Photogrammetrie • Fernerkundung • Geoinformation 1/2002, S. 11–14

The Amazon Rainforest Monitoring Satellite – SSR-1

JANIO KONO, MÁRIO QUINTINO, HIMILCON CARVALHO, BERNARDO RUDORFF & CARLOS SANTANA, São Jose dos Campos, SP – Brazil

Abstract: The Brazilian Amazon region is the greatest rainforest in the world and it is undergoing complex and fast changes influenced by human activities and natural events. It is of extreme importance to Brazil to have an efficient monitoring system in order to manage the natural resources and to protect the environment of this region. The SSR system presents an innovative solution to monitor the Amazon region, through a small remote sensing satellite placed in a low equatorial orbit, providing synoptic images of the entire region several times a day. The SSR images will be distributed directly to users, in a near real time basis, via small and low cost terrestrial stations. This paper presents the result of a feasibility study for the SSR payload, showing a payload concept and analyzing the accomplishment of the requirements.

Zusammenfassung: *Ein Beobachtungssatellit für den Amazonas-Regenwald – SSR-1.* Die Amazonasregion Brasiliens ist das größte Regenwaldgebiet der Welt und unterliegt derzeit komplexen und schnell voranschreitenden Veränderungen durch Aktivitäten des Menschen und natürliche Faktoren. Für Brasilien ist es äußerst wichtig, auf ein gutes Kontrollsystem bei der Bewirtschaftung der natürlichen Ressourcen und für den Umweltschutz der Region zurückgreifen zu können. Mit einem Fernerkundungs-Kleinsatelliten in einem äquatorialen Orbit, präsentiert das SSR-System eine innovative Lösung für die Beobachtung der Amazonasregion mit einer Wiederholrate der Überfliegung mehrmals am Tag. Abgesehen vom Missionszentrum wird das System auch in der Lage sein, die SSR-Daten über kleine Niedrigkosten-Bodenstationen den Nutzern direkt zugänglich zu machen mit einer Datenübertragung nahezu in Echtzeit. Dieser Aufsatz zeigt sowohl die Ergebnisse einer „feasibility“ Untersuchung der SSR Nutzlast als auch ein Konzept für die Anwendung der Nutzlast und evaluiert, ob die Vorbedingungen durchgeführt werden können.

Introduction

The Brazilian Remote Sensing Satellite (*Satélite de Sensoriamento Remoto* – SSR) is a small satellite which is part of the Brazilian National Space Activities Program. The Program has as main objectives: 1) to develop application satellites that fulfill Brazilian needs; and 2) to develop Brazilian technological knowledge and industry. The Brazilian Amazon region is the greatest rainforest in the world, with an area close to 5 million km^2 which is comparable to the entire west Europe. The Amazon region is undergoing complex and fast changes influenced mainly by human activities (forest fires, deforestation, wood and mineral extraction) and natural events (rain, flooding and droughts). It is of extreme importance to Brazil in ecological, economical and strategical terms to have an efficient monitoring system to manage the natural resources and to protect the environment of this region. Such a monitoring system must have the capability to provide a fast response to either natural or man made events, which leads to the demand of quick access to ready available data, acquired on a high rate basis, which are not available nowadays. One important factor that precludes the efficient monitoring of tropical regions is the severe cloud cover conditions associated with the low revisit rate of the current available optical remote sensing satellite systems. In-

1432-8364/02/2002/0011 $ 1.00

deed, most satellites have sun-synchronous orbit, with a revisit period of 1 to 30 days, which is not adequate to monitor fast changing events such as ongoing fires and deforestations. For instance, with the revisit period of 16 days of the Landsat images it is common to have less than one cloud free scene a year in certain parts of the Amazon region. With the SSR it should be possible to acquire cloud free images, either directly or via multitemporal composed images.

SSR Mission Requirements

The SSR intends to solve the lack of available data for monitoring purposes in the Amazon region, through an innovative solution. Taking advantage of the geographic localization of the Amazon region, the SSR should be placed in a low equatorial orbit providing synoptic images of the entire region several times a day. The sensor should have an Earth surface swath of 2200 km able to image the entire planet region comprised between the latitudes of 5° North and 15° South. The images should be provided in 4 spectral bands in the visible-VIS (blue, green, red) and near infrared-NIR plus a mid infrared band-MIR. The spatial resolution at nadir should be 40 m for the VIS/NIR bands and 500 m for the MIR band.

