E83-10395
~~CR-172937~~
TM-85336



# IMPACT OF LANDSAT MSS SENSOR DIFFERENCES ON CHANGE DETECTION ANALYSIS

William C. Likens
Robert C. Wrigley
NASA Ames Research Center
Moffett Field, California 94035

(E83-10395) IMPACT OF LANDSAT MSS SENSOR DIFFERENCES ON CHANGE DETECTION ANALYSIS (NASA) 21 p HC A02/MF A01 CSCL 05B

N83-32145

Unclas
G3/43 00395

# IMPACT OF LANDSAT MSS SENSOR DIFFERENCES ON CHANGE DETECTION ANALYSIS

William C. Likens
Robert C. Wrigley
NASA Ames Research Center
Moffett Field, California 94035

ABSTRACT

The work presented has its origins in change detection work carried out at the Ames Research Center in 1981. At that time we co-registered a Landsat-1 and a Landsat-3 scene for the San Bernardino, California area and carried out image differencing as one means of identifying areas of land cover change. It was quickly noted that many spurious or false changes were being delineated in addition to real changes in the scene. These differences were found to be related to differences in the sensors, ground processing, atmosphere, and cover dependent sun angle effects. The data needed to be normalized in some manner to remove these effects. Contingency tables between the images were constructed in order to develop a transfer function relating digital values for individual points in one image to values for those same points in the other image. These functions for each band were used to normalize one date to the other.

In the present study we sought to reverse the above approach by using change detection techniques to pinpoint differences between sensors. Alternately, the use of change detection techniques with Landsat-4 and earlier Landsat MSS sensors can be thought of as a user-oriented test of any insurmountable differences between the sensors when used for change detection. Scattergrams between co-registered scenes (a form of contingency analysis) are used to radiometrically compare data from the various MSS sensors.

Initially, three MSS scenes were acquired and compared for the San Francisco area. These data were not simultaneously imaged; the Landsat-3 scene was acquired four days earlier than the Landsat-4 scene and the Landsat-2 scene was almost exactly a year earlier to minimize cover type and seasonal changes. However, a search of the EROS Data Center's MSS data base indicated two orbits when data from both Landsat-4 and an earlier Landsat were simultaneously recorded. Three scene pairs of simultaneous coverage were ordered for comparisons. In all cases of same date coverage, the scene pairs were acquired within three minutes or less of each other. Any differences between scenes can then be assumed to be solely a function of sensor differences, as atmospheric effects, sun angle, and scene content will be identical between scenes. This assumption is made, but does not

completely hold true in the case of the San Francisco data because the atmosphere is likely to have changed between dates.

The method of analysis was to co-register 512 by 512 pixel subwindows for all data pairs followed by scattergram generation and analysis. In all cases, the Landsat-4 data were used as the base to which other images were registered.

Scattergrams were generated between images for each band. These scattergrams plot the digital number (DN) found for each point in Landsat-4 against the DN recorded for that location in Landsat-2 or 3. Mode (maxima) values were derived from the scattergrams (y-axis modes for fixed x values as well as x-axis modes for fixed y values) and used to visually fit a linear regression (automated regression calculations were distorted by outliers). The regression line represents the relative radiometric transfer function relating Landsat-4 MSS to earlier MSS radiometry. Root mean sqaure (RMS) errors of the registrations varied between .1 and 1.5 pixels. The relatively large errors resulted from a line length error in the Landsat-4 MSS (discussed later).

Radiometric calibration information is also available for each of the MSS sensors. These can be used to predict the relative radiometric transfer functions between sensors.

The relative radiometric differences between Landsats -3 and -4 appear approximately the same as predicted by the calibration information. Comparisons of Landsats -2 and -3 (table 4), and -2 and -4 (table 3), however, show that the actual radiometry of Landsat-2 differs significantly from the calibration specifications. This may reflect drift in sensor sensitivity, optical degradation of the scan mirror and telescope, or changes in the radiance minimum and maximum constants used in ground processing. Often, changes in sensor calibration are not well disseminated and are thus unavailable to data users.

While radiometric values for Landsats-3 and -4 appear roughly the same as predicted by the calibration specifications, the San Francisco scene pair shows the high degree to which atmosphere can affect relative readings of features on different days. Atmospheric effects (up to 12 digital counts bias added to signal in band 1) in the Landsat-3 scene have caused features to saturate to a much greater degree than in the corresponding Landsat-4 scene, or in other scene pairs.

The saturation of Landsat-4 at relatively low radiance levels (compared to Landsats-1, -2, and -3) in bands 1 and 3 may result in loss of useful information for some data applications, including change detection.

While in the process of generating scattergrams, several geometric artifacts were noted. All bands of each Landsat-4 image contained noise interference patterns. These patterns appeared to have two components; diagonal striping with a period of about 3.5 pixels, and concentric arcs with a period of 10 - 12 pixels. Over water areas, the noise was noted to have a magnitude of 2 digital counts in band 4.

Sweep offsets were noted in all but the San Francisco Landsat-4 scenes. The San Francisco scene was acquired before Thematic Mapper data acquisition began on the West Coast. All other scenes fall in a time period during which it is probable that TM and MSS were turned on concurrently, indicating the problem may be related to sensor interactions. The offsets result from varying line lengths, and are readily corrected by stretching all lines to a constant length using line length information imbedded in the right edge of the image. The problem occurs only in A-format tapes and is corrected during the geometric processing applied to generate P-tapes.

There appear to be no major problems preventing use of Landsat-4 MSS with previous MSS sensors for change detection, provided the interference noise can be removed or minimized. This noise may result in detection of spurious changes, as well as affect other uses of the data, including image classification. Analysis of dark (water and forests), rather than light, features will be most impacted because the noise will form a higher percentage of the total response at low DN values. The patterns are sweep dependent, and within a sweep it is not clear that they are completely systematic. The pattern is present even when TM is off. The problem was detected before launch (left uncorrected because of the cost of repair), and is caused by interference between the revised MSS power supply (the power bus on Landsat-4 is different than on previous Landsats) and the sensor's one kilohertz data quantitizer. The frequency of the interference is known to drift because of drift in power supply frequency. The identical problem has been identified in Landsat-D Prime and should be corrected.

Any data normalizations for change detection should be based upon the data, rather than solely upon calibration information. While the observed relative radiometric transfer function between Landsats-3 and -4 was approximately as predicted, there were still significant deviations. Also, actual calibration specifications used in ground processing are not always made widely available, and published figures for Landsat-2 appear incorrect for recent data. Normalizing based upon data content also can have the advantage of allowing simultaneous normalization of the atmosphere as well as the radiometry.

