A MULTISENSOR DATA SET OF AN URBAN AND COASTAL SCENE

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ABSTRACT
Multisensor and multispectral data become increasingly available to the photogrammetric and remote sensing community. These data sets will have a profound impact on the automation of photogrammetric procedures, such as DEM generation and object recognition. In order to study new concepts or to validate algorithms, standard data sets are important. As part of an ongoing effort of WG III/5 to establish such data sets, multisensor and multispectral data have been collected over the coastal areas of Ocean City, Maryland. This paper describes the site, the sensors and the raw, as well as the processed data. Moreover, procedures on how to obtain data, and plans to further process them, are described. It is hoped that researchers make use of the data sets and share their experience.

1 INTRODUCTION
More and more airborne and spaceborne sensors become available to the photogrammetric and remote sensing community than ever before. While their spatial, spectral, and temporal resolution increases, the cost associated with data collection decreases. This trend will have a significant impact on data acquisition, particularly when several sensors are mounted on the same platform. More important, the availability of multisensor and multispectral data will greatly influence all subsequent processes, such as DEM generation, classification, object recognition, and image understanding.

To exploit the full potential of multisensor and multispectral data sets and to employ it in a synergistic fashion, considerable research is necessary. Take fusion as an example. How does one cope with different sensor geometries, on what level should data or derived information be merged? What exactly are multispectral features and how can they be extracted and grouped? The list of important questions and research topics seems endless.

For testing new ideas, or validating algorithms, standard data sets are important. As part of an ongoing effort of WG III/5 to establish such standard data sets, multisensor data has been collected over the coastal areas around and over Ocean City, Maryland. Large scale aerial photography, multispectral data, and laser altimetry data have been collected at the same time. Recently, a hyperspectral data mission has been flown over the same area. We describe in this paper the different data sets, their availability and plans for further processing.

2 SITE DESCRIPTION
As part of an ongoing effort of WG III/5 to establish standard data sets, a multisensor data set has been collected over the coastal areas of Maryland on April 25 and 30, 1997 (Figure 1). Ocean City, located in the northern part of the site, is an urban area. Its main road along the peninsula (north-south direction) is flanked by high-rise buildings on the east and residential areas on the west side. Along the east coast are a number of sandy beaches while harbors and docks are found on the west side. South of Ocean City is Assateague Island, separated by a narrow channel. Assateague Island is a protected area with natural vegetation and large sand dunes along the east coast. The Assateague State Park is in the northern part of the island and the Chincoteague National Wildlife refuge is in the south.

3 DATA ACQUISITION
The data set includes panchromatic aerial photography, multispectral scanner imagery, and scanning laser altimetry data. As part of the laser altimetry suit precise GPS positions and INS attitude have also been recorded. Both, the laser scanner and the multispectral scanner were mounted on NASA’s P-3B aircraft. The aerial camera was operated...
independently by the National Geodetic Survey (NGS), but on the same day. Csatho and Schenk, 1998, present examples from the different sensor data.

### 3.1 Laser Scanner

Digital elevation data were acquired by the Airborne Topographic Mapper (ATM) laser system on both April 25 and April 30, 1997 (Figure 2.c-d). The ATM is a conical scanning laser altimeter developed by NASA for precise measurement of surface elevation changes in polar ice sheets, ocean beaches and drainage systems (Krabill et al., 1995). The instrument combines high pulse rate with a scanning capability.

For the collection of the data set, the ATM was equipped with a Spectra Physics TFR laser transmitter that provides a 7 nsec wide, 250 µJ pulse at frequency-doubled wavelength of 523 nm in the blue-green spectral region. The laser beam of the ATM is reflected toward the surface by a mutating mirror that has adjustable off-nadir settings of 5, 10 and 15°. The scan mirror is spun at 10 or 20 Hz, producing a series of overlapping spirals of data points as the aircraft moves forward. For the data acquisition mission, the pulse rate was selected to 3,000 Hz. The nominal operating altitude of 600 m lead to an illuminated footprint size of approximately 1.5 m on the ground. To provide multiple coverage, two scanning laser systems were mounted on the P-3B aircraft, collecting data simultaneously.

