National Aeronautics and Space Administration

GALACTIC COSMIC RADIATION (GCR) MEASUREMENTS MADE BY M-42 ACTIVE DOSIMETERS ON NASA BALLOON FLIGHTS (NEW MEXICO & ANTARCTICA) RESEMBLE LEVELS EXPECTED AT MARS

David J. Smith, NASA Ames Research Center (david.j.smith-3@nasa.gov)

ASGSR, November 2020

On behalf of Thomas Berger, Karel Marsalek, Bartos Przybyla, Daniel Matthiä, Joachim Aeckerlein, Markus Rohde, Michael Wirtz, Ralf Möller, Leandro James, Michael Lane, Prital Johnson, Marianne Sowa

The Space Radiation Environment

- **Sun – Solar Particle Events (SPE)**

Protons (depends on the solar cycle)

- **Galactic Cosmic Radiation (GCR)**

Ions (from protons to iron)

- **Trapped Radiation Belts (Van Allen Belts)**

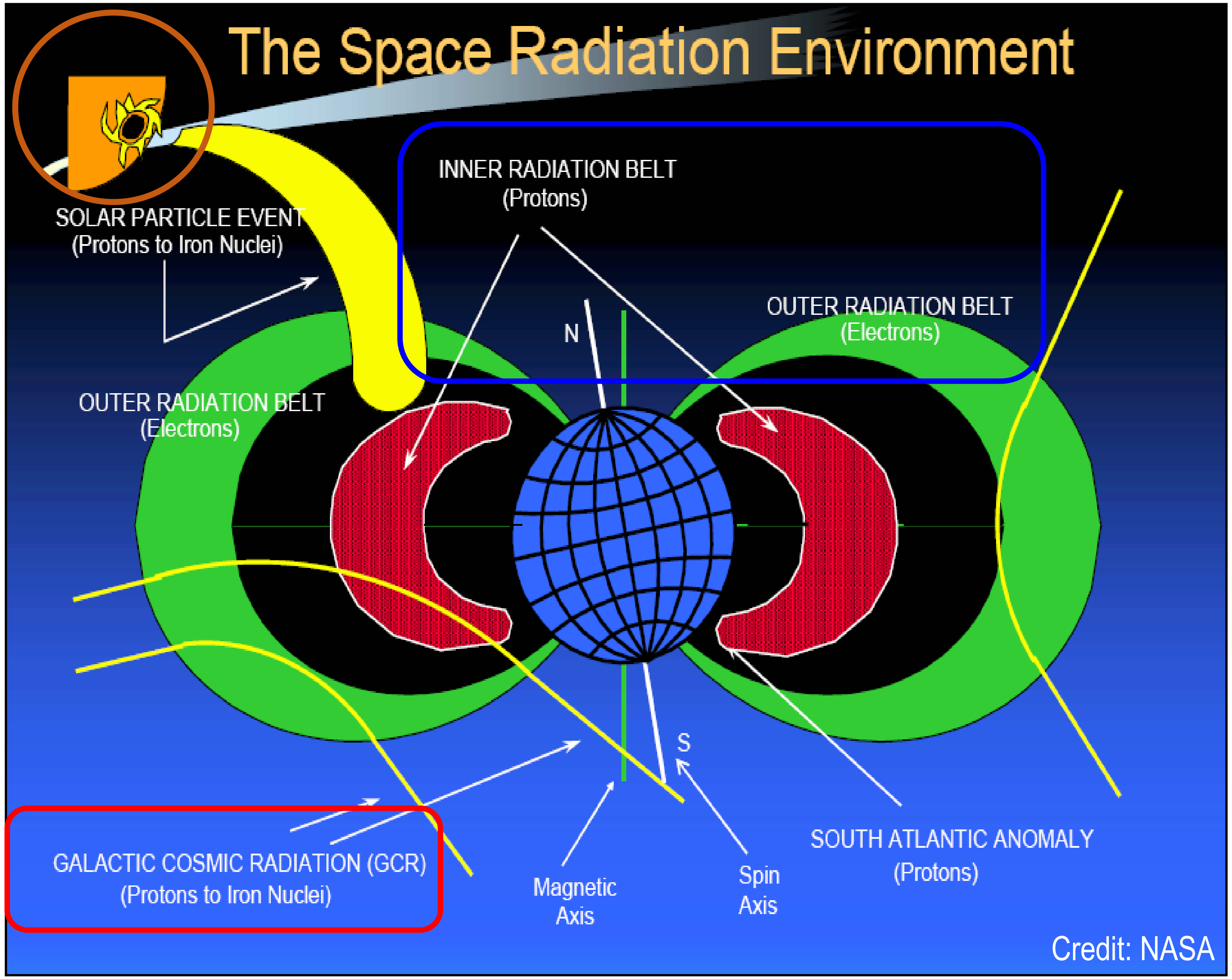
Low energy protons and electrons (for ISS orbit)

- **Beyond Low Earth Orbit (LEO):**

  GCR and SPE

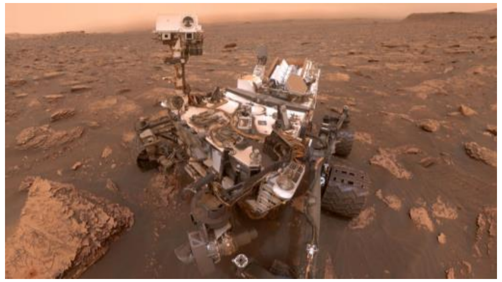
  –no protection from the Earth magnetic field

  –much harsher environment for exploration



Can we use high altitude, long duration scientific balloon experiments as “surrogate” for Mars radiation?

6x10^7 km

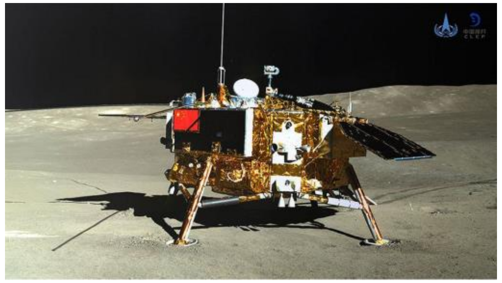


Mars
MSL-RAD

212 µGy/day

Data: MSL-Rad team (Berger et al. *J. Space Weather. Space Clim.* 2020) https://doi.org/10.1051/swsc/2020028

3x10^5 km



Moon
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316 µGy/day

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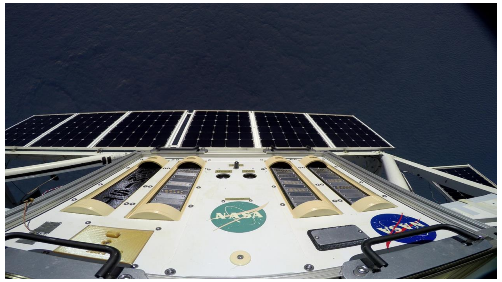

Balloon

?

The DLR M-42 Radiation Detector

Review of Scientific Instruments ARTICLE scitation.org/journal/rsi

The German Aerospace Center M-42 radiation detector—A new development for applications in mixed radiation fields

