TANDEM-X: A New Area of Global Digital Elevation Data

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ABSTRACT

The last two decades have seen an unprecedented development in the satellite-based Earth observation industry. The combination of an increasing number of operational satellites, the higher resolution of the acquired data and the advances in the processing techniques have enabled a wider adoption of satellite data and the development of a diverse range of products and applications.
In the next decade over 200 Earth observation satellites are expected to be launched by government and commercial operators, enabling the development of improved and novel space-based applications as well as the advancement of existing applications. Thus the operation of TanDEM-X will open up a new era of globally available high quality Digital Elevation Models (DEM). Together with the already operational TerraSAR-X, TanDEM-X will form a high-precision radar interferometer and acquire the data basis for a global DEM of an unprecedented quality, accuracy, and coverage.

1. GLOBAL MAPPING CHALLENGES

The capability of space-based Earth observation, providing 3 dimensional data of any place on the Earth, at any time and without any territorial restrictions is of high interest for various fields of applications as well as of high strategic relevance for national defense issues. A variety of space-based sensors provide geospatial information data vital for decision makers to manage global mapping challenges. In order to deliver the right information to the customer the key challenge is to select the most appropriate data of the optimal accuracy, spatial and temporal resolution out of the large variety of available data. In this environment and in addition to non-accessible data sets and capabilities, commercial space-based services become of increasing interest for mapping and monitoring tasks. Capabilities of commercial Earth observation spacecraft and satellite constellations are continuously improving and nowadays satisfy the needs of the global user community. This includes short development cycles and innovative financing models.

2. GERMANY'S SAR CAPABILTIES

Over the last decades Germany has established a globally unique SAR technology line, supported by the national high-tech strategy, and developed by Astrium GmbH in Friedrichshafen in close cooperation with the German Aerospace Center (DLR). The most recent member of this SAR family is the TanDEM-X mission, which consists of the two satellites TerraSAR-X and TanDEM-X (Fig.1), both developed in Public Private Partnership (PPP) between DLR and Astrium GmbH. TerraSAR-X was launched in June 2007 and the commercial services, provided by Infoterra GmbH (the German part of Astrium's GEO-Information Services Division), started in January 2008. Image data distribution is in compliance with German Law, the so-called Satellite Data Security Law ("SatDSiG"). The X-band SAR sensor provides a spatial resolution of 1 m and even better. The pixel location accuracy is within the pixel size. TerraSAR-X offers weather-independent, extremely reliable and precise image acquisitions, as well as input

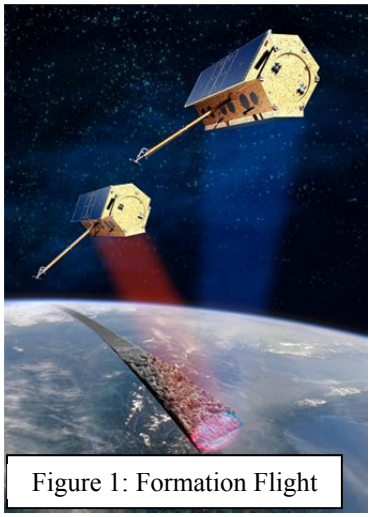

Figure 1: Formation Flight

data for elevation measurements, change detection and surface motion monitoring capabilities. In 2009, the U.S. National Geospatial-Intelligence Agency (NGA) confirmed the outstanding geolocation accuracy of the data. Direct reception services can be implemented for customers around the globe. Currently ground stations in Germany, Japan and in the U.S. including the mobile Eagle Vision System receive TerraSAR-X data.

