MISSIONS OF THE DORIS SYSTEM

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RESUME – Ce document a pour objet de donner un aperçu des applications du système DORIS, principalement dans les domaines de l'altimétrie océanographique et de la géodésie. Il indique quelles sont les missions opérationnelles qui utilisent DORIS et celles pour lesquelles DORIS est candidat. Il décrit succinctement les principes de fonctionnement du système et en donne les principales performances.

ABSTRACT - The purpose of this paper is to provide an overview of the DORIS applications in support of radar altimetry or geodetic missions. It mentions the operational programs currently using the DORIS system as well as the future programs for which DORIS is a candidate payload.

1- HISTORY :

The DORIS (Doppler Orbitography and Radiopositioning Integrated by Satellite) was designed and developed by CNES, the Groupe de Recherche Spatiale GRGS (CNES/CNRS/Université Paul Sabatier) and IGN in 1982 to cover new requirements concerning precise orbit determination. As such, DORIS was proposed in support of POSEIDON oceanographic altimetric experiment and was embarked on the TOPEX satellite (launched in August 92). DORIS is then part of the scientific payload, and is a primary sensor for the orbit determination which requires an accuracy in the order of 2 to 3 cm to achieve the large scale ocean monitoring needed for the altimetric mission. The in-flight validation of DORIS was achieved before the TOPEX/POSEIDON experiment, by flying an experimental DORIS payload on board the observation satellite SPOT 2 (launched in 1990).

2- MISSIONS :

Although the DORIS system was originally designed to perform very precise orbit determination of low Earth orbiting satellites for ocean altimetry experiments, many applications have been developed since.
In particular, DORIS was approved for flying on board SPOT3 (launched in September 93) and SPOT4 (launched in March 98) in its capacity to provide precise positioning of ground based stations. This capacity has proved to be very useful for many scientific applications, especially in geodesy. Thanks to DORIS, scientists from the GRGS has shown that the present-day tectonic motion of the main plates is comparable to their motion averaged on the last 3 million years. Thanks to DORIS it is also possible to measure the motion of the rotation axis and of the geocenter, due to mass redistribution in the Earth interior. DORIS has also contribute to improve the computation of gravity field models. Finally, DORIS allows the calibration of tide gauge by measuring very accurately the vertical motion of the crust at gauge sites.

In the case of SPOT4 a real time on board orbit determination capability, called DIODE, has been added to DORIS to provide SPOT images users with satellite ephemeris.
The DORIS System has also been selected by the European Space Agency to determine the precise orbit of the ENVISAT-1 Satellite to study Earth Environment.

Moreover, DORIS is currently candidate to be embarked on various satellites or experiments:

- on ACES platform (ESA experiment related to very high precision time and frequency references, planned to be flown on the International Space Station). DORIS is used for precise position and velocity platform determination in order to compensate for relativity effects on the time and frequency references provided by the different ACES equipment.
- on the SPOT 5 follow-on missions satellite (LEO earth observation satellite) for on-board real-time orbit determination, through the use of DIODE, and to continue DORIS/SPOT missions (ground stations network monitoring, ground stations positioning and geodetic survey).
- The possibility to use a simplified and less accurate DORIS instrument to perform satellite autonomous navigation is being studied for the future PROTEUS minisatellites and for CNES microsatellites project, as an heritage of the DORIS/DIODE mission on SPOT4 which proved its accuracy and availability (more than 99% of the time).

Other missions to which DORIS could contribute are under investigation:

- Concerning the navigation function: the ATV (Automatic Transfer Vehicle) and the “ALOS interfering wheel”. DORIS has also been proposed to the European Commission to contribute to the architecture of the Radio navigation satellite system GALILEO, for the purpose of orbit restitution and synchronization ;
- Concerning altimetric missions: the CRYOSAT mission, currently studied by ESA for the purpose of ice observation; the AltiKa project of microsatellite dedicated to altimetry in Ka band.

