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

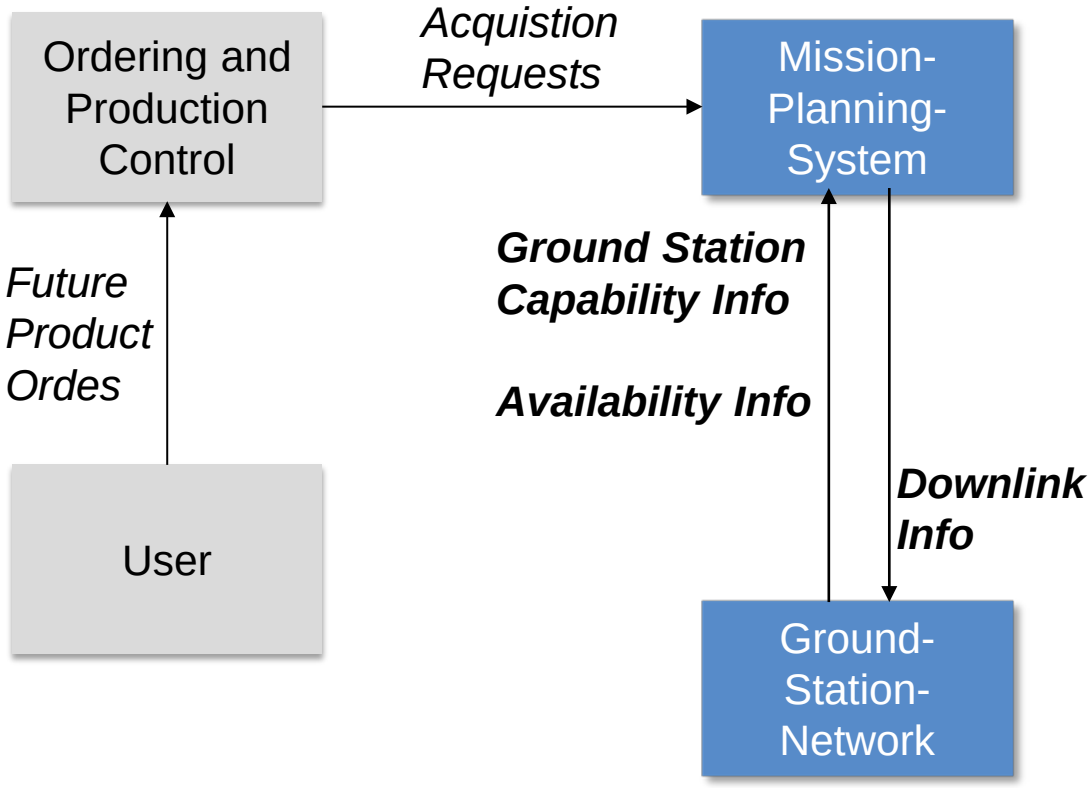
- The interfaces between the Mission Planning System and the Ground Station Network are the following (timing in parenthesis):

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)



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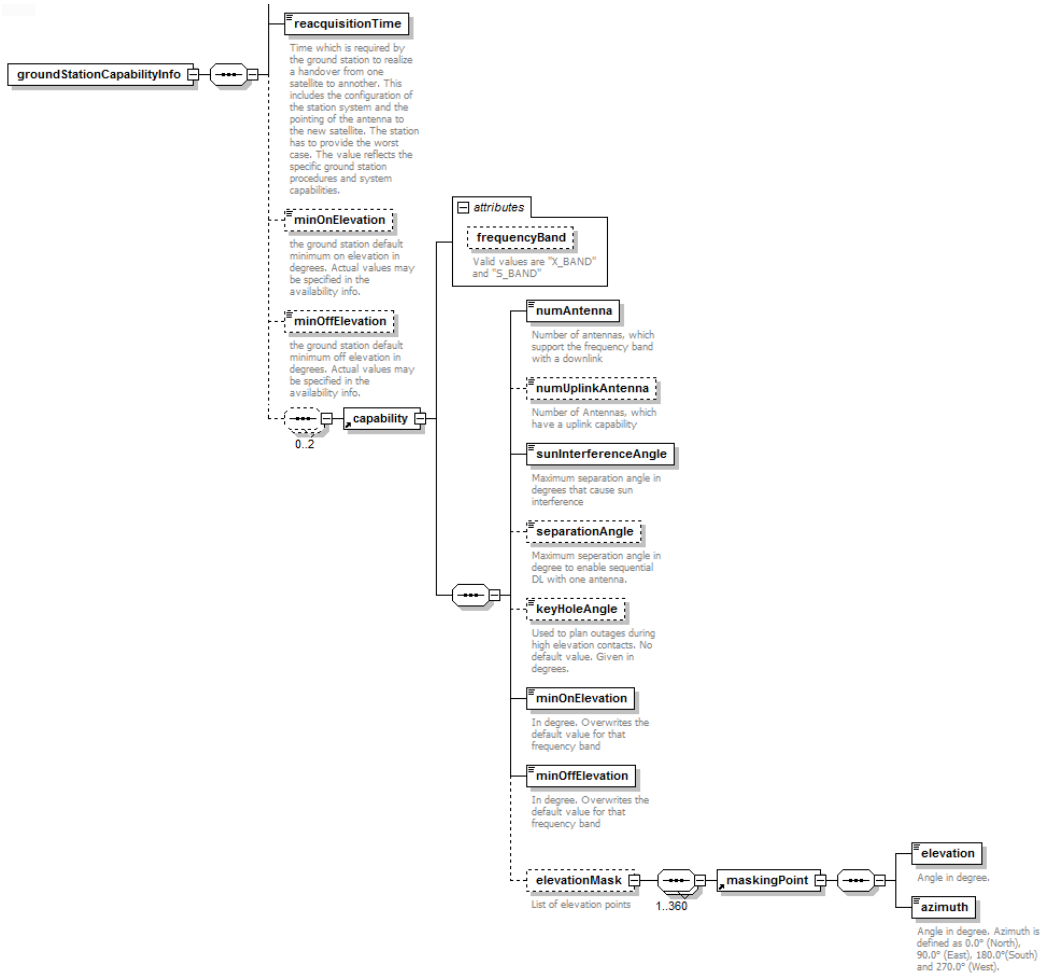

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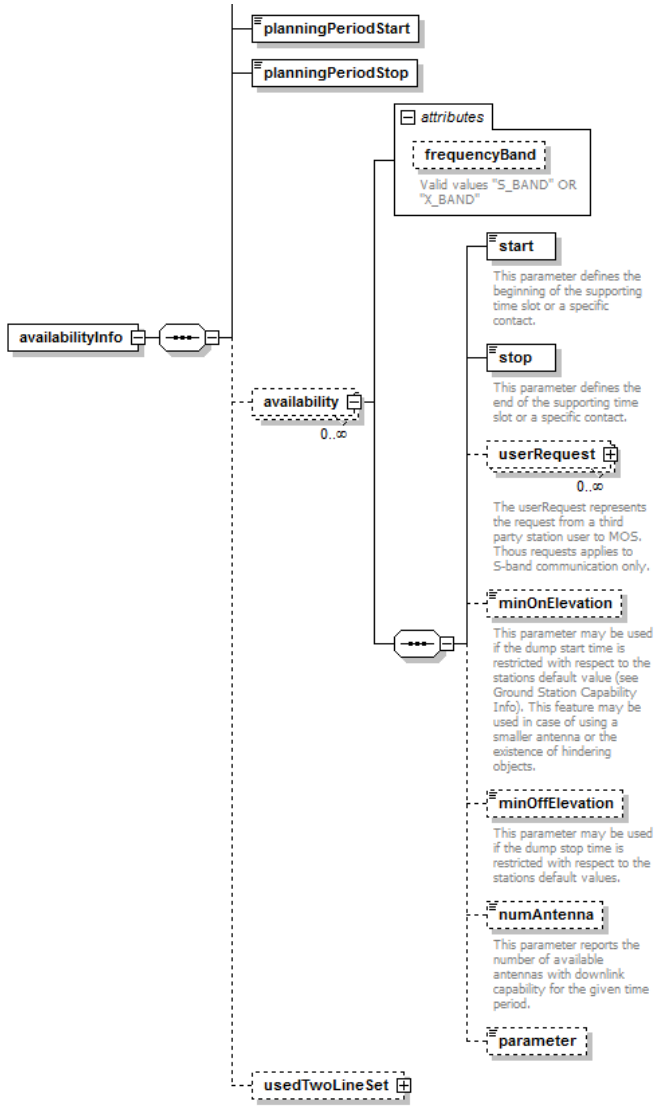

