Zero-G Corp.
September 2011 Campaign

September 15-23, 2011

Ellington Field, TX

Manifest

- 001-PS Suborbital Flight Environment Monitor – Karolyn Ronzano/NASA ARC
- 004-PS Printing the Space Future – Jason Dunn/Made in Space
- 008-P Indexing Media Filtration – Juan Agui/NASA GRC
- 011-P Cryocooler – Ben Longmier/Ad Astra
- 012-P Crew-Autonomous Biological Telemetric experiment – Rob Ferl & Anna lisa Paul/University of Floriday
- 013-P Realtime Instrumentation for Monitoring Radiation-Induced DNA Degradation in Space – Howard Levine/NASA KSC
- 014-P Heat Pipe Limits in Reduced Gravity Environments – Mark Gibson/NASA GRC

001-PS Suborbital Flight Environment Monitor (SFEM)

STATUS QUO

Suborbital Flight Environmental Monitor (SFEM)

Validation testing completed, function/fit tested completed, ready for flight

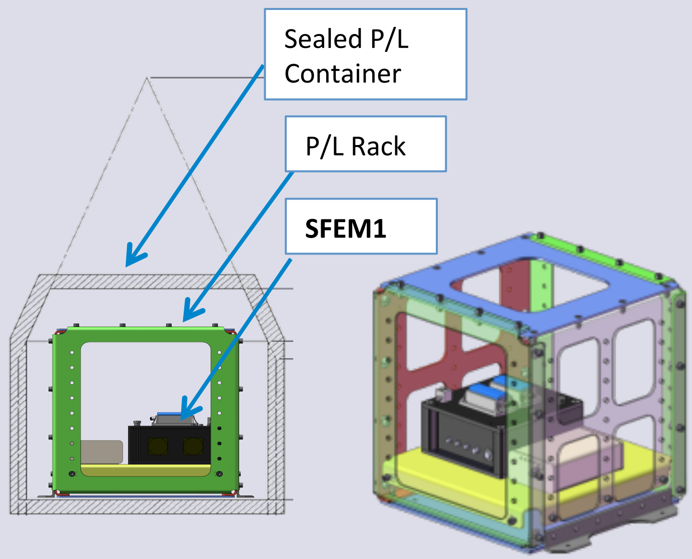
NEW INSIGHTS

Technology Focus Area:
Environmental Sensors
Specific Benefits of Technology:
Environmental characterization

All presently conceivable sRLV scientific experiments will require knowledge of the actual flight environment as a function of time during the flight. This unit will be flown on all NASA sponsored flights to provide that data to all investigators.

MAIN ACHIEVEMENT: The Suborbital Flight Environment Monitor (SFEM) is a compact, self-contained payload that will monitor and record on-board environmental parameters of interest during a sRLV flight. These include 3-axis accelerations and G-loads, ambient pressure, relative humidity and temperature. The SFEM uses commercially available instruments.

HOW IT WORKS: The compact, ~12lb. package is designed for remote, stand-alone shock and vibration, temperature, pressure and relative humidity measurement. The SFEM can record data for up to 4 hours with 1 hour in-flight. The SFEM's mechanical interface is robust, yet simple and requires no modification to any vehicle. The SFEM will be bolted to a rack structure which is bolted to a sealed payload container inside the launch vehicle fairing.



QUANTITATIVE IMPACT

Flight Measurement Requirements:

Flight Profile/Acceleration level(s): 10^{-3} G's to 200Gs (0 to 1000 Hz)

Relative Humidity: 0 – 100%; +/- 3% at 25°C

Pressure: 0 to 2000 mbar; +/- 5 mbar in reading range of 750 to 1000 mbar

Temperature: -10 to 60°C; +/- 1°C

Vehicle Interfaces:

Mode of Operations: Autonomous

Power requirements: None

Experiment specifications: *Mass/ Dimensions*: 4.87 lbs / 5.81in x 5.46in x 3.43in

END-OF-PHASE GOAL

Record launch environmental data for multiple suborbital rockets

- Define the sRLV payload integration process
- Characterize the payload environment for future NASA-sponsored payload applications and the next generation SFEM

The Suborbital Flight Environment Monitor (SFEM) is a compact, self-contained payload that will monitor and record on-board environmental parameters of interest to investigators during a sRLV flight.