# IMPACT OF LANDSAT MSS SENSOR DIFFERENCES ON CHANGE DETECTION ANALYSIS

## INTRODUCTION

The work presented has its origins in change detection work carried out at the Ames Research Center in 1981. At that time we co-registered a Landsat-1 and a Landsat-3 scene for the San Bernardino, California area and carried out image differencing as one means of identifying areas of land cover change (ref. 1). It was quickly noted that many spurious or false changes were being delineated in addition to real changes in the scene. These differences were found to be related to differences in the sensors, ground processing, atmosphere, and cover dependent sun angle effects. The data needed to be normalized in some manner to remove these effects. Contingency tables between the images were constructed in order to develop a transfer function relating digital values for individual points in one image to values for those same points in the other image. These functions for each band were used to normalize one date to the other. This normalization approach is very similar to the histogram equalization approach now used to remove detector striping from the Landsat-4 MSS data. Once normalized, real changes in scene features were more easily identifiable and most of the spurious changes were eliminated.

In the present study we sought to reverse the above approach by using change detection techniques to pinpoint differences between sensors. Alternately, the use of change detection techniques with Landsat-4 and earlier Landsat MSS sensors can be thought of as a user-oriented test of any insurmountable differences between the sensors when used for change detection. Scattergrams between co-registered scenes (a form of contingency analysis) are used to radiometrically compare data from the various MSS sensors.

## MSS DATA SELECTION

Initially, three MSS scenes were acquired and compared for the San Francisco area. These data were not simultaneously imaged; the Landsat-3 scene was acquired four days earlier than the Landsat-4 scene and the Landsat-2 scene was almost exactly a year earlier to minimize cover type and seasonal changes. However, a search of the EROS Data Center's MSS data base indicated two orbits when data from both Landsat-4 and an earlier Landsat were simultaneously recorded. Three scene pairs of simultaneous coverage were ordered for comparisons (Table 1). In all cases of same date coverage, the scene pairs were acquired within three minutes or less of each other. This is effectively simultaneous coverage. Any differences between scenes can then be assumed to be solely a function of sensor differences, as atmospheric effects, sun angle, and scene content will be identical between scenes. This assumption is made, but does not completely hold true in the case of the San Francisco data because the atmosphere is likely to have changed between dates. The time of acquisition in GMT is shown in the last five digits of the scene ID. All data were acquired in the EDIPS A-tape format (radiometric corrections only) rather than the P format (geometric correction) in order to prevent degradation of data characteristics through resampling. The Landsat-4 scene of southeast New Mexico was also ordered in the P-tape format in order to assess how well EDIPS geometric processing corrects for some geometric irregularities noted in the various Landsat-4 MSS data sets. Of the four Landsat-4 scenes, it appears probable that the Thematic Mapper sensor was turned on concurrently with the MSS in all but the San Francisco acquisition (which was acquired before West Coast TM data acquisition began).

Table 1. MSS Data Selection.

| Location | Sensor | Date | Scene ID | Path, Row |
|---|---|---|---|---|
| San Francisco | 4 | 10/12/82 | 84008818134 | 44,34 |
| | 3 | 10/08/82 | 83167818102 | 47,34 |
| | 2 | 10/04/81 | 82244718013 | 47,34 |
| Southeast New Mexico | 4 | 11/09/82 | 84011617005 | 32,37 |
| | 2 | 11/09/82 | 82284816571 | 34,37 |
| Connecticut | 4 | 12/22/82 | 84015915012 | 13,31 |
| | 3 | 12/22/82 | 83175314594 | 14,31 |
| New Hampshire | 4 | 12/22/82 | 84015915010 | 13,30 |
| | 3 | 12/22/82 | 82175314591 | 14,30 |

## RADIOMETRIC ANALYSIS USING SCATTERGRAMS

The method of analysis was to co-register 512 by 512 pixel subwindows for all data pairs followed by scattergram generation and analysis. In all cases, the Landsat-4 data were used as the base to which other images were registered. Manually selected control points were acquired by visual examination of the data using a color video monitor. The control point pairs were input into a registration function that was used to register the data.

Scattergrams were generated between images for each band. These scattergrams plot the digital number (DN) found for each point in Landsat-4 against the DN recorded for that location in Landsat-2 or 3. Mode (maxima) values were derived from the scattergrams (y-axis modes for fixed x values as well as x-axis modes for fixed y values) and used to visually fit a linear regression (automated regression calculations were distorted by outliers). The regression line represents the relative radiometric transfer function relating Landsat-4 MSS to earlier MSS radiometry. Data values plotted in the scattergrams are those recorded on the A-tapes (dynamic range of band 4 previously scaled from 0 - 63, is now rescaled to 0 - 127 in all data processed since 1979). Nearest neighbor resampling, rather than bi-linear or cubic convolution, was used in the registration to preserve the radiometric integrity of the data. Root mean sqaure (RMS) errors of the registrations varied between .1 and 1.5 pixels. The relatively large errors resulted from a line length error in the Landsat-4 MSS (discussed later). A rigorous registration was not deemed necessary for the radiometric assessment; because although misregistrations will increase the scattergram variance, they are unlikely to affect the trend of mode values.

Table 2. MSS Radiometric Calibration Information.

| | Landsat-2* | | Landsat-3* | | Landsat-4** | |
|---|---|---|---|---|---|---|
| | Radiance*** | | | | | |
| Band | Min | Max | Min | Max | Min | Max |
| 1 | .08 | 2.63 | .04 | 2.59 | .02 | 2.3 |
| 2 | .06 | 1.76 | .03 | 1.79 | .04 | 1.8 |
| 3 | .06 | 1.52 | .03 | 1.49 | .04 | 1.3 |
| 4 | .11 | 3.91 | .03 | 3.83 | .10 | 4.0 |

* reference 2.
** reference 3.
*** Radiance in the band in mW/cm**2*steradian

Radiometric calibration information is also available for each of the MSS sensors (ref. 2 and 3, and table 2). These can be used to predict the relative radiometric transfer functions between sensors. The predicted and actual transfer functions are listed in Tables 3, 4, and 5, and constitute the primary product of this study. The scattergram plots generated are shown in Figures 1 through 6.

CONCLUSIONS ON RADIOMETRY

The relative radiometric differences between Landsats -3 and -4 appear approximately the same as predicted by the calibration information. Comparisons of Landsats -2 and -3 (table 4), and -2 and -4 (table 3), however, show that the actual radiometry of Landsat-2 differs significantly from the calibration specifications. This may reflect drift in sensor sensitivity, optical degradation of the scan mirror and telescope, or changes in the radiance minimum and maximum constants used in ground processing. Often, changes in sensor calibration are not well disseminated and are thus unavailable to data users.

Standard processing since 1979 has decompressed band 4 data for all MSS senors, resulting in a data range of 0 - 127. This has been true for data from all the Landsat satellites, except for Landsat-4 MSS data processed between launch and October 23, 1982. Histograms of all data acquired for this study show values in band 4 ranging above 63, indicating that the radiance maximum (Rmax) has been set to 127 for all sensors and not just in Landsat-4 data.

