TerraSAR-X Mission Status

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***Abstract* — TerraSAR-X is Germany's first national remote sensing satellite being implemented in a public-private partnership between the German Aerospace Centre (DLR) and EADS Astrium GmbH, with a significant financial contribution from the industrial partner. This radar satellite, which is to be launched in June 2007 will supply high-quality radar data for purposes of scientific observation of the Earth for a period of at least five years. At the same time it is designed to satisfy the steadily growing demand of the private sector for remote sensing data in the commercial market.**

This contribution will describe first the public-private partnership scheme, the roles and responsibilities of the partners as well as the overall project organization. The mission and system design will then be described, followed by a brief overview of the satellite, the related Ground Segment and the applied data policy. The contribution will then focus on the actual mission status. Finally a brief outlook will be given on the activities to come.

Keywords-SAR, radar satellite, high resolution, public-private-partnership, project organization, mission concept

I. INTRODUCTION

TerraSAR-X is a new German radar satellite that will provide high-resolution high-quality, multi-mode X-band SAR-data for scientific research and applications as well as commercial purposes. It is realized in a public private partnership between the German Aerospace Center (DLR) and the EADS-Astrium GmbH. Under the PPP-agreement DLR is the owner of TerraSAR-X and all of its data, built the ground segment and will operate and control the satellite and the sensor. Under contract to DLR, EADS Astrium GmbH was responsible for the design, integration, test and launch of the satellite and its radar-instrument. DLR's ground segment furthermore will calibrate, receive, process, archive and distribute the X-band SAR data throughout the 5 years of operation. The scientific use of the TerraSAR-X data will be within DLR's responsibility while the commercial exploitation rights were exclusively granted to Infoterra GmbH, a subsidiary of EADS as part of the private element of the PPP scheme.

II. THE PUBLIC-PRIVATE PARTNERSHIP

TerraSAR-X will be the first space project in Germany to be realised in a public-private partnership (PPP), with considerable financial contribution by industry. The partnership model is based on a cooperation agreement that was signed by the DLR and EADS Astrium GmbH on March 25, 2002. The objective is for equal partners to cooperate, with each making an equitable contribution towards a joint project in order to meet their own needs. Going beyond the traditional process of awarding government-funded contracts, this approach is based on cooperative project management. Having different objectives, both sides contribute their resources, jointly implementing the project and utilising its results afterwards. The advantage of this approach is that it permits meeting scientific goals while supporting industrial marketing needs at the same time. In this way, investments are secured which a single partner would be unable to provide on its own.

Under the partnership agreement, EADS Astrium GmbH has been awarded a contract by DLR to develop, build, and launch the satellite. For its part, DLR develops the satellite's operating system as well as its instrument-calibration and payload ground segment for receiving, processing, archiving, calibrating, and distributing the radar data. In addition, the DLR will be responsible for the operation of the satellite over a period of five years.

EADS Astrium undertook to set up a distribution system and commercialize the TerraSAR-X data and products through its fully-owned subsidiary Infoterra GmbH. In return for the exclusive right to commercialize TerraSAR-X data, EADS Astrium GmbH agreed to contribute to the development cost of the satellite. In addition, EADS Astrium will contribute

with a sales-dependent share of the operating cost for the satellite during its operational phase and invest considerable sums in marketing the satellite's data and products as well as in creating data of (?) a distribution system.

In general, TerraSAR-X will serve two main goals: The first goal is to provide the strongly supportive scientific community with multi-mode X-Band SAR data. The broad spectrum of scientific application areas include Hydrology, Geology, Climatology, Oceanography, Environmental Monitoring and Disaster Monitoring as well as Cartography (DEM Generation) and Interferometry. Representing the federal government, the DLR will be the sole owner of the TerraSAR-X data and coordinate their scientific utilisation.

The second goal is the establishment of a commercial EO-market in Europe, i.e. the development of a sustainable EO-business so that follow-on systems can be completely financed by industry from the profit. Taking into account the expected business development, the PPP-agreement is aiming at:

- the self-sustainability of the business,
- the implementation and operation of a follow-on system TerraSAR-X2 by industry,
- scientific exploitation rights for DLR also for TerraSAR-X2.

If the business develops as foreseen today, EADS Astrium GmbH will finance a follow-on system after the satellite's service life has ended, thus securing the continuity of the business.

III. Project Organization

The overall project management for the TerraSAR-X project is located in the directorate for space projects (DLR-RD) in Bonn, as shown in **Fig. 1**. Under contract to DLR, EADS Astrium GmbH in Friedrichshafen/Germany is developing the TerraSAR-X satellite, whereas DLR-institutes in Oberpfaffenhofen will provide the related Ground Segment for control of the satellite and the SAR-instrument, the calibration as well as the data reception, archiving and distribution.

