SPACE TECHNOLOGY PROPOSAL OPTION FOR THE AMAZON REGION REMOTE SENSING.

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ABSTRACT

This paper presents a remote sensing technological option which satisfies specific application requirements and explores geographical Amazon characteristics with tailored spacecrafts and orbits. A comparative analysis shows that a special designed spacecraft can provide better performance than conventional solutions at lower costs.

1. INTRODUCTION

The monitoring of the natural resources and of the environment of the Amazon region is a fundamental requirement for a rational exploration, what implies the use of remote sensing techniques. The remote sensing can use multipurpose spacecraft as SPOT, LANDSAT, CBERS or otherwise use special designed spacecraft considering the specificity of the region. The current generation of remote sensing spacecraft is designed to wide international applications and thus can not cover all specific requirements for Amazon Region Remote Sensing.

The Remote Sensing of the Amazon Region must provide information leading to the understanding of the Amazon as a system with a series of processes: hydrological,geographical, climatic, man activities, biological cycles, biogeochemical cycles, forest fires and soil wastes. The monitoring of these processes involves a large number of requirements which can only be fulfilled by numerous independent instruments and mission characteristics. The payload instruments and the spacecraft deal with the following: high, moderate and low temporal resolution; high, moderate and low spatial resolution; high, moderate and low spectral resolution; and very-high spatial and spectral resolution for biogeochemical analysis. This paper presents a technological concept which is able to satisfy specific remote sensing requirements and explores geographical Amazon characteristics with a tailored spacecraft and orbit. The geographical location of the Amazon forest allows a near equatorial orbit which makes feasible to obtain new and original information, for example related data with the convergence intertropical zone dynamics phenomena. The use of single or a small number of mission related equipments permits to choose a spacecraft platform for the mission needed thus optimizing cost and performance.

Technical and cost comparative analysis are presented and show that a special designed spacecraft can provide better performance than conventional solutions at lower costs. The proposed technological concept is based on the use of a small class multi mission bus and a specific mission payload in a modular integration approach. The multipurpose bus concept drastically reduces the development cost and the dedicated payload sharply permits to achieve specific mission objectives.

2. MULTIPURPOSE SPACECRAFTS

The Multipurpose Remote Sensing spacecrafts are designed to satisfy requirements in such way to maximize user's applications. This design concept results in an almost standard remote sensing. The payload has general purpose aims which limit the attitude and orbit parameters inside of small design margins.

For example, requirements of orbit stability define the altitude around 800Km, full earth coverage and local time stability define orbital heliosyncronism and the pixel size defines the attitude behavior and concept (Hammond, 1977). Table 1 presents for comparisons purposes orbital and attitude parameters for multipurpose remote sensing spacecrafts. Table 2 presents for illustration, the mass and power budget of the CBERS spacecraft.

TABLE 1
ATTITUDE AND ORBIT PARAMETERS

	SPACECRAFTS		
PARAMETERS	CBERS	SPOT	LANDSAT
Inclination	98.5 deg	98.7 deg	98.2 deg
Orbital Cycle	26 days	26 days	16 days
Mean Altitude	778km	832km	715km
Swath Width	113	108	172
Drift rate (3 sigma)	.001deg/s	.0005deg/s	.008deg/s

TABLE 2
MASS AND POWER BUDGET (CBERS)

SUBSYSTEM	CBERS MASS (KG)	CBERS POWER(WATTS)
AOCS	150	146.5
TT&C	40	57.3
Power	180	12.0
OBDH	50	46.0
Solar Array	45	-
Structure	210	-
Thermal	40	65.0
Payload	500	676.0
Others	185	87.3
Total	1400	1100.0

The typical general purpose payload parameters are defined to comply with requirements for agricultural, forestry, hydrology and geology. The needs of agricultural remote sensing are the more stringent with respect to spatial resolution and coverage cycle.

The spectral domain, band-width and radiometric sensitivity are established through the other applications. The spatial resolutions need for agricultural applications have been designed in the range of 20-70m and the coverage cycle around 20days. The spectral bands (Kasturirangan, 1985) are chosen in the range of .45-.9 micrometers in order to be sensitive to sedimentation (.45-.52 micrometers), green reflectance (.52-.59 micrometers), clorophyl absorption (.62-.68 micrometers) and green biomass (.77-.86 micrometers). Other universal themes can be generated through various combinations of these bands. The radiometric resolution typically is quantified into 8 bits words in order to detect 256 grey levels. Table 3 summarize the payload parameters for multiuser spacecrafts.

