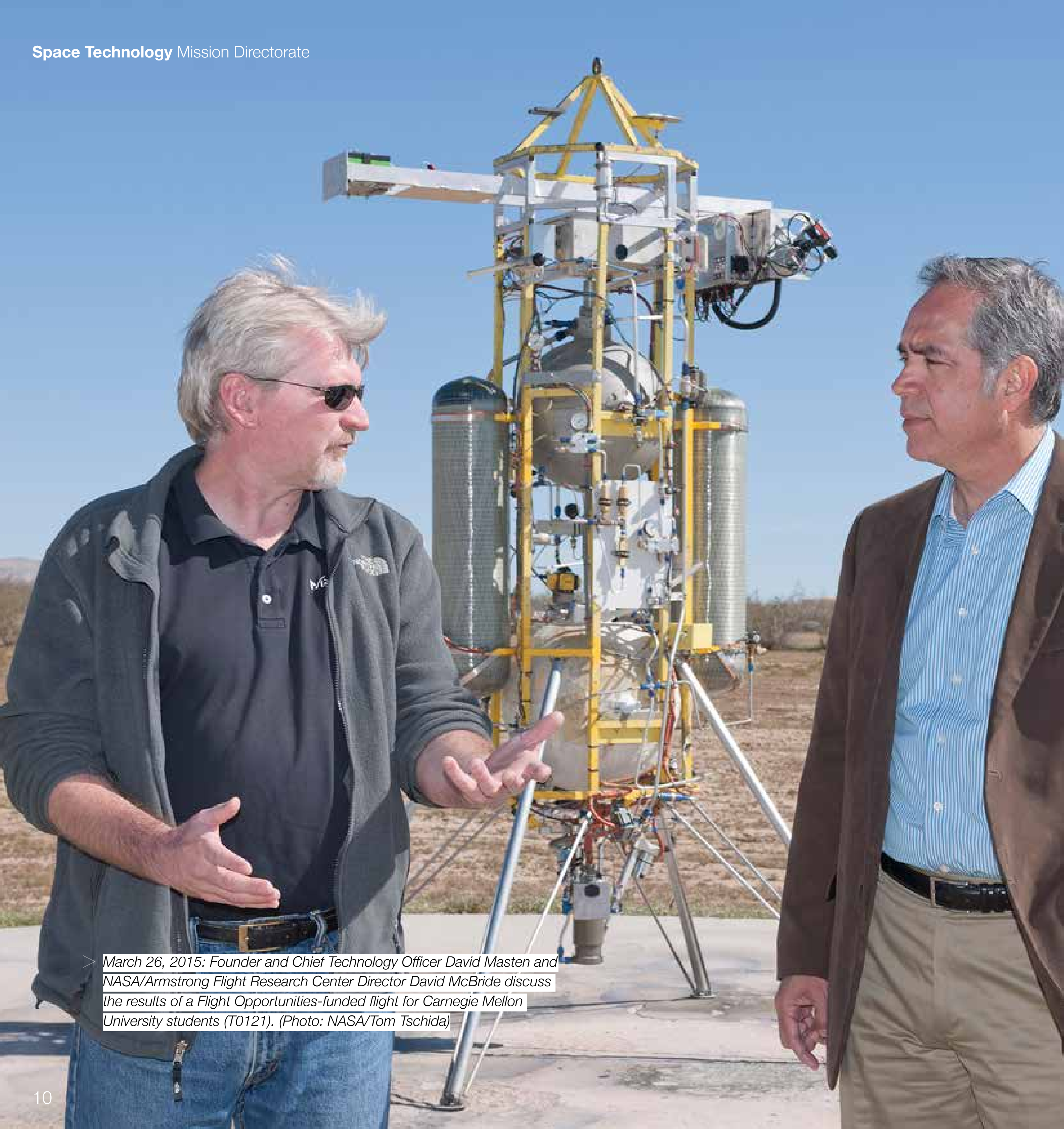
The 2010 National Space Policy charged **NASA** to "implement a new space technology development and test program, working with industry, academia, and international partners to build, fly, and test several key technologies that can increase the capabilities, decrease the costs, and expand the opportunities for future space activities."

The **Space Technology Mission Directorate** (STMD) was established to implement this Space Policy; the STMD technology portfolio consists of nine uncoupled development programs and one activity (RED), together covering hundreds of technology projects.

NASA Innovative Advanced Concepts (NIAC)
Center Innovation Fund (CIF)
Space Technology Research Grants (STRG)
***(SBIR/STTR)**
Centennial Challenges (CC)
Flight Opportunities (FO)
Regional Economic Development (RED)
Small Spacecraft Technology (SST)
Game Changing Development (GCD)
Technology Demonstration Missions (TDM)

-- STMD programs (and one activity)
http://www.nasa.gov/directorates/spacetech/programs

* Small Business Innovation Research (SBIR)/Small business Technology TRansfer (STTR)



March 26, 2015: Founder and Chief Technology Officer David Masten and NASA/Armstrong Flight Research Center Director David McBride discuss the results of a Flight Opportunities-funded flight for Carnegie Mellon University students (T0121). (Photo: NASA/Tom Tschida)

Commercial Partnerships Portfolio

Laguduva "LK" Kubendran
Portfolio Executive, Commercial Partnerships/STMD/NASA
NASA HQ

Late FY2015, the Space Technology Mission Directorate established the **Commercial Partnerships Portfolio** (CPP). Building on the success of the Flight Opportunities program, the Commercial Partnerships Portfolio is responsible for establishing and implementing a Commercial Space strategy for the Mission Directorate.

Focused initially on three of STMD's existing nine programs (and the *Regional Economic Development* activity), the goal of the Commercial Partnerships Portfolio is to engage the established and emerging aerospace markets, private citizens and economic regions to leverage common interests and increase collaboration.

▷ *August 25, 2015: Xaero-B, the new platform from Masten Space Systems, performs a tethered night flight to assess suitability of the platform for testing a starshade technology that would enable a future space mission to perform spectroscopy of Earth-like planets as far away as 60 light years (T0092). (Photo: NASA/Lauren Hughes)*

"The term 'commercial,' for the purposes of this policy, refers to space goods, services, or activities provided by private sector enterprises that bear a reasonable portion of the investment risk and responsibility for the activity, operate in accordance with typical market-based incentives for controlling cost and optimizing return on investment, and have the legal capacity to offer these goods or services to existing or potential nongovernmental customers."

-- Sector Guidelines, 2010 National Space Policy of the United States of America

Invest in the commercial space technology sector to address NASA technical challenges and benefit the commercial space sector

Implementation Goal #3
2015 STMD Strategic Implementation Plan

Transform NASA missions and advance the Nation's capabilities by maturing crosscutting and innovative space technologies

NASA Strategic Objective 1.7
STMD Primary Lead Responsibility

Expand the frontiers of knowledge, capability, and opportunity in space

NASA Strategic Goal #1

SBIR/STTR

Advancement and commercialization of new space technologies developed by small business

Centennial Challenges (CC)

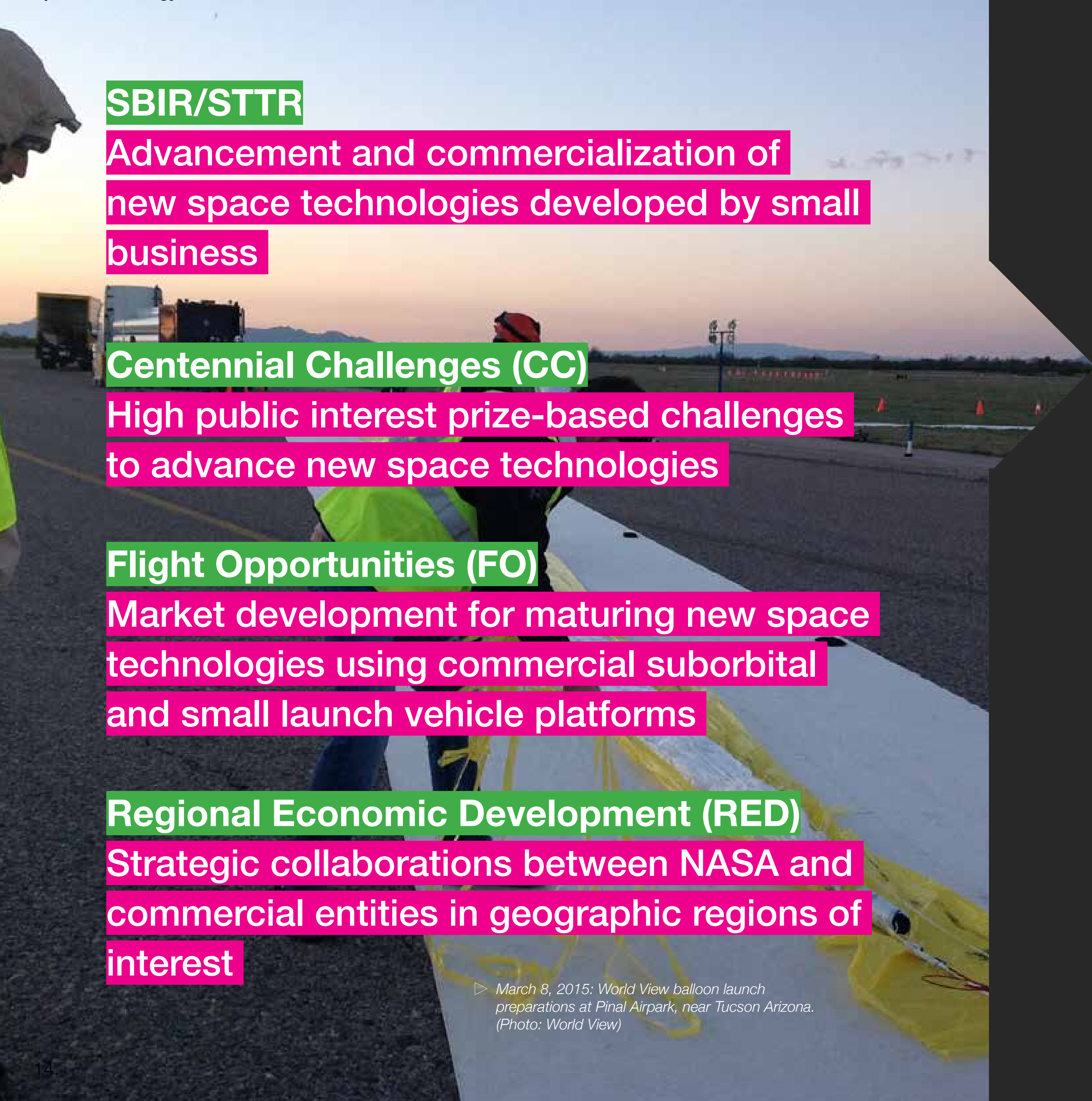
High public interest prize-based challenges to advance new space technologies

Flight Opportunities (FO)

Market development for maturing new space technologies using commercial suborbital and small launch vehicle platforms

Regional Economic Development (RED)

Strategic collaborations between NASA and commercial entities in geographic regions of interest



March 8, 2015: World View balloon launch preparations at Pinal Airpark, near Tucson Arizona. (Photo: World View)

Programs in CPP

SBIR/STTR, Centennial Challenges, Flight Opportunities and Regional Economic Development

The three programs and one activity in the Commercial Partnerships Portfolio each have their own role in supporting space technology development. Bringing these programs together creates synergy, for example by enabling the most promising technologies resulting from SBIR/STTR and Centennial Challenges to further mature through flight testing using the commercial flight services Flight Opportunities is helping to establish.

SBIR/STTR is the largest program in the Portfolio. Its goal is to fund innovative research conducted by small business with an angle towards downstream infusion into NASA missions and/or commercialization of the research in either space-based or terrestrial applications.

Centennial Challenges (CC) uses prize competitions to advance new space technologies by leveraging the innovative ideas from private citizens and small organizations.

Flight Opportunities (FO) provides commercial suborbital flight demonstrations of technology solutions and stimulates a viable and cost effective orbital and sub-orbital flight market.

Regional Economic Development (RED), an activity previously managed by the NASA Office of the Chief Technologist (OCT), leverages NASA capabilities to support public-private collaborations leading to regional economic development by the local business sectors of critical importance to NASA and the region of interest. A recent success of RED is the collaboration among NASA/STMD, Office of Naval Research (ONR), Department of Energy (DoE), and economic development partners on the space coast that will lead to the creation of the world's first commercial electron-beam additive manufacturing facility.

October 23, 2014: UP Aerospace CEO Jerry Larson (left) and Paul de Leon (FO Campaign Manager) pose with the recovered payload section of the SL9 sounding rocket at the White Sands Missile Range (WSMR). The payload bay landed by parachute after reaching an altitude of 408,305 ft (124 km). Within approximately one hour the payloads are returned to the UP Aerospace launch facilities where the researchers will be able to access their experiments. (Photo: WSMR)

Flight Opportunities
Program Update

Progress in 2015

Ronald Young
Level II Program Manager
NASA/Armstrong Flight Research Center

Progress in our program can be measured along three different axes: (1) market development (nurturing supply & demand), (2) flight testing & maturation of new technologies, and (3) new initiatives. Market development and flight testing have been our consistent focus for the last five years. New initiatives allow us to adapt our strategy to best tailor to the needs of the R&D community and the emerging commercial suborbital and smallsat orbital launch industry (see chart on pages 22/23).

Market development

One of the primary objectives of the Flight Opportunities program has been to help establish a viable market for flight testing and maturation of new space technologies using commercial suborbital flight services. Over the last five years, this effort has resulted in a functioning mechanism by which both U.S. government researchers and the broader U.S. based space technology development community can access and purchase operational commercial suborbital flight test services to achieve their technology development goals.

Whereas this was initially accomplished by NASA serving as an intermediary for all parties, matching payloads with flights and managing the flight campaigns, the goal from the start has been for NASA to move out of the middle once the proper mechanisms were in place for non-U.S. government researchers to procure these flight services independent from NASA. NASA in turn could revert back to focusing on the flight testing needs of U.S. government researchers.

With the sunsetting of the original "*Announcement of Flight Opportunities*" (AFO) solicitation in December 2014 and the introduction of the STMD-wide SpaceTech-REDDI* NRA solicitation, this operating model came a step closer into view. Through Appendix F1 of the SpaceTech-REDDI solicitation, the Program selects proposals from academia and industry that result in flight grants provided to the Principal Investigator (PI) to directly purchase the requested flight services from a qualified U.S. based flight vendor. In addition to taking NASA out of the middle, this new approach is also intended to encourage researchers to get 'skin in the game' by supplementing the Program's capped funding with other sources of funding.

U.S. government research (including NASA's) will continue to be managed and manifested by the Flight Opportunities program, using flight services available through commercial IDIQ contracts. The first four flight vendors with whom these contracts were established just before the start of FY2015 are UP Aerospace,

** Space Technology REsearch, Development Demonstration and Infusion*
https://nspires.nasaprs.com/external/solicitations/summary.do?method=init&solId={C4700383-CA28-812D-2968-EB26EAE285A6}

September 4, 2015: University of Louisville and Carnegie Mellon University are jointly developing technology for surgical treatment of an injured astronaut during a trip to Mars or when living in a Lunar colony. Working with low or no gravity makes it more difficult to use surgical instruments, perform surgical tasks, and handle medical fluids. To address these challenges, a hermetic surgery system (HeSS) is being matured that creates a hermetically sealed surgical field by isolating the wound and creating an aqueous environment within the surgical field while leveraging current single incision laparoscopic surgical (SILS) techniques and instruments in clinical use. (Photo: NASA/Lauren Harnett)

NASA's Flight Opportunities program has selected seven space technology payloads for flights on commercial, parabolic or suborbital launch vehicles to demonstrate new space technologies. [...] This selection represents the first Research, Development, Demonstration, and Infusion (REDDI) Appendix F1 cycle of the original 2014 NASA Research Announcement."

NASA Release 15-07, April 22, 2015*

Virgin Galactic, Masten Space Systems, and World View. In September 2015, just before the close of FY2015, Near Space Corporation became the fifth IDIQ flight vendor through the first of a series of annual on-ramp opportunities. With the introduction of the REDDI-F1 flight grants, the Program now tracks nine commercial flight providers: five IDIQ flight providers, and four flight providers who's flight service quotes were part of awarded REDDI-2014-F1 and REDDI-2015-F1 flight grants (see table on next page).

Selection of U.S. government 'internal' flight demand has so far been handled on an ad-hoc basis. One of the plans for FY2016 is to establish a quarterly solicitation to further promote the availability of these commercial flight services for U.S. government research.

Flight testing new technologies

Flight activity in 2015 was dominated by five parabolic flight campaigns with the NASA/C9. With the scheduled retirement of the C9 aircraft, an effort was made to allow flight testing of all flight-ready payloads that so far had not yet performed a flight test due to either a schedule conflict or the payload not being ready before. On the flight provider side, World View performed its first balloon flight for the Program in March 2015, and Masten Space Systems introduced its new vehicle 'Xaero-1B' for the August 2015 night flight with PI Webster Cash of University of Colorado (T0092). Further details on the 2015 flight activity are provided in the next section on page 31.

New initiatives

In FY2014, Flight Opportunities issued a Request for Information (RFI) to explore new ways to support the emerging commercial launch industry. Inspired by this RFI, an STMD-wide solicitation called "Tipping Point/ACO" was released in the latter half of FY2015 to U.S. industry and the research community. The two separate solicitations, released in tandem, aimed to advance the agency's goals for robotic and human exploration of the solar system by shepherding

* *http://www.nasa.gov/press-release/nasa-selects-commercial-lower-cost-suborbital-firms-to-test-space-technologies*
** *http://www.nasa.gov/press-release/nasa-announces-new-public-private-partnerships-to-advance-tipping-point-emerging-space*

"NASA has secured partnerships with 22 U.S. companies through two solicitations ['Tipping Point' and ACO] to advance the agency's goals for robotic and human exploration of the solar system by shepherding the development of critical space technologies.

[...]

NASA secured partnerships with 13 U.S. companies through the Announcement of Collaborative Opportunity (ACO) solicitation, "Utilizing Public-Private Partnerships to Advance Emerging Space Technology System Capabilities." Through these partnerships, NASA provides technical expertise and test facilities to aid industry partners in maturing key space technologies."

NASA Release 15-225, November 19, 2015**

the development of critical space technologies in partnership with the commercial space industry. With the Announcement of Collaborative Opportunity (ACO) solicitation, NASA secured partnerships with 13 U.S. companies. Through these partnerships, NASA provides technical expertise and test facilities to aid industry partners in maturing key space technologies. As one of the participating STMD programs in the solicitation, Flight Opportunities funded and will oversee six awards made under two of the four ACO topic areas (see description of awards on page 25). Awards under Topic 1 include Virgin Galactic and UP Aerospace, two of the Program's current IDIQ flight providers, fulfilling the original objective to establish a new mechanism through which the Program can provide direct support to the development of new capabilities by contracted commercial flight vendors.

Based on the success of the Tipping Point/ACO solicitation, plans are currently being developed to issue a new 'Tipping Point' solicitation in FY2016.

REDDI	IDIQ2	
x		Blue Origin, Kent, WA
x		EXOS Aerospace, Caddo Mills, TX
	x	UP Aerospace, Highlands Ranch, CO
x	x	Virgin Galactic, Mojave, CA
x	x	Masten Space Systems, Mojave, CA
	x	Near Space Corporation., Tillamook, OR
	x	World View Enterprises, Tuscon, AZ
x		Integrated Spaceflight Services, Boulder, CO
x		Zero Gravity Corporation, Arlington, VA

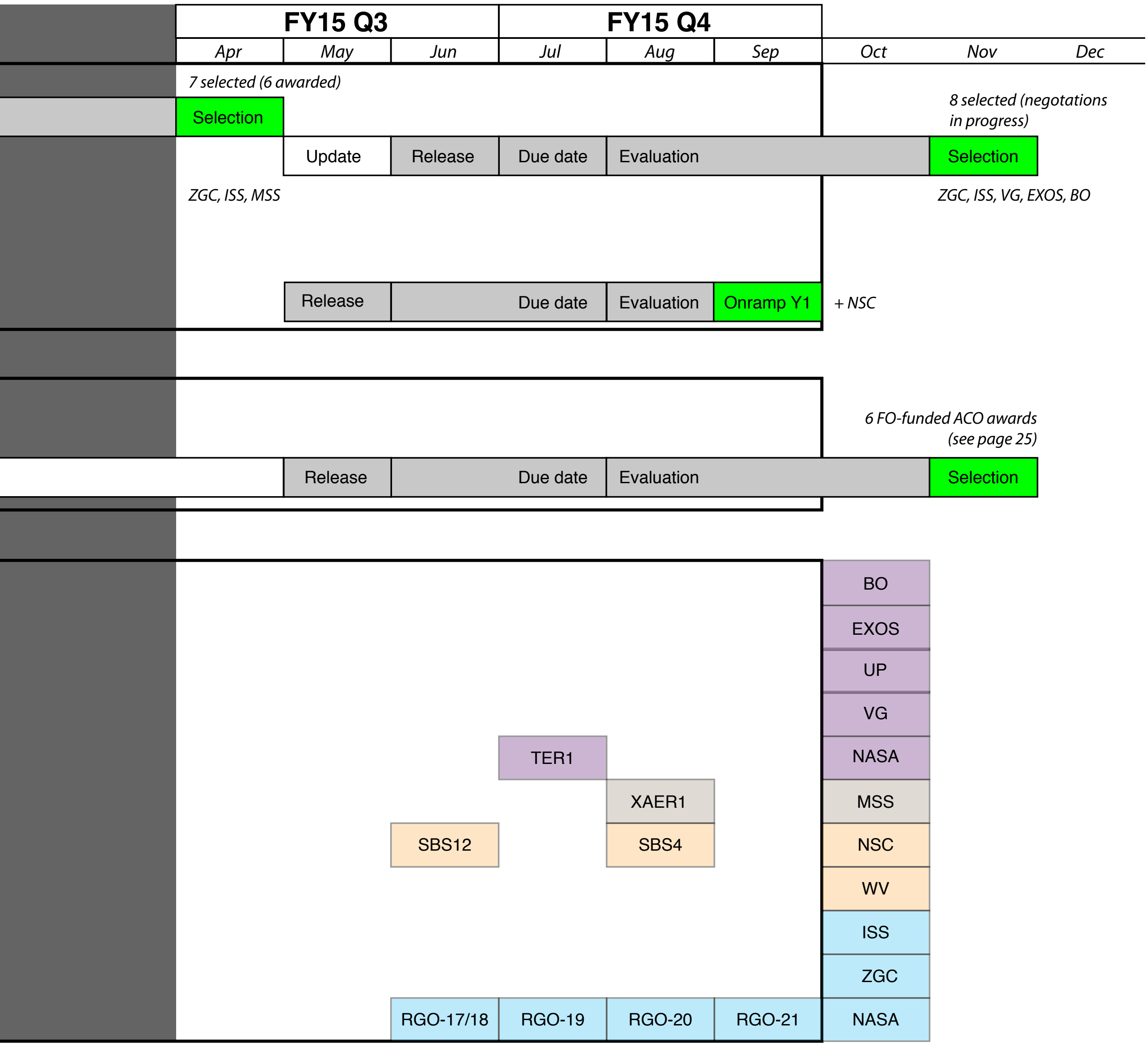
Nine commercial flight providers are tracked that have either been part of awarded REDDI-2014/2015-F1 Flight Grants or are on IDIQ contract for USGOV flight services.

