National Aeronautics and Space Administration

Space Technology Mission Directorate

Flight Opportunities

2014 Annual Report

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ZERO

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◁ *August 20, 2014: NASA pilot and five-time Space Shuttle astronaut Kenneth Cockrell prepares the NASA C9 aircraft for the second leg of 20 microgravity parabolas over the Gulf of Mexico. (Photo: NASA/Bill Stafford)*

Cover Photo: Masten Space System's XA-0.1B "Xombie" vertical-launch, vertical-landing reusable rocket. (Photo: NASA/Tom Tschida)

Introduction

Welcome to our second Annual Report. In this report, we continue our story of how NASA is working with the U.S. commercial space sector and the research community to advance national space interests and develop technologies critical to NASA's future missions.

FY14 was a year of transition for our Program. As the industry continues to evolve, we aim to stimulate broader adoption of the commercial flight services offered beyond our Program. In a change to our solicitation strategy, the Program will therefore start providing awards with fixed funding levels to space technology developers from academia and industry. This will allow them to directly purchase flights from U.S. suborbital flight vendors that best meet their needs. In doing so, the Program is facilitating a more direct interaction and encouraging organizations from academia and industry to augment government funding by investing institutional funds in the purchase of suborbital flight services. This revised approach is in line with our mandate to foster a commercial market with NASA as one of many customers. We will continue to support U.S. Government flight demonstration needs by manifesting payloads from within NASA and other government agencies on commercial flights using the latest IDIQ2 contracts. The Program currently has four operational flight providers under contract to provide flight services for U.S. Government payloads and will on-ramp new flight providers as they enter commercial operations.

As the suborbital industry expands its flight capabilities, the Program will co-evolve and help broaden the relevant space environments available to the space technology community. To this end, we have started a new 'Announcement of Collaborative Opportunity' (ACO) aimed at establishing public-private partnerships with commercial flight providers interested in further developing their suborbital and orbital launch capabilities with NASA assistance. Through this ACO, the Program aims to support and ultimately offer orbital flight opportunities for nano- and small satellite class spacecraft.

FY14 was also the first year in which technologies tested through our Program were deployed to the International Space Station - most notably the '3D printing in Zero-G' experiment featured later in this report. Meanwhile, on July 15, 2014, DARPA announced that it had selected Program flight providers Masten Space Systems, XCOR Aerospace, and Virgin Galactic as part of winning teams for their Experimental Spaceplane XS-1 program.

With the programmatic adjustments started in FY14, we believe the Program is well aligned to continue to foster and support the U.S. commercial spaceflight industry for the benefit of NASA and the nation. We hope you enjoy reading this report.

LK Kubendran
Program Executive
NASA HQ

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

▷ *NASA Small Business Program Team of the Year for 2013: Flight Opportunities Team. Pictured from left to right are Charles Bolden (NASA Administrator), Laguduva R. Kubendran (NASA HQ Space Technology Mission Directorate, Flight Opportunities Program Executive), Ron Young (Flight Opportunities Program Manager), Christopher Baker (Flight Opportunities Campaign Manager), Joel Lozano (Flight Opportunities Contract Specialist), Charles Rogers (NASA Armstrong's Acting Director of Exploration and Space Technology Programs), David D. McBride (NASA Armstrong Center Director), and Glenn A. Delgado (NASA Associate Administrator, Office of Small Business Programs). (Photo: NASA/Jim Ross)*

Flight Opportunities
FY14: A Year Of Transition

◁ *June 20, 2014: Astrobotic Technology's newly developed autonomous landing system (T0067) was put to the test when it controlled 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. (Photo: NASA/Ken Ulbrich)*

"Transform NASA missions and advance the Nation's capabilities by maturing crosscutting and innovative space technologies…NASA's Space Technology Mission Directorate (STMD) investment strategy addresses the broad range of technology areas identified in our Space Technology Roadmaps, as prioritized by the National Academies. This portfolio approach spans the entire technology life cycle, utilizing a combination of early stage conceptual studies, discovering entirely new technologies (technology readiness level (TRL) 1-3); rapid competitive development and ground-based testing (TRL 3-5) to determine feasibility; and flight demonstrations in a relevant environment to complete the final step toward mission infusion (TRL 5-7)… Through challenging new missions, multi-use technologies, and stimulation of commercial space markets, NASA's STMD expands capabilities in space and on Earth."

NASA Strategic Plan 2014

"United States Government departments and agencies, within their authorized capacity, shall encourage and facilitate the U.S. commercial space transportation industry to increase industry robustness and cost effectiveness, foster innovation-driven entrepreneurship and international competitiveness, and benefit the U.S. economy."

National Space Transportation Policy 2013

"The report of the National Academy of Sciences, Revitalizing NASA's Suborbital Program: Advancing Science, Driving Innovation and Developing Workforce, found that suborbital science missions were absolutely critical to building an aerospace workforce capable of meeting the needs of current and future human and robotic space exploration. The designee shall be responsible for the development of short- and long term strategic plans for maintaining, renewing and extending suborbital facilities and capabilities. The Administrator shall establish a Commercial Reusable Suborbital Research Program within the Space Technology Program that shall fund the development of payloads for scientific research, technology development, and education, and shall provide flight opportunities for those payloads to microgravity environments and suborbital altitudes. The Commercial Reusable Suborbital Research Program may fund engineering and integration demonstrations, proofs of concept, or educational experiments for commercial reusable vehicle flights. The program shall endeavor to work with NASA's Mission Directorates to help achieve NASA's research, technology, and education goals."

NASA Authorization Act of 2010 Section 907

The Flight Opportunities Program within the Space Technology Mission Directorate (STMD) helps fulfill the strategic objective of transforming NASA missions and advancing U.S. spaceflight capabilities by fostering the operational readiness and transition of innovative space technologies into future activities.

LK Kubendran / Ronald Young
Program Management
NASA/Armstrong Flight Research Center

STMD pursues crosscutting technologies to enhance national capabilities and enable more challenging missions for NASA. Adoption of advanced technologies for space applications is constrained by the limited opportunities to demonstrate them in relevant operational environments. Flight Opportunities seeks to increase the availability and affordability of space access for technology maturation by employing commercial flight services and developmental partnerships.

Through the Flight Opportunities Program, STMD selects promising technologies from industry, academia and government, to be tested in a relevant environment through flights on commercial launch vehicles. This approach takes technologies from a laboratory environment and gives them flight heritage, while also stimulating the development and utilization of U.S. commercial spaceflight capabilities and infrastructure. Within this context, the program goal addresses the NASA Strategic Plan (2014), the National Space Transportation Policy (2013), and the NASA Authorization Act of 2010 (see on the left).

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

Flight Opportunities FY11-14 Budget

Supply: Commercial Flight Services

For flight demonstrations performed under the Program, Flight Opportunities procures commercial flight services on reusable launch vehicles. The commercial nature and reusability of the launch vehicles are emphasized in order to support the U.S. space industry and encourage launch vehicle technological innovation, responsiveness and cost effectiveness.

A robust and vibrant commercial space transportation market is necessary to provide the affordable, frequent, and ready access to the space environment that is integral to the success of the Program. As such, the Program has sought to foster both the payload market and expansion of the qualified vendor base for performing technology demonstration missions. The current solicitation strategy for flight and integration services evolved with feedback and data from both the research community and the U.S. commercial spaceflight industry.

The Program established its second commercial (FAR Part 12) Indefinite Delivery Indefinite Quantity (IDIQ) contract for integration and flight services in FY 2014. Mission profiles and vehicle capabilities of interest to the research community were more diverse than originally anticipated in FY 2011. The new IDIQ2 contract therefore contains on-ramping and expansion clauses, allowing the Program to add new capabilities driven by the research community to the contract, as they become commercially available. The Program will reopen the solicitation for flight services at least once a year to encourage new vendors and foster commercial competition.

To further promote improvements to the reliability, responsiveness, performance, and cost effectiveness of current and future U.S. space transportation systems, the Program in FY 2014 issued a Request for Information (RFI) looking for areas in which access to NASA expertise and facilities could assist commercial development. Based on the results of this RFI, STMD will pursue public-private partnerships or other agreements with industry starting in FY 2015 for the development and demonstration of vehicle technology enhancements. To help close gaps in initial operational capabilities, the Program will enter into partnerships with the commercial suborbital and small orbital launch industry for access to relevant NASA facilities, personnel and technical information.

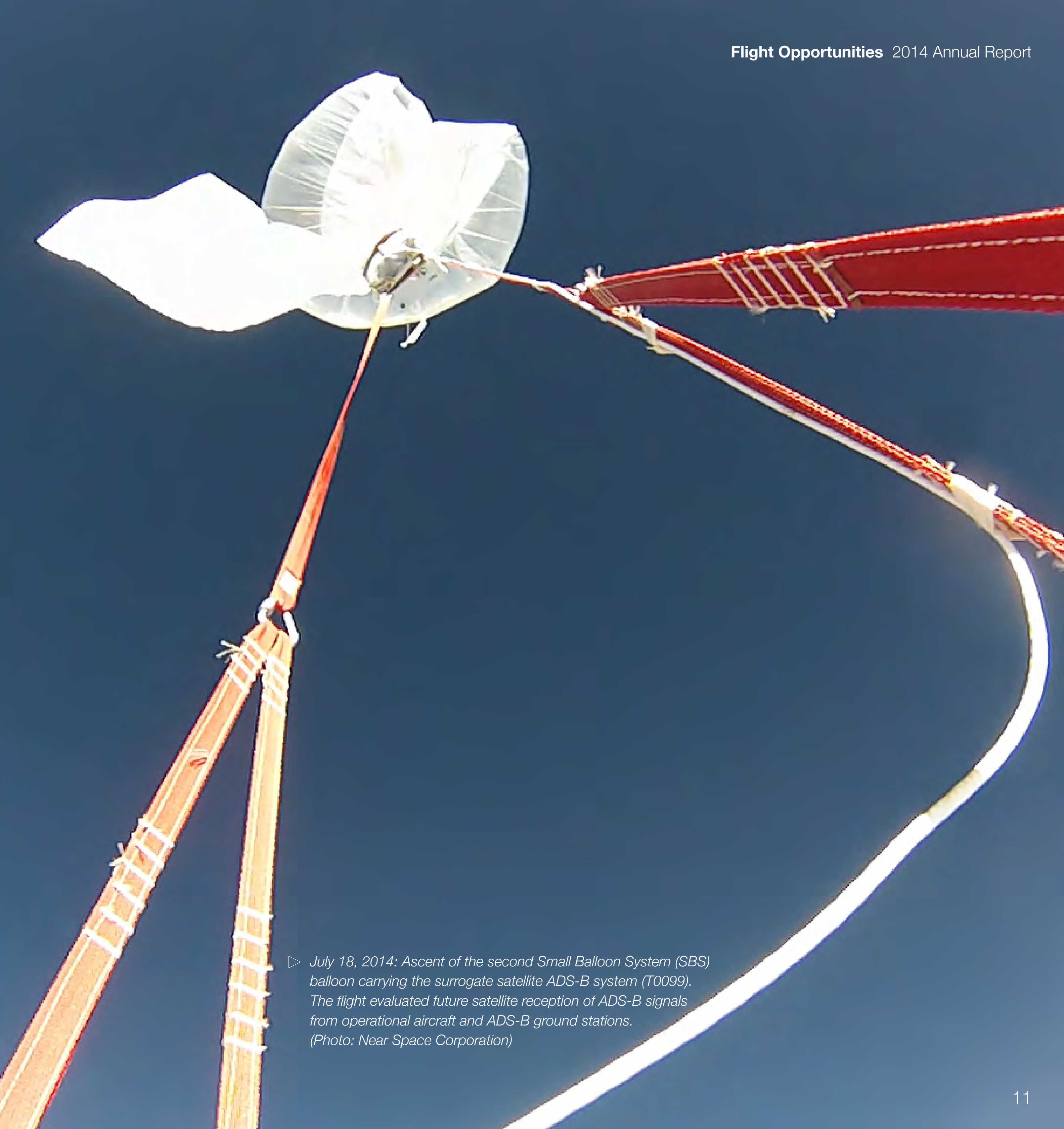
Agreements with industry will be aimed at increasing the availability of launch platforms that can provide flight demonstration services or expansion of capabilities for current launch platforms to better meet the technical requirements of the research community. The program will also continue to support demonstration opportunities for technologies that enhance the capabilities of launch vehicles and encourage the commercialization of technologies developed or demonstrated through the Program.

		IDIQ1	IDIQ2	1st FO flight	FO flights FY11-14	Flight designation
1	Armadillo Aerospace, Heath, TX	√				
2	Masten Space Systems, Mojave, CA	√ *	√	**FY12** (11/16/2011)	10	Xombie
3	Near Space Corporation, Tillamook, OR	√		**FY13** (01/20/2013)	8	SBS, NBS or HASS
4	UP Aerospace, Highlands Ranch, CO	√	√	**FY12** (04/05/2012)	3	UP
5	Virgin Galactic, Mojave, CA	√	√	**TBD**		
6	World View Enterprises, Tuscon, AR		√	**FY15** (03/08/2015)		
7	Whittinghill Aerospace, Camarillo, CA	√				
8	XCOR Aerospace, Mojave, CA	√				
9	Zero Gravity Corporation, Arlington, VA	**		**FY11** (07/19/2011)	16 ***	RGO

** Pre-existing contracts were used to fly with Masten Space Systems during IDIQ1*

*** Parabolic flight weeks were operated through the NASA/JSC Reduced Gravity Office (RGO). The contract with Zero Gravity Corporation ended June 2014.*

**** Parabolic flight weeks are counted as 1 flight*



▷ *July 18, 2014: Ascent of the second Small Balloon System (SBS) balloon carrying the surrogate satellite ADS-B system (T0099). The flight evaluated future satellite reception of ADS-B signals from operational aircraft and ADS-B ground stations. (Photo: Near Space Corporation)*

Demand: Technology Development

The Program selects crosscutting technologies that align with NASA technology investment priorities and are applicable to multiple Government missions or have a viable commercial application. Technologies selected for flight demonstration are expected to enhance or enable multiple future space exploration and utilization missions. Under all Program solicitation mechanisms, a total of 140 technologies were selected for testing between FY 2011 and FY 2014.

The payload solicitation strategy was developed with the intention of fostering a viable commercial market. Realization of such a market is in the national interest and can drive both an increased cadence and a reduction in cost for future NASA technology demonstration missions.

Starting in FY 2011, the solicitation strategy has had a phased approach, designed to establish Flight Opportunities as an anchor customer for commercial reusable suborbital and orbital spaceflight services, encourage early adoption by other organizations, and then gradually reduce the Program's involvement in the marketplace to that of being one of multiple customers. In furtherance of this strategy, the Program has utilized several payload solicitation mechanisms. Through these diverse solicitations, the Program partners with industry, academia and government for technology demonstrations:

- **NASA Research Announcements (SpaceTech-REDDI-F)**
  Funding flight demonstrations up to a fixed value with the responsibility for the flight contract placed on the payload provider
- **NASA Research Announcements**
  Funding the development of technology payloads
- **Announcements of Flight Opportunities (AFO)**
  Funding flight demonstrations using commercial flight contracts established by NASA *[phased out]*

In addition to the program-lead announcements, Flight Opportunities accommodates (and stimulates) research and technology payloads coming directly from other programs within STMD and other NASA Mission Directorates. Payloads from other programs are selected according to that organization's competitive selection and peer-review processes.

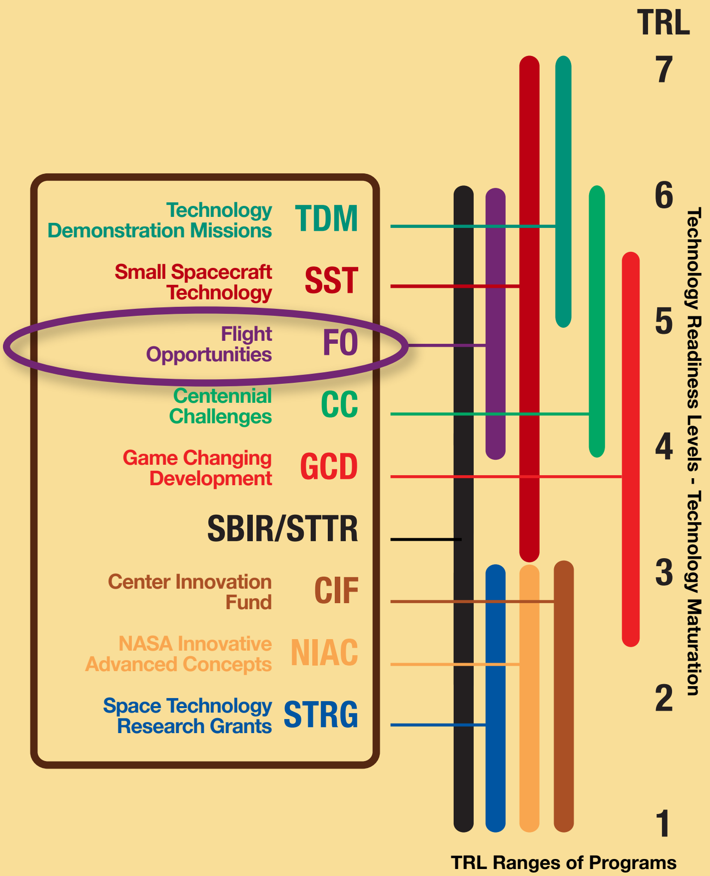
	FY11	FY12	FY13	FY14	TOTAL
Technology payloads selected	**19**	**55**	**50**	**16**	**140**
Parabolic [P]	*12*	*21*	*26*	*13*	72
sRLV [S]	*4*	*29*	*14*	*3*	50
Balloon [B]		*3*	*7*		10
Parabolic <-> sRLV [PS]	*3*	*1*	*1*		5
Balloon <-> sRLV [SB]		*1*	*2*		3

	FY11	FY12	FY13	FY14	TOTAL
Payload-flights achieved	**20**	**30**	**33**	**51**	****** 85/49 **= 134**
Parabolic	**13/7*	*18/7*	*6/12*	*30/8*	*67/34* = **101**
sRLV		*2/3*	*5/5*	*3/6*	*10/14* = **24**
Balloon			*5*	*3/1*	*8/1* = **9**

(more details in Program Metrics section)

** number of payload-flights: 13/7 means 13 were 'first flight' for a payload while 7 were 're-flights' for previously flown payloads.*
*** 85 unique technologies (T#s) have been flight tested. 49 payload-flights consisted of re-flights or previously flown payloads.*

Flight Opportunities for NASA Space Technology



NASA Space Technology (Mission Directorate)

Flight Opportunities is one of nine programs in NASA's Space Technology Mission Directorate (STMD). Space Technology conducts rapid development and infusion of space technologies that enable NASA's missions and increase the Nation's capabilities in space.

Space Technology Research and Development

To advance the state of the art, NASA sources technology from the entire pool of potential technology providers: industry, academia, small businesses, other government agencies, individual entrepreneurs, and NASA Centers. The Space Technology Research and Development portfolio supports a combination of early stage conceptual studies that focus on discovering entirely new technologies; rapid competitive development and ground-based testing of promising technologies; and flight demonstration of successful technologies to complete the final step prior to mission infusion. By supporting projects at all technology readiness levels, Space Technology creates a technology pipeline, starting with innovation and early stage technology investigations, and eventually resulting in mature, ready-to-utilize technologies that increase the nation's in-space capabilities.

To learn more, go to www.nasa.gov/spacetech


T+163.5 seconds
Vehicle Apogee
384,100 feet MSL
72.7 miles

▷ *November 12, 2013: View of the Earth from an altitude of 117 km (72.7 mi). Launched from the UP Aerospace Launch Pad One complex at Spaceport America (NM), SpaceLoft-8 carried 6 experiments selected by the Flight Opportunities Program. The flight exposed the experiments to four minutes of microgravity. (Photo: UP Aerospace)*

▷ *Total mission duration of SpaceLoft-8 from launch to touch down was just under 13 minutes. The vehicle lands by parachute and is recovered by helicopter and brought back to the launch complex within two hours. (Photo: UP Aerospace)*


SL8
FRAGILE
HANDLE
WITH CARE
FRAGILE
HANDLE
WITH CARE

▷ *Once the vehicle has been successfully recovered and brought back to the launch site, UP Aerospace staff work with the various payload teams to retrieve their experiments from the reusable upper section of the fuselage. (Photo: UP Aerospace, on the left: Jerry Larson, CEO UP Aerospace)*

▷ *Experiments are mounted in cylindrical payload canisters such as the one seen in this image. Principal Investigator Andrei Zagrai is seen here with his team from the New Mexico Institute of Mining and Technology after recovering their payload testing Structural Health Monitoring technology for commercial space vehicles (T0038). Pictured from left to right, sitting: Wade Thomas, Robert Cook, Matthew Shubert; standing: Andrei Zagrai, Levi Magnuson, John (Lloyd) Puckett, Paul de Leon (NASA), Jon Schlavin, Jaclene Schlavin, Benjamin Cooper, Cameron Lucas, Kevin Hill, Benjamin Warner. (Photo: UP Aerospace)*

Technology Maturation Through Flight Testing

A Stepping Stone to Low Earth Orbit and Beyond

◁ *September 11, 2010: NASA astronaut Tracy Caldwell Dyson, Expedition 24 flight engineer, looks through a window in the Cupola of the International Space Station. The image was a self-portrait using natural light. (Photo: NASA - ISS024-E-014263)*

Stephan Ord / Alexander van Dijk / Dougal Maclise (retired)
Technology Management
NASA/Ames Research Center

Between FY 2011 and FY 2014 a total of 32 flight campaigns were flown, resulting in 134 payload-flights and a total of 85 technologies tested in 3 different relevant flight environments (variable gravity, high altitude exposure, and low altitude Entry, Descent and Landing). The 140 technologies selected to date are intended for operational use in a diverse range of space environments, including suborbital flight, low-Earth orbit (e.g. the International Space Station), the Moon, Mars and beyond.

FY 2011 - FY 2014

32 Campaigns flown

85 Technologies tested

134 Payload-flights

Technology development at the prototype and subsystem level may require several iterations before progressing toward mission use. Flight testing enabled through Flight Opportunities is therefore usually part of a broader technology maturation plan, where the technology advances from design and laboratory testing to flight test iterations, (often) back to design, and finally to flight validation and infusion into the relevant mission application.

Many researchers and technologists return to the Flight Opportunities Program to test new design configurations based on lessons learned from previous flights. For most technologies, this iterative testing and maturation does not stop with Flight Opportunities and may continue into low-Earth Orbit with the help of other NASA programs such as the International Space Station (ISS).

Each technology development path is unique. One example which demonstrates the role of Flight Opportunities is the development of the 3D printer for zero gravity applications by Made In Space, Inc. Early development of this system included flying both "commercial of the shelf" 3D printers and a custom-build 3D printer of Made in Space's own design on a parabolic flight in FY 2011. Based on the test results from that flight series, Made In Space identified key issues in the microgravity operation of their system and were able to secure SBIR funding to further develop a dedicated zero gravity 3D printer. Over a year later, they tested their new design in a second parabolic flight series to validate the system before sending it to the ISS for further testing in low-Earth orbit. Results from this on-orbit test bed are informing the design of a second generation 3D printer, the Additive Manufacturing Facility (AMF), which will be launched and integrated into an

April 24, 2014 (top image): Prof. Kerri Cahoy of MIT AeroAstro (left, PI for T0089) observes the MicroMAS test object during a parabolic maneuver. The goal of the microgravity flight campaign was to validate the performance of the reaction wheels and custom scanner assembly in zero gravity and to test the closed-loop attitude stabilization algorithms on a free-floating platform. (Photo: NASA/Bill Stafford) ▷

March 4, 2015, 2:30:01 a.m CST (bottom image): Deployment of the MicroMAS and LambdaSat cubesats from the International Space Station in low-Earth Orbit. (Photo: NASA/NanoRacks) ▷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DARPA

ISS express rack to provide a commercial in-space 3D printing service in late 2015. Meanwhile, the team continues to use parabolic flight to test new materials and hardware improvements intended for future evolutions of the 3D printing technology.

One of the key observations after four years of flight testing is that many of the technology developers who apply to Flight Opportunities are targeting a downstream deployment of their hardware to the ISS. Not only does the ISS serve as a target application for technologies related to human habitation in space, it is also proving to be a valuable test environment for a wide range of other space exploration and utilization technologies. Since it would be unsafe and inefficient to send unproven technologies directly to the ISS for testing, other means are needed to bridge the gap between a laboratory proven technology and one that is ready for deployment to the ISS. By enabling access to short periods of microgravity, the commercial flight services available through Flight Opportunities enable technology developers to bridge this gap, both in terms of risk reduction for space hardware, and in testing operational procedures that will be used onboard the ISS (astronaut time onboard the ISS is one of the most highly constrained resources on orbit).

In addition to ISS applications, Flight Opportunities has seen a steady increase in proposals to test technologies related to small and nano satellites. With the rapid rise in popularity of small and nano satellites, testing subsystems in microgravity (e.g. solar panel hinges and antenna or tether deployment mechanisms) provides valuable engineering data to rapidly advance the maturation of these emerging satellite systems. Combined with the ability to conduct the tests firsthand, suborbital flight testing offers a useful risk reduction tool as well as a valuable educational opportunity for students and researchers working on this new class of affordable space missions.

