

MicroStrat

A Cross-Continental High Altitude Balloon Mission for Astrobiology Research

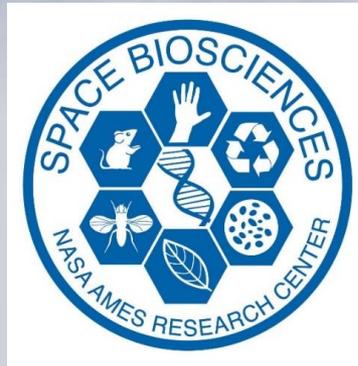
Research Associates: NASA Ames Space Life Sciences Training Program (SLSTP) 2017

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Co-Is: Chris Mason, Alexa McIntyre (Weill Cornell Medicine)





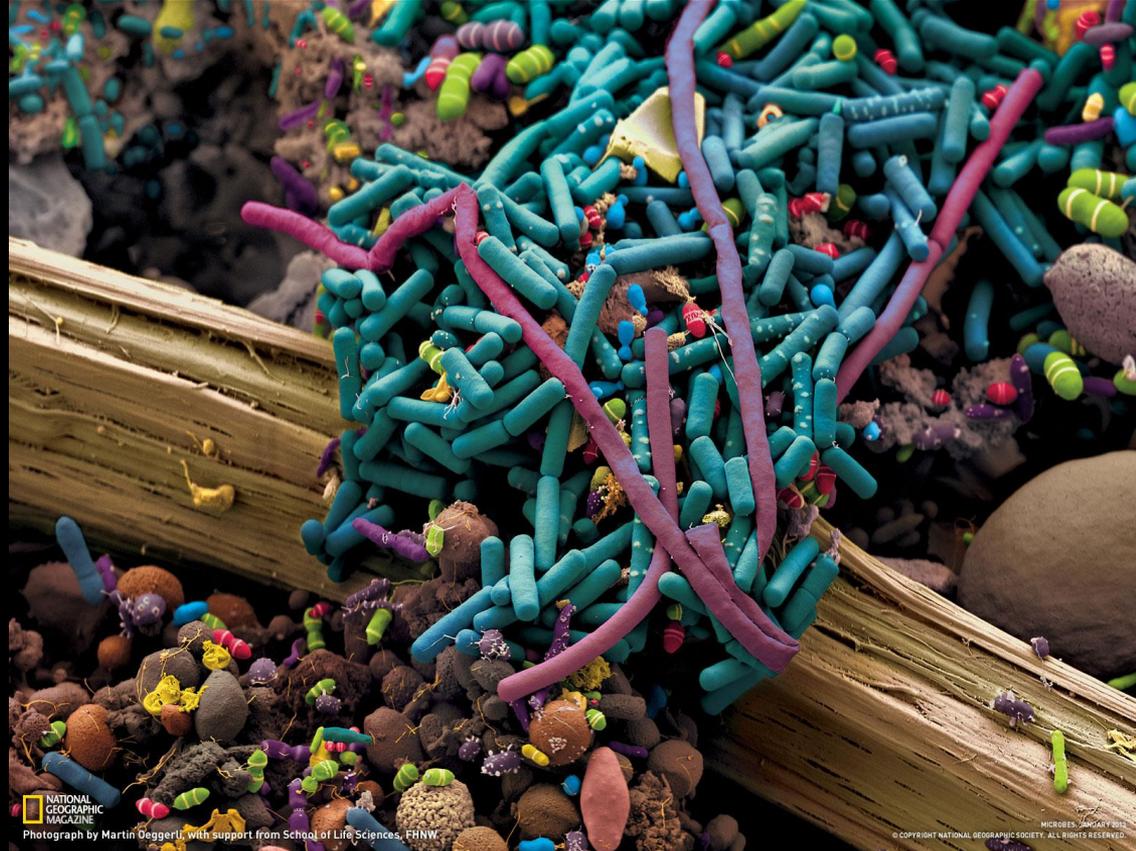
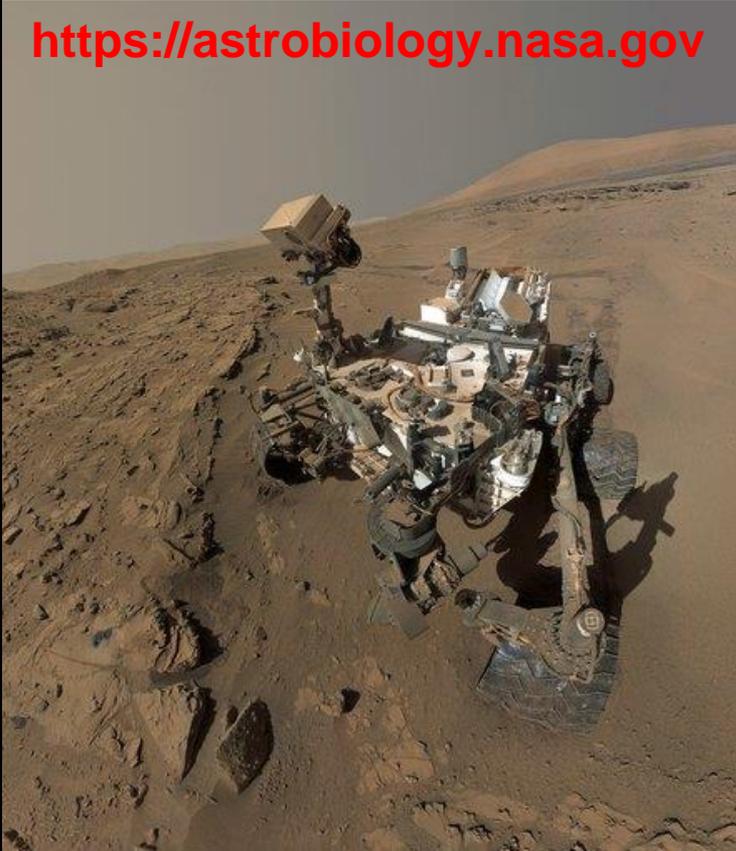


<https://www.nasa.gov/ames/research/space-biosciences/david-j-smith-laboratory>



Astrobiology is the study of the origin, evolution, distribution, and future of life in the universe.