	FY11	FY12	FY13	FY14	FY15
Budget (M$)	**10**	**10**	**10**	**10**	**10**

Flight Opportunities FY2011-FY2015 Budget

REDDI	IDIQ2			Sep	FY15 Q1 Oct	FY15 Q1 Nov	FY15 Q1 Dec	FY15 Q2 Jan	FY15 Q2 Feb	FY15 Q2 Mar
		MARKET DEVELOPMENT								
		Solicited Payloads (non U.S. government)			*AFO phased out Dec. 2014 (prev. selected PLs remain in Pool)*					
		SpaceTech-REDDI-2014-F1		Release		Due date	Evaluation			
		SpaceTech-REDDI-2015-F1								
		SpaceTech-REDDI Flight Vendors*								
		Directed Payloads (U.S. government only)								
		Directed Payload Solicitation			*As in previous years, directed PLs in FY2015 were selected on an ad-hoc basis (total 7 selected)*					
		IDIQ2 Flight Vendors		Selection	*<- Initial 4 IDIQ2 awards: MSS, UP, VG, WV*					
		NEW INITIATIVES								
		Tipping Point/Announcement of Collaborative Opportunity (ACO)								
		RFI Commercial Capabilities		Release		Due date	Evaluation			
		STMD-wide Tipping Point/ACO Solicitation								Solicitation development
		FLIGHT TESTING NEW TECHNOLOGIES †								
x		Blue Origin	*sRLV*							
x		EXOS Aerospace	*sRLV*							
	x	UP Aerospace	*sRLV*		UP-04					
x	x	Virgin Galactic	*sRLV*		*VG research flights are delayed due to the test flight accident on Oct 31, 2014*					
		NASA/Terrier-Black Brant	*Sounding*							
x	x	Masten Space Systems	*VTVL*				XOM6			XOM7
	x	Near Space Corporation	*Balloon*							
	x	World View	*Balloon*							T20-01
x		Integrated Spaceflight Services	*Parabolic*							
x		Zero Gravity Corporation	*Parabolic*							
		NASA/C9	*Parabolic*							

** Flight Vendors which were part of selected REDDI-2014 -F1 and REDDI-2015-F1 proposals*
† NO REDDI payloads were flown in 2015. Flight activity consisted solely of previously selected AFO/NRA/Directed payloads.


FY15 Q3
FY15 Q4
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
7 selected (6 awarded)
Selection
8 selected (negotations in progress)
Update
Release
Due date
Evaluation
Selection
ZGC, ISS, MSS
ZGC, ISS, VG, EXOS, BO
Release
Due date
Evaluation
Onramp Y1
+ NSC
6 FO-funded ACO awards (see page 25)
Release
Due date
Evaluation
Selection
BO
EXOS
UP
VG
TER1
NASA
XAER1
MSS
SBS12
SBS4
NSC
WV
ISS
ZGC
RGO-17/18
RGO-19
RGO-20
RGO-21
NASA

"These [...Tipping Point/ACO...] awards enable us to **continue to foster partnerships with the commercial space sector** that not only leverage capabilities to meet NASA's strategic goals, but also focus on U.S. industry markets that are at a tipping point for commercialization and infusion. At NASA, technology drives exploration and **partnering with the private sector to develop new space technologies** supports the innovation economy and creates jobs."

Steve Jurczyk, Associate Administrator
Space Technology Mission Directorate

http://www.nasa.gov/press-release/nasa-announces-new-public-private-partnerships-to-advance-tipping-point-emerging-space

TOPIC 1: NANOSATELLITE AND SUBORBITAL REUSABLE LAUNCH SYSTEMS DEVELOPMENT

Virgin Galactic of Long Beach, CA

LauncherOne Collaborative Opportunity to Advance Emerging Space Capabilities

This project provides significant improvements to the LauncherOne vehicle including composite propellant tanks, LOX/RP-1 pump fed engines, and autonomous flight safety. Virgin Galactic will be working with the NASA Ames Research Center to mature critical areas of development using Ames' specific expertise in aerothermodynamics, aircraft simulation, and small satellite launch vehicle enabling technologies.

UP Aerospace, Inc. of Littleton, CO

Spyder: A Dedicated CubeSat Launcher

This project develops and demonstrates a dedicated cubesat launcher, Spyder. Spyder is a small 6U cubesat payload launch vehicle that is dedicated to NASA, U.S. government, and commercial payloads. UP Aerospace will partner with NASA Marshall Space Flight Center to perform development tests leading to a demonstration flight of a commercial payload.

Generation Orbit Launch Services of Atlanta, GA

Advanced Design and Manufacture of Cryogenic Propellant Tanks for Air Launched Liquid Rockets

This project focuses on the design, manufacture, and test of a composite cryogenic tank as an evolutionary path for the Generation Orbit Launch Services vehicle, GOLauncher 1. The company will be partnering with NASA Langley Research Center to design, manufacture, and test a composite cryogenic tank utilizing the Langley-developed tow-steering composite layup method for load path control.

Generation Orbit Launch Services of Atlanta, GA

Technology Maturation and Flight Validation for Air Launched Liquid Rockets

This project focuses on a single stage liquid rocket, GoLauncher 1, launched from a Gulfstream III, capable of delivering payloads up to 1,000 pounds on high-altitude suborbital and suppressed hypersonic trajectories. Generation Orbit Launch Services is partnering with the NASA Armstrong Flight Research Center to conduct a flight test campaign for the GOLauncher1 Inert Test Article (ITA), which is a mass properties and aerodynamics simulator for the GOLauncher 1 vehicle. The campaign includes three major elements: aircraft integration, captive carry, and release testing.

TOPIC 5: SMALL, AFFORDABLE, HIGH PERFORMANCE LIQUID ROCKET ENGINE DEVELOPMENT

Garvey Spacecraft Corp. of Long Beach, CA

Enhancement of Nanosat Launch Vehicle Booster Main Engine Using 3D Additive Manufacturing Techniques

This project focuses on applying 3D additive manufacturing to fabricate an integrated injector for a 5,000 lbf-thrust LOX/propylene rocket engine. For this project, Garvey Spacecraft Corp. (GSC) will utilize NASA Marshall Space Flight Center capabilities in additive manufacturing, as well as design and analysis, to enhance engine performance. GSC will provide requirements, initial designs, and conduct static fire testing.

Dynetics, Inc. of Huntsville, AL

Hydrogen Peroxide/Kerosene Engine Development

This project focuses on designing, fabricating, and delivering 1000 lbf peroxide/kerosene upper stage engines. The program will consist of Dynetics designing, fabricating, and delivering peroxide/kerosene engines. The NASA Marshall Space Flight Center will then test these engines to verify performance parameters.

Six ACO partnerships between NASA and U.S. companies funded by Flight Opportunities. Through these partnerships, NASA provides technical expertise and test facilities to aid industry partners in maturing key space technologies.

Suborbital Flight Testing for Technology Development & Maturation

Demand and Funding Sources

With the establishment of the Commercial Partnerships Portfolio, it is worth taking a closer look at the market context for Flight Opportunities.

Flight Opportunities was established in FY2011 with two specific goals in mind: (1) facilitate the maturation of cross-cutting space technologies of interest to NASA, and (2) encourage and facilitate the growth of the U.S. commercial space industry. Similar in spirit to the Commercial Orbital Transportation Services (COTS), Commercial Resupply Services (CRS), and Commercial Crew Development (CCDev) programs, Flight Opportunities aims to establish and use commercial flight services to fulfill a U.S. government need, thereby stimulating the establishment of commercial space capabilities and services. For Flight Opportunities, this need is centered around space technology development, in particular the maturation of new space technologies across the so-called 'Valley of Death' (TRL4-6).

The underlying premise is that for new space technologies to be considered for infusion, these technologies need to be tested, demonstrated, and validated in a relevant environment. Partnering with the commercial suborbital launch industry to realize these commercial flight services benefits NASA as these flight services will help mature technologies for future NASA missions.

◁ *March 26, 2015: LVS system by NASA/JPL. See page 61 for more details. (Photo: NASA/Tom Tschida)*

	Submitted	Selected	
AFO 1-8	152	98	64%
REDDI-2014-F1	20	6	30%
GCD NRA App. A&E	81	25	31%
DIRECTED		24	
TOTAL	**253**	**153**	

# of proposals submitted/selected (FY2011-FY2015)

Space technology community as customer
Over the last five years, the Program has served as an early customer to the emerging suborbital launch industry by buying flights to test technologies it selects from the broader U.S. technology development community. Across the four entry points into the program, this resulted in the selection of 129 technology payloads out of 253 submitted proposals, plus 24 directed payloads (153 total, see table above). A brief refresher on the origin and context of the GCD NRA Appendix A and E payloads is provided top right.

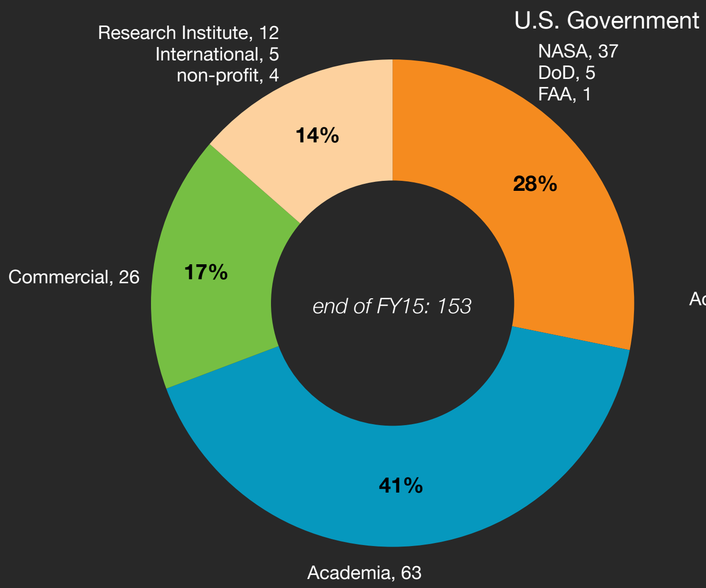
The PI affiliation for the 153 selected payloads is plotted on the right. At first glance, this distribution might be considered to represent the 'demand' side of the market. However, it might be more accurate to consider the organizations funding the technology development to drive the demand, since it is ultimately their interest in developing and maturing the technology that drives demand for the flight testing services. When looking at the funding source of the 153 payloads, it becomes apparent that the U.S. government, and to a large extent NASA, is the single largest funding agency for these technologies (95, bottom right).

Technology Development for Suborbital Flight Opportunities

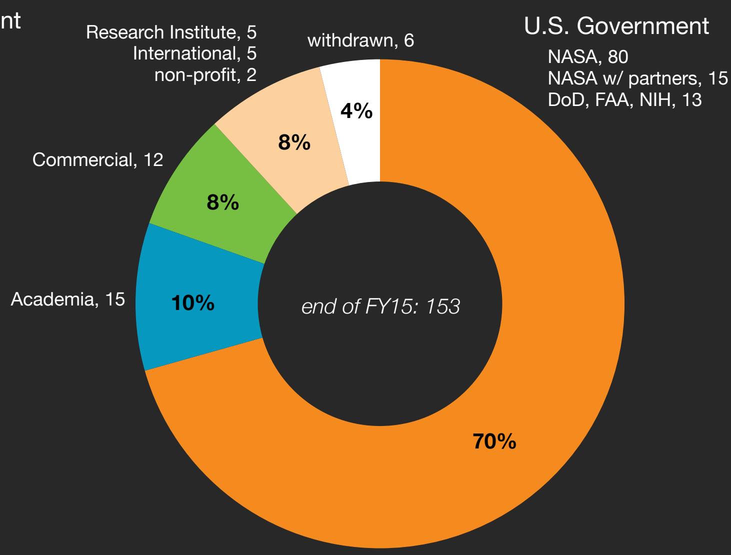
GCD NRA Appendix A (2012) and E (2013)

In 2012 and 2013, the program collaborated with the STMD Game Changing Development program (GCD) to select and fund promising new space technologies that could be demonstrated using sRLV and balloon platforms available through Flight Opportunities. Under the first Appendix A solicitation of the GCD "Game Changing Opportunities In Technology Development" NRA, the program made awards ranging from $100k to $500k totaling $3.5M to 14 proposals to develop sRLV payloads or capability enhancements to suborbital vehicles to accommodate payloads. A second round of ten NRA technology payloads was awarded in 2013 under Appendix E, with awards ranging from $100k to $250k. These technologies were selected at a TRL3 level, and are currently in varying stages of ongoing ground-based technology development or preparing for/conducting flight tests. In 2014, an additional award was made, bringing the total number of awards to 25 payloads selected through the GCD NRA solicitations.

Appendix A: http://www.nasa.gov/home/hqnews/2012/jul/HQ_12-221_Suborbital_Payloads_Selected.html
Appendix E: http://www.nasa.gov/press/2013/august/nasa-selects-innovative-technology-proposals-for-suborbital-flights



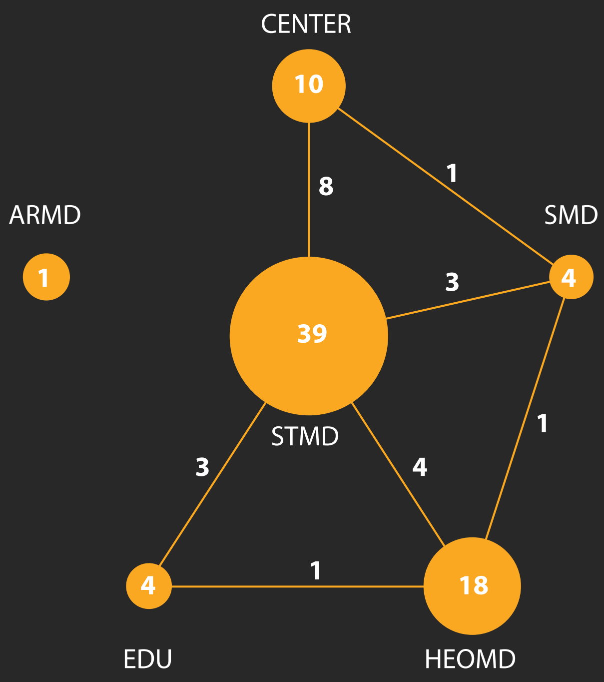
PI affiliation of 153 selected flight test proposals.



Technology development funding source for 153 selected flight test proposals. [where available]

The finding that NASA is the largest funding source is not surprising, since the proposal review was largely set up to favor technologies of interest to NASA. More generally, it is commonly understood that one of NASA's roles as the national space agency is to fund early stage space technology development. Technologies proposed for flight testing to the Flight Opportunities program largely fall into this category.

Looking further into the NASA funding sources, the data shows STMD to be the largest contributor as intended (see graph on the right). An impression of the breadth of NASA programs involved in funding the technology development is provided below. In addition to these and other NASA-programmatic sources, most NASA centers contribute in some form to the technology demonstration activities, as well as other State and Federal organizations (e.g. DoD, FAA, Space Florida, etc).



Primary funding origin for the 95 (80+15) NASA-funded technology development efforts selected in Flight Opportunities. [cross bars represent shared funding]

Space Technology Mission Directorate (STMD)

Center Innovation Fund (CIF)
Flight Opportunities (FO)
Game Changing Development (GCD)
Innovative Partnerships Program (IPP)
NASA Innovative Advanced Concepts (NIAC)
SBIR/STTR
Small Spacecraft Technology (SST)
Space Technology Research Grants (STRG)
Technology Demonstration Missions (TDM)

Science Mission Directorate (SMD)

New Frontiers (for OSIRIS-Rex)
Undergraduate Science Instrument Program (USIP)

Human Exploration & Operations Mission Directorate (HEOMD)

Advanced Exploration Systems (AES)
Human Research Program (HRP)
ISS Program
National Space Biomedical Research Institute (NSBRI)
Satellite Servicing Capabilities Office (SSCO)
Space Life & Physical Sciences Research & Applications (SLPSRA)

Aeronautics Research Mission Directorate (ARMD)

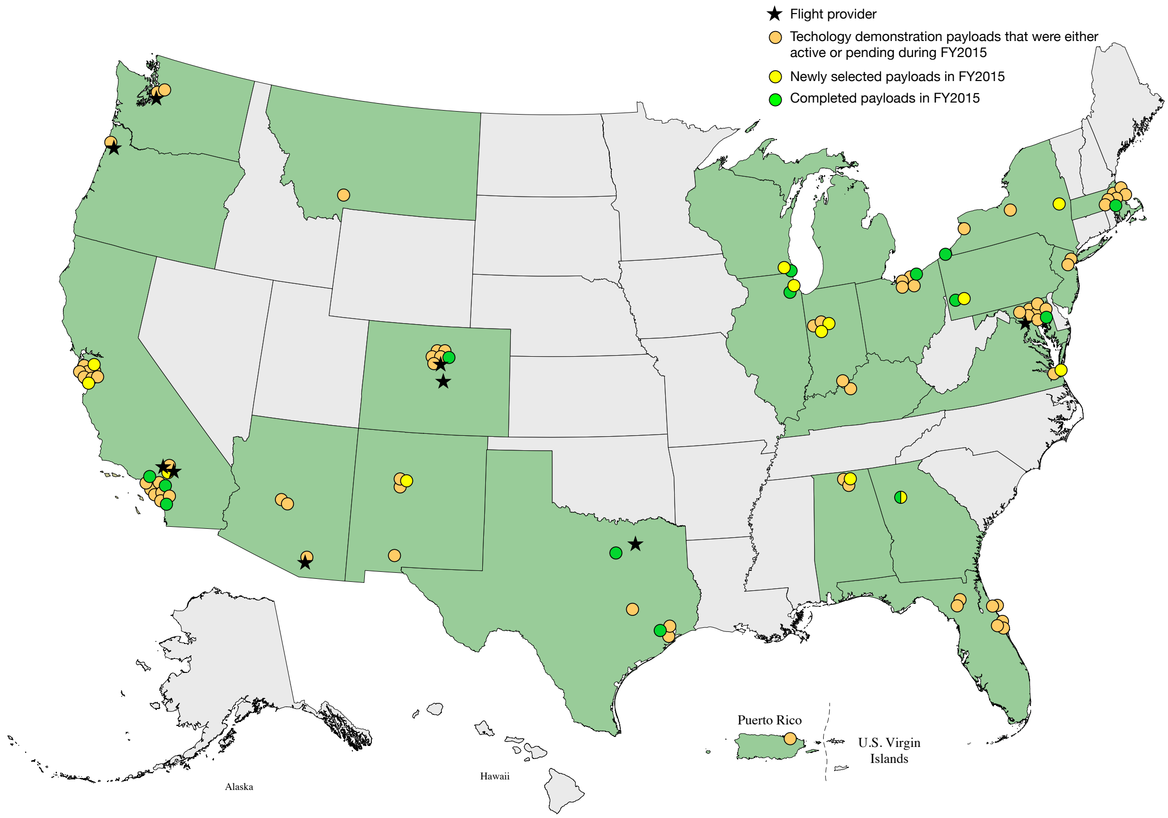
Vehicle Systems Safety Technologies (VSST)

Education Program

Experimental Program to Stimulate Competitive Research
Minority University Research and Education Project (MUREP)
Space Grant Consortia

Examples of NASA programs funding technology development selected for flight testing in Flight Opportunities.

▷ *February 2, 2016: Panel on NASA Commercial Opportunities and Engagement at the 19th FAA Commercial Space Transportation Conference, Washington DC, moderated by Pam Underwood, Deputy Manager, Operations Integration Division, FAA/ AST. From left to right: Darren Befell, Senior Technical Integration Manager, NASA Launch Services Program (LSP); Ben Feng, Program Manager, NASA Commercial Resupply Services Program (CRS); Ron Young, Program Manager, NASA Flight Opportunities Program (FO); Lisa Colloredo, Associate Program Manager, NASA Commercial Crew Program (CCDev); and Marc Timm, Program Executive, NASA Commercial Space Flight Development. (Photo: FAA)*



Distribution of active payloads across the U.S.

Flight Provider	Campaign	(first) Flight Date	# PLs	# Flights	sRLV (PL-flights)	VTOL (PL-flights)	Balloon (PL-flights)	Parabolic (PL-flights)
UP Aerospace	SL9 (UP-04)	October 23, 2014	4	1*	4			
Masten Space	Xombie-06 (FOALS 1 & 2)	December 4, 2014	1	2		2		
World View	T20-01	March 8, 2015	2	1			2	
Masten Space	Xombie-07 (CMU USIP)	March 26, 2015	1	1		1		
NASA	RGO-17	June 9, 2015	5	1				5
NSC	SBS-12	June 21, 2015	1	1			1	
NASA	RGO-18	June 23, 2015	1[†]	1				1
NASA	Terrier-01	July 7, 2015	2	1	2			
NASA	RGO-19	July 21, 2015	3	1				3
NSC	SBS-04	August 6, 2015	1	2			2	
Masten Space	Xaero-01 (Starshade)	August 25, 2015	1	1		1		
NASA	RGO-20	August 25, 2015	4	1				4
NASA	RGO-21	September 3, 2015	3	1				3
			29	15	**6**	**4**	**5**	**16**
					31 PL-flights total			

** parabolic campaigns are counted as 1 flight*
† shared flight week with other NASA customer (e.g. Glenn Research Center)

Chronology of 13 Program-sponsored FY2015 flight campaigns.

13 Campaigns, 29 Payloads flown, 31 Payload Flights

Stephan Ord
Technology Manager
NASA/Ames Research Center

Gregg Noffz
Program Chief Engineer
NASA/Armstrong Flight Research Center

Paul De Leon (ARC), Robert Roe (JSC), Joe Hernandez (AFRC), Chris Baker (AFRC)
Campaign Managers / Contracting Officer Representatives (COR)

The Program completed 13 flight campaigns in FY2015, using all four operational IDIQ2 flight providers, in addition to two NASA platforms (Terrier-Black Brant and NASA/C9). A total of 29 technology demonstration payloads (T#) were flown, with Principal Investigators from Academia (15), U.S. Government (10), and commercial companies (4).