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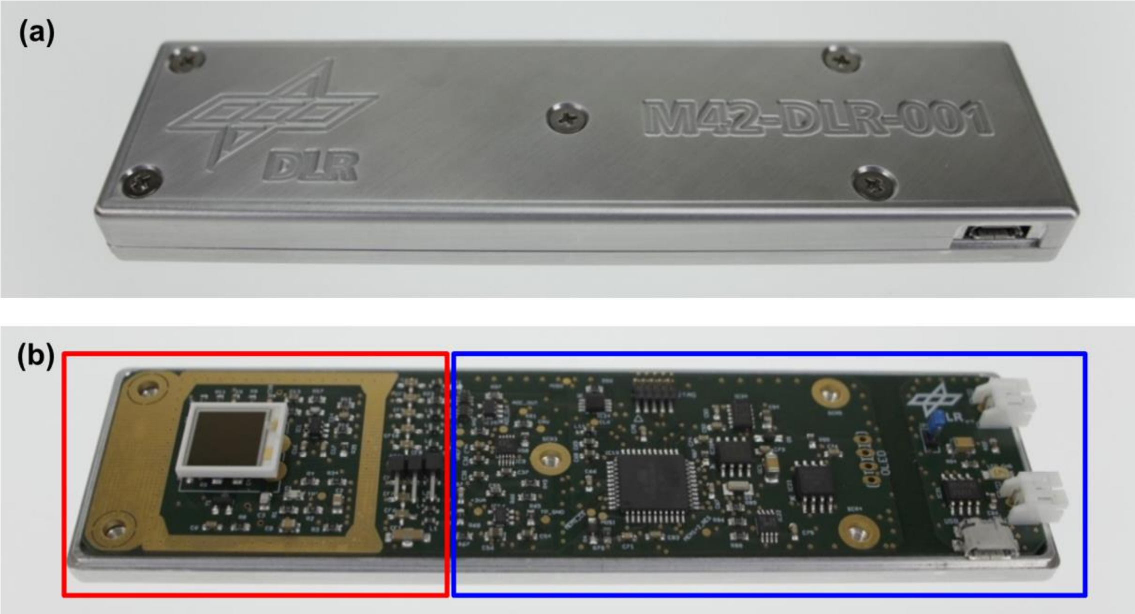
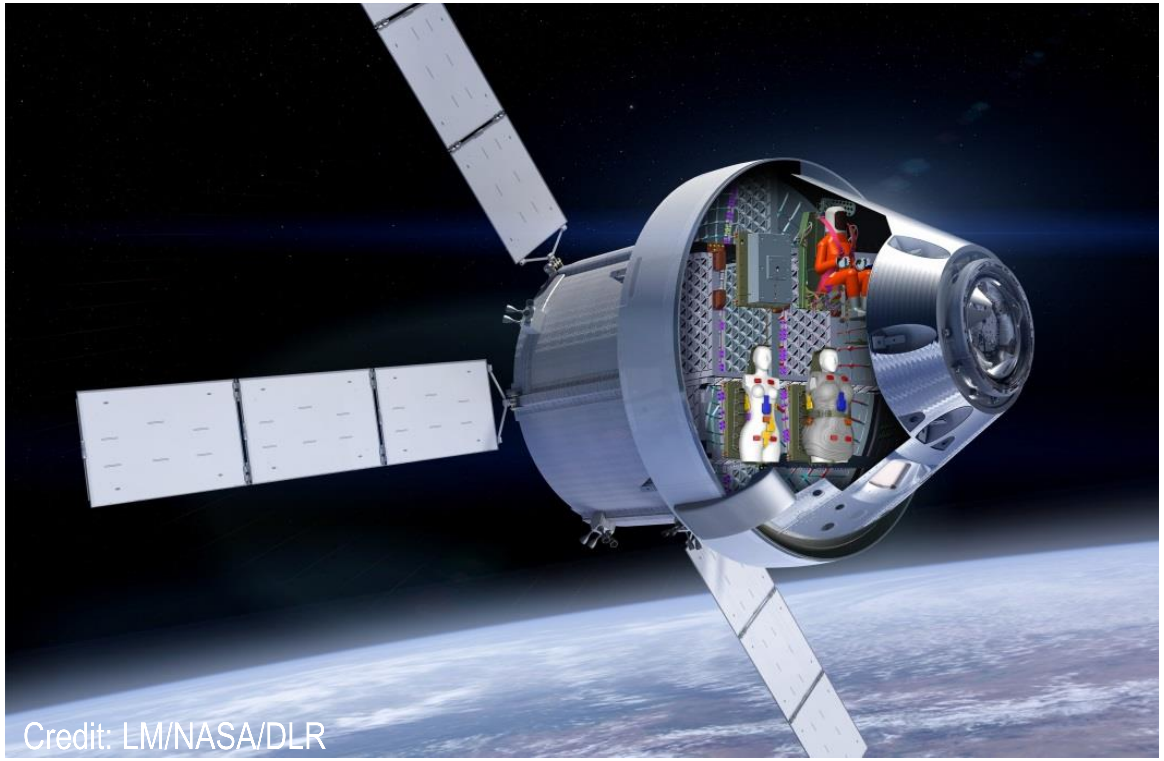
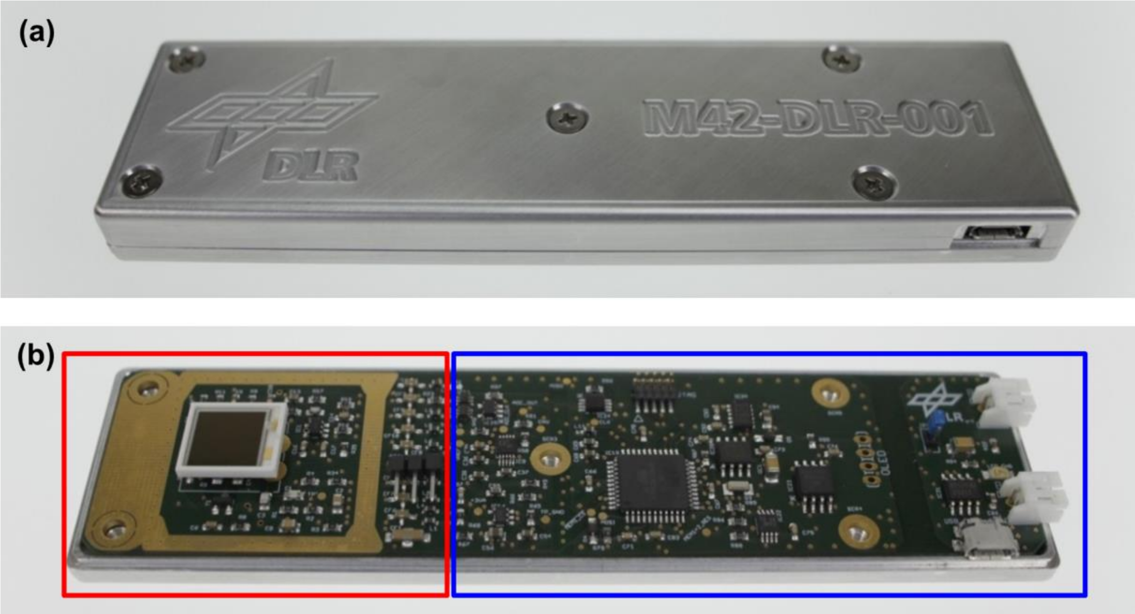


M-42 Aim: The M-42 systems were developed based on the following internal DLR requirements: they should be **small, lightweight, have very low power consumption**, have various **built-in environmental sensors**, such as temperature, pressure, and acceleration, and should be able to be adjustable for the energy deposition range within the radiation detector. At the end, the **system shall be easily adaptable for relevant research purposes and should be and will be used as “plug and play” instruments for radiation protection dosimetry.**

The DLR M-42 Radiation Detector: To be Flown on NASA Artemis I Mission



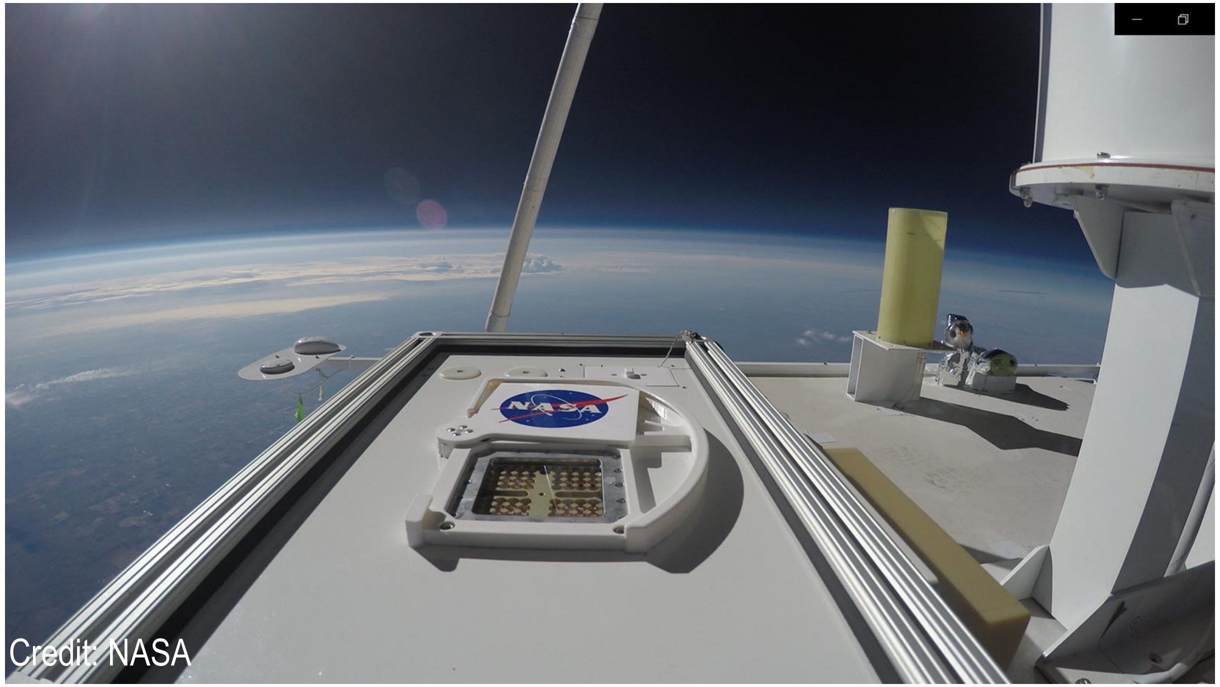


M-42 upcoming mission: Within the NASA Artemis I mission 16 M-42 detectors will be mounted within the two female phantoms HELGA and ZOHAR to record the radiation dose these phantoms receive on the way to and back from the Moon.
See also: Matroshka AstroRad Radiation Experiment (MARE) https://www.dlr.de/me/mare/

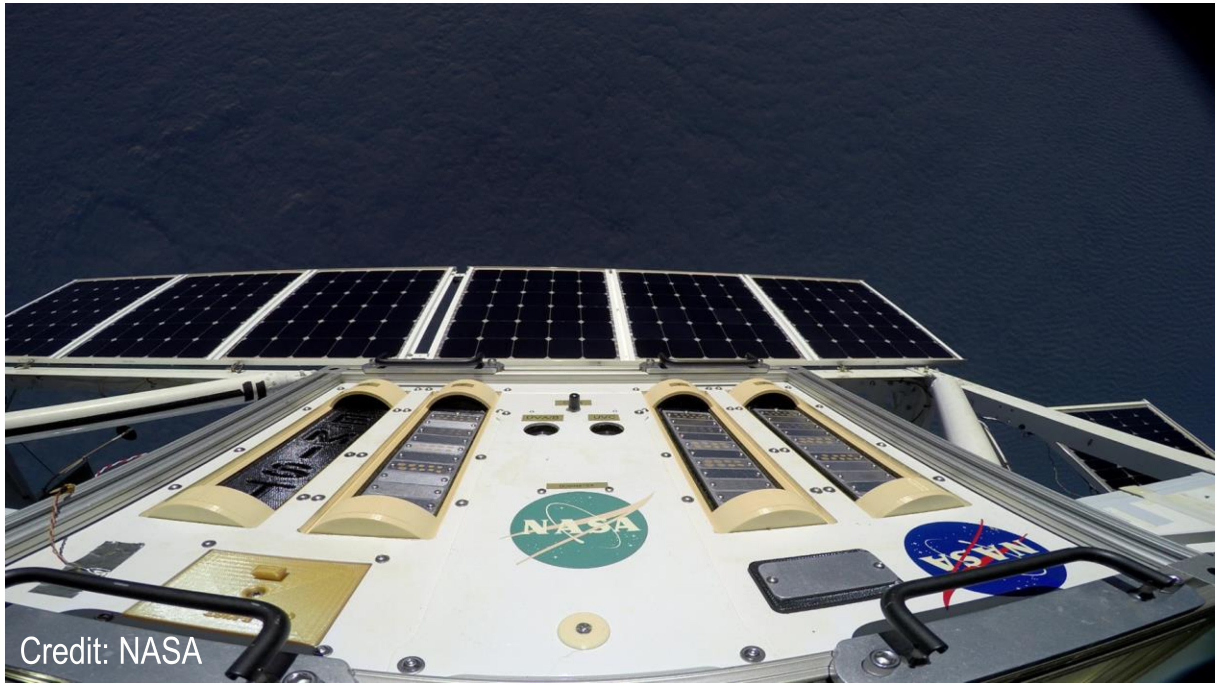
Two long duration balloon experiments carried out in collaboration between NASA Ames and DLR