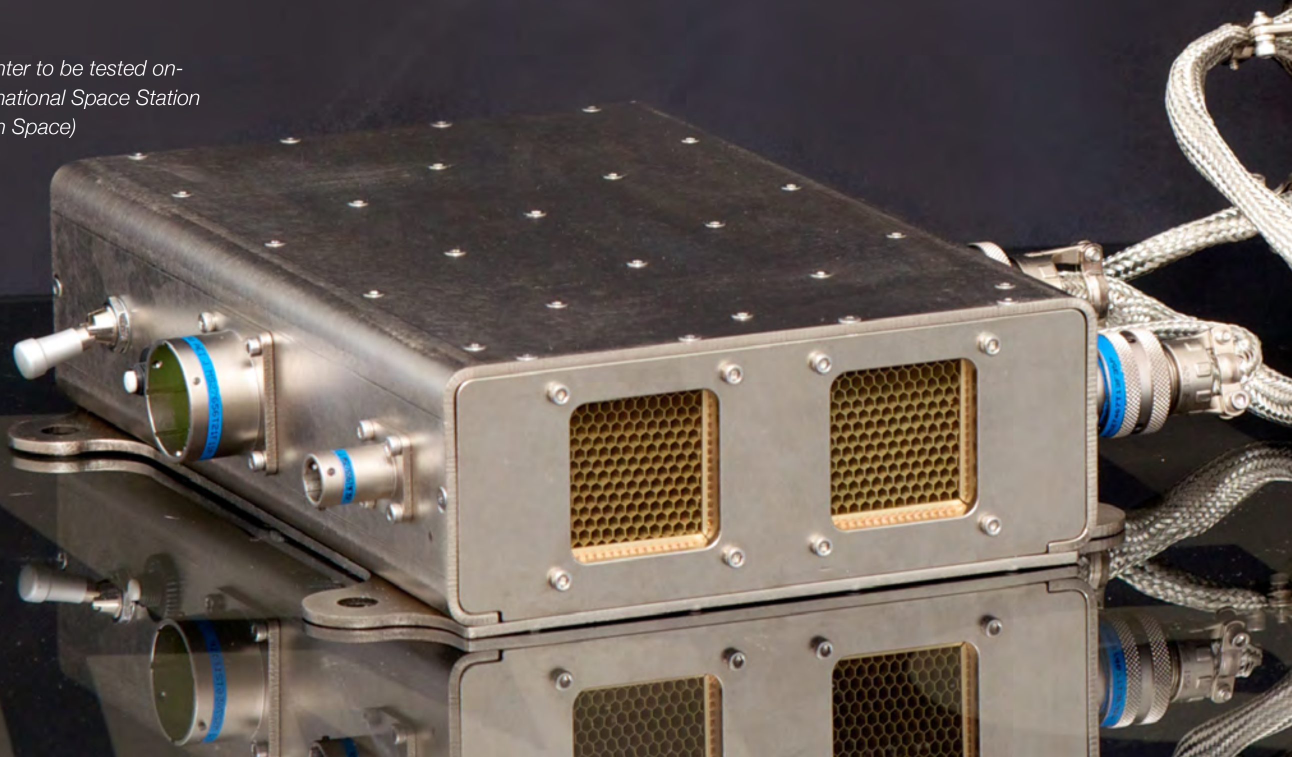
Entry, Descent and Landing (EDL) systems are an important enabling technology that cuts across many application domains. One of the great challenges to exploring the solar system is being able to land robots, humans and other assets on the surface of planets, moons and other small bodies. Initially, this was not an area where the Program anticipated being able to make a valuable contribution. However, following early demand, Masten Space Systems was able to establish itself as a flight service provider offering access to low-altitude, rocket powered Vertical Take-Off and Landing (VTOL) testbeds that can help test final descent sensors and navigation algorithms. Starting with a Program funded activity to integrate the GENIE navigation, guidance and control payload from Draper Laboratories, the “Xombie” platform has provided valuable flight testing opportunities for systems from Draper, NASA/JPL and Astrobotic Technology inc. that may help land the next generation of U.S. spacecraft on the Moon, Mars, and elsewhere in the solar system.

The following pages contain several examples of how the Flight Opportunities Program is leveraging the U.S. commercial spaceflight industry and workforce to advance space technologies to meet future mission and National needs.

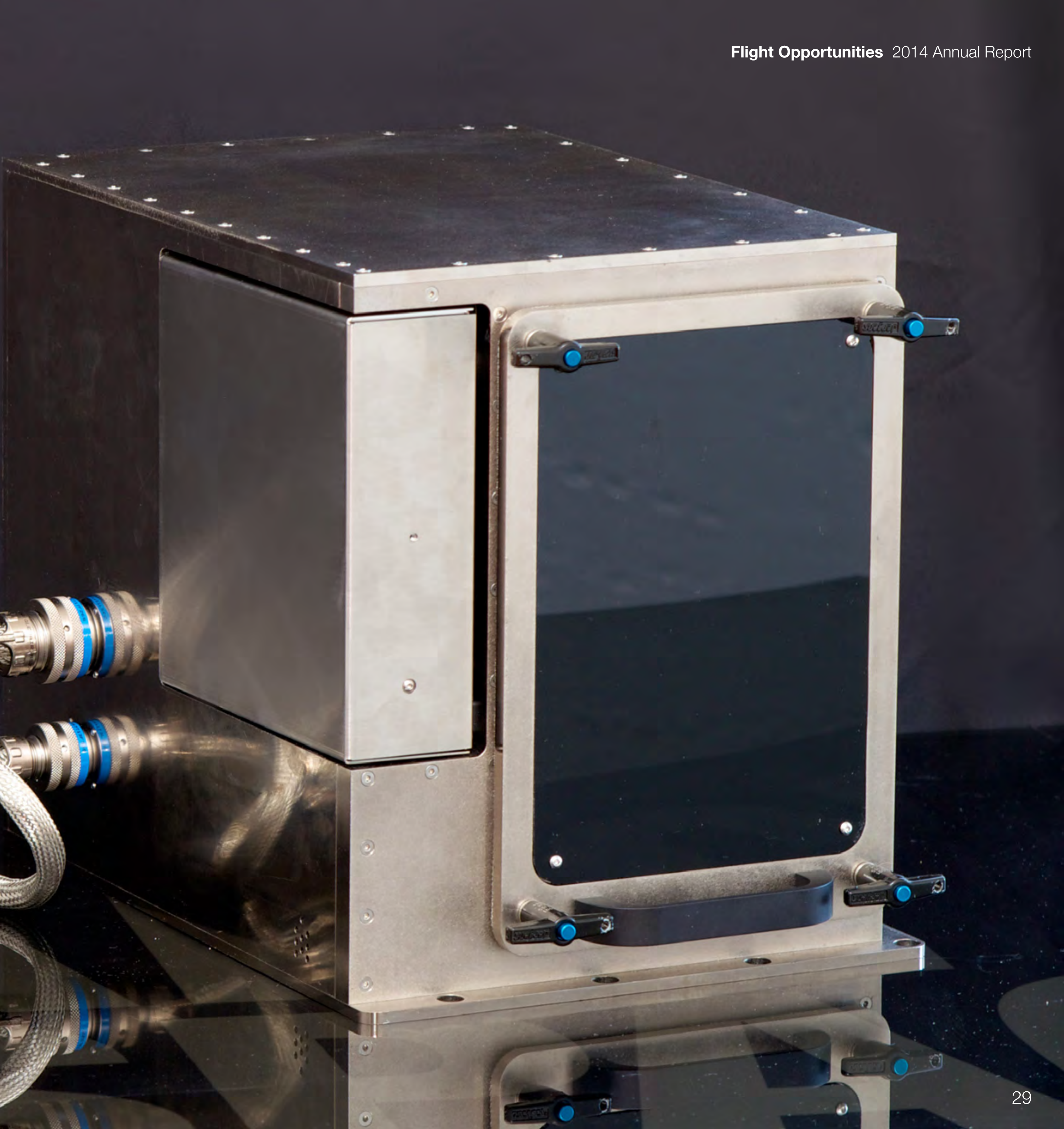
◁ *April 25, 2013 (top image): The research team from the University of Maryland and Aurora Flight Sciences Corporation observe the Resonant Inductive Near-field Generation System (RINGS) hardware (T0065) as it tries to settle in free float during in parabolic maneuver. (Photo: NASA/Devin Boldt)*

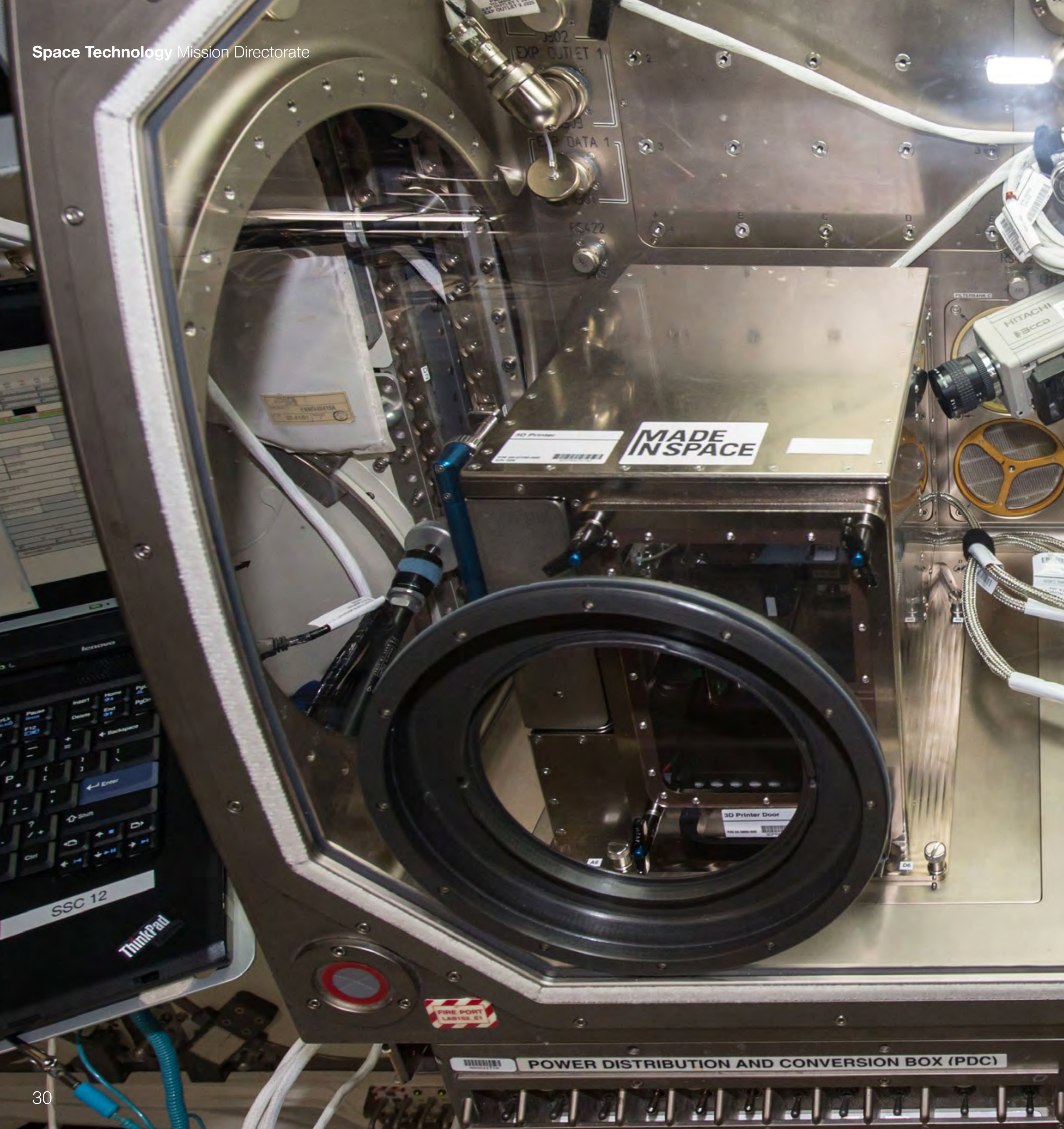
◁ *November 4, 2013 (bottom image): In the ISS’s Kibo laboratory, NASA astronaut Michael Hopkins, Expedition 37 flight engineer, conducts a session with the Resonant Inductive Near-field Generation System, or RINGS. The SPHERES-RINGS system uses the local generation of electromagnetic fields by the vehicles of a spacecraft cluster to control their relative degrees of freedom without consuming propellant. (Photo: NASA)*

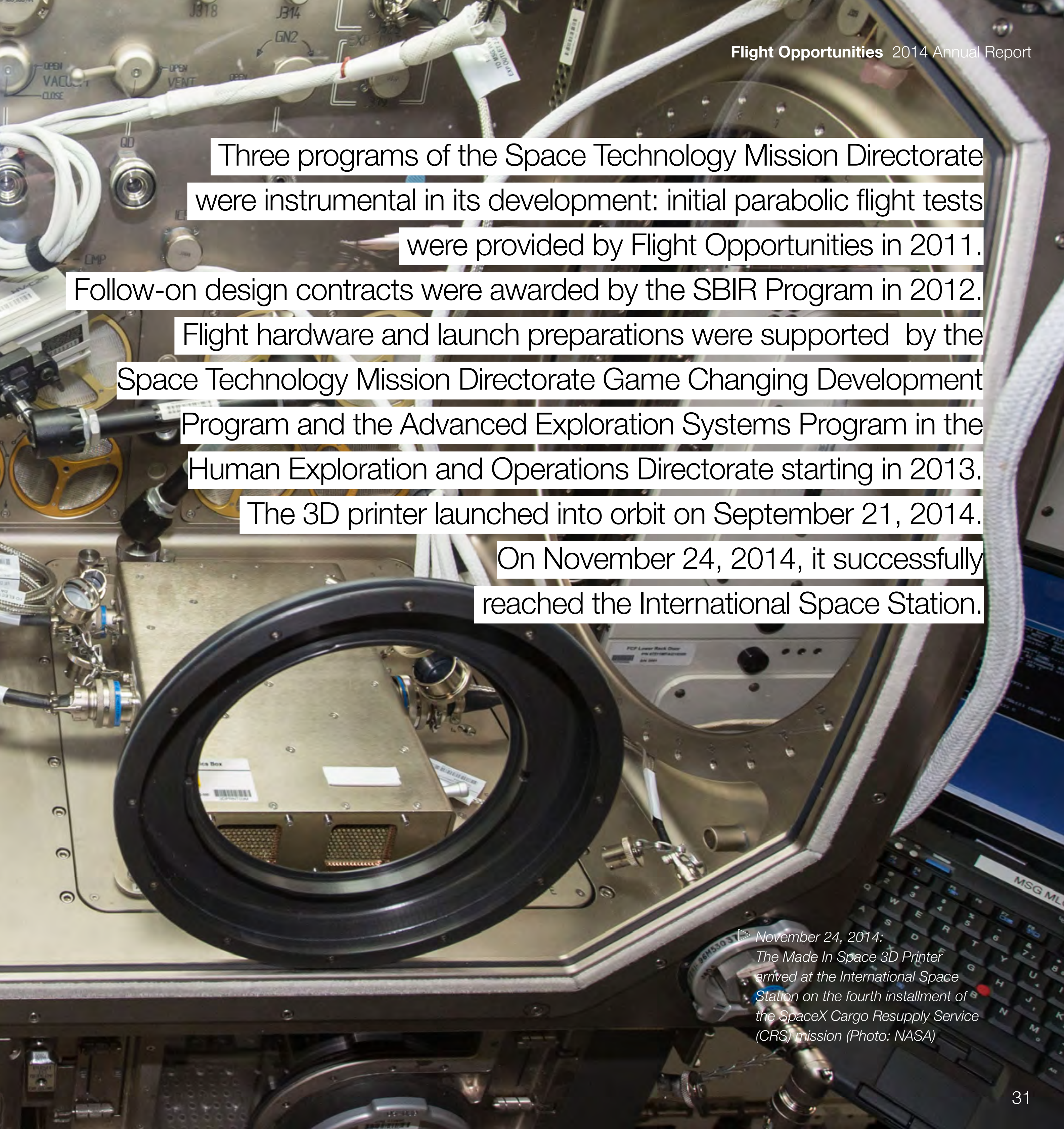
In 2011, NASA and Made In Space joined forces to design, build and test the first ever 3D printer for in-space applications. Dubbed the "3D Printing in Zero-G Experiment", this initial version of the zero-G printer serves as a test bed for understanding the long-term effects of microgravity on 3D printing.



▷ *The first 3D Printer to be tested on-board the International Space Station (Photo: Made In Space)*



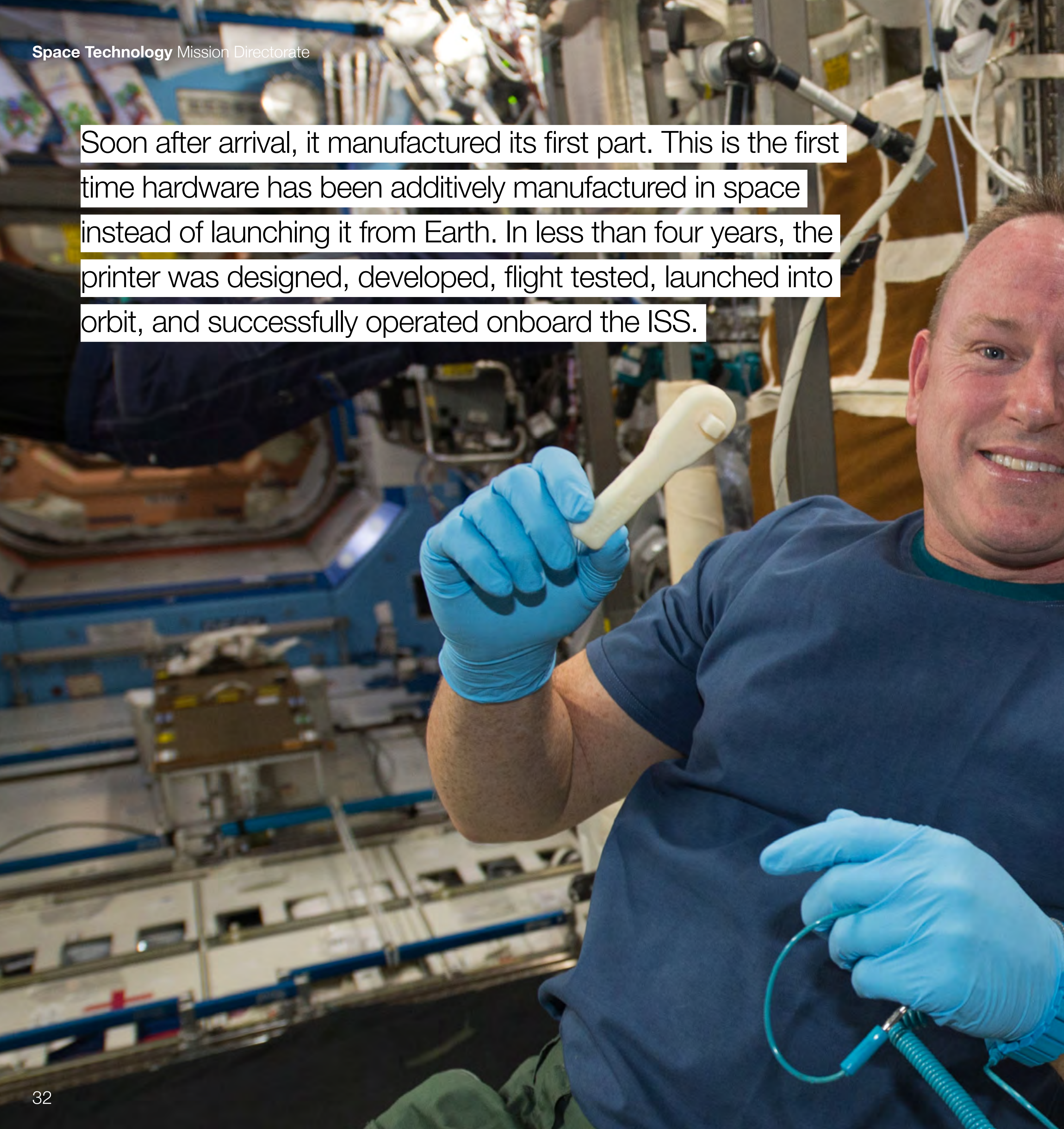

EXP OUTLET 1
EXP DATA 1
RS422
3D Printer
MADE IN SPACE
HITACHI
3D Printer Door
lenovo
SSC 12
ThinkPad
FIRE PORT
POWER DISTRIBUTION AND CONVERSION BOX (PDC)

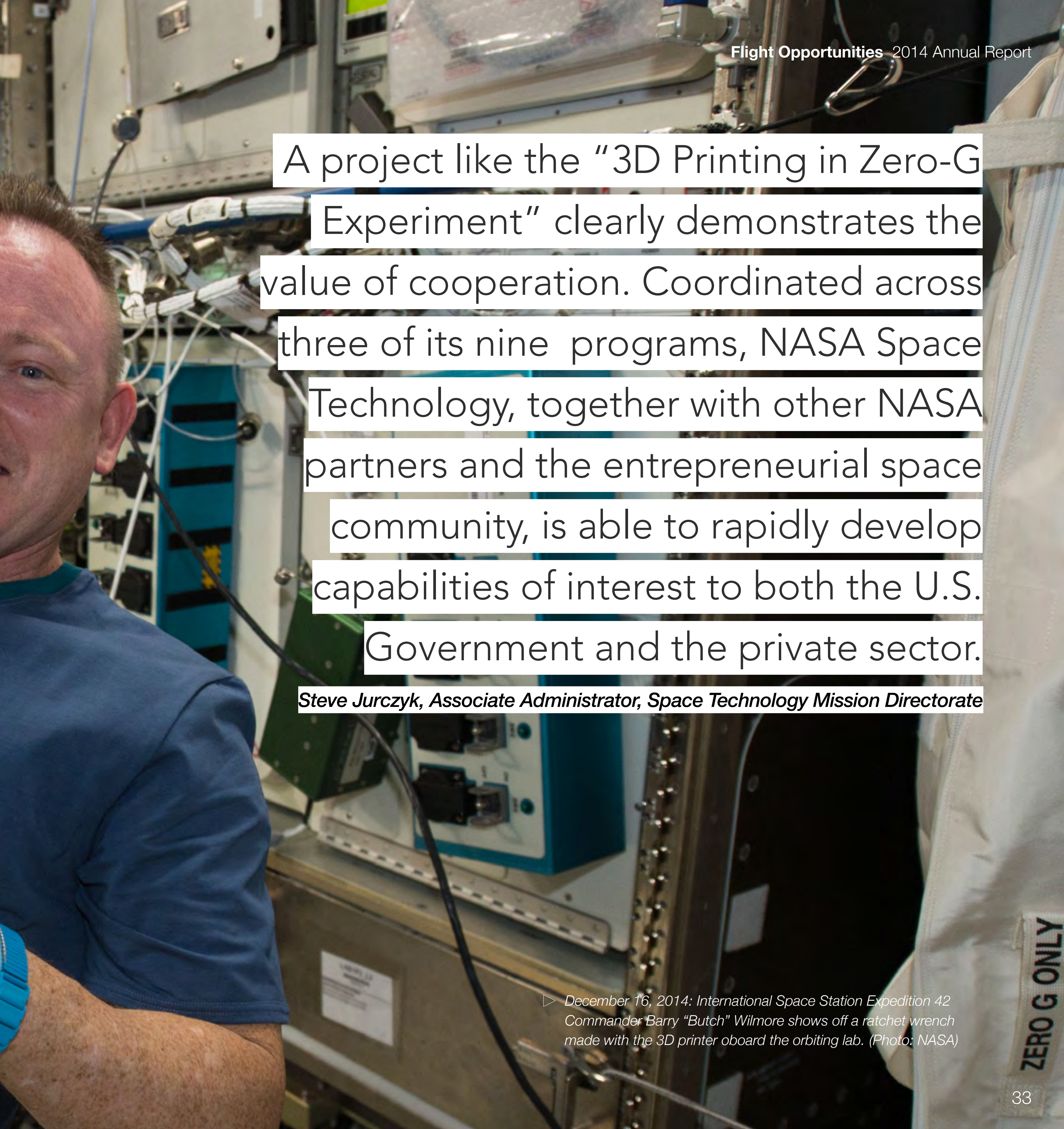


Three programs of the Space Technology Mission Directorate were instrumental in its development: initial parabolic flight tests were provided by Flight Opportunities in 2011. Follow-on design contracts were awarded by the SBIR Program in 2012. Flight hardware and launch preparations were supported by the Space Technology Mission Directorate Game Changing Development Program and the Advanced Exploration Systems Program in the Human Exploration and Operations Directorate starting in 2013. The 3D printer launched into orbit on September 21, 2014. On November 24, 2014, it successfully reached the International Space Station.

▷ November 24, 2014: The Made In Space 3D Printer arrived at the International Space Station on the fourth installment of the SpaceX Cargo Resupply Service (CRS) mission (Photo: NASA)

Soon after arrival, it manufactured its first part. This is the first time hardware has been additively manufactured in space instead of launching it from Earth. In less than four years, the printer was designed, developed, flight tested, launched into orbit, and successfully operated onboard the ISS.





A project like the "3D Printing in Zero-G Experiment" clearly demonstrates the value of cooperation. Coordinated across three of its nine programs, NASA Space Technology, together with other NASA partners and the entrepreneurial space community, is able to rapidly develop capabilities of interest to both the U.S. Government and the private sector.