The table on the opposite page shows the chronology of the FY2015 flight campaigns, starting with the UP Aerospace SL9 launch in October 2014. The same campaigns, grouped by flight environment and including a listing of the payloads flown on each campaign is provided on page 32.

Page 33 provides multi-year trends in technology demonstration payloads selected, payload-flights achieved, and payloads completed. 14 payloads succesfully completed flight testing in FY2015, bringing the total of completed payloads to 69. Low altitude Vertical Take Vertical Landing (VTVL) is split out as a separate category from sRLV to better differentiate between high altitude sRLV flights and low altitude descent and landing (the latter is currently only provided by Masten Space Systems).

Pages 34-37 shows the progression of the payload pool on a timeline spanning FY2011-FY2015. This chart includes a total of 94 payloads, the 81 that were active (60) or pending (21) at the start of FY2015, and the 13 payloads newly selected in FY2015. With the delay in availability of large volume, high altitude suborbital flights, four payloads originally scheduled for sRLV flights made use of an opportunity to buy down risk by flying on a parabolic flight campaign in 2015 (see T0035, T0053, T0081 and T0083).

Pages 38-43 provide the same pool of 94 payloads categorized by the four STMD strategic themes. The thirteen newly selected payloads in FY2015 are marked in yellow. Seven payloads were selected through REDDI-2014-F1, of which six eventually resulted in grants awarded to the PI. An additional seven payloads were selected through the ‘Directed’ process. REDDI-2015-F1 selections are not included since these were announced after FY2015.

29 technology demonstration payloads (T#) flown in FY2015

Campaign	T#	Title	PI	Organization	State
SL9	**T0021**	Application of controlled vibrations to multiphase systems	Ricard Gonzalez-Cinca	University of Alambama, Huntsville	AL
	T0077	Facility for Microgravity Research and Submicroradian Stabilization using sRLVs	Scott Green	Controlled Dynamics, Inc.	CA
	T0080	Advanced Micro Sun Sensor	C. Christian Liebe	NASA/Jet Propulsion Laboratory	CA
	T0088	An FPGA-based, Radiation Tolerant, Reconfigurable Computer System with Real Time Fault Detection, Avoidance, and Repair	Brock LaMeres	Montana State University	MT
Xombie-06	**T0137**	Fuel Optimal and Accurate Landing System Test Flights	Andrew Johnson	NASA/Jet Propulsion Laboratory	CA
Xombie-07	**T0121**	Flyover Mapping and Modeling of Terrain Features	William ‘Red’ Whittaker	Carnegie Mellon University	PA
Xaero-01	**T0092**	Precision Formation Flying Sensor	Webster Cash	University of Colorado	CO
T20-01	**T0097**	Planetary Atmosphere Minor Species Sensor	Robert Peale	University of Central Florida	FL
	T0124	Gannon University’s Cosmic-Ray Calorimeter (GU-CRC)	Nicholas Conklin	Gannon University	PA
SBS-12	**T0141**	Demonstration of Enabling Communications Technologies for Future Low-Cost Small Earth Return Vehicles	Dominic DePasquale	Terminal Velocity Aerospace	GA
SBS-04	**T0066**	Guided Parafoil High Altitude Research	Allen Lowry	Airborne Systems North America	CA
RGO-17	**T0001**	Suborbital Flight Environment Monitor (SFEM)	Stephan Ord	NASA/Ames Research Center	CA
	T0053	Validating Telemetric Imaging Hardware for Crew-Assisted and Crew-Autonomous Biological Imaging in Suborbital Applications	Rob Ferl	University of Florida	FL
	T0100	Creation of Titanium-Based Nanofoams in Reduced Gravity for Dye-Sensitized Solar Cell Production	Kristen Scotti	Northwestern University, Evanston	IL
	T0123	Microgravity Propellant Gauging Using Modal Analysis	Kevin Crosby	Carthage College	WI
	T0126	Validating Microgravity Mobility Models for Hopping/Tumbling Robots	Issa Nesnas	NASA/Jet Propulsion Laboratory	CA
RGO-18	**T0057**	Hybrid Ultimate Lifting Kit (HULK) Device Demonstration during Parabolic Flight	Gail Perusek	NASA/Glenn Research Center	OH
RGO-19	**T0020**	Microgravity Multi-Phase Flow Experiment for Suborbital Testing (MFEST)	Kathryn M. Hurlbert	NASA/Johnson Space Center	TX
	T0027	Autonomous Cell Culture Apparatus for Growing 3-Dimensional Tissues in Microgravity	Zarana P. Shavers	NASA/Johnson Space Center	TX
	T0081	Demonstration of Variable Radiator	Richard ‘Cable’ Kurwitz	Texas A&M University	TX
RGO-20	**T0083**	Design and Development of a Micro Satellite Attitude Control System	Manoranjan Majji	State University of New York, Buffalo	NY
	T0132	Effects of Microgravity on Intracranial Pressure	Benjamin Levine	University of Texas Southwestern Medical Center	TX
	T0135	Testing ON-OFF Gecko Adhesive Grippers in Microgravity	Aaron Parness	NASA/Jet Propulsion Laboratory	CA
	T0138	Reduced Gravity Flight Demonstration of SPHERES INSPECT	Alvar Saenz Otero	MIT	MA
RGO-21	**T0035**	Near-Zero Gravity Cryogenic Line Chilldown Experiment in a Suborbital Reusable Launch Vehicle	Jacob Chung	University of Florida	FL
	T0049	Parabolic Flight Evaluation of a Hermetic Surgery System for Reduced Gravity	George Pantalos	University of Louisville	KY
	T0131	Enhanced Dynamic Load Sensors for ISS (EDLS-ISS) Operational Feasibility for ARED	Christopher Krebs	Aurora Flight Sciences Corporation	VA
Terrier-01	**T0073**	Radial Core Heat Spreader	Marc A. Gibson	NASA/Glenn Research Center	OH
	T0075	Exo-Atmosperic Aerobrake	Marc Murbach	NASA/Ames Research Center	CA

13 Program-sponsored flight campaigns in FY2015

Technology demo payloads (T#) selected	FY11	FY12	FY13	FY14	FY15	TOTAL
	19	55	50	16	13	**153**

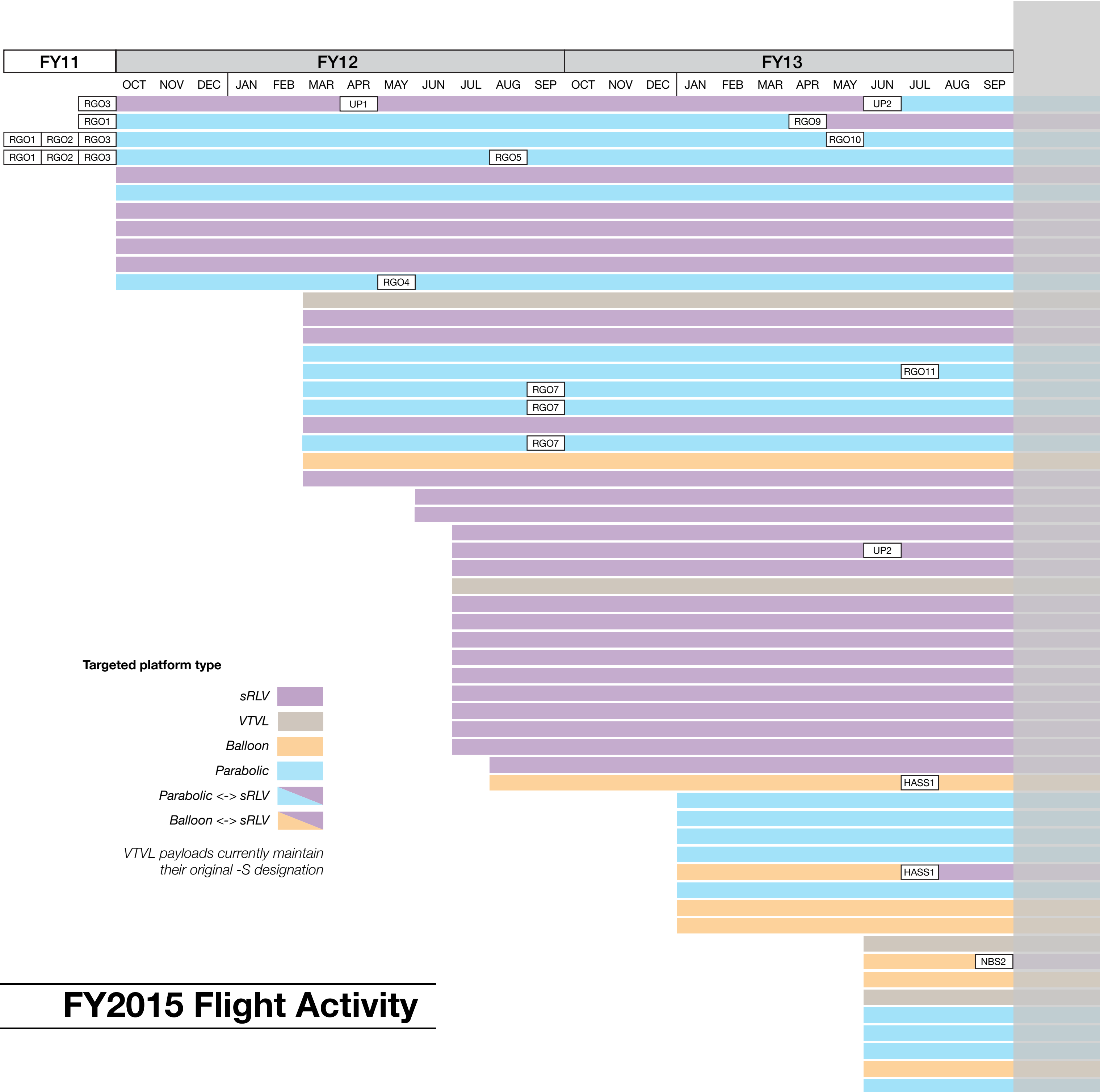
Campaigns		FY11	FY12	FY13	FY14	FY15	TOTAL
sRLV	UP Aerospace		1	1	1	1	**4**
	NASA/Wallops					1	**1**
VTVL	Masten Space Systems		1	2	2	3	**8**
Balloon	Near Space Corporation			4	4	2	**10**
	World View					1	**1**
Parabolic	Zero Gravity Corporation	3	4	4	3		**14**
	NASA/C9				2	5	**7**
	TOTAL	**3**	**6**	**11**	**12**	**13**	**45**

Payload-Flights	FY11	FY12	FY13	FY14	FY15	TOTAL
sRLV		2	6	6	6	**20**
VTVL		3	4	3	4	**14**
Balloon			5	4	5	**14**
Parabolic	20	25	18	38	16	**117**
TOTAL	**20**	**30**	**33**	**51**	**31**	**165**

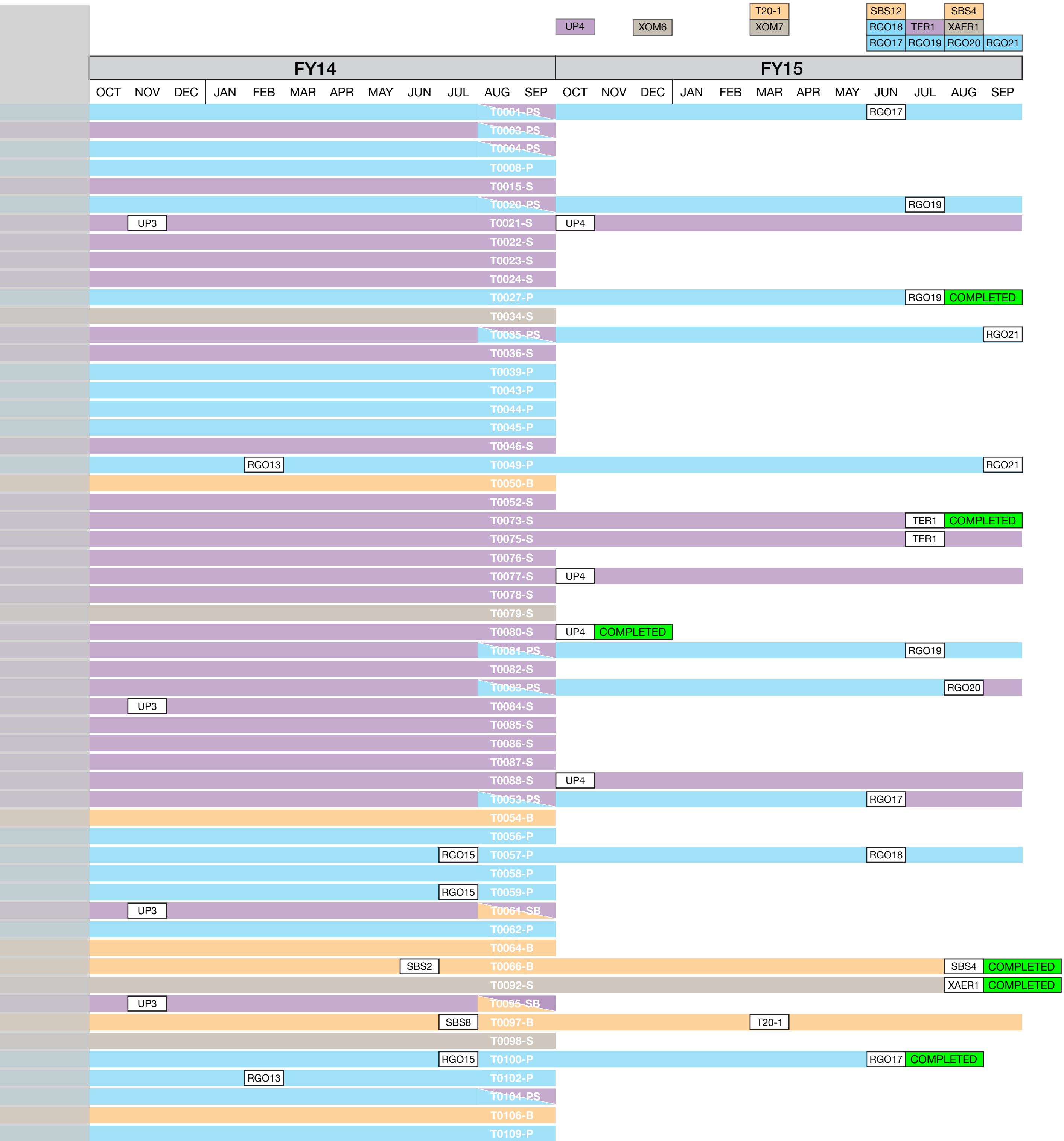
Technology demo payloads (T#) completed	FY11	FY12	FY13	FY14	FY15	TOTAL	Completed	**Active**	**Pending**	Withdrawn	
sRLV [S]			3	1	2	**6**	6	**18**	**12**	2	38
VTVL [V]			2	1	2	**5**	5	**4**	**1**		10
Balloon [B]			1	1	3	**5**	5	**7**	**2**		14
Parabolic [P]	3	8	11	23	7	**52**	52	**17**	**7**	2	78
Parabolic <> sRLV [PS]								**8**	**1**		9
Balloon <> sRLV [SB]				1		**1**	1	**3**			4
TOTAL	**3**	**8**	**17**	**27**	**14**	**69**	**69**	**57**	**23**	**4**	**153**

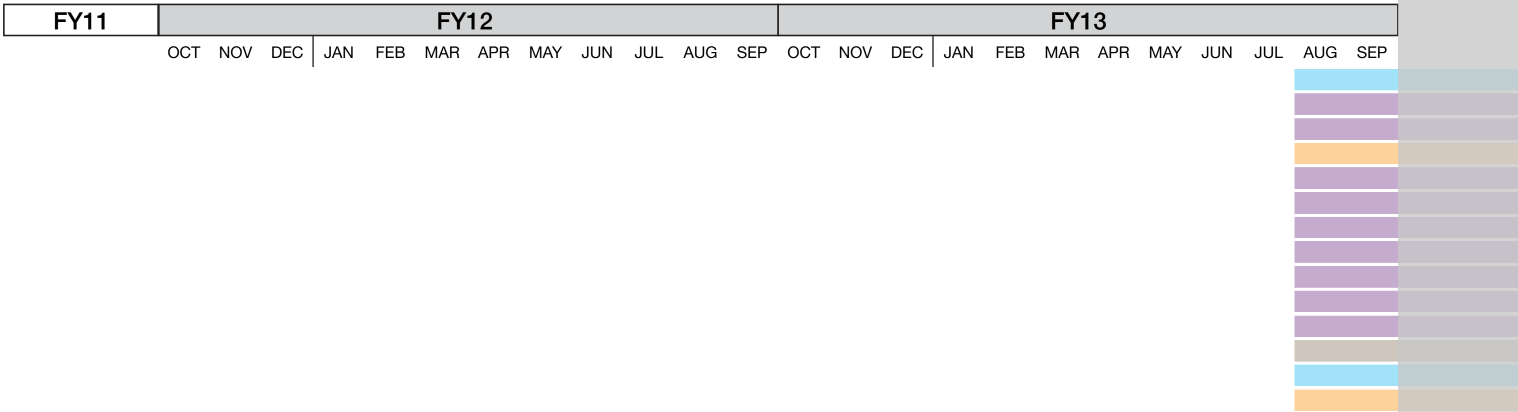
Payload Pool
End of FY15 status

Trends in technology demonstration payloads selected (T#), flight campaigns, payload-flights, and completed demonstration payloads over the period FY2011-FY2015.



FY2015 Flight Activity


T20-1
SBS12
SBS4
UP4
XOM6
XOM7
RGO18
TER1
XAER1
RGO17
RGO19
RGO20
RGO21
FY14
FY15
OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP
T0001-PS RGO17
T0003-PS
T0004-PS
T0008-P
T0015-S
T0020-PS RGO19
UP3 T0021-S UP4
T0022-S
T0023-S
T0024-S
T0027-P RGO19 COMPLETED
T0034-S
T0035-PS RGO21
T0036-S
T0039-P
T0043-P
T0044-P
T0045-P
T0046-S
RGO13 T0049-P RGO21
T0050-B
T0052-S
T0073-S TER1 COMPLETED
T0075-S TER1
T0076-S
T0077-S UP4
T0078-S
T0079-S
T0080-S UP4 COMPLETED
T0081-PS RGO19
T0082-S
T0083-PS RGO20
UP3 T0084-S
T0085-S
T0086-S
T0087-S
T0088-S UP4
T0053-PS RGO17
T0054-B
T0056-P
RGO15 T0057-P RGO18
T0058-P
RGO15 T0059-P
UP3 T0061-SB
T0062-P
T0064-B
SBS2 T0066-B SBS4 COMPLETED
T0092-S XAER1 COMPLETED
UP3 T0095-SB
SBS8 T0097-B T20-1
T0098-S
RGO15 T0100-P RGO17 COMPLETED
RGO13 T0102-P
T0104-PS
T0106-B
T0109-P

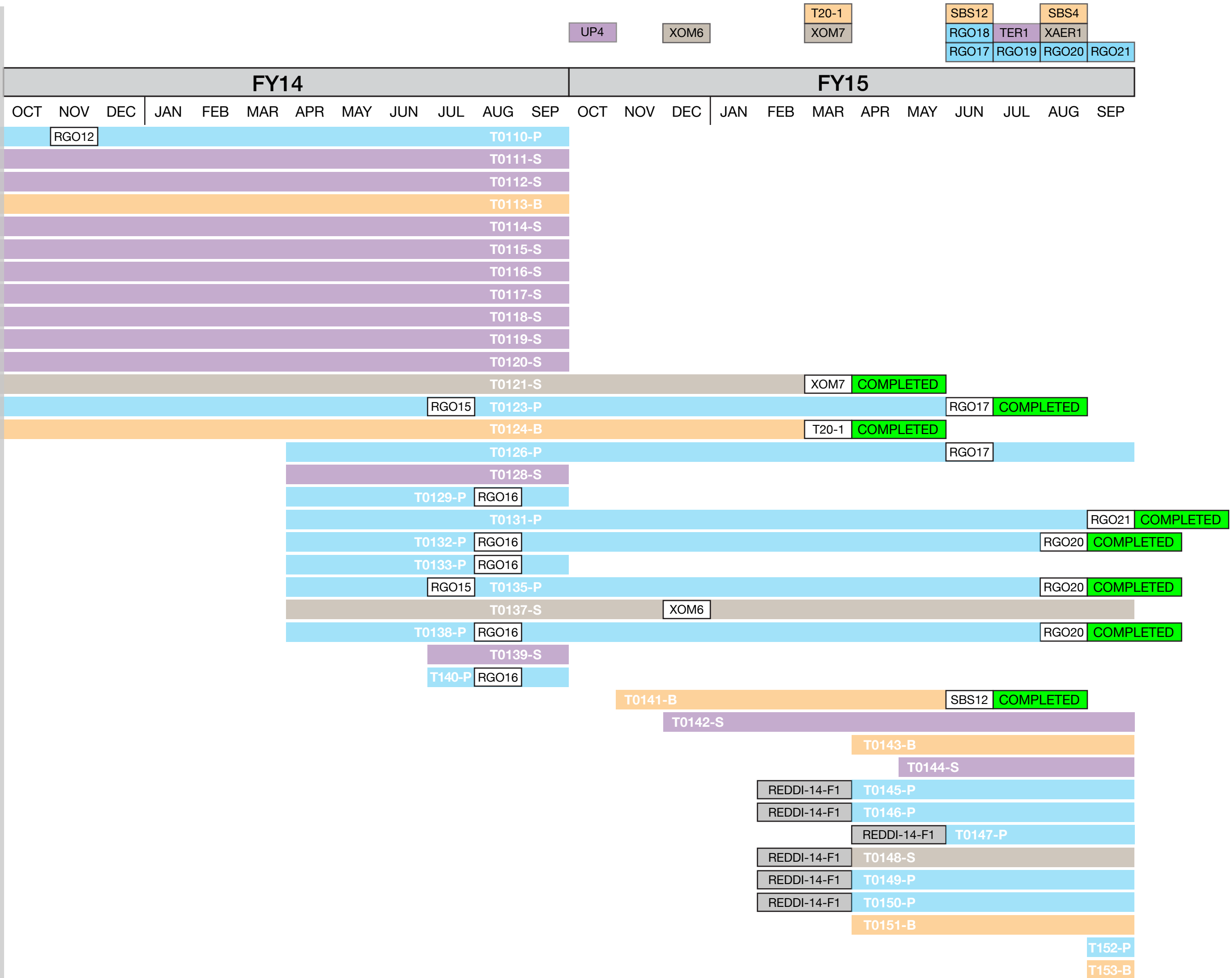


Targeted platform type

sRLV
VTVL
Balloon
Parabolic
Parabolic <-> sRLV
Balloon <-> sRLV

VTVL payloads currently maintain their original -S designation

FY2015 Flight Activity


UP4
XOM6
T20-1
XOM7
SBS12
SBS4
RGO18
TER1
XAER1
RGO17
RGO19
RGO20
RGO21
FY14
FY15
OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP
RGO12 T0110-P
T0111-S
T0112-S
T0113-B
T0114-S
T0115-S
T0116-S
T0117-S
T0118-S
T0119-S
T0120-S
T0121-S XOM7 COMPLETED
RGO15 T0123-P RGO17 COMPLETED
T0124-B T20-1 COMPLETED
T0126-P RGO17
T0128-S
T0129-P RGO16
T0131-P RGO21 COMPLETED
T0132-P RGO16 RGO20 COMPLETED
T0133-P RGO16
RGO15 T0135-P RGO20 COMPLETED
T0137-S XOM6
T0138-P RGO16 RGO20 COMPLETED
T0139-S
T140-P RGO16
T0141-B SBS12 COMPLETED
T0142-S
T0143-B
T0144-S
REDDI-14-F1 T0145-P
REDDI-14-F1 T0146-P
REDDI-14-F1 T0147-P
REDDI-14-F1 T0148-S
REDDI-14-F1 T0149-P
REDDI-14-F1 T0150-P
T0151-B
T152-P
T153-B