https://www.nasa.gov/ames/aerobiology/

MARSBOx

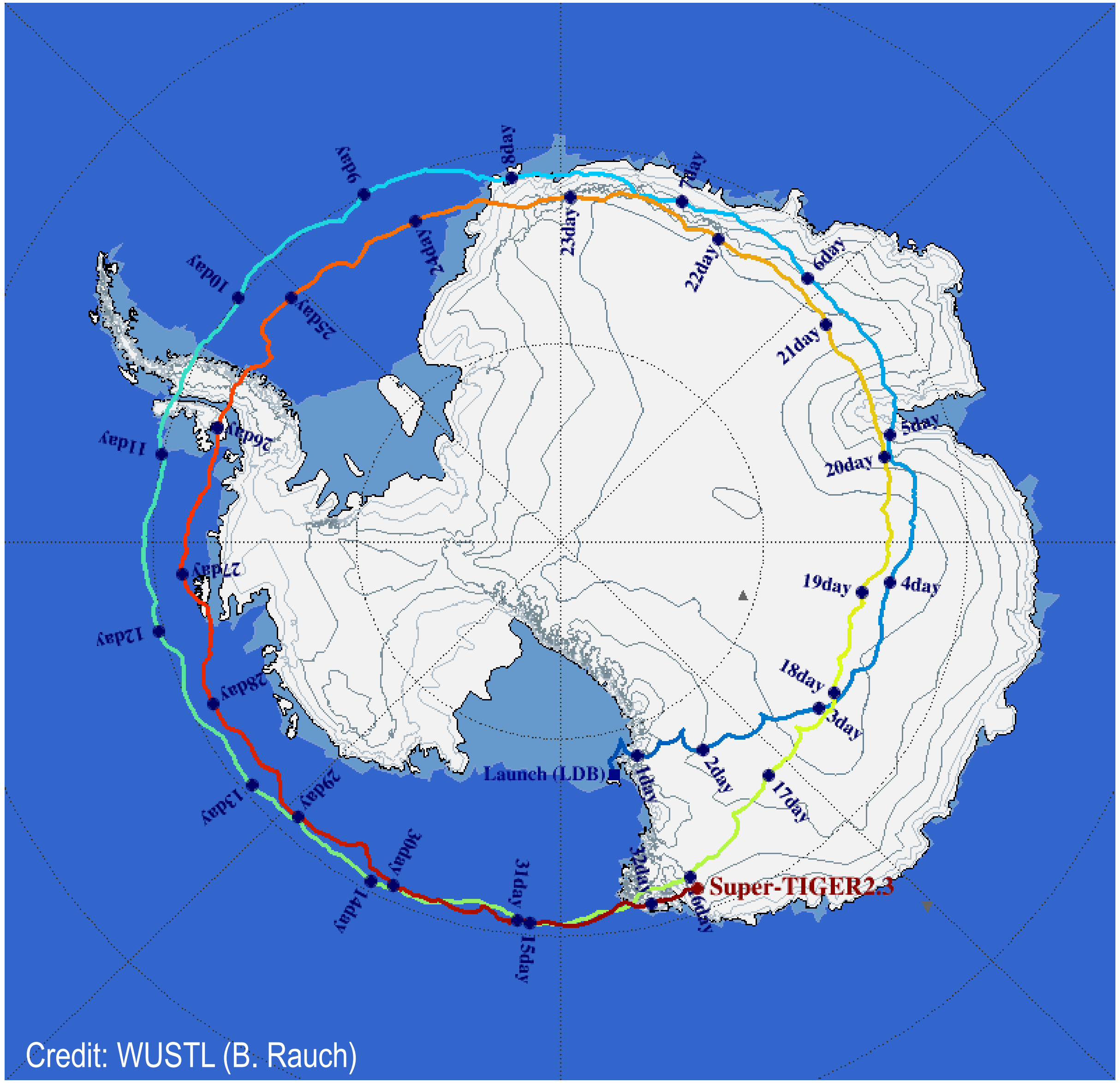


E-MIST



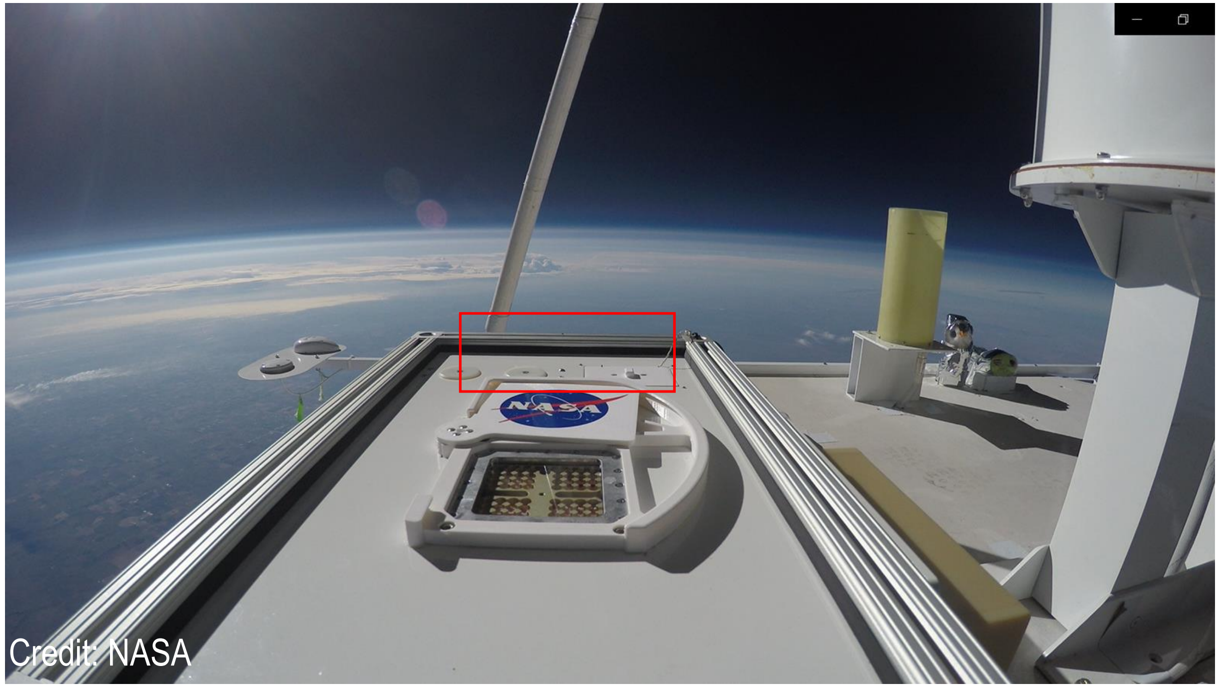
Experiment	Location	Date	R_C
MARSBOx	New Mexico	23 Sept. 2019	4.5
E-MIST	Antarctica	15 Dec. 2019 – 12 Jan. 2020	0 to 1.29

Antarctica: SuperTiger2.3 and E-MIST

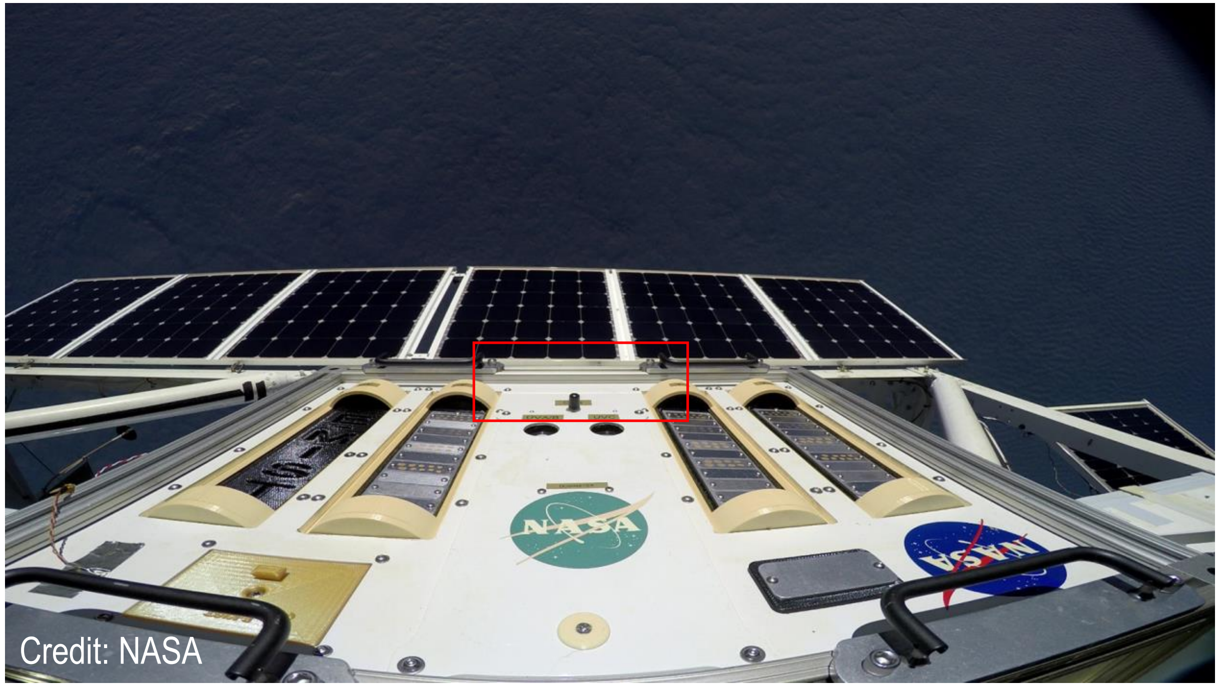


Two long duration balloon experiments carried between NASA Ames and DLR: M-42 Dosimeters