<https://astrobiology.nasa.gov>



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Photograph by Martin Deegger, with support from School of Life Sciences, FRNW

MICROBES, JANUARY 2013

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The stratosphere is part of a Radiation Continuum (Ground < Near Space < Low Earth Orbit < Deep Space)

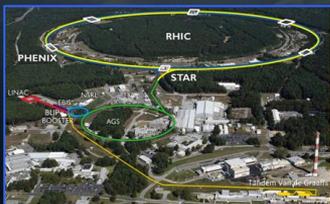


This is where we want to go
(deep space radiation)

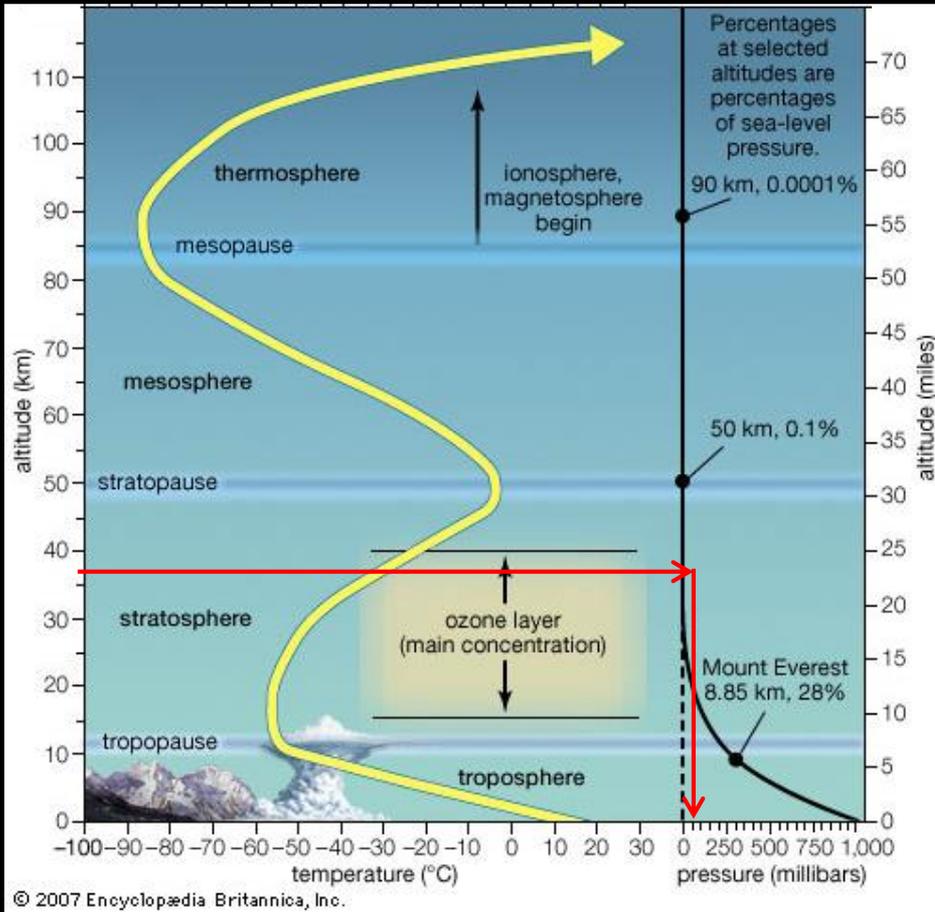
This is where balloons fly
(Near Space radiation)

This is where most NASA radiation
research occurs (low Earth orbit)

