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TanDEM-X Space Segment Overview (1/2)

- SAR Interferometry mission for generation of precise global Digital Elevation Model according to Level-3 Standard (12 m posting, 2 m accuracy)

- Orbital constellation of two SAR satellites:
  - TerraSAR-X
  - TanDEM-X (Rebuild of TerraSAR-X with minor adaptations)

- Typical distance of 250 m - 1 km between satellites during DEM acquisition phase
TanDEM-X Space Segment Overview (2/2)

Main requirements

- S/C lifetime: 5 years after in-orbit commissioning (extension of in-orbit lifetime > 1 year for TerraSAR-X)
- Reliability: 0.81 after 5 years
- Fully one-failure tolerant S/C design

Additional aspects

- Extended operational profile
  - up to 400 s active + 300 s Rx only SAR-operation per orbit (original scenario < 170s per orbit)
  - Extension of downlink scenario (additional G/S network INU, OHG, KIR)
  - Resource optimised operation
    (modelling of energy within MPS, XDA hot standby switching)

- Additional safety mechanisms to prevent collision and SAR illumination
Design Differences – General

In preparation of the TanDEM-X Mission, the TerraSAR-X satellite was already equipped with:

- Sync Horn Antennas for exchange of radar sync pulses between TerraSAR-X and TanDEM-X (incl. related change of Leaf Amplifier Assemblies and control S/W)
- Improved PRF timing accuracy by change / modification of SAR Central Electronics Timing Generator Module

**TDX is a rebuild of TSX with the following additional features:**

- Cold Gas System for Fine Constellation Control
- Inter-Satellite Link Receiver (ISL Rx) for one-way transmission of position, attitude and status information from TerraSAR-X to TanDEM-X
Design Differences – Sync Horns

- Six circular-polarised horn antennas
- Omni-directional coverage
- Sync Horns are fed by the LAA TR-Modules – 2 TRMs feed 1 Sync Horn
- Built-in redundancy (only 3 dB signal reduction if one TRM fails)
- One horn antenna is active at a time (selected by ground planning)
Design Differences – Cold Gas System

- Cold Gas System design heritage and off-the-shelf units as on CHAMP, GRACE and Cryosat
- Cold Gas delta-v needed for constellation maintenance: 16.7 m/s, equivalent to 32.8 kg gaseous N2
- Tank capacity: 36 kg @ 280 bar, providing ~10% margin
- 40 mN Thrusters
- Typically one manoeuvre pair per day
**Design Differences – Inter Satellite Link**

- **TSX HK S-Band Downlink** system is used to transmit data to TDX.
- TDX is equipped with S-band Receiver for TSX downlink signal (ISL Rx).
- ISL Decoder Unit prepares data for TDX On-Board Computer.
- Data Transmission: GPS position information plus attitude and TSX status data once every 10 seconds.
- Nearly continuous link during close formation (small gaps during equator crossing).
Design Differences – TAFF

- **TanDEM Autonomous Formation Flight (TAFF)**
  - Real-time onboard autonomous formation keeping module
  - Plan and execute formation control maneuvers autonomously with a higher frequency (e.g. every 2-5 orbital revolutions)
  - Improvement of relative orbit accuracy increases the quality of the data products
  - Algorithm developed by DLR GSOC
  - Integrated into TDX AOCS (Astrium On-Board S/W)

- **TAFF working principle**
  - TDX receives S-band telemetry of TSX over one-way Inter-Satellite Link (1 telemetry packet every 10 seconds)
  - TAFF runs with 0.1 Hz and gets GPS data from TDX and TSX as input
  - TAFF uses Cold Gas propulsion System to control the formation
Safety Mechanisms (1/3)

Magnetic Torquer controlled Safe mode

- Additional safe mode based on magnet-torquers to avoid orbit change (reduction of collision risk)
- Monitoring of bus voltage and critical temperatures
- Thruster-based safe mode remains as safety-net to ensure survival of satellite
- Default ASM mode (RCS or MTQ) can be configured from ground
- ASM-MTQ successfully demonstrated during commissioning phase (long term and dynamic test cases for TSX and TDX)
Safety Mechanisms (2/3)

Exclusion Zone Logic

- Logic in OBC SW to suppress SAR transmission during orbit (exclusion) zones defined by Ground Segment (using actual orbit position)
- Data takes are only allowed in nominal AOCS modes (NOM-AH, NOM-RL, NOM-SSL)
- Different exclusion zones for right and left looking data takes defined
- SAR transmission is blocked inside exclusion zones
- Active data takes are aborted if the data take is running into exclusion zone
- On-board exclusion zone function successfully demonstrated during commissioning phase
- Similar logic in Ground Segment (using planned orbit position)
Safety Mechanisms (3/3)

Sync Warning Data Takes

- Dedicated simultaneous Data Takes on both satellites using a Sync Horn pair via setting of LAA relays (same signal routing as for ‘Sync Link’ pulse exchange for bistatic performance)

- ICU SW for signal detection and comparison with signal threshold: a ‘negative contact’ causes event to OBSW to suppress SAR transmission

- Sync Warning Data Takes active since having reached close formation

Inter Satellite Link Monitoring

- TDX ‘listens’ to TSX status via TT&C S-Band (low power/low data rate) using additional ISL receivers/decoders

- TDX OBSW suppresses TDX SAR transmission and disable TAFF in case of non-nominal TSX status

- PVT data also transferred for TAFF experimental SW on TDX
Spacecraft Status and Resources

General Health State

- All units running on nominal chain
- Most equipments checked during LEOP or commissioning phase
- No degradation effects
- Low rate of correctable bit errors and no uncorrectable bits detected in SSMM or other RAM devices
- Excellent state of resources
- Unit Operation times and switch on/off cycles within specified limits
Resources – Propellant and Cold Gas

- Propellant and Cold Gas budgets
  - TSX used Propellant 21.1 kg of 76 kg
  - TDX used Propellant 6.8 kg of 76 kg
  - TDX used Cold Gas 3.5 kg of 36 kg (implies ~45 months formation flight)
Resources – Battery Stress

TDX Commissioning Phase: (June-Dec 2010)
- Avg. DoD: 1.9 %
- Max. DoD: 11.5 %
- Designed to 5% average

TSX (Oct-Dec 2010)
- Avg. DoD: 1.3 %
- Max. DoD: 8.3 %
- Increased DoD after start of DEM acquisition phase
Current degradation of TSX battery is 14% (to be confirmed by ABSL)
In Orbit Lifetime

- **TSX Life Time (nominal 5.5 years)**: ~1 year
- **TDX Life Time (nominal 5.5 years)**: ~1 year
- **At least 3 years of joint operation**
- **Estimated 8+1 years of TerraSAR-X operation**

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