Get There

Improve the ability to efficiently access and travel through space

PAYLOAD POOL *(End of FY2015 status, REDDI-2015-F1 and ACO15 awards not included, payloads selected in FY15 marked yellow)*
^ P/S/B = number of completed payload-flights on Parabolic/sRLV/Balloon respectively (bold = flew in FY2015). Usually the letter associated with the T# designation uniquely identifies the targeted platform type. If ambiguous, flights are given by platform type.
** highlighted later in this report*

T#	Status	P/S/B	Origin	Title/Organization
T0003-PS	ACTIVE	2/-/-	AFO1	On-Orbit Propellant Storage Stability *Embry-Riddle Aeronautical University*
T0020-PS	ACTIVE	**3**/-/-	AFO2	Microgravity Multi-Phase Flow Experiment for Suborbital Testing (MFEST) *NASA/Johnson Space Center*
T0021-S	ACTIVE	**2**	AFO2	Application of controlled vibrations to multiphase systems *Universitat Politècnica de Catalunya / University of Alabama, Huntsville*
T0024-S	ACTIVE		AFO2	RF Gauging of the Liquid Oxygen Tank on sRLV *NASA/Glenn Research Center*
T0035-PS	ACTIVE	**1**/-/-	AFO3	Near-Zero Gravity Cryogenic Line Chilldown Experiment in a Suborbital Reusable Launch Vehicle *University of Florida*
T0039-P	PENDING		AFO3	Fuel Mass Gauging Based on Electrical Capacitance Volumetric Tomography Techniques *NASA/Goddard Space Flight Center*
T0043-P	PENDING	1	AFO3	Parabolic Flight: Validation of Electro-Hydrodynamic Gas-Liquid Phase Separation in Microgravity *New Jersey Institute of Technology*
T0056-P	PENDING		AFO5	UAH ChargerSat - 2 Parabolic Flight Testing *University of Alabama, Huntsville*
T0061-SB	ACTIVE	-/1/1	AFO5	Flight Testing of a UAT ADS-B Transmitter Prototype for Commercial Space Transportation Using sRLV *Embry-Riddle Aeronautical University*
T0073-S*	COMPLETED	**1**	DIR.	Radial Core Heat Spreader *NASA/Glenn Research Center*
T0078-S	PENDING		NRA1	Enhanced Thermal Switch *Johns Hopkins University Applied Physics Laboratory*
T0081-PS	ACTIVE	**1**/-/-	NRA1	Demonstration of Variable Radiator *Texas A&M University*
T0083-PS	ACTIVE	**1**/-/-	NRA1	Design and Development of a Micro Satellite Attitude Control System *State University of New York, Buffalo*
T0084-S	ACTIVE	1	NRA1	Suborbital Test of a Robotics-Based Method for In-Orbit Identification of Spacecraft Inertia Properties *New Mexico State University*
T0086-S	ACTIVE		NRA1	Saturated Fluid Pistonless Pump Technology Demonstrator *University of Colorado*
T0087-S	PENDING		NRA1	Electric-hydrodynamic Control of Two-Phase Heat Transfer in Microgravity *New Jersey Institute of Technology*

Continued on next page...

Get There (cont.)

T#	Status	P/S/B	Origin	Title/Organization
T0088-S*	ACTIVE	**1**	NRA1	An FPGA-based, Radiation Tolerant, Reconfigurable Computer System with Real Time Fault Detection, Avoidance, and Repair *Montana State University*
T0106-B	ACTIVE		AFO6	Low-Cost Suborbital Reusable Launch Vehicle (sRLV) Surrogate *GSSL Inc.*
T0109-P	ACTIVE		AFO6	Advanced Optical Mass Gauge *Mass Dynamix, Inc.*
T0116-S	ACTIVE		NRA2	Operational Demonstration of the MPS-120 CubeSat High-impulse Adaptable Modular Propulsion System *Aerojet General Corporation*
T0117-S	PENDING		NRA2	1U CubeSat Green Propulsion System with Post-Launch Pressurization *Busek Co. Inc.*
T0118-S	PENDING		NRA2	Iodine RF Ion Thruster Development *Busek Co. Inc.*
T0119-S	ACTIVE		NRA2	Inductively Coupled Electromagnetic (ICE) Thruster System Development for Small Spacecraft Propulsion *MSNW LLC*
T0120-S	PENDING		NRA2	Advanced Hybrid Rocket Motor Propulsion Unit for CubeSats (PUC)r *The Aerospace Corporation*
T0123-P	COMPLETED	**2**	USIP	Microgravity Propellant Gauging Using Modal Analysis *Carthage College*
T0126-P*	PENDING	**1**	AFO8	Validating Microgravity Mobility Models for Hopping/Tumbling Robots *NASA/Jet Propulsion Laboratory*
T0128-S	ACTIVE		AFO8	Zero-gravity Green Propellant Management Technology *Purdue University*
T0133-P	ACTIVE	1	AFO8	Payload Separation Performance of a New 6U CubeSat Canisterized Satellite Dispenser *Air Force Research Laboratory*
T0138-P	COMPLETED	**2**	AFO8	Reduced Gravity Flight Demonstration of SPHERES INSPECT *Massachusetts Institute of Technology*
T0142-S	ACTIVE		DIR.	Affordable Vehicle Avionics (AVA) *NASA/Ames Research Center*
T0145-P	ACTIVE		REDDI14	Low-Gravity Flow Boiling on Modern Textured Surfaces *Purdue University*
T0147-P	ACTIVE		REDDI14	Modal Propellant Gauging in Microgravity *Carthage College*
T0150-P	ACTIVE		REDDI14	Advancing Diaphragm Modeling Technology for Propellant Management *Purdue University*

Land There

Enable the capability of landing more mass, more accurately, in more locations throughout the solar system

T#	Status	P/S/B	Origin	Title/Organization
T0034-S	ACTIVE		AFO3	Terrain Relative Navigation Descent Imager (TRNDI) *Draper Laboratory*
T0064-B	ACTIVE		AFO5	Deployable Rigid Adjustable Guided Final Landing Approach Pinions (DRAG FLAPs) *Masten Space Systems Inc.*
T0066-B*	COMPLETED	**3**	AFO5	Guided Parafoil High Altitude Research *Airborne Systems North America of CA, Inc.*
T0075-S	ACTIVE	**1**	DIR.	Exo-Atmosperic Aerobrake *NASA/Ames Research Center*
T0095-SB	ACTIVE	-/1/1	AFO6	Test of Satellite Communications Systems on-board Suborbital Platforms to Provide Low-Cost Data Communications *Solstar Communications*
T0098-S	ACTIVE		AFO6	Navigation Doppler Lidar Sensor Demonstration for Precision Landing on Solar System Bodies *NASA/Langley Research Center*
T0115-S	ACTIVE		NRA2	EDL Technology Development for the Maraia Earth Return Capsule *NASA/Johnson Space Center*
T0121-S*	COMPLETED	**1**	USIP	Flyover Mapping and Modeling of Terrain Features *Carnegie Mellon University*
T0137-S	ACTIVE	**2**	AFO8	Fuel Optimal and Accurate Landing System Test Flights *NASA/Jet Propulsion Laboratory*
T0139-S	ACTIVE		DIR.	ADEPT *NASA/Ames Research Center*
T0141-B*	COMPLETED	**1**	NRA2	Demonstration of Enabling Communications Technologies for Future Low-Cost Small Earth Return Vehicles *Terminal Velocity Aerospace*
T0148-S	PENDING		REDDI14	Demonstration of One-Fault Tolerant Precision Navigation for Autolanding Airless Bodies: Flight Two *Astrobotic Technology, Inc.*
T0151-B	ACTIVE		DIR.	PRANDTL-M *NASA/Armstrong Flight Research Center*
T0153-B	ACTIVE		DIR.	Mars Electric Reusable Flyer *NASA/Langley Research Center*

Transform the ability to observe the universe and answer the profound questions in Earth and space sciences

Observe There

T#	Status	P/S/B	Origin	Title/Organization
T0015-S	ACTIVE		AFO1	Electromagnetic Field Measurements on sRLV *Johns Hopkins University Applied Physics Laboratory*
T0022-S	ACTIVE		AFO2	Environment monitoring suite on sRLV *Johns Hopkins University Applied Physics Laboratory*
T0023-S	PENDING		AFO2	Measurement of the Atmospheric Background in the Mesosphere *Silicon Valley Space Center*
T0046-S	PENDING		AFO3	Polar Mesospheric Cloud Imaging and Tomography Experiment *Space Science Institute*
T0050-B	ACTIVE		AFO3	Flight Demonstration of an Integrated Camera and Solid-State Fine Steering System *Southwest Research Institute*
T0076-S	PENDING		NRA1	Demonstration of Vertically Aligned Carbon Nano-tubes for Earth Climate Remote Sensing *Johns Hopkins University Applied Physics Laboratory*
T0085-S	ACTIVE		NRA1	SwRI Solar Instrument Pointing Platform *Southwest Research Institute*
T0092-S*	COMPLETED	**1**	AFO6	Precision Formation Flying Sensor *University of Colorado*
T0097-B*	PENDING	2	AFO6	Planetary Atmosphere Minor Species Sensor *University of Central Florida*
T0102-P	PENDING	1	AFO6	Demonstration of Adjustable Fluidic Lens in Microgravity *University of Arizona*
T0111-S	PENDING		NRA2	Rocket Flight of a Delta-Doped CCD Focal Plane Array for CHESS *Arizona State University*
T0112-S	ACTIVE		NRA2	Spacecraft Disturbance Isolation and Rejection Platform (SDIRP) *NASA/Jet Propulsion Laboratory*
T0113-B	PENDING		NRA2	Focal Plane Actuation to Achieve Ultra-High Resolution on Suborbital Balloon Payloads *Arizona State University*
T0114-S	PENDING		NRA2	Technology Demonstration of Graphene Ion Membranes for Earth and Space Applications *Johns Hopkins University Applied Physics Laboratory*
T0124-B*	COMPLETED	**1**	USIP	Gannon University's Cosmic-Ray Calorimeter (GU-CRC) *Gannon University*
T0129-P	ACTIVE	1	AFO8	Testing of a Microgravity Rock Coring Drill Using Microspines *NASA/Jet Propulsion Laboratory*

Live There

Make it possible to live and work in deep space and on planetary bodies

T#	Status	P/S/B	Origin	Title/Organization
T0004-PS	ACTIVE	4/-/-	AFO1	Printing the Space Future *Made in Space, Inc.*
T0008-P	ACTIVE	4	AFO1	Indexing Media Filtration System *Aerfil LLC*
T0027-P*	COMPLETED	**2**	AFO2	Autonomous Cell Culture Apparatus for Growing 3-Dimensional Tissues in Micro-gravity *NASA/Johnson Space Center*
T0036-S	ACTIVE		AFO3	Collisions Into Dust Experiment on a Commercial Suborbital Vehicle *University of Central Florida*
T0044-P	ACTIVE	1	AFO3	Sintering of Composite Materials under Reduced Gravity Conditions *Advanced Technical Institute I.T.I.S "E. Fermi", Italy*
T0045-P	ACTIVE	1	AFO3	Evaporative Heat Transfer Mechanisms within a Heat Melt Compactor (EHeM HMC) Experiment *NASA/Glenn Research Center*
T0049-P	ACTIVE	**3**	AFO3	Parabolic Flight Evaluation of a Hermetic Surgery System for Reduced Gravity *University of Louisville*
T0052-S	ACTIVE		AFO3	Collection of Regolith Experiment (CORE) on a Commercial Suborbital Vehicle *University of Central Florida*
T0053-PS	ACTIVE	**1**/-/-	AFO4	Validating Telemetric Imaging Hardware for Crew-Assisted and Crew-Autonomous Biological Imaging in Suborbital Applications *University of Florida*
T0057-P*	ACTIVE	**2**	AFO5	Hybrid Ultimate Lifting Kit (HULK) Device Demonstration during Parabolic Flight *NASA/Glenn Research Center*
T0058-P	PENDING		AFO5	Assessing Otolith-Organ Function with Vestibular Evoked Myogenic Potentials (VEMPs) in Parabolic Flight *Johns Hopkins University School of Medicine*
T0059-P	ACTIVE	1	AFO5	On the performance of a nanocatalyst-based direct ammonia alkaline fuel cell (DAAFC) under microgravity conditions *University of Puerto Rico, Rio Pedras*
T0062-P	PENDING		AFO5	In-Flight Lab Analysis Technology Demonstration in Reduced Gravity *NASA/Glenn Research Center*
T0079-S	ACTIVE		NRA1	Autonomous Flight Manager for Human-in-the-Loop Immersive Simulation and Flight Test of Terrestrial Rockets *Draper Laboratory*
T0082-S	PENDING		NRA1	Dynamic Microscopy System *Techshot, Inc.*
T0100-P	COMPLETED	**2**	AFO6	Creation of Titanium-Based Nanofoams in Reduced Gravity for Dye-Sensitized Solar Cell Production *Northwestern University*
T0104-PS	PENDING		AFO6	Real Time Conformational Analysis of Rhodopsin using Plasmon Waveguide Reso-nance Spectroscopy *University of Arizona*

Continued on next page...

Live There (cont.)

T#	Status	P/S/B	Origin	Title/Organization
T0110-P	ACTIVE	1	DIR.	Wet Lab *NASA/Ames Research Center*
T0131-P	COMPLETED	**1**	AFO8	Enhanced Dynamic Load Sensors for ISS (EDLS-ISS) Operational Feasibility for ARED *Aurora Flight Sciences*
T0132-P*	COMPLETED	**2**	AFO8	Effects of Microgravity on Intracranial Pressure *University of Texas Southwestern Medical Center*
T0135-P*	COMPLETED	**2**	AFO8	Testing ON-OFF Gecko Adhesive Grippers in Microgravity *NASA/Jet Propulsion Laboratory*
T0140-P	ACTIVE	1	DIR.	Lunar Plants *NASA/Ames Research Center*
T0146-P	ACTIVE		REDDI14	Droplet Pinning in Microgravity *Rensselaer Polytechnic Institute*
T0149-P	ACTIVE		REDDI14	Microgravity Fabrication of Freeze-cast Titanium Foams *Northwestern University*
T0152-P	ACTIVE		DIR.	ISS Life Science Glovebox (LSG) Crew Restraint *NASA/Ames Research Center*

Other

T#	Status	P/S/B	Origin	Title/Organization
T0001-PS	ACTIVE	**2**/2/-	DIR.	Suborbital Flight Environment Monitor (SFEM) *NASA/Ames Research Center*
T0054-B	ACTIVE	1	AFO4	Stratospheric Parabolic Flight Technology *Purdue University*
T0077-S*	ACTIVE	**2**	NRA1	Facility for Microgravity Research and Submicroradian Stabilization using sRLVs *Controlled Dynamics Inc*
T0080-S	COMPLETED	**1**	NRA1	Advanced Micro Sun Sensor *NASA/Jet Propulsion Laboratory*
T0143-B	ACTIVE		DIR.	ORS Bi-Static RF Imager *Air Force Research Laboratory*
T0144-S	ACTIVE		DIR.	PULSAR *NASA/Marshall Space Flight Center*

October 23, 2014: The Montana State Radiation Tolerant, Reconfigurable Computer System payload (T0088) is dismounted from the SL9 payload section after recovery from WSMR. (Photo: UP Aerospace)

Flight Testing
2015 Highlights

▷ *October 23, 2014, 07:33 am: Four NASA-sponsored experiments were exposed to nearly four minutes of microgravity when UP Aerospace launched the SpaceLoft 9 rocket from the company's Launch Pad One at Spaceport America, NM. The payload section reached a maximum altitude of 408,305 feet (124 km) MSL and landed downrange within the target area at White Sands Missile Range. (Photo: The Las Cruces Bulletin/Todd Dickson) More campaign photos at: https://flic.kr/s/aHsk25B9uv*

UP Aerospace launched its third Program-sponsored flight on October 23, 2014. SpaceLoft 9 (SL9) included three technologies flown in collaboration with STMD's Game Changing Development Program: a vibration isolation platform from Controlled Dynamics (T0077), an advanced micro sun sensor from NASA's Jet Propulsion Laboratory (T0080), and a radiation-tolerant computer system from Montana State University (T0088). The fourth experiment from the Universitat Politècnica de Catalunya, Spain (through its U.S. partner University of Alabama, Huntsville) investigated the effect of controlled vibrations on multiphase flow systems such as those found in environmental systems and fuel tanks (T0021).

Including SL6*, UP Aerospace to date has successfully launched four SpaceLoft flights with Program-sponsored payloads (approximately one per year). These flights have successfully delivered 13 technologies to the edge of space, achieving a total of 18 payload-flights. Building on the success of the SpaceLoft suborbital launch vehicle, UP Aerospace is currently developing a dedicated cubesat orbital launcher called 'Spyder' (see ACO awards on page 25).

** SL6 launched the first two Program-sponsored payloads in April 2012 as a rideshare with the Department of Defense' Office for Operationally Responsive Space (ORS).*

▷ *The Vibration Isolation Platform (VIP) mounted inside a mid-deck locker. The free-floating platform can be distinguished by the three black circular markings facing up. The device mounted on the platform is a test payload that measures the acceleration environment. (Photo: Controlled Dynamics)*

SL9

T0077 Facility for Microgravity Research and Submicroradian Stabilization using sRLVs

PI: Scott Green, Controlled Dynamics Inc.

Controlled Dynamics Inc. (CDI) is developing an economical, high-performance facility for both microgravity research and submicroradian stabilization. Based on Space Shuttle-proven vibration isolation technology, the Vibration Isolation Platform (VIP) is a payload mounting interface which includes active stabilization and six degree-of-freedom (6-DOF) non-contact isolation.

Suborbital microgravity research

The target application at the time of selection in 2012 was for microgravity research onboard sRLVs. By integrating the vibration isolation technology into sRLVs, the ambient flight environment can be reduced by over two orders of magnitude during operation. Using the combination of non-contact isolation and active attenuation, it will provide quiescent environments for research payloads on the order of 1 micro-g rms or better over a broadband frequency range (>0.1Hz) during the coast phase of an sRLV flight.

During launch, re-entry, and landing, the research payload is mechanically secured to the vehicle. The research payload is automatically released on a 6-DOF free-floating platform during the coast phase of flight. Non contact Lorentz-force actuators apply control forces to the platform to correct for measured disturbances either caused by the payload itself or transmitted through any payload umbilicals connecting the payload to the sRLV (e.g., power, data, fluid, etc.). The actuators also provide small restoring forces, consistent with the microgravity/pointing requirements of the payload, which keeps the platform centered within its stroke so that it inertially tracks the coasting sRLV. Both space-flight data and research studies have shown this 6-DOF non-contacting isolation approach to achieve the best possible payload isolation during flight.

Orbital microgravity research

Following initial development, the technology is now further extended to include application onboard the International Space Station (ISS). A grant awarded by the Center for the Advancement of Science in Space (CASIS) in 2015 will deploy the platform to the ISS in 2016 where it has the potential to improve space experiments in crystallization; cell, tissue, and plant culturing; and other studies.

Deep-space optical communications

Building on this foundation, CDI has spun-off a NASA Phase I/II SBIR with NASA/JPL to develop the VIP platform for deep-space optical communications. Optical communication links provide higher data transfer rates with lower mass, power, and volume than conventional radio-frequency links. For deep space applications at long operational ranges, high performance stabilization of the space terminal data link is required. To meet this need, CDI's proposed approach is to design the VIP to achieve better than 0.5microradian-rms stabilization for all frequencies above 0.1Hz when operating on a spacecraft. The SBIR Phase I developed the

Continued on next page...

"From suborbital, to orbital, to deep space, Flight Opportunities provided the basis to advance and validate our isolation technology."