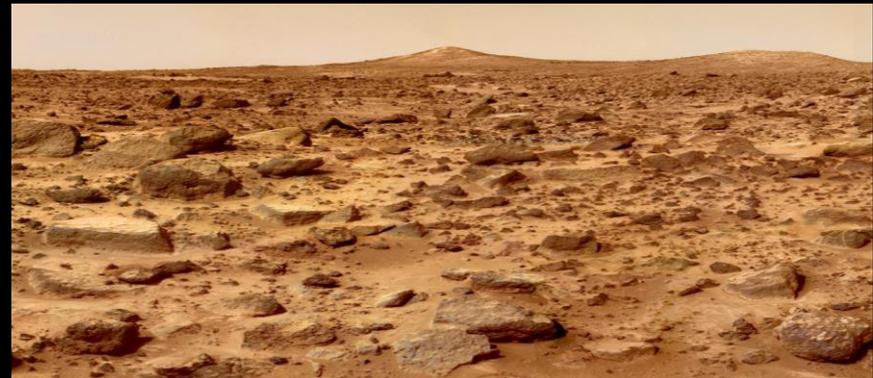
Ground radiation simulations



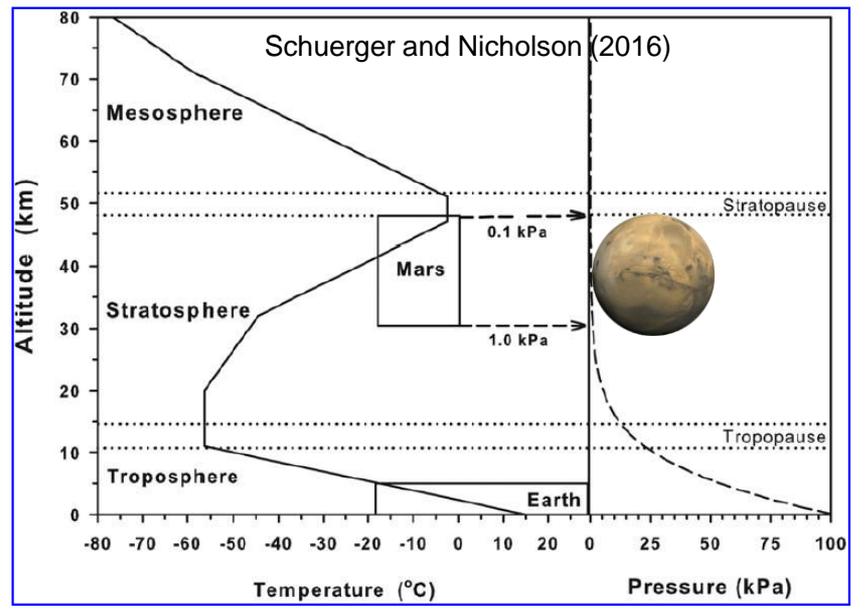
Earth's Atmosphere



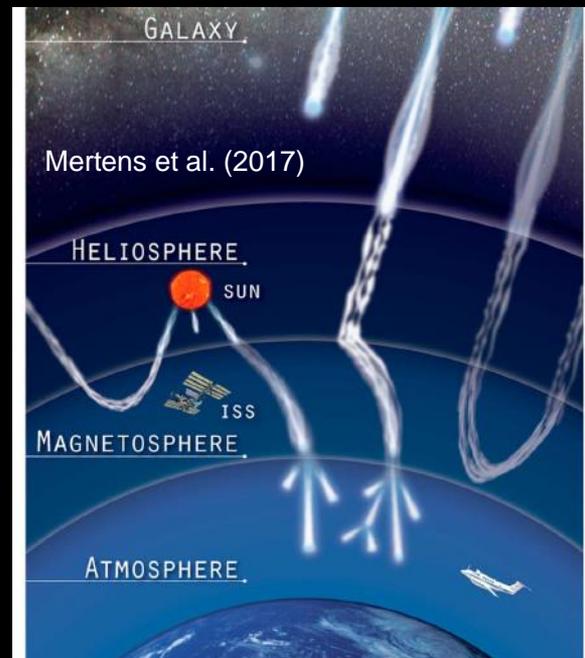
Using the stratosphere as a Mars analog environment



Overview of Near Space Conditions



There are two sources of cosmic rays: (1) the ever-present galactic cosmic rays (**GCR**), with origins outside the solar system; (2) solar energetic particles (**SEP**) (or solar cosmic rays)



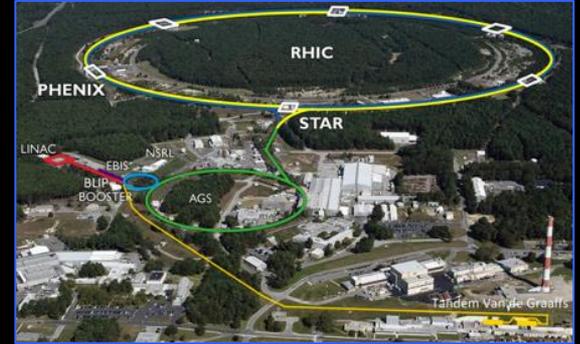
Location	UVB Total (W m ⁻²) 280-315 nm	UVC Total (W m ⁻²) 100-280 nm	Ionizing Radiation (mGy/d)	Pressure (kPa)	Temp (°C)	RH (%)
New Mexico (35 km ASL)	10.6	2.60	0.066	2.84	-30	< 10
Mars (surface)	8.38	3.18	0.200	0.700	-53	<< 1

Energetic particle radiation from space continuously bombards the Earth's atmosphere. Cosmic radiation has sufficient energy to penetrate deep within the atmosphere and adversely affect biology.

*Values averaged from Nicholson et al. (2002), Hassler et al. (2014), Mertens et al. (2017), Khodadad et al. (2017)

