Determining the Best Time to Send Humans to Mars

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Introduction

Astronaut safety is a top priority of space travel missions. A number of factors must be considered to maintain their safety, especially those regarding space weather. Space weather can originate from inside our solar system (SPE (solar particle events)) or outside our solar system (GCR (galactic cosmic rays)). Astronauts are more suseptable to SPE and GCRs en route to Mars because of a lack of Earth's magnetosphere. **This poster focuses on solar storms, solar cycles, and galactic cosmic rays relative to a spacecraft's position.**

Baseline Radiation Exposure

- human exposure on Earth surface is 6.2 mSv annually (EPA, 2024)
- human exposure en route to Mars is 1.8 mSv a day (Wallace & NGO, 2023)
- NASA's preset exposure limit is 600 mSv (George, 2024)

Solar Particle Events & Mars Travel

- sunspots are an indicator of SPE
- solar flares & CME occur most often at solar max
- sunspot number (ssn) is highest at solar max

To specifically avoid SPE, Mars travel should not occur during solar max when both CME and solar flares are most active.

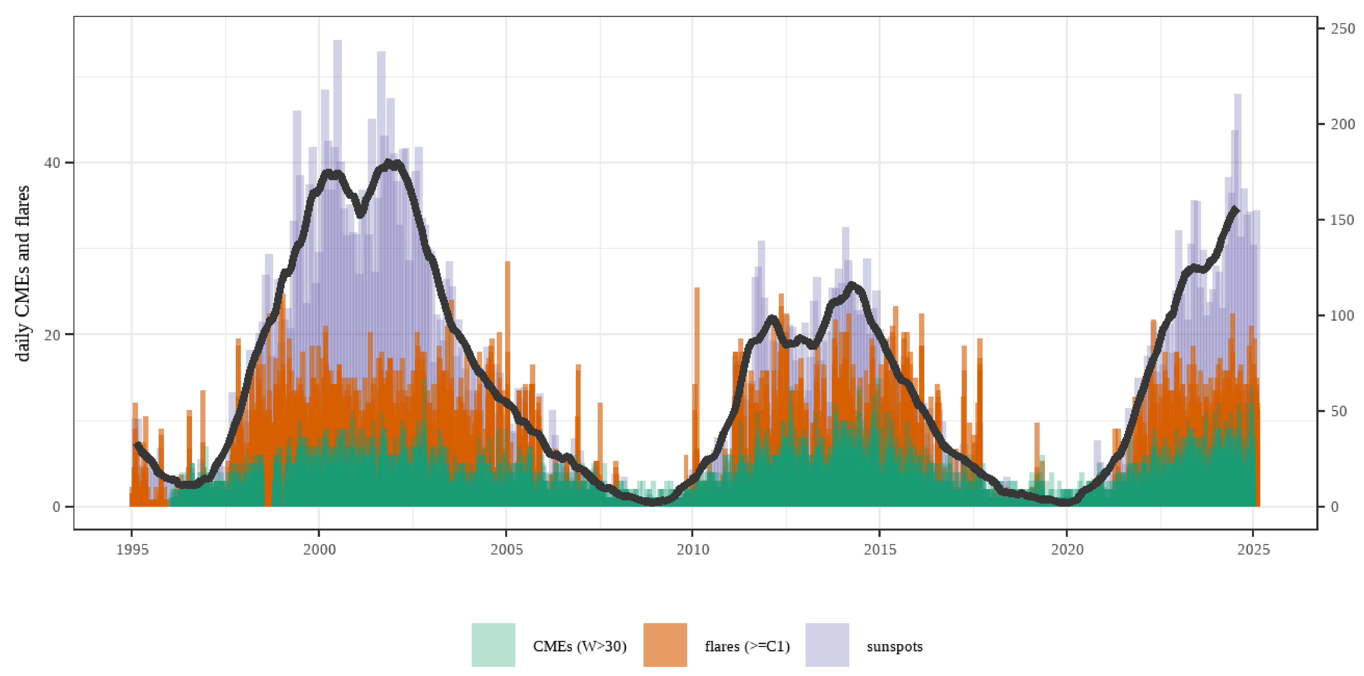

Figure A. Comparison of CME, solar flares, and sunspots.

Solar Cycles & Mars Travel

- solar cycles ~ 11 years
- Hohmann Mars launch windows ~ 26 months
- adverse conditions more likely to occur at solar max

Ideal launch windows are reduced due to timing with the solar cycle.

