Automation challenges of the Mission Planning System and the Ground Station Network within the TerraSAR-X/TanDEM-X Ground Segment

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Overview

• **Introduction**
  • The Mission Planning System and the Ground Station Network within the combined TerraSAR-X/TanDEM-X Ground Segment and its interfaces
  • The evolution of the Ground Segment 2007 – 2015
  • The different TSX/TDX flight configurations since 2010

• **The different flight formations from a ground stations point of view**
  • Specific analysis activities by flight dynamics
  • Analysis of the contact times for the different flight configurations
  • the updates of the interfaces and workflows, the timeline horizon and reaction times of mission planning and the ground stations

• **The scheduling of the down link within mission planning and the resulting workflows and interfaces**
  • The ground station pool concept
  • The near-real time down link scheduling

• **Summary**
Introduction – The Interfaces between MPS and GSN within the combined TerraSAR-X/TanDEM-X Ground Segment

• The interfaces between the Mission Planning System and the Ground Station Network are the following (timing in parenthesis):

**GS ⇒ MPS:**
- GSC: Ground station capability (2 weeks for mobile Stations, other > 1 month)
- AVI: Availability Info (1-2 weeks, for special applications ~1 day)

**MPS ⇒ GS**
- DLI: Downlink info (6-18 hours, ~1 hour for special applications)

[Diagram of the interfaces between the Mission Planning System and the Ground Station Network]
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TerraSAR-X Mission (2007)

- S-Band Uplink and Downlink: Weilheim
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TerraSAR-X Mission (2007)

- S-Band Uplink and Downlink: Weilheim
- X-Band: Neustrelitz (Prime)
- Direct-Access Stations (3 fixed)
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TerraSAR-X Mission (2010)

- S-Band Uplink and Downlink: Weilheim
- X-Band: Neustrelitz (Prime)
- Direct-Access Stations (3 fixed, plus 1 mobile) O’Higgins (Background)
- S-Band: Support for via 3 additional ground stations
Introduction – The MPS and GSN within the combined TerraSAR-X/TanDEM-X Ground Segment


- S-Band Uplink and Downlink: Weilheim, Neustrelitz, O’Higgins, Inuvik, Svalbard
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**TanDEM-X Mission (2010)**

- S-Band Uplink and Downlink: Weilheim, Neustrelitz, O’Higgins, Inuvik, Svalbard
Introduction – The MPS and GSN within the combined TerraSAR-X/TanDEM-X Ground Segment


- S-Band Uplink and Downlink: 5 Stations
- X-Band:
  - 15 TerraSAR-X
  - 3 TanDEM-X
Introduction – The MPS and GSN within the combined TerraSAR-X/TanDEM-X Ground Segment


- S-Band Uplink and Downlink: 5 Stations
- X-Band:
  - 15 TerraSAR-X
  - 3 TanDEM-X
  - 3 new TerraSAR-X stations soon
- ~85 Contacts per day and satellite (~50 currently used)
Introduction –
The evolution of the Ground Segment 2007 – 2015

• 2007 – 2010: The TerraSAR-X only Ground Segment
  ⇒ one mission, one satellite

• Since 2010: The combined TerraSAR-X/TanDEM-X ground segment
  ⇒ two missions and two satellites

• Since Sep 2014: TanDEM-X Science Phase
  ⇒ Different Flight Configurations of the two satellites
  ⇒ Specific Operation Modes of the Satellites

And as much as possible transparent to the TerraSAR-X mission!
Introduction –
The different TanDEM-X (TSX/TDX) flight configurations since 2010

• 2010 pursuit monostatic phase with 20 km along track separation for TDX commissioning
  ⇒ near formation
• 2010 – 2014 bi-static phase, with <1 km along track separation and normal between 120 m – 500 m
  ⇒ close formation
• Sep 2014 – Mar 2015 again pursuit monostatic, but 76 km
  ⇒ far formation
• Since Mar 2015 bi-static phase, with <1 km along track separation and normal max. 3.6 km (large horizontal base line)
  ⇒ close and near formation is alternating every 24 minutes 😊

And as much as possible transparent to the TerraSAR-X mission!
The different flight formations and the ground station – The close scenario

- Typical distances for normal and along-track is **below 1km**, depending on the antenna characteristics, as example the real close formation of Aug/Sep 2014 is shown below, with 300m along track offset and supported by TAFF (TanDEM Autonomous Formation Flight)
- **S-Band**: Both spacecraft can be commanded with **one antenna** only, incl. HK-data-reception, in **parallel**
- **X-Band**: As the X-Band downlink frequency of TSX&TDX is identical: X-Band data of both spacecraft can be received with **one antenna** only, but **sequentially** only

7m RMS along-track accuracy!
The different flight formations and the ground station – The near scenario

- Typical distances for normal and along-track is **above 1km**, depending on the antenna characteristics, as example the transition from the 20 km to '0'km formation in Oct 2010 is shown below
- **S-Band**: Both spacecraft can be commanded with **two antennas***, incl. HK-data-reception, in **parallel**
- **X-Band**: As the X-Band downlink frequency of TSX&TDX is identical: X-Band data of both spacecraft can be received with **two antennas***, but sequentially only

