The Shuttle Radar Topography Mission

Thomas A. Hennig\textsuperscript{1}, Jeffrey L. Kretsch\textsuperscript{2}, Charles J. Pessagno\textsuperscript{3}, Paul H. Salamonowicz\textsuperscript{2}, and William L. Stein\textsuperscript{2}

\textsuperscript{1} National Imagery & Mapping Agency
Directorate of Operations
4600 Sangamore Road
Bethesda, Maryland, 20816-5003, USA
\textsuperscript{2} National Imagery & Mapping Agency
Technology Office
12300 Sunrise Valley Drive
Reston, Virginia, 22091, USA
{hennigta, kretschj, pessagnoc, salamonp, steinb}@nima.mil

Abstract. Elevation data is vital to successful mission planning, operations and readiness. Traditional methods for producing elevation data are very expensive and time consuming; major cloud belts would never be completed with existing methods. The Shuttle Radar Topography Mission (SRTM) was selected in 1995 as the best means of supplying nearly global, accurate elevation data. The SRTM is an interferometric SAR system that flew during 11-22 February 2000 aboard NASA’s Space Shuttle Endeavour and collected highly specialized data that will allow the generation of Digital Terrain Elevation Data Level 2 (DTED\textsuperscript{®} 2). The result of the SRTM will increase the United States Government’s coverage of vital and detailed DTED\textsuperscript{®} 2 from less than 5% to 80% of the Earth’s landmass. This paper describes the shuttle mission and its deliverables.

1 Introduction

The attempt to create a digital dataset called Digital Terrain Elevation Data (DTED\textsuperscript{®}) has been ongoing since the 1970s. However, progress has been very slow, with about 70% of the world collected to DTED\textsuperscript{®} 1 (3 arc second post spacing) standards, and less than 5% to DTED\textsuperscript{®} 2 (1 arc second post spacing) standards. DTED\textsuperscript{®} consists of a matrix of elevation posts at uniform spacing and specified elevation accuracy sampled to represent the earth’s surface. It can be used to make elevation models and fly-thrus for mission planning, and modeling and simulation. Other examples of use include trafficability determinations, line of sight projections, determination of drainage, and use for route planning and airline safety.

The National Imagery and Mapping Agency (NIMA) is responsible for providing global imagery and geospatial information to government users. Elevation data provides a key ingredient to the readiness of NIMA’s customers. Elevation
data is one of three components of Foundation Data, which is comprised of elevation data, feature data, and imagery data. Both the Department of Defense (DoD) and the Intelligence Community have recognized the need for a global dataset of elevation at one arcsecond spacing since at least 1995.

Growing computer processing, display and communication capabilities made the need for DTED® support acute. In 1995, the DoD Joint Staff and the Intelligence Community recognized the need for a common understanding of the operational environment and that a major inhibitor was the lack of availability of digital terrain elevation data which is vital to successful mission planning, operations and readiness. The question was how to provide it quickly. For years the most efficient method to collect elevation data was stereo photogrammetric compilation. It was far more efficient than ground surveys, requiring only a few control points on the ground. A cartographer at an analytical plotter could map vast tracks of land. However, the work is labor intensive. Furthermore, much of the world is almost perpetually cloud covered. This, combined with competition for the imaging resources for purposes other than mapping, made acquisition of adequate source over much of the globe impractical. Several converging developments were to lead to a solution to the problem.

2 Interferometric Synthetic Aperture Radar

Synthetic Aperture Radar (SAR) was developed in the 1950s after being conceived by C.A Wiley. In the 1960’s airborne imaging SAR systems were in operation. In the 1970s SEASAT, a spaceborne radar, operated for several weeks and demonstrated the possibilities of radar mapping from space. Use of SAR imagery addressed the cloud issue. However, most SAR systems are mono imaging systems. Stereo acquisition is a major collection issue and processing of stereo SAR imagery is labor intensive like the traditional photogrammetric approach. An overview of the history of SAR can be found in [1] and [2].

The development of the interferometric SAR (IFSAR) technique for obtaining elevation data was the last key item. A brief summary is provided here. For a more thorough presentation on the technique see [3] and [4]. The single pass IFSAR technique is based on using interference of the radar return at two separate antennas. A repeat pass approach can be used but suffers from major decorrelation issues. By the early 1990’s an airborne IFSAR system was operational. Figure 1 illustrates the geometry of single pass IFSAR. A radar observation is made of the topography \( Z(y) \) from each endpoint of the baseline \( B \). In repeat pass interferometry these could be done at different times, in single pass they are done simultaneously. Several configurations can be used for single pass interferometry. The Shuttle Radar Topography Mission (SRTM) works by radiating a pulse from one antenna and measuring the difference in phase of the signal returns to each antenna. From Figure 1 we can derive the expression

\[
Z(y) = h\left\{\frac{\lambda \phi}{2\pi}\right\}^2 - B^2 \right \}/2(B \sin(\alpha - \theta) - \left(\frac{\lambda \phi}{2\pi}\right)) \} \cos \theta
\]