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Small Satellite

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Figure 1 - Small satellites

Introduction

The first satellite, Sputnik-1, launched on October 4, 1957 was a small satellite. The success of launching a manmade object into earth orbit was a phenomenal achievement, even though its user performance of sending a few radio signals was minimal.

It took an equivalent large effort to develop a usable platform for lunar, planetary and earth observation with components assuring orbital performance, attitude control, sensor operation, telecommunication of signals and ground reception and ground processing of these.

While the U.S. lunar missions succeeded in building the Lunar Orbiter missions 1 to 5 to achieve this goal in preparation for the lunar landing in the years 1966 and 1967, it took until 1972 to launch a general earth observing platform in the Landsat program of the US [3].

Earth observation is a relatively minor application branch of satellite technology, and the use of satellites is primarily important for telecommunications, and to a lesser extent to scientific missions.

Large satellites have always been built by governments and large consortia, which had sufficient funding to assure reliable long range operation without severe mass and power restrictions. E.g. the communication satellite Intelsat 6 was built for 10 to 14 year operation with a mass of 6 x 4 x 12 meters dimension and 4600 kg producing 2600 W power by solar panels. A medium size small satellite of today has a mass of 50 kg, accommodating a space of 0.6 x 0.4 x 0.3 m producing only 30 W of power by batteries.

Nevertheless it can perform well for specific purposes as small satellites integrated by Surrey University in the UK have proven (UoSAT 2 launched 1984). Surrey's marketing claims that 95 % of performance of large satellites can be reached with small satellites at 5 % of the cost or 70 % performance at 1 % of the cost (Wei Sun, IAA Symposium on Small Satellites for Earth Observation, Berlin, April 2-6, 2001).

The classification of satellites according to mass is usually as follows:

- large satellites: mass > 1000 kg
- medium satellites: mass 500 to 1000 kg
- mini satellites: mass 100 to 500 kg
- micro satellites: mass 10 to 100 kg
- nano satellites: mass 1 to 10 kg
- pico satellites: mas 0.1 – 1 kg
- fenito satellites: mass < 100 g.

It is obvious that the performance of the satellites will depend on the necessary auxiliary devices, which lead to additional mass requirements. The usability of small satellites is therefore generally restricted to micro, mini, and medium satellites [1].

Satellite uses

Satellite customers in the 1980's and 1990's as:

- Commercial 37.1 %
- Military 35.1 %
- Government 17.3 %
- University 5,4 %
- Amateur 5.1 %.

The application of these satellites in that period is [1]:

- communications 69.2 %
- science 14.4 %
- technology demonstration 11.0 %
- military 2.3 %
- education 1.7 %
- earth observation 1.4 %.

Required components for operation of a small satellite for earth observation

Launch

For satellite launches several competitive possibilities exist. They can be launched by a separate mission or in piggyback. Recently retrievable launch vehicles, such as the German Phoenix are under development. Traditionally, launchers have been used in the Russian Federation, in India, from ESA, and in the United States. A launch cost estimate is about 10 000 $ per 1 kg of mass. A retrievable launcher would cut this cost to about half [2].

Choice of Orbit

The choice of the orbit is crucial for the performance of an earth observation satellite. Geostationary orbits at 36 000 km are preferred for communication satellites. Earth observation satellites prefer sunsynchronous polar orbits at orbital heights between 400 and 1000 km. If the observations are aimed at specific areas of the globe, then lower inclinations combined with elliptical orbits (150 to 500 km) can be chosen. Such orbits do not provide ideal illumination conditions, however. The choice of the orbit determines repeatability of sensing [3].

Attitude and Orbit Controls

The orbit can best be monitored by an on-board GPS satellitereceiver. The positions of the satellite are downlinked and monitored in the ground facilities. Orbit corrections are possible by hydrocyne propulsion systems with the need to carry this fuel on board. The attitude of the satellite is warranted first by 3 axes gyros. For higher precisions a sun sensor is required. After monitoring the attitude on the ground the propulsion systems can carry out the attitude corrections for pointing of sensors. For smaller corrections the sensor my be reoriented [4].

Sensors

For earth observations sensors are required, which sense reflections of the earth within the range of the electromagnetic spectrum. Optical and thermal (passive) sensors require sensitive elements, which need to be read out and transmitted to earth. Onboard processing by microprocessors is possible. Active sensors (such as radar) require antennas for transmission of electromagnetic pulses and for reception of the backscattered reflections from the ground. Obviously passive sensors require less mass. The sensor limitations for use in small satellites have been discussed in detail in the paper “High resolution mapping with small satellites” by Rainer Sandau, presented to the ISPRS 2004 Congress (1). They refer mainly to optical and thermal sensors. They are:

- Spatial resolution by the optical system, which is governed by the diffraction limitation;
- Sensitivity of the detector elements requiring a minimum exposure time of about 1 msec;
- Image motion, due to the forward motion of the satellite movement in the order of 7.4 km/sec or 7.4 m/msec.

