SOFTWARE VALIDATION TEST PLAN AND REPORT ENVI®, Version 4.1

Prepared for

U.S. Nuclear Regulatory Commission
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3/29/05
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1 SCOPE OF VALIDATION

ENVI® (the Environment for Visualizing Images) developed by Research Systems, Inc. (RSI), is an image processing software for visualization, exploration, analysis, and presentation of airborne and satellite remotely sensed images. The software has flexibility to design and implement any particular analysis strategies being an essential tool for image processing across a variety of disciplines.

This Test Plan and Report will validate four selected techniques, specifically:

- File Management
- Mosaicking DOQ Data
- Basic SAR Analysis
- Basic Multispectral Analysis using Multispectral and Hyperspectral Tools

Software validation of ENVI® should confirm that the software can correctly perform the above listed functions with original or RSI provided remote sensing data.

2 REFERENCES

ENVI, The Complete Remote Sensing Package, http://www.rsinc.com/envi/index.asp.

ENVI User's Guide, ENVI Version 4.1, September 2004 Edition, PDF document.

ENVI Tutorials, September 2004 Edition, PDF document.

3 ENVIRONMENT

3.1 Software

- System: Microsoft® Windows XP Professional

3.2 Hardware

- Computer: Intel® Pentium 4
- CPU 2.8 GHz
- Memory: 496 MB RAM

4 PREREQUISITES

None.

5 ASSUMPTIONS AND CONSTRAINTS

None.

6 TEST CASES

6.1 File Management

6.1.1 Objective

Demonstrate that ENVI® can handle a variety of satellite image formats. ENVI should identify and read a large number of image formats including GeoTIFF, JPEG, BMP, HDF, BSQ, ERDAS Imagine (.img) and MrSID. Those are the most common used image formats at the CNWRA.

6.1.2 Test Input

Remote sensing datasets: IKONOS PAN/MSI data, product 72309, IR band, (IMG and MrSID) courtesy of spaceimaging.com; Landsat 4 TM WRS-2, Path 040, Row 034, band 4, June 29, 1989, (GeoTIFF, BMP, JPEG) courtesy of the University of Maryland–Global Land Cover Facility; ASTER data AST_L1B SC:AST_L1B.003:2003286125 data (HDF) courtesy of NASA, GSFC, MITI, ERSDAC, JAROS and the U.S./Japan ASTER Science Team; and RSI's RADARSAT bonnrsat.img (BSQ) and RSI's Landsat TM can_tmr.img (BSQ) test data. All images with the exception of ILONOS data are available in the data directory.

6.1.3 Test Procedure

1. Open ENVI 4.1 and Select **File** > **Open Image File.**

2. When the **Enter Data Filenames** dialog appears, change the browsing location to **ENVI_validation Data** directory and select each individual file available for testing (use SHIFT button to select all datasets at once or CTRL button for individual selection). Those files are: bonnrsat.img, can_tmr.img, landsat_p040r34_t890629.bmp, landsat_p040r34_t890629.jpg, landsat_p040r34_t890629_nn4.tif, nir_72309_jan01.img, nir-72309-jan01.sid, pg-PR1B0000-2001062102_114_001. Select **Open**. ENVI automatically extracts the header information and enters the image bands into the Available Bands List Window. Resize the Available Bands List Window to see the content of each dataset. Please note the variability in the number of bands (e.g., one band for bonnrsat.img, landsat_p040r34_t890629_nn4.tif, nir_72309_jan01.img, -PR1B0000-2001062102_114_001 versus multiband datasets for the rest of the files) spatial sizes (ASTER data has two spatial sizes which are packaged as two separated datasets) and geo-information (the .jpg, .bmp, can_tmr.img and bonnrsat.img datasets are not georeferenced, the rest have UTM, Zone 11N projection).

3. Load each monoband dataset as a **Gray Scale** image and multiband images as **RGB Color** images. Do this by using the following steps.

a. For a monoband dataset: Click the **Grey Scale** button. Select the band inside the dataset. For example, select Band_1 for the nir_72309_jan01.img. Click **Load Band** button. Repeat the step for the next multi-band dataset.
b. For a multiband dataset: Click the **RGB Color** button. Pair any three dataset bands to the RGB guns. For example, to display a Landsat TM RGB color composite using bands 3,2,1, click **R** and then click the **TM Band1** (0.4850); **G** and then **TM Band 2** (0.5600); and **B** and **TM Band 3** (0.6600). Click **Load RGB** button. Repeat the step for the next multiband dataset.

4. Close all opened datasets by selecting **Close All Files** option under **File** menu in **Available Bands List** dialog.

6.1.4 Test Results

PASS/FAIL: The test is successful if all required results are obtained in Section 6.1.3.

This test **PASSED.** The following comments substantiate the PASSING grade.

- ENVI correctly displayed original geospatial datasets. Problems could exist if the Header Info Dialog is displayed, instead of the Available Bands List window.
- The GeoTIFF, HDF and ERDAS Imagine and MrSID files had correctly displayed the geographic information (all these datasets have a UTM projection, and Zone 11N).

Tester: Debora Waiting Deborah Waiting Test Date: 3/21/05

6.2 Mosaicking DOQ Data

6.2.1 Objective

Demonstrate that ENVI can correctly (i) mosaic two digital orthophoto quarterquads (DOQ) datasets into a single composite image and (ii) resample data to a different pixel size. The correctness of mosaic's registration will be checked against ESRI® Texas roads dataset.

6.2.2 Test Input

Two data files named 2998282b.tif and 2998281b.tif are used in this test. Those files correspond to two adjacent DOQs (i.e., the East and West Castle Hills quads, 2998 block degree, Bexar County, TX). Each DOQ is a 2.5-meter ground resolution, quarter-quadrangle (3.75-minutes of latitude by 3.75-minutes of longitude) image. These files are provided in a Universal Transverse Mercator Projection (UTM) with North American Datum of 1983. The geographic extent of each DOQ is equivalent to a quarter-quad plus approximately 300 meters margin area. Both files (2998281b.tif and 2998282b.tiff) were previously downloaded and placed in the ENVI_validation Data directory. The Data directory contains also the ESRI Texas major roads vector dataset component of the 2000 ESRI Data & Maps CD, previously re-projected from Geographic Coordinates to UTM Zone 14.

