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# LANDSAT 3 RETURN BEAM VIDICON RESPONSE ARTIFACTS:

## A Report on RBV Photographic Product Characteristics and Quality Coding System





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# LANDSAT 3 RETURN BEAM VIDICON

# RESPONSE ARTIFACTS[1]

## BACKGROUND

The return beam vidicon (RBV) sensing systems employed aboard Landsats 1, 2, and 3 have all been similar in that they have utilized vidicon tube cameras. These are not mirror-sweep scanning devices such as the multispectral scanner (MSS) sensors that have also been carried aboard the Landsat satellites. The vidicons operate more like common television cameras, using an electron gun to read images from a photoconductive faceplate.

In the case of Landsats 1 and 2, the RBV system consisted of three such vidicons which collected remote sensing data in three distinct spectral bands. Landsat 3, however, utilizes just two vidicon cameras, both of which sense data in a single broad band. The Landsat 3 RBV system additionally has a unique configuration. As arranged, the two cameras can be shuttered alternately, twice each, in the same time it takes for one MSS scene to be acquired. This shuttering sequence results in four RBV "subscenes" for every MSS scene acquired, similar to the four quadrants of a square. See Figure 1.

Each subscene represents a ground area of approximately 98 by 98 km. The subscenes are designated A, B, C, and D, for the northwest, northeast, southwest, and southeast quarters of the full scene, respectively. RBV data products are normally ordered, reproduced, and sold on a subscene basis and are in general referred to in this way.

Each exposure from the RBV camera system presents an image which is 98 km on a side. When these analog video data are subsequently converted to digital form, the picture element, or pixel, that results is 19 m on a side with an effective resolution element of 30 m. This pixel size is substantially smaller than that obtainable in MSS images (the MSS has an effective resolution element of 73.4 m), and, when RBV images are compared to equivalent MSS images, better resolution in the RBV data is clearly evident. It is for this reason that the RBV system can be a valuable tool for remote sensing of earth resources.

Until recently, RBV imagery was processed directly from wideband video tape data onto 70-mm film. This changed in September 1980 when digital production of RBV data at the NASA Goddard Space Flight Center (GSFC) began. The wideband video tape data are now subjected to analog-to-digital preprocessing and corrected both radiometrically and geometrically to produce high-density digital tapes (HDT's). The HDT data are subsequently transmitted via satellite (Domsat) to the EROS Data Center (EDC) where they are used to generate 241-mm photographic images at a scale of 1:500,000. Computer-compatible tapes of the data are also generated as digital products.

Of the RBV data acquired since September 1, 1980, approximately 2,800 subscenes per month have been processed at EDC.

[1]Artifact: an object or structure not normally present, but produced by an external (as human) agency or action.

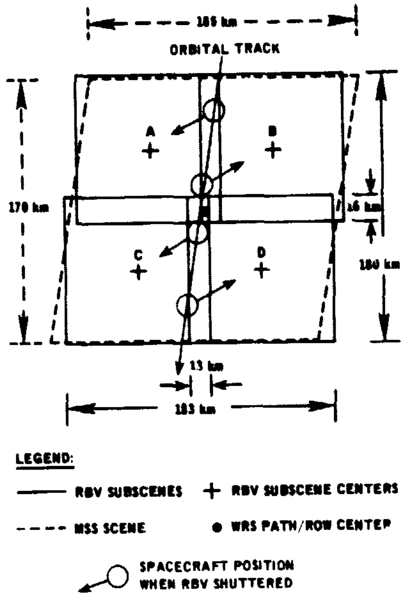


Figure 1. RBV Shuttering Arrangement

## STATEMENT OF PROBLEM

Analysis of large volumes of Landsat 3 RBV digital data which have been converted to photographic form has led to the firm identification of several visible artifacts in the imagery. These artifacts have been identified, categorized, and traced directly to specific sensor response characteristics. Furthermore, analysis has determined that none are easily removed. All cases remain under active study for possible image enhancements at some point in the future.

The purpose of this document is to describe these artifacts based on the best information available at this time. Examples of affected imagery are presented in order to help the reader recognize the various artifacts when they occur, thereby enabling him to distinguish better between image content and innate defects caused by the sensor system.