While radiometric values for Landsats-3 and -4 appear roughly the same as predicted by the calibration specifications, the San Francisco scene pair shows the high degree to which atmosphere can affect relative readings of features on different days. Atmospheric effects (up to 12 digital counts bias added to signal in band 1) in the Landsat-3 scene have caused features to saturate to a much greater degree than in the corresponding Landsat-4 scene, or in other scene pairs (table 5).

The saturation of Landsat-4 at relatively low radiance levels (compared to Landsats-1, -2, and -3) in bands 1 and 3 may result in loss of useful information for some data applications, including change detection.

OTHER OBSERVATIONS

While in the process of generating scattergrams, several geometric artifacts were noted (figures 7 and 8). All bands of each Landsat-4 image contained noise interference patterns. These patterns appeared to have two components; diagonal striping with a period of about 3.5 pixels, and concentric arcs with a period of 10 - 12 pixels. Over water areas, the noise was noted to have a magnitude of 2 digital counts in band 4.

Sweep offsets were noted in all but the San Francisco Landsat-4 scenes (example shown figure 9). The San Francisco scene was acquired before Thematic Mapper data acquisition began on the West Coast. All other scenes fall in a time period during which it is probable that TM and MSS were turned on concurrently, indicating the problem may be related to sensor interactions. The offsets result from varying line lengths, and are readily corrected by stretching all lines to a constant length using line length information imbedded in the right edge of the image. The problem occurs only in A-format tapes and is corrected during the geometric processing applied to generate P-tapes.

## CONCLUSIONS

There appear to be no major problems preventing use of Landsat-4 MSS with previous MSS sensors for change detection, provided the interference noise can be removed or minimized. This noise may result in detection of spurious changes, as well as affect other uses of the data, including image classification. Analysis of dark (water and forests), rather than light, features will be most impacted because the noise will form a higher percentage of the total response at low DN values. The patterns are sweep dependent, and within a sweep it is not clear that they are completely systematic. The pattern is present even when TM is off. The problem was detected before launch (left uncorrected because of the cost of repair), and is caused by interference between the revised MSS power supply (the power bus on Landsat-4 is different than on previous Landsats) and the sensor's one kilohertz data quantitizer (ref. 4). The frequency of the interference is known to drift because of drift in power supply frequency (ref. 4). The identical problem has been identified in Landsat-D Prime and should be corrected.

Any data normalizations for change detection should be based upon the data, rather than solely upon calibration information. While the observed relative radiometric transfer function between Landsats-3 and -4 was approximately as predicted, there were still significant deviations (most noticable in band 3). Also, actual calibration specifications used in ground processing are not always made widely available, and published figures for Landsat-2 appear incorrect for recent data. The Landsat-4 specifications cited in this report (valid since August 1982) were not widely known until several months after their implementation. Normalizing based upon data content also can have the advantage of allowing simultaneous normalization of the atmosphere as well as the radiometry.

## REFERENCES

1. Likens, W., K. Maw. 1982. Updating Landsat-Derived Land-Cover Maps Using Change Detection and Masking Techniques. Technical Papers of the American Society of Photogrammetry, 1982 Fall Convention, Ft. Lauderdale, Florida.

2. Robinove, C. J. 1982. Computation with Physical Values from Landsat Digital Data. Photogrammetric Engineering and Remote Sensing. Vol. 48, No. 5, pp. 781-784.

3. Singh, A. 1983. Landsat-4 MSS Radiometric Correction: Methods and Results. Landsat-4 Scientific Characterization Early Results Symposium (this volume). Goddard Space Flight Center, Greenbelt, MD.

4. Personal communication from Peter Malherbe, Electrical Engineer, General Electric.

Table 3. Digital values for selected radiances. Landsat-2 vs.-4 (MSS)

| | Predicted Corresponding Values | | Observed Corresponding Values* | | | |
|---|---|---|---|---|---|---|
| | | | New Mexico | | San Francisco | |
| | LS 2 | LS 4 | LS 2 | LS4 | LS 2 | LS 4 |
| Band 1 | 0 | 5 | 0 | 0 | 0 | 2 |
| | (.08mw/cm2ster) | | | | | |
| | 111 | 127 | 121 | 127 | 125 | 127 |
| | (2.3mw/cm2ster) | | | | | |
| Band 2 | 0 | 1 | 2 | 0 | 0 | 1 |
| | (.06mw/cm2ster) | | | | | |
| | 127 | 124 | 127 | 120 | 127 | 107 |
| | (1.76mw/cm2ster) | | | | | |
| Band 3 | 0 | 2 | 1 | 0 | 0 | 1 |
| | (.06mw/cm2ster) | | | | | |
| | 125 | 127 | 119 | 127 | 122 | 127 |
| | (1.3m2/cm2ster) | | | | | |
| Band 4 | 0 | 0 | 0 | 1 | 0 | 1 |
| | (.11mw/cm2ster) | | | | | |
| | 127 | 125 | 127 | 115 | 127 | 115 |
| | (3.91mw/cm2ster) | | | | | |

*Derived from linear regression of modes.

Table 4. Digital values for selected radiances.
Landsat-2 vs.-3 (MSS)

| | Predicted Corresponding Values | | Observed Corresponding Values* San Francisco | |
|---|---|---|---|---|
| | LS 2 | LS 3 | LS 2 | LS 3 |
| Band 1 | 0 | 2 | 0 | 0 |
| | (.08mw/cm2ster) | | | |
| | 125 | 127 | 117 | 127 |
| | (2.59mw/cm2ster) | | | |
| Band 2 | 0 | 2 | 0 | 0 |
| | (.06mw/cm2ster) | | | |
| | 127 | 125 | 120 | 127 |
| | (1.76mw/cm2ster) | | | |
| Band 3 | 0 | 3 | 0 | 0 |
| | (.06mw/cm2ster) | | | |
| | 124 | 127 | 127 | 118 |
| | (1.49mw/cm2ster) | | | |
| Band 4 | 0 | 3 | 0 | 0 |
| | (.11mw/cm2ster) | | | |
| | 124 | 127 | 120 | 127 |
| | (3.83mw/cm2ster) | | | |

*Derived from linear regression of modes.