6.2.3 Test Procedure

1. Open the test data files by selecting **File** > **Open Image File** option in the Available Bands List dialog window. Select the 2998282b.tif file then hold down the Shift key and select the 299821b.tif file.

2. Select the Georeferenced mosaicking function by selecting **Basic Tools** > **Mosaicking** > **Georeferenced** from the ENVI main menu. The Map Based Mosaic dialog appears.

3. Select **Import** > **Import Files**. Using the Shift key, select the two available files. Click **OK**.

The two images will automatically be placed in their correct geographic locations within the Mosaic Preview display. In this display, the images have independent 2% contrast stretches applied by default.

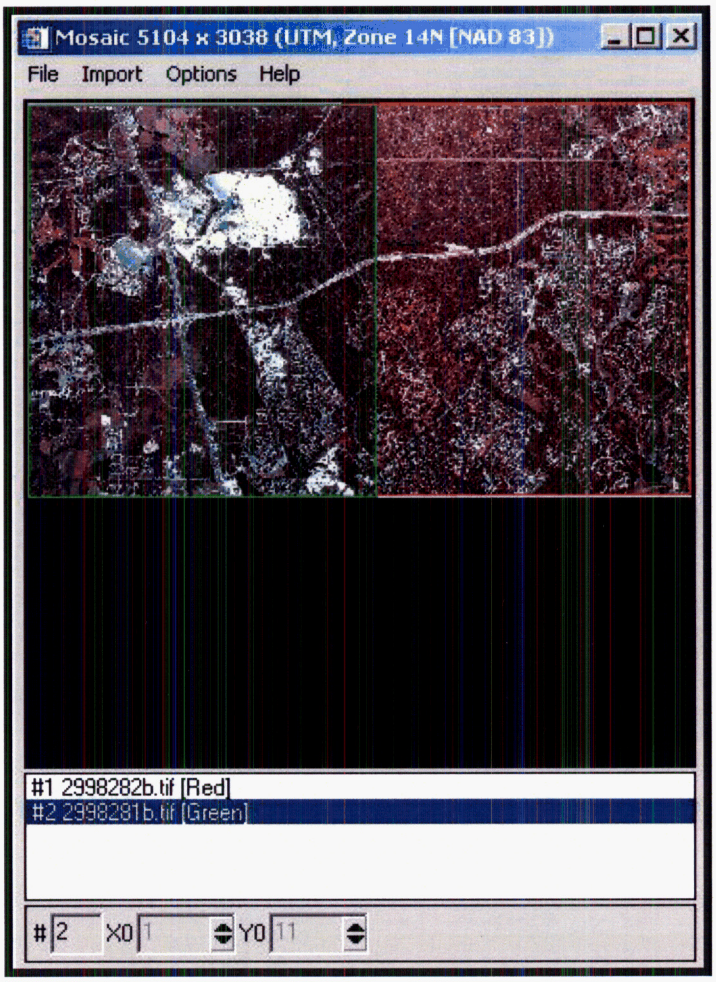

Figure 1. The Mosaic Dialog

5. Notice the contrast between the two images (e.g., the 2998281b.tif image with the green outline is slightly darker than the 2998282b.tif image with the red outline). With ENVI, color balancing can be performed by doing the following:

   a. In the Mosaic dialog, right click on the 2998281b.tif filename and choose **Edit Entry**.

   b. Select **Adjust** on the **Color Balancing** to define this dataset as the one for which the contrast adjustment will be performed. Choose **OK**.

   c. Right click on the name of the 2998282b.tif file, and choose **Edit Entry**. In the resulting dialog, under **Color Balancing**, choose **Fixed**. This indicates that the contrast of this image will not be changed. Choose **OK**.

   d. From the **Mosaic** dialog choose **File** > **Apply**.

   e. In the resulting **Mosaic Parameters** dialog, there is now a **Color Balance using** option near the bottom. Leave this value at **stats from overlapping regions**.

6. Use the **Choose** button to locate the ENVI validation Output directory. Enter mosaic.img as the name for the output filename. Set 5.00 m as the new values for the **Output X** and **Output Y** pixel sizes. Choose **OK**. The resulting mosaic will be entered into the **Available Bands List** when it is finished.

7. Display the new mosaic in an RGB display with Mosaic (Band 1) as red, Mosaic (Band 2) as green, and Mosaic (Band 3) as blue. Note that the contrast between the two images is much less visible (Figure 2).