To date, seven generic categories of sensor response artifacts have been identified:

1. Shading and Stairsteps (Figures 3 and 4)
2. Corners out of Focus (Figure 5)
3. Missing Reseaus (Figure 6)
4. Reseau Distortion and Data Distortion (Figure 7)
5. Black Vertical Line (Figure 8)
6. Grain Effect (Figure 9)
7. Faceplate Contamination (Figures 10 and 11).

An additional category under study, but not yet determined to be caused by sensor response, is a geometric artifact (Figure 12) which appears to be peculiar to RBV imagery. These phenomena are only the most common found to date, and it is realized that the list may be by no means inclusive.

The artifacts can occur singly or in combination. In some cases, their impact on data usability is serious, resulting in total loss of image content. In other cases, only minor defects exist and the overall quality of the image is considered good. Between these two extremes, the case most often found is that a partial reduction in overall image quality occurs. This can create problems for the photo interpreter, such as when two or more visible defects combine to make the discernment of image detail more difficult; or it can result in actual loss of detail in specific areas, such as when significant ground features are suppressed or obscured due to a single type of artifact. In the latter instance especially, scenes that are radiometrically "flat" to begin with (desert scenes, water, cloud-covered areas) exhibit the worst effects.

A large fraction of the RBV data processed and recorded on HDT's to date suffer from this reduction in overall quality. When subsequently converted to film or digital products, therefore, most of the data are downgraded during quality assessment. Because the average background scene radiance varies as it does, the defects in the imagery appear to be random in terms of both magnitude and location in the image area.

The situation clearly presents a problem both for the user and for EDC Quality Assurance personnel. Users have a right to be concerned about the potential for poor image quality in the products they order, for image quality is generally an indication of usability. Quality Assurance personnel, on the other hand, have the difficult task of establishing an image quality rating for data which may vary unpredictably and whose ultimate usability to some customers is impossible to determine.

## Impact on Users

From the serious user's point of view, an image that is only partially affected by artifacts is one that still contains unaffected, usable data. It may be impossible to predict where the artifacts will occur in the image spatially, but many users are willing to take this risk. These same users are also aware that the mere occurrence of a given defect does not necessarily mean that that part of the image automatically becomes "unusable." They may find, for example, that they can work around certain defects once they learn what those defects do to the image. The scientific value of an image for a specific application is therefore something that only the user can determine.

For these reasons, RBV data affected by sensor response artifacts are being made readily available. It is realized that the aesthetic appearance of an image is of little importance to the scientist. In addition, in spite of the ostensible deficiencies, a good amount of usable RBV data *is* being produced. The philosophy has been taken that as long as users are aware of the problem, its impact will not be as great.

Casual users, of course, may see things differently. Because the majority of data acquired to date includes areas having the flat field radiance response mentioned previously, very few RBV images have been processed that would be suitable for display purposes. It is an intent of this document, in fact, to demonstrate that situation through examples. Any user ordering RBV imagery should be aware that, although useful scientifically, RBV data may not always be aesthetically pleasing to the eye.

## Quality Assurance Procedures

From a Quality Assurance point of view, the RBV data now being received fit none of the pre-established criteria that are used to judge the quality of other Landsat data. Normally, all Landsat data are subjected to a stringent inspection procedure which is designed to identify the number, type, and extent of visual defects in an image. The image quality rating is established accordingly based on this qualitative assessment. This system works well because the deficiencies are known (having been recognized over the years), and their nature is understood. The impact of each on the usability of final photographic products can be judged with high accuracy.

The RBV data are different. The sensor-caused artifacts are typical of those experienced by other vidicon users; however, their impact on Landsat data users has not yet been completely established due to a lack of experience in dealing with these data by the user community as a whole. The perceived product deficiencies are thus very difficult to categorize. *A decision was therefore made not to downgrade RBV image quality because of sensor-caused defects.* Instead, the normal qualitative assessment procedure has been replaced by a procedure in which relative image quality is rated based upon the perceived utility of the data. Figures 2A through 2D show four examples of RBV imagery which represent the four possible quality ratings that can be given at EDC. A rating of "8" is given to denote a "good" image; a "5" equals "fair"; a "2" equals "poor"; and a "0" equals "unusable." The examples give an indication of what percentage of the image content must be lost for an image to receive one of these ratings. About 60 percent of the RBV data received and processed by EDC since September 1, 1980, have been rated good or fair.

