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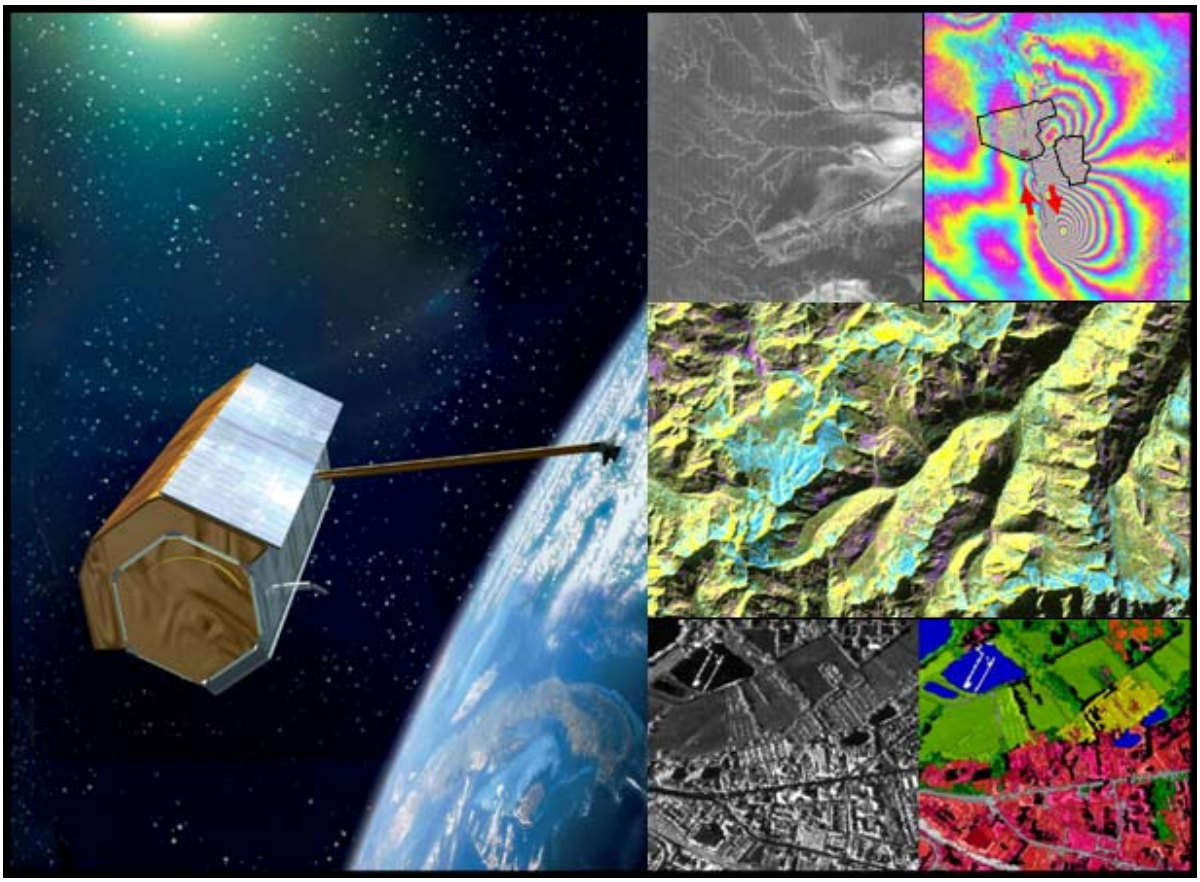
TerraSAR-X Science Plan



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1 INTRODUCTION

1.1 PURPOSE AND SCOPE

The purpose of this document is to provide background of the TerraSAR-X mission for investigators who intend to use TerraSAR-X data for the scientific purposes. It describes data policy issues, the procedure for getting access to the TerraSAR-X data and pricing issues.

Subject to the science plan is the provision of TerraSAR-X data and products for scientific purposes.