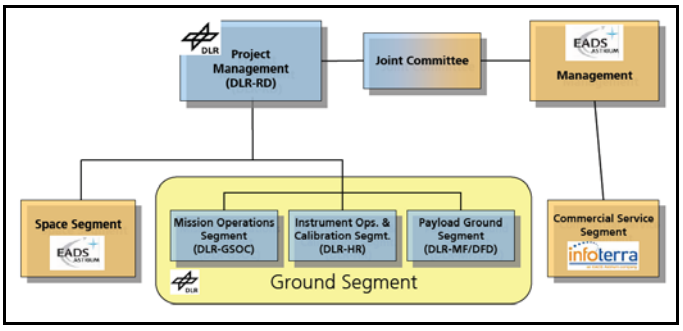

Fig. 1 TerraSAR-X Project Structure

Within this context, DLR has the following responsibilities [1]:

- Overall Project Management
- Managenment of the TerraSAR-X contract with Astrium
- Development of the Ground Segment
- System engineering, calibration/verification
- Satellite operations (GSOC: Weilheim station)
- Data receiption (Neustrelitz), processing, archiving and distribution
- Science coordination

EADS Astrium/Infoterra on the other hand will be in charge of the development, assembly and launch of the TerraSAR-X satellite (as contractor to DLR) as well as of the business related activities like

- X-Band based product research & development
- X-Band based market development
- Development of a commercial service segment
- Commercial exploitation of TerraSAR-X data
- Implementation and operation of a follow-on system TerraSAR-X2.

IV. Mission and System Design

A. *The Mission Design*

The TerraSAR-X satellite will be launched from Baikonur on a Russian/Ukrainian DNEPR-1 launch vehicle with a 1.5 m long fairing extension. Once in orbit the satellite will be operated from the Mission Control Center in Oberpfaffenhofen. In the system baseline, two ground stations in Germany are foreseen. Weilheim is used as the TT&C station and Neustrelitz serves as the central receiving station for the 300 Mbps X-Band downlink (**Fig. 2**). Beyond that, additional Direct Access Stations - commercial partners of the Infoterra GmbH - are foreseen to extend the baseline receiving station concept [1].

Parameter	Mission Orbit
Orbit Type	Sun-synchronous repeat orbit
Repeat Period	11 days
Repeat cycle	167 orbits in the repeat
Orbits per day	15 2/11
Equatorial Crossing time	18.00hrs +/- 0.25 h ascending pass
Eccentricity	0.0011° – 0.0012°
Inclination	97.443823
Argument of Perigee	90°
Altitude at Equator Ground track repeatability	514.8 km within +/- 250 m per repeat cycle

Tab. 1 TerraSAR-X Orbit Parameters

A Sun-synchronous Dawn Dusk Orbit with an 11 day repeat period defined in **Tab. 1** was selected as a good

compromise between radar performance and order to-acquisition time and revisit time.

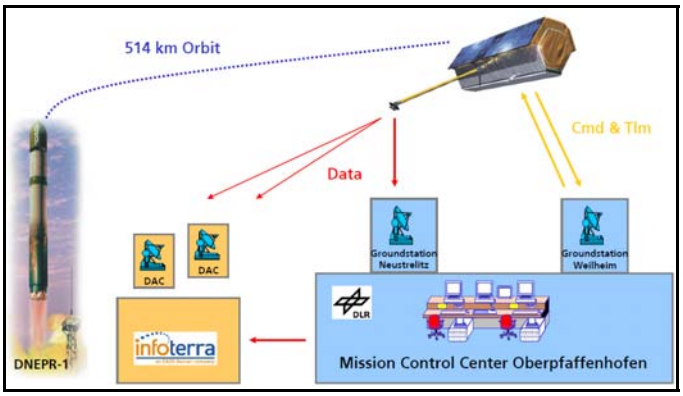

Fig. 2 TerraSAR-X Mission Concept

B. The TerraSAR-X Satellite

The TerraSAR-X satellite bus is a heritage from the successful Champ and Grace missions. The satellite configuration of TerraSAR-X is shown in **Fig. 3**.

The TerraSAR-X features an advanced high-resolution X-Band Synthetic Aperture Radar based on the active phased array technology [6] which allows the operation in Spotlight-, Stripmap- and ScanSAR Mode with two polarizations in various combinations. It combines the ability to acquire high resolution images for detailed analysis as well as wide swath images for overview applications ([2], [3] and [5]). The experimental Dual Receive Antenna (DRA) Mode allows to independently receive the echoes from the two azimuth antenna halves. This new experimental mode enables the use of interesting new features like Along Track Interferometry, full polarimetric data acquisition and the enhancement of the stripmap azimuth resolution [4].

Fig. 3 TerraSAR-X Space Segment

In addition to the SAR-instrument, two Secondary Payloads will fly on the TerraSAR-X spacecraft:

1. the Laser Communication Terminal (LCT), a Technology Demonstrator for a inter-satellite communication link developed by TESAT/Backnang in contract to DLR, and
2. the Tracking, Occultation and Ranging Instrument Package (TOR), a dual-frequency GPS tracking receiver and a laser reflector set for high-precision orbit determination and occultation measurements provided by the Geo-forschungszentrum Potsdam (GFZ) and the University of Texas, Center for Space Research.