Considering the high quality of DORIS products in terms of measurements accuracy, stations network global coverage and operationality of data production (measurements, orbits determination, beacons positioning), IERS has decided since 1994 to include DORIS solutions, in the same way as GPS, Laser or VLBI solutions, in the ITRF determination process (precise location and mouvement of selected sites). DORIS measurements are also used for comparison with other technics for Earth rotation and Polar motion. DORIS thus contributed to ITRF 94, 96 and 97 and will contribute to ITRF 2000.

In order to reinforce the international use of the DORIS system as a reference means of radio-positioning and navigation, and to facilitate the access to DORIS products to a wider community of international users, CNES and IGN are conducting the project to create an « IDS » (International DORIS Service), similar in terms of organization and objectives to the existing International Services dedicated to GPS or VLBI or Laser Ranging. This IDS, steered by an International Governing Board, will have as main objectives to support the use of DORIS system and products, to define standards, to promote research and development activities to improve system performance, operationality and applications, and to interact with the users community.

3- DORIS SYSTEM DESCRIPTION

3-1General principals :

Doris is based upon the accurate measurement of the Doppler shift of radiofrequency signals transmitted from ground beacons and received on board the spacecraft when it passes over.
Measurements can be made on two frequencies 2.03625 GHz for precise Doppler measurement and 401.25 MHz for ionospheric correction. At present, the 401.25 MHz is also used for measurements time-tagging and auxiliary data transmission.
The whole DORIS system as shown in *figure 1* comprises on board packages, a permanent beacons network, and a ground control and data processing centre. There are currently 54 permanent beacons scattered around the world in more than 30 countries.