The almost identical spacecraft to TerraSAR-X has been launched as TanDEM-X (TerraSAR-X add-on for Digital Elevation Measurement) in June 2010, now flying in a unique satellite formation with TerraSAR-X at distances of only a few hundred meters, allowing stereoscopic views. The formation will collect the so-called interferometric data pairs over the entire global land mass to establish a globally homogeneous Digital Elevation Model (DEM). Multiple coverages and a sophisticated editing workflow secure an almost void-free and reliable height model. Key features of this DEM are its relative vertical accuracy of better than 2 m within a horizontal raster of 12m x 12 m, covering the entire land surface of the Earth, i.e. 150 Mio. km^2 (Fig.2). Thus, the successful start of the close formation flight in late 2010 marked the beginning of a new era of global digital elevation data provision. The delivery start is planned for regional DEMs from 2013 and for the full global coverage from 2014 onwards. During the three years of DEM data collection the formation will continue to remain available for regular radar imaging, thanks to an optimised acquisition plan.

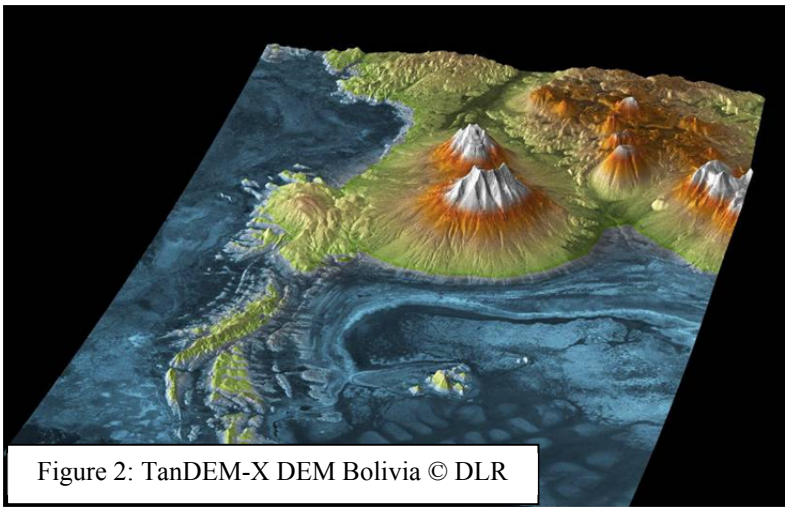

Figure 2: TanDEM-X DEM Bolivia © DLR

3. SAR SATELLITE DATA FOR EARTH OBSERVATION

SAR (Synthetic Aperture Radar) is one of the important capabilities allowing reliable Earth observation in all weather conditions, day and night. In addition to the pure SAR imagery, SAR data contains phase information that can be used to detect slight changes below the spatial resolution of the SAR sensor (called "Coherence Change Detection" – CCD). Further, changes within the range of the spatial resolution can be indicated by using the intensity (amplitude) of the SAR data (called "Amplitude Change Detection" – ACD). The evaluation of CCD (Fig.3) and ACD data enables a change analysis, i.e. the precise identification and accurate current change information about any (remote) area of interest. Astrium GEO-Information Services offers such an analysis capability with its web-based change detection platform "SPOTMonitoring", where the user can take advantage of information derived from multi-source and multi-resolution satellite imagery. Today, approx. 60 sites around the globe are regularly

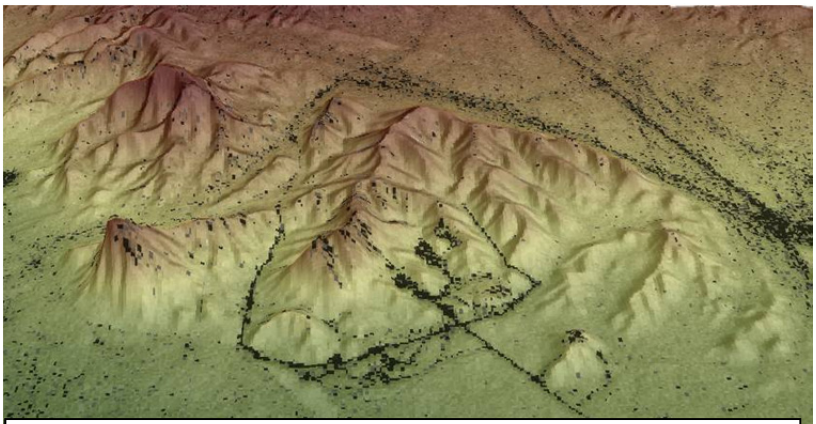

Figure 3: Combination of a CCD and DEM for a site in Iran

monitored, for operational use of defense and security agencies, large corporations and international organisations. Additionally, the geo-information experts offer individual, site-specific automated change detection services based on radar imagery.

