Imaging Thermal He^+ in Geospace From the Lunar Surface

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Introduction: By mass, thermal plasma dominates near-earth space and strongly influences the transport of energy and mass into the earth's atmosphere [1]. It is proposed to play an important role in modifying the strength of space weather storms by its presence in regions of magnetic reconnection in the dayside magnetopause and in the near to mid-magnetotail [2],[3]. Ionospheric-origin thermal plasma also represents the most significant potential loss of atmospheric mass from our planet over geological time. Knowledge of the loss of convected thermal plasma into the solar wind versus its recirculation across high latitudes and through the magnetospheric flanks into the magnetospheric tail will enable determination of the mass-balance for this mass-dominant component of the Geospace system and of its influence on global magnetospheric processes that are critical to space weather prediction and hence to the impact of space processes on human technology in space and on Earth.

Our proposed concept addresses this basic issue of Geospace dynamics by imaging thermal He^+ ions in extreme ultraviolet light with an instrument on the lunar surface. The concept is derived from the highly successful Extreme Ultraviolet imager (EUV) [4] flown on the Imager for Magnetopause-to-Aurora Global Exploration (IMAGE) spacecraft [5]. From the lunar surface an advanced EUV imager is anticipated to have much higher sensitivity, lower background noise, and higher communication bandwidth back to Earth. From the near-magnetic equatorial location on the lunar surface, such an imager would be ideally located to follow thermal He^+ ions to high latitudes, into the magnetospheric flanks, and into the magnetotail.

The EUV Geospace Imaging Concept: The concept involves designing a 30.4-nm imager and science package that meets the science requirements and engineering resources of a lunar sortie mission. No advances are needed in the design of the detector or instrument electronics. Our baseline optical approach is to modify the sensor head design of the IMAGE EUV imager, which returned unprecedented images of the plasmasphere. The optical design is driven by the need for a wide field of view and high throughput and is similar to the single-reflection Schmidt camera without the usual corrector plate. For good reflectivity at 30.4 nm, the mirror has a multilayer coating. Light reflected from the mirror is focused on the spherical focal surface of the photon-counting detector.

A range of specific optical design paths to achieving our scientific goals are to be considered. These include cameras with fields of view of 8° and 14°, with a variety of combinations of sensitivity and spatial resolution. These options include 1) spatial resolution several times better than that of IMAGE EUV and comparable sensitivity, to 2) reduced spatial resolution compared to IMAGE EUV, but with sensitivity higher by a factor >200. Other design enhancements over IMAGE EUV will improve the SNR for our mission. To reject scattered sunlight more effectively, we will provide more effective baffling of the entrance aperture, and change the design and location of the camera's venting ports. During quiet times, a substantial part of the background noise in EUV arises because of imperfect trapping of the He 58.4-nm emission from the local interstellar medium. We plan to investigate multilayer designs with improved trapping of this wavelength.

A demonstration of the instrument concept is provided in Figure 1, where a prototype Geospace image is modeled from the lunar surface based on the Dynamic Global Core Plasma Model [6] of equatorial thermal plasma density for a storm in October 2000. For this example, the same IMAGE EUV integration time of 10 minutes is used with 100-times the sensitivity, using a single imaging camera. Poisson and instrumental noise are included in this realistic imager simulation. The plume plasma can clearly be followed all the way to the magnetopause boundary in the simulated image.

The Lunar Surface Science Package: IMAGE EUV (which has three sensor heads) has a mass of 15.6 kg and requires about 9 W of power. Our preliminary

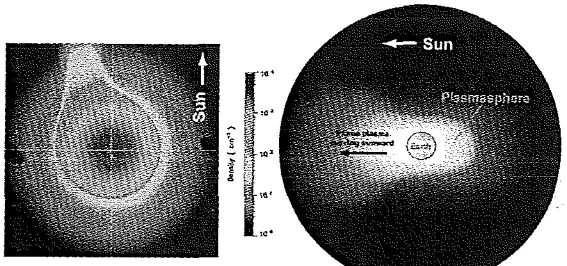

Figure 1

mass estimates for the design alternatives show that a practical set of cameras and associated electronics would have a mass of about 25 kg. When combined with ancillary components, the instrument will easily fit into the 40-kg target allocation. The optical properties are independent of scale, so that we are free to reduce the size of the sensor heads to reduce mass, as long as the resulting sensitivity remains adequate. The power required will be comparable to IMAGE EUV, especially since the requirement to handle data acquired on a spinning spacecraft, and the attendant processing load, will be absent in the conceived lunar surface instrument.

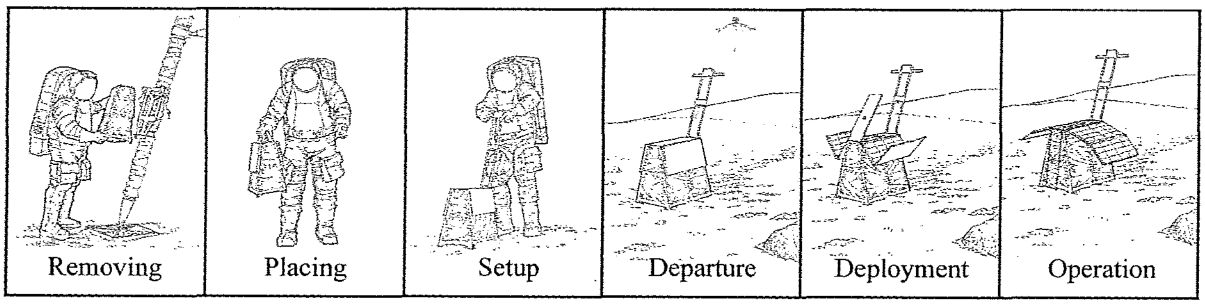

Figure 2

Any instrumentation, optical or otherwise, seeking extended operation on the lunar surface must consider the possible influence of dust accumulation on its surfaces. We suggest that pioneering science instrumentation to be operated on the lunar surface will need to be augmented by sensors specifically designed to monitor and characterize the effects of dust. The feasibility and accommodation requirements for including simple sensors to monitor dust accumulation on various surfaces, electrostatic charging, and effects of dust on the corresponding subsystem components should be studied. In addition, consideration should be given to basic sensors that would be necessary to monitor the solar ultraviolet luminosity and solar wind flux, which are the dominant external drivers of surface electrostatic charging and dust transport. Prototype mitigation components might also be included, such as vibrators (cell phone-type) and surface geometry/treatment.

Ground rules and assumptions for the baseline design are derived from the Lunar Surface Access Module (LSAM) lander that is used as reference from NASA's Exploration Systems Architecture Study (ESAS) report. The properties of the package and its setup are constrained by anticipated EVA requirements for mass and handling. The landing site is near-earth facing and low lunar latitudes, although implementation at any earth observing location appears possible with changes in imager and solar panel orientation. The package becomes operational after crew departure from the surface to avoid projected dust during launch. The package is to be removed from the lander and deployed with only minimal crew involvement and without tools. Figure 2 shows a prototype scenario for this lunar sortie mission. No surface preparation is anticipated and an uneven or sloped surface, within constraints, will be acceptable. Since the proposed science package concept has strong flight heritage and in many ways is simplified over previous free-flier missions, risk and cost will be low.

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