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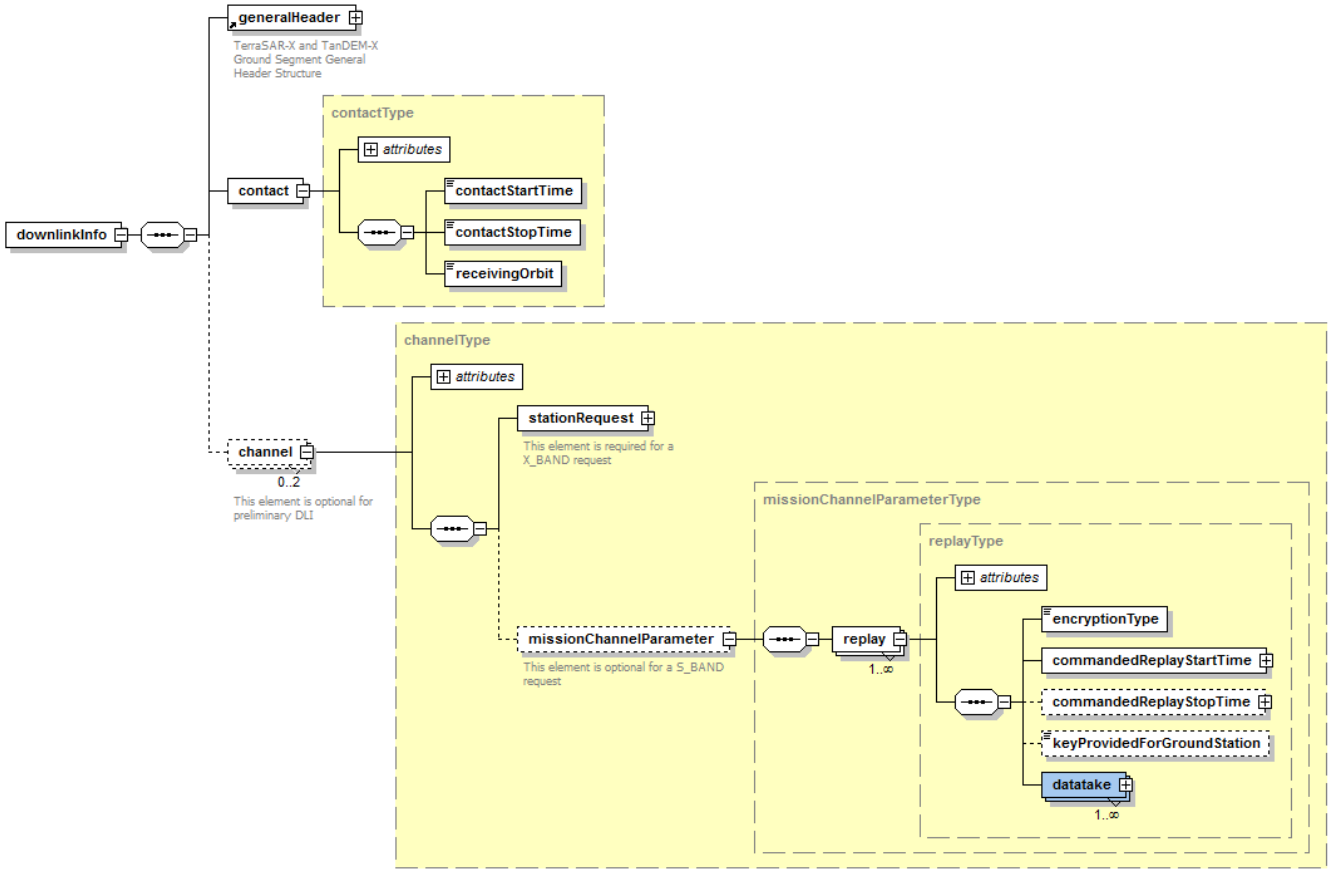
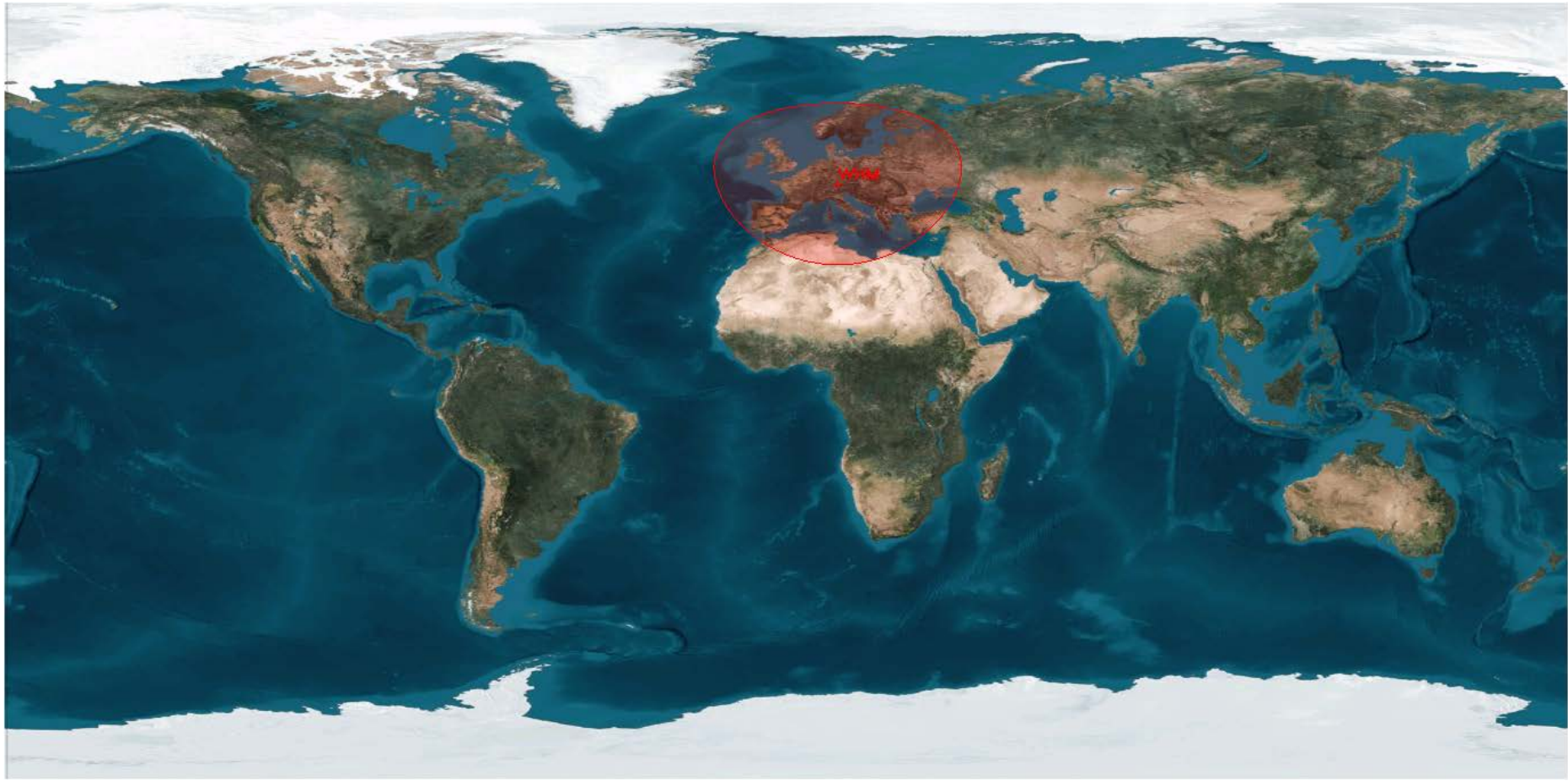


Introduction – The MPS and GSN within the combined TerraSAR-X/TanDEM-X Ground Segment

TerraSAR-X Mission (2007)

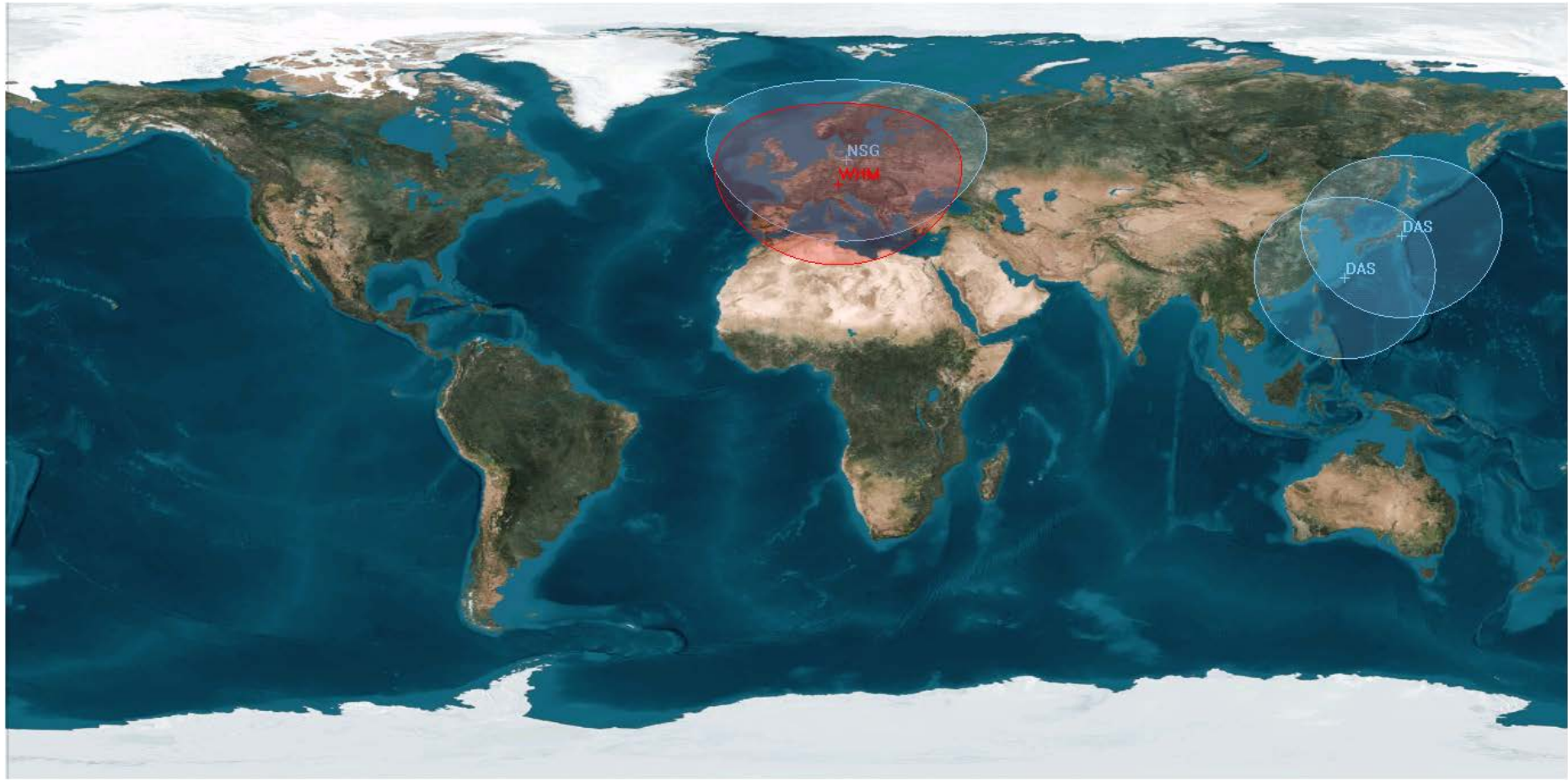
- S-Band Uplink and Downlink: Weilheim



Introduction – The MPS and GSN within the combined TerraSAR-X/TanDEM-X Ground Segment

TerraSAR-X Mission (2007)

