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REQUIREMENTS FOR PARTICULATE MONITORING SYSTEM FOR SPACE STATION

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Abstract. We recommend that a stereo camera system should be utilized as a diagnostic for the particulate environment surrounding the Space Station. This system should have sufficient sensitivity to identify contaminated periods, to isolate the effects of sources and activities and to determine optical clearing times. A reasonable compromise between sensitivity and other operational constraints is recommended. Sensitivity comparable to the film camera systems should suffice, but long periods of unattended operation and remotely controlled exposure sequences are essential requirements.

Introduction

Particulates surrounding space structures have been recognized to have a potentially serious impact on the ability to perform optical observations from space based platforms. Their effects will be manifested as scattered solar or reflected local emissions in the ultraviolet through near IR spectral regions. At wavelengths beyond 3 μm particle reflected earthshine and thermal self emission will dominate its signature (Rawlins and Green, 1987). In addition to providing broad spectral interference, the particulate emission will be spatially/temporally varying posing serious constraints on radiometric (non-imaging) systems. Particulates may cross a field of view in less than a second and even within this time non-spherical particles have been observed to have rapidly varying emission levels as various aspects of its surface are presented to the observation system.

The recommended guidelines in JSC 30426 (1986) call for the environment to be constrained to having less than one particle per orbit detectable in a 1.5×10^{-5} steradian field of view. For 90% of the time only particles with diameters less than 5 μm are permitted to be present within 10 km of the station within the volumes designed as optical observations viewing regions.

The diversity of orbital observations of particulates have been reviewed previously (Green, 1988). The particulates arise from ground processing, crew activities on-orbit (such as EVAs, dumps) and orbital interactions (such as erosion, micrometeorite impacts).

The previous observations have demonstrated that solar illumination angle is the key parameter in the visible. Observations of the Shuttle environment have been limited to particulates larger than 40 μm diameter at distances of less than 100m from the Shuttle. The occurance of these particulates was very variable ranging from nearly no up to 50 particles detectable in a 10^{-5} sr field of view. Scaling to the densities expected for sizes down to 5 μm will require modeling. The IECM data indicates that smaller particles are more numerous and that observed velocities (obtained by a careful analysis of stereo film data [Miller, 1983; Clifton and Owens, 1988; Clifton and Benson, 1988; Miller and Clifton, 1988]) ranged from 0.3 to 3 m/s. Models of the particle trajectory indicate that both the initial ejection velocity and drag contribute to the observed trajectory.

The film camera systems have proven that stereoscopic operation can provide accurate range and velocity determinations. They also provided essential long term trend data. Film camera shutter exposure sequences (Miller, 1983; Green et al., 1987) limit observations to processes on the 0.3 to 10 second or two minute time scales. Only particulates larger than 40 μm could be detected during the sunlit portion of the orbit. Sensitivity thresholds could be substantially altered by varying film speed, exposure duration, and post processing/image enhancement techniques. Although film provided a high information density archival storage medium, response correction was a tedious procedure and data analysis occurred long after the mission. Real time warnings or correlations were not possible.

A Recommended Particulate Monitor for Space Station

A diagnostic monitor for Station should attempt to overcome the limitations of the camera systems described above yet retain adequate sensitivity. Sensitivity sufficient to monitor the environment to the levels recommended in the guidelines does not appear to be achievable except by large observatory facilities such as Space Telescope, IRT or SIRTF (whose requirements contributed to guideline establishment). Moreover it is very desirable for the particulate monitor to be small, continuously operating and require low maintenance. A reasonable compromise between sensitivity and the other operational constraints is to recommend a system with sensitivity comparable to the film camera systems which can operate unattended for long periods of time and which is remotely controllable to permit exposure sequencing to be varied so that the range of orbital effects can be more easily interrogated over the entire orbital cycle. A stereoscopic system will again permit position and velocity information to be deconvolved to determine source locations and times. Both passive and active systems should be considered. Mounting on a trackable platform will permit large spatial volumes to be probed for locally severe environments.

This particulate monitoring system easily lends itself to being part of a larger total environment monitoring system. Although its size would be dictated by the optical baffles required for out of field light rejection, the detection elements can be made lightweight and should have low power requirements.

We recommend that the system should have sufficient sensitivity to identify contaminated periods, to isolate the effects of sources and activities and to determine clearing times. A low maintenance camera system meeting these specifications will prove to be a useful diagnostic for guiding observational measurement periods and identify orbital sources, trends and time scales.

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