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Automatic Co-Registration of Quickbird Data for Change Detection Applications

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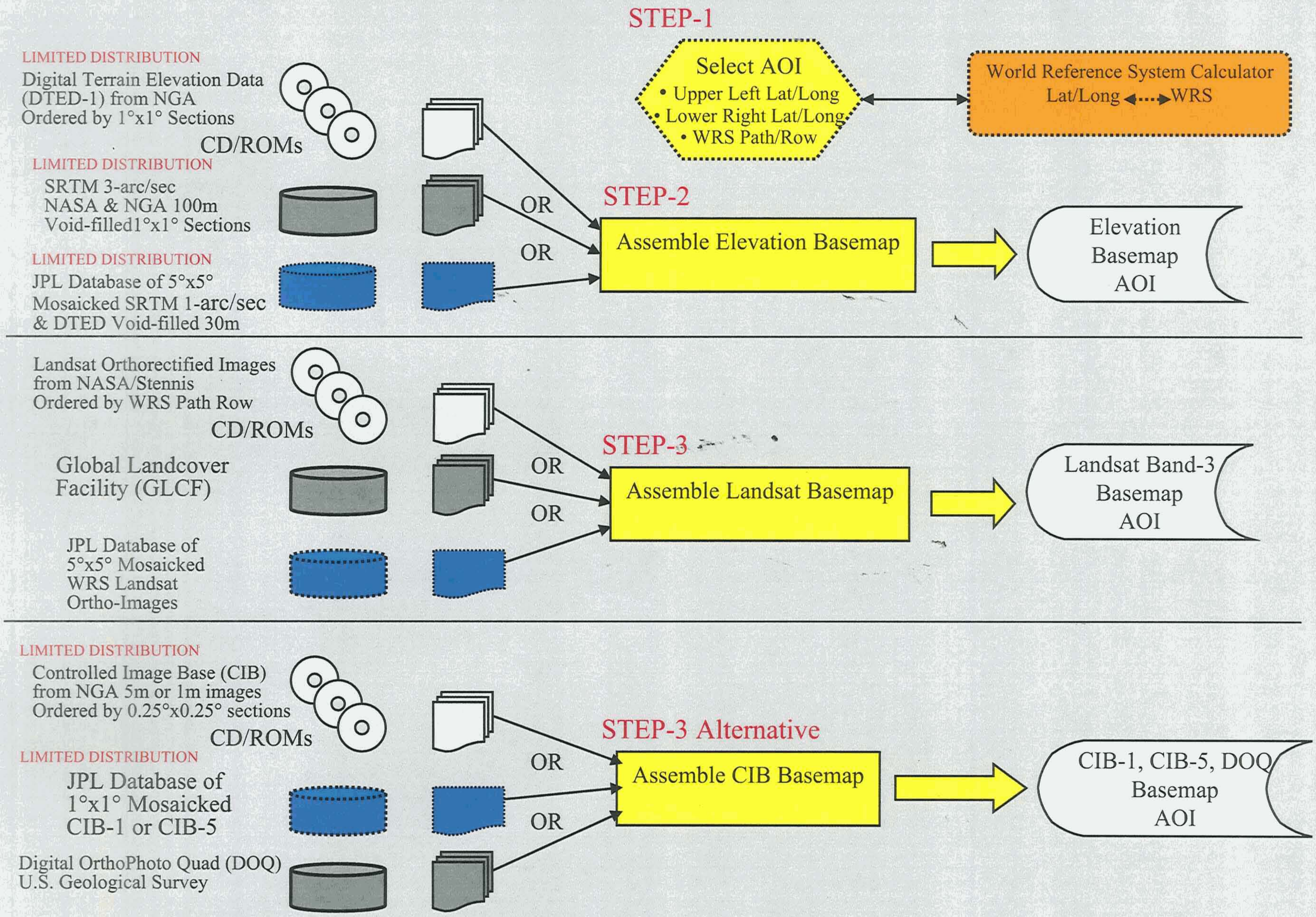
Overview

- Automatic Co-Registration Procedure (Automatic Fusion of Image Data System - AFIDS)
  - concept of operation
  - user interface
  - processing flow
  - image processing toolkit
  - schematic
- Quickbird test case
- Ikonos test case
- Summary
- Backup

AFIDS concept of operation

- Change detection requires subpixel registration of images taken at different pointing angles
- This requires orthorectification of the images
- AFIDS uses image processing techniques to rectify images to an image map base (for projection characteristics) and to a terrain map base (for relief correction)
- The necessary accuracy for change detection is attained by a final correlation of the "master" and "secondary" mapped images
- Only one resampling is required
- Process is automated
- Uses GeoTiff georeferencing concepts
- Based on NASA/JPL's "VICAR" Image Processing System using tcl/tk tools for the gui/interface

Ortho-Rectified Basemap Production



AFIDS processing flow

- Approximately locate the data using satellite position and pointing header information
- Correlate (~500 control points) to a map base (Landsat or CIB), adjust for elevation (DTED or SRTM), discard bad correlations
  - Produce ultrafine grid for adjustment to map base and produce mapped image
  - Calculate ultrafine grid for elevation offsets using elevation base and spacecraft model
- Produce elevation corrected image and correlate it again to map base (~600 control points), produce ultrafine grid
- Produce ultrafine grid for output mapping

AFIDS processing flow (Cont.)

