TERRASAR-X: A PRE-LAUNCH STATUS REPORT

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ABSTRACT

TerraSAR-X is a new German radar satellite that shall be launched end of June 2006 with a lifetime of 5 years. It carries a high frequency X-band SAR sensor that can be operated in three different modes and various polarizations. The Spotlight-, Stripmap- and ScanSAR-modes provide high resolution images for detailed analysis as well as wide swath data whenever a larger coverage is required. Imaging will be possible in single, dual and quad-polarization. TerraSAR-X will be an operational SAR-system for scientific and commercial applications.
Innovative and unique features with respect to spaceborne systems are the high geometric (1m-25m) and radiometric resolution together with the single, dual and quad-polarization capability. Additionally several incidence angle combinations will be possible and double side access can be realized by satellite roll maneuvers. The satellite will be positioned in an 11 days repeat orbit. 95 % of the Earth's surface can be seen within 2.5 days after commanding, also in the very high resolution Spotlight mode. In principle all modes of TerraSAR-X are of interest for the observation of urban areas. In particular the high geometric resolution of Spotlight and Stripmap modes open new perspectives on the high precision mapping of settlements, industrial areas and infrastructure like roads and railway tracks. Due to the general benefits of SAR systems like the weather independent observation capability a frequent land use mapping and change detection is possible. Multi-polarization enables further improvements on the classification of the radar data. The short revisit times allow to immediately image areas affected by a disaster for damage assessments.
The TerraSAR-X Pre-Launch Announcement of Opportunity (June13 – October 4, 2005) was the first chance applying for data. 205 proposals were submitted and 197 were accepted. Five main themes were addressed in the call namely "land cover and vegetation", "risk management and security"," water resources", "ocean, marine and polar applications" and "SAR methods and research".

1. INTRODUCTION

TerraSAR-X is a new German radar satellite that shall be launched end of June 2006. The mission's objectives are the provision of high-quality, multi-mode X-band SAR-data for scientific research and applications as well as the establishment of a commercial EO-market and to develop a sustainable EO-service business. It is realized in a close cooperation between the German Ministry of Education and Science (BMBF), the German Aerospace Center (DLR) and the Astrium GmbH. DLR built the ground segment, will operate the satellite control system and the payload ground segment for receiving, processing, archiving and distribution of the X-band SAR data. DLR is also responsible for the instrument control and calibration, the 5 years of operation and the scientific use of the TerraSAR-X data. Under DLR contract Astrium currently builds the satellite. Furthermore Astrium set up a distribution system for the commercial use of the TerraSAR-X data and products and value adding through its subsidiary the Infoterra GmbH.

The potential of SAR data for urban studies has been demonstrated. For example the detection of settlements, the mapping and analysis of urban land use patterns as well as the assessment of the impact of human activities on the environment were investigated. SAR interferometry further more improves the capabilities for this purpose by using the coherence information and measuring surface motions. (1) outlines potential contributions of TerraSAR-X for the observation of urban areas.

2. TERRASAR-X SPACE SEGMENT

2.1. SATELLITE

The satellite will be positioned in a sun-synchronous 11 days repeat orbit. The altitude is 514.8 km at the equator. In order to support SAR interferometry small baselines of ±250m tube with respect to a reference orbit shall be maintained (2).

