



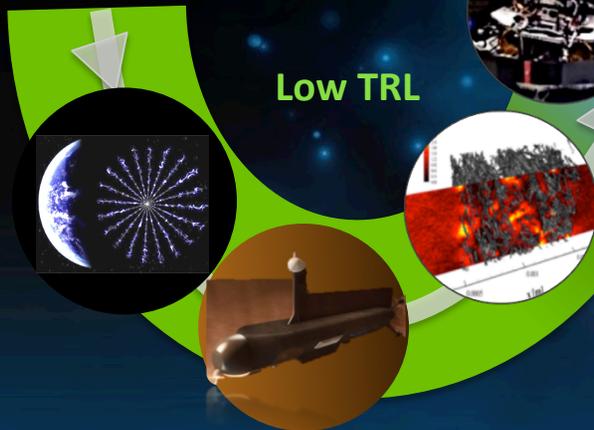


# Space Technology Pipeline



## Early Stage

- NASA Innovative Advanced Concepts
- Space Tech Research Grants
- Center Innovation Fund



Low TRL



Mid TRL

Game Changing Development

Small Spacecraft Technologies

## Commercial Partnerships

- SBIR /STTR
- Flight Opportunities
- Centennial Challenges
- Regional Economic Development



High TRL

Technology Demonstration Missions

TECHNOLOGY PIPELINE



# Flight Opportunities: Raising TRL using commercial suborbital platforms

- ... sRLV
- ... Balloons
- ... Parabolic
- ... VTVL



# TRL Raising in Flight Opportunities



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

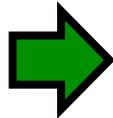
TRL definitions: <https://flightopportunities.nasa.gov/resources/trl>



# Relevant Environments with Suborbital



... sRLV  
... Parabolic



## Relevant Environment

**Reduced gravity**  
( $\mu$ g,  
Lunar,  
Martian)

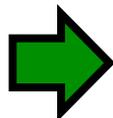
## Tech development examples

Human spaceflight (e.g. habitation, physiology)  
Material science/space biology research (removing gravitational influence on physical processes)

## Current Providers

UP Aerospace,  
Zero Gravity Corporation,

... sRLV  
... Balloons

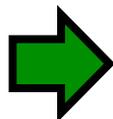


**High Altitude**  
(short/long  
duration)

Radiation exposure,  
atmospheric sensing,  
helio/astrophysics  
observation instrumentation,  
airspace management

UP Aerospace,  
Near Space Corporation,  
World View

... sRLV  
... Balloons  
... VTVL



**Entry, Descent  
& Landing (EDL)**

Planetary atmosphere  
deceleration  
Entry guidance, navigation &  
control  
Autonomous landing & hazard  
avoidance

UP Aerospace (ejection)  
Near Space Corporation,  
World View,  
Masten Space Systems



# How to use Flight Opportunities



## **Suborbital flight testing: a valuable tool in the space technology development toolkit**

- Gather needed design data (knowledge payloads)
- Design, test & iterate early prototypes of spaceflight h/w
  - Reduce risk for critical subsystems of technology
  - Test operational procedures
- Access to relevant environments through suborbital can help separate the imagined from the real and uncover the unexpected at an early stage in the technology development cycle

