Challenges of the TanDEM-X Commissioning Phase

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Abstract

The goal of the TanDEM-X mission is to generate a highly accurate digital elevation model (DEM). The mission comprises two versatile radar satellites orbiting closely together in a controlled helix formation. This configuration allows single-pass interferometry in order to acquire a DEM of the whole earth within three years. This time constraint demands a short commissioning of the satellite constellation, which has to be accurate and cover all components involved. The paper describes this challenge of commissioning the constellation and the different phases. It explains the systems involved and the activities to be performed.

1 Introduction

The TanDEM-X mission is a unique satellite mission foreseen to derive a digital elevation model (DEM) with never achieved accuracy on global scale [1]. While the absolute height accuracy is aimed to be better than ten meters, the relative accuracy in a 100 km x 100 km area shall undercut a height error of two meters. This can only be realised with very stable and accurate radar instruments. Hence, an exhaustive commissioning of the spacecraft and the ground system after launch is mandatory. This commissioning phase includes all the tasks to be performed before an operational use of both satellites for DEM acquisition is released.

The paper will start with the challenges of the TanDEM-X Commissioning Phase and then give an overview on the three phases the commissioning phase is divided in. In the second part, the tasks that have to be performed are described in more detail, providing their content as well as time constraints and difficulties.

2 Challenges

2.1 Mission schedule

The TerraSAR-X satellite was launched in June 2007. Since the successful commissioning phase with accurate instrument configuration the satellite is flying very stable and reliable. However, its warranted life time is limited. For acquiring the DEM globally with the specified quality, two acquisitions of the whole Earth are required lasting one year each. Difficult terrain like mountainous areas needs to be acquired three or even four times due to shadow and layover effects. To ensure a sufficient overlap for DEM acquisition, the TanDEM-X commissioning phase has to be performed as fast as possible.

2.2 Complexity

The TanDEM-X mission has two main purposes: the acquisition of the global DEM on the one hand and the nominal continuation of the TerraSAR-X acquisitions as are now on the other. Even though the TanDEM-X satellite is mainly identical to the TerraSAR-X satellite, the complexity of the system is more than doubled. Two examples: acquisitions need to be equally distributed to both satellites and the processing chains now consist of a nominal SAR chain and an additional interferometric one [2].
In addition, all these extensions of the system have to be integrated during the operationally running TerraSAR-X mission, like an open-heart surgery. To not disturb commercial and science users requiring TerraSAR-X images, down times of the systems have to be kept as short as possible.

2.3 Close Formation

For the first time two satellites will be operated within a nominal distance of a few hundred meters only. Safety is ensured by flying in a so-called “helix formation”, where the TanDEM-X satellite orbits in a slightly separated orbital plane than the TerraSAR-X satellite. This constellation avoids the risk for a collision [3].

2.4 Exclusion Zones

The tight formation includes the risk of mutual illumination during radar activities. Since the intensity of the radar signal has very high peaks, there is a certain probability of destroying the electronic equipment of the other satellite. Therefore, a three-step fail-safe concept has been implemented that has to be considered when planning the mission timeline.

2.5 Experience from TerraSAR-X

In opposite to these challenges, invaluable experience was gained during commissioning and operation of the TerraSAR-X satellite. In addition, the TerraSAR-X satellite operates very stable and accurate even after two years of operation. This fact ensures the team that the challenges can be mastered successfully.

3 Commissioning Phase Plan

The commissioning phase can be divided into three main phases, as shown in Fig. 1.

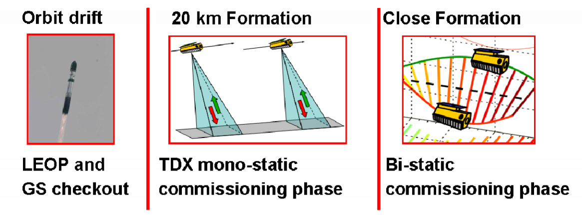

Figure 1: Three phases of the commissioning phase

The duration of the first phase is dependant on the launch date and lasts between 20 to 30 days. Initial part is the Launch and Early Orbit Phase (LEOP) that includes the satellite checkout after launch, the release of the antenna boom for data downlink and the test of the S/C systems. In addition, all ground systems run through pre-defined checkout procedures. Beginning with the LEOP (which takes approx. 7 days) the TanDEM-X Satellite drifts towards the TerraSAR-X satellite in order to obtain a position of 20 km behind the TerraSAR-X satellite at the end of the first phase.

