Large Scientific Balloons for Red Risk School's *Radiation Round Table*

National Aeronautics and Space Administration

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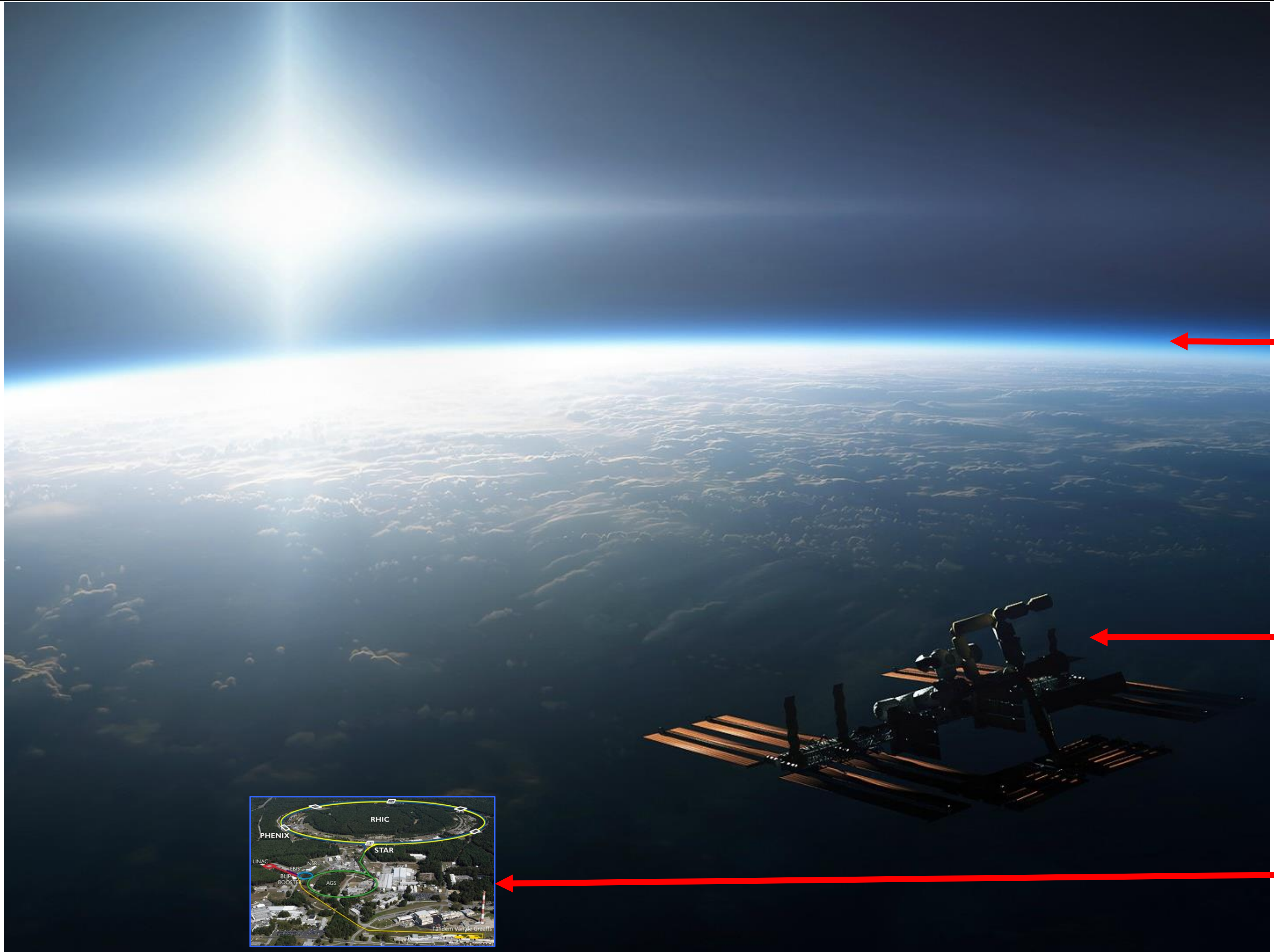
April 28, 2020

NASA Ames Research Center

How to Study Space Radiation

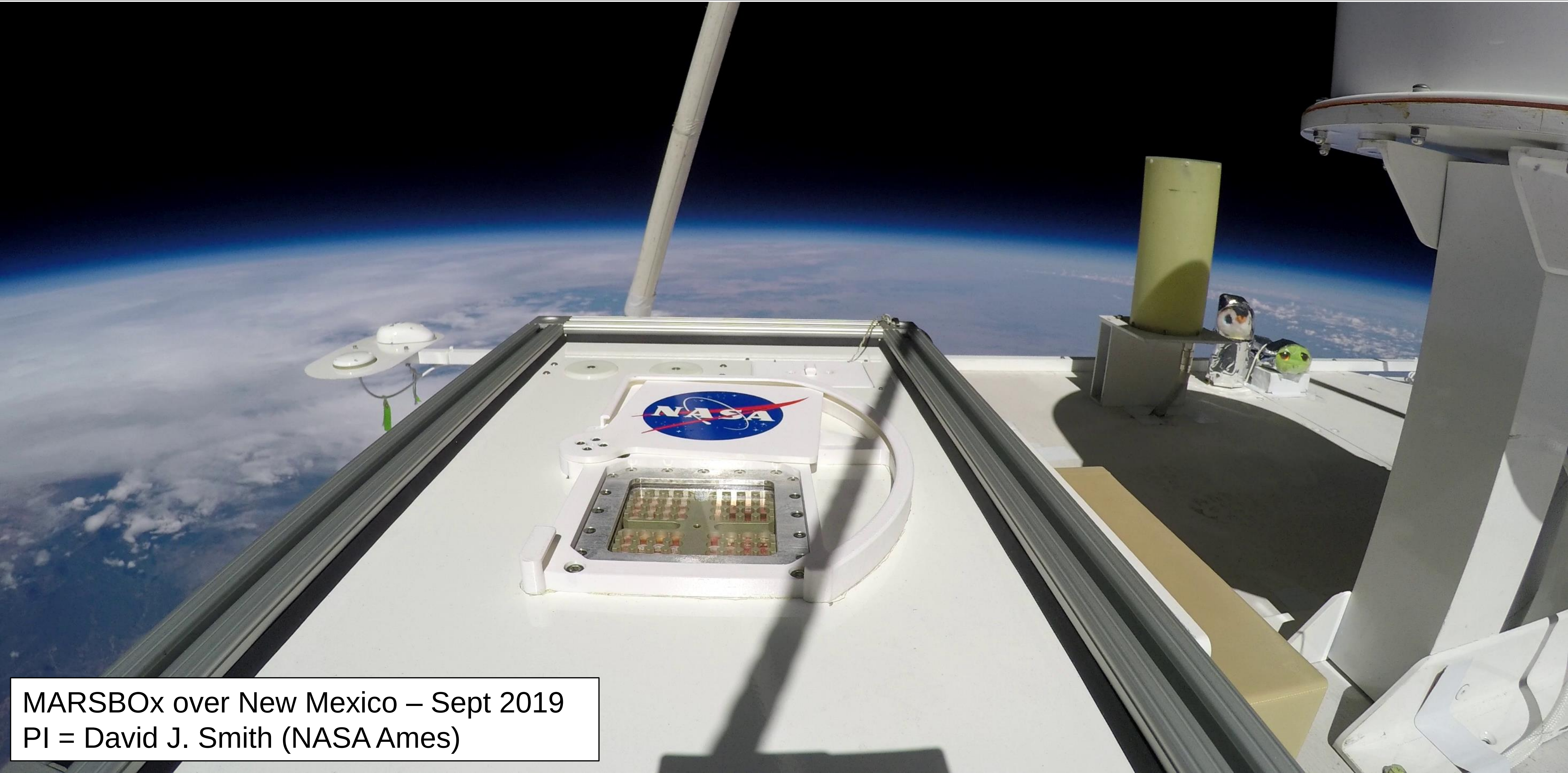


This is where balloons fly (Near Space)

Low Earth orbit

Ground simulations

Earth's Stratosphere is Within Reach



MARSBOx over New Mexico – Sept 2019
PI = David J. Smith (NASA Ames)