The parameters shown in Tables 1 and 3 illustrate the standard characteristics of these spacecrafts: low temporal resolution, altitude between 700 and 800Km, radiometric resolution near .5%, spatial resolution in the 20-80m range and standard red, green and blue spectral bands. In spite of additional features sometimes introduced in these spacecrafts, for example the wide field images in the CBERS or the skewed images in the SPOT, it is clear from tables that any dedicated features are introduced. From the parameters it can be seem that, for example, there are no flexibility for biogeochemical cycles analysis or fires monitoring.

TABLE 3
SUMMARY CHARACTERISTICS OF VISIBLE IMAGERS

	SPACECRAFT CBERS	SPACECRAFT SPOT	SPACECRAFT LANDSAT
SPATIAL RESOLUTION (Meters)	20 - 80	20 - 10 (PAN)	30 - 80
Spectral Bands (microns)	VISIBLE .51 - .73 .45 - .52 .52 - .59 .63 - .69 .77 - .89 .50 - 1.1	VISIBLE .50 - .59 .61 - .69 .79 - .90 .50 - .90	VISIBLE .45 - .52 .52 - .60 .63 - .69 .76 - .90 .60 - .70 .70 - .80 .80 - 1.1
RADIOMETRIC RESOLUTION	8 bits .5%	8 bits .5%	8 bits .5%

3. SPECIFIC SPACECRAFT PROPOSAL

This paper proposes to use dedicated spacecrafts for specific mission objectives. In the monitoring of fires, for example, it is necessary to have a high temporal resolution, while the spatial and spectral requirements are less stringent. These features impose a special orbit choice but do not require stringent attitude requirements being possible to use spin stabilization. However, a biogeochemical cycle monitoring, due to the need of high spatial resolution stringent attitude requirements imposes three axis stabilization. This paper describes two basic platforms which could be adopted to Remote Sensing of the Amazon Region: a spin and a three axis stabilized spacecraft. The payload mass and power for the two options are compatible with high performance missions. It can be illustrated comparing with the Advanced Very High Resolution Radiometer-AVHRR currently flying in the NOAA series. The AVHRR weight is less than 30Kg and the operating power is less than 28.5watts.

The spin stabilized spacecraft which orbital view is shown in Figure 1, is based in a small spacecraft bus concept developed for the Brazilian Complete Space Mission(MECB) for data collection.

An imaging sensor is mounted in an active despun section which rotates with the same angular speed but in the opposite direction to the angular velocity of the spacecraft main body, in such way that keeps the camera field of view pointing to the Earth. This very simple concept, applied for specific Earth's regions, allows taking high quality images. In spite of, the stabilization concept being not adequate for stringent pointing requirements, the drift rate and jitter can be specified to be small because of the inherent characteristics of the stabilization, which involves small torques and low oscillatory perturbations. The mass and power budgets of the equipments which flies in this spacecraft are presented in Table 4. The attitude control involves a nutation damper, solar sensors, pencil horizon sensors, magnetometer and a torque rod set. The control of the spin axis and skew maneuvers can be done on-board.

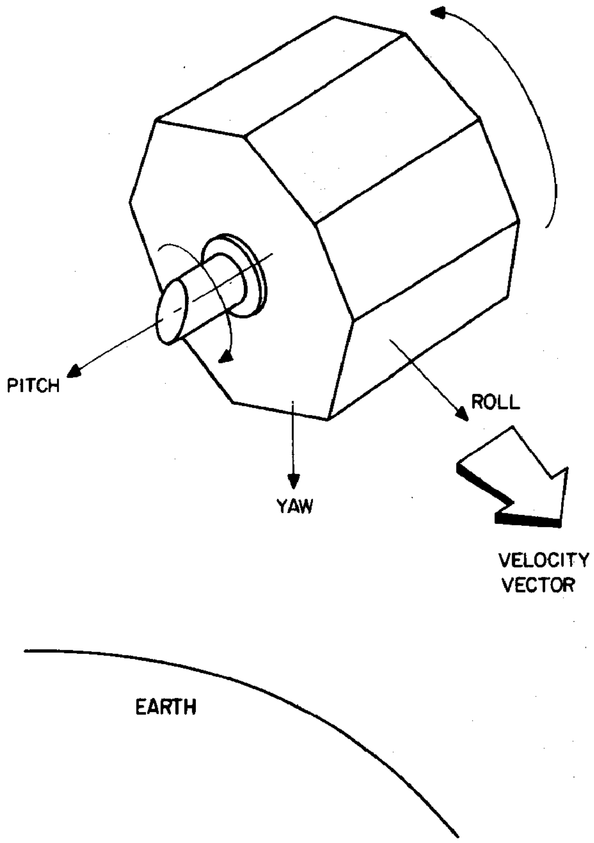

Fig. 1 - Proposed Spin Stabilized Spacecraft

TABLE 4
SUBSYSTEM MASS-POWER BUDGET

SUBSYSTEM	SPIN STABILIZED	
	MASS (KG)	POWER(WATTS)
AOCS	14	3
TT&C	26	14.5
Power	28	7.5
OBDH	15	6.5
Payload	35	15
Structure	37	-
Thermal	1	-
Others	7	0.5
Total	171	47