- Produce mapped and elevation adjusted image, correlate to site image, output ultrafine grid
- Repeat last step if large pixel size difference between satellite image and site image, produce ultrafine grid
- Compose all of the ultrafine grids into a single grid and apply it to the raw satellite image to produce the final image product
- The final grid can be applied to the other spectral bands

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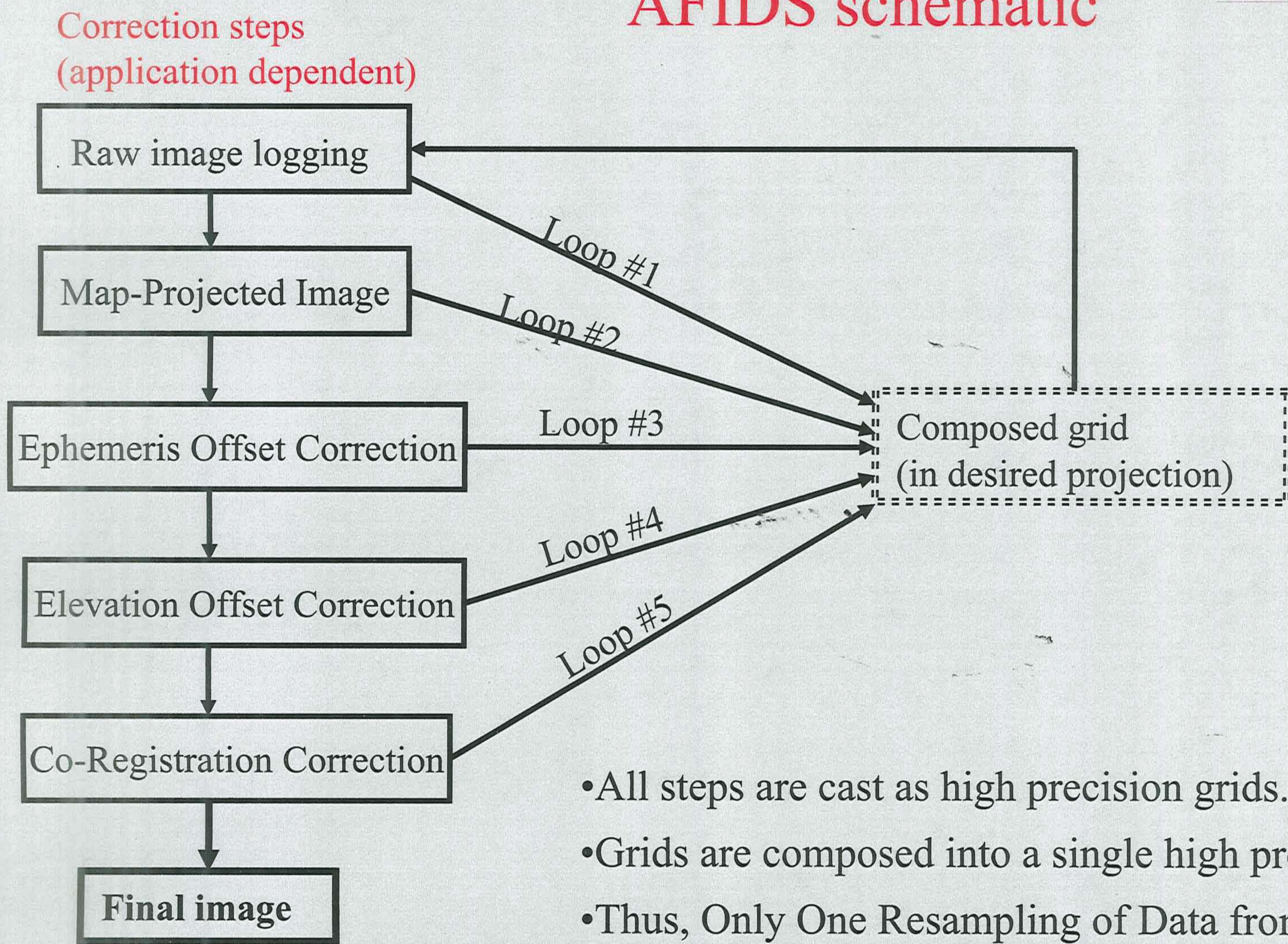
AFIDS schematic



- All steps are cast as high precision grids.
- Grids are composed into a single high precision grid.
- Thus, Only One Resampling of Data from Raw format to final coregistered Image.

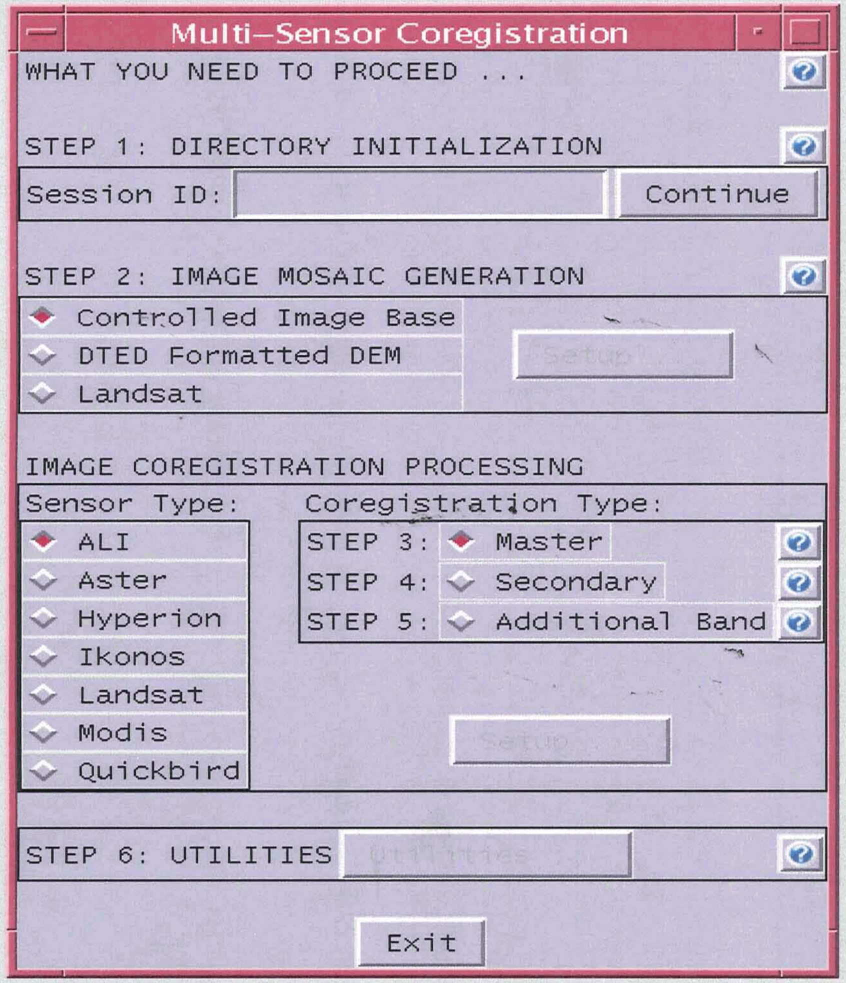
AFIDS image processing toolkit

- Adaptive image correlator
- Ultrafine grid composition routine
- Ultrafine grid image warping routine
- Surface fitting routine with polynomial and piecewise linear modes, output ultrafine grid
- Spacecraft models for seven choices in AFIDS
- Map coordinates in image label
- Map processing in tables of data
- Interactive and batch modes

