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MANNED MARS MISSION
SOLAR PHYSICS:
SOLAR ENERGETIC PARTICLE PREDICTION AND WARNING

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ABSTRACT

There are specific risks to the crew of the manned Mars mission from energetic particles generated by solar activity. Therefore, mission planning must provide for solar monitoring and solar activity forecasts. The main need is to be able to anticipate the energetic particle events associated with some solar flares and, occasionally, with erupting filaments.

A second need may be for forecasts of solar interference with radio communication between the manned Mars mission (during any of its three phases) and Earth.

These two tasks are compatible with a small solar observatory that would be used during the transit and orbital phases of the mission. Images of the Sun would be made several times per hour and, together with a solar x-ray detector, used to monitor for the occurrence of solar activity. The data would also provide a basis for research studies of the interplanetary medium utilizing observations covering more of the surface of the Sun than just the portion facing the Earth[1].

THE RISKS

Severe injury or even death can result from exposure to solar energetic particles. The Earth's magnetosphere and atmosphere protects us on the surface of the Earth. In space, beyond the Earth's magnetosphere, there is no equivalent protection except for that offered by the spacecraft itself.

Energetic particles exist in negligible fluxes at all times. However, occasionally the Sun emits bursts of these "solar cosmic rays" in fluxes sufficient to cause the above-mentioned risks. When this happens, the particles travel outward into the solar system at a large fraction of the speed of light, with a flux that falls off inversely with the square of the distance from the Sun. It takes at least 15 to 20 minutes for them to reach the Earth, corresponding approximately to at least 30 minutes to reach Mars. The "events" can last up to several days.

THE SOLAR PHENOMENA

The solar events are flares and erupting filaments.[2,3,4] A flare occurs in a solar active region around a sunspot group. A filament lies along a neutral line dividing regions of oppositely directed photospheric large scale magnetic field.

Flares can be directly observed in the hydrogen-alpha spectral line and regular solar flare patrols are made at several observatories around the world. These same observatories monitor the appearance, maturation, and death of sunspots and the general evolution of the sunspot cycle. The relationships between flares and sunspots is well enough understood so that flare forecasts and warnings now are issued daily, in the form of a prediction of the probability that a flare of a particular magnitude will occur and whether there will be energetic particles. These predictions are significantly better than guesswork.

Erupting filaments normally produce fewer energetic particles than do flares - although not always. It is only in recent years that the role of erupting filaments in the overall picture of solar activity has been even appreciated. Filaments are monitored along with sunspots but, although it is possible to assign a probability to filament eruption, no predictions are presently being made for filament eruptions.

Filaments and sunspots are rooted in the photosphere of the Sun so that they rotate with the Sun - which goes through one complete revolution every 25.5 days (sidereal). Thus, the activity would only be on the disk of the Sun for 12.75 days out of any given solar rotation - or half the time. This reduces the risk from isolated activity because the energetic particles are beamed out into space but cannot travel around the limb of the Sun. Unless extremely close to the limb, any activity behind the limb would have no life-endangering effects. However, there is often more than one activity center on the Sun so that the sum of risks from each individual center needs to be considered.

In conjunction with the monitoring of filaments and flares, the entire menagerie of solar phenomena is observed and mapped daily. Most data is collected from the Earth's surface, although energetic particles and whole-disk x-ray emission are observed from space. By the time of the manned Mars mission, there will be x-ray telescopes and coronagraphs in orbit that are dedicated to synoptic solar observations for the purpose of monitoring and forecasts.

SOLAR ASTRONOMY

Solar optical observations show the photospheric structure of the Sun and, with simple filters, map the large scale magnetic field structure, sunspots, filaments, and flares. During a large part of the transit, the side of the Sun exposed to the spacecraft will be invisible from the Earth. Observations of the sun in the hydrogen-alpha spectral region would therefore be necessary for solar flare/erupting filament prediction and warning. These observations would be made during all three phases of the mission. A second option would be to place at least two spacecraft in 1 AU orbits but evenly separated in longitude with respect to the Earth. These two options are evaluated in Table 1, with a preference being indicated for placing a solar telescope on the Mars Mission spacecraft due to transmission delays in the second option.

Additional solar observations are possible with more complex instruments - including magnetic field and velocity measurements. However, it is probable that these observations would be more efficiently and accurately made from Earth orbit spacecraft.

The inclusion of a 25- to 40-cm telescope for solar observations with supporting equipment such as special filters will make possible many interesting non-solar observations. The position of several of the solar system bodies may be tracked with exceptional accuracy. Planets can be observed to determine their albedo in the UV and visible ranges. Opportunities may occur for the observation of stellar occultation by the outer planets, and ephemerides should be developed for these observations. Other opportunities may occur for the observation of cataclysmic variables.