Steve Jurczyk, Associate Administrator, Space Technology Mission Directorate

▷ *December 16, 2014: International Space Station Expedition 42 Commander Barry "Butch" Wilmore shows off a ratchet wrench made with the 3D printer oboard the orbiting lab. (Photo: NASA)*

Sustained investments in space technology advance the Agency's space exploration, science and aeronautics capabilities. Since the Flight Opportunities Program has such a diverse portfolio of payloads, the range of technologies selected for testing have been broadly categorized across the application themes below.

Improve the ability to efficiently access and travel through space — **Get There**

Enable the capability of landing more mass, more accurately, in more locations throughout the solar system — **Land There**

Make it possible to live and work in deep space and on planetary bodies — **Live & Work There**

Transform the ability to observe the universe and answer the profound questions in Earth and space sciences — **Observe There**

Enhance the nation's aerospace capabilities and ensure its continued technological leadership — **Invest Here**

◁ *November 12, 2013: Dr. Ou Ma (PI for T0084) of New Mexico State University (NMSU) is developing a robotics-based spacecraft on-orbit inertia identification method. UP Aerospace SL-8 was the first suborbital test flight (of two) to test the technology. In the image, NMSU graduate student Gerardo Martinez shows the payload embedded in an UP Aerospace canister to the camera. (Photo: NASA)*

Getting There

Access to, and the ability to operate in the space environment are key to being able to travel to other destinations. 58 of the 140 technology payloads address this theme. Since most other aspects of the space environment can be simulated on Earth (e.g. high vacuum, radiation), these payloads usually target microgravity (and lunar/Martian gravity) using parabolic and/or sRLV platforms.

^ P/S/B = number of completed payload-flights on Parabolic/sRLV/Balloon respectively. Usually the letter associated with the T# designation uniquely identifies the targeted platform type. If ambiguous, flights are given by platform type.
Completed projects are colored and show the Fiscal Year in which the project was concluded.
** Featured in FY13 Annual Report*

Robotics

Robotics is a broad area of research with multiple application areas. T0009 and T0060 focused on satellite servicing and were featured in the FY13 Annual Report. Knowledge gained during these tests is currently being used in on-orbit satellite servicing experiments onboard the ISS. Three other payloads (T0125, T0127, T0138) are suborbital risk reduction demonstrations for future use of the SPHERES robotic test-bed onboard the ISS.

T#	P/S/B^	Status	Title/Organization
T0138-P	1	ACTIVE	Reduced Gravity Flight Demonstration of SPHERES INSPECT *Massachusetts Institute of Technology*
T0084-S	1	ACTIVE	Suborbital Test of a Robotics-Based Method for In-Orbit Identification of Spacecraft Inertia Properties *New Mexico State University*
T0127-P	1	FY14	Reduced Gravity Flight Demo of SPHERES Universal Docking Ports *Massachusetts Institute of Technology*
T0125-P	1	FY14	Human Exploration Telerobotics (HET) Smartphone *NASA/Ames Research Center*
T0105-P	1	FY14	DYMAFLEX: DYnamic MAnipulation FLight EXperiment *University of Maryland*
T0060-P	1	FY13*	Dynamic and Static Behavior of a Flexible Fuel Hose in Zero-G *Jackson and Tull*
T0009-P	2	FY12*	Autonomous Robotic Capture *NASA/Goddard Space Flight Center*

ADS-B Flight Testing

In order to allow efficient access to, and return from space, future commercial suborbital and orbital launch and re-entry systems need to be safely integrated into the National Airspace System (NAS). Together with the FAA, NASA is conducting increasingly complex demonstrations onboard balloons and suborbital reusable launch systems to demonstrate viability of ADS-B (*Automatic Dependent Surveillance - Broadcast)* technology beyond its current design altitude of 60,000ft. The latest evaluation under T0099-B included two high altitude balloon flights to assess overhead reception of ADS-B signals from operational aircraft and ground stations by future satellite platforms. More detail on these test flights is provided on the following pages.

T#	P/S/B	Status	Title/Organization
T0106-B		ACTIVE	Low-Cost Suborbital Reusable Launch Vehicle (sRLV) Surrogate *GSSL Inc.*
T0061-SB	-/1/1	ACTIVE*	Flight Testing of a UAT ADS-B Transmitter Prototype for Commercial Space Transportation Using sRLV *Embry-Riddle Aeronautical University*
T0099-B	2	FY14	Satellite-Based ADS-B Operations Flight Test *GSSL Inc.*
T0033-B	1	FY13*	Flight Testing of UAT ADS-B Transmitter Prototype for Commercial Space Transportation *Embry-Riddle Aeronautical University*
T0002-S	2	FY13*	Automatic Dependent Surveillance-Broadcast (ADS-B) *FAA Commercial Space Transportation*

Structural Health Monitoring

Integration of health monitoring technology into vehicles will improve the reliability of space systems. Two independent technology development efforts completed flight testing in FY14. Each of the teams is using the knowledge gained through these tests to inform further development and miniaturization of the health monitoring hardware.

T#	P/S/B	Status	Title/Organization
T0093-P	1	FY14	Wireless Strain Sensing System for Space Structural Health Monitoring *University of Texas, Arlington*
T0038-SB	-/1/1	FY14*	Structural Health Monitoring for Commercial Space Vehicles *New Mexico Institute of Mining and Technology*

▷ *October 11, 2013: Payload hang test with the TAMLACE payload inside the Small Balloon System (SBS) gondola. The 1090ES ADS-B transponder antenna can be seen underneath the gondola. It is suspended 6 feet below the gondola during flight. (Photo: Near Space Corporation)*

Satellite-based ADS-B Operations Flight Test (T0099)

Russ Dewey (PI)
Near Space Corporation

Nick Demidovich (Co-I)
FAA Office of Commercial Space Transportation

Bruce Webbon (NASA Campaign Manager)
NASA/Ames Research Center

Automatic Dependent Surveillance-Broadcast (ADS-B) is a surveillance technology for tracking aircraft as part of the Next Generation Air Transportation System. ADS-B enhances safety by making an aircraft visible, real-time, to Air Traffic Control (ATC) and to other appropriately equipped ADS-B aircraft with position and velocity data transmitted every second. The United States will require the majority of aircraft operating within its airspace to be equipped with some form of ADS-B Out by January 1, 2020.

The international aviation community is also currently migrating to ADS-B. One current limitation to the worldwide implementation of ADS-B is a lack of ground stations (and hence position broadcasts to other aircraft) over large transoceanic and polar areas that are critical to the commercial aviation marketplace. To incorporate these areas under the ADS-B 'umbrella', there are plans to include ADS-B nodes on future satellite platforms, including both Iridium and GobalStar next generation satellites.

Flying a surrogate satellite ADS-B system

To date, there has been little testing of the efficacy of overhead collection as it applies to the ADS-B architecture. Near Space Corporation (NSC) and CNS Aviation Services therefore partnered to fly a surrogate satellite ADS-B system at high altitude to evaluate overhead reception of both Universal Access Transceiver (UAT; 978 MHz) and 1090 Extended Squitter (ES) ADS-B signals from operational aircraft and ADS-B ground stations by future satellite platforms. Selected under AFO6, the Flight Opportunities Program awarded the team two NSC-provided balloon flights. CNS Aviation provided the Transportable ADS-B Multi Link Airborne Coverage Evaluator (TAMLACE) dual frequency ADS-B transceiver that was integrated with the balloon systems for the tests. The FAA-AST Commercial Space Office sponsored CNS Aviation to modify the TAMLACE system to incorporate very high altitude GPS capabilities and an internal data recorder for all uplink and downlink ADS-B related messages on both 1090ES and 978UAT systems.

Two successful balloon flights

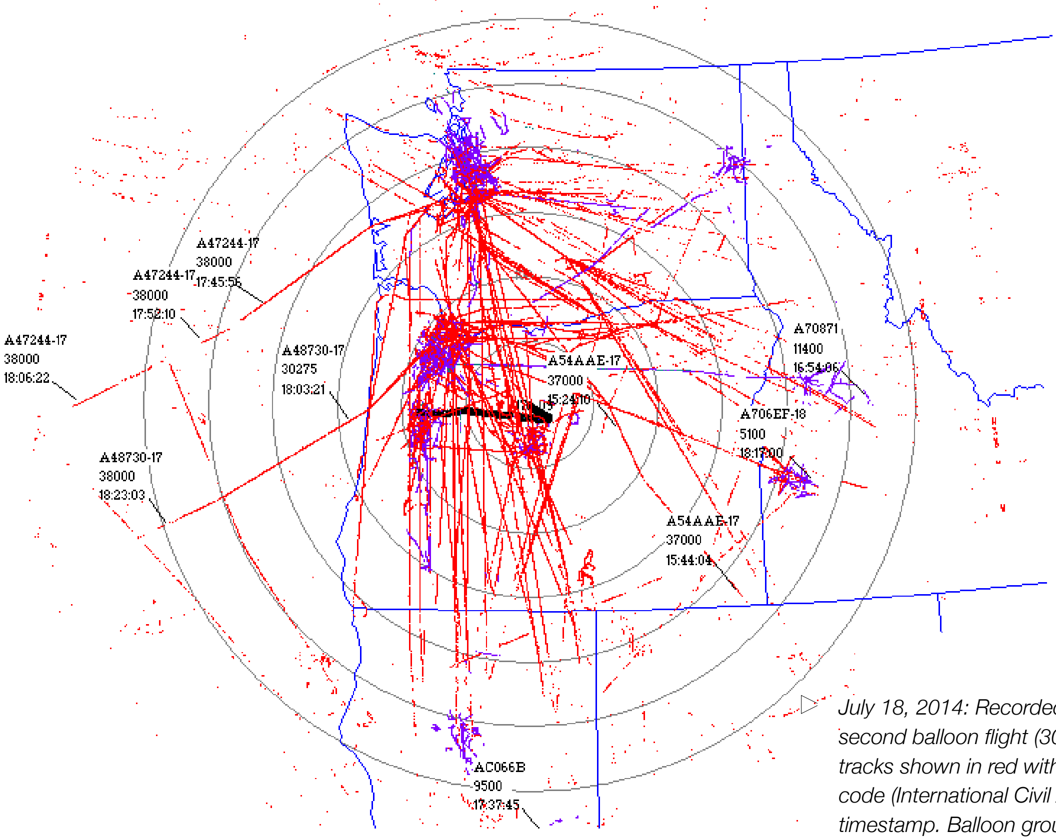
The first NSC balloon was launched on 5 December 2013 from NSC's Johnson Near Space Center (JNSC) in Tillamook, OR. The balloon reached an altitude of 95,000' (29km) and remained at that altitude for 1.3 hours. The goal of this first test flight was to capture ADS-B broadcasts in real-time from both commercial and general aviation aircraft equipped with ADS-B transponders on both frequencies from well above the target aircraft, effectively simulating ADS-B reception from satellites. Overall results were very encouraging and showed that communications between the balloon-borne TAMLACE ADS-B package and the FAA network of Surveillance and Broadcast Service (SBS) ground stations was very good on both links. The test flight also marked the first time a 1090ES ADS-B signal from a high altitude platform had been received and processed "on the glass" at an FAA Air Route Traffic Control Center, "Seattle Center" in this case.

The data collected was compared by the FAA's William J. Hughes Technical Center with ADS-B data that had been received in real-time by 18 ADS-B Ground Based Terminals (GBTs) that were within line of sight of the balloon, to evaluate its completeness and the efficiency of overhead ADS-B collection. The results showed excellent correlation between the data collected by the payload and that collected by GBTs. The payload detected ADS-B broadcasts from targets over 300nm away, in excess of what was expected and well beyond the range that can be collected from the ground. The payload also continuously received Traffic Information Service-Broadcasts (TIS-B) and Flight Information Service – Broadcasts (FIS-B) whenever it was within line-of-sight of a GBT.

On 18 July 2014, Near Space Corporation (NSC) successfully launched the second balloon from the Madras Regional Airport (OR). The second flight repeated the first flight's success. It was specifically launched to collect data during the period of highest daily aviation air traffic density (10-11am PDT) as determined by the FAA's Seattle Center.

Looking ahead

In summary, the overall results were very encouraging and showed that communications between the balloon borne TAMLACE payload and the FAA ground SBS network of ground stations was very good on both links. Air to Air ADS-B reception range as seen by the payload's 1090ES receiver was on the order 350 nm max range and the potential exists for longer range reception using a more sensitive 1090ES receiver. Lessons learned will support development and refinement of satellite-based ADS-B architectures which are particularly important for effective coverage of large open ocean areas with no ADS-B ground stations to enhance trans-oceanic air safety. Until satellite-based ADS-B is operational, a balloon-based capability could also be used (on-demand) to augment the existing ADS-B system. This would create the ability to track aircraft where there are currently gaps in ADS-B coverage, including coastal areas, trans-oceanic aircraft and mountainous regions where there are gaps in coverage below certain altitudes. Such a balloon-based system would be an enabling technology for a mobile range capability to enhance flight safety for launches from remote locations. This capability would augment/improve downrange surveillance capability for commercial spaceports and government ranges.



July 18, 2014: Recorded 1090ES and UAT traffic during the second balloon flight (300nmi area of solid tracks). Aircraft tracks shown in red with identification tag including ICAO code (International Civil Aviation Organization), altitude and timestamp. Balloon ground track shown as heavy black line. Hotspot above black line is Portland airport. Further north is Seattle airport. (Photo: CNS)

December 5, 2013: launch of the first balloon carrying the surrogate satellite-based ADS-B payload to an altitude of 95,000ft (29 km). (Photo: Near Space Corporation)

Thermal Control

Thermal control is vital for any system designed to operate in the space environment. This is an active field of research to develop technologies to maintain (sub)systems within allowable temperature limits. To date, all completed flight tests for thermal control systems were performed using parabolic flight, with five of the six remaining payloads targeting an sRLV platform. A similar pattern can be observed across most areas, hinting both at a natural progression in the research and the limited availability of sRLV flights to date.

Starting from the earliest completed activity (bottom of table), data gathered from T0006 was used in combination with data from the MABE experiment onboard the ISS to quantify changes to boiling heat transfer relative to gravitational acceleration. Results of this research were published in 2012 (see publications on pages 86/87). Additional research on flow boiling was conducted under T0005 and continues outside of Flight Opportunities. The cryocooler characterization (T0011) was successfully completed and feeds into the design of the Variable Specific Impulse Magnetoplasma Rocket (VASIMR) by the Ad Astra Rocket Company. Two other thermal control efforts led to additional technology development and further flight testing. The Air Force research conducted under T0017 led to T0091 and the NASA research under T0014 led to T0073.

T#	P/S/B	Status	Title/Organization
T0081-S		ACTIVE	Demonstration of Variable Radiator *Texas A&M University*
T0073-S		ACTIVE	Radial Core Heat Spreader *NASA/Glenn Research Center*
T0020-PS	2/-/-	ACTIVE	Microgravity Multi-Phase Flow Experiment for Suborbital Testing (MFEST) *NASA/Johnson Space Center*
T0087-S		PENDING	Electric-hydrodynamic Control of Two-Phase Heat Transfer in Microgravity *New Jersey Institute of Technology*
T0078-S		PENDING	Enhanced Thermal Switch *Johns Hopkins University Applied Physics Laboratory*
T0043-P	1	PENDING	Parabolic Flight: Validation of Electro-Hydrodynamic Gas-Liquid Phase Separation in Microgravity *New Jersey Institute of Technology*
T0091-P	1	FY14	Resilient Thermal Panel: Microgravity Effects on Isothermality of Structurally Embedded Two Dimensional Heat Pipes *Air Force Research Laboratory*
T0014-P	3	FY13*	Heat Pipe Limits in Reduced Gravity Environments *NASA/Glenn Research Center*
T0041-P	1	FY12	Effects of Reduced Gravity on Flow Boiling and Condensation *Purdue University*
T0017-P	1	FY12	Iso-grid, Thermal-Structural Panel (IsoTherm) *Air Force Research Laboratory*
T0011-P	4	FY12	Cryocooler Vibrational Characterization *Ad Astra Rocket Company*
T0005-P	2	FY12	Advanced Two-Phase Heat Exchangers Design Tools *University of Maryland*
T0006-P	1	FY11	Electric Field Effects on Pool Boiling Heat Transfer *University of Maryland*

Propellant Management

Long duration spaceflight relies on the efficient use and management of propellants. One important aspect of propellant management is the development of accurate and robust methods of mass gauging in both settled and unsettled propellant states. The traditional way to gauge the amount of propellants in a low-gravity environment is to 'settle' the liquid in the tanks by accelerating the vehicle (which acts like a gravity vector to concentrate the liquid at the 'bottom' of the tank) and measuring the liquid level. This can, however, lead to inaccuracies, resulting in the need for additional propellant mass to cover the uncertainty. Novel ways to gauge propellant levels in low-gravity environments through RF, modal analysis and optical means show promise and have been (or are scheduled to be) flight tested on parabolic microgravity flights. T0007 has successfully concluded parabolic flight testing and is currently awaiting an opportunity to continue on an sRLV under T0024. Several other propellant mass gauging-related subsystems are scheduled for demonstration on both parabolic and sRLV flights (T0039, T0109, T0123). Other propellant management technologies listed include a new propellant management device by SpaceX (T0136) and a new technology for controlling multiphase flows using controlled harmonic vibrations (T0021).

T#	P/S/B	Status	Title/Organization
T0128-S		ACTIVE	Zero-gravity Green Propellant Management Technology *Purdue University*
T0123-P	1	ACTIVE	Microgravity Propellant Gauging Using Modal Analysis *Carthage College*
T0109-P		ACTIVE	Advanced Optical Mass Gauge *Mass Dynamix, Inc.*
T0086-S		ACTIVE	Saturated Fluid Pistonless Pump Technology Demonstrator *University of Colorado*
T0035-S		ACTIVE	Near-Zero Gravity Cryogenic Line Chilldown Experiment in a Suborbital Reusable Launch Vehicle *University of Florida*
T0024-S		ACTIVE	RF Gauging of the Liquid Oxygen Tank on sRLV *NASA/Glenn Research Center*
T0021-S	1	ACTIVE	Application of controlled vibrations to multiphase systems *Universitat Politècnica de Catalunya / University of Alabama, Huntsville*
T0003-PS	2/-/-	ACTIVE	On-Orbit Propellant Storage Stability *Embry-Riddle Aeronautical University*
T0039-P		PENDING	Fuel Mass Gauging Based on Electrical Capacitance Volumetric Tomography Techniques *NASA/Goddard Space Flight Center*
T0136-P	1	FY14	Dragon V2 Propellant Management Device Microgravity Validation *Space Exploration Technologies*
T0007-P	2	FY11	Radio Frequency Mass Gauge on Parabolic Flights *NASA/Glenn Research Center*

Cubesats

Most of the completed (colored) projects listed below have successfully launched to orbit or are scheduled for launch. T0032 was launched in November 2013, T0065 was operated onboard the ISS, T0089 was deployed from the ISS into low-Earth orbit and T0047 is a competitor in the Air Force "University Nanosat Program" (UNP). Of the nine active/pending payloads, seven were selected at a TRL-3 level through NRA1/NRA2 where ground-based development was factored into the timeline.

T#	P/S/B	Status	Title/Organization
T0133-P	1	ACTIVE	Payload Separation Performance of a New 6U CubeSat Canisterized Satellite Dispenser *Air Force Research Laboratory*
T0119-S		ACTIVE	Inductively Coupled Electromagnetic (ICE) Thruster System Development for Small Spacecraft Propulsion *MSNW LLC*
T0116-S		ACTIVE	Operational Demonstration of the MPS-120 CubeSat High-impulse Adaptable Modular Propulsion System *Aerojet General Corporation*
T0088-S		ACTIVE	An FPGA-based, Radiation Tolerant, Reconfigurable Computer System with Real Time Fault Detection, Avoidance, and Repair *Montana State University*
T0083-S		ACTIVE	Design and Development of a Micro Satellite Attitude Control System *State University of New York, Buffalo*
T0056-P		ACTIVE	UAH ChargerSat - 2 Parabolic Flight Testing *University of Alabama, Huntsville*
T0120-S		PENDING	Advanced Hybrid Rocket Motor Propulsion Unit for CubeSats (PUC)r *The Aerospace Corporation*
T0118-S		PENDING	Iodine RF Ion Thruster Development *Busek Co. Inc.*
T0117-S		PENDING	1U CubeSat Green Propulsion System with Post-Launch Pressurization *Busek Co. Inc.*
T0130-P	1	FY14	Reinventing the wheel: parabolic flight validation of reaction spheres *NASA/Goddard Space Flight Center*
T0101-P	1	FY14	Testing a CubeSat Attitude Control System in Microgravity Conditions *University of Central Florida*
T0096-P	2	FY14	Testing the Deployment and Rollout of the DragEN Electrodynamic Tether for CubeSats *Saber Astronautics Australia Pty. Ltd.*
T0089-P	1	FY14	Technology Maturation of a Dual-Spinning CubeSat Bus *Massachusetts Institute of Technology*
T0055-P	1	FY14	Structural Dynamics Test of STACER Antenna Deployment in Microgravity *Massachusetts Institute of Technology*
T0047-P	3	FY14	Boston University Student Proposal for Deployable Solar and Antenna Array Microgravity Testing *Boston University*
T0065-P	1	FY13*	Reduced Gravity Flight Demonstration of the Resonant Inductive Near-field Generation System (RINGS) *University of Maryland*
T0032-P	1	FY12	UAH CubeSat Parabolic Flight Testing *University of Alabama, Huntsville*

▷ *February 27, 2014: University of Florida researcher Nick Pelaez (T0101) observes a Cubesat prototype in free flight during one of the parabolas of the RGO-13 campaign. The objective of this test flight was to test a cubesat attitude control system that relies on two magnetic induction coils mounted on orthogonal sides of the cubesat. These coils interact with the Earth's magnetic field, resulting in rotation of the cubesat to a desired orientation. (Photo: NASA/Bill Stafford)*

June 20, 2014: Integration of the Astrobotic payload onto the Xombie vehicle at the Masten Space Systems office in Mojave, CA. (Photo: NASA/Ken Ulbrich)

Landing There

Entry, Descent & Landing (EDL) is an important cross-cutting technology in which NASA has invested across multiple STMD programs. EDL testing conducted through Flight Opportunities ranges from low-altitude descent and landing using lander testbeds, to high-altitude release and descent from balloons, and suborbital re-entry and descent after ejection from an sRLV.

Suborbital Re-entry & Descent

T#	P/S/B	Status	Title/Organization
T0139-S		ACTIVE	ADEPT *NASA/Ames Research Center*
T0115-S		ACTIVE	EDL Technology Development for the Maraia Earth Return Capsule *NASA/Johnson Space Center*
T0075-S		ACTIVE	Exo-Atmosperic Aerobrake *NASA/Ames Research Center*

High Altitude Release & Descent

T#	P/S/B	Status	Title/Organization
T0066-B	1	ACTIVE	Guided Parafoil High Altitude Research *Airborne Systems North America of CA, Inc.*
T0064-B		ACTIVE	Deployable Rigid Adjustable Guided Final Landing Approach Pinions (DRAG FLAPs) *Masten Space Systems Inc.*

Low-altitude Descent & Landing

T#	P/S/B	Status	Title/Organization
T0137-S		ACTIVE	Fuel Optimal and Accurate Landing System Test Flights *NASA/Jet Propulsion Laboratory*
T0121-S		ACTIVE	Flyover Mapping and Modeling of Terrain Features *Carnegie Mellon University*
T0098-S		ACTIVE	Navigation Doppler Lidar Sensor Demonstration for Precision Landing on Solar System Bodies *NASA/Langley Research Center*
T0034-S		ACTIVE	Terrain Relative Navigation Descent Imager (TRNDI) *Draper Laboratory*
T0067-S	3	FY14	Autolanding for Robotic Precursor Missions *Astrobotic Technology, Inc.*
T0068-S	2	FY13*	Fuel Optimal Large Divert Guidance for Planetary Pinpoint Landing (G-FOLD) *NASA/Jet Propulsion Laboratory*
T0016-S	5	FY13*	Guidance Embedded Navigator Integration Environment (GENIE) *Draper Laboratory*

Autolanding for Robotic Precursors (T0067)

Kevin Peterson (PI) and Lauren Schneider
Astrobotic Technology, Inc.

Nathan O'Konek & Kellie Gerardi
Masten Space Systems

Chris Baker (NASA Campaign Manager)
NASA/Armstrong Flight Research Center

On June 20, 2014, an autonomous autolanding system developed by Astrobotic Technology Inc. successfully commanded a propulsive lander to a safe landing in a hazard field at the Mojave Air and Space Port. Using cameras and feature recognition algorithms to match terrain observed beneath the rocket with an onboard map of the area, the Astrobotic Autolanding System (AAS) was able to independently determine the vehicle's location within a few meters (yards) and land safely on the ground. The AAS used a LIDAR to create a three-dimensional scan of the surface during descent (see image on the left), then mapped out the location of objects larger than 25 centimeters (10 inches) and selected a clear section of the target landing area. The technology behind the AAS extends a decade of cutting edge robotics research by Astrobotic partner Carnegie Mellon University in autonomous ground vehicles and helicopters. This capstone flight was the third in a series of AAS flights on Masten Space Systems' XA-0.1B Xombie vehicle that were funded by Flight Opportunities.