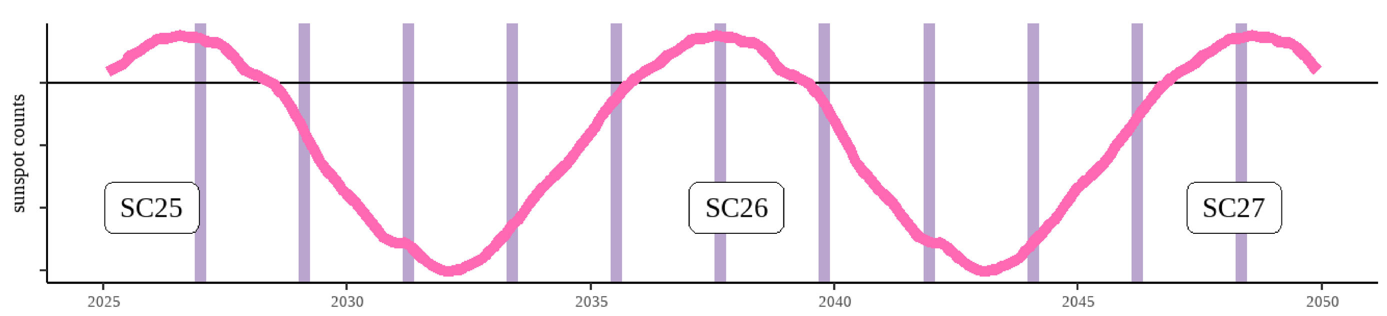

Figure B. Predicted solar cycles (pink) compared to Mars launch windows (purple).

Galactic Cosmic Rays & Mars Travel

GCRs are highly energetic particles traveling through space, originate from outside our solar system, and pose a hazard to astronaut health.

- increase risk of cancer for affected astronauts
- have the lowest flux at solar max due to an intense solar magentic field resulting from CME

To avoid GCRs, do not travel to Mars during solar minimum.

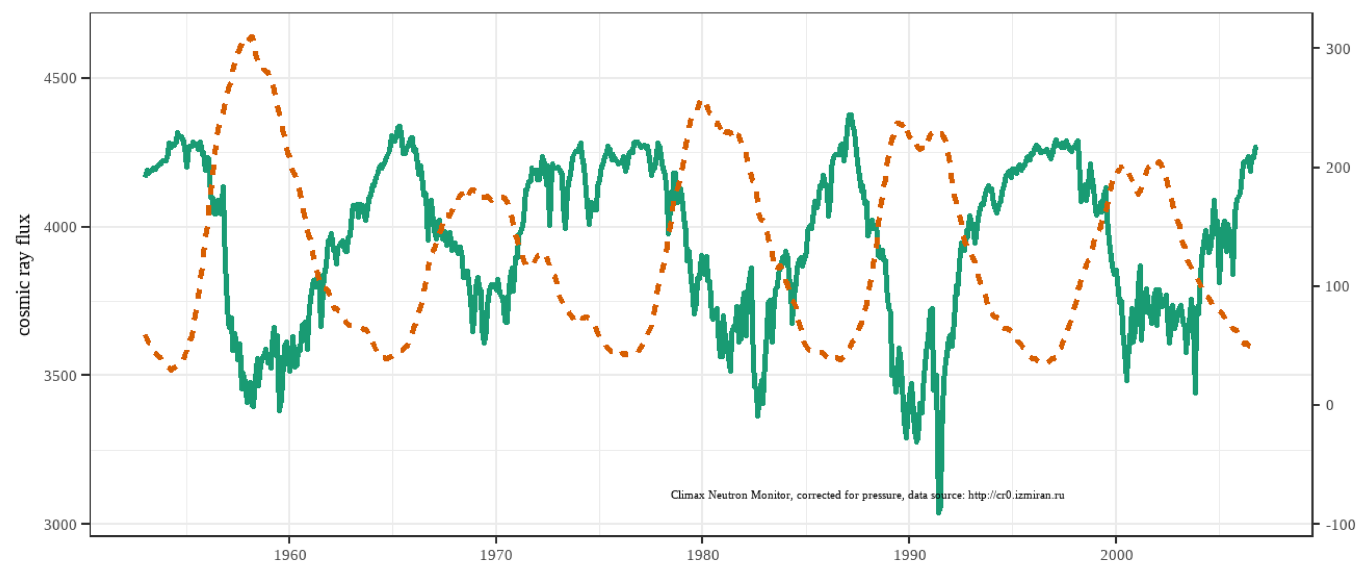

Figure C. Cosmic ray flux (green) from neutron monitors versus sunspot number (red).

