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GROUND CONTROL REQUIREMENTS FOR PRECISION PROCESSING OF ERTS IMAGES

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REQUISITOS DE CONTROL TERRESTRE PARA LA ELABORACION
PRECISA DE IMAGENES ERTS

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Resumen

Con el vuelo exitoso del satélite ERTS-1* ahora se dispone de imágenes tomadas desde una altura orbital. Estas imágenes son utilizables en la elaboración de productos tales como fotoplanos a escala de 1:1.000.000 y las ampliaciones de estos hasta una escala de 1:250,000. Para mantener el error de ubicación a menos de cien metros, los puntos de apoyo designados para la elaboración exacta deben seleccionarse cuidadosamente de manera que las imágenes de los puntos aparezcan claramente y que estén bien definidas en cuanto a X e Y. Las coordenadas de los puntos de apoyo medidas en los mapas corrientes de siete y medio y de quince minutos existentes proporcionan la precisión suficiente para cualquier sistema de imágenes expaciales que se ha explicado hasta ahora. Este procedimiento relaciona los puntos a los datos verticales y horizontales aceptados. Los mapas a escala tan pequeña como 1:250,000 pueden usarse como fuentes de información para las coordenadas, pero para guardar la exactitud deseada, deben usarse mapas a escala de 1:100,000 o mayores cuando las haya disponibles.

*ERTS-1 - El primer satélite para la tecnología de los recursos terrestres.

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Abstract

With the successful flight of the ERTS-1 satellite, orbital-height images are available for precision processing into products such as 1:1,000,000-scale photomaps and enlargements up to 1:250,000 scale. In order to maintain positional error below 100 meters, control points for the precision processing must be carefully selected, clearly definitive on photos in both X and Y. Coordinates of selected control points measured on existing 7½- and 15-minute standard maps provide sufficient accuracy for any space imaging system thus far defined. This procedure references the points to accepted horizontal and vertical datums. Maps as small as 1:250,000 scale can be used as source material for coordinates, but to maintain the desired accuracy, maps of 1:100,000 and larger scale should be used when available.

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INTRODUCTION

The first Earth Resources Technology Satellite (ERTS-1) was successfully launched by NASA on July 23, 1972. The predicted 900 km (492 n. mi.) near-polar orbit was achieved to near perfection. The satellite is sun-synchronous; that is, at any given part of an orbit, local sun time (approximately 10 AM) remains the same. The sensors on board produce multispectral images of the earth for use in earth resources investigations and in 18-day cyclic coverage provide a redundancy of scenes for studies of time-variant phenomena.

With regard to geometric properties, the most precise sensors aboard are the three return-beam vidicon (RBV) cameras configured to focus on the same scene covering an area of 185 x 185 km (100 x 100 n. mi.) in three spectral bands--green, red, and near infrared. The multispectral scanner (MSS), also aboard, provides coverage of the same scene in four spectral bands, imaging in a continuous 185-km swath along the orbital ground track. The MSS produces better spectral imagery than the RBV but of lower geometric quality.

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The image data is transmitted to earth over two wideband S-band data links. On the ground it is reconstituted using an electron beam recorder (EBR) on 70-mm film in frames for each spectral band. These frames appropriately annotated are the so-called bulk (or system corrected) images. Selected scenes from the bulk imagery are precision-processed (scene-corrected) to receive radiometric and geometric corrections to the internal geometry. The output of precision processing consists of film prints enlarged to 9 1/2 inch format in a UTM projection at 1:1,000,000 scale. In general, scenes with extensive (50% or more) cloud cover are not suitable for precision processing. The internal geometry of precision-processed imagery will allow enlargement of the scenes up to 1:250,000 scale without exceeding the horizontal tolerance of National Map Accuracy Standards (NMAS). This improved geometry is obtained at the expense of a reduction in image quality.

All ERTS bulk and precision-processed products are available to the public through the:

EROS Data Center
Sioux Falls, S.Dak. 57198

Popular formats are 70-mm film negatives and 1:1,000,000-scale prints, transparencies, and color composites.