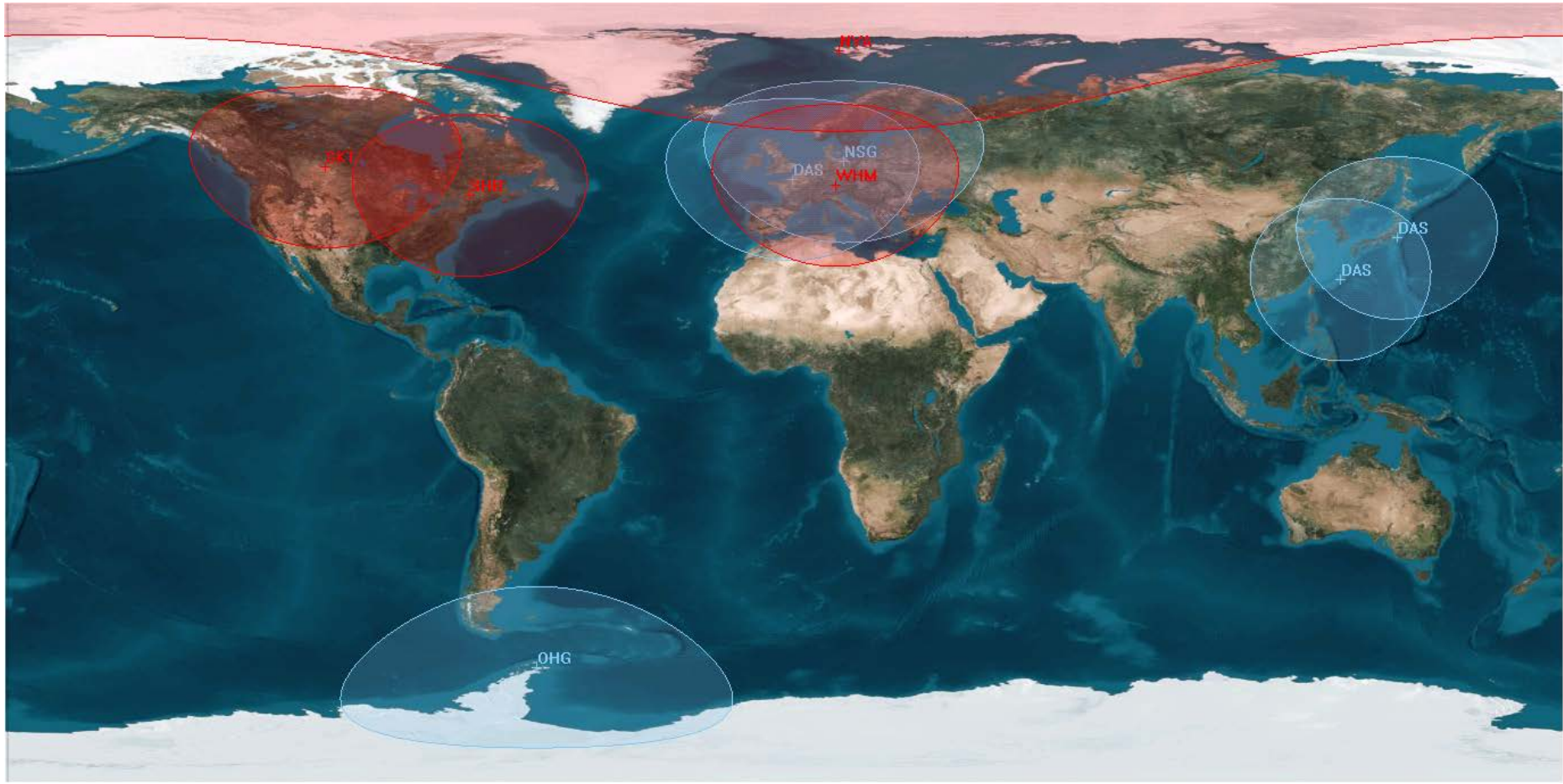
- S-Band Uplink and Downlink: Weilheim
- X-Band: Neustrelitz (Prime)
- Direct-Access Stations (3 fixed)



Introduction – The MPS and GSN within the combined TerraSAR-X/TanDEM-X Ground Segment

TerraSAR-X Mission (2010)

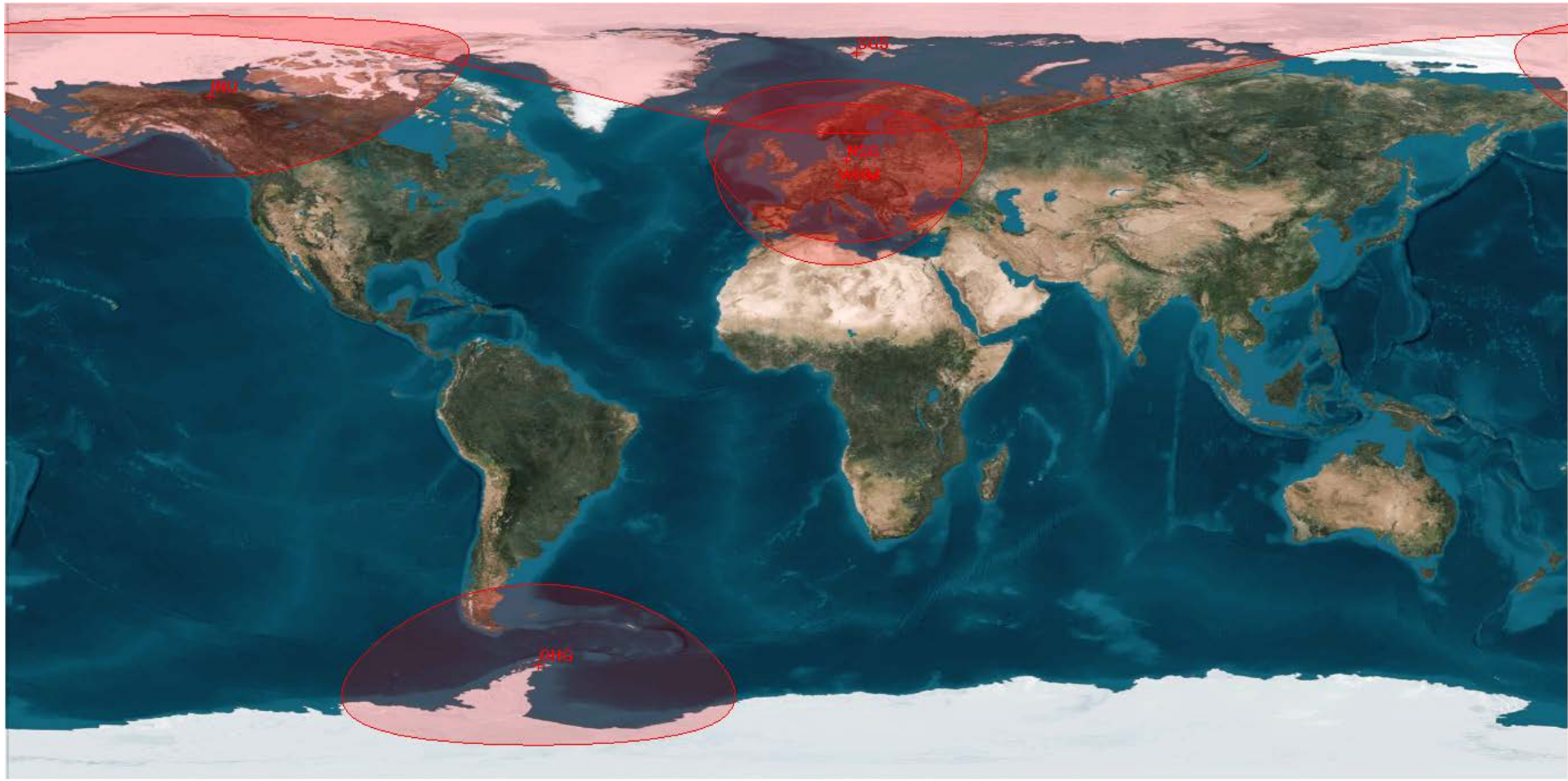
- S-Band Uplink and Downlink: Weilheim
- X-Band: Neustrelitz (Prime)
- Direct-Access Stations (3 fixed, plus 1 mobile) O'Higgins (Background)
- S-Band: Support for via 3 additional ground stations



Introduction – The MPS and GSN within the combined TerraSAR-X/TanDEM-X Ground Segment

TanDEM-X Mission (2010)

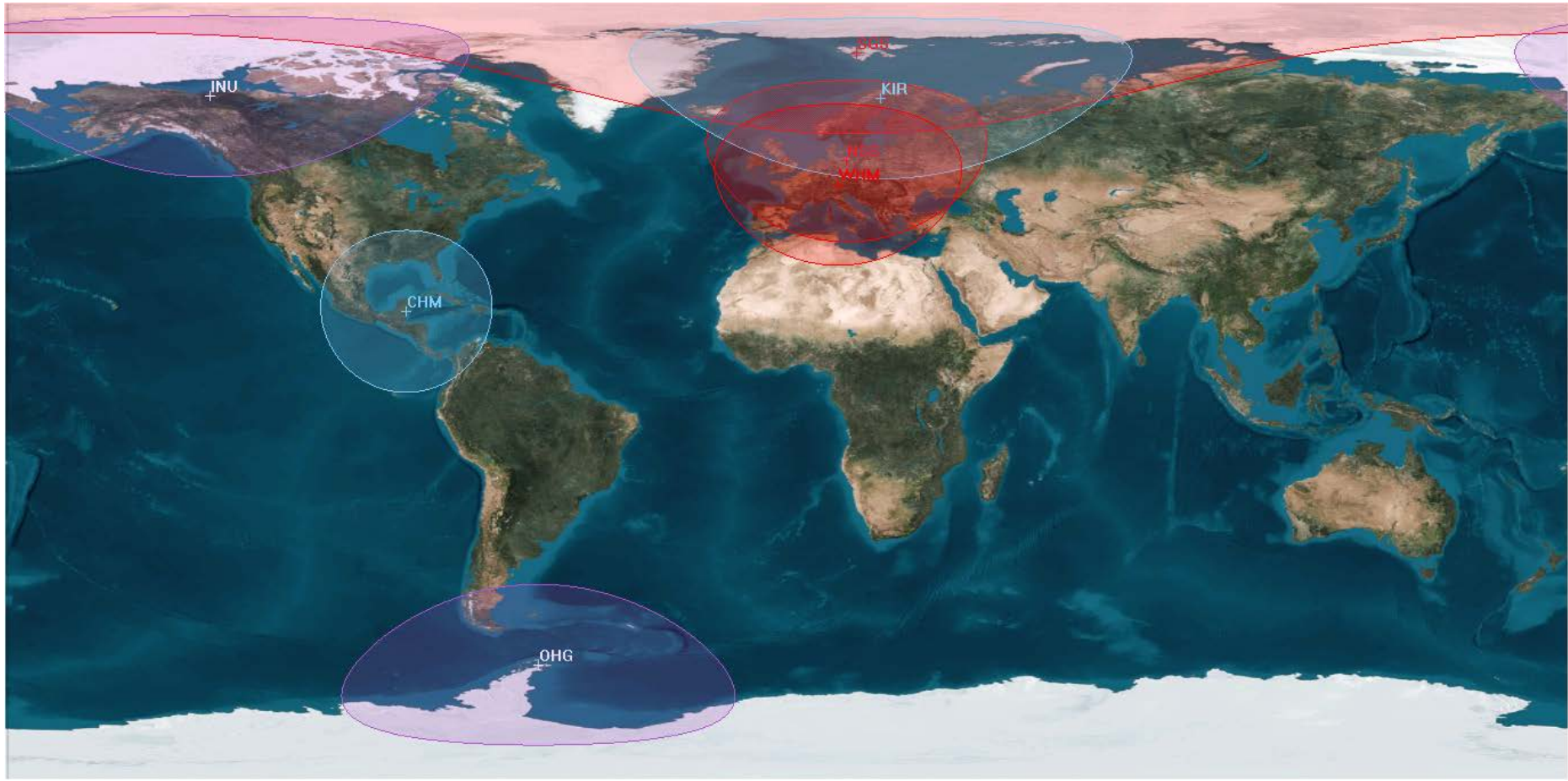
- S-Band Uplink and Downlink: Weilheim, Neustrelitz, O'Higgins, Inuvik, Svalbard



