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Space Remote Sensing Developments of Cartographic Importance

By Alden P. Colvocoresses

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GEOLOGICAL SURVEY
RESTON, VA. 22092

In Reply Refer To:
WGS–Mail Stop 520

September 15, 1986

Memorandum for the Record (EC –89–Landsat)

By: Research Cartographer (EROS Cartography)

Subject: Space Remote Sensing Developments of Cartographic Importance

Several developments have occurred during the past year which demonstrated the cartographic value of space data. They are as follows:

- Automated topographic mapping with Landsat Thematic Mapper (TM) data, by MacDonald Dettwiler.
- Chernobyl, USSR, image analysis based on Landsat and SPOT data.
- Acquisition and analysis of SPOT stereo data of Libya, North Africa.
- Preparation of the Denali, Alaska, image map.
- Geometric analysis of TM data.
- Space and aircraft monitoring of hydrilla in the Potomac River below Washington, D.C.

Automated Topographic Mapping

At the March 1985, ASPRS/ACSM Annual Convention, MacDonald Dettwiler displayed and distributed copies of their Adam River, Canada, topographic and image maps as part of project "Meridian." These maps are based on Landsat Thematic Mapper (TM) data and have the following basic characteristics:

- Scale = 1:50,000
- Contour interval = 500 ft

The image map lacks adequate color presentation but it does show that Landsat TM data, when necessary, can be meaningfully displayed at the 1:50,000 scale.

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The topographic line map is considered to be of high significance for the following reasons:

- It was compiled by automated stereo correlation, which is believed to be a "first" for a complete quadrangle.

- The estimated height measurement accuracy of 70 m (rms) would support a contour interval of only about 750 ft, but this still demonstrates the potential of a properly designed stereo space system. The base–to–height ratio of the Landsat TM image data is only about 0.1 and the pixel size is 30 m. By using a base–to–height ratio of 0.5 and 10–m pixels—as has been proposed* for space mapping systems—height measurement accuracy (rms error) should drop from 70 m to perhaps 5 m and thus support a 20–m contour interval, which is a recognized standard for 1:50,000–scale mapping.

- 30–m, or even 10–m, data will not provide all the data expected for a 1:50,000–scale line map. However, the Adam River map clearly demonstrates that the 30–m TM data does provide the basic planimetric information expected to properly depict such an undeveloped area in map form. Of course, information on boundaries, names, road classification etc., involves data that cannot be obtained from either space or aircraft imagery.

- The planimetric accuracy of both maps is reported to meet NATO Class A standards, which are similar to U.S. National Map Accuracy Standards. Experience with TM data indicates that such standards may be met at the 1:50,000 scale. However, this involves very precise registration of the image data to the grid and graticule.

Further information may be obtained on this work from:

Project Meridian
MacDonald Dettwiler
3751 Shell Road
Richmond, B.C. Canada V6X 2Z9

Chernobyl (USSR) Image Analysis

A nuclear accident occurred the night of April 25–26, 1986, at Chernobyl, USSR and both the Landsat and SPOT satellites were able to record the scene within the next few days. Landsat had also recorded the scene several times prior to the accident. From the standpoint of mapping from space the following applications were well demonstrated in the Chernobyl case and are considered significant:

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* ISPRS, 1984, Report of the Committee for "Acquisition and Processing of Space Data for Mapping Purposes" International Archives of Photogrammetry and Remote Sensing, XVth Congress, Volume XXV, part A8a, Commission IV, pp. 326–363.

- The near– and thermal–infrared wavebands of the Landsat Thematic Mapper clearly demonstrated the power of multispectral sensing from space . The thermal band 6 (10.4 to 12.5 μm) mapped the small temperature differences in the cooling pond of the nuclear power plant and thus indicated when the plant was in operation. However this band does not have the dynamic range to respond to the several hundred degrees of temperature differences that were created by the nuclear accident. On the other hand the two near–infrared bands 5 and 7 (1.55 to 1.75μm and 2.08 to 2.35 μm) did record the temperature anomaly associated with the accident. Since there are many natural occurring conditions such as forest fires and molten lava which create comparable temperatures on the order of 1000° to 1500 °K (727 to 1227°C) the ability to record such hot areas is of general interest and importance.