The geometric correction in precision processing for each scene requires a set of ground control points identified on the imagery. To provide control points for precision processing, the U.S. Geological Survey selected photoimage control points for the 50 States at an

approximate spacing of 30 km (16 n. mi.). Prominent features assumed to be visible on ERTS imagery were scaled from topographic maps, and their coordinates along with appropriate identifiers and codes were stored on punched cards, creating a data bank of about 10,000 points in all. The precision processor uses the control-point images with their associated coordinates to transform the ERTS scenes for map format.

POINT SELECTION

The control point data for precision processing are being updated by reference to actual ERTS imagery as more coverage becomes available. To maintain the accuracy tolerance of the map products at the scales outlined above within the NMAS, precision-processed imagery should have a standard error in position of less than 100 m at ground scale. About one-third of this error is budgeted to errors in the ground referencing system. Control fed into the precision-processing system, therefore, must be obtained from the best available source. Control selected for ERTS imagery also will suffice for imagery from future systems of greater resolution and geometric fidelity if, and only if, sufficient care is taken in selecting points and determining coordinates for them.

At least nine well-spaced photoimage control points are needed for full precision processing (see figs. 1 and 3). The points should be definitive in both x and y and must have corresponding coordinate data available in a recognized reference system with sufficient accuracy to make precision processing worthwhile (see figs. 2 and 4).

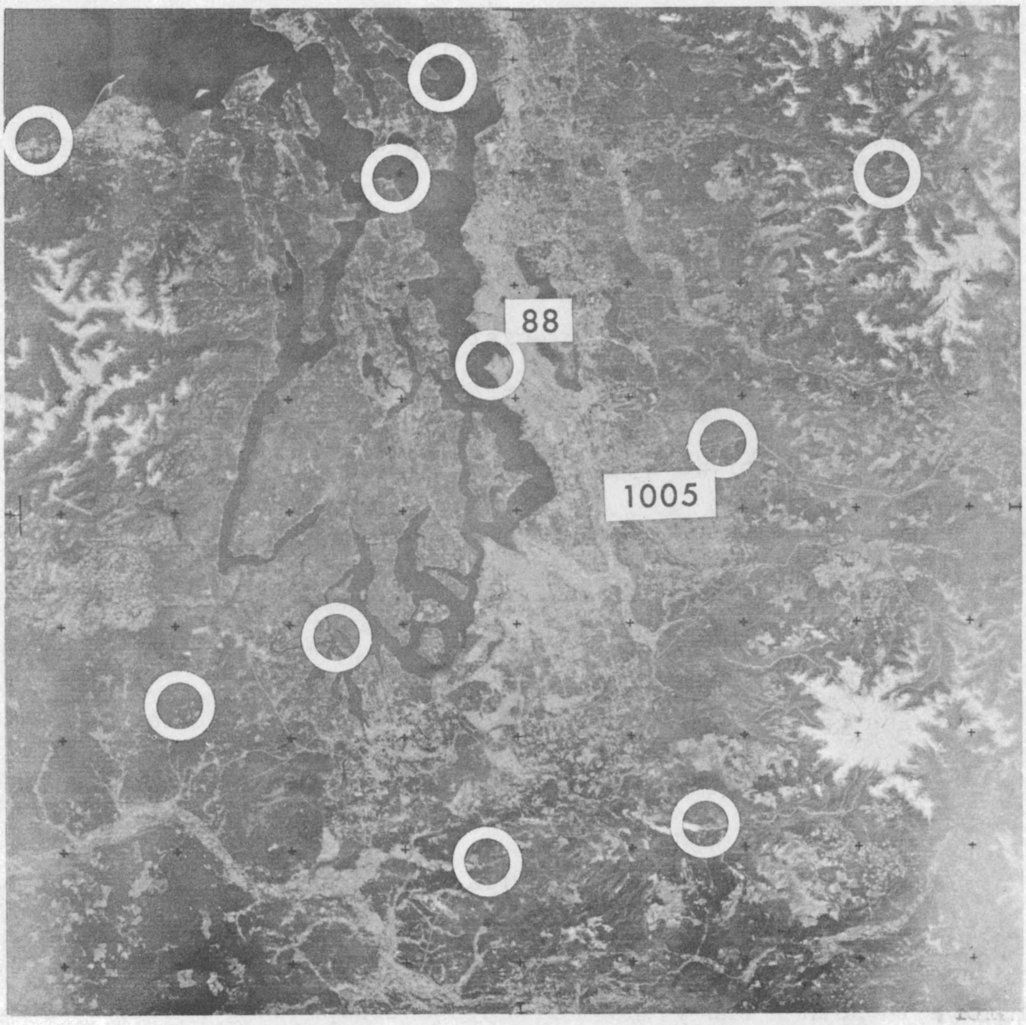
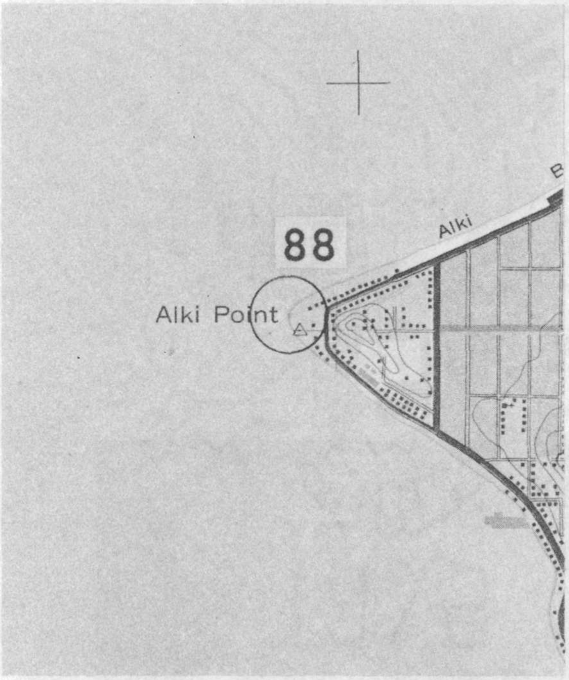


