# OHB PLATFORMS FOR CONSTELLATION SATELLITES

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## ABSTRACT

After an introduction into the complex task of mission design for satellite constellations, this paper provides an overview of the platform concepts for constellation satellites that have been developed at OHB-System. The objectives of these constellations cover Earth Observation, Communication, Navigation, and Reconnaissance. For the SAFIR-2 satellite system OHB performed the development of the gravity-gradient stabilised micro-satellite, which provides global bi-directional telecommunication services. Within the INES study, OHB performed the predevelopment of a LEO constellation for the European Global Navigation Satellite System. INES was configured as a 63/9/3 *Walker* constellation of three-axis stabilised mini-satellites. OHB-System, as the European service provider of the ORBCOMM communications system, recently has performed a predevelopment of a next generation mini-satellite bus to replace the current Microstar™ platform. SAR-Lupe is a satellite constellation for synthetic aperture reconnaissance, which is scheduled for launch later this year. It consists of up to five spacecraft in three different polar orbit planes, at an altitude of 500 km. The ESA mission named Swarm aims at the mapping of the geomagnetic field with unprecedented accuracy. OHB-System has performed the design development of these spacecraft, the main scientific instrument of which is a magnetometer package carried on an articulated boom.

## 1 GENERAL REQUIREMENTS FOR SATELLITE CONSTELLATIONS

The use of satellite constellations to achieve mission objectives is common in all applications, i.e.

- in global positioning systems, e.g. GPS, GLONASS, GALILEO
- in recent global personal communications systems, e.g. ORBCOMM and IRIDIUM,
- in civilian and military remote sensing systems, e.g. RapidEye,
- in scientific Earth observation constellations, e.g. CLUSTER.

Specifying a constellation by defining the orbit elements for each satellite and their relative position generally is a complex problem and overwhelming in its range of options. A reasonable way to begin is by considering a constellation with all satellites in circular orbits at a common altitude and inclination [1].

Except for scientific satellite constellations, for most applications, Earth coverage is the key reason for using multiple satellites. Thus the basic trade-off in constellation design is coverage as a measure of performance versus the number of satellites as a measure of cost. Although there exist no general rules in terms of constellation design, some helpful considerations can be made. With respect to constellation maintenance, all orbit planes of the constellation should be invariant w.r.t. orbit perturbations, and the amount of orbit planes $p$ should be low, because each orbit plane requires at least one launch. The performance plateaux of a constellation, i.e. the system latency or revisit time, is dependent upon the amount of orbit planes $p$ that are replenished with spacecraft. Therefore, a low amount $p$ is equally beneficial, as it is when considering the case of a satellite failure. In this case, a graceful degradation can easily be achieved, such that through phasing manoeuvres the remaining spacecraft can be evenly redistributed [2]. Generally, the existence of the *van Allen* radiation belts can be considered as a altitude region that should be avoided for LEO satellite constellations. As can be concluded from the preceding remarks and from existing satellite constellations, the requirements and the actual design of a constellation satellite can be very different.

Satellite constellations for Earth observation have many common aspects with those for telecommunication. The satellite design for both applications will be described in this paper, although the mission objectives determine the type of payload and the demands for resources and ACS.

## 2 SATELLITE FOR INFORMATION RELAYING – SAFIR-2

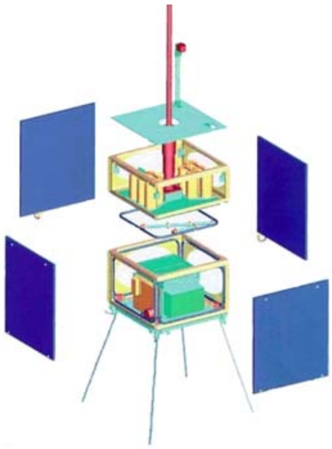

**Figure 1: SAFIR Exploded View**

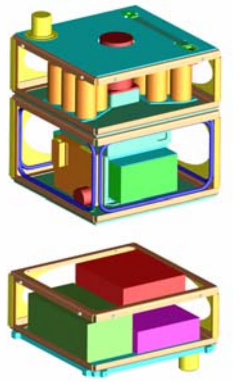

**Figure 2: SAFIR with Payload Extension Box**

For the SAFIR satellite system OHB performed the development of the gravity-gradient stabilised spacecraft. It provides global bi-directional telecommunication services for short messaging and positioning telegrams. For this project OHB has developed a ground station, which currently operates the 2 satellites. The satellites main features are an overall power demand of 28 W, a mass of 60 kg and a cubic volume of 0.45 $m^3$. The passive attitude stability is enhanced by an active control loop with magnetic coils as actuators. The achieved attitude accuracy is limited to $\sigma \leq 10°$. The ACS sensor suite comprises a magnetometer and a horizon sensor.

The satellite bus has a modular design, which can be extended by a second payload compartment.