Introduction – The MPS and GSN within the combined TerraSAR-X/TanDEM-X Ground Segment

TanDEM-X Mission (2010)

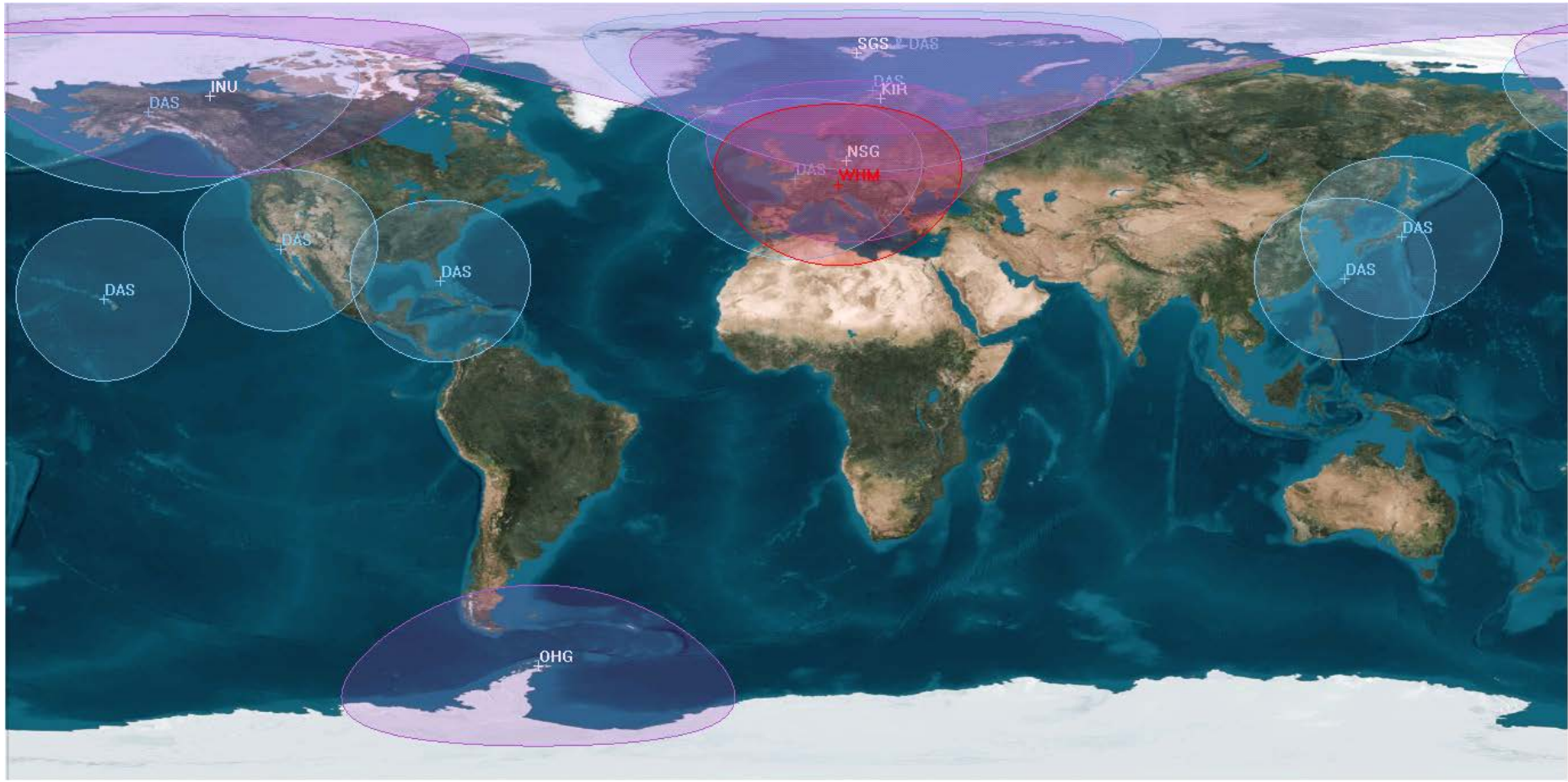
- S-Band Uplink and Downlink: Weilheim, Neustrelitz, O'Higgins, Inuvik, Svalbard
- X-Band: O'Higgins, Inuvik, Kiruna, Chetumal (2011 - 2013)



Introduction – The MPS and GSN within the combined TerraSAR-X/TanDEM-X Ground Segment

TerraSAR-X and TanDEM-X Mission (2015)

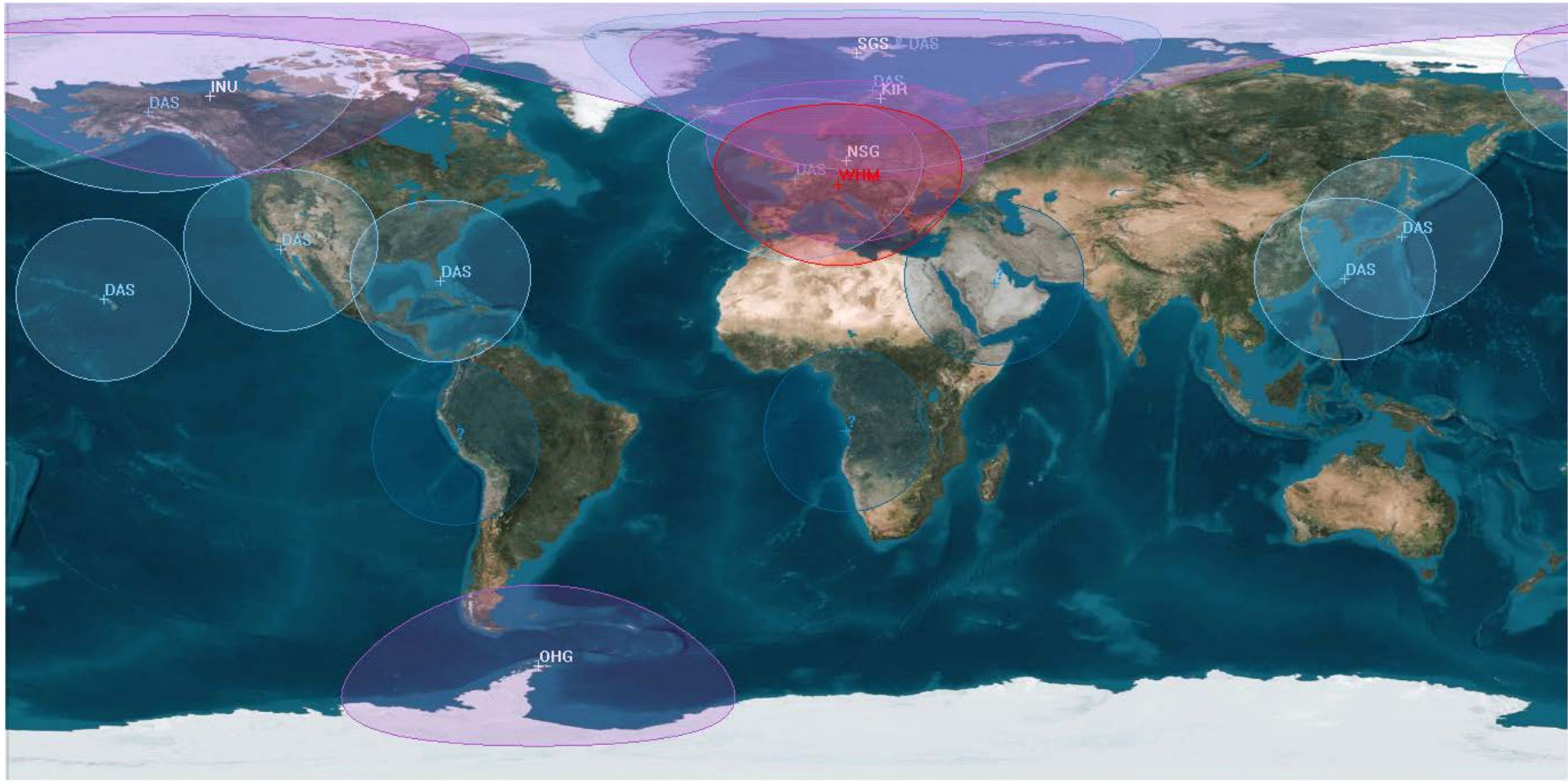
- S-Band Uplink and Downlink: 5 Stations
- X-Band:
  - 15 TerraSAR-X
  - 3 TanDEM-X



Introduction – The MPS and GSN within the combined TerraSAR-X/TanDEM-X Ground Segment

TerraSAR-X and TanDEM-X Mission (2015)

- 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!

