# THE INTERFEROMETRIC CARTWHEEL FOR ENVISAT

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ABSTRACT
CNES and DLR have investigated the possibility of a formation flight of a cluster of passive radar micro-satellites with the Envisat earth observation satellite. The mission goal is to achieve a Digital Elevation Model of the solid Earth of unequalled coverage and accuracy.

## 1. SAR INTERFEROMETRY AND THE CARTWHEEL CONCEPT

One of the major applications of Synthetic Aperture Radar (SAR) Interferometry is the generation of Digital Elevation Models (DEMs) of the Earth surface /1/. Figure 1 depicts how two SAR sensors can be arranged in order to form an interferometer. If the interferometric system shall be implemented in space, the satellites would have to fly „in parallel and/or on top of each other". At the first look this is impossible from orbit mechanics but in /2/ it was disclosed how interferometric baselines can be obtained with stable satellite orbits. These orbits must have small eccentricities which deviate only slightly from the reference (circular) orbit. Several (n) satellites on such elliptical orbits whose axes are mutually rotated by 360deg/n form a configuration referred to as the „Interferometric CartWheel". Fig. 2 shows how the (elliptically shaped) wheel rolls along a reference orbit around the globe. The typical major axis of the wheel is in the km-range. Obviously, the baseline length varies continuously over the orbit revolution. This complicates interferometric processing and poses a strong requirement on accurate orbit determination. At least three satellites are required to generate an across track baseline at any geographic latitude.

SAR interferometry was first operationally demonstrated with ERS satellites flying in a tandem configuration. Due to this separation in time the data suffered from an effect called "temporal scene de-correlation". This problem was overcome in 2000 with a single-pass interferometer on the Shuttle Radar Topography Mission /3/ where a secondary SAR receiver was mounted on top of a 60m long mast. Due to this fixed and relatively short interferometric baseline the sensitivity of the instrument was limited. Furthermore the Space Shuttle can not reach a polar orbit and the mapping was restricted to latitudes between 60deg north and 55deg south.

The Interferometric CartWheel combines the advantages of its two predecessors:

a) single-pass interferometry in order to avoid scene de-correlation
b) variable and sufficiently large baseline lengths in order to obtain selectable sensitivities of the interferometric instrument.

## 2. PASSIVE SAR SENSORS FOR THE ENVISAT

As a matter of fact standard single channel SAR sensors exist in space or will be launched in future and need only to be augmented by simple passive SAR receiver satellites. A formation flight of a CartWheel with such a SAR satellite is depicted in

Figure 3. One attractive host or “illuminator” satellite for the CartWheel is the Envisat from the European Space Agency /4/. It shall be launched in summer of 2001 and by the time when the CartWheel is in orbit its behaviour will be very well understood and its radar performance very well proven. The giant solar panels of Envisat deliver more than 6 kW of electrical energy and the launch mass of the satellite is more than 8 tons. The peak power of the radar is 2,5kW.

CNES /5/ and Alcatel Space Industries /6/ have performed studies of the required Interferometric CartWheel satellite payload. It consists mainly of a radar dish antenna, a SAR receiver, a digitizer, a solid state mass memory and the telemetry down-link unit. It has been shown that by using highly integrated electronics the weight of the overall payload including the antenna will be in the range of 30kg only! The average power consumption will be less than 30W.

CNES has designed a micro-satellite which can carry such a payload with a launch mass up to 120kg. A series of at least 16 satellites will be built by industry for various projects. Four satellites will be dedicated to the first CartWheel mission. The micro-satellites will have a minimum life time of 1 year with a potential of 2 years. A rotatable solar panels of 0,6m by 1,2m each can deliver 150W of electrical power (Fig. 4).

## 3. MISSION GOAL AND TIME SCHEDULE

Due to the sun-synchronous orbit of the Envisat nearly the whole globe can be covered. Preliminary performance analyses show that a global DEM with a sampling of 30m and a relative height error in the range of only 1m to 3m can be achieved with special modes of the Envisat radar /7/.

In order to meet the specified in-orbit life time of Envisat of 5 years, the development of the CartWheel payload has to be started in spring 2001. It has been estimated that the payload development, the integration and testing of four CartWheel satellites can be performed in approximately three years. The launch in late summer 2004 will be followed by a four month commissioning phase before the operational phase takes place during the year 2005. Three satellites will actually be used, while the fourth is considered as a spare.

The mission goal is to cover all landmass of the earth with ascending and descending data takes. This can be achieved if the system operates for approximately 5 minutes per orbit and for one year. This estimate includes margins for the operations of the host satellite, the CartWheel satellites and the X-Band receiving stations.