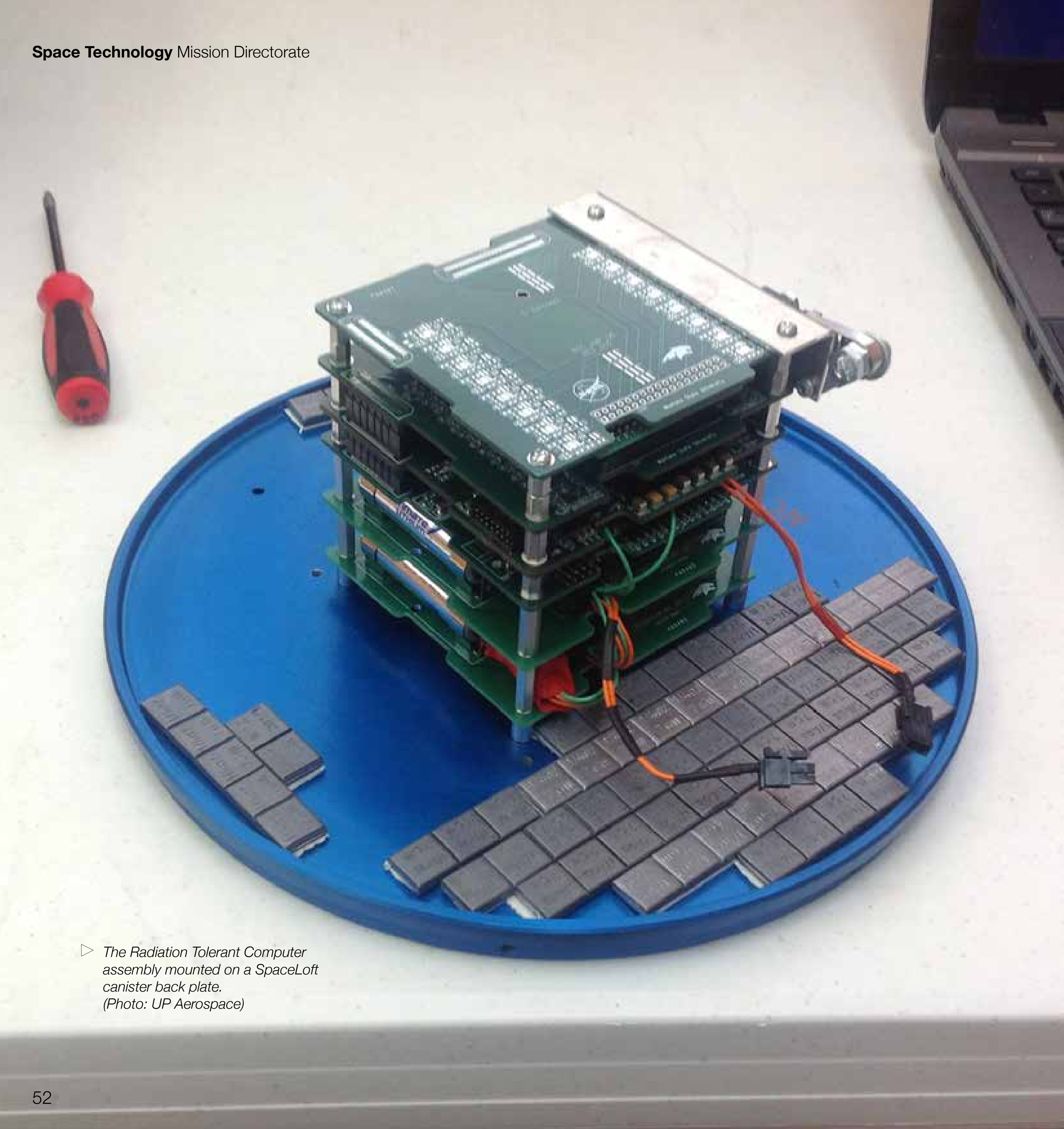
design concept, demonstrated robustness through sensitivity studies, demonstrated performance through simulation, and established the feasibility of the approach to meet the space terminal isolation requirements. Component testing of the sensors and actuators further demonstrated that the design will meet the performance requirements. These tests and analyses advanced the technology to TRL-4. Phase II continues the development by ground testing an end-to-end prototype on a soft suspension testbed to demonstrate overall performance in a simulated low-g operational environment.

The value of Flight Opportunities

Flight Opportunities has fostered the isolation technology from its beginning. In collaboration with the Game Changing Development Program, it sponsored the prototype development through an award under GCD NRA Appendix A (July 2012). As part of this award, the Program provides valuable access to suborbital flight platforms and the relevant environment of microgravity to mature the technology and demonstrate its capabilities in a space-relevant freefall environment. Results from the SL9 test flight indicate that the VIP meets the performance specifications. Funds invested in developing and extending this technology offer a high return-on-investment due to the unmatched performance of the technology and its general applicability to a broad range of host vehicles.

More information:
https://flightopportunities.nasa.gov/technologies/77

▷ *October 23, 2014: Scott Green (PI, left) and Brian Weltmer of Controlled Dynamics assess the Vibration Isolation Platform (VIP) post-flight. The VIP can be seen mounted on top of a SpaceLoft canister. (Photo: NASA/Paul de Leon)*



The Radiation Tolerant Computer assembly mounted on a SpaceLoft canister back plate. (Photo: UP Aerospace)

SL9

T0088 An FPGA-based, Radiation Tolerant, Reconfigurable Computer System with Real Time Fault Detection, Avoidance, and Repair

PI: Brock LaMeres, Montana State University

Montana State University, in collaboration with NASA's Goddard Space Flight Center, is developing the Radiation Tolerant, FPGA-based SmallSat Computer System (RadSat). RadSat exploits a commercial off-the-shelf (COTS) Field Programmable Gate Array (FPGA) with real-time partial reconfiguration to provide increased performance, power efficiency and radiation tolerance at a fraction of the cost of existing radiation hardened computing solutions for space applications. This technology is ideally suited for small spacecraft that require state-of-the-art on-board processing in harsh radiation environments but where using radiation hardened processors is cost prohibitive.

Technology relevance to NASA

The NASA Earth Science Decadal Survey states the need for on-board processing and power efficiency that far exceeds existing computer systems in order to meet NASA's future science goals. Additionally, the problem statement for the flight computing needs in NASA Technology Area 11 (TA11): Technology & Processing Roadmap is "ultra-reliable, radiation hardened platforms which, until recently, have been costly and limited in performance." The TA11 roadmap also calls for innovative computing architectures to meet the needs of both science and engineering and emphasizes the need for scalable processing platforms that include intelligent fault-tolerant technologies to increase the robustness of computing platforms for long-duration missions.

With the prevalence of computer systems in all future NASA missions, improving the capability of space computers has significant relevance and broad-scale impact across all NASA programs. Using COTS FPGAs to implement space computer systems has the greatest potential to increase on-board processing and power efficiency while at the same time providing platform scalability and reduced cost. Using COTS FPGAs allows increased computation and power efficiency by taking advantage of advances in commercial fabrication processes.

Computing in a high-radiation environment

Space computers must operate in a harsh radiation environment that leads to multiple types of failures. Radiation effects are separated into two broad categories: Total Ionizing Dose (TID) and Single Event Effects (SEE). Each of these failure mechanisms are caused by ionizing radiation striking the integrated circuit substrate and depositing unwanted energy.

RadSat uses a novel fault mitigation strategy developed by Montana State University (MSU) that takes advantage of partial reconfiguration of modern COTS FPGAs. In this approach an FPGA is divided into redundant tiles, each with the characteristics that they can fully contain a computer system core and also be individually reprogrammed using partial reconfiguration. At any given time, three of the tiles run in triple modulo redundancy (TMR), with the rest of the tiles reserved as spares. The TMR voter is able to detect

Continued on next page...

faults in the active triad by voting on the tile outputs. Meanwhile, a configuration memory scrubber continually runs in the background to detect faults in the configuration memory of both the active and inactive tiles. In the event of a fault in the active triad, (either detected by the TMR voter or scrubber), the damaged tile is replaced with a known good spare and foreground TMR operation continues. The damaged tile is repaired in the background by reinitializing its configuration memory through partial reconfiguration. The advantage of this approach is that foreground operation can continue while the faulted tile is repaired and reintroduced into the system in the background, thus increasing system availability.

This approach has been implemented on an Artix-7 200T FPGA with 9 Xilinx MicroBlaze soft processors. This 0.28um processor implementation has achieved a performance of 234 Million Instructions Per Second (MIPS) at 1 watt of power consumption, representing a significant improvement in both performance and power efficiency compared to more widely adopted radiation hardened computer systems. The Rad-Sat computer system is architected such that the fault mitigation procedures are abstracted from the developer. The computer system simply appears as a soft processor-based computer system with all of the flexibility inherent in implementing such a system on a programmable fabric. TID immunity is inherently provided through the 0.28um process node and SEE immunity is provided by the tile replacement procedure in the background.

Continued on next page...

▷ *October 17, 2014: Jerry Larson (CEO and Launch Manager, UP Aerospace) mounts the Radiation-Tolerant Computer assembly during final integration for the SpaceLoft 9 mission. (Photo: UP Aerospace)*

Maturing the technology through flight testing
The technology readiness level of this computer system has steadily increased over the past eight years. Initial funding to build the first prototype was provided by the Montana Space Grant Consortium in 2008. NASA's *Experimental Program to Stimulate Competitive Research* (EPSCoR) subsequently funded the development of a more functional prototype to perform radiation tests at the Texas A&M Radiation Effects Facility. NASA's Education Office provided follow-up funding to develop the computer into flight hardware for demonstration on high altitude balloon systems, both in Montana and at NASA (a total of nine high altitude balloon flights).

STMD first provided funding through selection in the GCD NRA Appendix A round of solicitation to demonstrate the computer system in suborbital space on SL9 and on a second sounding rocket flight in 2016. In parallel, NASA EPSCoR selected the technology for a six-month demonstration on the ISS in 2016. And finally, through STMD's Small Spacecraft Technology Program, the computer technology is currently being integrated into a 3U CubeSat for an orbital flight demonstration through the NASA Educational Launch of Nanosats (ELaNa) program. The launch date for this orbital demonstration flight is tentatively scheduled in the 2016-17 timeframe.

As of 2015, the technology has been licensed to Tyvak who is considering using this computer in future missions. Tyvak designs, builds and provides Nano-Satellite and CubeSat space vehicle products and services that target advanced state-of-the-art capabilities for government and commercial customers.

More information:
https://flightopportunities.nasa.gov/technologies/88

▷ *October 23, 2014: Brock LeMeres (PI, right) and Sam Harkness (graduate student) from Montana State University hold up the recovered RadSat test bed after a successful ride to suborbital space aboard SpaceLoft 9. In the background, Jerry Larson (second from right) and his son Erik Larson (UP Aerospace launch coordinator). (Photo: UP Aerospace)*

▷ *March 26, 2015: Masten Space Systems team (from left to right): Joey Oberholtzer, Jake Teufert, Tyler Roberson, Ellen Moyer, Nathan O'Konek, Ben Dagang, Reuben Garcia, Kyle Nyberg, David Masten, Luke Farrell, Jeff Gibson, Wyatt Rehder, Travis O'Neal, Kellie Gerardi, Erik Franks, Jonathan Powers, Scott Nyberg, Sean Mahoney. (Photo: NASA/Tom Tschida)*

Masten Space Systems conducted three Program-sponsored flight campaigns in FY2015: closed loop testing of real-time terrain relative navigation together with fuel optimal large divert guidance for NASA/JPL (T0137, a continuation from earlier flight tests in 2013 under T0068), a student team from Carnegie Mellon University testing novel sensors to detect and map lunar caves (T0121), and a first for Masten, a night flight to investigate the viability of the Xaero platform as a starshade testbed (T0092).

Masten Space Systems grew out of the 2009 Lunar Lander Challenge organized by NASA's Centennial Challenges Program (one of the three programs in the Commercial Partnerships Portfolio). Starting with its first Program-sponsored flight in 2011, the company has successfully provided valuable low altitude landing tests for six technology payloads in the Program pool, with a total of 14 payload-flights.

The maturation of Masten's core RLV and VTVL precision landing capabilities have paved the way for Masten to develop applications in adjacent market segments. In August 2015, the company was awarded follow-up funding (Phase 1B) as part of DARPA's "XS-1" reusable spaceplane program (alongside competing prime contractors Boeing and Northrop Grumman). Separately, Masten was competitively selected as a commercial partner under NASA's Lunar Cargo Transportation and Landing by Soft Touchdown (Lunar CATALYST) initiative.

“This represents a huge step forward in our future capabilities for safe and precise Mars landing, and demonstrates a highly effective approach for rapid, low-cost validation of new technologies for the entry, descent and landing of spacecraft. This same technology has valuable applications to landing on the moon, asteroids and other space targets of interest.”

Chad Edwards, chief technologist of the Mars Exploration Directorate at JPL

Xombie-06

T0137 Fuel Optimal and Accurate Landing System Test Flights

PI: Andrew Johnson, NASA/Jet Propulsion Laboratory

It's tricky to get a spacecraft to land exactly where you want. That's why the area where the Mars rover Curiosity team had targeted to land was an ellipse that may seem large, measuring 12 miles by 4 miles (20 by 7 kilometers).

Engineers at NASA's Jet Propulsion Laboratory in Pasadena, California, have been developing cutting-edge technologies that would enable spacecraft to land at a specific location on Mars -- or any other planetary body -- with more precision than ever before. In collaboration with Masten Space Systems in Mojave, California, they have tested these technologies onboard a high-tech demonstration vehicle called the Autonomous Descent and Ascent Powered-flight Testbed (ADAPT). ADAPT is a test system built on Masten's XA-0.1B "Xombie" Vertical Take-Off and Landing (VTOL) reusable rocket. The Xombie platform provides a good approximation of Mars-like descent conditions through high-speed descent rates at low altitudes, conditions that are difficult to achieve through conventional flight test platforms.

Onboard this rocket, two sophisticated lander technologies were tested during the Xombie-06 campaign (December 2014): Terrain Relative Navigation with a sensor called the Lander Vision System (LVS), and the Guidance for Fuel-Optimal Large Diverts (G-FOLD) algorithm. ADAPT had two successful test flights, one on December 4, 2014, and the second on December 9. In both cases, the rocket reached a maximum altitude of 1,066 feet (325 meters) before beginning its descent.

◁ *December 9, 2014: the Xombie rocket carrying the ADAPT system reached a maximum altitude of 1,066 feet (325 meters) before beginning its descent. (Photo: NASA/Tom Tschida)*

The terrain-relative navigation capability provided by LVS allows Xombie to precisely determine its position without requiring GPS. To do so, ADAPT first takes a series of pictures of the terrain below it during descent. These pictures are then compared to an image of the terrain stored onboard, allowing the vehicle to autonomously find its position relative to the landing site. The spacecraft can then use this information to correct its course to get as close to the targeted landing site as possible within its capability, and make a smooth, pinpoint landing.

G-FOLD is an algorithm, developed at JPL and at the University of Texas at Austin, that calculates the optimal path to divert a spacecraft to a target landing site in real time. G-FOLD was earlier tested onboard Xombie in March of 2013 (T0068). It allows onboard calculation of divert trajectories that obtain the maximum performance from every kilogram of propellant.

The combination of LVS and G-FOLD allowed the Xombie rocket to begin to change the course of its descent at about 623 feet (190 meters) in the air on December 9. The rocket then flew the newly calculated course to successfully reach the target landing pad located 984 feet (300 meters) to the east.

More information:
https://flightopportunities.nasa.gov/technologies/137

Article adapted from: http://www.jpl.nasa.gov/news/news.php?feature=4514

JPL, a division of the California Institute of Technology, Pasadena, manages the ADAPT project and funded the ADAPT payload development. The LVS prototype was designed, developed and tested by the Mars Technology Development program of NASA's Science Mission Directorate.

March 26, 2015: Masten ground crew, interns Ellen Moyer and Wyatt Rehder, prepare Xombie for flight of the CMU students' sensor package. (Photo: NASA/Tom Tschida)

Xombie-07

T0121 Flyover Mapping and Modeling of Terrain Features

PI: William ‘Red’ Whittaker, Carnegie Mellon University

Carnegie Mellon University (CMU) students developed a sensor package to analyze large pits in the surface of the moon or Mars that could lead to openings of caves. The package was launched recently on Masten Space Systems’ XA-0.1B Xombie suborbital technology demonstration rocket during a NASA-sponsored launch and landing at the Mojave Air and Space Port in Mojave, California.

The computer vision technology sensor package was mounted on top of Masten’s vertical-takeoff, vertical-landing rocket, named Xombie. The rocket ascended to about 111 meters or nearly 365 feet, traversed over a simulated hexagon pit then returned to its pad. The total flight time was 64 seconds.

“We are working with Carnegie Mellon students who are developing a technology to build maps and 3-D models of the features of the moon,” said Nathan O’Konek, Masten’s director of business operations. “Our lander test vehicles are able to simulate landing trajectories that a lander on the moon would actually follow; we descend at rates similar to what a lunar lander would follow at low altitudes. We fly their instrument and they take imagery of the terrain that validates that the instruments are going to be able to do the same thing on the moon.”

The sensor package is planned for a robotic lunar mission to explore a pit on the moon’s surface for a first close look at its geometry, geology, and origin to determine whether the pit is an entrance to a cave. These openings are thought to be lava tubes that possibly explain the moon’s volcanic past. The pits also hold potential for future explorers providing shelter from the extreme temperatures, meteorites and radiation on the moon.

“Fictional speculation of lunar pits and caves goes back more than a century,” said Red Whittaker, CMU professor and mentor. “The first three pits ever identified were images taken by the Japanese Kaguya spacecraft (launched in 2007). “Evidence that these pits could be lunar lava tubes was first recognized during the Apollo era.”

Whittaker added, “Although the potential to use caves for human protection was enticing, there was no known way of getting into the caves, or lava tubes. The LRO (NASA’s Lunar Reconnaissance Orbiter) spacecraft further provided some evidence that certain pits exhibited caverns or overhanging walls that might be an access into the lava tubes.”

Once the spacecraft arrives at the moon, it will fly over the pit using the computer vision sensor package to create a 3-D map of the depression. After the fly over, the craft would land and travel to the pit for further investigation by the CMU-developed robot named Andy.

More information:
https://flightopportunities.nasa.gov/technologies/121

Article adapted from http://www.nasa.gov/centers/armstrong/Features/xombie_sensor_package.html

NASA’s Undergraduate Student Instrument Project (USIP) funded the CMU instrumentation package development. USIP is an educational flight opportunity of the agency’s Science Mission Directorate, which helps universities develop and fly science payloads to be flown on suborbital vehicles. Flight Opportunities funded the flight of the CMU sensors to fly on Masten Space Systems’ Xombie rocket.

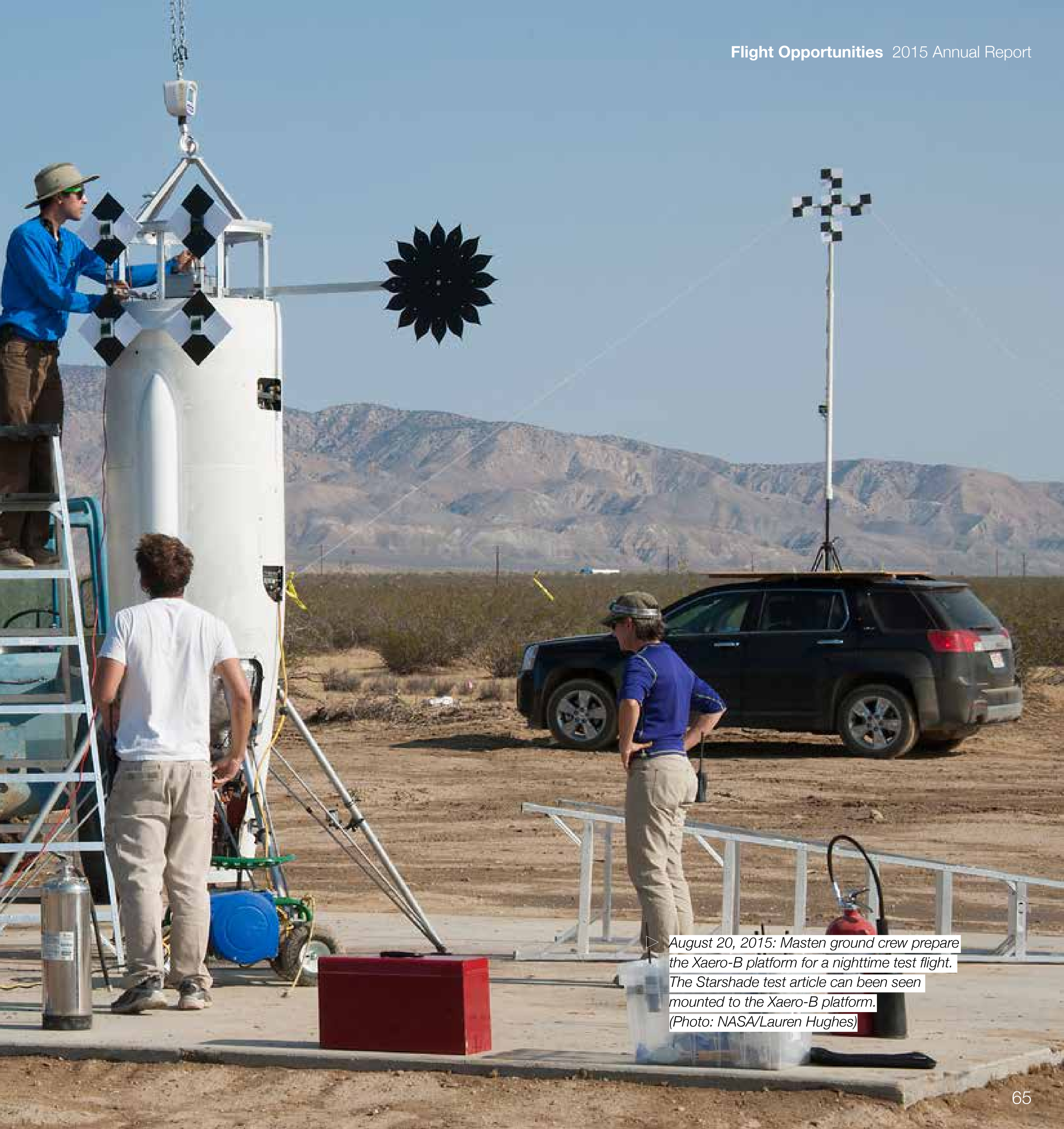
Xaero-01

T0092 Precision Formation Flying Sensor

PI: Webster Cash, University of Colorado
Co-I: Tiffany Glassman, Anthony Harness, Nathan Parrish, Ann Shipley, University of Colorado

The test objectives for this flight campaign were to investigate the viability of a vertical takeoff vertical landing (VTVL) rocket as a starshade platform and to test a vision based formation flying system that provides visual feedback to help position the vehicle in the line of sight to a background object. The vehicle performed exceptionally well and was able to maintain a stable hover for 20 seconds within a 15 cm cube, even in a 20 mph crosswind with a 60 cm starshade mounted to the vehicle.

More information: https://flightopportunities.nasa.gov/technologies/92



August 20, 2015: Masten ground crew prepare the Xaero-B platform for a nighttime test flight. The Starshade test article can been seen mounted to the Xaero-B platform. (Photo: NASA/Lauren Hughes)

"I was very satisfied with the payload integration effort and overall flight performance provided by World View. The World View team was very professional and accommodating to the payload provider needs."