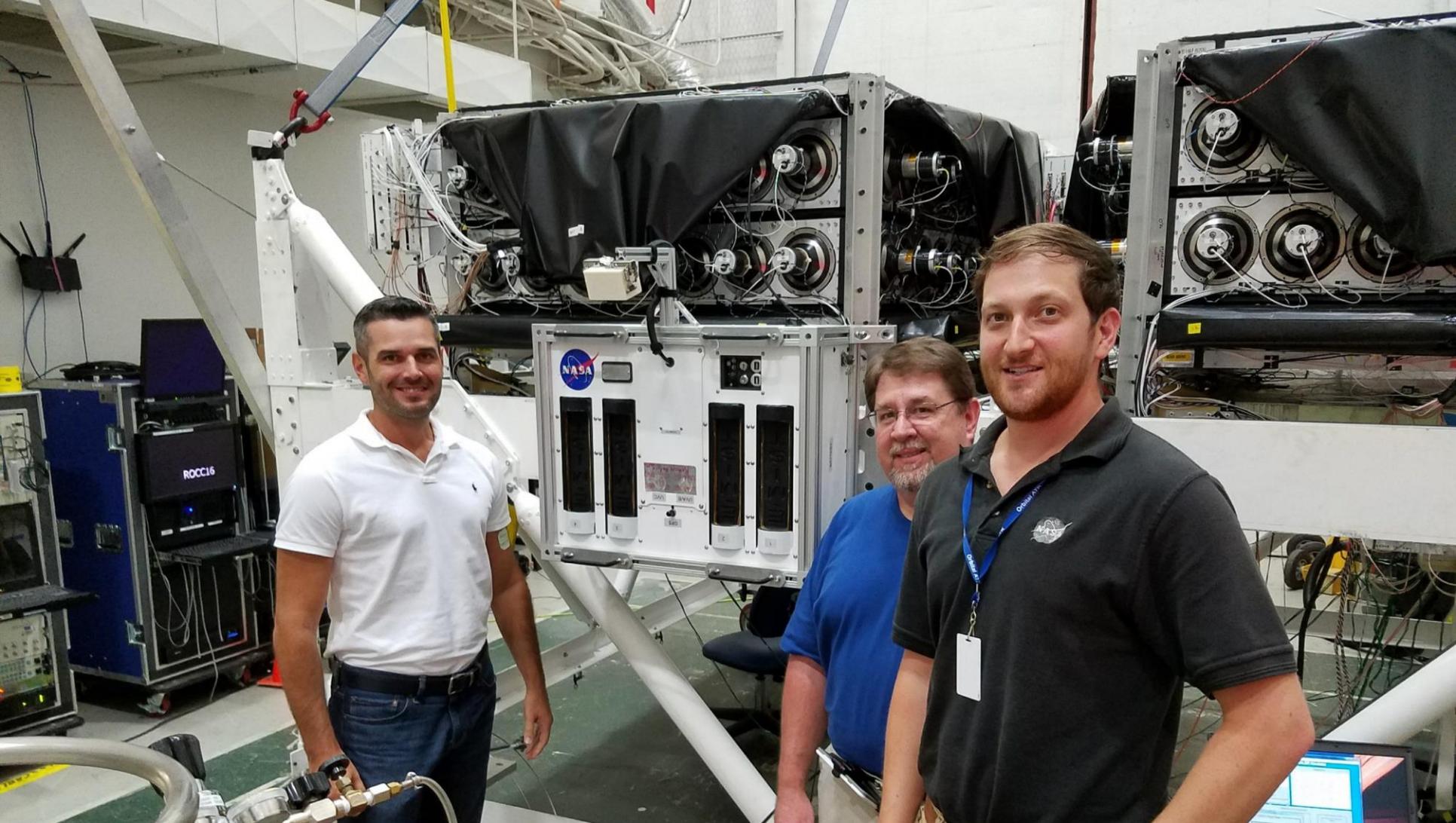
Limitation of Ground Based Facilities

- (1) Expensive to perform, (2) volume limited, and (3) unable to accurately mimic dynamic sunlight levels
- Short-lasting, small in size, and limited by acute doses of radiation; secondary scattering difficult to simulate
- The NASA Space Radiation Laboratory (NSRL) is capable of generating a range of ions from protons to uranium at relevant energies observed beyond LEO (from 50 MeV to 1000 MeV). Beam target size is limited to about 20 x 20 cm². The need to perform studies at **very low dose rates to replicate the space environment is not always practical at NSRL due to access limitations and cost.**



Figures courtesy of NASA BioSentinel science team







E-MIST: Recent Results



An 8-hour stratospheric flight on the NASA E-MIST balloon killed off even the hardest microbes.

David J. Smith/NASA

UV light could easily kill microbial stowaways to Mars

By [Joshua Sokol](#)

Mar. 28, 2017, 2:15 PM

ASTROBIOLOGY
Volume 17, Number 4, 2017
Mary Ann Liebert, Inc.
DOI: 10.1089/ast.2016.1549

Stratosphere Conditions Inactivate Bacterial Endospores from a Mars Spacecraft Assembly Facility

Christina L. Khodadad,¹ Gregory M. Wong,² Leandro M. James,³ Prital J. Thakrar,³ Michael A. Lane,³ John A. Catechis,¹ and David J. Smith⁴

Abstract

Every spacecraft sent to Mars is allowed to land viable microbial bioburden, including hardy endospore-forming bacteria resistant to environmental extremes. Earth's stratosphere is severely cold, dry, irradiated, and oligotrophic; it can be used as a stand-in location for predicting how stowaway microbes might respond to the martian surface. We launched E-MIST, a high-altitude NASA balloon payload on 10 October 2015 carrying known quantities of viable *Bacillus pumilus* SAFR-032 (4.07×10^7 spores per sample), a radiation-tolerant strain collected from a spacecraft assembly facility. The payload spent 8 h at ~ 31 km above sea level, exposing bacterial spores to the stratosphere. We found that within 120 and 240 min, spore viability was significantly reduced by 2 and 4 orders of magnitude, respectively. By 480 min, $<0.001\%$ of spores carried to the stratosphere remained viable. Our balloon flight results predict that most terrestrial bacteria would be inactivated within the first sol on Mars if contaminated spacecraft surfaces receive direct sunlight. Unfortunately, an instrument malfunction prevented the acquisition of UV light measurements during our balloon mission. To make up for the absence of radiometer data, we calculated a stratosphere UV model and conducted ground tests with a 271.1 nm UVC light source (0.5 W/m^2), observing a similarly rapid inactivation rate when using a lower number of contaminants (640 spores per sample). The starting concentration of spores and microconfiguration on hardware surfaces appeared to influence survivability outcomes in both experiments. With the relatively few spores that survived the stratosphere, we performed a resequencing analysis and identified three single nucleotide polymorphisms compared to unexposed controls. It is therefore plausible that bacteria enduring radiation-rich environments (e.g., Earth's upper atmosphere, interplanetary space, or the surface of Mars) may be pushed in evolutionarily consequential directions. Key Words: Planetary protection—Stratosphere—Balloon—Mars analog environment—E-MIST payload—*Bacillus pumilus* SAFR-032. Astrobiology 17, 337–350.