## 3 INES CONSTELLATION

Within the INES study, OHB performed the predevelopment of a LEO constellation for the European Global Navigation Satellite System. INES was configured as a 63/9/3 Walker constellation of a small three-axis stabilised satellite. The orbit altitude was 1500 km and the inclination 62.5°. The INES payload was to determine the ephemeris parameters and to transmit the INES time and a navigation signal. The pointing accuracy was determined to 3 $\sigma \leq 2.5°$; the satellite's mass to 260 kg. The payload consisted of a navigation computer, frequency synthesizer and conditioner and two antennas. The mean satellite power amounted to 158 W. It is generated with deployable solar panels, Solar Array Drive Assemblies and yaw-steering .

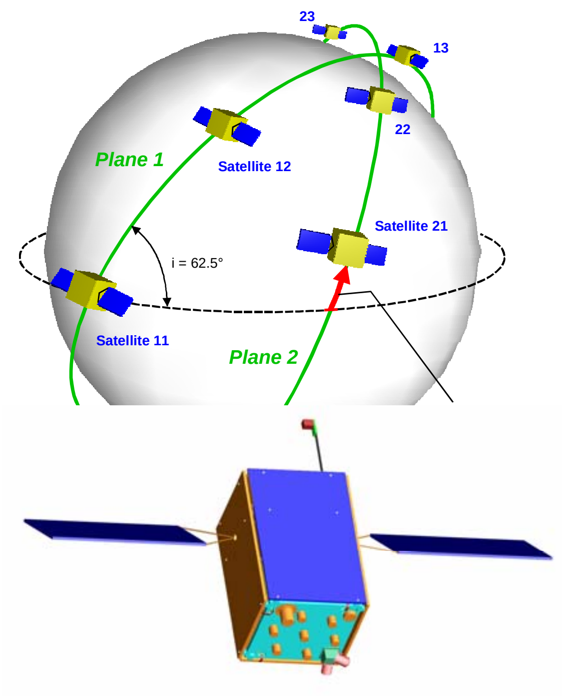


**Figure 4: INES Satellite Design**

## 4 SAR-LUPE CONSTELLATION

SAR-Lupe is a satellite constellation for synthetic aperture reconnaissance. It consists of up to five spacecraft in three different polar orbit planes, at an altitude of 500 km. The spacecraft feature a mass of 770 kg and an average power of 250 W. For an increased integration time of the radar image and an enhanced resolution, the three-axis stabilised satellite performs a slewing manoeuvre during imaging.

The SAR-Lupe satellite concept is characterised by the following features:

- Large conventional parabolic SAR antenna, which is rigidly mounted to the satellite structure to achieve a simple mechanical design
- SAR antenna dual used for imaging and data transmission
- Attitude Control System, which performs high accuracy manoeuvres of the entire satellite for pointing during imaging
- Integrated and modular design for satellite bus and SAR payload sensor
- Few and simple mechanisms yield reliability and cost efficiency
- All satellite control commands are produced in the ground station, which simplifies the OBDH architecture
- Command data relaying through Inter-Satellite Link yields reduced system response time

The ACS features 3 operational modes and an accuracy of $\sigma \leq 0.05°$. Its actuators comprise reaction wheels and magnetic coils; its sensor suite consists of a star tracker assembly with $\sigma \leq 0.01°$ accuracy, a magnetometer and sets of sun sensors and gyroscopes. The OCS compensates the altitude decrease due to the residual air drag and relies on a mono-propellant hydrazine system.

Telemetry is done within the X-band, and tele-control and housekeeping data are exchanged via S-band radio waves. The power subsystem features

- 2.4 $m^2$ solar panel of Ga As solar cells
- 550 W @ EOL and perpendicular to radiation of light
- 2 x 50 Ah battery capacity $NiH_2$ batteries
- 2900 W / 100 A peak power / current

From this concept OHB's standard medium-sized platform with agile and precise pointing capabilities is derived.