004-PS Printing The Space Future

Adapting Additive Manufacturing Technology for Zero-Gravity

STATUS QUO

Additive Manufacturing in Zero-G

- Limited zero-gravity testing and physical analysis of 3D printing in zero-g on micro/macro scale
- No testing of building extended structures
- Experimental box is flight ready

NEW INSIGHTS

Technology Focus Area:
Additive Manufacturing (AM)

Specific Benefits of Technology:
Enables In-Situ Manufacturing

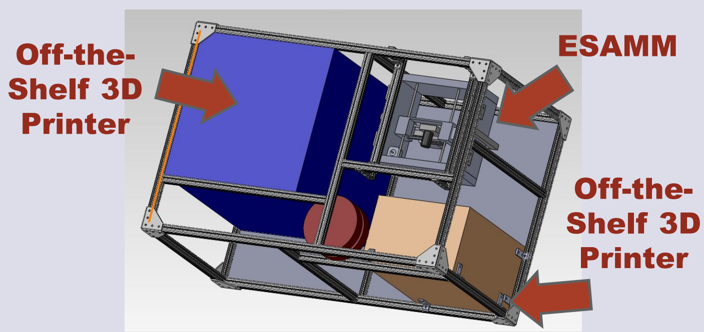
All current space missions depend on Earth. AM will enable in-space manufacturing of parts, spacecraft and large extended structures. Rather than transporting the final part from Earth, only printers and feedstock need to withstand launch stresses.

MAIN ACHIEVEMENT:

This experiment will test the underlining physics of additive manufacturing (AM) in zero-g. Parts will be built in zero-g. Post-flight stress tests and micro/macro analysis will then be compared to parts built on Earth. Using a newly conceptualized Extended Structure Additive Manufacturing Machine (ESAMM), this experiment will also test the concept of building extended structures in zero-gravity. The current ESAMM prototype builds structures several feet long, while a future scaled up model could build in-space structures kilometers in length.

HOW IT WORKS:

AM “prints” parts by adding material layer by layer, causing an efficient use of material. Two OTS AM machines will build cross sections of functional parts. The ESAMM uses worms gears to provide travel in the third direction allowing for a theoretical unlimited amount of layers to be built. The worm gears ride along teeth built into the structure by the AM process.



QUANTITATIVE IMPACT

Flight Experiment Requirements

- ESAMM builds “core sample”, a part printed continuously during flight.
- Two OTS FDM printers will fly to test fundamental physics of AM and compare results with ESAMM

Experiment Specifications

- Dimensions: 44in x 22in x 24in

END-OF-PHASE GOAL

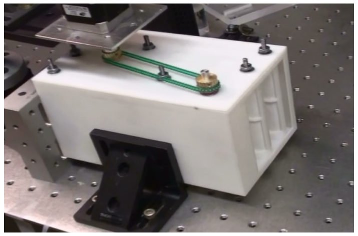
Analyze functionality and physics of AM in zero-g environment

- Demonstrate key in-space manufacturing technology
- Flight qualify 3 total AM machines
- Post flight non-destructive and destructive testing of machined parts from flight

Additive manufacturing (often called 3D printing) is an efficient, fast and increasingly automated manufacturing method that will enable the development of in-space infrastructure.

008-P Indexing Media Filtration System for Long Duration Space Missions

STATUS QUO



Indexing Media Filtration System for Long Duration Space Missions

- Development of advanced particulate filtration systems for long duration missions that feature long service life, regenerability, and require minimal to no crew-tended maintenance
- Replacing filters is typical for 1-g systems but impractical in space.
- Laboratory tested.