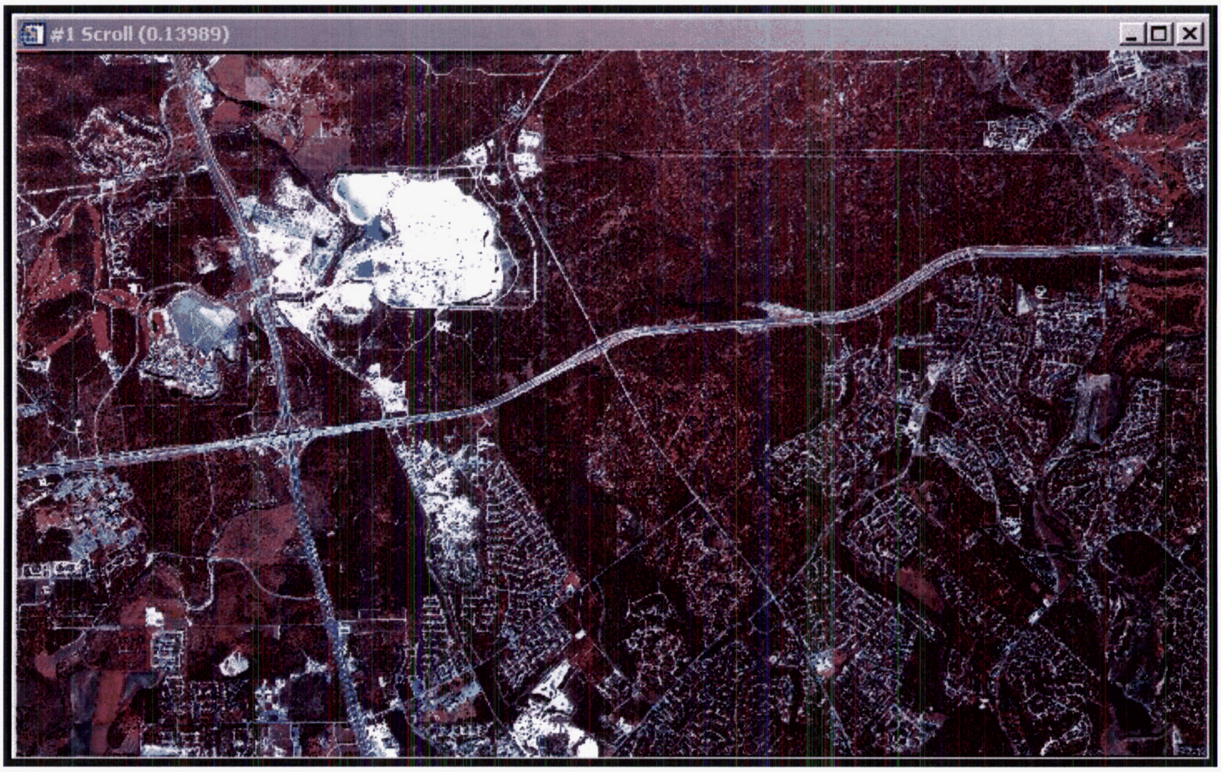

Figure 2. The Result of the Mosaicking Process

8. From the Image Menu select **Overlay** > **Vectors**. In the **Vector Parameters: Cursor Query** dialog click **File** > **Open Vector File**. Change the **File of type** to Shapefile (*.shp). Navigate to ENVI_validation Data directory, and select the txrds.shp file. Click **Open**. In the **Import Vector Files Parameters,** click the **OK** button**.** The roads will be loaded and displayed in white over the DOQ mosaic. To change the color, select **Edit** > **Edit Layer Properties** in the **Vector Parameters: Cursor Query** dialog. Right click the Color button. From **Items 1:20** select color Green. Click **OK** in the **Edit Vector Layers** window**.**

9. Visualize the overlay between the vector layer and the DOQ mosaic image.

10. Close all open datasets by selecting Close All Files option under **File** menu in **Available Bands List** dialog.

6.2.4 Test Results

PASS/FAIL: The test is successful if all required results are obtained in Section 6.2.3.

This test **PASSED.** The following comments substantiate the PASSING grade.

- ENVI correctly mosaicked the DOQ images. The contrast between the two DOQ datasets almost disappeared when the color balancing technique was used.

- ENVI correctly overlaid the road data on top of the DOQ mosaic image. The eventual misalignments were expected because the ESRI dataset has a much coarser accuracy compared to the pixel size of the DOQ images (i.e., the ESRI dataset meets the National Map Accuracy standards of +/- 167 feet).

Tester: Deborah Waiting Deborah Waiting Test Date: 3/21/05

6.3 Basic SAR Analysis

Radar remote sensing has a number of advantages over the optical remote sensing because it allows obtaining data virtually under any time and conditions. Because radar and optical systems operate in different parts of the electromagnetic spectrum (e.g., optical systems operate in the 0.4–12 um and radar in the 0.8–100 cm range), the inferred characteristics of the surface materials have no direct relationship one to another. However, this complementarity is mostly beneficial providing additional insights about the nature of surface materials. One of the most used radar remote sensing data types is the Synthetic Aperture Radar (SAR) data, subject of this test. SAR proved to be essential in a large variety of applications from geology and agriculture to ocean and sea ice. Recently, by exploring phase information on pairs of SAR data, ground subsidence could be measured with centimeter or even millimeter accuracy. Those techniques (i.e., radar interferometry techniques) open the possibility of using SAR data in other areas, such as earthquake or subsidence monitoring (like the ones caused by mining activities, tunneling, or fluid dynamics).

6.3.1 Objective

Demonstrate that ENVI can correctly perform basic single-band SAR data analysis. The following components will be tested:

- Browsing the SAR Data Header Information
- Ingest Verification
- Contrast Stretching, Adaptive Filters
- Speckle Reduction
- Density Slicing

This test is using the steps described in the "Multispectral Classification" section of the ENVI Tutorials handbook.

6.3.2 Test Input

Data used for the test is a subset of a RADARSAT 1 Path Image, Fine Beam 2, December 17, 1995, Bonn, Germany. This image (e.g. *bonnrsat.img*) is part of the ENVI test dataset. For convenience, a copy of it was placed in the **ENVI_validation Data** directory

6.3.3 Test Procedure

1. Read and display SAR header data. The information listed in the header file is needed for the situations when in-depth InSAR processing is performed.

   a. Open the data files by selecting **File** > **Open Image File**. Select the bonnrsat.img then load it as a Gray Scale image (see Paragraph 6.1.3). To enhance the image (use the **Enhance** option on the ENVI pull-down menu) apply different stretching techniques such as **Equalization** and **Square Root**. Note the changes in the brightness characteristics of the image.

   b. Select **Radar** > **Open/Prepare Radar File.** Select **View Radarsat Header** and open the bonnrsat.001 file. The header information displayed in the **CEOS Header Report** window should be similar to the one shown in Figure 3.

c. Close the **CEOS Header Report** window.

