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C. R. Geoscience 337 (2005) 1223–1224
COMPTES RENDUS GEOSCIENCE
http://france.elsevier.com/direct/CRAS2A/

Perspective

The DORIS system: a fully operational tracking system to get orbit determination at centimeter accuracy in support of Earth observations

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Available online 24 August 2005

1. Results and prospect

Very recently, Willis et al. [10] presented very important geodetic applications of the French DORIS system at the 'Institut géographique national' (IGN), DORIS meaning *Doppler Orbitography and Radio positioning Integrated by Satellite* (altitude in the order of 700–1400 km). It is of great interest to emphasize the context of the development of this system and its prospect at the international level.

In the early 1980s, scientific objectives were to determine temporal variations of the Earth surface, sea surface and land surface, but it was not clear whether appropriate tools could be proposed for that. For the sea surface, the more advanced technique was the satellite radar altimeter, the interest of which was demonstrated by the SEASAT satellite. Thanks to this technique, the accuracy of the vertical range of the sea surface could be measured with 1–2-cm accuracy provided that the position of the satellite is referred to an absolute terrestrial reference system with the same 1-cm accuracy everywhere. The sea surface height is the sum of two geophysical signals: the marine geoid signal and the oceanographic signal (tides, ocean circulation, and rise from greenhouse effect). Therefore, for the interpretation of the sea-surface variations, it is a prerequisite to compute a very accurate referenced orbit. CNES and NASA decided to join their effort in order to build up a fully optimised system, the TOPEX/Poseidon altimeter project (T/P 1992) with DORIS onboard, which then was also placed on JASON-1 (2001), ENVISAT (2002) and in the future on JASON-2 (2007) and possibly on Pleiades satellites (2008 and beyond). At this time, no other systems could meet the requirements, but DORIS had the good potential capability. At the time of decision of DORIS the analysis of the error budget for the radial component determination gave a nominal value of 13 cm, whose 10 cm could be attributed to the orbit error. DORIS was decided to overcome the problem [5].

The DORIS system is based on the onboard measurement of the Doppler effect of signals emitted by ground radio beacons equipped with ultra stable oscillators. DORIS uses a dual-frequency Doppler uplink (400 MHz and 2 GHz) to precisely get the position of a satellite with respect to a permanent geodetic worldwide network of 55 to 60 stations. DORIS is a heritage of the ARGOS system working since 1978.

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doi:10.1016/j.crte.2005.07.007

The system was successfully tested on the Earth-observation satellite SPOT-2 (1990) designed for getting images of the Earth everywhere, and then enhanced for 15 years. There were three generations of beacons and three generations of receivers. The miniaturization of electronic components has reduced instrument weight and size by a factor of four. The current instrument weighs 1.5 kg and occupies 1.5 l; the DORIS instruments have now two channels for recording two measurements simultaneously. In the interval of ten years, the instrumental orbit error has been reduced by a factor of 10 and *is now at the 1-cm level as required* [4]. The success was mainly due to the improvement of the oscillators, the fully automated stations, the global tracking coverage, the use of a unique time scale in the system.

In parallel, new requirements appear to refer the orbit and the positions of the satellite in an absolute terrestrial system based on the DORIS data, but also merged with the other geodetic data (Satellite Laser Ranging – SLR –, Global Positioning System – GPS – Very Long Based Interferometry – VLBI) to guarantee the accuracy [1,8]. *An international DORIS service* was set up including all the international community with the purpose to precisely determine on a regular basis with all the existing satellites equipped with DORIS [9]: the Earth's rotation parameters, the motion of the centre of mass of the Earth with respect to the Earth crust, a terrestrial DORIS reference system including the motions of station positions [6,7], as explained in the paper by Willis quoted above.

But a new attractive opportunity appeared to compute onboard in real-time precise orbits of satellites. It was the *DIODE system* [2,3], which is now a part of the DORIS instrument and can compute an orbit with a precision within few meters and up to the decimetre level for the radial component. This new possibility is decisive for an operational system enabling to deliver oceanographic products for meteorology in real time as well as products from any Earth-observation satellites, provided that another parameter can be known, the attitude, which is now possible with the existing solar and stellar sensors. DIODE was successfully tested on SPOT-4 (1998).

2. Conclusion

Unparalleled results have been obtained thanks to DORIS optimized for altimetry missions, but more generally for any Earth-observation missions (see CRYOSAT satellite in 2005) as a facility onboard including the real time, an autonomy capability and interesting capabilities for monitoring a satellite constellation, as shown by the T/P-Jason tandem mission. More information on the DORIS System can be found on the website Aviso (http://www-aviso.cnes.fr). Many thanks are addressed to Michel Lefebvre who reviewed this note.

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