NEW INSIGHTS

Technology Focus Area:
Life Support Systems
Specific Benefits of Technology:
Long life cabin filtration

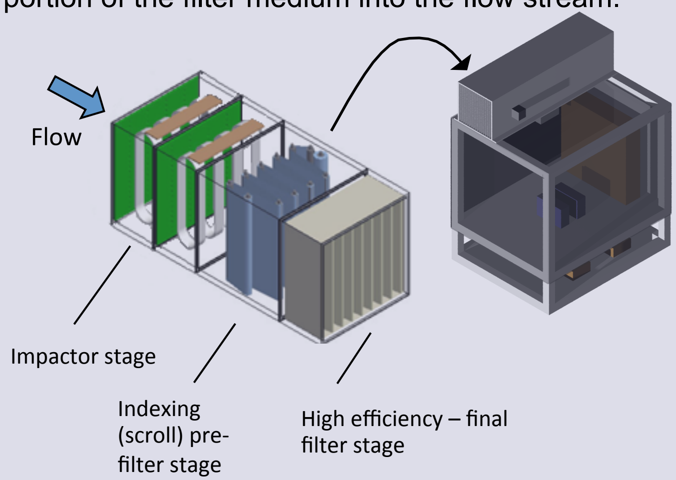
- **Indexing media increases filter area and efficiency.**
- **Indexing reduces filter replacement need.**
- **Indexed media may be regenerated.**

MAIN ACHIEVEMENT:

Develop sustainable regenerable dust mitigation techniques appropriate for space environments.

HOW IT WORKS:

Indexing Media Filtration System uses an advancing web mechanism to advance a fresh portion of the filter medium into the flow stream.



Large particles are separated by impactor plate.

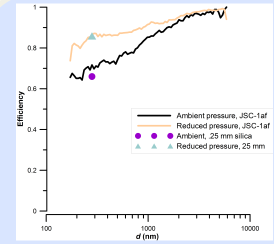
Majority of particles are filtered by indexing media.

Fine particles captured by HEPA filter.

ASSUMPTIONS AND LIMITATIONS:

- Adequate filtration for long duration space missions is unavailable in industry.

QUANTITATIVE IMPACT



Collection efficiency

Flight testing will address the effect of gravity on:

- dust separation capability.
- Collection of large particulates (that tend to settle out in 1-g).
- Dust collection efficiency.
- In-place media indexing..
- Reduced or microgravity operation of the system.

Expected outcome: A prototype filtration system with at least an order of magnitude longer life than state of the art filters, and a particle size filtration range that can be tuned to mission requirements.

END-OF-PHASE GOAL

Particulate removal in spacecrafts, habitats, airlocks and pressurized rovers.

- *Enhance the life of filtration systems*
- *Reduce launch requirements*
- *Reduction of system maintenance.*

Filter system components may be renewed, thus extending life and decreasing maintenance

011-P Cryocooler Vibration Analysis for VF-200

Rocket Company

Ad Astra

STATUS QUO

Sunpower CryoTel™ (CT) cryocooler testing to date.

- Prior µg campaigns, SEED 2010 and FAST 2010, establish commercial technology at TRL 6.
- Thermal testing of CT cryocooler testing in-situ with High Temperature Super Conducting (HTSC) magnet presented need for vibration mitigation at CT-HTSC interface.

Significance of Study:

Vibration characterization

NEW INSIGHTS

Ad Astra's VF-200, VASIMR® (Variable Specific Impulse Magnetoplasma Rocket) Flight - 200 kW, scheduled for testing aboard the ISS in 2014, nozzles plasma propellant via a core of mechanically sensitive HTSC magnets, conduction cooled by CT cryocoolers. Investigation of CT vibration modes will advance TRL of cryocooler technology while simultaneously down selecting mounting interface design.