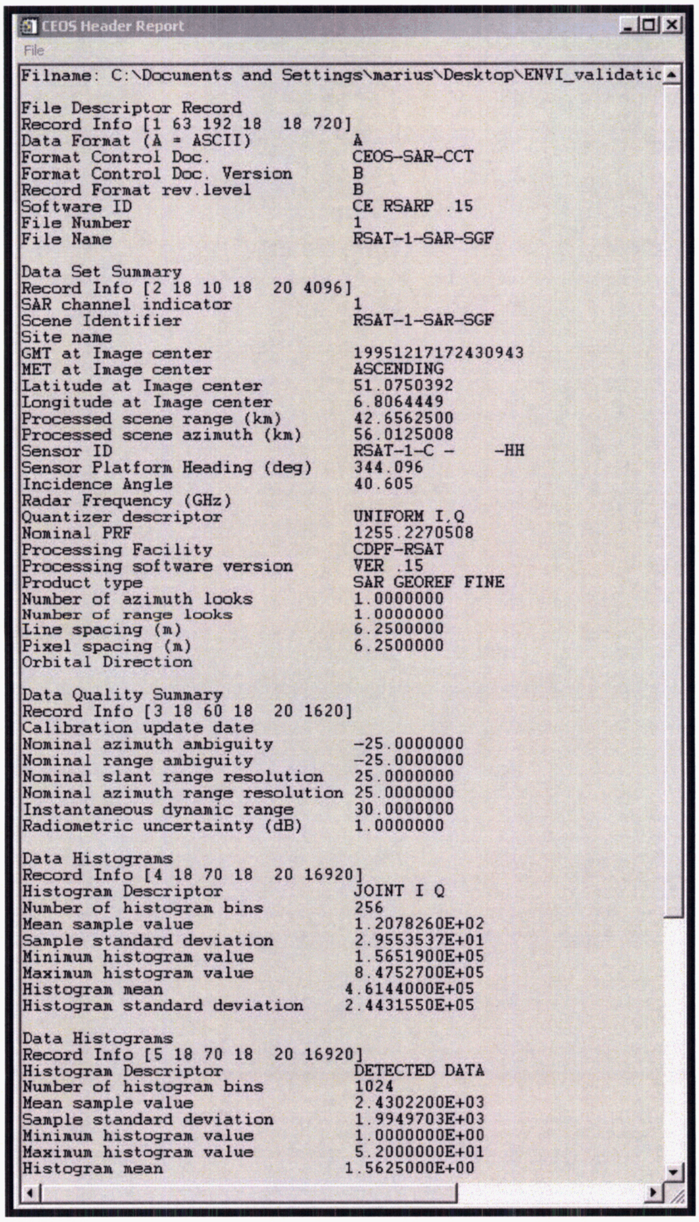

Figure 3. RADARSAT Header Information

2. Remove the noise (speckle) in ERS data using the **Frost** adaptive filter.

One of the problems associated with radar data is the presence of noise. The noise is inherent in a SAR system, due to the coherent nature of the radar signal. In this test, a **Frost** filter is used to reduce speckle while preserving the edges in the data. The filter replaces the initial value of a pixel, which is a value calculated based on the distance from the filter center, local variance, and the *dampling* factor. Steps to apply the **Frost** filter to the RADARSAT image follow.

a. Apply a 2% stretch to the image displayed in Display number 1. Use **Enhance** > **[Scroll] Linear 2%**.

b. On the **Available Bands List** dialog, click **Display number 1**, then **New Display**. A new empty display is created. Minimize the **Available Bands List** dialog.

c. Select **Radar** > **Adaptive Filters** > **Frost**. Choose bonnrsat.img as the input image and use the default 3x3 filter size with a *Damping* factor of 1. Enter an output filename in the ENVI validation Output directory and click **OK**. Load the newly created file in Display number 2.

d. Select **Tools** > **Link** > **Link Displays** to link the Frost filtered image with the 2% linear stretch image shown Display number 1. In the **Link Displays** dialog, click the **OK** button. Click the left mouse button in any linked window to visualize the effect of the adaptive filter.

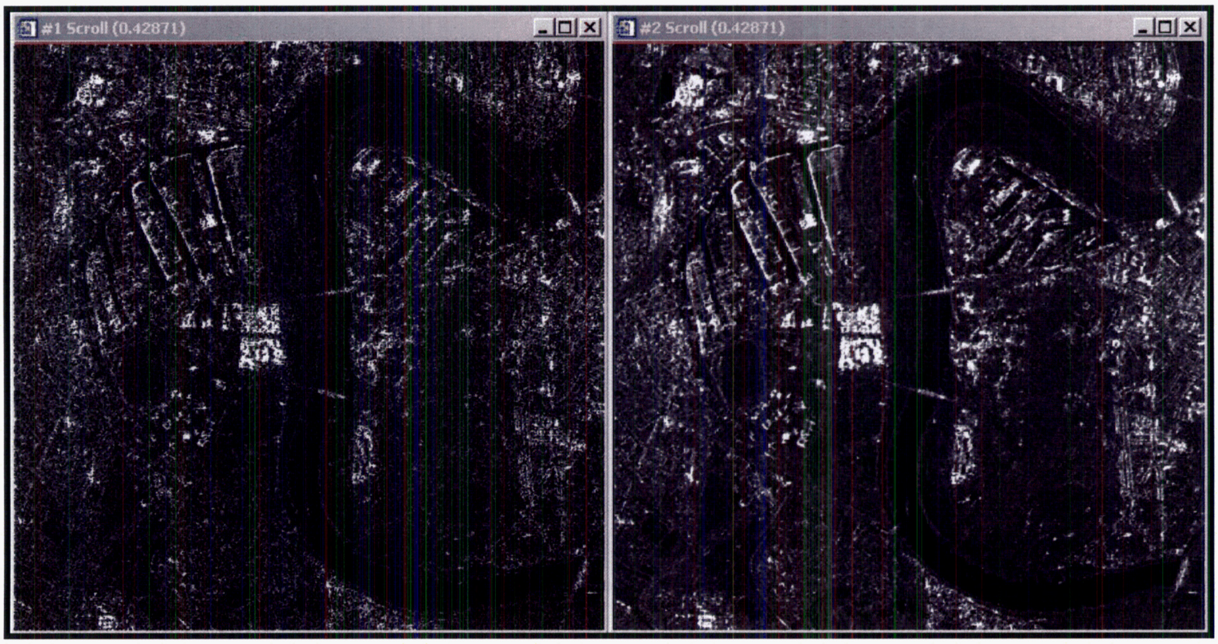

Figure 4. RADARSAT Image. Left 2% Stretch Image. Right After Applying a Frost Filter, 3x3 Window Size with a Dampling Factor of 1.

