JPL Research and Development

AFIDS Automated
Fusion of Image Data System
User Guide

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Spiral Development Version: 4.0p

Prepared for:
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Contents

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1. SCOPE

1.1 Identification

This AFIDS User Guide was prepared at the Jet Propulsion Laboratory (JPL) under Task Order NMO-715813, Project Number 103026-1.1 (Advanced Image Processing Prototypes), and performed under management of the California Institute of Technology (CALTECH) via contract with the National Aeronautics and Space Administration (NASA-CALTECH contract NAS7-03001). Historic funding for AFIDS software development has come from the JPL "Optical Processing and Algorithm Target Recognition" task, the "NIMA GIAT Development Automatic Co-Registration" task, and earlier co-funding by the Earth Science Technology Office, NASA Code Y, through a task entitled "Automated Image Data Fusion System."

1.2 Overview

This document describes how to use spiral development version 4.0p of the Automated Fusion of Image Data System (AFIDS) software package, including a description of the underlying VICAR/IBIS software (upon which AFIDS is built), the concept of operations (CONOPS), Users Guide, and supporting documentation and software. In brief, the AFIDS software package provides a semi-automated approach for co-registering selected satellite imagery (without human selection of tiepoints, and with only one image resampling) for a given multidate satellite dataset covering the same area, assuming the matching images do not contain significant disparaging differences such as cloud, seasonal, or time-displacement variations. Once registered, a connected component change detection capability is available to assist in automated target recognition. As a side benefit, AFIDS can also upgrade the accuracy of the rational polynomial coefficients rpc(s) for Quickbird, Ikonos, and NTM image datasets. For NTM imagery, special high resolution chips can be generated centered on "BE" locations. The software runs under Sun Solaris and Red Hat Linux operating systems.

1.3 License Agreement

AFIDS is built upon the VICAR/IBIS software. The United States Government has a non-exclusive, non-transferable, royalty-free worldwide license to VICAR. Third party use of VICAR is limited to uses for, or on behalf of NGA and the US Army (who hold a current license), but any further use must be negotiated with the NASA Patent Office. Other organiziations wishing to use AFIDS should obtain a license from Caltech/JPL. For licensing information, contact the Caltech/JPL Administrator for Software Licensing, 4800 Oak Grove Drive, Mail Code 202-233, Pasadena, CA 91109-8099, Phone 818-393-3424.

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2. APPLICABLE DOCUMENTS and DATABASES

2.1 Applicable Documents

(1) JPL, "AFIDS Automated Fusion Image Data System User Guide," Version 4.0d, 09JUN06. (Previous User Guide).
(2) JPL, "AFIDS Automated Fusion Image Data System User Guide," Version 2.1, 28SEP04. (Previous User Guide).
(3) JPL, "VICAR User's Guide," Document D-4186 Rev B, 14OCT94.
(4) JPL, "The Multi-Mission Image Processing Laboratory (MIPL)," and "The VICAR Image Processing System," http://www-mipl.jpl.nasa.gov/
(5) Bryant, N., A. Zobrist, and T. Logan, 2004. "Precision Automatic Co-Registration Procedures for Spacecraft Sensors," Paper #6550. Presented at: ASPRS Annual Convention, Denver, CO., May 27. (Appendix A).

2.2 Supporting Databases

Beginning with AFIDS Version 2.3, two JPL-prepared databases are available to support the AFIDS coregistration of satellite imagery on a global basis (Refer to Section 5.3). These databases include: 1) A global 1 arc-second (30m) DEM (Digital Elevation Model) database; and 2) A global 1 arc-second (30m) Landsat Band 3 (Red wavelength) database. The combined databases occupy about 850GBs of disk space.

2.2.1 Digital Elevation Database

The DEM database is a one arc-second (~30m) SRTM (Shuttle Radar Topography Mission) digital elevation model (DEM) global dataset, that has had its "voids" (radar shadow areas) filled with NGA's "DTED-1" data, oceans flattened, and coastlines cut to DTED-1 boundaries. This global database uses DTED-1 data above 60 degrees Latitude, and uses "GLOBE" 1KM to fill in any remaining elevation holes. The resulting "srtm_filled" database comprises 19,240 1x1 degree files that are mosaicked together by AFIDS (as needed) to provide the topographic relief offsets that are essential to any image coregistration process. The data is provided in Geographic (Platte Carree) projection. This dataset is currently restricted to qualifying U.S. Government Agencies, and is provided in VICAR format.

2.2.2 Landsat Database

The Landsat database is a one arc-second (~30m) global mosaic preparded using advanced JPL-developed brightness optimization techniques to ensure adjacent scene matching, and topographically corrected to ensure a correct Geographic (Platte Carree) projection. The Landsat data are primarily derived from early-mid 1990s imagery with some 2000 updates. The utilized Landsat is the best cloud-free data available, although cloud-obscuration is a fact in many cloud-prone geographic areas. The global database is provided in 5x5 degree files that are mosaicked together by AFIDS (as needed) to provide orthographic map projection characteristics. This data is provided in VICAR format, and is *not* restricted to U.S. Government Agencies.

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3. AFIDS OVERVIEW

3.1 Software Foundations

AFIDS is built upon the VICAR/IBIS software. VICAR (Video Image Communication And Retrieval) is a comprehensive command-line image processing system originally developed in the mid-1960s to support the Nation's unmanned space exploration program. IBIS (Image-Based Information System) is a raster-based Geographic Information System (GIS) developed in the 1970s as a fully integrated subsystem of VICAR. While both systems have continued to evolve through the years, it is the IBIS portion that has focused on developing an integrated and comprehensive set of semi-automated image co-registration software capabilities. This software set is generally referred to as the "GT" routines for their integrated use and compatibility with GeoTIFF georeferencing algorithms.

VICAR makes use of the Transportable Applications Executive (TAE) for its command-line interface. TAE was developed by the NASA Goddard Space Flight Center and provides a standardized interface between the user and the large library of VICAR/IBIS application programs. While this interface and library are fully available to the user, a series of user-modifiable text "procedures" contain the command-lines that call the application programs to perform the co-registration process. Note these "procedures" use the ".pdf" suffix, but are *not* related to the Adobe Acrobat 'pdf' file format (VICAR usage precedes the Acrobat usage). Refer to Appendix C for a tutorial on the command-line use of VICAR.

Since AFIDS version 2.0, a user-friendly interface (gui) based on "tcl tk" (tool command language toolkit; pronounced "*tickle tk*") has been used to reduce the need for users to interface with VICAR command line procedures. "tcl tk" is copyrighted by the University of California, Sun Microsystems and others, and is classified by the DOD as "Commercial Computer Software," but carries no costs, license, or limitations on its use.

3.2 Operating Systems

The AFIDS version of VICAR/IBIS currently operates on SUN Microsystem computers running the Solaris 8, 9 and 10 Operating Systems. Beginning with AFIDS version 3.0, support for the RedHat Linux Enterprise 3 and 4 Operating Systems was added, allowing operation on properly equipped 32 or 64-bit PC workstations.

3.3 Concept of Operations

The AFIDS software currently supports the co-registration of multidate ALI, ASTER, Hyperion, Ikonos, Landsat, MODIS, NTM, and Quickbird imagery. When multidate imagery is obtained, one of the dates is identified as the "master," to which all "secondary" dates are registered. The master scene should be as clear and cloud-free as possible, be a near-nadir view, and have the best overlapping 'position' with respect to the secondary scenes, which may be offset due to variations in flight paths.

The basic co-registration concept begins with an orthorectified ‘image base’ (in Platte Caree projection) to provide an approximate cartographic mapping and projection. The satellite datasets are initially registered to the 'image base' to obtain its projection characteristics. The medium resolution Hyperion, ALI, Aster, and Landsat satellites use a Landsat-based image base, and the high spatial resolution Ikonos, Quickbird, and NTM satellites use a CIB1 or CIB5 (Controlled Image Base, 1 or 5 meter) image base. The low resolution MODIS satellite does not require an image base. Digital elevation models are used to correct perspective shifts due to spacecraft height and view-angle. Satellite images are co-registered to the Landsat or CIB database using an automated and recursive series of FFTs (Fast Fourier Transforms) to create a large set of very accurate tiepoints, which are used to warp the images. This approach requires from three (e.g., for geosynchronous weather satellite imagery) to six (e.g., for polar weather satellite imagery) sequential processing steps to warp the dataset by resampling pixel values. To avoid degradation of the data by multiple resamplings, each warp is represented by an “Ultra-Fine” grid of tiepoints. For successive warps, the grids are composed mathematically into a single grid such that only one resampling occurs. The “Ultra-Fine” grid can currently contain over four million points (1000x1000 grid recommended), facilitating very high precision pixel adjustments. A publication describing the process in greater detail is provided in Appendix A.

To help with the analysis and assessment of coregistered imagery, the AFIDS system provides tools for overlaying generated images with their base mosaicks or master images, displaying registration points, calculating RMS (Root-Mean-Square) and other accuracy measurements, displaying georeference details, and exporting data in GeoTIFF format. In a future version, it is planned to support an automated 'up-stream' server that performs co-registration *unattended* by the user.

To assist in automating the target recognition process, a “Change Detection” utility (RID Connected Component Analysis, Section 5.8) is available. This utility allows the user to create a visual color-coded mask of the 'change detection' (image subtraction) between two image dates, using spectral thresholds and custom filters to focus on the specific characteristics of a desired target pixel set.

Quickbird, Ikonos, and NTM imagery may come referenced with rpc(s) (rational polynomial coefficients). The rpc(s) are encoded with the spacecraft projection model that controls the imagery’s earth georeference detail. However, the original coefficients generally require accuracy adjustments. Since AFIDS version 2.9, an option has been available to more accurately re-define the rpc(s) and update the parent image, with output in GeoTiff format. The high accuracy of the refined rpc coefficients allows for the optional preparation of small high resolution image chips that are centered on user provided Battlefield Entity coordinates.

3.4 Obtaining Satellite Imagery

The AFIDS software currently co-registers ALI, ASTER, Hyperion, Ikonos, Landsat, MODIS, NTM, and Quickbird satellite imagery. The primary method for obtaining this data should be to order it through your existing institutional data acquisition channels. However, some conventional civilian and non-military channels are also available as described below. See Appendix C for a description of each sensor system's bands and wavelengths. NTM is described in a separate document.

3.4.1 Landsat Data

Landsat (Land satellite) data is used by AFIDS in two ways: 1) As a 'mosaic image base' for imparting map projection characteristics; and 2) As data to be co-registered for current or historic interest analysis. The former must be orthorectified, the latter should *not* be orthorectified.

3.4.1.1 Landsat Data for Mosaic Databases

If you have the JPL Landsat database, you do *no*t need *orthorectified* landsat imagery. Otherwise, orthorectified Landsat 4, 5, and 7 Thematic Mapper (TM and ETM) data in UTM projection and TIFF format can be obtained from the NASA Stennis Space Center (SSC). Data can usually be requested on CD-ROM or DVD formats. There is no charge for this data.

Scientific Data Purchase Project
Earth Science Applications Directorate
National Aeronautics and Space Administration
Stennis Space Center, MS 39529
Phone: 228-688-1989 (Alternate numbers: -2526 and -1408)

You should know the Latitude/Longitude center of your satellite AOI, and use a Landsat Path/Row chart to determine the desired Landsat image's Path and Row coordinates. Typically, two north/south adjacent Landsat images are required to support Hyperion co-registration.

Landsat images can also be downloaded for free through the internet from the Global Land Cover Facility (GLCF) at the University of Maryland. Be sure to select only the orthorectified version from the available options, and include the metadata file.

http://glcf.umiacs.umd.edu/data

3.4.1.2 Landsat Data for Landsat Image Analysis

For Landsat image analysis, order the L0R (or uncorrected) imagery. In addition to the University of Maryland site, Landsat MSS, Thematic Mapper (TM), Extended Thematic Mapper (ETM), and ETM+ files can be obtained from the U.S. Geological Survey (USGS; for a fee) at their EarthExplorer web site:

http://edcsns17.cr.usgs.gov/EarthExplorer/

Enter as 'guest,' then enter the desired geographic coordinates under 'Spatial Coverage.' Select a Landsat version under 'Data Set Selection,' and fill out the rest of the form as appropriate. Your specification of the L0R (uncorrected) landsat version occurs at checkout.

The USGS also offers their 'GloVis' (Global Visualization) Viewer web site:

http://edc.usgs.gov/products/satellite.html

Enter the Latitude and Longitude of your area of interest, select the "Sensor" (e.g., Landsat 7 ETM+), and click "View Imges".

3.4.2 ASTER Data

The ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) sensor is aboard the EOS Terra space platform, and provides 14 bands of VNIR, SWIR, and TIR spectral imagery. This data can be obtained (for a fee) from the "Earth Observing System Data Gateway" via either of the following two internet links:

http://edcimswww.cr.usgs.gov/pub/imswelcome/index.html
http://redhook.gsfc.nasa.gov/~imswww/pub/imswelcome/

After entering the gateway via 'guest', select the 'Land: ASTER' button, then choose:

"ASTER EXPEDITED L1B REGISTERED RADIANCE AT THE SENSOR V00*n*"

Fill-out the rest of the form, search the database, and order the data as appropriate. After a short time, the data will either be placed on an ftp site (for your download) or shipped to you on CD-ROM or tape. Be sure to include the metadata file if downloading from the web. Level 2 Temperature and Emissivity data are not available on the web.

3.4.3 MODIS Data

MODIS (MODerate-resolution Imaging Spectroradiometer) sensor data is generated from both the EOS Terra and Aqua space platforms. There are 36 bands (actually 38, see Appendix C) of spectral data that can be obtained at 1km resolution (250m and 500m datasets are not currently supported by AFIDS.) The data can be obtained (for free) from the same "Earth Observing System Data Gateway" web sites as for the ASTER datasets.

http://edcimswww.cr.usgs.gov/pub/imswelcome/index.html
http://redhook.gsfc.nasa.gov/~imswww/pub/imswelcome/

After entering the gateway via 'guest', select the 'Land: MODIS/Aqua' or 'LAND: MODIS/Terra' button, then choose (one at a time):

MODIS/AQUA CALIBRATED RADIANCES 5-MIN L1B SWATH 1KM V00*n*
MODIS/AQUA GEOLOCATION FIELDS 5-MIN L1A SWATH 1KM V00*n*
and/or
MODIS/TERRA CALIBRATED RADIANCES 5-MIN L1B SWATH 1KM V00*n*
MODIS/TERRA GEOLOCATION FIELDS 5-MIN L1A SWATH 1KM V00*n*

Fill-out the rest of the form, search the database, and order the data as appropriate. The imagery will be placed either on an ftp site (for your download) or shipped to you on CD-ROM or tape.

3.4.4 Hyperion Data

Earth Observing-1 (EO-1) Hyperion hyperspectral imagery consists of 224 (of 242) bands in the 0.43 to 2.4um spectral range at 30 meters ground resolution. Bands 225-242 are all zero data. The data are available from the USGS over the internet for a $500 fee:

http://edcsns17.cr.usgs.gov/EarthExplorer/

Enter as 'guest,' then enter the desired geographic coordinates under 'Spatial Coverage.' Select 'EO1-Hyperion' under 'Data Set Selection,' and fill out the rest of the form as appropriate. The data can also be ordered by contacting the USGS directly:

Customer Services
U.S. Geological Survey
EROS Data Center
47914 252nd Street
Sioux Falls, SD 57198-0001
Phone: 800-252-4547 or 605-594-6933
Fax: 605-594-6589
Email: custserv@usgs.gov
Monday – Friday, 8:00am to 4pm (Central Time)

3.4.5 Ikonos Data

Ikonos "Geo" imagery consists of 1.0 meter resolution Panchromatic band and four 4.0 meter resolution multispectral bands in the Blue, Green, Red, and NIR wavelengths. The data are available from SpaceImaging, Inc., and/or several independent suppliers. Pricing is dependent upon the data volume. Request the GeoTIFF format. Contact:

Space Imaging, Inc.
12076 Grant Street
Thornton, CO 80241 USA
http://www.spaceimaging.com
1-800-232-9037 or 301-254-2000, or by email at info@spaceimaging.com

3.4.6 Quickbird Data

Quickbird "Basic" imagery consists of a 0.61 meter resolution Panchromatic band and four 2.44 meter resolution multispectral bands in the Blue, Green, Red, and NIR wavelengths. The data are available from DigitalGlobe, Inc., and/or several independent suppliers. Pricing is dependent upon the data volume. Request the GeoTIFF format. Contact:

DigitalGlobe, Inc.
1900 Pike Road, Longmont, CO 80501-6700 USA
http://www.digitalglobe.com
1-800-496-1225 or 303-702-5561, or by email at info@digitalglobe.com

3.4.7 ALI Data

Earth Observing-1 (EO-1) ALI (Advanced Land Imager) data consists of ten bands ranging from the 0.43 to 2.35um spectral range at 30 meters ground resolution. Bands 1 is a 10m Panchromatic file with a 0.48-0.69 um spectral range. The data are available from the USGS over the internet for a $250 fee. Be sure to select only the Level 1R (Radiometrically corrected) product:

http://edcsns17.cr.usgs.gov/EarthExplorer/

Enter as 'guest,' then enter the desired geographic coordinates under 'Spatial Coverage.' Select 'EO1-Advanced Land Imager' under 'Data Set Selection,' and fill out the rest of the form as appropriate. The data can also be ordered by contacting the USGS directly:

Customer Services
U.S. Geological Survey
EROS Data Center
47914 252nd Street
Sioux Falls, SD 57198-0001
Phone: 800-252-4547 or 605-594-6933
Fax: 605-594-6589
Email: custserv@usgs.gov
Monday – Friday, 8:00am to 4pm (Central Time)

4. AFIDS INSTALLATION AND LAUNCHING

Version 4.0p of AFIDS operates in a runtime mode on Sun Solaris 8, 9, and 10 computer systems, and 32 or 64 bit PCs equipped with the Red Hat Linux Enterprise 3 or 4 operating systems. A System Administrator should perform the installation.

4.1 AFIDS Distribution Files

AFIDS is nominally distributed on a CD-ROM containing the following files:

- afids_4p_*date*.tar.Z	(Complete AFIDS/VICAR software package)
- AFIDS_User_Guide	(AFIDS Users Guide in Word and Acrobat formats)
- Readme_Install.txt	(Section 4 from the AFIDS User Guide)

4.2 Installing Over an Older Version

If this installation is to replace a pre-existing version, first delete the entire previous installation and it's directory:

```
rm –rf  /opt/afids_4.0
```

4.3 File Locations

In the **/opt** directory (or wherever you want to install AFIDS), uncompress and untar the "afids_4p_*date*.tar.Z" file.

uncompress afids_4p_*date*.tar.Z   or   gzip –d afids_4p_*date*.tar.Z
tar xvpf afids_4p_*date*.tar

This creates a directory (about 2.0GB in size) called:

afids_4.0   NOTE: If you choose an alternate path to afids_4.0, be sure there are NO CAPITAL letters or hypens in the path name!

Change your location to /opt/afids_4.0 (or wherever), and from within /opt/afids_4.0, install the software by typing:

```
./install
```

4.4 Shell and Path Suggestions

VICAR uses the "tcsh" shell. However, the AFIDS installation internalizes the tcsh shell such that users can operate AFIDS regardless of the shell they prefer. In order to run AFIDS *outside* the installation directory, the following Path information should be entered:

cshell or tcshell - Add this to the end of your ~/.cshrc file:
setenv PATH "/opt/afids_4.0:${PATH}"

bash shell - Add this to the end of your ~/.bash_profile:
PATH=/opt/afids_4.0:${PATH}
export PATH

NOTE:
Replace "/opt" with your actual path to /afids_4.0.

sh shell - Add this to the end of your ~/.profile:
PATH=/opt/afids_4.0:${PATH}
export PATH

Note that these changes will not take effect until a new shell is started, or type:

rehash

4.5 Setting Up A User Directory

In the course of AFIDS coregistration processing, several subdirectories and scratch files are created. To contain these files, it is recommended that each user create a directory where they intend to (repeatedly) use AFIDS (and have ownership permissions).

1) Create an AFIDS Working directory, for example: mkdir afids
2) Change your directory location to the new directory: cd afids
3) Launch AFIDS (See next Section).

4.6 Launching AFIDS

To launch AFIDS, move to your working directory (/afids). Open an "X" window and type:

afids or ./afids

or type the full path (to /opt/afids_3.0) if you have not enhanced your PATH variable as described in Section 4.4 above.

The "Multi-Sensor Coregistration" main interface 'gui' should appear (Figure 4-1). Click the "?" help buttons for information on how to run AFIDS, or review the (expanded) Help Files in Section 5.

Each time AFIDS is run in a directory, five subdirectories are created (if not already there):

baseraw – A place to put raw Landsat and CIB data for mosaicking.
basemos – A place to store completed Landsat and CIB mosaics.
dtedraw – A place to put raw SRTM and DTED DEM files for mosaicking.
dtedmos – A place to store completed SRTM and DTED DEM mosaics.
scratch – A place for AFIDS to place temporary files.