The first system employed a scanner frequency of 20 scan/sec with an off-nadir setting of 15°. This resulted in a swath width of approximately 300 m (half of the aircraft altitude above ground level (AGL)). The distribution of the data points on the ground was more or less uniform with an average distance of 5 m between the footprint centers. The second system operated at a scanner frequency of 10 scan/sec with an off-nadir setting of 10°, resulting in a swath of 0.35 AGL (210 m). This set-up provided higher data density along the scan line (the average across-track separation was only 2 m), but the maximum distance between the consecutive scans reached 10 m.

The ATM system is has been developed to measure the surface elevation of ice sheets with 10 cm RMS accuracy (Krabill et al., 1995). In order to achieve this accuracy, the trajectory of the aircraft is determined by using kinematic GPS techniques (Krabill and Martin, 1987). This involves processing the difference in the GPS dual-frequency carrier-phase derived ranges from a fixed receiver located over a precisely known benchmark, and a mobile receiver located on the aircraft. Throughout the flights, the bank angle of the aircraft was kept below 10-15° angles to avoid loss of carrier phase lock on the airborne GPS receiver. GPS data sets were obtained with the aircraft parked close to the fixed receiver for about 45 minutes before and after each flight. These stationary data sets are used to resolve ambiguities in carrier phase for each frequency between the fixed and mobile receivers for subsequent application during the processing of the in-flight data.

Additionally, the local meteorological conditions (pressure, temperature and humidity) were recorded for subsequent application during post-mission processing. These data are combined with a precise ephemeris of the GPS constellation into a point-to-point range difference solution for the trajectory of the aircraft. Because of the relatively low noise in the phase data no filtering or smoothing is required.

A rigorous ground calibration of the laser scanner is conducted before and after each mission by measuring the range between the laser firing point and a target (Krabill et al., 1995). A calibration curve is obtained for different target reflectivities by reducing the laser power with neutral grade filters. Based on this calibration the measured laser range is corrected for range walk. Flights above level surfaces (ocean, lakes) are used for the determination of the exact relationship between the laser and INS coordinate system. The position of the laser footprint on the surface is computed from the position (GPS) and orientation (INS) of the aircraft, and the laser range by using a set of coordinate transformations (for details on the procedure see Lindeberger, 1993 or Vaughn et al., 1996).

A vertical accuracy of better than 10 cm RMS has been achieved by the ATM system on ice sheets and airport runways (Krabill et al., 1995, and Roman et al., 1997). These areas are flat and smooth and their surface has high reflectivity. In case of urban areas with rough and sloping surfaces and non-uniform reflectivity distribution, larger errors are to be expected.

### 3.2 Multispectral scanner

Multispectral data were collected around the Wallops Flight Facility (Figure 1) and over Ocean City (Figure 2.b) by a Daedalus AADS-1260 airborne multispectral scanner from the National Geodetic Survey (NGS). The system is also called airborne MSS because originally it has been developed for airborne simulation of the Landsat MSS satellite system. The AADS-1260 is a multispectral line scanner with eleven multispectral line scanner with eleven spectral bands in the visible, near infrared and thermal infrared. The scan head contains an internal motor/mirror/incremental encoder assembly. The scanning mirror reflects the radiation onto the focusing optics and hence onto a beam splitter which diverts the optical radiation (0.38-1.10 µm) to the 10 channel spectrometer and the infrared radiation (8-14 µm) to a single element solid state detector. The scan head is equipped with a visible calibration lamp and thermal reference sources to provide quantitative data. The image scene is stabilized by these references on each revolution of the scanning mirror. With the aid of a gyrometer that is mounted on the scan head, roll of up to 15° is automatically compensated. The instantaneous field of view is 2.5 mrad yielding a ground resolution of 1.5 m in the middle of the swath for the 600 m nominal flight height. The swath of ±43° is divided into 716 pixels. With increasing scan angle the pixel size gets larger and reaches 2.8 meter at the boundary of the image. The gray values for each pixel are derived from digitized video with variable gain setting and 8 bit resolution.