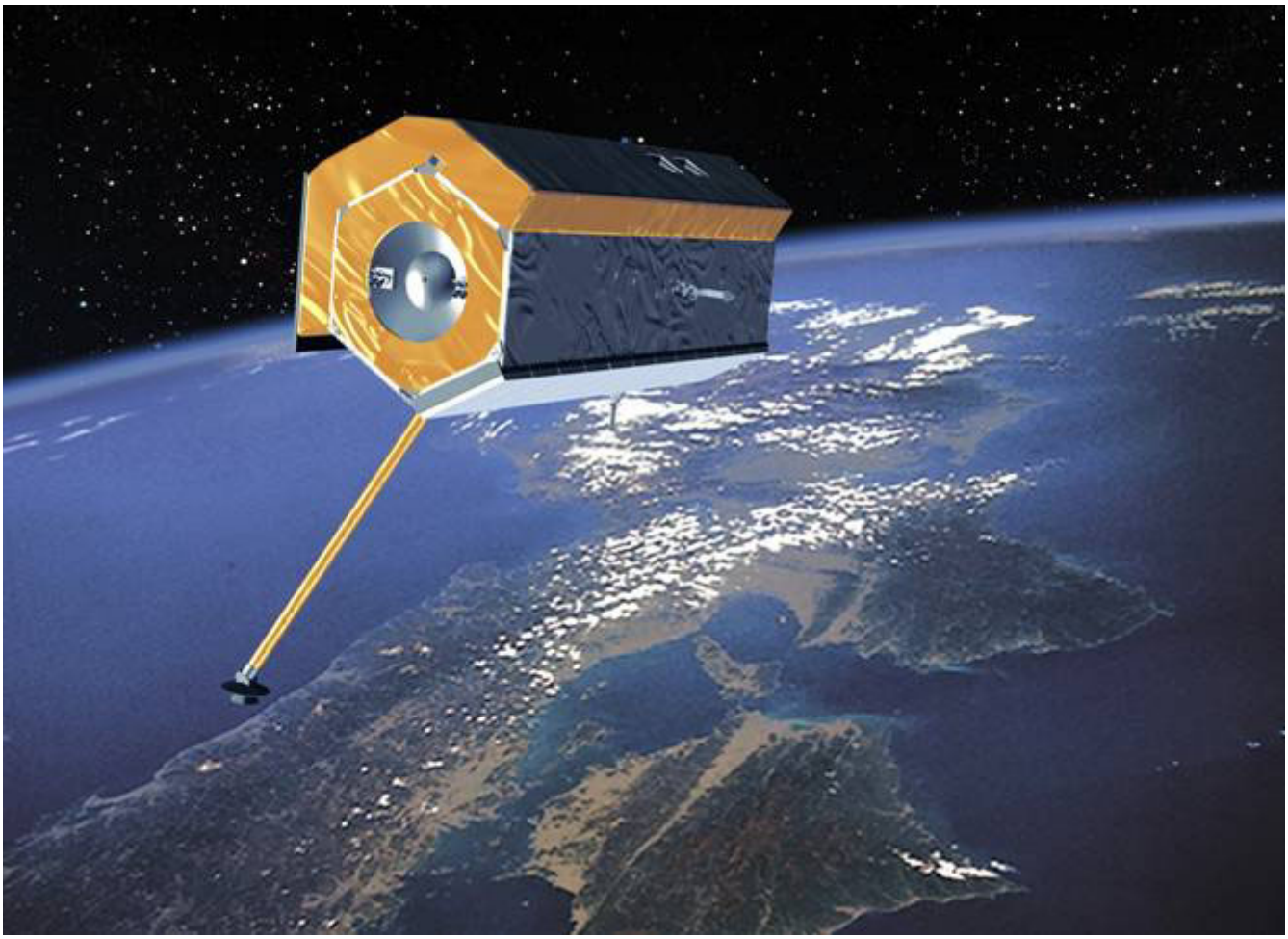

Figure 1: Hierarchical network of image segmentation

Figure 1 shows some details of the TerraSAR-X satellite. The satellite bus is a heritage from the successful Champ and Grace missions and features a primary structure with a hexagonal cross section. The solar panel is mounted on the left side. The SAR antenna is visible on the bottom-right side. The X-band downlink antenna is mounted on a 3.3 m long deployable boom in order to prevent interference with the X-Band SAR instrument. This concept enables simultaneous data acquisition and data down link.
The high precision satellite pointing control and determination is achieved with star trackers located close to the antenna plane so that an antenna bore sight pointing accuracy of

65 arcsec (3σ) is achieved (3). The precise orbit determination is performed with a GPS receiver and raw data post processing on the ground.
Two additional Secondary Payloads will fly on the TerraSAR-X spacecraft. The Laser Communication Terminal (LCT) built by TESAT under DLR contract is a Technology Demonstrator for inter-satellite communication link. The Tracking, Occultation and Ranging Instrument Package (TOR) provided by Geoforschungszentrum Potsdam (GFZ) and the University of Texas, Center for Space Research is a redundant dual-frequency GPS tracking receiver and a laser reflector set that will provide a high-precision orbit determination capability for TerraSAR-X.