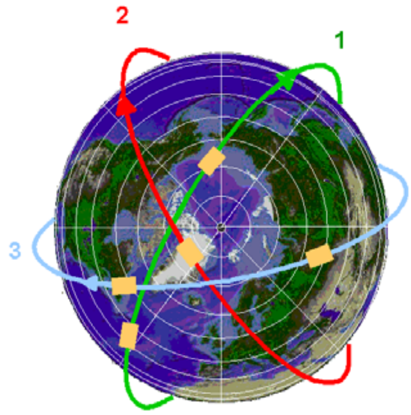


**Figure 5: SAR-Lupe Constellation**

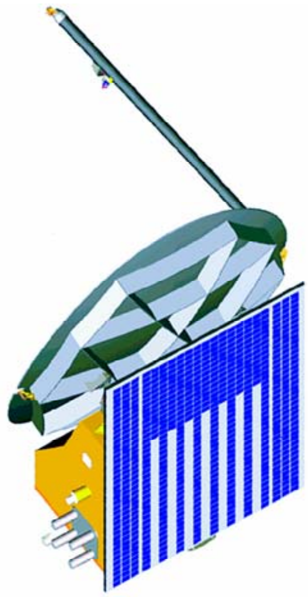

**Figure 6: SAR-Lupe Satellite**

## 5 SWARM CONSTELLATION

The ESA mission named Swarm aims at the mapping of the geomagnetic field. The space segment consists of a constellation of three satellites in two near-polar LEO orbit planes. OHB-System has performed the design development of these spacecraft, the main scientific instrument of which is a magnetometer package carried on an articulated boom. The combination with an Electric Field Instrument and an Accelerometer impose stringent requirements on the satellite design. Attitude control, i.e. constant NADIR pointing, is performed with an accuracy of $\sigma \leq 1°$ and by a combination of magnetorquers and a cold gas reaction control system. The spacecraft's wet mass approximates 300 kg. Due to the sun-asynchronous orbits, the overall power equals a moderate 110 W. From this concept OHB derived its standard small-sized platform.

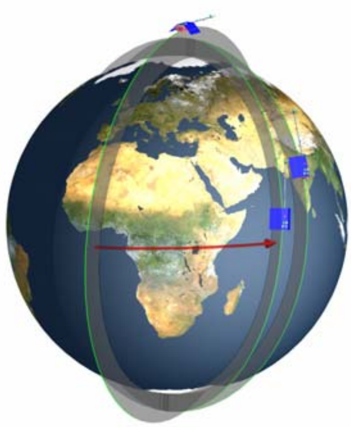

**Figure 7: Swarm Mission Constellation**

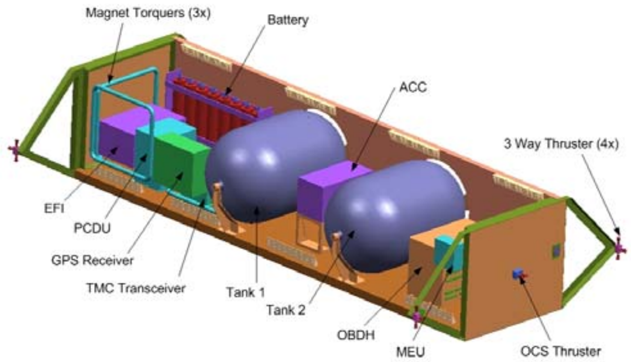


**Figure 9: Swarm Subsystem Cutaway View**

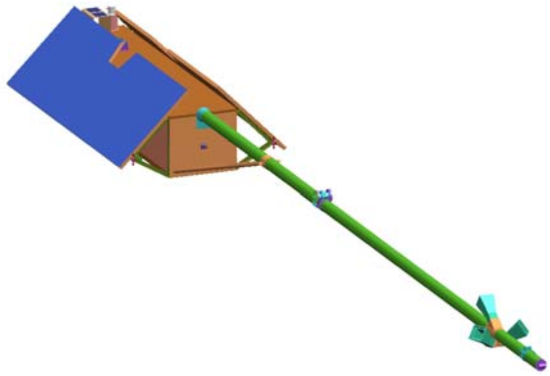

**Figure 8: Swarm S/C with deployed magnetometer boom**

The measurement requirements for the distinction of the different sources of the geomagnetic field demand a constellation of spacecraft that perform simultaneous measurements at different locations. The Swarm spacecraft A and B will fly in close vicinity on positions of up to 150 kilometres apart in the east-west direction near the equator, equal to a RAAN separation of 1.5 degrees. Their orbit altitudes will initially be 450 kilometres, but will gradually decrease to as low as 300 kilometres by the end of the mission, which enables more accurate measurements of magnetism originating from the Earth's crust. Swarm C will remain at above 500 kilometres altitude throughout the mission. The three Swarm spacecraft will be launched by a single COSMOS launcher and ejected into an intermediate orbit, from which they will ascend or descend through *Hohmann* transfer manoeuvres. Together with an acquired slight deviation in inclination, the different orbit perturbations will generate a constant change in relative RAAN angle between the two orbit planes. The desired 90° RAAN plane separation is achieved within approx. 3 years.

## 6 ORBCOMM-NEXT GENERATION

OHB-System is the European service provider of the ORBCOMM communications system. This system consists of 35 LEO Satellites, which orbit at an altitude of 775 km and in a constellation of six orbit planes. As the orbit planes feature different orbit perturbations, a dedicated station keeping has to be performed. The first generation spacecraft perform their orbit manoeuvres through the solar pressure acting on the solar panels, which are orientated like solar sails.

OHB recently performed a predevelopment of a second generation ORBCOMM spacecraft. This spacecraft possesses a cold gas OCS for constellation maintenance, but is basically gravity-gradient stabilised, for which purpose the NADIR-pointing antenna is dual-used.

## 7 REFERENCES

[1] Wertz, et al.: *Space Mission Analysis and Design*, 3RD ed. Space Technology Library, 2003.
[2] Fortescue, P.; Stark, J.; Swinerd, G.: *Space Systems Engineering*, 3RD ed. Chichester: John Wiley, 2003.
[3] OHB-System AG Website: *http://www.fuchs-gruppe.com*