Interesting terrain is challenging terrain

Robotic missions today target the center of large, statistically safe landing areas. However, many targets of scientific interest are located in terrain with challenging topography such as currently inaccessible areas on Mars, the Moon or the jagged, icy surface of Europa. In order to land safely at these sites, the spacecraft requires knowledge of its location relative to the target and the ability to detect and react to surface hazards as it approaches for landing. NASA, Astrobotic and others seek to demonstrate new capabilities for precision landing and autonomous hazard avoidance to enable future missions to access these new areas for exploration.

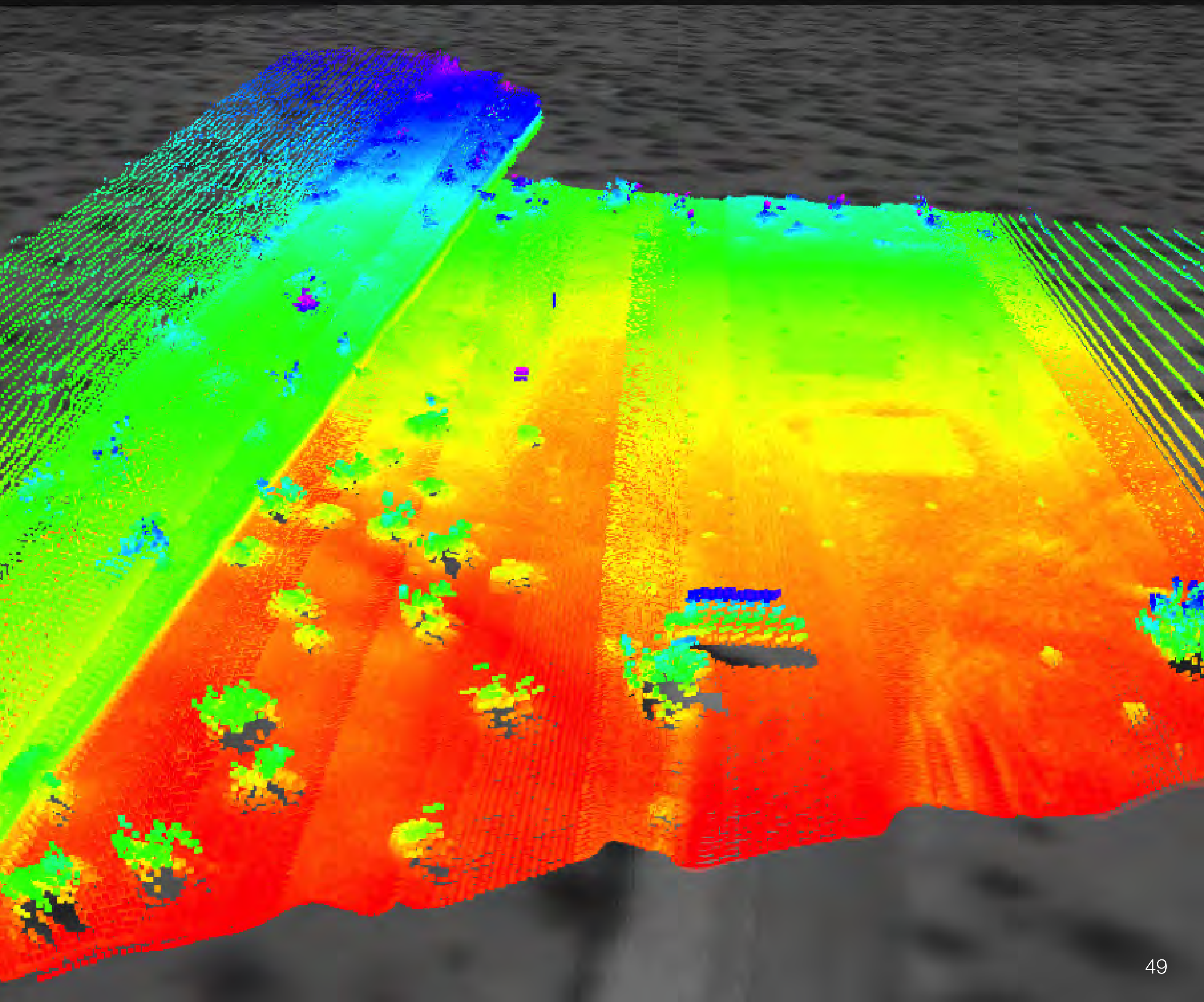
Google Lunar XPRIZE and the Lacus Mortis lava plain

Astrobotic, along with partner Carnegie Mellon University, plans to launch a robotic lunar mission that will attempt to explore a pit in the Moon's Lacus Mortis ("Lake of Death") lava plain and claim the Google Lunar XPRIZE. Astrobotic is targeting the pit because it is a high-value target that could yield valuable data for scientific discovery and future exploration. In addition to the 100m wide pit, imagery from orbiting spacecraft has revealed other challenging terrain features in the intended landing area, including several large craters and a rille. Moreover, it is expected that Lacus Mortis will be strewn with rocks and other hazards too small to be visible in existing satellite imagery. This mission will therefore require the Astrobotic spacecraft to overfly the Lacus Mortis pit to land safely, and precisely, near its edge.

Astrobotic Autolanding System (AAS)

The Astrobotic Autolanding System (AAS) will use a technique known as Terrain Relative Navigation (TRN) to navigate precisely above the lunar surface. TRN uses sensor systems and feature recognition software to match observed terrain with a preloaded map. The AAS combines inertial measurements and map registration of imagery captured by onboard cameras to determine a spacecraft's position relative to the surface. Already used for military applications in GPS-denied environments, TRN is essential for accurate landing of spacecraft beyond Earth and its orbiting GPS constellation.

June 20, 2014: Composite view of the Mojave desert seen though the Astrobotic landing sensors mounted on the Masten Xombie vehicle. ▷ The Astrobotic system uses sensor input, including the LIDAR elevation data seen here, to identify safe landing areas. Two of the three Masten landing pads are visible as square shaped slight color variations on the right side of the image. Sandbags placed to simulate rocks and other small hazards are visible as small dots around the pads. The larger elevation changes seen are caused by bushes and a safety barricade. (Photo: Astrobotic Technology)



June 20, 2014: The Xombie lander after touch down on one of the two open landing pads at the Mojave Air and Space Port. The central landing pad (foreground) and the cleared area around the three pads was set with sandbags to simulate rocks and other landing hazards. (Photo: NASA/Ken Ulbrich)

Precisely targeting a location that avoids large obstacles from altitude is only part of the solution. To land safely in rough terrain, a robotic vehicle must be aware of, and react to, the smaller scale features of landscape beneath it. During the final descent to the lunar surface, the AAS will use a LIDAR to create a three-dimensional point cloud of the target landing area. The system assembles this surface scan to reveal rocks, ditches, steep slopes, and other potential hazards to the lander. From these data, the AAS autonomously identifies and selects a portion of the target area that is free of impediments to a safe landing.

Simulating the lunar landing on Earth

One of the challenges in developing hardware and software to land a spacecraft is finding ways to test the system in a relevant operational environment before it leaves the Earth. Gantry systems, helicopters, and supersonic aircraft fulfill vital roles in evaluating how a new technology will perform in specific portions of a landing trajectory, but there are few true terrestrial analogs of a lunar or Martian landing. Prior to the flights on Xombie, the technologies behind the AAS were matured through autonomous helicopter landings, small ro-

LAVA TUBES

Lava tube caves are formed by volcanic activity; the top layer of a channel of lava cools and forms a crust, leaving a void space when the hotter lava in the center of the channel flows out. These caves typically form close to the surface and can range from a single tube to a complex labyrinth that can extend for miles. Skylights, formed by cave ceiling collapse, can provide entrance into these caves. Signs of ancient volcanic activity are prevalent on the Moon. Several skylights have been characterized from orbital image data. Astrobotic is planning a mission to land and explore near a potential skylight in the Lacus Mortis region. Lacus Mortis is located in a plain of basaltic lava flow with winding valleys (sinuous rilles) believed to be collapsed lava tubes.

In April 2012, two pits (one a potential skylight) in Lacus Mortis were identified by NASA's Lunar Reconnaissance Orbiter Camera (LROC). Imagery from lunar orbit shows that one pit has a partially collapsed wall that may form a ramp traversable by a robotic rover, potentially providing access to a collapsed lava bubble or part of a network of dried lava tubes from the Moon's early history. Scientific investigation of lava tube caves can yield discoveries related to cave morphology, formation mechanisms, mineral and volatile concentrations, and astrobiology.

EXPLORATION BEYOND THE MOON

Advanced landing capabilities like those demonstrated by the AAS are needed to enable new science and exploration missions beyond the Moon. Precision landing is necessary for multi-mission scenarios such as landing a sample-return spacecraft near a Mars rover, or cargo and supplies near a manned expedition.

The combination of precision landing with hazard detection and avoidance also opens up new destinations for exploration. Martian terrain features like mountains and canyons have high value in revealing the geological history of the planet, but are challenging targets for landing. Each Mars mission makes tradeoffs between safety and science. Advanced landing capabilities would not address safety issues such as dust depth or sufficient solar power, but would greatly relax other safety constraints such as rock density and slope.

Other challenges come from a lack of accurate a priori knowledge of the surface, such as when landing on an unmapped asteroid or in an environment with shifting surface features. For example, when contemplating missions to the surface of Europa, where the ice re-forms and the topography will change between a mapping mission and a landing mission, the necessity of new autonomous landing technologies is apparent.

torcraft flight, and simulation. However, before the work began on implementing the AAS with space-rated sensors and avionics, Astrobotic sought to conduct an end-to-end validation of the AAS' precision guidance and hazard detection capabilities in an environment relevant to their intended lunar landing.

To evaluate the AAS during the propulsive lander flight tests, Astrobotic and Masten collaborated on a framework that enabled two of the flights to take place without prior knowledge of exactly where the rocket would choose to land. As the vehicle descended from a 260 meter (853 foot) apogee and moved downrange toward the landing area, the AAS scanned the ground with its LIDAR to map objects larger than 25 centimeters (10 inches) and select a safe touchdown point in the target area. Because much of the cleared landing area would look safe to a system designed to touchdown on the lunar surface, engineers placed sand bags as mock hazards to corral the vehicle towards the three concrete landing pads. To further exercise the AAS, the center landing pad, which Xombie was targeting at launch, was deliberately fouled by placing sand bags around its edges. This left the other two pads as the only locations in the target area free of hazards.

Using an onboard safety system that monitored input from the AAS, Astrobotic and Masten were able to realistically test the system by leaving it free to choose any location for landing. If the AAS selected a landing point other than one of the two open pads, Masten software would override the prototype system to land the vehicle safely. These successful tests made possible by Flight Opportunities has enabled Astrobotic to begin work on a space-rated version of the AAS system for their commercial lunar lander.

Extension to future NASA missions

Systems capable of precisely navigating a lander to a specific target and then autonomous selecting a safe landing location near that target are critical to enabling missions to destinations with challenging topography and limited communication. In April of 2014, NASA announced selection of three U.S. companies, including Astrobotic and Masten, to partner with the Agency under the NASA Lunar Cargo Transportation and Landing by Soft Touchdown (Lunar CATALYST) initiative. This activity seeks to advance lander capabilities for delivery of payloads to the surface of the Moon. Commercial lunar transportation capabilities could support science and exploration objectives such as sample returns, geophysical network deployment, resource prospecting, and technology advancements. NASA is also studying the potential use of Terrain Relative Navigation on the Mars 2020 mission to allow the rover to land closer to sites of high scientific interest.

▷ *June 20, 2014: The combined Masten/Astrobotic team. From left to right: Kerry Snyder, Steve McGuire, Neal Bhasin, Scott Nietfeld, Nick Robbins, Travis O'Neal, Dennis Poulos, Joey Oberholtzer, Jeff Gibson, Kevin Peterson, David Masten, Tyler Roberson, Ben Dagang, Nathan O'Konek, Kyle Nyberg, Wennie Tabib, Reuben Garcia, and Aaron Acton (Photo: NASA/Ken Ulbrich)*

Living & Working There

Technologies to enable humans to live and work in deep space and on planetary bodies is an important theme in the Program's portfolio. To date, payloads in this area have largely targeted parabolic flight because it is currently the only platform that allows for human operators and human test subjects to be onboard.

Space Habitation & Work Environments

After a series of successful parabolic flight tests, a novel fire suppression system for the ISS is scheduled for launch to the Station in 2015/2016 (T0010/T0070). The Italian nanoparticle migration and capture device *Diapason* successfully concluded ISS testing in combination with a suborbital flight test in June 2013 (T0019). T0040/T0059 represents ongoing research as part of a Next Generation Life Support System under development in the STMD Game Changing Development program. Research on dust and regolith by University of Central Florida PI Josh Colwell aims to collect data on accretion of dust in microgravity to both inform models of early solar system formation and help with dust mitigation methods for future operations on moons, asteroids, and other solar system bodies (T0029/T0036/T0052).

T#	P/S/B	Status	Title/Organization
T0135-P	1	ACTIVE	Testing ON-OFF Gecko Adhesive Grippers in Microgravity *NASA/Jet Propulsion Laboratory*
T0079-S		ACTIVE	Autonomous Flight Manager for Human-in-the-Loop Immersive Simulation and Flight Test of Terrestrial Rockets *Draper Laboratory*
T0059-P	1	ACTIVE	On the performance of a nanocatalyst-based direct ammonia alkaline fuel cell (DAAFC) under microgravity conditions for water reclamation and energy applications *University of Puerto Rico, Rio Pedras*
T0052-S		ACTIVE	Collection of Regolith Experiment (CORE) on a Commercial Suborbital Vehicle *University of Central Florida*
T0036-S		ACTIVE	Collisions Into Dust Experiment on a Commercial Suborbital Vehicle *University of Central Florida*
T0008-P	4	ACTIVE	Indexing Media Filtration System *Aerfil (with NASA/Glenn Research Center)*
T0045-P	1	PENDING	Evaporative Heat Transfer Mechanisms within a Heat Melt Compactor (EHeM HMC) Experiment *NASA/Glenn Research Center*
T0108-P	1	FY14	Demonstration of Food Processing Equipment *Makel Engineering, Inc.*
T0029-P	2	FY14	Physics of Regolith Impacts in Microgravity Experiment *University of Central Florida*
T0070-P	1	FY13*	Portable Fire Extinguisher *NASA/Johnson Space Center (with ADA Technologies)*
T0040-P	2	FY13	Microgravity Effects of Nanoscale Mixing on Diffusion Limited Processes Using Electrochemical Electrodes *University of Puerto Rico, Rio Pedras*
T0019-S	1	FY13*	Diapason *DTM Technologies*
T0010-P	1	FY11*	Validation of a Fine Water Mist Fire Extinguisher *ADA Technologies*

Human Health

T#	P/S/B	Status	Title/Organization
T0132-P	1	ACTIVE	Effects of Microgravity on Intracranial Pressure *University of Texas Southwestern Medical Center*
T0131-P		ACTIVE	Enhanced Dynamic Load Sensors for ISS (EDLS-ISS) Operational Feasibility for ARED *Aurora Flight Sciences*
T0110-P	1	ACTIVE	Wet Lab *NASA/Ames Research Center*
T0057-P	1	ACTIVE	Hybrid Ultimate Lifting Kit (HULK) Device Demonstration during Parabolic Flight *NASA/Glenn Research Center*
T0049-P	2	ACTIVE	Parabolic Flight Evaluation of a Hermetic Surgery System for Reduced Gravity *University of Louisville*
T0027-P	1	ACTIVE	Autonomous Cell Culture Apparatus for Growing 3-Dimensional Tissues in Microgravity *NASA/Johnson Space Center*
T0104-PS		PENDING	Real Time Conformational Analysis of Rhodopsin using Plasmon Waveguide Resonance Spectroscopy *University of Arizona*
T0062-P		PENDING	In-Flight Lab Analysis Technology Demonstration in Reduced Gravity *NASA/Glenn Research Center*
T0058-P		PENDING	Assessing Otolith-Organ Function with Vestibular Evoked Myogenic Potentials (VEMPs) in Parabolic Flight *Johns Hopkins University School of Medicine*
T0134-P	1	FY14	Noninvasive Hemodynamic Monitoring in Microgravity, Phase II (Arterial Stiffness) *Stanford University*
T0103-P	1	FY14	Optical Coherence Tomography (OCT) in Microgravity *Wyle Laboratories*
T0094-P	1	FY14	Monitoring Tissue Oxygen Saturation in Microgravity *University of Oxford*
T0090-P	1	FY14	Testing Near-Infrared Neuromonitoring Devices for Detecting Cerebral Hemodynamic Changes in Parabolic Flight *Massachusetts General Hospital*
T0031-P	3	FY14	Activity Monitoring during Parabolic Flight *University of Washington*
T0030-P	1	FY14	Microgravity Health Care *Henry Ford Health System*
T0025-P	3	FY14	Assessing Vestibulo-ocular Function and Spatial Orientation in Parabolic Flight *Johns Hopkins University School of Medicine*
T0051-P	2	FY13	Non-Invasive Hemodynamic Monitoring in Microgravity *Stanford University*
T0048-P	2	FY13	Effects of Reduced and Hyper Gravity on Functional Near-Infrared Spectroscopy (fNIRS) Instrumentation *NASA/Glenn Research Center*
T0026-P	2	FY13*	Evaluation of Medical Chest Drainage System *Orbital Medicine, Inc.*
T0013-P	3	FY13	Monitoring Radiation-Induced DNA Degradation *NASA/Kennedy Space Center*
T0028-P	1	FY12	Demonstration of non-invasive acquisition of physiologic variables from spaceflight participants *The Vital Space Team*

Human Health (previous page)

Long duration human health in space is the single largest category of payloads in the Program, with many of the payloads relating to ongoing research funded by NASA's Human Research Program (HRP). Several of these payloads were reflown across multiple campaigns to gather more test data or, in some cases, to make adjustments after hardware failures during earlier campaigns. For this type of research, a measure of success is the number of published papers (papers are listed on pages 86/87). As in other categories, parabolic flight here also provides a valuable risk reduction precursor for hardware scheduled to be sent to the International Space Station.

Plant Science

T0012/T0053 is an example of repurposing flight hardware originally designed for the Space Shuttle to be used onboard suborbital and parabolic vehicles. As featured in the FY13 Annual Report, the objective of this hardware is to study the effect of the early onset of microgravity on gene expression in plants. After several iterations on parabolic flight, the hardware is currently ready and awaiting an opportunity to be flown onboard an sRLV. The Lunar Plants project (T0140) was selected from the STMD Center Innovation Fund (CIF) and aims to grow the first plants on the Moon. It is targeted to fly to the Moon onboard one of the Google Lunar XPRIZE contestants. Parabolic flight testing serves as risk reduction for this mission.

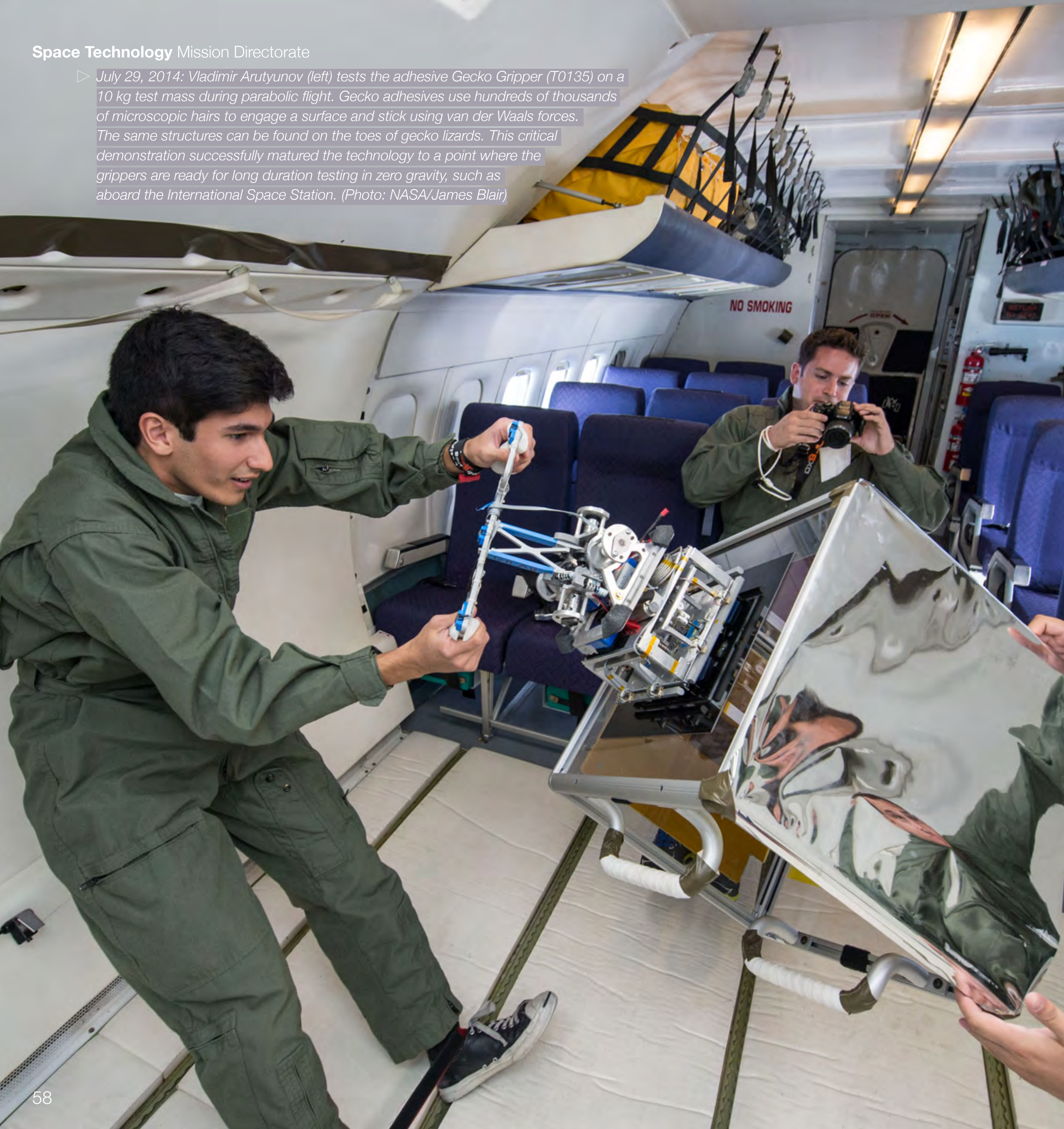
T#	P/S/B	Status	Title/Organization
T0140-P	1	ACTIVE	Lunar Plants *NASA/Ames Research Center*
T0053-S		ACTIVE*	Validating Telemetric Imaging Hardware for Crew-Assisted and Crew-Autonomous Biological Imaging in Suborbital Applications *University of Florida*
T0012-P	4	FY14*	Telemetric Biological Imaging *University of Florida*

Materials Development & 3D Printing

New materials and 3D printing are promising areas of research onboard the ISS for which suborbital flight testing continues to serve as a valuable risk reduction precursor.

T#	P/S/B	Status	Title/Organization
T0100-P	1	ACTIVE	Creation of Titanium-Based Nanofoams in Reduced Gravity for Dye-Sensitized Solar Cell Production *Northwestern University*
T0004-PS	4/-/-	ACTIVE*	Printing the Space Future *Made in Space, Inc.*
T0044-P	1	PENDING	Sintering of Composite Materials under Reduced Gravity Conditions *Advanced Technical Institute I.T.I.S "E. Fermi", Italy*

November 20, 2013: NASA is currently addressing spaceflight-induced visual impairment and intracranial pressure (VIIP) through medical operations monitoring as well as through research activities. A component of these activities is the visualization of the crewmembers' retinas in-flight. Optical Coherence Tomography (OCT) allows high resolution imaging of the retinal surface, retinal nerve fiber layer thickness, and other functions including choroid thickness analysis. With this experiment, a research team including Douglas Ebert (PI for T0103, left), David Ham (right) and David Alexander (not shown) evaluated alternate OCT hardware configurations in microgravity, including ergonomic and operational considerations for each configuration. The "free float" OCT scanning technique shown in this image has since been successfully used on the ISS for data collection for the Fluid Shifts ISS flight experiment. (Photo: NASA/Robert Markowitz)



July 29, 2014: Vladimir Arutyunov (left) tests the adhesive Gecko Gripper (T0135) on a 10 kg test mass during parabolic flight. Gecko adhesives use hundreds of thousands of microscopic hairs to engage a surface and stick using van der Waals forces. The same structures can be found on the toes of gecko lizards. This critical demonstration successfully matured the technology to a point where the grippers are ready for long duration testing in zero gravity, such as aboard the International Space Station. (Photo: NASA/James Blair)

August 19, 2014: Stanford researcher Richard Wiard (left) and Principal Investigator Gregory Kovacs (T0134, center) are suspended in free fall, strapped into experimental hardware monitoring their ballistocardiogram (BCG). The BCG is a noninvasive method of hemodynamic monitoring that measures the force due to the ejection of blood by the heart with each heartbeat. When a subject's feet are tightly mounted to the scale with boot bindings, the small force caused by each heartbeat can be sensed. (Photo: NASA/James Blair)

▷ *April 23, 2013: Andreas Zoellner (left) and Eric Hultgren of Stanford University observe the Caging System for Drag-free Satellites (T0063). The free-flying experiment tested the design of a caging mechanism (launch lock) for deployment of a drag-free test mass in microgravity. (Photo: NASA/Lauren Harnett)*

Observing There

The value of suborbital flight in transforming the ability to observe the universe and answer the profound questions in Earth and space sciences comes in many different forms. Traditional uses of balloons and sounding rockets include flight demonstrations to mature scientific instrumentation and to perform short-duration outward facing scientific observations above the more dense layers of the atmosphere.