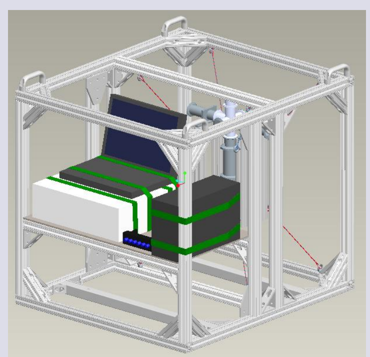
VIBRATION ANALYSIS ACHIEVEMENT

OVERALL OBJECTIVE:

The SunPower CryoTel™ (CT) model cryocooler is a compact Stirling engine device capable of rejecting 10-15 Watts at 40K, ideal for the baseline VF-200. Significant vibrations induced by CT operation pose a hazard to system integrity by degradation of the High Temperature Superconducting (HTSC) magnetic field. The study will advance a solution to mitigate this problem by furthering understanding of CT vibrational characteristics. The experiment is designed to isolate the CT mass system from the experiment frame, reducing the uncertainty associated with vibration transfer.

TEST METHOD:

3-axis accelerometers strategically instrumented throughout experiment provide comprehensive vibration responses at varying cryocooler power levels. Cryocooler operation monitored by current and temperature measurements.



CAD model of experiment rig

QUANTITATIVE IMPACT

Flight Requirements:
40 parabolas/flight x 4 flights

Vibration Measurement:
Accelerometer specifications:
Adjustable sensitivity: +/- 3g or +/11g
Supply voltage: 2.2V-16V
Supply current: 0.5 mA

Experiment interfaces:
Mode of Operations:
Autonomous, LabVIEW controlled.
Power requirements: 115 VAC.

Experiment Specifications:
Mass/Dimensions:
220 lbs. 33in x 33in/ x 37.5in.

END-OF-PHASE GOAL

Measure vibrational characteristics of cryocooler operation.

- Determine natural frequency and intensity of vibrations as a function of test parameters (cryocooler power, g-load, mounting arrangement)
- Offer initial design solution for vibration mitigation.

Sunpower Cryotel™ platform will provide lightweight and compact cryocooling capabilities for the VF-200 test flight aboard the ISS in 2014.

012-P Validating Telemetric Imaging Hardware for Crew-Autonomous Biological Imaging in Parabolic and Suborbital Applications

STATUS QUO

Evaluating the molecular response of biology in response to novel environments.

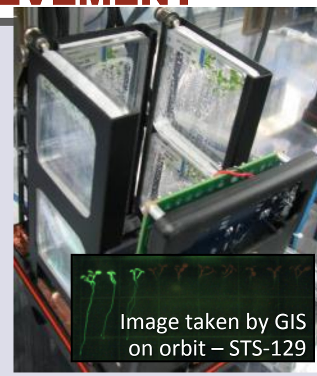
- gene reporters, genomic tools – often require extensive crew time for sampling
- next generation gene reporters and telemetric instrumentation facilitates real-time data collection, independent of crew

NEW INSIGHTS

First key insight. Organisms can be engineered to report changes in response to their environment in ways we can monitor.

Second key insight. We can engineer hardware and instrumentation to collect those data in real time.

TAGES ACHIEVEMENT



MAIN ACHIEVEMENT:
The TAGES GFP and GUS engineered biology has flown on orbit for long term evaluation of gene expression responses to the spaceflight environment, and successfully reported

HOW IT WORKS:
The GFP Imaging System (GIS) is equipped with LEDS that illuminate GFP gene reporters, and a camera/filter system that can collect fluorescent data

ASSUMPTIONS AND LIMITATIONS:

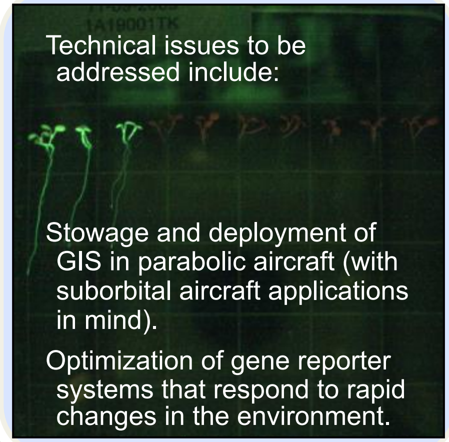
- Have not yet collected telemetric data during the initial stages of launch and transition to orbital environment.