<http://online.liebertpub.com/doi/full/10.1089/ast.2016.1549>

A New Mission of Opportunity

August 21st, 2017:

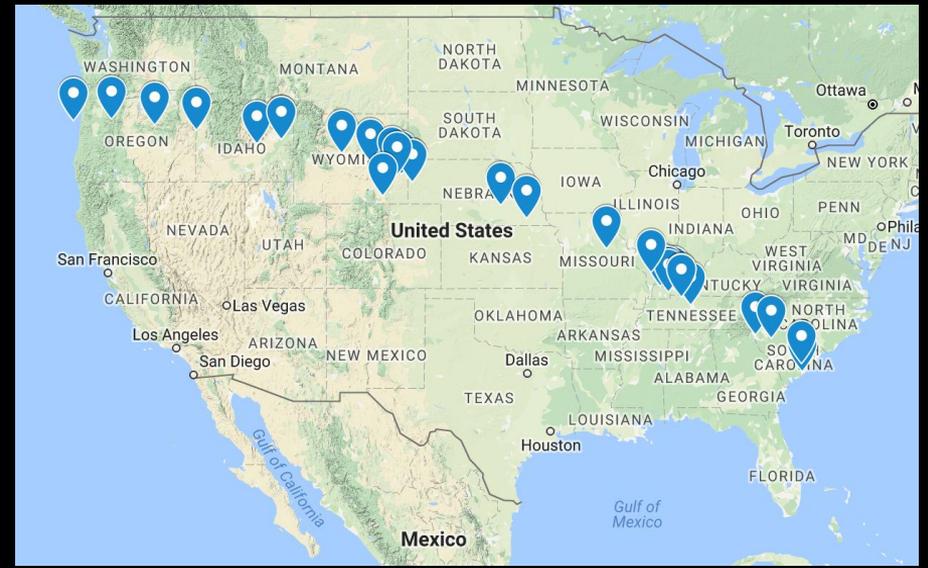
A total solar eclipse occurred across the United States from Oregon to South Carolina.

Student-built High Altitude Balloons (HABs) were launched from across the country through the Eclipse Ballooning Project run by Montana State (Eclipse.montana.edu) with the main purpose of photographing the eclipse and taking environmental measurements.



Credit: MSU Eclipse Ballooning Project / Creative Commons

MicroStrat =
10 States
34 Teams
39 Balloons
200+ Students
100,000 ft ASL



2 Primary Questions...



Question 1: During a full solar eclipse, is the stratosphere an even better Mars analog?

	Earth's Middle Stratosphere (~36 km)	Martian Surface (by Curiosity Rover)	Earth's Surface
Pressure	0.962 kPa	0.7kPa	101.325 kPa
UVA (315-400nm)	84.3 W m ⁻²	39.0 W m ⁻²	2.0 W m ⁻²
UVB (280-315nm)	10.6 W m ⁻²	8.38 W m ⁻²	.007 W m ⁻²
UVC (100-280nm)	2.6 W m ⁻²	3.18 W m ⁻²	Negligible
Ionizing Radiation	.066 mGy/d	.200 mGy/d	.0161 mGy/d (FAA max)
Temperature	-60°C → 0°C	-80°C → 0°C	0 → 30°C
Relative Humidity	<10%	<1%	Variable

Question 2: How are microbes affected by Mars-like conditions?



Credit: David J .Smith (NASA)

Exposing Microorganisms in the Stratosphere (E-MIST) – Previously-Flown NASA Mission

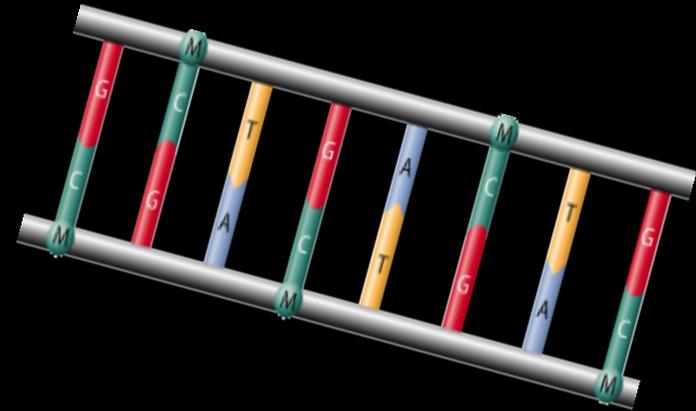
- Files hardy bacterial strains to upper atmosphere in order to measure resistance to environmental extremes.
- Astrobiology:
Defining the limits of habitability
- Planetary Protection:
Understanding the bio-burden we inadvertently carry into space



Post-flight Plan for MicroStrat



1. Effect of exposure conditions (duration, temperature, UV, altitude) on spore survival rates
2. Genomic differences pre- & post-flight
SNPs, indels, fatal mutations
3. Epigenetic changes:
DNA methylation: spore vs. vegetative states
& effect of stratospheric conditions
4. RNA expression: spore vs. vegetative states



What Flew?



