

EARTH OBSERVATION CONCEPT INVOLVING PORTABLE DATA RECEIVING AND PROCESSING EQUIPMENTS  
WOM-8 SYSTEM

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ABSTRACT

This paper details an earth observation space system involving portable data receiving and processing equipments. The use of on board data compression make feasible the UHF transmission of the Earth Observations Data. Using fixed wide field antennas, the data are received directly from the remote sensing satellite for digital processing. It is proposed a system for global coverage with a temporal resolution of two pass per day. Eight satellite orbit in two heliosynchronous orbital plane. The cost shows to be low for both space and ground segments. A technological mission using piggy-back launching can demonstrate the feasibility of the concept at very low cost.

KEY WORDS: Earth Observation; On-Board Data Compression; Lightsats; Decentralized Image Processing; Mini Remote Sensing Center.

1. INTRODUCTION

The new technologies like data compression, segmented CCD and solid state mass memory, make feasible powerful system concepts at reasonable costs. Tate (1991) proposed an experimental imaging system for tactical applications. The system motivation is to use data compression to obtain a very high spatial resolution. Linde (1980) and Baker (1984) describe the technique called Vector Quantization.

This paper explores data compression to make feasible the UHF transmission of the Earth Observation Data. The UHF telecommunication technology permits the link between space and ground using simple antennas. The idea is to use low cost and low weight satellite. The Pegasus launcher could be used to orbit four satellites simultaneously.

The main characteristic of the system is the Direct Receiving Concept (DDR). The DDR concept involves a proper data transmission design to link the satellite with the end user ground station. It is supposed that the end user receive real time image around a circular area with one swath band radius. The system flexibility permits enlarge the opportunities for remote sensing applications.

The system may be based in some standard satellite bus. In this paper parameters from the UoSAT small satellites are used in the feasibility demonstrations. More details about the UoSAT small satellites can be found in Sweeting (1989). The UoSAT modular equipments may be considered in the operational mission. But it is particularly attractive for the technological demonstration mission because of low cost. Combining the UoSAT (or similar) technology with a piggy-back launching, an effective technological mission can be performed.

2. SYSTEM DESCRIPTION

The system is to have very high temporal resolution. The goal is to obtain two full earth coverage each 12 hours. The space resolution and the spectral bands are designed for monitoring of forests, firing, pollution and sea biomass. The imager is a CCD camera with a wide field imaging capacity. The camera has two spectral bands at .63 - .69 micrometers and .77 - .89 micrometers.

A similar camera is been developed for the Remote Sensing Brazilian Satellites (Rayalu et alli, 1990;

Ghizoni and Yiyuan, 1990). To obtain a temporal resolution of two pass a day, eight satellites are necessary orbiting in two heliosynchronous plane. The relevant characteristics of the sensor and orbit are:

|   |            |
|---|------------|
| Orbital Altitude .....                  | 640. Km    |
| Inclination .....                       | 98. Deg    |
| Orbital Period (P) .....                | 1.63 Hours |
| Consecutive Equator Crossing (P/4) .... | 24.5 Min   |
| Distance Between Equator Crossing ..... | 680. Km    |
| Camera Coverage Band .....              | 740. Km    |
| Number of Pixels .....                  | 3456       |
| Pixel .....                             | 210. m     |
| Field of View .....                     | 60. Deg    |
| Quantization .....                      | 8 Bits     |
| Uncompressed Data Rate .....            | 1.1 Mbit/s |
| Compression .....                       | 16:1       |
| Compressed Image Telemetry .....        | 70 Kbit/s  |

Using the two heliosynchronous orbital plane, the satellites will cross the equator in the ascending node at the correspondent local time. The planes can be chosen conveniently such as four satellites cross the equator at 09:00 hours in the morning and other four cross at 03:00 hours in afternoon. The proper angular drift between each two satellites in the orbital plane permits adjacent swath for consecutive orbits. The Figure 1 illustrates the orbital view of the satellites. The Figure 2 schematics the orbital pass around the equator. In other words, the system is designed to perform four complete full coverage during a day.