Precise elevation data is the initial foundation of any accurate geospatial product, particularly when the integration of multi-source imagery and data is performed based upon it. Topographic mapping, communication network planning, hydrologic modeling, air traffic security and, last but not least, the reliable orthorectification of high-resolution satellite imagery are only examples of the wide range of applications that benefit from precise, reliable elevation data. For example, the addition of elevation information to SAR and optical imagery allows a deeper insight into the actual terrain conditions of a point of interest, supporting a sound interpretation of items that may be unclear when viewed in pure 2D imagery.

In addition to monitoring the occurrences apparent on the Earth's surface, innovative methodologies also enable the detection of changes caused by sub-surface activities. TerraSAR-X radar satellite data is ideally suited to detect movements of the Earth's surface in the millimetric range. These precise monitoring applications can be utilised in construction site monitoring of e.g. tunnels, subways or bunkers, for supervising effects of sub-surface mining or underground gas storage. However, such slight displacements of the surface can also give an indication of an ongoing underground expansion of existing facilities or the excavations of tunnels and caves (Fig. 4). The uniquely precise geolocation accuracy of TerraSAR-X data and the derived information assures that the extracted details can easily be integrated into the monitoring systems used by the respective user organisations today. Further, such radar-based evaluations are significantly enhanced when they are backed by additional satellite data and/or auxiliary information such as DEMs.

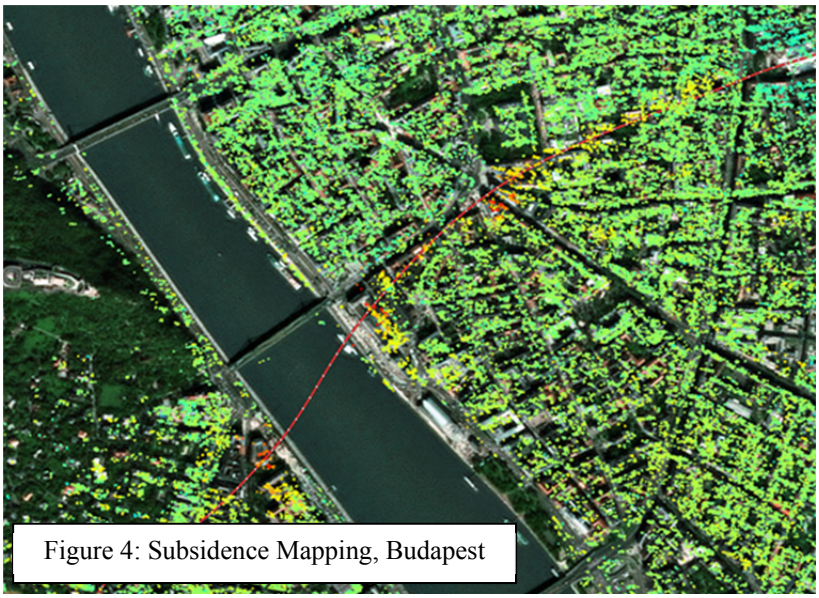

Figure 4: Subsidence Mapping, Budapest

4. CONTINUITY OF SATELLITE SERVICES

Considering a design lifetime of about 5.5 years and consumables for more than 7 years for the first generation fleet, the availability of TerraSAR-X Services until at least 2017 should be secured. Thereafter, a second generation satellite mission is to be deployed. The TerraSAR-X-2 system will benefit from an advanced SAR sensor technology. By utilising 600 MHz bandwidth in X-band for SAR remote sensing, a resolution of up to 50 cm and even better could be offered. Commercial distribution of image data will, as for the first generation, be conducted by Astrium GEO-Information Services, in strict compliance with the German SatDSiG. TerraSAR-X Services based on TerraSAR-X-2 would comprise heritage modes and products from the first generation, as well as enhanced products and services such as full polarimetric images, wider swaths, very high resolution images and AIS information for ship identification. The data dissemination concept of the upcoming radar spacecraft would continue to support already registered receiving stations. For the second generation of TerraSAR-X, the operational experience of the first missions, valuable customer feedback, as well as a harmonisation in terms of data and ordering standards between the