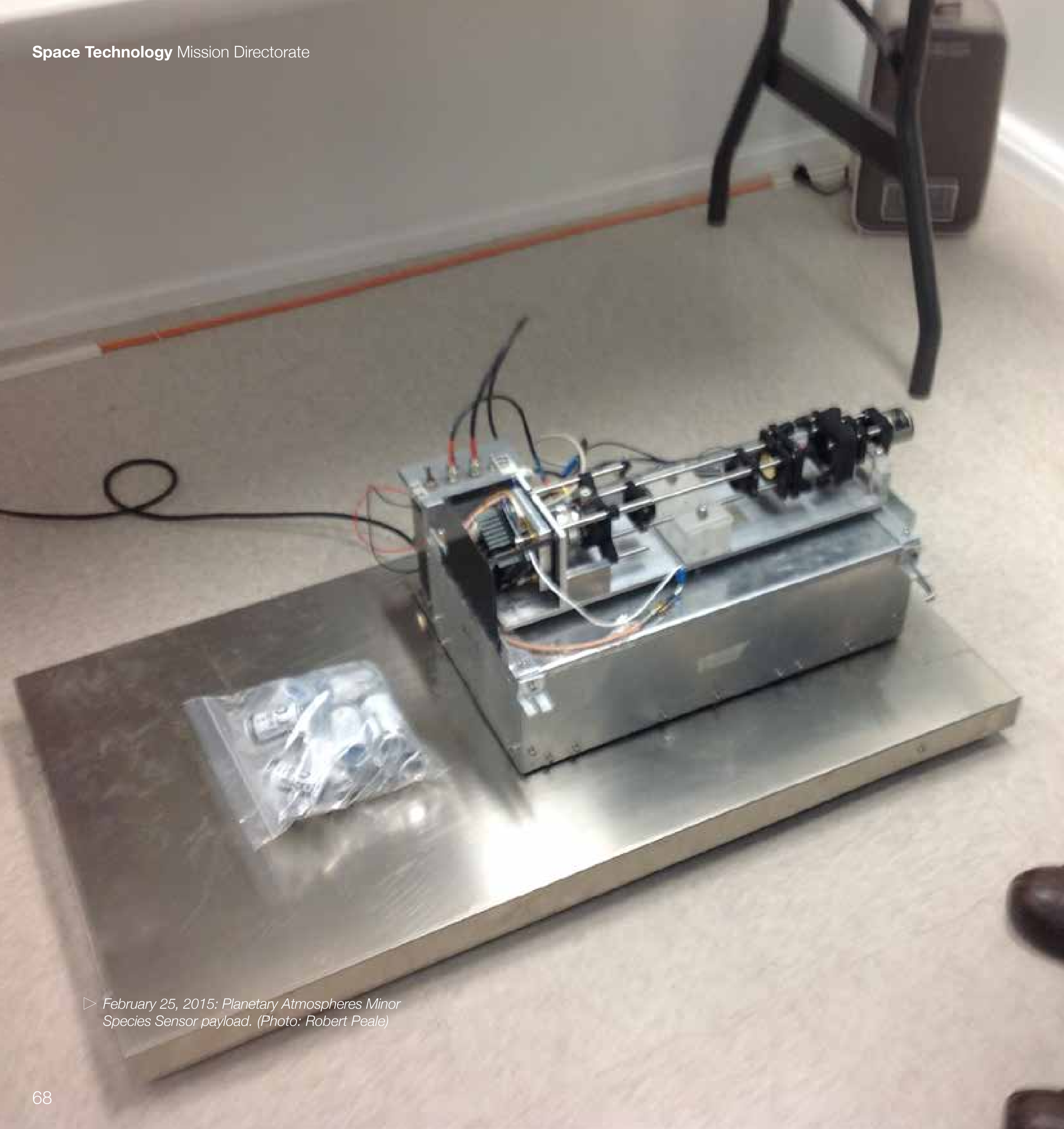
Paul De Leon
NASA/FO Campaign Manager

▷ *March 8, 2015: Balloon launch preparations at Pinal Airpark, Arizona. (Photo: World View)*

WORLD VIEW

NASA's newest American commercial near-space services provider, World View of Tucson, Arizona, successfully launched its first Program-sponsored Tycho balloon from Arizona's Pinal Airfield on March 8, 2015. The flight is another example of NASA partnering with U.S. businesses to procure and demonstrate viable commercial services to near-space that advance our nation's emerging space markets and space technology capabilities while also supporting agency mission needs.

The World View Tycho balloon reached an altitude of 105,000 feet (32 km) and loitered above 98,425 feet for nearly an hour and 45 minutes to test University of Central Florida's (UCF) Planetary Atmospheres Minor Species Sensor (T0097) and Gannon University (GU) Cosmic-Ray Calorimeter (T0124).



▷ *February 25, 2015: Planetary Atmospheres Minor Species Sensor payload. (Photo: Robert Peale)*

T20-01

T0097 Planetary Atmospheres Minor Species Sensor

PI: Robert Peale, University of Central Florida

The Planetary Atmospheres Minor Species Sensor (PAMSS) is an intracavity laser absorption spectrometer that uses an infrared quantum cascade laser (QCL) to detect trace gases. Trace gases can have a large impact on chemical reactions that control larger abundances of important atmospheric gases, such as pollutants and greenhouse gases. Trace gases can also indicate for geologic and biologic activities. Knowledge of the presence, concentration, and spatial distribution is important on other planets as well as on Earth. A problem is that current methods of high sensitivity trace gases must interrogate over a range of altitudes and areas to obtain sufficient signal, and they are unable to quantify local concentrations and rapid spatial variations.

Enter PAMSS

In PAMMS, atmospheric samples enter the open external laser cavity, where laser gain allows optical path length through the sample to exceed a kilometer due to multiple reflections between cavity mirrors that are separated by centimeters. This potentially gives exponentially higher sensitivity for detection of ultra-trace gases. Planetary science applications include detection of life on Mars, greenhouse chemistry on Venus, and compositional analysis for exotic atmospheres on Saturn's moon Titan. Earth science applications include the detection and analysis of climate changing gases, ozone, acid rain, and air pollution. Terrestrial applications include medical breath tests to diagnose disease and explosives detection for public safety.

Maturing the technology through flight testing

By sending the experimental sensor, which is the size of a toaster oven, into the stratosphere (about 20 miles above the Earth), the team obtained data on system performance. This will inform future design improvements, so that PAMSS may survive and function in harsh extraterrestrial environments of extreme cold and low pressures. The sensor is designed to detect trace gases at parts per trillion levels, and it has the potential to be far more sensitive than, for example, the spectral sensors used currently on Mars, where the sensitivity is barely sufficient for the detection of methane, a bio-indicator gas.

A key performance criterion for the instrument is the maintenance of optical alignment, as indicated by a laser voltage error signal. After passing through the open section of the laser cavity, the beam must pass through the QCL's active region, whose dimension is only 10 micrometers. Misalignment can be caused by accelerations experienced during handling and launch or by extreme temperature changes. Initial analysis of the laser error signal shows that alignment was affected by the large drops in temperature, but it returned nearly to its initial optimal value when the temperature returned to room temperature. Artifacts in the obtained spectra as a result of gusting cold winds that changed the detector baseline were also observed. Both of these issues can be remediated by suitable design changes.

Continued on next page...

The fact that PAMSS collected data in the relevant environment establishes it at TRL6. The initial instrument was a table top laboratory prototype, operating with general purpose power supplies, computer, oscilloscope, and liquid-nitrogen cooled detector, all operating off wall-plug power. The final instrument that flew was completely self-contained, comprising a fully enclosed and shielded electronics unit, with dimension 46 cm x 23 cm x 15 cm, and a laser/optics unit with dimension 46 cm x 10 cm x 8 cm. The two subunits were mated and communicated via shielded cables. The entire system operated off Lithium batteries with a lifetime of eight hours, and the total mass was 11 kg. Lessons learned will inform future design improvements that will enable PAMSS to demonstrate the same high level of sensitivity as documented in the lab.

More information:
https://flightopportunities.nasa.gov/technologies/97

Funding for the development of PAMSS came from the Center for Microgravity Research and Education – a joint venture of UCF and Space Florida – and the Florida Space Institute, which is managed by UCF and located in Central Florida Research Park, adjacent to the university.

▷ *March 2, 2015 (from right to left): Rolfe Bode, Robert Peale (PI), and Chris Fredricksen prepare the payload incorporating the PAMSS unit for launch on the World View balloon. (Photo: NASA/Paul de Leon)*

▷ *March 2, 2015: Gannon University students prepare the GU-CRC payload for flight at the World View payload integration facilities. Students shown are (left to right): Codi Wasser, Leslie Moukoro, Brandon Lawrence and Ryan Mong. (Photo: NASA/Paul de Leon)*

"Over the past two years, it has been a pleasure and a privilege to work with the twenty undergraduate students who have participated on this project and see them grow as individuals and as a team. If the students have learned half as much as I have along the way, this has been time very well spent."
-- Dr. Nicholas Conklin

T20-01

T0124 Gannon University's Cosmic-Ray Calorimeter (GU-CRC)

PI: Nicholas Conklin, Gannon University

The main objective for the Cosmic-Ray Calorimeter experiment was to excite undergraduate students about space science by giving them an opportunity to design, construct, and test a science payload while familiarizing students with the research process, including time management, documenting activities, and external reviews. When students are given the responsibility of starting a project from the ground up, it provides appreciation for all the effort required. Students learn how to work with others of different disciplines, gain knowledge from each other, develop lab skills, and teach one another. These skills cannot be taught in class, only learned by the successful completion of a project such as this one.

The scientific goal of the Cosmic-Ray Calorimeter payload was to collect charge and energy data of incident cosmic rays within the energy range of 1-100 GeV using a high-altitude balloon platform. During the flight, all payload subsystems performed as expected, and the temperature of the payload remained well within design specifications. On the day of the flight, over 100,000 cosmic-ray events were collected and recorded to the onboard SD card. Agreement between previous measurements and data from this flight demonstrated the suitability of a new technology, silicon photomultipliers (SiPMs), for use in scientific-ballooning payloads.

More information:
https://flightopportunities.nasa.gov/technologies/124

Article adapted from
http://www.nasa.gov/centers/armstrong/Features/world_view_balloon.html

NASA's Undergraduate Student Instrument Project (USIP) funded the Gannon University instrumentation package development. USIP is an educational flight opportunity of the agency's Science Mission Directorate, which helps universities develop and fly science payloads to be flown on suborbital vehicles. Flight Opportunities funded the flight of the Gannon University sensor to fly on World View's Tycho balloon.

▷ *June 21, 2015: Tim Lachenmeier (CEO of Near Space Corporation) shows Paul de Leon (standing, FO Campaign Manager) the expected ground track of the balloon carrying payload T0141. (Photo: Near Space Corporation)*

Near Space Corporation (NSC) completed three Program-sponsored balloon flights in 2015: one high altitude drop test of a prototype Earth-return capsule for Terminal Velocity Aerospace (T0141), and two high altitude drop tests of a novel guided parafoil for Airborne Systems (T0066). Additional balloon flights were scheduled throughout the year but had to be postponed due to unforeseen weather conditions in the Pacific Northwest (NSC's operating base).

Including the three flights of 2015, NSC has successfully completed ten balloon flights for the Program, testing nine unique technologies over the course of 12 payload-flights.

June 21, 2015: NASA's Flight Opportunities program funded the flight test for the new type of orbital entry return capsule aboard Near Space Corporation's (NSC) high-altitude balloon. (Photo: Near Space Corporation)

SBS-12

T0141 Demonstration of Enabling Communications Technologies for Future Low-Cost Small Earth Return Vehicles

PI: Dominic DePasquale, Terminal Velocity Aerospace, LLC

A prototype capsule that one day will return science experiments to Earth was tested by releasing it from a high-altitude balloon in Tillamook, Oregon. Technology like this capsule could one day return biological samples and other small payloads from space in a relatively short time.

NSC personnel launched the balloon to an altitude of about 101,400 feet (31 km) on June 21, 2015. The capsule, developed by Terminal Velocity Aerospace (TVA) of Atlanta, Georgia, then was released and descended at a velocity similar to what it would experience during an actual entry from space. The flight of the capsule demonstrated mission-enabling technologies including low-cost communications and electronics systems, along with a stem cell sample return experiment provided by Dr. Abba Zubair of the Mayo Clinic in collaboration with the Center for Applied Space Technology (CAST-ARMM) and Morehead State University.

“This launch is critical to ensuring that we have fast, safe, reliable and affordable ways to return important science back to Earth,” said Paul De Leon, a campaign manager for the program from NASA’s Ames Research Center in Moffett Field, California. “Small entry capsules like Terminal Velocity’s will allow scientific samples from the International Space Station, or more distant destinations like an asteroid, to return to Earth more regularly, which will provide researchers the samples quicker.”

While there was an anomaly with the TVA capsule parachute deployment, the capsule electronics, data loggers, and experimental payload were successfully recovered in good condition.

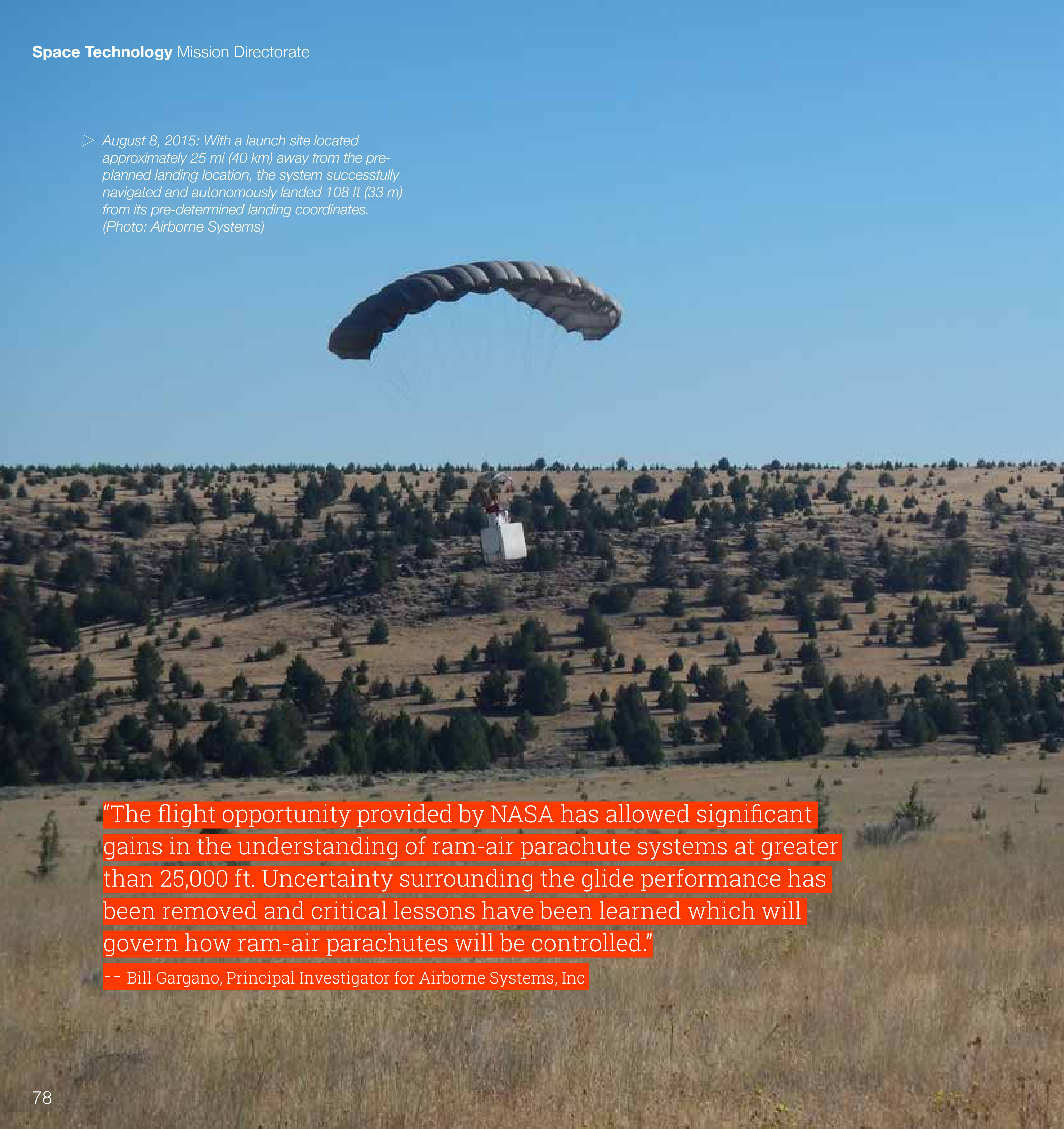
The flight data provided the first validation of the Automatic Dependent Surveillance-Broadcast (ADS-B) tracking technology in the descent profile of an Earth reentry vehicle. For this test, TVA partnered with Embry-Riddle Aeronautical University for customization of a space-capable ADS-B unit. Additional support was provided by the FAA Office of Commercial Space Transportation.

The test also confirmed the ability to transmit through a NASA Ames-developed thermal protection material that is transparent to radio frequencies. TVA plans to use two different Ames-developed materials to protect future operational capsules from the extreme heat generated during reentry.

“We are pleased with the outcome of this test and grateful to NASA for supporting the flight opportunity,” said Dominic DePasquale, who served as Principal Investigator of the project for TVA. “The results are a testament to the hard work of our engineering team and partners, and they are a major step toward an affordable orbital shipping service that will greatly enhance utilization of space for medicine, materials and other applications.”

More information:
https://flightopportunities.nasa.gov/technologies/141

Article adapted from http://www.nasa.gov/centers/armstrong/features/nsc_prototype_capsule_tested.html



August 8, 2015: With a launch site located approximately 25 mi (40 km) away from the pre-planned landing location, the system successfully navigated and autonomously landed 108 ft (33 m) from its pre-determined landing coordinates. (Photo: Airborne Systems)

"The flight opportunity provided by NASA has allowed significant gains in the understanding of ram-air parachute systems at greater than 25,000 ft. Uncertainty surrounding the glide performance has been removed and critical lessons have been learned which will govern how ram-air parachutes will be controlled."

-- Bill Gargano, Principal Investigator for Airborne Systems, Inc

SBS-04

T0066 Guided Parafoil High Altitude Research

PI: Bill Gargano, Airborne Systems North America of CA, Inc.

The Guided Parafoil High Altitude Research (GPHAR) program is an on-going effort to extend and mature the capabilities of parafoil system technology for space recovery or near space recovery applications above 25,000 ft (7.6 km). The current state of the art for ram-air parachute systems enables deployments in the 20,000 ft (6 km) range enabling up to 80,000 ft (24 km) of crossrange. This technology will extend deployments up to 50,000 ft (15 km) and beyond, thereby nearly tripling the crossrange capability*.

Parachute systems for space applications

Airborne Systems provides parachute recovery systems for a wide range of space applications and is currently providing the recovery system for the NASA Orion space capsule and several commercial space companies. There is a growing desire for recovery systems that provide extended crossrange capability and are steerable to enable precision landing of payloads. The expansion of the controllable flight envelope of these parachutes would provide a game changing capability for a broad range of applications including not just traditional space recovery, but future NASA interplanetary space missions and in-air space vehicle recovery.

Maturing the technology through flight testing

There are three subject technologies to be advanced in this project: the ram-air parachute, the airborne guidance unit and associated parachute guidance and control algorithms.

** Most modern parachutes are self-inflating "ram-air" airfoils known as a parafoil that provide control of speed and direction similar to paragliders.*

A total of three high altitude test flights were conducted with Near Space Corporation. On June 6, 2014, the first flight test (SBS-02) was successfully launched to an altitude of 57,122 ft (17.4 km) from Tillamook, Oregon and realized the first program objective: demonstration of low density/high velocity deployment and performance of a guided ram-air parachute at altitudes beyond the current state of the art. Two additional flights were conducted on August 6 and August 8, 2015, from Madras, Oregon. Following their releases at 60,706 ft (18.5 km) and 60,964 ft (18.6 km), the systems successfully navigated and autonomously landed just 230 ft (70 m) and 108 ft (33 m) from their pre-determined landing coordinates, respectively. The launch sites were located approximately 50 mi (80 km) and 25 mi (40 km) away from the pre-planned landing locations. Building on the lessons learned from the first flight, important advancements to key challenges of parafoil flight in low density atmosphere were achieved, namely a more challenging dynamic deployment and the autonomous flight and control of the parafoil.

These flight opportunities provided by NASA have allowed significant gains in the understanding of parafoil parachute systems at greater than 25,000 ft. The resultant data and learning experienced in this test program will be beneficial to NASA, commercial space companies, and the military.

More information:
https://flightopportunities.nasa.gov/technologies/66

Airborne Systems currently provides the recovery systems for NASA's Orion, SpaceX Dragon, Boeing CST-100, and Blue Origin capsules.

June 6, 2014: A view of the canopy in flight making an intentional right turn during the first drop test of the guided parafoil. (Photo: Airborne Systems)

▷ *July 25, 2014: NASA/JSC Reduced Gravity Office (RGO) members in front of the NASA/C9 'Weightless Wonder VI' (from left to right): William Tarver (doctor), Dominique Del Rosso (RGO lead), Michael Giles (pilot), Terry Lee (RGO deputy lead), Kevin Krolczyk (assistant test director), Raymond Heineman (pilot) and Alyson Hickey (flight engineer). (Photo: NASA/James Blair)*

Due to the unavailability of a commercial parabolic flight provider, NASA's Reduced Gravity Office (RGO) continued service of the NASA/C9 aircraft throughout FY2015 to continue parabolic flight testing for Flight Opportunities and other NASA customers. With an eye on the scheduled decommissioning of the NASA/C9 at the end of CY2015, the Program made an effort to facilitate flight testing for all flight-ready parabolic payloads in the pool. A total of 16 technology payloads were tested.

Including two parabolic flight weeks late FY2014, the NASA/C9 aircraft has flown seven flight weeks enabling 36 payload-flights for 30 unique technology payloads*. In comparison, Zero Gravity Corporation to date has flown 15 campaigns over the course of 2011-2014, realizing 81 payload flights for 51 unique technologies.

NASA also flew two NASA 'directed' payloads on a Terrier-Black Brant sounding rocket from Wallops Flight Facility in Virginia.

**parabolic flight weeks are counted as 1 flight*

June 10, 2015: Robert Reid (left) and Issa Nesnas (PI) prepare the hedgehog experiment in between two parabolas. (Photo: NASA/James Blair)

RGO-17

T0126 Validating Microgravity Mobility Models for Hopping/Tumbling Robots

PI: Issa Nesnas, NASA/Jet Propulsion Laboratory

Hopping, tumbling and flipping over are not typical maneuvers you would expect from a spacecraft exploring other worlds. Traditional Mars rovers, for example, roll around on wheels, and they can't operate upside-down. But on a small body, such as an asteroid or a comet, the low-gravity conditions and rough surfaces make traditional driving all the more hazardous.

Enter Hedgehog: a new concept for a robot that is specifically designed to overcome the challenges of traversing small bodies. The project is being jointly developed by researchers at NASA's Jet Propulsion Laboratory in Pasadena, California; Stanford University in Stanford, California; and the Massachusetts Institute of Technology in Cambridge.