Figure 1.--ERTS-1 photograph of the Puget Sound area with sample control points. Numbered points 88 and 1005 are shown on map chips in figure 2.



Section of 1:24,000-scale topographic map

Point # 88

Description W. tip Alki Pt.

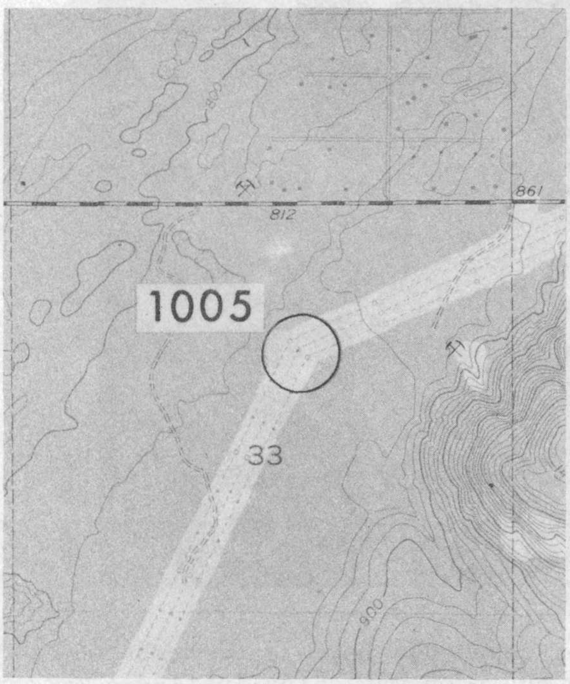
Area Seattle, Wash, USA

Coordinates:
- UTM Zone
- N
- E
- Latitude 47° 34' 36.0"
- Longitude 122° 25' 11.0"
- Elevation 0 Ft. M

Map Name: Duwamish Head, Wash. 7½

Photo # 1006-18313-2

Spheroid Clarke 1866



Section of 1:24,000-scale topographic map

Point # 1005

Description Power line bend

Area Washington State, USA

Coordinates:
- UTM Zone 10
- N 5,244,840 m
- E 581,580 m
- Latitude
- Longitude
- Elevation 825 Ft. M

Map Name: Cumberland Wash. 7½

Photo # 1006-18313-2

Spheroid Clarke 1866

Figure 2.--Map data on two control points shown in figure 1.