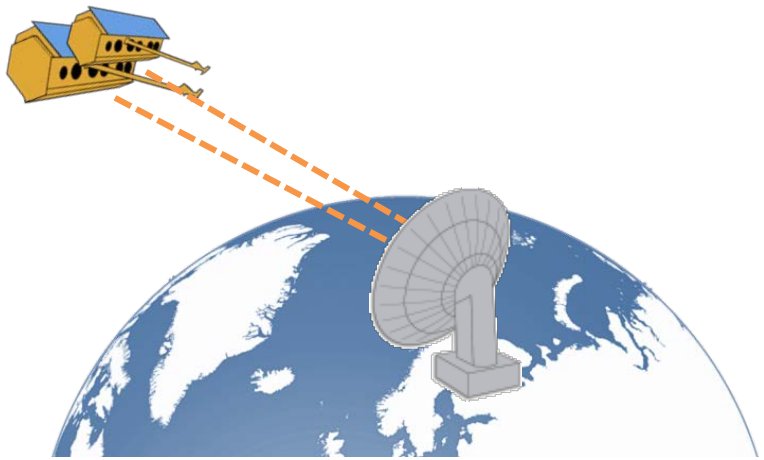
Introduction – The different TanDEM-X (TSX/TDX) flight configurations since 2010

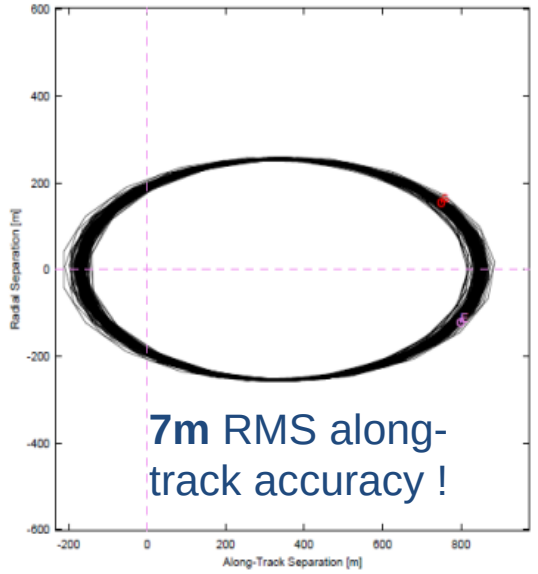
- 2010 pursuit monostatic phase with 20 km along track separation for TDX commissioning
  ⇨ near formation
- 2010 – 2014 bi-static phase, with <1 km along track separation and normal between 120 m – 500 m
  ⇨ close formation
- Sep 2014 – Mar 2015 again pursuit monostatic, but 76 km
  ⇨ far formation
- 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!

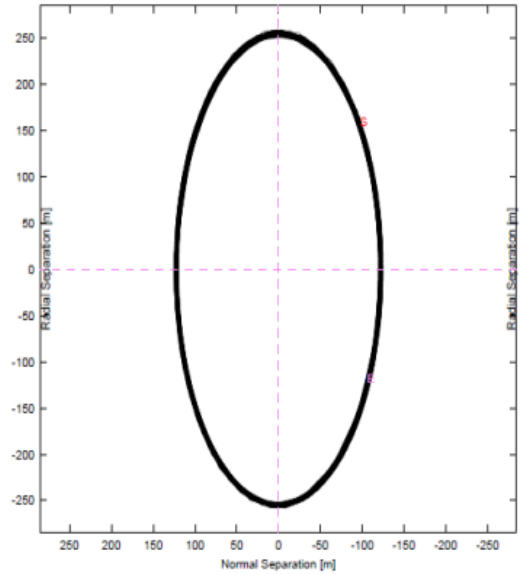
The different flight formations and the ground station – The close scenario

- 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





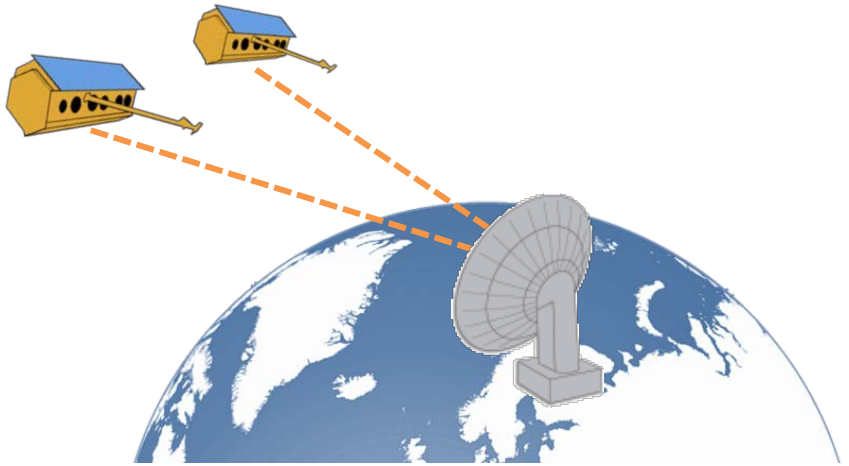
7m RMS along-track accuracy !

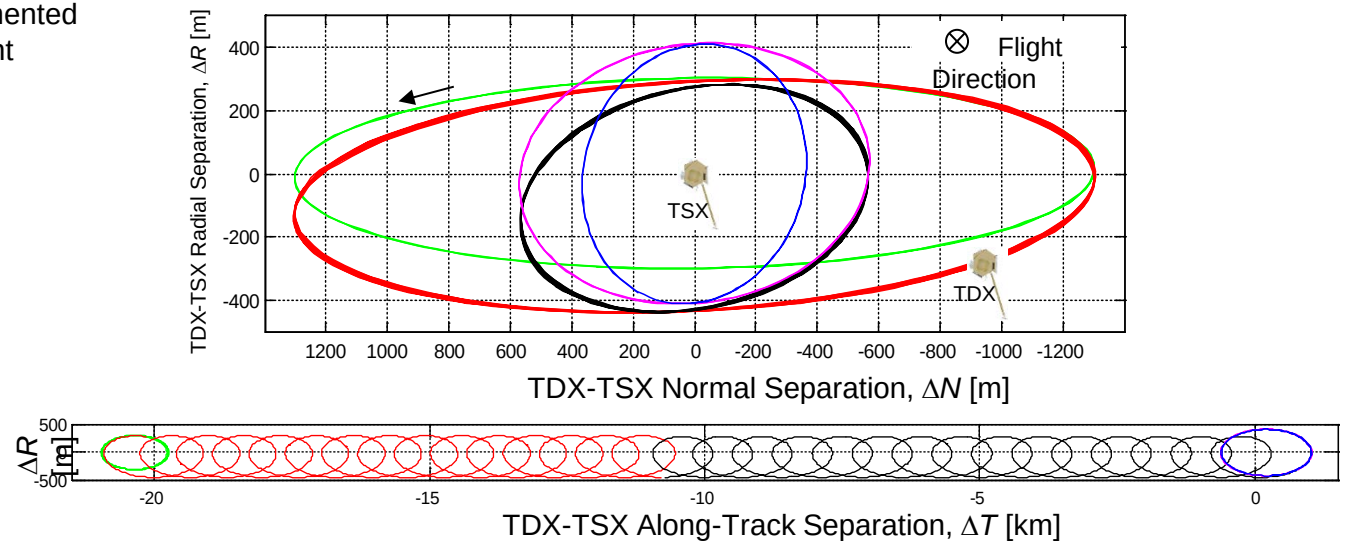


The different flight formations and the ground station – The near scenario

- 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

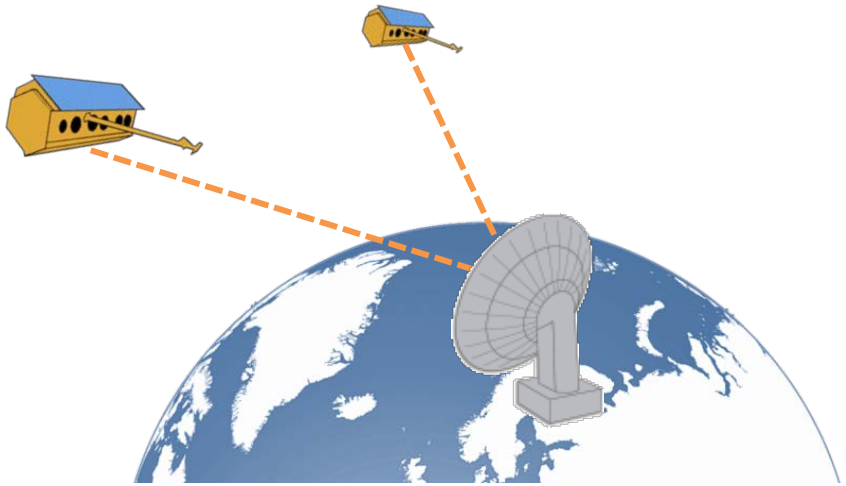
* with specific enhancements in the antenna control, for example already implemented on the German Antarctic Receiving Station in O'Higgins, one antenna is sufficient