1.2 STRUCTURE OF THIS DOCUMENT

The purpose of chapter 2 is to introduce the TerraSAR-X mission, space and ground segment, the project goals, and data policy issues. Chapter 3 provides information on how scientists will get access to TerraSAR-X data. Chapter 4 describes the scientific objectives of the TerraSAR-X mission. Potential contributions of TerraSAR-X are provided in detail in a separate volume as Annex to this document.

1.3 APPLICABLE DOCUMENTS

[A1] TerraSAR-X Nutzlastbodensegment Projektplan Phase C/D, TX-PGS-PL-1000, Issue 2.0, 5.8.2003

[A2] TerraSAR-X Security Requirements and Data Policy Principles, TX-PD-RS-003, Issue 1.0, March 15, 2004

[A3] Kooperationsvereinbarung über die Zusammenarbeit bei Aufbau und Nutzung des Satelliten TerraSAR-X, 25.März 2002

1.4 REFERENCE DOCUMENTS

[R1] TX-PGS-DD-3302 – Basic Product Specification Document

[R2] TX-PGS-DD-3303 – Experimental Product Description

2 THE TERRASAR-X MISSION

TerraSAR-X is an operational, advanced SAR-satellite system for scientific and commercial applications that shall be launched in mid 2006. It will carry a new high resolution satellite operating in the X-band at 9.65 GHz. The scheduled lifetime is 5 years. TerraSAR-X (TS-X) is realised in a close co-operation between the German Aerospace Centre (DLR) and the EADS Astrium GmbH. DLR will implement the satellite control system as well as the payload ground segment for receiving, processing, archiving and distribution of the X-band SAR data. DLR is also responsible for the instrument's operation and calibration, the 5 years of operation and the scientific use of the TerraSAR-X data. EADS Astrium will develop, build and launch the satellite under DLR contract. The Infoterra GmbH, a subsidiary of EADS Astrium, will set up a distribution system for the commercial use of the TerraSAR-X data and products on its own cost. The commercial data distribution and value adding will be the task of the Infoterra GmbH.

2.1 PROJECT GOALS

The mission will serve two main objectives:

- to provide the scientific community with high-quality, multi-mode X-band SAR-data for scientific research and applications; and
- to support the establishment of a commercial EO-market and to develop a sustainable EO-service business, based on TerraSAR-X derived information products.

2.2 DATA POLICY ISSUES

The TerraSAR-X satellite will be the property of the German Aerospace Centre (DLR). DLR retains the title to and ownership of all primary and any derived products to the extent that the contribution of TerraSAR-X is substantial and recognisable.

The research result will be the property of the investigator. The processed TerraSAR-X data may only be used for scientific, non-commercial purposes.

DLR will provide satellite operations and payload operations scheduling, generation and dissemination of standard products, quality control and archiving of these data. DLR will facilitate access to the data by producing and maintaining a unified global catalogue of all TerraSAR-X data.

TerraSAR-X data will be archived at least for the active lifetime of the mission, and, pending on the approval of related funding, also after the end of the mission.

The co-operation agreement grants the EADS Astrium GmbH 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.

A priority scheme will be applied to the satellite tasking. In case of a conflict between scientific and commercial use of the same priority the commercial request shall have precedence.

The commanding/acquisition and data provision are governed by national security regulations.

The status "Scientific Use" needs to be gained via a selection process (e.g. an Announcement of Opportunity (AO)).

The usage of TerraSAR-X data is regulated via a license agreement.

The TerraSAR-X mission has specific scientific objectives (see chapter 4). TerraSAR-X data will be provided to satisfy these objectives in particular for any approved projects.

2.3 TERRASAR-X SYSTEM

The entire TerraSAR-X system is shown in Figure 1 below providing the context on how the payload ground segment is interfaced to the rest of the TerraSAR-X segments. The major elements of the TerraSAR-X system are:

- the space segment consisting of the platform and the SAR instrument,
- the overall ground segment including the payload ground segment, as described below,
- the service segment providing service for scientific and commercial users, the latter are serviced by Infoterra and
- the user segment which is represented by science users and commercial users.