Credit: David J. Smith & Joey Varelas (NASA)

Paenibacillus xerothermodurans

Spore Forming

Extremely resistant to heat

Found in the soil

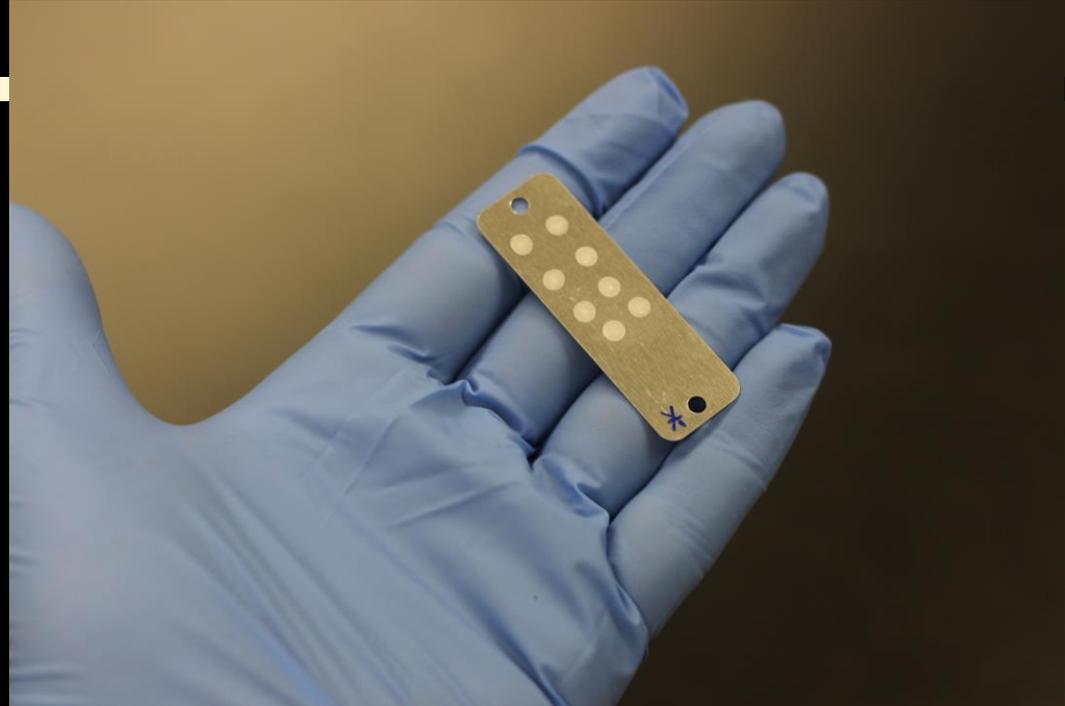
Non hazardous - BSL1 bacteria

Isolated from soil outside of spacecraft assembly clean room at Kennedy Space Center

Experimental Coupons



- 10 aliquots (20 μ L) of samples in sterile water. Roughly 10^7 spores per aliquot.
- Post Flight PVA Peel
- Use liquid PVA solution to peel bacteria off coupon for subsequent analysis.
- Coupon weight: <1g



Field Kits Sent to All Participating Teams



- Sterile Petri Dish with experimental coupons
- Forceps
- Alcohol disinfecting wipes
- Nitrile gloves
- Sterile Prep Pad
- Industrial Velcro (pre-attached)
- Standard Operating Procedure (w/ pictures for simplicity)
- SDS for all materials

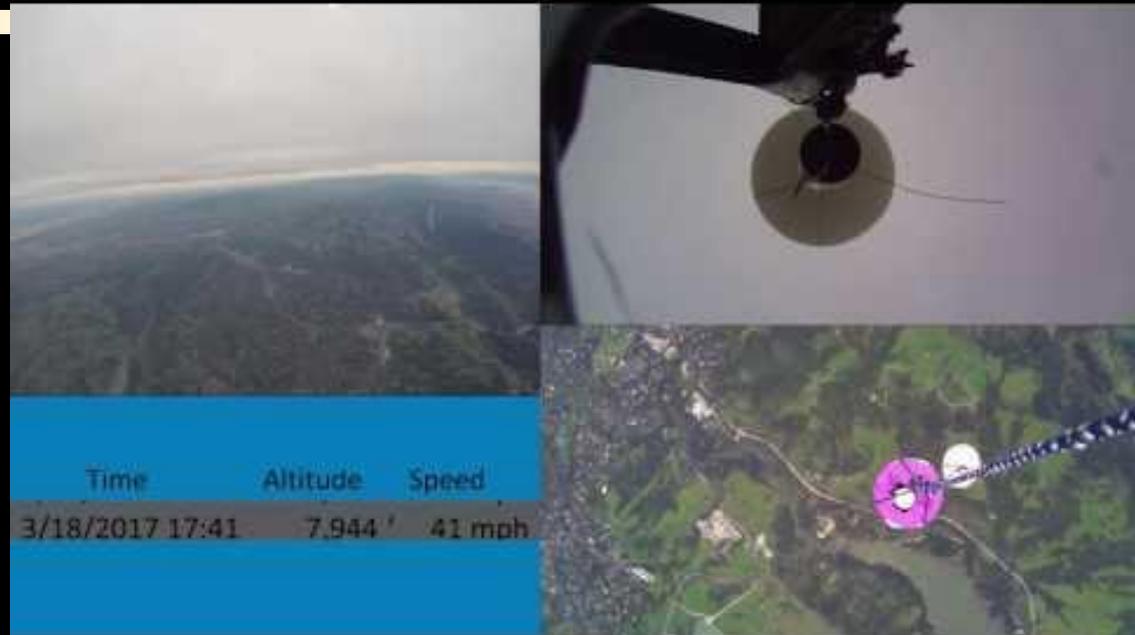






Risks and Challenges

- Descent can be violent, coupon could be dislodged
- Adhesive can fail at subzero temperatures
- May take multiple hours to reclaim payload
- Payloads may be unrecoverable
- Some payload data forfeited
- Contamination of samples is almost inevitable



Credit: EBARC Henry-1

Photos from the Field (Oregon Team)



Photo Credit: Daniela Bezdán

Photos from the Field (Oregon Team)