Summary: Geo-Coregistration Procedures Accuracy Assessment (RMSE @ 90%)

Sensor	Description	Pixels RMSE Master-to Base CIB	Pixels RMSE Second-Image to Master	Meters RMSE Master-to Base CIB	Meters RMSE Second-Image to Master
Quickbird -small relief	Iraq **03Dec02 86°elv 10°az (M)** 03Apr03 70°elv 02°az	1.102 pixel To CIB-5	0.270 pixel	0.63m	0.1m
Ikonos -urban scene	Los Angeles, CA **23Aug01 74°elv 101°az (M)** 28Aug01 74°elv 202°az	14.23 pixel To CIB-5	8.8 pixel	14.2m	8.8m

AFIDS user interface



Currently Operational on Sun Solaris and Red Hat Linux Operating Systems

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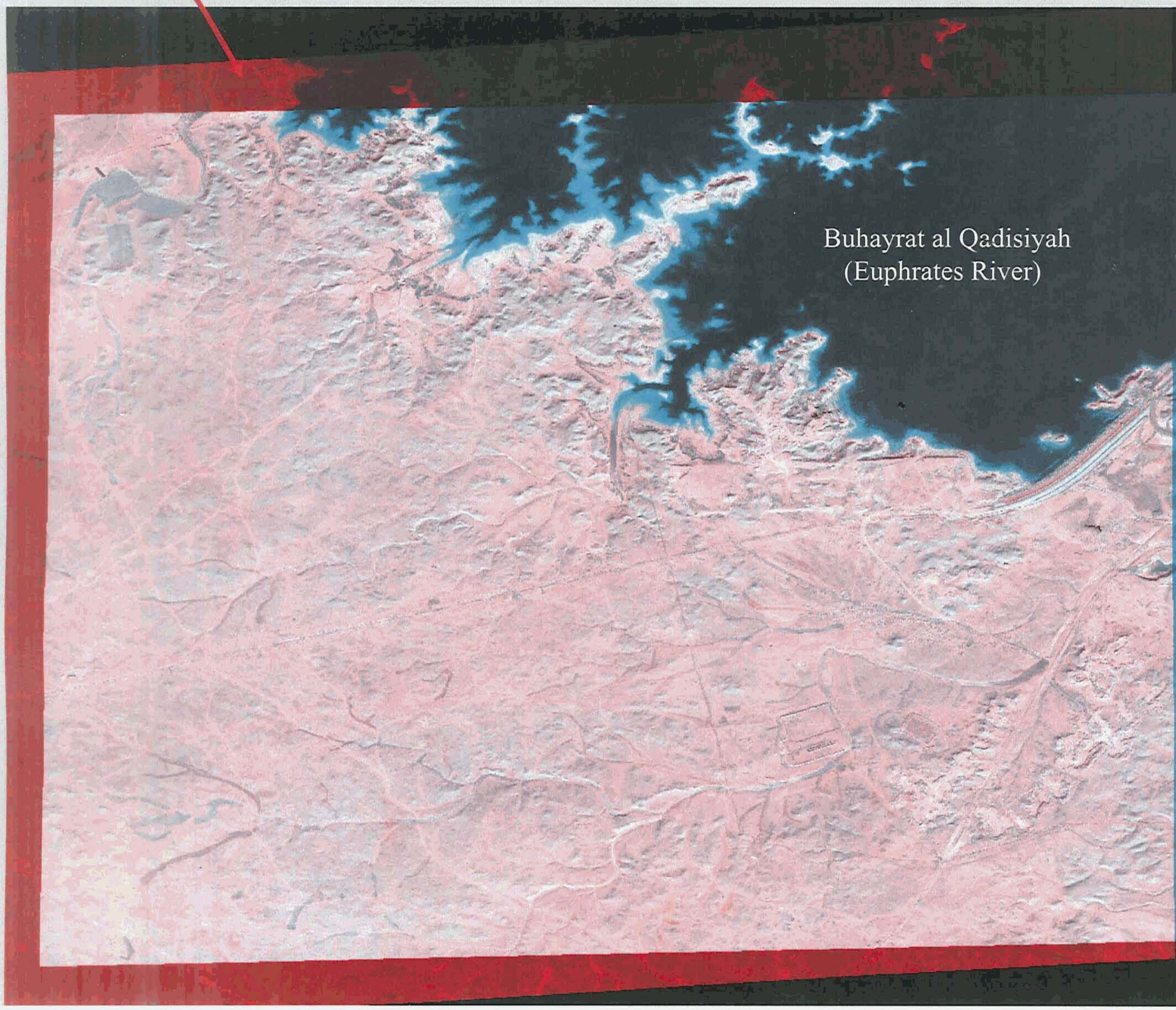
Quickbird Multi-Date Registration over Iraq

01APR03 Scene



Partial Quickbird Scenes:
- Original size 11500x17000
- Extraction size 6080x8350