Additional "final*key*" and "raw*key*" directories are also created each time a new Session ID is entered in Step 1 (See Section 5.2). The keyword *key* (as in "final*key*") is user supplied.

4.7 Exiting AFIDS

To quit and exit AFIDS, click the "Exit" button at the bottom of the main user interface (Figure 4-1).

4.8 Using VICAR

VICAR is now automatically available through AFIDS after installation. Launch VICAR by typing vicar at the Unix prompt. Refer to Appendix C for information on how to use VICAR.

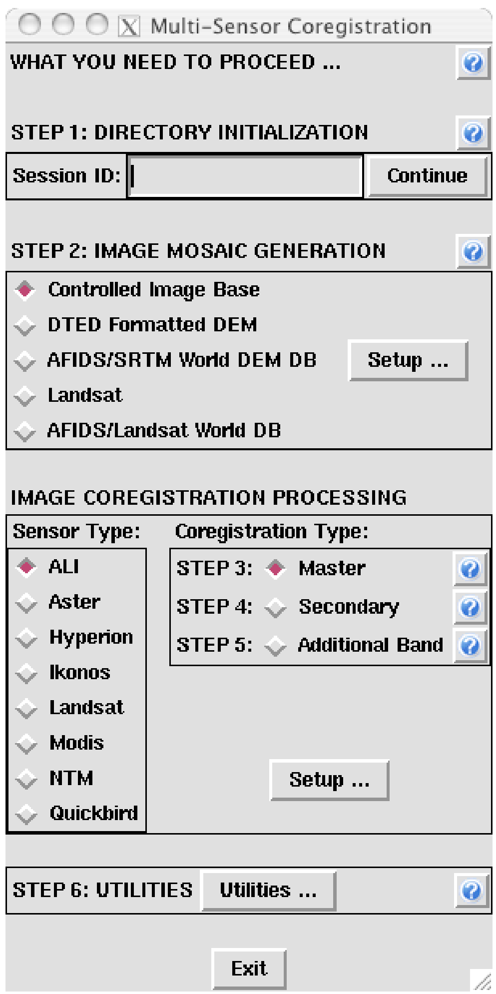

Figure 4-1: Initial AFIDS user interface.

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5. AFIDS HELP FILES (User Guide)

The following User Guide information is an expanded version of the Online Help files.

5.1 Check List – Here's What You Need To Proceed

5.1.1 √ **Select two (or more) multidate satellite images** (of the same sensor type) from the list/description below (e.g., two or more multidate Hyperion images). Choose one image/date to be the "Master," to which the "Secondary" image(s) will be coregistered. If registering a new image to a previously registered image, you will need the directory location and filename of the previously registered image file. Output image products can be generated in UTM or Platte Carree map projections, or matched to an external GeoTIFF's projection.

- Ikonos "Geo" Panchromatic and/or Multispectral Imagery in TIFF (.tif) format with their metadata (.met) and header (.hdr) files. The Ikonos Pan channel is 1.0m resolution, and the Multispectral bands (blu, grn, red, nir) are 4.0m resolution. The Pan channel should be the "Master" (unless only Multispectral data is being registered).

- Quickbird "Basic" Panchromatic and Multispectral Imagery in TIFF or NITF (.TIF or .NTF) formats with the TIFF metadata (.IMD) file. The NITF version uses metadata and rpc parameters that are stored in the NITF file. The Quickbird Pan channel is 0.61m resolution, and the Multispectral bands (blu, grn, red, nir) are 2.44m resolution. The Pan channel is used as the "Master" for both Panchromatic AND Multispectral data that are being registered.

- Hyperion Hyperspectral Imagery in HDF (.L1R) format (not GeoTiff) with their metadata (acs.hdf) file. The 30m resolution Hyperion data file contains 224 (of 242) spectral channels (0.43 to 2.4um).

- Aster Level 1B (and 1A) Imagery in HDF (.hdf or no suffix). The Aster metadata file is not required. Aster bands 1, 2, and 3N are 15m visual wavelengths; bands 4-9 are 30m shortwave; and bands 10-14 are 90m thermal infrared. ONLY Aster imagery taken during the day can be registered (night data is not supported). Use of Level 1B imagery (versus 1A) is strongly recommended.

- MODIS MOD021KM (1km) spectral imagery and MOD03 (Geophysical metadata) in HDF format (.hdf and .hdf.met). The input can be either daytime or nighttime imagery, but only day-to-day or night-to-night imagery can be registered (no day/night registration). The registered output imagery is usually either UTM or Platte Carree map projection, but the UTM projection may cross two or more zones due to the large geographic extent of the MODIS imagery. Only MOD021KM Level-1B (1km) imagery containing 38 bands are currently supported. MODIS band wavelengths range from 0.64 to 14.24um. All bands are output at 1km resolution.

- Landsat Uncorrected (L0R, or otherwise “raw”) Landsat MSS, TM, ETM, or ETM+ Imagery in TIFF (.b03; *nn3.tif) or USGS "NLAPS" (.I3 or .FST) format with their metadata (.met, .ip3, .H1, or .MTL) file. The 80m Landsat MSS contains 4 files. The 30m TM and ETM Landsats contain 7 or 8 spectral channels (blu, grn, red, nir, fir, tir, Geology Shortwave, and 15m Panchromatic). Landsat coregistration is a separate process from the creation of the Landsat base map mosaic (Section 5.1.5 below).

- ALI Imagery in HDF (.M1R) format (not GeoTiff) with their metadata (acs.hdf) file. The 30m resolution ALI data file contains 10 spectral channels (0.43 to 2.4um), with band 1 being a 10m resolution Panchromatic channel.

- NTM (National Technical Means) data in NITF (.NTF) format with rpc parameters. See separate document for details.

5.1.2 √ **AOI - Gather Lat/Long coordinates describing your image Area Of Interest**. Review your satellite image’s Metadata to obtain Latitude and Longitude coordinates completely surrounding your imagery`s geographic area. Also note your particular subarea AOI coordinates (if different from the whole image). You will need to expand the whole-image coordinates for specifying the DEM, and CIB or Landsat mosaic dimensions. For NITF imagery, this information can be obtained using AFIDS in Step 1 of Section 5.2.

5.1.3 √ **Landsat/CIB - Obtain Orthorectified Landsat OR CIB Compressed Image Base data that completely covers your image’s geographic area**. (Skip this step if you have the JPL Landsat database *and* are registering Hyperion, ALI, Aster, or other Landsat imagery.) AFIDS requires either a Landsat or CIB “image base” to impart map projection characteristics during the coregistration process. Choose either CIB or Landsat data, but NOT both. The Landsat data is required for Hyperion, ALI, and Landsat coregistration tasks, and is also the best choice for Aster data. Choose CIB for Ikonos, Quickbird, and NTM. For a Landsat image base, obtain orthorectified Landsat 4, 5, or 7 data in UTM map projection and TIFF format (Section 3.4.1). Up to four Landsat images can be mosaicked at one time, or extract an area from the AFIDS/Landsat World Database file (if available; Section 2.2). For a CIB image base, obtain Compressed Image Base 1 or 5-meter (not 10m) CDROMs. The CIB CDROMs can be used directly or copied to a hard disk. The CIB CDROM should completely cover the image`s geographic area, but keep the area small, as the file size can quickly become very large. Data from up to four CIB CDROMs can be accessed for one mosaic.

5.1.4 √ **DEM - Obtain Digital Elevation Model (DEM) "DTED" CDROMs completely covering the image area, or use the AFIDS/SRTM L2 World DEM** database (if available; Section 2.1). DEM data is used to correct for topographic relief displacement during the coregistration process. The DTED CDROMs can be used directly, or the CD`s DEM files can be copied to a hard disk. If copied to disk, be sure to preserve the DTED directory structure (e.g., ~/dtedraw/dted/e042/34.dt1; Longitudes always have 3 digits) and use LOWER CASE characters. If the image`s geographic area crosses a DTED CDROM boundary, the data from both CDROMs must be copied to disk. Both DTED Level 1 and Level 2 are supported. Up to 30 DEM cells can be mosaicked at a time. DTED data is NOT used by MODIS (use the provided “~/data/vdev/etop02nobath.hlf” two-minute DEM).

5.2 STEP 1: DIRECTORY INITIALIZATION

The first step is to enter a unique 1-10 character **task identifier** (keyword or project ID "key") for this task/project effort, then click the 'Continue' button to begin the automatic task of creating two internal directories (final*key* and raw*key*). Avoid names that start with an "x," and don't use any special characters or spaces. Note that the rest of the gui is not operational until a task name is entered. When returning to AFIDS, re-enter the previous task name.

Figure 5-1: STEP 1 - Enter a 1-10 character name that defines your task. The name is used in naming several internal directories. Then click the "Continue" button.

Be sure to review your data's metadata files and note the geographic coordinates and viewing angles. For Quickbird, Ikonos, and NTM NITF images, use the "NITF Geometry" tool obtained through the "Step 6: Utilities…" Button on the main AFIDS gui, and described in Section 5.73 "Information Utilities."

5.3 STEP 2: IMAGE MOSAIC GENERATION

This step creates two mosaic files that are used internally to correct map projection and topographic relief displacement errors. The two DEM options are used to create a "dtedmos" file for all imagery selections except MODIS. The two Landsat options are used to create a "basemos" file for ALI, Aster, Hyperion, and Landsat imagery selections. The CIB option is used to create a "basemos" file for the remaining Ikonos, Quickbird, and NTM imagery selections. For this Step 2, you must create both "dtedmos" and "basemos" files (as identified above). Create a DTED DEM (Digital Elevation Model) mosaic, CIB (Controlled Image Base 1 or 5-meter) mosaic, and/or Landsat mosaic file, by selecting the appropriate Step 2 button followed by the "Setup…" button, to begin the data preparation process. To use either of the "AFIDS…." options, you must have the JPL-prepared global bases (Section 2.2). Otherwise, you must have access to individual DTED-1, Landsat UTM Band 3 files, and/or CIB 1 or 5 meter cdrom datasets. Note, for Quickbird and NTM images in NITF format with rpcs, a CIB image base is recommended but not required. If not provided, the user will be required to enter a Latitude/Longitude Sample/Line control point.

5.3.1 **Controlled Image Base Mosaic (For Ikonos, Quickbird, and NTM):**

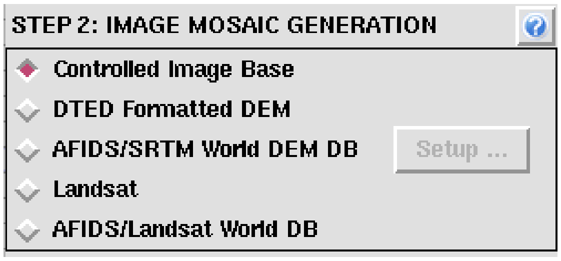

Figure 5-2: Click the "Controlled Image Base" button to make 1 or 5m CIB mosaicks used in the coregistration of Ikonos and Quickbird images. Then click "Setup".

- **CIB Source Directory**: As shown in Figure 5-3, a mosaic from up to four CIB 1 or 5-meter datasets can be made. Copy the CIB CDROM to hardisk when multiple datasets are required. CIB 1 and 5 meter sources should not be mixed. Use the Browse button to locate the CIB's "a.toc" file. CIB 10-meter data are not supported. Make a CIB mosaic when coregistering Ikonos, Quickbird, NTM, and optionally, Aster imagery. MODIS does not require a CIB image base. It is recommended that NITF datasets (NTM and Quickbird/NITF with rpcs) use a CIB image base, but they can be registered without a CIB by providing a control point (Section 5.4).

- **Output Mosaic**: Use the default Output Filename or add "**_cib.img**" to the end of your filename. The preferred output directory location is "/basemos".

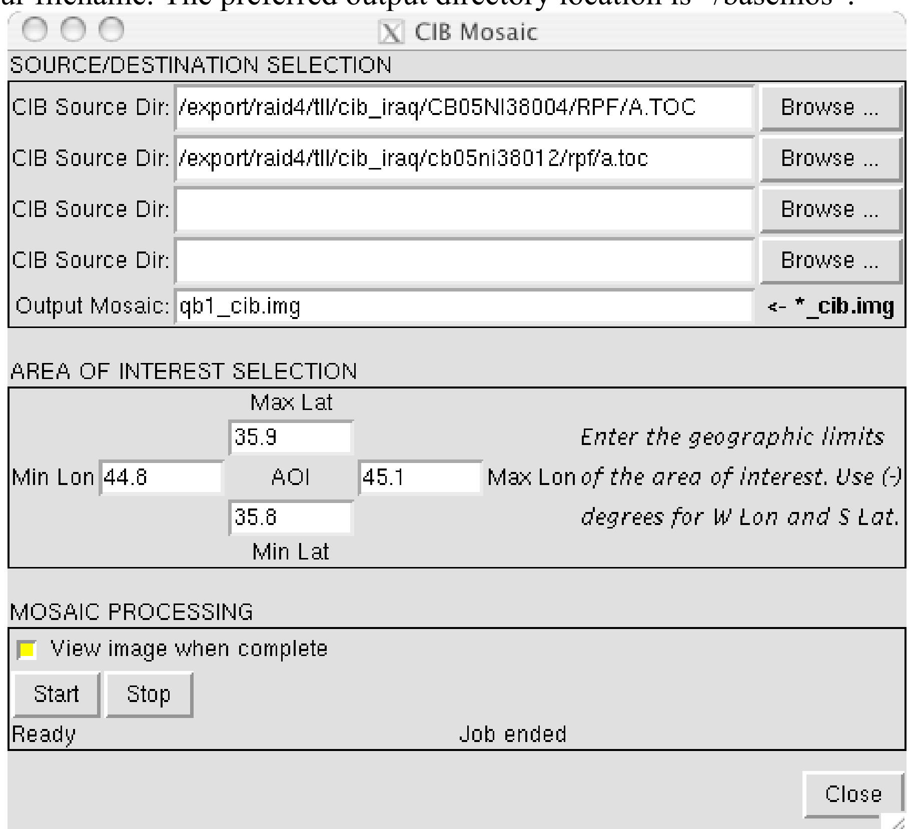

Figure 5-3: Dialog box for creating a CIB mosaic.

- **AOI Selection**: Enter the Geographic Limits of the CIB data to be mosaicked. Use (-) for West and South. The CIB CDROM should completely cover the image`s geographic area, but don’t over extend the boundaries as a very large file can result. Fractional latitude and longitude boundaries are recommended (Figure 5-3).

- Select the "**View image when complete**" button to display the mosaic at completion. In the display program, click the "Zoom Factor" button and choose 'Zoom to Fit' to see the entire image. Select "Tools/Stretch..." to display a variety of optional contrast enhancement options ('Gaussian' usually works best). Select "File/Exit" to quit and close the display program.

- Click the "**Start**" to begin the mosaic process.

5.3.2 **DTED Formatted DEM Mosaic (All Image Types except MODIS):**

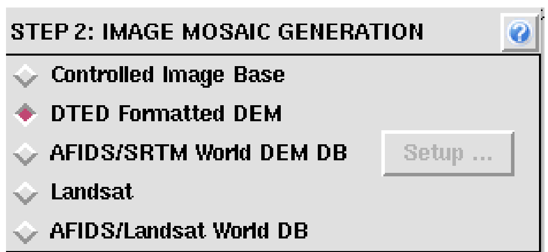

Figure 5-4: Click the above button to make 30 or 90m DTED mosaicks. Use the AFIDS/SRTM World DEM DB option instead, if possible (Section 5.3.3).

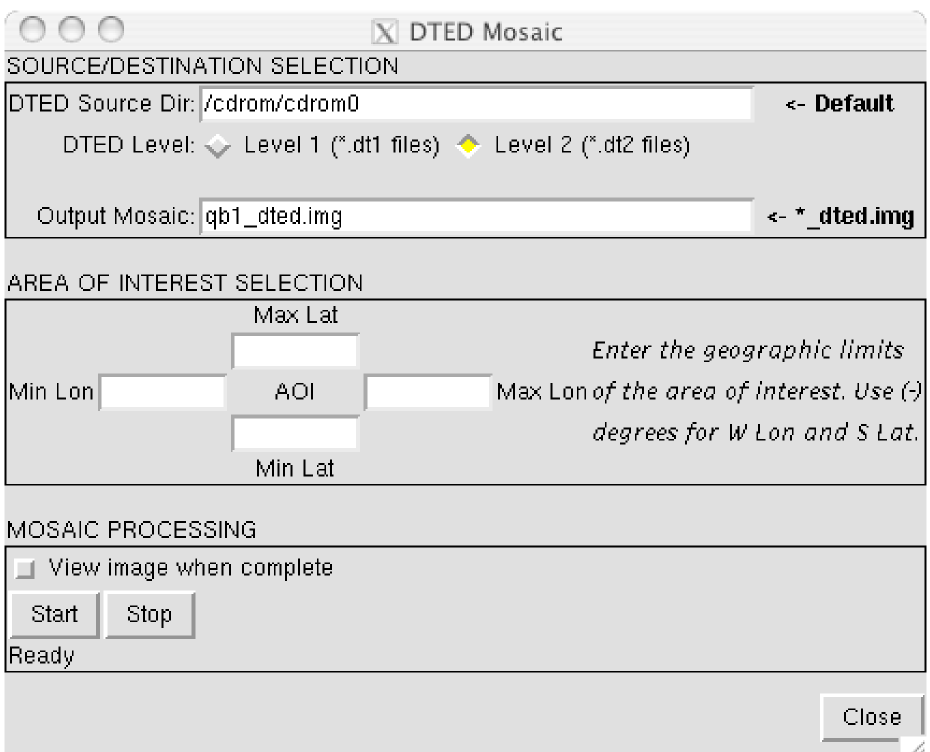

Figure 5-5: Dialog box for creating a DTED mosaic. Use **/mnt/cdrom** for linux CD mounts.

- Note, for MODIS, always use the provided “~/data/vdev/etop02nobath.hlf” DEM file.

- **DTED Source Directory**: Select the DTED source (CDROM or hard disk directory). DTED CDROMs can be used directly (IF all the DEMs are on one CDROM), or the CDROM’s DEM files can be copied to a hard disk using the provided “/dtedraw” directory. If copied to hard disk, be sure to preserve the DTED directory structure (e.g., ~/dtedraw/dted/e042/34.dt1; Longitudes always have 3 digits) and use **LOWER CASE** characters. If the image's geographic area crosses a DTED CDROM boundary, the data from both CDROMs must be copied to disk. If reading from the CDROM, be sure to put it in the computer's CDROM tray.

- **DTED level**: Click whether the DEM data are Level 1 (90m; 3-arcsecond) or Level 2 (30m; 1-arcsecond).

- **Output Mosaic**: Use the default Output Filename whenever possible. The default directory location is /dtedmos.

- **AOI Selection**: Enter the Geographic Limits of the DEM data to be mosaicked. Use (-) for West and South. The specified area should be larger than the satellite image`s geographic coordinates.

- Select the "**View image when complete**" button to display the mosaic at completion. In the xvd display program, click the "Zoom Factor" button and choose 'Zoom to Fit' to see the entire image. Select "Tools/Stretch..." to display a variety of optional contrast enhancement options ('Gaussian' usually works best). Select "File/Exit" to quit and close the display program.

- Click the "**Start**" button to begin the mosaic process.

5.3.3 **AFIDS/SRTM GLOBAL DEM MOSAIC (All Imagery Except MODIS):**

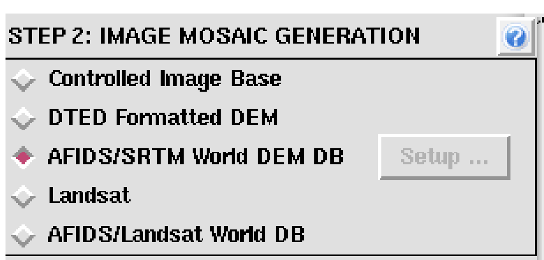

Figure 5-8: Click the “AFIDS/SRTM” button then the “Setup” button to display a dialog box for creating Elevation mosaics using the JPL-prepared SRTM Elevation database.

- Note, this option requires access to the JPL-prepared global 1-arc second AFIDS/SRTM L2 World DEM database (Refer to Section 2.2.1).

- **SRTM Source Directory:** Locate the AFIDS/SRTM elevation database. Once found, it will be ‘remembered’ for subsequent acquisitions.

- **Output Mosaic:** Use the Browse button to define the directory path and filename for the output file. Usually, output this file to the /dtedmos directory. AFIDS will automatically add "**_dem.img**" to your filename.

- **AOI Selection:** Enter the Geographic Limits of the DEM data to be mosaicked. Use (-) for West and South. The specified area should be larger than the satellite image's geographic coordinates. Only **integer** values can be entered.

- Click the "**Start"** button to begin the mosaic process.