EXPECTED PERFORMANCE:

- We are testing the limits of bio-engineering and telemetric-engineering – comparisons will be made to GUS reporter-gene systems to gauge efficacy of GFP imaging in the parabolic flight timeframe.

REQUESTED BUDGET AND SCHEDULE:

(N/A; no budget provided; solely a flight opportunity on parabolic aircraft)



END-OF-PHASE GOAL

The projected impact of this experiment is the validation of the GIS hardware for parabolic and sub-orbital applications, and the further understanding of how terrestrial biology responds to novel environments at the molecular level.

Plants and humans share more than 50% of their genomes and basic processes – understanding how a plant responds non-terrestrial environments provides keen insight into human biology as well. Further, developing hardware and biology that can work in concert, without human attention, can provide data collection in situations outside the safe reach of humans, such as on satellites and regions beyond the confines of low earth orbit.

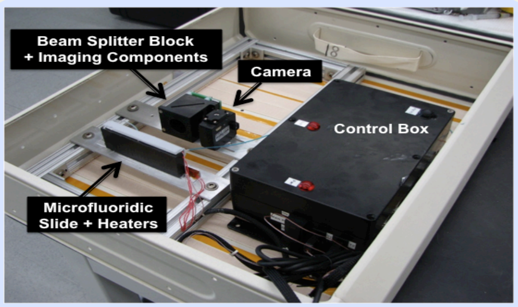
013-P Real Time Instrumentation for Monitoring Radiation Damage to DNA (RTDNA)

Problem: Exposure to space-based radiation induces DNA (Deoxyribonucleic Acid) damage that poses a risk to the crew.

Solution: Develop a miniaturized device that can monitor DNA damage in real-time, thereby helping to understand the details of radiation exposure in space and serving as a rapid warning device for the crew.

Project Goal: Develop a miniature device that can monitor DNA damage in real-time.

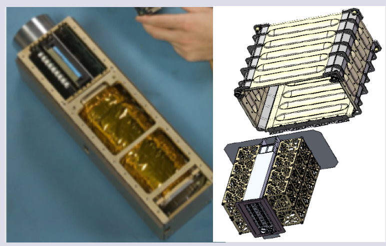
Risk To Be Mitigated: Precise temperature regulation is key to the device's operation, necessitating the assessment of thermal control in the convectionless microgravity environment.



A microfluidic prototype unit was built to test the micro-fluidic system, including imaging, illumination and thermal control, in a reduced gravity environment while exercising all systems, especially the thermal and micro-fluidics, under various gravity conditions.

Project Overview:
This project is developing a miniaturized microfluidic (lab-on-a-chip) device that is designed to monitor DNA damage, in real-time, resulting from radiation exposure in space.

The instrument under development will ultimately (a) use the Polymerase Chain Reaction (PCR) to amplify DNA, (b) use fluorescent imaging to monitor radiation-induced changes in DNA composition, (c) initially fly on a nanosat and characterize its orbit by recirculating a reservoir of unshielded DNA and monitoring **"cumulative"** radiation-induced damage to the DNA over time, (d) subsequently be deployed on ISS in the NanoRack facility or an alternative platform.



Nanosat configuration (left). NanoRack platform currently envisioned as potential carrier for ISS applications (right).

Projected Schedule:

(1) Parabolic Tests in Sept. 2011.

(2) Nanosat to fly in 2012-13.

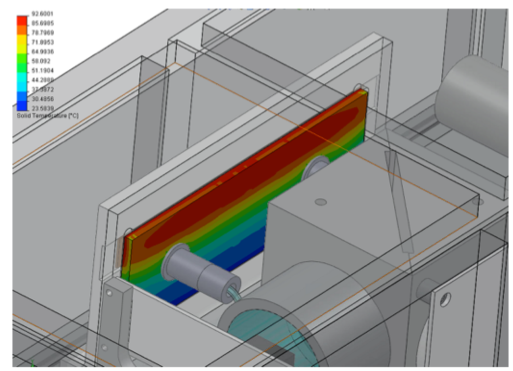
(3) Hardware ISS modifications in 2012-13.

