

# GRAVES Space Surveillance System: Life Extension and Upgrade Program

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## ABSTRACT

Onera, associated with SME Degréane Horizon, has been notified by DGA, French MOD Procurement Agency, for the refurbishment contract of GRAVES System, aiming at extending the life time of the system up to 2030.

GRAVES System (Grand Réseau Adapté à la VEille Spatiale = Large Radar Array for Space Survey) is a Space Surveillance system, whose main mission is building a Space Picture for military intelligence, by autonomously building and maintaining a catalog of space objects. It is the only European designed system able to autonomously detect and catalog space objects in Low Earth Orbits. The catalog of the objects' orbits enables to predict their position and trajectory and process some useful information, like collision warnings, fragmentation analysis...

This contract will enable to guarantee the system to be operational up to 2030, making it possible for the French Air Force to have an up to date space picture, know the position of foreign satellites and predict the threats to our assets.

The paper will present an overview of the system, the lifetime expansion works and the possible foreseen performance improvements that make it a key component of a possible future European SST system.

## 1 Presentation of the system

GRAVES development started in the early 90's, with preliminary experiments and studies. A breadboard was built in 1993 by ONERA. First continuous experiments were led in 1999, enabling a two months continuous experiment in 2001, validating the functionalities of the system. This led to a first contract for ONERA to extend the system to its present physical state, being declared operational in December 2005 [1].

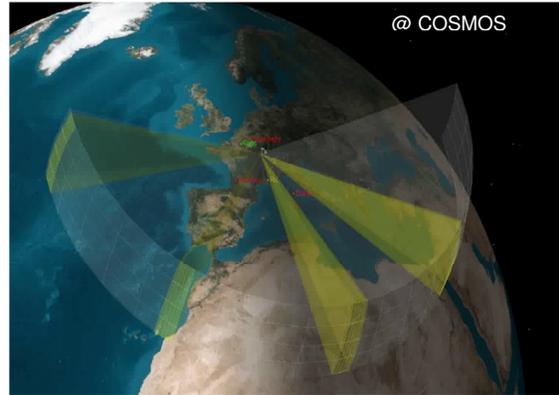


Figure 1. GRAVES fence principle

GRAVES system is based on three sites, two corresponding to a bistatic radar, the third being the processing site. The radar works with a VHF continuous wave pure carrier transmission. The four transmitter arrays (cf. Fig. 2) cover each one 45 degrees in azimuth and 20 degrees in elevation. This individual Field of Regard is scanned by electronic deflection, forming a fence in the sky regularly scanned (cf. Fig. 1).



Figure 2. GRAVES transmission site

The reception site (cf. Fig. 3) is located near Apt, 400km South to the transmission site that is near Dijon. The 60 m diameter reception array receives the signal reflected on the Low Earth orbiting objects crossing the Field of Regard, the signal being modified due to Doppler effect. Digital beamforming is performed in over one thousand different directions to detect the

objects. Associated signal processing is performed real time on the site.



*Figure 3. GRAVES reception site*

The detections are sent to the third site, the data processing site. Tracking is performed to associate the detections corresponding to the same objects and reject false alarms. This tracking is performed on the basis of a “Track While Scan” mode. The association is performed for the current pass, and a long term association is also performed to build and maintain a catalog of orbits. The orbits and associated ephemerids are processed several times a day to get associated operational products: manoeuvres detection, conjunction prediction...

All stages of the system are fully automated, working 24/7, requesting no human intervention except maintenance. The radar itself has no moving parts, making it particularly robust, that is an important characteristic for a permanent survey asset.

GRAVES mission is a defense intelligence mission, aiming at gathering information about active objects in LEO. GRAVES performances enable to regularly detect and catalog over 2500 objects in LEO, ensuring its main mission and contributing to others. The specified performance is to be able to catalog objects between 400 and 1000 km altitude, with a detection performance of minisats at an altitude of 1000km.