3. Density Slice.

This technique allows visualization of radar differences using a colormap constructed based on a priori assignment of colors to image brightness intervals. The test will create a density sliced image with four levels, with higher radar backscatter values presented in the warmer colors.

a. In the Frost Filtered image display, choose **Tools** > **Color Mapping** > **Density Slice**. Click **OK**.

b. In the newly created window, the number of default ranges is 8. Change it (**Options** > **Set Number of Default Ranges**) to a different number and then click

Clear Ranges. Calculate the new density slice ranges (**Options** > **Apply Default Ranges**) and click the **Apply** button.

c. Display the radar image using a pre-defined range scheme. From the **Density Slice** window choose **File** > **Restore Ranges** and select the dslice.dsr file. Click **Open**. Four slice ranges should show in the **Defined Density Slice Ranges**. Click **Apply** in the Density Slice dialog to update the image.

d. Note the feature patterns and colors on the image and compare them with Figure 5.

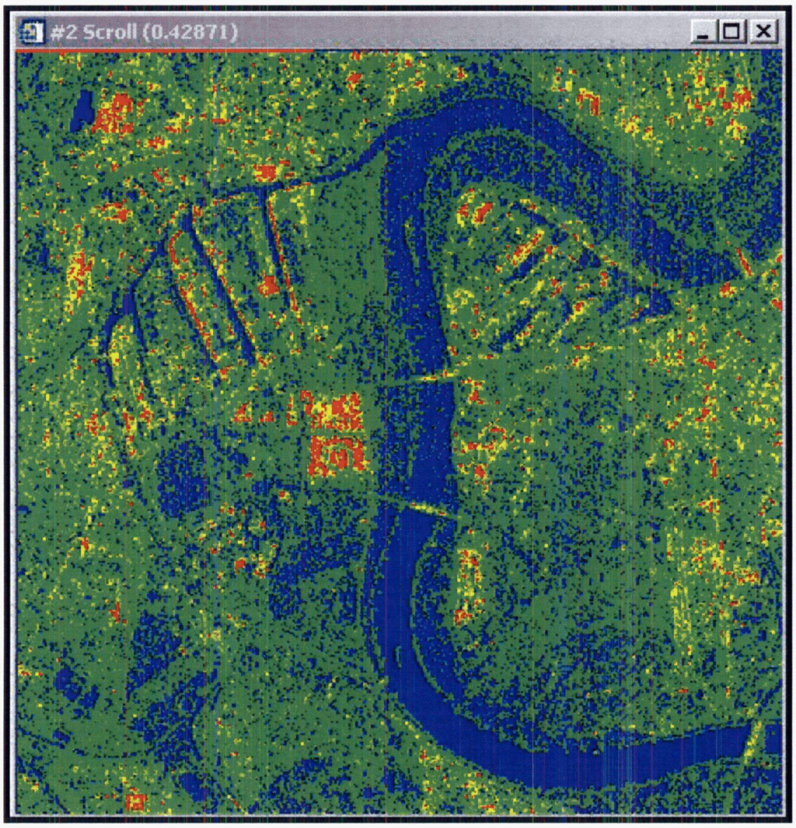

Figure 5. Density Slice Technique Applied to the RADARSAT Image

4. Close all opened datasets by selecting **Close All Files** option under **File** menu in **Available Bands List** dialog.

6.3.4 Test Results

PASS/FAIL: The test is successful if all required results are obtained in Section 6.4.3.

This test **PASSED.**

Tester: Deborah Waiting Deborah Waiting Test Date: 3/21/05

6.4 Basic Multispectral Analysis using Multispectral and Hyperspectral Tools

6.4.1 Objective

This test demonstrates ENVI's ability to perform a multispectral analysis. Results from an unsupervised (IsoData) and supervised (parallelepiped) classification will be first examined. Finally, the test will evaluate the accuracy of classification by comparing it with the one generated by RSI.

This test is based on the "Multispectral Classification" section of the ENVI Tutorials handbook.

6.4.2 Test Input

Landsat Thematic Mapper (TM), ENVI test data from Canyon City, Colorado contained in the file can_tmr.img. This data is already converted from digital numbers (DN) to reflectance values. The dataset is part of the ENVI tutorial data, and a copy of it is conveniently placed in the **ENVI_validation Data** directory.

6.4.3 Test Procedure

1. Read and display Landsat TM Data.

Start **ENVI**. Open the data files by selecting **File** > **Open Image File**. Select the can_tmr.img file. Click sequentially on bands 4, 3, and 2. Click on the **Load RGB** button to load the image.

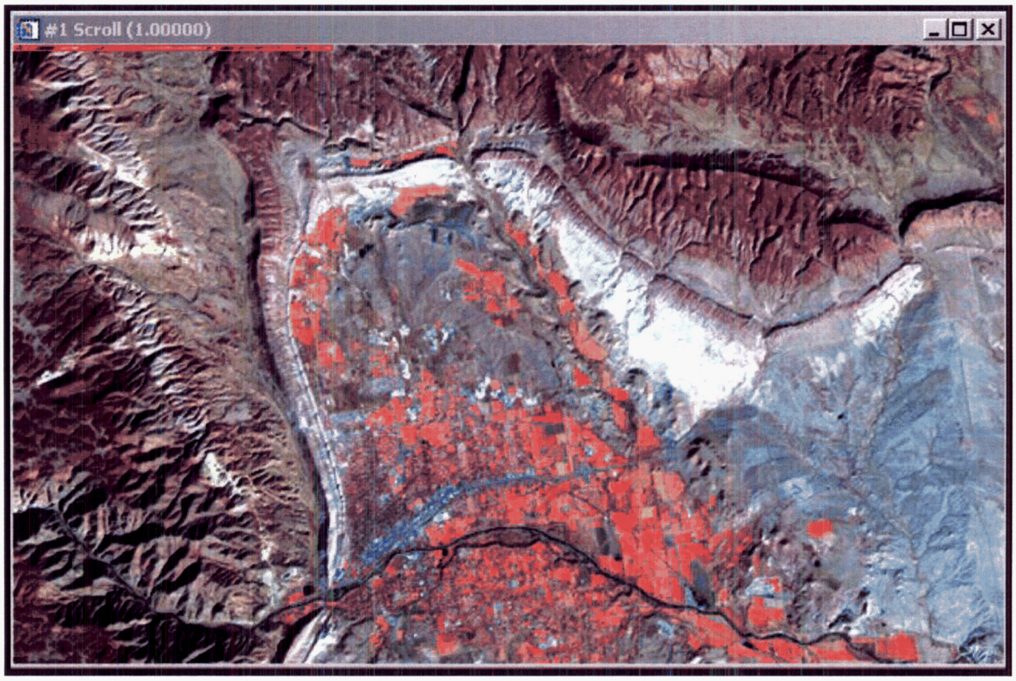

Figure 6. Landsat TM Color Composite R4, G3, B2

On a 4, 3, and 2 color-composite, bright red areas (which denote high infrared reflectance) correspond to healthy vegetation, along the rivers or under cultivation. In this image dataset, darker red areas correspond mainly to coniferous trees.

