figuration is how long will it stay together when the orbits precess due to the departures from spherical symmetry of the Earth's gravitational field and the effects of the lunar and solar fields. To check this we have calculated orbits using the Merged Simplified General Perturbations Propagator (MSGP4), in Satellite Tool Kit, version 4.03, produced by Analytical Graphics Inc. This software includes moments of the Earth's gravitational field up to the fourth geopotential coefficient, J_4, and includes lunar and solar gravitational effects.

Twenty-one satellites were started at the same time and in the same plane with a perigee of 1.4 R_E and apogees at $1R_E$ intervals from 5 to 25 R_E. Orbital periods range from about 0.3 to 2.8 days. The major axis of the initial orbits was chosen along the Earth-Sun line with apogee on the night side. The arbitrarily chosen launch date was January 1, 1999, and results are insensitive to the actual launch date. Although several planes near the equatorial plane are expected in the actual configuration only the orbital plane at 10 degrees to the equatorial plane was calculated in detail. Others planes with different inclinations will be quantitatively similar. Figures 1a, b, c and d show the satellite orbits at annual intervals. The plots are in inertial coordinates and are shown as a projection onto the equatorial plane. The color-coding indicates an effective density of satellites. This density is obtained by observing the number of satellites in an area of $0.1R_E$ by $0.1R_E$ every minute. The sum of these numbers over a three-day period is defined as the density at that point. The three-day average allows complete orbits even for the high apogee orbits. However, some aliasing is apparent in the initial picture and persists in the later ones.

In addition to the high satellite density due to a common initial perigee for all satellites, all of the orbits show high densities near apogee because the satellites are moving most slowly there. During the first year, relatively little precession occurs and the dominant motions relative to the magnetosphere are that the orbits are fixed in inertial space. This allows observation of the tail, flanks and subsolar region during the course of the first year. Precession is a stronger effect on the low apogee orbits since they spend more time in the near-Earth distorted gravitational field. At the end of three years the low apogee orbits have precessed about 360 degrees ahead of the high apogee ones. It is significant, however, that even at the end of three years, particularly the high apogee orbits, a high-density configuration remains allowing high-resolution coverage.

Using the same orbital parameters and the CRESRAD 94 program, radiation doses per year were calculated for extremely active conditions. The lowest apogee orbit remains in the radiation (both inner proton and outer electron) belts for the largest fraction of the orbital period and therefore receives the maximum dosages of 1 Mrad/yr (in SiO_2) behind an assumed equivalent thickness of 30 mils of aluminum. The dosage for higher apogees decreases roughly as the reciprocal of the period. Therefore orbits beyond a $9R_E$ apogee will receive less than 500krad/yr (in SiO_2). The electronic components selected are all radiation hard to 1Mrad and 30 mils aluminum equivalent passive shielding is included in the design.

3. Communication Requirements

Initially our mission concept had considered laser communication by means of a modulated retro-reflector on the satellite. This system turned out to be barely feasible and would certainly have required significant development of both ground and satellite components. By contrast, as discussed below, an RF system can be developed based on
and the ground receiving station. In order to minimize RF pow
quirements the satellites will store data taken over most of the
and download it at perigee.

3.1 Required Data Transmission Rate

Data points taken every 20 seconds should insure a sufficien
rate to capture phenomena of interest to the development of m
scopic magnetospheric phenomena. The primary data to be obtai
a set of three-axis magnetometer readings. Each field component s
be measured to the larger of ±0.5nT resolution or 1%. In prin
each measurement can be stored in a 12-bit floating point numb
sign bit, 4 exponent bits, and 7 mantissa bits). This requires 36 bi
3-axis data point. Additionally 2-axis spacecraft attitude informat
needed but the data transmission requirement for this can be red
by calculation based on periodically updated measured spin prope
Allowing for housekeeping information and other possible data req
ments, 128 bits of data transmission per data point has been allo
for.

The orbital periods for the furthest members of the constell
are slightly less than three days. Assuming one 128 bit data point
20 seconds along the orbit, the satellites must carry approximatel
Mbits of data storage. A conservative memory requirement for
satellite is then 4 Mbits, which, in the worst case, allows for the p
bility of storing data for two orbital periods. It should be noted
several safety margins have been included to arrive at the 4
memory specification, and the true safety margin as compared to t
mitting only the 3 axis magnetometer data is more than a fact
eight even for high apogee orbits.

One minute is a convenient data download time. The satellite
moves about $0.1R_E$ in that time and will stay easily in view of a re
ing station. Additionally a large constellation requires the ground
tion to receive many separate data streams. If a one minute trans
sion from each of 500 satellites is read every orbit, the receiver
cycle would be about 30%. As will be discussed in Section 6, on
satellite orbit is known, allowances for acquisition time do not
appreciably to this. Also overlapping transmissions will be significa
reduced by having each satellite transmission repeated for ten min
while the satellite is near perigee. Nevertheless a duty cycle of 30
less seems advisable.

This requires a data transmission rate of ~70Kb/sec.

3.2 Link Equation

The following assumptions have been used in calculating the tr
mission power needed on the satellite:

1. A Scientific Atlanta 11.3m receiving dish as the ground sta receiver having a gain over temperature (G/T) specificatio 25.35 dB.
2. An S band transmission frequency.
3. A maximum range 6378km ($1R_E$) at which accurate transmis must be achieved.
4. Bi-Phase shift keying (BPSK) modulation at the 70 kbps rate.
5. A signal to noise ratio of 10.8 dB which gives a bit error rat $<10^{-6}$.
6. A dipole transmitting antenna on the satellite with the dipole perpendicular to the plane of the orbit.
7. Losses of 6dB.