(4) ISS deployment in 2013.

(5) ISS operation for 1 year post-installation.

(6) Subsequent operation TBD.

FAST Parabolic Flight Objectives:
(1) Demonstrate the microfluidic slide's fluid circulation within various gravity environments (0-2G).
(2) Study the effects of the microgravity environment on the thermal gradients within the microdevice as it can possibly have negative effects on PCR when desired thermal settings are altered.
(3) Evaluate whether a newly designed prototype camera is capable of meeting all project requirements under 0G conditions before implementation into a nanosat configuration.

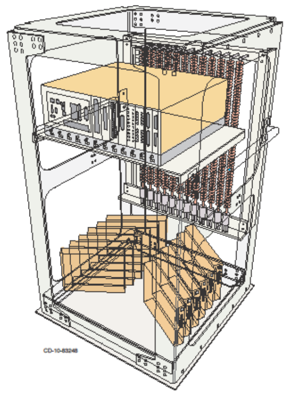


Modeled Temperature Gradient Within Payload's Microfluidic Chip.

This RTDNA microfluidic system will allow for rapid and continuous genetic analysis of DNA samples in a small package that can be flown on a nanosatellite. The ultimate goal is to help understand the details of radiation exposure in space and potentially serve as a radiation rapid warning device for astronauts.

014-P Thermosyphon Array with Controlled Operation (TACO)

STATUS QUO



Thermosyphon Array with Controlled Operation (TACO)

NEW INSIGHTS

Technology Focus Area:
Heat Pipes as Thermosyphons

Specific Benefits of Technology: Improved radiator technology for cooling fission power systems

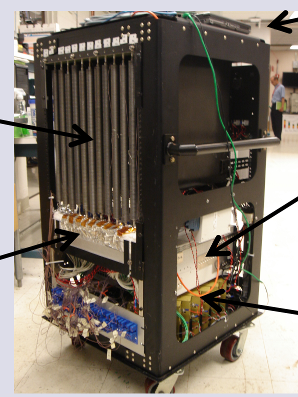
Data regarding the flooding limit of heat pipes operating as thermosyphons is traditionally gathered at Earth gravity (1g). To design thermosyphons that will work in a reduced gravity environment, more data needs to be collected regarding the flooding limit in a low-g environment.

MAIN ACHIEVEMENT:

The TACO will provide thermosyphon flooding limit data that can be used to validate flooding limit modeling for reduced gravity environments. Data will be gathered for the simulated gravitational accelerations of the moon (1/6g) and Mars (1/3g).

HOW IT WORKS:

The experiment consists of 12 vertically oriented heat pipes (thermosyphons) that are heated by a series of cartridge heaters. The heaters are controlled by a laptop, and the temperatures of the heat pipes are monitored by thermocouples. A heat pipe has flooded when a spike in the evaporator temperature is observed. All equipment is neatly contained in an aluminum, low-g flight approved rack.



QUANTITATIVE IMPACT

Flight Measurement Requirements:

- Flooding limit measurements at 1/6g and 1/3g

Power Requirements:

- 4x115 VAC outlets
- Total Current: 51 Amps
- Total Power: 5865 Watts

Experiment Specifications:

- Dimensions (L,W,H): 24.0, 24.0, 42.19 [in]

Weight: 270 [lbs]

END-OF-PHASE GOAL

Record thermosyphon flooding limit data in reduced gravity

- *Develop an accurate model to predict the onset of flooding in a closed two-phase thermosyphon*
- *Utilize model to design heat pipes that can be used as part of a surface fission power system for the moon or Mars.*

The Thermosyphon Array with Controlled Operation (TACO) is a fully contained, semi-autonomous system designed to provide data regarding thermosyphon operation in a low-g environment.