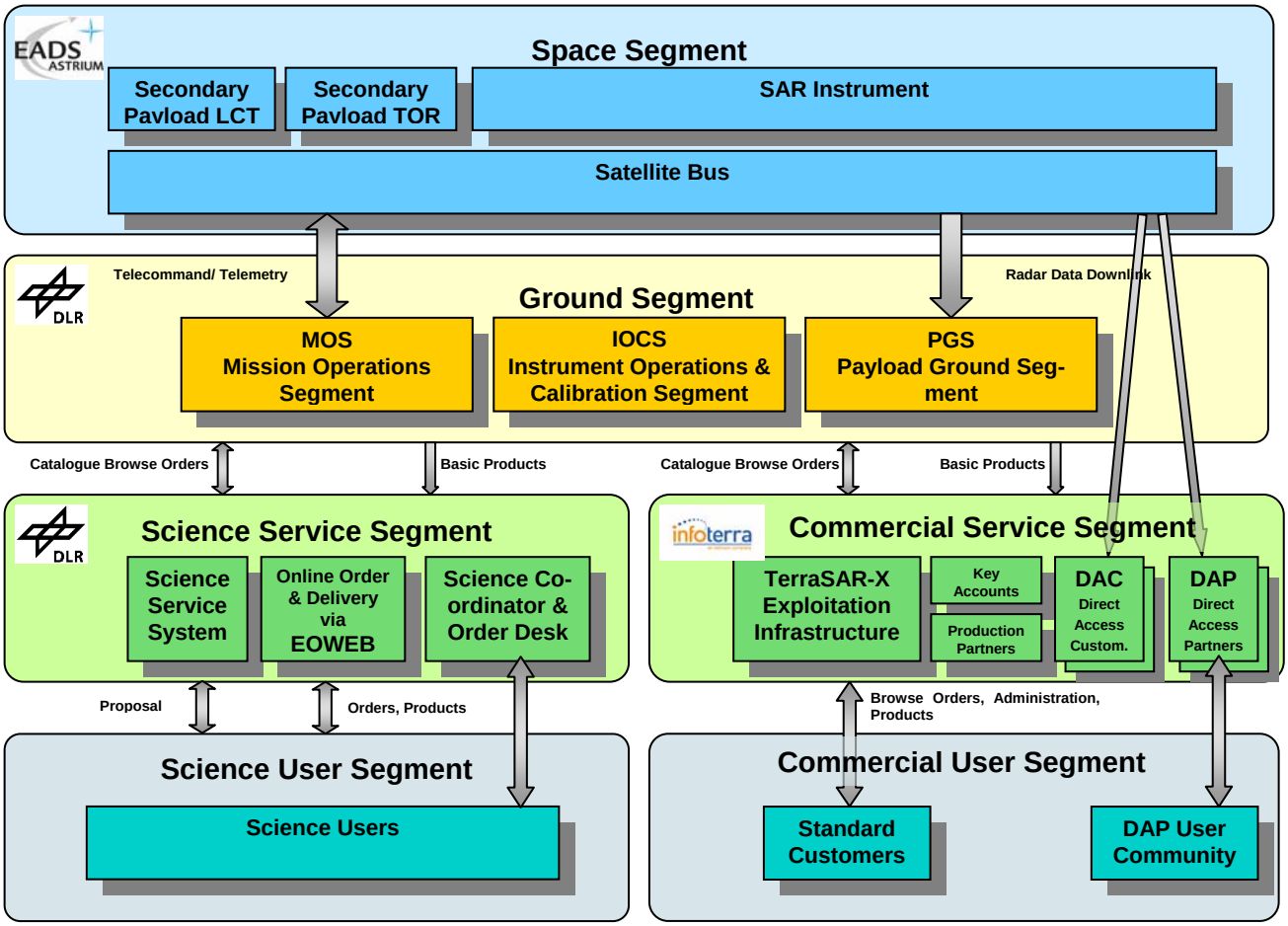

Figure 1: TerraSAR-X System

2.4 TerraSAR-X Spacecraft and Sensor

TerraSAR-X is a new German radar satellite that shall be launched in mid 2006 with the Russian DNJEPR-1 launch vehicle. The scheduled lifetime is 5 years. It's high frequency X-band SAR sensor can be operated in different modes and polarisation. The SpotLight- (1.3 m), StripMap- (3.3 m) and ScanSAR-modes (14.8 m) provide high resolution SAR images for detailed analysis as well as wide swath data whenever a larger coverage is required. Imaging will operationally be possible in single and dual polarisation. Quad-polarised data will be available on an experimental basis. Beam steering enables observation in different incidence angles and double side access can be realized by satellite roll maneuvers. Figure 2 shows some details of TerraSAR-X satellite. The solar panel is mounted on the left of the satellite bus. The SAR antenna is visible on the bottom side. The X-band downlink antenna is mounted on a small boom in order to avoid interference with the SAR-antenna.