Outline of Presentation

I. Near Space radiation environment

II. Overview of large scientific balloons

III. Three recent balloon payload examples

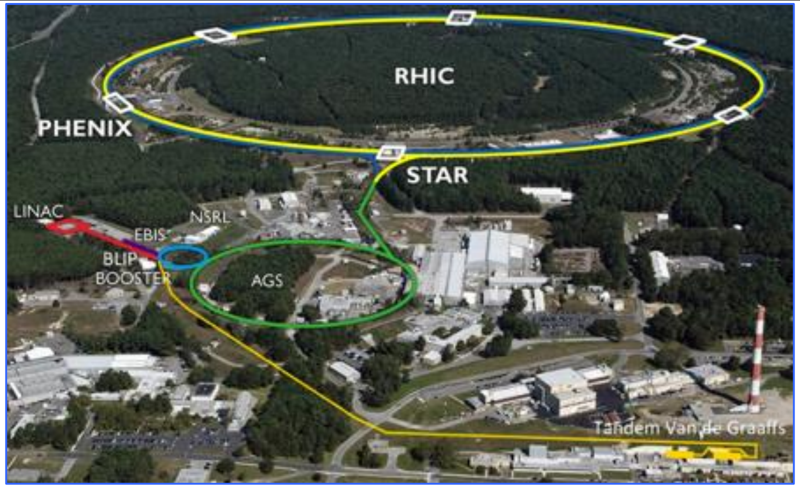
IV. How to get onboard

Limitations of Ground-Based Facilities

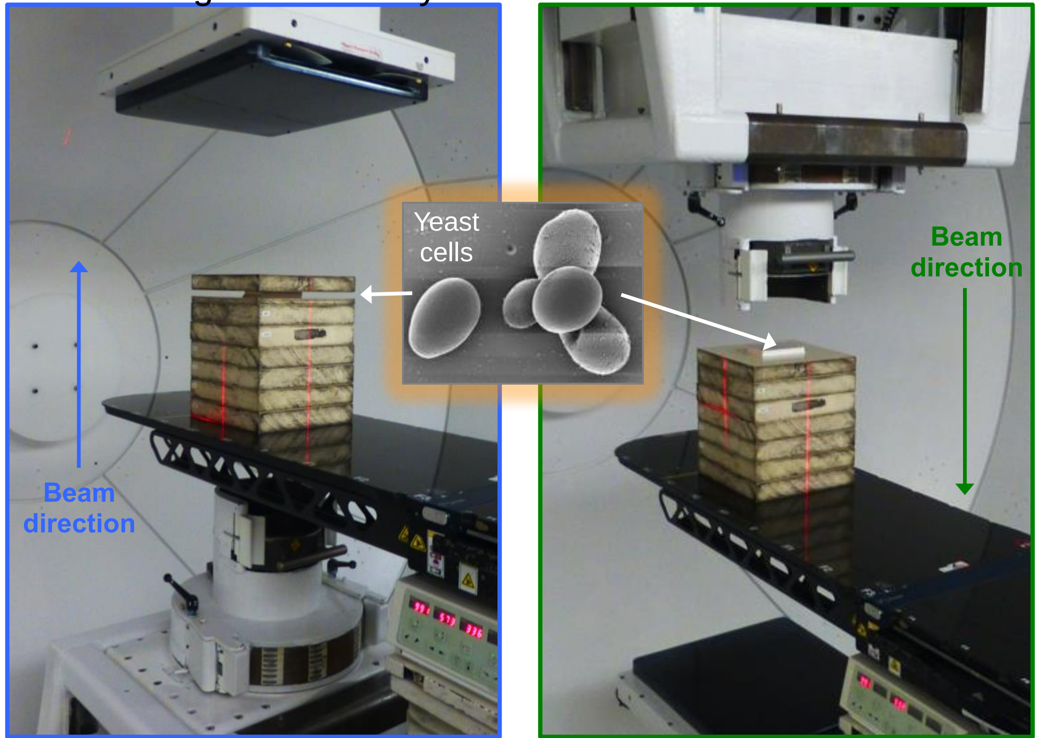
(1) Expensive (~$6K/hr for beam time)

(2) Volume limited

(3) Variable quality and dose (unable to mimic dynamic radiation)



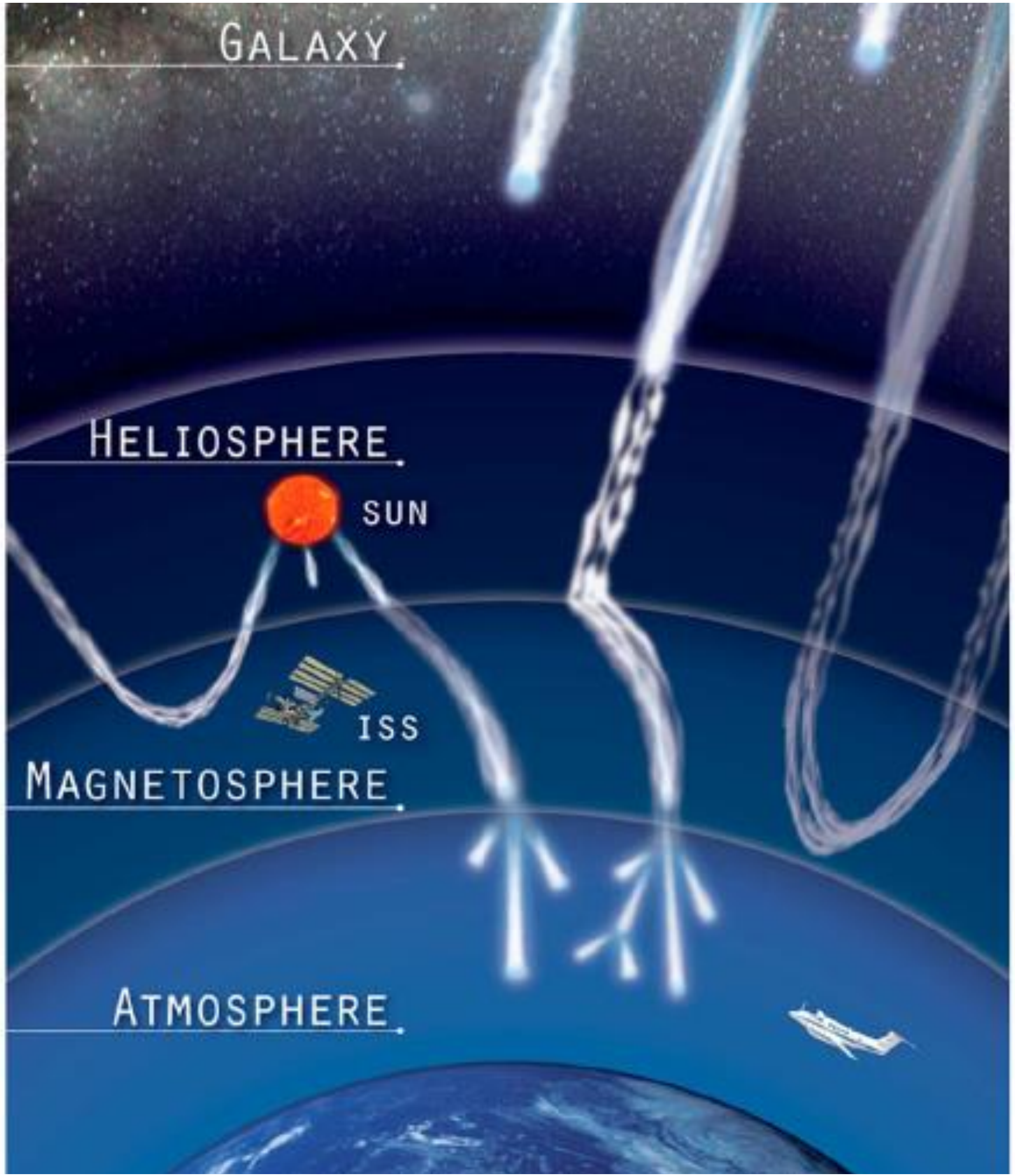
Figures courtesy of NASA BioSentinel Team



• Experiments tend to be **<u>short-lasting</u>, <u>small</u>** in size (beam area ~20 x 20 cm^2), and subjected to **<u>acute doses of radiation</u>**

• In contrast, the middle stratosphere **(Near Space)** has a **<u>natural</u>, <u>fuller composition of low dose rate ionizing radiation and secondary scattering</u>**

Near Space Radiation



<u>Space Radiation</u>:

(1) Ever-present galactic cosmic rays (**GCR**), with origins outside the solar system

(2) Transient solar energetic particles (**SEP**)

Energetic particle radiation from space continuously bombards (and penetrates) the Earth's atmosphere.

At altitudes where balloons float!

Mertens et al. (2017)

Large Scientific Balloons

GRAVITATIONAL AND SPACE RESEARCH
JOURNAL OF THE AMERICAN SOCIETY FOR GRAVITATIONAL AND SPACE Research

Smith and Sowa (2017)

Review Article

Ballooning for Biologists: Mission Essentials for Flying Life Science Experiments to Near Space on NASA Large Scientific Balloons

David J. Smith and Marianne B. Sowa

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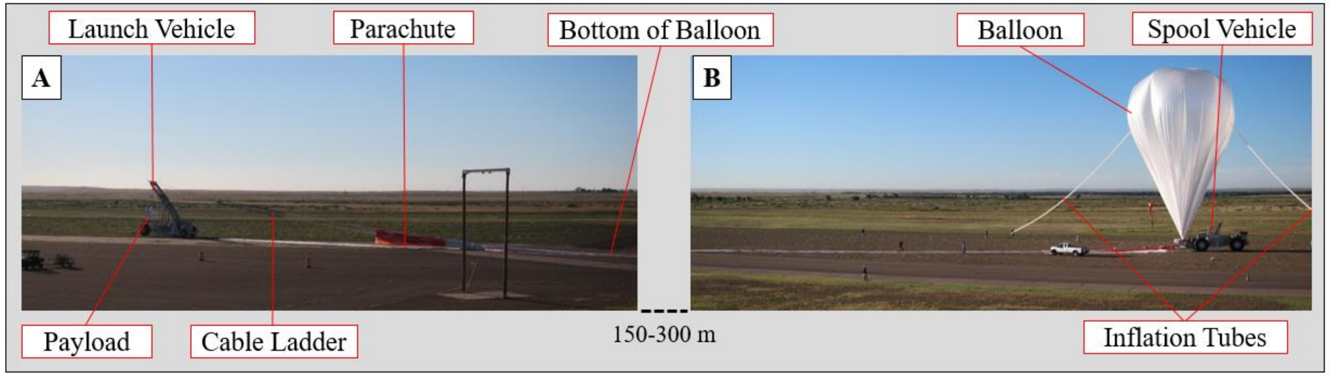
ABSTRACT

