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2.3 WORKSHOP RATIONALE

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For the future, we've got to worry about how we can actually do data processing in a manner that produces data which is of greater accuracy by the time we use it. Very likely we are going to be dealing with a set of sensors which may not be on a given spacecraft. This says that the data may or may not be optimized for the type of processing which we are going to apply. This in turn gives us some implications on the processing needed prior to analysis, i.e., geographic registration and the whole question of how to get data geocoded and in condition to register one set of data to the other. There are also questions of on-board processing, data compression, and various special pipeline parallel processor elements which are going to be required to get the data through the system in the reasonable time.

As illustrated by Figure 1, we're dealing with a set of processing in one piece of this total system starting with a sensor, a set that goes through a preprocessing step, becomes archived, and is extracted from the archive; the data is processed and finally applied to user models. We're trying to put the data in a condition so that when the users request through the system they can get the set of data they want in the condition they require.

In the general area of preprocessing we are going to be dealing with a number of potential topics, among which is geometric rectification (which, of course, is our main interest here). The question of radiometric preprocessing in terms of this conference comes into play regarding whether or not the radiometric properties of the data have any effect on our ability to do any of the geometric operations required. For instance in the earlier Landsats, until the data were properly destriped, the correlations which were done for registration of ground control points tended to lock in on a striping rather than on the data. For spatial resolution, we are concerned about frequency responses for interpolation kernels and what effect they may have on applications. For georeferencing and cataloging, if one can't find the data, it doesn't do one much good. Georeferencing simply says that if we can register any given set of data to a reference (I'll call it a grid), then, implicitly, various data sets are "more or less" registered to each other and part of that more or less is what we want to talk about in this workshop and panel sessions. What we're trying to do is make the data correct, make data sets compatible so they can be used together, and eventually make them available, which means put them in such a condition that when we call for them from the archives, we get can get the data back fairly expediciously.

Now the net result: the net use of the data in the long run is extraction of information. Most of the models which are now being developed required data from numerous data sets. One example of the potential interplay of sets of data from various sources is illustratd in Figure 2, which indicates some of the interplays between data for a particular problem having to do with weather questions. I don't expect to go through this illustration in detail except to indicate that there are a lot of crossing arrows and many particular processes that have to be modeled in solving the users information extraction problem.

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*Edited oral presentation.

This calls for data from various sources in order to allow multiple users to expeditiously do their problem solving.

Use of various data sets together is one thing, using data sets together with data from other sources such as maps, or producing data in which the required output information is map-related is another. What's involved basically, is to produce a data set in which the indiviual data items in one form of geographic coding are implicitly related to a given position on the ground, because we have defined where the entire image matrix lies on the ground. Thus we can convert latitude and longitude into a line and pixel in the data set. In addition to the question of using data sets from various sources there is a general question of being able to put it into the archives and get it out of the archives in a geographically coded sense, so that we can begin to produce data in a form that will make that whole process fairly expeditious.

The requirements involved the removal of distortions and then placing of that rectified data in an archive where we can retrieve it; placing rectified data on the ground in a given location is reviewed in Table 1. This is not supposed to be a definative list, but a little table of some of the sources of geometric distortion. Many of the items which are included in the table and and figures are going to be subjects of the panel discussions. What I want you to think about is the fact that there are a number of causes of distortion: some of them in the sensor itself, some of them in the spacecraft in terms of its pointing, and some of them which are implicit in a remote sensing system (such as the fact that the earth is round). And it may well be useful in your panel discussions to consider the sequence of causes of distortions and decide whether or not that sequence of causes of distortions gives you any clues as to the sequence to remove the distortions and what might be done in that process. Depending on which types of distortions you are faced with you may treat them differently. Again these types of items and their specifics are the kinds of things that you will be discussing in the panel meetings.

