Abstract. In this paper we outline one possible implementation of a magnetospheric constellation mission. We present a mission aimed at measuring the global instantaneous structure and time variation of magnetic fields throughout critical volumes of the magnetosphere. The concept is to place a large number of simply-instrumented nanosatellites (less than 1 kg) into elliptical orbits with apogees ranging from 5 to 25 R_E. In our study, the overarching goal is to achieve the maximum number of satellites. To implement this constellation, we consider several key aspects, including: orbit evolution; communications; nanosatellite and bus design; launch and initial orbit insertion; and ground station requirements. Our analysis demonstrates that using current technologies, a mission consisting of several hundred nanosatellites is feasible and could fit within the scope of the NASA Solar-Terrestrial Probe mission concept.

1. Introduction

Measurements on the magnetospheric particles endfields have been carried out traditionally by means of single satellites. This has led to a number of difficulties in the interpretation of the data. For example, the distinction between spatial and temporal variations of the magnetospheric flow is not inherent in the data but can only be disentangled by invoking other assumptions. More generally the global pictures of the flow and magnetic field configuration are not immediately apparent in the data but depend on considerable interpretation. Recently the concept of launching a constellation of satellites has received more attention. Several concepts are discussed in this monograph. This paper addresses the question of how large a number of satellites can be placed in orbit in a constellation so that a time dependent picture of magnetic fields can be obtained. It will be shown that a constellation composed of several hundred satellites appears to be within the scope of a Solar-Terrestrial Probe line mission costs.

Admittedly, a three-dimensional picture with this many pixels still corresponds to rather low resolution. Nevertheless, the advantages of a picture over localized measurements from individual or a small group of satellites are very significant. The maxim of a picture being worth a thousand words, in spite of over use, contains considerable truth. The availability of pictures has been the cornerstone in the development of many fields of science. Most closely related to magnetospheric flow is the field of aerodynamics where the dominant tools in development of the field have been schlieren or interferometric pictures. Optical and higher resolution microscopes have been critical in the development of biology and many aspects of solid state physics. Typically each increase in microscope resolution has led to new discoveries. A comprehensive discussion of the need for constellations to advance our understanding in magnetospheric physics can be found in the Sun-Earth Connection Roadmap, 1997.

The nominal mission under consideration would place satellites in orbits with a common perigee at 1.4R_E and apogees ranging from 5-25R_E into five planes with inclinations ranging between ±15°. Ea satellite would measure the magnetic field at 20 second intervals a would store and then telemeter data to receiving stations at perigee. any instant, this constellation would cover a relatively small range, le than 6 hours in local time, and during the year would observe all of t critical regions of the middle magnetosphere; the tail configuration a substorm development as well as the magnetopause, magnetoshea and bow shock in the flanks and the subsolar regions.

In addition to providing a quantitative picture of events, data fro such a kilo-constellation would show incoming boundary conditio clearly. When portions of the configuration extend beyond the bo shock, incident waves would be defined not only as to their magnitu but also as to their structure and plane. The resulting three dime sional development of phenomena in the magnetosphere a magnetosheath would be observed by the inner portions of the co stellation. This would avoid the ambiguities resulting from the prese limited data availability. As another example, while the constellation in the tail, external disturbances incident on the current sheet will detectable, thus helping to resolve the question of whether or n substorms are internally or externally triggered.

The proposed launch scenario would involve placing a bus into 1.4 R_E by 5R_E orbit. This bus would carry the satellites and also rocket motor, propulsion fuel, guidance and control equipment, a satellite release mechanisms. Acceleration would occur at perigee w a slow burn and as the perigee velocity is increasing, satellites wou be released individually. Thus each succeeding satellite would have slightly higher velocity and thus apogee. Since this scenario monoto cally accelerates the bus through the various satellite orbits, it elim nates a requirement for propulsion on the individual satellites and al minimizes the propulsion fuel required.

The launch scenario, as described above, would place all satelli in a single plane. Since plane changes require significant amounts propulsion fuel, placement of satellites into several planes will be a complished by separate ground launches. As will be shown, a Pegas XL launch, which is relatively inexpensive, can place 48 or more sat lites into a series of orbits with perigees at 1.4R_E and apogees rangi from 5R_E to 25R_E. An alternative approach might be to use a larg rocket launch and then place five buses into different planes.

The selection of a high perigee altitude increases the range ov which the satellite is visible from a ground station and, therefore, duces the number of ground stations required. Link equation calcul tions show that at a range of 6378 km (1R_E) transmission from t satellite with power equivalent to an ordinary cellular telephone wou provide accurate communication to a moderately priced ten-meter ceiving dish.

In order to achieve these objectives the mass of the individual sat lites must be kept to an absolute minimum. This in turn requires th only the absolutely necessary functions be retained and that they implemented in the simplest possible fashion. For the present analy the only measurement that will be made is the 3-axis magnetic fie and, of course, the required satellite orientation. There will be no a tive station keeping or attitude control systems utilized.

Reliability requirements on individual satellites can be greatly duced as compared to conventional satellites. With a large number

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Science Closure and Enabling Technologies for Constellation Class Missions, edited by V. Angelopoulos and P. V. Panetta, pp. 51-57 , U Berkeley, Calif., 1998.