The satellite will be positioned in a polar sun-synchronous orbit. The inclination will be 97,44°. The repeat cycle is 11 days, with ground track repeatability within ± 250 m. Within one repeat period 167 orbits are contained. The satellites attitude will be 515 km.

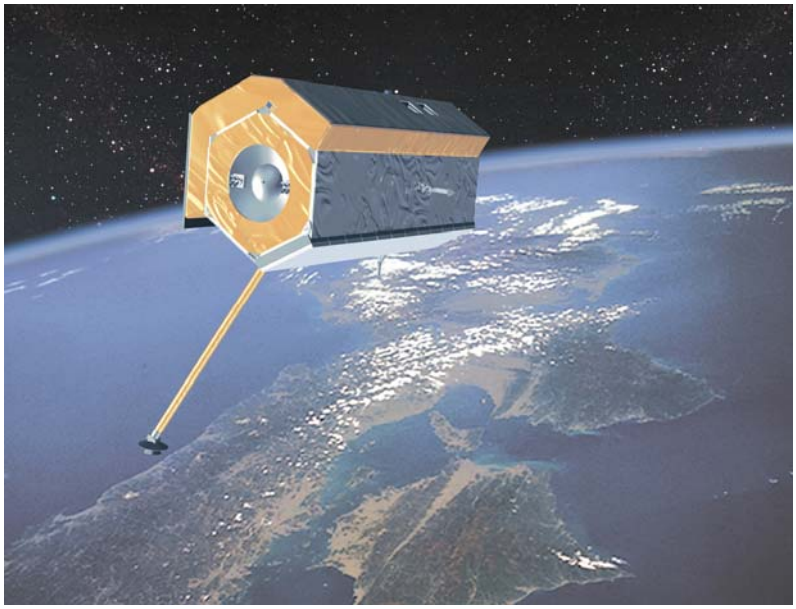

Figure 2: Artist view on TerraSAR-X

The SAR system will be supplemented by two secondary payloads.

The Tracking, Occultation and Ranging (TOR) experiment of the Geo-Research Centre GFZ and the University of Texas will provide a redundant two-frequency-GPS receiver and a laser reflector set. The experiment will generate and deliver highly precise orbits that will further improve the location accuracy of the TS-X products but also interferometric applications.

The Laser Communication Terminal (LCT) is a technologic demonstration for inter-satellites communication links.

2.5 TERRASAR-X GROUND SEGMENT

The TerraSAR-X ground segment and it's service infrastructure act as the interface between the user services and the spacecraft. It controls and operates the TerraSAR-X satellite platform as well as the SAR sensor, performs all issues required for the instrument calibration, acquires and archives the SAR data and generates the basic products.