19DEC02 Scene

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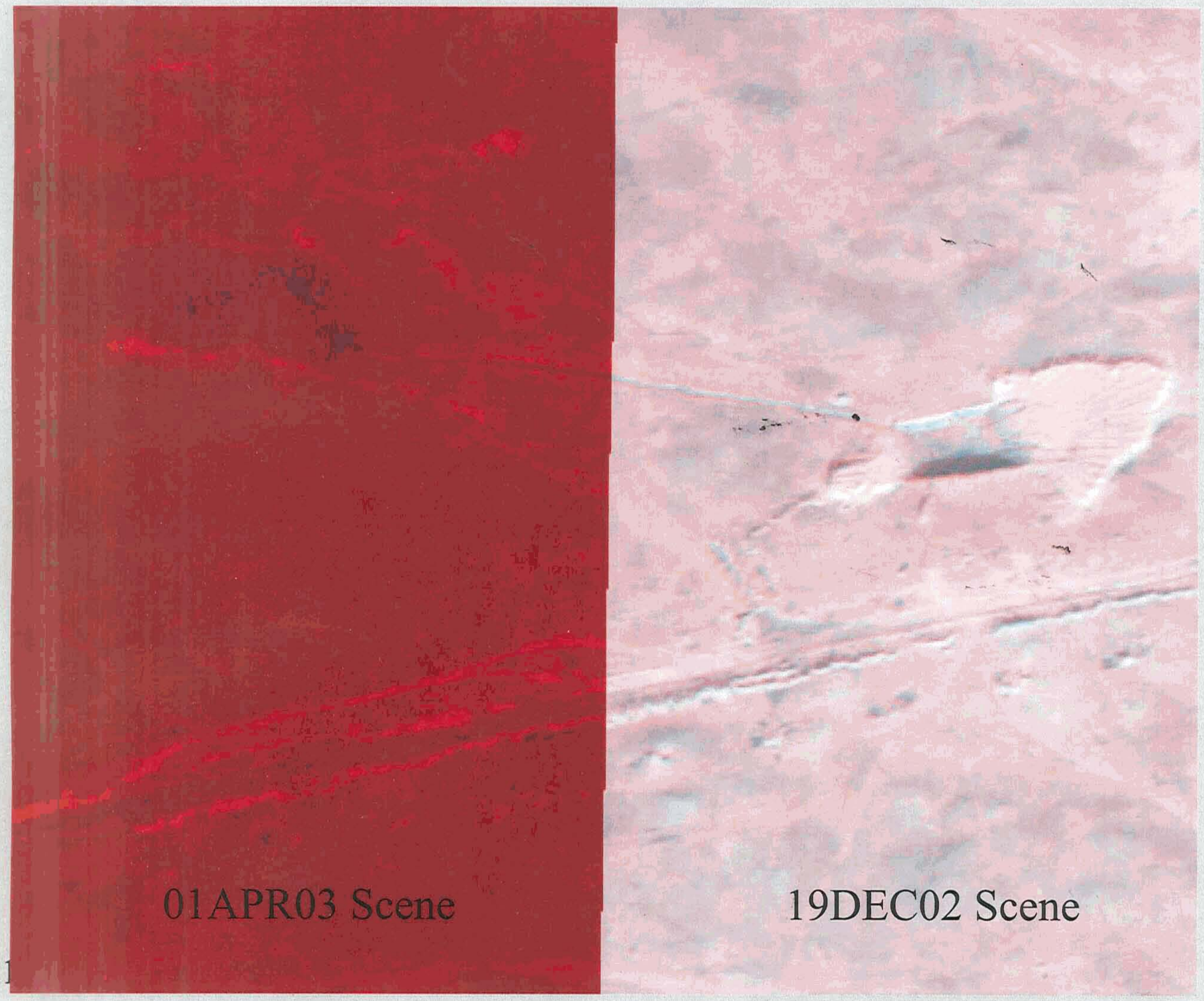
Quickbird Multi-Date Registration over Iraq



Edge Registration Example

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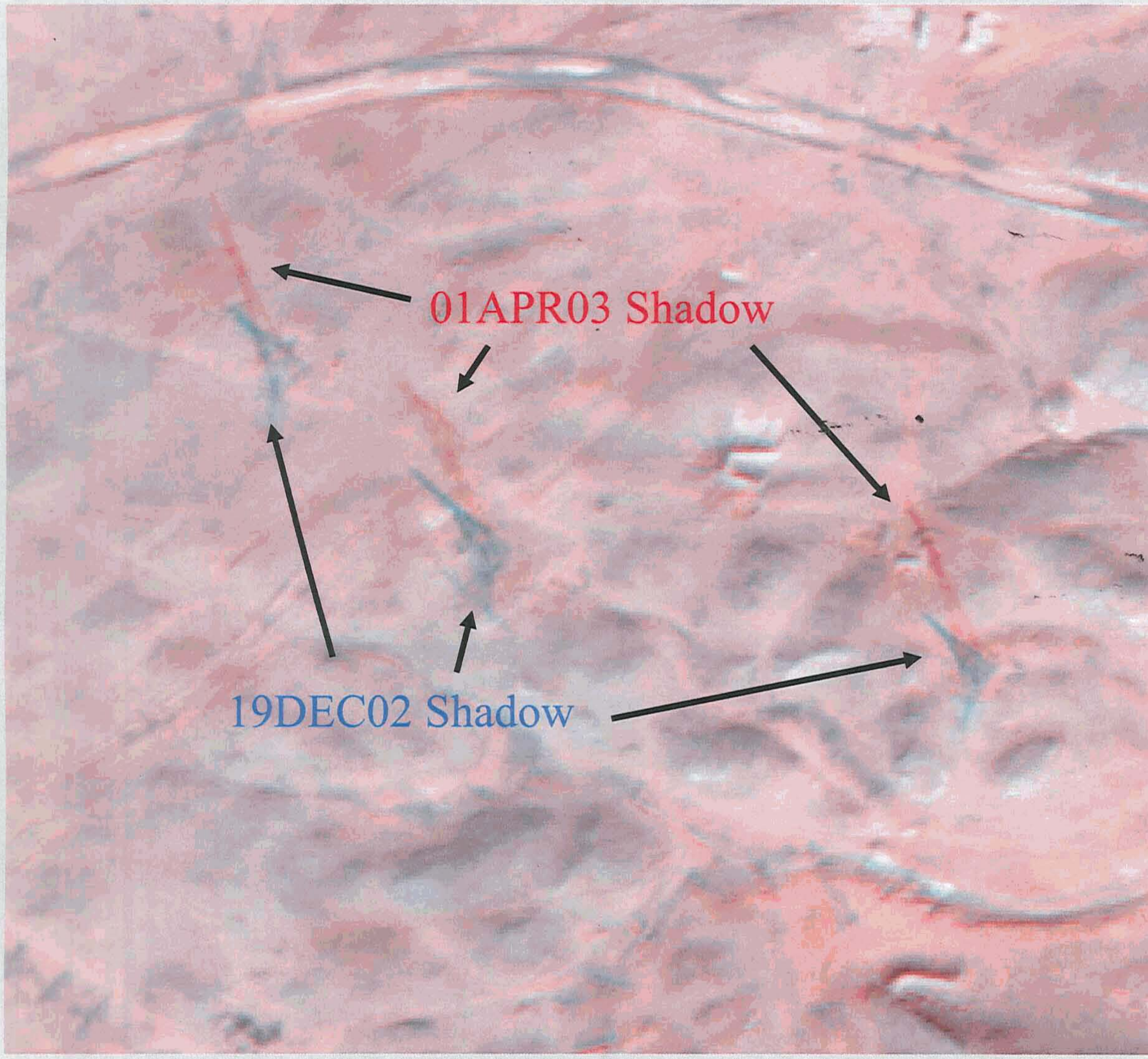
Quickbird Multi-Date Registration over Iraq