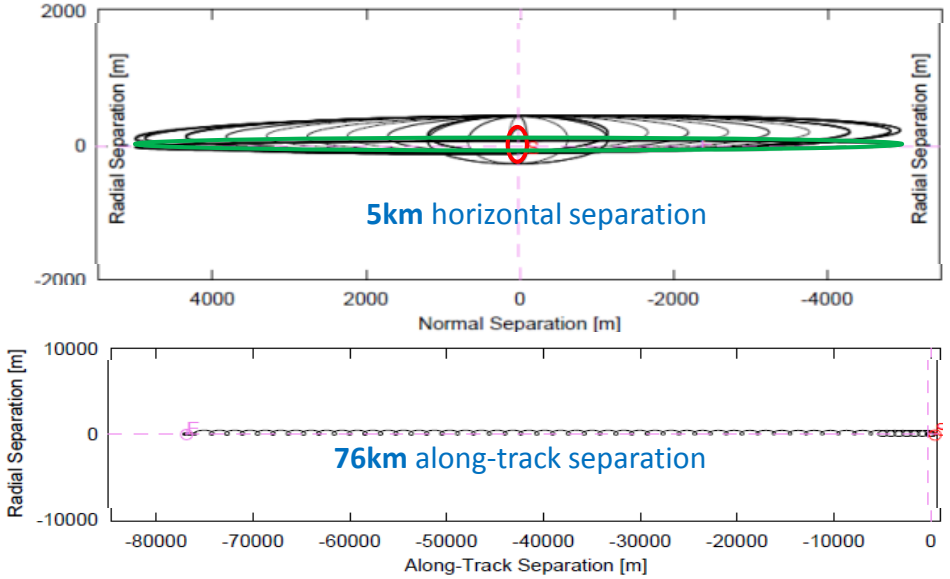




The different flight formations and the ground station – The far scenario

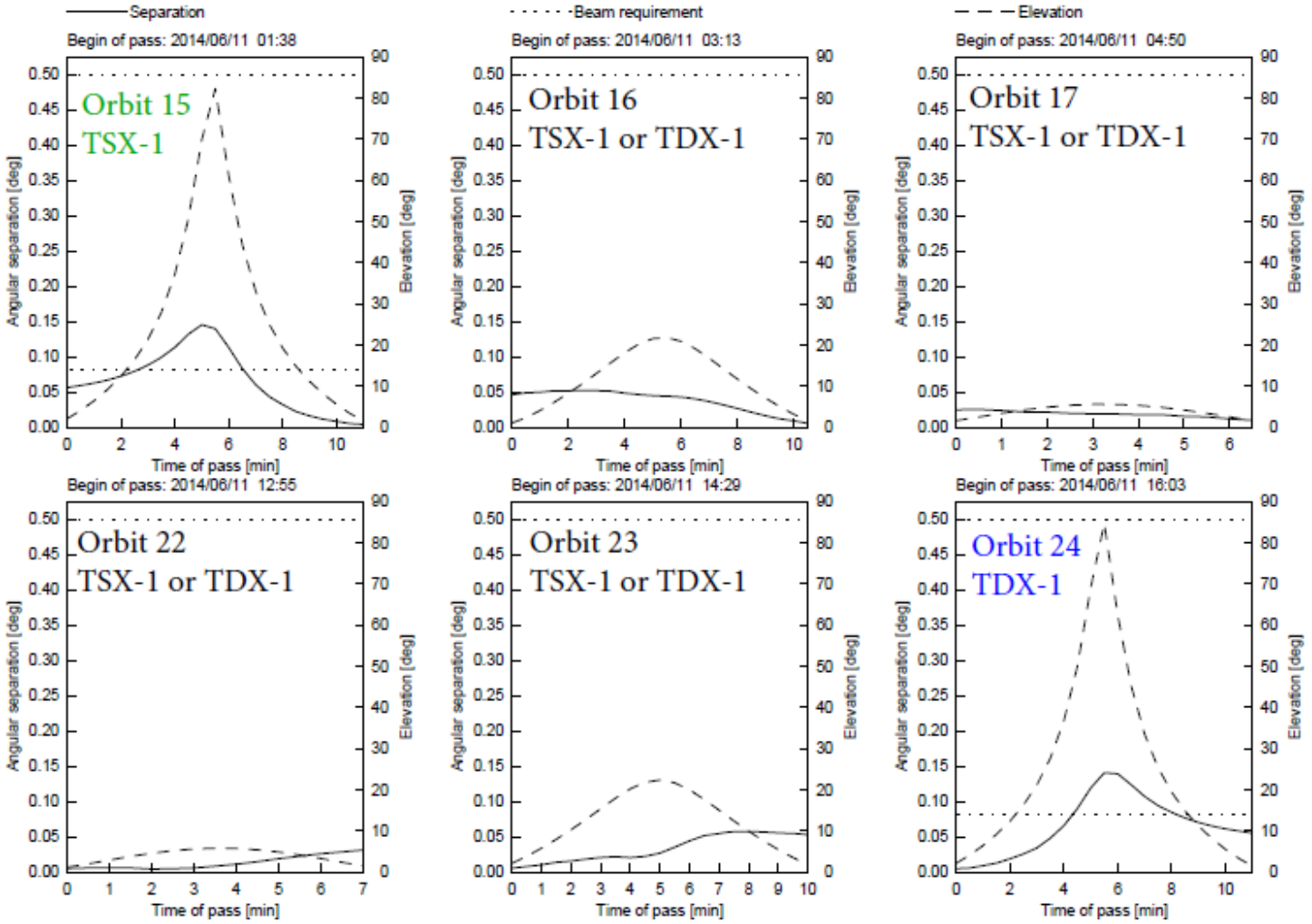
- Typical distances for normal and along-track is **above 50km**, depending on the antenna characteristics, as example the transition ‘0’km to 76 km formation in Sep 2014 is shown below
- **S-Band**: Both spacecraft can be commanded with **two antennas**, incl. HK-data-reception, in **parallel**
- **X-Band**: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





The different flight formations and the ground station – Analysis by flight dynamics for the large horizontal baseline configuration

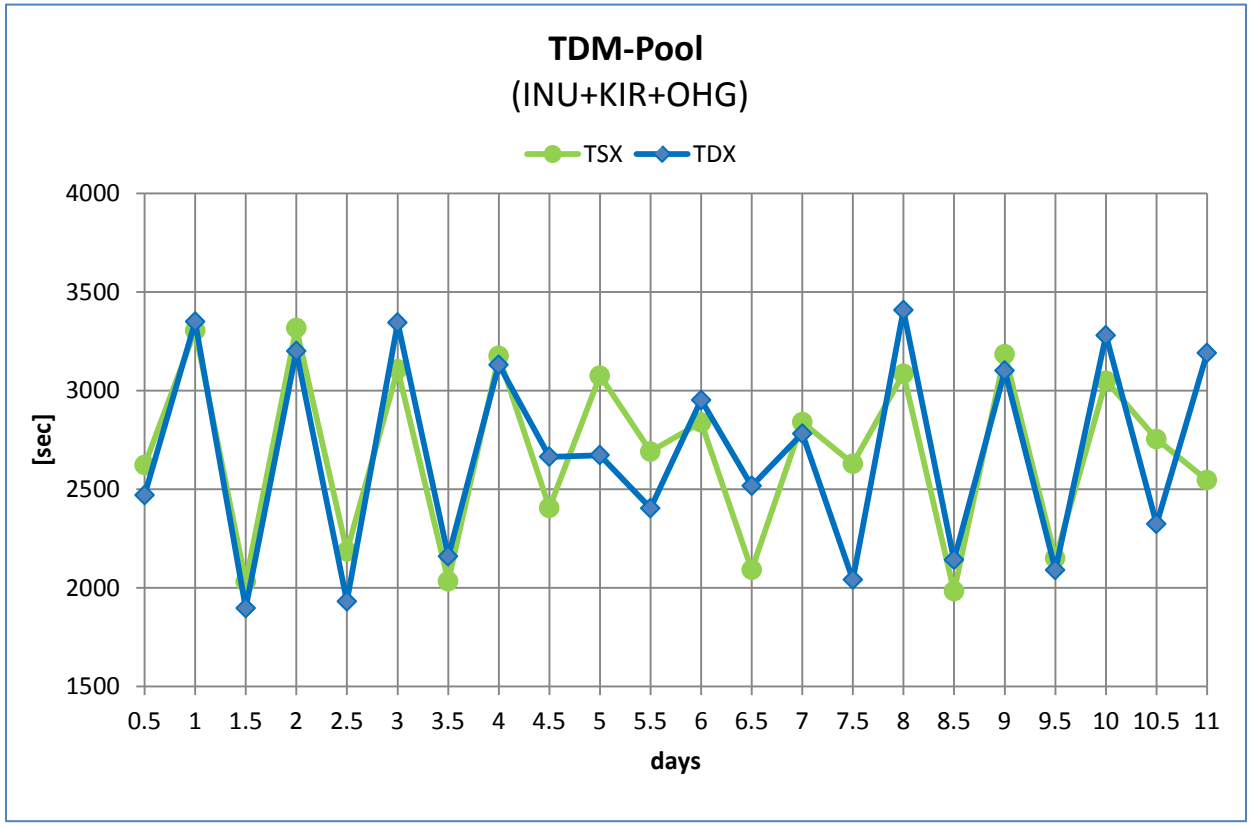
- During the large horizontal baseline flight configuration the satellites are seen as a ‘virtual’ close or near formation depending on the antenna
  - geographical region,
  - its characteristics and
  - the current elevation to the satellite(s)
- The analysis was done for all of the TerraSAR-X/TanDEM-X 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)