C. The TerraSAR-X Ground Segment

The TerraSAR-X Ground Segment is the central element for controlling and operating the TerraSAR-X satellite, for calibrating its SAR instrument, and for archiving the SAR-data as well as generating and distributing the basic data products. The overall TerraSAR-X Ground Segment and service infrastructure consists of two major parts

- the ground segment which is provided by DLR and
- the commercial exploitation and service infrastructure (TSXX) developed by Infoterra.

The DLR Ground Segment is based on existing national infrastructure as much as possible and will be optimized for flexible response to (scientific and commercial) User requests and fast image product turn-around times. It is composed of three major elements [1]:

- the Mission Operations Segment (MOS) provided by the German Space Operation Center (GSOC),
- the Instrument Operation and Calibration Segment (IOCS) provided by the Microwaves and Radar Institute (IHR), and
- the Payload Ground Segment (PGS) provided by the German Remote Sensing Data Center (DFD) and the DLR Remote Sensing Technology Institute (IMF).

The scientific exploitation of the TerraSAR-X data will be coordinated by DLR, which is the point of contact for all science users. Commercial customers, on the other hand, will have to contact Infoterra for access to TerraSAR-X data (**Fig. 4**). In addition to the baseline station in Neustrelitz, Infoterra will set up additional receiving stations for so-called Direct Access Customers (DACs) respectively Direct Access Partners (DAPs). These so called Direct Access Stations are foreseen to extend the baseline receiving station concept.

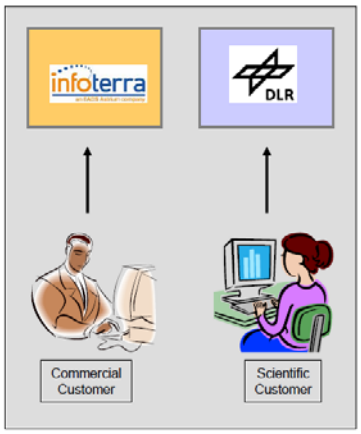

Fig. 4 TerraSAR-X Data Access

V. PROJECT STATUS

The satellite integration at EADS Astrium in Friedrichshafen as well as the final environmental test campaign at the IABG facilities in Munich have been completed by end of 2006 (see **Fig. 5**). After extensive final system tests including both the Space and the Ground Segment, the Satellite Flight Acceptance Review as well as the Ground Segment Readiness Review have been successfully passed by end of January 2007.

In February 2007 TerraSAR-X has then been transported to the launch site in Baikonur, where all the necessary satellite tests were completed as expected.

Unfortunately, the TerraSAR-X launch was delayed due to a launch failure of the DNEPR-1 rocket in June 2006. The launch provider Kosmotras was able to clearly identify the cause of the accident and has implemented appropriate measures to prevent the occurrence of a similar failure. Nevertheless, all subsequent launches were delayed by several months. On April 17th, 2007, the DNEPR-1 resumed operation with the successful launch of the Egyptsat satellite from Baikonur. Launch of the TerraSAR-X is now scheduled for June 2007.

After 2 weeks of Launch-and-Early-Orbit-Phase (LEOP) and a commissioning phase of 5 months duration, which include the bus and SAR-instrument functional check-out as well as the calibration of the basic instrument modes, the operational phase will start late 2007. The system is designed for at least 5 years of operation.

Fig. 5 TerraSAR-X during testing at IABG

VI. SUMMARY

The launch of TerraSAR-X into orbit will realize for the first time in Germany an Earth observation project in a public-private partnership with considerable financial contribution by industry. This enables an innovative mission to be carried out which could not have been financed otherwise, a mission with a large potential for scientific use as well as for the sustainable commercialization of Earth observation data.

The mission will provide a new class of high quality X-band SAR products due to its high resolution capability and the high flexibility of its antenna. In addition it provides the capability of repeat-pass interferometry due to tight orbit control within a range of +/- 250 m The new Dual Receive Antenna mode offers new applications like along track interferometry, full polariometric data acquisition and Stripmap resolution enhancement.

In August 2006, DLR and EADS Astrium have agreed to continue their successful cooperation with the TanDEM-X mission. The TanDEM-X satellite, an almost identical rebuilt of TerraSAR-X, will - from mid 2009 onwards - fly together with TerraSAR-X in a close tandem configuration. Main objective of the TanDEM-X mission will be the acquisition of global, high-quality DEM-data of the Earth's surface with HRTI-3 (High Resolution Terrain Information level 3) quality (**Fig. 6**).

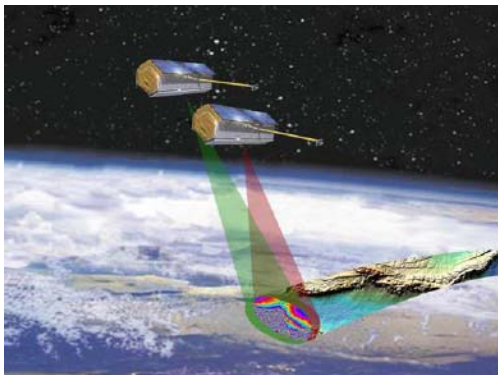

Fig. 6 TanDEM-X Configuration

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