National Aeronautics and Space Administration

Space Technology Mission Directorate

Flight Opportunities

2013 Annual Report

www.nasa.gov

July 20, 2011: Sathya Gangadharan and his fellow researchers board G-Force One at Ellington Field (TX) for the first parabolic flight of the Flight Opportunities program. (Photo: NASA/Robert Markowitz)

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June 21, 2013: LK Kubendran (second from left) and Ron Young discuss the successful recovery of payloads with Jerry Larson of UP Aerospace (right) after the SL-7 flight. (Photo: NASA/Paul de Leon)

Program Overview

This is the first Annual Report of NASA's Flight Opportunities program. As the first publication for the program, this Annual Report is telling the story from the beginning, the years FY11-FY13. Capitalizing on the U.S. commercial reusable suborbital industry, the program facilitates access to near space for a variety of users with greater frequency, reliability, and affordability.

In FY11, we selected seven commercial flight providers to provide suborbital flights. Through several rounds of Announcements of Flight Opportunities, we selected more than 100 technology payloads to be flown on suborbital and parabolic flight platforms. FY13 was our busiest year to date: our program sponsored flight demonstration of 31 technologies from universities, industry, and government utilizing 5 suborbital flights provided by Masten Space Systems and UP Aerospace, 4 balloon flights provided by Near Space Corporation, and 4 parabolic flight campaigns onboard Zero-Gravity Corporation's 727 aircraft.

2014 will be an exciting year for many of the flight providers. They are in various stages of providing commercial service: Virgin Galactic has conducted several powered flights of their SpaceShipTwo and are expecting to fly their first suborbital flight in 2014; Whittinghill Aerospace is discussing range options for their first suborbital test flight of mCLV; XCOR is working on their vehicle integration, ground testing and first flight of Lynx; Even though Armadillo Aerospace was the first vendor to receive an FAA license, the company went into hibernation because of lack of funding. A new company, Exos Aerospace, has been formed to carry on Armadillo's vision to develop reusable suborbital and orbital vehicles.

To foster a sustainable suborbital market, moving forward in 2014, we plan to encourage and assist the space technology developer community to purchase and fly technology payloads on commercial suborbital platforms of their choice. The program will continue to fly government payloads using commercial flight providers to be selected in 2014.

We hope you enjoy reading our report, and that you will agree we have come a long way from back in 2010 when all this was still just an idea in the making.

LK Kubendran
Program Executive

Ronald Young
Program Manager


GRADALL

Flight Opportunities
Goals, Progress & Metrics

◁ *May 10, 2011: Masten Space Systems performs a tethered flight test with their Xaero vehicle at the Mojave Air & Space Port (Mojave, CA). (Photo: NASA)*

"A robust and competitive commercial space sector is vital to continued progress in space. The United States is committed to encouraging and facilitating the growth of a U.S. commercial space sector that supports U.S. needs, is globally competitive, and advances U.S. leadership in the generation of new markets and innovation-driven entrepreneurship."

- National Space Policy, June 2010

The Flight Opportunities program directly answers the call of the President's National Space Policy, the NASA Strategic Plan, and Section 907 of the NASA Authorization Act of 2010 (P.L. 111-267). By purchasing flights on U.S. commercial vehicles, the program encourages and facilitates the growth of the commercial suborbital market while simultaneously providing pathways to advance the technology readiness of a wide range of new launch vehicle and space technologies.

Creating innovative new space technologies

One of the greatest challenges NASA faces in incorporating advanced technologies into future space missions is bridging the mid Technology Readiness Level gap (TRL 5-7, aka "Valley of Death"). Between laboratory prototype demonstration, and operational readiness for a space mission, a new technology must go through rigorous system level testing in relevant operational environments. Access to these relevant test environments has been costly and infrequent. The cost of access to space remains prohibitively expensive with launch costs to low-Earth orbit ranging from $10,000 to $15,000 per pound for small payloads. Adding these launch costs to the cost of demonstration hardware and operations capability presents a major hurdle in the maturation of compelling space technologies.

The Flight Opportunities program addresses this problem by increasing access to commercially available microgravity and high-altitude atmospheric environments. The program makes these environments accessible to science and technology payloads from government, academia and industry. Suborbital flights provide the potential for relevant environment testing at a small fraction of the costs required for orbital flights.

Encouraging and facilitating the growth of the U.S. commercial suborbital space industry

As an early adopter of commercial suborbital capabilities to advance space technology, the Flight Opportunities program helps establish a stable customer base for an emerging commercial suborbital market. As the suborbital flights become commercially available, researchers and technology developers can accelerate maturation of their technologies through more frequent inflight testing.

"Create the innovative new space technologies for our exploration, science, and economic future."

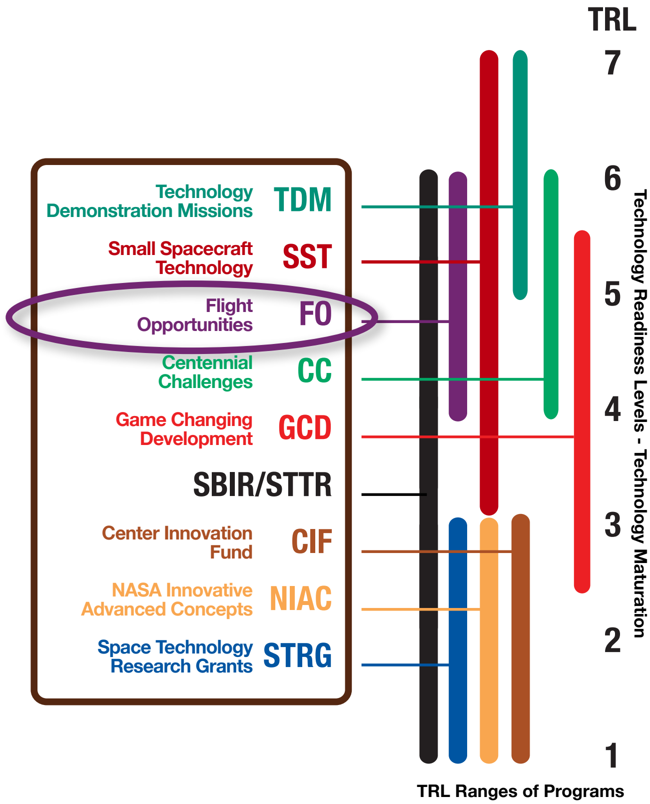
- 2011 NASA Strategic Plan, Goal 3, February 2011

Supporting workforce development

The National Research Council (NRC) report 'Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future' defends the importance of maintaining a technologically competent workforce. As noted in the legislative mandate for the Flight Opportunities program, and by the NRC review of NASA's Suborbital Program, utilization of suborbital platforms provides critical training opportunities needed to sustain a skilled aerospace workforce. Without an ability to perform these critical relevant environment tests, not only do these new technologies remain on the shelf, but also the workforce that might otherwise gain the experience to employ these new approaches remains underutilized and untrained. The Flight Opportunities program brings new opportunities for the next generation of technologists and space scientists, allowing them to learn from real science and technological development experiences.

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

Flight Opportunities FY11-13 Budget



Flight Opportunities program within the Space Technology Mission Directorate (STMD). STMD serves as the Agency's technology development and demonstration engine, working with industry, academia, other Government agencies and international partners to conceptualize, develop, build, test and demonstrate key space capabilities.

Origins of the Flight Opportunities program

FAST

In 2008, the Agency's Innovative Partnerships Program (IPP) used microgravity flights aboard the commercially-owned aircraft operated by the Zero Gravity Corporation for the first time to test hardware and technologies. These flights were part of NASA's Facilitated Access to the Space Environment for Technology Development and Training (FAST) activity. FAST provided opportunities for emerging technologies to be tested in the relevant environment, thereby increasing their maturity and the potential for their use in NASA programs and in commercial applications.

CRuSR

NASA, the Commercial Spaceflight Federation (CSF), and the Universities Space Research Association (USRA) began collaboration with commercial suborbital transportation providers in 2008 to explore the opportunities for science, technology, education and workforce development enabled by frequent, affordable, autonomous and human-tended suborbital research. Two workshops were organized to further these goals. The first workshop ,'Suborbital Science Workshop I", was focused on Earth and Space Science. It was organized in conjunction with the American Geophysical Union (AGU) Fall 2008 Meeting. The second workshop,'Suborbital Science Workshop II', focused on biomedical and microgravity science. It was held in conjunction with the Aerospace Medical Association 2009 Annual Meeting. Following these two successful workshops, the Commercial Reusable Suborbital Research (CRuSR) Office, set up by the Agency's Innovative Partnerships Program (IPP), issued an RFI in December 2009 to gather information from potential flight providers. The purpose of this RFI was to facilitate the sharing of information about commercial suborbital vehicles with the emerging research community.

The first Next-Generation Suborbital Researchers Conference (NSRC) was held in February 2010 and brought the burgeoning suborbital researchers community together in Boulder, Colorado. In August of 2010, the first CRuSR contracts for experimental test flights were awarded to Armadillo Aerospace and Masten Space Systems, and initial efforts were started to develop, integrate and fly a payload rack of NASA payloads on both vehicles.

CRuSR and FAST become Flight Opportunities

With the establishment of the Office of the Chief Technologist in FY11 and the Space Technology Mission Directorate in FY13, NASA merged FAST and CRuSR into a newly established program called Flight Opportunities (FO). The Flight Opportunities program was established with two specific goals in mind: (1) to facilitate the maturation of cross-cutting space technologies for NASA's Space Technology Mission Directorate, and (2) to encourage and facilitate the growth of the U.S. commercial space industry.

President Barack Obama signs the National Aeronautics and Space Administration Authorization Act of 2010 in the Oval Office, Monday, Oct. 11, 2010. The Authorization Act included Section 907 detailing the provision for the CRuSR program. (Photo: Official White House Photo by Pete Souza) ▷

SEC. 907. COMMERCIAL REUSABLE SUBORBITAL RESEARCH PROGRAM.

(a) IN GENERAL.—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.

(b) MANAGEMENT.—The Administrator shall designate an officer or employee of the Space Technology Program to act as the responsible official for the Commercial Reusable Suborbital Research Program in the Space Technology Program. The designee shall be responsible for the development of short- and long term strategic plans for maintaining, renewing and extending suborbital facilities and capabilities.

(c) ESTABLISHMENT.—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.

(d) REPORT.—The Administrator shall submit a report annually to the appropriate committees of Congress describing progress in carrying out the Commercial Reusable Suborbital Research program, including the number and type of suborbital missions planned in each fiscal year.

(e) AUTHORIZATION.—There are authorized to be appropriated to the Administrator $15,000,000 for each of fiscal years 2011 through 2013 to carry out this section.

Progress On Strategic Objectives

OBJECTIVE 1: FLIGHT OPPORTUNITIES
- Raise the operational readiness of the flight vehicles by buying early flight manifests
- match these flight slots with solicitations for payloads that use the flights to advance future space technologies

OBJECTIVE 2: PAYLOAD DEVELOPMENT
- Provide competitive funding for the development of technology payloads that would use suborbital flights for technology demonstration purposes or to perform other space technology objectives

OBJECTIVE 3: ENGINEERING AND INTEGRATION DEMONSTRATIONS
- Provide competitive funding for the direct technology and capability development targeted for suborbital vehicle systems.

Buying early flight manifests
Initial program activities in FY11 focused on acquiring commercial flight services from U.S. providers (Objective 1). NASA requested capability statements from the flight providers and held an industry day prior to issuing an RFP on March 26, 2011. In August 2011, NASA placed seven U.S. commercial service providers on Indefinite Delivery Indefinite Quantity (IDIQ) contracts (see table). At the time, these commercial vendors were at various stages of development of their flight vehicles -- some had flown, while others were still in development. Selections were made on the basis that the provider showed evidence of a capability to provide flight services within a two-year period of performance. Three of the seven providers (Near Space Corporation, UP Aerospace, and Virgin Galactic) were subsequently placed on task order to provide flights in FY12 and FY13. NASA utilized other existing contract mechanisms to fly payloads on the Masten XA-0.1-B "Xombie" vehicle and the Zero Gravity Corporation aircraft.

Matching flight manifests with payloads
The program created three entry points to establish the demand side of the program (also Objective 1):
1) Announcement of Flight Opportunities (AFO)
2) NASA Research Announcement (NRA) for technology development payloads
3) Directed payloads by other NASA programs and Mission Directorates.

1. ***Armadillo Aerospace**, Heath, Texas*
2. ***Near Space Corporation.**, Tillamook, Ore.*
3. ***Masten Space Systems**, Mojave, Calif.*
4. ***UP Aerospace**, Highlands Ranch, Colo.*
5. ***Virgin Galactic**, Mojave, Calif.*
6. ***Whittinghill Aerospace**, Camarillo, Calif.*
7. ***XCOR Aerospace**, Mojave, Calif.*

Contracted Flight Service Providers 2011-2013 (IDIQ1)
(IDIQ = Indefinite Delivery Indefinite Quantity contract)

Announcement of Flight Opportunities (AFO)
In December 2010, NASA released an announcement of opportunity for payloads, referred to as the Announcement of Flight Opportunities (AFO). This announcement makes flights available for technology testing that benefits NASA's future space missions through alignment with the NASA Space Technology Roadmaps. The original AFO 'umbrella' solicitation remains open until Dec. 31, 2014. All individuals and organizations, U.S. and non-U.S, are eligible to submit a response to this Announcement.

Periodic updated calls were issued as new flight manifests or capabilities became available. Payloads were selected on a no-exchange-of-funds basis and were awarded via a non-reimbursable Space Act Agreement (SAA) or other agreement. At the end

NASA Seeks Proposals For Technology Flight Demonstrations And Information About Suborbital Flight Services, NASA press release 10-345, Dec 21, 2010

"NASA is seeking proposals from researchers interested in testing new technologies during suborbital flights. The agency also is requesting information from commercial suborbital reusable launch vehicle providers and commercial payload integrators about carrying the technology payloads [...] The solicitation is being made by NASA's Flight Opportunities program, which is designed to foster development of a commercial reusable suborbital transportation industry while developing new technologies and improving microgravity research. When available, such reusable vehicles will provide lower-cost, more frequent, and more reliable access to space."

http://www.nasa.gov/home/hqnews/2010/dec/HQ_10-345_Flight_Opp.html

of FY13, a total of 6 AFO calls were concluded with a total of 85 payloads competitively selected through this process.

NASA Research Announcement (NRA) for technology development payloads

In addition to the open AFO, the program took steps to increase development of small-scale experiments for suborbital testing (Objectives 1 and 2). Under a NASA Research Announcement (NRA), the program provided funding for the development and flight of test payloads. In anticipation of the release of this NRA, the program issued a request for information (RFI) in FY11 to ascertain interest from the technology community in using sRLVs for demonstration. The responses received for this RFI indicated that the technology community confirmed interest in utilizing the sRLV platforms for technology demonstration.

In FY12, the program collaborated with the STMD Game Changing Development (GCD) program to release the first NRA to develop technology payloads that would utilize commercial reusable suborbital launch vehicles. The program specifically aimed to fund technology proposals that could be demonstrated using the sRLV platforms that the program had on existing task orders. Under the first NRA (NRA1), the program made awards ranging from $100k to $500k totaling $3.5M to 14 proposals to develop sRLV payloads or capability enhancements to suborbital vehicles to accommodate payloads. A second round of ten NRA technology payloads was awarded in FY13, with awards ranging from $100k to $250k (NRA2). In total, 24 (14+10) payloads have been selected through this process to date.

Directed payloads

At the end of FY13, a total of 11 technology payloads were selected as 'directed', sponsored by other NASA programs and Mission Directorates.

An additional four payloads were selected as part of the Undergraduate Student Instrument Project (USIP) program, bringing the total number of selected payloads to 124. More details about several of the 124 technology payloads are provided later in this report.

Funding technology and capability development targeted for suborbital vehicle systems

Recognizing the early stage of emerging reusable, suborbital systems and capabilities for market applications, the NASA Authorization Act allowed for NASA to fund engineering and integration demonstrations (Objective 3). With commercial vertical takeoff and vertical landing (VTVL) rocket vehicles available in the marketplace, the program funded the development of VTVL capabilities to host payloads for landing technology demonstrations.

Draper Laboratories was selected to develop a commercial vertical test capability that could host a variety of research and


Road closed
for Rocket test
road will be closed for
5 min. before test
Airport Security
SPEED
LIMIT
24 1/2

technology payloads. Draper tasked Masten Space Systems to provide the vehicle to support and demonstrate flight capabilities utilizing Draper's GENIE (Guidance Embedded Navigator Integration Environment). GENIE is an integrated hardware and software avionics platform capable of providing real-time AGNC (Autonomous Guidance, Navigation and Control) solutions for landing in hazardous terrains. The goal of this project was to demonstrate AGNC technology capable of safe and precise planetary landings applicable to a broad range of NASA missions. In addition, GENIE seeks to extend closed loop performance capability of VTVL rockets to help validate its capability for supporting future payloads seeking lunar or mars-like approach trajectory environments while demonstrating technologies here on Earth. In total, the Draper/Masten team completed five flight campaigns to date.

Collaboration with Partners

Flight Opportunities established collaborations with several partners, both inside NASA and in the wider community (see below).

INSIDE NASA

Space Technology Mission Directorate (STMD)

The program sponsored two NASA Research Announcements (NRA1 and NRA2) in collaboration with STMD's Game Changing Development program. The Game Changing Development program is monitoring the progress of these selected payload developments and their potential benefit to Agency needs.

Science Mission Directorate (SMD)

In support of the Science Mission Directorate (SMD), the program has been included as a potential source for flight opportunities on available platforms in the following solicitations: Research Opportunities in Space and Earth Sciences (ROSES; 2010-to-date), Hands-on Project Experience (HOPE; 2011-to-date), Earth Sciences Technology Office (ESTO) NRA for In-Space Validation of Earth Science Technologies (InVEST; 2011), and the Undergraduate Student Instrument Project (USIP; 2012). In 2013, the first 4 payloads were selected into the program from the USIP program.

Human Exploration and Operations Mission Directorate (HEOMD)

The program tested software originally developed by HEOMD for robotic lunar landers on the Masten Space Systems XA-0.1-B "Xombie" vehicle. In FY12, HEOMD solicited life sciences microgravity research payloads that could utilize various flight platforms including commercial suborbital vehicles available through Flight Opportunities (NASA Research Announcement NNJ12ZSA002N - Research and Technology Development to Support Crew Health and Performance in Space Exploration Missions).

WIDER COMMUNITY

Operationally Responsive Space/Air Force Research Laboratory (ORS/AFRL)

The program collaborated with the United States Air Force Office of Operationally Responsive Space (ORS) to rideshare on an ORS suborbital flight on UP Aerospace Space-Loft 6 to fly the Suborbital Flight Environment Monitor (SFEM). In return, the program agreed to manifest an ORS payload, Global Positioning Beacon, on UP Aerospace Space-Loft 7, which successfully launched in May 2013. The program expects to continue such partnerships to share rides in the future.