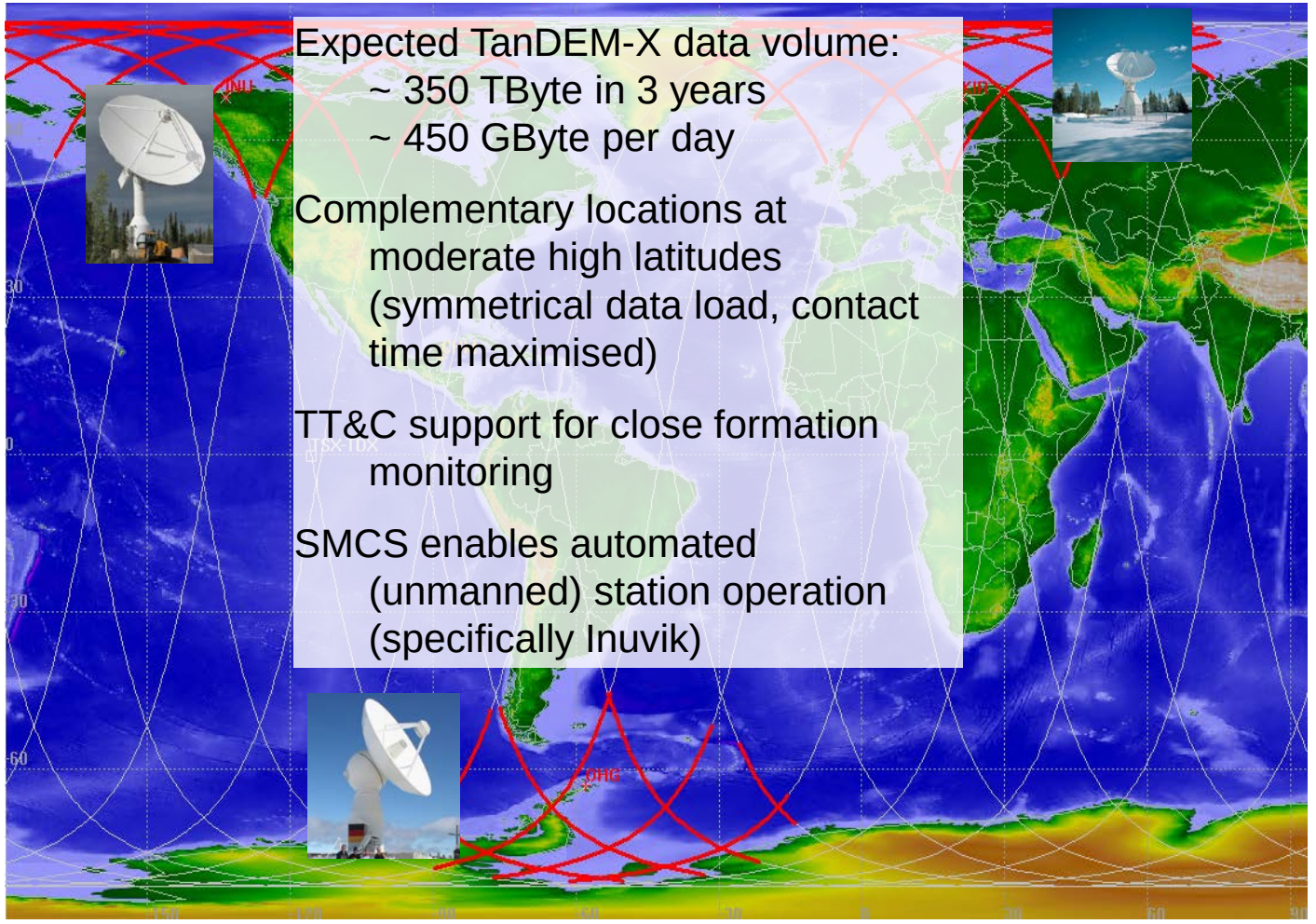
The different flight formations and the ground station – The contact times of the TanDEM-X pool

- 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 contact times of the TanDEM-X Pool for the near and far configuration

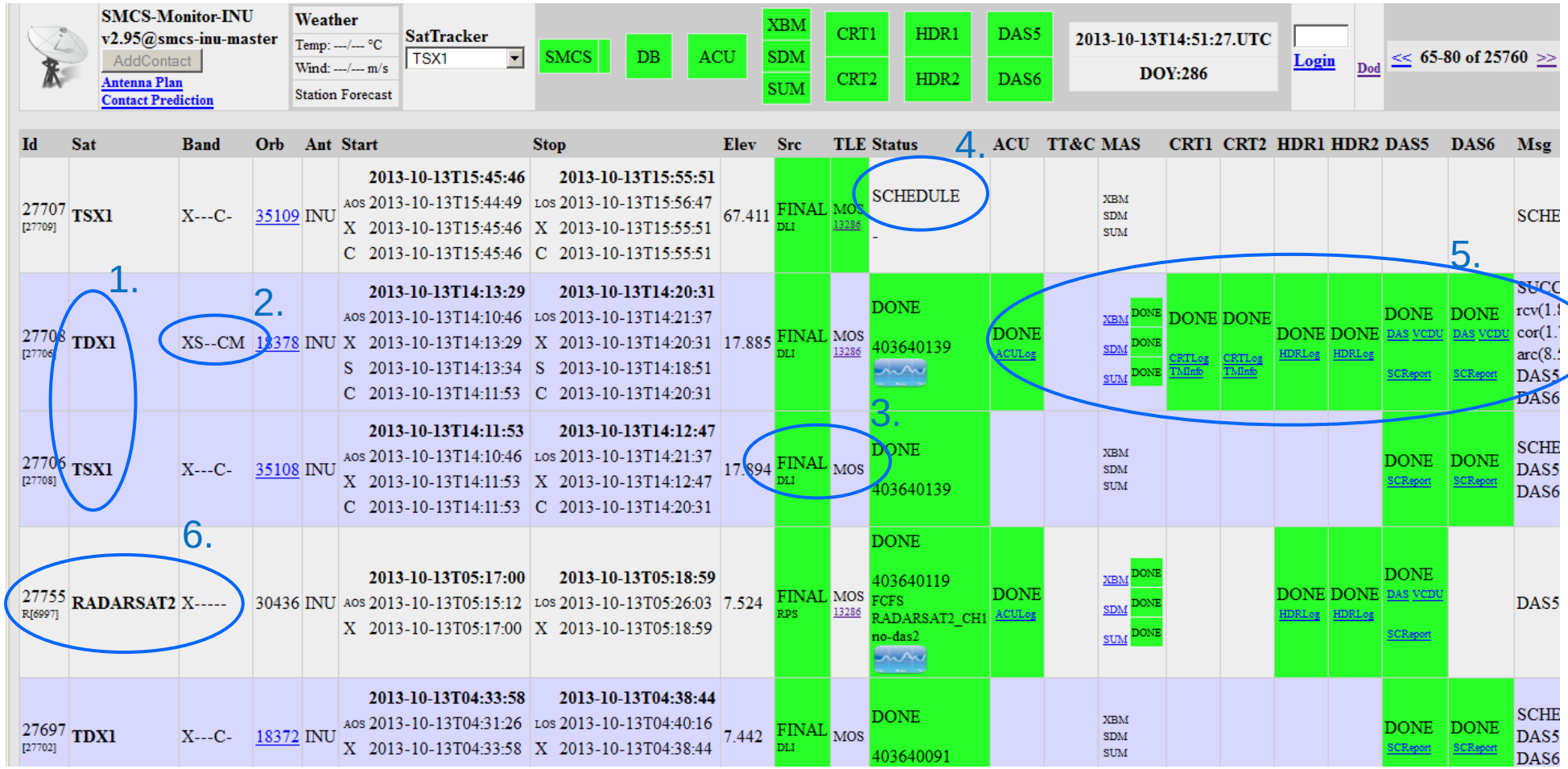


The different flight formations and the ground station – The TanDEM-X Ground Station Network



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



Id	Sat	Band	Orb	Ant	Start	Stop	Elev	Src	TLE	Status	ACU	TT&C	MAS	CRT1	CRT2	HDR1	HDR2	DAS5	DAS6	Msg
27707 [27709]	TSX1	X---C-	35109	INU	2013-10-13T15:45:46 AOS 2013-10-13T15:44:49 X 2013-10-13T15:45:46 C 2013-10-13T15:45:46	2013-10-13T15:55:51 LOS 2013-10-13T15:56:47 X 2013-10-13T15:55:51 C 2013-10-13T15:55:51	67.411	FINAL DLI	MOS 13286	SCHEDULE -			XBM SDM SUM							SCHE
27708 [27706]	TDX1	XS--CM	13378	INU	2013-10-13T14:13:29 AOS 2013-10-13T14:10:46 X 2013-10-13T14:13:29 S 2013-10-13T14:13:34 C 2013-10-13T14:11:53	2013-10-13T14:20:31 LOS 2013-10-13T14:21:37 X 2013-10-13T14:20:31 S 2013-10-13T14:18:51 C 2013-10-13T14:20:31	17.885	FINAL DLI	MOS 13286	DONE 403640139	DONE ACULog		XBM DONE SDM DONE SUM DONE	DONE CRTLog TMInfo	DONE CRTLog TMInfo	DONE HDRLog	DONE HDRLog	DONE DAS VCDU SCReport	DONE DAS VCDU SCReport	SUCC rcv(1. cor(1. arc(8. DAS5 DAS6
27706 [27708]	TSX1	X---C-	35108	INU	2013-10-13T14:11:53 AOS 2013-10-13T14:10:46 X 2013-10-13T14:11:53 C 2013-10-13T14:11:53	2013-10-13T14:12:47 LOS 2013-10-13T14:21:37 X 2013-10-13T14:12:47 C 2013-10-13T14:20:31	17.894	FINAL DLI	MOS	DONE 403640139			XBM SDM SUM					DONE SCReport	DONE SCReport	SCHE DAS5 DAS6
27755 R[6997]	RADARSAT2	X-----	30436	INU	2013-10-13T05:17:00 AOS 2013-10-13T05:15:12 X 2013-10-13T05:17:00	2013-10-13T05:18:59 LOS 2013-10-13T05:26:03 X 2013-10-13T05:18:59	7.524	FINAL RPS	MOS 13286	DONE 403640119 FCFS RADARSAT2_CH1 no-das2	DONE ACULog		XBM DONE SDM DONE SUM DONE			DONE HDRLog	DONE HDRLog	DONE DAS VCDU SCReport		DAS5
27697 [27702]	TDX1	X---C-	18372	INU	2013-10-13T04:33:58 AOS 2013-10-13T04:31:26 X 2013-10-13T04:33:58	2013-10-13T04:38:44 LOS 2013-10-13T04:40:16 X 2013-10-13T04:38:44	7.442	FINAL DLI	MOS	DONE 403640091			XBM SDM SUM					DONE SCReport	DONE SCReport	SCHE DAS5 DAS6

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 3days ⇨ 3months 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 !!!