Despite centuries of scientific balloon flights, only a handful of experiments have produced biologically relevant results. Yet unlike orbital spaceflight, it is much faster and cheaper to conduct biology research with balloons, sending specimens to the near space environment of Earth's stratosphere. Samples can be loaded the morning of a launch and sometimes returned to the laboratory within one day after flying. The National Aeronautics and Space Administration (NASA) flies large unmanned scientific balloons from all over the globe, with missions ranging from hours to weeks in duration. A payload in the middle portion of the stratosphere (~35 km above sea level) will be exposed to an environment similar to the surface of Mars—temperatures generally around -36°C, atmospheric pressure at a thin 1 kPa, relative humidity levels <1%, and harsh illumination of ultraviolet (UV) and cosmic radiation levels (about 100 W/m^2 and 0.1 mGy/d, respectively)—that can be obtained nowhere else on the surface of the Earth, including environmental chambers and particle accelerator facilities attempting to simulate space radiation effects. Considering the operational advantages of ballooning and the fidelity of space-like stressors in the stratosphere, researchers in aerobiology, astrobiology, and space biology can benefit from balloon flight experiments as an intermediary step on the extraterrestrial continuum (i.e., ground, low Earth orbit, and deep space studies). Our review targets biologists with no background or experience in scientific ballooning. We will provide an overview of large balloon operations, biology topics that can be uniquely addressed in the stratosphere, and a roadmap for developing payloads to fly with NASA.

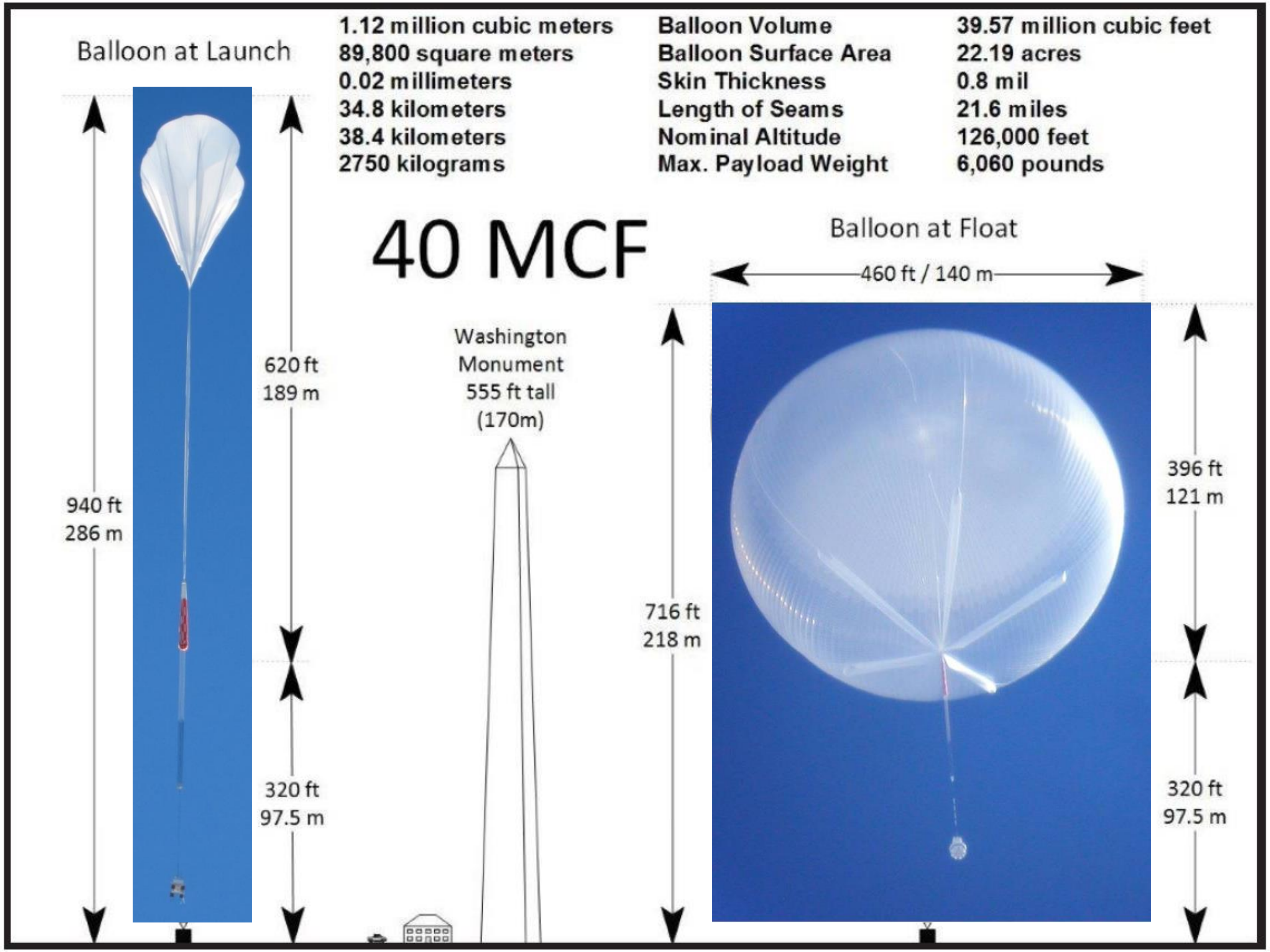
INTRODUCTION

In 1783, a hydrogen balloon lifted off from Paris, France, starting the era of scientific