There are a series of problems involved in attempting to match one interest to the other; I won't try to go through those because you have a set of questions which has been outlined for the various panels as a guide to thinking. I do have Figure 3, which will indicate the type of problem we are involved with in doing the correlation of images to maps. Some of you may be familiar with this process, and some of you may not, so I'll indicate it briefly. We are trying to find a piece of an image and it's location with respect to a map. We take each piece of an image control point area, taking a series of those that are scattered around the face of a total frame, then that series of ties between line and pixel and the location on the ground (latitude and longitude) gives you the data you need to do a geometrical warping of the image, so that when you complete the dewarping process, you now have an image which can lay on the ground -- hopefully with all pixels registered. The essence of the process simply is that maps and images do not cross-correlate very neatly in a computer, as maps and features in images look different. We've got a real problem in trying to define a way to do that correlation. The way it is currently being done is to optically correlate, that is optically mix and overlay, and shuffle around until they match, a digital display of a small piece of image and a piece of a map. When those two are optically mixed, then a surveyed point on the map can be located in the small piece of visual image by running a digital cursor around on the display until it overlays the particular ground control surveyed point. The computer would know where the cursor is in line and pixel coordinates, and you'll tell it in latitude and longitude where it is on the map. That gives you a tie between this little piece of image, which in the NASA parlance is a ground control point chip, and the ground. We know from the geometry of the general situation approximately where the is in the incoming frame, so we pull out a large piece of the incoming frame digitally, and we know from whence we got it. Now we have two images. Those can be cross-correlated in a computer more or less accurately, and since we know the position of the surveyed benchmark in the little piece of image, we can determine through cross-correlation the position of each little piece within the large incoming image to tie the large incoming image's line and pixel with latitude and longitude. We have the transfer data now to take that into the total frame domain, tie individual ground control points to the ground, and develop the equations needed for the entire image. That's the kind of process we currently go through. It requires building a library of ground control points ahead of time, so when the incoming frames come we can do this cross-correlation expeditiously on the way through the system, two-hundred frames a day. Anything that people can think of during the workshop to improve the process will be appreciated.

The process that I described for ground control points requires that that particular control point be known in x, y, and z altitude, and the basic dewarping is normally a process of fitting a best-fit plane through that set of ground control points. That's fine, but, as you know, in hilly country there are intermediate points in the image, which may or may not be on that same plane. If you have hills or valleys in between, they are going to be displaced by a distance which is a function of the angle from which you are viewing those particular points, i.e., the relief displacement question. I worked up a little graph (Figure 4) which shows that relief displacement is larger than you like to believe when you are dealing with pixels of the Thematic Mapper size. In particular, although a repeat visit over a given area on the ground is intended to be a new image from precisely the same point, in practice that would not be true. It will be from some other point nearby. And the question is how bad does that slight displacement displace pieces of the image which are not on the same best fit plane. Well, here is the net result when you scale the Thematic Mapper pixels. It says, that with a surprisingly small difference in elevation between a given local point and the best fit plane, with a surprisingly small separation of the two vantage points (and remembering that the scatter of repeat visits on a given point is in the neighborhood of 5-10 km), there is a fairly large displacement potentially of pixels which are not on that original plane. Even though you have a good fit to normal control points, you may or may not have some other problems in areas of high relief. In particular with Landsat, the overlap area from side to side is a 170-km line of displacement between the wings of paraoverlap images from adjacent tracks. We are going to get a fair amount of displacement distortion due to elevation alone.

While there are a number of other items which we could talk about, I think that is enough to give you the flavor of the kinds of problems that we see coming up: potential areas of distortion, potential areas of lack of registration of the images to the ground. There are a number of specific questions which have been outlined for the various individual panels and you will get your crack at thinking about these and some of the other topics as you get into the panel discussion.