- Geometric registration of two unlike space data systems. Landsat TM data of April 29, 1986, and SPOT panchromatic data of May 1, 1986, provided excellent dual coverage of the Chernobyl area. The multispectral TM data is of 30–m resolution and near vertical, whereas the SPOT data was of 10–m resolution and taken at 8.4° off the vertical. Registering such data sets was of obvious importance but also presented a real challenge to the image data processor. EROS Data Center personnel, using a manual approach for selecting commonly identifiable control points and then fitting one set to the other (SPOT to Landsat), achieved such registration throughout a limited (3.5 by 3.5 km) area within a 12–hour period. To register unlike data sets over sizable areas by such a manual method would of course, be very expensive and time consuming. However, others (see Automated Topographic Mapping) have demonstrated the automated correlation of unlike data sets, and it may be assumed that SPOT and Landsat data sets will be correlated (registered) by automated means when so justified.

- Cloud attenuation in correlated data sets. In the Chernobyl area a few small clouds occurred in the TM imagery whereas the SPOT data was cloud free. The two sets were combined with an H.I.S. (hue, intensity, Saturation) transform which went a long way towards eliminating the effects of both the clouds and cloud shadows. Although color (hue and saturation) were not restored in these areas, the intensity derived from the SPOT data provided excellent image detail in the areas of cloud and cloud shadows on the TM imagery.

- Height measurements from shadow measurements on SPOT data. A large hyperbolic cooling tower is recorded on the SPOT data about 2 km ESE of the nuclear plant, The shadow of this tower is well defined and falls on a reasonably flat area surrounding the tower. Technical data provided by SPOT indicates the following:

  — attitude of image (angle off the vertical)—8.4°
  — Sun zenith angle—38.5°

  with such data the height of the tower can be estimated from the shadow length. In this case, the tower was estimated to be 100 m which is about the same as the towers at the U.S. nuclear power plant at Three Mile Island. In addition to large man–made objects, natural features such as icebergs, cliffs, mountains, and clouds cast shadows from which height estimates can be made from such satellite data.

Further information on the use of satellite data in conjunction with the Chernobyl accident may be obtained from:

Chief, EROS Data Center
U.S. Geological Survey
Sioux Falls, South Dakota 57198

SPOT Stereo Data

Shortly after the launch of the French satellite SPOT (February 21, 1986) stereo coverage was obtained of selected areas for technical analysis of the SPOT stereo mode. One such stereopair is of Libya, North Africa, obtained on the 24–25 of February. Although these images may be classed as an engineering test, they clearly demonstrate the power of stereo data of 10–m resolution. This stereopair has a base–to–height ratio of approximately 0.53, and the Sun elevation is about 45°. Geometric analysis of this data is being conducted by the Institut Geographique National (IGN) of France. Informal reports indicate relative height measurement accuracies on the order of 10 m (rms) being obtained from this pair. Prints of the pair, of about 1:100,000 scale, show a multitude of cultural and natural features. This is a relatively barren area of high contrasts on which topography, drainage, and the sparse vegetation are well defined. Cultural features, especially pipelines, are clearly visible, as are roads and other man–made features of reasonable size. The advantage of stereo imagery to improve resolution over the monoscopic view is well demonstrated by these images.

Further information on SPOT data may be obtained from:

SPOT Image Corporation
1897 Preston White Drive
Reston, Virginia 22091–4326

Denali, Alaska, Image Map

During July 1986, the U.S. Geological Survey published the Denali National Park and Preserve, Alaska, satellite image map. Data thereon are as follows:

- Scale – 1:250,000
- Source – Landsat MSS (80 m) data of 1979–84
- Form – conventional false–color infrared—vegetation as red
- Estimated positional accuracy—140 m (rms)
- Base and backup – Printed on plastic with conventional line map on reverse
- Price (as of 1986)—$7.00 plus shipping

This image map is significant in that Mt. McKinley (Denali) involves perhaps the greatest relief of any land mountain in the world in that it rises over 5,000 m (17,000 ft) above its base. Relief displacement was <u>not</u> removed and yet the map maintained good geometric positional accuracy through careful selection of the nearly orthographic space imagery. A paper describing this map has been submitted to Photogrammetric Engineering and Remote Sensing as the Denali Image Map. A copy is available from either:

Douglas R. Binnie
U.S. Geological Survey
EROS Data Center
Sioux Falls, South Dakota 57198

or

Alden P. Colvocoresses
U.S. Geological Survey
Mail Stop 520
Reston, Virginia 22092

Geometric analysis of TM Data

Although several reports exist as to the high geometric fidelity of Landsat imagery, the National Mapping Division of the U.S. Geological Survey only recently conducted its own objective test to confirm Landsat accuracy. The data involved a 40– by 40–km portion of a TM scene in the Washington, D.C. area. An image of about 1:237,000 scale was printed by the EROS Data Center on a MacDonald Dettwiler Color Fire 240 recorder. The digital input data involved the four subscenes of a full TM image as processed through the Thematic Mapper Image Procession System (TIPS) on the Space Oblique Mercator projection as sold to the public by EOSAT through the EROS Data Center. The image, in color transparency form, was geometrically tested on a coordinatograph against 10 well–distributed control points determined from 1:24,000–scale maps. The result was as follows:

rms error of 11.68 m

> Using the 90% (NMAS) criterion the error was 17.3 m which equates to an accuracy requirement at a scale of 1:34,000.