Transmission Line Tower Shadows

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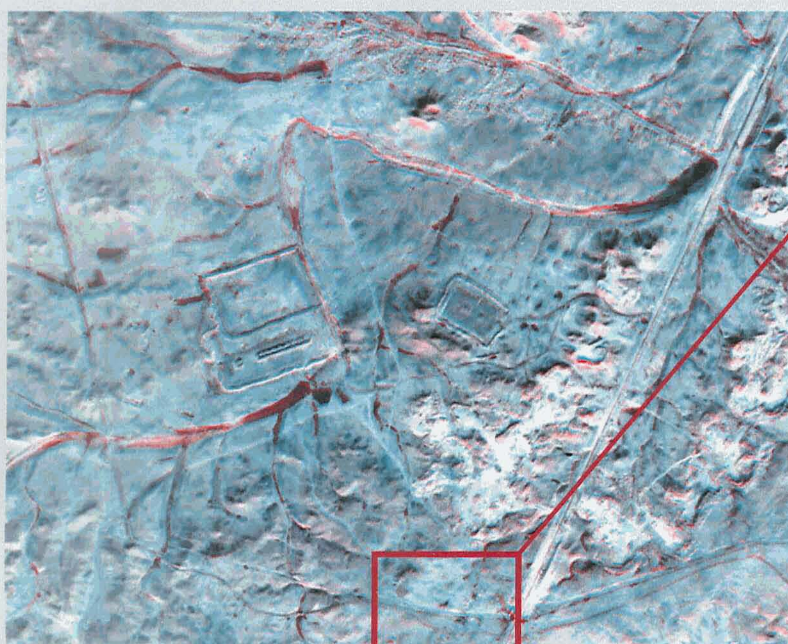
Quickbird Multi-Date Registration over Iraq Rural Uncultivated Area

Overview



01APR03 and 19DEC02 Scenes

Detail

↘=Dark Red rectangles are dark vehicles in December 2002 scene.
↘=Pale red areas are newly disturbed soil in April 2003 scene.
↙=Shadow differences between dates

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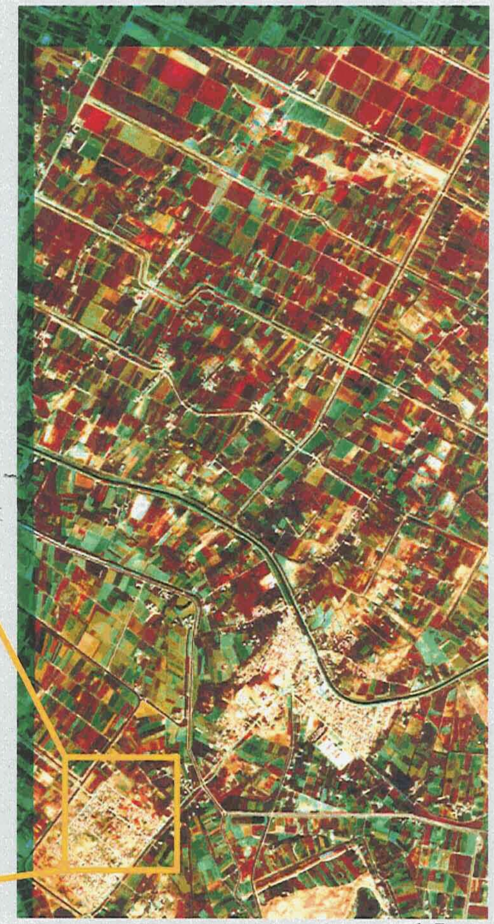
Quickbird Multi-Date Registration over Iraq Agricultural Scene

01APR03 and 19DEC02 Scenes

Subarea: Full Resolution

Co-Registered



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Ikonos Multi-Date Co-Registration Dodger Stadium, Los Angeles