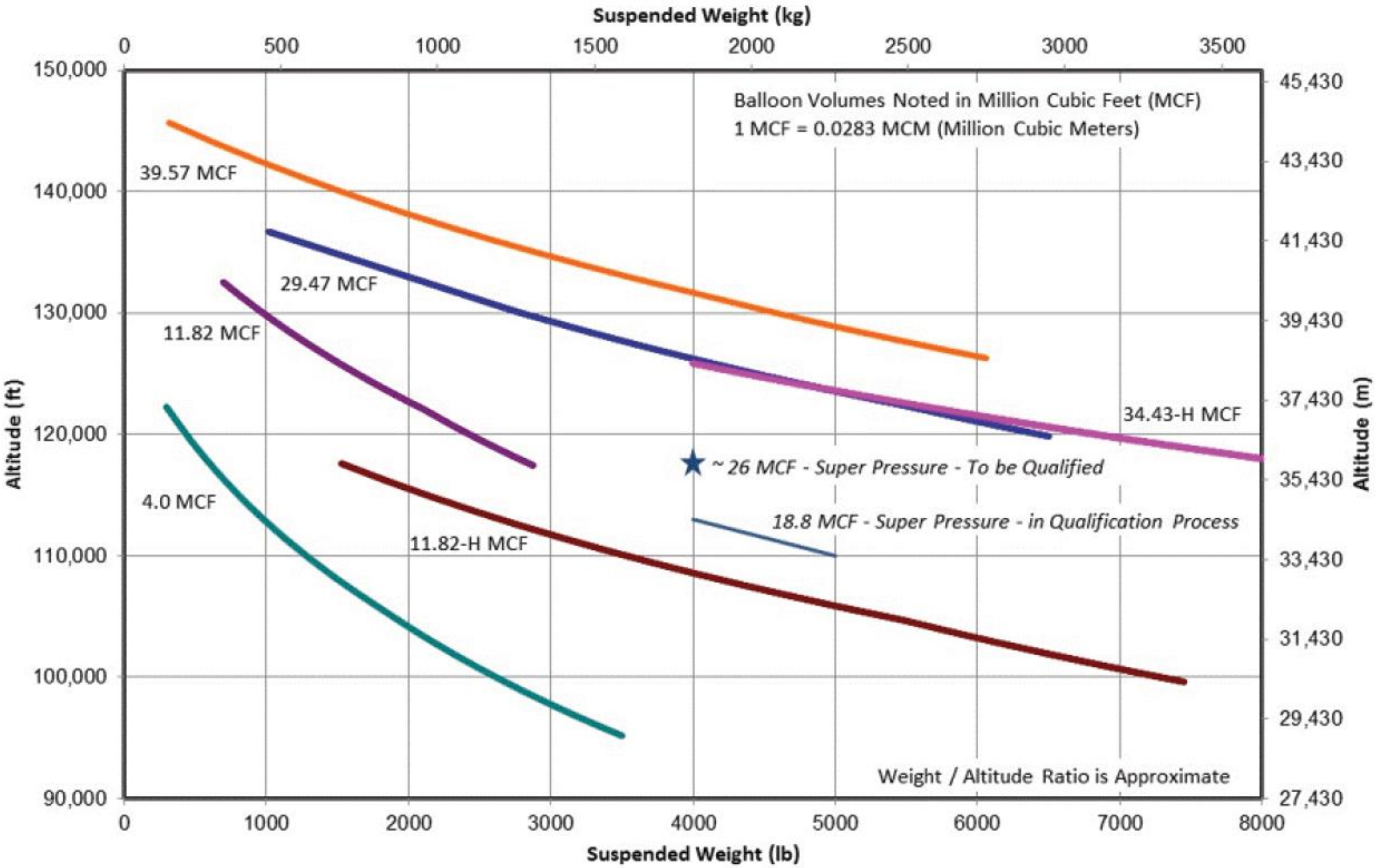
Large Scientific Balloons: Size

Background figure courtesy of NASA Balloon Program Office



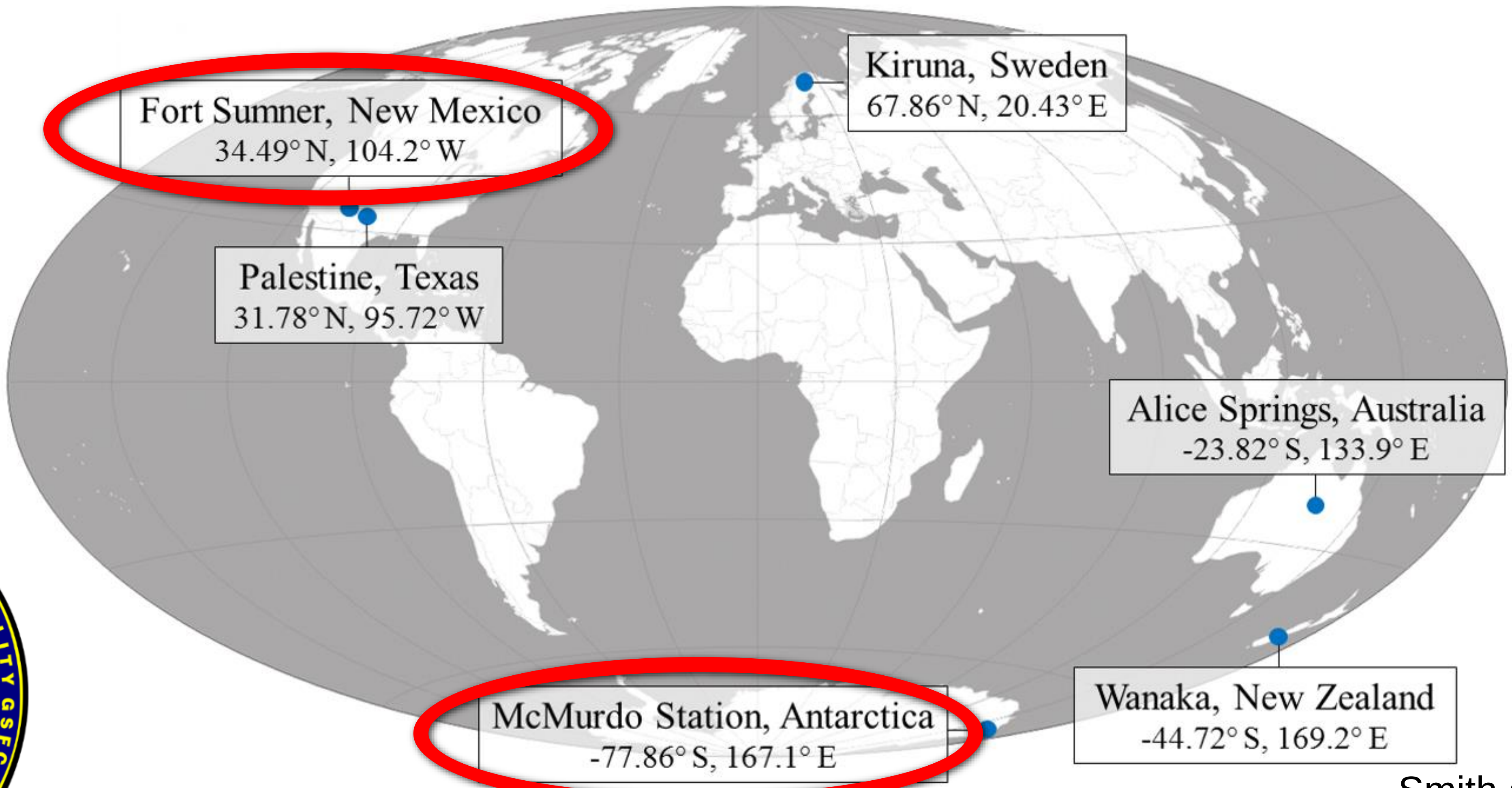
Large Scientific Balloons: Lift Capacity

Figure courtesy of NASA Balloon Program Office



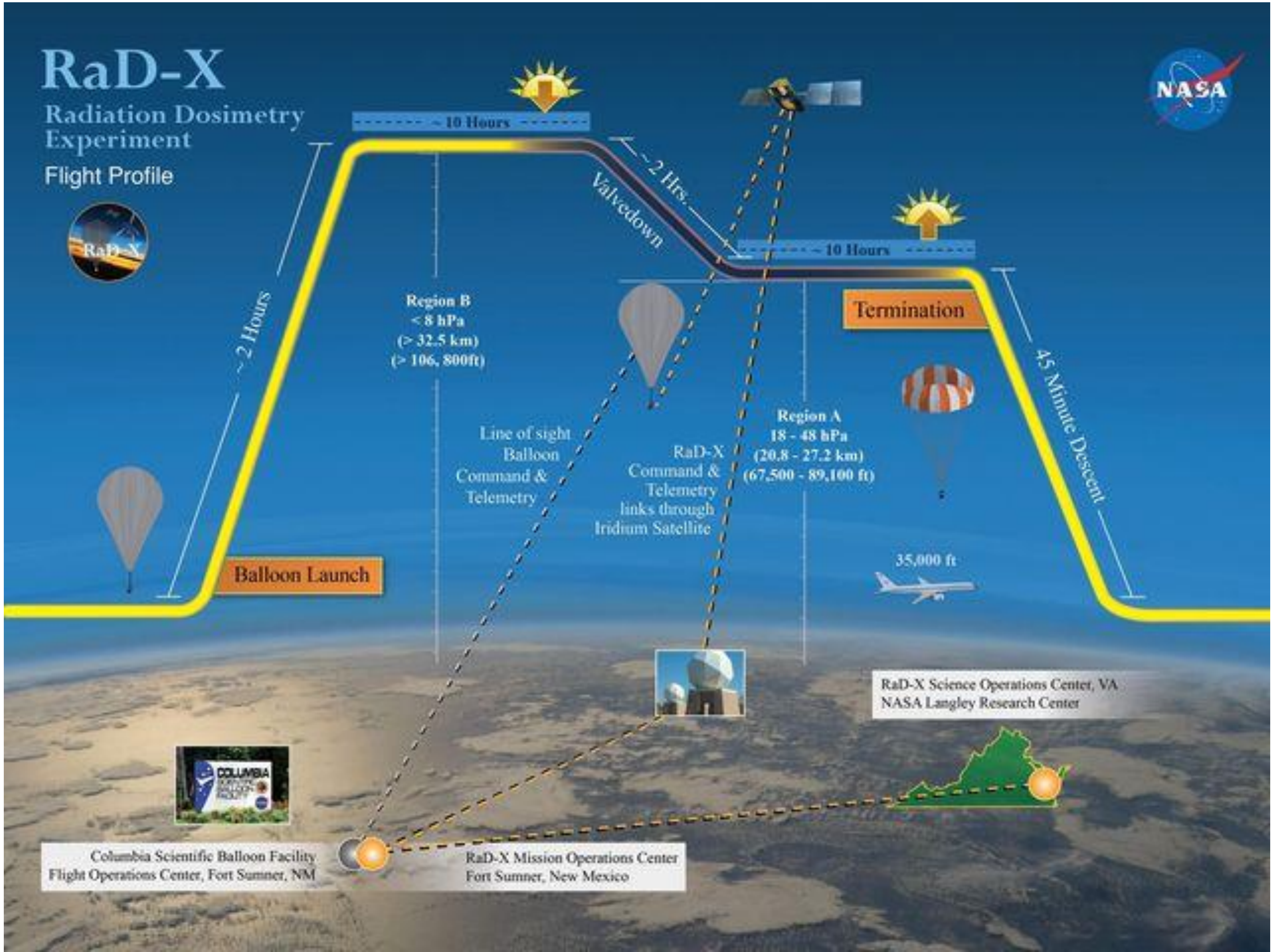
Large Scientific Balloons: Launch Sites

The **NASA Balloon Program Office (BPO)** is located at Goddard Space Flight Center's Wallops Flight Facility (WFF) at Wallops Island, Virginia (https://sites.wff.nasa.gov/code820/). It oversees operations for a portfolio of 10 to 16 annual missions sponsored and approved by NASA's Science Mission Directorate.