Federal Aviation Administration (FAA)

The program has established a fruitful collaboration with the FAA Commercial Space Transportation office (FAA/AST). Over the three years, the collaboration ranged from working together to work out the launch license responsibilities and agreements, to flight testing several FAA/AST funded payloads, both directly with FAA or through its Center of Excellence for Commercial Space Transportation (COE CST).

Educational Institutions

The Program worked with the NASA Office of Education and the New Mexico Space Grant Consortium (NMSGC) to identify collaborative opportunities for NASA-unique education and research opportunities.

◁ *Signs designate areas of the Mojave Air and Space Port closed in preparation for a flight of Masten Space Systems' XA-0.1-B "Xombie" (Photo: NASA/Chris Baker)*

Community Building

The program actively participated in several annual conferences where both prospective users and flight service providers met to share ideas and results from initial test flights. These included the yearly Next-Generation Suborbital Researchers Conference (NSRC), the International Symposium for Personal and Commercial Spaceflight (ISPCS), the FAA/AST Commercial Space Transportation Conference and the Commercial and Government Responsive Access to Space Technology Exchange (CRASTE).

The program maintained a website (flightopportunities.nasa.gov) where information about flight vehicles and selected technology payloads was made available to the interested public. A mailing list (600+ subscribers) and social media were used to dessiminate information about upcoming solicitations and relevant industry news.

Neil Armstrong (left) draws a large crowd at the 2012 Next-Generation Suborbital Researchers Conference (NSRC-2012). Mr. Armstrong presented a keynote on "Reflections on the X-15 and Early Suborbital Flights". (Photo: Alexander van Dijk) ▷


XCOR
AEROSPACE
Coffee Break

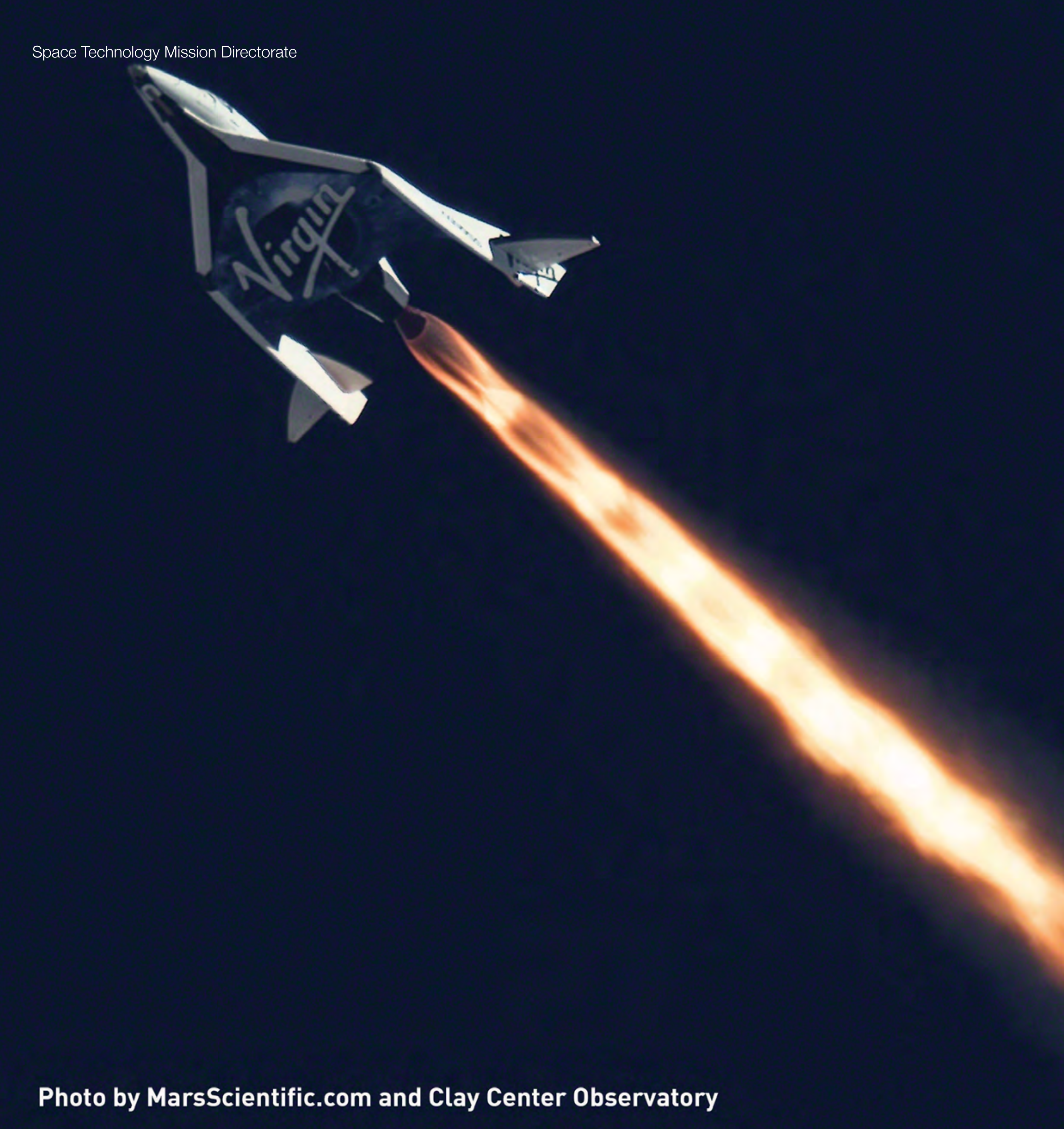


Photo by MarsScientific.com and Clay Center Observatory

Testing critical

Exploration Technologies

while stimulating the

Commercial Space Industry

Looking Ahead

Over the last three years, the Flight Opportunities program has been diligently working to comply with the requirements specified in the NASA Authorization Act of 2010. The program plans to continue the brisk pace of activities in FY14 and beyond. Several suborbital, balloon and parabolic flights have been scheduled, including the first Virgin Galactic SpaceShipTwo flight. The program has also scheduled an additional follow-on flight vendor solicitation and subsequent contracts/tasks will be issued to the pool of providers to accommodate NASA's specific payload requirements as the providers mature their commercial vehicles to flight status.

Through these activities, the Flight Opportunities program is accomplishing the mission of the Space Technology Mission Directorate to develop and mature critical technologies, while simultaneously stimulating commercial space and enabling development of the aerospace workforce at-large. As the program pursues these activities in FY14 and beyond, it anticipates meeting the increasing demand from technologies generated through the Space Technology Mission Directorate, thus aiding in the continued growth of this emerging suborbital and parabolic space sector.

◁ *September 5, 2013: SpaceShipTwo completed its second powered flight over the Mojave desert. (Photo: MARS Scientific)*

Program Metrics

The following Flight Opportunities program goals and metrics were set out in the FY12-14 program plan (December 12, 2011). The period reported on for this FY11-13 report overlaps two years with the program plan.

Program Metric Payload pipeline expectation FY12-14

	FY11	FY12	FY13	FY14
Internal (NRA, USIP, Directed)	**16%**	**31%**	**31%**	
FY 12-14 target	-	0%	25%	50%
External (AFO)	**84%**	**69%**	**69%**	
FY12-14 target	-	100%	75%	50%

This metric tracks the origin of the selected technology payloads. It is anticipated that over the course of the three years an increasing number of payloads will be directed to the program from within NASA (e.g. sister programs within STMD).

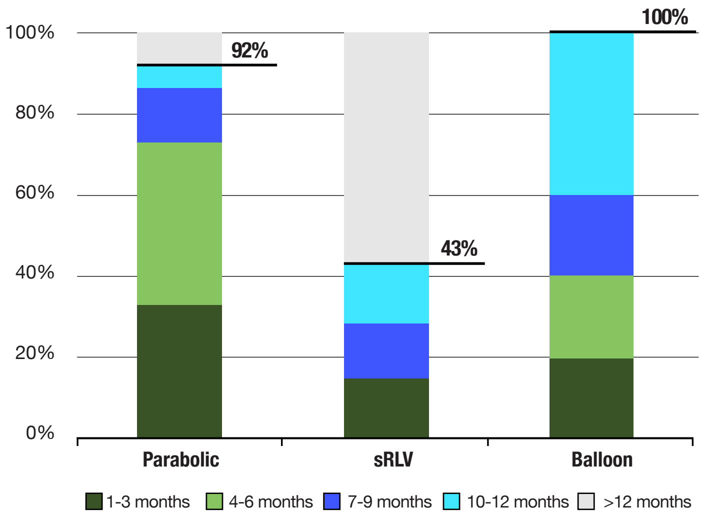
Program Metric Payloads flown, parabolic flight weeks and total vendors on contract

	FY11	FY12	FY13	FY14	TOTAL (FY11-13)
Payload-flights (per FY)	**20**	**30**	**33**		**83**
FY12-14 target	-	30	45	60	75
Parabolic flight weeks (per FY)	**3***	**4**	**4**		**11**
FY12-14 target	-	4	4	4	8
Total vendors on contract	**7**	**7**	**7**		
FY12-14 target	-	5	7	7	

** Parabolic flight weeks typically consist of 4 flights over the course of one week.*

This metric details the anticipated flight activity FY12-14 vs the actual flight activity up to FY13. Sofar, both the target number of total payload-flights (75) and yearly number of parabolic flight weeks (4 per FY) have been achieved. Seven sRLV flight providers were put on contract under IDIQ1 (Aug 2011). At the end of FY13, four of these seven are providing active flight services. In addition, parabolic flight services are provided through the NASA/JSC Reduced Gravity Office, resulting in a total of eight flight providers on contract.

Program Objective *Provide frequent and timely opportunities to flight conditions that simulate relevant space environments for manifested technology payloads*



Metric: Fly 100% of the flight-ready payloads selected for flight on at least one demonstration flight

By the end of FY13, a total of 49 technology payloads were flight tested (of 124 total): 37 flew on parabolic aircraft, 7 on sRLV platforms and 5 used balloons. Of the payloads flown on parabolic campaigns, 92% were tested within 12 months of selection. For sRLV this metric was 43%, and for balloons 100%. The remaining 75 payloads have not yet been flight tested because either the payload was not ready, the flight provider was not ready, or the proposal was selected just before the end of FY13 (AFO6, NRA2 and USIP1).

Program Objective *Foster Commercial Suborbital Flight Services: Identify and develop initiatives that promote tipping points for commercialization in ways appropriate to NASA and Flight Opportunities resources*

Metric: Develop at least one strategic partnership or contract per year that enables the commercialization of the suborbital space industry

FY11 7 flight providers were put on contract under the IDIQ1 contract

FY12 The first NRA call (NRA1) issued in collaboration with the STMD Game Changing Development program resulted in 14 proposal selections specifically targeting sRLV flights (of 40 submitted)

FY13 The second NRA call (NRA2) resulted in the selection of 10 sRLV proposals (of 41 submitted).


XCOR
AEROSPACE

An Emerging Industry
FY11-13 Timeline

◁ *January 25, 2013: Former NASA Chief Technologist Mason Peck (left) shields his ears from the noise as an XCOR aerospace propulsion engineer test fires a small rocket engine with an experimental nozzle. (Photo: NASA/Tom Tshida)*

FY11 Q1

President Obama signs NASA Authorization Act of 2010 (including section 907)

AFO1 and IDIQ1 RFI released

October 2010	November 2010	December 2010

"Representatives of more than 20 aerospace firms both large and small met with officials of NASA's Flight Opportunities program at NASA's Armstrong Flight Research Center Jan. 25 during an Industry Day meeting for potential providers of sub-orbital reusable launch vehicle and payload integration services." www.nasa.gov/centers/dryden/Features/flight_opportunities_day.html

FY11 Q2

Flight Opportunities Industries Day
January 25, 2011

NSRC-2011 conference
Orlando, FL

January 2011	February 2011	March 2011

January 25, 2011: Michelle Murray of the FAA/AST presents an overview of different types of launch licenses to participants at the Flight Opportunities Industry Day at the NASA/Armstrong Flight Research Center (Photo: NASA)

FY11 Q3

"NASA has selected 16 payloads for flights on the commercial Zero-G parabolic aircraft and two suborbital reusable launch vehicles as part of the agency's Flight Opportunities program. The flights provide opportunities for space technologies to be demonstrated and validated in relevant environments." www.nasa.gov/home/hqnews/2011/may/HQ_11-147_Zero-G_Pyaloads.html

AF01 awarded

IDIQ1 RFP released

AF02 released

April 2011 | **May 2011** | **June 2011**

July 21, 2011: a look out the window of the G-Force One aircraft during a parabola over the Gulf of Mexico. (Photo: NASA/Bill Stafford)

FY11 Q4

The first program flights were a continuation of the FAST parabolic flight program: three parabolic flight weeks in the summer of 2011, each only a month apart (RGO-01,02,03). A total of 13 payloads where flown, four of which flew during more than one of the three weeks, allowing fast iterative improvements to be flight tested and validated in a short timeframe.

July 2011

- **RGO-01** **July 19, 2011**

August 2011

- IDIQ1 awarded
- **RGO-02** **August 30, 2011**

September 2011

- sRLV workshop NASA/GSFC
- **RGO-03** **Sept 20, 2011**

"Made In Space credits much of its early innovation to the work performed through the Flight Opportunities program. During 2011 we flew over two hours of microgravity manufacturing time with our 3D printers on the G-Force One parabolic aircraft. From this we developed a foundation for the development of our 3D Printer for the ISS."

Jason Dunn, CTO Made in Space Inc.

FY12 Q1

Xombie-01 (C1: open loop free flight)
November 15, 2011

Xombie-01 (C2: closed loop tethered hop flight)
December 20-22, 2011

AF02 awarded

ISPCS-2011 conference
Las Cruces, NM

AF03 released

October 2011 | November 2011 | December 2011

Xombie-01: A series of flight tests of the Draper Laboratory 'Guidance Embedded Navigator Integration Environment' (GENIE) payload integrated onboard the Masten Space XA-0.1-B 'Xombie' vehicle. C3 flight (above): February 2, 2012. C5 flight (right): March 25, 2013. (Video stills: Masten Space Systems, https://www.youtube.com/user/mastenspace)

FY12 Q2

Masten Space Systems' Xombie suborbital rocket lifted off the launch pad February 2 while being controlled by Draper Laboratory's Guidance Embedded Navigator Integration Environment (GENIE) system. The rocket rose 164 feet, moved laterally 164 feet, and then landed on another pad after a 67-second flight.

Xombie-01 (C3: closed loop demonstration flight)
February 2, 2012

NRA1 released

NSRC-2012 conference Palo Alto, CA

AF03 awarded

January 2012 | **February 2012** | **March 2012**

FY12 Q3

"The vehicle performed perfectly from liftoff to touchdown", said UP Aerospace President, Jerry Larson. He added, "This is a proud day for us in being able to display the remarkable performance of the SpaceLoft vehicle with proven performance, precision, safety, and mission success." www.upaerospace.com/SpaceLoft-6.html

UP Aerospace SL-6 launch, April 5, 2012

AF04 released

RGO-04

sRLV workshop NASA/JPL

April 2012	May 2012	June 2012

At 8:18 a.m. SpaceLoft-6 lifted off from Spaceport America making this the 6th space launch and the 10th launch overall for UP Aerospace. The vehicle reached an altitude of 385,640 feet, and returned from space landing successfully on White Sands Missile Range. SpaceLoft-6 carried payloads for the Department of Defense (ORS), as well as the first space flown payload for NASA's Flight Opportunities program.

UP Aerospace launch facility, Spaceport America, NM (Photo: NASA/Paul de Leon)

FY12 Q4

"Not only did the flights provide valuable insight into their satellite's performance in a space-like environment, but "it's pure gold," Darling says, for student spaceflight engineers to be able to count this among their experiences. "We're all really interested in aerospace careers." RGO-05 participants from Boston University (T0047), www.bu.edu/today/2012/defying-gravity

NRA1 awarded

AF05 released

RGO-05

AF04 awarded

RGO-06

RGO-07

July 2012

August 2012

September 2012

FY13 Q1

"This experience was one of the most rewarding we've had on a personal and professional level. Not only did we get data that would be impossible to get otherwise, we also obtained insight into the behavior of our hardware in its future environment in the zero-g of space." RGO-10 participant Edward Cheung, Jackson and Tull (T0060)

AF06 released

ISPCS-2012 conference Las Cruces, NM

October 2012 | November 2012 | December 2012

"We are pleased with the immediate success we have been able to bring to NASA's Flight Opportunities program with our relatively mature low-cost platform," said NSC President Tim Lachenmeier. "The program provides a unique win-win-win situation for NASA, technology developers and NSC." www.nasa.gov/topics/technology/features/nsc_balloon.html

FY13 Q2

First Balloon launch (SBS-01) January 20, 2013

AF05 awarded

NBS-01

RGO-08

Xombie-02 (C4/C5)

January 2013 | February 2013 | March 2013

On January 20, 2013, the New Mexico Institute of Mining and Technology (NMT) team launched a high altitude balloon payload supported by Flight Opportunities. The launch services were provided by Near Space Corporation from a site at Madras (OR) airport. The payload carrying a number of structural health monitoring (SHM) experiments was launched at 11:07 am local time, with 1 hour and 36 minutes of ascent, 57 minutes of float and approximately 30 minutes of descent. The payload was recovered undamaged. The flight was successful and yielded a considerable volume of data for the embedded ultrasonics structural health monitoring approach and wireless sensing. The experiment demonstrated basic proof-of-concept for a spacecraft ultra-sonic SHM system. (Photo: Andrei Zagrai, pictured right. On the left, Nick Demidovich of the FAA/AST)

FY13 Q3

"Student and government payloads shot skyward June 21 on a suborbital flight sponsored by NASA's Flight Opportunities Program, part of NASA's Space Technology Mission Directorate. During a 15-minute journey, the experiments sped 74 miles high above Earth, safely tucked inside a SpaceLoft-7 rocket." www.nasa.gov/content/sky-high-experiments-fly-from-spaceport-america

April 2013
- NRA2 released
- RGO-09
- 1st powered flight of Virgin Galactic's SpaceShipTwo

May 2013
- NSRC-2013 conference Broomfield, CO

June 2013
- RGO-10
- AF06 awarded
- SL-7 launch

September 20, 2013: View of the Mojave Air & Space Port (Mojave, CA) from the XA-0.1-B 'Xombie' platform (Video still: Masten Space Systems)

“With engineers and officials from NASA’s Jet Propulsion Laboratory watching, Masten Space Systems’ XA-0.1-B “Xombie” took to the sky again in the Fall of 2013. The flight on Sept. 20 was the conclusion of a test campaign to assess the performance of JPL’s Guidance for Fuel Optimal Large Diverts (G-FOLD) algorithm under mission conditions.” www.jpl.nasa.gov/news/news.php?release=2013-247

FY13 Q4

HASS-01
RGO-11
Xombie-03 (G-FOLD 1)
Xombie-03 (G-FOLD 3)
NBS-02

July 2013 | August 2013 | September 2013

"The Flight Opportunities Program supports both the development of innovative space technology and the emerging suborbital industry by using commercial suborbital vehicles to test concepts that could further mankind's exploration and understanding of the universe," said Christopher Baker, a campaign manager for the program. "The collaboration between JPL and Masten to test G-FOLD is a great example of how we hope to further the exploration of the solar system while building up the industrial base needed to advance future space endeavors."