Blue:
Present on 23 /08/01
Absent on 28/08/01

Red:
Present on 28 /08/01
Absent on 23/08/01

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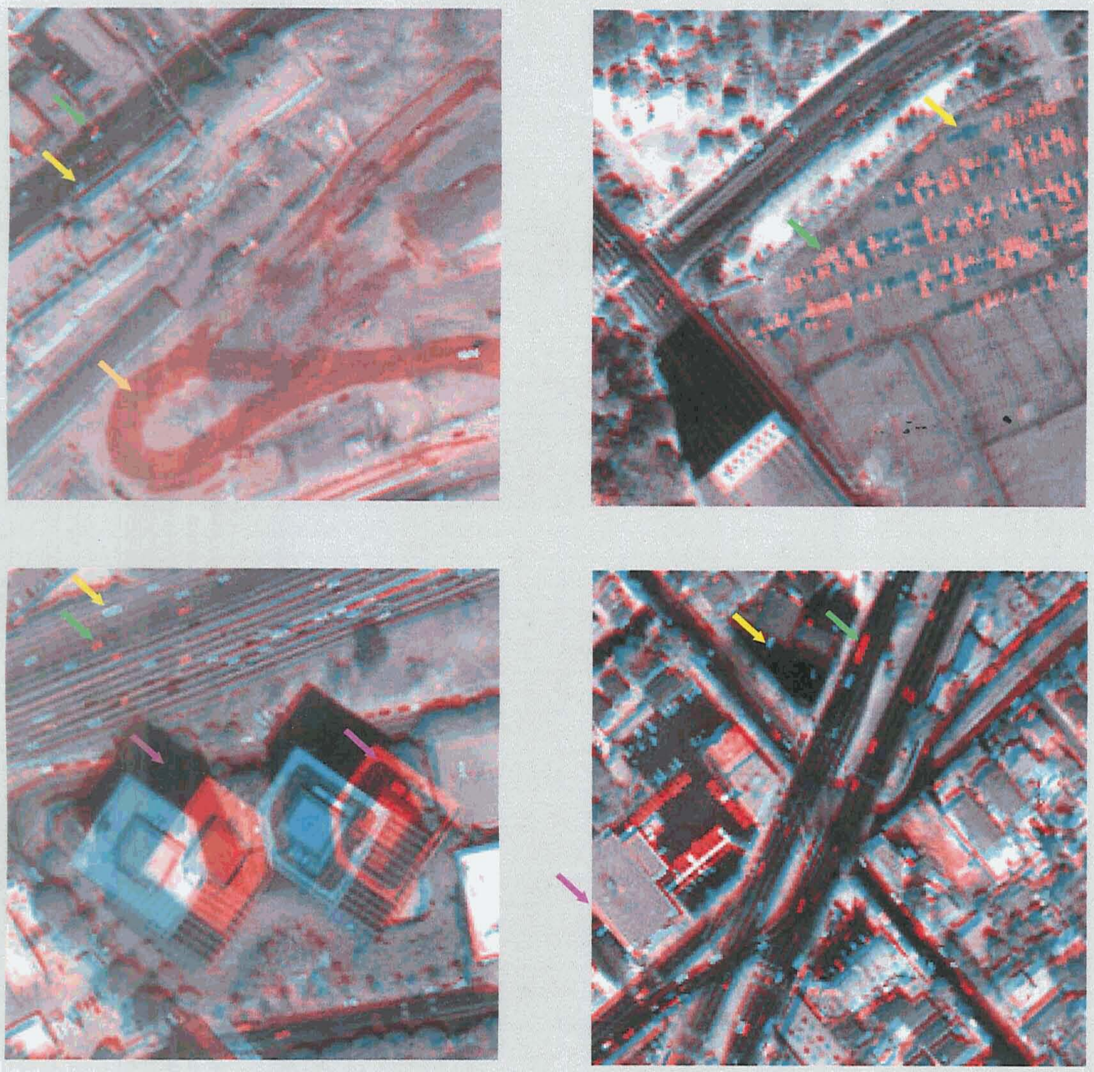
Ikonos Multi-Date Co-Registration Los Angeles Case Detail



= Vehicles Present on 23 /08/01 Absent on 28/08/01

= Vehicles Present on 28 /08/01 Absent on 23/08/01

= New Construction Present on 28 /08/01 Absent on 23/08/01

= Shadow & Parallax Differences 28 /08/01 vs 23/08/01

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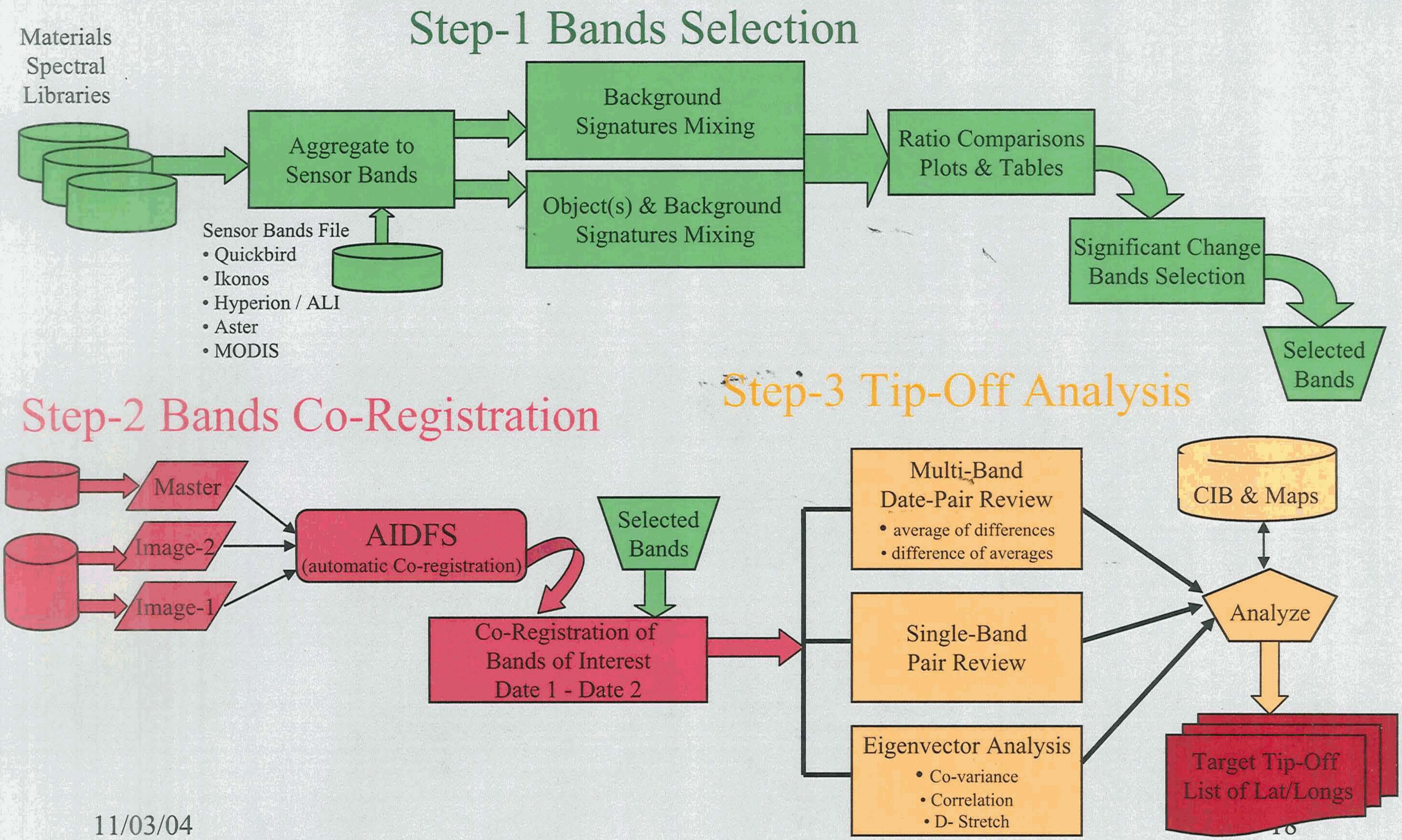
Concept Summary for Prototype Tip-Off System