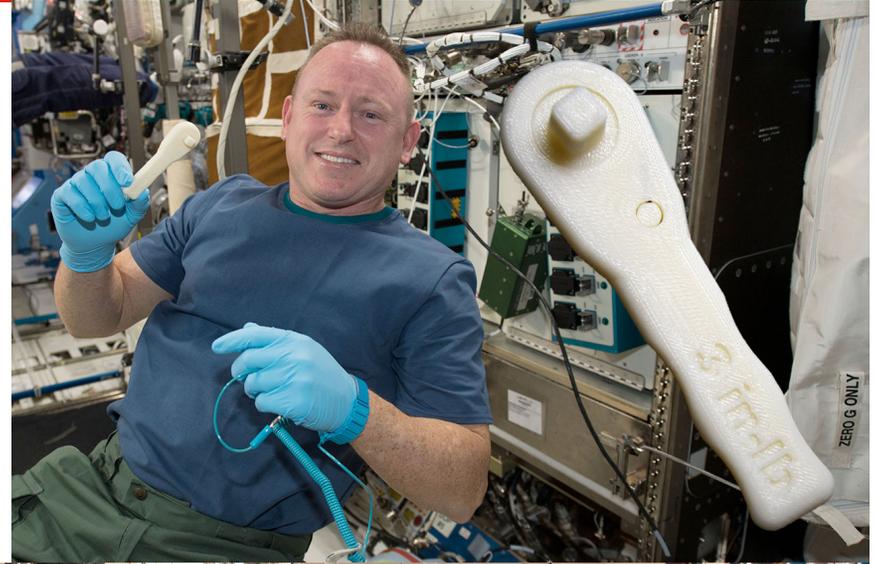


# TRL Raising Examples

# Risk Reduction for ISS testing ( $\mu g$ )



**Parabolic flight has proven to be a valuable, low cost platform for risk reduction and technology demonstration before ISS testing deployment.**



# Data Gathering informs Prototype Design 1 ( $\mu g$ )