Technology Maturation Through Flight Testing

Status & Examples

◁ *January 11, 2011: Masten Space Systems facilities at the Mojave Air and Space Port, Mojave CA. (Photo: NASA/Dougal Maclise)*

"Future leadership in space requires a foundation of sustained technology advances that can enable the development of more capable, reliable, and lower-cost spacecraft and launch vehicles."
America's Future in Space: Aligning the Civil Space Program with National Needs, National Research Council

With the establishment of the Space Technology Mission Directorate, technology development has once again become an important area of focus for the Agency. The Flight Opportunities program plays a unique role in that it combines efforts to create new markets with the aim to mature a broad range of technologies of interest to NASA. The emerging suborbital launch industry itself is strongly involved in technology development towards reusable launch vehicle capability. By serving as an early customer, the program directly supports this development. At the same time, by utilizing the flight test capabilities enabled by this emerging industry, NASA is able to offer flight testing to a much wider community of space technology developers.

Working as the Technology Manager for the program, these first three years have been both extremely busy and very rewarding. Functioning as a 'startup' within STMD and the Agency, we operated on the intersection between supply and demand. We initiated the payload pipeline with the release of the Announcement of Flight Opportunities (AFO), a broad solicitation requesting payload flight test proposals from the community at large. As we selected payloads into the pool, both we and our Flight Service Provider partners learned a great deal about the needs and wants of the researchers community, which translated back to some of the services being developed by the industry. Masten Space Systems for example decided to focus on providing Entry, Descent and Landing (EDL) flight test services, in part based on the demand we were able to channel from the research community.

Our very first program flights were a continuation of the FAST program with three parabolic campaigns over the summer of 2011, each only a month apart. Made in Space Inc., a company profiled later in this report, is a great example of how such rapid iterative flight testing can lead to new crosscutting technologies. Based on lessons learned from their 2011 flights, they were able to secure subsequent SBIR funding to the point where they are now on contract with NASA to deliver the first ever additive manufacturing (3D printing) test bed to the International Space Station (ISS) in FY14.

Parabolic flight testing is a relatively mature market, with decades of experience for NASA and an existing user community. So it is no wonder we found a steady demand for this type of flight testing. For the newer platforms, payloads were selected as new vehicles and flight test capabilities became available. We then worked closely with the Flight Service Provider to achieve the first test-flights for these payloads. Some examples of these are highlighted later in this report, specifically for the sRLV and balloon flight tests.

Our mandate, as part of STMD, has largely been focused on facilitating technology maturation. However, we have not lost sight of the potential value of this new industry for a variety of science applications. In fact, since these vehicles are so new, many of the capabilities that will enable scientific research first need to be developed. This was the very intent of the two NRA calls released in FY12 and FY13. Several science enabling sRLV technology development efforts are now under way, as can be seen in the overall list of technology payloads provided later in this report.

The Flight Opportunities program fits in the mid TRL technology development region (TRL 4-6/7), where a technology has completed lab testing and is ready for testing in the environment relevant to its later application. In the past this relevant test environment could only be provided for brief periods (10 to 20 seconds) on parabolic aircraft flights, on expensive sounding rocket launches that could provide several minutes of microgravity, but where the payload (test article) was not retrieved, or on very expensive launches to low Earth orbit or to ISS. The expense of the flights and the long lead-time required for preparation for orbital launches presented a big barrier to the maturation of new technologies, a barrier that became known as "The Valley of Death", where most new technologies ended up on a shelf due to lack of available funding. The emerging commercial reusable suborbital launch companies offer a cheaper and more efficient path through this "Valley". Working with these companies to utilize and further develop their capabilities is only a logical choice.

Dougal Maclise
Technology Manager

June 21, 2013: Dougal Maclise (left) and NASA Flight Opportunities Campaign Manager Paul de Leon look on as SL7 leaves the launch site at Spaceport America. The UP Aerospace launch control team can been seen sitting in the back. (Video still: NASA)

Building the Payload Pipeline

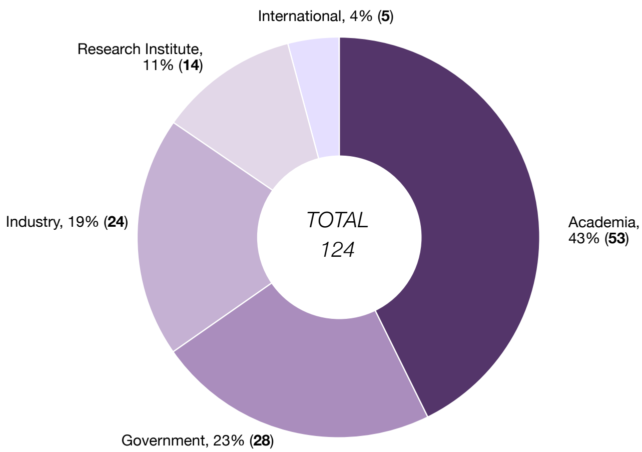
With the objective to support the nascent suborbital market, the focus in the first three years has been on establishing the flight test demand. By the end of FY13, 124 technology payoads had been selected into the program (54% of 228 submitted) with the largest subset coming in through the Announcement of Flight Opportunities (85). The AFO served as a good instrument to generate initial demand while other STMD programs built up their own lower-TRL development pipelines. AFO selections were made based on the technology's cross-cutting benefit to NASA and the spaceflight industry as well as the team's experience. In order to be eligble for selection, the proposal needed to demonstrate that the technology proposed was at a TRL-4 or higher at the time of submission. Starting in FY12, two NASA Research Announcement (NRA) solicitations added an additional 24 payloads to the pool specifically targeting sRLV capability enhancements (14 from the first and 10 from the second). Several of these were at TRL-3, with additional ground-based development and testing needed before the payload could be manifested onboard any of the vehicles.

Payloads selected (submitted) per Fiscal Year (FY) by solicitation

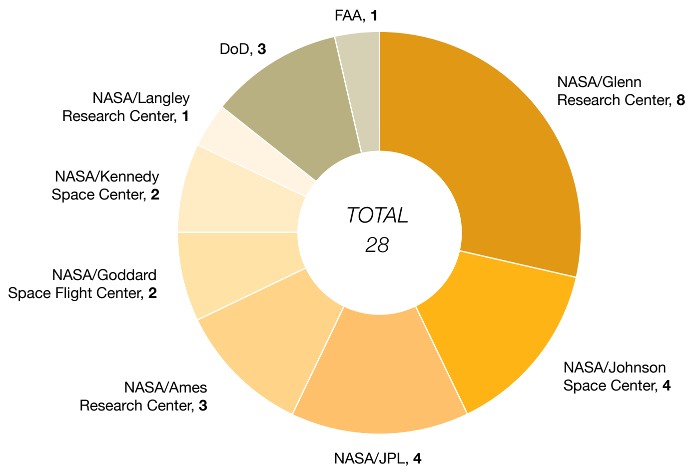
	FY11	*FY12*	*FY13*	*Total*
PLs selected	**19**	**55**	**50**	**124 (228)**
USIP			*4**	*4 (4)*
NRA		*14 (40)*	*10 (41)*	*24 (81)*
Directed	*3 (-)*	*6 (-)*	*2 (-)*	*11 (11)*
AFO	*16 (23)*	*35 (51)*	*34 (58)*	*85 (132)*

** USIP selection was part of larger solicitation by the Science Mission Directorate*

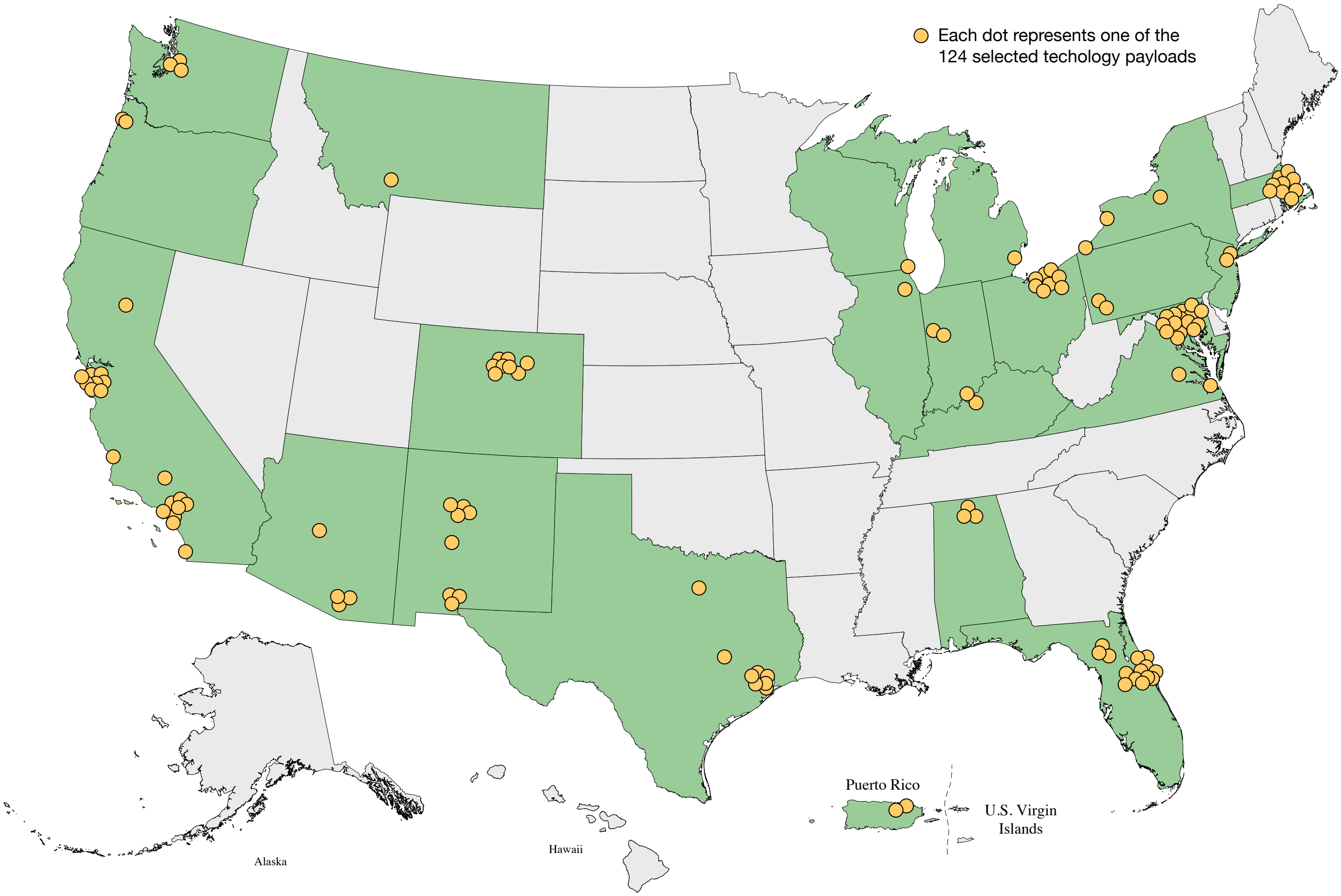
The biggest share of selected payloads originated from the academic community (43%). The U.S. Government and industry contributed 23% and 19% respectively, with most of the U.S. Government payloads submitted by NASA researchers. To date, five payloads have been sourced from international parties, two from Italy, one from Spain, one from Australia, and one from the United Kingdom.



Breakdown by organization type for 124 selected payloads.

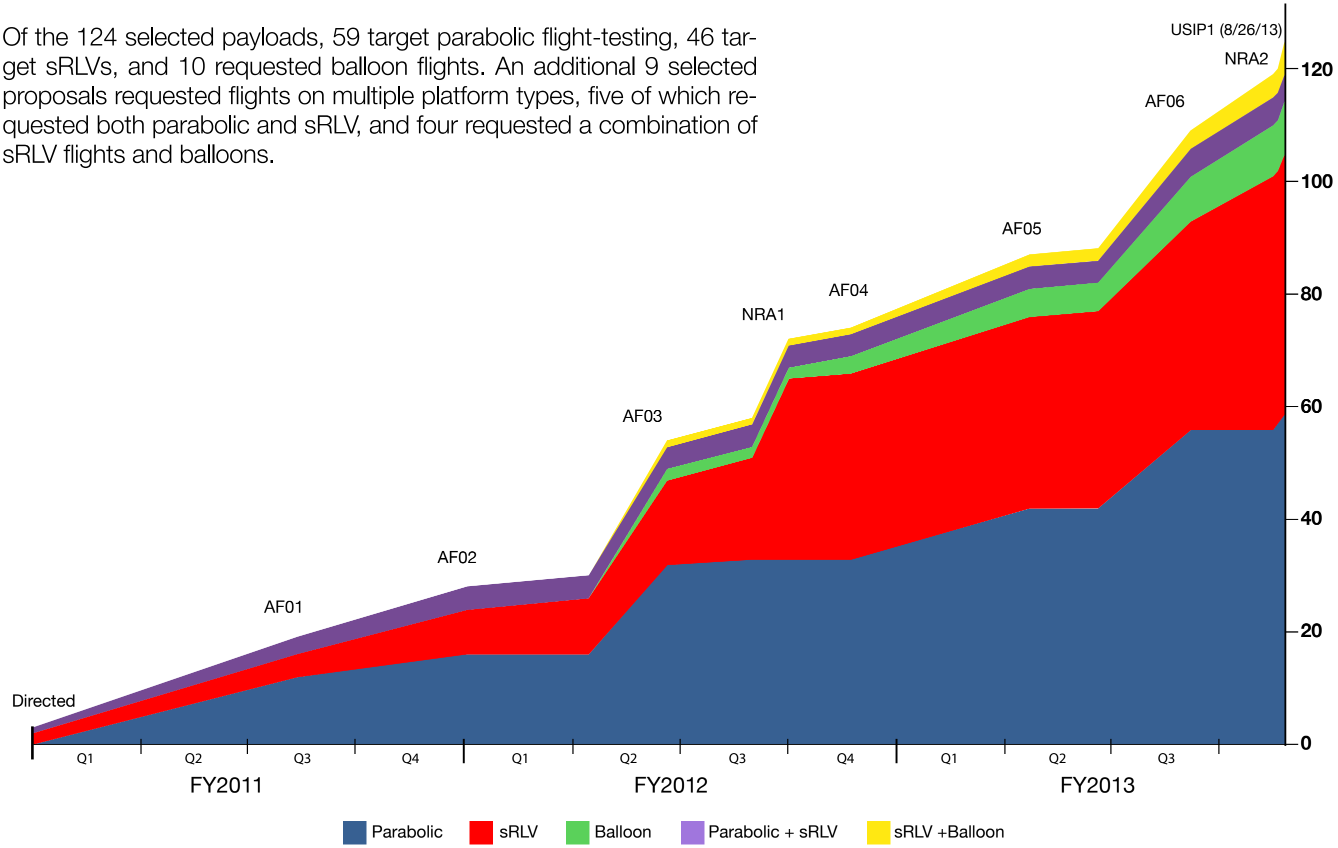


Breakdown by origin for 28 selected U.S. Government payloads. (NASA: 24, DoD: 3, FAA: 1)

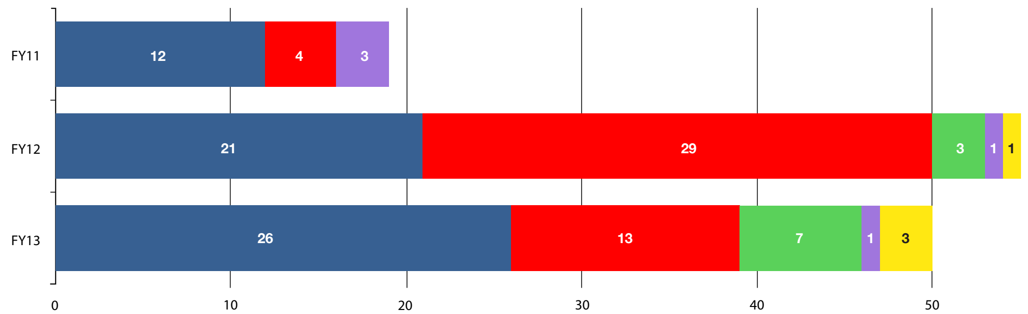


Distribution of selected payloads across the US.

Of the 124 selected payloads, 59 target parabolic flight-testing, 46 target sRLVs, and 10 requested balloon flights. An additional 9 selected proposals requested flights on multiple platform types, five of which requested both parabolic and sRLV, and four requested a combination of sRLV flights and balloons.

