Serving the TerraSAR-X Mission For Over Eight Years:
Current Status and Recent Extensions of the TerraSAR-X Ground Segment

Birgit Schättler, Egbert Schwarz, Falk Mrowka, Thomas Fritz
and Ground Segment Team
German Aerospace Center (DLR)

Advanced SAR Workshop 2015, St. Hubert, Canada, 22-Oct-2015
Outline

• Mission Context

• Production Statistics

• Acquisition Mode Portfolio

• Ground Station Network

• Implications of TanDEM-X Science Phase

• Near-Real Time Capabilities
Mission Context

**TerraSAR-X Mission**
- classical SAR imaging
- individual SAR image based on end user orders
- short-term tasking and immediate product delivery

**TanDEM-X Mission**
- interferometric SAR acquisitions
- consistent high-resolution global DEM world-wide
- long-term acquisition and DEM production planning

TanDEM-X acquisition = TSX and TDX acquisition
TerraSAR-X acquisition = TSX or TDX acquisition

Joint space segment: TSX and TDX satellites

Common TerraSAR-X / TanDEM-X ground segment
TerraSAR-X and TanDEM-X: On-Going Missions

- Battery degradation: ~ 25 % for TSX, ~ 17 % for TDX
- Hydrazine left: ~ 43% for TSX, ~ 63 % for TDX
- Cold gas (flight formation fine control): less than 1 year left
  - formation flying based on hydrazine already done during TDX CP
  - alternative concepts under evaluation

courtesy: S. Buckreuss, TerraSAR-X Mission Manager
Growing Number of TerraSAR-X Acquisitions

> 26000 expected in 2015

Total Number of Basic and Experimental Product Acquisitions Per Year

<table>
<thead>
<tr>
<th>Year</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>12765</td>
<td>15173</td>
<td>15928</td>
<td>13969</td>
<td>17354</td>
<td>20047</td>
<td>24009</td>
</tr>
</tbody>
</table>

Acquisitions from 01.01. until 30.09. 2015

- Basic
  - SM: 14164
  - SC std: 2049
  - SC wide: 1198
  - SL: 1225
  - HS: 622
  - SM Quad: 1857
  - SM ATI: 5
  - SM ATIS: 2

- Experimental
  - 0
## Current TerraSAR-X Acquisition Mode Portfolio for Basic Products

<table>
<thead>
<tr>
<th>mode</th>
<th>coverage az x rg [km²]</th>
<th>resolution class [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wide ScanSAR (SC wide)</td>
<td>200 x (194–266)</td>
<td>40</td>
</tr>
<tr>
<td>ScanSAR (SC)</td>
<td>150 x 100</td>
<td>18</td>
</tr>
<tr>
<td>Stripmap (SM)</td>
<td>50 x 30</td>
<td>3</td>
</tr>
<tr>
<td>Spotlight (SL)</td>
<td>10 x 10</td>
<td>1.7 – 3.5</td>
</tr>
<tr>
<td>High Resolution Spotlight (HS)</td>
<td>5 x 10</td>
<td>1.4 – 3.5</td>
</tr>
<tr>
<td>High Resolution Spotlight 300 MHz (HS-300)</td>
<td>5 x (5 – 10)</td>
<td>1.1 – 1.8</td>
</tr>
<tr>
<td>Staring Spotlight (ST)</td>
<td>(2.5 – 2.8) x ~ 6</td>
<td>0.24 az, 1.0 rg (complex)</td>
</tr>
</tbody>
</table>

*TerraSAR-X Basic Product Specification  TX-GS-DD-3302 Issue 1.9*

Wide ScanSAR and Staring Spotlight operationally introduced in 2013
Staring Spotlight over Fennimore, Wisconsin, USA (2013)
Staring Spotlight over Fennimore, Wisconsin, USA (2013)

Staring Spotlight over Ottawa, Canada, 2015-10-06
Staring Spotlight over Ottawa, Canada, 2015-10-06
Ground Stations Used By TerraSAR-X Ground Segment
- Configuration at Mission Start

