

These assumptions require a transmitter power of 50 mW. Commercially available cell phones radiate comparable or larger powers. For example the Qualcomm Q™ transmits a maximum power of 200mW. The total weight of the entire cell phone including the LCD, keys, case, microphone, speaker, vibrator, batteries sufficient for 1.5 hours talk time, etc. is 162 grams. Eliminating the components that are not needed, it will be assumed that about 40 grams of RF circuitry would be sufficient for the satellite application. Required redesign has not been considered yet. One of the open questions is the need for radiation hardness. As discussed below, all of the components in the main board are available in versions that are radiation hardened to 1 Mrad. The parts in the RF system are all bipolar. Since these are much less sensitive to radiation we do not anticipate a major difficulty.

The assumption (3) of a maximum range of  $1R_g$  and the earlier assumption of a perigee of  $1.4R_g$  (2640km altitude) are based on keeping the number of ground stations required for continuous data retrieval from the constellation at a reasonably low level. They were derived on the idealized geometric picture that if data could be retrieved along a horizontal line of sight these numbers would allow a receiving station to receive from satellites whose position is within 45 degrees of the ground station, corresponding to a requirement of only four ground stations around the globe. More realistically, limitations on possible ground station locations and the fact that at least 5 or 10 degrees from the horizon must be allowed for the line of sight it is likely that closer to ten ground stations will be required.

The assumption (5) that the transmitting antenna is a dipole oriented roughly perpendicular to the plane of the orbit gives a roughly 2 dB gain over an omni-directional antenna but does require satellite orientation. This will be accomplished by releasing satellites with a spin and including a damping mechanism so that rotation will be maintained around the axis with the largest moment of inertia. Thus no active mechanisms are required.

## 4. Satellite Design

The general satellite configuration is shown in Figure 2. The outer cylindrical surface consists of solar cells. The transmitting antenna is along the axis of the cylinder. Satellite spin will maintain the orientation of both the antenna and the solar cells within 10 or 20 degrees. The satellite electronics including batteries will be concentrated in the center. The actual magnetometer location is dependent upon being able to minimize spacecraft magnetic fields. It is expected that it can be located within the cylindrical volume. The sun sensor looks radially outward and will determine the phase of the rotation. Additionally in conjunction with the magnetometer it will determine the direction of the spin axis.

As compared to typical satellite designs this mission is particularly stringent in terms of requiring low mass, low power and a relatively high degree of radiation hardness. Additionally, in view of the large numbers of satellites involved, the design must address manufacturability—simplicity of fabrication, assembly and calibration. On the other hand, the large number of satellites also reduces the reliability requirements. Failure of a few satellites simply reduces the number of data points but it does not lead to mission failure.

Figure 3 shows a general schematic of the electronics. The separate sections will be discussed below except for the RF circuitry, which has already been discussed in Section 3.

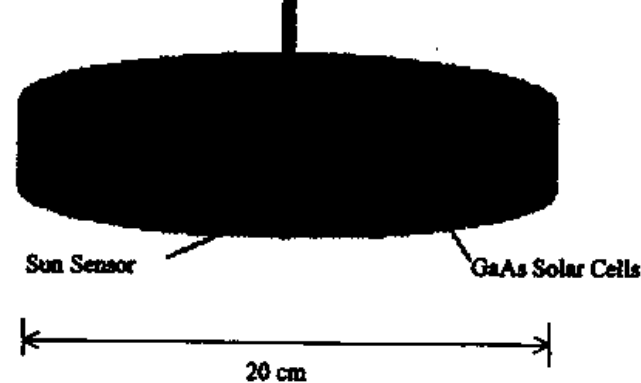


Figure 2. External view of satellite configuration. Circuitry will be near the center and magnetometer will be internal. Adequate magnetic cleanliness can be achieved.

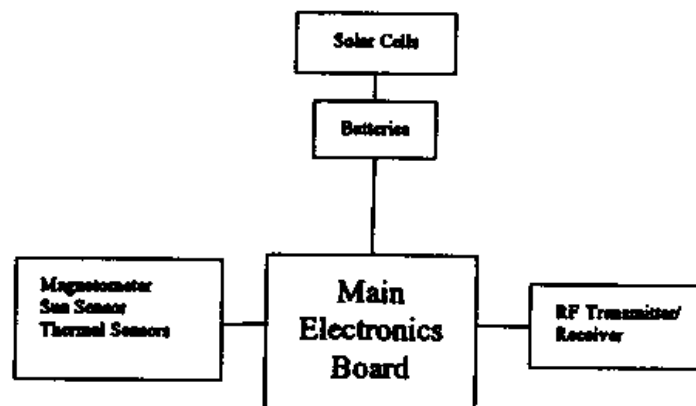


Figure 3. Overall block diagram of circuits.

### 4.1 Power Supply

The power supply is being designed for one Watt average power from solar cells. Peak power requirements up to five watts largely for data transmission will be available by using battery storage. Both these numbers somewhat exceed the present estimates of power requirements and allow for some of the inherent inefficiencies due to voltage regulation. Additionally some of the higher apogee satellites may be eclipsed for about four hours and battery storage must be sufficient to maintain operation during that time.

The overall size of the satellite is determined predominantly by the solar cells and the average power requirement. GaAs solar cells have an efficiency of 18.5%. Allowing for a 10% degradation in power output due to 1Mrad of radiation damage, a cylindrical radius of 10 cm and a height of 3cm will provide over one watt of average power. Radiation degradation is consistent with 12 mils of glass over the solar cell that brings the mass of the shielded cells to 40 g (Ray et al, 1991).

Ten minutes of data transmission at five watts requires approximately one watt hour of energy storage. Operation through eclipse for four hours at one watt is more stringent and requires four watt hours of energy storage. This can be accomplished with the equivalent of four AA, rechargeable NiCD batteries in series. The basic electronics is designed to operate at +5 volts with a switched capacitor power inverter to provide a small amount of power at -5 volts.

### 4.2 Main Electronics Board

The main board interfaces with the power supply, the sensors and