Several applications to monitor and study the Amazon region are being proposed with the SSR images, such as: a) quantitative evaluation of deforested areas; b) detection of burning and burned areas; c) characterization and classification of vegetation cover; d) natural vegetation regrowth; e) phenology of vegetation; f) agricultural activities; g) flooding and inundation; and h) mining activities. Since not only the Amazon region will be covered by the SSR images but also the whole equatorial belt around the world, other useful information should be provided by the SSR to: a) desertification studies; b) oceanography; c) geology; d) solar radiation, among others. The SSR mission aims to provide relevant data to both scientific community and governmental agencies.

To reduce the latent time in data distribution, besides the standard centralized mission center, the system should also have the capability to distribute the SSR data directly to users in a near real time basis, via small and low cost stations. The SSR system will consist of the satellite and its ground segment.

Mission Constraints

The SSR payload shall be modular and compatible with the Brazilian multimission platform and existing Ground Segment. The following constraints apply for the SSR payload module: a) payload module mass limit is 100 kg; b) average power shall be less than 140 W; c) down link bit rate shall be less than 150 Mb/s; and d) mission lifetime in orbit shall be 4 years.

SSR mission peculiarities

Due to its unusual orbit and large swath width, this system brings some difficulties and challenges compared to usual systems with satellite in sun-synchronous orbits. One peculiar characteristics is the wide variation range of solar incidence angles over the target. In an equatorial orbit, during a 12 minutes pass the satellite will span 3 time zones. This means that in a single image, the local time in one extreme will be 3 hours less than the local time in the other extreme, with great changes not only in illumination conditions but also in the size and direction of shadows. Besides that fact, the satellite should pass over a region several times a day (approximately every 100 min) and, therefore, solar azimuth will vary greatly for the different passes. Another important factor is the extreme view conditions to image regions between latitudes of 10° S and 15° S. For instance, at 15° S the viewing geometry has an off-nadir angle of 56° and target view angle of 20° above the horizontal. This will cause a significant increase of the length of the path through the atmosphere, introducing fading and distortions that will require special atmospheric correction techniques and procedures. In addition, the spatial resolution will be degraded from 40 m at nadir to 200 m at 15° S.

In order to assess the technical feasibility of the payload a study for the SSR payload was performed by DLR – *Deutsches Zentrum für Luft- und Raumfahrt*, in the frame of scientific and technological cooperation with INPE. The objective of this study was to demonstrate the capability to meet the requirements, to assess the quality of image in the extremes of the coverage and to show the compatibility with the Brazilian multimission satellite platform. As part of this study an airborne flight campaign was performed in the Amazon region using the HyVista hyperspectral camera-HyMap.

SSR-1 Payload Concept

The study presents a payload concept that can fulfill the majority of the requirements and constraints. The payload design has taken into account the following principles: a) well-proven technology; b) small size; c) low power; and d) low cost. The baseline SSR imaging system consists of a VIS/NIR sensor unit, a MIR sensor unit, a Digital Data Processing and Control unit, and a RF unit.

The VIS/NIR sensor is a pushbroom CCD camera with three optical heads, combined to achieve the FOV and geometrical resolution requirements. Each focal plane assembly has 5 parallel CCD lines, one for each spectral band. This design is based on the DLR High Resolution Stereo Camera (HRSC) heritage. The five spectral bands are blue (B1; 0.447–0.502 μm), green (B2; 0.518–0.566 μm), red (B3; 0.636–0.682 μm), NIR (B4; 0.786–0.890 μm) and an additional channel (B5; 0.814–0.844 μm) for the estimation of the water vapor content, that will be used in an atmospheric correction procedure. The main optic characteristics of the three lenses are: 1) focal length of 137 mm for north and middle lenses and 190 mm for South lens; 2) f number of 4.85 for all three lenses; 3) FOV of 31.8° for north and middle lenses and 23.1° for south lens; 4) aperture of 115 mm for north and middle lenses and 100 mm for south lens; and orientation from nadir of $+15°$, $-17°$ and $-44.5°$ for north; middle and south lens, respectively. The detectors are Thomson THX 7834C linear CCD image sensor with 12000 pixels. The ground sample distance achieved with this configuration is approximately 50 m, 100 m and 200 m at 5°, 10° and 15° of latitude, respectively. The output of the CCD detectors is converted to digital by a 14 bits A/D converter. This high resolution A/D converter will allow to accommodate the whole signal dynamic range and to operate in all illumination conditions without gain switching. The estimated raw bit rate for this camera is 252 Mbps. Due to the limited downlink rate of 150 Mb/s, data compression will be employed. The selected method is online compression, using Constant Rate Wavelet based Image Compression (CWIC).