MARSBOx → M-42



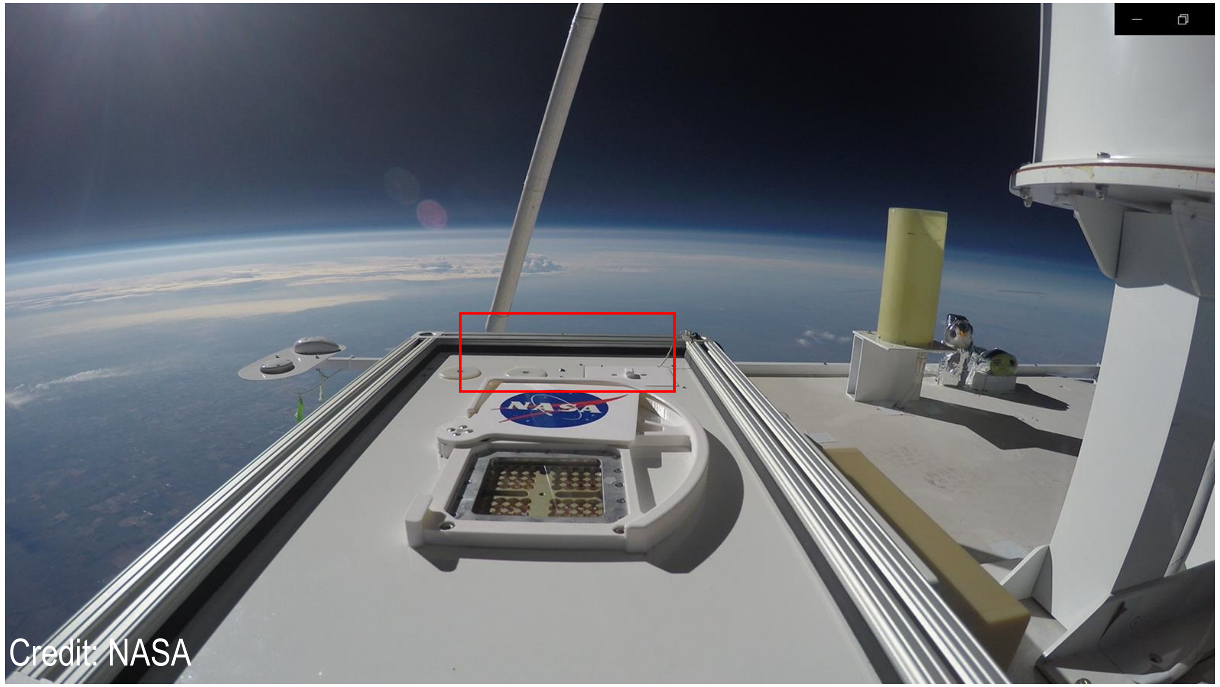
E-MIST → M-42



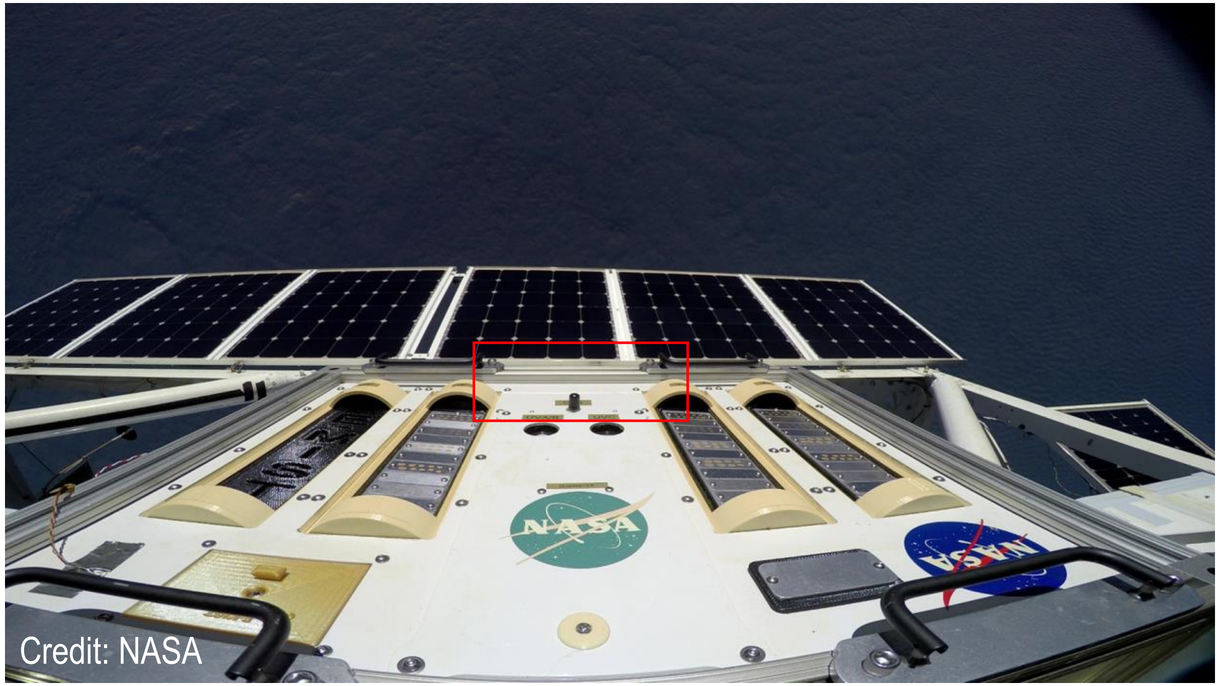
The M-42 dosimetry instruments were connected (power) over USB and switched on after launch of the balloon. Data were stored in the non-volatile memory of the system. Read out of the data was performed at DLR upon return of the instruments.

Two long duration balloon experiments carried between NASA Ames and DLR: M-42 Dosimeters

MARSBOx → M-42



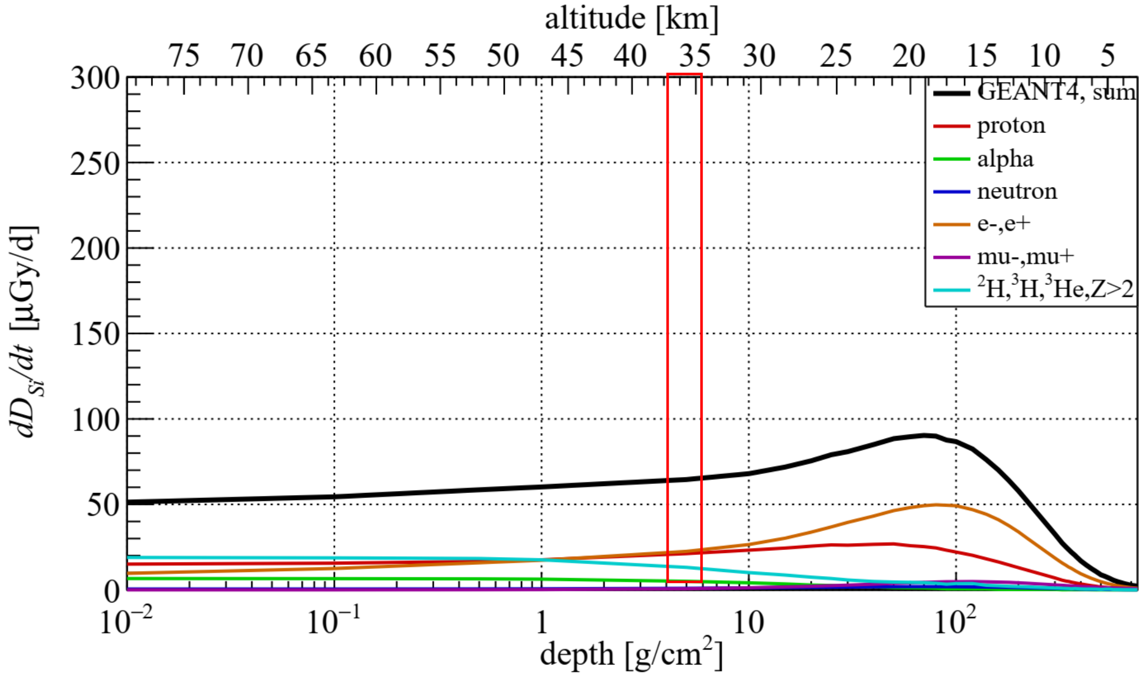
E-MIST → M-42



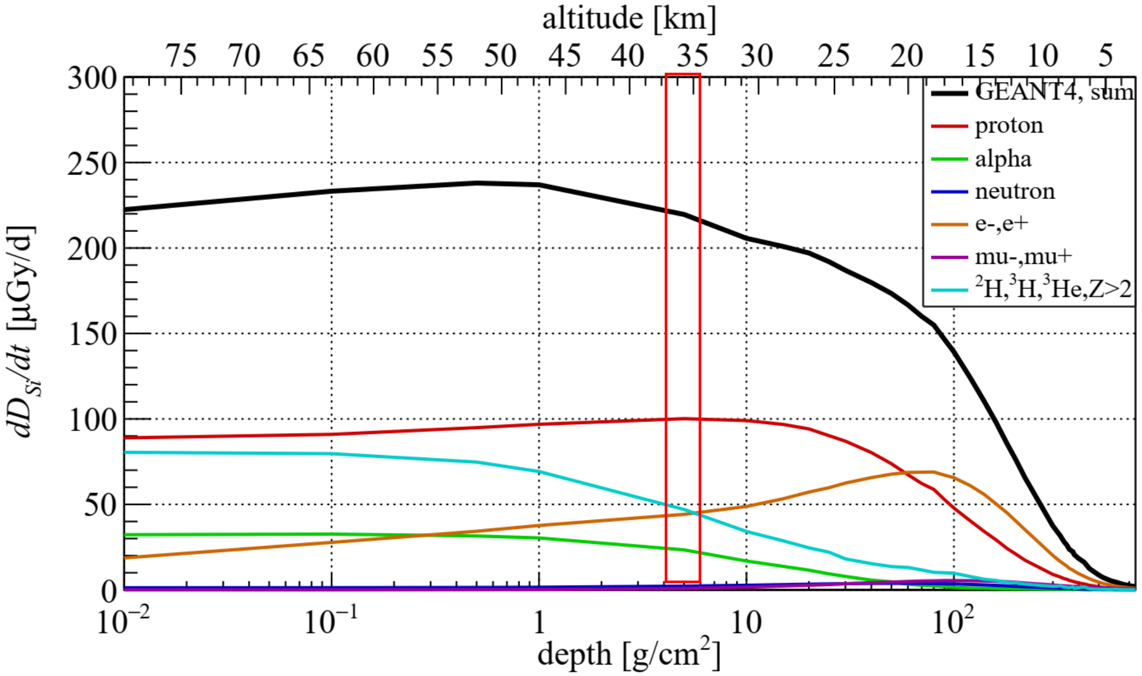
Experiment	M-42 P/N	Integration interval [min]	Measurement time	Data files [#]	Duration [hours]
MARSBOx	001	5	23.09.2019 14:08 – 21:13	766	7.08
E-MIST	003	30	15.12.2019 13:55 – 12.01.2020 14:55	1345	672.5

New Mexico and Antarctica: Difference due to the geomagnetic cut off (R_C) which gives the shielding effect of the Earth magnetic field against incoming galactic cosmic radiation (GCR)