The basic concept is a cube with spikes that moves by spinning and braking internal flywheels. The spikes protect the robot's body from the terrain and act as feet while hopping and tumbling.

Two Hedgehog prototypes -- one from Stanford and one from JPL -- were tested aboard NASA's C9 aircraft for microgravity research in June 2015. During 180 parabolas, over the course of four flights, these robots demonstrated several types of maneuvers that would be useful for getting around on small bodies with reduced gravity. Researchers tested these maneuvers on different materials that mimic a wide range of surfaces: sandy, rough and rocky, slippery and icy, and soft and crumbly.

"We demonstrated for the first time our Hedgehog prototypes performing controlled hopping and tumbling in comet-like environments," said Robert Reid, lead engineer on the project at JPL.

Hedgehog's simplest maneuver is a "yaw," or a turn in place. After pointing itself in the right direction, Hedgehog can either hop long distances using one or two spikes or tumble short distances by rotating from one face to another. Hedgehog typically takes large hops toward a target of interest, followed by smaller tumbles as it gets closer.

During one of the experiments on the parabolic flights, the researchers confirmed that Hedgehog can also perform a "tornado" maneuver, in which the robot aggressively spins to launch itself from the surface. This maneuver could be used to escape from a sandy sinkhole or other situations in which the robot would otherwise be stuck.

The JPL Hedgehog prototype has eight spikes and three flywheels. It weighs about 11 pounds (5 kilograms) by itself, but the researchers envision that it could weigh more than 20 pounds (9 kilograms) with instruments such as cameras and spectrometers. The Stanford prototype is slightly smaller and lighter, and it has shorter spikes.

Both prototypes maneuver by spinning and stopping three internal flywheels using motors and brakes. The braking mechanisms differ between the two proto-

Continued on next page...

types. JPL's version uses disc brakes, and Stanford's prototype uses friction belts to stop the flywheels abruptly.

"By controlling how you brake the flywheels, you can adjust Hedgehog's hopping angle. The idea was to test the two braking systems and understand their advantages and disadvantages," said Marco Pavone, leader of the Stanford team, who originally proposed Hedgehog with Nesnas in 2011.

"The geometry of the Hedgehog spikes has a great influence on its hopping trajectory. We have experimented with several spike configurations and found that a cube shape provides the best hopping performance. The cube structure is also easier to manufacture and package within a spacecraft," said Benjamin Hockman, lead engineer on the project at Stanford.

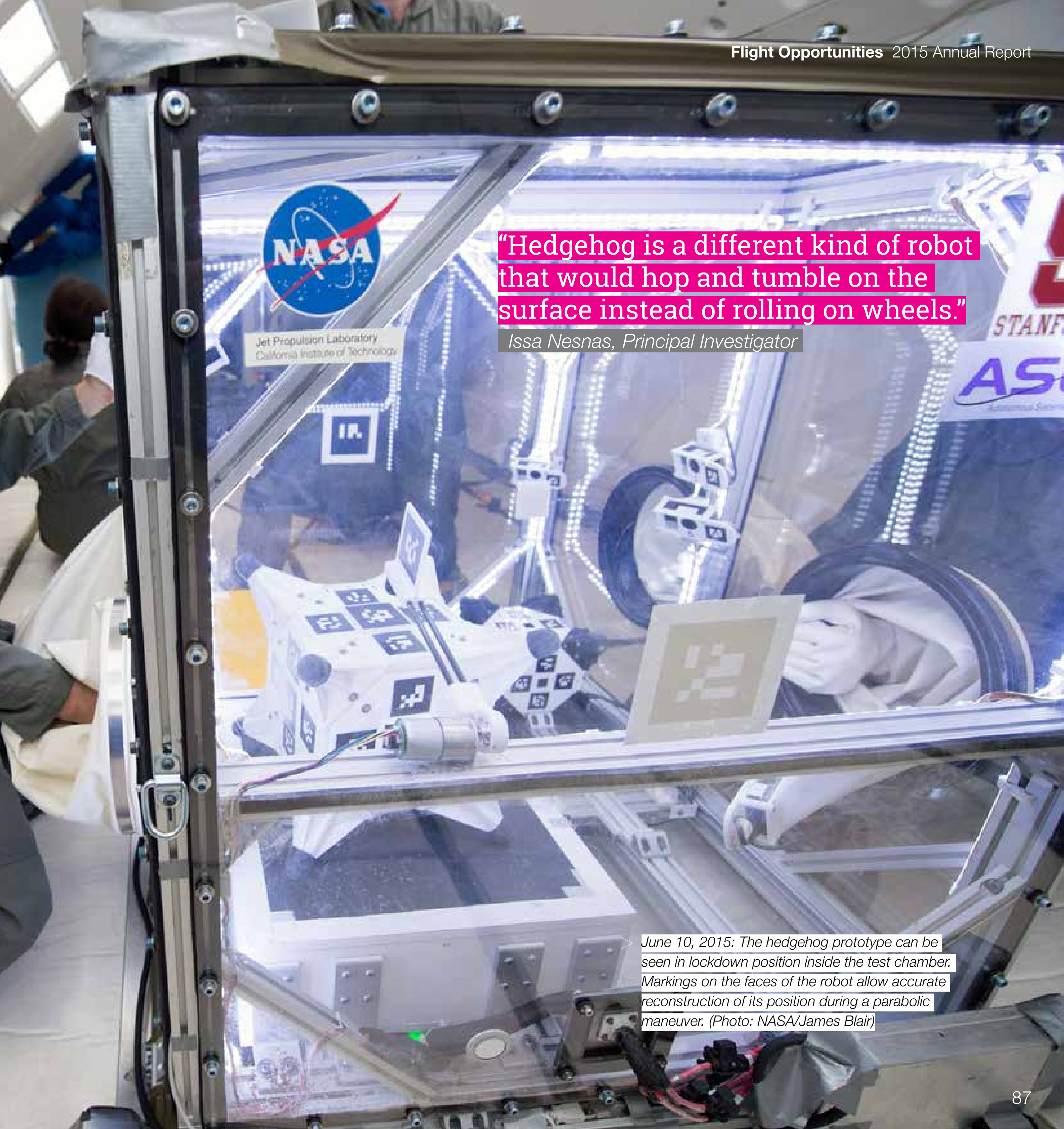
The researchers are currently working on Hedgehog's autonomy, trying to increase how much the robots can do by themselves without instructions from Earth. Their idea is that an orbiting mothership would relay signals to and from the robot, similar to how NASA's Mars rovers Curiosity and Opportunity communicate via satellites orbiting Mars. The mothership would also help the robots navigate and determine their positions.

The construction of a Hedgehog robot is relatively low-cost compared to a traditional rover, and several could be packaged together for flight, the researchers say. The mothership could release many robots at once or in stages, letting them spread out to make discoveries on a world never traversed before.

More information:
https://flightopportunities.nasa.gov/technologies/126

Article adapted from http://www.jpl.nasa.gov/news/news.php?feature=4712

Hedgehog is currently in Phase II development through the NASA Innovative Advanced Concepts (NIAC) Program, and is led by Pavone. The flight development and testing were supported by NASA's Center Innovation Fund (CIF) and NASA's Flight Opportunities Program (FO), which were led by Nesnas. NIAC, CIF and FOP are programs in NASA's Space Technology Mission Directorate, located at the agency's headquarters in Washington. JPL is managed by the California Institute of Technology for NASA. Stanford University, MIT and JPL collaborate on the project.



“Hedgehog is a different kind of robot that would hop and tumble on the surface instead of rolling on wheels.”

Issa Nesnas, Principal Investigator

June 10, 2015: The hedgehog prototype can be seen in lockdown position inside the test chamber. Markings on the faces of the robot allow accurate reconstruction of its position during a parabolic maneuver. (Photo: NASA/James Blair)

▷ *June 25, 2015: The device's rowing mode allows for high cadence aerobic activity. (Photo: NASA/Robert Markowitz)*

RGO-18

T0057 Hybrid Ultimate Lifting Kit (HULK) Device Demonstration during Parabolic Flight

PI: Justin Funk, ZIN Technologies
Co-I: Gail Perusek, NASA/Glenn Research Center

Long-duration space flight poses many hazards to the health of the crew. Among those hazards is the physiological deconditioning of the musculoskeletal and cardiovascular systems due to prolonged exposure to microgravity. To combat this erosion of physical condition space flight may take on the crew, NASA's Human Research Program (HRP) is charged with developing Advanced Exercise Concepts to maintain astronaut health and fitness during long-term missions, while keeping device mass, power, and volume to a minimum.

The HULK is a pneumatic-based exercise system, which provides both resistive and aerobic modes to protect against human deconditioning in microgravity. Its design targeted the ISS Advanced Resistive Exercise Device (ARED) high level performance characteristics. The HULK parabolic flight campaign, conducted through the NASA Flight Opportunities program at Ellington Field, resulted in the creation of device-specific data sets including low fidelity motion capture, accelerometry and both inline and ground reaction forces. These data provide a critical link in understanding how to vibration-isolate the device in both ISS and space transit applications. Secondarily, the study of human exercise and associated body kinematics in microgravity allows for more complete understanding of human to machine interface designs to allow for maximum functionality of the device in microgravity.

More information:
https://flightopportunities.nasa.gov/technologies/57

This research is funded by NASA's Human Research Program (HRP). The HRP is an applied research and technology program that investigates and mitigates risks to astronaut health and performance in support of exploration missions and provides countermeasures and technologies for human space exploration.

July 24, 2015: Zarana Patel (PI) monitors the test onboard the NASA/C9 aircraft. The cell culture chambers can be observed inside the payload rack. (Photo: NASA/Lauren Harnett)

RGO-19

T0027 Autonomous Cell Culture Apparatus for Growing 3-Dimensional Tissues in Microgravity

PI: Zarana Patel, NASA/Johnson Space Center

The objective of this project is to develop, test, and verify the functionality of a fully automated cell culture apparatus that will allow for the growth of three-dimensional (3-D) cultures in microgravity. These 3-D cell cultures can be used to accurately model fully differentiated normal human tissue for the study of the effects of radiation and other non-radiation space environment stressors on multiple biological processes. Additionally, the 3-D organotypic cultures can provide a realistic model for the evaluation of countermeasures such as drug delivery. The long-term objective of this work is to develop an automated cell culture apparatus that can be used to efficiently study the growth of 3-D cell cultures aboard the ISS.

The purpose of our flight campaigns in May 2012 and July 2015 was to test our bioreactor in a microgravity environment. We demonstrated for the first time ever that these 3-D tissue models can be utilized for microgravity research, due to the very successful testing of our automated bioreactor on the C9 parabolic aircraft. Current work focuses on the scale-up of the hardware so that enough biological samples can be cultured in order to successfully conduct a life sciences experiment on the ISS. The opportunity through Flight Opportuntiies to test our 3-D cell culture equipment on a microgravity platform was invaluable for its technology maturation.

More information:
https://flightopportunities.nasa.gov/technologies/27

This research is funded by NASA's Space Biology Program. The Space Biology Program funds and performs biological research and technology development necessary to enable NASA's long-term human exploration mission and also benefit life on Earth.

▷ *August 27, 2015: The full team involved in the flight tests for T0132 pose in front of the NASA/C9 aircraft at Ellington Field, TX. (Photo: NASA/Bill Stafford)*

RGO-20

T0132 Effects of Microgravity on Intracranial Pressure

PI: Benjamin Levine, University of Texas Southwestern Medical Center

Some long duration astronauts have had diminished visual acuity (eye sight) during and after long duration spaceflight. Serious visual impairment is not only problematic for an individual astronaut, but may be mission threatening for a long-duration crew. The mechanism(s) causing this problem remains largely unknown. The current working model is that intracranial pressure, which includes pressure behind the eye, leads to compression of the eye and its nerves. Additional factors may further increase intracranial pressure and exacerbate visual symptoms including small increases in the partial pressure of carbon dioxide in the ISS atmosphere and resistive exercise training.

The critical assumption of the above hypothesis is that microgravity causes elevated intracranial pressure. The only way to confirm this theory with confidence is to make direct, invasive measurements of intracranial pressure during and throughout the elimination of gravity. Therefore, the primary objective of this project was to directly measure intracranial and central venous pressure, alongside cerebral hemodynamics, and the visual apparatus during periods of real microgravity onboard parabolic flight. To achieve these objectives, a test configuration was developed that allowed continuous invasive monitoring alongside high-resolution ultrasound in human subjects during multiple parabolas. The configuration also allowed the human test subjects to transiently breathe additional carbon dioxide and perform leg press exercise as found onboard the ISS.

The main finding from the series of parabolic flights in August 2014 and August 2015 was that in all subjects, intracranial

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pressure actually fell below that observed in the supine posture during microgravity. This pattern of falling intracranial pressure in microgravity was observed during every parabola, in all subjects. Central venous pressure also fell during each parabola, which confirms previous observations onboard the Space Shuttle (SLS-1, SLS-2, D-2) and during parabolic flight. Together these data provide convincing evidence that the removal of gravity, specifically in the Gx direction, has a dramatic effect on central venous and intracranial pressure. Importantly this “gravitational unloading”, outweighs any cephalad fluid shifts, as the ultimate response was a reduction in intracranial pressure compared to the supine position (though elevated compared to upright).

The ultimate conclusions from these experiments were that neither short nor long term cephalad fluid shifts caused prolonged pathological elevations in intracranial pressure. In fact, removing gravity reduced intracranial pressure compared to the supine position. These data have been communicated at a number of scientific meetings and are recognized as a major breakthrough in our understanding of visual impairments in astronauts. A manuscript has been submitted to journal ‘Nature’.

More information:
https://flightopportunities.nasa.gov/technologies/132

This research is funded by NASA’s Human Research Program (HRP) through the National Space Biomedical Research Institute (NSBRI). The HRP is an applied research and technology program that investigates and mitigates risks to astronaut health and performance in support of exploration missions and provides countermeasures and technologies for human space exploration.

▷ *August 27, 2015: Setup of the experiment inside the NASA/C9 aircraft. (Photo: NASA/Bill Stafford)*

August 27, 2015: T0135 researcher Christine Fuller tries to grapple a free-floating cylindrical object using the gecko gripper prototype during one of the RGO-20 campaign's parabolas. (Photo: NASA/Bill Stafford)

RGO-20

T0135 Testing ON-OFF Gecko Adhesive Grippers in Microgravity

PI: Aaron Parness, NASA/Jet Propulsion Laboratory

A piece of tape can only be used a few times before the adhesion wears off and it can no longer hold two surfaces together. But researchers at NASA's Jet Propulsion Laboratory in Pasadena, California are working on the ultimate system of stickiness, inspired by geckos.

Thanks to tiny hairs on the bottom of geckos' feet, these lizards can cling to walls with ease, and their stickiness doesn't wear off with repeated usage. JPL engineer Aaron Parness and colleagues used that concept to create a material with synthetic hairs that are much thinner than a human hair. When a force is applied to make the tiny hairs bend, that makes the material stick to a desired surface.

Behind this phenomenon is a concept called van der Waals forces. A slight electrical field is created because electrons orbiting the nuclei of atoms are not evenly spaced, so there are positive and negative sides to a neutral molecule. The positively charged part of a molecule attracts the negatively charged part of its neighbor, resulting in "stickiness." Since the material relies only on van der Waals forces for adhesion, its sticking power is not affected by temperature, pressure, and radiation, making it attractive for use in a space environment.

"The grippers don't leave any residue and don't require a mating surface on the wall the way Velcro would," Parness said.

During parabolic flights in July 2014, the gecko-gripping technology was run through a series of tests, demonstrating its ability to grapple a 20-pound (10 kilogram) cube and a 250-pound (100 kilogram) person. In this more recent campaign in August 2015 (RGO-20), the team further demonstrated mobility on a flexible blanket surface as well as grappling free-floating cylindrical targets (1 meter diameter) for the first time.

As a result of the successful flight tests, in part, the Gecko Gripper technology was recently launched to the International Space Station (OA-6, March 2016) to continue testing in a longer-duration microgravity environment. Success in this long duration microgravity test will enable infusion of the technology for a variety of applications to be seriously considered by the ISS Program as well as future long-duration space systems like the Deep Space Habitat and human missions to Mars.

Parness and his team are also testing the Lemur 3 climbing robot, which has gecko-gripper feet, in simulated microgravity environments. The team thinks possible applications could be to have robots like this on the space station conducting inspections and making repairs on the exterior. The mobility demonstrations are not being demonstrated during the immediate ISS experiment, but could be scheduled as a follow-on experiment aboard the station in 2017.

More information:
https://flightopportunities.nasa.gov/technologies/135

Article adapted from http://www.jpl.nasa.gov/news/news.php?feature=4688

This research was first funded in 2013 by the DARPA Phoenix program. Since 2013, it has been been concurrently funded by STMD's Center Innovation Fund (CIF). ISS demonstration is funded through JPL-internal funds.

Two Radial Core Heat Spreader (RCHS) engineering units (dimpled disks) are shown integrated in the cylindrical payload section of the Terrier-Black Brant launch vehicle. (Photo: NASA/Michelle Murphy)

Terrier-01

T0073 Radial Core Heat Spreader

PI: Marc A. Gibson, NASA/Glenn Research Center

For more than five decades, radioisotope power systems have played a critical role in the exploration of space, enabling missions of scientific discovery to destinations across the solar system. NASA and the U.S. Department of Energy (DoE) are working together to ensure that this vital space power technology will be available to enable and enhance ambitious solar system exploration missions in this decade and beyond.

Radioisotope power systems

Radioisotope power systems (RPS) are a type of nuclear energy technology that converts heat produced by the natural radioactive decay of plutonium-238 to produce electric power for operating spacecraft systems and science instruments.

Thermal energy conversion for space power systems has had numerous advancements over the past decade, both in static and dynamic power conversion systems. One of the most significant dynamic power conversion technologies is the Stirling Converter, which is currently in development as part of the Stirling Cycle Technology Development Project under the Radioisotope Power Systems Program Office.

RPS thermal control

A new method of transferring heat from the Stirling Convertor to the radiator housing using two-phase heat pipe technology has been developed at the NASA's Glenn research Center in Cleveland, Ohio. This technology has been named the Radial Core Heat Spreader (RCHS) and uses a titanium structure and capillary wick with water as the working fluid (see image on the left). The RCHS provides a passive thermal control option for current and higher power Radioisotope Stirling Generators. For a 130W heat rejection application, the RCHS provides a 4:1 decrease in mass over current state of the art with similar thermal performance (750g to 175g).

Numerous prototypes of the RCHS where fabricated and underwent laboratory and reduced gravity (parabolic flight) performance testing to address as many of the design requirements as could be affordably tested (see T0014, 2011-2013). The technology successfully endured the ground and flight tests (thermal performance was unaffected by 0-2g gravity levels), verifying TRL6 for fission systems and TRL5 for radioisotope systems.

The maturity difference between fission and radioisotope systems is due to the fact that fission reactors can be started and stopped but radioisotope heat sources cannot, as they are constantly releasing radioactive decay heat. This unique difference allows fission systems to launch "cold". Conversely, radioisotope systems are fueled at the launch pad and immediately require thermal control. Knowing this, it is apparent that the RCHS can serve dual purposes for fission and radioisotope systems but requires the technology to be tested in the launch environment.

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The power system must actively cool the Pu238 GPHS fuel modules from the time of loading, just prior to launch, to the end of the mission. The launch environment creates significant challenges for the RCHS heat pipe as the capillary wick must pump the working fluid against hyper-gravity launch accelerations. These accelerations originate from typical vertical and longitudinal sources as well as rotational sources caused by the spin/despin and tipoff of the launch vehicle during ascent.

A sounding rocket capable of providing greater than five minutes of microgravity and up to 120 lbs. (54 kg) of experiment payload was required, something that currently is not available commercially in the Flight Opportunities program. The RCHS technology was therefore launched on a NASA Terrier-Black Brant IX sounding rocket on July 7, 2015. Two identical RCHS units were flown in the experiment section of the rocket with one oriented in the horizontal XY plane and the other in the vertical YZ plane. The units were oriented in this way to test the best and worst case configuration that might be used on future spacecraft. The objective of the experiment was to test the RCHS's thermal performance throughout the launch environment and into the microgravity environment.

The experiment provided the necessary test environment and succeeded in maturing the RCHS technology to TRL-6 across both applications, encouraging the next generation of radioisotope powered generators to use the RCHS's unique capabilities.

More information:
https://flightopportunities.nasa.gov/technologies/73

The development of the RCHS is funded by NASA's Radioisotope Power Systems program.

July 7, 2015: The Terrier MK70 Black Brant Mk1 launches from Pad 2 at NASA Wallops Island. The rocket reached an altitude of 332.4 km before falling back to Earth and landing in the Atlantic Ocean off the coast of Virginia. The Program-funded flight launched two payloads, the Exo-Atmospheric Aerobrake from NASA/Ames Research Center (T0075) and the Radial Core Heat Spreader (RCHS) from NASA/Glenn Research Center (T0073). (Photo: NASA/Carl Bowman)

Commercial Platforms
Profiles

REDDI

IDIQ2


BLUE ORIGIN

Blue Origin

REDDI

New Shepard

Platform

Blue Origin was created to develop spacecraft and launch systems with the goal of contributing to an enduring human presence in space. Blue Origin is developing the New Shepard system, a fully reusable vertical takeoff, vertical landing (VTVL) space vehicle that operates from the company's private West Texas Launch Site. The New Shepard flight test campaign began in 2015, and in the first year of operations Blue Origin flew the same vehicle above the 100-kilometer Karman line three times. The New Shepard capsule's interior is an ample 530 cubic feet (15 m3), designed for six astronauts and/or Payload Stacks. The capsule features the largest windows in spaceflight history, covering a third of the capsule for unparalleled views of both space and Earth.

Flight profile

The New Shepard system consists of a pressurized capsule atop a booster. The combined vehicles launch vertically, accelerating for approximately two and a half minutes before main engine cutoff. Several seconds after engine cutoff, the capsule separates from the booster and is pushed away by mechanical springs. From this point, the capsule and booster coast and reenter separately. Both vehicles experience microgravity for a period of about three minutes before returning to Earth. The booster maneuvers back to a landing pad, restarts its engine, and deploys landing gear to perform a rocket-powered vertical landing. The capsule reenters and lands under a three-parachute canopy with assistance of a retro-thrust system to reduce landing loads.

Payloads may be installed in the capsule as late as on the pad the morning of flight. A nominal mission is approximately 11 minutes long, and payloads are accessible within hours of landing. From pre-flight pad activities until the capsule separates from the booster near apogee, escape is an option if needed, ensuring the capsule and its contents can quickly move away from any hazard.