Scientific instrumentation

Of the 19 payloads in this category, eleven can be considered to fit under scientific instrumentation development (see below). Three payloads will test new high-precision instrument pointing systems for future balloon flights (T0050, T0113) and sRLV missions (T0085). Other payloads are planning to test promising new materials or key subsystems that will enable future science missions (e.g. T0063, T0076, T0114). T0092 aims to use one of Masten's VTVL vehicles to test a new navigation device that will enable precision alignment of spacecraft over large distances in deep space, a capability necessary to enable a future 'starshade' mission to perform spectroscopy of Earth-like planets as far away as 60 light years from Earth.

T#	P/S/B	Status	Title/Organization
T0126-P		ACTIVE	Validating Microgravity Mobility Models for Hopping/Tumbling Robots *NASA/Jet Propulsion Laboratory*
T0124-B		ACTIVE	Gannon University's Cosmic-Ray Calorimeter (GU-CRC) *Gannon University*
T0097-B	1	ACTIVE	Planetary Atmosphere Minor Species Sensor *University of Central Florida*
T0092-S		ACTIVE	Precision Formation Flying Sensor *University of Colorado*
T0050-B		ACTIVE	Flight Demonstration of an Integrated Camera and Solid-State Fine Steering System *Southwest Research Institute*
T0114-S		PENDING	Technology Demonstration of Graphene Ion Membranes for Earth and Space Applications *Johns Hopkins University Applied Physics Laboratory*
T0113-B		PENDING	Focal Plane Actuation to Achieve Ultra-High Resolution on Suborbital Balloon Payloads *Arizona State University*
T0111-S		PENDING	Rocket Flight of a Delta-Doped CCD Focal Plane Array for CHESS *Arizona State University*
T0102-P	1	PENDING	Demonstration of Adjustable Fluidic Lens in Microgravity *University of Arizona*
T0085-S		PENDING	SwRI Solar Instrument Pointing Platform *Southwest Research Institute*
T0076-S		PENDING	Demonstration of Vertically Aligned Carbon Nano-tubes for Earth Climate Remote Sensing *Johns Hopkins University Applied Physics Laboratory*
T0063-P	1	FY13	Caging System for Drag-free Satellites *Stanford University*

In-situ measurements of the upper atmosphere

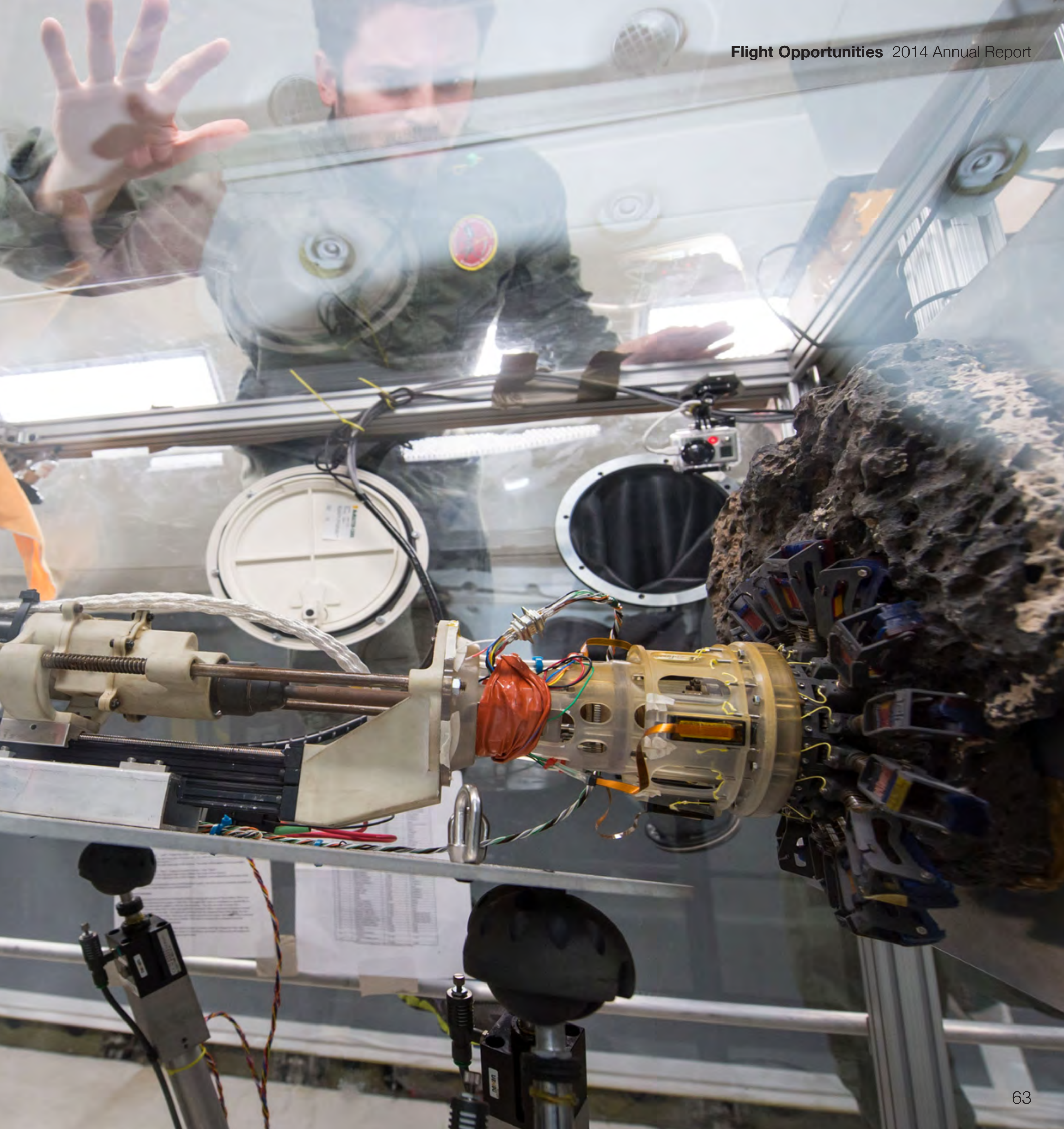
One of the original promises of the new reusable suborbital platforms is their ability to perform in-situ measurements and observations in the Earth's mesosphere and lower thermosphere (~50-120 km). This section of the Earth atmosphere has earned the nickname 'ignorosphere' because of the inability to reach it without a rocket. It is too high for weather balloons and too low for satellites to dip down to gather information. Four payloads that were selected early on in the Program are developing technology that will enable this new field of research.

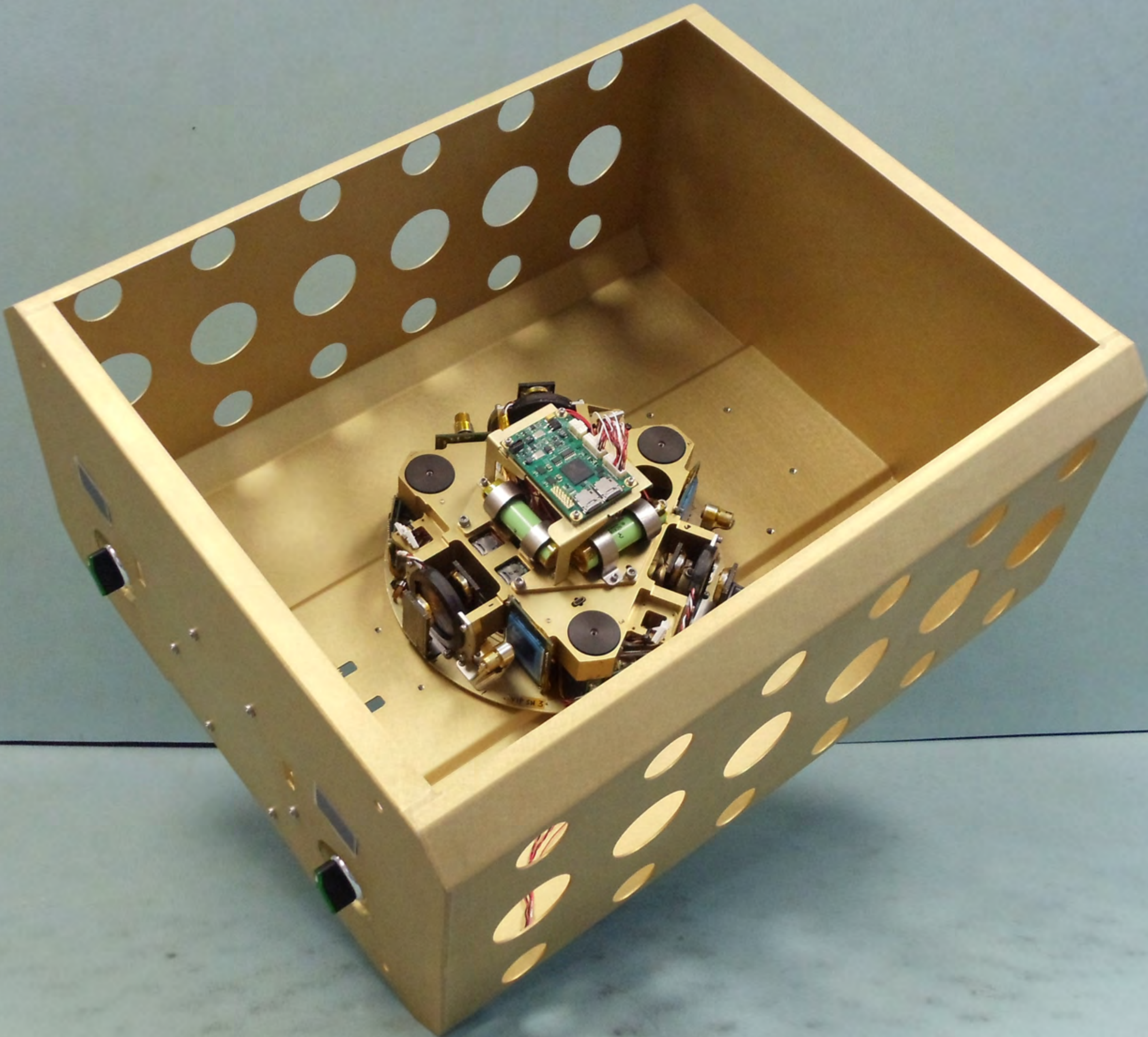
T#	P/S/B	Status	Title/Organization
T0022-S		ACTIVE	Environment monitoring suite on sRLV *Johns Hopkins University Applied Physics Laboratory*
T0015-S		ACTIVE	Electromagnetic Field Measurements on sRLV *Johns Hopkins University Applied Physics Laboratory*
T0046-S		PENDING	Polar Mesospheric Cloud Imaging and Tomography Experiment *Space Science Institute*
T0023-S		PENDING	Measurement of the Atmospheric Background in the Mesosphere *Silicon Valley Space Center*

Microgravity testing of science and exploration instruments

T#	P/S/B	Status	Title/Organization
T0129-P	1	ACTIVE	Testing of a Microgravity Rock Coring Drill Using Microspines *NASA/Jet Propulsion Laboratory*
T0122-P	1	FY14	Microgravity Experiment on Accretion in Space Environments *University of Central Florida*
T0037-P	1	FY13	Particle Dispersion System for Microgravity Environments *SETI Institute*
T0042-P	1	FY12*	OSIRIS-REx Low-Gravity Regolith Sampling Tests *Lockheed Martin Inc.*

August 22, 2014: Principal Investigator Aaron Parness (T0129) looks down on the microgravity rock coring drill as the C9 aircraft goes through a parabolic maneuver. (Photo: NASA/James Blair) ▷





Investing Here

Every technology payload flown represents an investment in the U.S. suborbital industry. The additional nine payloads listed below represent a variety of unique technology developments and capability enhancements for suborbital vehicles. The Vibration Isolation Platform (VIP, T0077) was originally selected by the Game Changing Development (GCD) program under NRA1 to increase the quality of the microgravity environment for research payloads flying on suborbital vehicles. Controlled Dynamics has also engaged in a Phase II SBIR with NASA/JPL to develop elements of the system into an isolation platform for deep-space optical communications. The VIP was subsequently selected by the Center for the Advancement of Science in Space (CASIS) to provide a controlled acceleration environment for experiments onboard the International Space Station where vibrations from life support and other machinery impact the quality of the microgravity.

T#	P/S/B	Status	Title/Organization
T0112-S		ACTIVE	Spacecraft Disturbance Isolation and Rejection Platform (SDIRP) *NASA/Jet Propulsion Laboratory*
T0095-SB	-/1/1	ACTIVE	Test of Satellite Communications Systems on-board Suborbital Platforms to Provide Low-Cost Data Communications for Research Payloads, Payload Operators, and Space Vehicle Operators *SatWest*
T0080-S		ACTIVE	Advanced Micro Sun Sensor *NASA/Jet Propulsion Laboratory*
T0077-S	1	ACTIVE	Facility for Microgravity Research and Submicroradian Stabilization using sRLVs *Controlled Dynamics Inc*
T0054-B	1	ACTIVE	Stratospheric Parabolic Flight Technology *Purdue University*
T0001-PS	1/2/-	ACTIVE	Suborbital Flight Environment Monitor (SFEM) *NASA/Ames Research Center*
T0082-S		PENDING	Dynamic Microscopy System *Techshot, Inc.*
T0069-S	2	FY14	Global Positioning Beacon (GPB) *Kirtland AFB*
T0071-S	1	FY13	New Mexico Student Groups #1 and #2 for SL-7 *New Mexico Space Grant Consortium*

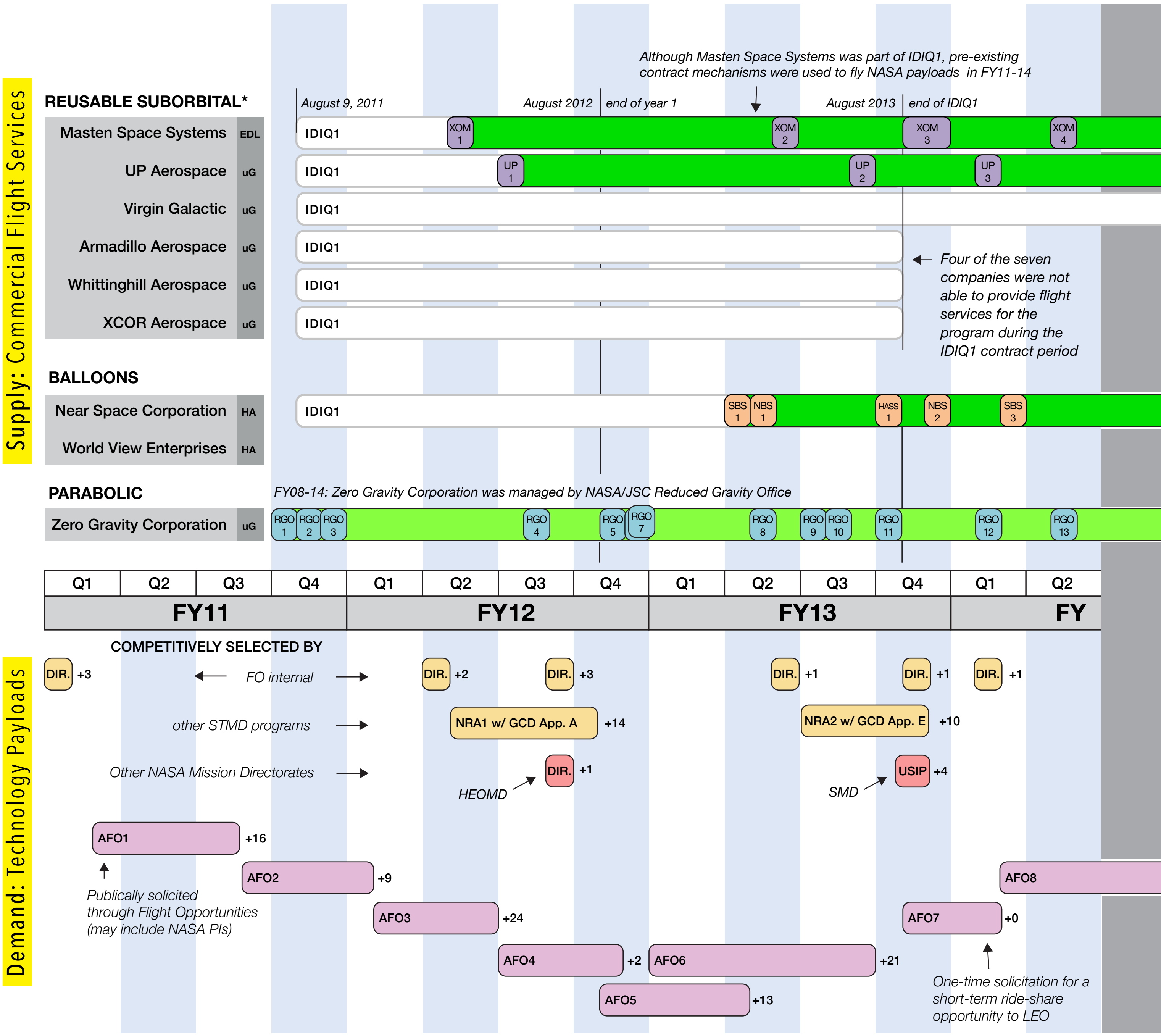
◁ *The Vibration Isolation Platform (VIP) depicted inside a standard-sized middeck locker (T0077). (Photo: Controlled Dynamics)*

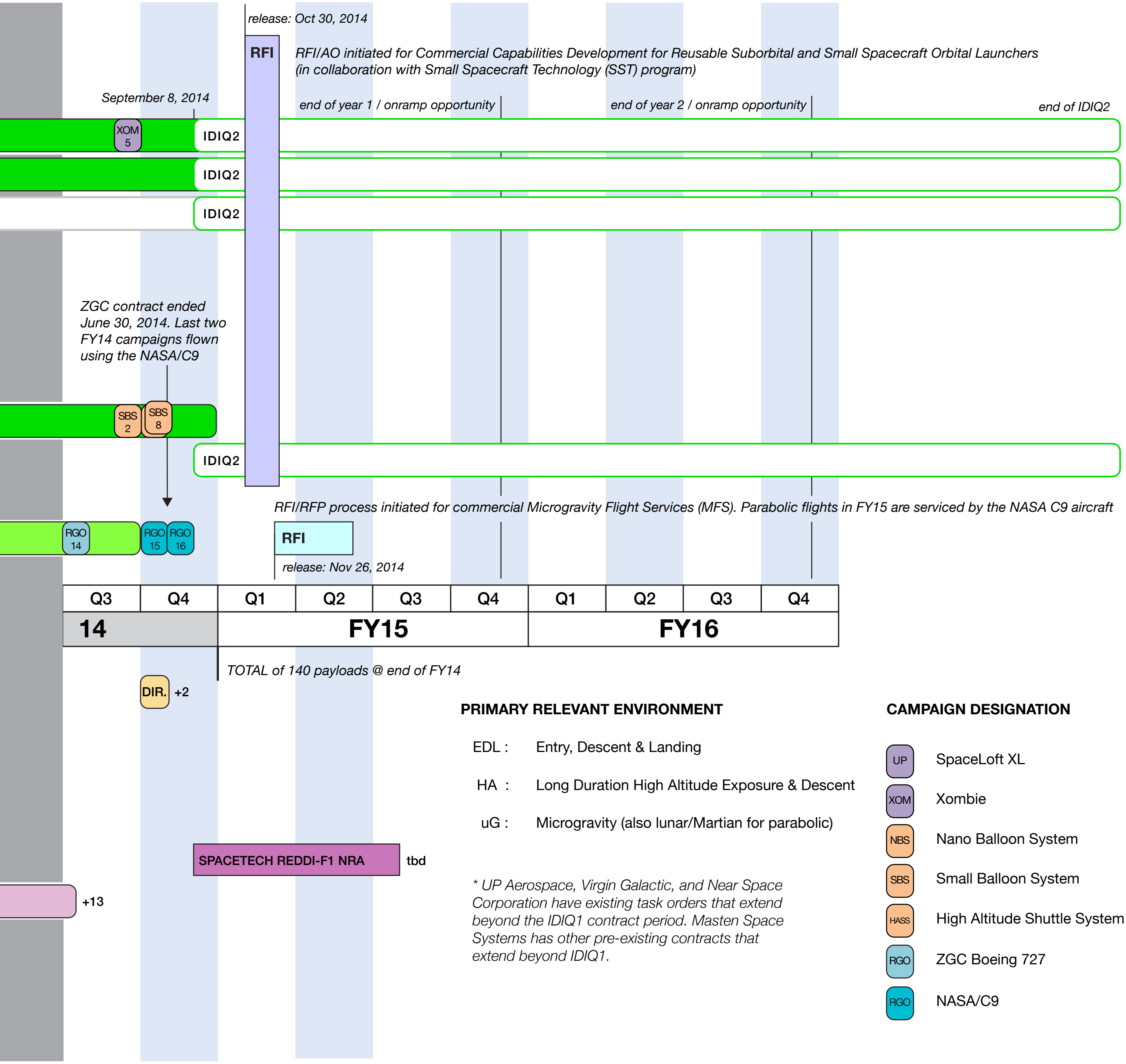

03
0008
U.S. NAVAL TEST PILOT SCHOOL
GRADUATE

Program Metrics
FY11-14

◁ *July 25, 2014: Members of a team lead by Principal Investigator Michael Schubert of Johns Hopkins University School of Medicine (T0025-P) test their ability to maintain eye position during varying gravity levels. Exposure to novel gravitational environments elicits alterations in sensorimotor responses, such as changes in coordinated head-and-eye movements and variations in spatial perception and memory. Functional consequences include an impaired ability to read, disorientation, dizziness, postural and locomotor disturbances, and motion sickness. The goal of this research is to develop a portable hand-held device that measures sensory and motor function. It addresses a specific request from NASA to enable a single test subject (crewmember) to assess his/her sensorimotor function in no more than 20 minutes. (Photo: NASA/James Blair)*

FY11- FY16 Overview of Flight Activities and Payload Solicitations



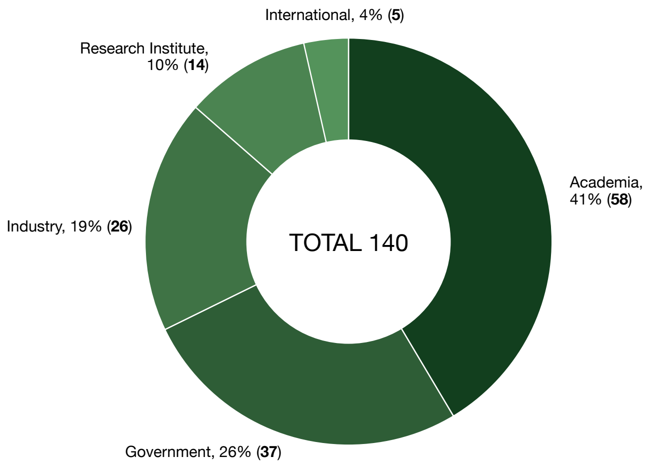

release: Oct 30, 2014
RFI
RFI/AO initiated for Commercial Capabilities Development for Reusable Suborbital and Small Spacecraft Orbital Launchers (in collaboration with Small Spacecraft Technology (SST) program)
September 8, 2014
end of year 1 / onramp opportunity
end of year 2 / onramp opportunity
end of IDIQ2
XOM 5
IDIQ2
IDIQ2
IDIQ2
ZGC contract ended June 30, 2014. Last two FY14 campaigns flown using the NASA/C9
SBS 2
SBS 8
IDIQ2
RFI/RFP process initiated for commercial Microgravity Flight Services (MFS). Parabolic flights in FY15 are serviced by the NASA C9 aircraft
RGO 14
RGO 15
RGO 16
RFI
release: Nov 26, 2014
Q3
Q4
Q1
Q2
Q3
Q4
Q1
Q2
Q3
Q4
14
FY15
FY16
TOTAL of 140 payloads @ end of FY14
DIR. +2
SPACETECH REDDI-F1 NRA
tbd
+13
PRIMARY RELEVANT ENVIRONMENT
EDL : Entry, Descent & Landing
HA : Long Duration High Altitude Exposure & Descent
uG : Microgravity (also lunar/Martian for parabolic)
* UP Aerospace, Virgin Galactic, and Near Space Corporation have existing task orders that extend beyond the IDIQ1 contract period. Masten Space Systems has other pre-existing contracts that extend beyond IDIQ1.
CAMPAIGN DESIGNATION
UP SpaceLoft XL
XOM Xombie
NBS Nano Balloon System
SBS Small Balloon System
HASS High Altitude Shuttle System
RGO ZGC Boeing 727
RGO NASA/C9

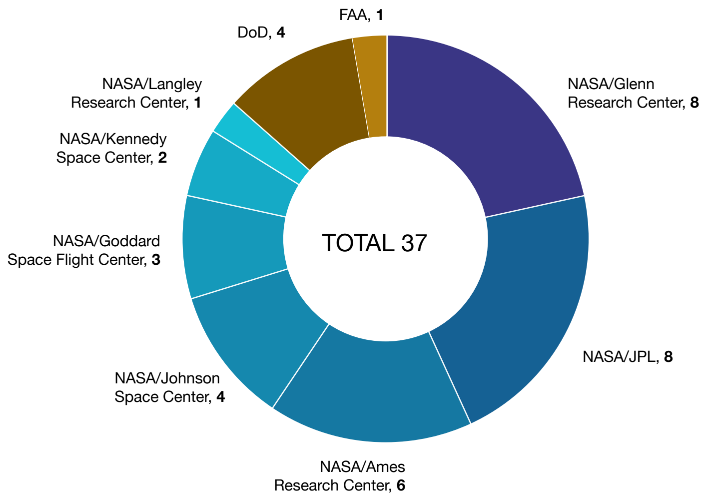
Flight Service Provider (FSP) contractual status