Figure 2A. Example of a Quality "8" RBV Image

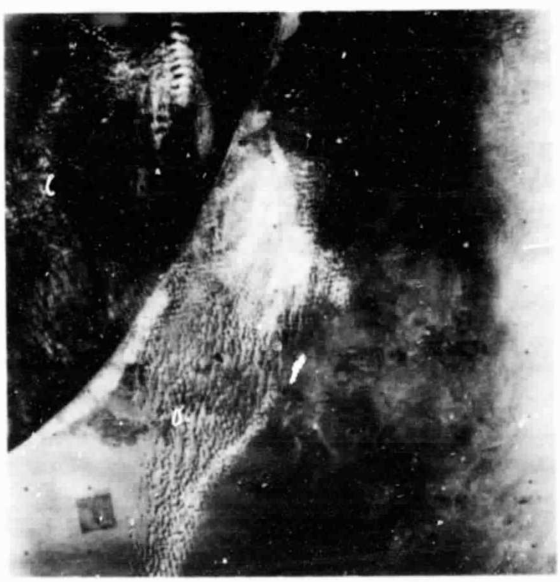

Figure 2B. Example of a Quality "5" RBV Image

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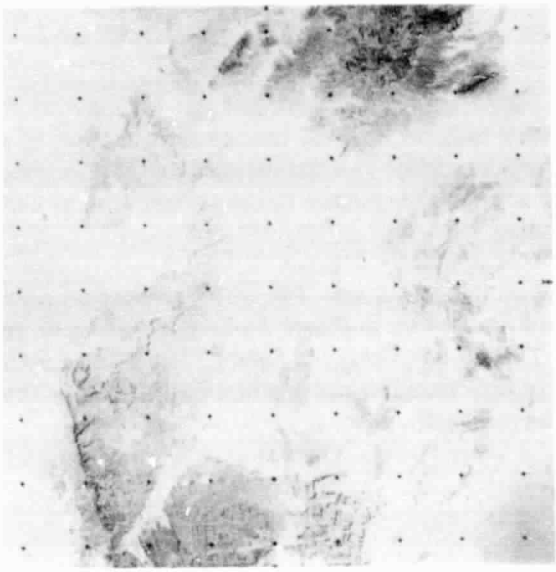

Figure 2C. Example of a Quality "2" RBV Image

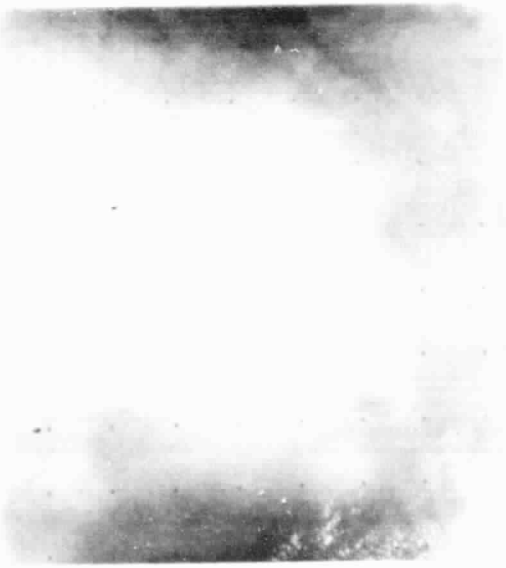

Figure 2D. Example of a Quality "0" RBV Image

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## EXAMPLES

The remainder of this document is devoted to brief discussions and examples of the RBV image defects that are occurring at this time. None of them are easily correctable. Questions on any aspect of the information presented may be directed to:


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### Shading and Stairsteps

Prelaunch testing of the RBV cameras involved placing each in front of a light source and measuring camera response as the light level was varied. This test revealed that the responses were neither uniform from camera to camera nor uniform across either camera faceplate. The lack of uniformity across the individual camera faceplates is called shading.

Shading is most obvious when the data acquired lie within a relatively narrow range of gray levels. Differences from camera to camera can be seen in Figure 3 where overall scene density varies considerably between two adjacent subscenes. The left-hand image in Figure 3 also shows how variations in camera response from point to point across the camera faceplate can produce camera-unique shading patterns. Some shading is evident in the right-hand image, as well.