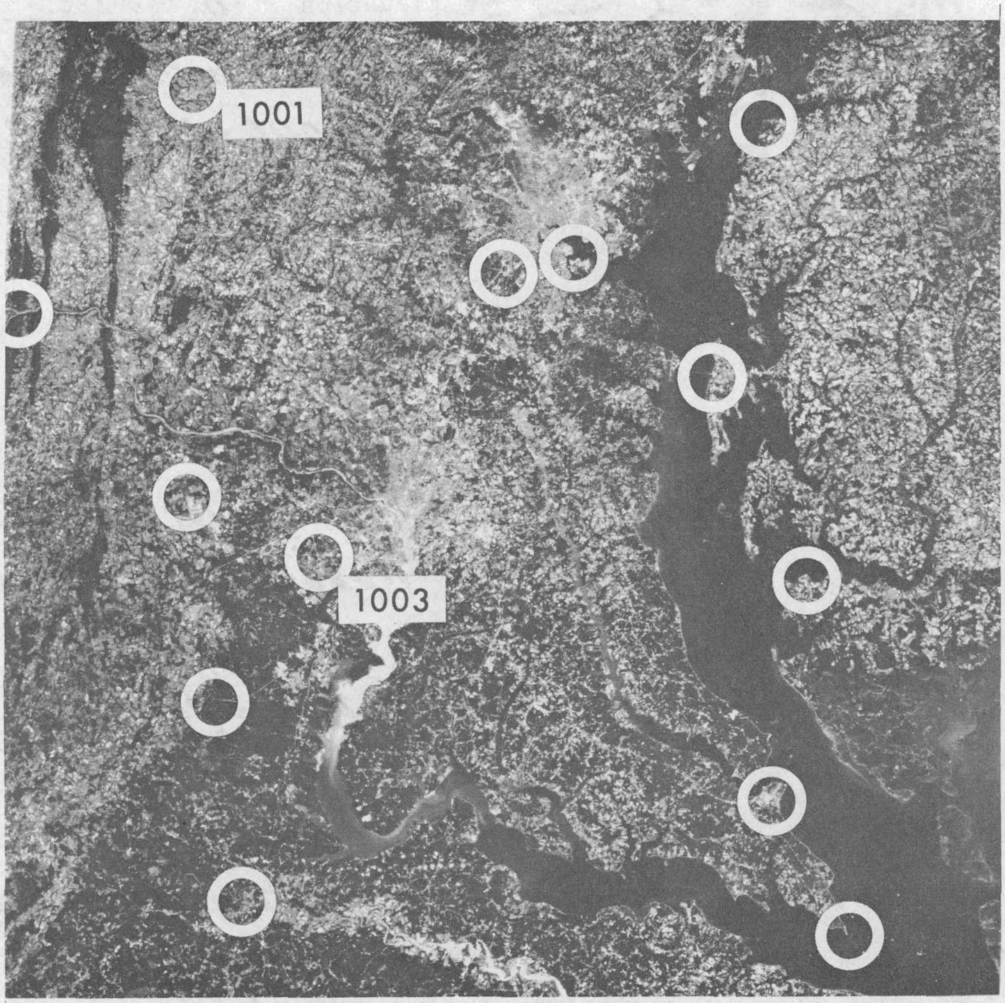
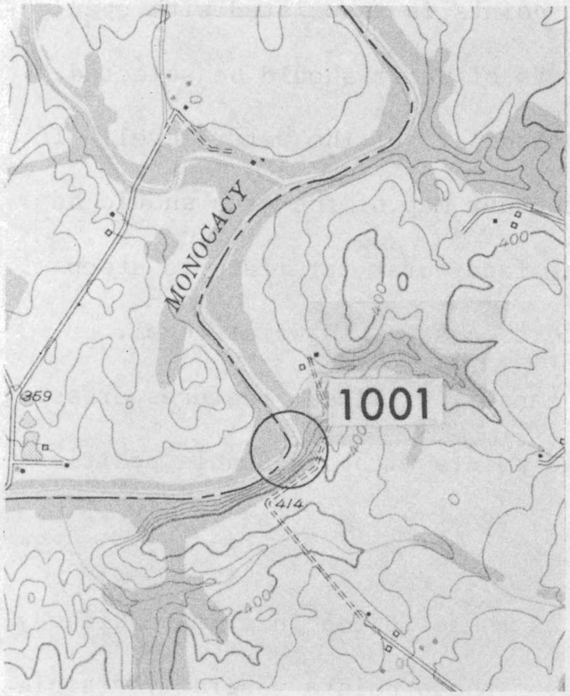


Figure 3.--ERTS-1 photograph of the Chesapeake Bay area. Numbered points 1001 and 1003 are shown on map chips in figure 4.