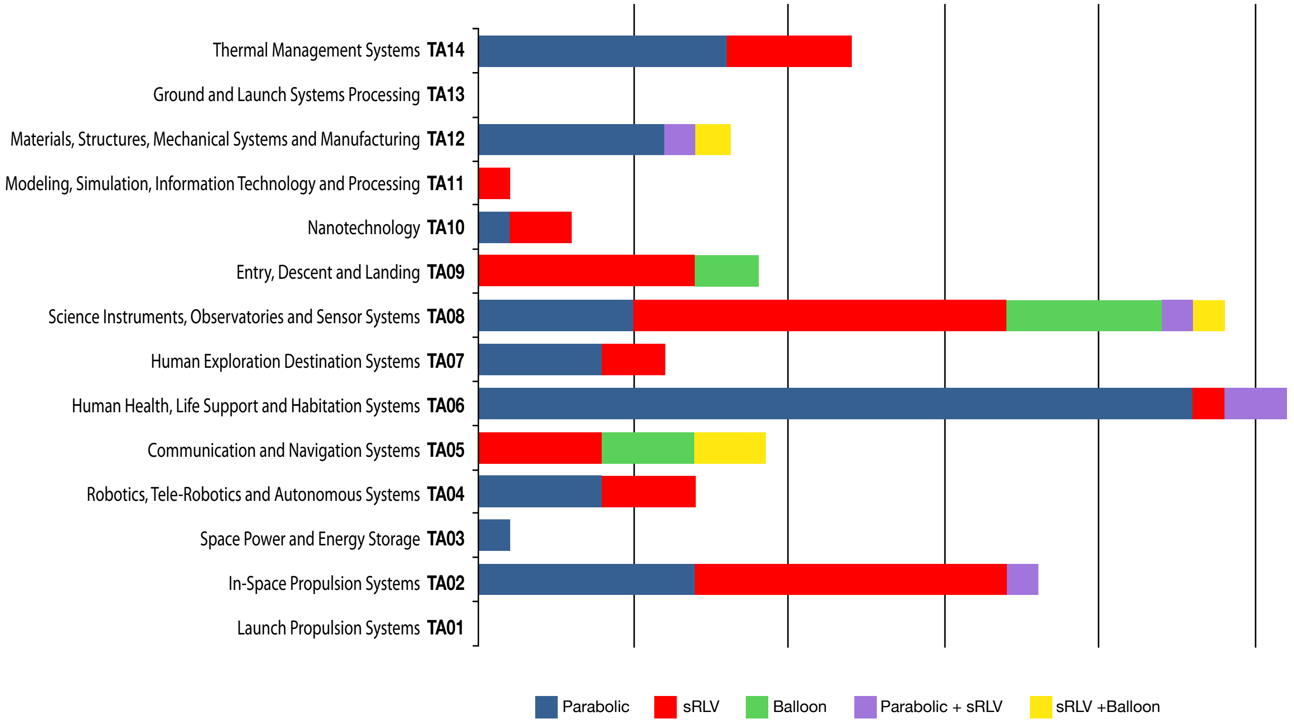


Build up of the payload pipeline over FY11-13



Breakdown of requested platform type for selected payloads per Fiscal Year (FY)

The 124 payloads cover most of the 14 Technology Areas. The Technology Area (TA) breakdown below shows a clear preference in the Human Health, Life Support, and Habitation Systems (TA06) category for parabolic flight testing. Several of those are also targeting the Virgin Galactic SpaceShipTwo platform, which provides a very similar flight environment, but provides longer duration microgravity time. For sRLV and balloon flight testing, the primary Technology Area are In-Space Propulsion Systems (TA02), Science Instruments, Observatories and Sensor Systems (TA08), and Entry, Descent and Landing (TA09).

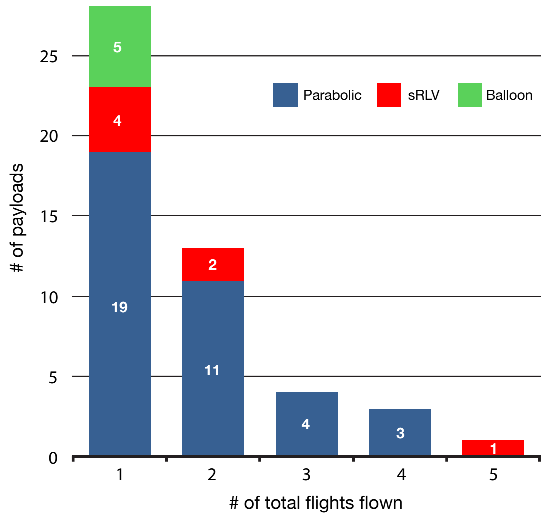


Technoloy Area (TA) breakdown of selected payloads.
(for more information about TAs, see www.nasa.gov/offices/oct/home/roadmaps)

Flight Testing Status (as of 09/30/2013)

By the end of FY13, 49 of the 124 payloads had undergone at least one flight test. Several of these payloads flew multiple times, bringing the total number of unique payload-flight combinations to 83 (see table).

Overall, the flight rate picked up each year. In FY11, three parabolic flight campaigns, each consisting of 4 flights, were completed with a total of 20 payload-flights. In FY12, four parabolic flight campaigns were completed. In addition, Masten Space Systems flew the GENIE payload from Draper Laboratories three times, and two payloads were flown alongside DoD experiments on the UP Aerospace SpaceLoft SL-6. The latter was the first experience flying payloads out of the facilities at Spaceport America in New Mexico. In FY13 the flight rate grew to 13 flights with a total of 33 payload-flights. The balloon flights added a fourth company, Near Space Corporation, to the program's list of flight providers. The balloon flights were flown from Madras and Tillamook (OR). By the end of FY13 one more flight services provider was added, Virgin Galactic, which brought the total list of companies 'on task order' to five. While the first Virgin Galactic flights are scheduled to start in late CY2014, twelve payloads are already scheduled for the first of two flights with Flight Opportunities.



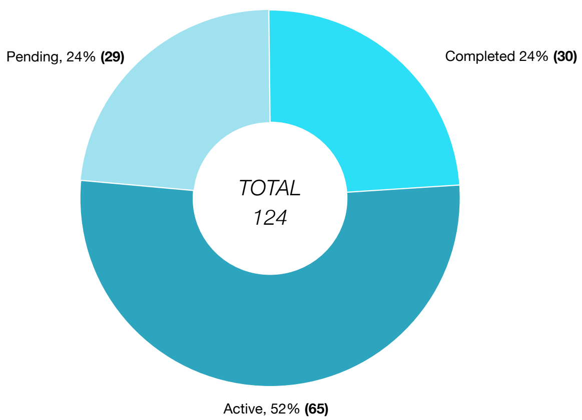
Number of flights per payload (of the 49 flown payloads)
(parabolic campaigns are counted as 1 flight)

Flight activity per Fiscal Year (FY)

	FY11	*FY12*	*FY13*	*Total*
Payload-flights	**20**	**30**	**33**	**83**
first flight	*13*	*20*	*16*	*49*
additional flight	*7*	*10*	*17**	*34*
Flights peformed	**3**	**8**	**13**	**24**
balloon			*4*	*4*
sRLV		*4*	*5*	*9*
parabolic	*3***	*4*	*4*	*11*

** One full FY12 parabolic manifest (5 payloads) was reflown in FY13 due to bad weather*
*** Parabolic flight campaigns are counted as 1 flight*

To date, 30 payloads have completed their targeted risk reduction objective and have moved on to other activities (e.g. ISS demonstration). A total of 65 payloads are still active. The remaining 29 payloads are considered 'pending', either because their hardware development is still at a pre-flight stage (e.g. the NRA payloads), the target flight vehicle is not yet available, or other programmatic reasons.



Payload status as of 09/30/2013

IDIQ1 Flight Service Providers on contract at the end of FY13

	IDIQ1	On task	1st FO flight	FO flights FY11-13	Flight designation
1	Armadillo Aerospace, Heath, TX	no			
2	Near Space Corporation, Tillamook, OR	**YES**	**FY13** (01/20/2013)	4	SBS or NBS
3	Masten Space Systems, Mojave, CA	**YES***	**FY12** (11/16/2011)	7	Xombie
4	UP Aerospace, Highlands Ranch, CO	**YES**	**FY12** (04/05/2012)	2	UP
5	Virgin Galactic, Mojave, CA	**YES**	**TBD**		
6	Whittinghill Aerospace, Camarillo, CA	no			
7	XCOR Aerospace, Mojave, CA	no			
	Zero Gravity Corporation	**YES****	**FY11** (07/19/2011)	11†	RGO

** Masten Space Systems established a contractual agreement prior to IDIQ1*
*** Zero Gravity Corporation operated through the NASA/JSC Reduced Gravity Office (RGO)*
† parabolic flight weeks

Payload-flights FY11-13

	Campaign	(first) Flight Date	# Payloads	# Flights	Parabolic (PL-flights)	sRLV (PL-flights)	Balloon (PL-flights)	
	RGO-01	July 19, 2011	9^	1*	9			
FY11	RGO-02	August 30, 2011	4†	1	4			
	RGO-03	September 20, 2011	7	1	7			
	Xombie-01 (C1-C2-C3)	February 2, 2012	1	3		3		
	UP-01 (SL6)	April 5, 2012	2	1		2		
FY12	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			
	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			
FY13	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	
			79	24	63	15	5	83 PL-flights total

^ one payload was replaced for two new ones mid week
** parabolic campaigns are counted as 1 flight*
† shared flight week with NASA Education Office or other external party

Technology Maturation Examples

Strategic Space Technology Investment Plan (SSTIP)

In December 2012, NASA released the Strategic Space Technology Investment Plan (SSTIP). It provides guidance for NASA's space technology investment during the years 2012-2016, within the context of a 20-year horizon. NASA's technology investments are designed to focus on technology development activities that will rapidly produce critically needed mission-capabilities to revolutionize the way we explore, discover, and work in space.

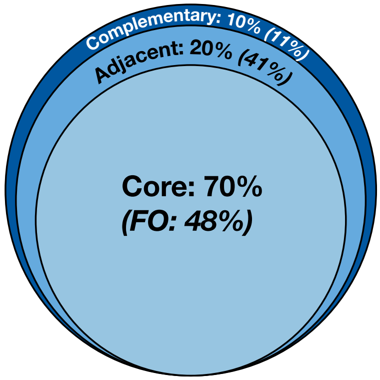
NASA's investment approach as described in the SSTIP is characterized by three categories of investment concentration to guide future space technology expenditures. These categories of concentrated investment are known as Core, Adjacent, and Complementary. While the SSTIP was published two years after the Flight Opportunities program was established, the portfolio of technology payloads in the program was found to align favorably with this Agency level strategy, as shown here on the right.

Technology profiles

The following pages provide 13 profiles written by the Principle Investigators (PI), detailing the risk reduction achieved as a result of the flight testing performed through the program. This is a subset of the total number of 49 teams who performed flight tests in the FY11-13 timeframe.

The broad variety of technologies and associated flight test objectives becomes apparent in the profiles. Some of the teams required a single parabolic flight campaign to validate a technology as part of higher level, critical path requirement (e.g. a Preliminary Design Review). Several others came in with a detailed Technology Maturation Plan (TMP), outlining a maturation path from TRL-4 to TRL-6 with details on the test flight objectives for each of the desired flight tests. Yet other teams were initially focused on gathering science data on physics phenomena (e.g heat flow in microgravity), and later came back to test protoypes designed using the information gathered.

Several of the teams performing parabolic flight testing have gone on to perform demonstrations onboard the International Space Station. In general, the ISS appears to be one of the important future destinations of several of the technologies performing risk reduction through the Flight Opportunities program.



Distribution of selected technology payloads across three levels of the SSTIP framework. (source: NASA SSTIP) [FO = Flight Opportunities]

Launch and In-space Propulsion (TA01, TA02)
High Data Rate Communications (TA05)
Lightweight Space Structures and Materials (TA12)
Robotics and Autonomous Systems (TA04)
Environmental Control and Life Support Systems (TA06)
Space Radiation Mitigation (TA06)
Scientific Instruments and Sensors (TA08)
Entry, Descent, and Landing (TA09)

Core investment areas outlined in the Strategic Space Technology Investment Plan (SSTIP) and related Technology Areas. (source: NASA SSTIP)

Technology Readiness Level

Because of the many hazards involved in space exploration, there exists a formal method for reducing the risks of using newly developed technologies. To measure the readiness of a new technology for mission use, its progress is tracked through the Technology Readiness Levels (TRL) 1 to 9 (see table).

The first four levels (TRL 1-4) mainly address proving that the basic concept behind the technology is valid and are usually achieved by analysis and testing in the laboratory. The next three levels (TRL 5-7) are achieved by testing the technology in the environment for which it is intended to operate. Usually this entails testing a prototype of the technology - progressing from a component, to a subsystem, to a full system - in an operational environment. It is for advancement through this range, from TRL 4-6/7, that the Flight Opportunities program facilitates flight testing in a relevant environment. Technologies sucessfully tested through the Flight Opportunities program are then available for advancement to TRL-8 and potential infusion into future missions. The last two TRL levels (TRL 8-9) mark the highest level of the technology maturation. TRL-8 is achieved when the actual system is completed and qualified for the mission through testing and demonstration in the operational environment. TRL-9 is achieved when the system has successfully completed a mission.

TRL 1	*Basic principles observed and reported*
TRL 2	*Technology concept and/or application formulated*
TRL 3	*Analytical and experimental critical function and/or characteristic proof of concept*
TRL 4	*Component and/or breadboard validation in laboratory environment*
TRL 5	*Component and/or breadboard validation in relevant environment*
TRL 6	*System/subsystem model or prototype demonstration in a relevant environment*
TRL 7	*System prototype demonstration in an operational environment*
TRL 8	*Actual system completed and 'flight qualified' through test and demonstration*
TRL 9	*Actual system flight proven through successful mission operations*

Technology Readiness Level (TRL) Definitions (source: NASA SSTIP)

Technology Definition*:*
A solution that arises from applying the disciplines of engineering science to synthesize a device, process, or subsystem, to enable a specific capability (source: NASA SSTIP)

July 21, 2011: Juan Agui of NASA/Glenn Research Center explains the payload for his research on 'Indexing Media Filtration System for Long Duration Space Missions' to NASA/JSC reviewers during the Test Readiness Review (TRR) at Ellington Field, TX. (Photo: NASA/Robert Markowitz)

Enabling Manufacturing in Space

Written by Jason Dunn (PI), CTO Made In Space Inc.

Made In Space, Inc. is a space manufacturing company built with the goal of enabling humanity's future in space. Founded in 2010, Made In Space determined that the most significant problem for space development and exploration was the supply chain. Building spacecraft and objects on Earth and launching them to space is time consuming, costly and logistically complicated. Made In Space quickly seized on the possibility of using additive manufacturing, or 3D printing, as a means to allow manufacturing to take place on location in space.

Development on-site in space has many key advantages. The fabrication of some systems in space would benefit from not having to withstand the stresses of launch. Costs are reduced by orders of magnitude. The timeframe to create small satellites, parts and tools moves from months to hours. Additive manufacturing holds great promise for many applications in space, including the possibility of using in-situ printing materials from extra-terrestrial resources.

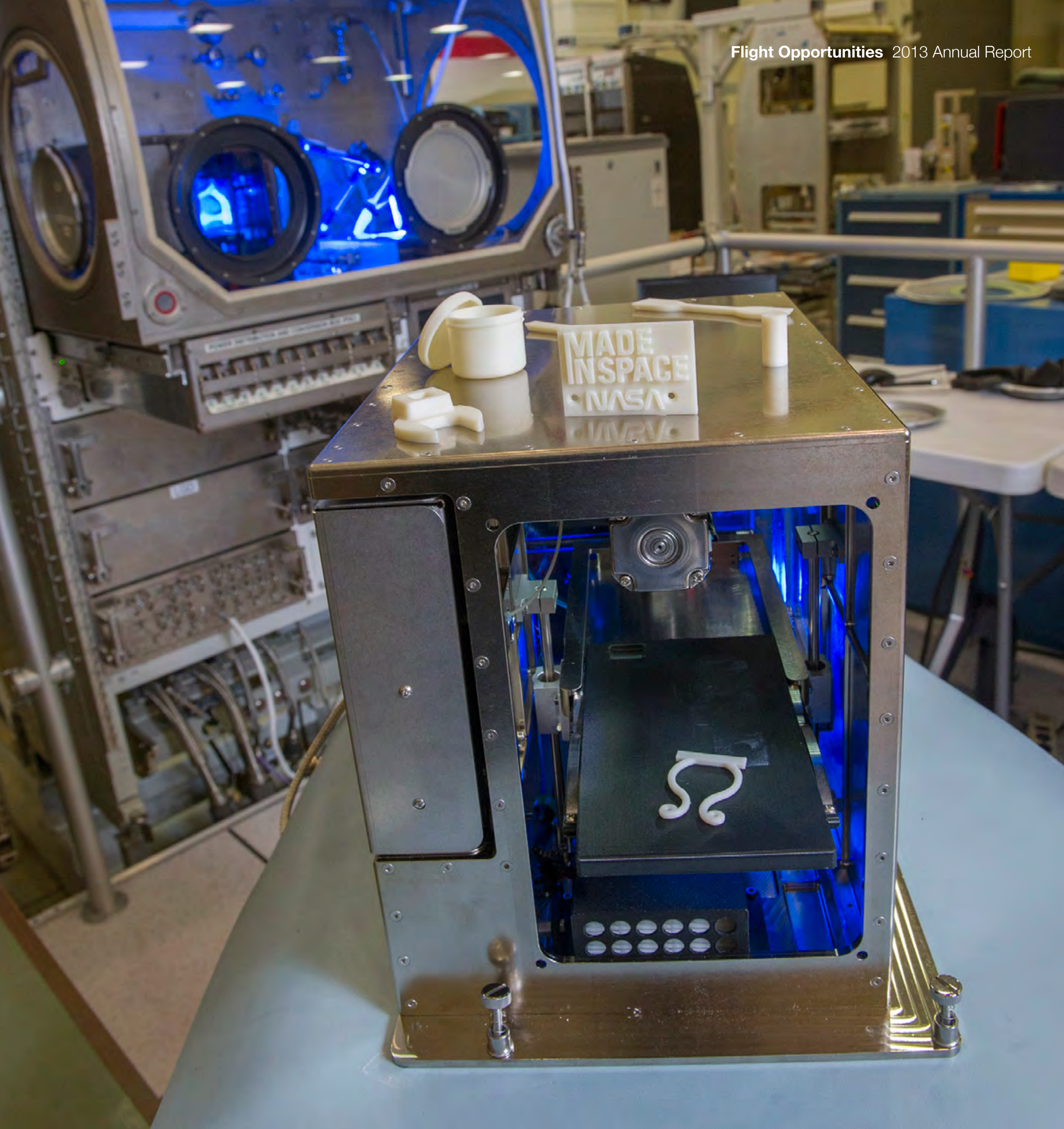
Made In Space initially performed flight tests in the summer of 2011. Our goal was to validate 3D printing technology by comparing commercial-off-the-shelf units with our customized printer that was designed for use in microgravity. Several parts were fabricated using extrusion-based printing, and the layer resolution, tolerances, and strength characteristics were studied in detail. By making inflight observations and modifying both the hardware and the software in between flights, we were able to rapidly optimize the technology for operation in microgravity.

As a result of our initial parabolic flights, a Phase-3 SBIR grant was obtained to develop a 3D printer testbed for deployment onboard the ISS. In 2013, Made In Space successfully tested their prototype 3D printer on the microgravity test flights. This testbed is currently manifested to arrive at the ISS in August 2014. We are coordinating our development with the NASA Marshall Space Flight Center (MSFC), who has also contracted the development of an Additive Manufacturing Facility (AMF) for shipment and permanent integration with the ISS in 2015. This AMF will be commercially available to terrestrial businesses, research facilities and individuals who wish to essentially email their hardware to space.