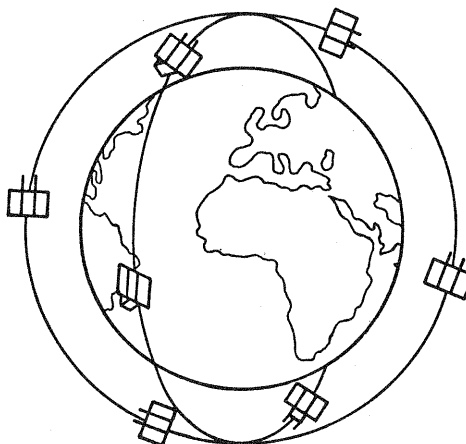


Fig. 1 - Orbital view of the satellites.

The camera composes of collecting optics, spectral separation assembly, CCD, pre-amplifier, A/D circuits, and computer interface. The payload includes yet the modulator, transmitter module and the data compression chip (CPC). The CPC works coupled with the Computer Module. The block diagram of the payload is shown in the Figure 4. The payload power consumption is composite by the estimates: 5 W for the imager electronics; 2 W for the modulator and transmitter module; and 3 W in addition to the computer because of the CPC.

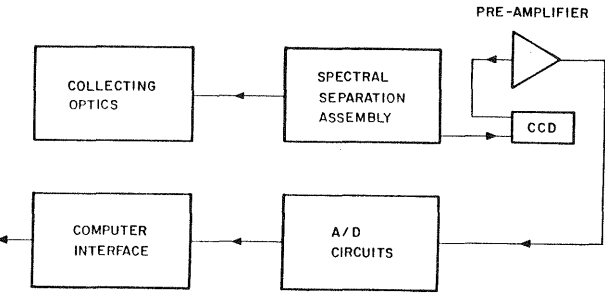


Fig. 4 - Payload functional diagram.

5. MASS BUDGET AND LAUNCHING

The launching can be performed using small launchers as Scout, Brazilian Launcher - VLS or Pegasus. Following Pegasus figures from Orbital Science Corporation, the launch performance can be 300 Kg in a polar orbit with a perigee of 300 Km and apogee of 640 Km. The four satellites are deployed in this transfer orbit. Orbital maneuvers provide the circularization and the proper orbital angular drift among satellites. The estimates for Hidrazine consumption are 5 Kg, 3 Kg for orbit circularization and 2 Kg for orbital maintenance considering an orbital life of 5 Years. The maneuver strategy need around two weeks to be completed. The satellite mass budget is as follow:

Each satellite:

|  |        |
|--|--------|
| - Basic Platform .....                     | 40. Kg |
| - Tank + Truster + Electronics .....       | 3. Kg  |
| - Camera + Electronics + Transmitter ..... | 10. Kg |
| - Hidrazine .....                          | 5. Kg  |
| - Margin .....                             | 7. Kg  |
| - Total .....                              | 65. Kg |

The launching mass budget is as follow:

|                               |         |
|-------------------------------|---------|
| - Four Satellites .....       | 260. Kg |
| - Satellites / Launcher ..... | 25. Kg  |
| - Margin .....                | 15. Kg  |
| - Total .....                 | 300. Kg |

The mechanical architecture of the proposed satellites is modular, and it involves a monoblock structural concept. The electronic boxes are substituted by frames supporting the electronic boards. The general concept of the proposed satellites and the UoSAT are different. In spite of this, the UoSAT is a reference for the mass budget considering the modular and integration concept adopted. The Figure 5 shows mechanical views of the camera for a two lens mounting option. The satellite configuration is depicted in Figures 6 and 7.