The MIR sensor is a pushbroom camera with two optical heads with 32° FOV, combined to increase the total FOV. Each optical head has one focal plane assembly with two staggered 512 pixels HgCdTe line detectors. A stirling type split cooler will be used to refrigerate the detectors, which shall operate at the temperature of 80 K. This design is based on the DLR BIRD heritage. Due to the high power consumption and the degradation of the geometrical resolution at high latitudes, it was decided not to cover the whole swath width of 2200 km with this sensor. The MIR sensor will cover the swath between 5° N and 5° S, with a GSD varying from 500 m to 700 m. The MIR sensor shall cover the mid infrared spectral band from 3.4 to 4.2 m and the output of the detectors is converted to digital by a 14-bit A/D converter. Since this dynamic range is not enough to avoid saturation, the sensor performs real-time processing to detect high illuminated pixels and reacquire those portions of the image with smaller integration time. The MIR sensor shall have a Noise Equivalent Temperature Difference better than 0.5 K. In order to improve the performance of fire detection in the presence of smoke, the inclusion of a TIR sensor was recommended by DLR.

All payload items are mounted on a dedicated panel, which provides the interface with the platform. This solution simplifies the interface definition, assembly, integration and test activities. The camera heads are mounted in a common optical bench to meet the co-alignment requirements. The payload module key parameters are: a) mass of 95 kg; b) volume of 1084 mm × 1130 mm × 322 mm; and c) power of 375W / 97W (without heater).

The accomplishment of the mission requirement was demonstrated using data from a flight campaign in order to simulate SSR-1 data and performing computer simulations to assess the performance of the sensor in different conditions. The flight campaign was carried out using the HyMap sensor (Cocks et al. 1998) in April 2000 over Amazon rain forest in the State of Acre, Brazil. To simulate the SSR-1 data the following scenarios were addressed: a) varying solar illumination condition over daytime; b) varying viewing geometry over wide angle; and c) target and atmospheric characteristics.

To simulate the varying solar illumination condition it was planned to acquire HyMap images every two hours from 8:00 AM to 4:00 PM. However, due to intense cloud cover conditions during the period allowed for the flight campaign (two weeks) data were acquired only for one favorable day around 8:00 and 10:00 AM. For the 8:00 AM path data were acquired at both nadir and off-nadir (up to 65°) by banking the airplane in order to simulate the viewing geometry over a wide angle. The targets were typical Amazon rain forest and deforested areas with pasture for cattle raising.

The main conclusions for the accomplishment of the mission requirements can be summarized as follows: 1) the noise equivalent reflectance for the blue, green, red and near infrared channels can be fulfilled under a standard atmosphere (10 km meteorological range) for up to 8° S; further south this can be fulfilled only under good atmospheric conditions (23 km meteorological range); 2) at the southern extremity of the swath (15° S) the slant view shading effects may pose problems; for instance, at the latitude of 15° S, a tree with an height of 40 m will project a shade of 115 m; 3) strong view angle effects can be corrected taking into account turbidity, water vapor content and wavelength dependence of the aerosol scattering; 4) the influence of view angle on water vapor column content proofed to be systematic and should be correctable; 5) due to radiometric effects, in combination with the slant view shading and cloud shadows, the number of useful images are strongly restricted, despite of the high data acquisition rate; 6) although much less HyMap data were acquired than initially planned they proved to be very useful not only to simulate illumination and viewing conditions but also to define the band characteristics; 7) interpretation of the HyMap data showed that even under extreme view angles important data products like the NDVI and water vapor path content can be extracted; and 8) future studies are necessary to develop standard methods adapted to the special characteristics of the SSR-1 images influenced by both sensor and target.

Conclusion

The preliminary results of the study show that the majority of the SSR requirements can be fulfilled with a payload composed by two instruments: a VIS/NIR and a MIR camera. It was concluded that due to power and mass limitations of the small satellite, it will not be possible to meet the geometric resolution and the swath width for the MIR camera. It was also found that a significant loss in the image quality will occur for latitudes between 13° S and 15° S. Nevertheless, due to its high revisit rate, images from these region can be useful for certain applications. The introduction of a TIR camera was recommended due to its suitability to perform accurate fire detection during daylight in the presence of smoke.

Address of the authors:
Janio Kono, M.S., Mário Marcos Quintino da Silva, B.S., Himilcon de Castro Carvalho, Ph.D., Bernardo Friedrich Theodor Rudorff, Ph.D. & Carlos Eduardo Santana, Ph.D.
National Space Research Institute – INPE
Av dos Astronautas, 1758, São Jose dos Campos
12227-010, SP – Brazil
kono@dss.inpe.br