MARSBOx → $R_C = 4.5$



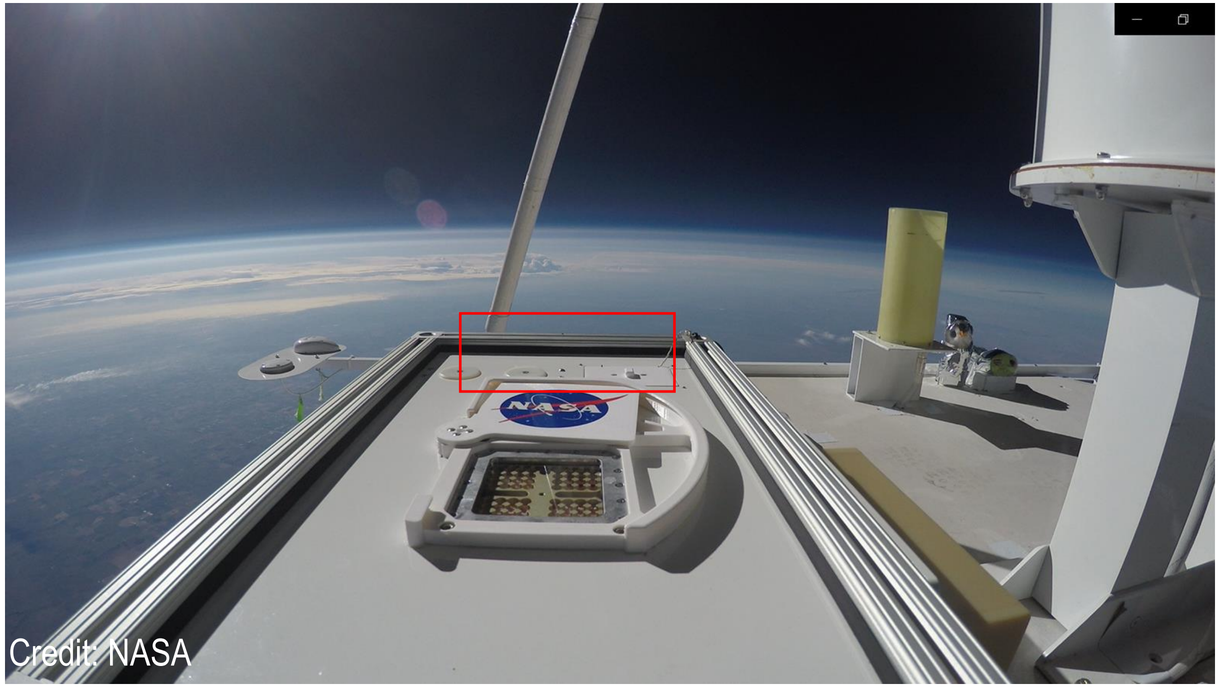
E-MIST → $R_C = 0$



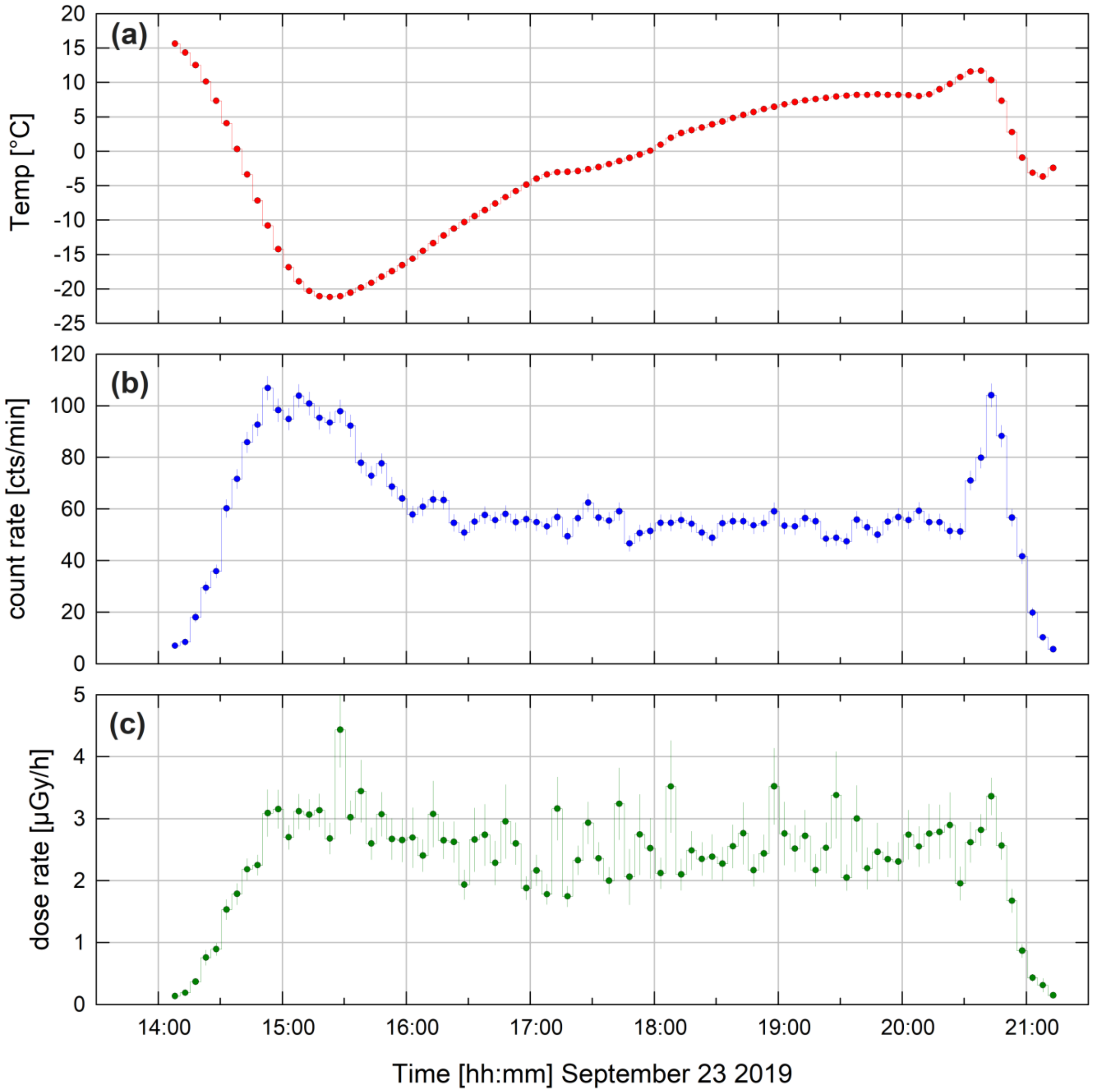
The calculated absorbed dose in Si versus altitude for the New Mexico (*left*) and the Antarctica (*right*) balloon flights.
All calculations performed by DLR (T. Berger et al.)
Note: Flight altitudes are given with *red rectangles*.

Data: New Mexico

MARSBOx → M-42

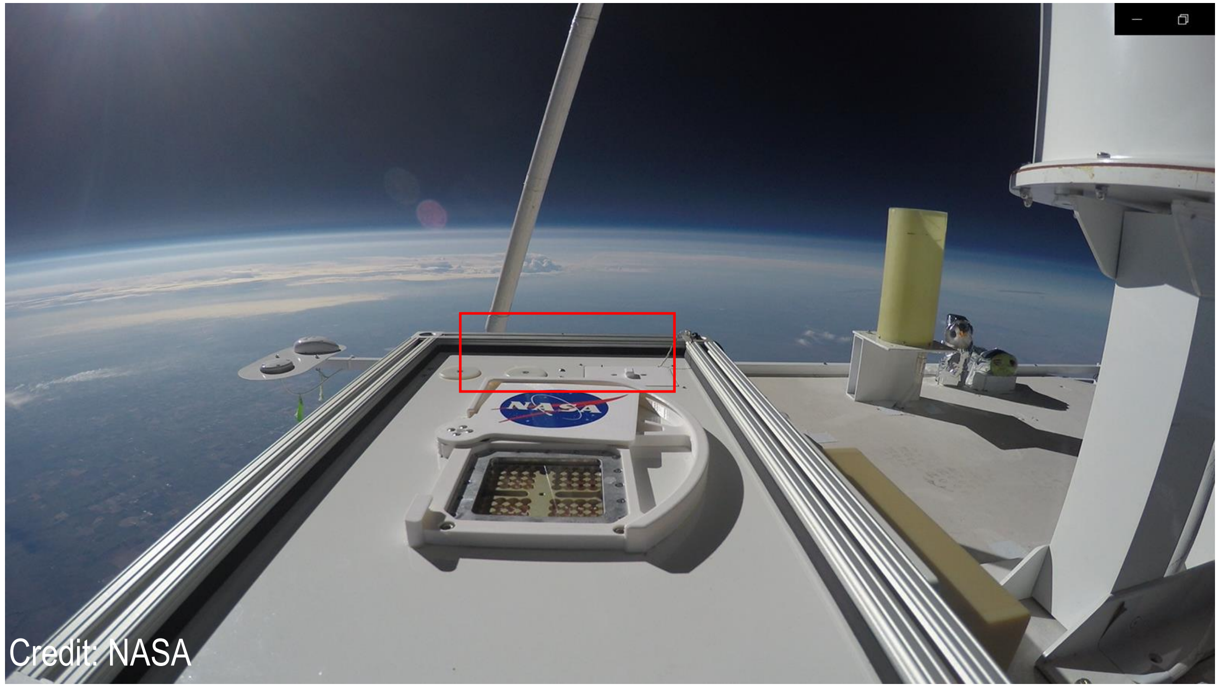


The measured temperature (red), count rate (blue) and absorbed dose rate (green) for the MARSBOx flight on 23 September 23 2019.