The orbital view of the three axis stabilized spacecraft is shown in Figure 2. The stabilization is provided by a single momentum wheel oriented perpendicular to the orbital plane which acts as a reaction wheel during slews. The momentum wheel provides a constant momentum bias which gives attitude stiffness for two axis and do not constraint the motion around the bias axes. There are two control laws for pointing and maneuvering the satellite: a control law to nullify drift and drift rate around the wheel rotation axes where the actuation torque is provided by the momentum wheel and a control law to change the angular momentum axes and damping the nutational motion. Because of the three axis stabilization high performance sensors and control law can be used allowing to comply with stringent pointing and drift rate requirements for advanced high performance missions.

The attitude and orbit control subsystem besides of the momentum wheel includes a horizon sensor, magnetometer, sun sensor, a torque road group, thrusters and depending on pointing and drift rate requirement the Attitude Control System may also need to include an inertial measurement unit. The mass-power budget of the equipments which flies in this spacecraft are presented in Table 5.

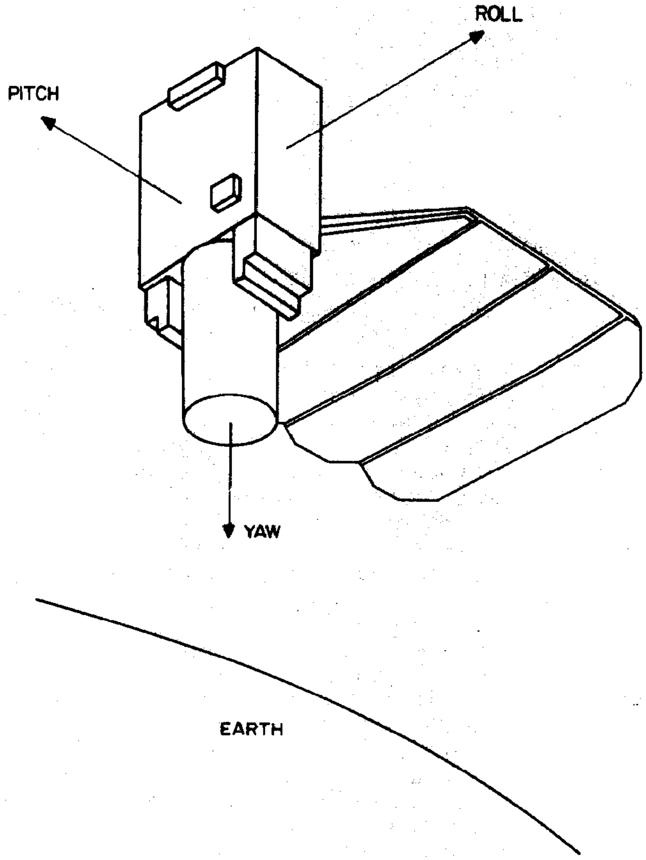

Fig. 2 - Proposed Three-Axis Stabilized Spacecraft

The spacecraft is designed with two major parts: the subsystem bay and the payload bay, the platform(subsystem bay) is a rectangular box with sides 0.915, 0.40, 0.690m and mates with the standard small launchers (Scout, VLS).

TABLE 5
SUBSYSTEM MASS-POWER BUDGET

SUBSYSTEM	THREE AXIS STABILIZED MASS (KG)	POWER(WATTS)
AOCS	30	40
TT&C	28	18
Power	18	7
Fuel	15	-
Solar Array, BAPTA	18	3
Structure	30	-
Thermal	3	-
Adapter, Others	10	-
Payload (less than)	68	17
Total	220	85

The two basic options can be applied for any designed orbit, here, for illustration and also to show its feasibility, three options for orbits are proposed:a heliosyncronous, an equatorial orbit and a low inclination orbit. Table 6 presents the main parameters of these three orbits. Figure 3 illustrates the 2 days coverage of heliosyncronous orbit, Figure 4 illustrates the 2 days coverage of the low equatorial orbit and Figure 5 depicts schematically the skewed view coverage for the equatorial orbit.