DLR Weilheim Station (WHM) for TT&C and S-Band mission timeline uplink twice per day

DLR Neustrelitz Station (NSG) for X-Band and S-Band downlink 4 – 5 times per day
Ground Segment TerraSAR-X Ground Stations  
- Current Configuration

DLR Weilheim Station (WHM) for TT&C and S-Band
mission timeline uplink twice per day

DLR Neustrelitz Station (NSG) for X-Band, TT&C and S-Band
downlink 4 – 5 times per day

KSAT Svalbard Station (SGS) for X-Band and S-Band
nominal: 2 contacts around noon, additional contacts e.g. for NRT

DLR Inuvik Station (INU) for TT&C, S-Band and X-Band

DLR Antarctica Station (OHG) for TT&C, S-Band and X-Band
nominal: TanDEM-X, but also TerraSAR-X background, TerraSAR-X NRT

SSC Kiruna Station (KIR) for X-Band
nominal: TanDEM-X, but also filling with TerraSAR-X
TanDEM-X Science Phase - Formation Flight Configurations and DRA Operation

09'14 – 03’15
pursuit monostatic flight configuration
76 km (10 sec) along-track separation between TSX and TDX

03’15 – 09‘15
bistatic flight configuration with varying large cross-track baselines
up to 3.6 km horizontal separation between TSX and TDX

since 10‘15
close bistatic flight configuration with small along-track baselines

since 12’14
operation of experimental dual-receive antenna (DRA) configuration
quad pol and along-track interferometry acquisitions
TanDEM-X Science Phase - TerraSAR-X Mission Impacts

09'14 – 03’15

pursuit monostatic flight configuration
76 km (10 sec) along-track separation between TSX and TDX

=>

TanDEM-X acquisition = TSX acquisition + TDX acquisition
= 2 TerraSAR-X like acquisitions

*TerraSAR-X Like Products* available for users
TerraSAR-X Like Data Takes Available in EOWEB for External User Product Ordering

<table>
<thead>
<tr>
<th></th>
<th>2014</th>
<th>2015</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>SM</td>
<td>1900</td>
<td>2027</td>
<td>3927</td>
</tr>
<tr>
<td>SC std</td>
<td>885</td>
<td>206</td>
<td>1091</td>
</tr>
<tr>
<td>SC wide</td>
<td>231</td>
<td>50</td>
<td>281</td>
</tr>
<tr>
<td>SL</td>
<td>100</td>
<td>190</td>
<td>290</td>
</tr>
<tr>
<td>HS</td>
<td>270</td>
<td>312</td>
<td>582</td>
</tr>
<tr>
<td>ST</td>
<td>407</td>
<td>470</td>
<td>877</td>
</tr>
<tr>
<td>SM Quad</td>
<td>272</td>
<td>567</td>
<td>839</td>
</tr>
<tr>
<td>SM ATI</td>
<td>77</td>
<td>53</td>
<td>130</td>
</tr>
<tr>
<td>Total</td>
<td>4142</td>
<td>3875</td>
<td>8017</td>
</tr>
</tbody>
</table>
TerraSAR-X Like Products in EOWEB

Dedicated EOWEB product collections

Data take pairs taken 10 sec apart
TerraSAR-X Like Products in EOWEB

TerraSAR-X Science  sss.terrasar-x.dlr.de

Tandem-X Science  https://tandemx-science.dlr.de/
TanDEM-X Science Phase - TerraSAR-X Mission Impacts

03’15 – 09’15

bistatic flight configuration with varying large cross-track baselines
up to 3.6 km horizontal separation between TSX and TDX

=>

Preferred Satellite Concept in mission planning timeline generation

if baseline exceeds given margin and resources allow:
perform TerraSAR-X data take on TSX satellite (reference orbit)
since 12’14

operation of dual-receive antenna (DRA) configuration
quad pol and along-track interferometry acquisitions
no downlink possible during DRA data taking

=>

Ground Station Pool Concept
mission planning timeline generation and on-ground SAR production
– use of additional X-band contacts
– online raw data transfer from stations SGS and KIR to NSG
– grouping of stations into one receiving station pool
– mission planning uses next free downlink slot a for given data take
TerraSAR-X NRT System Capabilities