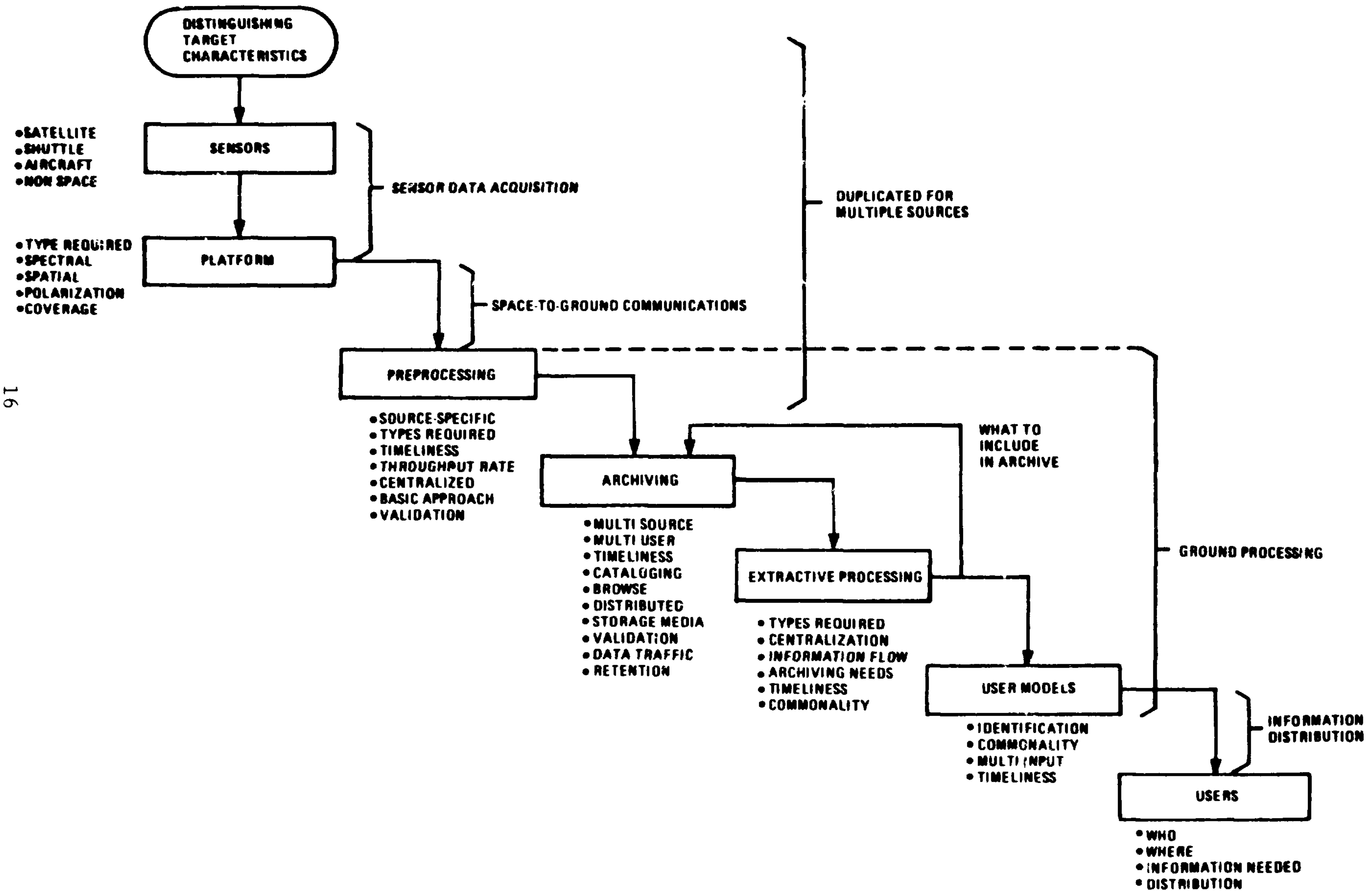


Figure 1. Technological Components And Issues Of Total Information System Structure