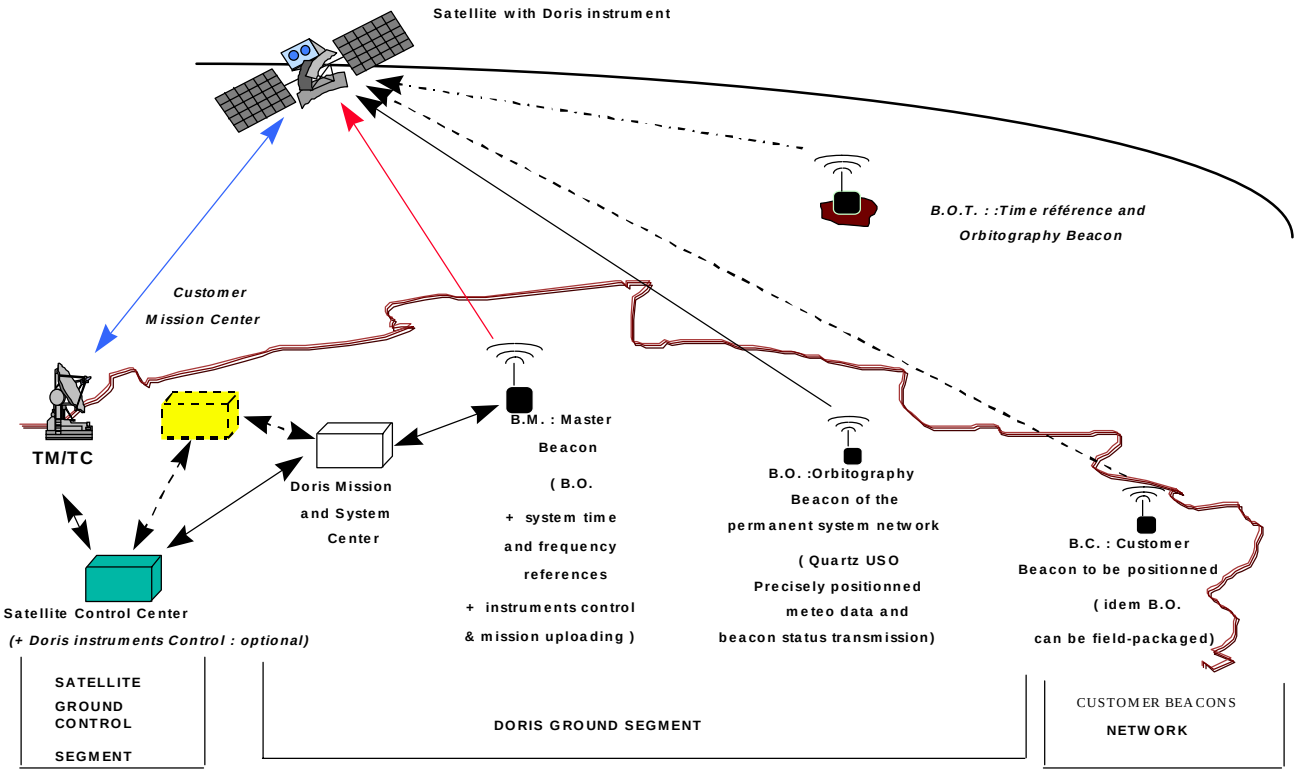

figure 1 - DORIS system overview

3-2 System enhancements :

New DORIS on board instruments have been developed to be flown on board JASON-1 (TOPEX/POSEIDON follow on mission) and on SPOT5 satellite platforms. These new instruments (known as Miniaturized 2nd Generation) have similar performances as the DORIS/ENVISAT instrument but with significant decrease in mass, volume and power consumption characteristics.

The next generation of DORIS beacons (third generation DORIS beacon), presently under development, will have the capability to transmit time-tagging modulation and auxiliary data on both frequencies to allow the use of DORIS beacons signals by monofrequency (2.03625 GHz) on board instrument dedicated to orbital navigation purposes (typically for real time orbit determination with an accuracy of few meters).
At the same time, these new beacons will implement the ability to transmit their signals on slightly shifted frequencies with respect to the nominal system frequencies, in order to avoid the risk of « Doppler collisions » in case of the use of the DORIS system from high altitude orbits (MEO, IGSO, GEO) and to allow regional increase in the number of DORIS beacons.
Another major improvement brought about this third generation beacons is that they broadcast the current complete date (year/month/day/hour/minute/seconds) in TAI scale which allows the in-flight DORIS instruments to perform their initialization process - from equipment turn-on to satellite position, velocity and time estimation - in a fully autonomous way, without any ground command or uploading.
Beacon data transmission (synchronization word, auxiliary data, uploading in case of Master Beacons) is performed according to a 10 seconds sequencing. This 10 seconds beacon sequence is synchronized with respect to TAI within $\pm$ 1 seconds to guarantee a correct reception of these beacon data by the in-flight instruments.

4- PERFORMANCES :

For DORIS on SPOT satellites, only internal criteria can be used for the orbit quality assessment, such as residuals after orbit restitution and comparisons of solutions with over lapping data. For DORIS on TOPEX external criteria can be used in addition to the previous ones, such as comparison between the Precise Orbit Determination (POD) performed by CNES with DORIS data and the POD performed by NASA by using Laser Satellite Ranging.
The final accuracy that can be achieved depends on whether the data is processed by the on-board package or by the ground processing center.
Actually, the radial accuracy of POD calculated by the ground processing center, is in the order of 2 to 3 centimeters with DORIS/TOPEX and 5 to 6 cm with DORIS/SPOT data. It can be obtain with a delay of one month. This accuracy is better than 20 cm if the delay is 48 hours.
The orbit calculated in real time by the on-board package is determined with an accuracy of better than 4 m RMS in all axes.
For the positioning aspects, DORIS is able to detect beacons motion of the order of 1 to 10 mm per year. This performance could be improved in the future if DORIS is embarked simultaneously on 4 satellites or more, located at an appropriate altitude (between 800km and 1300km).

5- CONCLUSION

The number of DORIS applications has constantly increased since the system became operational. Many other applications have still to be discovered, given the design of the DORIS system and its planned improvements. Furthermore, the DORIS system will be available beyond 2010, thanks to the long term requirements of altimetric and geodetic missions to maintain an operational space-based accurate location service.