Payload configuration

With a high-quality microgravity environment, an apogee of over 100 km, and a comfortable shirt-sleeve cabin environment, the New Shepard system is ideal for microgravity physics, gravitational biology, technology demonstrations, and educational programs. Users also have the opportunity for Earth, atmospheric, and space science research. And as human flights begin, researchers and test subjects will be able to fly with payloads for hands-on experimentation.

Blue Origin has developed a custom payload system to host experiments inside the New Shepard capsule. Each Payload Stack replaces a seat in the cabin, for a total of up to six Stacks per flight. Each Stack is a modular system consisting of up to six Payload Lockers atop a Payload Support Enclosure, which provides power, data recording, command, and control services to experiments. A Single Payload Locker provides a useable interior experiment volume of 1.73 cubic feet (approximately 49 liters) of usable volume, supporting payloads up to 25 lbm (11 kg). In addition to the Single Payload Locker, standard interfaces include 2U (10x10x20cm) and Double Payload Locker volumes. Blue Origin can also accommodate custom solutions for larger payloads and payloads with access to the space environment. Benchtop development units are provided for programming in a researcher's lab in the months leading up to flight, enabling rapid iteration and flight-like testing for greater mission assurance.

More information: https://www.blueorigin.com/payloads


Image courtesy of Armadillo Aerospace

EXOS Aerospace

REDDI

SARGE

Platform
The EXOS team has designed, built, flown, and retrieved for re-use, rockets that are reliable and reusable. It has developed and tested over a hundred rocket engines and dozens of flying vehicles.

The EXOS Suborbital Active Rocket with GuidancE (SARGE) is 20 inch (0.5 m) wide by 431.176 inch (10.95 m) rocket that lofts payloads of 50 kg to an altitude of 100 km and offers 2 to 4 minutes of microgravity time. Cold gas attitude control thrusters provide a high quality zero-G environment for scientific payloads. The SARGE may be flown multiple times, as soon as the next day, with minimal and low cost refurbishment time between flights. The proven LOX/Ethanol engine technology allows a soft launch (~7G) and SARGE is a no-spin rocket with a gimbaled engine, keeping scientific experiments in a better environment to succeed. It lands within 50 to 200 meters of the launch site and payloads may be recovered within 15 to 30 minutes of launch. SARGE is a reliable, recoverable, re-usable rocket, lowering costs, and decreasing wait times.

Flight profile
SARGE is launched from Spaceport America using an Active Launch Control System (ALCS) and the rocket's Autonomous Guidance Unit (AGU). At 40 seconds into the flight (10 km altitude), SARGE reaches the speed of sound. At 60 seconds (Mach 1.5 & 3.0G), the Master Flight Computer (MFC) cuts off the main engine. At 80 seconds (53 km), the low-G environment begins. At 207 seconds (136 km), the low-G portion of the flight (0.005G) reaches apogee. Rolls at apogee are "nulled" by a cold gas Attitude Control System (ACS), providing highest quality microgravity for payload providers (~4 minutes). After apogee, SARGE's free-fall descends for a further ~120 seconds until 70 km. The nose cone ejects with a supersonic, ballistic drogue which brings the vehicle in a near "tail down" attitude to decelerate the vehicle to a velocity suitable for deployment of the main parachute. After approximately 420 seconds under drogue, the MFC deploys the main parachute, which has its own Autonomous Guidance Unit (AGU), and fly-guides the vehicle back within 50 meters of the original launch position.

Payload configuration
The payload bay configuration of the SARGE has a diameter of 19.625 inch (498 mm) and a height of 34.0 inch (915 mm) (extendable). Total payload mass is 110 lbm (50 kg). The ambient environment during flight ranges from 0-60 degC, 10-12.5 PSIA. Payload providers may communicate with experiments throughout the flight and retrieve the payload within minutes of landing near the launch site. Power during flight is available as a non-standard service at 5, 12 and 28 VDC. Integration and recovery is available up to approximately 2 hours before and after launch.

More information: http://exosaero.com


Fundamental Technology Solutions
LOCKHEED MARTIN
UP Aerospace
SL7

UP Aerospace

REDDI IDIQ2

SpaceLoft-XL

Platform

The SpaceLoft™ is a reusable launch vehicle that was developed by UP Aerospace in 2006 as a microgravity research platform for education, scientific research, and commercial payloads. The vehicle consists of an expendable carbon composite solid rocket booster, avionics and recovery section, and a payload bay. The SpaceLoft™ launch system is designed with robust margins of safety, and redundancy throughout all mission critical systems. The first test flight of SpaceLoft™ occurred in September of 2006 with the first mission to successfully reach space in April of 2007. The SpaceLoft™ payload delivery system has flown commercially over 10 times with over 40 payload customers. It is flight proven and fully operational. In November 2015, UP Aerospace successfully demonstrated a new payload deployment capability on SpaceLoft 10, opening the opportunity for future entry, descent and landing technologies to be tested and matured under Flight Opportunities.

Flight profile

SpaceLoft™ is ground launched from Spaceport America using a remote hydraulic launcher and automated launch systems. The solid rocket motor burns for 12 seconds and reaches space within 60 seconds. A de-spin system slows the roll rate to near zero when microgravity experiments can begin to be conducted. The payload section remains weightless in excess of 4 minutes.

During the re-entry phase of the flight the booster section is released and the payload and recovery sections are balanced to trim in a horizontal orientation to slow the vehicle. At about a mile above the ground, redundant onboard controls release the drogue parachute system which orientates the payload section in a vertical heads-down attitude. Ten seconds after drogue deployment, the main parachute is released and provides a soft landing on White Sands Missile Range. UP Aerospace and Army recovery crews are immediately dispatched to the landing site to retrieve the payload(s). The payloads are flown back to Spaceport America where they are unloaded from the payload bay and provided back to the customers onsite.

Payload configuration

The heart of the SpaceLoft™ payload delivery system is the patent pending Payload Transportation System™ (PTS). Each standard SpaceLoft™ mission contains seven PTS containers with a choice of two different sizes. The PTS10 is the larger of the two with internal dimensions measuring 23.5 cm tall and a diameter of 24.8 cm. The PTS4 internal dimensions are 8.3 cm in height and a diameter of 24.8 cm. All PTS containers have access to the space environment through an opening in the vehicle airframe and access panels. Options for each PTS include discrete command, power modules, and telemetry which can be customized to match specific payload requirements.

More information: http://www.upaerospace.com


Virgin
N202VG
aabar

Virgin Galactic

REDDI IDIQ2

SpaceShipTwo

Platform
SpaceShipTwo (SS2), an air-launched, suborbital space plane, uses similar technologies, construction methods, and design features as SpaceShipOne (SS1), the Ansari XPRIZE-winning vehicle developed by Scaled Composites. SS2 is 18.3 m (60 ft) long with a large cabin approximately 2.3 m (90 in.) in diameter that is designed to carry the equivalent of six passengers and two pilots. Close in size to a Falcon 900 executive jet, the cabin is able to provide ample room for passengers to experience weightlessness or for large payloads to operate in the microgravity environment.

Flight profile
A standard space flight for SS2 begins with the vehicle mated to a carrier aircraft called WhiteKnightTwo (WK2), a four-engine, dual-fuselage jet. The mated pair takes off from a conventional runway and climbs to an altitude of approximately 15 km (50,000 ft.). At this altitude, SS2 is released from WK2 and, after gaining adequate separation, fires its rocket motor for approximately one minute. The vehicle quickly pulls in a vertical climb and rapidly gains altitude, reaching expected speeds around Mach 3.5. After rocket motor cutoff, the vehicle is designed to provide astronauts or payloads a high-quality microgravity environment for approximately 3-4 minutes. SS2 reenters the atmosphere in a patented 'feathered' configuration, providing reentry at known conditions for increased safety and decreased loads. After reentry, the vehicle is reconfigured as a glider and makes an unpowered landing on the same runway used for initial takeoff.

Payload configuration
SpaceShipTwo has standard cabin configurations for tourism flights (providing seats for customers) and research flights (providing a modular rack system for payloads). The payload rack hardware is capable of interfacing directly with Space Shuttle Middeck Lockers as well as other standard or custom structures of varying size that follow similar interfacing requirements. Each payload can range in size from an experiment that can fit inside a Middeck Locker to a 100 kg system that takes up the full volume of an astronaut-seat equivalent. Each standard research flight is supported by a Flight Test Engineer in the cabin, who will be able to complete simple tasks such as payload power activation in-flight.

More information: http://www.virgingalactic.com

From left to right: Xaero-B - Xodiac - Xombie

Masten Space Systems

REDDI IDIQ2

Xaero-B/Xodiac

Platform

Since 2009, Masten Space Systems' Reusable Launch Vehicles (RLVs) have flown trajectories that accurately replicate the descent profiles necessary to land spacecraft on the Moon and Mars. These profiles feature high speed descent rates at low altitudes that cannot be achieved by conventional flight test platforms. By utilizing commercial-off-the-shelf hardware and strict adherence to narrowly-defined performance and functionality requirements, Masten has developed a commercially-proven, repeatable formula for designing, building and flying innovative rocket-powered vehicles. Masten's flight-test focused, incremental approach to technology development, design, and reusable operations was hard-wired into the company's DNA on the road leading to its success in the 2009 Northrop Grumman Lunar Lander Challenge.

The XA-0.1-E "Xaero-B" and "Xodiac" rockets are fully reusable vertical takeoff and vertical landing (VTVL) launch vehicles used for low speed and low altitude testing. In the past four years, Masten has conducted 10 distinct RLV flight campaigns in support of customers including NASA's Flight Opportunities program and NASA/JPL's Guidance and Control Analysis Group.

Flight profile

Custom flight profiles are developed to best accommodate the mission requirements for each payload flight test. The vehicles have been used to simulate both lunar and Martian landing profiles and are capable of high speed descent rates not achievable through helicopter testing. The highest altitude flight performed for a payload to date is 499m and the longest downrange translation for a payload flight is 804m. Masten's rockets are capable of precision landing and have demonstrated centimeter level accuracy.

Payload configuration

The vehicle is equipped with a hypervisor that enables third party guidance, navigation and control (GN&C) systems and avionics packages to control them in flight while maintaining Masten's GN&C as a supervisor and always-on safety net. The vehicle can be configured to test a wide range of systems and sensors. Masten engineers routinely work with technology developers to develop interfaces between the XA-0.1-E rocket and experimental software and hardware payloads. Masten's campaign-tested payload qualification and integration processes help provide a streamlined path for technology maturation throughout the course of tool conception, development and flight test.

More information: http://masten.aero

Near Space Corporation

REDDI IDIQ2

HASS/SBS/NBS

HASS
NSC's High Altitude Shuttle System (HASS) combines an innovative Tactical Balloon Launch System with a special high altitude unmanned Shuttle for payload recovery. The unpowered Shuttle returns payloads by gliding to pre-specified landing sites, allowing payloads to be rapidly turned around and re-flown. Payload providers desiring enhanced flight path control or the ability to make iterative payload changes between frequent, high altitude flight tests will find NSC's HASS to be an appropriate platform. Standard HASS flights can lift payloads of up to 10 kg (5 kg per payload "slot") to altitudes of 28 km for flights of up to six hours. Non-standard options include higher altitudes and longer flight durations. For HASS, the primary payload bay is the space within the enclosed physical constraints of the Shuttle centerbody with payload attachment and access provided through its bottom hatch. The payload tray is available for primary payload use within the 10 kg (22 lbs) maximum payload weight limit, and specified center of gravity (CG) constraints.

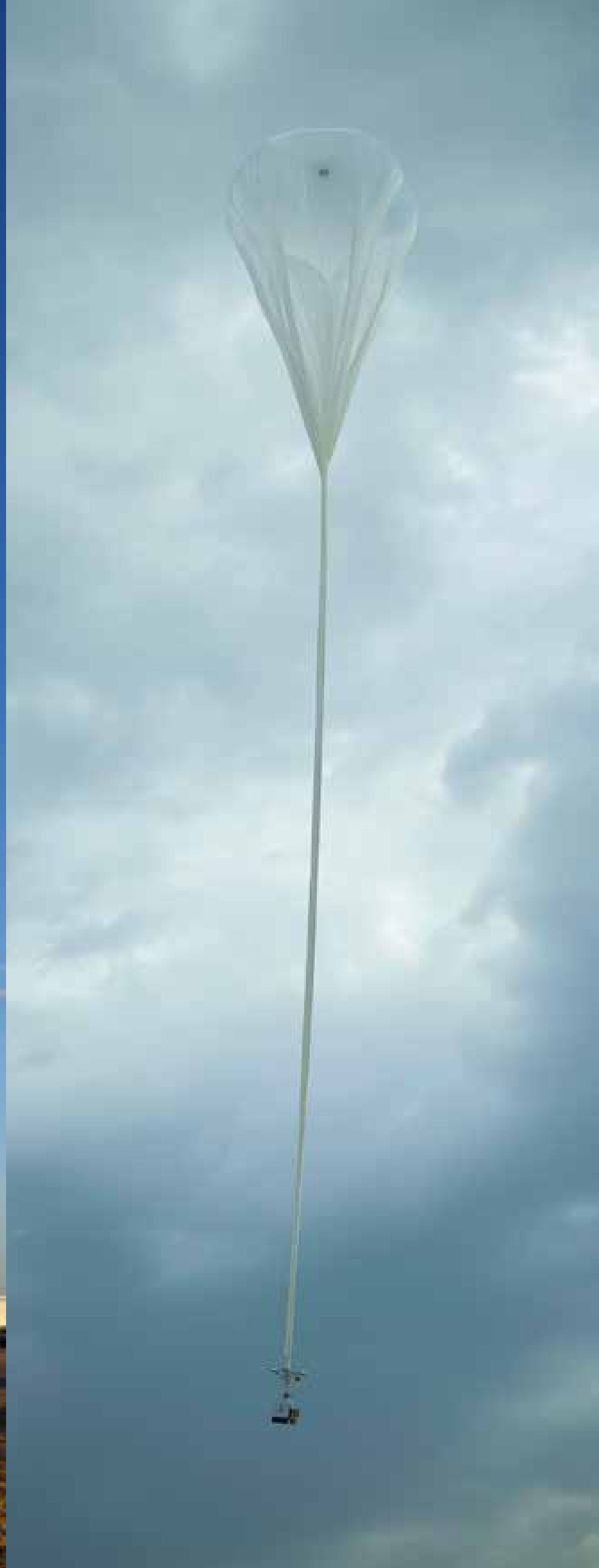
SBS/NBS
The Small Balloon System (SBS) offers many of the advantages of the High Altitude Balloon System (HASS), but exchanges the gliding payload return vehicle for the simplicity of a traditional high altitude balloon vehicle with a parachute recovery system. Standard SBS flights can lift payloads of up to 40 kg (full manifest, 20 kg/payload "slot") to altitudes of 35 km for flights of up to six hours. Non-standard options include larger payload masses, higher altitudes, longer flight durations, and remote launch sites. The system is approved for flights outside of a normal test range environment, with standard operations conducted out of NSC's Tillamook, Oregon Balloon Facility or Madras, Oregon. The SBS is well suited for small satellite and spacecraft subsystem developers wanting to raise their Technology Readiness Level (TRL) and qualify their payload in a relevant environment.

The Nano Balloon System (NBS) is an ideal platform for payloads with minimal integration requirements. Standard flights can lift payloads up to 40 kg (3 kg/payload "slot") to altitudes of 30 km for flights of up to six hours. Several non-standard options are available, including a variety of standard or custom thermal insulated housings to accommodate different payload shapes and volumes, as well as the ability to send limited payload commands and provide onboard data recording. Standard flights are conducted out of NSC's Tillamook, Oregon Balloon Facility or Madras, Oregon.

Flight campaigns
NSC flies the majority of flights of all qualified vehicles during two annual flight campaigns: Spring (1st week in May thru 2nd week in July) or Fall (2nd week in September thru the 3rd week of October). Payload acceptance and integration occurs no later than one month prior to the start of each flight campaign. Additionally, each of NSC's qualified flight vehicles is now offered with reduced payload "slot" pricing for payloads that don't require a full manifest.

NSC Unmanned Aerial System (UAS) operations
NSC actively operates an FAA designated UAS Test Range at the Tillamook, Oregon flight facility. An FAA Certificate of Authorization (COA) currently permits UAS test flights to 5000ft AGL with high altitude UAS operations (to 130,000ft) in the near future.

More information: http://www.nsc.aero



World View Enterprises

REDDI IDIQ2

Tycho 20/285

Platform

Holding world records in manned and unmanned high altitude ballooning, flight operations and aerodynamic descent, World View is capable of performing a wide range of mission operations and accommodating unique payload requirements. World View is changing how the edge of space is used for research and education, from development of a concept through proposal support and successfully flying missions on a commercially operated vehicle.

The Tycho stratocraft is named after the Danish astronomer Tycho Brahe (1546–1601). As Brahe was the source of data used by others to make powerful discoveries, Tycho stratocraft provide researchers stratospheric access to make new discoveries. The Tycho platform is modular, allowing it to be customized for a wide variety of unique mission needs including telemetry, payload control, power and thermal control.

World View has missions manifested for up to 4,000 kg at a variety of altitudes. We also offer two standard Tycho platforms for specific payload mass ranges. Tycho285, the larger of the two, carries payloads up to 285 kg to altitudes of up to 43 km. Tycho20, the smaller of the two, can launch payloads up to 20 kg to altitudes of 32 km. Tycho20 requires less infrastructure than that needed to launch and operate the much larger Tycho285. However, Tycho20 can also be configured to be launched to higher altitudes of up to 46 km. The two-vehicle Tycho stratocraft family provides cost savings for small payload masses while also offering proven heavy-lift capability. Both Tycho stratocraft share the same avionics, balloon envelope technology, and similar recovery systems.

Flight profile

World View has performed flights with the Tycho stratocraft systems with payloads ranging from 2 to 285 kg, with durations ranging from five minutes to 12 hours at target float altitudes varying from 15 to 41.5 km. These systems share heritage with those used for the record-setting StratEx manned balloon flights performed in October 2014. World View also has the capability to launch and fly payloads up to 4,500 kg into the stratosphere, and welcomes the opportunity to discuss and plan such missions directly.

Payload configuration

Tycho285 allows direct connection of a single payload to the vehicle or via a payload support module (PSM) that facilitates payload integration and allows for a number of smaller individual payloads onto a single flight. Tycho20 uses a simple Payload Support Frame (PSF) for payload attachment. A summary of the standard Tycho stratocraft interfaces is provided in the Payload User's Guide available at the link below.

More information: http://worldview.space


zero G
G-FORCE ONE
www.goZeroG.com
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Zero Gravity Corporation

REDDI

G-Force One

Platform
The Boeing 727-200F is a three-engine, swept-wing aircraft specially modified for reduced gravity operations. The interior contains 38 seats for researchers and crew in the rear of the aircraft and an open research area approximately 20m (67ft) long in the forward section of the cabin. Seats in the rear can be utilized for smaller experiments as well.

Flight profile
The reduced gravity environment is achieved by flying the aircraft through a series of parabolic maneuvers. This results in short periods of less than one "G" acceleration. The length of these reduced gravity periods depend on the "G" level required for the specific test and the specifics of the aircraft. Approximate durations are: negative-G to 1/10-G 15 sec, zero-G 23 seconds, Lunar (1/6-G) 30 seconds, Martian (1/3-G) 40 seconds. These maneuvers may be flown consecutively (i.e. roller coaster fashion) or separated by enough time to alter the test setup. Each parabola is initiated with a 1.8-G pull-up and terminated with a 1.8-G pullout. Normal missions, lasting approximately two hours, consist of 40 parabolic maneuvers, and originate and terminate at Orlando Sanford International Airport in Florida. The test area in both aircraft is equipped with electrical power, portable compressed gas racks, an overboard vent, accelerometer data, and photo lights. Workspace is available on the ground for buildup and checkout of test equipment to ensure its operation before installation in the airplane.

Payload configuration
A floor plan schematic and cross sectional view of the cabin is available in the Interface Control Documentation. Test equipment is usually loaded through the cargo door, which is 2.3m (90 inches) high and 3.4m (134 inches) wide.

More information: https://www.gozerog.com

Computer rendering by Integrated Spaceflight Services

Integrated Spaceflight Services

REDDI

S3 A343

Platform
Integrated Spaceflight Services (ISS) is the Research and Educator partner of Swiss Space Systems (S3) and provides reduced gravity flights using S3's modified Airbus A340-300 (A343). The S3 A343 (expected to be available in 2017) will be the largest reduced gravity aircraft in the world, having four engines, a wingspan of 60.3 m, and an interior cabin of 50.4 m x 5.3 m. The cabin is divided into two experimental areas: a forward research area 7.4 m in length that seats 11, and an afterward research area 24.4 m in length that seats 35. Beneath its main deck, the S3 A343 has large cargo compartments for autonomous or remotely operated research payloads.

Flight profile
The S3 A343 can fly microgravity, lunar and Martian gravity profiles. A typical microgravity flight is 2 hours for 15 parabolas. Parabolas start from steady horizontal flight and are executed in three consecutive maneuvers. First, the aircraft climbs at an angle of 47 degrees for 20 seconds in pitch-up maneuver that initiates the parabola and creates hypergravity conditions between 1.5 and 1.8 G. Partway up the climb, the thrusters are throttled back and aircraft coasts in near weightlessness to the apex of the parabola. It then pitches its nose down at an angle of 47 degree with the horizon and begins to fall. The near weightless duration is between 20 and 25 seconds. Moments later, the thrusters are fully throttled on and the aircraft is brought back into horizontal flight in a 20-second pull-out maneuver that puts the aircraft in another state of hypergravity between 1.5-1.8 G. These maneuvers are repeated for subsequent parabolas. The S3 A343 will be first reduced gravity aircraft with autopilot close-loop control for the parabolic maneuvers and is expected to result in high-quality microgravity conditions for researchers.

Payload configuration
Research payloads for the main deck enter through loading doors 19.30 m x 10.7 m located between the fore and aft research areas. A standard-sized research payload of 1 m x 1.3 m x 1.7 m will have 2.5 m2 of dedicated floor space in the cabin for equipment and researchers. There is the capability to accommodate long experiments up to 0.9 m x 3.5 m x 1.7 m. Large cargo doors take industry-standard LD3 containers.

More information: http://integratedspaceflight.com

This Annual Report is available online at:
https://issuu.com/nasafo/stacks

More information:
http://www.nasa.gov/flightopportunities
http://flickr.com/nasafo/sets
http://twitter.com/nasafo

Space Technology Mission Directorate:
http:www.nasa.gov/spacetech

For questions/comments, please contact nasa-flightopportunities@nasa.gov

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