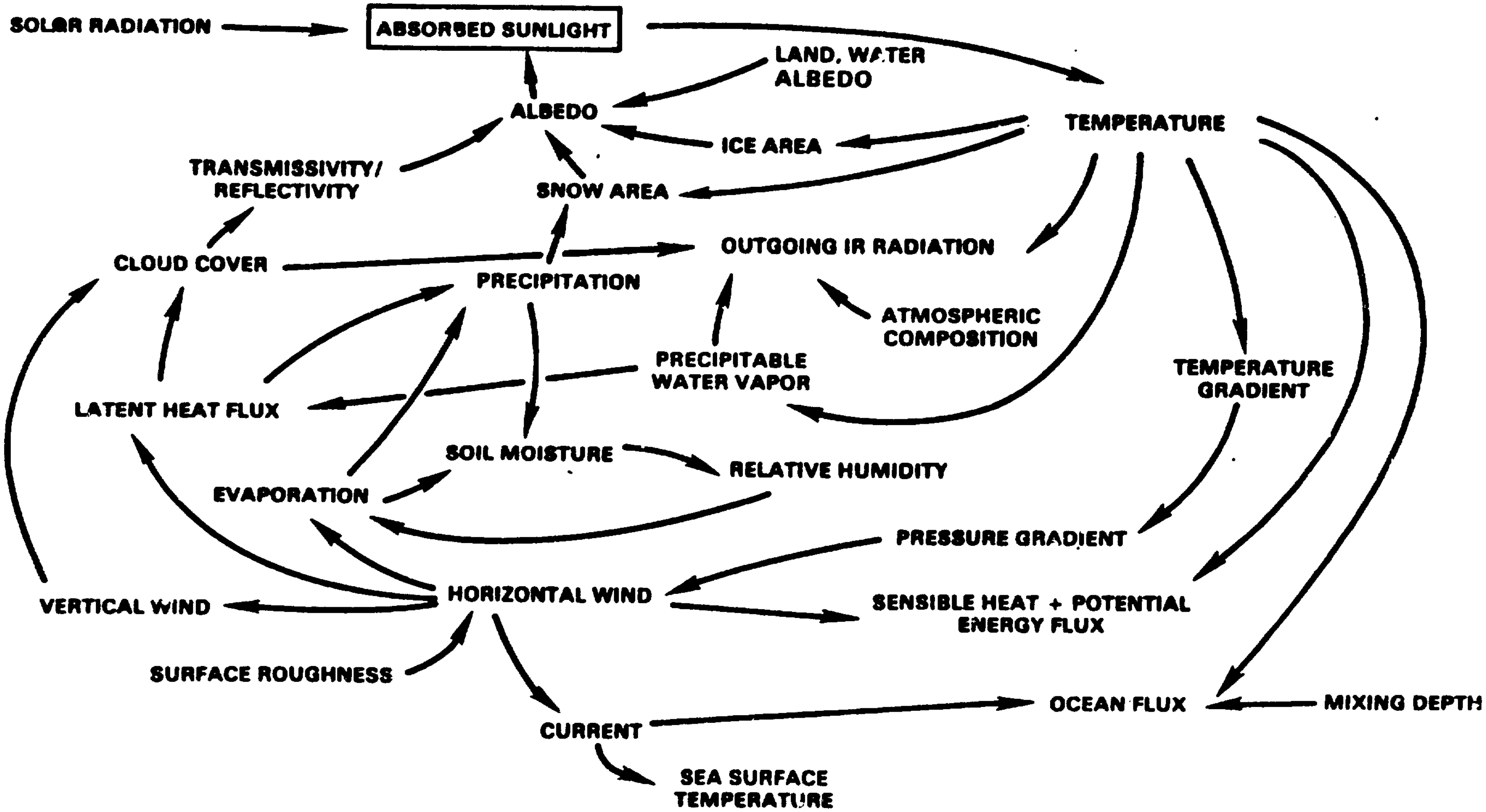
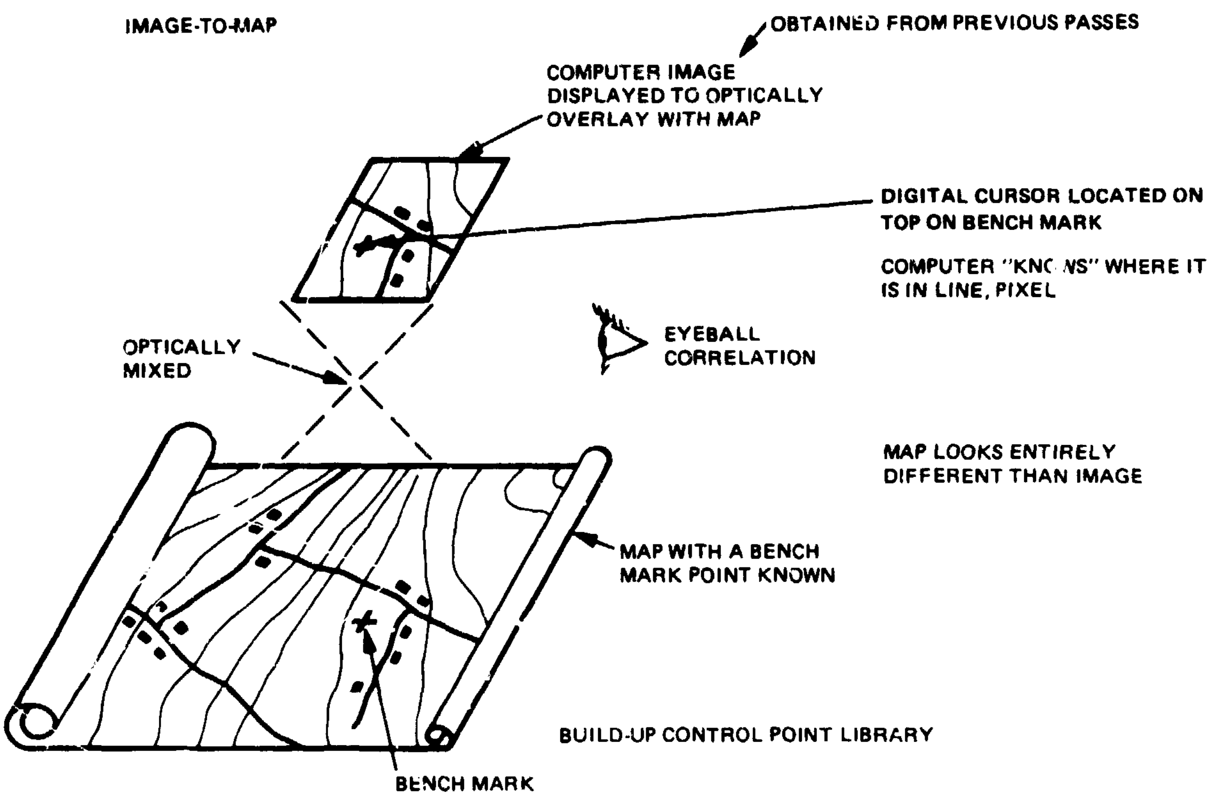