If higher resolutions than 7 m are desired, then image motion compensation must be applied. This is possible by time delay integration sensors (TDI), in which instead of a single array of detector elements across the platform motion a number of arrays in direction of the platform motion are utilized, over which the detector signals are averaged before readout. High resolution sensors with ground resolutions better than 7 m therefore not only need smaller resolution elements, e.g. by staggered arrays, but also means of image motion compensation, wither by TDI arrays or by rotation of the satellite sensor during the exposure time.

Power

For the requirements of on-board sensing, processing and the reception and transmission of sensing and auxiliary data, as well as for the control options of the satellite power systems must be provided. The principal source are batteries (NiCd, NiH or Li-Ion). For longer duration missions they need to be charged by solar energy, which has to be collected by solar panels.

Data Readout

The charges received at the sensor elements of the arrays need to be transmitted at appropriate readout rates to the ground stations during a ground station contact time of about 10 minutes. At a rate of 100 Mb/s up to 60 GB of data can be transmitted. If higher data rates are required data compression must be utilized for transmission.

Ground Station Processing

The received signals at a ground antenna must be stored and processed at the ground station facility [5].

Conclusions

Simple imaging of the ground requires a linear array sensor perpendicular to satellite motion. Images of such a sensor system require geocoding. This is possible using the transmitted GPS and attitude orbital data within accuracy limitations. Ground control points can increase the accuracy of geocoding. However, the images cannot be orthorectified onto a cartographic projection unless a digital elevation model of the terrain is known from other sources, and used in the ground processing chain. To be independent of the knowledge of the digital elevation model stereo sensing can be utilized, using at least two sensor systems operating with a forward and a backward inclination along the orbital path against the nadir. Rainer Sandau describes the possible stereo sensing configurations in his paper, which have been utilized in satellite systems (1). As the swath widths for small satellite sensors are usually small due to the use of narrow angle optical systems optimal base/height ratios of 1:1 permitting to acquire digital elevation models with sufficient accuracy are difficult to achieve.

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Orientation and Navigation Device in Ancient Time

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1. Introduction

Orientation and navigation was done without any special devices in the ancient. People observed natural phenomena by experiments and obtain results for determining orientation. Avian Navigation and Orientation is a good example. It is typically accomplished only by ‘experienced’ birds - birds that had become familiar, on a smaller scale, with a local area or, on a larger, migratory scale, have successfully completed a migratory journey at least once [1].

In the ancient Nabataean people used the stars for orientation in the sea or desert . Arabs measured the altitude above the horizon to a known star, and then deduced from this the altitude of the Pole Star, (since the Pole Star was the one star that did not move in the sky) [2].

Another very simple navigation method that was used by many early dhow captains was simply the position of the Sun or North Star above the boat. By standing on various locations on the boat, they could place the Sun or North Star above, right, left or behind the dhow. As long as they kept the stars at a correct position above the rigging they were assured that they would arrive at their destination.

Besides that from an Arab perspective there are three basic monsoon winds. First of all, from April to June, the Kaws wind blows southwest. Later the Dammani SW monsoon blows from August to the middle of October. At this time, the monsoon changes direction, and the Azyab monsoon blows in a NE direction [2].

2. Examples of orientation and navigation devices

2.1. Kamal

A more accurate, but still simple instrument was known as a kamal. This was a small parallelogram of horn or wood measuring about one by two inches with a string inserted in the center. On the string were nine knots at measured intervals.

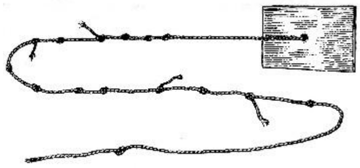

Figure 1 - Kamal

The end of the string was held in the teeth. The lower edge of the horn was placed on the horizon while the horn was moved along the string until the upper edge touched the required star. The knot at which the horn covered the exact distance signified a certain number of isba' of altitude of the star. The altitude of the Pole Star could then be deduced from the rahmani. An alternative way of using a kamal was to move the knots through the teeth until the piece of horn or wood covered the required star altitude. Vasco da Gama's pilot from Malindi used a kamal, and the Portuguese adopted it and eventually modified the spacing of the knots to measure