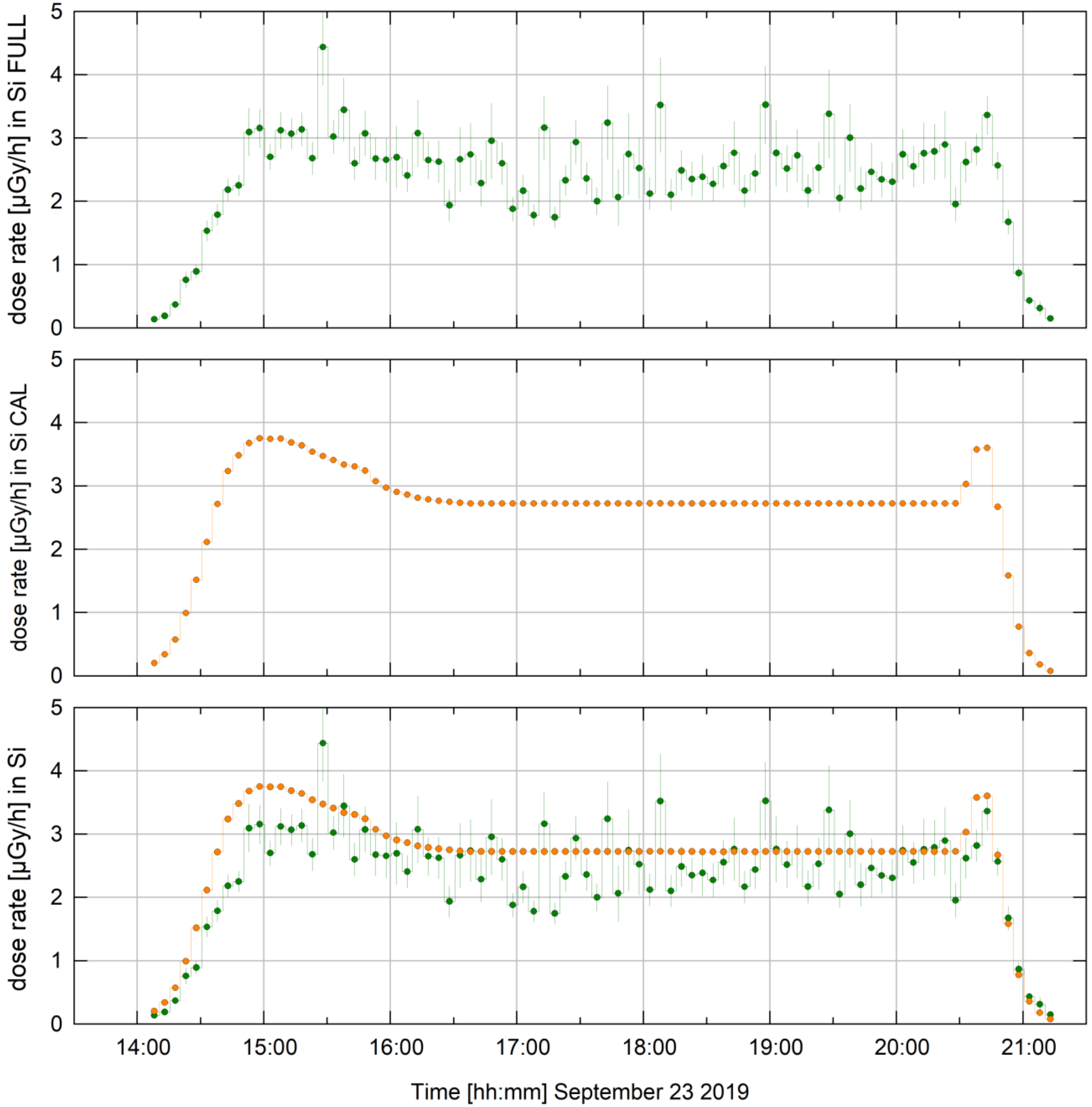


Data: New Mexico

MARSBOx → M-42

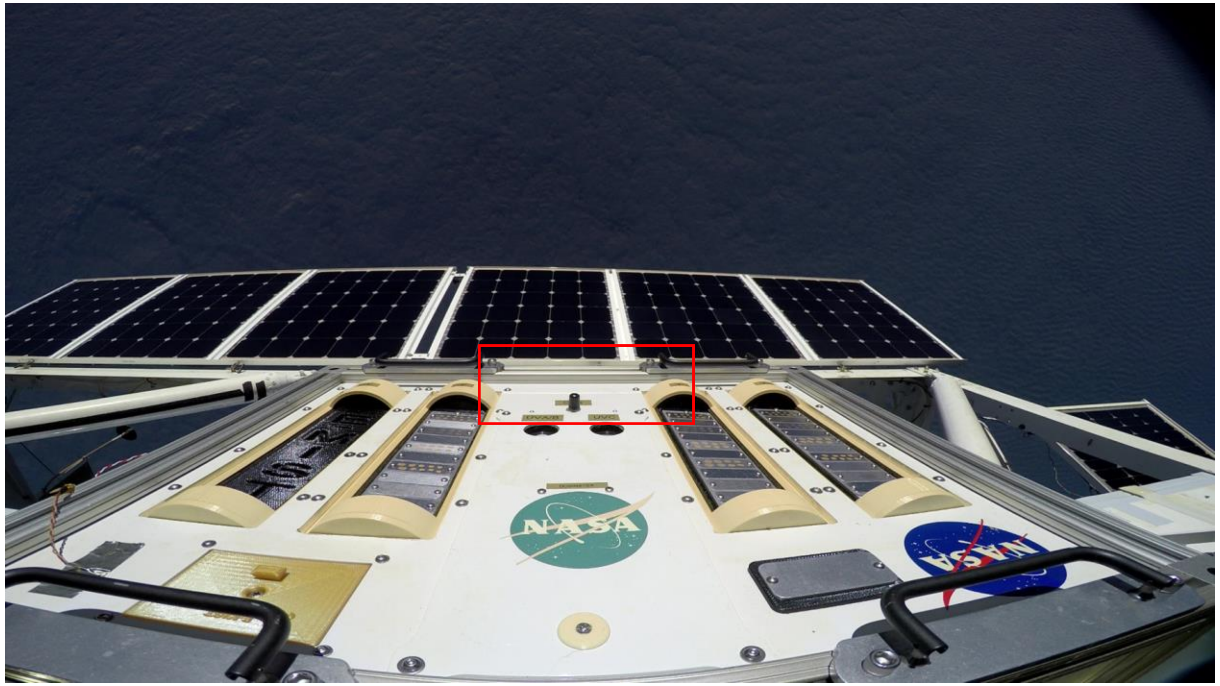


Comparison of measured absorbed dose rate (green) and calculated absorbed dose rate (by DLR) (orange) for the MARSBOx flight on 23 September 2019.