Smith and Sowa (2017)

Radiation Dosimetry Experiment (RaD-X)



- Launched Sept 2015 (from Ft. Sumner, NM), flown to **36.6 km**
- Average dose rates in the stratosphere were **0.064 mGy/d** (Mertens et al., 2016)
- MSL rover on the surface of Mars: **0.18 to 0.225 mGy/d** (Hassler et al., 2014)

Mertens et al. (2017)

Radiation Dosimetry Experiment (RaD-X)

Norman et al. (2017)

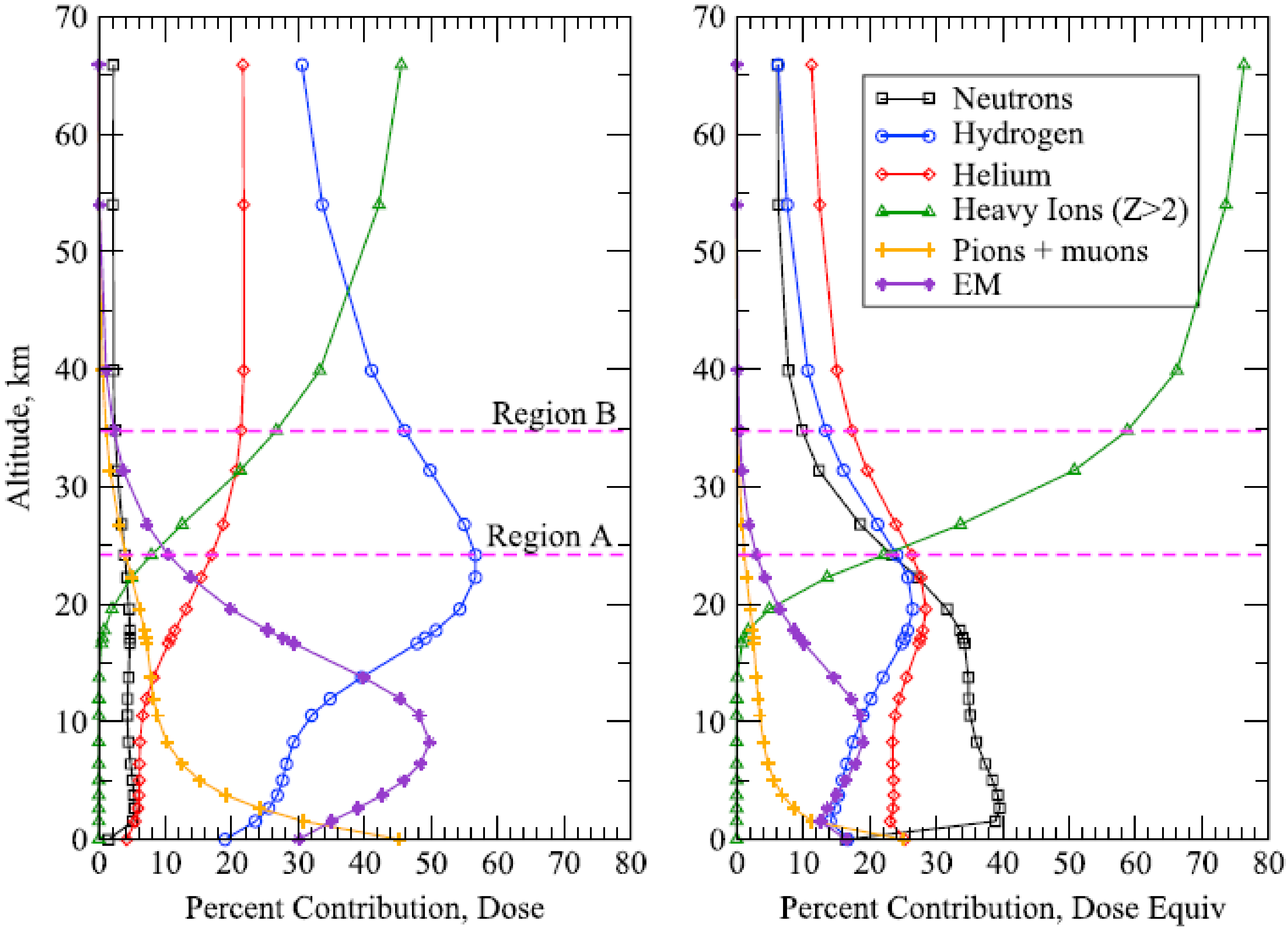
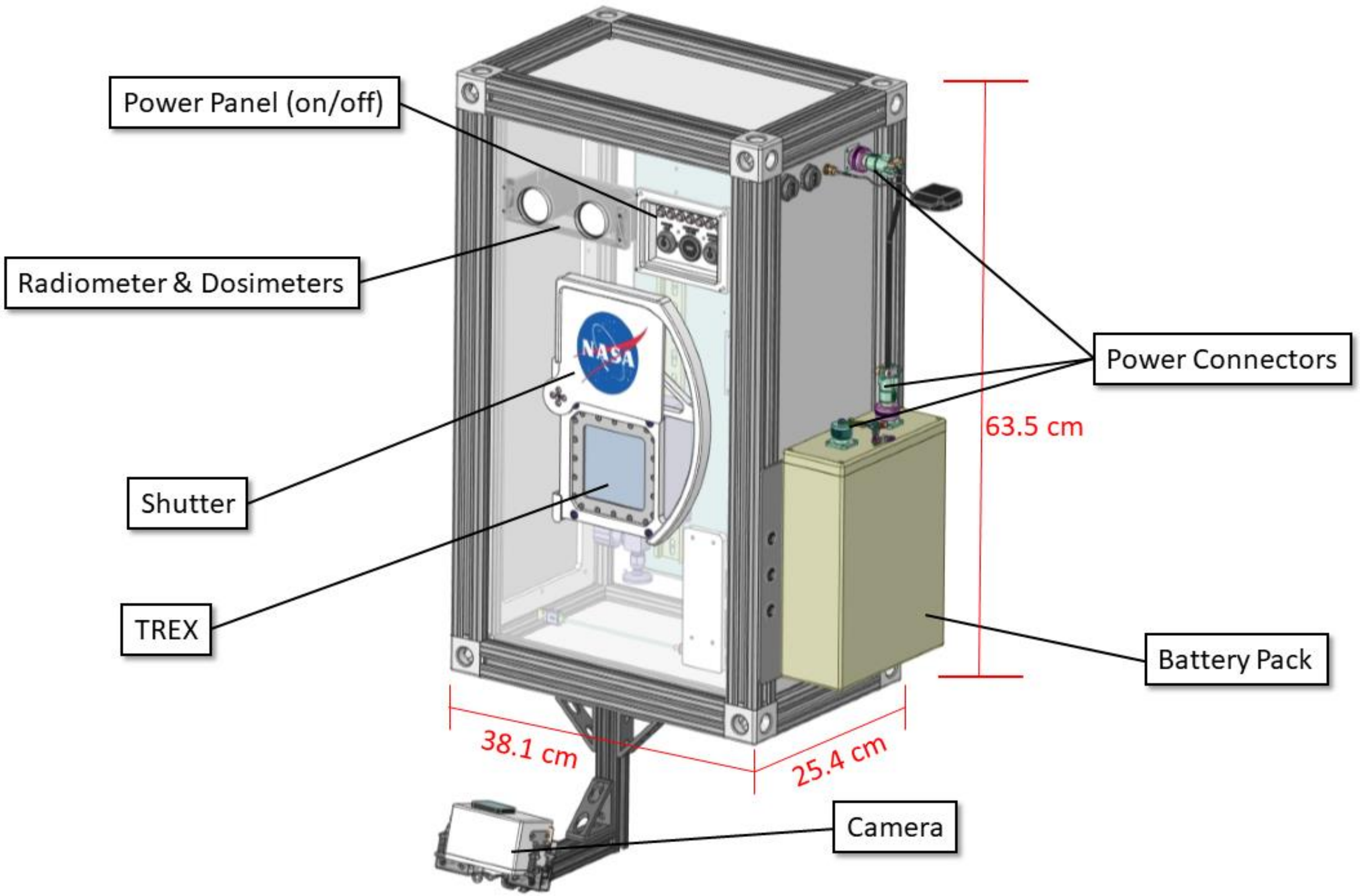


Figure 7. The percent contribution to (left) dose and (right) dose equivalent by different particle groups as a function of altitude for the RaD-X flight (25–26 September 2015) from the three GCR models. Horizontal dashed lines correspond to average altitude for Regions B and A for reference.