## **Thermosyphon Flooding in Reduced Gravity Environments**

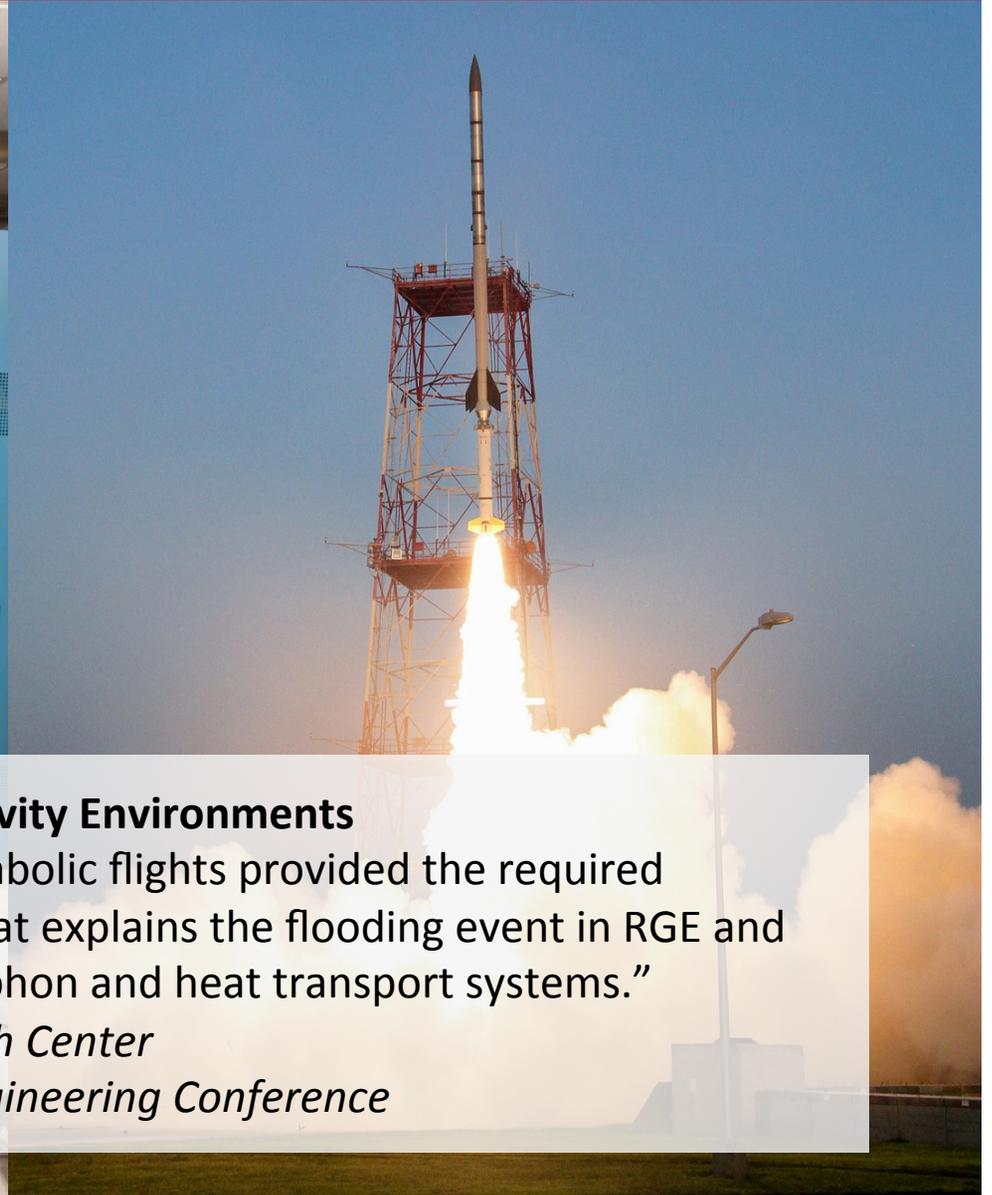
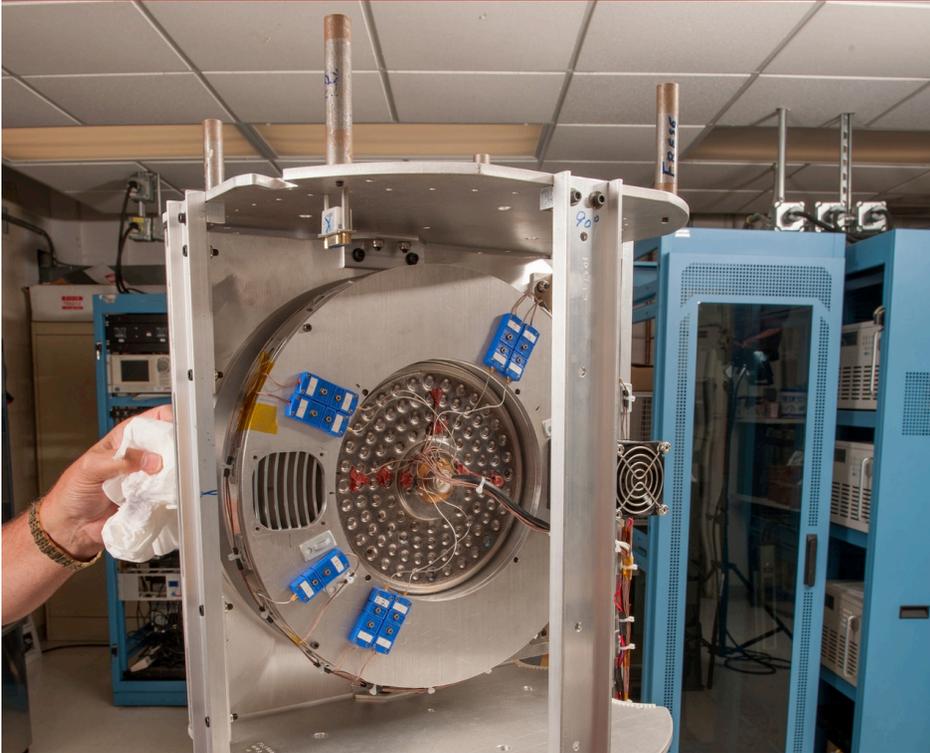
“The condenser flooding phenomenon associated with gravity aided two-phase thermosyphons was studied using parabolic flights to obtain the desired reduced gravity environment (RGE).