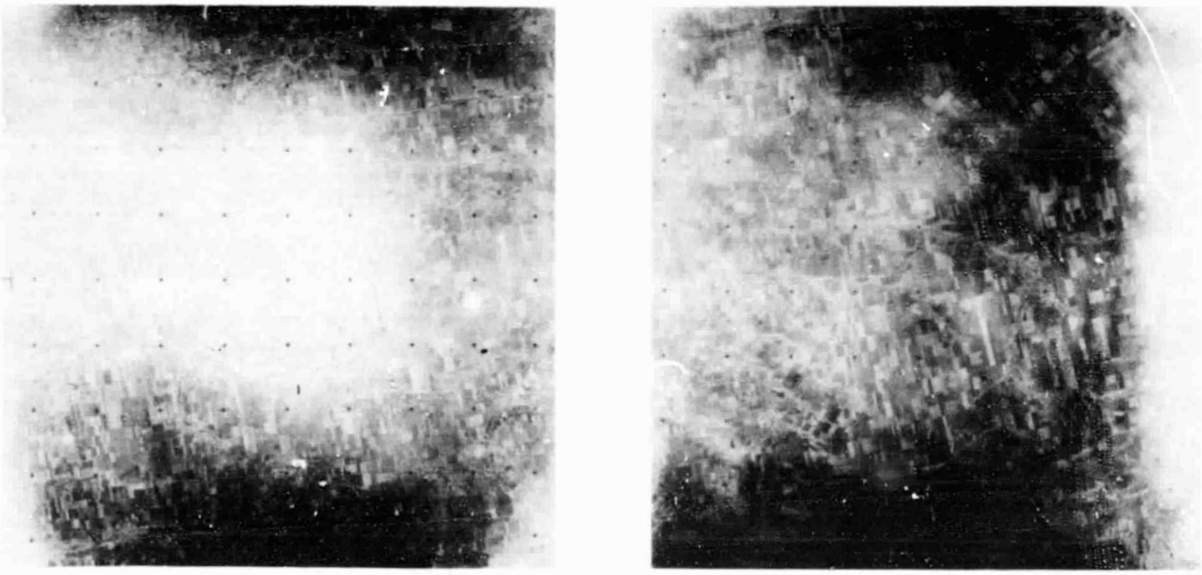

Figure 3. Examples of Shading in Two Adjacent Subscenes

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The prelaunch tests were performed in order to collect enough information to minimize these differences during ground processing after launch. Although minimization has been accomplished, it has been impossible to remove these effects totally. The result is a residual, spatially-varying, gray-level-dependent shading in most RBV images. Shading is unique to each subscene, and it affects some images more than others.

Related to shading is an effect known as "stairsteps." Some RBV data contain localized areas where the image data have fallen into certain anomalously regular patterns. These patterns are characterized by edges which resemble a staircase viewed from the side. Such patterns can be seen in Figure 4 as series of concentric polygons. Other patterns can occur, but the stairstep characteristic will always be present.

Stairsteps are induced by ground processing and occur as a result of imperfect deshading when the raw input data lie outside established high- and low-radiance limits. Both high-radiance and low-radiance stairsteps therefore occur. Both types are related to camera response characteristics similar to those described above for shading.

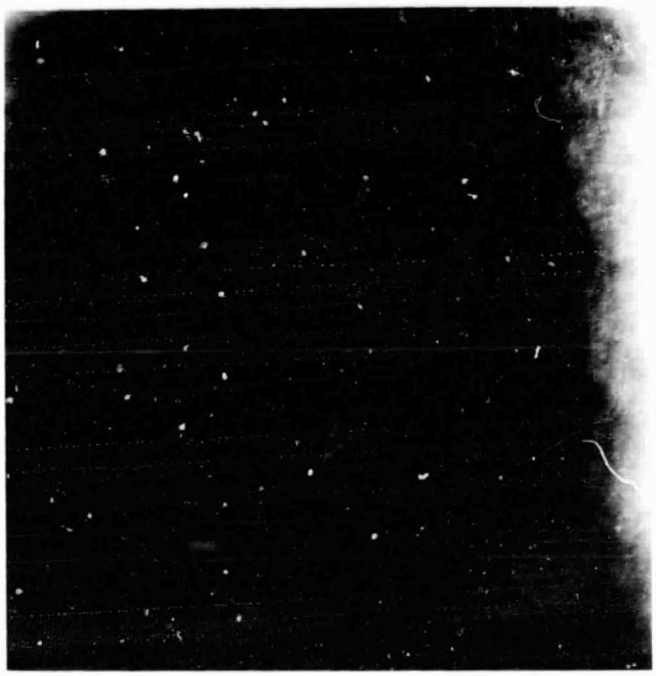

Figure 4. Examples of Stairsteps

## Corners Out of Focus

For some RBV data, it is obvious that the corners of the image are out of focus when compared to the more central parts of the image. This is a vidicon tube characteristic and can be seen in the raw data. While the optics system could be at fault, the cause is much more likely to be thermal perturbations or a phenomenon known as "beam-landing" error. The effect is aggravated by imperfect deshading and the presence of high-frequency noise (causing spatial distortions) when either of these occur. Figure 5 is a good example of a poorly focused corner. Note the blurred reseau mark.