		IDIQ1	IDIQ2	1st FO flight	FO flights FY11-14	Flight designation
1	Armadillo Aerospace, Heath, TX	√				
2	Masten Space Systems, Mojave, CA	√ *	√	**FY12** (11/16/2011)	10	Xombie
3	Near Space Corporation, Tillamook, OR	√		**FY13** (01/20/2013)	8	SBS, NBS or HASS
4	UP Aerospace, Highlands Ranch, CO	√	√	**FY12** (04/05/2012)	3	UP
5	Virgin Galactic, Mojave, CA	√	√	**TBD**		
6	World View Enterprises, Tuscon, AR		√	**FY15** (03/08/2015)		
7	Whittinghill Aerospace, Camarillo, CA	√				
8	XCOR Aerospace, Mojave, CA	√				
9	Zero Gravity Corporation, Arlington, VA	**		**FY11** (07/19/2011)	16 ***	RGO

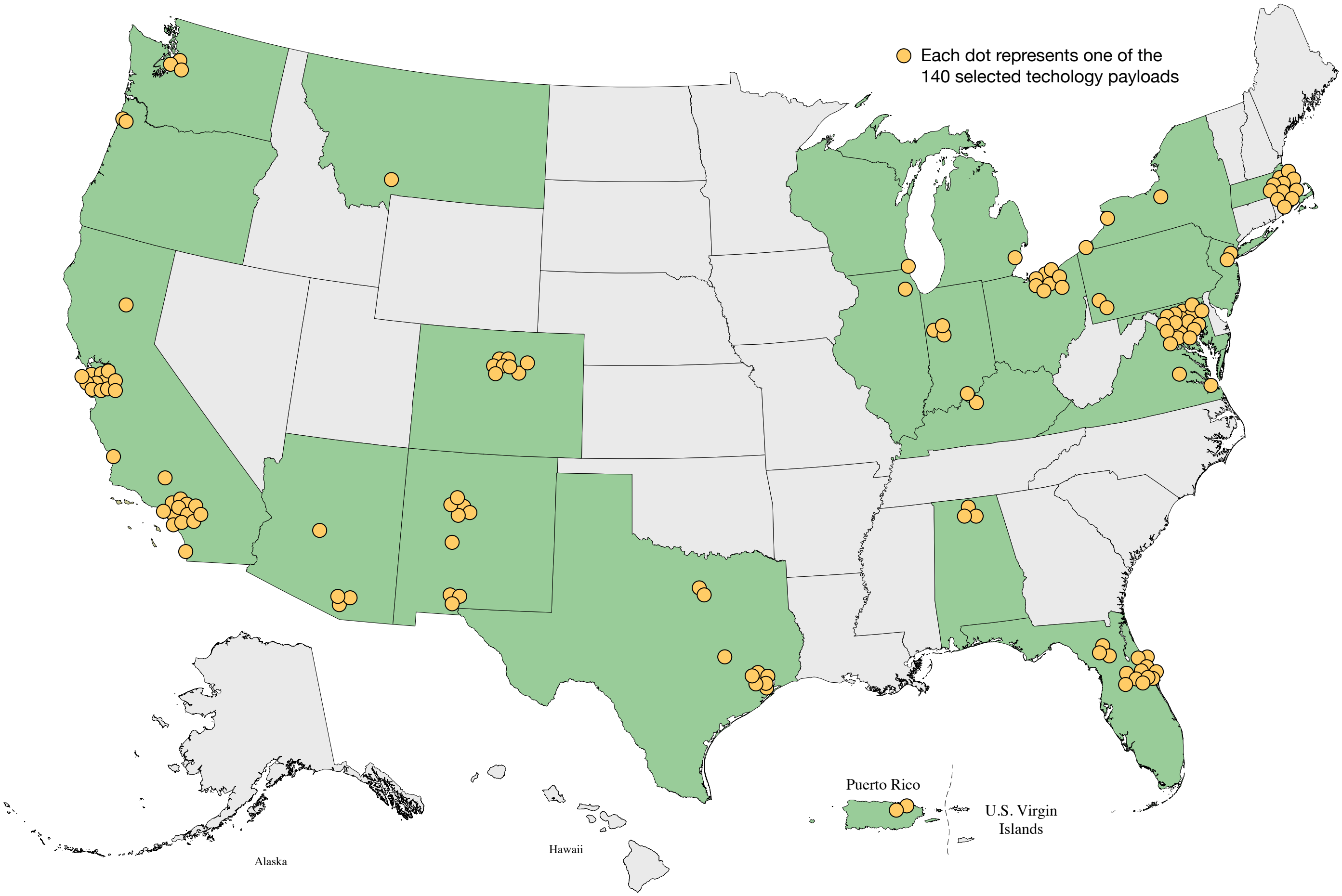
** Pre-existing contracts were used to fly with Masten Space Systems during IDIQ1*
*** Parabolic flight weeks were operated through the NASA/JSC Reduced Gravity Office (RGO). The contract with Zero Gravity Corporation ended June 2014.*
**** Parabolic flight weeks are counted as 1 flight*

Payload origin by organization category & government entity





Payload origin within the U.S.



FY11-14 payload selection & flight activities

The table on the top right shows the number of selected (submitted) proposals for each solicitation mechanism over the four fiscal years in which the Program has been in operation (FY11-FY14). Once a payload is selected, it is categorized and labeled according to the platform type targeted for flight demonstration (Parabolic, sRLV and/or Balloon). As can be seen in the bottom right half of the same table, 72 of the selected payloads target parabolic flight, and 50 target sRLV flight. The middle table on the right shows the number of unique payload-flights achieved over the course of four years: 134 payload-flights through 32 campaigns (most campaigns have multiple flights and/or multiple payloads, see table below on this page). Of the 134 payload-flights, 85 were 'first-flight' for a technology payload and 49 were re-flights for those already flown. The last table on the right shows the number of completed payloads and the current status of the payload pool on the far right. By the end of FY14, 55 teams had concluded their flight testing with the Program. The decision to end flight testing is usually made by the researcher based on their satisfaction with the results. In 12 cases (parabolic only) NASA made the determination that the submitted flight recycle request was out-of-scope of the selected proposal.

	Campaign	(first) Flight Date	# Payloads	# Flights	Parabolic (PL-flights)	sRLV (PL-flights)	Balloon (PL-flights)	
FY11 (3)	RGO-01	July 19, 2011	9^	1*	9			
	RGO-02	August 30, 2011	4†	1	4			
	RGO-03	September 20, 2011	7	1	7			
FY12 (6)	Xombie-01 (C1-C2-C3)	February 2, 2012	1	3		3		
	UP-01 (SL6)	April 5, 2012	2	1		2		
	RGO-04	May 16, 2012	8	1	8			
	RGO-05	August 16, 2012	5†	1	5			
	RGO-06	September 11, 2012	6	1	6			
	RGO-07	September 27, 2012	6	1	6			
FY13 (11)	SBS-01	January 20, 2013	1	1			1	
	NBS-01	February 15, 2013	1	1			1	
	RG0-08	February 26, 2013	6	1	6			
	Xombie-02 (C4 & C5)	March 22, 2013	1	2		2		
	RGO-09	April 23, 2013	5	1	5			
	RGO-10	June 4, 2013	3†	1	3			
	UP-02 (SL7)	June 21, 2013	6	1		6		
	HASS-01	July 19, 2013	2	1			2	
	RGO-11	July 30, 2013	4†	1	4			
	Xombie-03 (G-FOLD 1 & 3)	August 22, 2013	1	2		2		
	NBS-02	September 26, 2013	1	1			1	
FY14 (12)	UP-03 (SL8)	November 12, 2013	6	1		6		
	RGO-12	November 19, 2013	5	1	5			
	SBS-03	December 4, 2013	1	1			1	
	Xombie-04 (AAS 1)	February 21, 2014	1	1		1		
	RGO-13	February 25, 2014	7	1	7			
	RGO-14	April 24, 2014	6	1	6			
	SBS-02	June 6, 2014	1	1			1	
	Xombie-05 (AAS 2 & 3)	June 12, 2014	1	2		2		
	SBS-08	July 17, 2014	1	1			1	
	SBS-05	July 18, 2014	1	1			1	
	RGO-15	July 22, 2014	8	1	8			
	RGO-16	August 19, 2014	12**	1	12			
			129	37	101	24	9	134 PL-flights total

^ one payload was replaced for two new ones mid week
** parabolic campaigns are counted as 1 flight*

*** RGO-16 was a double campaign spanning 2 weeks.*
† shared flight week with NASA Education Office or other external party

		FY11	FY12	FY13	FY14	TOTAL
Selection mechanism	*NRA*		*14 (40)*	*10 (41)*		*24 (81)*
	Directed	*3 (-)*	*6 (-)*	***6 (-)*	*3 (-)*	*18 (18)*
	AFO	**16 (23)*	*35 (51)*	*34 (58)*	*13 (20)*	*98 (152)*
Technology payloads selected		**19**	**55**	**50**	**16**	**140 (248)**
	Parabolic [P]	*12*	*21*	*26*	*13*	72
	sRLV [S]	*4*	*29*	*14*	*3*	50
	Balloon [B]		*3*	*7*		10
	Parabolic <-> sRLV [PS]	*3*	*1*	*1*		5
	Balloon <-> sRLV [SB]		*1*	*2*		3

** selected (submitted)*
*** includes 4 proposals selected through Science Mission Directorate USIP program*

		FY11	FY12	FY13	FY14	TOTAL
Campaigns completed	*balloon*			*4*	*4*	*8*
	sRLV		*2*	*3*	*3*	*8*
	parabolic	*3*	*4*	*4*	*5*	*16*
Payload-flights achieved		**20**	**30**	**33**	**51**	****** 85/49 **= 134**
	Parabolic	**13/7*	*18/7*	*6/12*	*30/8*	*67/34* = **101**
	sRLV		*2/3*	*5/5*	*3/6*	*10/14* = **24**
	Balloon			*5*	*3/1*	*8/1* = **9**

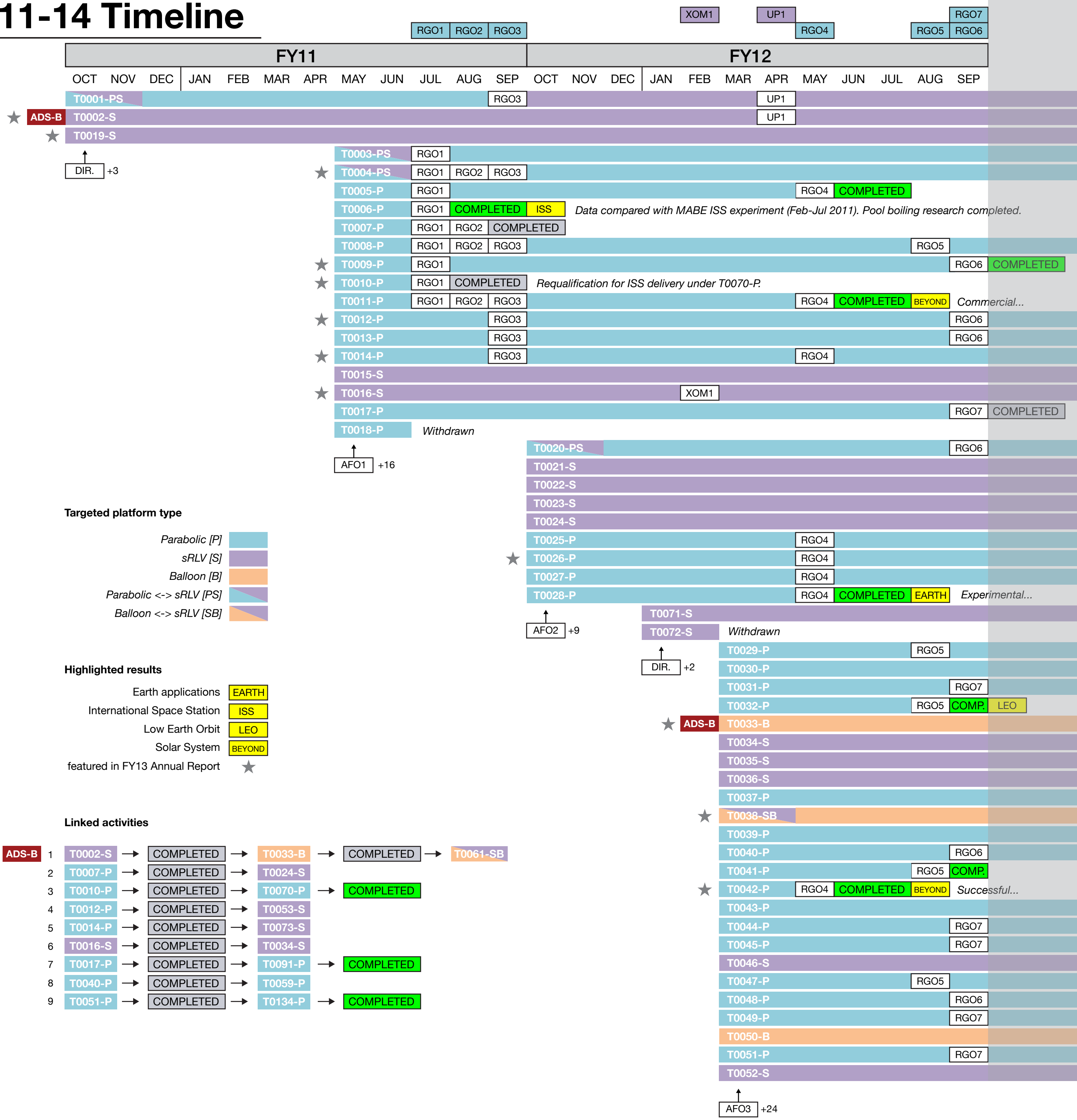
** number of payload-flights: 13/7 means 13 were 'first flight' for a payload while 7 were 're-flights'.*
*** 85 unique technologies (T#s) have been flight tested. 49 payload-flights consisted of re-flights or previously flown payloads.*

	FY11	FY12	FY13	FY14
Flight testing COMPLETED COMPLETED **(Total)**	**3**	**11**	**28**	**55**
Parabolic [P]	*3*	*11*	*22*	*45*
sRLV [S]			*5*	*7*
Balloon [B]			*1*	*2*
Parabolic <-> sRLV [PS]				
Balloon <-> sRLV [SB]				*1*

Completed	*Active*	*Pending*	*Withdrawn*		
55	***60***	*21*	*4*	=	*140*
45	***18***	*7*	*2*	=	*72*
7	***29***	*12*	*2*	=	*50*
2	***7***	*1*		=	*10*
	4	*1*		=	*5*
1	***2***			=	*3*

End of FY14 flight test status for the 140 selected technology payloads

FY11-14 Timeline



Targeted platform type

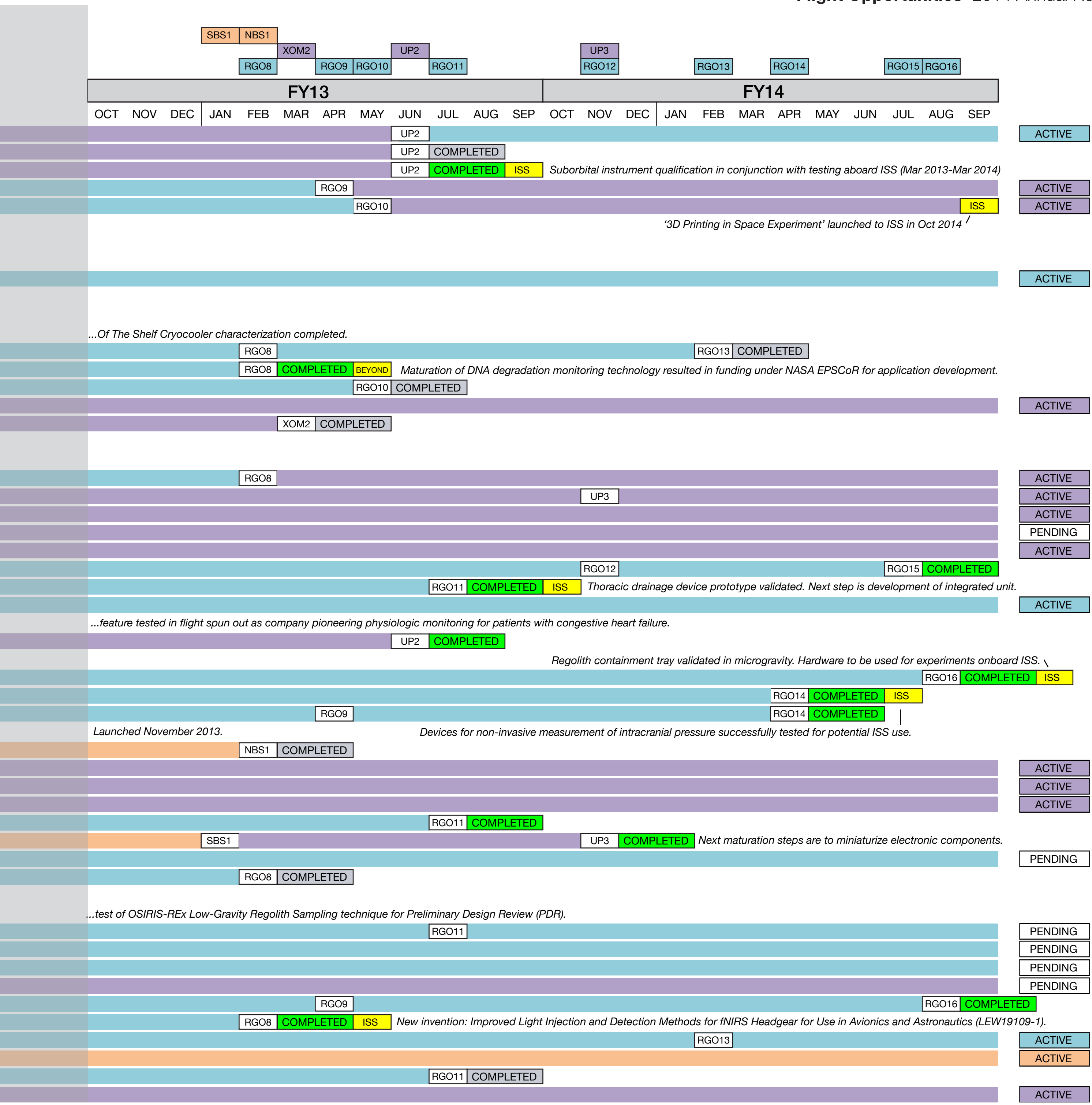
- *Parabolic [P]*
- *sRLV [S]*
- *Balloon [B]*
- *Parabolic <-> sRLV [PS]*
- *Balloon <-> sRLV [SB]*

Highlighted results

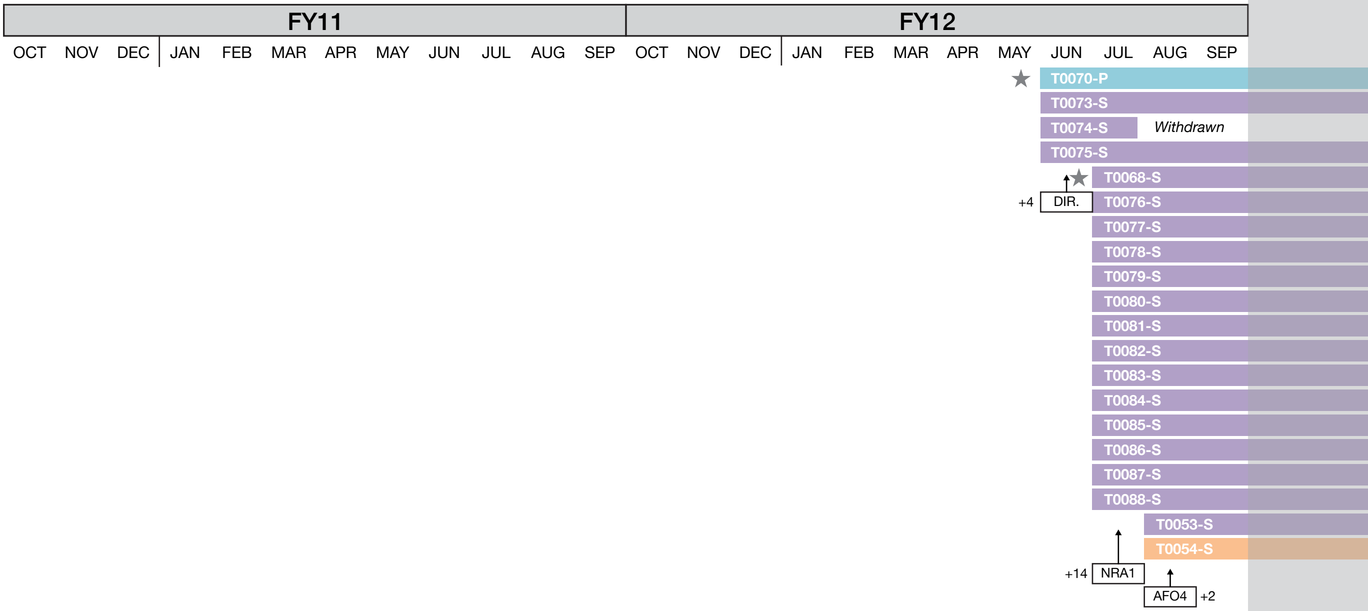
- Earth applications — EARTH
- International Space Station — ISS
- Low Earth Orbit — LEO
- Solar System — BEYOND
- featured in FY13 Annual Report — ★

Linked activities

ADS-B	1	T0002-S	→ COMPLETED	→	T0033-B	→	COMPLETED	→	T0061-SB
	2	T0007-P	→ COMPLETED	→	T0024-S				
	3	T0010-P	→ COMPLETED	→	T0070-P	→	COMPLETED		
	4	T0012-P	→ COMPLETED	→	T0053-S				
	5	T0014-P	→ COMPLETED	→	T0073-S				
	6	T0016-S	→ COMPLETED	→	T0034-S				
	7	T0017-P	→ COMPLETED	→	T0091-P	→	COMPLETED		
	8	T0040-P	→ COMPLETED	→	T0059-P				
	9	T0051-P	→ COMPLETED	→	T0134-P	→	COMPLETED		


SBS1
NBS1
XOM2
UP2
UP3
RGO8
RGO9
RGO10
RGO11
RGO12
RGO13
RGO14
RGO15
RGO16
FY13
FY14
OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP
UP2 ACTIVE
UP2 COMPLETED
UP2 COMPLETED ISS
Suborbital instrument qualification in conjunction with testing aboard ISS (Mar 2013-Mar 2014)
RGO9 ACTIVE
RGO10 ISS ACTIVE
'3D Printing in Space Experiment' launched to ISS in Oct 2014
ACTIVE
...Of The Shelf Cryocooler characterization completed.
RGO8 RGO13 COMPLETED
RGO8 COMPLETED BEYOND
Maturation of DNA degradation monitoring technology resulted in funding under NASA EPSCoR for application development.
RGO10 COMPLETED
ACTIVE
XOM2 COMPLETED
RGO8 ACTIVE
UP3 ACTIVE
ACTIVE
PENDING
ACTIVE
RGO12 RGO15 COMPLETED
RGO11 COMPLETED ISS
Thoracic drainage device prototype validated. Next step is development of integrated unit.
ACTIVE
...feature tested in flight spun out as company pioneering physiologic monitoring for patients with congestive heart failure.
UP2 COMPLETED
Regolith containment tray validated in microgravity. Hardware to be used for experiments onboard ISS.
RGO16 COMPLETED ISS
RGO14 COMPLETED ISS
RGO9 RGO14 COMPLETED
Launched November 2013.
Devices for non-invasive measurement of intracranial pressure successfully tested for potential ISS use.
NBS1 COMPLETED
ACTIVE
ACTIVE
ACTIVE
RGO11 COMPLETED
SBS1 UP3 COMPLETED
Next maturation steps are to miniaturize electronic components.
PENDING
RGO8 COMPLETED
...test of OSIRIS-REx Low-Gravity Regolith Sampling technique for Preliminary Design Review (PDR).
RGO11 PENDING
PENDING
PENDING
PENDING
RGO9 RGO16 COMPLETED
RGO8 COMPLETED ISS
New invention: Improved Light Injection and Detection Methods for fNIRS Headgear for Use in Avionics and Astronautics (LEW19109-1).
RGO13 ACTIVE
ACTIVE
RGO11 COMPLETED
ACTIVE

