Aerial Survey of the Maldives

The April 2008 issue of GIM International (page 11) summarised a project to map the Maldives as an example of how aerial photogrammetry is today applied for mapping large, complex areas. The authors provide further details of the Maldives project, its biggest achievement being first-time-ever 1:25,000 topographic maps of the entire country and 1:1,000 maps of sixteen islands.<P>

Republic of Maldives is a chain of islands in the Indian Ocean, spreading north-south over 868km and covering 90,000km2, 99% of which is water. The land area consists of 1,192 islands populated by 280,000 (2001) people. At the turn of the millennium ideas emerged for replacing by more detailed maps the 1:300,000 maps published in 1993 to cover the whole of Maldives. A project was subsequently prepared by the National Remote Sensing Agency (NRSA), Hyderabad, Department of Space (DOS), Government of India aimed at:
-establishing a WGS-84 national datum
-preparing digital maps at scale 1: 25,000 using 1: 40,000 aerial photos for entire Maldives
-preparing 1:1,000 digital maps using 1:6,000 aerial photographs for sixteen islands
-establishing a remote-sensing centre at Male, capital of Maldives.
Most challenging was to bring all data into a single grid coordinate system for the entire country.

WGS-84 Datum
World Geodetic System (WGS)-84 is a datum available worldwide and capable of supporting densification of national geodetic networks for purposes including mapping and GIS applications, navigation, hydrography, monitoring sea-level variation, geoid modelling and deformation analysis. Thirteen primary GPS stations were created on different islands. The selection criteria for locating these stations included: (1) open to sky without obstructions, for satellite signals, (2) elevation angle larger than 10 degrees, and (3) at least one station lying in a one-degree geographical grid. The reference station in Male belongs to the International GNSS Service (IGS), formerly the International GPS Service. The thirteen stations have concrete monuments topped by brass marker plate. To determine their accurate coordinates, each station has been equipped with geodetic-grade, dual-frequency GPS receiver, measuring for at least three days from 6 a.m. to 6 p.m. at 30-second intervals. At least four satellites should be simultaneously visible at any one time, with as cut-off angle 15°. Initially, only static, multi-station, differential GPS processing was implemented. After manual account of cycle slips on L1 and L2, double-difference carrier-phase measurements were used to obtain the final solutions. Post-fitted, precise ephemeris data was used, since real-time broadcast ephemeris data entails approximations up to 3.6m. IGS stations at Bangalore (India), Diego Garcia island (Indian Ocean), Singapore and Manama in Bahrain are used as reference hub stations; their WGS-84 coordinates have an accuracy of 2cm horizontally and 4cm vertically.

GPS
The GPS receivers should not only be able to simultaneously track twelve satellites, but should also be dual-frequency, with as main selection criteria:
-L1 pseudo-distance measurements, uncertainty < 0.2m
-L2 carrier-phase measurements, uncertainty < 0.1cm
-L1 pseudo-distance measurements (from encoded pcode), uncertainty 0.1cm
-full wavelength on L2
-low phase and code noise?-high sampling rate for L1 and L2
-high memory capacity with low power consumption.

Baseline distances between the stations are high, and IGS stations around Maldives are up to a few thousand kilometres away. Since commercial GPS post-processing software for long baselines is unavailable, software from University of Bern was used, it having the ability to detect cycle slips and handle long GPS baselines in sessions taking up to weeks. Furthermore, the Bernese software has improved mathematical models for automatic estimation of tropospheric effects, flexible strategies for estimating several unknowns, and was earlier used to establish New Zealand’s Geodetic Datum 2000 and to support the Malaysian geoid project.

Flight Plan
Figures 2 and 3 show the workflow for creating digital maps at scales 1:25,000 (small-scale) and1:1,000 (large-scale). The small-scale map should accurately depict shape and size of land area, clearly demarcating land and water boundary, atolls, built-up areas, roads and vegetation; this all established in the countrywide grid. Since 99% of the territory is covered by water and the cloud-free window is small, good flight planning is crucial. Sources including Indian Remote Sensing Satellites (IRS 1C/1D) images, atlas maps and old maps were used to prepare flight plans, optimised in terms of money, time and use of aerial film with the help of World Wide Mission Planning (WWMP) software. For planning, managing and execution of small-scale mapping, the country was divided intoseven blocks, the shape of each determining whether main flight runs were carried out north-south or east-west. The small landmass meant many more than normal across-runs were flown to tie the blocks. Across-runs were selected such that as many islands as possible lie at the intersection with main flight runs. The flight plan for large-scale mapping of the sixteen selected islands was similarly constructed and photo scale of preference was 1:6,000.

Aerial Survey
Ground control points (GCP) for small-scale mapping were established at 42 well distributed, pre-installed targets, size 5m by 5m, occupied by a geodetic-grade, dual-frequency GPS receiver which measured over a three-hour period. For large-scale mapping, GPS measurements were performed over one hour on ground points identified in aerial photos. These GPS measurements, carried out in conjunction with at least two primary reference stations, were processed using SKIPRO GPS post-processing software with reference to

nearest primary reference stations. The run-lines were determined by pre-target GPS control data.

In 2004, during February, the ideal cloud-free season in the region, black/white analogue photos were taken using a Zeiss RMK15/23 camera integrated with INS and Kinematic GPS, onboard a Beech Super King Air B-200 guided during flight by a Computer Controlled Navigation System. Using the international airports of Male and Gan as bases, 25 rolls of film (240mm), each having a capacity of 275 frames, were exposed over 95 hours. The analogue photos were scanned with a photogrammetric scanner, the 1:40,000 photos at 21-micron and the 1:6,000 photos at 7-micron pixel size. Aero-triangulation was then carried out to determine the six exterior orientation parameters of each frame using GCPs. The onboard INS and Kinematic GPS integrated with the camera make possible direct determination of these parameters; henceforth the number of GPCs can be reduced to a minimum. Nevertheless, since only 1% of the country is land, the number of GCPs was too small, so that the GPS positions determined onboard were used as initial control and given more weight. Tie points can be automatically determined in digital images using matching techniques. Block adjustment was done simultaneously with both main and across strips. Other input, such as camera calibration file, flight-plan index, overlaps, image scale and image sequences were also necessary. The average precision of image measurements is 0.5 to 1 pixel.

GIS Database

For both 1:25,000 and 1:1000 maps, GIS databases of 82 layers were created using object-oriented technology with open GIS standards in an ArcGIS environment. To keep compatibility with existing base-maps in AutoCAD format, the GIS data uses the same reference system, including datum, projection and spatial extent. The databases are seamless, to facilitate applications such as censor and utilities. A Universal Transverse Mercator (UTM) reference grid was created to cover the entire Maldives by 1:25,000 scale maps. The grids have an interval of 10,000m and gridlines are drawn for 1-degree, 15-minutes and 7½ -minute intervals. The numbering scheme corresponds to the International Map of the World. Since part of the country is below the equator, positive coordinates were obtained everywhere by shifting the origin to the Southern Hemisphere. The vertical datum is WGS-84.

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