*Marc A. Gibson (PI), NASA Glenn Research Center*

*10th International Energy Conversion Engineering Conference, 2012*



# Data Gathering informs Prototype Design 2 ( $\mu g$ )



## **Thermosyphon Flooding in Reduced Gravity Environments**

“Results from laboratory testing and parabolic flights provided the required information to construct a new model that explains the flooding event in RGE and can be used to develop future thermosyphon and heat transport systems.”

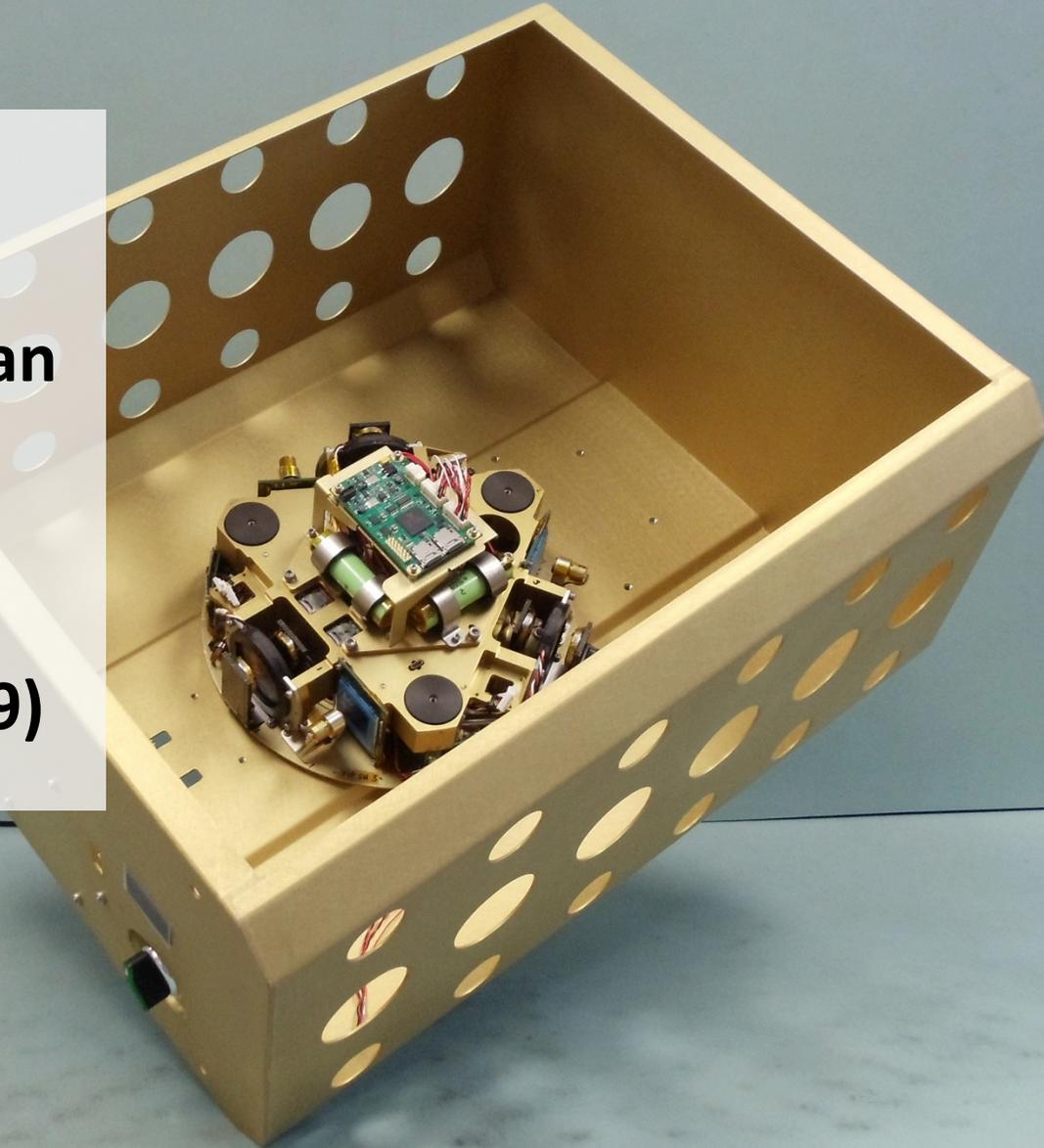
*Marc A. Gibson (PI), NASA Glenn Research Center*

*10th International Energy Conversion Engineering Conference*

# Vibration Isolation platform ( $\mu g$ )



**TRL raising for  
sRLV capability  
development can  
progress into  
'operational  
environment'  
readiness (TRL 9)**