Figure 5. Enlarged Corner Area Illustrating Poor Focus

## Missing Reseau Marks

The reseau marks that have been inscribed on the faceplate of each camera can appear to be lost in an image when they occur among data that lie at either radiance extreme. For low-radiance data, the reseaus merge into the background and are obscured. For high-radiance data, the reseaus can be washed out or lost due to a vidicon characteristic called "blooming." The latter effect is probably a result of the gain setting on the RBV sensor and cannot be corrected by ground processing. Figure 6 is an enlargement of an image where high-radiance image data have caused reseau marks to be missing.

## Reseau Distortion and Data Distortion

Distortion in reseau marks and image data can occur when the raw data contain time-code-induced anomalies. The enlargement in Figure 7 contains some reseau marks that are badly curved, and the image data near them, as well as elsewhere, are similarly distorted. Minor data losses in the time-code signal are thought to cause this horizontal shifting of data. Although this effect is not restricted to any area in an image, it is usually most pronounced in the corners of the image.

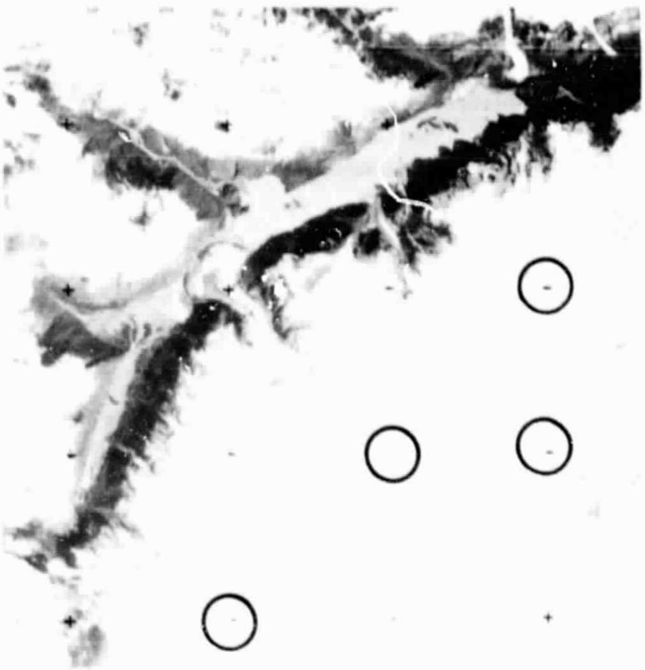

Figure 6. Examples of Incomplete or Missing Reseau Marks

Figure 7. Examples of Data Distortion

## Black Vertical Line

Image data acquired by camera no. 2 (which acquires subscenes B and D) contain a thin black line along the left vertical edge of the image. This is evident when the left edge of the image contains high-radiance data. Figure 8 is one example. This artifact occurs as a result of both hardware and software problems in the ground processing system. Its impact on image quality is strictly cosmetic, and it is shown here more for completeness than for any other reason.

## Grain Effect

Production of a large volume of RBV data has resulted in the identification of specific images that contain a "graining" or a fabric-type appearance. The enlargement in Figure 9 shows an example of bad graining in the upper left corner. The grain effect has been found to exist in almost all of the data processed to date. Probably attributable to some form of noise, the grain effect is currently under analysis at GSFC where attempts are being made to properly characterize it.

## Faceplate Contamination

Two categories of faceplate contamination exist. These have been designated as "hot spots" and "tears."

Figure 10 shows an example of a hot spot in the upper left corner of the image. It correlates to a flaw in the photoconductive layer of the vidicon, appearing as a blurred white spot. Hot spots are repeatable from image to image and their prominence is dependent upon the gray level of the image data written over them. Other hot spots exist in Figure 10 but are not as noticeable. Visual detection of hot spots is possible only when the average background scene radiance is low enough to permit them to stand out.

