TanDEM-X Achievements and Team Performance

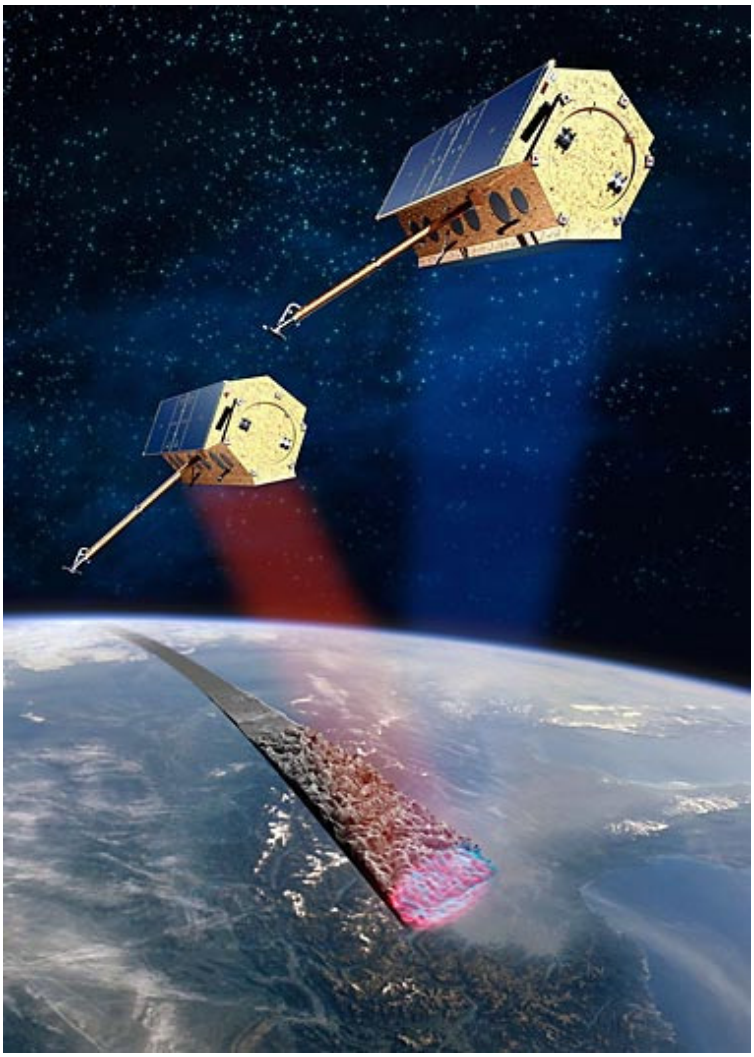
The Mission

The TanDEM-X mission (TerraSAR-X add-on for Digital Elevation Measurement) comprises two nearly identical earth observation satellites, TerraSAR-X (TSX) and TanDEM-X (TDX). Both are equipped with a powerful modern radar system called Synthetic Aperture Radar (SAR). It permits observing the earth's surface not only in daylight but also when it is obscured by darkness and/or clouds.

Like the two eyes that enable people to see in three dimensions, its two antennas make TanDEM-X the first-ever system capable of generating a three-dimensional elevation model of the entire surface of the earth. Moreover, the two satellites are equipped with devices to synchronize the two radar instruments as well as with an autonomous on-board navigation controller. To complete the system, there is a highly complex ground segment which also supports the ongoing operation of the TerraSAR-X mission.

TerraSAR-X has already been launched on a Dnepr rocket from the Baikonur cosmodrome in Kazakhstan on June 15, 2007. TanDEM-X was launched on 21. June 2010. For the first time ever, this second radar sensor in space will permit generating a global digital elevation model with a vertical resolution of two meters. The horizontal grid will measure twelve by twelve meters.

The TSX & TDX (TanDEM-X) operations team has been nominated for the **SpaceOps "Award for Outstanding Achievement (AOA)"**. The following brief summary gives an overview of the challenges and highlights of the TSX & TDX mission and the exceptional performance of the mission operations team.



TerraSAR-X and TenDEM-X in close formation flight

Outstanding Achievements

Routine operations in close formation:

- *Design of close formation flight*: A stable formation is realized by a slight separation of TSX and TDX in eccentricity and inclination. The resulting relative motion of TSX and TDX is helix like. The concept well established in GEO stationary orbit has been established the first time for routine operations in low earth orbit.
- *Close formation*: Inter satellite distances down to 150m have been realized.
- *Long term*: The helix like relative motion has to be maintained for at least three years (since October 2010)
- *Formation reconfigurations*: The characteristics of the helix relative motion are adjustable. In this sense TSX and TDX constitute a configurable Synthetic Aperature Radar (SAR) interferometer. Several reconfiguration of the helix like motion have been performed until now.
- *Safety measurements*: Precautional measures have been established against collision of TSX and TDX and against mutual radar illumination of the partner satellite (which could lead to irreversible damage of the partner satellites radar instrument)
- *TanDEM-X Autonomous formation flight (TAFF):* TAFF is an algorithm which has been developed and incorporated in the TDX on-board software .It enables TDX to perform autonomously TSX-TDX relative navigation and control. During two test campaigns TAFF functioned smoothly.