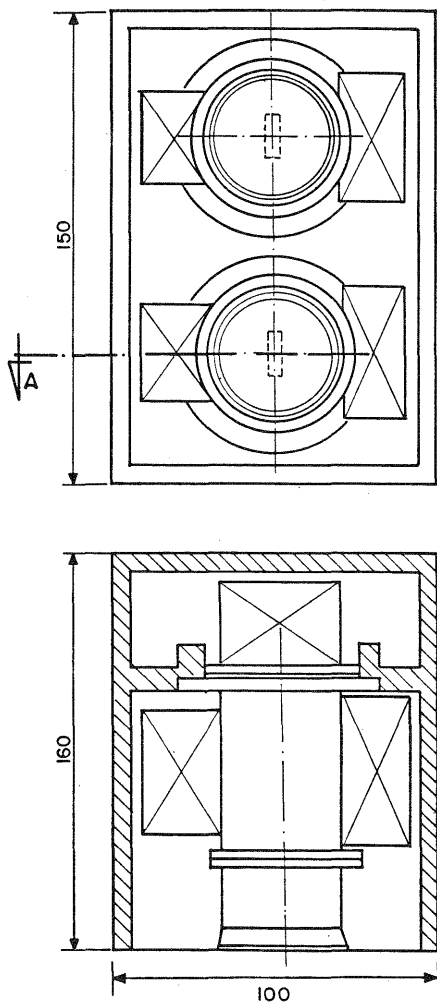


Fig. 5 - Mechanical view of the camera (two lens option).

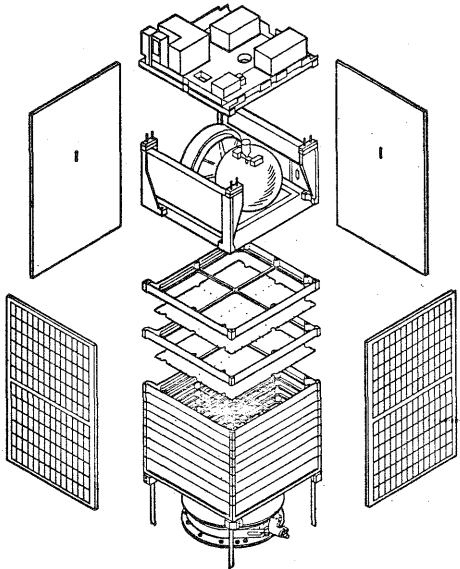


Fig. 6 - Exploded view of the satellite.

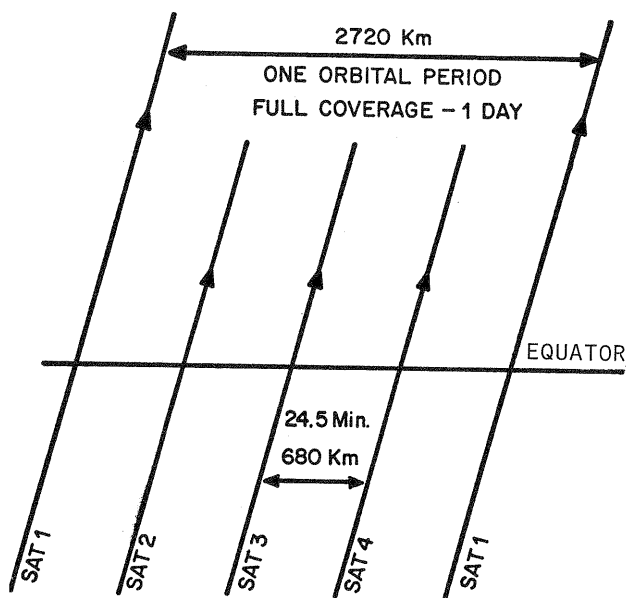


Fig. 2 - Equator crossing schematics.

### 3. DATA COMPRESSION AND COMMUNICATION LINK

Tate (1991) proposes a small imaging satellite for tactical applications. The data compression shows to be very important to reduce ground data link band width, and to reduce on-board storage while producing images of very high spatial resolution. The compression system is based in a specialized integrated circuit called the "Codebook Processing Chip - CPC". The CPC was developed at Utah State University for general purpose image compression applications. The CPC processes in high speed the Vector Quantization Compression Algorithm. This makes on-board data compression a powerful tool to improve the performance and to permit new concepts in remote sensing systems.