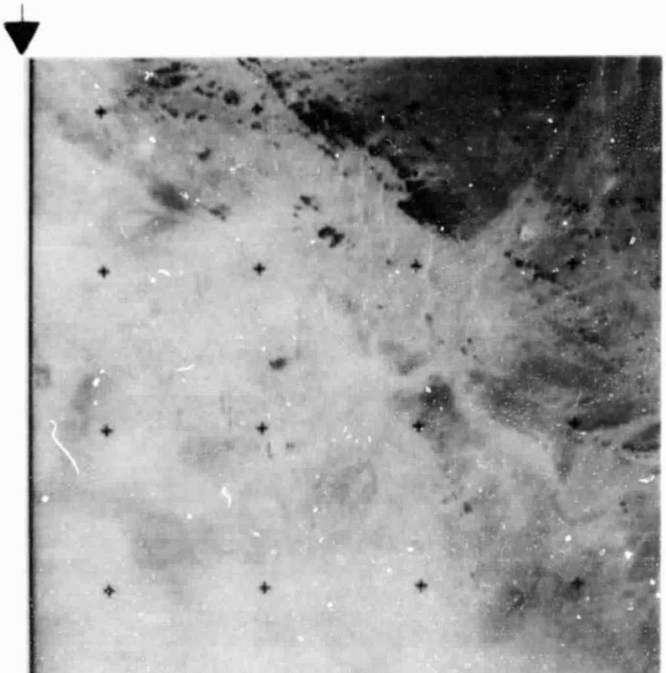

Figure 8. Image with Black Vertical Line

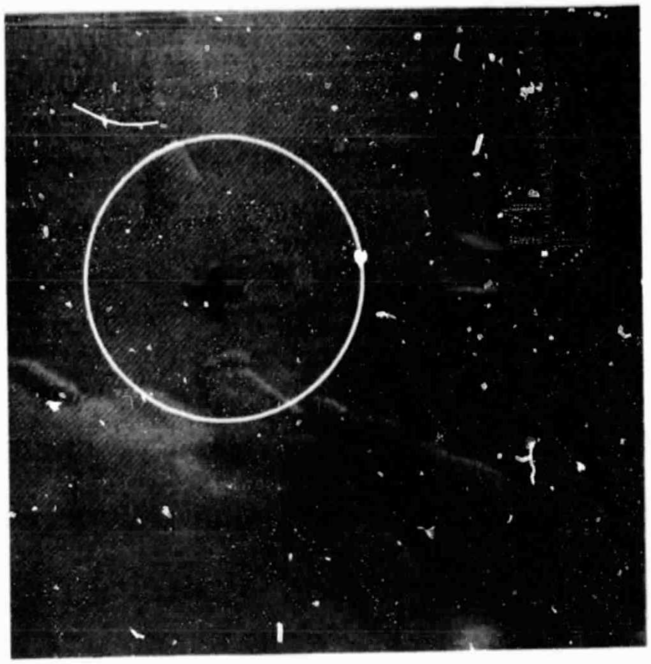

Figure 9. Example of Graining

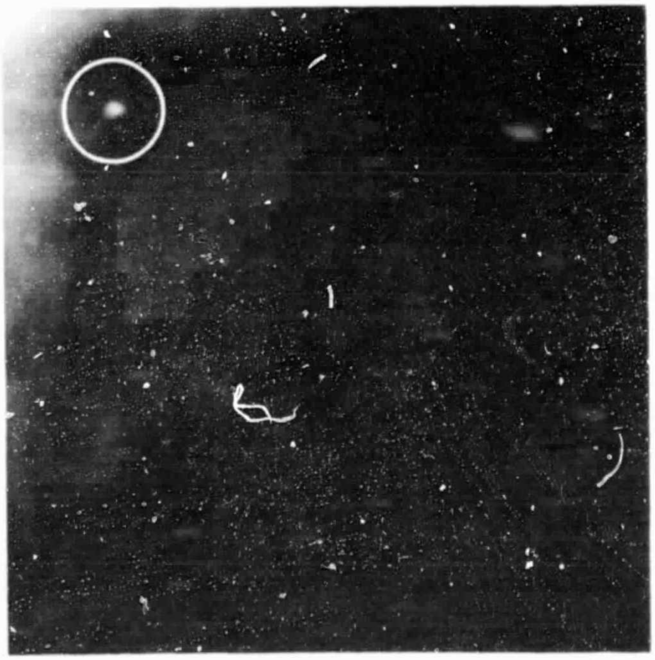

Figure 10. Example of Hot Spot

The second type of faceplate contamination cannot be seen clearly unless the proper combination of sun angle and scene radiance exists. When these conditions exist, one can detect bright white pinhole-size spots that are each accompanied by a black "shadow" of unknown origin. These are termed tears. The enlargement in Figure 11 has examples of tears; at this scale the tear shadows actually seem to be the dominant feature. Tears can be attributed to two causes. In some cases, they are a manifestation of minor flaws in the photoconductive layer of the vidicon. In other cases they represent localized areas of condensate on the camera faceplate. They always occur in the same place, and their detection is dependent upon the gray level of the image data written over them. They appear to be permanent.