FY11-14 Timeline



Targeted platform type

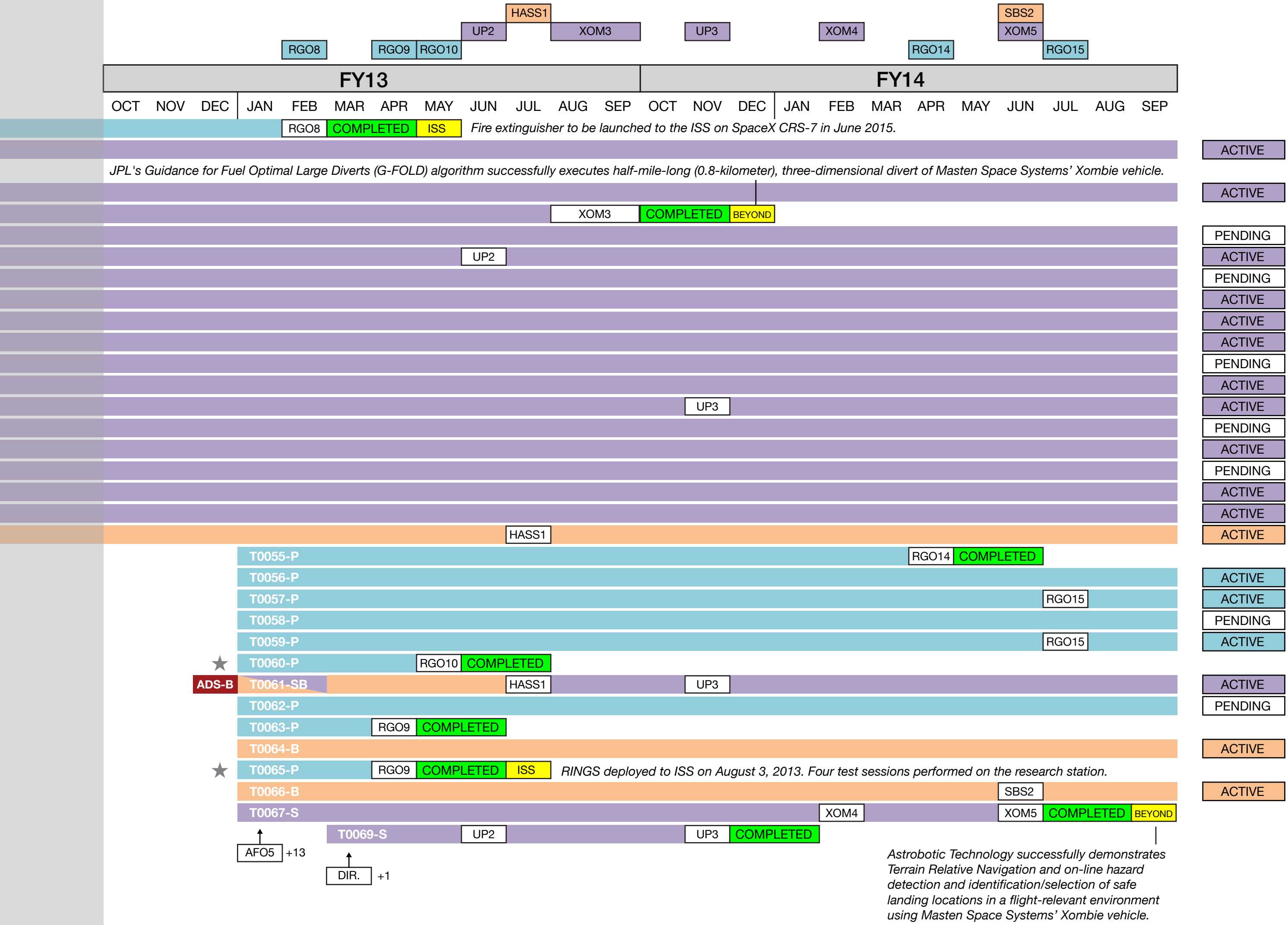
Parabolic [P]
sRLV [S]
Balloon [B]
Parabolic <-> sRLV [PS]
Balloon <-> sRLV [SB]

Highlighted results

Earth applications: EARTH
International Space Station: ISS
Low Earth Orbit: LEO
Solar System: BEYOND
featured in FY13 Annual Report: ★

Linked activities

ADS-B	1	T0002-S	→ COMPLETED	→	T0033-B	→ COMPLETED	→	T0061-SB	
	2	T0007-P	→ COMPLETED	→	T0024-S				
	3	T0010-P	→ COMPLETED	→	T0070-P	→ COMPLETED			
	4	T0012-P	→ COMPLETED	→	T0053-S				
	5	T0014-P	→ COMPLETED	→	T0073-S				
	6	T0016-S	→ COMPLETED	→	T0034-S				
	7	T0017-P	→ COMPLETED	→	T0091-P	→ COMPLETED			
	8	T0040-P	→ COMPLETED	→	T0059-P				
	9	T0051-P	→ COMPLETED	→	T0134-P	→ COMPLETED			


HASS1
UP2
XOM3
UP3
XOM4
SBS2
XOM5
RGO8
RGO9
RGO10
RGO14
RGO15
FY13
FY14
OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP
COMPLETED
ISS
Fire extinguisher to be launched to the ISS on SpaceX CRS-7 in June 2015.
ACTIVE
JPL's Guidance for Fuel Optimal Large Diverts (G-FOLD) algorithm successfully executes half-mile-long (0.8-kilometer), three-dimensional divert of Masten Space Systems' Xombie vehicle.
BEYOND
PENDING
T0055-P
T0056-P
T0057-P
T0058-P
T0059-P
T0060-P
ADS-B
T0061-SB
T0062-P
T0063-P
T0064-B
T0065-P
RINGS deployed to ISS on August 3, 2013. Four test sessions performed on the research station.
T0066-B
T0067-S
T0069-S
AFO5 +13
DIR. +1
Astrobotic Technology successfully demonstrates Terrain Relative Navigation and on-line hazard detection and identification/selection of safe landing locations in a flight-relevant environment using Masten Space Systems' Xombie vehicle.

FY11-14 Timeline

FY11												FY12											
OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP

Targeted platform type

Parabolic [P]

sRLV [S]

Balloon [B]

Parabolic <-> sRLV [PS]

Balloon <-> sRLV [SB]

Highlighted results

Earth applications EARTH

International Space Station ISS

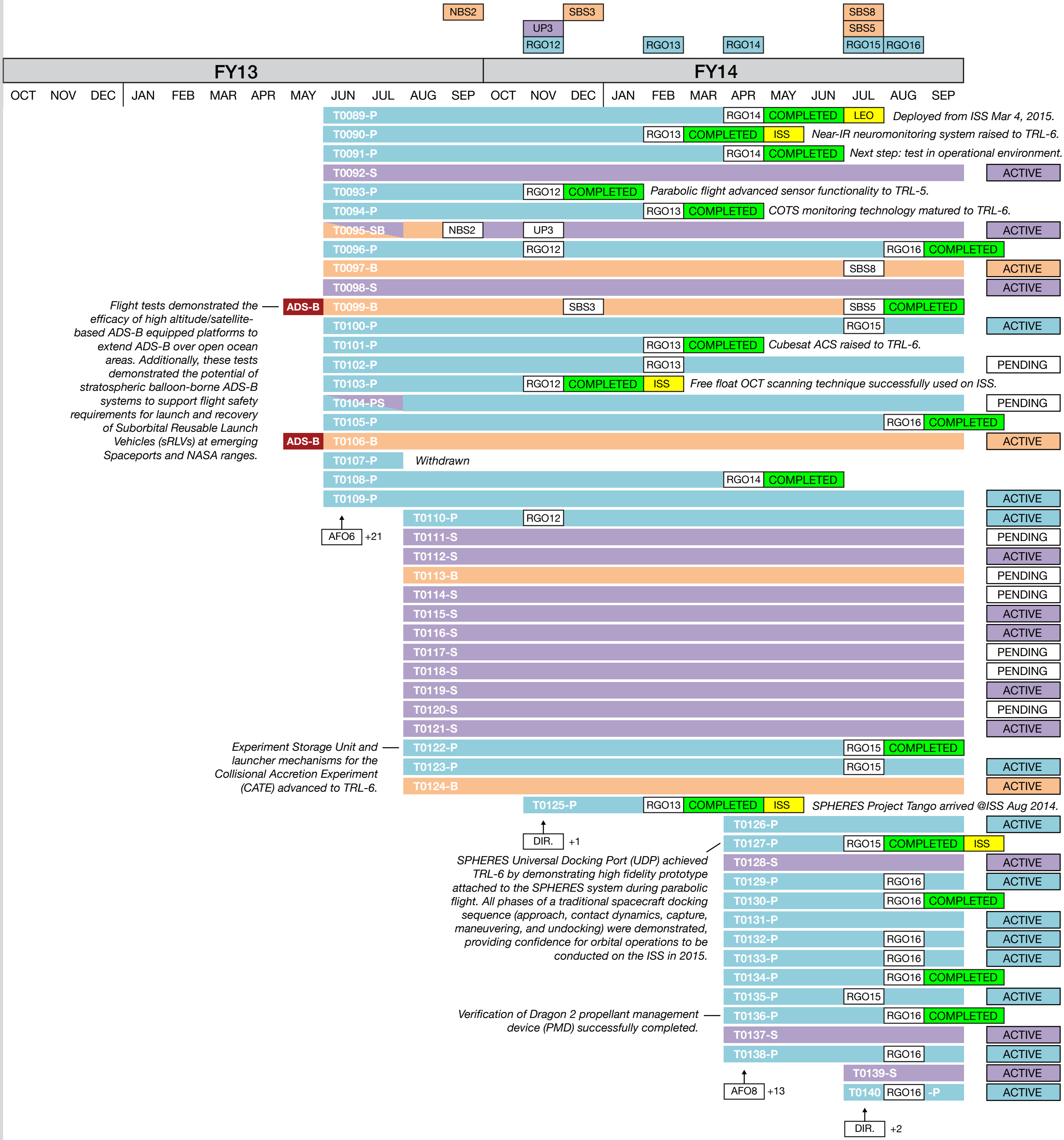
Low Earth Orbit LEO

Solar System BEYOND

featured in FY13 Annual Report ★

Linked activities

ADS-B	1	T0002-S	→	COMPLETED	→	T0033-B	→	COMPLETED	→	T0061-SB
	2	T0007-P	→	COMPLETED	→	T0024-S				
	3	T0010-P	→	COMPLETED	→	T0070-P	→	COMPLETED		
	4	T0012-P	→	COMPLETED	→	T0053-S				
	5	T0014-P	→	COMPLETED	→	T0073-S				
	6	T0016-S	→	COMPLETED	→	T0034-S				
	7	T0017-P	→	COMPLETED	→	T0091-P	→	COMPLETED		
	8	T0040-P	→	COMPLETED	→	T0059-P				
	9	T0051-P	→	COMPLETED	→	T0134-P	→	COMPLETED		


NBS2
SBS3
UP3
RGO12
RGO13
RGO14
SBS8
SBS5
RGO15
RGO16
FY13
FY14
OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP
T0089-P RGO14 COMPLETED LEO Deployed from ISS Mar 4, 2015.
T0090-P RGO13 COMPLETED ISS Near-IR neuromonitoring system raised to TRL-6.
T0091-P RGO14 COMPLETED Next step: test in operational environment.
T0092-S ACTIVE
T0093-P RGO12 COMPLETED Parabolic flight advanced sensor functionality to TRL-5.
T0094-P RGO13 COMPLETED COTS monitoring technology matured to TRL-6.
T0095-SB NBS2 UP3 ACTIVE
T0096-P RGO12 RGO16 COMPLETED
T0097-B SBS8 ACTIVE
T0098-S ACTIVE
Flight tests demonstrated the efficacy of high altitude/satellite-based ADS-B equipped platforms to extend ADS-B over open ocean areas. Additionally, these tests demonstrated the potential of stratospheric balloon-borne ADS-B systems to support flight safety requirements for launch and recovery of Suborbital Reusable Launch Vehicles (sRLVs) at emerging Spaceports and NASA ranges.
ADS-B T0099-B SBS3 SBS5 COMPLETED
T0100-P RGO15 ACTIVE
T0101-P RGO13 COMPLETED Cubesat ACS raised to TRL-6.
T0102-P RGO13 PENDING
T0103-P RGO12 COMPLETED ISS Free float OCT scanning technique successfully used on ISS.
T0104-PS PENDING
T0105-P RGO16 COMPLETED
ADS-B T0106-B ACTIVE
T0107-P Withdrawn
T0108-P RGO14 COMPLETED
T0109-P ACTIVE
T0110-P RGO12 ACTIVE
AFO6 +21
T0111-S PENDING
T0112-S ACTIVE
T0113-B PENDING
T0114-S PENDING
T0115-S ACTIVE
T0116-S ACTIVE
T0117-S PENDING
T0118-S PENDING
T0119-S ACTIVE
T0120-S PENDING
T0121-S ACTIVE
Experiment Storage Unit and launcher mechanisms for the Collisional Accretion Experiment (CATE) advanced to TRL-6.
T0122-P RGO15 COMPLETED
T0123-P RGO15 ACTIVE
T0124-B ACTIVE
T0125-P RGO13 COMPLETED ISS SPHERES Project Tango arrived @ISS Aug 2014.
DIR. +1
T0126-P ACTIVE
T0127-P RGO15 COMPLETED ISS
SPHERES Universal Docking Port (UDP) achieved TRL-6 by demonstrating high fidelity prototype attached to the SPHERES system during parabolic flight. All phases of a traditional spacecraft docking sequence (approach, contact dynamics, capture, maneuvering, and undocking) were demonstrated, providing confidence for orbital operations to be conducted on the ISS in 2015.
T0128-S ACTIVE
T0129-P RGO16 ACTIVE
T0130-P RGO16 COMPLETED
T0131-P ACTIVE
T0132-P RGO16 ACTIVE
T0133-P RGO16 ACTIVE
T0134-P RGO16 COMPLETED
T0135-P RGO15 ACTIVE
Verification of Dragon 2 propellant management device (PMD) successfully completed.
T0136-P RGO16 COMPLETED
T0137-S ACTIVE
T0138-P RGO16 ACTIVE
T0139-S ACTIVE
AFO8 +13
T0140 RGO16 -P ACTIVE
DIR. +2

T#	Origin	Title
T0001-PS	Directed	Suborbital Flight Environment Monitor (SFEM)
T0002-S	Directed	Automatic Dependent Surveillance-Broadcast (ADS-B)
T0003-PS	AFO1	On-Orbit Propellant Storage Stability
T0004-PS	AFO1	Printing the Space Future
T0005-P	AFO1	Development and Validation of Design Tools for Advanced Two-Phase, Space Heat Exchangers
T0006-P	AFO1	Electric Field Effects on Pool Boiling Heat Transfer in Low-G Environments
T0007-P	AFO1	Testing of the Radio Frequency Mass Gauge on Parabolic Flights
T0008-P	AFO1	Indexing Media Filtration System for Long Duration Space Mission
T0009-P	AFO1	Autonomous Robotic Capture in Near-Zero Gravity to Validate Ground-Based Contact Dynamics Simulation of Space Operations
T0010-P	AFO1	Validation of Atomization Mechanism and Droplet Transport for a Spacecraft Fine Water Mist Portable Fire Extinguisher in Microgavity
T0011-P	AFO1	Cryocooler Vibrational Characterization for the VASIMR ISS Demonstration Mission
T0012-P	AFO1	Validating Telemetric Imaging Hardware for Crew-Autonomous Biological Imaging in Parabolic and Suborbital Application
T0013-P	AFO1	Real-Time Instrumentation for Monitoring Radiation-Induced DNA Degradation in Space
T0014-P	AFO1	Heat Pipe Limits in Reduced Gravity Environments
T0015-S	AFO1	Electromagnetic Field Measurements on sRLV
T0016-S	AFO1	Guidance Embedded Navigator Integration Environment (GENIE)
T0017-P	AFO1	Iso-grid, Thermal-Structural Panel (IsoTherm)
T0018-P	AFO1	Sub-System Coupling for Grey Water Purification (VPCAR)
T0019-S	Directed	DIAPASON
T0020-PS	AFO2	Microgravity Multi-Phase Flow Experiment for Suborbital Testing (MFEST)
T0021-S	AFO2	Application of Controlled Vibrations to Multiphase Systems
T0022-S	AFO2	Environment Monitoring Suite on sRLV
T0023-S	AFO2	Measurement of the Atmospheric Background in the Mesosphere
T0024-S	AFO2	RF Gauging of the Liquid Oxygen Tank on a Suborbital Reusable Launch Vehicle
T0025-P	AFO2	Assessing Vestibulo-ocular Function and Spatial Orientation in Parabolic Flight
T0026-P	AFO2	Evaluation of Medical Chest Drainage System Funtional in the Microgravity Environment
T0027-P	AFO2	Autonomous Cell Culture Apparatus for Growing 3-Dimensional Tissues in Microgravity
T0028-P	AFO2	Demonstration of Non-Invasive Acquisition of Physiologic Variables from Spaceflight Participants
T0029-P	AFO3	Physics of Regolith Impacts in Microgravity Experiment
T0030-P	AFO3	Microgravity Health Care
T0031-P	AFO3	Activity Monitoring during Parabolic Flight
T0032-P	AFO3	UAH CubeSat Parabolic Flight Testing
T0033-B	AFO3	Flight Testing of UAT ADS-B Transmitter Prototype for Commercial Space Transportation
T0034-S	AFO3	Terrain Relative Navigation Descent Imager (TRNDI)
T0035-S	AFO3	Near-Zero Gravity Cryogenic Line Chilldown Experiment in a Suborbital Reusable Launch Vehicle
T0036-S	AFO3	Collisions Into Dust Experiment on a Commercial Suborbital Vehicle
T0037-P	AFO3	Particle Dispersion System for Microgravity Environments
T0038-SB	AFO3	Structural Health Monitoring for Commercial Space Vehicles
T0039-P	AFO3	Fuel Mass Gauging Based on Electrical Capacitance Volumatric Tomography Techniques
T0040-P	AFO3	Microgravity Effects of Nanoscale Mixing on Diffusion Limited Processes Using Electrochemical Electrodes
T0041-P	AFO3	Effects of Reduced Gravity on Flow Boiling and Condensation
T0042-P	AFO3	OSIRIS-REx Low-Gravity Regolith Sampling Tests
T0043-P	AFO3	Parabolic Flight: Validation of Electro-Hydrodynamic Gas-Liquid Phase Separation in Microgravity
T0044-P	AFO3	Sintering of Composite Materials under Reduced Gravity Conditions
T0045-P	AFO3	Evaporative Heat Transfer Mechanisms within a Heat Melt Compactor (EHeM HMC) Experiment
T0046-S	AFO3	Polar Mesospheric Cloud Imaging and Tomography Experiment
T0047-P	AFO3	Boston University Student Proposal for Deployable Solar and Antenna Array Microgravity Testing

PI	Organization	State	Org Type	TA	# P/S/B	end FY14 Status
Steve Ord	NASA/Ames Research Center	CA	Government	TA08	1/2/-	Active
Nick Demidovich	FAA Commercial Space Transportation	DC	Government	TA05	-/2/-	Completed
Sathya Gangadharan	Embry-Riddle Aeronautical University	FL	Academia	TA02	2/-/-	Active
Jason Dunn	Made in Space, Inc.	CA	Industry	TA12	4/-/-	Active
Jungho Kim	University of Maryland	MD	Academia	TA14	2/-/-	Completed
Jungho Kim	University of Maryland	MD	Academia	TA14	1/-/-	Completed
Greg Zimmerli	NASA/Glenn Research Center	OH	Government	TA02	2/-/-	Completed
Rajagopal Vijayakumar	Aerfil (w/ NASA GRC)	NY	Industry	TA06	4/-/-	Active
Brian Roberts	NASA/Goddard Space Flight Center	MD	Government	TA04	2/-/-	Completed
Thierry Carriere	ADA Technologies	CO	Industry	TA06	1/-/-	Completed
Chris Olsen	Ad Astra Rocket Company	TX	Industry	TA02	4/-/-	Completed
Rob Ferl	University of Florida	FL	Academia	TA08	4/-/-	Completed
Howard G. Levine	NASA/Kennedy Space Center	FL	Government	TA06	3/-/-	Completed
Marc A. Gibson	NASA/Glenn Research Center	OH	Government	TA14	3/-/-	Completed
H. Todd Smith	Johns Hopkins University / APL	MD	Research Inst.	TA08		Active
Rick Loffi	Draper Laboratory	MA	Research Inst.	TA09	-/5/-	Completed
Hans-Peter Dumm	Air Force Research Laboratory	NM	Government	TA14	1/-/-	Completed
Walt Turner	NASA/Kennedy Space Center	FL	Government	TA06		Withdrawn
Ferdinando Cassese	DTM Technologies	ITALY	International	TA08	-/1/-	Completed
Katy Hurlbert	NASA/Johnson Space Center	TX	Government	TA06	2/-/-	Active
Ricard Gonzalez-Cinca	Universitat Politècnica de Catalunya	SPAIN	International	TA02	-/1/-	Active
H. Todd Smith	Johns Hopkins University / APL	MD	Research Inst.	TA08		Active
Sean Casey	Silicon Valley Space Center	CA	Industry	TA08		Pending
Greg Zimmerli	NASA/Glenn Research Center	OH	Government	TA02		Active
Michael Schubert	Johns Hopkins Univ. School of Medicine	MD	Academia	TA06	3/-/-	Completed
C. Marsh Cuttino	Orbital Medicine, Inc.	VA	Industry	TA06	2/-/-	Completed
Zarana Patel	NASA/Johnson Space Center	TX	Government	TA06	1/-/-	Active
Ravi Komatireddy	The Vital Space Team	CA	Industry	TA06	1/-/-	Completed
Josh Colwell	University Of Central Florida	FL	Academia	TA07	2/-/-	Completed
Scott Dulchavsky	Henry Ford Health System	MI	Research Inst.	TA06	1/-/-	Completed
Peter Cavanagh	University of Washington	WA	Academia	TA06	3/-/-	Completed
Francis Wessling	Univ. Of Alabama Space HW Club	AL	Academia	TA12	1/-/-	Completed
Richard Stansbury	Embry-Riddle Aeronautical University	FL	Academia	TA05	-/-/1	Completed
Rick Loffi	Draper Laboratory	MA	Research Inst.	TA09		Active
Jacob Chung	University of Florida	FL	Academia	TA02		Active
Josh Colwell	University Of Central Florida	FL	Academia	TA07		Active
John Marshall	SETI Institute	CA	Research Inst.	TA08	1/-/-	Completed
Andrei Zagrai	NM Institute Of Mining And Technology	NM	Academia	TA12	-/1/1	Completed
Manohar Deshpande	NASA/Goddard Space Flight Center	MD	Government	TA02		Pending
Carlos Cabrera	University of Puerto Rico	PR	Academia	TA06	2/-/-	Completed
Issam Mudawar	Purdue University	IN	Academia	TA14	1/-/-	Completed
Joe Vellinga	Lockheed Martin Inc.	CO	Industry	TA07	1/-/-	Completed
Boris Khusid	New Jersey Institute Of Technology	NJ	Academia	TA14	1/-/-	Pending
Carmelo Mandarino	Advanced Technical Inst. "E. Fermi"	ITALY	International	TA07	1/-/-	Pending
Eric Golliher	NASA/Glenn Research Center	OH	Government	TA06	1/-/-	Pending
Jason Reimuller	Space Science Institute	CO	Research Inst.	TA08		Pending
Ted Fritz	Boston University	MA	Academia	TA12	3/-/-	Completed