The data compression permits the transmitter power compatible with the proposed system. The Figure 3 shows the visibility circle around the end user. The limited circle requires communications only in high elevation angle. This aspect contributes for the low power transmission requirement. The relevant parameter used in the data link are:

|                               |         |
|-------------------------------|---------|
| Frequency, F (MHz)            | 400     |
| Bit Rates, R (Kbit/s)         | 100     |
| Eb/No (BER = 1.E-05)          | 9.6     |
| G/T - Receiver (dB/K)         | -20     |
| Boltzmann Constant, K(dBj, K) | -228.6  |
| Losses, L (dB)                | 6.0     |
| Margin, M (dB)                | 3.0     |
| Maximum elevation, D (Meters) | 1.0E+06 |

Using these parameters the Equivalent Isotropically Irradiated power (EIRP) results:

|      |          |
|------|----------|
| EIRP | -9.5 dBw |
|------|----------|

and assuming a on-board antenna gain of 10 dBw, 1.0 dBw of connection losses, the output power results:

|           |         |
|-----------|---------|
| RF output | 350. mW |
|-----------|---------|

The calculated RF output shows low transmission power requirement. Similar satellites recommend reserve 3W for the Modulator and Transmitter module.

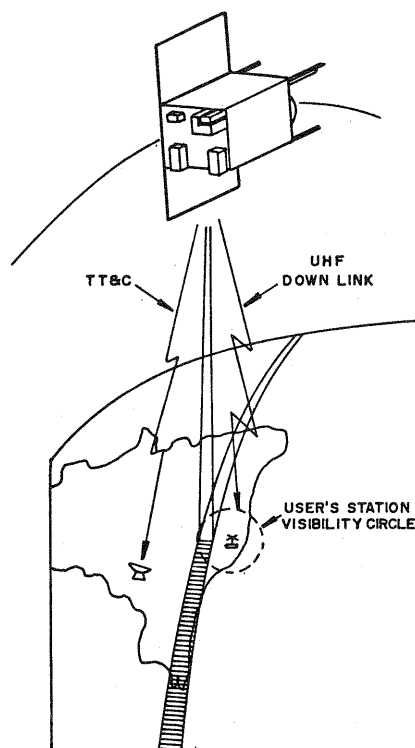


Fig. 3 - The direct data receiving concept.

### 4. SATELLITE DESCRIPTION

The proposed push-broom imager requires 3-axis stabilized satellite. The selected design is the momentum wheel stabilization with closed loop control. The wheel provides stiffness in roll and yaw by the gyroscope effect, and stiffness by a closed loop action of the reaction torque of the wheel. The magnetorques are used for dessaturation of the wheel and for pointing control of the roll and yaw axis. Pointing accuracy better than 2 degrees can be achieved. While the attitude determination errors are supposed to be better than 1 degree in three axis. During the shadow period of the orbit a map of the Earth's magnetic field determines the angular drift in the yaw direction.

The attitude control principal components are:

- Momentum Wheel ..... 2 W, 3 Kg
- Magnetorquers ..... 3-axis, 12 A sq.m
- Digital Sun Sensor .... FOV 64 Deg/Accuracy 1 Deg
- Magnetometer ..... 1 W, Accuracy 1 Deg.

Besides the attitude control subsystem the satellite is based in standards subsystems. The main standard modules are:

- Nickel Cadmium Battery Pack (6 AH 12/24 V)
- Power Conditioning and Distribution - Output 15 W
- Telemetry and Telecommand - 100 mW
- 80C186 On-board Computer - Multitask Features - 2W
- 4 Mbytes RAM Disc
- Solar Arrays - .7 sq.m, 35 W (BOL)
- Structural Blocks, Screen and thermal Materials.

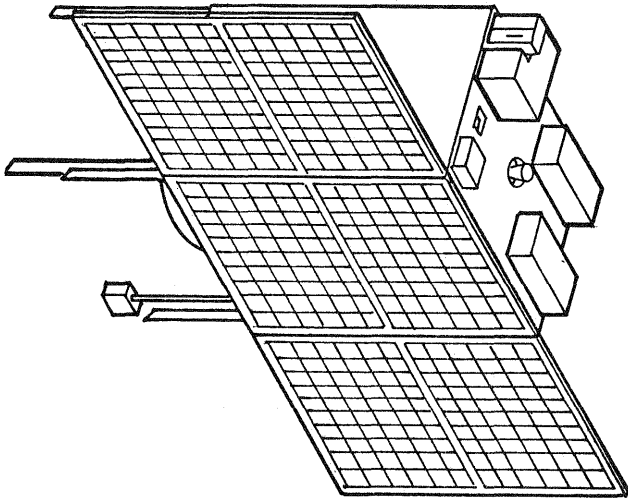


Fig. 7 - External view of the satellite.