CONCURRENT OBSERVATIONS

In order to utilize the solar observations for research purposes, concurrent observations of other solar and interplanetary processes will be made from the manned Mars mission. The intent is to make a coordinated set of scientific observations aimed at solving specific problems. The problems that can be addressed deal with the interaction between solar particulate and electromagnetic emissions and the dynamics and evolution

TABLE 1

OPTIONS

Requirement	Observation and prediction of solar activity that may affect the Manned Mars Mission
Solution	Observation and monitoring of the portion of the Sun facing towards the spacecraft at all times during mission
Options	1. Solar observatory on spacecraft 2. At least two other solar observatories in orbit around the Sun at 120 and 240 degrees away from the Earth, at 1 AU.
Recommendation	Option 2 would permit observation of the entire Sun at all times. It would also require at least a 30 minute delay time between detected activity and notification of the Mars Mission. Therefore, option 1 seems to be the only viable choice.

of the Martian atmosphere. Of particular interest are upper atmospheric dynamics and chemistry because this will show what is happening to the water in the atmosphere.

Some coordinated experiments are shown in Table 2[1].

SPACE ENVIRONMENT SERVICES CENTER (DOC/NOAA/ERL/SEL)

Space environment services are provided by this agency (SESC) for the entire U.S. -- both civilian and military. Their activities are briefly summarized in Tables 3 through 7. Their services are essential to the Mars mission because they provide ongoing interpretation of the state of the Sun and both short and long term predictions. They would use the observations made from the Mars mission to assess current risks. They are analogous to the Weather Bureau providing weather conditions and forecasts to the whole continent as a supplement to the observations made and broadcast by a local TV station. The TV station can tell if there is a tornado right now, but the Weather Bureau provides warnings to be on the lookout for a tornado in 6 hours[5].

TABLE 2

COORDINATED EXPERIMENT PACKAGE (INCOMPLETE)

Instrument	Location
Magnetometer and plasma detector to measure interplanetary parameters	Orbiter
Low energy plasma analyzer to measure ionospheric dynamics/constituents	Free Flying Low Orbiter
Ionospheric topside sounder	Orbiter
Ionosonde	Surface
Lidar	Surface
Meteorological Instruments	Surface

TABLE 3

ABBREVIATED SUMMARY OF DATA SOURCES USED BY SESC

Type	Primary Source
Solar Patrol	
x-rays, 1 minute averages	Geostationary satellite
Hydrogen alpha, continuous	Ground observatories
Radio, 10.7 cm, 1 minute	Ground observatories
Solar Synoptic	
Hydrogen alpha	All are ground based
White light images	
Ca K-line images	
Helium 10830 images (shows coronal holes)	
Magnetograms (full disk and regional)	
Sunspot reports	
Solar mean field	
10.7 cm radio flux	
Energetic particle patrol	
Protons to 500 MeV, 1 minute averages	Synchronous orbit satellite
Miscellaneous	
Neutron monitor, 15 minute averages	Ground based
High latitude riometers (energetic protons), 15 minute averages	
Ionosondes, hourly (solar ionizing radiation)	

TABLE 4

SESC DATA DISTRIBUTION SYSTEMS

Telephone:

- FTS (Federal Telephone System)
- WATS (Wide Area Telephone Service)
- Commercial Telephone Service
- Dedicated Telephone Lines (Hot Lines)
- Recorded Information Numbers

Teletype:

- ATN (Astro-geophysical Teletype Network)
- AUTODIN (U.S. Government Teletype Service)
- Commercial Teletype Services
- Secondary Networks

Computer Links:

- Space Environment Laboratory Data Acquisition and Display System (SELDADS) Public User
- Dedicated Data Links

WWV Shortwave Broadcasts

Mail

TABLE 5

SESC OBSERVED INDICES AND ACTIVITY SUMMARIES

- Solar Active Region Summary Report
- Sunspot Number
- Flare (and Other Event) Lists
- Solar Neutral Line Analysis and Synoptic Maps
- Ten Centimeter Flux
- Solar Proton Events and Proton Flux
- SST Radiation Levels
- Geomagnetic A- and K- indices
- Substorm Log
- Sector Boundaries (at 1 AU)

TABLE 6

SESC ALERT CATAGORIES

SOLAR FLARES

- X5 (1-8 Angstrom X-ray Classification)
- X1
- M5
- 3B (Optical Classification)
- 2B
- 1B

MAGNETIC DISTURBANCES

- A >= 50 (real time A measured at Boulder)
- A >= 30
- A >= 20
- K >= 6 (real time K measured at Boulder)
- K >= 5 observed in successive three-hour intervals
- K >= 5
- K >= 4
- Sudden Commencement

RADIO BURSTS/NOISE STORMS

- 10 cm Radio Burst Greater Than 100 Flux Units
- 245 MHz or Noise Storm
- Type II and/or Type IV Decametric Emission

PROTON EVENTS

Proton Flux (E > 10 MeV) > 10 $cm^{-2}sec^{-1}sterad^{-1}$

TABLE 7

SESC PREDICTIONS

LONG TERM SOLAR ACTIVITY AND SOLAR RADIATION LEVELS

- Smotthed sunspot number (1 month - 10 years)
- Geomagnetic activity and ten-centimeter flux (1 month - 10 years)
- General level of solar activity (27 days)

SOLAR ACTIVITY - SHORT TERM

- Solar Flares (1, 2, 3 days)
- Solar proton events (1, 2, 3 days + post flare prediction)

SOLAR RADIATION LEVELS - SHORT TERM

- Ten-centimeter flux (1, 2, 3 days)

REFERENCES

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