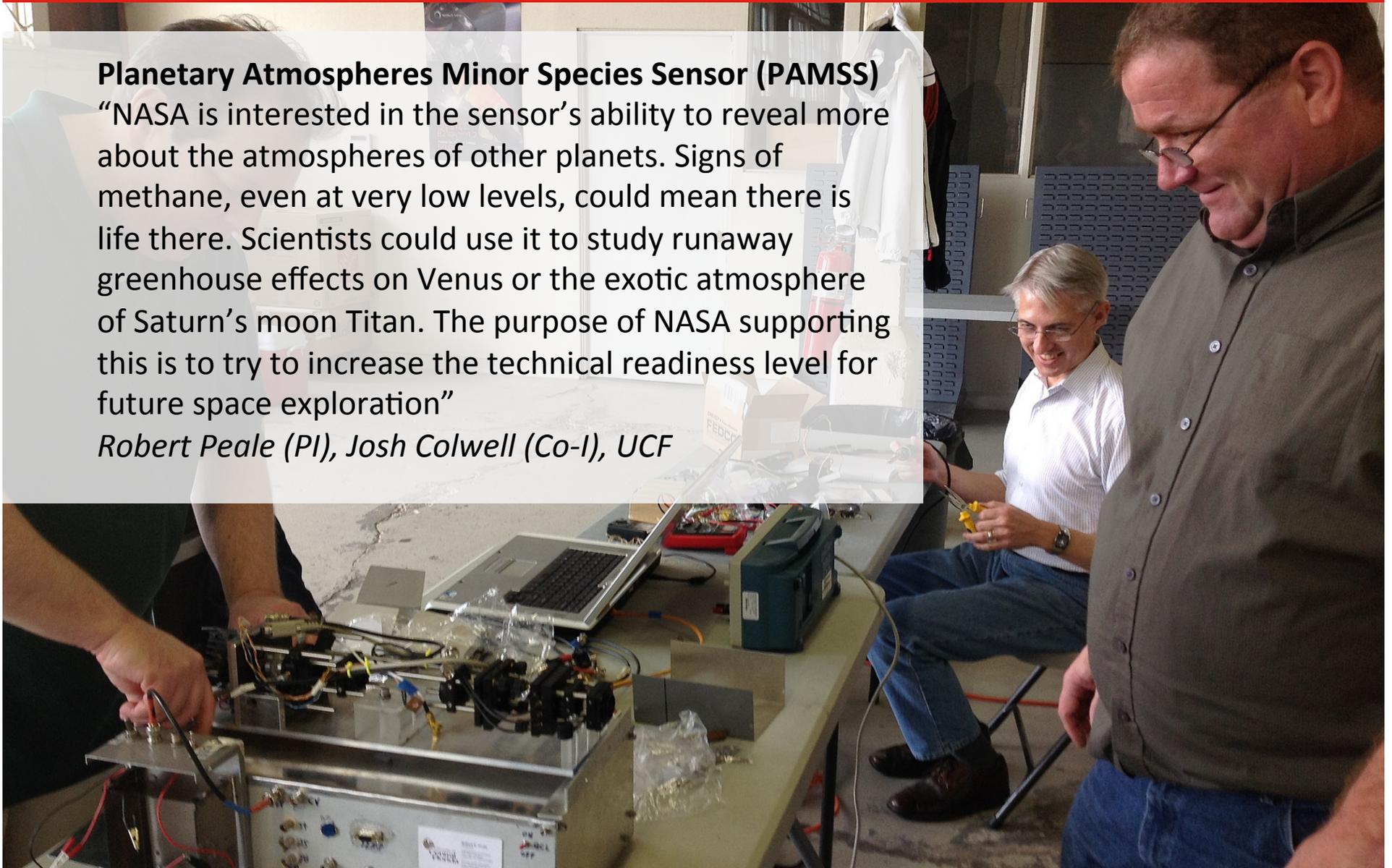
# Atmospheric Sensing (*high altitude*)



## **Planetary Atmospheres Minor Species Sensor (PAMSS)**

“NASA is interested in the sensor’s ability to reveal more about the atmospheres of other planets. Signs of methane, even at very low levels, could mean there is life there. Scientists could use it to study runaway greenhouse effects on Venus or the exotic atmosphere of Saturn’s moon Titan. The purpose of NASA supporting this is to try to increase the technical readiness level for future space exploration”

*Robert Peale (PI), Josh Colwell (Co-I), UCF*



# Guided Parafoil Research (*high altitude*)



## **Guided Parafoil High Altitude Research (GPHAR) Flight at 57,122 ft., 23rd AIAA Aerodynamic Decelerator Systems Technology Conference, 2015**

“The GPHAR program is an on-going effort to extend the capabilities of parafoil system technology and mature it to increase the Technology Readiness Level (TRL) of parafoil systems for space recovery or near space recovery applications above 25,000 ft. This ambition requires testing parafoil parachutes in conditions beyond those currently demonstrated.”

*Bill Gargano (PI), Airborne Systems North America of CA, Inc.*



# Entry Guidance, Nav & Control (EDL)



## Entry Descent and Landing (EDL) Technology Development for the Marzia Earth Return Capsule

PI: Alan Strahan, NASA/Johnson Space Center



Alan Strahan (PI)  
NASA/JSC



Paul De Leon  
NASA Campaign Manager

# Autonomous Landing & Hazard Avoidance (EDL)



“Since 2011, the Autonomous Descent and Ascent Powered-Flight Testbed (ADAPT) has been used to demonstrate advanced descent and landing technologies onboard the Masten Space Systems (MSS) Xombie vertical-takeoff, vertical-landing suborbital rocket.”

*Flight testing of terrain-relative navigation and large-divert guidance on a VTVL rocket, AIAA SPACE 2015*



# **Suborbital Flight Testing**

**Think of it as an extension to your lab...  
into a relevant environment.**

[www.nasa.gov/flightopportunities](http://www.nasa.gov/flightopportunities)