2. Performing an unsupervised classification

Unsupervised classification uses statistical techniques to group n-dimensional data into classes with similar characteristics. Knowledge of the terrain present in the scene, as well as its spectral characteristics, is needed to assign information to the newly obtained classes.

This test will perform an unsupervised classification using the Iterative Self-Organizing Data Analysis Technique (IsoData) clustering algorithm. IsoData uses a minimum spectral distance formula to form spectrally distinct clusters. The algorithm repeats the clustering of the image until either a pre-defined maximum number of iterations or a pre-defined maximum percentage of unchanged pixels have been reached between two consecutive iterations.

a. From the ENVI pull down menu, select **Classification** > **Unsupervised** > **IsoData**. On the **Classification Input File Dialog** choose the can_tmr.img file. Click **OK**. For the IsoData parameters use all of the default values. Select **Memory** for the **Output Result** and then click **OK**.

b. Open the Memory1 dataset in the available band list and choose **New Display** on the pull-down menu. Then click on the **Load Band** button.

c. Select **Tools** > **Link** > **Link Displays**. Click **OK** to link the IsoData classification with the color composite image.

d. Compare the new classification to the color composite image. First, in the IsoData window, define an area of visualization by clicking and dragging a rectangle using the middle mouse button. Then, using the left mouse button move the newly created window over the entire classification image. Note the association between the features identified in the color image and the IsoData classes (Figure 7).

e. Close all opened datasets by selecting **Close All Files** option under the File menu in **Available Bands List** dialog.

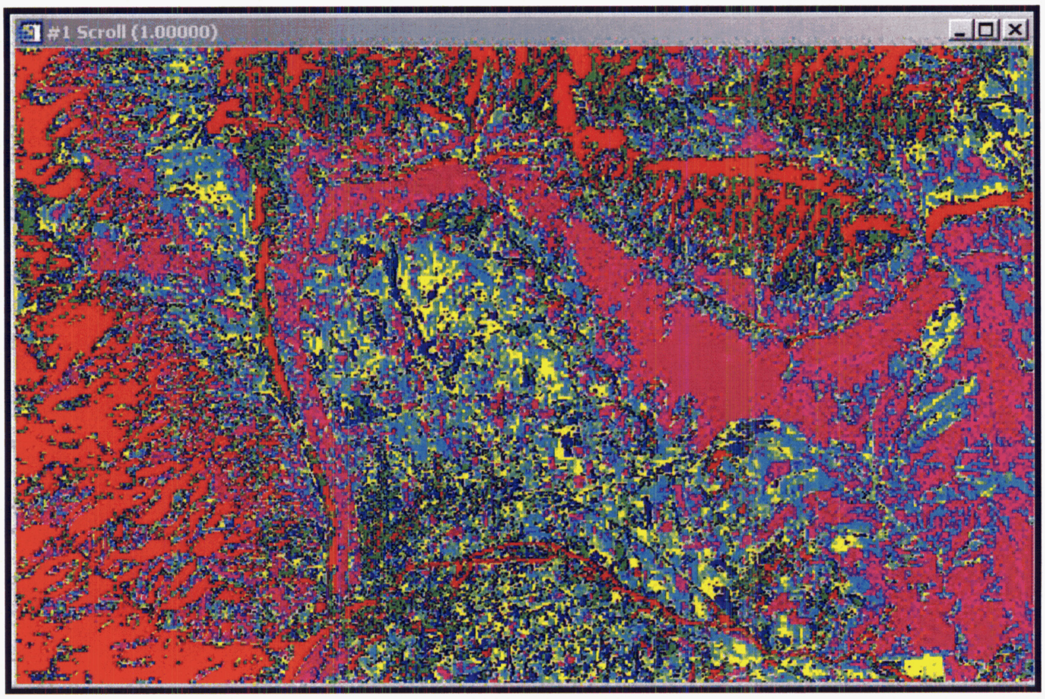

Figure 7. IsoData Classification

3. Performing a supervised classification.

Compared with an unsupervised classification, such as the one performed in Section 6.4.3, Number 2a, a supervised classification requires *a priori* selection of training areas. ENVI provides a broad range of traditional classification methods, including Minimum Distance, Parallelepiped, or Maximum Likelihood.

The test will use the Parallelepiped method as training areas, several predefined regions of interest (ROI). This method uses a simple decision rule to classify multispectral data. Based on this rule, the standard deviation threshold and the mean value of each selected ROI is used to define the decision boundaries of an n-dimensional parallelepiped in the image data space

Because the supervised classification requires knowledge of the area, this test will use training sites previously defined by RSI.

a. From the **Available Bands List** select the can_tmr.img dataset and load it as an RGB color imagine (Bands 4, 3, 2). See Section 6.1.3 for loading instructions for an RGB color image.

b. Restore ROI. From the **Image Viewer** menu bar, select **Overlay** > **Region of Interest**. In the **#1 ROI Tool** dialog choose **File** > **Restore ROIs**. The **Enter ROI Filename** dialog opens. Select CLASSES.ROI as the input file to restore. Click **Open**. In the **ENVI Message** window, note three regions that were restored. Click **OK**. In the **#1 ROI Tool**, delete the first record showing 0 Pixels and 0/0 Polygons.