Table 5. Digital values for selected radiances.
Landsat-3 vs.-4 (MSS)

| | Predicted Corresponding Values | | Observed Corresponding Values* | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | New Hampshire | | Connecticut | | San Francisco | |
| | LS 3 | LS 4 | LS 3 | LS4 | LS 3 | LS 4 | LS 3 | LS 4 |
| Band 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 2 |
| | (.04mw/cm2ster) | | | | | | | |
| | 112 | 127 | 119 | 127 | 115 | 127 | 127 | 120 |
| | (2.3mw/cm2ster) | | | | | | | |
| Band 2 | 0 | 1 | 3 | 0 | 0 | 0 | 0 | 1 |
| | (.04mw/cm2ster) | | | | | | | |
| | 127 | 126 | 127 | 125 | 127 | 127 | 127 | 107 |
| | (1.79mw/cm2ster) | | | | | | | |
| Band 3 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| | (.04mw/cm2ster) | | | | | | | |
| | 110 | 127 | 119 | 127 | 115 | 127 | 113 | 127 |
| | (1.3m2/cm2ster) | | | | | | | |
| Band 4 | 2 | 0 | 0 | 2 | 1 | 0 | 0 | 0 |
| | (.10mw/cm2ster) | | | | | | | |
| | 127 | 121 | 127 | 117 | 127 | 122 | 127 | 104 |
| | (3.83mw/cm2ster) | | | | | | | |

*Derived from linear regression of modes.

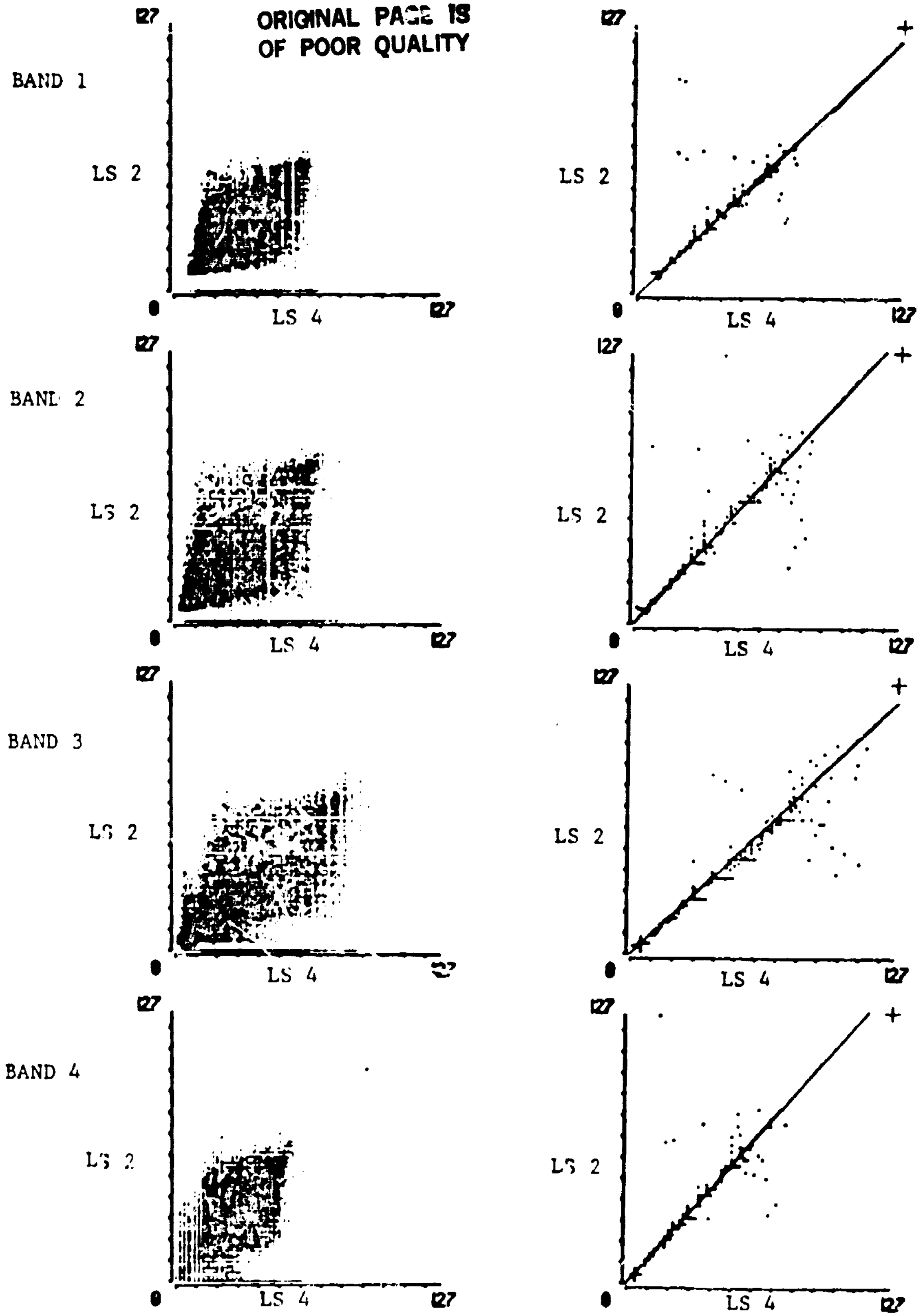


FIGURE 1. LANDSAT 2 vs. 4 MSS scattergrams (left) and maxima (right) for New Mexico scene pair acquired on Nov. 9, 1982.