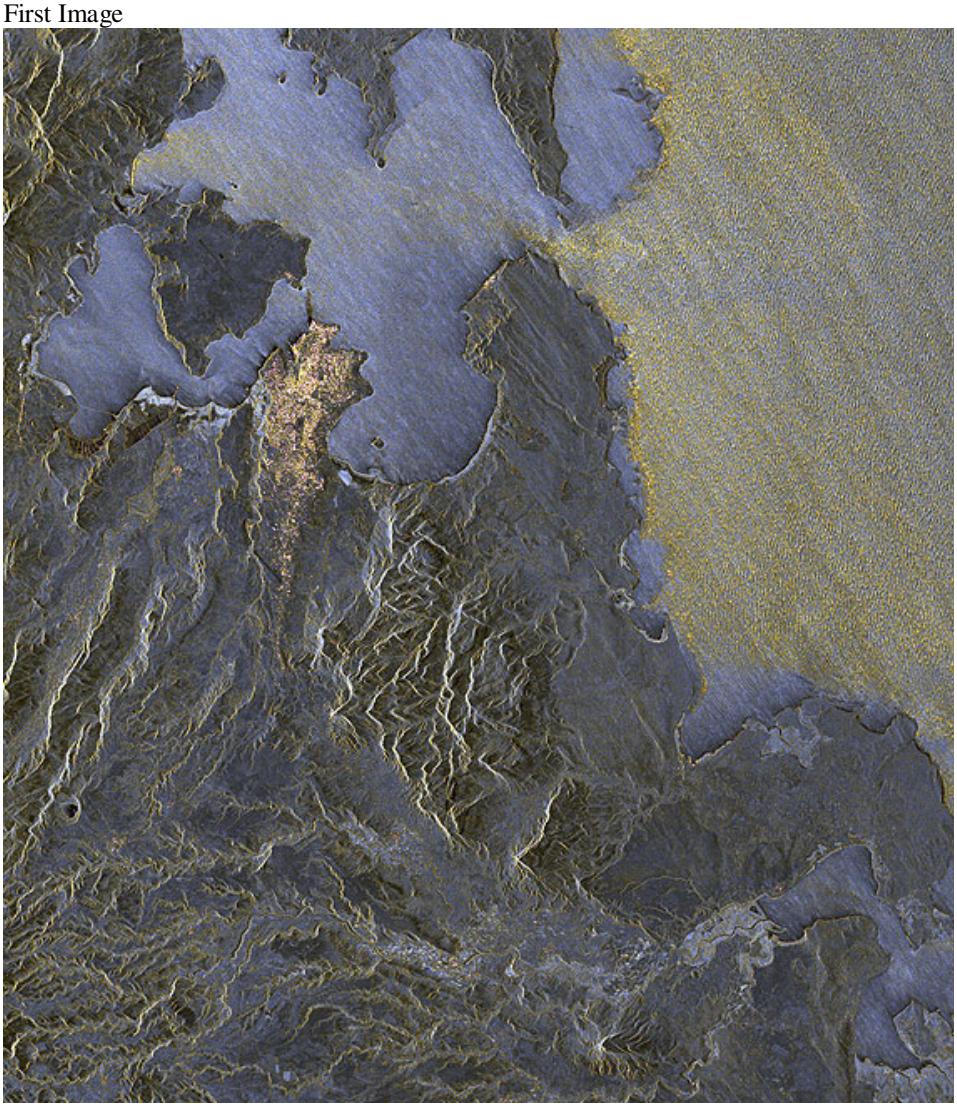
Complexity of the TSX-TDX planning problem:

- *Combination of two missions and two satellites*: TanDEM-X mission makes use of TSX and TDX spacecraft simultaneously; TerraSAR-X mission datatakes can be performed by either TSX or TDX. Therefore the Mission Planning System (MPS) of the

TerraSAR-X mission and the TanDEM-X Mission have to be combined.

- *High load*: The Mission Planning System has to handle up to 1000 orders per day with two planning runs/day
- *Timeliness*: An near real time service for TerraSAR-X mission with updates of datatakes until 1 hour before acquisition (limited in geo location) is supported
- *Complexity*: The planning problem has to respect approximately 200 constraints reflecting satellite inherent boundary conditions (e.g. power thermal limitations or memory limitations) as well as inter satellite dependencies (interference aspects or safety aspects).
- *Automation of the mission planning*: The planning system is fully automated. The tele-commands to be uploaded to TSX and TDX are generated unattended.

First Image



First TanDEM-X Image taken over Madagaskar

Detailed TSX & TDX Achievements

Management challenges:

- *Project structure*: The TSX-TDX ground segment involves four institutes in Oberpfaffenhofen, Germany. Within the ground segment more than 240 Interface Items have been established.
- *Project schedule*: TDX has been launched three years later than TSX. Therefore the extension of the TSX ground segment to a combined TSX-TDX ground segment had to be realized within an operational system.
- *Security*: After launch of TSX a law governing security aspect of high resolution Earth Observation data (Satellitendatensicherheitsgesetz) has been issued. The ground segment had to be adjusted to the new security requirements. The TSX&TDX project in the German Space Operations Center has been certified according to ISO27001 information security standards.

Operational challenges:

- *LEOP operations*: The Launch and Early Orbit Phases (LEOP) of TSX and TDX have been performed by the German Space Operations Center (GSOC) in 2007 and 2010. The first Synthetic Aperture datatakes could be successfully commanded, acquired and processed within the 5th mission day for TSX in 2007, respectively within the 4th mission day for TDX in 2010.
- *Recovery from spacecraft contingencies*: two severe TSX S/C contingencies could be successfully recovered in 2008
  - *In- orbit safe mode tests:* Before entering close formation flight the safe mode concept of TSX needed to be reworked to avoid on-board autonomous thruster usage. A new magnetic torque based safe mode has been tested in orbit.