More information: flightopportunities.nasa.gov/technologies/4

DESIGNATION	**T0004-PS**
SELECTION	**MAY 2011 (AFO1)**
PLATFORMS	**PARABOLIC, sRLV**
FLIGHTS TO DATE	**4 (PARABOLIC)**
PRIMARY TA	**TA12**

The Made In Space 3D printer will be the first manufacturing device in space. As part of a technology demonstration, the printer will showcase the ability to create parts, tool and mission-critical 3D prints on-site for astronauts. (Photo: NASA)


MADE
IN SPACE
NASA


NASA
PTR GROUP
JACKSON AND TULL

Developing In Space Satellite Servicing and Refueling Capabilities

Written by Brian Roberts (PI) and Dr. Edward Cheung (PI), Satellite Servicing Capabilities Office, NASA/GSFC

The Satellite Servicing Capabilities Office (SSCO) at NASA's Goddard Space Flight Center, in partnership with West Virginia, conducted evaluations of robotic contact dynamics during parabolic flights in 2011. Knowledge gained during these flights is being used to mature autonomous capture algorithms and enhance the accuracy of a simulation platform at NASA's Goddard Space Flight Center. This platform is used to support the development and validation of technologies required for future missions that can include autonomous capture and servicing of satellites in geosynchronous and low Earth orbit.

Our primary goal was to collect data that can be used to verify simulated free-floating behavior of a robot on the ground. Prior to the flights, the autonomous capture technology was at a technology readiness level (TRL) of 3. Testing autonomous capture in a relevant environment (i.e., near-zero gravity) raised the TRL to 4. The flights also advanced the TRL of the ground-based contact dynamics simulation platform by providing "truth" data about the behavior of a free-floating object being touched by a robotic manipulator.

More information: flightopportunities.nasa.gov/technologies/9

DESIGNATION	**T0009-P**
SELECTION	**MAY 2011 (AFO1)**
PLATFORM	**PARABOLIC**
FLIGHTS TO DATE	**2**
PRIMARY TA	**TA04**

In May 2013, we performed additional parabolic flight tests to study the behavior of a flexible fuel hose in zero gravity. Before these flights took place, we could not verify the accuracy of our behavioral models with high precision. Prior attempts by our team to determine the behavior characteristics were limited by the presence of gravity or the damping of water used as a microgravity simulation. Parabolic flight tests represented the most direct way to obtain data that could predict flexible hose performance in space.

Data gathered during these flights has significantly matured our technological understanding. We discovered how the fuel nozzle tool can be rotated and positioned to ensure safe handling of the fuel hose. This is an important step to our completion of a low-risk system design.

The Satellite Servicing Capabilities Office at NASA's Goddard Space Flight Center thanks the Flight Opportunities program for the opportunity to perform these mission-critical tests in a relevant environment.

More information: flightopportunities.nasa.gov/technologies/60

DESIGNATION	**T0060-P**
SELECTION	**JANUARY 2013 (AFO5)**
PLATFORM	**PARABOLIC**
FLIGHTS TO DATE	**1**
PRIMARY TA	**TA04**

(Not pictured)

◁ *July 20, 2011: flight testing of robotic contact dynamics by the NASA/GSFC Satellite Servicing Capabilities Office (SSCO) during the first parabolic flight week of the program (RGO-01). (Photo: NASA/Robert Markowitz)*

February 28, 2013: Fine Water Mist (FWM) Portable Fire Extinguisher (PFE) test configuration. Droplet size measurements in microgravity are performed inside the black enclosure to protect the cabin during flight. The Portable Fire Extinguisher is visible on the lower left side of the black box. (Photo: NASA/Bill Stafford)

Fire Suppression for the International Space Station

Written by Thierry Carriere (PI), CTO ADA Technologies

ADA Technologies partnered with NASA/Johnson Space Center, NASA/Glenn Research Center and the Colorado School of Mines to develop and demonstrate a novel Fine Water Mist (FWM) Portable Fire Extinguisher (PFE) for in-space applications. The FWM PFE uses a water/nitrogen mixture that is environment and people-safe and is targeted to replace current carbon dioxide extinguishers on the ISS that can create a hazardous breathing environment for the crew. The initial work was carried out under a NASA Small Business Research (SBIR) grant. The system was designed to provide versatile and effective fire suppression against a wide variety of fire threats in space environments typically inhabited by human crews. It was successfully ground-tested in all aspects of manned spacecraft environments except for its functionality in actual microgravity.

After our proposal was selected in May 2011, the FWM-PFE payload was flown on a multi-day parabolic flight campaign in July 2011. The system was enclosed and designed to measure water droplet size distribution and density in micro-g and validate that performance was similar to that seen in ground-based tests. The efficient transport of the water droplets through an area with obstructions was also evaluated since good water mist/nitrogen distribution is important for fire suppression (cooling the flame and reducing the oxygen content of the air).

The results indicated that droplet size distribution in microgravity was similar to the observations during 1-g ground tests, demonstrating that our proprietary atomization technology is independent of theavity environment. In tests featuring obstructions simulating payloads enclosed in ISS racks, the larger droplets of the spray in both gravity conditions tended to collect on obstructions first and thus be removed from the mist. However, laser light scattering measurements of the water mist plume indicated that the density of the plume in microgravity was double that seen in ground tests suggesting that water droplets traveled more effectively in microgravity. Thus we concluded that the ground tests are a worst-case scenario for the FWM-PFE and microgravity appears to improve water mist distribution around objects, a very positive observation.

ADA Technologies is now proceeding with development of ISS-engineered PFE systems. We also hope to provide these systems for fire suppression on commercial suborbital vehicles that propose to fly humans such as Virgin Galactic and Blue Origin as well as orbital vehicles such as Sierra Nevada and Space-X.

More information: flightopportunities.nasa.gov/technologies/10

DESIGNATION	**T0010-P**
SELECTION	**MAY 2011 (AFO1)**
PLATFORM	**PARABOLIC**
FLIGHTS TO DATE	**2**
PRIMARY TA	**TA06**

Understanding Genetic Events Characterizing Biological Response and Adapations to Early Phase of Spaceflight

Written by Rob Ferl (PI) and Anna-Lisa Paul (Co-I), University of Florida

There is strong evidence for rapid gene responses within parabolic and suborbital flight parameters that are very different from the gene responses after days on orbit. This leaves a large gap in knowledge regarding the early stages of spaceflight adaptation, and there is currently no means of collecting biologically relevant data in that timeframe. Our objective is to repurpose fluorescent imaging instrumentation developed for Shuttle and ISS experiments by recalibrating the hardware and data collection capabilities to timeframes optimal for parabolic flight and suborbital applications. The anticipated technical outcome of this project is a stand-alone, mission-autonomous technology that is monitored by telemetry and that is capable of recording molecular imaging data during parabolic and suborbital flight. The anticipated science outcome is an understanding of the molecular genetic events that characterize biological response and adaptations that occur during the early phases of entry into spaceflight.

The repurposed imaging system, the GFP Imaging System (GIS) imager, has been operated on the ISS for several increments collecting biosensor data. The biosensors are comprised of engineered plant lines equipped with a variety of genes designed to report the biological response of a plant, or plant tissue, to its environment. Data from plants engineered with Green Fluorescent Protein (GFP) reporters can be collected telemetrically. To date, our University of Florida (UFL) team has conducted three parabolic campaigns to mature the repurposed instrumentation technology. We completed our most recent campaign in March 2013. With our near-term suborbital research flight already scheduled, advancing the TRL for suborbital platforms was of particular interest. The successful parabolic demonstration of the FLEX GIS advanced its readiness to TRL 6-7 for suborbital flight within a middeck locker equivalent form factor.

This work contributes to the programmatic goal of our laboratory, which is dedicated to advancing and defining the technical limits of fluorescence biology telemetry imaging, and to raise that technology toward a readiness for deployment in any of a number of opportunities. This development effort also has longer term potential for small satellite and planetary lander applications, and speaks directly to aspects of the Nanotechnology Road Map (Technology Area 10), particularly the development of sensitive, next-generation imagers that can collect data telemetrically, and in real time.

More information:
flightopportunities.nasa.gov/technologies/12
flightopportunities.nasa.gov/technologies/53

DESIGNATION	**T0012-P / T0053-S**
SELECTION	**MAY 2011 (AFO1) / AUG 2012 (AFO4)**
PLATFORMS	**PARABOLIC, sRLV**
FLIGHTS TO DATE	**3 (PARABOLIC)**
PRIMARY TA	**TA08**

September 20, 2011: Co-Investigator Anna-Lisa Paul prepares a new set of test samples during the 1g turn-around inbetween parabolas 1-20 and 21-40 onboard the G-Force One aircraft. (Photo: NASA/Robert Markowitz)

Heat Pipes for Next Generation Space Power Systems

Written by Marc Gibson (PI), NASA/Glenn Research Center

NASA/Glenn Research Center (GRC) completed its technology demonstration of titanium water heat pipes after a series of successful parabolic test campaigns with Flight Opportunities. The GRC team supports the Game Changing Development 'Nuclear Systems Project' and the 'Radioisotope Power System Technology Advancement Project' with the goal of bringing titanium water heat pipes to a Technology Readiness Level six (TRL-6). The heat pipes are the main component of the heat rejection system used on nuclear power systems necessary to effectively radiate waste heat and cool the power convertors that provide electricity.

The research started in 2011 with the need to evaluate the gravity dependence of thermosyphons in reduced gravity environments that could only be provided via parabolic flight. The Flight Opportunities program provided the necessary flights for the research, which led to new experimental data and modeling correlations. The new information allowed the researchers to better understand the thermal limits of thermosyphons for use with lunar and Martian surface nuclear power systems that could one day provide electrical power for a long term human presence.

In 2013, the team conducted follow-on research on advanced heat pipe prototypes specifically designed for cooling the Advanced Stirling Convertor (ASC). The ASC is a power convertor that uses nuclear heat and converts it to electricity for spacecraft consumption. The flight campaigns allowed the team to prove the thermal performance of two specific designs that could be configured for Plutonium-based Radioisotope Power Systems (RPS) and Uranium-based Fission Power Systems (FPS) used in deep space science missions. Both heat pipe technologies used titanium as the structural envelope and water as the working fluid with the requirement of transferring 150W of thermal power from the ASC to the heat rejection radiator. The technologies met all thermal requirements in their relevant environment achieving TRL6. This technology advancement directly addresses NASA's need to provide higher power spacecraft for future deep space science missions.

More information: flightopportunities.nasa.gov/technologies/14

DESIGNATION	**T0014-P**
SELECTION	**MAY 2011 (AFO1)**
PLATFORM	**PARABOLIC**
FLIGHTS TO DATE	**3**
PRIMARY TA	**TA14**

June 6, 2013: Marc Gibson (right) and colleagues observe the free floating enclosure containing the prototype Radial Core Heat Spreader (RCHS II) Heat Pipe as the aircraft performs a zero-g parabola. The flight tests provided data on the thermal performance characteristics of the prototype Heat Pipe in both hyper gravity and micro gravity (Photo: NASA/Robert Markowitz) ▷

Testing Planetary Landing Technologies on Earth

Written by Richard Loffi (PI), Charles Stark Draper Laboratory

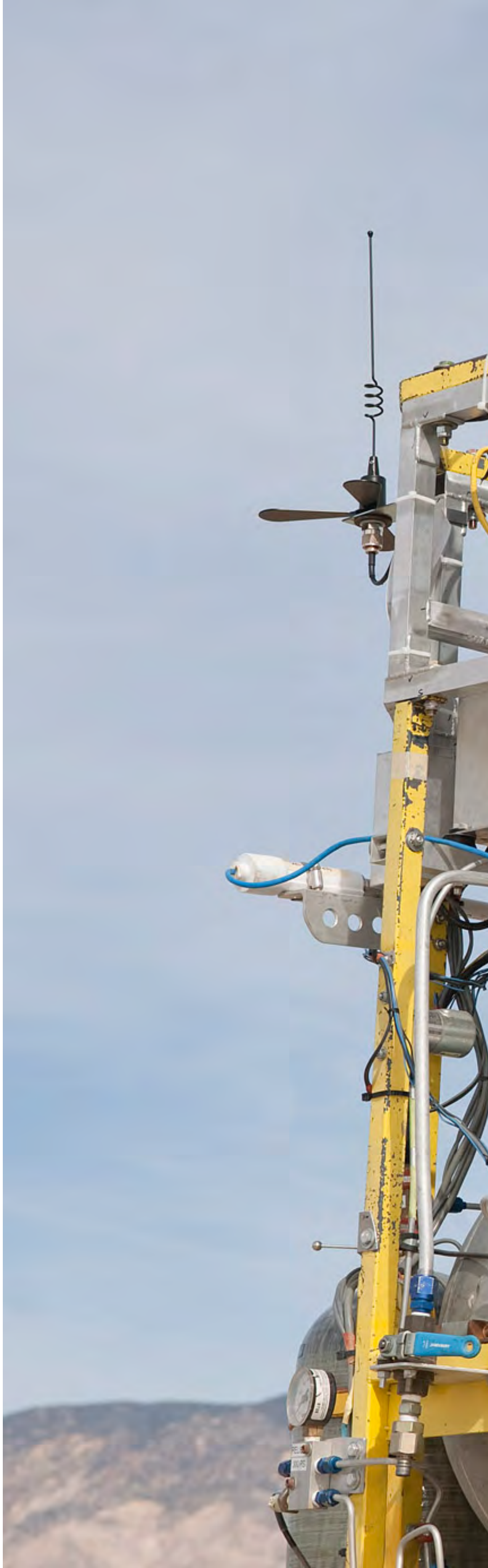
Draper's Guidance Embedded Navigator Integration Environment (GENIE) adapts mature Autonomous Guidance, Navigation and Control (AGNC) technology to provide commercial closed-loop sRLV flight demonstration capabilities for lunar and planetary entry descent and landing technologies. Leveraging systems developed under NASA's Autonomous Landing and Hazard Avoidance Technology (ALHAT) project and used on NASA's Morpheus Lander, the GENIE system provides a proven interface for testing of sensors, algorithms and other guidance technologies in flight. This allows existing AGNC systems and future technologies developed under that common architecture to be tested on commercial sRLV platforms such as Masten's XA-0.1-B "Xombie".

Starting in the summer of 2012, GENIE was integrated onboard the "Xombie" vehicle and the combined system was put through a series of open and closed loop tests: C1 (November 2011), an open loop free flight campaign, C2 (December 2011), a closed loop tethered hop campaign, C3 (February 2012), a closed loop demonstration commanding a 50m free flight pad-to-pad hop, and C4/C5 (March 2013), expanded envelope flights in both height and down range distance. The C4/C5 flights demonstrated performance of the sRLV to fly simulated lunar and planetary approach trajectories. This has extended the vehicle capabilities to support future lunar and planetary payload demonstrations.

Demonstration of the GENIE Precision Landing AGNC was the first step in an incremental approach to demonstrated autonomous landing and hazard avoidance technologies. GENIE has now progressed from TRL-4 to TRL-6 (system/subsystem prototyping demonstration in a relevant end-to-end environment, ground or space). Potential future flights using the matured GENIE could include terrain relative navigation and landing hazard avoidance sensors and advanced algorithms developed by Draper as well as demonstration of vehicles at higher altitudes with GENIE controlling a larger portion of the reentry, descent and landing trajectory.

More information: flightopportunities.nasa.gov/technologies/16

DESIGNATION	**T0016-S**
SELECTION	**MAY 2011 (AFO1)**
PLATFORM	**sRLV**
FLIGHTS TO DATE	**5**
PRIMARY TA	**TA09**



March 25, 2013: Tye Brady, principal investigator for Draper Lab's GENIE flight control system, makes final adjustments to the system on Masten Space Systems' Xombie technology demonstration rocket before liftoff. (Photo: NASA)

Sampling the Air in Microgravity for Hazardous Nanoparticles

Written by Fernando Cassese (PI), DTM Technologies, Modena, Italy

The DIAPASON is a small, lightweight, rugged, battery-powered air sampler system that captures nanoparticles less than 100 nm in size. Such particles are hazardous as they can reach the alveoli in the lung and enter the bloodstream. Of special interest are nanoparticles resulting from combustion and air pollution since they can be an invisible danger to human health in closed spacecraft or hazardous Earth environments. Inside the device, a technique called "thermophoresis" creates temperature gradients to capture particles of optimal size for analysis. The device supports efficient electronic microscopic (EM) and chemical analysis of particulates that become attached to built-in grids optimized for these methods.

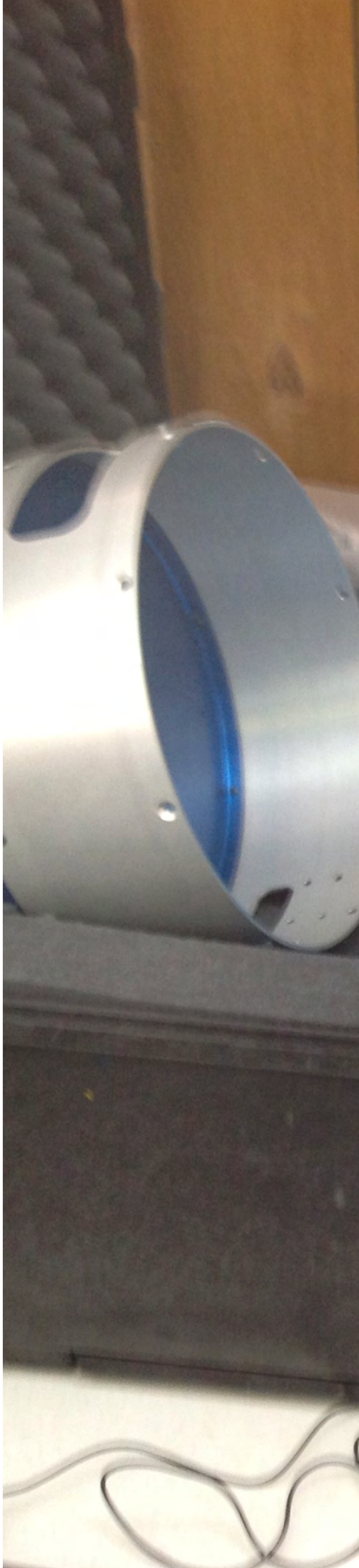
The Italian company DTM Technologies of Modena is developing the DIAPASON in collaboration with the Consiglio Nazionale delle Ricerche (CNR) in Bologna. Development of this technology began in 1997 when an international partnership was established between NASA and ASI (Italian Space Agency) to develop the system for future evaluation onboard the International Space Station (ISS).

A prototype of the DIAPASON was selected as directed payload by NASA in 2010. In 2013, the payload was manifested and successfully launched onboard the UP Aerospace SL-7 flight out of Spaceport America. A key goal for the flight was to be able to compare nanoparticles captured in microgravity with particles captured in a 1-g environment. The DIAPASON air intake system was sealed with an adhesive tape 3 hours before flight so the particulate capture during the flight was from the ground-based air sample. The payload survived the SL-7 flight and was recovered without damage. Results analyzed in the DTM lab showed that particles from a few nanometers up to about 2 μm were successfully captured in all grids of the instrument. For each grid, electron microscopy images were obtained to evaluate the qualitative and quantitative information of the deposited particles.