TABLE 6
MAIN ORBIT PARAMETERS

PARAMETERS	ORBIT POLAR	EQUATORIAL	NEAR-EQUATOR.
Semi-major axis	7017.7km	8059.0km	7101.8km
Altitude	639.7km	1681.0km	723.8km
Inclination	97.94deg	0	15 deg
Eccentricity	0	0	0
Swath	650.0km	-	182.0km
Coverage	4 days	2 hours	3.9 days
Repeatibility	14+3/4 day	12 day	14+1/4(360deg)
Orbit Period	1.63 hour	2.0 hour	1.65 hour

The skewed coverage can be obtained by the skewed zoom facilities in the camera or by spacecraft slew maneuvers around the roll axes.

The equatorial orbit period was chosen to be 2 hours which corresponds to an altitude of 1681Km. At this altitude the full coverage in the latitude range of +/-10degree can be obtained with a maximum nadir angle for skewed view of 32 degrees. The main characteristic of this orbit is to have a very high repeatability and local time synchronism.

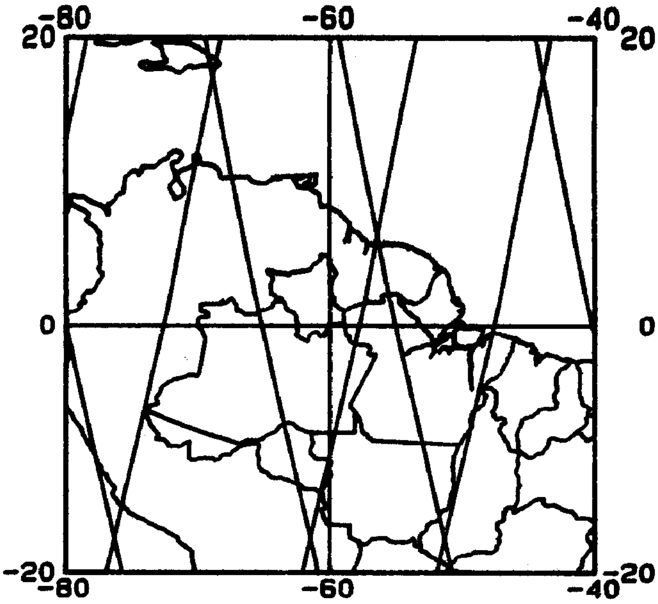

Fig. 3 - Heliosynchronous Orbit Coverage

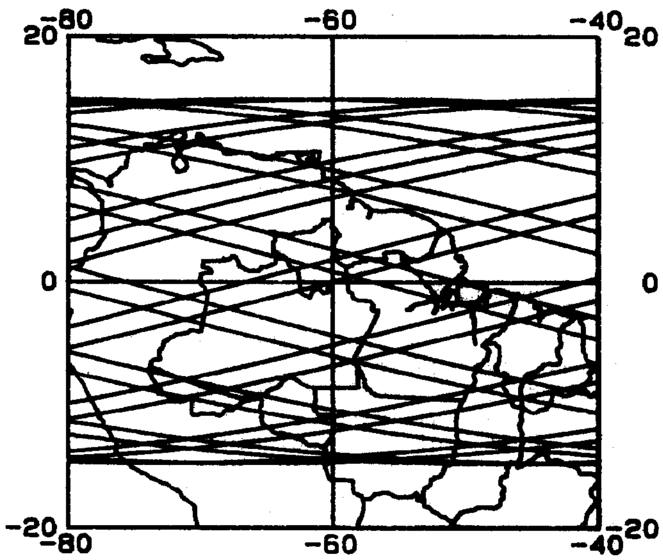

Fig. 4 - Near-Equatorial Orbit Coverage

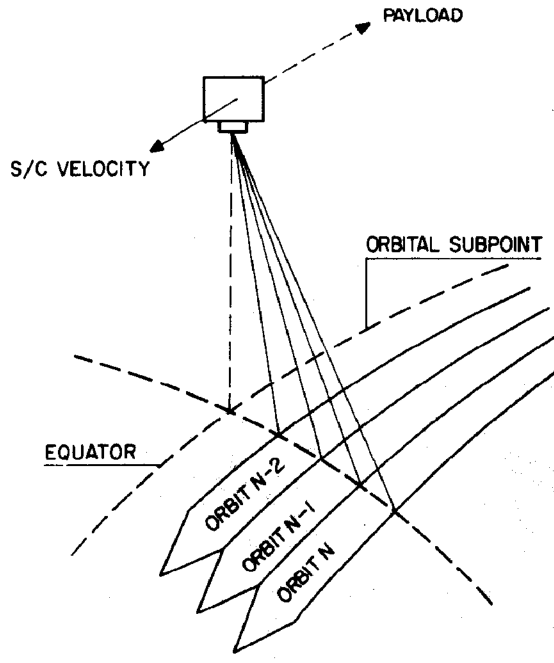

Fig. 5 - Skewed View Coverage

The near equatorial orbit was chosen to have altitude between 600 and 800Km and adjacent orbits after each orbit. Aiming repeatability the orbital period is given by $T = M/N*360/(360+\dot{\Omega})$, where M and N are integer numbers and $\dot{\Omega}$ is the precession velocity of the orbital plane. Considering that at inclination of 15 degrees the precession velocity of the orbital plane is approximately 6.47 degree/day a possible choice for the orbit is to adopt the pair (M,N)= (4, 57) which results T= 1.65 hour and altitude of 723.8Km. This orbit completes a diurnal and nocturnal coverage cycle in 3.9 days. The coverage cycle is 57 orbits what corresponds to an equatorial intertrace of 703.0Km and a swath width of 182.Km. Because of the choice of M and N the number of orbits in a 360 degrees geographical cycle is 14 + 1/4 which implies in adjacent orbits after each orbital period. This property can be seen in Figure 4.

4. COST ANALYSIS

Table 7 presents the estimated cost, assuming average costs for an optical payload dedicated to specific missions, for the proposed and multipurpose spacecrafts. The orbital costs of the dedicated spacecraft are estimated to be less than 20% of the multi purpose spacecraft cost. If the dedicated payload were included in a multipurpose spacecraft, it would be important to consider the cost per Kg of payload. This cost is smaller for the large spacecraft, however still a dedicated spacecraft can result in lower global cost, because of simpler on board and ground data processing facilities. The real time transmission eliminates recorders and permits high load local image data which corresponds to higher volume of remote sensing information per Kg in orbit.

TABLE 7
SPACECRAFT COSTS

	SPACECRAFT		
SUBSYSTEM	CBERS	DEDICATED (SPIN-STABILIZED	DEDICATED (SPIN-STABILIZED