Figure 2. Complex Problems Require Many Data Sources and Models Climate Cause-and-Effect Linkages

Table 1.

GEOMETRIC ERROR TABLE

CAUSES	MODEL	EXPECTED ERRORS
	SENSOR/SPACECRAFT DIST'S	NYQUIST IS SMALL
ANTENNA, SOLAR PANEL MOTION	JITTER	SINUSOIDAL - ≈10 PIXELS/CYCLE
ATTITUDE CONTROL SYSTEM	ATTITUDE DRIFT	SLOW, SYSTEMATIC - ≈SEVERAL CYCLE/FRAME POTENTIAL JITTER DURING CONTROL - SEVERAL PIXELS
SCAN LINE CORRECTOR	SCAN CORR (TM)	SEVERAL CYCLES/LINE
SPRING MOUNT	MIRROR SCAN	≈1 CYCLE/LINE
	EXTERNAL DIST'S	NYQUIST IS LARGE
ATTITUDE CONTROL ACCURACY	ATTITUDE PROJECTION	MANY FRAMES/CYCLE, UNLESS ATTITUDE JITTER
Δ ALTITUDE, GEOID	ROUND EARTH	MANY FRAMES/CYCLE
EARTH ROTATION	SKEW	CALCULATABLE TO FRACTIONAL PIXEL
EPHEM CONTROL, TIMING	S/C POSITION (EPHEM)	SEVERAL KM
EPHEM CONTROL	ALTITUDE	GLOBAL
	SCENE DIST'S	
TOPOGRAPHY, LACK OF S/C COINCIDENCE	RELIEF DISPLACEMENT	COULD BE PER PIXEL
	GCP INACCURACY	
BASIC SURVEY. GEOID	MAP LOCATION	FEW TO MANY PIXELS TO NO MAP
SEASONAL, LACK OF GOOD POINTS IN REQ'D LOCATION, CORRELATION TECHNIQUE	ABILITY TO CORRELATE	PARTIAL TO MANY PIXELS
	RCP INACCURACY	
SEASONAL, LACK OF REQ'D POINTS, CORRELATION TECHNIQUE	ABILITY TO CORRELATE	PARTIAL TO MANY PIXELS
DIFFERENCE BETWEEN WARPING MODEL AND REALITY	SCENE WARPING MODEL	PARTIAL TO MANY PIXELS
ALGORITHM SELECTION	NEAREST-NEIGHBOR WARPING	PARTIAL PIXEL