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AFIDS Software Deliveries Overview

Delivery Date	**07/12/04**	**09/27/04**	**12/27/04**	**03/27/05**	**06/27/05**	**09/27/05**
Platforms Supported	SUN Workstation with GUI	Add: PC/Linux Workstation with GUI	Add: SUN server	Add: SUN & Linux GUI enhancements	Add: SUN & Linux GUI enhancements Linux server	Add: Parallel Beowulf Cluster
Sensors Supported	Landsat, ASTER, MODIS Hyperion Ikonos Quickbird	Add: Advanced Land Imager (ALI), NTM/EO	Add: DMSP, GOES, Meteosat	Add: Full NTM support	Add: AVHRR	(updates as required or available)
Datasets Supported	DTED-1 SRTM-2 Landsat Ortho CIB-5 & -1	Add: VMAP-1 for water bdy	Add: Global SRTM, Landsat, CIB-5, CIB-1 Datasets	(updates as required or available)	(updates as required or available)	(updates as required or available)
Capabilities	Automatic Co-Registration	Add: Multi-scene Co-Registration; Mosaic Scenes; 15m DEMs with ASTER&SRTM	Add: Automatic Upstream Processing Support	Add: Image visualization front end	Add: Generic I/F to spacecraft models	Add: Graphics output support; FFTW algorithm

Summary

- The Earth has been digitally mapped several times at high labor and dollar cost
- Subsequent mappings can be done faster and cheaper using computer correlation to existing map bases
- Only one resampling
- Automated
- Fast and cheap mapping allows image fusion to a high degree of accuracy

BACKUP

Automatic Co-Registration Procedure for High-Resolution Commercial Imagery

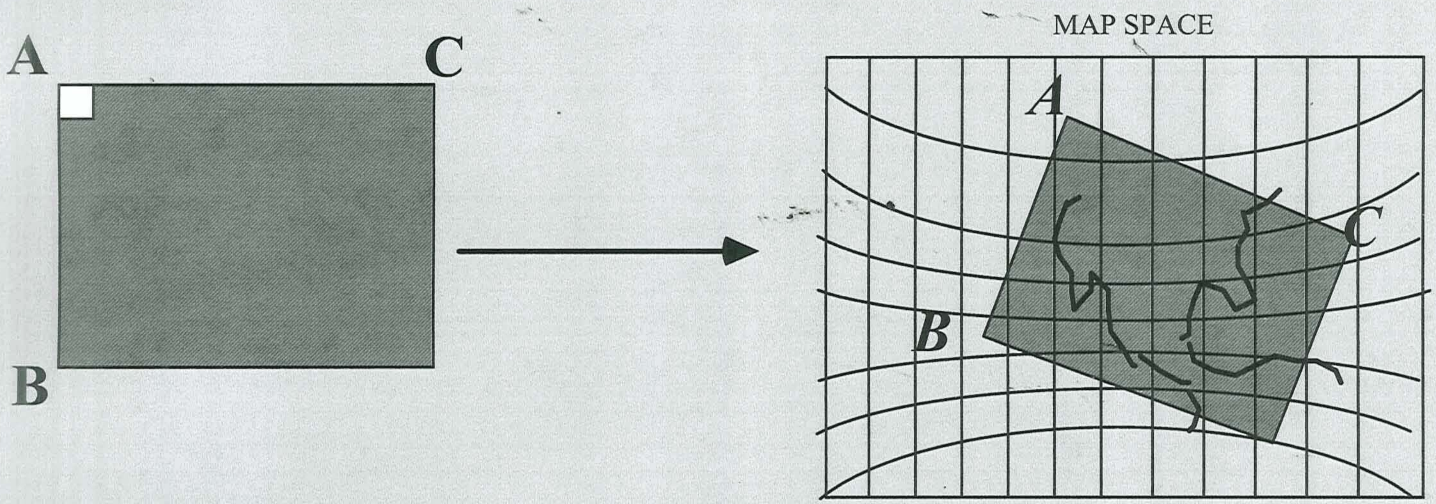
- Steps:
  1. Map project and position image using ephemeris provided
  2. Co-register a grid of tiepoints (typically 10x10) in image to master Controlled Image Base (CIB) or Digital Orthophoto Quads (DOQ) orthorectified mosaic database using a median elevation height for the scene
  3. Using an elevation model, ray-trace correct for horizontal shifts caused by terrain and sensor view angle. Compute an ultra-fine mesh grid of offsets (e.g. 500x500)
  4. Identify first image as the Master, co-register subsequent images to the master. Master should be most-close to a nadir view.
  5. Project to desired projection for area of interest as required
- Reference:

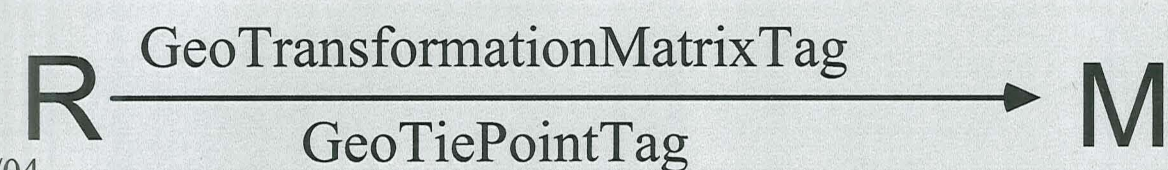
Nevin A. Bryant, Thomas L. Logan, Albert L. Zobrist, "Precision Automatic Co-RegistrationProcedures for Spacecraft Sensors", Paper 6550 published in the ASPRS Annual Meeting Proceedings, Denver, CO, May 27, 2004

Essential Algorithms & Procedures:

(1) GeoTIFF Label Embedding

Raster Data is often related to Map/Model space by simple rotation, translation and scaling.