The overall TerraSAR-X ground segment is provided by DLR. The DLR Ground Segment is composed of three major elements:

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

The major tasks of these three elements are:

Mission Operations Segment

- Spacecraft Control and Command
- Orbit Maintenance & Analyses
- Acquisition Planning
- Provision of Orbit and Attitude Files for SAR Processing

Instrument Operation and Calibration Segment

- Instrument Operations
- Instrument and SAR System Calibration
- Instrument Monitoring and System Performance Controlling
- Operational Long-Term Overall System Performance
- Provision of Instrument and Calibration Information for SAR Processing

Payload Ground Segment

- Data Reception and Archiving
- Basic Product Generation
- Product Delivery and User Services

2.6 TERRASAR-X SCIENCE USER SEGMENT

Contrary to the commercial sector science users will be served directly by DLR. This task will be performed by the **Science Coordinator** and the **Payload Ground Segment**. "Human support" will be provided by the Science Coordinator and the Order Desk. DLR's data portal EOWEB will serve as ordering and product delivery interface. Proposal submission and evaluation interface will be the Science Service System.

2.6.1 SCIENCE COORDINATION

The Science Coordinator and the Order Desk of the Payload Ground Segment will provide support to scientific users.

The Science Coordinator structures, stimulates and co-ordinates the scientific use of the data provided by the TerraSAR-X satellite. He is the interface between the science community and the TerraSAR-X Ground Segment. This includes

- the implementation and co-ordination of a TerraSAR-X Science Team by holding workshops and meetings,
- the collection of requirements, comments and recommendations,
- the preparation and implementation of the selection process for scientific users,
- the proposal evaluation and data policy issues,
- the solution of order conflicts (science internally and with the commercial sector),
- the reporting (review of report from the investigators, reports to the TS-X project),
- and the publication of results.

The Science Team consists of the PIs of the pre-launch AO (see chapter 3.2.1).

2.6.2 SCIENCE SERVICE SYSTEM

Purpose of the Science Service System is the proposal submission, evaluation and reporting.

2.6.3 PAYLOAD GROUND SEGMENT

The Payload Ground Segment will provide

- the technical interfaces for the proposal submission,
- the order submission for both acquisition and product generation,

- an order and help desk,
- the product generation and delivery.

The Order Desk is the entry point for all kind of user and customer inquiries. It is available via phone, fax or e-mail during normal working hours. The ordering process itself needs to be performed by the scientific users themselves via EOWEB.

The main functions of the Order Desk with respect to scientific users are:

- Advice investigators about available products and order mechanism of TerraSAR-X products.
- Register investigators for ordering of TerraSAR-X products via EOWEB upon authorisation by the Science Coordinator and perform the necessary steps for the authorisation for ordering via EOWEB.
- Accept complaints from investigators and forward complaints to the relevant operations function or issue an anomaly report and transport response to scientific user.
- Advice investigators in cases of repeated order rejecting as a consequence of conflicts or a high system load.
- Advice investigators about planned system unavailability and their effects and duration.

3 SCIENTIFIC USE OF TERRASAR-X DATA

3.1 DEFINITION

Every use of TerraSAR-X data and basic products for basic and application oriented research by national or international research establishments or through government sponsored projects is considered scientific, non-commercial use, including the development of future applications for scientific and/or operational use.

Every utilisation of TerraSAR-X data/products that is not targeting the commercial use with profit orientation is a scientific use.

This includes the use of TerraSAR-X data/products:

- by educational (schools, universities, etc.) and research institutions (DLR, ESA, NASA, etc.),
- for preparation and execution of government financed education-, research- and development-programmes,
- for preparation and execution of data exchange with international partners of the FRG to support research- and educational programmes,
- for demonstration of new applications for potential users,
- for use within the TerraSAR-X project (calibration, validation, quality assurance, public outreach, experimental instrument operations, etc.).

3.2 DATA ACCESS

3.2.1 ANNOUNCEMENT OF OPPORTUNITY

The status "Scientific Use" needs to be gained via a selection process. For this purpose an Announcement of Opportunity (AO) will be released approximately one year before the launch. The AO will be open for three months. The proposals will pass an evaluation procedure and accepted proposals will get the status "Scientific Use" that is non-transferable and revocable.

Proposals will be submitted via a web interface. Each proposal will go through a scientific and technical evaluation. DLR will ensure an independent and fair review of the project proposals. DLR reserves the right to apply simplified evaluation procedures for already approved and funded projects. The evaluation rules will be described in a dedicated document.