CORRELATION FOR CONTROL POINT LOCATION BY CONVOLUTION

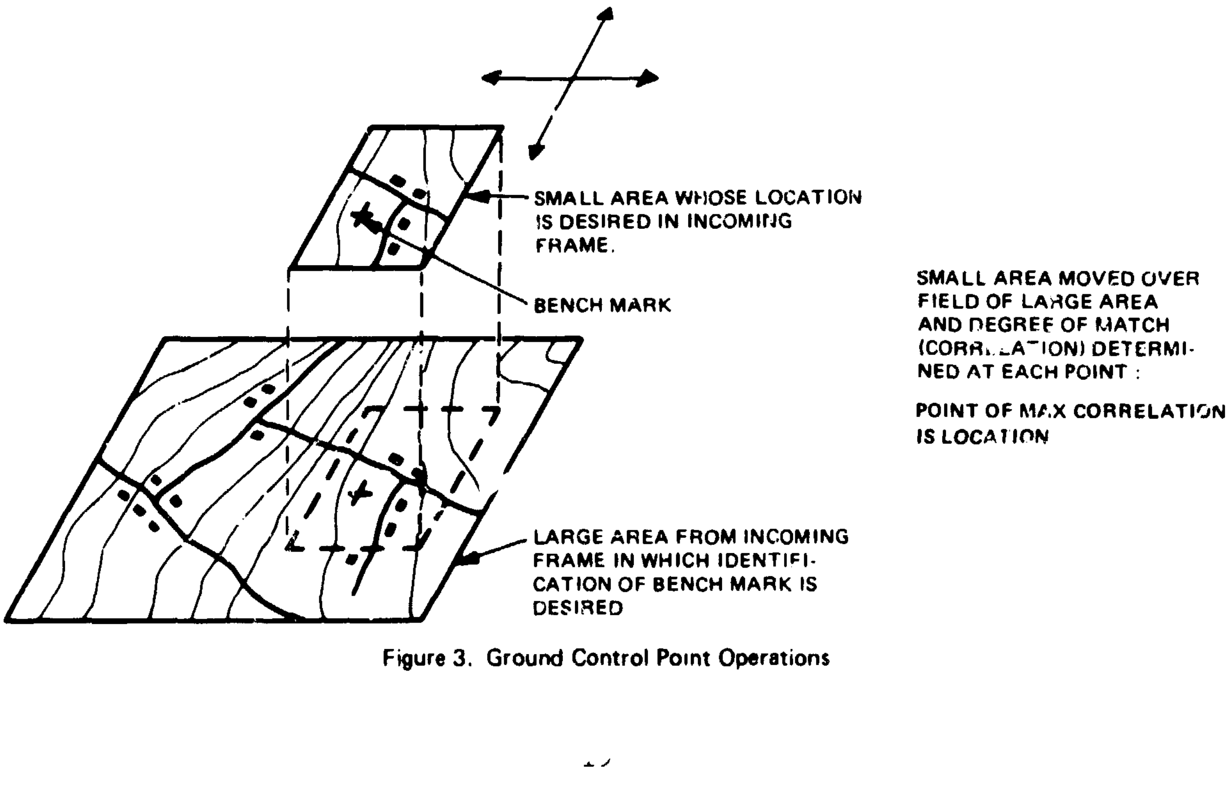