A more complex version of the DIAPASON has since been deployed onboard the ISS during a May-Nov 2013 on-orbit increment by Italian astronaut Luca Parmitano. The SL-7 flight with several minutes of microgravity provided a low-cost opportunity to validate the DIAPASON and provided clear evidence that the ISS system results should be accurate and that a future commercial version of DIAPASON planned for Earth applications would also provide high-quality data. Since all mission objectives were fulfilled, the fundamental qualification process of DIAPASON was successful and the technology verification of space flight readiness was achieved.

More information: flightopportunities.nasa.gov/technologies/19

DESIGNATION	**T0019-S**
SELECTION	**OCTOBER 2010 (DIRECTED)**
PLATFORM	**sRLV**
FLIGHTS TO DATE	**1**
PRIMARY TA	**TA08**



June 19, 2013: Federico Bartolamasi (left) and Davide Santachiara from the Italian company DTM Technologies prepare the DIAPASON payload before integration into the UP Aerospace SpaceLoft-7 rocket. (Photo: NASA)


NASA SHUTTLE SUPPORT
ORBITAL MEDICINE, INC
DRY SUCTION
ECI Healthcare
ATS

Evaluating a Medical Chest Drainage System for Space

Written by Marsh Cuttino (PI), Orbital Medicine Inc.

One of the common complications of chest trauma is the development of a collapsed lung, with air and blood entering the pleural cavity (the potential space between the lung and the chest wall). The medical terms for this are pneumothorax and hemothorax. These conditions are treated by inserting a tube into the space between the lung and chest wall, and attaching a thoracic drainage device with a suction source. The current medical devices used to fix this problem require fluids, and must stay in an upright position. Orbital Medicine, Inc has created a prototype thoracic drainage device that is able to separate the blood from the air, and re-inflate an astronauts lung in microgravity. Our technology uses a novel combination of devices that are FDA approved for human use with customization to optimize performance independent of the gravity environment.

A prototype of this device was tested over the course of two parabolic flight campaigns to ensure that the design concepts were valid. One limitation of the ground based laboratory testing is that the microgravity fluid effects of the two-phase blood/air mixture cannot be simulated. Therefore testing in a relevant environment is required. The May 2012 parabolic flights utilized a prototype system tested only on the ground. Knowledge gained from those flights resulted in a system upgrade to TRL-5 that included new air-fluid separation valves and use of blood simulant to assess fluid flows. A vortex separator was utilized that captures fluids in deep V-shaped grooves aided by surface tension and capillary fluid flows. The upgraded system was reflown on a July 2013 parabolic flight campaign with data capture by direct flight team observations, onboard video and photos.

The next step is to build and test an integrated unit that is compact and self-contained. The outline and general scope of the final device has been determined, however the optimal configuration will be based upon the parabolic flight test results. Repeating the testing in parabolic flight should be an effective means of evaluating the final device function. Completion of this level of testing would give the system a TRL of 5.

More information: flightopportunities.nasa.gov/technologies/26

DESIGNATION	**T0026-P**
SELECTION	**MAY 2011 (AFO1)**
PLATFORM	**PARABOLIC**
FLIGHTS TO DATE	**2**
PRIMARY TA	**TA06**

◁ *May 16, 2012: Dr. Marsh Cuttino (left) and Dr. Gregory Kovacs observe the functioning of the Medical Chest Drainage System during a zero gravity parabola. (Photo: NASA/James Blair)*

Demonstration and Evaluation of ADS-B Technology for Commercial Space Operations Onboard Reusable Suborbital launch Vehicles

Written by Nick Demidovich, FAA Commercial Space Transportation Office (FAA/AST)

Support of suborbital reusable launch vehicles (sRLVs) for commercial space transportation requires considerations for safe integration into the National Airspace System (NAS). The number, variety and locations of commercial space operations in the US continue to increase. The current need to sterilize airspace to accommodate the (more predictable) ascent and (somewhat less predictable) descent of these vehicles necessitates the suspension or diversion of air traffic within a volume of airspace. In the future these operations must become routine with minimal effect on other users of the airspace.

The FAA is implementing Automatic Dependent Surveillance – Broadcast (ADS-B) as the NextGen surveillance system intended to augment the current Air Traffic Management (ATM) infrastructure. ADS-B technology is used for surveillance by air traffic control and situational awareness for pilots. Full deployment and integration is planned for 2020. The ADS-B architecture is designed to support the current NAS with intent to support monitoring of flights below 60,000 ft. The potential application of ADS-B for tracking of flights above 60,000 feet is promising and warrants exploration and concept development. This project's goal is to demonstrate viability and test the functional envelope of experimental ADS-B payloads for suborbital commercial space operations. Continual, incremental progress has been made over the last three years in maturing the experimental ADS-B payload, raising its TRL as a result of repeated integration efforts and subsequent flights on various Flight Opportunities-funded platforms. This research presents the potential for adaptation of existing ADS-B technology to support operations for sRLVs and manned stratospheric balloons exceeding current technology limits (primarily altitude, velocity and acceleration).

SELECTION/DESIGNATION	**MULTIPLE**
PLATFORMS	**sRLV, BALLOON**
FLIGHTS TO DATE	**2 (BALLOON), 3 (sRLV)**
PRIMARY TA	**TA05**

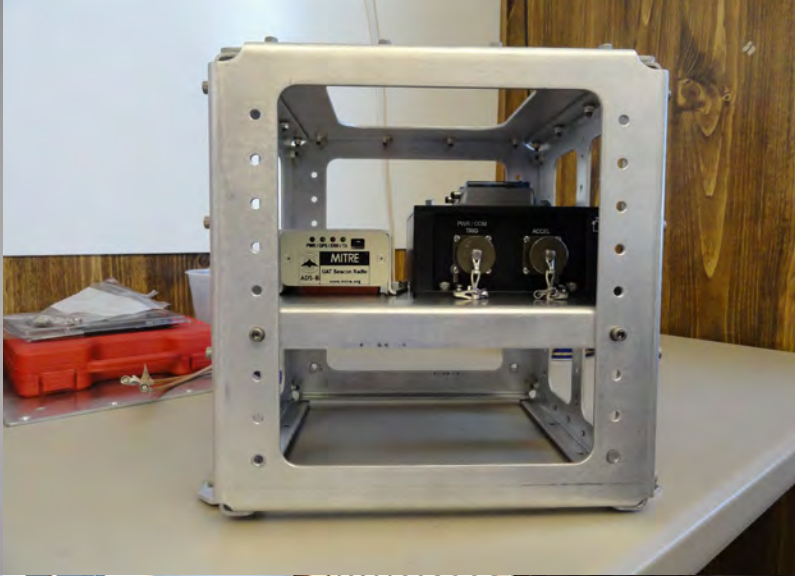
Starting in 2011, an ADS-B payload designed for aircraft by MITRE Corporation was integrated on the Masten Xaero and Xombie vehicles and flown on Xombie tethered and free flights. In 2012 and 2013, an ADS-B payload designed for aircraft was "ruggedized" by MITRE Corporation for the more severe environment of suborbital rocket flight, then integrated and flown onboard the UP Aerospace SpaceLoft vehicle, each time with better performance. The lessons learned from these tests informed the design of a new, advanced experimental ADS-B payload (based on the original MITRE design). It was specifically designed by Embry-Riddle Aeronautical University (ERAU) for suborbital commercial space operations with FAA funding. During 2013, the same advanced experimental ERAU payload was also flown onboard unmanned high altitude balloon platforms by Near Space Corporation. Through these flight tests, the team concluded that the upgraded ADS-B payload developed by ERAU has reached TRL-7, which is indicative of being proven within its operational environment. Future test flights and demonstrations are required to transition the prototype to TRL-8 (i.e. moved out of prototype phase).

Increasingly complex demonstrations of ADS-B technology have shown potential to eventually permit FAA to track high-altitude balloons and reusable launch vehicles in the national air space as they do aircraft, though much work (including further flight testing) remains to be done to formally implement this concept. Finally this technology has the potential for tracking expendable launch vehicles (ELVs) and re-entry vehicles (RVs) as it matures. Future research and subsequent flight tests on suborbital vehicles to higher altitudes and velocities followed by flights on actual ELVs and RVs will enable it to make progress towards this goal.

More information:
flightopportunities.nasa.gov/technologies/2
flightopportunities.nasa.gov/technologies/33
flightopportunities.nasa.gov/technologies/61

January 2011: Integration test of ADS-B payload onboard Masten Space Systems Xaero. (Photos: NASA) ▷


MITRE
UAT Beacon Radio
ADS-B


MITRE
ADS-B
ACCEL


menu
00:11:26 Z 2011 Jan 06 -- CPU system time
00:11:07 Z -- RF heart beat
00:00:00 Z 1970 Jan 01 at 0.0x -- data stream time
DELL

Structural Health Monitoring for Commercial Space Vehicles

Written by Andrei Zagrai (PI), New Mexico Institute Of Mining And Technology

The advent of commercial space travel has inspired engineers to rethink design and operation of space transportation systems. Structural health monitoring (SHM) is seen as a promising technology to reduce time to launch and operation costs with simultaneous improvements in the safety of commercial space vehicles. It is envisioned that SHM would be an integral part of the "black box" and would record information on structural integrity during all stages of spaceflight. Consideration of SHM data is useful in pre-flight diagnostics, in-orbit operation and tuning, and in analysis of structural behavior during spacecraft reentry. SHM information would also play a prominent role in space vehicle re-certification for the next flight.

Despite its obvious future use, application of SHM for spacecraft has not been thoroughly studied. Difficulty in testing in a real space environment is one of the prime impeding obstacles. Our aim therefore is to validate several SHM approaches by advancing the understanding of sensor behavior in a relevant environment (e.g. influence of space weather, effect of re-entry conditions and many other factors).

As a first step, sensor data was collected during a high-altitude balloon flight in early 2013. The flight profile of the high-altitude balloon included 1 hour and 36 minutes of ascent, 57 minutes of float at 102,000 ft and approximately 30 minutes of descent. The payload contained various SHM experiments including impedance measurements, passive detection (acoustic emission), active interrogation using ultrasonic guided waves, and wireless strain/temperature sensing. Results from this initial flight suggest potential of active diagnosis for continuous SHM of space vehicles and indicates specifics of using off-the-shelf sensor solutions in the near-space environment. Future flights are scheduled on sRLV vehicles to expose similar sensors to other aspects of the relevant environment for eventual use.

More information: flightopportunities.nasa.gov/technologies/38

DESIGNATION	**T0038-SB**
SELECTION	**MARCH 2012 (AFO3)**
PLATFORMS	**sRLV, BALLOON**
FLIGHTS TO DATE	**1 (BALLOON)**
PRIMARY TA	**TA12**

January 20, 2013: With snow-capped Mt. Jefferson in the Cascade Range providing the backdrop, the New Mexico Tech (NMT) team prepares the launch of the Structural Health Monitoring (SHM) technology payload. The team present at the Madras (OR) airport included NASA Flight Opportunities Campaign Manager Bruce Webbon (left), Nick Demidovich of the FAA Commercial Space Transportation Office (third from left) and PI Andrei Zagrai of NMT (fourth from left). (Photo: Andrei Zagrai)

Testing Asteroid Sample Collection Hardware

Written by Joseph Vellinga (PI), Lockheed Martin Inc.

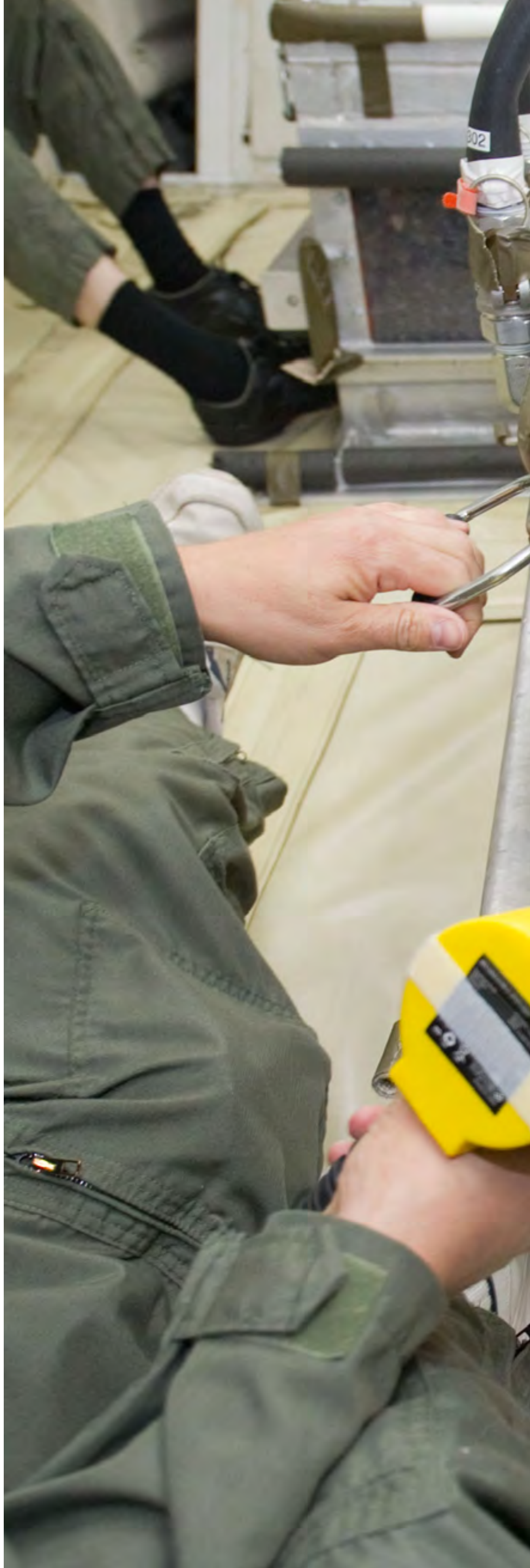
Lockheed Martin Space Systems is partnered with NASA/Goddard Space Flight Center and the University of Arizona to develop the flight system (spacecraft) and perform the mission operations for the OSIRIS-REx mission. OSIRIS-REx (Origins, Spectral Interpretation, Resource Identification, and Security Regolith Explorer) is an asteroid study and sample return mission scheduled for launch in the Fall of 2016. The spacecraft will collect a pristine sample using a gas-driven regolith levitation (fluidization) approach and return it to Earth to study it for clues about the composition of the very early Solar System. The explorer's sampler head is designed to approach the asteroid's surface in a near zero-g environment, make contact for about 5 seconds which triggers the release of pressurized gas, capture the levitated regolith sample (60g minimum), and then back away.

Previous microgravity flight testing was conducted on NASA aircraft in 2007 and 2009 during the early prototype design and development phase of our sampling system in order to reach TRL-5. Reaching TRL-6 prior to conduct of the OSIRIS-REx Preliminary Design Review (PDR) in March 2013 was essential, so additional flights supporting technology maturation were needed.

We flew our prototype sampling system on a parabolic flight campaign in May 2012. Five test chambers were operated for each flight for a total of 20 low gravity test runs. A scientifically representative range of simulated regoliths were successfully collected on all runs except the run that intentionally did not have gas release (to verify that no regolith was collected unintentionally). These tests validate the effectiveness of the gas fluidization sampling technique for asteroid or comet nucleus sample return missions with significant margin to mission requirements. Based in part on these flight tests, we successfully completed the PDR in March 2013 and have now started the actual flight hardware development for the September 2016 launch date.

More information: flightopportunities.nasa.gov/technologies/42

DESIGNATION	**T0042-P**
SELECTION	**MARCH 2012 (AFO3)**
PLATFORM	**PARABOLIC**
FLIGHTS TO DATE	**1**
PRIMARY TA	**TA07**



May 16, 2012: The sampler head is shielded from the simulated regolith by a movable barrier prior to entering a zero gravity parabola. The pneumatically controlled mini arm in the sampling test fixture automatically performs the test per the set-up established by the operators. (Photo: NASA/James Blair)

April 24, 2013: NASA astronaut Gregory Chamitoff observes the RINGS in free float as the airplane goes through a microgravity parabola. The system is in shear deployment, used to demonstrate rotational motion in Electromagnetic Formation Flight (EMFF). (Photo: NASA/Robert Markowitz)

Propellant-less Propulsion using Locally Generated Magnetic Fields

Written by: Ray Sedwick (PI), University of Maryland

RINGS, the Resonant Inductive Near-field Generation System, is a joint DARPA/NASA funded program to demonstrate and mature two technologies that could enable future space missions involving formations of multiple spacecraft. The first of these technologies, referred to as “Electromagnetic Formation Flight” or EMFF, is a propellant-less propulsion technology that uses locally generated magnetic fields to produce forces and torques between the vehicles. The second technology is a form of wireless power transfer (WPT) referred to as resonant inductive coupling (RIC), a non-radiative and largely non-directional power transfer approach that could be used to power a fleet of small spacecraft. The RINGS project is a collaborative effort among The University of Maryland Space Power and Propulsion Lab (UMD SPPL), Aurora Flight Sciences (AFS), and the Massachusetts Institute of Technology (MIT). To maximize productivity during planned ISS test sessions, our aim was to use a parabolic flight campaign to conduct preliminary formation flight testing and begin the control algorithm refinement process.

The RINGS payload was selected by the Flight Opportunities program under AFO5 and flew 4 months later on a G-Force One microgravity parabolic aircraft campaign in April 2013. The multi-day testing and data collection campaign allowed optimization of our control algorithms. For the first time, we were able to submit the payload to 6 Degrees Of Freedom (DOF) testing under multiple operational scenarios, including system mass and inertial identification and fundamental formation control maneuvers. The RINGS system demonstrated an impressive dynamic response to generated magnetic fields, providing the attraction, repulsion and shear forces necessary to fully control a spacecraft cluster. The WPT was also demonstrated at different separation distances and relative orientations.

Our test data supported the models developed to predict controlled motion of the RINGS but testing in longer-duration microgravity on the ISS will be essential for full validation. RINGS was launched in August of 2013 and is currently undergoing testing onboard the ISS as part of the SPHERES test bed.