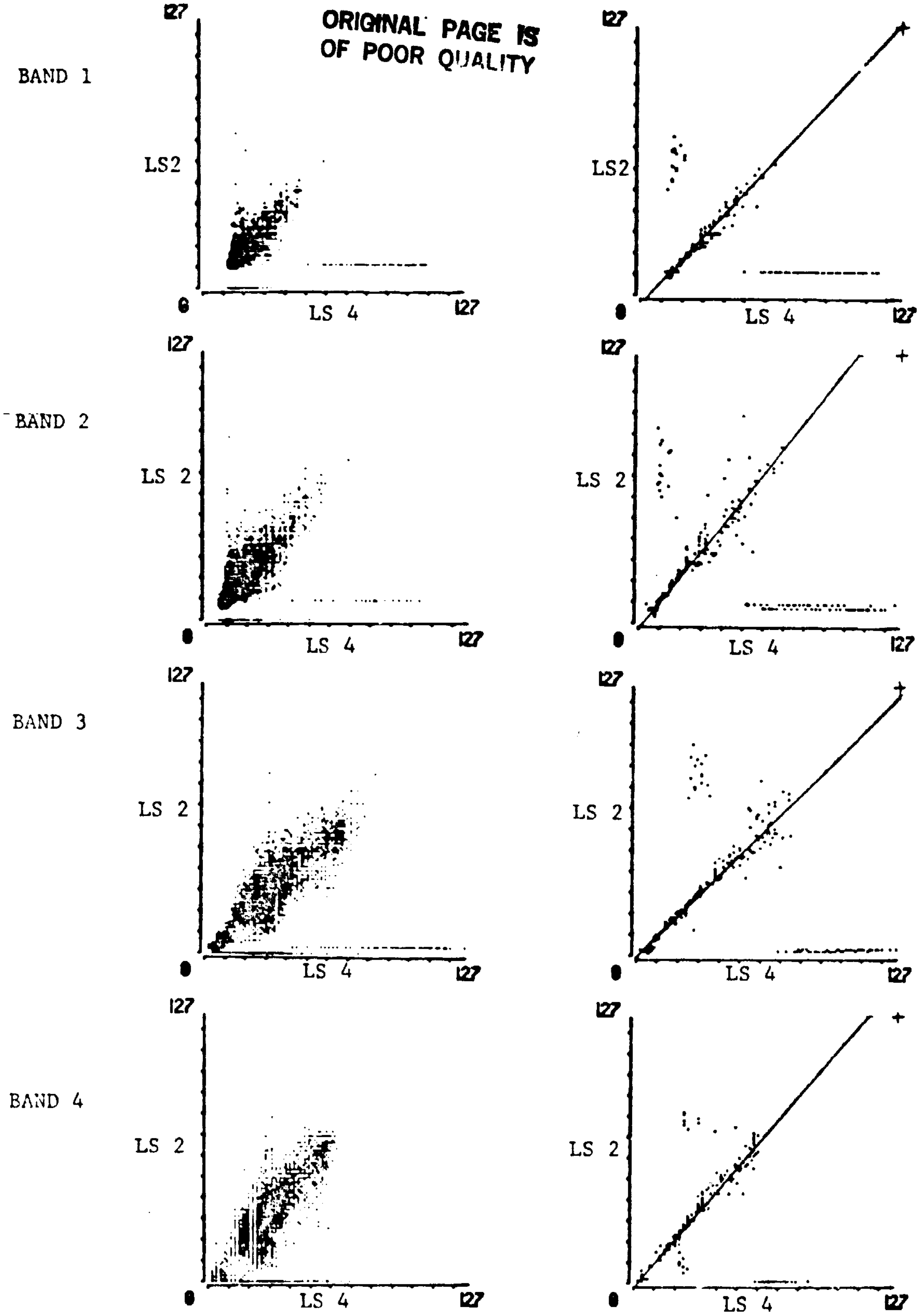


FIGURE 2. LANDSAT 2 (Oc ⁺, 1981) vs 4(Oct 12,1982) MSS spectral scattergrams (left) and maxima (right) for San Francisco scene pair.

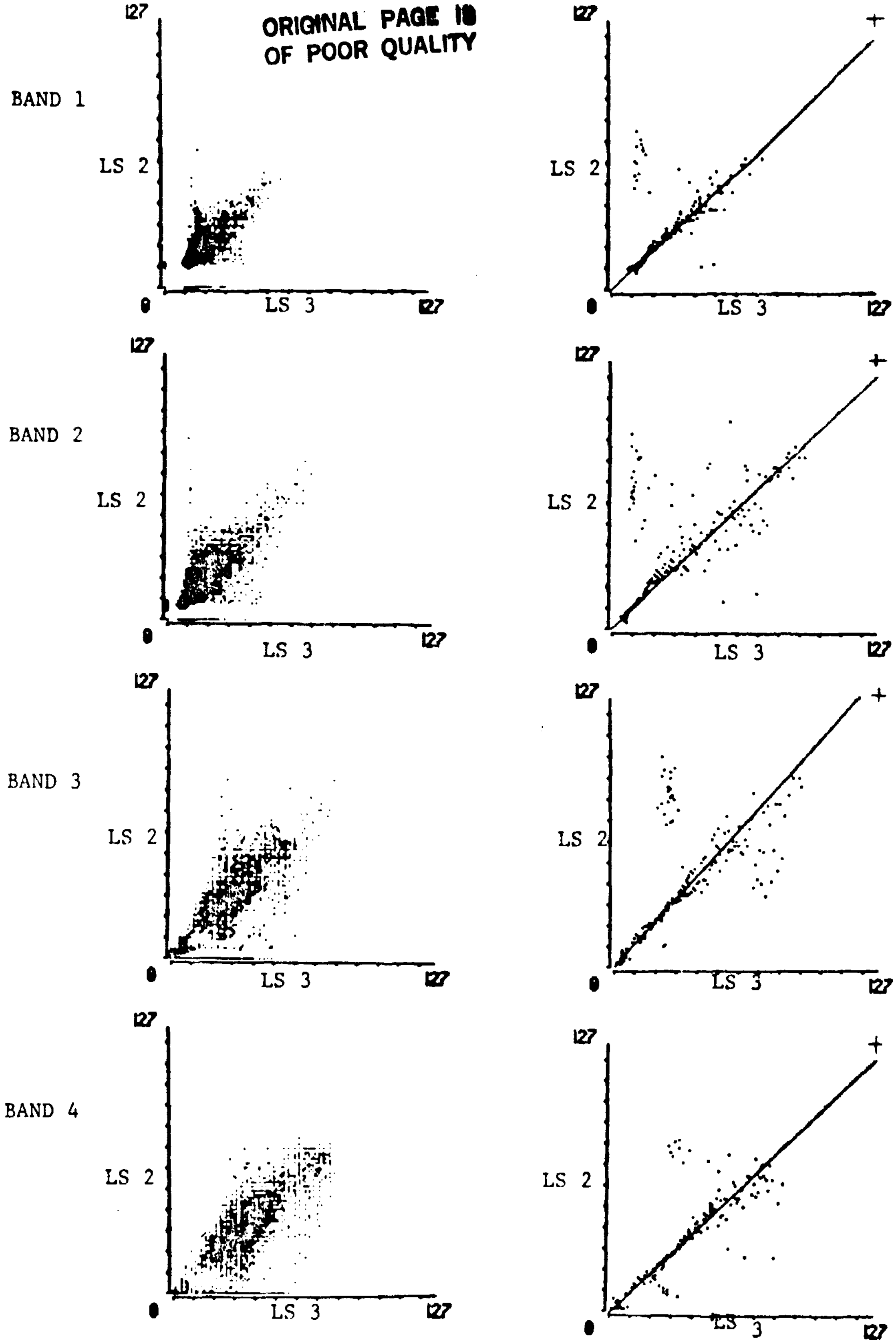


FIGURE 3. LANDSAT 2 (Oct 4, 1981) vs. 3 (Oct 8, 1982) MSS spectral scattergrams (left) and maxima (right) for San Francisco.