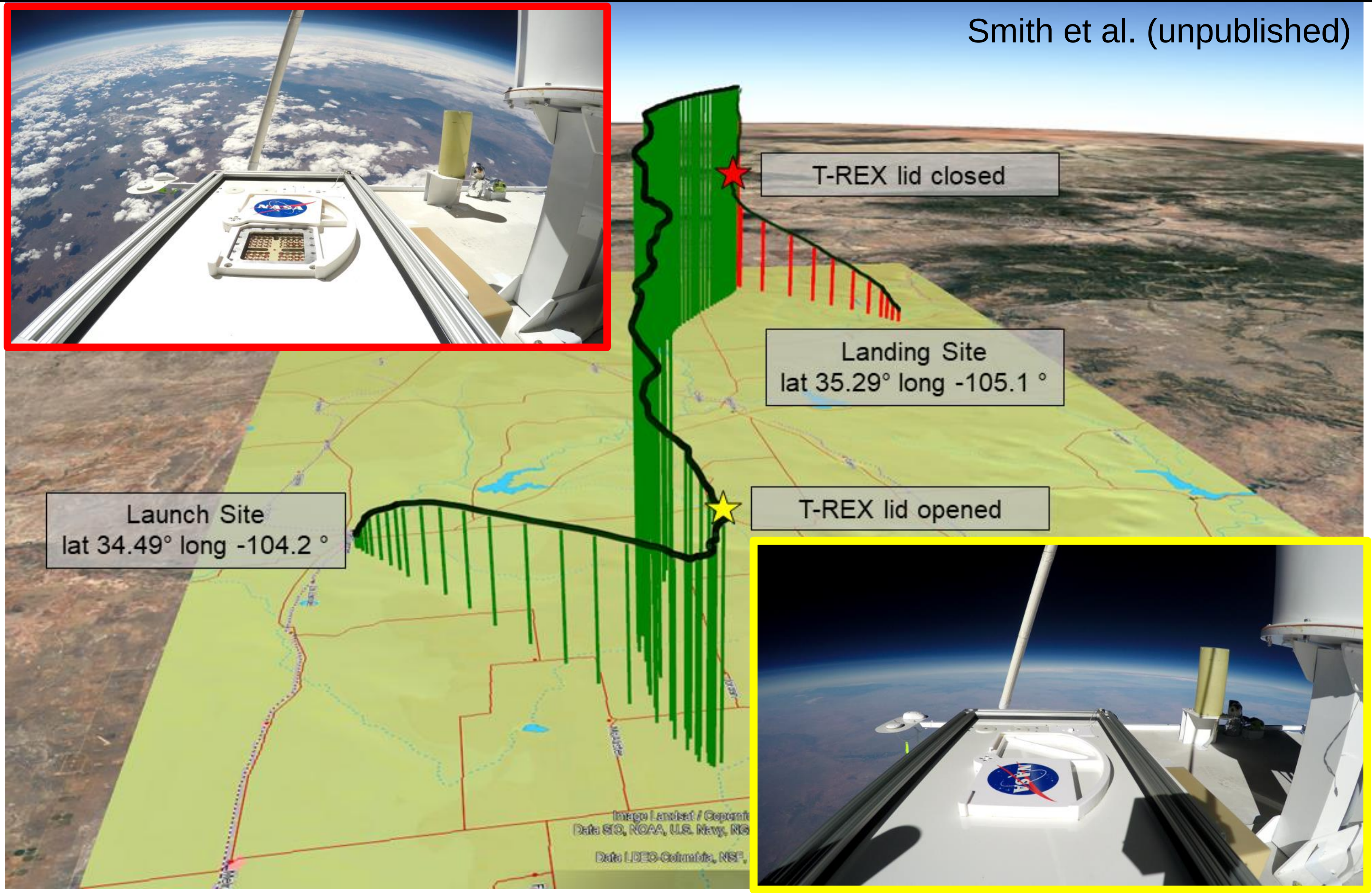
Microbes in Atmosphere for Radiation, Survival, and Biological Outcomes Experiment (MARSBOx)

- Flown September 2019
- 18 kg payload – bolts onto gondola
- Flexible on mission altitude, duration, launch dates, etc.
- DLR dosimeters (passive & active) as well as microbe container (T-REX)
- Self-powered (CU-J141-V1 battery)
- Samples pre-loaded, stable & safe; gas mix can be added (pressurized enclosure)
- No balloon facility or in-field support requirements

Smith et al. (unpublished)



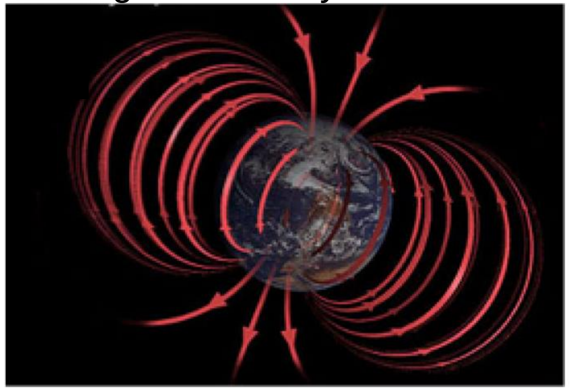
MARSBOx Flight: September 2019



Smith et al. (unpublished)