More information: flightopportunities.nasa.gov/technologies/65

DESIGNATION	**T0065-P**
SELECTION	**JANUARY 2013 (AFO5)**
PLATFORM	**PARABOLIC**
FLIGHTS TO DATE	**1**
PRIMARY TA	**TA04**

Increasing Landing Accuracy for the Next Mars Mission

Written by:
MiMi Aung, Daniel P. Scharf, Martin W. Regehr/Jet Propulsion Laboratory, California Institute of Technology
Behçet Açıkmese/University of Texas at Austin
David Masten/Masten Space Systems, Inc.
Chris Baker/NASA Flight Opportunities Program

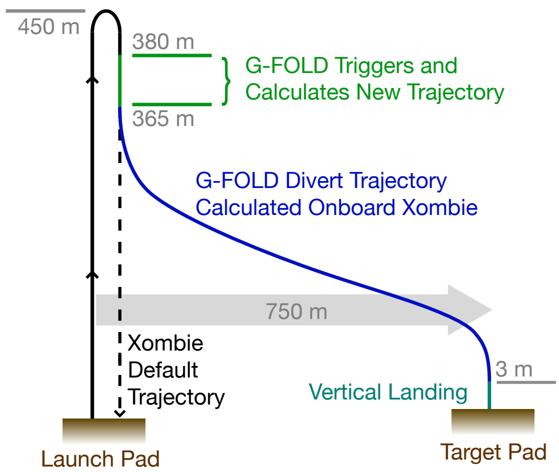
Spacecraft can accumulate large position and velocity errors during the entry phase of a planetary landing due to atmospheric and inertial navigation uncertainties and limited control authority. The powered descent phase, which is the last phase of Entry, Descent, and Landing (EDL), is when the lander can make a controlled maneuver to correct for these errors to reach a targeted point with pin-point accuracy. This maneuver must be planned onboard in real time because the state of the lander at the start of powered descent phase cannot be predicted in advance. Powered descent guidance algorithms used since the Apollo era do not optimize fuel usage and significantly limit how far the landing spacecraft can be diverted during descent. Jet Propulsion Laboratory's Guidance algorithm for Fuel Optimal Large Diverts (G-FOLD) autonomously computes fuel optimal landing trajectories in real time and provides a key new technology required for planetary pinpoint landing.

In a series of test flights utilizing Masten's XA-0.1B Xombie spacecraft lander testbed, progressively more complex executions of the G-FOLD algorithm were conducted under descent conditions not achievable through other testing methods. On July 30, 2013, to simulate a course correction during Martian powered descent to landing, Masten's Xombie was first commanded into a fast vertical descent beginning at 400 meter altitude with a default descent trajectory back to the launch pad instead of the desired target landing site 750 meters away. About 20 meters into this descent, the G-FOLD software automatically triggered and calculated a new flight profile in real time to the targeted landing site. The rocket then used this G-FOLD profile to successfully divert 750 meters to the target (see diagram). Xombie took to the sky again on September 20, 2013. More ambitious than the previous flight, this test had the Xombie vehicle initially traveling diagonally away from the target landing site. This test flight simulated a worst-case spacecraft landing maneuver and forced the G-FOLD algorithm to calculate, in real time, a three-dimensional flight path that reversed direction to reach the target landing site.

This accurately executed 800-meter three-dimensional divert shows what G-FOLD could mean for future space missions. For the Mars Curiosity landing scenario, G-FOLD could provide six times more divert range than the software used to land Curiosity. Such a capability would be needed for a safe landing on the jagged icy surface of Europa or for the coordinated landings of personnel and material required for human exploration of Mars. G-FOLD also can reduce the difficulty of future robotic missions, allowing rovers to land closer to features of interest instead of driving long distances to reach them. A future rover similar to Curiosity might be able to land right next to a target of scientific interest like Mount Sharp instead of an extended drive there.

More information: flightopportunities.nasa.gov/technologies/68

DESIGNATION	**T0068-S**
SELECTION	**JULY 2012 (NRA1)**
PLATFORM	**sRLV**
FLIGHTS TO DATE	**2**
PRIMARY TA	**TA09**



September 20, 2013: A Xombie technology demonstrator from Masten Space Systems, Mojave, Calif., is braking during the end of a long divert at Mojave Air and Space Port on a test for NASA's Jet Propulsion Laboratory. The vehicle is a vertical-takeoff, vertical-landing experimental rocket. It is being used in collaboration with NASA/Armstrong Flight Research Center to evaluate performance of JPL's Fuel Optimal Large Divert Guidance (G-FOLD), a new algorithm for planetary pinpoint landing of spacecraft. (Photo: NASA/Masten Space Systems/Carl Seubert)

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

Principle Investigator	Organization	State	Org Type	TA	AFO#	Status	
Sathya Gangadharan	Embry-Riddle Aeronautical University	FL	Academia	TA02	AFO1	Active	*1*
Jason Dunn	Made in Space, Inc.	CA	Industry	TA12	AFO1	Active	*2*
Jungho Kim	University of Maryland	MD	Academia	TA14	AFO1	Completed	*3*
Jungho Kim	University of Maryland	MD	Academia	TA14	AFO1	Completed	*4*
Greg Zimmerli	NASA/Glenn Research Center	OH	Government	TA02	AFO1	Completed	*5*
Rajagopal Vijayakumar	Aerfil (w/ NASA GRC)	NY	Industry	TA06	AFO1	Active	*6*
Brian Roberts	NASA/Goddard Space Flight Center	MD	Government	TA04	AFO1	Completed	*7*
Thierry Carriere	ADA Technologies	CO	Industry	TA06	AFO1	Completed	*8*
Chris Olsen	Ad Astra Rocket Company	TX	Industry	TA02	AFO1	Completed	*9*
Rob Ferl	University of Florida	FL	Academia	TA08	AFO1	Active	*10*
Howard G. Levine	NASA/Kennedy Space Center	FL	Government	TA06	AFO1	Completed	*11*
Marc A. Gibson	NASA/Glenn Research Center	OH	Government	TA14	AFO1	Completed	*12*
H. Todd Smith	Johns Hopkins University / APL	MD	Research Inst.	TA08	AFO1	Active	*13*
Rick Loffi	Draper Laboratory	MA	Research Inst.	TA09	AFO1	Pending	*14*
Hans-Peter Dumm	Air Force Research Laboratory	NM	Government	TA14	AFO1	Completed	*15*
Walt Turner	NASA/Kennedy Space Center	FL	Government	TA06	AFO1	Completed	*16*
Katy Hurlbert	NASA/Johnson Space Center	TX	Government	TA06	AFO2	Active	*17*
Ricard Gonzalez-Cinca	Universitat Politècnica de Catalunya	SPAIN	International	TA02	AFO2	Active	*18*
H. Todd Smith	Johns Hopkins University / APL	MD	Research Inst.	TA08	AFO2	Active	*19*
Sean Casey	Silicon Valley Space Center	CA	Industry	TA08	AFO2	Pending	*20*
Greg Zimmerli	NASA/Glenn Research Center	OH	Government	TA02	AFO2	Pending	*21*
Michael Schubert	Johns Hopkins Univ. School of Medicine	MD	Academia	TA06	AFO2	Active	*22*
C. Marsh Cuttino	Orbital Medicine, Inc.	VA	Industry	TA06	AFO2	Completed	*23*
Zarana Patel	NASA/Johnson Space Center	TX	Government	TA06	AFO2	Active	*24*
Ravi Komatireddy	The Vital Space Team	CA	Industry	TA06	AFO2	Completed	*25*
Josh Colwell	University Of Central Florida	FL	Academia	TA07	AFO3	Active	*26*
Scott Dulchavsky	Henry Ford Health System	MI	Research Inst.	TA06	AFO3	Active	*27*
Peter Cavanagh	University of Washington	WA	Academia	TA06	AFO3	Active	*28*
Francis Wessling	Univ. Of Alabama Space HW Club	AL	Academia	TA12	AFO3	Completed	*29*
Richard Stansbury	Embry-Riddle Aeronautical University	FL	Academia	TA05	AFO3	Completed	*30*
Rick Loffi	Draper Laboratory	MA	Research Inst.	TA09	AFO3	Pending	*31*
Jacob Chung	University of Florida	FL	Academia	TA02	AFO3	Active	*32*
Josh Colwell	University Of Central Florida	FL	Academia	TA07	AFO3	Active	*33*
John Marshall	SETI Institute	CA	Research Inst.	TA08	AFO3	Completed	*34*
Andrei Zagrai	NM Institute Of Mining And Technology	NM	Academia	TA12	AFO3	Active	*35*
Manohar Deshpande	NASA/Goddard Space Flight Center	MD	Government	TA02	AFO3	Pending	*36*
Carlos Cabrera	University of Puerto Rico	PR	Academia	TA06	AFO3	Completed	*37*
Issam Mudawar	Purdue University	IN	Academia	TA14	AFO3	Completed	*38*
Joe Vellinga	Lockheed Martin Inc.	CO	Industry	TA07	AFO3	Completed	*39*
Boris Khusid	New Jersey Institute Of Technology	NJ	Academia	TA14	AFO3	Pending	*40*
Carmelo Mandarino	Advanced Technical Inst. "E. Fermi"	ITALY	International	TA07	AFO3	Active	*41*
Eric Golliher	NASA/Glenn Research Center	OH	Government	TA06	AFO3	Pending	*42*
Jason Reimuller	Space Science Institute	CO	Research Inst.	TA08	AFO3	Pending	*43*

AFO		Title
44	T0047-P	Boston University Student Proposal for Deployable Solar and Antenna Array Microgravity Testing
45	T0048-P	Effects of Reduced and Hyper Gravity on Functional Near-Infrared Spectroscopy (fNIRS) Instrumentation
46	T0049-P	Parabolic Flight Evaluation of a Hermetic Surgery System for Reduced Gravity
47	T0050-B	Flight Demonstration of an Integrated Camera and Solid-State Fine Steering System
48	T0051-P	Non-Invasive Hemodynamic Monitoring in Microgravity
49	T0052-S	Collection of Regolith Experiment (CORE) on a Commercial Suborbital Vehicle
50	T0053-S	Validating Telemetric Imaging Hardware for Crew-Assisted and Crew-Autonomous Biological Imaging in Suborbital Applications
51	T0054-B	Stratospheric Parabolic Flight Technology
52	T0055-P	Structural Dynamics Test of STACER Antenna Deployment in Microgravity
53	T0056-P	UAH ChargerSat-2 Parabolic Flight Testing
54	T0057-P	High Eccentric Resistive Overload (HERO) Device Demonstration during Parabolic Flight
55	T0058-P	Assessing Otolith-Organ Function with Vestibular Evoked Myogenic Potentials (VEMPs) in Parabolic Flight
56	T0059-P	On the Performance of a Nanocatalyst-Based Direct Ammonia Alkaline Fuel Cell (DAAFC) Under Microgravity Conditions for Water Reclamation and Energy Applications
57	T0060-P	Dynamic and Static Behavior of a Flexible Fuel Hose in Zero-G
58	T0061-SB	Flight Testing of a UAT ADS-B Transmitter Prototype for Commercial Space Transportation Using sRLV
59	T0062-P	In-Flight Lab Analysis Technology Demonstration in Reduced Gravity
60	T0063-P	Caging System for Drag-free Satellites
61	T0064-B	Deployable Rigid Adjustable Guided Final Landing Approach Pinions (DRAG FLAPs)
62	T0065-P	Reduced Gravity Flight Demonstration of the Resonant Inductive Near-field Generation System (RINGS)
63	T0066-B	Guided Parafoil High Altitude Research
64	T0067-S	Autolanding for Robotic Precursor Missions
65	T0089-P	Technology Maturation of a Dual-Spinning CubeSat Bus
66	T0090-P	Testing Near-Infrared Neuromonitoring Devices for Detecting Cerebral Hemodynamic Changes in Parabolic Flight
67	T0091-P	Resilient Thermal Panel: Microgravity Effects on Isothermality of Structurally Embedded Two Dimensional Heat Pipes
68	T0092-S	Precision Formation Flying Sensor
69	T0093-P	Wireless Strain Sensing System for Space Structural Health Monitoring
70	T0094-P	Monitoring Tissue Oxygen Saturation in Microgravity
71	T0095-SB	Test of Satellite Communications Systems on-board Suborbital Platforms to Provide Low-Cost Data Communications for Research Payloads, Payload Operators, and Space Vehicle Operators
72	T0096-P	Testing the Deployment and Rollout of the DragEN Electrodynamic Tether for CubeSats
73	T0097-B	Planetary Atmosphere Minor Species Sensor
74	T0098-S	Navigation Doppler Lidar Sensor Demonstration for Precision Landing on Solar System Bodies
75	T0099-B	Satellite-Based ADS-B Operations Flight Test
76	T0100-P	Creation of Titanium-Based Nanofoams in Reduced Gravity for Dye-Sensitized Solar Cell Production
77	T0101-P	Testing a CubeSat Attitude Control System in Microgravity Conditions
78	T0102-P	Demonstration of Adjustable Fluidic Lens in Microgravity
79	T0103-P	Optical Coherence Tomography (OCT) in Microgravity
80	T0104-PS	Real Time Conformational Analysis of Rhodopsin using Plasmon Waveguide Resonance Spectroscopy
81	T0105-P	DYMAFLEX: DYnamic MAnipulation FLight EXperiment
82	T0106-B	Low-Cost Suborbital Reusable Launch Vehicle (sRLV) Surrogate
83	T0107-P	Characterizing CubeSat Deployer Dynamics in a Microgravity Environment
84	T0108-P	Demonstration of Food Processing Equipment
85	T0109-P	Advanced Optical Mass Measurement System

Principle Investigator	Organization	State	Org Type	TA	AFO#	Status	
Ted Fritz	Boston University	MA	Academia	TA12	AFO3	Active	*44*
Angela Harrivel	NASA/Glenn Research Center	OH	Government	TA06	AFO3	Completed	*45*
George Pantalos	University of Louisville	KY	Academia	TA06	AFO3	Active	*46*
Eliot Young	Southwest Research Institute	CO	Research Inst.	TA08	AFO3	Active	*47*
Greg Kovacs	Stanford University	CA	Academia	TA06	AFO3	Completed	*48*
Josh Colwell	University of Central Florida	FL	Academia	TA07	AFO3	Active	*49*
Rob Ferl	University of Florida	FL	Academia	TA08	AFO4	Active	*50*
Steven Collicott	Purdue University	IN	Academia	TA08	AFO4	Active	*51*
Kerri Cahoy	Massachusetts Institute of Technology	MA	Academia	TA12	AFO5	Active	*52*
Francis Wessling	University of Alabama	AL	Academia	TA14	AFO5	Active	*53*
Aaron Weaver	NASA/Glenn Research Center	OH	Government	TA06	AFO5	Active	*54*
Mark Shelhamer	Johns Hopkins Univ. School of Medicine	MD	Academia	TA06	AFO5	Pending	*55*
Carlos Cabrera	University of Puerto Rico, Rio Pedras	PR	Academia	TA03	AFO5	Active	*56*
Allyson Buker	Jackson and Tull	DC	Industry	TA04	AFO5	Completed	*57*
Richard Stansbury	Embry-Riddle Aeronautical University	FL	Academia	TA05	AFO5	Active	*58*
Emily Nelson	NASA/Glenn Research Center	OH	Government	TA06	AFO5	Pending	*59*
Rob Byer	Stanford University	CA	Academia	TA08	AFO5	Completed	*60*
Scott Nietfeld	Masten Space Systems Inc.	CA	Industry	TA09	AFO5	Active	*61*
Ray Sedwick	University of Maryland	MD	Academia	TA04	AFO5	Completed	*62*
Allen Lowry	Airborne Systems N. America of CA, Inc.	CA	Industry	TA09	AFO5	Active	*63*
Kevin Peterson	Astrobotic Technology, Inc.	PA	Industry	TA09	AFO5	Active	*64*
Kerri Cahoy	Massachusetts Institute of Technology	MA	Academia	TA12	AFO6	Active	*65*
Gary Strangman	Massachusetts General Hospital	MA	Academia	TA06	AFO6	Active	*66*
Andy Williams	Air Force Research Laboratory	NM	Government	TA14	AFO6	Active	*67*
Webster Cash	University of Colorado	CO	Academia	TA08	AFO6	Active	*68*
Haiying Huang	University of Texas, Arlington	TX	Academia	TA12	AFO6	Active	*69*
Tom Smith	University of Oxford	UK	International	TA06	AFO6	Active	*70*
Brian Barnett	SatWest Consulting, LLC	NM	Industry	TA05	AFO6	Active	*71*
Jason Held	Saber Astronautics Australia Pty. Ltd.	AUSTRALIA	International	TA02	AFO6	Active	*72*
Robert Peale	University of Central Florida	FL	Academia	TA08	AFO6	Active	*73*
Farzin Amzajerdian	NASA/Langley Research Center	VA	Government	TA09	AFO6	Active	*74*
Russ Dewey	GSSL, Inc.	OR	Industry	TA05	AFO6	Active	*75*
Kristen Scotti	Northwestern University	IL	Academia	TA10	AFO6	Active	*76*
Eric Bradley	University of Central Florida	FL	Academia	TA02	AFO6	Active	*77*
James Schwiegerling	University of Arizona	AZ	Academia	TA08	AFO6	Active	*78*
Doug Ebert	Wyle Laboratories	TX	Industry	TA06	AFO6	Active	*79*
Victor Hruby	University of Arizona	AZ	Academia	TA06	AFO6	Pending	*80*
David Akin	University of Maryland	MD	Academia	TA04	AFO6	Active	*81*
Tim Lachenmeier	GSSL, Inc.	OR	Industry	TA05	AFO6	Active	*82*
Kira Abercromby	California Polytechnic State University	CA	Academia	TA12	AFO6	Active	*83*
Susana Carranza	Makel Engineering, Inc.	CA	Industry	TA07	AFO6	Active	*84*
Jason Reimuller	Mass Dynamix, Inc.	CA	Industry	TA02	AFO6	Pending	*85*

NRA		Title
86	T0068-S	Fuel Optimal Large Divert Guidance for Planetary Pinpoint Landing (G-FOLD)
87	T0076-S	Demonstration of Vertically Aligned Carbon Nano-tubes for Earth Climate Remote Sensing
88	T0077-S	Facility for Microgravity Research and Submicroradian Stabilization using sRLVs
89	T0078-S	Enhanced Thermal Switch for Payload Autonomous Thermal Control
90	T0079-S	Autonomous Flight Manager for Human-in-the-Loop Immersive Simulation and Flight Test of Terrestrial Rockets
91	T0080-S	Advanced Micro Sun Sensor
92	T0081-S	Demonstration of Variable Radiator
93	T0081-S	Dynamic Microscopy System
94	T0083-S	Design and Development of a Micro Satellite Attitude Control System
95	T0084-S	Suborbital Test of a Robotics-Based Method for In-Orbit Identification of Spacecraft Inertia Properties
96	T0085-S	SwRI Solar Instrument Pointing Platform
97	T0086-S	Saturated Fluid Pistonless Pump Technology Demonstrator
98	T0087-S	Electric-hydrodynamic Control of Two-Phase Heat Transfer in Microgravity
99	T0088-S	An FPGA-based, Radiation Tolerant, Reconfigurable Computer System with Real Time Fault Detection, Avoidance, and Repair
100	T0111-S	Rocket Flight of a Delta-Doped CCD Focal Plane Array for CHESS
101	T0111-S	Spacecraft Disturbance Isolation and Rejection Platform (SDIRP)
102	T0113-B	Focal Plane Actuation to Achieve Ultra-High Resolution on Suborbital Balloon Payloads
103	T0114-S	Technology Demonstration of Graphene Ion Membranes for Earth and Space Applications
104	T0115-S	EDL Technology Development for the Maraia Earth Return Capsule
105	T0116-S	Operational Demonstration of the MPS-120 CubeSat High-impulse Adaptable Modular Propulsion System
106	T0117-S	1U CubeSat Green Propulsion System with Post-Launch Pressurization
107	T0118-S	Iodine RF Ion Thruster Development
108	T0119-S	Inductively Coupled Electromagnetic (ICE) Thruster System Development for Small Spacecraft Propulsion
109	T0120-S	Advanced Hybrid Rocket Motor Propulsion Unit for CubeSats (PUC)r