Investigators may form consortiums that commonly will utilise the TerraSAR-X data. For each proposal a Principle Investigator (PI) has to be identified that will act as an interface to the TerraSAR-X project. The

PI will be responsible

- to ensure the validity of the "Scientific Use" criteria for all investigators (including the Co-Is), any changes that might effect the national security regulations or the status "Scientific Use" have to be reported to DLR immediately,
- for the TerraSAR-X data distribution within the consortium,
- for the reporting to DLR and
- for the preparation of results concluding with the submission of a final report to DLR.

The PI's activities are considered to cover the total time period of the project approved by DLR.

The number of participants per proposal, it's duration as well as the required amount of data must be reasonable.

Depending on the mission and ground segment capabilities, limitations in data quantities may be allocated to each project/proposal.

DLR will provide the agreed amount of data to the PI to ensure the successful completion of the proposed investigation. DLR reserves the right to decide on the most appropriate timing and order.

The data may only be used for the agreed purpose. The investigators must not hand over TerraSAR-X data/products to third parties without authorization by DLR.

TerraSAR-X data will be provided as Basic Products as specified in [R1].

The availability of Experimental Products [R2] will be limited.

The provision of data requires the confirmation of the corresponding funding.

Scientific users have to sign a user license agreement.

The investigator must demonstrate the scientific use of the provided TerraSAR-X data by the submission of reports on a 6 months basis and a final report. The results shall be published. Information about the proposal (at least the executive summary and reports) will be made available through the project web page.

DLR plans to release further AOs related to specific topics.

3.2.2 GENERAL PROPOSAL SUBMISSION

A general proposal submission will be possible after the Commissioning Phase at least throughout TerraSAR-X's lifetime.

These proposals will not be related to a specific AO and can be submitted at any time.

The same evaluation criteria as for the AO will be applied.

3.2.3 PRIORITY SCHEME

A priority scheme will be applied to the satellite tasking. The main purpose of the priority scheme is to level the acquisition requirements of the individual users and - in a mid-term range - the share between science and commercial use.

The priority of a science proposal will be derived from the acquisition requirements. E.g. interferometric data sets must be acquired always in the same mode, same incidence angle and to a certain extent in dedicated time frames. This reduces the number of alternatives for the planning system in case of conflicts. In order to be considered in the planning process this application will get a high priority. On the other hand an application that requires data sets of a certain area e.g. during a few weeks time frame but without specific geometric conditions will get a lower priority. In case of a conflict this order still can be fulfilled as the much more alternative acquisitions exist.

Priority	Priority Class	Application Class
9	top	mission
8	high+	near real time applications
7	high	ground truth during acquisition
6	medium+	InSAR
5	medium	weekly observation
4	medium-	multi-frequency / multi-sensoral
3	low+	monthly observation
2	low	multi-parameter
1	low-	seasonal observation
0	background	mission

table 3-1: Priority classes to be applied to scientific use

The planned priority scheme is listed in table 3-1. Two priorities are reserved for the TS-X mission. The top priority class can only be set in case of urgent mission critical actions. Background orders are placed to use potential spare capacity of the system. The other priority classes are open for scientific and

commercial users. The application classes and priorities may be adapted to the acquisition requirements during the mission.

The corresponding priority will be assigned to the proposal during the evaluation process.

3.2.4 COST OF THE DATA

The investigator will get the data for the costs of fulfilling the user request. Subject to the user request are

- the acquisition planning and
- satellite commanding,
- data acquisition,
- processing,
- archiving,
- product provision and
- the provision of the user license.

The price might vary depending on the effort required to fulfil the request and the number of user licenses.

Discounts will be applied for larger order volumes, and for dedicated research programs and institutions contributing to the TerraSAR-X mission, especially by financial or operational support.

Special conditions might be applied for the AOs.

The applicable price list will be published.

For general proposal submission the price list will be made available in EOWEB.