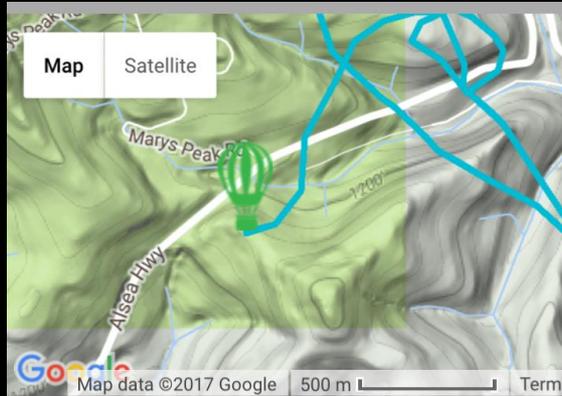


Photo Credit: Daniela Bezdán



OIT microstrat balloon

Photos from the Field (Oregon Team)



IMEI	Time-UTC	Date	Latitude	Longitude
300234064807740	19:0:0	2017-8-21	44.4648167	-12
300234064807740	18:59:30	2017-8-21	44.4647833	-12
300234064807740	18:59:0	2017-8-21	44.4647500	-12
300234064807740	18:58:32	2017-8-21	44.4647667	-12



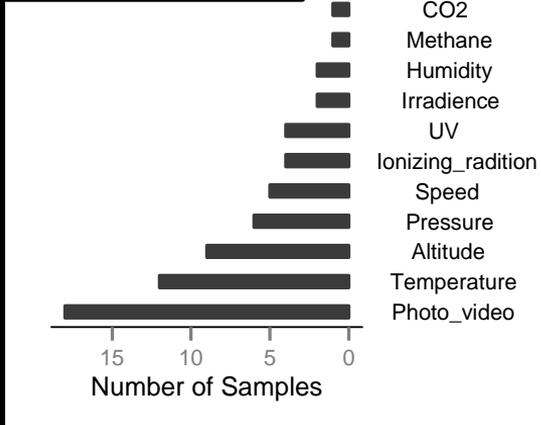
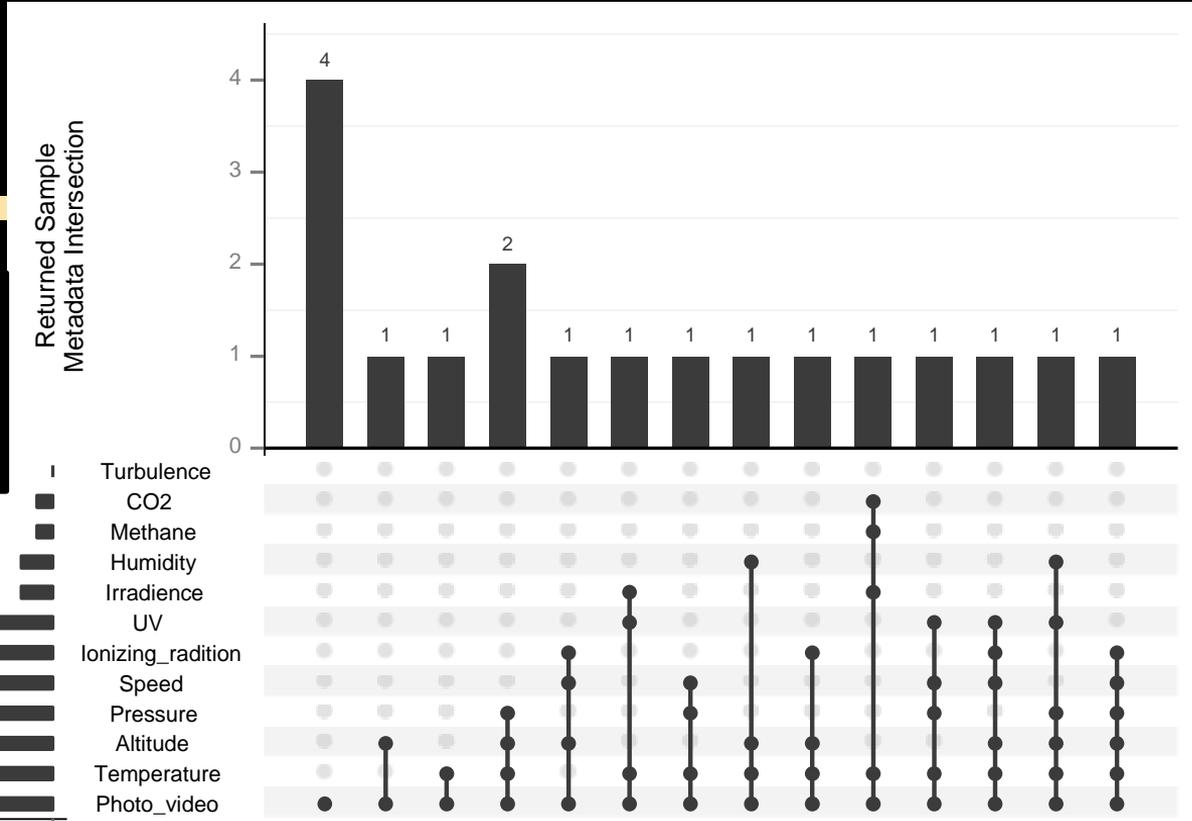
Photo Credit: Daniela Bezdán

Some Contamination Issues



- “The payload landed in a soybean field. The coupon came in direct contact with the soybeans and the soil.” –Kentucky
- “Control coupon dropped spore side down from roof of car to dusty dirt road.” – Washington
- “Since the payload landed in the alfalfa field, it made contact with the plants and soil surrounding it.” –Nebraska
- “Still looking for the payload in the pacific” –Oregon
- “The payload containing the coupon landing upside down in mud/cow feces.” – Montana

Available Metadata



MicroStrat Timeline and Progress to Date



June 13th-24th

Designated roles for project

July 10th-28th

Prepare all field kits

July 27th

NASA press release!