GeoTIFF Georeferencing Tag Descriptions

- ModelTiePointTag: This tag stores raster-to-model tiepoint pairs in the order (I,J,K, X,Y,Z...), where (I,J,K) is the point at location (I,J) in raster space with pixel-value K, and (X,Y,Z) is a vector in model space. A single tiepoint, together with the PixelScale tag (below), completely determines the relationship between raster and model space, provided the raster image is ortho-corrected to the map projection geometry of the model space.

- ModelPixelScaleTag: This tag is provided for defining linear, non-rotated transformations between raster and model space. The tag consists of the three DOUBLE format values (ScaleX, ScaleY, ScaleZ), where ScaleX and ScaleY give the horizontal and vertical spacing of the raster pixels. The ScaleZ is primarily used to map the pixel value of a digital elevation model into the correct Z-scale.

- ModelTransformationTag: This tag provided for defining exact linear (affine) transformations between raster and model space. The ModelTransformationTag may be used to specify the 3D transformation matrix and offset between the raster space (and its dependent pixel-value space) and the (possibly 3D) model space.

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GeoTIFF Functional Atributes

Decomposition of GeoTIFFGeodetic Model

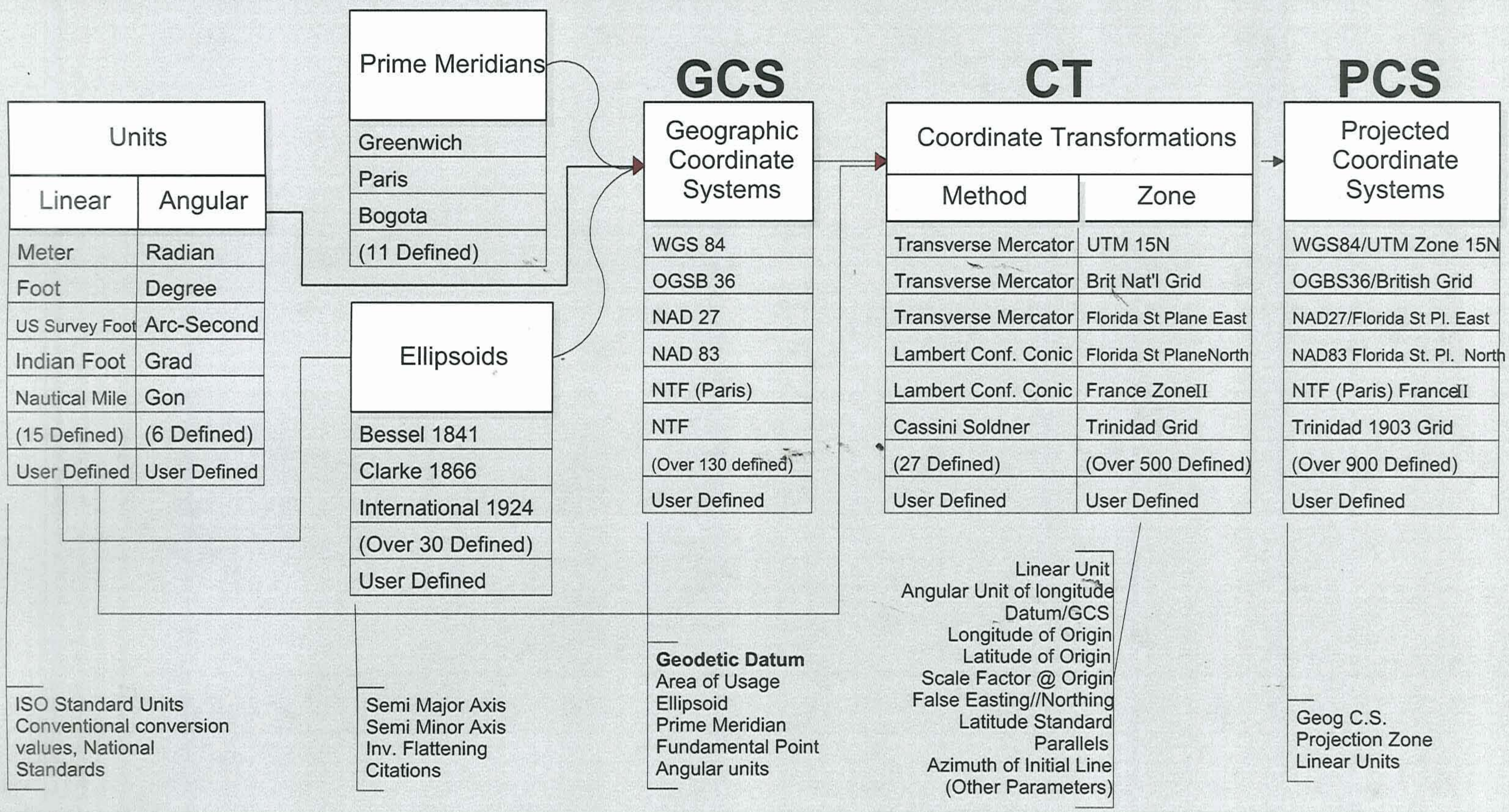

Figure 3: Graphic representation of cartographic hierarchy as implemented in GeoTIFF. Examples are shown for each class of variables, and available parameter fields are shown at botttom. Read left to right to "compose" from fundamental elements (Units) to derivative elements (PCS). Parameters by EPSG (European Petroleum Survey Group), and data model by POSC (Petrotechnical Open Software Corp). Vertical dimensions not show