Select the record by clicking the tab left of the **Region #1 ROI** and then click **Delete, Select All** records.

c. From the ENVI main menu, select **Classification** > **Supervised** > **Parallelepiped**. Select the can_tmr.img dataset. Click **OK**. In the newly opened **Parallelepiped Parameters** dialog, **Select All Items** from defined regions and set the **Output Result** to can_pclass.img. Leave **Output Rule Images** unchanged. Confirm that the output directory is **ENVI validation Output** directory. Leave the **Max stdev from Mean** on 3.00 (single value). Click **OK**.

d. Examine the result of the classification and compare it with the one obtained by RSI (Figure 4-3, Tutorial Guide). Figure 8 shows one similar to the RSI result. Note if any pattern differences exist between these two results.

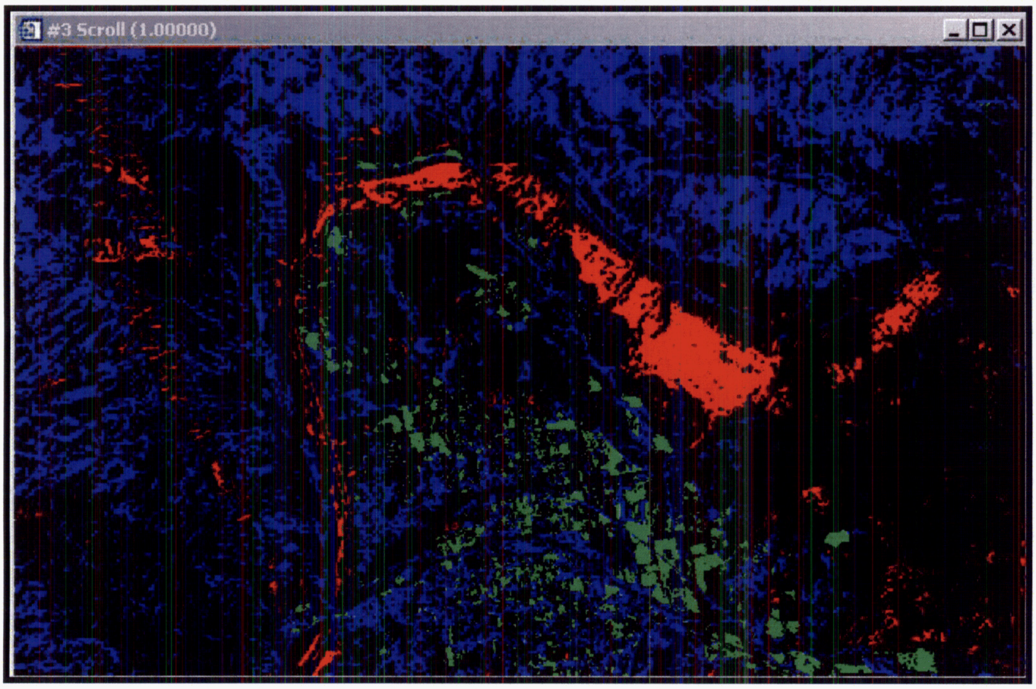

Figure 8. RSI's Parallelepiped Classification

4. Performing a supervised classification using hyperspectral tools

The following method employs tools that are generally used for analyzing hyperspectral data. Spectral Angle Mapper method is used to provide an alternative result for the classification created in Section 6.4.3, Number 3. First a set of spectras are collected from ROI.

a. Start the **Classification Input File** dialog from the ENVI main menu by selecting **Spectral** > **Mapping Methods** > **Endmember Collection**.

b. In the **Classification Input File** dialog, select as Input file the can_tmr.img dataset. Click **OK**.

c. Several classification methods can be used by choosing one of the 11 methods listed under **Algorithm**. For the purpose of this test, choose the **Spectral Angle Mapper** algorithm.

d. Import the pre-defined ROIs (**Import** > **from ROI/EVF from Input File** > **Select All Items** > **OK**) and create regions #1–#3. **Plot** these regions and compare the spectras with the ones displayed in Figure 9.

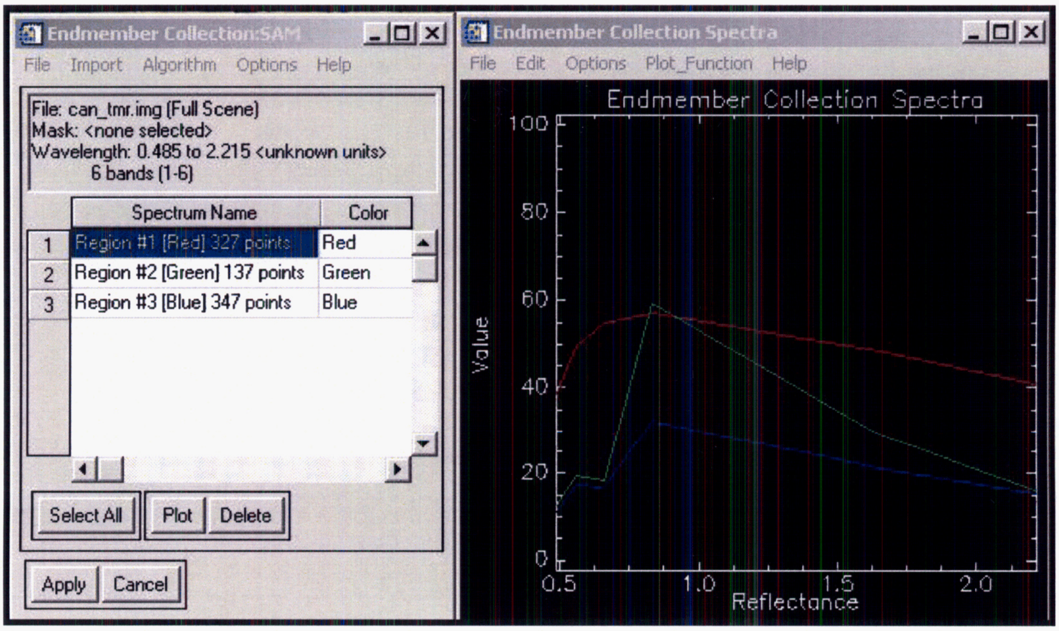

Figure 9. SAM Endmember Collection and Spectra

e. Click **Apply**. On the Spectral Angle Mapper Parameters Dialog enter the output filename can_sam.img (confirm that the output directory is **ENVI Validation Output** directory) and click **OK**. Compare the results with that shown in Figure 10.