5.3.4 **Landsat Basemap Mosaic (For ALI, Aster, Landsat, and Hyperion):**

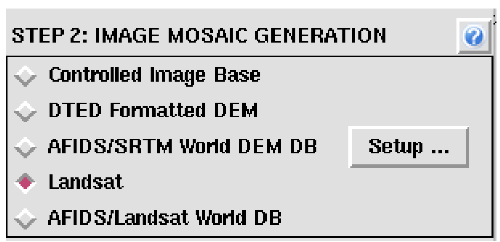

Figure 5-9: Click the "Landsat" button then the "Setup" button to display a dialog box for creating Landsat mosaics used for Aster, Hyperion, and ALI data.

- Note, Make a Landsat mosaic for Aster, Landsat, ALI, and Hyperion imagery, and a CIB mosaic for Ikonos, Quickbird, and NTM coregistration. MODIS magery does not require a CIB or Landsat mosaic to provide map projection characteristics.

- **Source/Destination Selection**: Choose one to four Landsat scenes (and metadata files) to be mosaicked (NOT the Landsat you may be coregistering). Only Landsat 4, 5, and 7 orthorectified datasets in UTM map projection and TIFF format can be used (Section 3.4.1). Be sure that the selected scenes have adjacent path/row coordinates. Click the Browse button to locate the input Landsat directory and file. Landsat band 3 (nn3) is preferred.

- **Output Mosaic**: Click the Browse button to select a directory/file location ("/basemos" is preferred). Use the default output filename, or add "**_landsat.img**" to the end of your filename.

- Select the "**View image when complete**" button to display the mosaic at completion. In the xvd display program, click the "Zoom Factor" button and choose 'Zoom to Fit' to see the entire image. Select "Tools/Stretch..." to display a variety of optional contrast enhancement options ('Gaussian' usually works best). Select "File/Exit" to quit and close the display program.

- Click the "**Start**" button to begin the mosaic process.

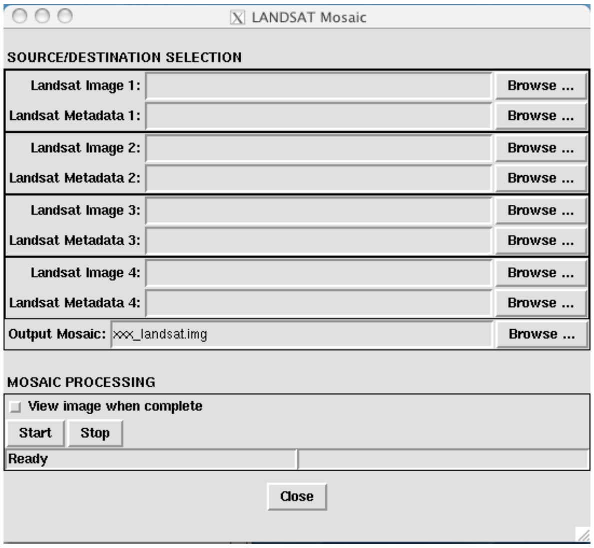

Figure 5-9: Dialog box used for creating a Landsat mosaic.

5.3.5 **AFIDS/Landsat Basemap Mosaic (For ALI, Aster, Landsat, and Hyperion):**

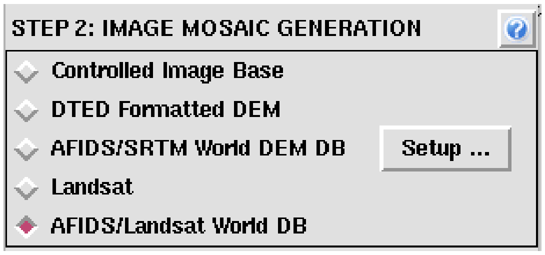

Figure 5-10: Click the “AFIDS/Landsat” button then the “Setup” button to display a dialog box for creating Landsat mosaics used for Aster, Hyperion, and ALI data.

- Note: This option requires access to the JPL-prepared global 1-arc second Landsat database (Section 2.2.2). Make a Landsat mosaic for Aster, Landsat, ALI, and Hyperion imagery, and a CIB mosaic for Ikonos, Quickbird, and NTM coregistration. MODIS imagery does not require a CIB or Landsat mosaic to provide map projection characteristics.

- **AFIDS WDB Source Directory**: Locate the Landsat mosaic database. Once found, it will be ‘remembered’ for subsequent acquisitions.

- **Output Mosaic**: Click the Browse button to select a directory/file location (“/basemos” is preferred). Use the default output filename, or add “**_landsat.img**” to the end of your filename.

- **AOI Selection:** Enter the Geographic Limits of the Landsat data to be mosaicked. Use (-) for West and South. The specified area should be larger than the satellite image`s geographic coordinates. Only **integer** values can be entered.

- Click the "**Start**" button to begin the mosaic process.

5.4 STEP 3: IMAGE COREGISTRATION PROCESSING – MASTER IMAGE

Step 3 creates the "Master" satellite image to which all other multidate images will be coregistered. BE SURE to FIRST choose the Image Type (ALI, Aster, Hyperion, Ikonos, Landsat, MODIS, NTM, Quickbird) you will be coregistering from the Sensor Type list (on the left side of the main menu). Click the "Setup" button to begin the "Master" task (Figure 5-11).

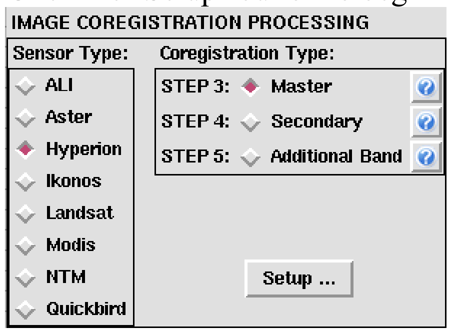

Figure 5-11: Click the Master button and Sensor Type to begin Step 3. Click “Setup”.

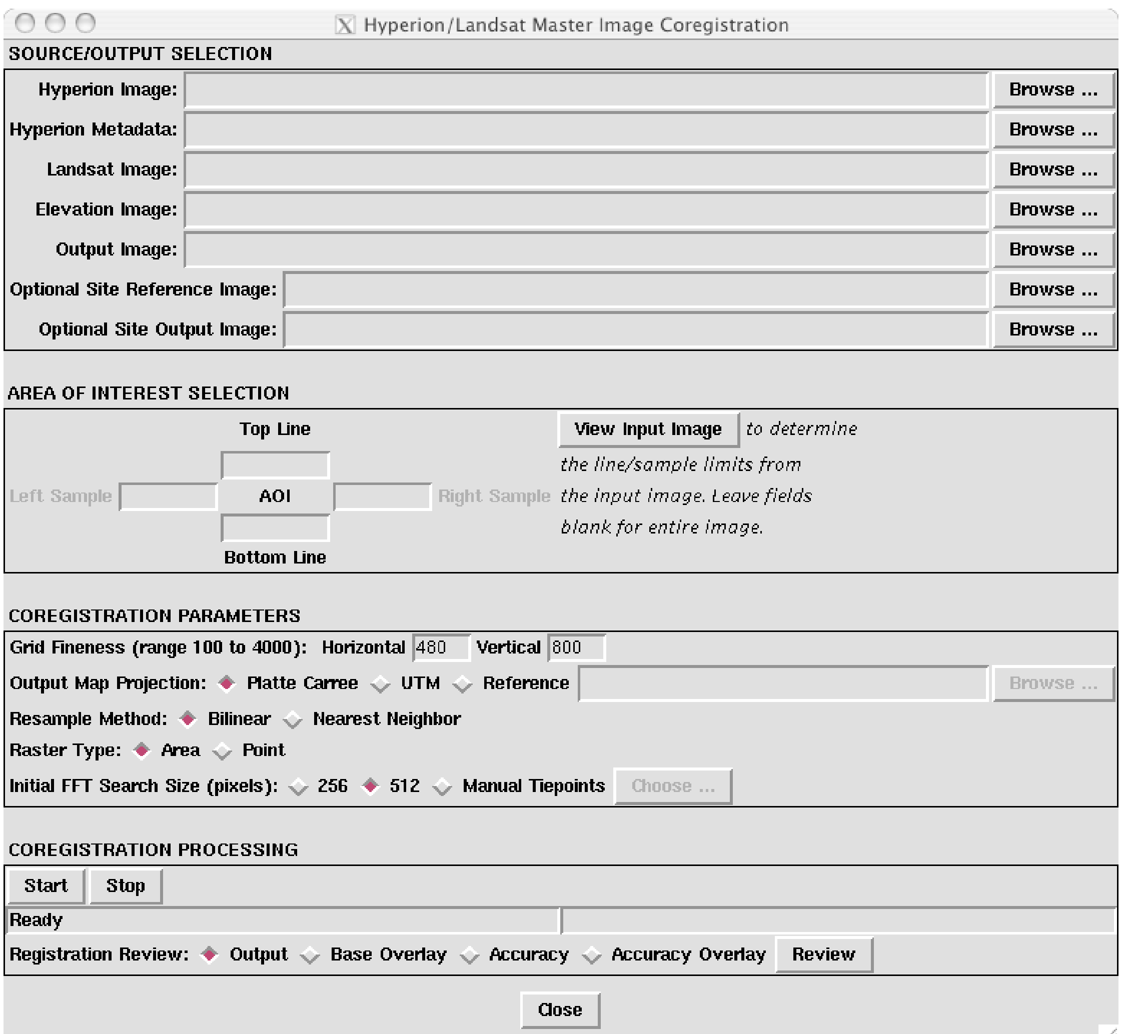

Figure 5-12: Hyperion-example of the Step 3 dialog box used to create a Step 3 Master image.

- **Source/Output Selection**:

- ALI: Click the top-most "Browse" button to find and select the raw ALI scene that is to become the "Master" image (.M1R), and to which all other secondary ALI scenes will be coregistered. Use the Browse button to locate the ALI “acs” Metadata (.hdf) file, and the Landsat mosaic and DTED Elevation files you created in Step 2. If the ACS file is unavailable, select any placeholder file, and (later) choose the “Manual Tiepoints” process. Then browse to select a location and filename to put your registered/map projected master image. The recommended output directory is the “final*xxx*” directory (created in Step 1 using the supplied *xxx* name). Browse/Enter filenames in the optional “Site Reference” input and output boxes ONLY IF you have a pre-existing georeferenced subarea image for which you want to produce a matching ALI subarea image file. NOTE, if the optional Site Reference file is provided, all subsequent processing will reference the subarea’s georeference (not the full image). The Site Reference file must be at least 1200x1200 pixels in size, and can be in either VICAR/GT or GeoTIFF format. The output is always VICAR/GT format. Note that ALI uses four separate sensors to cover a given area, and despite the AFIDS attempt to merge/feather the four images together, the ALI image will often show brightness boundaries between the sensors.

- Aster: Click the top-most "Browse" button to find and select the raw Aster scene that is to become the "Master" image (.hdf), and to which all other secondary Aster scenes will be coregistered. The Aster metadata (.met) file is not required. Use the Browse button to locate the Landsat mosaic and DTED Elevation files you created in Step 2. Then browse to select a location and filename to put your registered/map projected master image. The recommended output directory is the “final*xxx*” directory (created in Step 1 using the supplied *xxx* name). Browse/Enter filenames in the optional “Site Reference” input and output boxes ONLY IF you have a pre-existing georeferenced subarea image for which you want to produce a matching Aster subarea image file. NOTE, if the optional Site Reference file is provided, all subsequent processing will reference the subarea’s georeference (not the full image). The Site Reference file must be at least 1200x1200 pixels in size, and can be in either VICAR/GT or GeoTIFF format. The output is always VICAR/GT format.

- Hyperion: Click the top-most "Browse" button (Figure 5-11) to find and select the raw Hyperion scene that is to become the "Master" image (.L1R), and to which all other secondary Hyperion scenes will be coregistered. Use the Browse button to locate the Hyperion “acs” Metadata (.hdf) file, and the Landsat mosaic and DTED Elevation files you created in Step 2. If the ACS file is unavailable, select any placeholder file, and (later) choose the “Manual Tiepoints” process shown in Figures 5-11 and 5-12. Then browse to select a location and filename to put your registered/map projected master image. The recommended output directory is the “final*xxx*” directory (created in Step 1 using the supplied *xxx* name). Browse/Enter filenames in the optional “Site Reference” input and output boxes ONLY IF you have a pre-existing georeferenced subarea image for which you want to produce a matching Hyperion subarea image file. NOTE, if the optional Site Reference file is provided, all subsequent processing will reference the subarea's georeference (not the full image). The Site Reference file must be at least 1200x1200 pixels in size, and can be in either VICAR/GT or GeoTIFF format. The output is always VICAR/GT format.

- Ikonos: Click the top-most "Browse" button to find and select the raw Ikonos scene that is to become the "Master" image (.tif only), and to which all other secondary Ikonos scenes will be coregistered. Use the Browse button to locate the Ikonos Metadata (.txt or .met) file and Header (.hdr) files, as well as the CIB mosaic and DTED Elevation files you created in Step 2. If the metadata is unavailable or damaged, you will need to choose the "Manual Tiepoints" process. Browse to select a location and filename to put your registered/map projected master image. The recommended output directory is the "final*xxx*" directory (created in Step 1 using the supplied *xxx* name). In the "Optional Out RPC/TIFF" slot, browse or enter a path/name if you want to create a copy of the *input* Ikonos image with improved rational polynomial coefficients. The output format is GeoTIFF. Browse/Enter filenames in the optional "Site Reference" input and output boxes ONLY IF you have a pre-existing georeferenced subarea image for which you want to produce a matching Ikonos subarea image file. NOTE, if the optional Site Reference file is provided, all subsequent processing will reference the subarea's georeference (not the full image). The Site Reference file must be at least 1200x1200 pixels in size, and can be in either VICAR/GT or GeoTIFF format. The output is always VICAR/GT format.

- Landsat: Click the top-most "Browse" button to find and select the raw (unrectified) Landsat scene (refer to Section 3.4.1.2) band (usually Band 3) that is to become the "Master" image (nn3.tif, .b03, .I3, or .FST), and to which all other secondary Landsat scenes will be coregistered. Use the Browse button to locate the Landsat metadata file (.met, .ip3, .H1, or MTL.FST), and the Landsat mosaic and DTED Elevation files you created in Step 2. Then browse to select a location and filename to put your registered/map projected master image. The recommended output directory is the "final*xxx*" directory (created in Step 1 using the supplied *xxx* name). Browse/Enter filenames in the optional "Site Reference" input and output boxes ONLY IF you have a pre-existing georeferenced subarea image for which you want to produce a matching Landsat subarea image file. NOTE, if the optional Site Reference file is provided, all subsequent processing will reference the subarea's georeference (not the full image). The Site Reference file must be at least 1200x1200 pixels in size, and can be in either VICAR/GT or GeoTIFF format. The output is always VICAR/GT format.

- MODIS: Click the top-most "Browse" button to find and select the raw MODIS (MOD021KM) scene that is to become the "Master" image (.hdf), and to which all other secondary MODIS scenes will be coregistered. The master image also requires a Geolocation file (MOD03) file (.hdf) to provide metadata information. Because of the large size of many MODIS images, they are sometimes provided into two parts. If your MODIS file is provided in two parts, and your area of interest requires both parts, use the browse buttons to enter the second image/metadata information into the "Image 2/Geoloc 2" slots. MODIS does not require a CIB or Landsat mosaic, or a specially prepared DTED file. In the "Elevation Image" slot, browse to locate the

"~/data/vdev/etop02nobath.hlf" DEM file. Finally, browse to select a location and filename to put your registered/map projected master image. The recommended output directory is the "final*xxx*" directory (created in Step 1). Browse/Enter filenames in the optional "Site Reference" input and output boxes ONLY IF you have a pre-existing georeferenced subarea image for which you want to produce a matching MODIS subarea image file. NOTE, if the optional Site Reference file is provided, all subsequent processing will reference the subarea's georeference (not the full image). The Site Reference file must be at least 1200x1200 pixels in size, and can be in either VICAR/GT or GeoTIFF format. The output is always VICAR/GT format.

- Quickbird: Click the top-most "Browse" button to find and select the raw Quickbird Panchromatic (not Multispectral) scene that is to become the "Master" image (.tif or .ntf), and to which all other secondary Quickbird scenes will be coregistered. Use the Browse button to locate the Quickbird Metadata (.imd) file, as well as the CIB mosaic and DTED Elevation files you created in Step 2. If the metadata is unavailable or damaged, you will need to choose the "Manual Tiepoints" process. Browse to select a location and filename to output your registered/map projected master image. The recommended output directory is the "final*xxx*" directory (created in Step 1 using the supplied *xxx* name). In the "Optional Out RPC/TIFF" slot, browse or enter a path/name if you want to create a copy of the *input* Quickbird image with improved rational polynomial coefficients (requires NITF input). The output format is GeoTIFF. Browse/Enter filenames in the optional "Site Reference" input and output boxes ONLY IF you have a pre-existing georeferenced subarea image for which you want to produce a matching Quickbird subarea image file. NOTE, if the optional Site Reference file is provided, all subsequent processing will reference the subarea's georeference (not the full image). The Site Reference file must be at least 1200x1200 pixels in size, and can be in either VICAR/GT or GeoTIFF format. The output is always VICAR/GT format.

- NTM: See separate documentation. A CIB image is not required, but if not provided, the user must provide a control point. The "Optional Out RPC/TIFF" slot **MUST BE PROVIDED** for subsequent BE chip preparation (in Secondary dialog box).

- **Area Of Interest Selection**: Leave blank to coregister the entire image, or enter starting and ending image lines (rows) and samples (columns) to define a subarea for coregistration. This can be useful for trimming an image if the image area exceeds the Landsat/CIB or DTED mosaic. For Ikonos and Quickbird, a subarea of less than 15000x15000 is recommended (smaller dimensions will produce a better registration in mountainous areas), or increase the "Grid Fineness" for very large images. Multispectral subareas are not currently allowed (choose full scene). Click the "View Input Image" button to display the image and help identify the line/sample subarea limits. In the *xvd display* program, click the "Zoom Factor" button and choose 'Zoom to Fit' to see the entire image. Select "Tools/Stretch..." to display a variety of optional contrast enhancement options ('Gaussian' usually works best). Select "File/Exit" to quit and close the display program. The display may take a minute or two; be patient!

- Coregistration Parameters

- **Grid Fineness**: These values define the grid used by the (internal) automated tiepoint selection and matching routines. The default values have been optimized for each particular image type. Increase these values if the registration results are unsatisfactory, or images over 15000x15000. Generally, (Horz*Vert) < 1,000,000 preferred; <4,000,000 maximum (2000x2000 grid).

- **Output Pixel Size:** (Ikonos/Quickbird/NTM only): The default is the nominal panchromatic pixel size (Ikonos = 1.0; Quickbird = 0.61). The multispectral sizes are Ikonos = 4.0m and Quickbird = 2.44m.

- **Output Map Projection**: For all image types, choose Platte Carree (geographic; rectangular) or UTM output map projection, or provide your own Reference (target) map projection. Use the browse button to find your own existing AFIDS or external GeoTIFF target reference image. If the GeoTIFF file is from an external source, only the following projections are currently supported: Platte Carree, UTM, Albers Equal Area, and Lambert Conformal Conic with two standard parallels. Note that the large area coverage of MODIS images can cause projection problems in the far northern and southern latitudes (use the AOI Selection option, above, to remove extreme latitudes from the imagery).

- Resample Method: Use the default “Bilinear” interpolation for the best pixel matching and smooth pixel transitions. Use “Nearest Neighbor” to preserve pixel values, but with up to half-pixel offsets.

- Raster Type: Use “Area” to have the origin (0,0) in the upper left corner of the pixel. Use “Point” for the origin to be placed in the center of the pixel. Generally, “Area” is used for images and “Point” is used for DEMs and other map-like raster products. This option is overruled if the “Output Map Projection/Reference” option (above) is specified. This option can be helpful for georeference compatibility with commercially-generated imagery.

- **Acquisition Time** (MODIS only): Select whether the MODIS scene is Day or Night.

- Initial FFT Search Size (Hyperion and ALI): Use this option if the coregistration product is unsatisfactory. The smaller (196/256) FFT size often works better with images that have clouds present. Alternatively, an option is provided to manually find two or three tiepoints for guiding the automated FFT tiepoint process. This option is especially necessary if the Hyperion ACS metadata file is missing or damaged. After clicking the “Choose…” button, allow at least 30 seconds for two *xvd diplay* windows and a dialog box (Figure 5-12) to appear. Use the display program to find a common tiepoint near the top of the Hyperion image, and a second point near the bottom of the image. Other imagery may require three points. Enter the Line (row) and Sample (Column) numbers of the tiepoint pixels into the dialog box and click the “Accept” button.

- Sensor (ALI only): Always choose the default Panchromatic unless you don't have Panchromatic data with your Multispectral data.