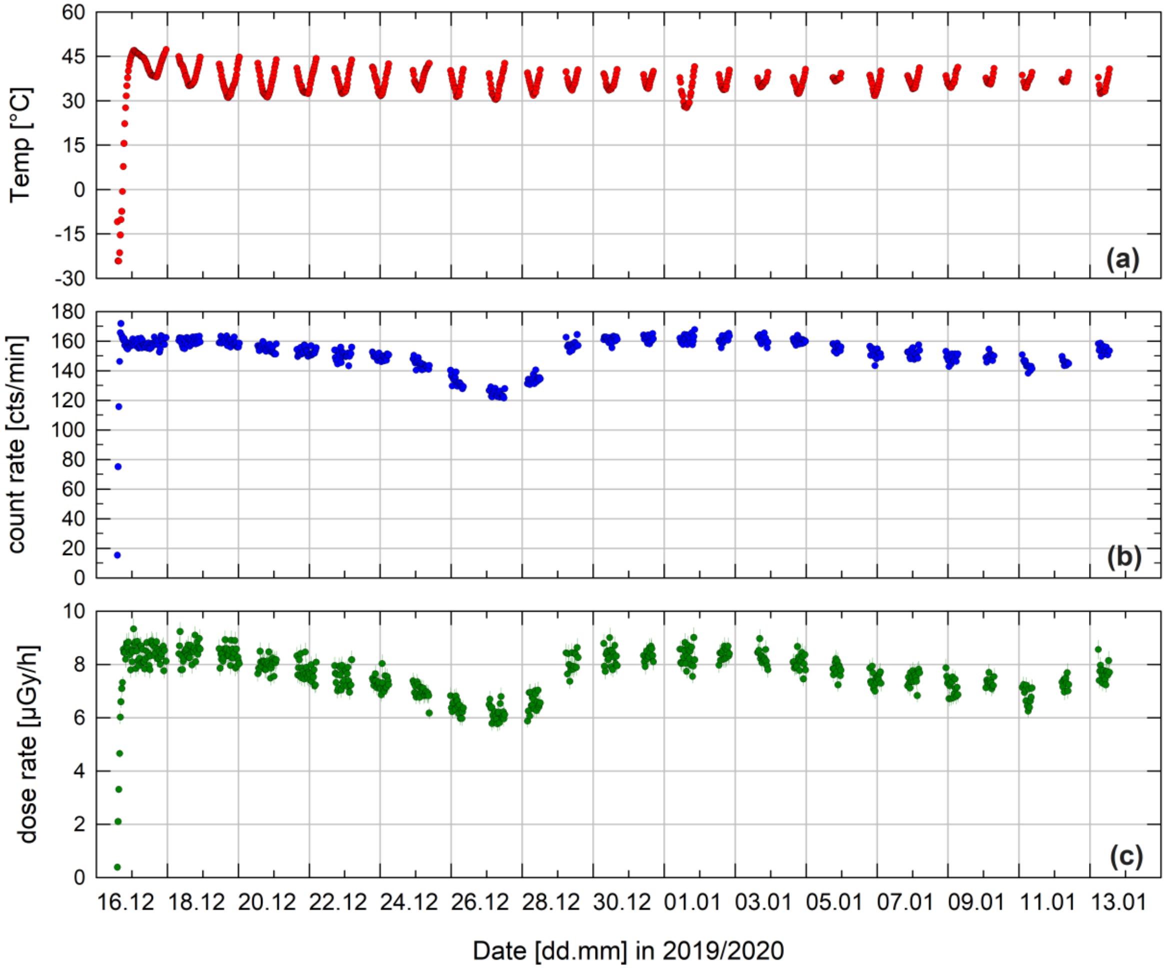


Data: Antarctica

E-MIST → M-42

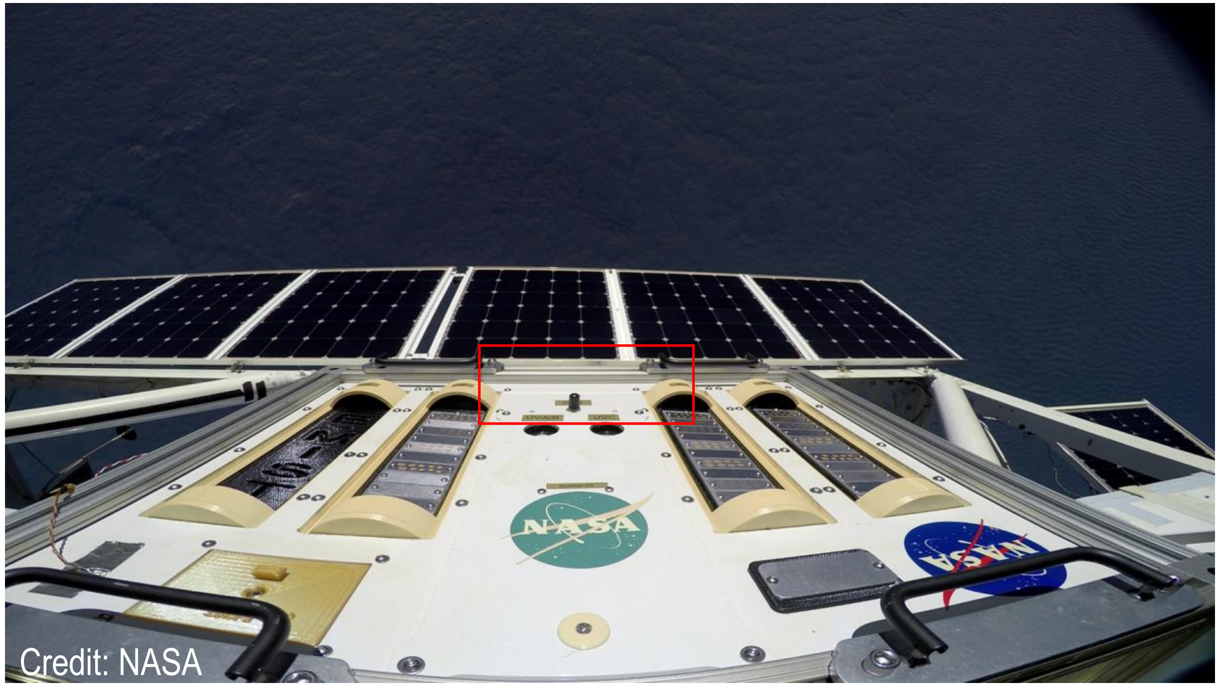


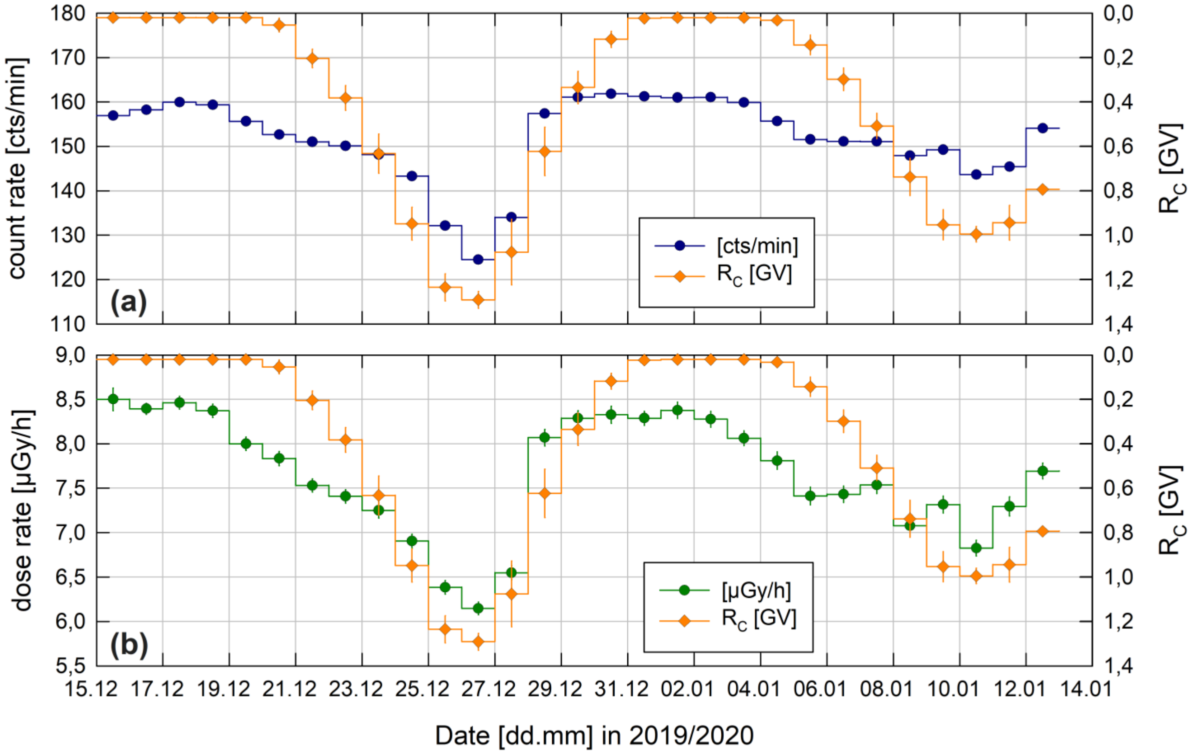
The measured temperature (red), count rate (blue) and absorbed dose rate (green) for the E-MIST flight from 12 December 2019 to 13 January 2020.



Data: Antarctica

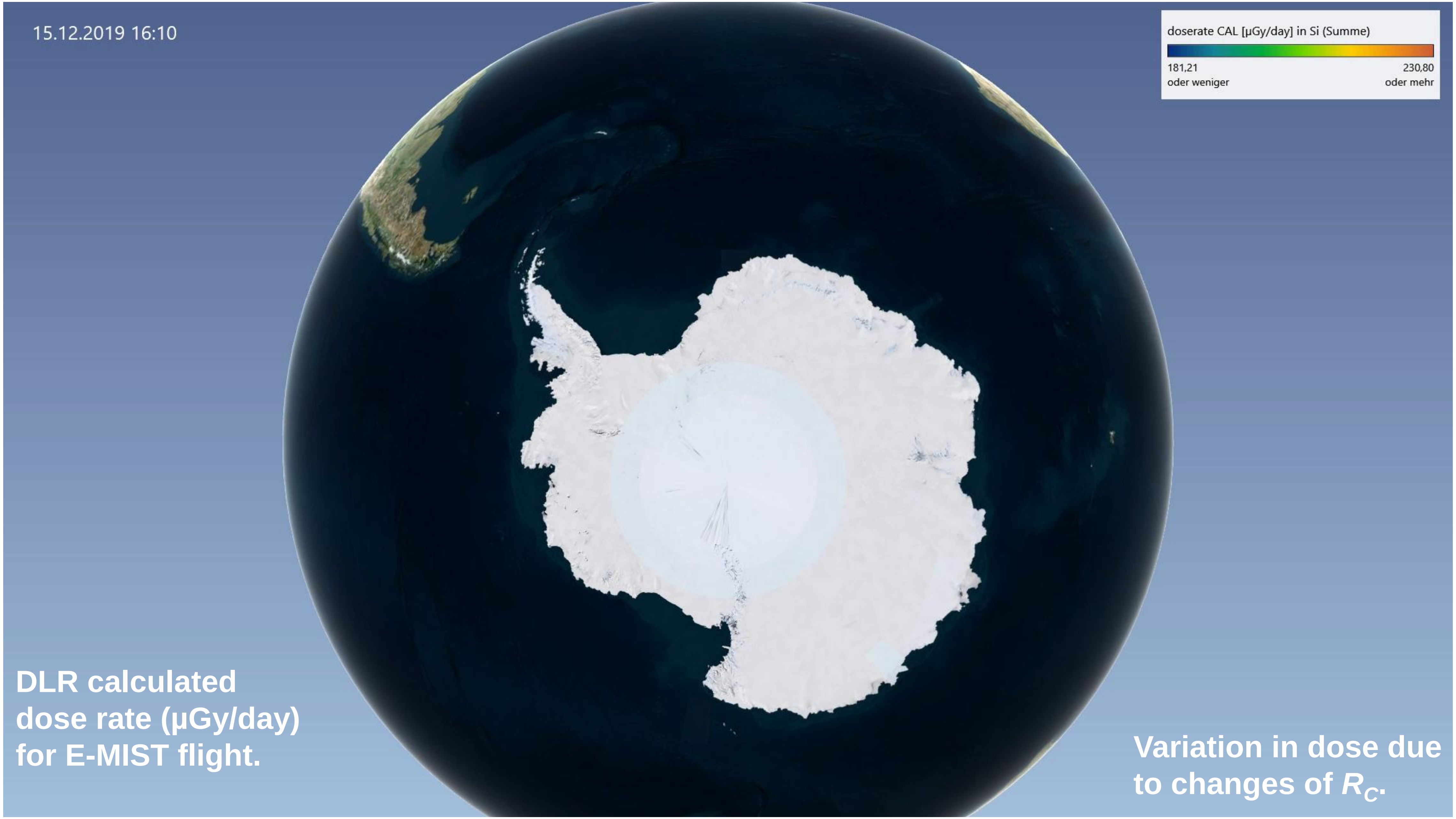
E-MIST → M-42





The measured count rate (blue) and absorbed dose rate (green) in comparison to the cut-off rigidity (*Rc*) for the E-MIST mission.