## 4. REFERENCES


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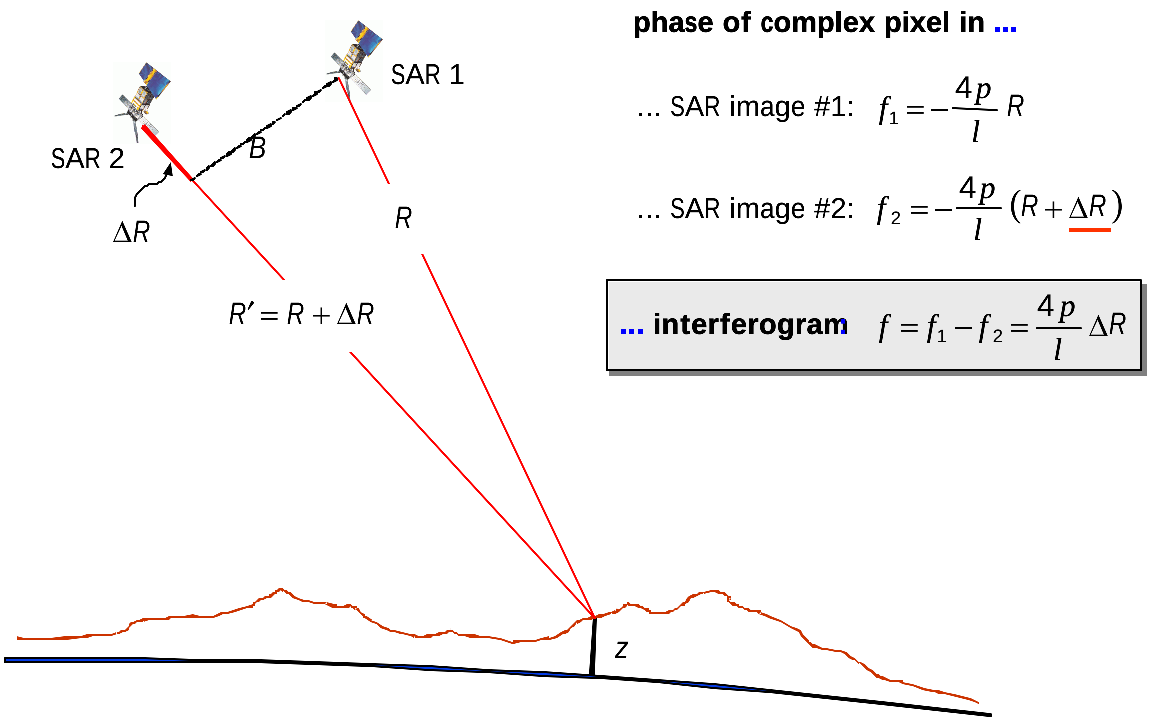