* with specific enhancements in the antenna control, for example already implemented on the German Antarctic Receiving Station in O’Higgins, one antenna is sufficient
The different flight formations and the ground station – The far scenario

- Typical distances for normal and along-track is **above 50km**, depending on the antenna characteristics, as example the transition ‘0’km to 76 km formation in Sep 2014 is shown below
- **S-Band**: Both spacecraft can be commanded with **two antennas**, incl. HK-data-reception, in **parallel**
- **X-Band**: X-Band data of both spacecraft can be received with **two antennas in parallel**

![Diagram showing flight formations and ground station](image-url)
The different flight formations and the ground station –
Analysis by flight dynamics for the large horizontal baseline configuration

• During the large horizontal baseline flight configuration the satellites are seen as a 'virtual' close or near formation depending on the antenna
  • geographical region,
  • its characteristics and
  • the current elevation to the satellite(s)

• The analysis was done for all of the TerraSAR-X/TanDEM-X stations (example on the right shows the result for the INU station (lat = +68deg) )

• Only the polar stations (lat ~ 80deg or higher) can receive X-Band data from both space crafts within one contact and with one antenna (close)
The different flight formations and the ground station – The contact times of the TanDEM-X pool

• For the TanDEM-X mission a balanced contact time ratio for TSX and TDX is essential
• For the close formation:
  The balancing is done by the Mission Planning System ‘automatically’
• For near and far formation:
  The balancing was done manually, see graphics on the right for the result
• Large horizontal baseline formation:
  Same as for near / far for convenience
The different flight formations and the ground station –
The TanDEM-X Ground Station Network

Expected TanDEM-X data volume:
~ 350 TByte in 3 years
~ 450 GByte per day

Complementary locations at moderate high latitudes
(symmetrical data load, contact time maximised)

TT&C support for close formation monitoring

SMCS enables automated (unmanned) station operation
(specifically Inuvik)
The different flight formations and the ground station – GSN Station Monitoring and Control – Operator Web View

1. TSX/TDX sequential downlink (Column ‘Sat’)
2. X-Band, S-Band, Uplink, etc. (Column ‘Band’)
3. Input Files DLI and TLE
4. Actual Status
5. If DONE: Detailed status for Antenna control, Cortex Receiver, Recording, Direct Archive System
6. also: support of other missions like Radarsat-2
The different flight formations and the ground station – The timeline horizon and reaction times

- NRT applications for TerraSAR-X vs. the mapping requirement of TanDEM-X
  - shared usage of onboard mass memory (SSMM)
  - down link planning for the both missions

- TerraSAR-X short term timeline of 3 days ⇒ 3 months long-term timeline for TanDEM-X
  - to forecast potential conflicts between TerraSAR-X and TanDEM-X acquisitions
  - to predict possible overutilization of the onboard mass memory of one of the missions (even the TanDEM-X acquisition plan is balanced in respect to the onboard mass memory usage)
    ⇒ Pre-planning of the TerraSAR-X and TanDEM-X downlink utilization !!!

- TerraSAR-X NRT applications can have influence to the TanDEM-X downlink planning
  - Final downlink information can change (incl. Satellite change)
  - Station itself is receiving the data
    ⇒ reaction time of the ground station of about one hour without any operator interaction
Downlink scheduling with the mission planning system – The ground station pool concept

• A **pool** of ground stations can be understood as a **virtual ground station** → All contacts of all stations within this pool are contacts of this virtual station

• Mission planning is allowed to schedule **parts** of the data of an acquisition to **different stations**, this is by design **chronological** (within 24h)

• The **transfer** of the data to the Processing facility can last between **minutes** up to **months**

  E.g.: Part 2 received on GS1 is available on the processing facility before Part 1, which was received on GS3

  ⇒ special **design enhancement**, incl. hardware, was needed on the processing facility
Downlink scheduling within the mission planning system –
The near-real time down link scheduling

• Default: Downlink scheduling for TerraSAR-X/TanDEM-X is based on the acquisition priority only

• For specific applications the time lag between the data acquisition and the data delivery is a key parameter

⇒ Request can be ordered as NRT application

⇒ Very useful together with the Pool feature 😊
Summary

- The Mission Planning System and the Ground Station Network of the TerraSAR-X/TanDEM-X ground segment were experiencing new challenges, especially due to the TanDEM-X science phase since last October.
- To allow a smooth operation of the mission planning system and the ground station network during the specific flight configurations and its transition phases of the science phase, an
  - elaborated analysis was done
  - just adaption of the configuration within the two systems needed
- In parallel to the mandatory extensions of the mission planning system and the ground station network, additional valuable new highlights are activated for TerraSAR-X
  - downlink pools
  - improved NRT downlink scheduling
- Even with all this new tasks, incl. decreasing the response time of the ground station to new mission planning requests below one hour, the interfaces and workflows are showing its robustness every day, allowing unattended operation of the two systems for months.

😊😊😊 Waiting for new visions of the TerraSAR-X/TanDEM-X customers 😊😊😊
Thank you for your attention!