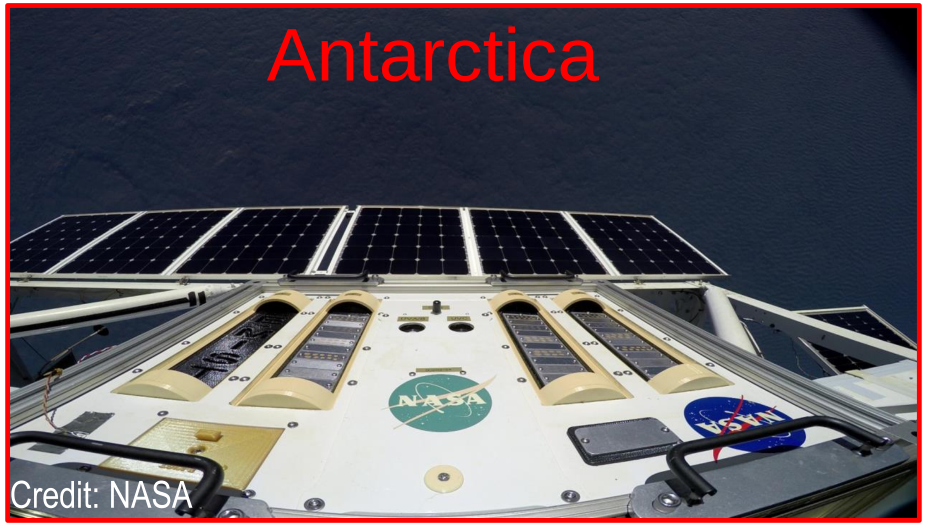
Note: higher R_C → higher geomagnetic shielding for galactic cosmic radiation → decreased dose and count rate

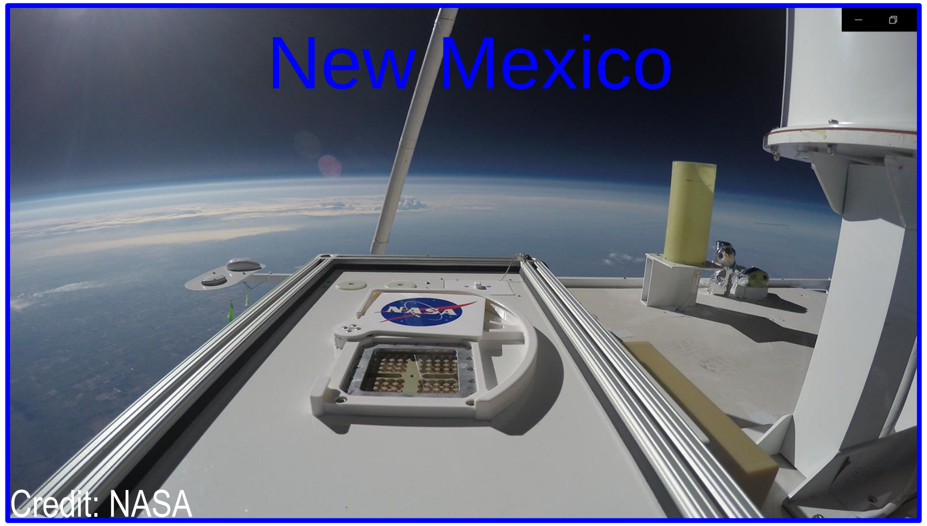


DLR calculated dose rate (µGy/day) for E-MIST flight.

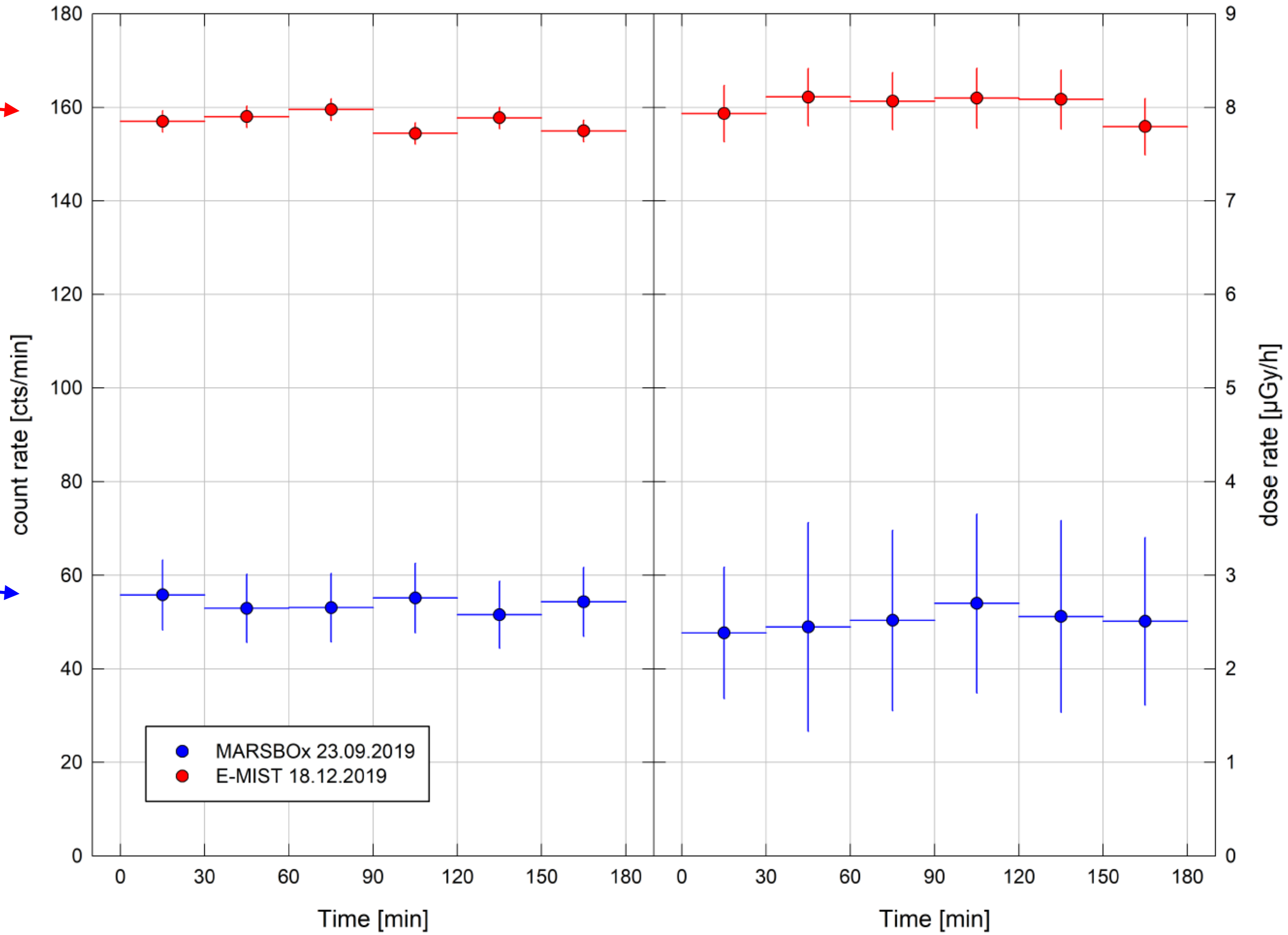
Variation in dose due to changes of R_C.

Comparison: MARSBOx vs. E-MIST (three hours)





Count rate and dose rates for E-MIST (red with R_C= 0) and for MARSBOx (blue with R_C = 4.5)



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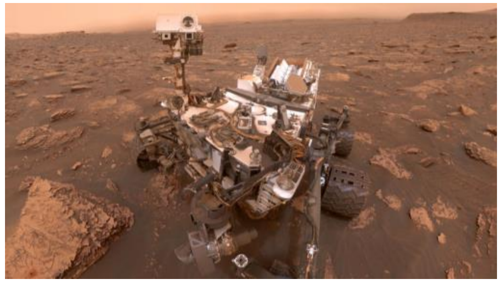
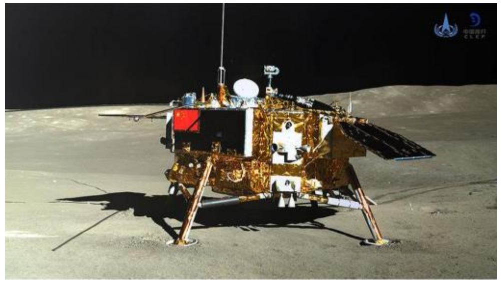


Mars — MSL-RAD — 212 µGy/day

Data: MSL-Rad team (Berger et al. *J. Space Weather. Space Clim.* 2020) https://doi.org/10.1051/swsc/2020028

3×10^{5} km



Moon — LND — 316 µGy/day

Data: LND Team (Zhang et al. *Sci.Adv.* 2020) https://doi.org/10.1126/sciadv.aaz1334

420 km

ISS — DOSTEL — 278 µGy/day

124 µGy/d GCR

154 µGy/d SAA (only for ISS)

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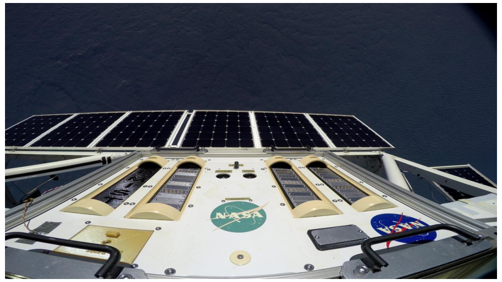
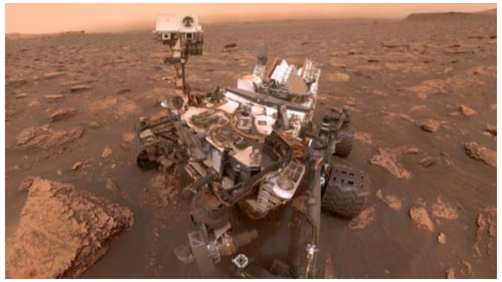


Balloon

?

Can we use high altitude, long duration scientific balloon experiments as “surrogate” for Mars radiation? → **YES**

$6x10^{7}$ km



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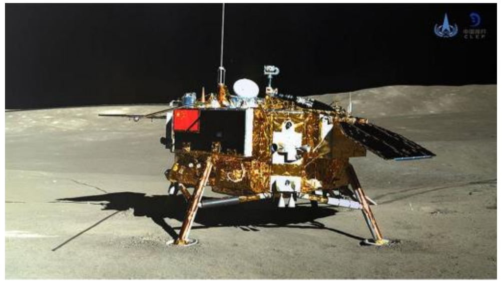

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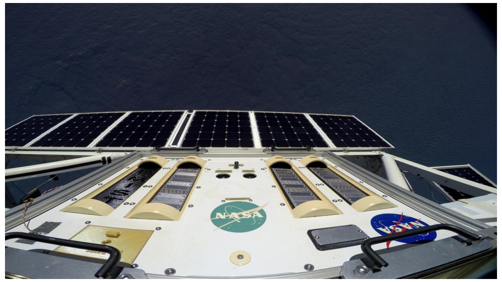

Balloon 192 µGy/day — Antarctica E-MIST

Balloon 60 µGy/day — New Mexico MARSBOx

Data: NASA Ames and DLR Team (to be submitted to *J. Space Weather Space Clim.)*

NOTE: All data provided within this presentation are preliminary and in review.

Thomas Berger, Karel Marsalek, Bartos Przybyla, Daniel Matthiä, Joachim Aeckerlein, Markus Rohde, Michael Wirtz, Ralf Möller, Leandro James, Michael Lane, Prital Johnson, Marianne Sowa and David J. Smith "*On the radiation environment during consecutive balloon flights over New Mexico and Antarctica*" will be submitted to the **Journal of Space Weather and Space Climate** (https://www.swsc-journal.org) in late October 2020.

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