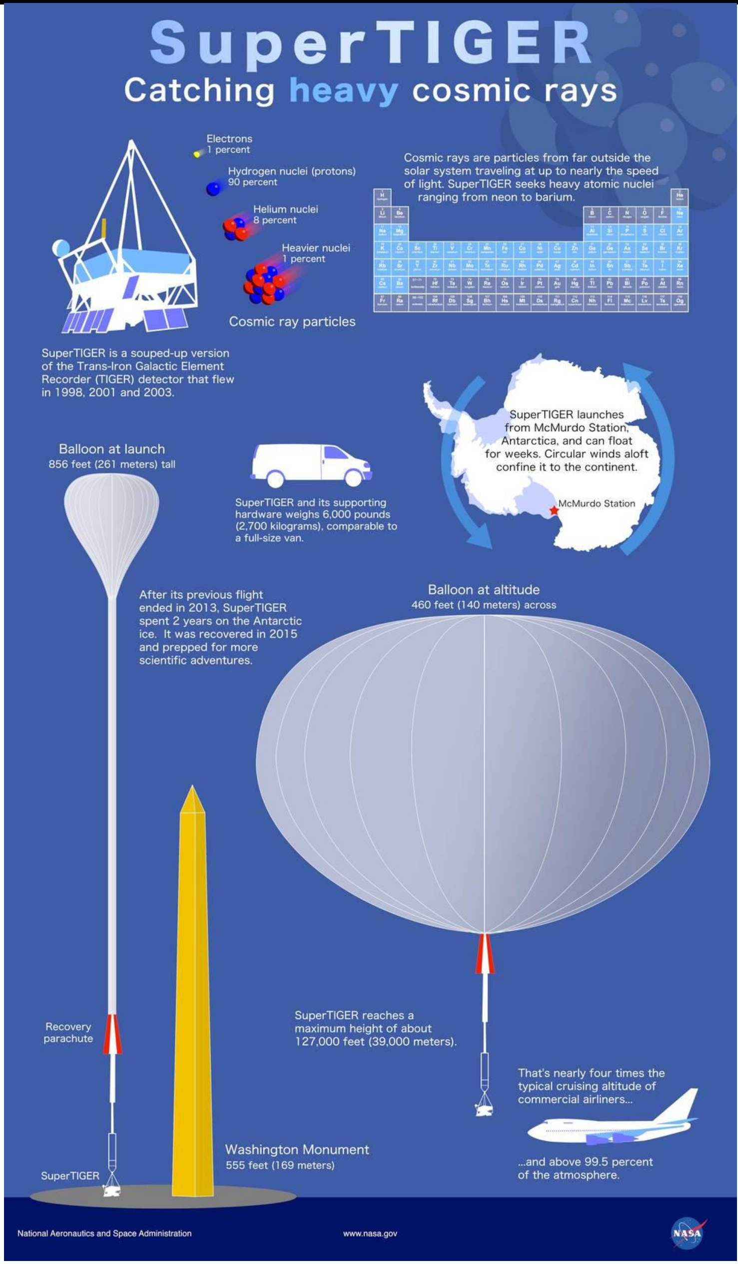
Long Duration Antarctic Balloon Flights

Figure courtesy of NASA

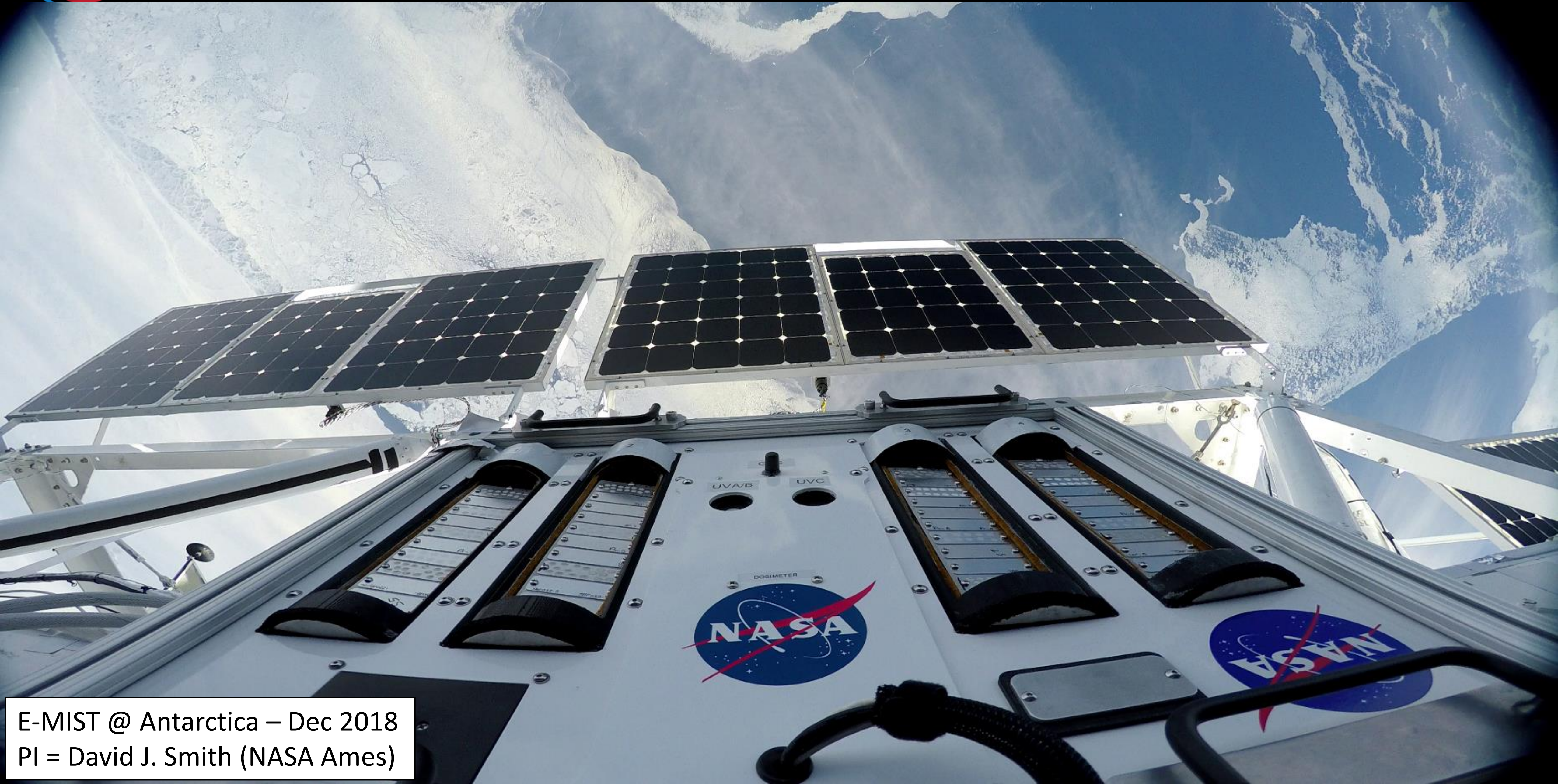


- Most cosmic radiation particles are deflected around the Earth by its magnetic field
- But solar and deep space particles can **penetrate through the magnetic north and south poles** at latitudes above 70°
- **Polar balloon flights** therefore provide **<u>more high energy particle radiation</u>**

Figures courtesy SuperTIGER Team (B. F. Rauch, WUSTL)



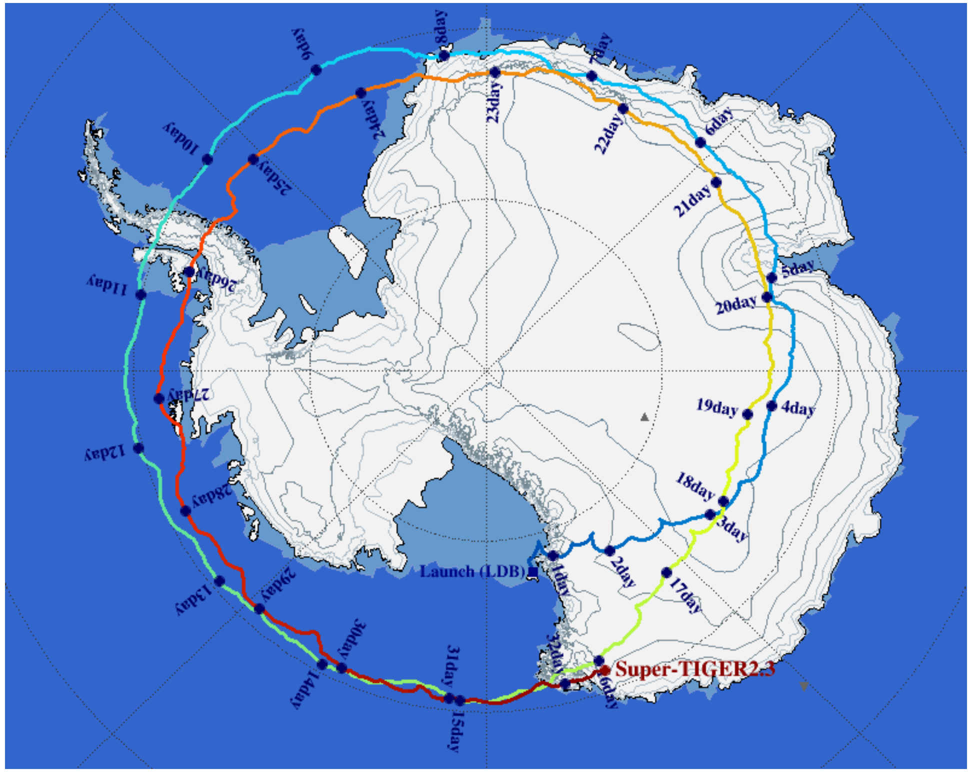
E-MIST Antarctic Balloon Flight



E-MIST @ Antarctica – Dec 2018
PI = David J. Smith (NASA Ames)

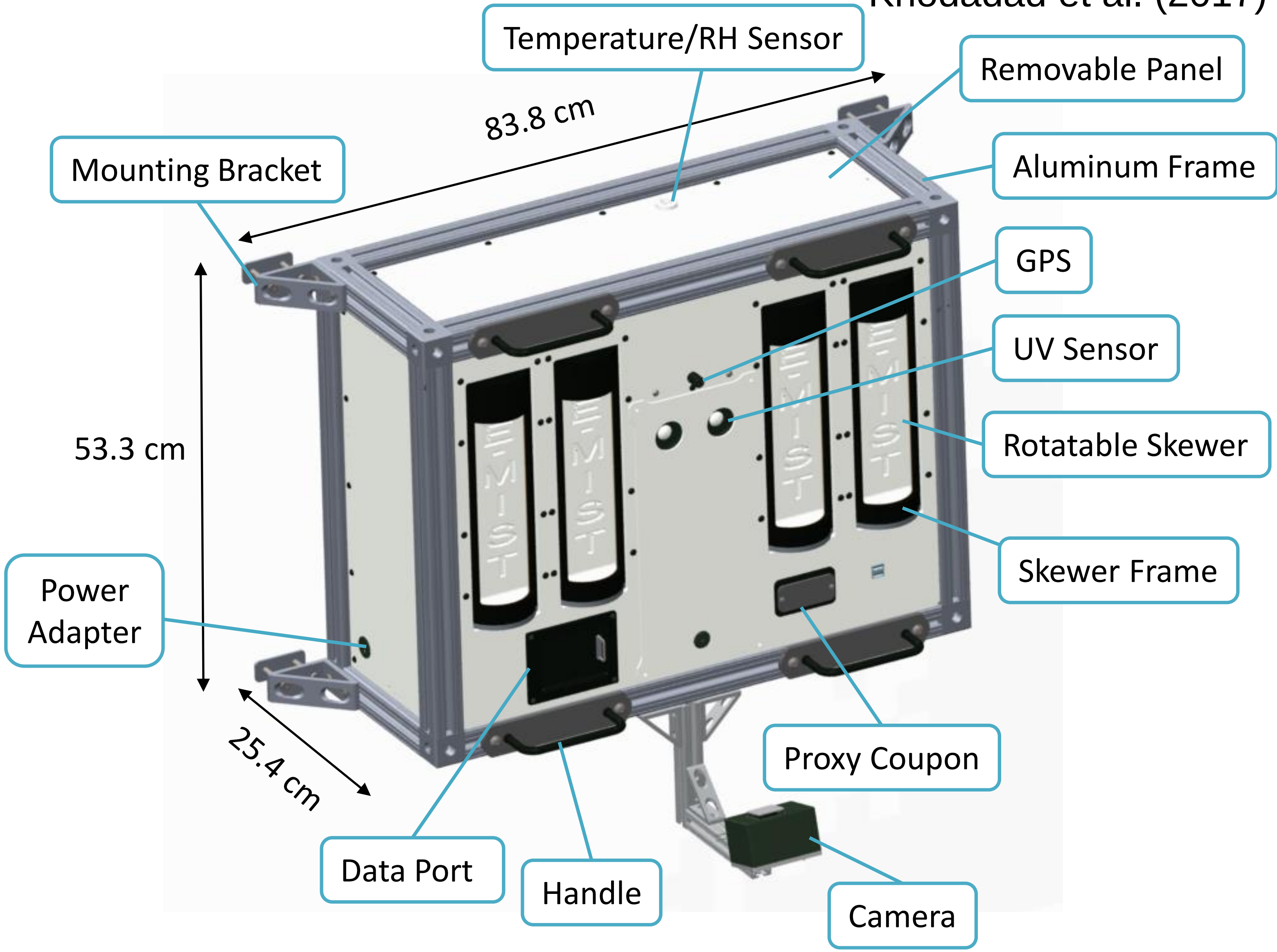
E-MIST Antarctic Balloon Flights

Figure courtesy SuperTIGER Team (B. F. Rauch, WUSTL)



- 3 Antarctic missions (2018-2020)
- 50 kg payload – bolts onto gondola
- Camera, UV sensors & dosimeters
- Thermal controls
- Powered by gondola

Khodadad et al. (2017)



E-MIST Payload Overview

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An 8-hour stratospheric flight on the NASA E-MIST balloon killed off even the hardiest 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