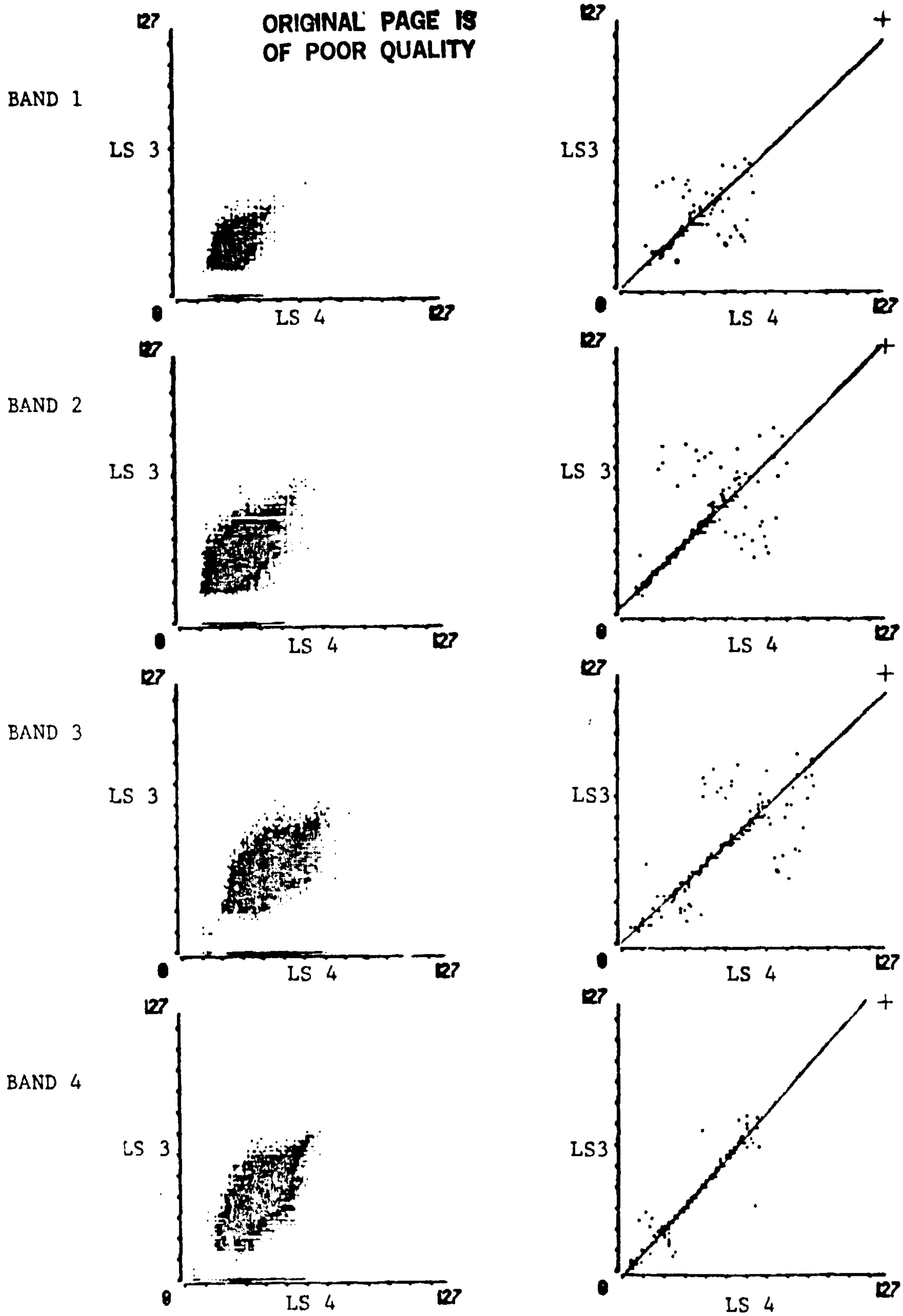


FIGURE 4 LANDSAT 3 vs 4 MSS spectral scattergrams (left) and maxima (right) for New Hampshire scene pair acquired on Dec. 22, 1982.

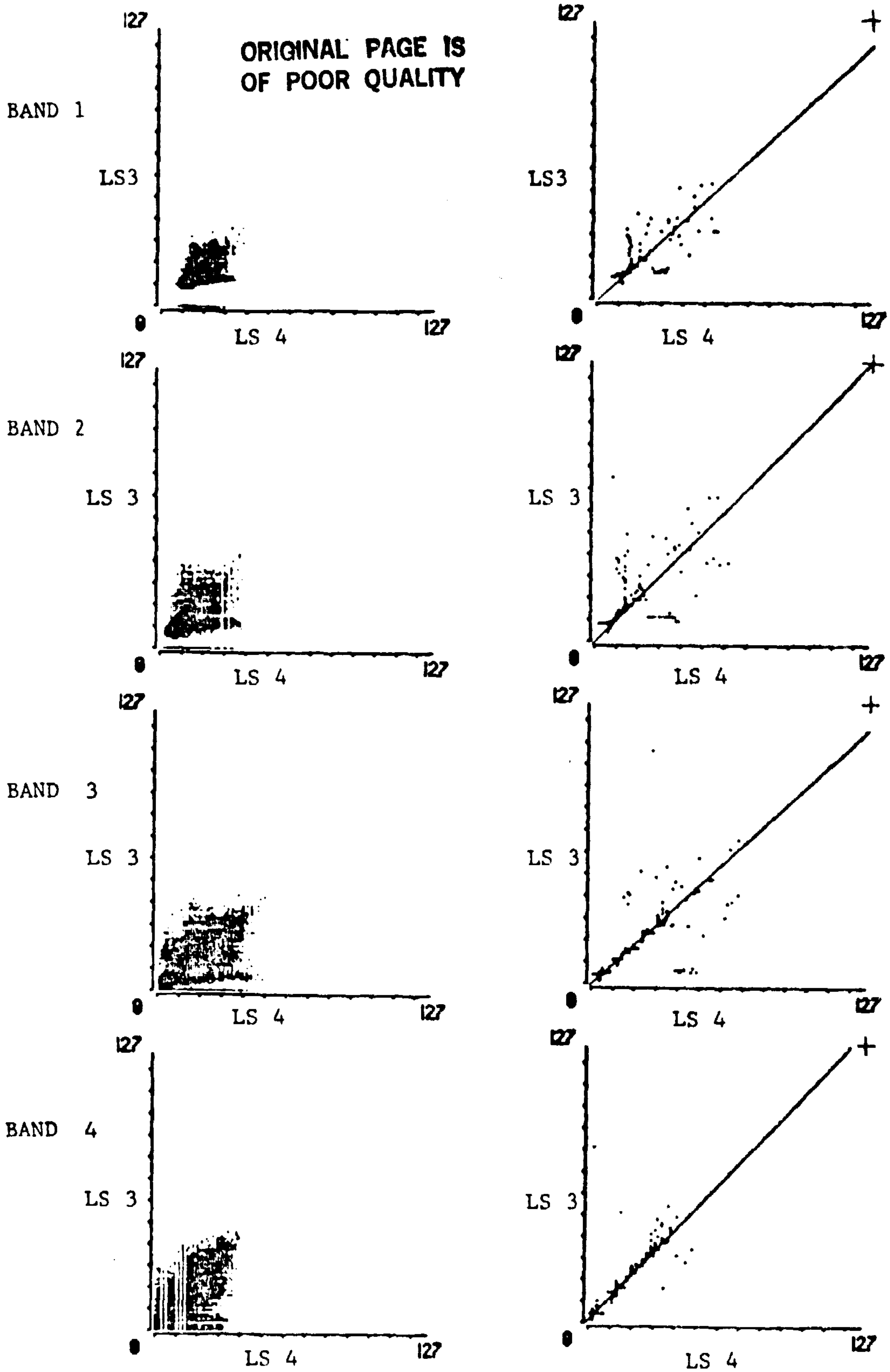


FIGURE 5. LANDSAT 3 vs 4 MSS scattergrams (left) and maxima (right) for Connecticut scene pair acquired on Dec. 22, 1982.