2.2. SENSOR

The TerraSAR-X SAR instrument is an active phased array X-Band system with a centre frequency of 9.65GHz and a maximum bandwidth of 300 MHz. The nominal range bandwidth is 150 MHz. The instrument is designed for multiple imaging modes like StripMap, SpotLight and ScanSAR operating with single-, dual- or full polarization. Additionally it allows for an experimental Dual-Receive-Mode, which is based on the usage of the antenna in two azimuth halves and utilizes the redundant electronics set as a second receiver channel. The Dual-Receive-Mode will enable along-track interferometry, e.g. for velocity measurements and traffic control, and a full polarimetric mode, by simultaneously receiving H and V with the two sub-apertures. More information about the satellite and the sensor is provided in (3). Details on the modes and products are described in (1).
The space segment is currently in the integration phase. Environmental testing will start in March 2006. After the Flight Acceptance Review in May 2006 the TerraSAR-X satellite will be shipped to Baikonour. The launch is planned for June 30th, 2006. After a commissioning phase of 6 months duration the operational phase will start in early 2007. The order interface shall be opened in December 2006.

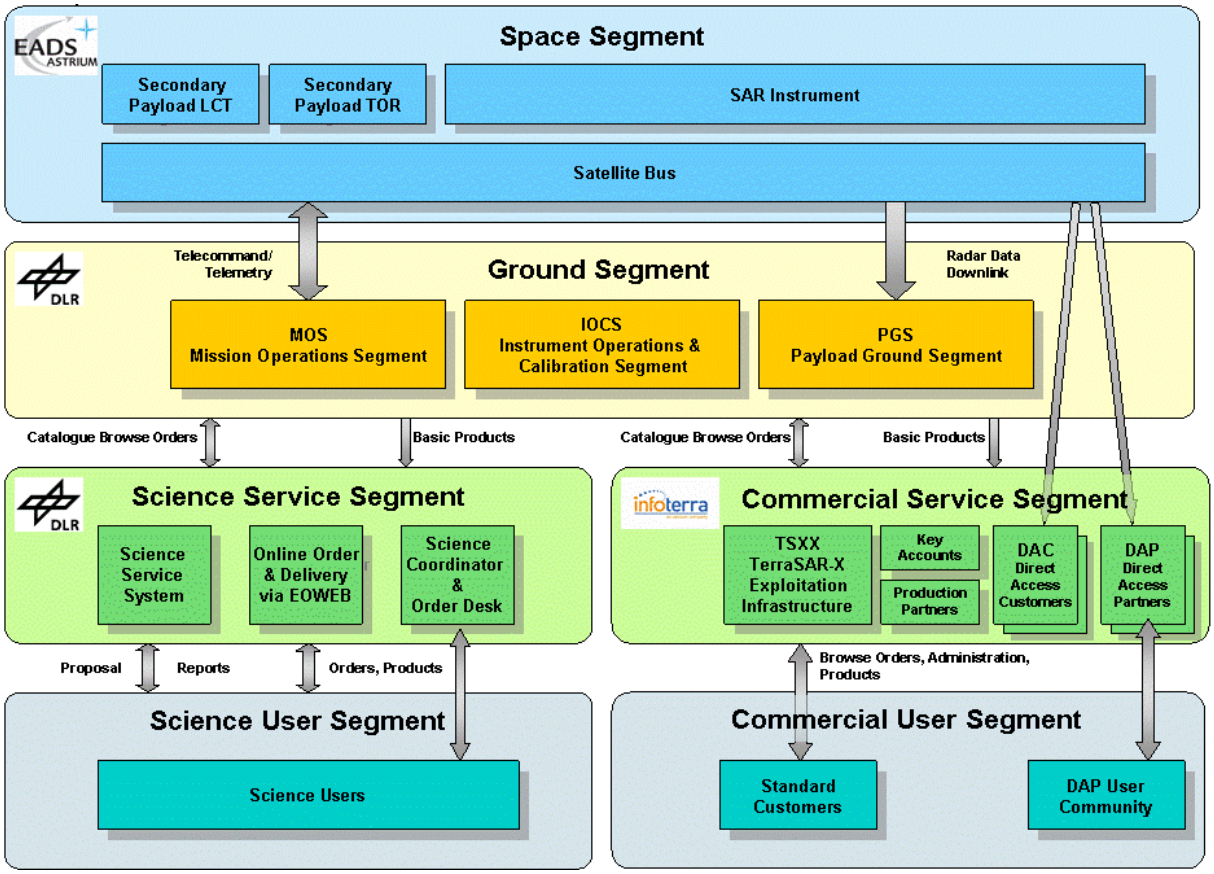

Figure 2: TerraSAR-X System

3. 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. It consists of the Mission Operations Segment (MOS), the Instrument Operations and Calibration Segment (IOCS) and the Payload Ground Segment (PGS). It provides the main functions Space and Ground Segment planning, orbit control and analyses, spacecraft telemetry reception and command, data reception and archiving, calibration and performance analyses, product generation, delivery and provision of user services.
The TerraSAR-X Ground Segment is supplemented by the Science and Commercial Service Infrastructure as shown in Figure 2. The Commercial Service Infrastructure is currently implemented by the Infoterra GmbH. PGS will be the order interface and product provision facility for the scientific user community.

The Ground Segment subsystems MOS, IOCS and PGS successfully passed the Technical Acceptance Review (TAR) in December 2005. This milestone released the final integration into the overall TerraSAR-X Ground Segment. This phase will be completed by the Ground Segment Readiness Review which is planned for May 9th, 2006.

4. SCIENTIFIC USE

4.1. GENERAL ISSUES

The TerraSAR-X satellite will be the property of the German Aerospace Centre (DLR). The Astrium GmbH has the exclusive commercial exploitation rights. The scientific exploitation rights remain with DLR. The satellite tasking time shall be equally shared between scientific and commercial users.