During the second phase, the mono-static commissioning phase, the TanDEM-X satellite is commissioned in order to be able to acquire SAR images with the same accuracy as the TerraSAR-X satellite does. This includes instrument calibration and SAR product verification on the TanDEM-X satellite as well as acquisitions in pursuit mono-static mode. In addition, also the bi-static capabilities of the constellation can be tested with special configuration.
The last phase finally takes care of the calibration, verification and validation of the bi-static aspects. Most necessary for this is the establishment of the TanDEM-X/TerraSAR-X satellites close formation with distances of around 200 m in across-track between both satellites. Here, the first real bi-static acquisitions are acquired as well as DEMs for testing the interferometric processor and the DEM calibration chain.
When this phase is completed, the operational DEM acquisition will start in order to acquire and derive the global DEM.

4 Commissioning Phase Tasks

During the three phases, many different activities have to be performed. The most important tasks are explained below.

4.1 LEOP and Ground Segment Checkout Phase

Ground Station Checkout: The ground stations (satellite tracking) and the systems running at the ground stations (transcription and processing systems) have to be checked out.

Mission Planning System Checkout: The mission planning system will be checked out. The verification of the power thermal model, the splitting of replays, parallel SAR acquisition and data dump and test of the left looking mode are just the main tasks during this phase.

Obit/Attitude Product Checkout: Orbit and attitude products will be verified to provide the required accuracy.

Instrument Checkout: The instrument will be activated for the first time. The first performance parameters of the instrument have to be analysed and first initial acquisitions will be performed.

Order and Processing Chain Checkout: The complete chain from product ordering to the processed image has to be checked out. After the first acquisitions, the processing system will perform SAR processing in order to obtain the first image.

4.2 Mono-static Commissioning Phase

Formation Control: With an along-track distance of 20 km, the behaviour of both satellites in the formation will be studied before entering the close formation.

Calibration: The SAR instrument calibration is the main driver for the duration of this phase. A defined number of acquisitions over the ground targets at the DLR Calibration Field in southern Germany [4] are required for an accurate calibration. To achieve the same accuracy as obtained for the TerraSAR-X satellite, two cycles for geometrical and pointing calibration are required. Using the precise antenna model verified on TerraSAR-X, the absolute calibration can be reduced to only three cycles. Only few selected beams have to be calibrated in order to determine the absolute calibration factor of the instrument.

Performance: The verification of the SAR performance is important to ensure the product quality. Here, the Noise Equivalent Sigma Zero (NESZ) and the side lobe rations are evaluated among others. During the bi-static phase, this will be performed for the complete formation as well including also coherence measurements.

Product Verification: Product verification is required to verify the image quality specified by the SAR product specification. The product verification also ensures that inter-changeability of the products from both satellites.

Synchronisation: The synchronisation is an important and new task for TanDEM-X. As both satellites comprise independent local oscillators and with the differences affecting the accuracy of the height measurement, a synchronisation measurement between both oscillators is required. The performance of this synchronisation link has to be verified with special data takes.

Baseline Characterisation: Using different test sites, the baseline between both satellites is evaluated in order to eliminate constant offsets.

4.3 Bi-static Commissioning Phase

Bi-static Commanding: The commanding of bi-static acquisitions is a new task for TanDEM-X. Therefore, adjustment and optimisation is required in order to correctly set parameters like the echo windows, pulse repetition frequency, synchronisation pulse rate and so on.

DEM Error Model: Error models underlying the DEM calibration have to be verified.

Interferometric Processing: The TanDEM-X Interferometric Processor generates interferometric SAR images, performs the co-registration and phase unwrapping and provides raw DEMs. This complex process is verified and the settings are adjusted.

DEM Calibration and Mosaicking Tests: The raw DEMs are then calibrated in height and mosaicked by the DEM Calibration and Mosaicking processor. This is the driver during the phase. In order to gain experience in calibration and mosaicking, large areas at test sites all over the world are used for acquiring test DEMs. For the schedule this means that four repeat cycles are required in order to acquire four parallel images.

5 Conclusion

The commissioning phase planning provides an overview on the tasks to be performed during the TanDEM-X commissioning phase. The main challenges of the commissioning phase, which are the tight schedule, the close formation flight and the extension of an operatically running system, are pointed out. The three phases are packed with different verification tasks and justification activities. However, with the experience gained on TerraSAR-X and the highly stable TerraSAR-X satellite itself, the TanDEM-X team looks forward to a successful TanDEM-X commissioning phase.

Acknowledgement

The authors want to explicitly thank all participants of the commissioning phase meetings at DLR, for all productive discussions and the resulting commissioning phase plan.

The TanDEM-X project is partly funded by the German Federal Ministry for Economics and Technology (Förderkennzeichen 50 EE 0601).

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