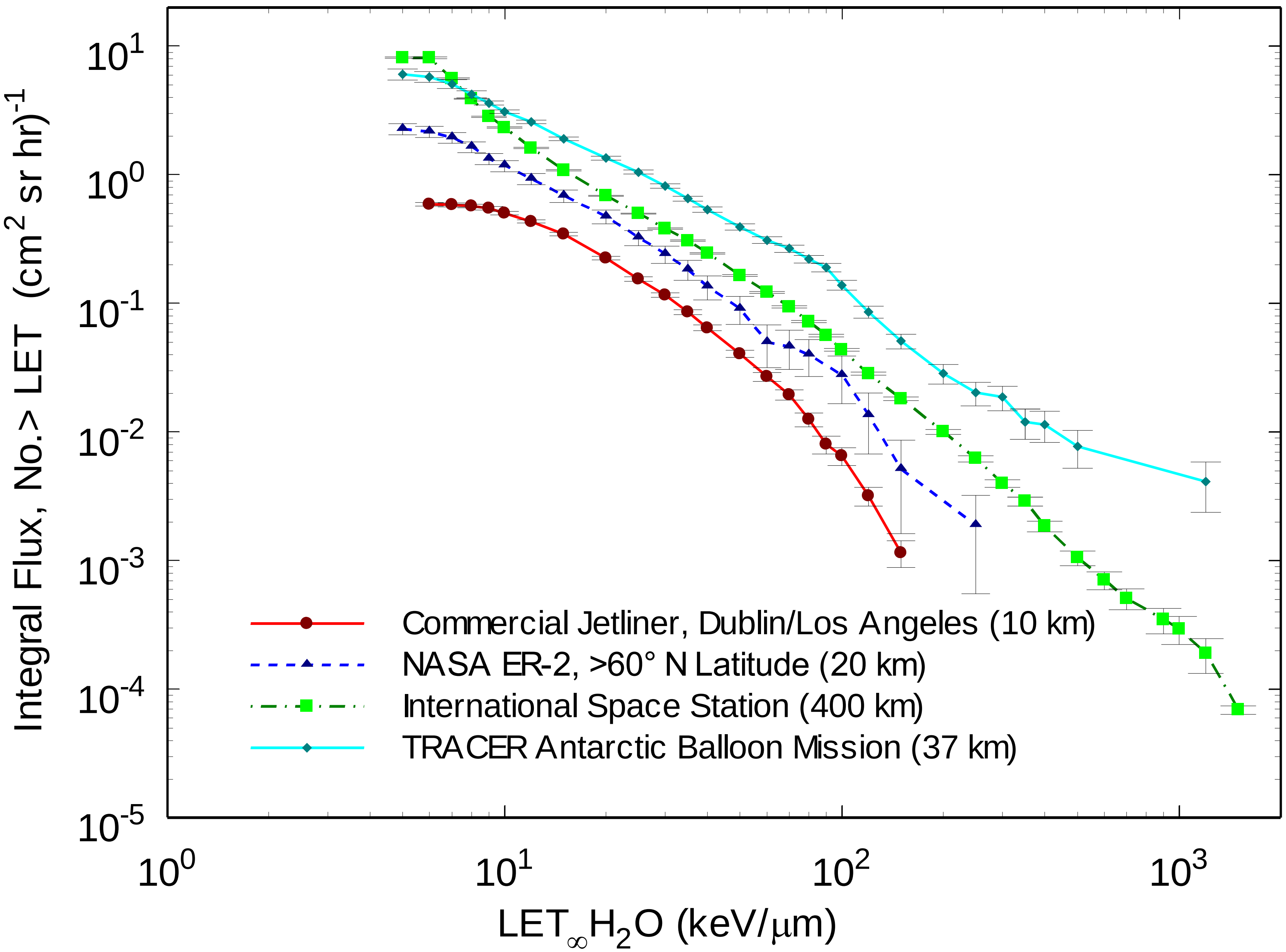
Christina L. Khodadad,[1] Gregory M. Wong,[2] Leandro M. James,[3] Prital J. Thakrar,[3] Michael A. Lane,[3] John A. Catechis,[1] and David J. Smith[4]

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.

Antarctic TRACER Balloon Mission

Figure courtesy of
Eric Benton
(Oklahoma State University)



Antarctic TRACER Balloon Mission

Table courtesy of Eric Benton (Oklahoma State University)

Exposure	Average Altitude (km)	Average Dose Rate (mGy/hr)	Average Dose Equivalent Rate (mSv/hr)	Mean Quality Factor
Dublin/Los Angeles	10	2.52 ± 0.16	5.28 ± 0.40	2.10 ± 0.17
ER-2 >60°N	20	8.41 ± 1.29	12.77 ± 2.72	1.52 ± 0.36
ER-2 ~34°N	20	2.38 ± 0.62	4.45 ± 1.43	1.87 ± 0.67
TRACER Antarctic Balloon	37	5.47 ± 0.31	25.98 ± 1.68	4.75 ± 0.36
ISS maximum	400	10.36 ± 0.54	18.81 ± 1.11	1.82 ± 0.13
ISS minimum	400	6.88 ± 0.42	14.06 ± 0.93	2.04 ± 0.16

Mars (Curiosity Rover)

~8.33 mGy/hr

Hassler et al. (2014)

Flying with NASA Balloon Program Office

File Tools View OF-300-12-F Rev. D- Balloon Flight Support Application_.docx [Read-Only] - Word

Balloon Flight Support Application

Payload Acronym: ____________________

Payload Name: ____________________

This form identifies science group requirements for NASA/CSBF Conventional, Long-Duration Balloon (LDB), Super-Pressure Balloon (SPB), and Mission of Opportunity (piggyback) flight support.

Submit applications to CSBF as follows:

Type	Previously Flown Payloads	First Flight Payloads
Conventional	One to two years prior to requested launch date	Three years prior to requested launch date
LDB/SPB	Three years prior to requested launch date	Three years prior to requested launch date
Mission of Opportunity	Six months prior to integration with primary payload	Six months prior to integration with primary payload

Please complete and sign a separate application in as much detail as possible for each individual balloon flight planned and return to:

E-Mail to: HUGO.FRANCO@NASA.GOV
SHELBY.ELBORN@NASA.GOV
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Completion instructions and other information regarding this application are contained in support documents available on the CSBF Web site at http://www.csbf.nasa.gov/convdocs.html, http://www.csbf.nasa.gov/docs.html and http://www.csbf.nasa.gov/ldbdocs.html.

Part I Flight Type

Conventional Flight
Is this a conventional flight (typically from Palestine, TX or Fort Sumner, NM)? Yes ☐ No ☐

LDB Test Flight
Is this request for an engineering or science validation mission for a future LDB/SPB flight? (An engineering or science validation flight, normally from the continental United States, is considered a conventional balloon flight.) Yes ☐ No ☐

LDB Flight
Is this request for a Long-Duration Balloon (LDB) flight? Yes ☐ No ☐

SPB Flight
Is this request for a Super Pressure Balloon (SPB) flight? Yes ☐ No ☐

PiggyBack
Is this a request to fly as a mission of opportunity (piggyback) on a science flight? Yes ☐ No ☐

Student Payload
Is this request associated with NASA's Undergraduate Student Instrument Project (USIP) Educational Flight Opportunity program? Yes ☐ No ☐

Part II Science

Disciplines

Highlight or underline the discipline applicable to the flight covered by this application.

Astrophysics Division	IR, Submillimeter, Radio	**Heliophysics Division**	Geospace Sciences
	Cosmic ray, particle		Solar and Heliospheric Physics
	X-ray		Upper Atmosphere Research
	Ultraviolet and Visible	**Solar System Exploration**	
	Gamma-Ray	**Special Projects**	

Flight applications due in April (annually)

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NASA has released Tech Flights 2020 solicitation. The solicitation details, **including a Q&A document that is updated on an ongoing basis**, can be found on NSPIRES. Mandatory proposal abstracts are due April 17, 2020, at 5pm EDT. Final proposals are due May 22, 2020, at 5pm EDT.

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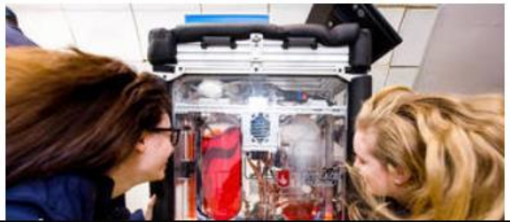
Researchers from U.S.-based industry, academia, and other non-NASA organizations can compete for funding through NASA's Tech Flights solicitations. Awardees receive a grant or collaborative agreement allowing them to purchase flights directly from a U.S. commercial flight vendor that best meets their needs.

To qualify:



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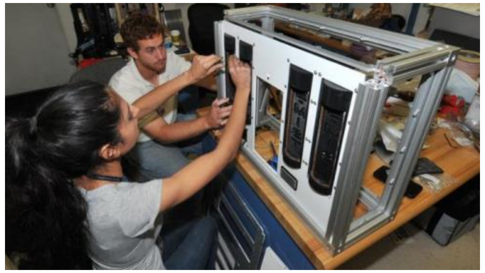

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Countless co-authors, colleagues and collaborators