commercial SAR data providers will be taken into account for the benefit of the TerraSAR-X Services customers worldwide. The implementation of TerraSAR-X-2 is envisaged to commence in the successful work sharing of the PPP with DLR. Extension options to the first TerraSAR-X-2 satellite include an inclined satellite, the formation flight to enable TanDEM-X second generation (height accuracy better than 1 m), and the build up of a constellation, enabling revisits of less than 10 hours.

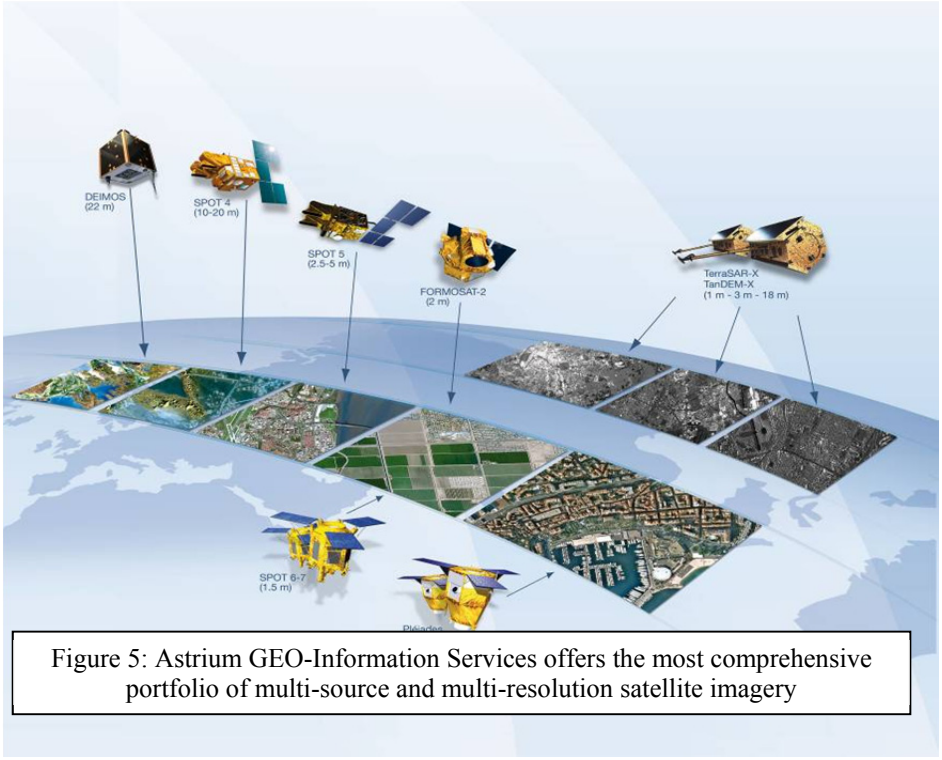

Figure 5: Astrium GEO-Information Services offers the most comprehensive portfolio of multi-source and multi-resolution satellite imagery

The TerraSAR-X-2 program is currently undergoing feasibility studies with technology developments running in parallel. The launch of the first satellite is envisaged for 2015.

The future is promising with the new upcoming high resolution radar and optical spatial sensors and missions in Europe (e.g. TanDEM-X, Pléiades, SPOT 6 / 7, TerraSAR-X-2). The new business division Astrium GEO-Information Services, bringing together teams and assets of Spot Image and Infoterra, is a unique one-stop-shop for a portfolio of multi-source and multi-resolution optical and radar satellite imagery (Fig. 5), offering expertise across the entire geo-information value chain to the benefit of a worldwide user community.