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110	T0001-PS	Suborbital Flight Environment Monitor (SFEM)
111	T0002-S	Automatic Dependent Surveillance-Broadcast (ADS-B)
112	T0019-S	DIAPASON
113	T0069-S	Global Positioning Beacon (GPB)
114	T0070-P	Portable Fire Extinguisher (formerly T0010-P)
115	T0071-S	New Mexico Student Groups #1 and #2 for SL-7
116	T0072-S	New Mexico Student Groups #3 and #4 for SL-8
117	T0073-S	Radial Core Heat Spreader
118	T0074-S	Miniature Altitude Determination System
119	T0075-S	Exo-Atmosperic Aerobrake
120	T0110-P	Wet Lab

USIP

121	T0121-S	Flyover Mapping and Modeling of Terrain Features
122	T0122-P	Microgravity Experiment on Accretion in Space Environments
123	T0123-P	Microgravity Propellant Gauging Using Modal Analysis
124	T0124-B	Gannon University's Cosmic-Ray Calorimeter (GU-CRC)

Principle Investigator	Organization	State	Org Type	TA	NRA#	Status	
Behcet Acikmese	NASA/Jet Propulsion Laboratory	CA	Government	TA09	NRA1	Completed	86
H. Todd Smith	Johns Hopkins University / APL	MD	Research Inst.	TA10	NRA1	Pending	87
Scott Green	Controlled Dynamics Inc.	CA	Industry	TA08	NRA1	Active	88
Douglas Mehoke	Johns Hopkins University / APL	MD	Research Inst.	TA14	NRA1	Pending	89
Rick Loffi	Draper Laboratory	MA	Research Inst.	TA04	NRA1	Pending	90
Sohrab Mobasser	NASA/Jet Propulsion Laboratory	CA	Government	TA05	NRA1	Active	91
Richard Kurwitz	Texas A&M University	TX	Academia	TA14	NRA1	Active	92
John Vellinger	Techshot, Inc.	IN	Industry	TA08	NRA1	Pending	93
Manoranjan Majji	State University of New York, Buffalo	NY	Academia	TA02	NRA1	Active	94
Ou Ma	New Mexico State University	NM	Academia	TA04	NRA1	Active	95
Craig DeForest	Southwest Research Institute	CO	Research Inst.	TA08	NRA1	Pending	96
Ryan Starkey	University of Colorado	CO	Academia	TA02	NRA1	Active	97
Boris Khusid	New Jersey Institute of Technology	NJ	Academia	TA14	NRA1	Active	98
Brock LaMeres	Montana State University	MT	Academia	TA11	NRA1	Active	99
Paul Scowen	Arizona State University	AZ	Academia	TA08	NRA2	Pending	100
Gerardo Ortiz	NASA/Jet Propulsion Laboratory	CA	Government	TA08	NRA2	Pending	101
Paul Scowen	Arizona State University	AZ	Academia	TA08	NRA2	Pending	102
H. Todd Smith	Johns Hopkins University / APL	MD	Research Inst.	TA10	NRA2	Pending	103
Alan Strahan	NASA/Johnson Space Center	TX	Government	TA09	NRA2	Active	104
Christian Carpenter	Aerojet General Corporation	WA	Industry	TA02	NRA2	Pending	105
Michael Tsay	Busek Co. Inc.	MA	Industry	TA02	NRA2	Pending	106
Kurt Hohman	Busek Co. Inc.	MA	Industry	TA02	NRA2	Pending	107
John Slough	MSNW LLC	WA	Industry	TA02	NRA2	Pending	108
John DeSain	The Aerospace Corporation	CA	Research Inst.	TA02	NRA2	Pending	109
Dougal Maclise	NASA/Ames Research Center	CA	Government	TA08		Active	110
Nick Demidovich	FAA Commercial Space Transportation	DC	Government	TA05		Completed	111
Ferdinando Cassese	DTM Technologies	ITALY	International	TA08		Completed	112
Jason Armstrong	Kirtland AFB	NM	Government	TA05		Completed	113
Branelle Rodriguez	NASA/Johnson Space Center	TX	Government	TA06		Completed	114
Pat Hynes	New Mexico Space Grant Consortium	NM	Academia	TA06		Completed	115
Pat Hynes	New Mexico Space Grant Consortium	NM	Academia	TA06		Completed	116
Roshanak Hakimzadeh	NASA/Glenn Research Center	OH	Government	TA14		Active	117
Sohrab Mobasser	NASA/Jet Propulsion Laboratory	CA	Government	TA05		Pending	118
Marc Murbach	NASA/Ames Research Center	CA	Government	TA09		Active	119
Macarena Parra	NASA/Ames Research Center	CA	Government	TA06		Active	120
William Whittaker	Carnegie Mellon University	PA	Academia	TA08	USIP1	Pending	121
Josh Colwell	University of Central Florida	FL	Academia	TA08	USIP1	Active	122
Kevin Crosby	Carthage College	WI	Academia	TA02	USIP1	Active	123
Nicholas Conklin	Gannon University	PA	Academia	TA08	USIP1	Pending	124

“As anchor tenant for technology maturation, NASA Flight Opportunities continues to play an important role in the emergence of a viable commercial reusable suborbital launch industry.”

Michael Lopez-Alegria, Commercial Spaceflight Federation

One of our primary goals has been to foster the emerging commercial reusable transportation industry. By contracting our test flights with emerging commercial flight providers, we serve as an anchor tenant in the suborbital research market. It has not always been an easy or straightforward path for many of these companies. The level of complexity faced in aerospace development is infamous enough to have been canonized in the American lexicon. Developing, manufacturing, and flight testing any new vehicle is a process that frequently exceeds any anticipated schedule. The commercial sector bears both the risk and the reward; the role our program plays to support this industry is by flying payloads in a space-like environment and advancing the development of cross-cutting technologies relevant to NASA's mission. We continue to actively purchase qualified flights and support the maturation of technologies that enhance the suborbital launch vehicle capabilities. The companies that are providing flight services to NASA are themselves developing space exploration technologies and benefit from what is being tested. In this way, the two pillars of the program, nurturing an emerging industry, and flight testing new technologies, amplify one another.

The program has presented some challenges within the Agency as it is a pathfinder that needed to develop and utilize new methods for NASA to work with commercial spaceflight companies. In particular, the purchase of fixed-priced commercial flight services represents a new way of working with the space industry and required some rethinking of how we accomplish our mission. Over the last several years, we have developed methods to assure a balance between offering frequent, low cost access to relevant environments while simultaneously maintaining appropriate levels of safety and government oversight.

Despite the challenges, the path that has been laid out for us by Congress and the Executive Branch is worth the investment. Our commercial partners are invested in the success of the U.S. spaceflight industry and a strong commercial space sector will benefit NASA and the nation. The Flight Opportunities program is proud to be a forerunner in the support and utilization of the commercial space industry.

Mark Collard, Platforms Manager

◁ *April 4, 2012: Runway at Spaceport America, NM. (Photo: NASA)*

Platforms
Profiles

◁ *February 11, 2013: Students from the New Mexico Institute of Mining and Technlogy watch up to see the balloon carrying their Structural Health Monitoring (SHM) technology payload take to the air (Photo: Andrei Zagrai)*

Xombie

Masten Space Systems

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. The vehicle placed in the 2009 NASA funded Northrop Grumman Lunar Lander Challenge X Prize and has recently served as a test platform for experimental spacecraft landing systems as a commercially available lander testbed. In the past three years, Masten has conducted eight distinct RLV flight campaigns in support of customers including NASA's Flight Opportunities program and NASA/JPL's Guidance and Control Analysis Group.

To date, Masten Space Systems has conducted nearly 300 rocket-powered reusable launch vehicle (RLV) flight tests and over 400 rocket engine tests at its facilities in Mojave, CA. The XA-0.1-B vehicle has also served as an internal research and development platform for Masten, and has demonstrated in-flight engine restarts and precision landing.

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
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. 10 seconds after drogue deploy 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) and fly it 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 two different sizes to choose from.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 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 payload integration process and certification for flight onboard the SpaceLoft™.

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

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 centerbody, the 10 kg (22 lbs) maxmum payload weight limit, and specified center of gravity (CG) constraints.

More information:
flightopportunities.nasa.gov/platforms/balloon/hass

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 hour. 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.

More information:
flightopportunities.nasa.gov/platforms/balloon/sbs

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:
flightopportunities.nasa.gov/platforms/balloon/nbs

G-Force One

NASA/JSC Reduced Gravity Office with Zero Gravity Corporation

Platform

The Boeing 727-200F is a three-engine, swept-wing aircraft specially modified for reduced gravity operations. The interior contains 30 seats for researchers and crew in the rear of the aircraft and an open research area approximately 20m (67ft) long in the forward section of the cabin.

The airplane provides about 10-17 seconds of near-zero gravity conditions during each parabolic maneuver. It can provide variable gravity levels between zero and one, including 0.16 g for lunar conditions and 0.38 g for Mars conditions. An increased gravity level of up to 1.8 g can be provided for up to one minute.

Flight Profile

Before starting a parabola, G-Force One flies level to the horizon at an altitude of 24,000 feet. The pilots then begins to pull up, gradually increasing the angle of the aircraft to about 45 deg to the horizon reaching an altitude of 34,000 feet. During this pull-up, passengers will feel the pull of 1.8 g. Next the plane is "pushed over" to create the zero gravity segment of the parabola. For the next 10-17 seconds everything in the plane is weightless. Next a gentle pull-out is started which allows the flyers to stabilize on the aircraft floor. This maneuver is repeated 30-40 times, each taking about ten miles of airspace to perform.

Payload Configuration

Approximately 20m (67ft) of cabin length is available for larger experiments. Seats in the rear can be utilized for smaller experiments as well. A floor plan schematic and cross sectional view of the cabin is available in the Interface Control Documentation. Test equipment is usually loaded through the cargo door, which is 2.3m (90 inches) high and 3.4m (134 inches) wide.

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


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 a known attitude 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 be as large as 200 lbs. and can take up the volume of a full astronaut-seat equivalent, although smaller payloads are also able to fly. 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


PSI
XCOR
AEROSPACE
EXPERIMENTAL
MIDLAND

Lynx

XCOR Aerospace

Platform

Lynx is the piloted, two-seat, fully reusable launch vehicle being developed by XCOR Aerospace to transport humans and payloads on a 30 minute suborbital flight up to 100 km (330,000 feet) and return in a safe, glide-back landing at the originating runway. As with any production aircraft development program, XCOR has planned an initial test article, followed by several models of production vehicles that address different needs and markets.

The Lynx Mark I is the initial flight test vehicle now under development at XCOR's Mojave, CA facilities. This prototype vehicle will be used to characterize and flight test the various sub-systems of the craft including life support, propulsion, tanks, structure, aeroshell, aerodynamics, re-entry heating and other design elements. It will undergo a flight test program beginning in 2014. The flight test program consists of a traditional envelope expansion regime in which the vehicle is gradually tested to its full flight profile. The Mark I will be placed into commercial service after being licensed as a launch vehicle under FAA rules. The Lynx Mark I will also be used to train pilots and crew for the Lynx Mark II. The Lynx Mark I is designed to achieve an altitude of 200,000 feet (approximately 61 km).

The Lynx Mark II will begin construction and assembly during the Lynx Mark I development program. The Mark II is the production version of the Lynx, servicing both the suborbital tourism market and all markets that make use of the Lynx's internal payload volumes, such as microgravity and biotechnology experiments. The Lynx Mark II uses the same propulsion and avionics systems as the Lynx Mark I, but has a lower dry weight and hence higher performance than the Mark I. The Mark II is designed to fly to 328,000 feet (approximately 100 km).

The Lynx Mark III is a highly modified derivative of the Lynx Mark II that features the ability to carry an external dorsal pod with either a payload experiment or upper stage capable of launching a small satellite into low earth orbit. Total payload capacity for the external dorsal pod is 650kg. The Lynx Mark III is a different vehicle from the Mark II, featuring upgraded landing gear, aerodynamics, core structural enhancements, and features a more powerful propulsion package and other modifications needed to carry the extra weight aloft.

Flight Profile

The Lynx takes off horizontally from a runway and almost immediately launches into a powered ascent attaining Mach 2.9 maximum airspeed. After about three minutes and at approximately 58 km (190,000 ft.) the engines are shutdown. Lynx then coasts upwards. At approximately four and half minutes Lynx reaches apogee of 100 km (328,000 ft.). After reentry and Max-G force pullout of 4-G, Lynx touches down on the runway. Mark I is anticipated to achieve a total of 105 seconds at or below 10-1g. The duration of Mark II micro-g time is anticipated to be 194 seconds at or below 10-1g. Lynx's aircraft-like capabilities allow high tempo operations, including up to four flights per day, rapid call-up (ready to fly in two hours), fast turnaround between flights (ready to fly again in no more than two hours), low maintenance intervals (designed for 40 flights before preventive maintenance action), and low cost operations.

Payload Configuration

The Lynx will offer several multi-mission primary and secondary payload capabilities including: in-cockpit experiments, externally mounted experiments, test pilot/astronaut training, upper atmospheric sampling, microsatellite launch/ballistic trajectory research (Mark III/US capability only), and personal spaceflight (space tourism). Primary payloads determine the flight trajectory, date and mission objectives. Secondary payloads are manifested with a primary payload, which may be a spaceflight participant, and do not control the flight date, trajectory or mission objectives. Lynx vehicles will carry primary payloads located in the area to the right of the pilot or in the case of the Mark III (US only) on the top of the vehicle in an experiment pod. Secondary payload spaces in all versions include a small area inside the cockpit behind the pilot or outside the vehicle in two areas in the aft fuselage fairing. For the Mark II version of the Lynx, the primary internal payload will accommodate a maximum mass of 120 kg (265 lbs.) to 100 km (330,000 ft.).

More information:
flightopportunities.nasa.gov/platforms/suborbital/lynx

STIG

Armadillo Aerospace

Platform

The STIG (Suborbital Transport with Inertial Guidance) family of vehicles is a 20"/500mm diameter, space capable vehicle offering up to three minutes of micro-G time. Being inertially guided and liquid bipropellant, STIG offers a gentle 4-G ride to space for a payload up to 50 kg with no spin stabilization necessary. Moreover, recovery utilizes a ballute decelerator in combination with a GPS guided parafoil to fly-glide the vehicle back to the launch site offering virtually immediate payload access. STIG was the first RLV (Reusable Launch Vehicle) to be granted a launch license by FAA/AST and is founded on the same technologies that Armadillo Aerospace developed while working on NASA's Project Morpheus Terrestrial Lunar Lander Analog vehicle now flying down at NASA/Kennedy Space Center.

Flight Profile

The "soft boost" of just 2-G increases gradually over a period of 60-seconds to roughly 4-G and can be customized to the payload provider's need including a pointing capability. The vehicle then coasts to apogee and descends to the outer regions of the atmosphere with at least three minutes of micro-G and more available on customized missions. At roughly 30-km AGL, the ballute is deployed and this decelerates the vehicle from supersonic through subsonic until, at 3-km AGL the main is deployed. The recovery system flight computer then determines current location and desired landing point and fly-glides the vehicle back to land at the launch team's feet.

Payload Configuration

Payload providers are given a payload rack that fits inside the 500mm payload section body tube. The payload can be provided with both power and triggering signals by the vehicle's main flight computer at key event time, e.g. end of boost, apogee, etc. The payload is checked out during the payload integration review which can take place at either the main assembly shop or in the field. Physical integration in the field can take place the day before launch or the morning of launch inside the vehicle preparation building. Time from integration to launch can be as little as an hour and, importantly, recovery can be in as little as twenty minutes after launch! The payload can be kept in an environmentally controlled, ambient pressure payload section, exposed to the space environment or, with special consideration, deployed during launch.

Update

The assets of Armadillo Aerospace have been bought from the founding partners by **Exos Aerospace Inc.** STIG is being replaced by the successor vehicle **SARGE** which will have similar conops but increased capabilities. Exos Aerospace is in the process of building a mini-fleet of vehicles and anticipates launching in the first quarter of 2015 with pathfinder payloads. The goal is to launch weekly throughout 2015, occasionally with multiple launches in one day.

More information:
flightopportunities.nasa.gov/platforms/suborbital/sarge

◁ *January 28, 2012: Ballute from STIG B taken at 94-km AGL, Spaceport America (Photo: Armadillo Aerospace)*

Minimum-cost Launch Vehicle (mCLV)

Whittinghill Aerospace

Platform

The mCLV is a space-capable, suborbital launch vehicle architected around an extremely simple and reliable nitrous oxide and HTPB hybrid propulsion system. The vehicle is two feet in diameter and 36 feet long, with a gross weight of 4,000 lbs. Given its heritage as an eventual common core module of a clustered orbital vehicle, this system has a great deal of performance to offer suborbital users.

Flight Profile

Owing to the launch vehicle's straightforward design, the system is launched from a mobile launch rail that can be repositioned to any FAA/AST licensable range. This allows payload users new flexibility in flight logistics. mCLV's impressive lift capability allows payloads up to 150 lbs to reach altitudes above 100 km and up to several minutes of microgravity time.

Payload Configuration

mCLV's large diameter offers the payload user a substantial internal volume in the standard payload fairing. In this standard space, there is approx. 3.5 cubic feet available on a 22-inch diameter universal payload mount plate. The fairing offers both RF-transparency as well as a set of both standard and customizable fairing penetrations for optical apertures, atmospheric sampling, external antenna mounts, etc. The vehicle also offers a set of pre-launch ground interfaces for power, data, and fluid connections to the payload. While NASA's Flight Opportunity program is built around offering a set of off the shelf, standardized launch services, the mCLV can be infinitely and quickly reconfigured to support missions that go beyond the bounds of these standard services. Whittinghill Aerospace's goal is to offer the payloader the most responsive and customizable service for any suborbital mission.

More information:
flightopportunities.nasa.gov/platforms/suborbital/mclv

◁ *George Whittinghill stands next to the mCLV flight vehicle at the Whittinghill Aerospace facilities in Camarillo, CA. (Photo: Whittinghill Aerospace)*

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

Layout: Alexander van Dijk & John Woebcke

July 21, 2011: Sathya Gangadharan leaves G-Force One at Ellington Field after a successful second flight test of the 'On-Orbit Propellant Storage Stability' payload. (Photo: NASA/Bill Stafford)

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