Structure/Thermal	11.1	1.2	2.1
Power	9.7	1.8	2.0
AOCS	16.9	1.1	5.0
TT&C/OBDH	9.8	1.9	1.9
AIT/Management	17.5	2.0	3.0
Payload	35.0	4.0	6.0
Total	100.0	12.0	20.0
Launching	30.0	6.0	6.0

Considering the Amazon region applications the image data can be transmitted in real time what implies in simpler data transmission compared to that when global data storage recorders are used. Other important point to be explored in the Amazon region applications is the use of low orbital inclinations aiming to reduce launching cost. This can be illustrated by the Pegasus launching capacity; this launcher is able to place, for example, 250Kg in 500Km polar circular orbit or 325Kg in 500Km equatorial circular orbit.

Additionally, traditional large budgets and long time scales have increased costs because of complex management, excessive reliability considerations and non-necessary documentation. The small spacecrafts make feasible to adopt efficient low cost solutions for management, reliability and documentation. The management approach have to minimize bureaucracy,in order to simplify interfaces and to use concise documentation. The unnecessary redundancies can be eliminated and non space qualified components and equipments can be used if realistic safety margin are adopted (Radbone, 1989)

5. CONCLUSIONS

In order to cover numerous applications, the modern multipurpose spacecrafts have got very complex and high cost.

These spacecrafts weight more than 1 ton and include high cost equipments and launching. The basic idea here is to develop tailored spacecrafts for specific objectives instead of to introduce new features in multiuser spacecrafts.

Basically two small buses were described which could be used for dedicated remote sensing missions. Both are already developed for MECB (Brazilian Complete Space Mission), the simpler one corresponds to the MECB data collecting spacecraft and the other is derived from the MECB remote sensing spacecraft. Both options can use small launchers consequently with low cost and flexible launching features. The data collecting based bus is spin stabilized, solar cells in the spacecraft body and without orbit maneuver capability, while the other is a three axis stabilized bus concept, deployable solar panels and if necessary including orbit maneuver capability.

The main conclusion is that Amazon region remote sensing have to be strongly considered in Brazil's space program planning.

The Brazilian space program can be decisive for the harmonic regional development and it can benefit itself by inducing favorable political actions. Additionally, the Brazilian technical capability and infrastructure in the space area is adequate for the proposed class of small spacecraft what means that an Amazon region remote sensing program can be developed using indigenous solution.

6. REFERENCES

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