- Optional Control Point: (For NTM or Quickbird NITF images only.) Required when correlation fails because the NITF image's rpc coordinates are inaccurate, or when the CIB image base is unavailable. Enter the Line (row) and Sample (column) for an accurately known Latitude and Longitude coordinate position.

- Manual Tiepoints (Quickbird, NTM, Ikonos only): Use this option if the correlation fails, is unsatisfactory, or you want to improve the accuracy of the rpc(s) through a better correlation. Requires a CIB image base. Upon clicking the "Choose…" button, two windows will appear (be patient, the second window may take a full minute). Find one common tiepoint between the input and CIB images (addition tiepoints are ignored). Click the "Accept" button (Figure 5-12) to record your entered values. Be sure to close the *xvd display* windows.

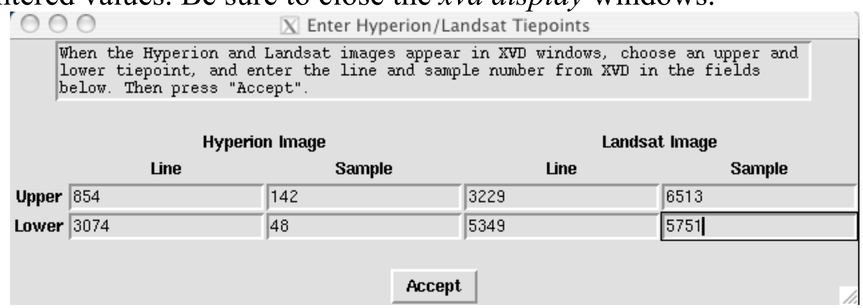

Figure 5-12: Dialog Box for Replacing Defective Tiepoints.

- Click the "**Start**" button to begin the Master Image Coregistration process.

- **Registration Review**: Four (4) optional tools are provided (Figure 5-11, bottom) to review the output registration accuracy. Note, if the optional Site Reference "subfile" is provided, the Registration Review will show the **full** image registration, although subsequent AFIDS processing will reference the subarea file.

- **Output**: Click this button and press "Review" to display the registered Master image.
- **Base Overlay**: Click this button and press "Review" to display the Master image superimposed on the Landsat or CIB mosaic used in the registration process. This option is useful for evaluating registration errors on an image/feature basis. This option is not available for MODIS datasets.
- **Accuracy**: Click this button and press "Review" to display a "Vector Magnitude" map. This map provides a coarse grid of vectors showing the direction and magnitude of "rubber sheeting" that occurred in the registration of the Master image to the Landsat/CIB map projection mosaic. The magnitudes are sized for display and are NOT to scale. They provide a 'relative' evaluation of a local point's spatial adjustment. A small 'tick' indicates the base point's location.
- **Accuracy Overlay**: Click this button and press "Review" to display the "Vector Magnitude" points overlayed on the registered Master image.

5.5 STEP 4: IMAGE COREGISTRATION PROCESSING – SECONDARY IMAGE

Creates the multidate "Secondary" satellite image that will be coregistered to your existing "Master" satellite image (created in Step 3 above). BE SURE the Image Type you will be coregistering has been correctly selected from the Sensor Type list (on the left side of the main menu), then click the "Setup..." button to begin the "Secondary" task.

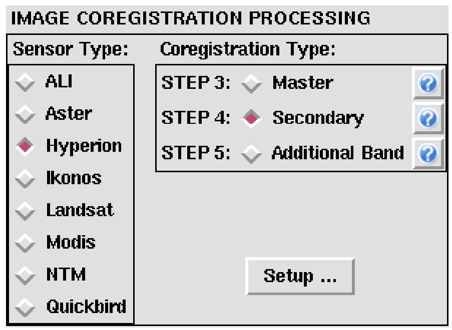

Figure 5-13: Select the “Secondary” button and Sensor Type to begin Step 4. Click “Setup”.

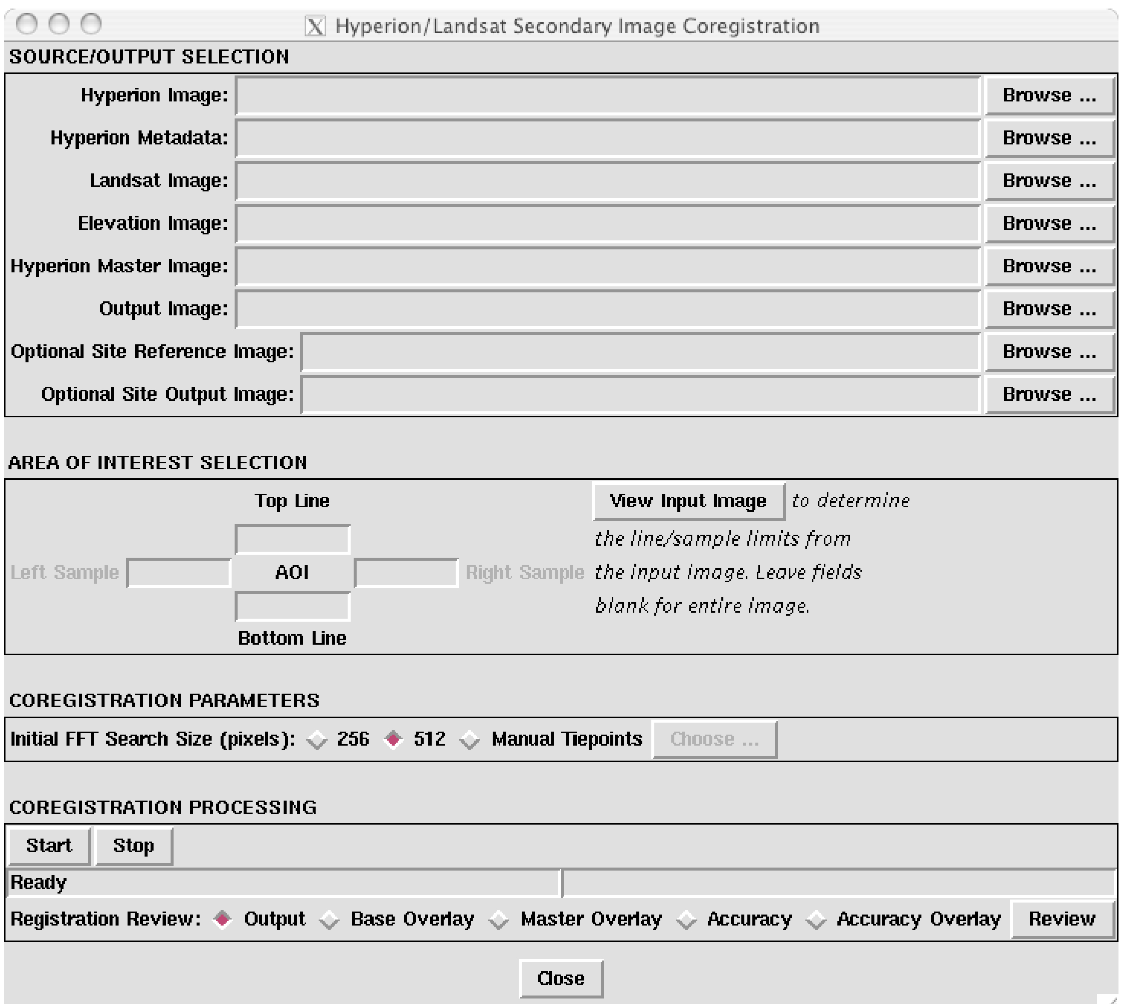

Figure 5-14: Hyperion-example of the dialog box used to create a Step 4 Secondary image.

- **Source/Output Selection**:

- ALI: Click the top-most "Browse" button to find and select the raw multidate ALI scene that is to become the "Secondary" image (.M1R), coregistered to the Master scene created in Step 3. Use the Browse button to locate the Secondary ALI's “acs” Metadata (.MET) file, and the Landsat mosaic and DTED Elevation files created in Step 2. If the ACS file is unavailable, select any placeholder file, and (later) choose the “Manual Tiepoints” process shown in Figures 5-14 and 5-12. Browse to locate the output Master ALI image from Step 3 (NOT the Site Reference output file from Step 3). Then browse to select a location and filename to put your registered/map projected Secondary image. The recommended output directory is the “final*xxx*” directory (created in Step 1 using the supplied *xxx* name). Browse/Enter filenames in the optional “Site Reference” input and output boxes ONLY IF you have a pre-existing georeferenced subarea image for which you want to produce a matching ALI subarea image file. NOTE, if the optional Site Reference file is provided, all subsequent processing will reference the subarea’s georeference (not the full image). The Site Reference file must be at least 1200x1200 pixels in size, and can be in either VICAR/GT or GeoTIFF format. The output is always VICAR/GT format. Note that ALI uses four separate sensors to cover a given area, and despite the AFIDS attempt to merge/feather the four images together, the ALI image will often show brightness boundaries between the sensors.

- Aster: Click the top-most "Browse" button to find and select the raw multidate Aster scene that is to become the "Secondary" image (.hdf), coregistered to the Master scene created in Step 3. By repeating this Step 4, several Secondary images can be coregistered to the Master image. The Aster metadata (.met) file is not required. Use the Browse button to locate the Landsat mosaic and DTED Elevation files you created in Step 2, and the output registered Master Aster image from Step 3 (Not the Site Reference output file from Step 3). Then browse to select a location and filename to put your registered/map projected Secondary image. The recommended output directory is the “final*xxx*” directory (created in Step 1 using the supplied *xxx* name). Browse/Enter filenames in the optional “Site Reference” input and output boxes ONLY IF you have a pre-existing georeferenced subarea image for which you want to produce a matching Aster subarea image file. NOTE, if the optional Site Reference file is provided, all subsequent processing will reference the subarea’s georeference (not the full image). The Site Reference file must be at least 1200x1200 pixels in size, and can be in either VICAR/GT or GeoTIFF format. The output is always VICAR/GT format.

- Hyperion: Click the top-most "Browse" button to find and select the raw multidate Hyperion scene that is to become the "Secondary" image (.L1R), coregistered to the Master scene created in Step 3. Use the Browse button to locate the Secondary Hyperion's “ACS” Metadata (.MET) file, and the Landsat mosaic and DTED Elevation files created in Step 2. If the ACS file is unavailable, select any placeholder file, and (later) choose the “Manual Tiepoints” process shown in Figures 5-14 and 5-12. Browse to locate the output Master Hyperion image from Step 3 (NOT the Site

Reference output file from Step 3). Then browse to select a location and filename to put your registered/map projected Secondary image. The recommended output directory is the “final*xxx*” directory (created in Step 1 using the supplied *xxx* name). Browse/Enter filenames in the optional “Site Reference” input and output boxes ONLY IF you have a pre-existing georeferenced subarea image for which you want to produce a matching Hyperion subarea image file. NOTE, if the optional Site Reference file is provided, all subsequent processing will reference the subarea’s georeference (not the full image). The Site Reference file must be at least 1200x1200 pixels in size, and can be in either VICAR/GT or GeoTIFF format. The output is always VICAR/GT format.

- Ikonos: Click the top-most "Browse" button to find and select the raw multidate Ikonos scene that is to become the "Secondary" image (.tif only), coregistered to the Master Ikonos scene created in Step 3. Use the Browse button to locate the Secondary Ikonos' Metadata (.txt or .met) file and Header (.hdr) files, as well as the CIB mosaic and DTED Elevation files created in Step 2. If the metadata is unavailable or damaged, you will need to choose the "Manual Tiepoints" process. Browse to locate the output Master Ikonos image from Step 3 (NOT the Site Reference output file from Step 3). Then browse to select a location and filename to put your registered/map projected Secondary image. The recommended output directory is the “final*xxx*” directory (created in Step 1 using the supplied *xxx* name). In the “Optional Out RPC/TIFF” slot, browse or enter a path/name if you want to create a copy of the *input* secondary Ikonos image with improved rational polynomial coefficients. The output format is GeoTIFF. Browse/Enter filenames in the optional “Site Reference” input and output boxes ONLY IF you have a pre-existing georeferenced subarea image for which you want to produce a matching Ikonos subarea image file. NOTE, if the optional Site Reference file is provided, all subsequent processing will reference the subarea’s georeference (not the full image). The Site Reference file must be at least 1200x1200 pixels in size, and can be in either VICAR/GT or GeoTIFF format. The output is always VICAR/GT format.

- Landsat: Click the top-most "Browse" button to find and select the raw (uncorrected) multidate Landsat scene (usually Band 3) that is to become the "Secondary" image (nn3.tif, .b03, .I3, or .FST), coregistered to the Master scene created in Step 3. By repeating this Step 4, several Secondary images can be coregistered to the Master image. Use the Browse button to locate the Landsat metadata (.met, .ip3, .H1, or MTL.FST) file, the Landsat mosaic and DTED Elevation files you created in Step 2, and the output registered Master Landsat image from Step 3 (NOT the Site Reference output file from Step 3). Then browse to select a location and filename to put your registered/map projected Secondary image. The recommended output directory is the “final*xxx*” directory (created in Step 1 using the supplied *xxx* name). Browse/Enter filenames in the optional “Site Reference” input and output boxes ONLY IF you have a pre-existing georeferenced subarea image for which you want to produce a matching Landsat subarea image file. NOTE, if the optional Site Reference file is provided, all subsequent processing will reference the subarea’s georeference (not the full image). The Site Reference file must be at least 1200x1200 pixels in size, and can be in either VICAR/GT or GeoTIFF format. The output is always VICAR/GT format.

- MODIS: Click the top-most "Browse" button to find and select the raw multidate MODIS (MOD021KM) scene that is to become the "Secondary" image (.hdf), coregistered to the Master screne created in Step 3. The Secondary image also requires it's Geolocation file (MOD03) file (.hdf) to provide metadata information. If your Master MODIS file was provided in two parts, your Secondary image may also be in two parts (the second part is not required). If there are two parts, use the browse buttons to enter the Part 2 image/metadata information into the “Image 2/Geoloc 2” slots. MODIS does not require a CIB or Landsat mosaic, or a specially prepared DTED file. In the “Elevation Image” slot, browse to locate the “~/data/vdev/etop02nobath.hlf” DEM file. Browse to locate the output Master MODIS image from Step 3 (NOT the Site Reference output file from Step 3). Finally, browse to select a location and filename to put your registered/map projected Secondary image. The recommended output directory is the “final*xxx*” directory (created in Step 1 using the supplied *xxx* name). Browse/Enter filenames in the optional “Site Reference” input and output boxes ONLY IF you have a pre-existing georeferenced subarea image for which you want to produce a matching MODIS subarea image file. NOTE, if the optional Site Reference file is provided, all subsequent processing will reference the subarea’s georeference (not the full image). The Site Reference file must be at least 1200x1200 pixels in size, and can be in either VICAR/GT or GeoTIFF format. The output is always VICAR/GT format.

- Quickbird: Click the top-most "Browse" button to find and select the raw multidate Quickbird Panchromatic scene that is to become the "Secondary" image, coregistered to the Master scene created in Step 3. The Secondary image must be the same original format as the Master (e.g., tif/tif; nitf/nitf; pan/pan). Use the Browse button to locate the Secondary image's Metadata (.imd) file, as well as the CIB mosaic and DTED Elevation files created in Step 2. If the metadata is unavailable or damaged, you will need to choose the “Manual Tiepoints” process. Browse to locate (/final*xxx*) the output Master Quickbird image from Step 3 (NOT the Site Reference output file from Step 3). Then browse to select a location and filename to put your registered/map projected Secondary image. The recommended output directory is the “final*xxx*” directory (created in Step 1 using the supplied *xxx* name). In the “Optional Out RPC/TIFF” slot, browse or enter a path/name if you want to create a copy of the *input* secondary Quickbird image with improved rational polynomial coefficients (NITF only). The output format is GeoTIFF. Browse/Enter filenames in the optional “Site Reference” input and output boxes ONLY IF you have a pre-existing georeferenced subarea image for which you want to produce a matching Quickbird subarea image file. NOTE, if the optional Site Reference file is provided, all subsequent processing will reference the subarea’s georeference (not the full image). The Site Reference file must be at least 1200x1200 pixels in size, and can be in either VICAR/GT or GeoTIFF format. The output is always VICAR/GT format.

- NTM: See separate documentation. A CIB image is recommended but not required.

- **Area of Interest Selection**: Leave blank to coregister the entire image, or enter starting and ending image lines (rows) and samples (columns) to define a subarea for coregistration. This can be useful for trimming an image if the image area exceeds the Landsat/CIB or DTED mosaic. For Ikonos and Quickbird, a subarea of less than 15000x15000 is recommended (smaller dimensions produce a better registration in mountainous areas), or increase the "Grid Fineness" for very large images. Click the "View Input Image" button to display the image and help identify the line/sample subarea limits. In the *xvd display* program, click the "Zoom Factor" button and choose 'Zoom to Fit' to see the entire image. Select "Tools/Stretch..." to display a variety of optional contrast enhancement options ('Gaussian' usually works best). Select "File/Exit" to quit and close the display program. The display may take a minute or two; be patient!

- Coregistration Parameters

> **- Initial FFT Search Size** (Hyperion only): Use this option if the coregistration product is unsatisfactory. The smaller (256) FFT size often works better with images that have clouds present. Alternatively, an option is provided to manually find two tiepoints for guiding the automated FFT tiepoint process. This option is especially necessary if the Hyperion ACS metadata file is missing or damaged. After clicking the "Choose…" button, allow 30 seconds for two *xvd diplay* windows and a dialog box (Figure 5-12) to appear. Use the display program to find a common tiepoint near the top of the Hyperion image, and a second point near the bottom of the image. Other imagery may require three points. Enter the Line (row) and Sample (Column) numbers of the tiepoint pixels into the dialog box and click the "Accept" button.
>
> **- Optional Control Point**: Optional for Quickbird and NTM NITF images. Only required if your image fails to correlate. Enter the Line (row) and Sample (column) for an accurately known Latitude and Longitude coordinate position.
>
> **- Manual Tiepoints** (Quickbird, NTM, Ikonos only): Use this option if the correlation fails, is unsatisfactory, or you want to improve the accuracy of the rpc(s) through a better correlation. Upon clicking the "Choose…" button, two windows will appear (be patient, the second window may take a full minute). Find one common tiepoint between the input and CIB images (addition tiepoints are ignored). Click the "Accept" button (Figure 5-12) to record your entered values. Be sure to close the *xvd display* windows.
>
> - Click the "**Start**" button to begin the Master Image Coregistration process.

- Battlefield Entity Selection Parameters (Quickbird and NTM Only; Figure 5-15): Use this option to create Master and Secondary chips centered on user-provided BE coordinates. Coordinates not found in the input imagery will be skipped. There is no current limit on the number of BE entries.

- **BE List:** Browse to find an ascii/text file containing Battlefield Entity coordinates in the following format: longtitude, latitude, BE#, and short text string (no blanks).

- **Output Chip Type:** Choose either VICAR or GeoTIFF output format.

- **Output Chip Prefix:** Short descriptive text placed at the beginning of the output chip's filename. May include a directory path.

- **Chip Pixel Size (meters):** Pixel resolution of the output chips. Can be smaller (higher resolution) than the Master/Secondary pixel size.

- **Chip Window Size (pixels):** The size of the output (square) chip images. The minimum size is 1200x1200. The default is 4096x4096.

- **Master Reference RPC:** Browse to find the Master Image's RPC tiff file created in Step 3 .

Figure 5-15: Secondary Image BE Parameters (NTM imagery only).

- **Registration Review**: Five (5) optional tools are provided (Figure 5-14, bottom) to review the output registration accuracy. Note, if the optional Site Reference "subfile" is provided, the Registration Review will show the **full** image registration, although subsequent AFIDS processing will reference the subarea file.

- **Output**: Click this button and press "Review" to display the registered Secondary image.
- **Base Overlay** (not available for MODIS): Click this button and press "Review" to display the Secondary image superimposed on the Landsat or CIB mosaic used in the registration process. This option is useful for evaluating registration errors on an image/feature basis.

- **Master Overlay**: Click this button and press "Review" to display the Secondary image superimposed on the Master image. This option is useful for evaluating registration errors on an image/feature basis.

- **Accuracy**: Click this button and press "Review" to display a "Vector Magnitude" map. This map provides a coarse grid of vectors showing the direction and magnitude of "rubber sheeting" that occurred in the registration of the Secondary image to the Master image. The magnitudes are sized for display and are NOT to scale. They provide a 'relative' evaluation of a local point's spatial adjustment. A small 'tick' indicates the base point's location.

- **Accuracy Overlay**: Click this button and press "Review" to display the "Vector Magnitude" points overlayed on the registered Secondary image.