Section of 1:24,000-scale
topographic map

Point # 1001

Description E. bend Monocacy R.

Area Maryland, USA

Coordinates:

UTM Zone 18

N 4,389,195 m

E 304,660 m

Latitude

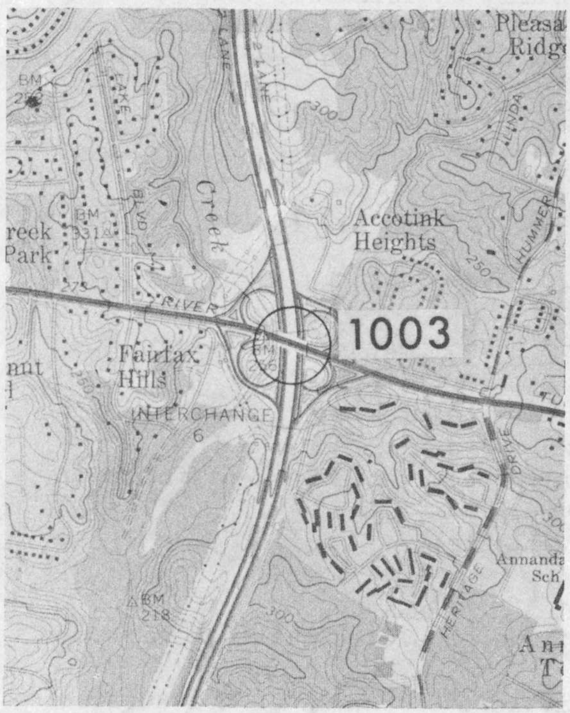
Longitude

Elevation 323 Ft. ______ M

Map Name: Emmitsburg, Md. 7½

Photo # 1080-15192-5

Spheroid Clarke 1866



Section of 1:24,000-scale
topographic map

Point # 1003

Description I-495 x-ing Va.236

Area Washington, D.C., USA

Coordinates:

UTM Zone 18

N 4,300,520 m

E 307,450 m

Latitude

Longitude

Elevation 256 Ft. ______ M

Map Name: Annandale, Va. 7½

Photo # 1080-15192-5

Spheroid Clarke 1866

Figure 4.--Map data on two control points shown in figure 3.

The most obvious group of control points is associated with open water (fig. 1). Points of land or points of water should be selected, however, with some information on the stability of the water level. If this information is not available, a contour map of the area should be studied to insure that the slope at the land-water interface is steep enough to minimize horizontal shift due to changes in water level. Oxbows, stream confluences and bends, canals, or linear features crossing bodies of water generally provide image points with dependable positions (fig. 3).

Newly constructed highways, such as those in the Interstate Highway system, comprise a second major source of photo points generally visible on ERTS imagery. Overpasses, bridges, or linear-feature crossings provide images that are sharp and generally unmistakable (fig. 3). Unfortunately, many maps predate the new highways, and geodetically defined coordinates are therefore not readily available.

The third source of useful points are crossings of linear features, such as pipe lines and power lines, railroads, and Federal and State highways. Abrupt changes in azimuth of these features are also definitive points (fig. 1). These linear features may not be obvious at first glance but, if detectable, are probably the best defined and most precise photogrammetric points available.

Airport runway crossings or junctions should be searched for and included, if visible, as they are equivalent to panels on conventional photographs. They are sharply defined points if the highly reflective

surface has not caused blooming or spreading. To reduce the positional errors resulting from edge blooming, the center of this type image should be selected rather than an edge.

In desert and mountain areas where good-quality points are sparse, natural phenomena such as volcanic cones, sharp ridge lines, drain intersections, stream-bed loops, or lava flows may be used. The determination of suitable ground coordinates is generally the limiting factor in selecting this kind of point. If a point is definitive in one direction only, a second point should be found nearby to define the coordinate in the other direction.