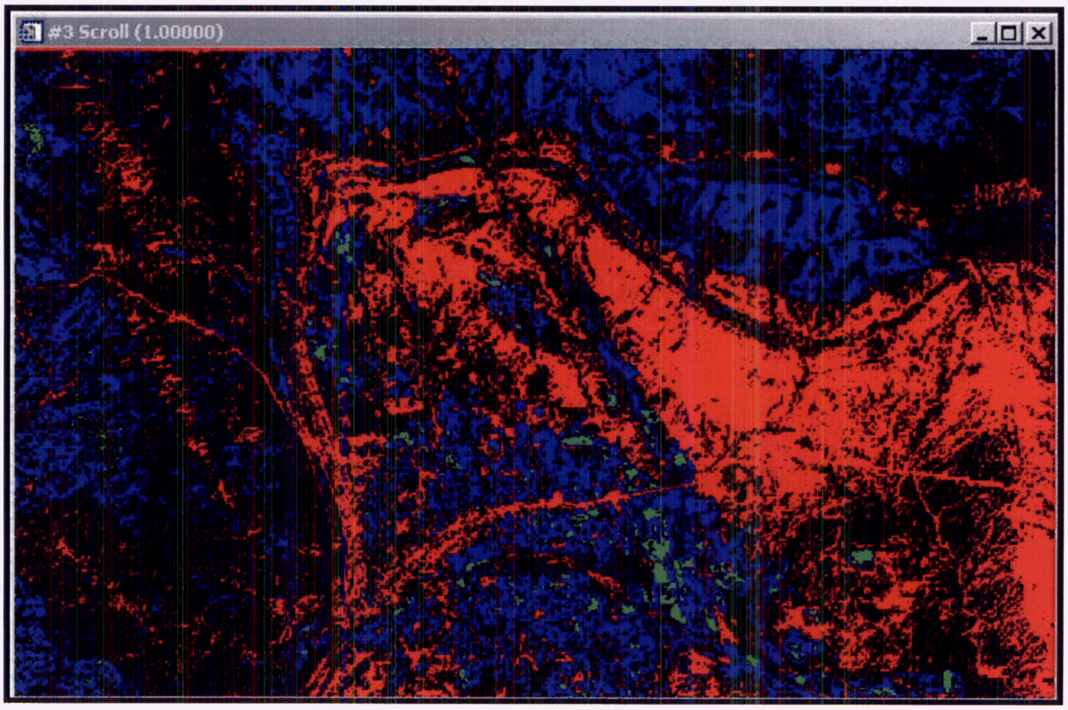

Figure 10. SAM Output

5. Post Classification Processing

To evaluate the accuracy of a classification method, a post-processing algorithm is required. This test will compare the classification results from Section 6.4.3, Numbers 3 and 4 by computing a confusion matrix. The SAM classification will be evaluated considering the output for the Parallelepiped method as the ground truth. Finally, the confusion matrix will be compared with the one generated by RSI.

a. From the ENVI pull down menu, select **Classification** > **Post Classification** > **Confusion Matrix** > **Using Ground Truth Image**. Select can_sam.img as the input classification file. Click **OK**. Select can_pclass.img as the ground truth input file. Click **OK**.

b. The corresponding classes are automatically matched in the **Match Classes Parameters** dialog window. Click **OK**.

c. On the **Confusion Matrix Parameters** dialog, output result to Memory and click **OK**. Compare the Prod. Acc. and User Acc. results with the ones obtained by RSI (Figure 4-7, Tutorial Guide). Results similar to that of RSI are shown in Figure 11.

Class Confusion Matrix

File

```
Confusion Matrix: C:\Documents and Settings\marius\Desktop\ENVI_validation\data\can_sam

Overall Accuracy = (161573/256000)  63.1145%
Kappa Coefficient = 0.2935

                    Ground Truth (Pixels)
     Class     Unclassified    Region #1     Region #2     Region #3          Total
 Unclassified        124589          965          2425         26311         154290
Region #1 [Re         45777         9180             0          1147          56104
Region #2 [Gr           281            0          2358            83           2722
Region #3 [Bl         13795            0          3643         25446          42884
        Total        184442        10145          8426         52987         256000

                   Ground Truth (Percent)
     Class     Unclassified    Region #1     Region #2     Region #3          Total
 Unclassified         67.55         9.51         28.78         49.66          60.27
Region #1 [Re         24.82        90.49          0.00          2.16          21.92
Region #2 [Gr          0.15         0.00         27.98          0.16           1.06
Region #3 [Bl          7.48         0.00         43.24         48.02          16.75
        Total        100.00       100.00        100.00        100.00         100.00


        Class    Commission     Omission          Commission            Omission
                  (Percent)    (Percent)            (Pixels)            (Pixels)
 Unclassified         19.25        32.45        29701/154290        59853/184442
Region #1 [Re         83.64         9.51         46924/56104           965/10145
Region #2 [Gr         13.37        72.02            364/2722           6068/8426
Region #3 [Bl         40.66        51.98         17438/42884         27541/52987

        Class    Prod. Acc.    User Acc.          Prod. Acc.           User Acc.
                  (Percent)    (Percent)            (Pixels)            (Pixels)
 Unclassified         67.55        80.75       124589/184442       124589/154290
Region #1 [Re         90.49        16.36          9180/10145          9180/56104
Region #2 [Gr         27.98        86.63           2358/8426           2358/2722
Region #3 [Bl         48.02        59.34         25446/52987         25446/42884
```

Figure 11. Confusion Matrix using the Output of the Parallelepiped Classifier as Ground Truth

6.4.4 Test Results

PASS/FAIL: The test is successful if all required results are obtained in Section 6.4.3.

This test **PASSED.**

Tester: Deborah Waiting ~~Deborah Waiting~~ Test Date: 3/21/05

7 CONCLUSION

The ENVI, Version 4.1 software has completed all tested features successfully.