T#	Origin	Title
T0048-P	AFO3	Effects of Reduced and Hyper Gravity on Functional Near-Infrared Spectroscopy (fNIRS) Instrumentation
T0049-P	AFO3	Parabolic Flight Evaluation of a Hermetic Surgery System for Reduced Gravity
T0050-B	AFO3	Flight Demonstration of an Integrated Camera and Solid-State Fine Steering System
T0051-P	AFO3	Non-Invasive Hemodynamic Monitoring in Microgravity
T0052-S	AFO3	Collection of Regolith Experiment (CORE) on a Commercial Suborbital Vehicle
T0053-S	AFO4	Validating Telemetric Imaging Hardware for Crew-Assisted and Crew-Autonomous Biological Imaging in Suborbital Applications
T0054-B	AFO4	Stratospheric Parabolic Flight Technology
T0055-P	AFO5	Structural Dynamics Test of STACER Antenna Deployment in Microgravity
T0056-P	AFO5	UAH ChargerSat-2 Parabolic Flight Testing
T0057-P	AFO5	High Eccentric Resistive Overload (HERO) Device Demonstration during Parabolic Flight
T0058-P	AFO5	Assessing Otolith-Organ Function with Vestibular Evoked Myogenic Potentials (VEMPs) in Parabolic Flight
T0059-P	AFO5	On the Performance of a Nanocatalyst-Based Direct Ammonia Alkaline Fuel Cell (DAAFC) Under Microgravity Conditions for Water Reclamation and Energy Applications
T0060-P	AFO5	Dynamic and Static Behavior of a Flexible Fuel Hose in Zero-G
T0061-SB	AFO5	Flight Testing of a UAT ADS-B Transmitter Prototype for Commercial Space Transportation Using sRLV
T0062-P	AFO5	In-Flight Lab Analysis Technology Demonstration in Reduced Gravity
T0063-P	AFO5	Caging System for Drag-free Satellites
T0064-B	AFO5	Deployable Rigid Adjustable Guided Final Landing Approach Pinions (DRAG FLAPs)
T0065-P	AFO5	Reduced Gravity Flight Demonstration of the Resonant Inductive Near-field Generation System (RINGS)
T0066-B	AFO5	Guided Parafoil High Altitude Research
T0067-S	AFO5	Autolanding for Robotic Precursor Missions
T0068-S	NRA1	Fuel Optimal Large Divert Guidance for Planetary Pinpoint Landing (G-FOLD)
T0069-S	Directed	Global Positioning Beacon (GPB)
T0070-P	Directed	Portable Fire Extinguisher (formerly T0010-P)
T0071-S	Directed	New Mexico Student Groups #1 and #2 for SL-7
T0072-S	Directed	New Mexico Student Groups #3 and #4 for SL-8
T0073-S	Directed	Radial Core Heat Spreader
T0074-S	Directed	Miniature Altitude Determination System
T0075-S	Directed	Exo-Atmosperic Aerobrake
T0076-S	NRA1	Demonstration of Vertically Aligned Carbon Nano-tubes for Earth Climate Remote Sensing
T0077-S	NRA1	Facility for Microgravity Research and Submicroradian Stabilization using sRLVs
T0078-S	NRA1	Enhanced Thermal Switch for Payload Autonomous Thermal Control
T0079-S	NRA1	Autonomous Flight Manager for Human-in-the-Loop Immersive Simulation and Flight Test of Terrestrial Rockets
T0080-S	NRA1	Advanced Micro Sun Sensor
T0081-S	NRA1	Demonstration of Variable Radiator
T0082-S	NRA1	Dynamic Microscopy System
T0083-S	NRA1	Design and Development of a Micro Satellite Attitude Control System
T0084-S	NRA1	Suborbital Test of a Robotics-Based Method for In-Orbit Identification of Spacecraft Inertia Properties
T0085-S	NRA1	SwRI Solar Instrument Pointing Platform
T0086-S	NRA1	Saturated Fluid Pistonless Pump Technology Demonstrator
T0087-S	NRA1	Electric-hydrodynamic Control of Two-Phase Heat Transfer in Microgravity
T0088-S	NRA1	An FPGA-based, Radiation Tolerant, Reconfigurable Computer System with Real Time Fault Detection, Avoidance, and Repair
T0089-P	AFO6	Technology Maturation of a Dual-Spinning CubeSat Bus
T0090-P	AFO6	Testing Near-Infrared Neuromonitoring Devices for Detecting Cerebral Hemodynamic Changes in Parabolic Flight
T0091-P	AFO6	Resilient Thermal Panel: Microgravity Effects on Isothermality of Structurally Embedded Two Dimensional Heat Pipes
T0092-S	AFO6	Precision Formation Flying Sensor
T0093-P	AFO6	Wireless Strain Sensing System for Space Structural Health Monitoring
T0094-P	AFO6	Monitoring Tissue Oxygen Saturation in Microgravity

PI	Organization	State	Org Type	TA	# P/S/B	end FY14 Status
Angela Harrivel	NASA/Glenn Research Center	OH	Government	TA06	2/-/-	Completed
George Pantalos	University of Louisville	KY	Academia	TA06	2/-/-	Active
Eliot Young	Southwest Research Institute	CO	Research Inst.	TA08		Active
Greg Kovacs	Stanford University	CA	Academia	TA06	2/-/-	Completed
Josh Colwell	University of Central Florida	FL	Academia	TA07		Active
Rob Ferl	University of Florida	FL	Academia	TA08		Active
Steven Collicott	Purdue University	IN	Academia	TA08	-/-/1	Active
Kerri Cahoy	Massachusetts Institute of Technology	MA	Academia	TA12	1/-/-	Completed
Francis Wessling	University of Alabama	AL	Academia	TA14		Active
Aaron Weaver	NASA/Glenn Research Center	OH	Government	TA06	1/-/-	Active
Mark Shelhamer	Johns Hopkins Univ. School of Medicine	MD	Academia	TA06		Pending
Carlos Cabrera	University of Puerto Rico, Rio Pedras	PR	Academia	TA03	1/-/-	Active
Allyson Buker	Jackson and Tull	DC	Industry	TA04	1/-/-	Completed
Richard Stansbury	Embry-Riddle Aeronautical University	FL	Academia	TA05	-/1/1	Active
Emily Nelson	NASA/Glenn Research Center	OH	Government	TA06		Pending
Rob Byer	Stanford University	CA	Academia	TA08	1/-/-	Completed
Scott Nietfeld	Masten Space Systems Inc.	CA	Industry	TA09		Active
Ray Sedwick	University of Maryland	MD	Academia	TA04	1/-/-	Completed
Allen Lowry	Airborne Systems N. America of CA, Inc.	CA	Industry	TA09	-/-/1	Active
Kevin Peterson	Astrobotic Technology, Inc.	PA	Industry	TA09	-/3/-	Completed
Behcet Acikmese	NASA/Jet Propulsion Laboratory	CA	Government	TA09	-/2/-	Completed
Jason Armstrong	Kirtland AFB	NM	Government	TA05	-/2/-	Completed
Branelle Rodriguez	NASA/Johnson Space Center	TX	Government	TA06	1/-/-	Completed
Pat Hynes	New Mexico Space Grant Consortium	NM	Academia	TA06	-/1/-	Completed
Pat Hynes	New Mexico Space Grant Consortium	NM	Academia	TA06		Withdrawn
Roshanak Hakimzadeh	NASA/Glenn Research Center	OH	Government	TA14		Active
Sohrab Mobasser	NASA/Jet Propulsion Laboratory	CA	Government	TA05		Withdrawn
Marc Murbach	NASA/Ames Research Center	CA	Government	TA09		Active
H. Todd Smith	Johns Hopkins University / APL	MD	Research Inst.	TA10		Pending
Scott Green	Controlled Dynamics Inc.	CA	Industry	TA08	-/1/-	Active
Douglas Mehoke	Johns Hopkins University / APL	MD	Research Inst.	TA14		Pending
Rick Loffi	Draper Laboratory	MA	Research Inst.	TA04		Active
Sohrab Mobasser	NASA/Jet Propulsion Laboratory	CA	Government	TA05		Active
Richard Kurwitz	Texas A&M University	TX	Academia	TA14		Active
John Vellinger	Techshot, Inc.	IN	Industry	TA08		Pending
Manoranjan Majji	State University of New York, Buffalo	NY	Academia	TA02		Active
Ou Ma	New Mexico State University	NM	Academia	TA04	-/1/-	Active
Craig DeForest	Southwest Research Institute	CO	Research Inst.	TA08		Pending
Ryan Starkey	University of Colorado	CO	Academia	TA02		Active
Boris Khusid	New Jersey Institute of Technology	NJ	Academia	TA14		Pending
Brock LaMeres	Montana State University	MT	Academia	TA11		Active
Kerri Cahoy	Massachusetts Institute of Technology	MA	Academia	TA12	1/-/-	Completed
Gary Strangman	Massachusetts General Hospital	MA	Academia	TA06	1/-/-	Completed
Andy Williams	Air Force Research Laboratory	NM	Government	TA14	1/-/-	Completed
Webster Cash	University of Colorado	CO	Academia	TA08		Active
Haiying Huang	University of Texas, Arlington	TX	Academia	TA12	1/-/-	Completed
Tom Smith	University of Oxford	UK	International	TA06	1/-/-	Completed

T#	Origin	Title
T0095-SB	AFO6	Test of Satellite Communications Systems on-board Suborbital Platforms to Provide Low-Cost Data Communications for Research Payloads, Payload Operators, and Space Vehicle Operators
T0096-P	AFO6	Testing the Deployment and Rollout of the DragEN Electrodynamic Tether for CubeSats
T0097-B	AFO6	Planetary Atmosphere Minor Species Sensor
T0098-S	AFO6	Navigation Doppler Lidar Sensor Demonstration for Precision Landing on Solar System Bodies
T0099-B	AFO6	Satellite-Based ADS-B Operations Flight Test
T0100-P	AFO6	Creation of Titanium-Based Nanofoams in Reduced Gravity for Dye-Sensitized Solar Cell Production
T0101-P	AFO6	Testing a CubeSat Attitude Control System in Microgravity Conditions
T0102-P	AFO6	Demonstration of Adjustable Fluidic Lens in Microgravity
T0103-P	AFO6	Optical Coherence Tomography (OCT) in Microgravity
T0104-PS	AFO6	Real Time Conformational Analysis of Rhodopsin using Plasmon Waveguide Resonance Spectroscopy
T0105-P	AFO6	DYMAFLEX: DYnamic MAnipulation FLight EXperiment
T0106-B	AFO6	Low-Cost Suborbital Reusable Launch Vehicle (sRLV) Surrogate
T0107-P	AFO6	Characterizing CubeSat Deployer Dynamics in a Microgravity Environment
T0108-P	AFO6	Demonstration of food processing equipment
T0109-P	AFO6	Advanced Optical Mass Measurement System
T0110-P	Directed	Wet Lab
T0111-S	NRA2	Rocket Flight of a Delta-Doped CCD Focal Plane Array for CHESS
T0112-S	NRA2	Spacecraft Disturbance Isolation and Rejection Platform (SDIRP)
T0113-B	NRA2	Focal Plane Actuation to Achieve Ultra-High Resolution on Suborbital Balloon Payloads
T0114-S	NRA2	Technology Demonstration of Graphene Ion Membranes for Earth and Space Applications
T0115-S	NRA2	EDL Technology Development for the Maraia Earth Return Capsule
T0116-S	NRA2	Operational Demonstration of the MPS-120 CubeSat High-impulse Adaptable Modular Propulsion System
T0117-S	NRA2	1U CubeSat Green Propulsion System with Post-Launch Pressurization
T0118-S	NRA2	Iodine RF Ion Thruster Development
T0119-S	NRA2	Inductively Coupled Electromagnetic (ICE) Thruster System Development for Small Spacecraft Propulsion
T0120-S	NRA2	Advanced Hybrid Rocket Motor Propulsion Unit for CubeSats (PUC)r
T0121-S	Directed	Flyover Mapping and Modeling of Terrain Features
T0122-P	Directed	Microgravity Experiment on Accretion in Space Environments
T0123-P	Directed	Microgravity Propellant Gauging Using Modal Analysis
T0124-B	Directed	Gannon University's Cosmic-Ray Calorimeter (GU-CRC)
T0125-P	Directed	HET SPHERES Smartphone
T0126-P	AFO8	Validating Microgravity Mobility Models for Hopping/Tumbling Robots
T0127-P	AFO8	Reduced Gravity Flight Demo of SPHERES Universal Docking Ports
T0128-S	AFO8	Zero-gravity Green Propellant Management Technology
T0129-P	AFO8	Testing of a Microgravity Rock Coring Drill Using Microspines
T0130-P	AFO8	Reinventing the wheel: parabolic flight validation of reaction spheres
T0131-P	AFO8	Enhanced Dynamic Load Sensors for ISS (EDLS-ISS) Operational Feasibility for ARED
T0132-P	AFO8	Effects of Microgravity on Intracranial Pressure
T0133-P	AFO8	Payload Separation Performance of a New 6U CubeSat Canisterized Satellite Dispenser
T0134-P	AFO8	Noninvasive Hemodynamic Monitoring in Microgravity, Phase II (Arterial Stiffness)
T0135-P	AFO8	Testing ON-OFF Gecko Adhesive Grippers in Microgravity
T0136-P	AFO8	Dragon V2 Propellant Management Device Microgravity Validation
T0137-S	AFO8	Fuel Optimal and Accurate Landing System (FOALS) Test Flights
T0138-P	AFO8	Reduced Gravity Flight Demonstration of SPHERES INSPECT
T0139-S	Directed	ADEPT
T0140-P	Directed	Lunar Plant Habitat

PI	Organization	State	Org Type	TA	# P/S/B	end FY14 Status
Brian Barnett	Solstar Communications	NM	Industry	TA05	-/1/1	Active
Jason Held	Saber Astronautics Australia Pty. Ltd.	AUSTRALIA	International	TA02	2/-/-	Completed
Robert Peale	University of Central Florida	FL	Academia	TA08	-/-/1	Active
Farzin Amzajerdian	NASA/Langley Research Center	VA	Government	TA09		Active
Russ Dewey	GSSL, Inc.	OR	Industry	TA05	-/-/2	Completed
Kristen Scotti	Northwestern University	IL	Academia	TA10	1/-/-	Active
Eric Bradley	University of Central Florida	FL	Academia	TA02	1/-/-	Completed
James Schwiegerling	University of Arizona	AZ	Academia	TA08	1/-/-	Pending
Doug Ebert	Wyle Laboratories	TX	Industry	TA06	1/-/-	Completed
Victor Hruby	University of Arizona	AZ	Academia	TA06		Pending
David Akin	University of Maryland	MD	Academia	TA04	1/-/-	Completed
Tim Lachenmeier	GSSL, Inc.	OR	Industry	TA05		Active
Kira Abercromby	California Polytechnic State University	CA	Academia	TA12		Withdrawn
Susana Carranza	Makel Engineering, Inc.	CA	Industry	TA07	1/-/-	Completed
Jason Reimuller	Mass Dynamix, Inc.	CA	Industry	TA02		Active
Macarena Parra	NASA/Ames Research Center	CA	Government	TA06	1/-/-	Active
Paul Scowen	Arizona State University	AZ	Academia	TA08		Pending
Gerardo Ortiz	NASA/Jet Propulsion Laboratory	CA	Government	TA08		Active
Paul Scowen	Arizona State University	AZ	Academia	TA08		Pending
H. Todd Smith	Johns Hopkins University / APL	MD	Research Inst.	TA10		Pending
Alan Strahan	NASA/Johnson Space Center	TX	Government	TA09		Active
Christian Carpenter	Aerojet General Corporation	WA	Industry	TA02		Active
Michael Tsay	Busek Co. Inc.	MA	Industry	TA02		Pending
Kurt Hohman	Busek Co. Inc.	MA	Industry	TA02		Pending
John Slough	MSNW LLC	WA	Industry	TA02		Active
John DeSain	The Aerospace Corporation	CA	Research Inst.	TA02		Pending
William Whittaker	Carnegie Mellon University	PA	Academia	TA08		Active
Josh Colwell	University of Central Florida	FL	Academia	TA08	1/-/-	Completed
Kevin Crosby	Carthage College	WI	Academia	TA02	1/-/-	Active
Nicholas Conklin	Gannon University	PA	Academia	TA08		Active
Terry Fong	NASA/Ames Research Center	CA	Government	TA04	1/-/-	Completed
Issa Nesnas	NASA/Jet Propulsion Laboratory	CA	Government	TA04		Active
Alvar Saenz Otero	Massachusetts Institute of Technology	MA	Academia	TA04	1/-/-	Completed
Steven Collicot	Purdue University	IN	Academia	TA02		Active
Aaron Parness	NASA/Jet Propulsion Laboratory	CA	Government	TA04	1/-/-	Active
Alvin Yew	NASA/Goddard Space Flight Center	MD	Government	TA05	1/-/-	Completed
Christopher Krebs	Aurora Flight Services	MA	Industry	TA06		Active
Benjamin Levine	University of Texas Southwestern Medical C.	TX	Academia	TA06	1/-/-	Active
Hans-Peter Dumm	Air Force Research Laboratory	NM	Government	TA12	1/-/-	Active
Greg Kovacs	Stanford University	CA	Academia	TA06	1/-/-	Completed
Aaron Parness	NASA/Jet Propulsion Laboratory	CA	Government	TA04	1/-/-	Active
Robin Titus	Space Exploration Technologies (SpaceX)	CA	Industry	TA02	1/-/-	Completed
Andrew Johnson	NASA/Jet Propulsion Laboratory	CA	Government	TA09		Active
Alvar Saenz Otero	Massachusetts Institute of Technology	MA	Academia	TA04	1/-/-	Active
Paul Wercinski	NASA/Ames Research Center	CA	Government	TA09		Active
Chris McKay	NASA/Ames Research Center	CA	Government	TA07	1/-/-	Active

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T0097 D. Maukonen, C.J. Fredricksen, A.V. Muraviev, A. Alhasan, S. Calhoun, G. Zummo, R.E. Peale, J.E. Colwell. Planetary Atmospheres Minor Species Sensor (PAMSS). In *SPIE Proceedings Vol. 9113: Sensors for Extreme Harsh Environments*, 2014. http://spie.org/Publications/Proceedings/Paper/10.1117/12.2050169

T0093 A. Mears, Y. Yao, Y. Hew, E. Castillo, F. Leal, B. Harris, H. Huang. Wireless strain sensing system for Structural Health Monitoring under various gravity levels. In *65th International Astronautical Congress*, 2014. http://iafastro.directory/iac/paper/id/21268/summary/

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T0068 D.P. Scharf, M.W. Regehr, G.M. Vaughan, J. Benito, H. Ansari, M. Aung, A. Johnson, J. Casoliva, S. Mohan, D. Dueri, B. Acikmese, D. Masten, S. Nietfeld. ADAPT demonstrations of onboard large-divert Guidance with a VTVL rocket. In *Aerospace Conference*, 2014, doi: 10.1109/AERO.2014.6836462 http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=6836462

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T0085 C.E. DeForest, G. Laurent, J. Brownsberger, J. Diller, T. Case1, K. Rodway, E. Anderson. The SwRI Solar Instrument Pointing Platform (SSIPP). NSRC-2013. http://www.boulder.swri.edu/NSRC2013/Site2/PDF/DeForest_abstract.pdf

T0084 G. Martinez, O. Ma. Test of a satellite inertia identification method using suborbital flight. NSRC-2013. http://www.boulder.swri.edu/NSRC2013/Site2/PDF/Martinez_abstract.pdf

T0077 S.A. Green. Payload Isolation for Microgravity Research on sRLVs. NSRC-2013. http://www.boulder.swri.edu/NSRC2013/Site2/PDF/Green_abstract.pdf

T0066 J. Barber. Recovery system considerations in sub-orbital vehicle design and experimental payloads. NSRC-2013. http://www.boulder.swri.edu/NSRC2013/Site2/PDF/Barber_abstract.pdf

T0038 A. Zagrai, N. Demidovich, B. Cooper, J. Schlavin, C. White, S. Kessler, J. Macgillivray, S. Chesebrough, L. Magnusion, L. Puckett, K. Tena, J. Gutierrez, B. Trujillo1, T. Gonzales. Structural Condition Assessment during High Altitude Stratospheric Balloon Flight. NSRC-2013. http://www.boulder.swri.edu/NSRC2013/Site2/PDF/Zagrai_abstract.pdf

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T0016 T. Brady, S. Paschall, D. Zimpfer, R. Loffi. A Next Generation Terrestrial Test Rocket. NSRC-2013. http://www.boulder.swri.edu/NSRC2013/Site2/PDF/Brady_abstract.pdf

T0015 H.T. Smith, L. Dyrud, L. Paxton. An updated perspective on requirements and challenges of using commercial suborbital reusable launch vehicles for upper atmospheric/lower ionospheric research. In NSRC-2012. http://www.boulder.swri.edu/NSRC2012/Site1//PDF/Smith-ATM.pdf

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▷ *December 5, 2013: post-landing recovery of the Small Balloon System (SBS) gondola carrying the TAMLACE payload testing reception of the surrogate Satellite-based ADS-B. (Photo: Near Space Corporation)*


UP

Platforms
Profiles

Xombie
Masten Space Systems

Introduction
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.

To date, Masten has completed more than 350 rocket-powered tether flights and more than 40 free flights on 5 different reusable rocket-powered launch vehicles. Masten has demonstrated aircraft-like reusability by flying a single vehicle three times in a single day and by flying three different vehicles in a single week. Masten vehicles routinely execute planetary landing trajectories that descend from 500m and include cross- and downrange divert maneuvers of up to 800m.

The maturation of Masten's core RLV and VTVL precision landing capabilities has paved the way for Masten to develop applications in adjacent market segments. In July 2014, the company was selected by DARPA as a prime contractor (alongside competing prime contractors Boeing and Northrup Grumman) for Phase 1 of DARPA's "XS-1" reusable spaceplane program. The performance of Masten's XA-0.1-B "Xombie" vehicle as a NASA's Flight Opportunities program test platform offered a concrete demonstration of the rapid turnaround and reusability that are central XS-1 program objectives. Separately, Masten was competitively selected as a commercial partner under NASA's Lunar Cargo Transportation and Landing by Soft Touchdown (Lunar CATALYST) initiative. Participation in the CATALYST program is accelerating Masten's application of the tenets of its design and build philosophy to the development of a pragmatically cost-effective robotic lunar lander that can be integrated with U.S. commercial launch capabilities to deliver payloads to the lunar surface.

Platform
The XA-0.1-B "Xombie" is a fully reusable vertical takeoff and vertical landing (VTVL) launch vehicle used for low speed and low altitude testing. In the past four years, Masten has conducted ten 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 vehicle has been used to simulate both lunar and Martian landing profiles and is 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. Xombie is capable of precision landing and has demonstrated 0.24m accuracy.

Payload Configuration and Integration
The vehicle is equipped with a hypervisor that enables third party guidance, navigation and control (GN&C) systems and avionics packages to control Xombie 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-B and experimental software and hardware tools. 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:
flightopportunities.nasa.gov/platforms/suborbital/xombie


Fundamental
Technology
Solutions
MOOG
LOCKHEED MARTIN
UP Aerospace

SpaceLoft-XL

UP Aerospace

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, is flight proven and fully operational.

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 provide back to the customers onsite.

Payload Configuration and Integration

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.

Once a payloader is signed up to a particular mission, the PTS container(s) are provided directly to the payloader to begin payload configuration, layout and mechanical mounting of hardware. Following a successful Payload Readiness Review, the PTS containers are then shipped back to UP Aerospace to complete the payload integration process and certification for flight onboard the SpaceLoft™.

More information:
flightopportunities.nasa.gov/platforms/suborbital/spaceloft-xl

Tycho 20/285

World View Enterprises

Introduction

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.

Platform

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 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 5 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:
flightopportunities.nasa.gov/platforms/balloon/tycho

HASS

Near Space Corporation

Platform
NSC's patent pending High Altitude Shuttle System (HASS) combines an innovative Tactical Balloon Launch System with a special high altitude unmanned Shuttle for payload recovery.

Flight Profile
The Tactical Balloon Launch System (TBLS) provides an unprecedented level of launch flexibility and responsiveness. Launching conventional stratospheric balloons typically requires relatively calm winds, established launch sites, and large support teams. The TBLS allows 2-3 persons to launch balloon-borne payloads from undeveloped remote launch sites in winds of up to 30 kts. This enhances the ability to overfly specific targets or fly desired profiles. The Shuttle semi-autonomously returns payloads to pre-specified landing sites, allowing payloads to be rapidly turned around and reused in reflights. 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.

Payload Configuration
Standard HASS flights can lift payloads of up to 10 kg 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 comprised of the center section of the Shuttle with payload attachment and access provided through its bottom hatch. This composite payload tray/hatch serves as the 'framework' onto which the payload is mounted. The standard HASS avionics suite is mounted on the forward part of the tray just prior to launch. All other real estate on the payload tray is available for primary payload use within the enclosed physical constraints of the Shuttle center-body, the 10 kg (22 lbs) maxmum payload weight limit, and specified center of gravity (CG) constraints.

SBS/NBS

Near Space Corporation

Small Balloon System
The Small Balloon System (SBS) offers many of the advantages of the High Altitude Balloon System (HASS), but exchanges the tactical launch system and 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 10 kg 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 (OR) Balloon Facility. 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.

Nano Balloon System
The Nano Balloon System (NBS) is an ideal platform for cubesat developers seeking to test their prototype in a space-like relevant environment. Standard flights can lift fully self-contained 1U CubeSats (1 kg, 10 cm sided cube) 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 (OR) Balloon Facility, and, due to its small size and mass, the Nano Balloon System can be operated under less restrictive regulations with increased operational flexibility. This system is ideal for payload providers seeking a quick and simple solution for operating a small passive payload in the near space environment.

More information on all three platforms:
flightopportunities.nasa.gov/platforms/balloon/nsc

G-Force One

NASA C9

C9

NASA/JSC Reduced Gravity Office

Platform

The Boeing C-9B is a two-engine, swept-wing aircraft similar to the McDonnell Douglas DC-9. NASA obtained the aircraft in August 2003 and modified it to support the Reduced Gravity Program. The C-9B is operated as a 'public use' aircraft within the meaning of the Federal Aviation Act of 1958, as amended. The interior contains 20 seats for researchers & crew in the rear of the aircraft. Approximately 45 feet of cabin length is available for test purposes. Seats in the rear can be utilized for smaller experiments as well.

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 2m (78 inches) high and 3.4m (135 inches) wide.

More information:
flightopportunities.nasa.gov/platforms/parabolic/c9

G-Force One

Zero Gravity Corporation

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 & 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.

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.

Note: *Until June of 2014, ZGC G-Force One flight operations for the Flight Opportunities program were managed by the NASA/JSC Reduced Gravity Office (RGO). After June 30, 2014, Zero Gravity Corporation solely operates as a commercial company.*

More information:
flightopportunities.nasa.gov/platforms/parabolic/gforce-one

Parabolic Flight Profile (for both aircraft)

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 Ellington Field in Houston, Texas. 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.


GALACTIC
aabar
aabar

SpaceShipTwo

Virgin Galactic

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, which provide seats for customers, and for research flights, which provide 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:
flightopportunities.nasa.gov/platforms/suborbital/spaceshiptwo

For more information, visit:
http://flightopportunities.nasa.gov
http://flickr.com/nasafo/sets
http://twitter.com/nasafo
For questions/comments, please contact nasa-flightopportunities@nasa.gov

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August 20, 2014: Terry Lee from the JSC/Reduced Gravity Office floats from the cockpit of the NASA C9 aircraft during one of the zero-g parabolas of the RGO-16 campaign. (Photo: NASA/Lauren Harnett)

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