5.6 Step 5: IMAGE COREGISTRATION PROCESSING – ADDITIONAL BANDS

Use this Step to extract and coregister the Ikonos/Quickbird Panchromatic and four multispectral (blu, grn, red, nir) bands, any of the 224 Hyperion hyperspectral bands, any of the 10 ALI bands, any of the 14 Aster bands, up to 8 Landsat bands, and any of the 38 MODIS bands from your Master/Secondary images coregisterd in Steps 3 and 4 above. Refer to Appendix B for a complete list of all the image sensor bands. This step must be repeated for each desired Aster and MODIS band. Multiple bands can be output for Hyperion, ALI, Ikonos and Quickbird. If the optional Site Reference file was used in Steps 3 or 4, the output additional bands will reflect the Site Reference dimensions. BE SURE the Image Type you will be coregistering has been correctly selected from the Sensor Type list (on the left side of the main menu), then click the "Setup..." button to begin the "Additional Band" task.

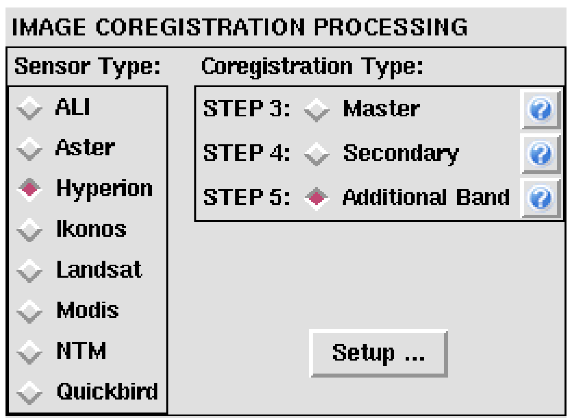

Figure 5-16: Select the “Additional Band” button and Sensor to begin Step 5. Click “Setup”.

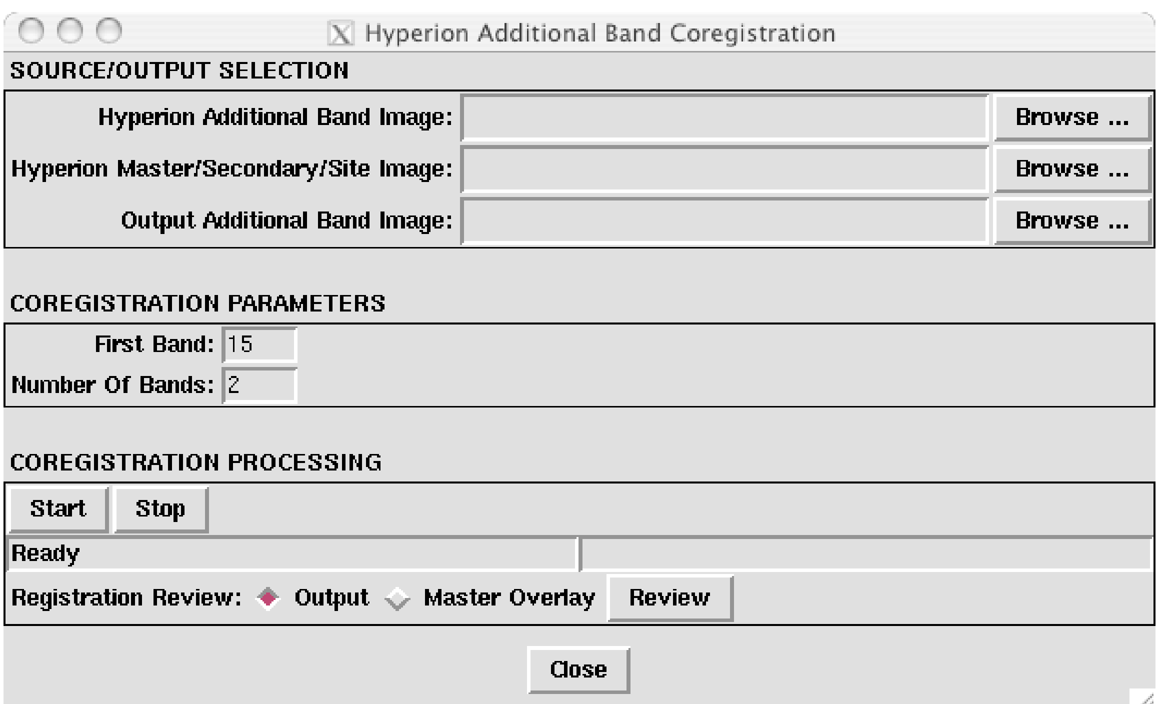

Figure 5-17: Hyperion-example of the dialog box used to create Step 5 “Additional Bands”.

- **Source/Output Selection**:

- ALI: Click the 'Additional Band' Browse button to find and select the original (raw) Master or Secondary ALI scene .hdf; .M1R) that you want to select bands from. In the second slot, browse to find the registered Master, Secondary, or Site Reference image created in Steps 3 or 4. If the selection is Master or Secondary, be sure the first slot is consistent, i.e., Master with Master, etc. Then browse to select a location and filename to put your output Band images. The software will append a band number at the end of your filename. The recommended output directory is the "final*xxx*" directory (created in Step 1 using the supplied *xxx* name).

- Aster: Click the 'Additional Band' Browse button to find and select the original (raw) Master or Secondary Aster scene (.hdf) that you want to select bands from. In the second slot, browse to find the registered Master, Secondary, or Site Reference image created in Steps 3 or 4. If the selection is Master or Secondary, be sure the first slot is consistent, i.e., Master with Master, etc. Then browse to select a location and filename to put your output Band. The recommended output directory is the "final*xxx*" directory (created in Step 1 using the supplied *xxx* name).

- Hyperion: Click the 'Additional Band' Browse button to find and select the original (raw) Master or Secondary Hyperion scene .hdf; .L1R) that you want to select bands from. In the second slot, browse to find the registered Master, Secondary, or Site Reference image created in Steps 3 or 4. If the selection is Master or Secondary, be sure the first slot is consistent, i.e., Master with Master, etc. Then browse to select a location and filename to put your output Band images. The software will append a band number at the end of your filename. The recommended output directory is the "final*xxx*" directory.

- Ikonos: Click the 'Additional Band' Browse button to find and select the (raw) Master or Secondary Ikonos Multispectral scene (.tif) that you want to select bands from. In the second slot, browse to find the registered Master, Secondary, or Site Reference image created in Steps 3 or 4. If the selection is Master or Secondary, be sure the first slot is consistent, i.e., Master with Master, etc. Then browse to select a location and filename to put your output Band. The software will append a band suffix at the end of your filename. The recommended output directory is the "final*xxx*" directory (created in Step 1 using the supplied *xxx* name).

- Landsat: Click the 'Additional Band' Browse button to find and select the additional Master or Secondary Landsat band (e.g., *_nn1.tif, *.I2, *.b04, or *.FST) that you want to coregister. In the second slot, browse to find the registered Master, Secondary, or Site Reference image created in Steps 3 or 4. If the selection is Master or Secondary, be sure the first slot is consistent, i.e., Master with Master, etc. Then browse to select a location and filename to put your output Band. The recommended output directory is the "final*xxx*" directory (created in Step 1 using the supplied *xxx* name). Repeat this process for each additional Landsat band to be coregistered.

- MODIS: Click the 'Additional Band' Browse button to find and select the original (raw) Master or Secondary MODIS scene (.hdf) that you want to select bands from. In the second slot, browse to select the input file's Geolocation file (MOD03) file (.hdf) to provide metadata information. If your MODIS file was provided in two parts, use the browse buttons to enter the Part 2 image/metadata information into the “Image 2/Geoloc 2” slots. In the fifth slot, browse to find the registered Master, Secondary, or Site Reference image created in Steps 3 or 4. If the selection is Master or Secondary, be sure the first slot is consistent, i.e., Master with Master, etc. Then browse to select a location and filename to put your output Band. The recommended output directory is the “final*xxx*” directory (created in Step 1 using the supplied *xxx* name).

- Quickbird: Additional Bands are currently supported for full image scenes only (i.e., AOI/subarea selection in Step 3 and 4 was left blank to select the whole scene). Click the 'Additional Band' Browse button to find and select the (raw) Master or Secondary Quickbird Multispectral scene that you want to select bands from (e.g., red, grn, blu, or nir). Use the Browse button to locate the Master/Secondary image's Metadata file. In the third slot, browse to find the registered Master, Secondary, or Site Reference image created in Steps 3 or 4. If the selection is Master or Secondary, be sure the first slot is consistent, i.e., Master with Master, etc. Then browse to select a location and filename to put your output Band. The software will append a band suffix at the end of your filename. The recommended output directory is the “final*xxx*” directory (created in Step 1 using the supplied *xxx* name).

- **Coregistration Parameters**: For ALI, enter the starting band number (1-10), and the number (quantity) of subsequent bands to be extracted and registered. For Aster, select the desired sensor type (Visual and Near InfraRed; Short Wave InfraRed; Thermal InfraRed) and the band number. Note that band 2 is the Aster “Master” band and is therefore excluded from the band selection menu. The Aster Surface Emissivity (AST05), Surface Kinetic Temperature (AST08), and Surface Radiance-TIR (AST09) can also be registered. For Hyperion, enter the starting band number (1-224), and the number (quantity) of subsequent bands to be extracted and registered. For MODIS, enter a band number between 1 and 36, except for bands 13 and 14 which are specified as "13L, 13H, 14L, 14H". This option is not used by Ikonos or Quickbird.

- **Acquisition Time** (MODIS only): Select whether the MODIS data is Day or Night time.

- Click the "**Start**" button to begin Coregistration and extraction of individual bands.

- **Registration Review**:

- **Output**: Click this button and press "Review" to display the registered band. If the Site Reference file was used in Steps 3 or 4, the display will show that file.

- **Master Overlay**: Click this button and press "Review" to display the selected ban superimposed on the Master or Secondary image. This option is useful for evaluating registration errors on an image/feature basis.

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5.7 STEP 6: GeoTIFF UTILITIES

5.7.1 Process Utilities

This set of optional utilities is for trimming and matching images in VICAR and GeoTIFF (.tif) formats, usually for export to another image processing software package. Note that the 'Remap' and 'Correlation' options involve a second resampling of the input imagery.

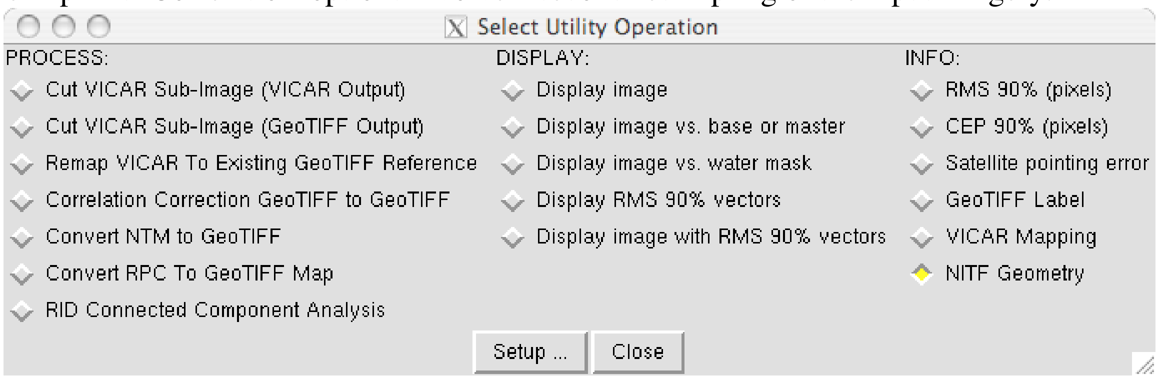

Figure 5-18: Optional Utilities selection box. Pick a Utility and click the “Setup…” button.

- Cut VICAR Sub-Image (VICAR Output): Use this option to cut a piece out of a Master or Secondary band generated using the AFIDS system. Both the input and output will remain in VICAR “gt” format.

- Click the "**Setup**" button to display a dialog box. Use the browse buttons to locate the input band (outputs from Steps 4, 5, or 6), and the desired location/filename of the subarea output image.

- Click the "**View Input Image**" button to view the input band, and write down the Beginning Line and Sample, and Ending Line and Sample of the desired subarea. Enter those numbers into the AOI slots.

- Click the "**View image when complete**" button to automatically display the subarea image after it has been generated.

- Click the "**Start**" button to begin the process.

- Cut VICAR Sub-Image (GeoTIFF Output): Use this option to cut a piece out of a Master or Secondary band generated using this Coregistration system, The output will be converted to GeoTIFF (georeferenced TIFF) format for export to another image processing software package.

- Click the "**Setup**" button to display a dialog box. Use the browse buttons to locate the input band (outputs from Steps 4, 5, or 6), and the desired location/filename of the subarea output image (.tif).

- Click the "**View Input Image**" button to view the input band, and write down the Beginning Line and Sample, and Ending Line and Sample of the desired subarea.

Enter those numbers into the AOI slots. Leave blank to convert the entire image to GeoTIFF format.

- Click the "**View image when complete**" button to automatically display the subarea image after it has been generated.

- Click the "**Start**" button to begin the process.

- Remap VICAR to Existing GeoTIFF Reference: Use this option to match (resample) a Master or Secondary band (generated using AFIDS), to your existing GeoTIFF image (.tif). Note that the GeoTIFF image must have georeference information in its TIFF header, and is currently limited to Platte Carree, UTM, Albers Equal Area, and Lambert Conformal Conic with Two Standard Parallels. The output will be converted to GeoTIFF (georeferenced TIFF) format for export to another image processing package. Also note that this option will not produce a pixel-to-pixel registration with the reference image; use the "Correlation Correction" after this remapping to obtain registration.

- Click the "**Setup**" button to display a dialog box. Use the first browse button to locate the VICAR-formatted input band (outputs from Steps 4, 5, or 6), Use the second browse button to locate the GeoTiff reference image (the image to which the input band will be mapped to). Use the third browse button to enter the desired location/filename of the output image (.tif).

- Click the "**View image when complete**" button to automatically display the remapped (resampled) image after it has been generated.

- Click the "**Start**" button to begin the process.

- Correlation Correction GeoTIFF to GeoTIFF: Use this option to obtain pixel-to-pixel registration between two GeoTIFF images (.tif). Note that both GeoTIFF images must have georeference information in their TIFF headers. The input will be resampled and output in GeoTIFF format.

- Click the "**Setup**" button to display a dialog box. Use the first browse button to locate the input GeoTIFF image that is to be registered. Use the second browse button to locate the GeoTiff reference image (the image to which the input band will be mapped). Use the third browse button to enter the desired location/filename of the output image (.tif).

- **Cut to Cover**: The default is recommended. Click 'Reference' if the input image is to be trimmed to match the dimensions of the Reference image (second input). Click 'Input' to retain all the input image's area, but note this option may result in an output image of different size and starting position than the reference image. The default is 'Reference'. “Gore Width” is the number of black pixels added to pad the input image when output.

- **Interpolation**: Choose the interpolation method. The default (Bilinear) is recommended. 'Bilinear' splits and resamples pixels, but gives a precise pixel-to-pixel fit. 'Nearest Neighbor' preserves pixel integrity by duplicating or removing pixels, but often produces half-pixel offsets.

- **Poly Fit**: Choose the desired polynomial fit. The default polynomial fit (Piecewise Linear) is recommended. Options include: Linear, Keystone, Quadratic, and Cubic.

- **Initial FFT Window Size**: The default is recommended. Increase this number if the initial output image registration quality is poor. Valid numbers are: 32, 64, 128, 256, 512, and 1024. The default is 64.

- **FFT Footprint Zoom**: The default is recommended. Increase this number if the output image registration quality is poor, and adjusting the "Initial FFT Window Size" parameter hasn't helped. This parameter expands the area under which the FFT will be calculated by "leap frogging" pixels. Small numbers (1-10) are best, if you need to change the default. Only for use with images that are <2 meter resolution.

- **Correlation Tolerance**: The default is recommended. This parameter controls which tiepoints are used in the resampling process. Lowering the Tolerance will increase the number of lower-quality tiepoints. Raising the Tolerance will decrease the total number of tiepoints, but the remaining tiepoints will be of very high quality. Adjust this parameter only if you are having problems obtaining a good registration.

- **Grid Fineness**: These values define the grid used by the automated tiepoint selection and matching routines. 500x500 or 1000x1000 are good choices over the default, but they will increase the processing time. Generally, Horz*Vert should be less than 1,000,000.

- Click the "**View image when complete**" button to automatically display the remapped (resampled) image after it has been generated.

- Click the "**Start**" button to begin the process.

- Convert NTM to GeoTIFF: Use this option to convert a NTM image dataset in NITF format to GeoTiff (georeferenced TIFF) format for export to another image processing software package.

- Click the "**Setup**" button to display a dialog box. Use the browse buttons to locate the input imagery and the desired location/filename of the output image (.tif).

- Click the "**View image when complete**" button to automatically display the imagery after it has been generated.

- Click the "**Start**" button to begin the process.

- Convert RPC to GeoTIFF Map: Use this option to re-project an AFIDS output GeoTIFF Quickbird, Ikonos, or NTM image dataset with rpc(s), to Platte Carree, UTM, or other existing GeoTIFF Reference image, with only a single resampling.

- Click the "**Setup**" button to display a dialog box. Use the browse buttons to locate the input imagery (.tif), an elevation file covering the input image, and the desired location/filename of the output image (.tif).

- Select all the desired processing parameters. Refer to Section 5.4 for descriptions. If the reference option is selected, browse to locate the GeoTIFF image you would like your input (GeoTIFF) image to match. For "**Coverage Selection**," choose 'Cover Reference' to trim (or fill) the input file to match the reference image's areal coverage. Choose 'Cover Input' to include only the input image's areal coverage.

- Click the "**View image when complete**" button to automatically display the imagery after it has been generated.

- Click the "**Start**" button to begin the process.

- RID Connected Component Analysis: The Registered Image Difference Connected Component Analysis function (Change Detection) utility is described in Section 5.8.

5.7.2 Display Utilities

This set of optional utilities is for displaying and comparing image datasets. The *xvd display* program is used for all image displays.

- Display Image: This option displays the requested VICAR image.

- Click the "**Setup**" button to display a dialog box. Use the Browse button and a select an image to be displayed.

- Click the "**Start**" button to begin the process.

- Display image vs. base or master: This option displays a selected image with either the Landsat or CIB mosaic (if the selected image was a "Master"), or if the selected image is a "Secondary," it displays it with the "Master."

- Click the "**Setup**" button to display a dialog box. Use the Browse button and a select an image to be displayed.

- Click the "**Start**" button to begin the process.

- Display image vs. water mask: This option displays a selected image against a coarse-scale land/water mask.

- Click the "**Setup**" button to display a dialog box. Use the Browse button and a select an image to be displayed.

- Click the "**Start**" button to begin the process.

- Display RMS 90% vectors: This option displays a "Vector Magnitude" map. This map provides a coarse grid of vectors showing the direction and magnitude of "rubber sheeting" that occurred in the registration of the Master to 'base image' or Secondary image to the Master image. The magnitudes are sized for display and are NOT to scale. They provide a relative evaluation of a local point's spatial adjustment. The small 'tick' indicates the base point's location.

- Click the "**Setup**" button to display a dialog box. Use the Browse button and a select an image to be displayed.

- Click the "**Start**" button to begin the process.

- Display image with RMS 90% vectors: This option displays the "Vector Magnitude" map overlaid on the selected image. This map provides a coarse grid of vectors showing the direction and magnitude of "rubber sheeting" that occurred in the registration of the Master to 'base image' or Secondary image to the Master image. The magnitudes are sized for display and are NOT to scale. They provide a relative evaluation of a local point's spatial adjustment. The small 'tick' indicates the base point's location.

- Click the "**Setup**" button to display a dialog box. Use the Browse button and a select an image to be displayed.

- Click the "**Start**" button to begin the process.

5.7.3 Information Utilities

This set of optional utilities is for displaying image accuracy and georeference information.

- RMS 90% (pixels): This option performs an accuracy test of the selected image against its reference image (Landsat/CIB mosaic or "Master"). It generates a coarse grid of correlation tiepoints to calculate a root-mean-square (RMS) value.

- Click the "**Setup**" button to display a dialog box. Use the Browse button and a select an image to be tested.

- Click the "**Start**" button to begin the process.

- CEP 90% (pixels): This option performs a Circular Error Probability (CEP) test of the selected image against its reference image (Landsat/CIB mosaic or 'Master'). Using a coarse grid of correlation tiepoints, the CEP provides a pixel accuracy distance within which points will fall half the time.

- Click the "**Setup**" button to display a dialog box. Use the Browse button and a select an image to be processed.

- Click the "**Start**" button to begin the process.

- Satellite pointing error: This option calculates the minimum satellite pointing error for an image, as measured between the ephemeris and the orthorectified base map locations, and considering the AFIDS built-in satellite model.

- Click the "**Setup**" button to display a dialog box. Use the Browse button and a select an image to be processed.

- Click the "**Start**" button to begin the process.

- GeoTIFF Label: This option lists the AFIDS /VICAR label on the selected image (i.e., 'label-list'). The output is displayed in the process window.

- Click the "**Setup**" button to display a dialog box. Use the Browse button and a select an image to be processed.

- Click the "**Start**" button to begin the process.

- VICAR Mapping: This option lists a VICAR image's GeoTIFF map coordinates and georeference information. The output is displayed in the process window.