Every use of TerraSAR-X data for basic and application oriented research performed by national or international research establishments or through government sponsored projects is considered scientific, non-commercial use. This includes the development of future applications for scientific and/or operational use. The criteria defining the scientific use in more detail are described in (4).
The status “Scientific Use” needs to be gained via a selection process. For this purpose an Announcement of Opportunity (AO) mechanism was implemented. A description of the intended research must be submitted via a web interface. More information and all relevant documentation are available on the project science page

http://www.caf.dlr.de/tsx/main/science_en.htm .

Each proposal goes through a scientific and technical evaluation. The acceptance results in the provision of the status “Scientific Use” that is non-transferable and revocable. A proposal specific account will be generated by DLR that will be used by the PI for ordering TerraSAR-X acquisitions and products. A first prototype of this order interface was released that can be accessed via the project science page (URL mentioned above). It allows checking the visibility of the area of interest.

A series of AOs is planned that will address specific topics. Beside these AOs a general proposal submission will be established allowing to send in research ideas at any time at least throughout TerraSAR-X’s lifetime. The same evaluation criteria will be applied as for the AOs. In this case the products will be provided for the costs of fulfilling the user request. The corresponding price list will be published. For the AOs special conditions might be applied like for the Pre-launch AO where data are electronically provided free of charge. If a delivery on DVD is required 50,- € will be charged per medium.

4.2. PRE-LAUNCH AO SUMMARY

The first chance applying for data was the TerraSAR-X Pre-Launch Announcement of Opportunity which was an international call for proposals. Submission was possible between June13 and October 4, 2005.

The AO's main objectives were the support of the calibration and validation activities, to initialize the scientific evaluation of the TerraSAR-X data and to stimulate the commercial exploitation. The Pre-launch AO was related to the provision of the basic products as specified in (5). The proposals built around the following themes:

- land cover and vegetation,
- risk management and security,
- water resources,
- ocean, marine and polar applications and
- SAR methods and research.

172 PIs from 29 countries submitted 205 proposals, 197 of those were accepted. Figure 3 shows the number of PIs per country.