#### 6. DEVELOPMENT PLAN AND COSTS

The development plan comprises nine satellites models. The first one will perform the proof of the concept in orbit. This satellite is to be launched in a piggy-back scheme using Ariane, Delta or Similar launcher. The piggy-back is considered because of the low price, and because of the large launcher typical environmental profiles. The schedule for this proof-of-concept mission is 18 months for launching and 6 months for orbital commissioning. Considering this experimental satellite can be launched in a proper final orbit, the propulsion subsystem can be eliminated. This can makes easier the achievement of the security launcher requirements.

During those two year the operational system is detailed by incorporating the experience of the experimental mission. The operational satellites must be designed for the environmental conditions of the Pegasus launching. The estimate to manufacturing the eight operational satellites is one year. Therefore the system is planned to be in full operation in three years.

The mini user station needs to be developed for the proof-of-concept mission. This mini station comprises a 13 dB (30 Deg of elevation) antenna, a receiver electronics and a digital image processing system. Considering the fast improvement of the performance of the computational hardware, it is expected to have complete mini stations at cost bellow 50,000 US\$. The Figure 8 shows a diagram of the user mini station.

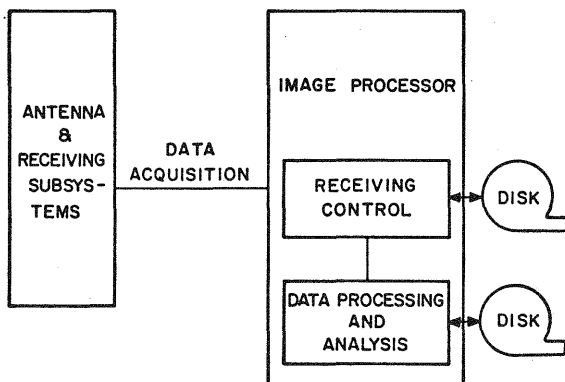


Fig. 8 - User mini stations functional diagram.

The development cost estimates is presented as follows:

#### Proof-of-Concept Mission:

|                        |                |
|------------------------|----------------|
| - Satellite Bus .....  | 1,500,000 US\$ |
| - Payload .....        | 400,000 US\$   |
| - Launching .....      | 400,000 US\$   |
| - Mini Station .....   | 400,000 US\$   |
| - Control Center ..... | 300,000 US\$   |
| - Sub-Total .....      | 3,000,000 US\$ |

#### Operational Mission:

|                             |                 |
|-----------------------------|-----------------|
| - Satellite Buses (8) ..... | 12,000,000 US\$ |
| - Payloads (8) .....        | 1,000,000 US\$  |
| - Launching (2) .....       | 16,000,000 US\$ |
| - TT&C Ground Station ..... | 5,000,000 US\$  |
| - Control Center .....      | 1,500,000 US\$  |
| - Sub-Total .....           | 35,500,000 US\$ |

#### Complete Mission:

|               |                 |
|---------------|-----------------|
| - Total ..... | 38,500,000 US\$ |
|---------------|-----------------|

The decentralized approach and the low cost of the user ground station will enlarge the remote sensing applications. This mini stations can be very attractive to be implemented in ecological reserves, large cities, Universities, fishery boats, remote areas and to be used in campaigns when real time is mandatory. The international market estimate is of 200 mini stations. The system can be profitable considering a five years time life and an annual use fee of 50,000 US\$ for each mini station.

#### 7. CONCLUSIONS

The proposed system introduces a new concept in Earth Monitoring. The image processing decentralization will be likely adopted in short future using indirect data dissemination trough communications satellite. This is expected to improve the application of the remote sensing in general. This paper demonstrates that technology is available for a powerful system for earth monitoring with commercial feasibility.

The advantages are real time access to observations, smaller data base and unlimited distribution of data. Sometimes real time monitoring and decentralization are mandatory. Typical examples are firing, fishery, pollution and meteorological storm monitoring.

The Direct Data Receiving Concept explores the digital earth imaging in a decentralized approach. The low cost of the ground equipments permits enlarge the participation of undeveloped countries. This point may be attractive for the participation of international organizations.

#### 8. REFERENCES

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