- Morning and evening timeline upload for a 12 h desirable / 12 h critical timeline with order deadline a few hours before
  => for data take at end of timeline: allow about 17 hours for tasking

- Product latency after downlink: about 10 – 20 minutes

- No orbit information available in X-band downlink
  => usage of predicted orbit information only

- NRT ground station pool
  => online raw data transfer to Neustrelitz

- Mission planning uses next possible pool contact for NRT downlink and schedules it as soon as possible within the chosen contact
TerraSAR-X NRT Processing at Inuvik and Antarctica O’Higgins Stations

- NRT processing systems installed both at Inuvik and O’Higgins
  => NRT processing at stations possible in future
  => but due to limited network performance:
    only NRT delivery of L1B quicklook products

- Once sufficient network performance from INU available (Mackenzie Valley Fibre Link)
  => Include INU into NRT ground station pool
First NRT Test Processings at German Antarctic Receiving Station (OHG)

Wide SC HH MGD RE over Antarctic Peninsula

Acquisition  2015-10-12T23:41:09  
Downlink  2015-10-12T23:41:57  
Processing  ~ 35 minutes

Scene 1: 2015-10-12T23:41:10  
Scene 2: 2015-10-12T23:41:25
Growing Demand in NRT Data Takes?

NRT Data Takes (SGS and NSG) in 2014

- 48%
- 40%
- 9%
- 1%
- 1%

NRT Data Takes (NSG, SGS) from Jan 1 until Sep 30 2015

- 34%
- 44%
- 13%
- 2%
- 6%
- 1%
TerraSAR-X NRT Support in October for ONR Arctic Sea State Campaign 2015

Research Vessel Sikuliaq in Beaufort Sea

Sea State and Boundary Layer Physics of the Emerging Arctic Ocean

http://www.apl.washington.edu/project/project.php?id=arctic_sea_state

TerraSAR-X support comprises

- additional SGS contacts used for D/L
- NRT L1b product delivery
- quicklook deliveries
- new: wind and wave charts

9 acquisitions (SM, SC, SC wide) between Oct 07 and Oct 18 and more to come
New NRT Feature under Test: Wind and Wave Charts

Scenes: TSX1_SAR_MGD_SE__SM_S_SRA_20151013T161558

Core Processors by Maritime Security Lab Bremen (Team Susanne Lehner)
XWAVE-2 (Pleskachevsky et al., 2015)  XMOD-2 (Jacobsen et al, 2013)
Latest Update from the Field
15 October 2015

We have been transiting through the ice pack and surveying the effects of the waves. Pancake ice is everywhere, but new ice is already filling in between the pancakes. Refreezing is occurring rapidly. Much of this has to do with the radiation balance, which is changing as the days get shorter and shorter. Today is cold and clear, and the sun did not emerge until 10:15 ADT. That sun won’t be up for long, and tomorrow it will be even less.

As we measure the ice "in situ," our colleagues are measuring it remotely. Today we have an aircraft survey above us by a team from the Naval Research Lab. We also have satellite observations several times per day. These measurements give us spatial context for what we are observing from the ship.

http://www.apl.washington.edu/project/project.php?id=arctic_sea_state
SM single VV (7 Scenes)
2015-10-13 16:15:29 – 16:16:21

Downlink 17:32 (NSG)
Delivery 18:19

=> 7 Scenes in 45 Minutes
Summary

TerraSAR-X mission on-going.

Recent and current TerraSAR-X ground segment upgrades

- to better serve the TerraSAR-X user community
  - new modes Wide SC and Staring Spotlight
  - NRT extensions, specifically in maritime products domain
  - Extension of downlink capacity
- to deal with TanDEM-X mission imposed constraints

We are looking forward for – hopefully – many more years of operations to come.

*TerraSAR-X is partly funded by the German Federal Ministry for Economic Affairs and Energy (50 EE 1328) and realized in a public-private partnership between DLR and AIRBUS Defence & Space*