The geometric distortion of a line-scanner image is a complex one since the exterior orientation of the data acquisition system and the ground pixel size change from pixel to pixel. For georeferencing the image, the platform position and orientation should be known with sufficient details. Although the GPS and INS units of the laser altimetry suit were continuously acquiring data during the flight, unfortunately the multispectral data were not a time tagged. That makes the precise georeferencing of the image almost a formidable task. At this stage, only the uncorrected imagery is available together with the approximate location of a few interest points of the multispectral image on the scanned map of Ocean City. These points may be helpful in identifying the different objects on the laser altimetry DEMs, and on the multispectral image.
The spectral bands of the multispectral scanner were as follows:

<table>
<thead>
<tr>
<th>Band</th>
<th>Wavelength (μm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Band 1</td>
<td>0.38-0.42</td>
</tr>
<tr>
<td>Band 2</td>
<td>0.42-0.45</td>
</tr>
<tr>
<td>Band 3</td>
<td>0.45-0.50 (visible, blue)</td>
</tr>
<tr>
<td>Band 4</td>
<td>0.50-0.55 (visible, green)</td>
</tr>
<tr>
<td>Band 5</td>
<td>0.55-0.60 (visible, green)</td>
</tr>
<tr>
<td>Band 6</td>
<td>0.60-0.65 (visible, red)</td>
</tr>
<tr>
<td>Band 7</td>
<td>0.65-0.69 (visible, red)</td>
</tr>
<tr>
<td>Band 8</td>
<td>0.70-0.79 (near-infrared)</td>
</tr>
<tr>
<td>Band 9</td>
<td>0.80-0.89 (near-infrared)</td>
</tr>
<tr>
<td>Band 10</td>
<td>0.92-1.10 (near-infrared)</td>
</tr>
<tr>
<td>Band 11</td>
<td>8-14 (thermal infrared, low gain)</td>
</tr>
<tr>
<td>Band 12</td>
<td>8-14 (thermal infrared, high gain)</td>
</tr>
</tbody>
</table>

### 3.3 Aerial Photography

Panchromatic aerial photography was acquired with an RC20 camera, also from NGS. Figure 2.a depicts the coverage over the southern part of Ocean City and northern part of Assateague Island. The strips continue both toward north and south.

**Camera:** UA9II 3043, focal length=152.74 mm

**Parameters:**
- Flight height: 372 743 1089 m
- Photoscale: 1/2.435 1/4.870 1/7.130

Some of the aerial photographs over Ocean City have been scanned with a resolution of 12.5 micron pixelsize.

### 3.4 Hyperspectral data

At the time of writing this paper, a hyperspectral data set was collected. The AVRIS scanner from JPL was installed in the NGS aircraft. The ground pixel size is about 4 meters and the radiometric resolution is 10 nm throughout the reflective spectrum.

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![Figure 1. Flight trajectories of the NASA P-3B aircraft from GPS data on April 25 (dashed line) and April 30 (solid line), 1997. The boxed area is enlarged in Figure 2.](image-url)
4 DATA SET FOR DISTRIBUTION

Our web site http://wwwphoto.eng.ohio-state.edu/isprs3 informs about the distribution of the data set. For the time being only data from the area enlarged in Figure 2, that is from the southern part of Ocean City, and the northern part of the Assateague Island are available.

4.1 Elevations derived from laser altimetry

The laser scanning data has been fully processed. The short data sets available on the ftp site include the geographic position of the laser footprint (latitude, longitude, ellipsoidal height) and the time of the data for each laser shot. The Cartesian terrestrial reference frame is ITRF 93 and the reference ellipsoid is World Geodetic System 1984 (WGS-84).

4.2 Multispectral image

The multispectral scanner imagery is in its original format without geometric and radiometric correction.
4.3 Aerial photographs

Selected aerial photographs can be made available as diapositives or paper prints. Some photographs over Ocean City have been scanned and are available in digital form at a resolution of 12.5 microns or at any level in the image pyramid. Our web site http://wwwphoto.eng.ohio-state.edu/isprs3 is updated frequently and contains detail information.

Other data, such as the full laser data set, can also be made available to interested users. The complete laser data set includes the following parameters: seconds since start of the file, latitude (degree), longitude (degree), elevation (degree), laser transmit power (relative unit), surface return energy (relative unit), scan azimuth (degree), pitch (degree), roll (degree), GPS time (HHMMSS.ss).

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