August 22nd

Coupons shipped to Cornell for Analysis

September +

Analysis underway

Jun

Jul

Aug

Sept

July 14th

Plate bacteria

July 3rd

Adhesion stress test, feedback for experimental design

August 1st

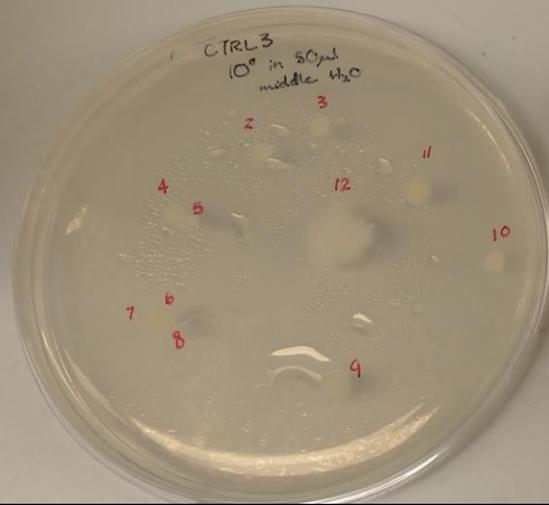
All kits will be shipped, with SOP and SDS

August 21st

Solar Eclipse!

Analysis Underway

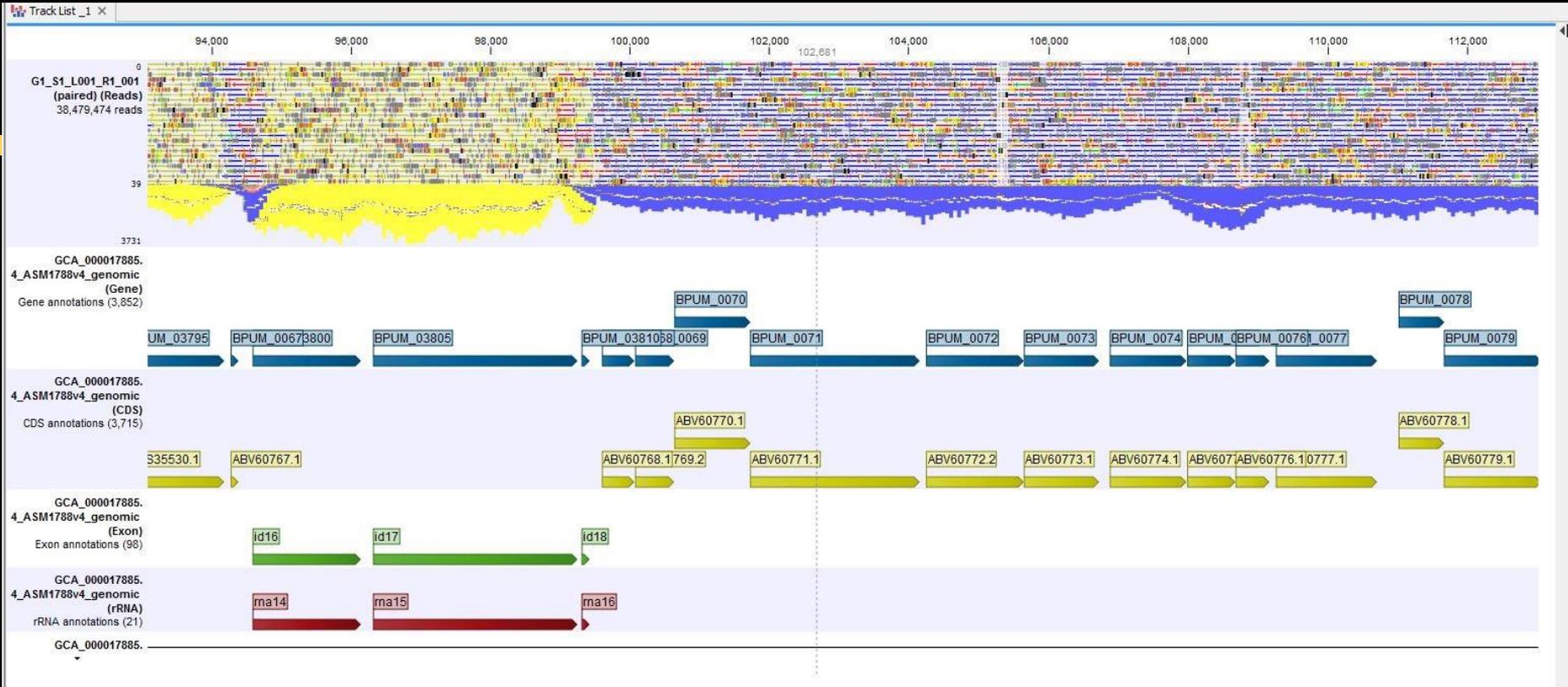
Credit: David J. Smith & Joey Varelas (NASA)



Credit: Alexa McIntyre



Analysis Underway





Student Flight Opportunities on Large NASA Balloons

<http://laspacespace.lsu.edu/hasp/>



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The High Altitude Student Platform

The High Altitude Student Platform (HASP) is designed to carry up to twelve student payloads to an altitude of about 36 kilometers with flight durations of 15 to 20 hours using a small volume, zero pressure balloon. It is anticipated that the payloads carried by HASP will be designed and built by students and will be used to flight-test compact satellites or prototypes and to fly other small experiments.

HASP includes a standard mechanical, power and communication interface for the student payload, based upon a flight tested design. This simplifies integration, allows the student payloads to be fully exercised, and minimizes platform development / operation costs. In addition, HASP is lightweight and has simple mission requirements, thus providing maximum flexibility in the launch schedule.





Acknowledgements

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Photo credit: Shepherd Kruse
(Colorado Team)

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