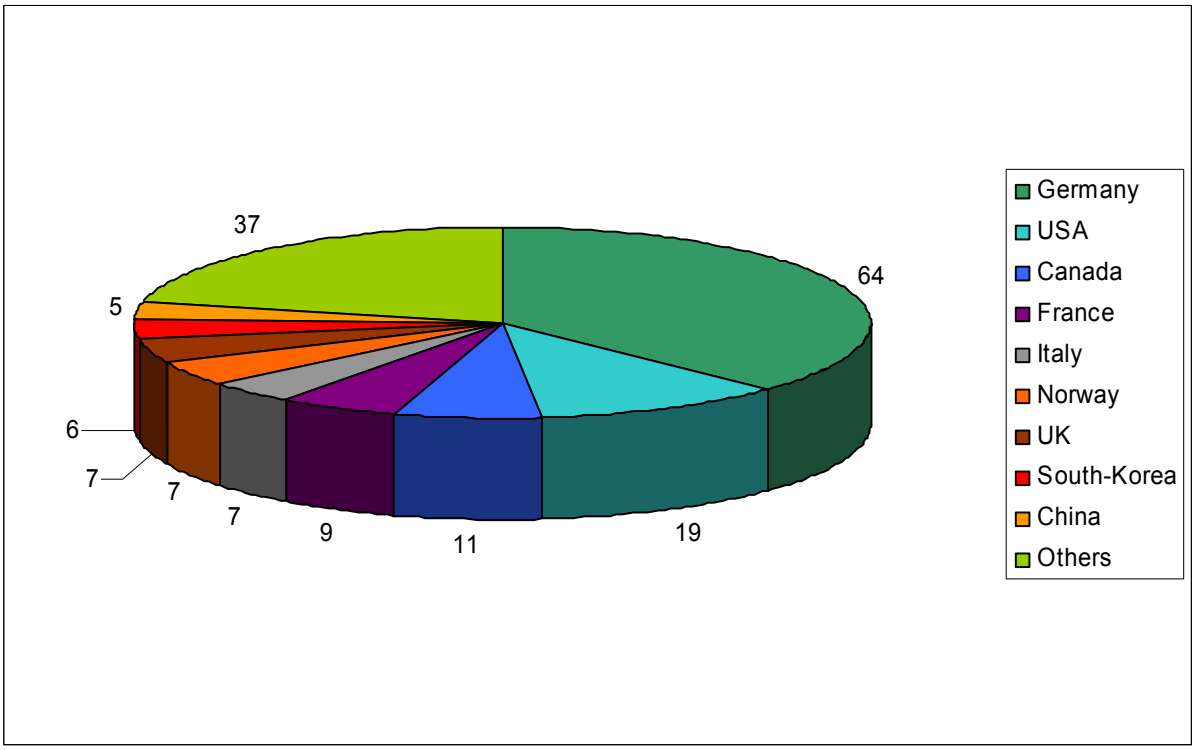

Figure 3: Number of PIs per country

The biggest group is the land cover and vegetation community with 58 proposals. 28 proposals addressed water resources, 44 ocean, marine and polar applications, 43 risk management and security and 32 SAR methods and research. The latter includes calibration and validation proposals as well. These numbers show that the interest in TerraSAR-X data is quite homogeneously distributed over the different application fields.

Urban area related research can be found in the land cover and vegetation but also the risk management and security groups. 17 proposals intend to investigate more generally land use and land cover which in some way includes the identification and classification of settlements and infrastructure as well. However 14 proposals specifically addressed urban development and monitoring issues.

Interferometric applications were assigned to the risk management and security theme. Differential interferometry is mostly applied over urban areas enabling the identification of surface movements caused by either mining activities, ground water extraction, crustal deformation or earthquakes. Coherence maps shall be used to improve the generation of damage assessment maps. The benefits of radar systems like all weather and day and night observation but also fast access can fully be employed for these questions.

4.2. FURTHER AOS

As mentioned already the pre-launch AO was limited to the use of the basic products. The provision of experimental mode data and experimental products (6) will be subject to another AO. This shall be released after their technical acceptance which is estimated to end of 2007 / early 2008.
Further AOs are planned addressing the synergistic evaluation of TerraSAR-X data with other SAR frequencies and optical data. A joined ESA/DLR AO is currently discussed which shall be related to a synergistic use of X-band, L-band (ALOS-PALSAR) and C-band (ENVISAT-ASAR). The call for proposals shall be released in the second half of 2006 after the launches of ALOS and TerraSAR-X. The combination of optical and radar data will be subject to a Rapid Eye / TerraSAR-X related AO.

Please watch the TerraSAR-X project web page for further information.

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