- Click the "**Setup**" button to display a dialog box. Use the Browse button and a select an image to be processed. Click the "**Start**" button to begin the process.

- NITF Geometry: This option lists selected metadata from NITF-formatted images provided by Quickbird, Ikonos, and NTM. The metadata includes the geographic coordinates for the four image corners and center, plus information that can affect registration quality including Oblique Angle, Roll Angle, Ground Sample Distance (GSD), and other information. The output is displayed in a new window.

- Click the "**Setup**" button to display a dialog box. Use the Browse button and a select an image to be processed. Click the "**Start**" button to begin the process.

5.8 Registered Image Difference (RID) Connected Component Analysis

The purpose of this utility is to create a visual color-coded mask of the 'change detection' (image subtraction) between two image dates, using spectral thresholds and custom filters to focus on the specific characteristics of a desired target pixel set. This approach will work for all AFIDS-supported sensor types where two images have been co-registered (NTM, Quickbird, Aster, Landsat, etc.). To start this process, select “RID Connected Component Analysis” from the Utilities Menu (Figure 5-18) and click the ‘Setup…” button to display the RID dialog box (Figure 5-19 below).

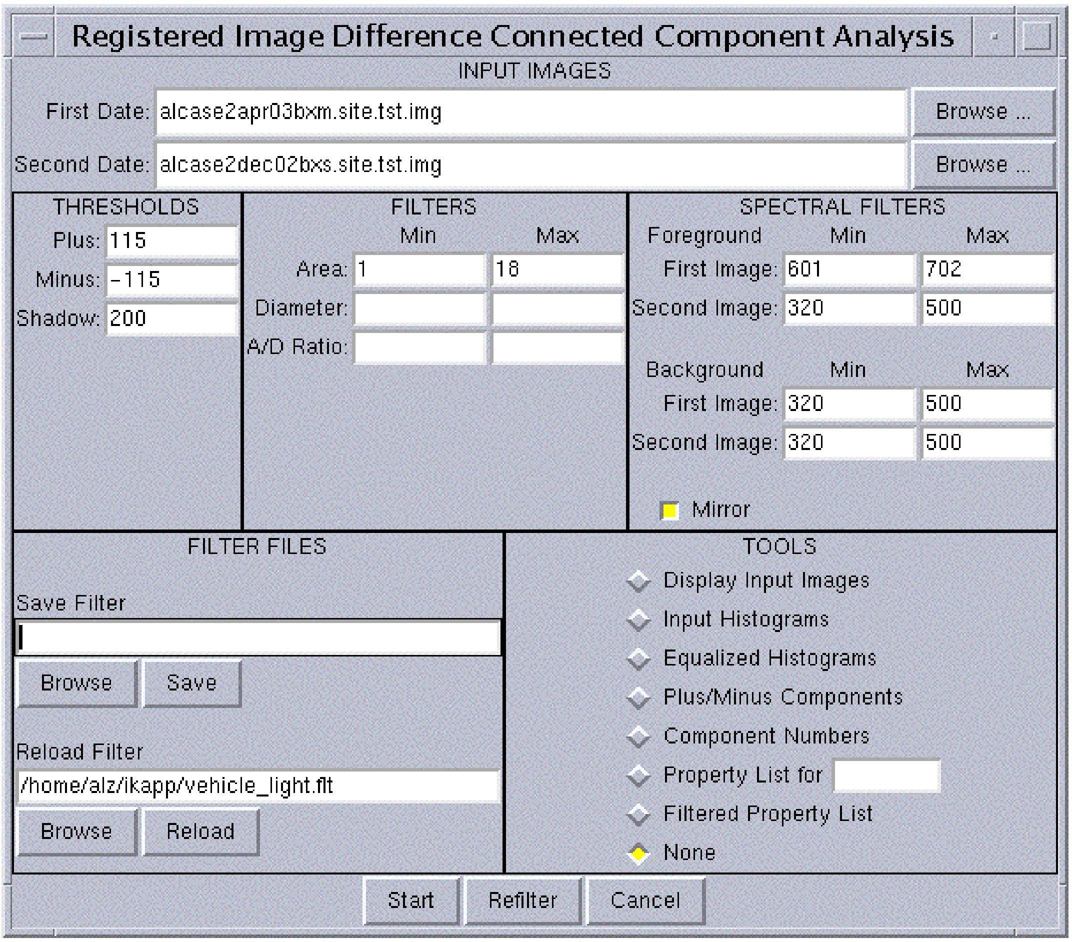

Figure 5-19: RID Connected Component Analysis Dialog Box.

The RID process has two phases: 1) “Filter Design,” which involves stepwise iteration of values and the viewing of results, and 2) “Filter Use,” which is the repeated application of pre-defined filters in a production environment. The “Filter Design” phase and process is described below in a series of steps:

- **Step 1, Input Images:** Use the ‘Browse’ buttons to locate the two co-registered images that are to be analyzed. Any AFIDS-registered images can be selected. For consistency, the first image should be the oldest date, and the second image should be the newest date. You should also know the location in the image of one or more target(s) of interest that you want to search for elsewhere in the image.

- **Step 2, Filter Files:** The “Save Filter” box is for saving your RID parameters. The “Reload Filter” box is for retrieving a saved RID parameter file. Use the ‘Browse’ buttons to locate a directory to save or retrieve the parameter file. The ‘.flt’ suffix MUST be entered as part of the file name. Be sure to click the ‘Save’ button to actually save your parameter file. A reloaded parameter file must be re-entered into the save box for it to be resaved after modification.

- **Step 3, Tools:** The options specified in the “Tools” box provide a methodology for filling in the remaining “Thresholds,” “Filters,” and “Spectral Filters” dialog boxes. Perform each of these tool options in order, from top to bottom. Be sure to click ‘OK’ when the “Job Ended” dialog box appears.

    - Click **“Display Input Images”** then click the ‘Start’ button. This will bring up two xvd display windows showing the two input images. These images are for reference and information. Reposition the displays on the monitor screen so they are available for subsequent review, but don’t cover the RID dialog box OR the xterm window.
    - Click **“Input Histograms”** then click the ‘Start’ button. This step will generate frequency histograms of the two input images and report them in the xterm window (scroll back for review). These histograms are primarily for reference and information.
    - Click **“Equalized Histograms”** then click the ‘Start’ button. Three equalized histograms will appear in the xterm window for: 1) The first Image; 2) The second Image (histogram-matched to the first Image); and 3) The difference image (of the two equalized images). For change detection, the primary interest is in the tails of the difference image, where the maximum ‘Plus’ and ‘Minus’ change has occurred between the two images.
        - Choose “cut-off” points from the (difference image) tails, and enter these values into the ‘Plus’ and ‘Minus’ boxes located in the “Thresholds” dialog box. The ‘Plus’ cut-off point (pixel value) indicates the lowest ‘bright’ pixel of ‘changed’ interest. All the values greater than the ‘Plus’ value will be considered in the subsequent processing. Correspondingly, the ‘Minus’ cut-off point indicates the highest ‘dark’ pixel of interest. These first ‘guesses’ can be iterated upon later.
        - If the difference image has a large spike at its ‘negative’ end, there may be some shadow, gore, water, or other dark featues in the imagery. Optionally, select a pixel value that cuts off the spike, and enter this pixel value in the ‘Shadow’ box located in the “Threshold” dialog box. All the image pixels below this threshold will be excluded from analysis. This first ‘guess’ can also be iterated upon later.

- Click **“Plus/Minus Components”** then click the ‘Start’ button. This step generates “Plus” and “Minus” image masks (0/1) and uses xvd to display them showing those areas that are above (plus) and below (minus) the specified thresholds. As displayed, ‘Light’ pixels are light pixels in Image 1 and dark pixels in Image 2. ‘Dark’ pixels are light pixels in Image 2 and dark pixels in Image 1.
    - These initial black and white displays are for review purposes. If one of the Plus or Minus displays is NOT picking up your known target location, then you should modify (broaden/lower) the Plus, Minus, and Shadow threshold values.
    - Alternatively, if one of the displays IS picking up your target, but is also selecting a lot of other unrelated pixels (noise) and objects are starting to coalesce, then you need to tighten/raise the thresholds.
    - This process can be iterated as many times as desired, but be SURE to click the ‘Start’ button (at the bottom of the RID dialog box) after changing the thresholds, to make the new values effective.
- Click **“Component Numbers”** then click the ‘Start’ button. This step assigns a unique number to every separate pixel group (“cluster” or “polygon”) found in the imagery. To ensure that every light and dark pixel group is visually displayable, the number one (1) million is added to all the dark (Minus) pixel groups, and the number two (2) million is added to all the light (Plus) pixel groups. The user must REMEMBER to subtract the 1 or 2 million to get the actual component number for a given pixel group (e.g., the number 2,017,154 is really 17,154).
    - Find and determine the pixel group number containing your target using the xvd display of the Plus/Minus image. Be prepared to enter this number in the next step.
- Click **“Property List for_____”**, enter the pixel group number from the previous step, then click the ‘Start’ button. Various statistics that describe the selected target pixel group will be displayed in the xterm window. Use these values to customize and hone the analysis to focus specifically on your target object’s particular spectral and shape characteristics, and all other pixel groups that are similar. Enter values in the “Spectral Filters” and “Filters” dialog boxes. Note that these parameters are optional, and some may not be appropriate or relevant for your particular target.
    - From the displayed property statistics, enter ‘Foreground’ and ‘Background’ thresholds in the “Spectral Filters” dialog box. ‘Foreground’ refers to the target pixel values, and ‘Background’ refers to the (contrasting) pixel area around the target. The entered minimum and maximum values should generally be +/- 50 of the spectral mean of your target pixel group. Values can be entered for both the first and second image, but filling all the parameters may not be necessary for your target case. Generally, provide

parameters for the First Image Foreground and Background, then fill in the rest as needed. This process can be iterated.

    - Mirroring (on by default) causes two searches for pixels matching the threshold criteria. The second search is a mirror image of the first, i.e., the spectral filter values for the first image and second image are interchanged, and the results are combined using the "and" logical.
    - From the displayed property statistics, enter minimum amd maximum values for the 'Area,' 'Diameter,' and 'Area/Diameter Ratio' fields in the "Filters" dialog box. 'Area' controls the number of pixels in the target pixel group (and subsequent similar target pixel groups to be found). 'Diameter' is for controlling the horizontal and vertical lengths of the target groups. 'A/D Ratio' is for controlling the shape of the target groups. Not all of these parameters may be relevant to your target's characteristics, and over specifying them might hinder detection.
  - Click **"Filtered Property List"** then click the "Start" button. This tool will generate statisitics for all the pixel group polygons in the color change detection image. However, only the first thirty (30) pixel group statisitics are printed to the xterm window. This information is provided primarily for reference purposes.
  - Click **"None"** then click the 'Start' button. This step resets all intermediate files and generates a color change detection image based upon all the selected thresholds and filters. A color image will display with Red indicating target pixel objects from Image 1, and blue indicating target pixel objects from image 2. If the change detection product does not meet your expectations, you can revisit any of the "Tools" to determine new "Filters" or "Spectral Filters" parameters. After making any changes, be SURE to click **"Refilter"** from the bottom of the RID dialog box. (Threshold Plus/Minus changes required use of the "Start" button.) Expect that several iterations may be necessary to obtain satisfactory results.
  - Click **"Refilter"** (at the bottom of the RID dialog box) if any changes are made in the "Filters" or "Spectral Filters" parameters (not "Thresholds") as part of an iteration process. This implements the new changes and generates a new color change detection display.

- **Step 4, Save Filter:** Be sure to save your filter parameters in the "Save Filter" box located in the "Filter Files" dialog box. Use the 'Browse' buttons to locate a directory to save the parameter file. The '.flt' suffix MUST be entered as part of the file name. Be sure to click the 'Save' button to actually save your parameter file.

This completes use of the first version of the AFIDS Registered Image Difference (RID) Connected Component change detection analysis tool.

APPENDIX A

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PRECISION AUTOMATIC CO-REGISTRATION PROCEDURES FOR SPACECRAFT SENSORS

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ABSTRACT

Automated sub-pixel co-registration and ortho-rectification of satellite imagery is required for precise change detection and analysis of low- (e.g. 1-4km weather satellite), moderate- (e.g. 30m Landsat) and high- resolution (e.g. Ikonos and Quickbird) space sensors. The procedure is "automated" in the sense that human-initiated tiepoint selection is not required, but ephemeris information associated with an image is relied upon to initiate the co-registration process. The methodology employs the additive composition of all pertinent dependent and independent parameters contributing to image-to-image tiepoint misregistration within a satellite scene. Mapping and orthorectification (correction for elevation effects) of satellite imagery defies exact projective solutions because the data are not obtained from a single point (like a camera), but as a continuous process from the orbital path. Standard image processing techniques can apply approximate solutions with sufficient accuracy, but some advances in the state-of-the-art had to be made for precision change-detection and time-series applications where relief offsets become a controlling factor. The basic technique first involves correlation and warping of raw satellite data points to an orthorectified Landsat (30m) or Controlled Image Base (1 or 5m) database to give an approximate mapping. Then digital elevation models are used to correct perspective shifts due to height and view-angle. This image processing approach requires from two (e.g. geosynchronous weather satellite imagery) to four (e.g. polar weather satellite imagery) sequential processing steps that warp the dataset by resampling pixel values. To avoid degradation of the data by multiple resampling, each warp is represented by an ultra-fine grid of tiepoints. For successive warps, the grids are composed mathematically into a single grid such that only one re-sampling occurs. Ultra-fine grids can currently be up to 1000 x 1000, or one million points.

Several examples of precision change detection will be presented from *Hyperion*, ASTER, *NOAA/GOES/VISR*, *NOAA/POES/AVHRR*, *MODIS Terra* and *Aqua, Ikonos,* and *Quickbird.*

INTRODUCTION

The remote sensing community has been more concerned with the co-registration of images than the comprehensive image rectification issues of the photogrammetry community [Brown, L. (1992), Chalermwat, P. (1999), Fonseca, L. (1997), Le Moigne, J. (1997)]. Terrain effects have been considered of minor impact by the remote sensing community until recently, when (a) higher resolution systems became available, (b) a greater emphasis on satellite data integration with GIS for business applications occurred, and (c) change detection and data fusion studies became more prevalent. For example, studies on the impact of misregistration on change detection analysis have shown that a misregistration of only one pixel can cause up to 50 percent error in some change detection applications [Townshend, J. (1992)], and in most applications, change detection is confused by misregistration [Khorram, S. (1999), Smith, D. (2001)]. The emerging standard for remotely sensed imagery data transfer has identified the basic requirement for orthorectification processing as well as adherence to map projection standards, datum accuracy standards, and metadata [ISO/TC 211 Secretariat, (2001), Kresse, W. (2001)]. It is the adverse impact of the independent variable of terrain upon pixel position knowledge that continues to demand attention despite our good understanding of satellite ephemeredes (position and attitude) and sensor geometric properties. Many sensor systems (e.g. AVHRR, MODIS, GOES, and Landsat) employ line scan designs that view off-nadir as much as 55 degrees, while other sensor systems with pushbroom imaging designs (e.g. ASTER, Ikonos, Quickbird and Hyperion) regularly acquire off-nadir views of as much as 25 degrees.

The development of our automatic orthorectification and mosaicking system has relied upon two key recent developments. The first is the general availability of digital elevation models (DEMs) with 1 arc second posting (nominally 30 m) for much of the US, and the upcoming release of DEMs for the world's landmasses between 60.3 degrees N/S from the Shuttle Radar Topography Mission (SRTM) [SRTM Website]. This permits the preparation of orthorectified satellite imagery using similar techniques to those developed by the photogrammetry community for aerial photographs. The second is the preparation of a complete set of orthorectified Landsat TM images for the world's landmass by the Earth Satellite Corporation for the NASA/Stennis Commercial Data Buy Program [Earthsat Website]. These two developments provide the key datasets necessary to prepare a baseline image dataset to which all satellite imagery datasets having a pixel resolution of 10m or greater can be automatically orthorectified to sub-pixel accuracy.

METHODS

The image processing system we use, Video Image Communication And Retrieval (VICAR) started development in 1962, and has accumulated hundreds of processing routines over the years [Castleman, K. (1979)]. A major feature of VICAR, and also of other major image processing systems is the ability to string together a command-line sequence of standard processes (each coded as a computer program) to accomplish a complex task. We were attracted to the possibility of applying a sequence of these programs to the problem of map projecting and co-registering space-based sensor data.

The contemplated steps were:

1. Sensor-specific corrections (e.g. edge of scan overlap ("bowtie") correction of MODIS and AVHRR datasets).
2. Map projection using three image corner points (obtained from the satellite file information). Presently always from a rotated UTM projection to Platte Carre' projection.
3. Application of the provided satellite image Latitude/Longitude reference grid as a residual to the mapping. Note: this is provided with ASTER, MODIS, AVHRR and GOES images, but not for Hyperion or Landsat images.
4. Corrective mapping using ortho-rectified Landsat data as a base map, then using a 2-D FFT correlation [Kuglin, C. (1975)] of the sensor data to the ortho-rectified Landsat to generate tiepoints for an input to a quadratic model for image warp. The quadratic model approximates tiepoint-offset errors associated with along- and across-track position knowledge, and roll/pitch/yaw elements not explicitly accommodated for by the ground data processing system.
5. Elevation correction (using digital elevation models and view angle of space platform to pixel).
6. Co-registration of a second acquisition to a first acquisition (using 2-D FFT correlation tiepoints of the second image to the first).

However, there were two major problems in this design. First, was the need to continuously keep track of each pixel's geolocation, which required the addition of file parameters that tracked pixel scale size and raster geography (map datum and projection). This problem was resolved through the use of GeoTIFF file extensions added at each step in the image processing chain [Ritter, N (1997)]. Second was the recognition that each operation that moves pixels in an image processing system, known as a warp, resamples the input pixels to calculate the output pixels causing a degradation of the data. This degradation occurs whether one uses a nearest-neighbor resampling, which incurs spatial degradation, or a bilinear or spline resampling, which incurs radiometric degradation. When images are mapped or registered, resampling has to be performed, but we asked ourselves if there was any way that the resampling could be kept to a minimum of one.

The alternative of combining all the steps of an image processing system into a single computer program was considered. This design would go way beyond turning the image processing programs into subroutines, because the sequence of steps would have to be applied to each pixel value, requiring the central execution loops of each program to be strung together in a single execution loop. Reprogramming in this way would be extremely programmer intensive and have a high chance of programming failure.

Ultra-Fine Grid Methodology for Image Processing

The solution devised for this problem was to create an additional datatype standard in the VICAR system. The data type, called an *Ultra-Fine Grid*, is a grid that pairs up with an image to specify how it is warped to produce an output image. The VICAR system has always used grids to specify warps, and had programs that performed the warp of the image using the grid. However, the grid was limited to about a 30 x 30 grid, typical of most image processing systems. This size of grid does not allow for a very accurate warp unless the warp is fairly smooth [Bernstein, C. (1987), Ochis, H. (2000)]. Using differential geometry, one can show that the error between grid points is approximated by the difference between a secant and an arc of a circle. The maximum of this difference decreases four times as the secant is halved. Thus, a grid of 1000 x 1000 will decrease this secant error by a factor of over 1000 compared to a 32 x 32 grid. Further, the grids are composed of floating or double precision numbers. That is, they can reference between the pixels that they refer to.

The second step of this solution is to have all relevant programs produce or use ultra-fine grids. The relevant programs are:

1. The warping program.
2. The elevation correction program.
3. The 2-D FFT image correlation program.

In addition, there is a key program that can convert non-grids into ultra-fine grid format. For example, the output from correlation is rarely a grid, since bland areas may not correlate. This program needs at least two modalities for converting non-grids to grids: (a) polynomial fits and (b) piece-wise linear fits.

The final key to this solution is a program that can compose two initial ultra-fine grids into a single ultra-fine grid. Repeated applications of this program are able to compose all of the image processing steps, each of which has its own grid, into a single grid (see Figure-1). The *Composed Gridding* approach avoids the problem of coarse gridding found in the classical image processing techniques of piecewise transformation or polynomial-based geometric correction algorithms, known to introduce horizontal position errors in even the flattest terrain [Bernstein, C. (1987), Ochis, H. (2000)]. The Composed Gridding approach also does not reduce digital elevation models to triangular irregular networks (TINs) commonly used in digital photogrammetry to lower ray-tracing computation [Lee, P. (1991), Schenk, T. (1997)]. Rather, it employs a new algorithm for image-to-image tiepoint generation that can efficiently accept up to one million points, or a 1000x1000 matrix. The procedure allows multiple steps to be performed by a toolbox of routines, each outputting an ultra-fine grid. The grids from the steps are mathematically combined into a composed ultra-fine grid. While every sensor is a unique case, the toolkit of routines can address each type of systematic and erratic component associated with horizontal adjustments. Since the grids are floating point numbers, they do not contribute to a resampling type error as the composition process takes place. Care must be taken so that the earlier transformations do not introduce errors that cannot be removed by later transformations. As an example of this, the 11 x 11 mapping grid provided with the ASTER satellite data must be applied after the data are mapped into Platte Care' (longitude-latitude) coordinates, otherwise the secant error of the 11 x 11 cells would be large and non-correctable.

