USING THE MOON AS A BASE FOR A HIGH-ENERGY AND OPTICAL SOLAR OBSERVATORY.

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Solar flares and coronal mass ejections (CMEs) are the most powerful explosions in the solar system. Over a period of minutes, they accelerate copious quantities of particles (electrons, protons, and heavier ions). Although the physical processes by which this is achieved are not fully understood, the general scientific consensus is that the energy originates in stressed coronal magnetic fields and is released through a process known as magnetic reconnection. Understanding the processes through which magnetic energy is converted into accelerated particles is fundamental to understanding particle acceleration in general, and in particular in the Earth's magnetosphere and in other astrophysical sources.

The larger flares are usually associated with CMEs that propagate outwards into the interplanetary medium, in turn producing shock-accelerated particles at their leading edges. Both particles accelerated directly in the flare and those produced by the CME can have devastating effects on spacecraft instrumentation and on astronauts that are not adequately shielded. The electric and magnetic disturbances caused by the interaction of the CME with the Earth's magnetosphere can, in turn, create havoc on terrestrial communications and power networks.

A return to the Moon will permit the construction of telescopes and instrumentation designed to observe the high-energy emissions produced by the Sun during flares and other eruptive events. Observing from the Moon will permit us to extend the energy range of solar (and cosmic ray) spectra below the energy cutoffs imposed by the Earth's atmosphere and also permit observations to be made free of complicating geomagnetic effects and the ~90-minute day/night observing cycles in all but Sun-synchronous Earth orbits. Further, since the Moon is seismically stable and has no wind, it provides an exceptionally large and stable platform on which to position observing instrumentation. The gradual rotation rate of the Moon permits an unobstructed view of the Sun with relatively constant background for half a lunar day (~14 days). Coincidentally, this is also half the solar rotation period, so that a long-lasting solar active region could be observed uninterrupted by night or increases in background from its first appearance over the East limb to its disappearance over the West limb some 13 days later. Much of this time would be when the region is most strongly connected magnetically to the Earth-Moon system and so presents the greatest hazards to communications, space-borne instrumentation, and astronaut health in the near-Earth space environment. The slow rotation rate of the Moon also allows horizon occultation measurements (at a drift rate ~ 0.5 arc seconds/second) to be made, allowing study of fine-scale features in solar active regions.

The proposed instrumentation would be a comprehensive, coordinated package consisting of soft X-ray, hard X-ray and gamma-ray imaging spectrometers (1 keV to >100 MeV), gamma-ray spectrometers (50 keV to 1 GeV), neutron spectrometers (10 MeV to >150 MeV), cosmic ray neutron monitors, optical/IR imaging spectrometers, optical interferometers (an array of small, diffraction-limited telescopes), optical vector magnetographs, optical coronagraphs, optical, UV, and EUV spectroheliographs, and radio imaging spectrometers. The masses of these components range from 1 to 100 kg, power and data rate requirements range from 1 – 100 W and 1 kbps to 1 Mbps, respectively. Each component would be based on existing heritage.

Together, this complement of instruments will permit a thorough study of the magnetic precursors to solar eruptive events, the particle acceleration processes that occur within the flare itself and at the CME-associated shock, and the relationship between solar conditions and the probability of hazardous particle events at 1 AU. During certain times of the year (depending on planetary alignment), it will also provide important diagnostic information on active regions that pose a hazard for spacecraft en route to, and orbiting, Mars.

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To provide nearly continuous coverage, some or all of the instrument packages could be replicated and reside near opposing limbs of the full moon within contact of ground stations on Earth, thereby enabling quasi-continuous monitoring of solar activity.

Because of the need to transport such instrumentation to the Moon on a lander spacecraft, typical instruments would have dimensions comparable to those on Earth-orbiting unmanned spacecraft, viz. size from below a meter to ~ 10 m and mass in the range 10 kg to 1000 kg. However, these values could be extended through lunar surface assembly of modular subcomponents (e.g., interferometer components). The instrumentation would need less than 1 kW of power to operate, which does not pose a significant constraint. Data telemetry rates could be of the order of (10-100) GB/day, and could be accomplished either through near-real-time telemetry directly to Earth stations, relay through lunar-orbiting spacecraft, or through in situ storage for collection by astronauts on EVA activity and subsequent return to the Earth.

During the early robotic and early human phase, the basic complement of instruments, with real-time data collection, would be established. During the later, hHuman exploration, phase more comprehensive instrumentation, with a combination of real-time telemetry and local data storage would be deployed.

In summary, the benefits of the proposed lunar instrumentation are twofold:

1. It will enable fundamental advances in our scientific understanding of the processes that lead to energy release and the acceleration of energetic charged particles by the Sun and hence in other, more distant and more energetic, astrophysical objects;

and

2. It will allow us to further our understanding of the conditions that lead to hazardous eruptive solar events, and hence to provide operationally-useful warnings (or “all-clears”) to enhance the safety and productivity of manned missions to the Moon and Mars.