Figure 3. Ground Control Point Operations

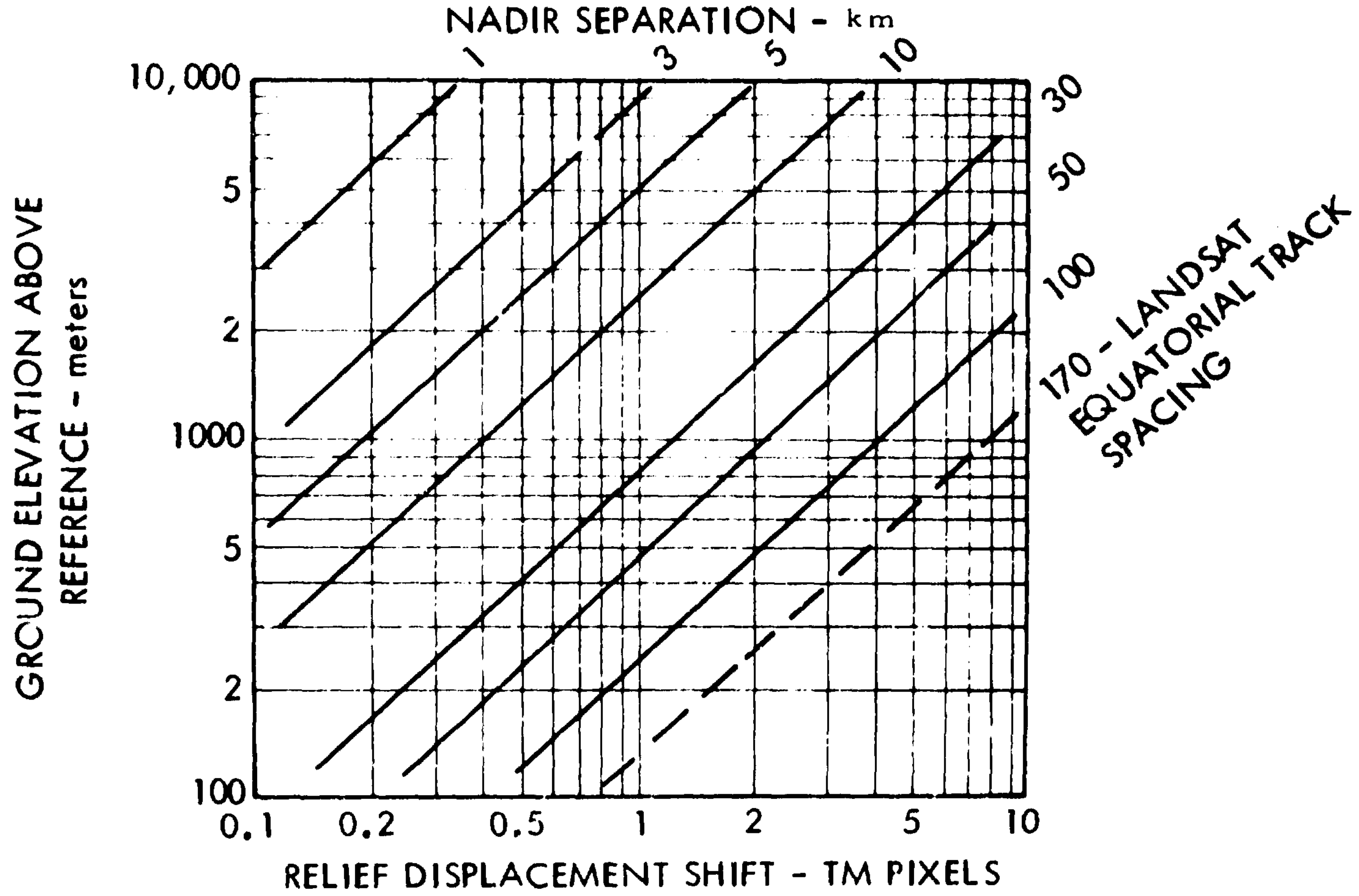


Figure 4. Relief Displacement Effects