Processing Steps Using Ultra-Fine Grids

The processing becomes a cycle or iteration through the steps that are necessary to produce the final image (see Figure-1). For example, image correlation might be a third step. The first two steps are performed, the first two resulting ultra-fine grids are composed, and the resulting grid is used to warp the input into a partially corrected output. This output then becomes an input into correlation. The output from correlation is turned into a new ultra-fine grid, which can be used with the previous two ultra-fine grids to produce a third stage partially corrected output. The last cycle of this cyclic process produces the final output. Some stages might not need the actual image, for example, the elevation correction works on the grid only. At the present time, the bowtie correction applied to whiskbroom sensors (MODIS and AVHRR) is carried out as a separate resample. This resample only affects pixels in the bowtie overlap area.

Calculating absolute as well as relative position error bounds for each of the steps is quite difficult. Calculating a position and error bound for the overall process is even more problematic since some of the later steps correct errors from earlier steps. At the present time we are looking at the visible errors in the final products, relative to either two co-registered images to a source map and the Landsat ortho-rectified base image, as a measurement of the accuracy of the overall process.

The VICAR image processing system allows for the steps of a complex process to be set up as a user-friendly procedure with input parameters that name the raw data sets. We have set up procedures for several space-based sensors as described in the next section.

Case Studies Review

Five case studies are described to illustrate key functions developed, and how they are combined for an application to automatic co-registration.

The first case study, AVHRR time series co-registration (see Figure-2), exercised all of the functions associated with orthorectification of satellite images to a common reference base, and, by definition to each other, thereby permitting accurate change detection and time series analysis. The NOAA/POES/AVHRR (approximately 1km per pixel resolution) has important systematic geometric distortions associated with expanding latitudinal coverage as the spacecraft progresses pole ward, and progressive distortions associated with the whisk-broom scanner that points as much as 55 degrees off-nadir. The POES/AVHRR also experience erratic geometric distortions associated with incomplete position and attitude knowledge. As the orbit of the POES/AVHRR is allowed to perturb daily, orthorectification for co-registration must be performed under varying conditions for each scene.

The second case study, MODIS *Terra* and *Aqua* scene co-registration (see Figure-3), was able to utilize the per pixel geometry information provided in an ancillary file with the MODIS instrument data. Latitude, longitude, and scanner incidence angle to the earth geoid are provided, reducing the co-registration problem to systematic incorporation of elevation offsets, which are only a few pixels at the most for the 1km resolution bands. The co-registration of MODIS *Aqua* and *Terra* scenes taken over a 24-hour period permits thermal inertia characterization of the ground surface.

The third case study, Landsat-7 co-registration (see Figure-4), required a more rigorous co-registration using a 1 arc second (~30m) digital elevation model to accommodate the horizontal offset at the scene edges caused by up to 7.5° look-angles off-nadir of the whisk-broom sensor, and account for the higher pixel resolution (30m).

The fourth case study, NOAA/GOES/VISR co-registration (see Figure-5), required correction of the latitude-longitude information provided through the application of a single large-area 2-D FFT to each image. This corrected an offset bias/error in the ephemeris information. Subsequent application of the per-pixel Lat/Long position information proved adequate for co-registration of the 8km resolution data except in regions near the East/West limbs and northern edges of an acquisition where elevation offsets occur. Co-registration of multiple thermal bands permits time-series analysis over extended time period.

The fifth and sixth case studies, ASTER and Hyperion imagery co-registration (see Figures –6 &-7), required the similar use of a 1 arc second (~30m) digital elevation model to accommodate horizontal offsets of their high-resolution pixel datasets (15m and 30m). These Push-broom line array sensors are better behaved than whisk-brooms, but the instruments can view as much as two orbit paths on either side of their current nadir path, with the result that earth-incidence angles of over 20° needed to be accommodated.

The seventh and eighth case studies, *Ikonos* and *Quickbird* imagery co-registration (see Figure-8), require the use of both a 1 arc second (~30m) digital elevation model and the use of the USGS 1m resolution Digital Orthophotoquad (DOQ) or Controlled Image Base (CIB) datasets to accommodate horizontal offsets of their high-resolution pixel datasets (1m and 0.62m respectively). These Push-broom line array sensors are well characterized, but the instruments can view several orbit paths on either side of their current nadir path, with the result that earth-incidence angles of over 25° needed to be accommodated. A complete correction of horizontal offsets associated with micro-terrain and vertical construction in urban areas was not attempted. Co-registration offsets on the order of several meters occur at the top of tall buildings even though the building bases are co-registered in each frame.

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Townshend, J.R.G. et.al. (1992), "The Impact of Misregistration on Change Detection" IEEE Transactions on Geoscience and Remote Sensing, Vol. 30, No.5, September, 1992, pp. 1054-1060

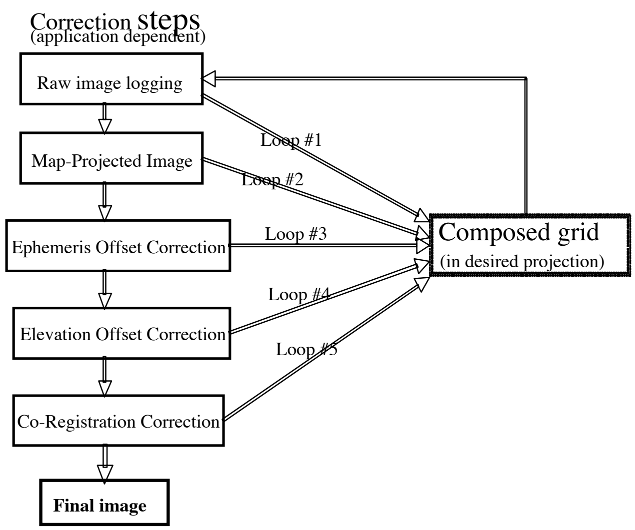


Figure 1. Composed Gridding Approach.
The *Composed Gridding* approach avoids the problem of coarse gridding found in standard image processing techniques, (piecewise transformation or polynomial-based geometric correction algorithms), and it does not reduce digital elevation models to triangular irregular networks (TINs). Rather, it employs a new algorithm for image-to-image tiepoint generation that can efficiently accept up to one million points, or a 1000x1000 matrix. The procedure allows multiple steps to be performed by a toolbox of routines, each outputting an ultra-fine grid. The grids from the steps are mathematically combined into a composed ultra-fine grid. Correction steps can now be applied sequentially without affecting spatial accuracy or signal-to-noise associated with multiple resampling of images.

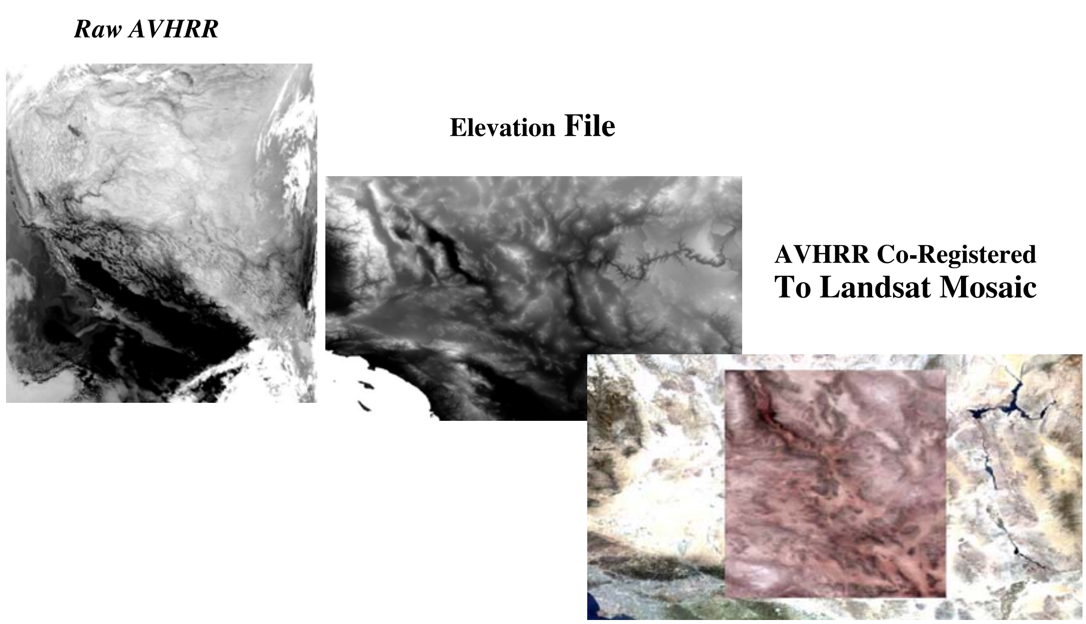


Figure 2. POES/AVHRR Multiple-Image Co-Registration.
AVHRR time series co-registration, exercised all of the functions associated with orthorectification of satellite images to a common reference base, and, by definition to each other, to permit accurate change detection and time series analysis. The raw AVHRR image needed to be first map projected, and then satellite-ephemeris corrected, after which horizontal offsets associated with elevation could be applied to assure precise co-registration.

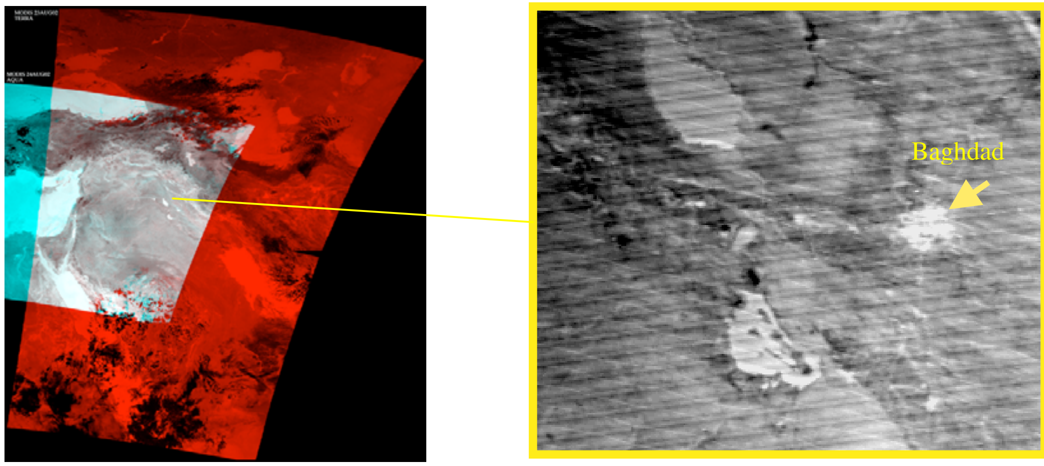


Figure 3. <u>MODIS Terra and Aqua Co-Registration</u>
MODIS long-wave infra-red images taken from both the *Terra* and *Aqua* platforms during the night of August 23-24, 2002 are co-registered here. The red image is an ascending image from *Terra*, and the blue image is a descending image from *Aqua*. As the images were acquired at approximately 10:30 pm and 2:30 am, the registered product presents thermal inertia differences in surface materials that have cooled down at different rates as the night progressed. Areas that cooled down more quickly appear whiter. The right image is an enlargement of a portion of the co-registered dataset.

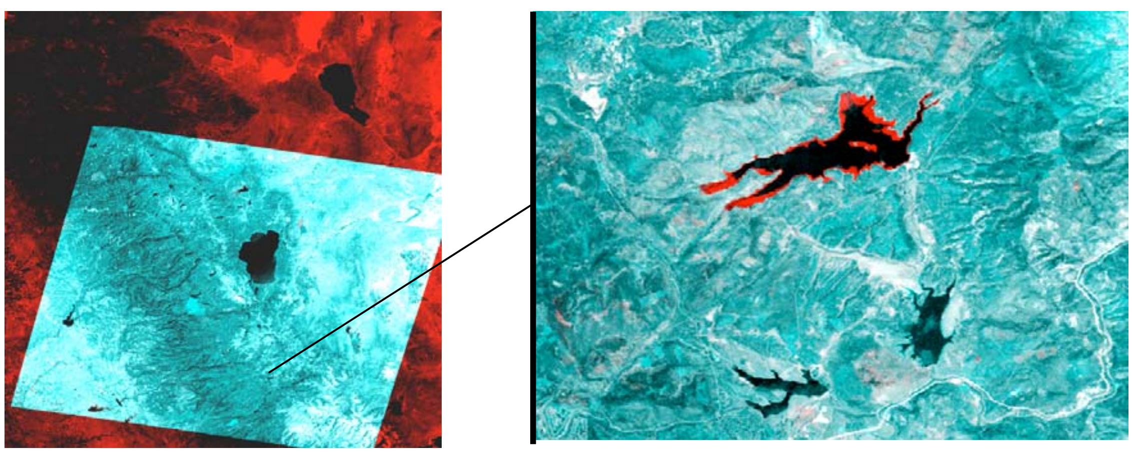


Figure 4. <u>Landsat-7 Co-Registration to the Orthorectified Landsat Mosaic (~1990)</u>
On the left, a Landsat-7 image has been co-registered to the orthorectified Landsat images in the region of Lake Tahoe California. The regional mosaic was compiled from the EarthSat orthorectified datasets prepared from Landsat-5 imagery acquired around 1990. The Landsat-7 image was acquired in 2002. On the right, the enlarged image highlights areas of change between 1990 and 2002 in red in the southern part of the scene.

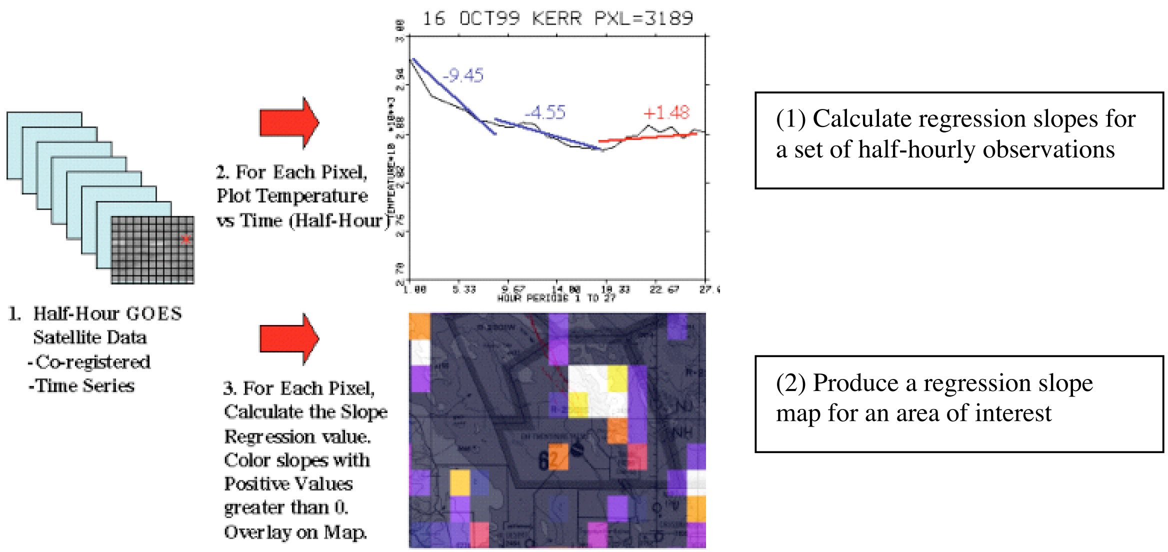
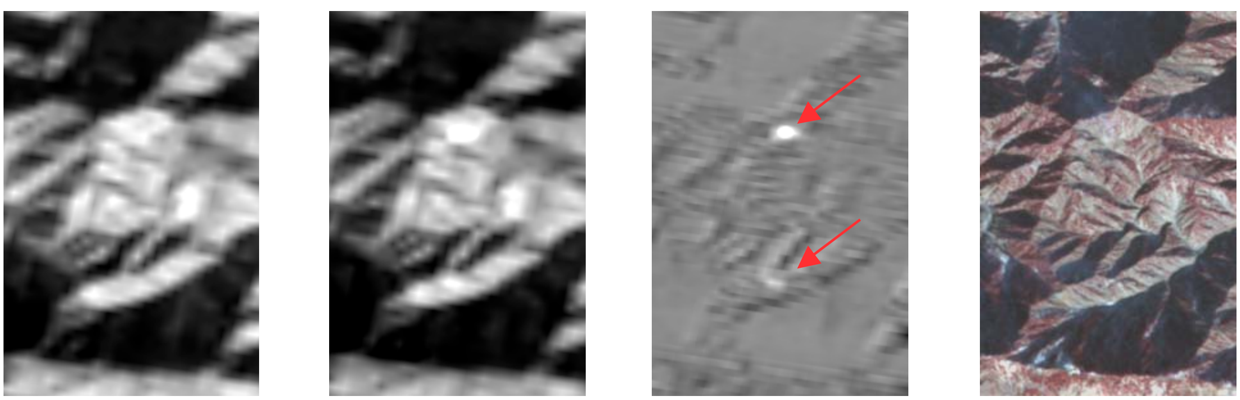


Figure 5. GOES Co-Registration for Time-Series Analysis
The co-registration of the 22+ GOES images taken during the period from sundown to sunrise the next morning permits the analyst to assess diurnal variations. Illustrated here is the case where the plot of a single pixel (designated number 3189 in the image matrix) shows a normal rapid drop in temperature at sunset and an anomalous rise in temperature in the late evening prior to sunrise. Regression slopes applied to segments of the time-series emphasize the changing temperature conditions for the location.



ASTER 08DEC01 THERMAL BAND 13 (90 METER RES)

ASTER 24DEC01 THERMAL BAND 13 (90 METER RES)

DIFFERENCE SHOWS HOT SPOTS

ASTER 24DEC01 VNIR 15m BANDS

Figure 6. ASTER Co-Registration of thermal imagery reveals hot spots.
The co-registration of the thermal bands in two ASTER images of the same area reveals "hot spots" in the difference image that cannot be attributed to sun angle effects or other natural phenomena. The co-registered VNIR image to the right provides context for analysis of the thermal anomaly.

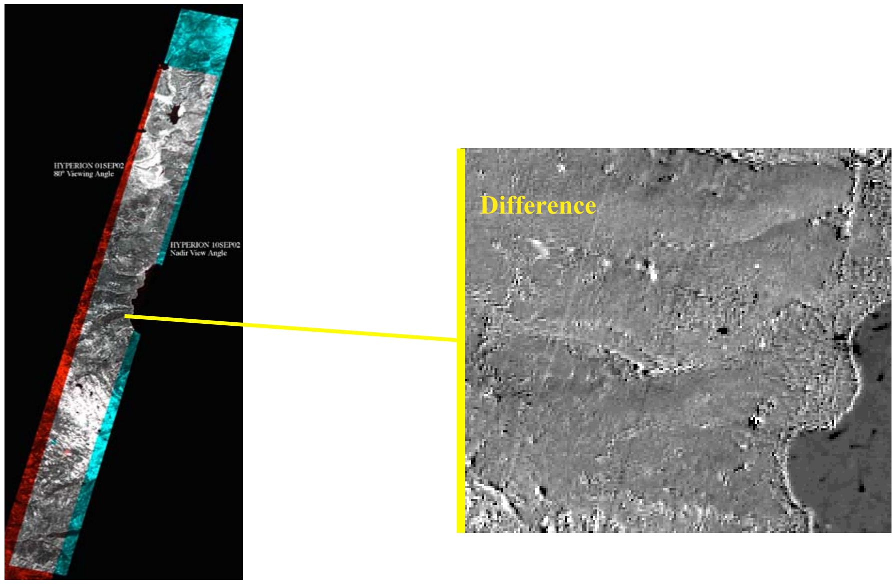


Figure 7. <u>Co-Registered *Hyperion* Hyperspectral images.</u>
On the left, two *Hyperion* hyperspectral images over the Sierra Nevada and Lake Tahoe California have been co-registered, and a single band from each date is displayed. The red image was taken on 1 September 2002 when the spacecraft was viewing the area of overlap (grayscale color) at an angle of 80°. The blue image was taken on 10 September 2002 when the spacecraft was viewing the area of overlap (grayscale color) at nadir. The difference image displays mostly unchanged conditions (gray), but a few boat wakes are visible as black streaks over the water, some white areas highlight low-lying water vapor clouds on 10 September 2002.