GCRs and Sunspot Correlation

Cosmic rays were expected *a priori* to be inversely related to solar sunspot activity. Correlgram analysis confirmed this expectation and indicated that cosmic rays minimum lagged solar sunspot maximum by **7 months** when correlations were most negatively related.

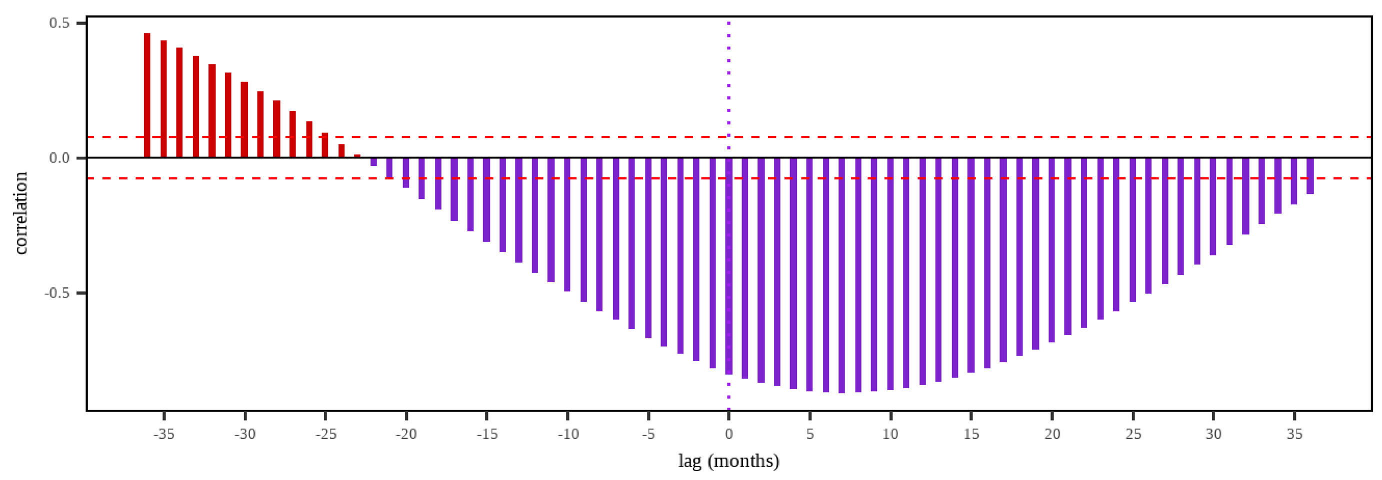

Figure D. Cosmic ray flux and solar sunspots correlation. Positive correlations (red) and negative or inverse correlations (purple) are observed. Horizontal lines indicate upper and lower limits; if data crosses these lines, it is significant. The most significant, negatively correlated data is observed when lagged 7 months.

Summary

To mitigate GCRs, travel to Mars should occur **7 months** after solar max. To mitigate SPE radiation, travel should occur during solar min. GCRs are a more concerning factor than SPE; SPE can possibly give warning or are short-lived. A hybrid of these conclusions should be created to find the best launch window for the lowest radiation exposure on a given mission to Mars.

Results are of interest to astronauts, space agencies, mission planners, system engineers, space weather professionals, and enthusiasts.

Bio

Briley Griffin is a Junior at Rock Creek High School in St. George, Kansas, USA. She is an Ambassador to the Al Worden Endeavour Scholarship (upper right hex logo). As part of Mission Team #20: USA, she created this logo with the help of her teammates. She plans on attending college for a science field in the fall of 2026. This poster serves as her Senior Exit Project, a graduation requirement at her high school.

Figure E. Briley standing next to ATLAS comet in October.

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Data for this study was obtained from

- NOAA SWPC https://www.swpc.noaa.gov
- CDAW Data Center https://cdaw.gsfc.nasa.gov
- Hong Kong Observatory https://www.hko.gov.hk/en/index.html
- United States Environmental Protection Agency https://www.epa.gov

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Wallace, C. S., & NGO, W. (2023). Journey to mars and cosmic radiation. Retrieved July 15, 2023, from https://www.hko.gov.hk/en/education/space-weather/effects-of-space-weather/00703-Journey-to-Mars-and-Cosmic-Radiation.html