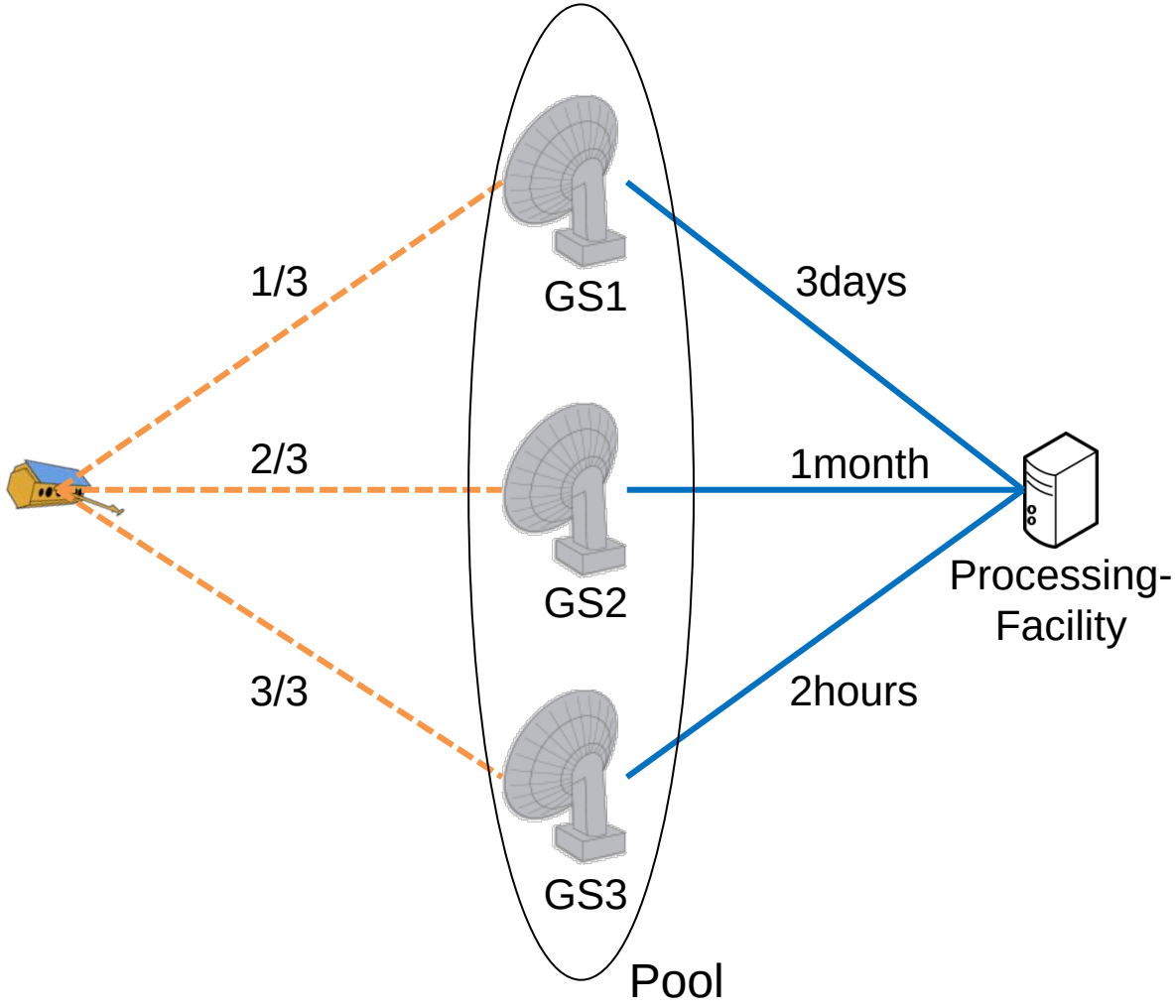
- TerraSAR-X NRT applications can have influence to the TanDEM-X downlink planning
  - Final downlink information can change (incl. Satellite change)
  - Station itself is receiving the data

  ⇨ 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

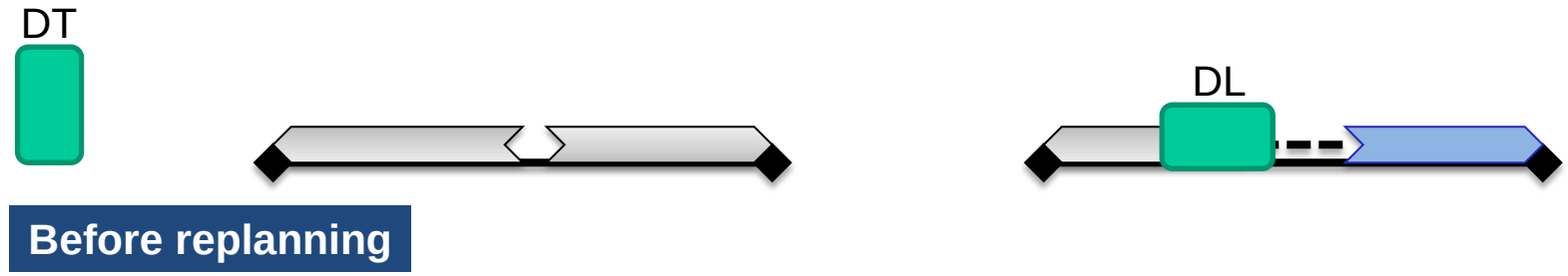
- A **pool** of ground stations can be understood as a **virtual ground station** → All contacts of all stations within this pool are contacts of this virtual station
- Mission planning is allowed to schedule **parts** of the data of an acquisition to **different stations**, this is by design **chronological** (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



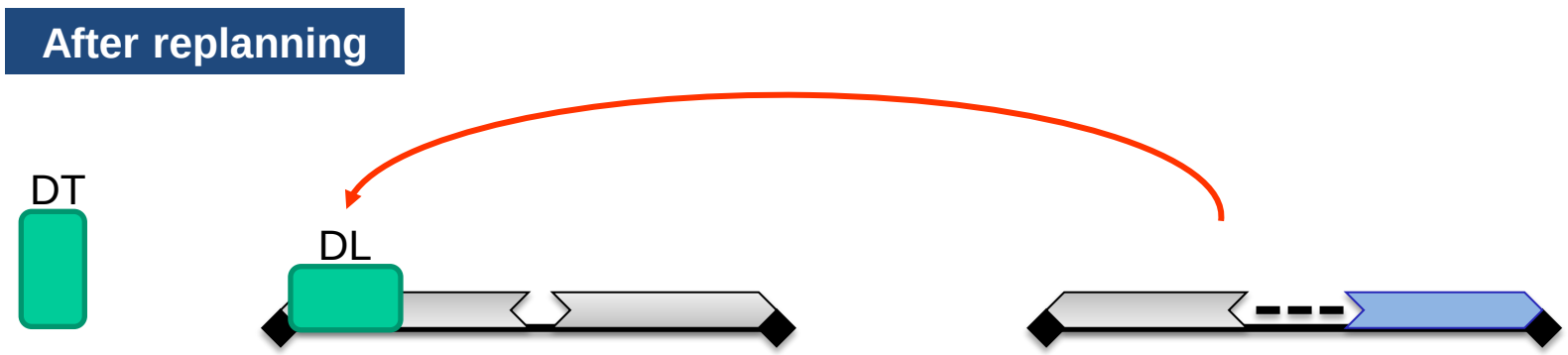
Downlink scheduling within the mission planning system – The near-real time down link scheduling

- 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

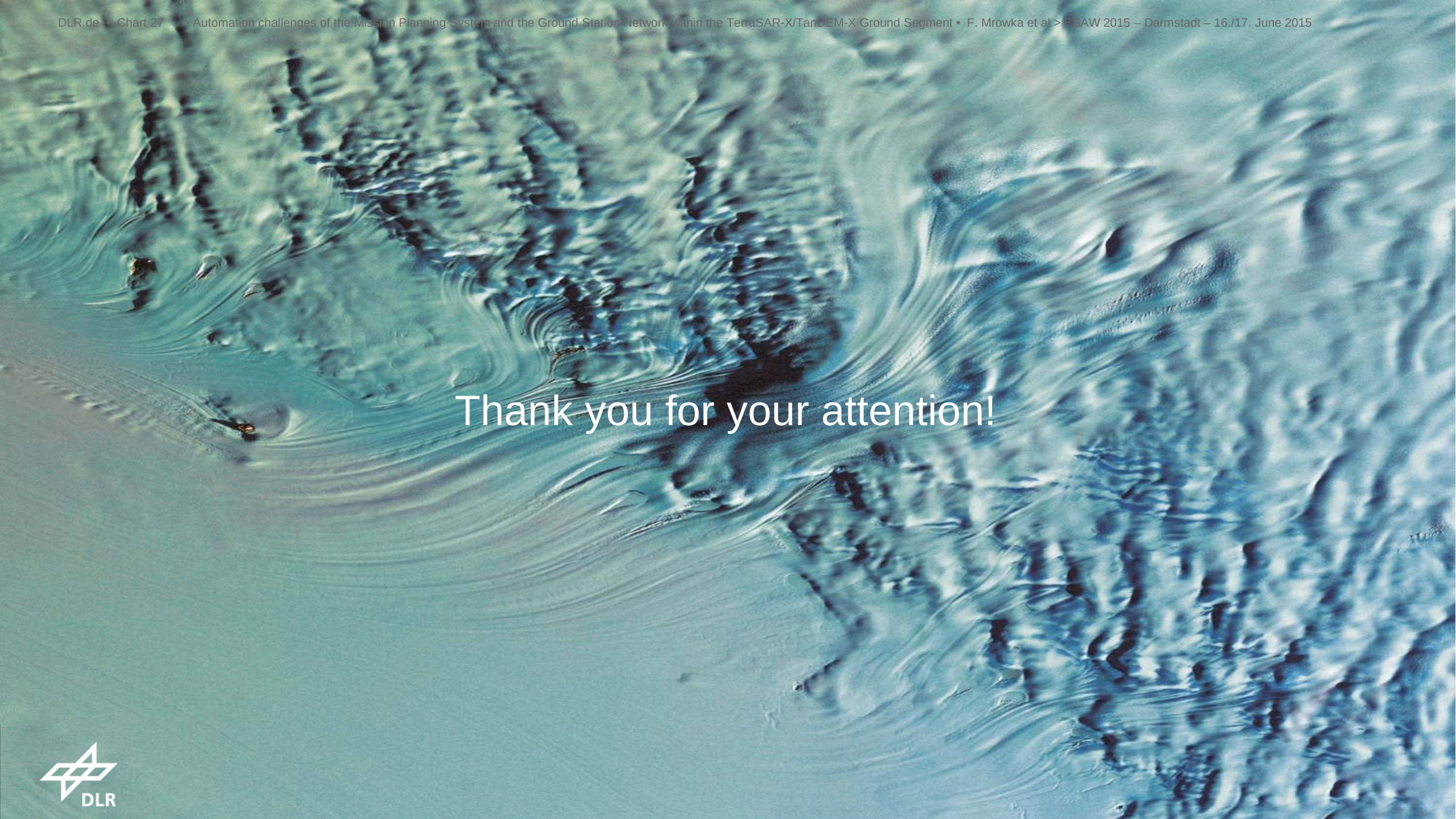


⇨ Very useful together with the Pool feature ☺

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 it's 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 it's 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!