**Figure 1:** Geometry of SAR Interferometry (satellite flight passes into the plane)

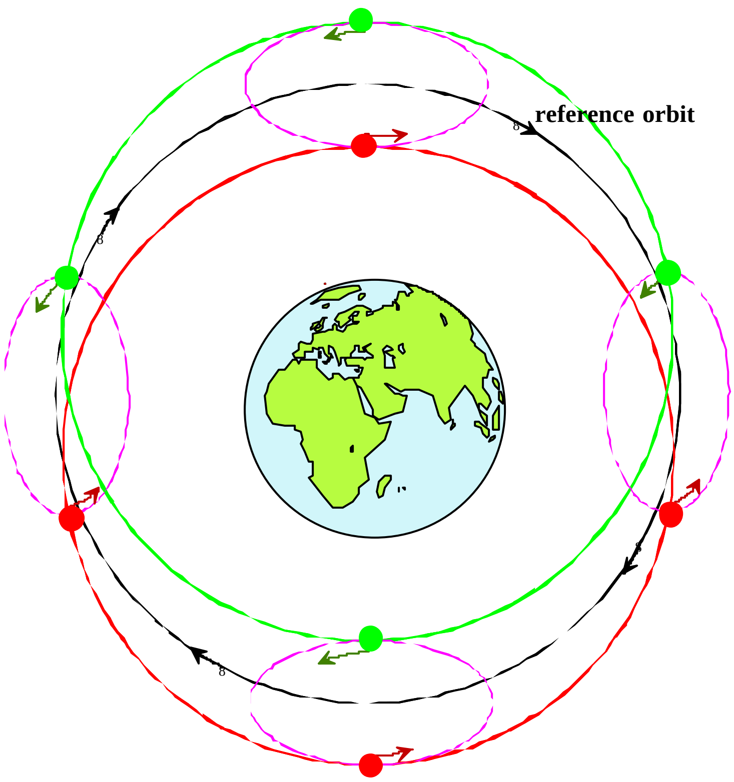


**Figure 2:** A CartWheel with two satellites

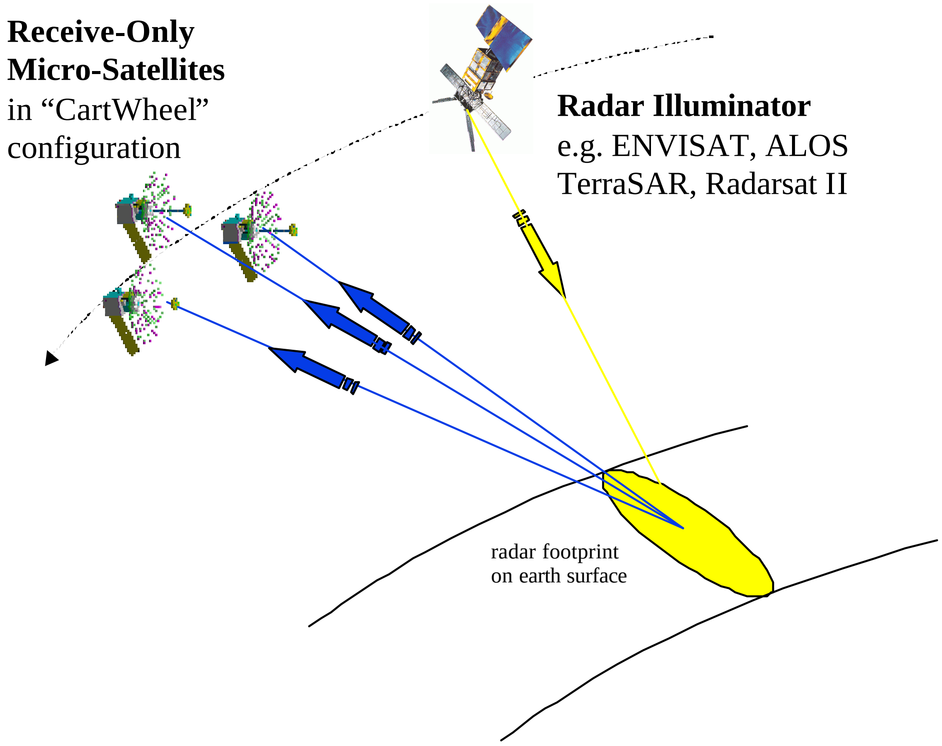


**Figure 3:** Bi-Static Interferometric SAR

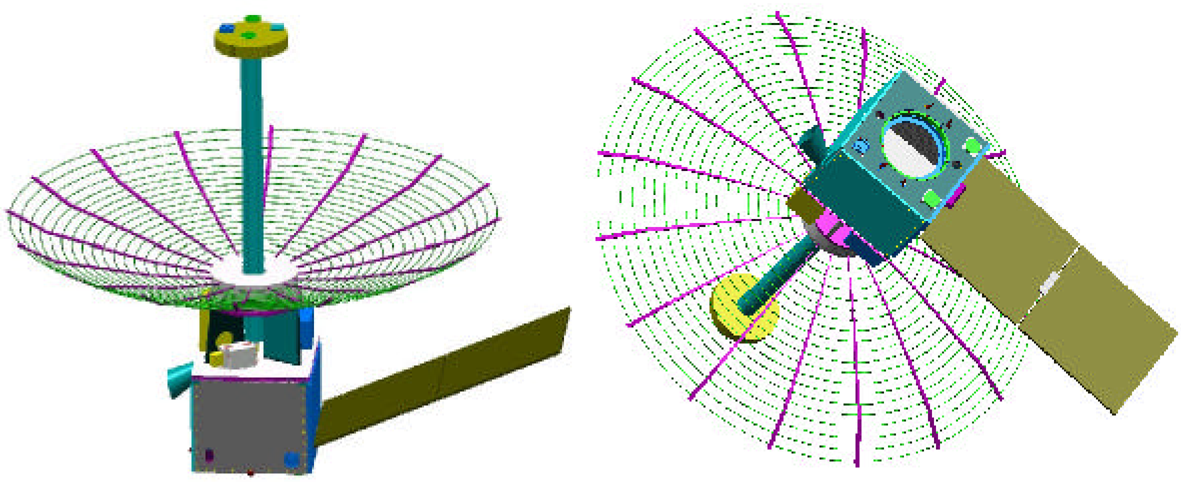

**Figure 4**: Perspective views of a CartWheel satellite