SOURCES FOR COORDINATE DATA

The coordinates for most space-photo points in the United States were scaled from 7.5- or 15-minute maps on the Universal Transverse Mercator (UTM) grid. Points taken from standard topographic maps are automatically on an acceptable reference system (the map projections are mathematically related to the spheroid) and have a readily obtainable elevation above sea level.

If large-scale maps of a particular area are unavailable, a smaller scale series may be used. Although the standard error of points obtained from maps at scales smaller than 1:100,000 will probably exceed the error budget assigned to ground control, positions taken from accurate maps at scales of 1:250,000 or even 1:500,000 may be useful in areas where no other identifiable control exists.

Other lists of coordinates may be available from various Government agencies, but rarely are they directly usable. For instance, Geological Survey Water-Supply Paper 1838 lists the coordinates of every major dam in the United States--but only to the nearest minute (1 n. mi.). The Department of Transportation has the coordinates of nearly every Interstate Highway structure in the United States--to the nearest 1/10 minute. These examples are given with the hope that, in the future, photoidentifiable points may be defined with greater precision. Vast quantities of ground-survey control in the United States are available, but the points are not tied to any photographic image and therefore are not directly usable for referencing imagery.

For space photos of totally uncontrolled or unmapped areas, users should determine whether or not the expense of extending field control is justifiable. Doppler measurements on U.S. Navy navigation satellites should be investigated for isolated position determinations in undeveloped areas. First- or second-order astronomic positioning, requiring less capital investment, is a further possibility. This method, however, requires highly trained personnel, and the resulting astronomic positions must be properly reduced to geodetic positions.

COORDINATE DETERMINATION AND CHECKING

Measuring map grid coordinates by coordinatograph with automatic readout is the preferred method of control point acquisition because it provides precision and reduces blunders. If this equipment is not available, hand scaling methods are economical and provide the required

accuracy for any space imaging system thus far defined. However, this procedure requires rigorous checking for blunders. Where gridded maps are available, manual scaling can be expedited by using a map coordinate reader. A limited number of coordinate readers for use in earth-resources projects are available from the Cartography Coordinator, EROS Program, U.S. Geological Survey, Washington, D.C. 20242.

A systematic check for blunders in identification of the photo points and the corresponding map points must be made in addition to a check of the scaled numerical values. The points measured and recorded by the USGS were checked by plotting the points on transparent material with an automatic plotter and overlaying the transparencies on corresponding 1:250,000-scale line maps. The same punched cards, with corrections if needed, that generated the plot on the transparencies were then used to generate the listed values given to NASA for precision processing, with no further human intervention. Quality checking is absolutely mandatory because of the many possible sources of blunders.

CONTROL STORAGE AND RETRIEVAL

Although the photo-control points of the U.S. were compiled by USGS under contract to NASA for precision processing of ERTS imagery, they provide a data base, in the form of punched cards and transparent overlays, for use in future space systems, such as Skylab, ERTS-B, and other systems not yet defined.

A computer program written in FORTRAN IV selectively retrieves the coordinates, converts them to UTM or decimal latitude and longitude, and lists them in both systems. Codes indicating quality and source, the elevation in feet and meters, a brief descriptor, and the 1:250,000-scale IMW map designation are also listed. The format of 1:250,000-scale maps (1° lat. by 2° long.) has been adopted as the most convenient output block. Complete U.S. map coverage at this scale is available. The transparencies overlayed on these maps give an excellent visual reference of the photocontrol points.

CONCLUSION

Within the context of the previous pages, the following are needed for full precision processing of ERTS imagery:

Nine well-spaced photo points per frame that are definitive in x and y and suitably identified by word, aerial photo, and map.

Coordinates for these points in the UTM or geographic system, with relative errors within 10 m desirable and within 30 m to be usable. The reference ellipsoid should be identified and any datum inconsistencies either defined or removed.

Elevation above sea level within 50 m desirable and within 150 m to be usable.

If available, standard large-scale topographic maps are an excellent source for coordinates and elevations of control points. If large-scale map coverage is nonexistent but a few referenced ground control points are available, these few points are better than none at all for partial processing.

It is highly recommended that a copy or record of photoidentified control points be retained for controlling future space photographs and for other uses.

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