Since 2005 and the date it has been declared operational, space environment has largely evolved, typical active objects getting smaller. Furthermore, GRAVES equipment get older, some being obsolescent. Thus, it has appeared important to preserve its mission and to proceed to a refurbishment. Associated to this refurbishment, an extension of performances will be studied and evaluated.

## **2 Lifetime Extension**

GRAVES is operational since 2005, based on some elements of the previous elements of the demonstrator.

Thus, some component may have been used for over 20 years. Even if the design is very robust and modular enough to ensure graceful degradation, some components now face obsolescence. In order to ensure an extension of the lifetime of the system. DGA, French MOD Procurement Agency, has awarded Onera and its co-contractor SME Degréane Horizon a contract to ensure the refurbishment of the system and study performances extensions. Degréane Horizon will perform the refurbishment of the transmission site. ONERA will be in charge of the reception and mission processing sites, as well as responsible for the performances of the system and their non-regression.

On the transmission site, there is a command building, linked with four shelters containing the transmitters, just at the back of the four antennas. The design relies on electronic beamforming to ensure the regular scanning of the fence. Degréane Horizon will perform an update of the transmission system, changing the transmitters and updating the cooling system in each shelter while ensuring that the transmitted power is the same with the same quality. Of course, the associated maintenance and logistical support studies will be made to ensure that the new design is at least as resilient as the previous one.

On the reception site, the receiving array is made of a large circular plate containing one hundred antennas. All the reception electronic is hosted in the associated building. The receiving electronic leads to the digitalization of the received signal in order to send it to the signal processing unit. That calculator used to be one of the most powerful real time computer in Europe. It enables to extract the detections corresponding to the objects crossing the illuminated fence, by forming more than one thousand beams to cover the illuminated zone. All this receiving and processing chain will be updated. The signal processing unit will be changed for modern processing assets, enabling to increase the performances in terms of detection, corresponding to improvements in the signal processing identified throughout the use of the system.

The data processing unit used by COSMOS to build and maintain the catalogue will also be updated by ONERA, to benefit from the latest processing capabilities. Orbital analysis functions will be added to analyse all the data gathered and better characterize the objects that are regularly observed.

The main challenge of the project is to minimize the impact of the refurbishment work on the mission of the system. The contractor considered the planning of the work with a great care to ensure that the system will continue running with constant performances. To ensure this, ONERA is in charge of the verification of the performances throughout the different steps of refurbishment. Those steps will consist in separated phases of work between the three sites, with verification

of the performances, to ensure non regression before continuing. The modularity of the system enables for instance to work on the transmission shelters one after another, without losing the ability to maintain the catalogue, thus maintaining the mission.

### **3 Performances Extension**

The lifetime extension work has been launched. It already includes some software performances improvements, especially through signal processing revision, as well through associated (and required) evolution of tracking. This may lead to the better cataloguing of more objects, considering that today GRAVES routinely detects, tracks and catalogues over 2500 objects.

Other possible improvements could be considered and studied. They would be subject of studies to evaluate the expected improvements in terms of performances. One important improvement could be the addition of antennas on the reception site, different possible steps being considered. Of course, this evolution would have a positive impact on the overall link budget, enabling to detect and catalogue many new objects, possibly smaller than those already followed. This would lead to an overall positive impact on safety, since it would be the

entry point of more autonomous evaluation of collision risks than the autonomous level already performed today.

Enabling the extension of the lifetime of GRAVES system is important for French operational capability of Space Surveillance. The foreseen evolutions would make GRAVES an even more valuable key contributor to an autonomous French or even European SST capability, contributing to protect our space assets.

### **4 Abbreviations and Acronyms**

COSMOS: Centre Opérationnel de Surveillance Militaire des Objets Spatiaux = Military Operational Center for Space Objects Surveillance

DGA : Direction Générale de l'Armement = French MOD Procurement Agency

GRAVES: Grand Réseau Adapté à la VEille Spatiale = Large Radar Array for Space Survey

### **5 References**

1. Michal Th., Eglizeaud J.P., Bouchard J. (2005). GRAVES: The new French System for Space Surveillance.