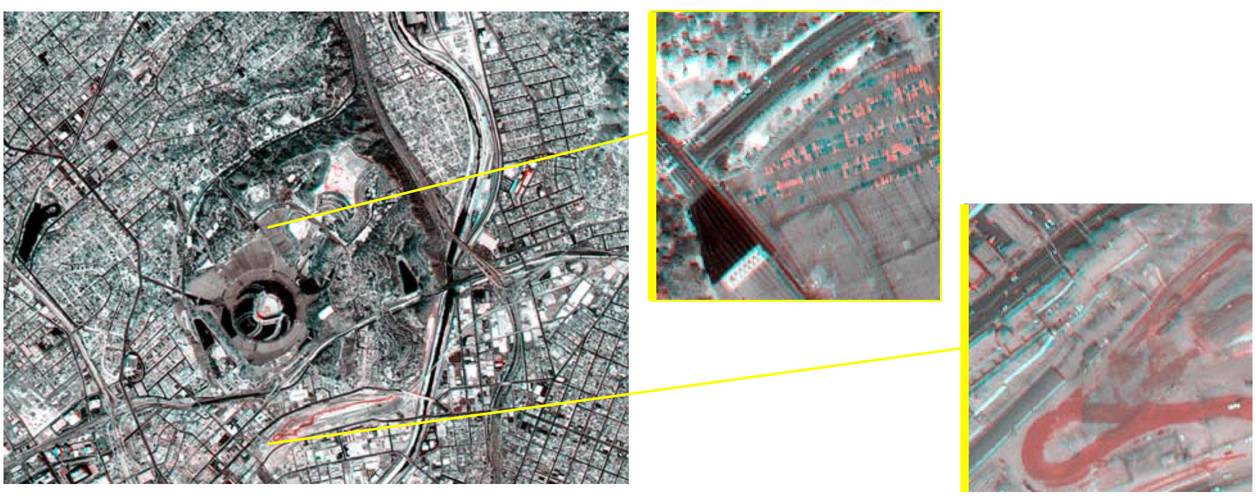


Figure 8. <u>Co-Registered *Ikonos* imagery of Los Angeles, California</u>
A portion of a pair of Ikonos images is displayed on the left, with close-up views on the right. Most of the image is gray, signifying little change between acquisitions. Blue colored areas note objects and brighter surface materials present on 23-AUG-02 but absent on 28-AUG-02, five days later. Red colored areas note objects and brighter surface materials present on 28-AUG-02 but absent on 23-AUG-02, five days earlier.

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APPENDIX B:
Image Sensor Bands

B.1 Aster Bands

AFIDS outputs all coregistered Aster products at 15m resolution.

Band	Wavelength	IFOV	LineXSamp	Format
Visual:				
1	0.5560	15m	8222x5205	Int*1
2	0.6610	15m	8222x5205	Int*1
3	0.8070	15m	8222x5205	Int*1
Shortwave:				
4	1.6560	30m	4111x2603	Int*1
5	2.1670	30m	4111x2603	Int*1
6	2.2090	30m	4111x2603	Int*1
7	2.2620	30m	4111x2603	Int*1
8	2.3360	30m	4111x2603	Int*1
9	2.4000	30m	4111x2603	Int*1
Thermal:				
10	8.2910	90m	1370x867	Int*2
11	8.6340	90m	1370x867	Int*2
12	9.0750	90m	1370x867	Int*2
13	10.6570	90m	1370x867	Int*2
14	11.3180	90m	1370x867	Int*2

B.2 Landsat-5 & 7 TM/ETM Bands

AFIDS outputs all Landsat mosaic products at 30m resolution.

1	450-520nm	30m	Blue
2	520-600nm	30m	Green
3	630-690nm	30m	Red
4	760-900nm	30m	Near-Infrared
5	1.55-1.75μm	30m	Far-Infrared
6	10.4-12.5μm	150m	Thermal-Infrared
7	2.08-2.34μm	30m	Geology Shortwave
8	500-900nm	15m	Panchromatic

B.3 Hyperion Bands

AFIDS outputs all coregistered Hyperion products at 30m resolution. Hyperion imagery contains 242 bands, although bands 225-242 are "zero (0 DN) Data" (and other bands).

Band	Wavelength	Bandwidth	IFOV	Notes
1	355.2889	11.3871	30m	0 Data
2	365.4642	11.3871	30m	0 Data
3	375.6392	11.3871	30m	0 Data
4	385.8146	11.3871	30m	0 Data
5	395.9902	11.3871	30m	0 Data
6	406.1650	11.3871	30m	0 Data
7	416.3402	11.3871	30m	0 Data
8	426.5157	11.3871	30m	
9	436.6912	11.3871	30m	
10	446.8665	11.3871	30m	
11	457.0418	11.3871	30m	
12	467.2173	11.3871	30m	
13	477.3922	11.3871	30m	
14	487.5679	11.3784	30m	
15	497.7429	11.3538	30m	
16	507.9184	11.3133	30m	
17	518.0938	11.2580	30m	
18	528.2688	11.1907	30m	
19	538.4444	11.1119	30m	
20	548.6194	11.0245	30m	
21	558.7944	10.9321	30m	
22	568.9696	10.8368	30m	
23	579.1455	10.7407	30m	
24	589.3205	10.6482	30m	
25	599.4959	10.5607	30m	
26	609.6713	10.4823	30m	
27	619.8464	10.4147	30m	
28	630.0220	10.3595	30m	
29	640.1972	10.3188	30m	
30	650.3727	10.2942	30m	
31	660.5480	10.2856	30m	
32	670.7225	10.2980	30m	
33	680.8987	10.3349	30m	
34	691.0732	10.3909	30m	
35	698.5488	10.4592	30m	
36	708.7239	10.5322	30m	
37	718.8994	10.6004	30m	
38	729.0749	10.6562	30m	
39	739.2499	10.6933	30m	
40	749.4254	10.7058	30m	

41	759.6003	10.7276	30m	
42	769.7763	10.7907	30m	
43	779.9514	10.8833	30m	
44	790.1269	10.9938	30m	
45	800.3019	11.1044	30m	
46	810.4772	11.1980	30m	
47	820.6521	11.2600	30m	
48	830.8278	11.2824	30m	
49	841.0031	11.2822	30m	
50	853.8787	11.2816	30m	
51	864.0533	11.2809	30m	
52	874.2291	11.2797	30m	
53	884.4044	11.2782	30m	
54	894.5793	11.2771	30m	
55	904.7547	11.2765	30m	
56	914.9299	11.2756	30m	
57	925.1055	11.2754	30m	
58	935.2809	11.2754	30m	0 Data
59	945.4555	11.2754	30m	0 Data
60	955.6313	11.2754	30m	0 Data
61	965.8060	11.2754	30m	0 Data
62	975.9818	11.2754	30m	0 Data
63	986.1571	11.2754	30m	0 Data
64	996.3327	11.2754	30m	0 Data
65	1006.5076	11.2754	30m	0 Data
66	1016.6827	11.2754	30m	0 Data
67	1026.8584	11.2754	30m	0 Data
68	1037.0334	11.2754	30m	0 Data
69	1047.2081	11.2754	30m	0 Data
70	1057.3845	11.2754	30m	0 Data
71	851.6206	11.0457	30m	0 Data
72	859.0096	11.0457	30m	0 Data
73	869.0977	11.0457	30m	0 Data
74	879.1867	11.0457	30m	0 Data
75	889.2754	11.0457	30m	0 Data
76	899.3629	11.0457	30m	0 Data
77	909.4515	11.0457	30m	
78	919.5414	11.0457	30m	
79	929.6392	11.0457	30m	
80	939.7272	11.0457	30m	
81	949.8165	11.0457	30m	
82	959.9052	11.0457	30m	
83	969.9932	11.0457	30m	
84	980.0825	11.0457	30m	
85	990.1709	11.0457	30m	
86	1000.2996	11.0457	30m	

87	1010.2983	11.0457	30m
88	1020.3978	11.0451	30m
89	1033.1943	11.0423	30m
90	1040.5928	11.0372	30m
91	1050.6923	11.0302	30m
92	1060.7916	11.0218	30m
93	1070.8884	11.0122	30m
94	1080.9869	11.0013	30m
95	1091.0869	10.9871	30m
96	1101.1860	10.9732	30m
97	1111.1852	10.9572	30m
98	1121.2827	10.9418	30m
99	1131.3796	10.9248	30m
100	1141.4791	10.9065	30m
101	1151.5784	10.8884	30m
102	1161.6750	10.8696	30m
103	1171.7742	10.8513	30m
104	1181.8739	10.8335	30m
105	1191.9724	10.8154	30m
106	1202.0714	10.7979	30m
107	1212.1685	10.7822	30m
108	1222.1671	10.7663	30m
109	1232.2656	10.7520	30m
110	1245.0643	10.7385	30m
111	1255.1642	10.7270	30m
112	1265.2617	10.7174	30m
113	1275.3610	10.7091	30m
114	1285.4579	10.7022	30m
115	1295.5581	10.6970	30m
116	1305.6564	10.6946	30m
117	1315.7549	10.6937	30m
118	1325.7531	10.6949	30m
119	1335.8503	10.6996	30m
120	1345.9513	10.7058	30m
121	1356.0491	10.7163	30m
122	1366.1476	10.7283	30m
123	1376.2450	10.7437	30m
124	1386.3452	10.7612	30m
125	1396.4424	10.7807	30m
126	1406.5430	10.8034	30m
127	1416.6400	10.8267	30m
128	1426.6381	10.8534	30m
129	1434.0377	10.8818	30m
130	1444.1356	10.9110	30m
131	1454.2347	10.9422	30m
132	1464.3330	10.9743	30m

133	1474.4312	11.0074	30m
134	1484.5316	11.0414	30m
135	1494.6284	11.0759	30m
136	1507.4277	11.1108	30m
137	1517.5256	11.1461	30m
138	1527.6246	11.1811	30m
139	1537.6234	11.2156	30m
140	1547.7222	11.2496	30m
141	1557.8209	11.2826	30m
142	1567.9187	11.3146	30m
143	1578.0168	11.3460	30m
144	1588.1156	11.3753	30m
145	1598.2136	11.4037	30m
146	1608.3145	11.4302	30m
147	1618.4110	11.4538	30m
148	1628.5120	11.4760	30m
149	1638.5100	11.4958	30m
150	1648.6046	11.5133	30m
151	1658.7042	11.5286	30m
152	1668.8027	11.5404	30m
153	1678.9042	11.5505	30m
154	1689.0038	11.5580	30m
155	1699.0990	11.5621	30m
156	1709.1986	11.5634	30m
157	1719.2977	11.5617	30m
158	1729.3962	11.5563	30m
159	1739.3950	11.5477	30m
160	1749.4908	11.5346	30m
161	1759.5894	11.5193	30m
162	1769.6912	11.5002	30m
163	1779.7866	11.4789	30m
164	1789.8877	11.4548	30m
165	1799.9869	11.4279	30m
166	1810.0840	11.3994	30m
167	1820.1830	11.3688	30m
168	1830.2804	11.3366	30m
169	1840.2794	11.3036	30m
170	1850.3776	11.2696	30m
171	1860.4781	11.2363	30m
172	1870.5732	11.2007	30m
173	1880.6752	11.1666	30m
174	1890.7740	11.1333	30m
175	1900.8710	11.1018	30m
176	1910.9688	11.0714	30m
177	1921.0684	11.0424	30m
178	1931.1655	11.0155	30m

179	1938.5679	10.9912	30m	0 Data
180	1948.5657	10.9698	30m	0 Data
181	1958.6614	10.9508	30m	0 Data
182	1968.7625	10.9355	30m	0 Data
183	1978.8605	10.9230	30m	0 Data
184	1988.9583	10.9139	30m	0 Data
185	1999.0563	10.9083	30m	0 Data
186	2009.1541	10.9069	30m	0 Data
187	2019.2529	10.9057	30m	0 Data
188	2029.3514	10.9013	30m	
189	2039.4520	10.8951	30m	
190	2049.4502	10.8854	30m	
191	2059.5498	10.8740	30m	
192	2069.6470	10.8591	30m	
193	2082.4453	10.8429	30m	
194	2092.5439	10.8242	30m	
195	2102.6404	10.8039	30m	
196	2112.7417	10.7820	30m	
197	2122.8384	10.7592	30m	
198	2132.9392	10.7342	30m	
199	2143.0381	10.7092	30m	
200	2153.0369	10.6834	30m	
201	2163.1338	10.6572	30m	
202	2173.2329	10.6312	30m	
203	2183.3296	10.6052	30m	
204	2193.4290	10.5803	30m	
205	2203.5291	10.5560	30m	
206	2213.6262	10.5328	30m	
207	2223.7253	10.5101	30m	
208	2233.8230	10.4904	30m	
209	2243.9216	10.4722	30m	
210	2253.9204	10.4552	30m	
211	2264.0208	10.4408	30m	
212	2274.1174	10.4285	30m	
213	2284.2166	10.4197	30m	
214	2294.3145	10.4129	30m	
215	2304.4126	10.4088	30m	
216	2314.5132	10.4077	30m	
217	2324.6104	10.4077	30m	
218	2334.7085	10.4077	30m	
219	2344.8081	10.4077	30m	
220	2354.9060	10.4077	30m	
221	2364.9045	10.4077	30m	
222	2375.0037	10.4077	30m	
223	2385.1013	10.4077	30m	
224	2395.2000	10.4077	30m	

B.4 Ikonos Bands

AFIDS outputs coregistered Ikonos products at 1m or 4m resolution.

Band	WaveLength	IFOV	Band Names
1	525-928nm	1m	Panchromatic
2	444-516nm	4m	Blue
3	506-595nm	4m	Green
4	631-697nm	4m	Red
5	757-852nm	4m	Near-Infrared

B.5 MODIS Bands

AFIDS outputs all coregistered MODIS products at 1km resolution.

Band	WaveLength	IFOV	Bandwidth	Example Usage
1	645nm	250m	50nm	Veg. Chlorophyll Absorp.
2	858nm	250m	35nm	Cloud/Veg. Land Cover
3	469nm	500m	20nm	Soil & Veg. Differences
4	555nm	500m	20nm	Green Vegetation
5	1240nm	500m	20nm	Leaf/Canopy Differences
6	1640nm	500m	24.6nm	Snow/Cloud Differences
7	2130nm	500m	50nm	Land/Cloud Properties
8	412nm	1000m	15nm	Chlorophyll
9	443nm	1000m	10nm	Chlorophyll
10	488nm	1000m	10nm	Chlorophyll
11	531nm	1000m	10nm	Chlorophyll
12	551nm	1000m	10nm	Sediments
13L	667nm	1000m	10nm	Sediments, Atmosphere
13H	667nm	1000m	10nm	Sediments, Atmosphere
14L	678nm	1000m	10nm	Chlorophyll Fluorescence
14H	678nm	1000m	10nm	Chlorophyll Fluorescence
15	748nm	1000m	10nm	Aerosol Properties
16	869nm	1000m	10nm	Aerosol/Atmosphere Properties
17	905nm	1000m	30nm	Cloud/Atmos Properties
18	936nm	1000m	10nm	Cloud/Atmos Properties
19	940nm	1000m	50nm	Cloud/Atmos Properties
20	3.75μm	1000m	0.18μm	Sea Surface Temp Fraction
21	3.96μm	1000m	0.059μm	Forest Finfraredes/Volcanoes
22	3.96μm	1000m	0.059μm	Cloud/Surface Temperature
23	4.05μm	1000m	0.061μm	Cloud/Surface Temperature
24	4.47μm	1000m	0.065μm	Tropospheric Temp/Cloud Fraction
25	4.52μm	1000m	0.067μm	Tropospheric Temp/Cloud Fraction

26	1375nm	1000m	30nm	Cinfraredrus Cloud Detection
27	6.72μm	1000m	0.36μm	Mid-Tropospheric Humidity
28	7.33μm	1000m	0.30μm	Upper-Tropospheric Humidity
29	8.55μm	1000m	0.30μm	Surface Temperature
30	9.73μm	1000m	0.30μm	Total Ozone
31	11.03μm	1000m	0.50μm	Cloud/Surface Temp
32	12.02μm	1000m	0.50μm	Cloud Height & Surface Temp
33	13.34μm	1000m	0.30μm	Cloud Height & Fraction
34	13.64μm	1000m	0.30μm	Cloud Height & Fraction
35	13.94μm	1000m	0.30μm	Cloud Height & Fraction
36	14.24μm	1000m	0.30μm	Cloud Height & Fraction

B.6 Quickbird Bands

AFIDS outputs coregistered Quickbird products at .61m or 2.44m resolution.

Band	WaveLength	IFOV	Band Names
1	450-900nm	61cm	Panchromatic
2	450-520nm	2.44m	Blue
3	520-600nm	2.44m	Green
4	630-690nm	2.44m	Red
5	760-900nm	2.44m	Near-Infrared

B.7 ALI Bands

AFIDS outputs coregistered ALI products at 30m resolution.

1	480-690nm	10m	Panchromatic
2	433-453nm	30m	Violet
3	450-515nm	30m	Blue
4	525-605nm	30m	Green
5	630-690nm	30m	Red
6	775-805nm	30m	Near-Infrared 1
7	845-890nm	30m	Near-Infrared 2
8	1200-1300nm	30m	Middle-Infrared
9	1550-1750nm	30m	Far-Infrared 1
10	2080-2350nm	30m	Far-Infrared 2

APPENDIX C:
VICAR/IBIS Tutorial

While the gui interface reduces the need for most direct interaction with VICAR command-line procedures, some interaction may be necessary (or desired) depending upon the situation. For this purpose, a quick introduction into the use of VICAR syntax is provided. Refer to the "VICAR User's Guide" (vug.tar in /afids_4.0/doc) for comprehensive instructions, reference information, and a list of basic programs. It is assumed that AFIDS has been fully installed and tested prior to this point (Section 4).

Launch VICAR by typing **vicar** at the Unix prompt. The system will respond with a Welcome Banner, several messages, and the vicar prompt:

%VICAR>

To leave/quit VICAR, type **exit**

%VICAR>**exit**

To execute a Unix command while in VICAR (except for 'ls'), type **ush** and the command:

%VICAR>**ush df -k**

To execute a VICAR application program, type it's name and parameters at the command line. For example, VICAR program "gen" is used to generate a test image with the output filename "a", 552 lines (rows), and 818 samples (columns):

%VICAR>**gen out=a nl=552 ns=818**

To verify the new file, read the file's label with the program "label-list":

%VICAR>**label-list inp=a** or just:
%VICAR>**label-l a**

To list the first 20 lines by 10 samples of the image "a" to your screen, use VICAR program "list":

%VICAR>**list a size=(1,1,20,10)**

To display the image on your screen, use the interactive VICAR display program "xvd":

%VICAR>**xvd a**

To identify all the parameters associated with a program, use the tutor mode (below). At the bottom of the tutor screen, type "**help *parameter***" to display information about the parameter (then **exit** to leave the parameter description). The tutor mode can also be used to run the program by filling in the parameter fields with values. Type **exit** to quit tutor mode, or **run** to execute the program (after filling in the parameter values):

%VICAR>**t gen** (or **tutor gen**)

To determine the function of a particular program (a partial list of programs can be found in the "VICAR User's Guide"), use the help mode (**exit** to quit):

%VICAR>**h gen** (or **help gen**)

The directory in which VICAR is run must have a "ulogon.pdf" to specify where VICAR searches for its programs. The location of basic VICAR programs is hardwired, but most of the co-registration programs are in a separate directory that must be specifically identified, for example "/opt/vdev". An example ulogon.pdf is:

```
procedure
body
write  "Executing from /home/tll"
setlib-delete library=($R2LIB)
setlib-add library=(/home/tll,/opt/vdev,$R2LIB)
end-proc
```

The "ulogon.pdf" demonstrates the basic syntax of a VICAR command-line 'procedure' or 'script'. The VICAR 'procedure' is a text file with the suffix ".pdf" (that predates Adobe Acrobat). The file must have the keywords "procedure", "body", and "end-proc", with some VICAR applications after the 'body' keyword. (The space between 'procedure' and 'body' is reserved for special declaration statements, if needed.) An example procedure is:

```
procedure
body
gen      a nl=250 ns=255
label-l  a
list     a size=(1,1,20,10)
hist     a
end-proc
```

The procedure can be written using any text editor such as **textedit**, **joe** or **vi.** Just be sure to end the filename with a ".pdf". To run the procedure in realtime, simply type its name at the VICAR prompt. To obtain a log of the running process, run the job in batch mode (below). If the procedure were named "testjob", the output logs would be named "testjob1.log" and "testjob1.log.stdout". (Note, logs can be printed using the **cat** command while the job is running.)

%VICAR>**testjob|run=batch|**

VICAR uses the exclamation point (!) to identify comment lines in the procedure. This can be useful for adding notes and descriptive text as well as bypassing program calls. The "goto *here*" command is also useful for jumping to different locations in a procedure. For example:

```
!This is a test
procedure
body
gen      a nl=250 ns=255
!Jump over the label-list program
goto next           !Any single word could be used in
!                   place of 'next'.
label-l  a
next>               !The ">" is required.
hist     a
end-proc
```

If a VICAR command-line must continue to a second line, place a plus sign (+) at the end of the first line to tell VICAR to continue to the next line.