Both types of faceplate contamination, hot spots and tears, are uncorrectable by ground processing.

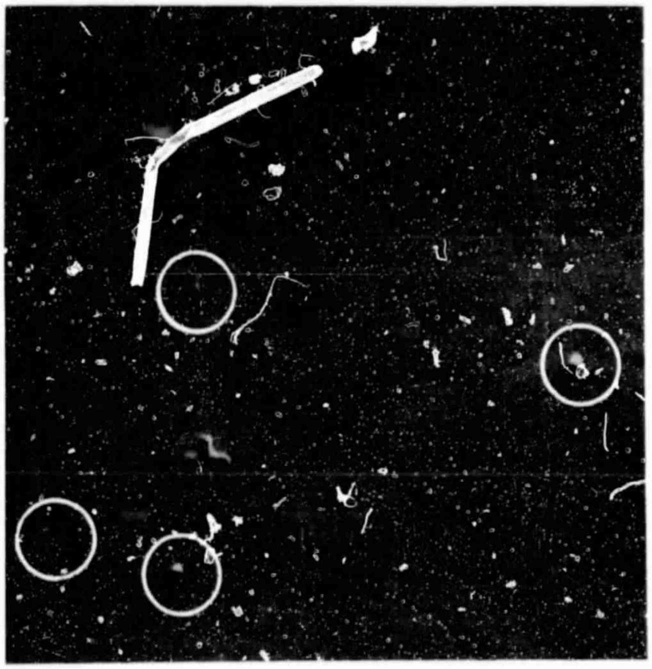

Figure 11. Examples of Tears

## Geometric Anomaly

A small fraction of RBV data has been found to contain a local geometric distortion. Image data in this category can be recognized by the presence of parallel lines restricted to the left one-third of the image. Such an area is highlighted in Figure 12. These lines always occur near the top and on the left-hand side of the subscene. They do not extend into any other one-third segment of the image data, and they are abruptly terminated at the boundary between the left one third of the data and the center one-third.

This artifact is introduced by ground processing and should be capable of being removed by the same means. A study is under way at GSFC to determine how this might best be done.

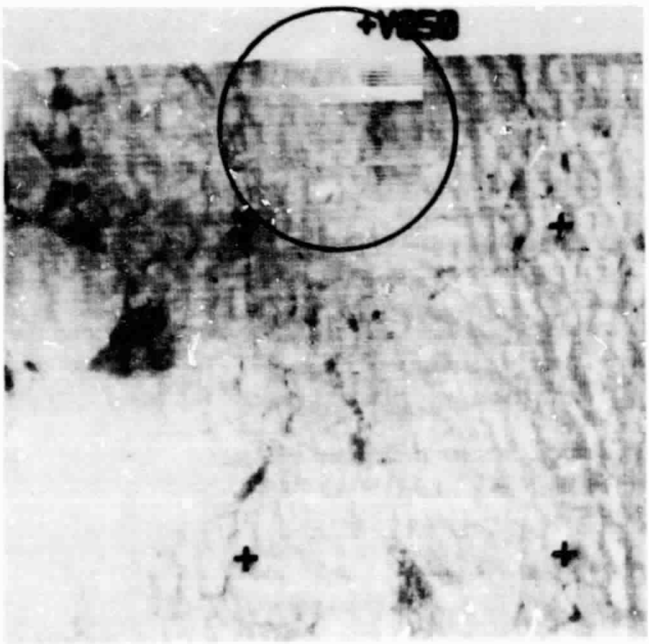

Figure 12. Example of RBV Geometric Anomaly