The rms figure of 11.68 m approaches one–third of the pixel dimension (30 m) which has been reported by others for both MSS and TM data. However, such accuracy only applies to a display derived from a single image and where relief is minimal. Moreover, the geodetic grid and graticule must be precisely tied to the image data––a procedure which is still under development. Nevertheless, it does appear feasible to develop 1:50,000–scale image maps from TM data which meet or approached U.S. National Map Accuracy Standards.

Further information on this test is available from:

Alden P. Colvocoresses
U.S. Geological Survey
Mail Stop 520
Reston, Virginia 22092

Space Mapping of Hydrilla--Potomac River below Washington, D.C.

On September 15, 1985, Landsat TM imagery was acquired of the upper tidal Potomac River below Washington, D.C. This imagery clearly recorded the extent of the submerged aquatic vegetation which includes hydrilla, a native plant of southeast Asia. The Landsat imagery compares favorably with aerial photographs taken 3 days earlier of the same area. Both the space and aerial images appear in the September 1986 issue of Photogrammetric Engineering and Remote Sensing.

Further information on hydrilla and its occurrence in the Potomac River may be obtained from:

The Chief Hydrologist
U.S. Geological Survey
Mail Stop 409
Reston, Virginia 22092

Summary

The above described examples of space data applications further indicated the fundamental advantages of the space mode for Earth sensing and particularly mapping. It is also significant to note that neither of the systems described (Landsat and SPOT) have three-dimensional comprehensive mapping of the Earth as a prime objective. It would appear that a system which has such an objective is fully justified. Information on such a system is available from the author of this memo.

Alden P. Colvocoresses

United States Department of the Interior

GEOLOGICAL SURVEY
RESTON, VA. 22092

Mail Stop 520

September 18, 1986

Memorandum

To: Recipients of USGS EC Memos

From: Research Cartographer, NMD

Subject: Extracts from September 1986 issue of Photogrammetric Engineering and Remote Sensing

Attached are copies of the following graphics extracted from subject issue.

- Cover - Landsat image of a reach of the tidal Potomac
- Frontispiece - An aerial mosaic of a portion of the same reach

Text which accompanies these graphics are copied below.

COVER PHOTO—Landsat Thematic Mapper image of hydrilla. On September 15, 1985 (11:15 a.m. EDT), Landsat (E-50563-15154) recorded this stretch of the Potomac River below Washington, D.C. These data were obtained at the same approximate half-tide stage exhibited by the aerial-photo mosaic Frontispiece (p. 1447), which was recorded three days earlier (September 12).

The scale of this image is approximately 1:80,000 and was generated by pixel replication (duplicate printing of the same pixel in both directions) by EROS Data Center of the U.S. Geological Survey. The darker areas in the river involve dense aquatic growth and associated clear water as contrasted with the turbidity of the main stream. North is at the top of this image and the Woodrow Wilson Bridge crosses the Potomac at the top right in this image.

See also "Hydrilla Mat or Aquatic Garden?", page 1453, for a discussion of the mosaic's significance and its relation to the Frontispiece aerial-photo mosaic.

HYDRILLA MAT OR AQUATIC GARDEN?—Both the Cover and the aerial-photo-mosaic Frontispiece (p. 1447) display a portion of the upper tidal Potomac River as of September 1985. The space (Cover) and aerial (Frontispiece) images were recorded a few days apart and both at approximately half-tide stage. Both image sets clearly depict the extent of submersed aquatic vegetation (darker areas), which includes the Southeast-Asian-plant hydrilla.

To many, such as shore-front-property owners, hydrillas and other plants are a nuisance, but they have played a key role in bringing new aquatic life to this previously barren stretch of tidal water. The darker areas now represent clear (non-turbid) water which sunlight penetrates, creating an aquatic garden full of plant and animal life.

The pros and cons of this lush growth of underwater plants are under continual discussion. But, there seems to be no question that this reach of the Potomac River is now much closer to the natural condition that existed before it was badly polluted by man, beginning some 60 years ago.

Although not shown in subject magazine the attached pertinent illustration of the same reach of the Potomac, as it appeared in 1916, is also attached. Please note that this memo is not part of EC 89 which is a U.S. Geological Survey Open-file report.

Alden P. Colvocoresses

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Attachments

POCKET CONTAINS
3 ITEMS.