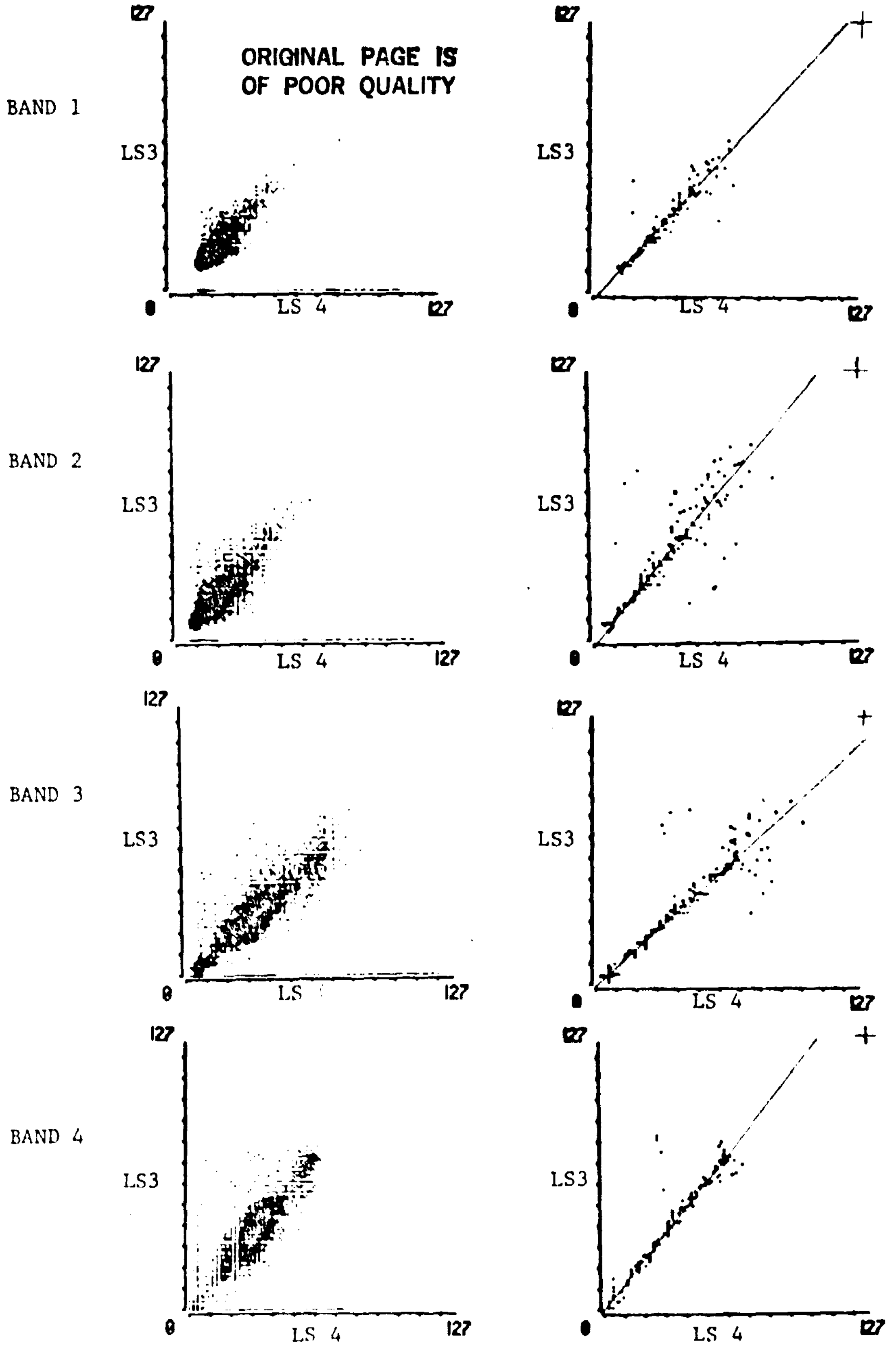


FIGURE 6. LANDSAT 3 (Oct 8, 1982) vs 4 (Oct 12, 1982) MSS spectral scattergrams (left) and maxima (right) for San Francisco.

FIGURE 7.

LANDSAT 4 MSS band 4 of Long Island subwindow of Conneticut scene. Enhanced to show interference patterns. The interference, shown here as black, is 2 digital counts brighter than the mean water value.

