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THE SPACE STATION NEUTRAL GAS ENVIRONMENT AND THE CONCOMITANT REQUIREMENTS FOR MONITORING

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Introduction

At 340 km, for typical conditions, the neutral atmospheric density is several times 10E8/cc and is thus more abundant than the ionized component by several factors of 10. At that altitude, the principal series is atomic oxygen with 10% N2, and 1% He, and trace amounts of O2, H, N, NO, and Ar. The constituent densities are highly variable with local time, latitude, and geophysical indices. The physical interaction with surfaces at orbital velocity leads to large build up of density on forward faces and great depletions in the wakes of objects. Chemical reactions lead to major modifications in constituent densities as in the case of the conversion of most colliding oxygen atoms to oxygen bearing molecules. The neutral environment about an orbiting body is thus a complex product of many variables even without a source of neutral contaminants. The addition of fluxes of gases emanating from the orbiting vehicle, as will be the case for the Space Station, with the associated physical and chemical interactions adds another level of complexity to the character of the environment and mandates a sophisticated measurement capability if the neutral environment is to be quantitatively characterized.

As an economic matter, it will be impractical to monitor, on a continuous basis, the directional neutral fluxes over the 4pi steradians that would be required to fully describe the neutral environment. Several instruments would be required with state-of-the-art velocity and directional determination capability, large dynamic range, high data rate, large power budget, and miscellaneous other costly attributes. An alternative approach is to employ a model of the environment that would be constrained and iterated by a less ambitious set of measurements. One or two sophisticated, directional mass spectrometers supplemented by total density gauges at several locations may provide an adequate input to the model to enable a reasonable characterization of the neutral environment. The requirements for the mass spectrometer and a total density gauge will be developed and a discussion as to the tradeoffs associated with the number of such instruments deployed will be given to help provide the basis for a reasonable assessment of the overall requirement.

Mass Spectrometer

The mass spectrometer has the advantage of non-specificity and is thus, in principal, capable of detecting all species within its design mass range. Certain practical considerations, however, impose limitations that must be understood and, in some cases, it may be necessary to provide alternative capability in order to achieve the desired measurement. Typical laboratory mass spectrometers have two particularly important limitations: 1) reactive atoms and radicals are modified on instrument surfaces and 2) sticky molecules like water, which is an important contaminant in most manned space flight situations, tend to accumulate on instrument surfaces creating an initial deficit in the measured amount, but subsequently and more importantly imposing a background contribution to the measurement that masks smaller incremental changes. Various techniques are available to mitigate both of these important limitations but their implementation adds complication to an already complex measurement.

Because the source of neutral species can be either ambient or contaminant, the velocity of a measured neutral can vary from virtual zero to the orbital velocity. To characterize the neutral environment through measurement, the velocities should be measured and the trajectory direction should be determined. These requirements pose significant additional complexity to the measurement. Fluxes measured in the direction of the velocity vector are enhanced above ambient by the velocity of the satellite and correspondingly decreased in the wake. The wake measurements can easily be dominated by instrument background contributions if great care is not taken to reduce or resolve this contribution.

Mass range and resolution tend not to be problems in this application. Generally, a mass range from 1-150 is adequate for most measurable contaminants, but extension to higher mass values poses no great difficulties. Unity mass resolution is sufficient for most purposes of this application and is easy to achieve. The instrument would be under control of a microprocessor providing a wide range of measurement programs which, together, permit both survey modes at moderate temporal resolution and single mass modes of very high temporal resolution and all combinations between these limiting cases.

An articulated or portable measuring unit could be capable of observing in all directions of the 4pi space. It would probably be preferable to include two instruments so that simultaneous observations at two view angles would be enabled. In some cases this could permit triangulation, and probably in most cases, the dual observation of a contaminant flux would be a powerful aid in identifying the source and/or scatterers of a measured species. The preliminary requirement will call for two instruments, but this is certainly a debatable point and one can argue for more or less. Total density gauges are reasonably simple to implement and would enhance the capability for spatial and temporal resolution of contaminant events. An array of 10-20 gauges is recommended. The details of their deployment and location would be determined through a study of the Space Station geometry using the model of the neutral environment.

Specifications for the Mass Spectrometer

1.	Implementation	Two identical instruments (articulated or portable to provide 4pi FOV.)
2.	Mass Range	1-150
3.	Mass Resolution	Unity
4.	Sensitivity	2.5E-3 counts/sec/part/cc source density
5.	Angular Resolution	5 degree solid angle
6.	Velocity Range	0-10 km/sec
7.	Velocity Resolution	0.5 km/sec
8.	Temporal Resolution	.016 sec/mass
9.	Data Rate	1000 bps/instrument (2KBS)
10.	Power	15 Watts/instrument (30 Watts)
11.	Weight	10 kg/instrument (20 kg)

Specification for the Total Density Gauges

1.	Implementation	Array of 16 gauges
2.	Sensitivity	3E-22 amps/part/cc
3.	Angular Resolution	TBD
4.	Temporal Resolution	Variable down to .001 sec
5.	Data Rate	Variable 0-1 KBS for the array
6.	Power	16 Watts for the array
7.	Weight	16 kg