The AO will comprise the corresponding pricing information.

4 SCIENTIFIC OBJECTIVES OF TERRASAR-X

The scientific objectives of TS-X will be oriented by the national research programs of the German Ministry of Education and Research (BMBF), DLR, the German Research Foundation (DFG), the Helmholtz Association of National Research Centres (HGF) as well as the "Global Monitoring for Environment and Security" (GMES) initiative of the European Union (EU) and the European Space Agency (ESA).

In particular the use of TS-X data shall help to extend the range of parameters observed and therewith to increase the knowledge of the factors determining the behavior of the environment. Furthermore the system shall support the management and monitoring of the Earth's resources and to better understand the solid Earth processes.

New and innovative technological features of the SAR instrument enable the improvement of existing and the development of new technologies and applications. Both application and technological development shall aim at a further improvement of the Earth observation services.

4.1 THEMATIC STRUCTURE

The proposals are expected to be built around the following thematic fields, four addressing applications and one the technological development:

- Land Cover and Vegetation
- Water Resources
- Ocean, Marine and Polar Application
- Risk Management and Security
- SAR Methods & Research

The scientific use of TerraSAR-X includes basic and application oriented research. The topics addressed above shall provide the frame of the research. It is not intended as a check list and is open for other topics as well. E.g. the GMES priority theme "Atmosphere" is not considered as a topic of its own, as SAR is not a primary sensor to atmospheric research. Nevertheless atmosphere related proposals can also be submitted. Applications and research that do not fit to themes listed above need to prove in more detail the suitability and the scientific benefit from the TerraSAR-X data.

4.2 SCIENTIFIC POTENTIAL OF TERRASAR-X

The scientific potential of TerraSAR-X is based on a combination of new features of the SAR instrument not being operationally available from space before. TerraSAR-X will be the first operational X-band SAR EO system, providing observation capabilities not available today. The multi-mode imaging capabil-

ity allows to observe the area of interest in very much detail (SpotLight mode) but also in ScanSAR mode whenever a larger context is required.

The very high geometric and radiometric resolutions enable very detailed analyses which will be of interest for all application fields. Today's SAR systems provide 15-25 m spatial resolution which is not detailed enough for many applications. E.g. the observation and monitoring of urban areas requires high resolution data as the objects of interest (houses) are very small and the cities themselves are highly structured. In order to be able to identify and derive suitable information the imaging system must provide high resolution data.

This can be even further improved using the high temporal resolution. TerraSAR-X will be operated in a 11 days repeat cycle. The temporal observation frequency can be adjusted to the user's needs. The visibility of specific targets on ground can be even more enhanced by using the multi-incidence angle as well as left and right looking capabilities. These features are important e.g. for risk assessment and security applications.

The single-, dual- and full-polarisation modes increase the classification capabilities. This is important not only for the variety of applications but also for methodological and technologic development. A new and innovative example for the latter is polarimetric interferometry (Pol-InSAR). Beside the technologic development Pol-InSAR will provide information for e.g. biomass estimation, ice and snow coverage and density and DEM improvement by estimating the true ground topography.

The well established SAR interferometry can be further developed. The precise attitude and orbit control and determination as well as phase stability allow performing repeat-pass interferometry .The high frequency and bandwidth as well as the high spatial and temporal resolutions open new perspectives for this technique. The X-band is even more sensitive to movements like existing SAR systems. The higher resolution supports the identification and separation of single scatterers. Furthermore the highly flexible active phased array antenna of TerraSAR-X enables the realisation of new imaging modes like the already mentioned along-track interferometry. Moving targets can be identified and sea currents can be measured.

The multi-beam together with left- and right-looking observation capability are very interseting for topographic mapping, DEM generation (stereo and InSAR) and road network detection.

Last but not least the X-band will provide excellent synergy to other SAR systems being in space at the same time. Examples are the L-band PALSAR of ALOS, potentially TerraSAR-L , but also C-band systems like Radarsat-2and Envisat-ASAR. The different frequencies can be used to further enhance the observation capabilities.