National Aeronautics and
Space Administration

**Ames Research Center**
Moffett Field, California 94035

ORIGINAL PAGE IS
OF POOR QUALITY

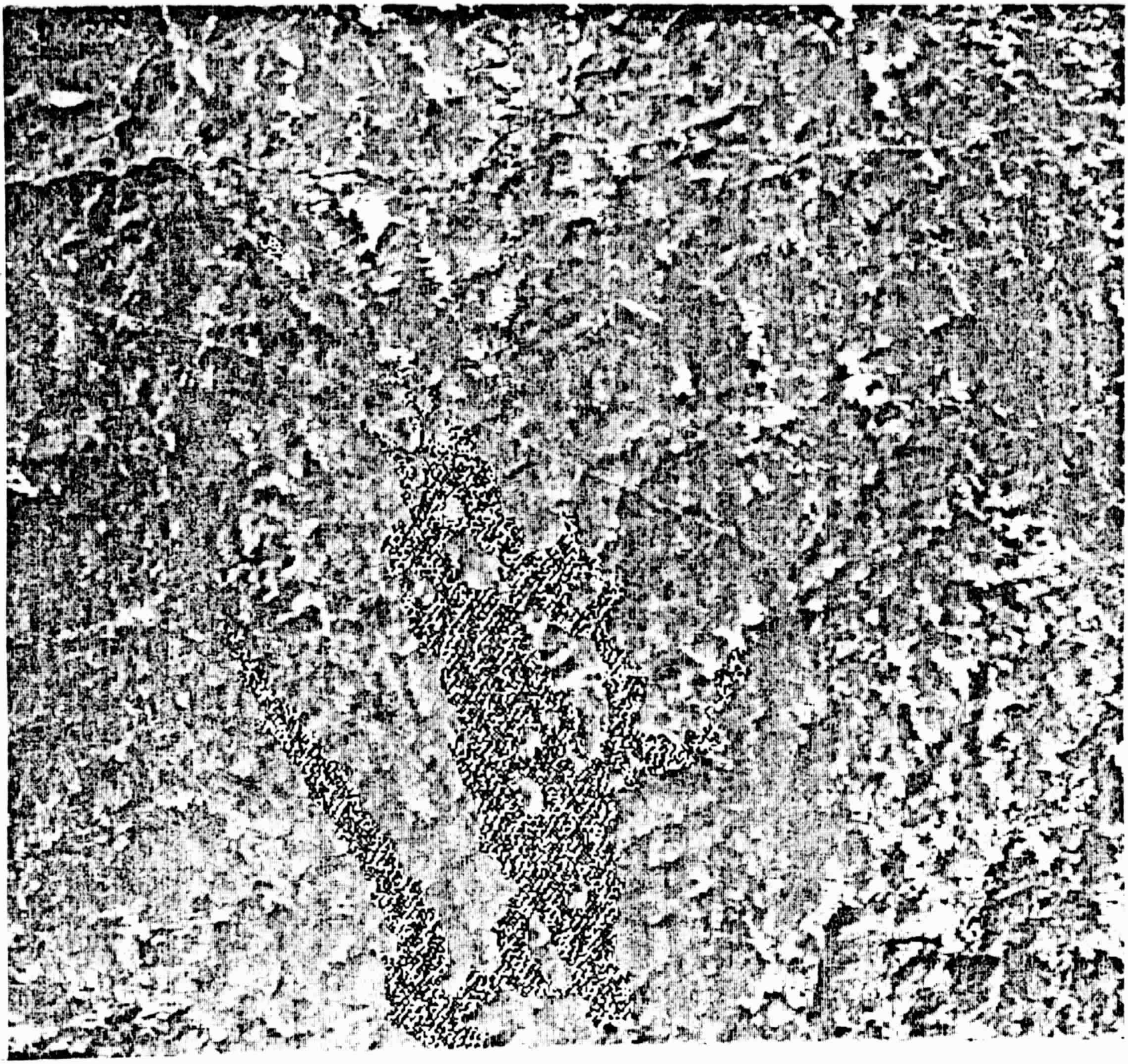

FIGURE 8.
LANDSAT 4 MSS band 4 subwindow from New Hampshire scene. Enhanced to show interference patterns visible in Quabbin Reservoir.

National Aeronautics and
Space Administration

**Ames Research Center**
Moffett Field, California 94035

ORIGINAL PAGE IS
OF POOR QUALITY

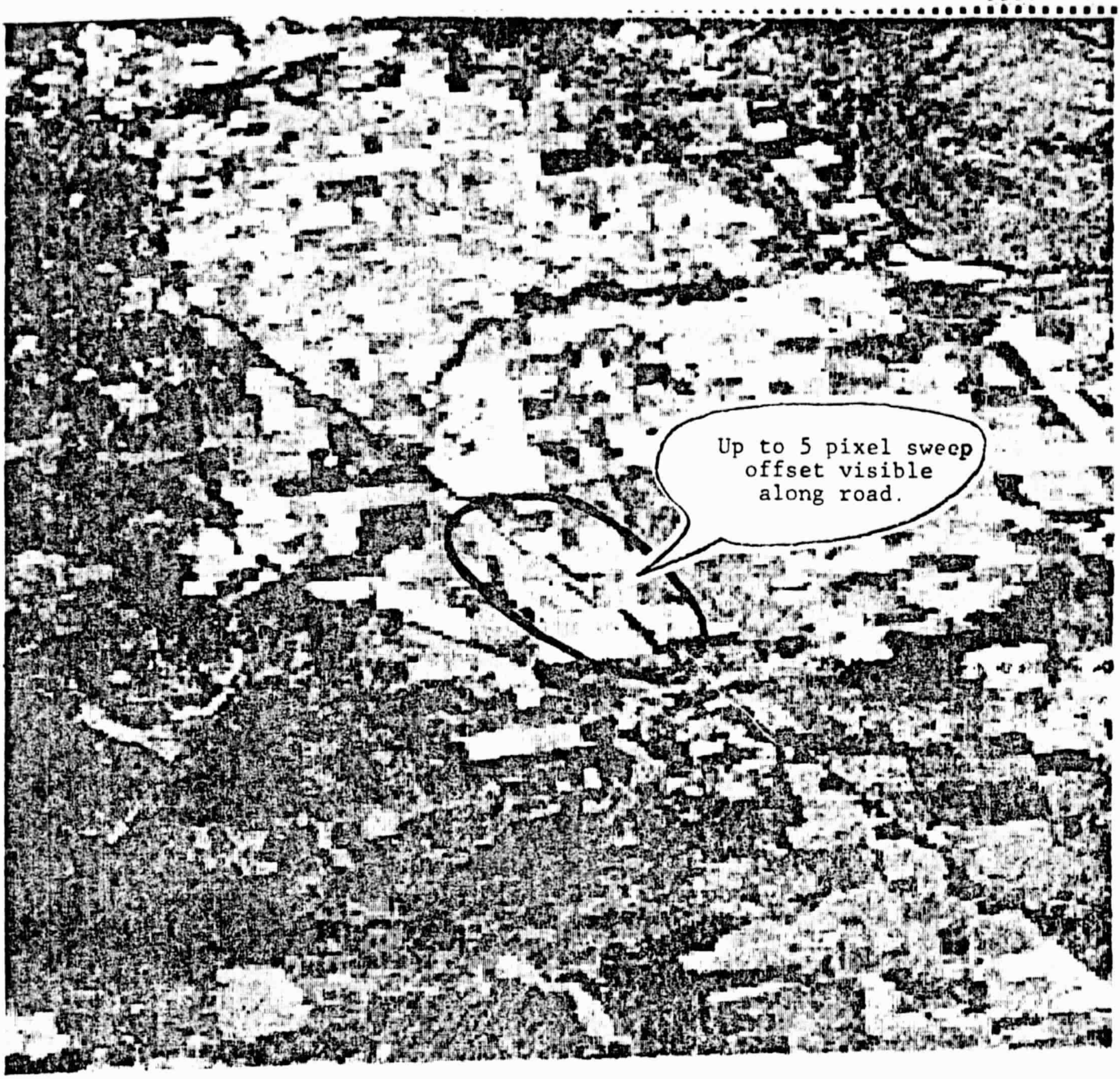


FIGURE 9. LANDSAT 4 MSS band 4 subwindow from southeast New Mexico showing sweep offset displacements along road.

National Aeronautics and
Space Administration

**Ames Research Center**
Moffett Field, California 94035