DIRSIG Models to Support LDCM

Digital Imaging and Remote Sensing Laboratory
Chester F. Carlson Center for Imaging Science
Rochester Institute of Technology

John R. Schott
http://dirsig.cis.rit.edu

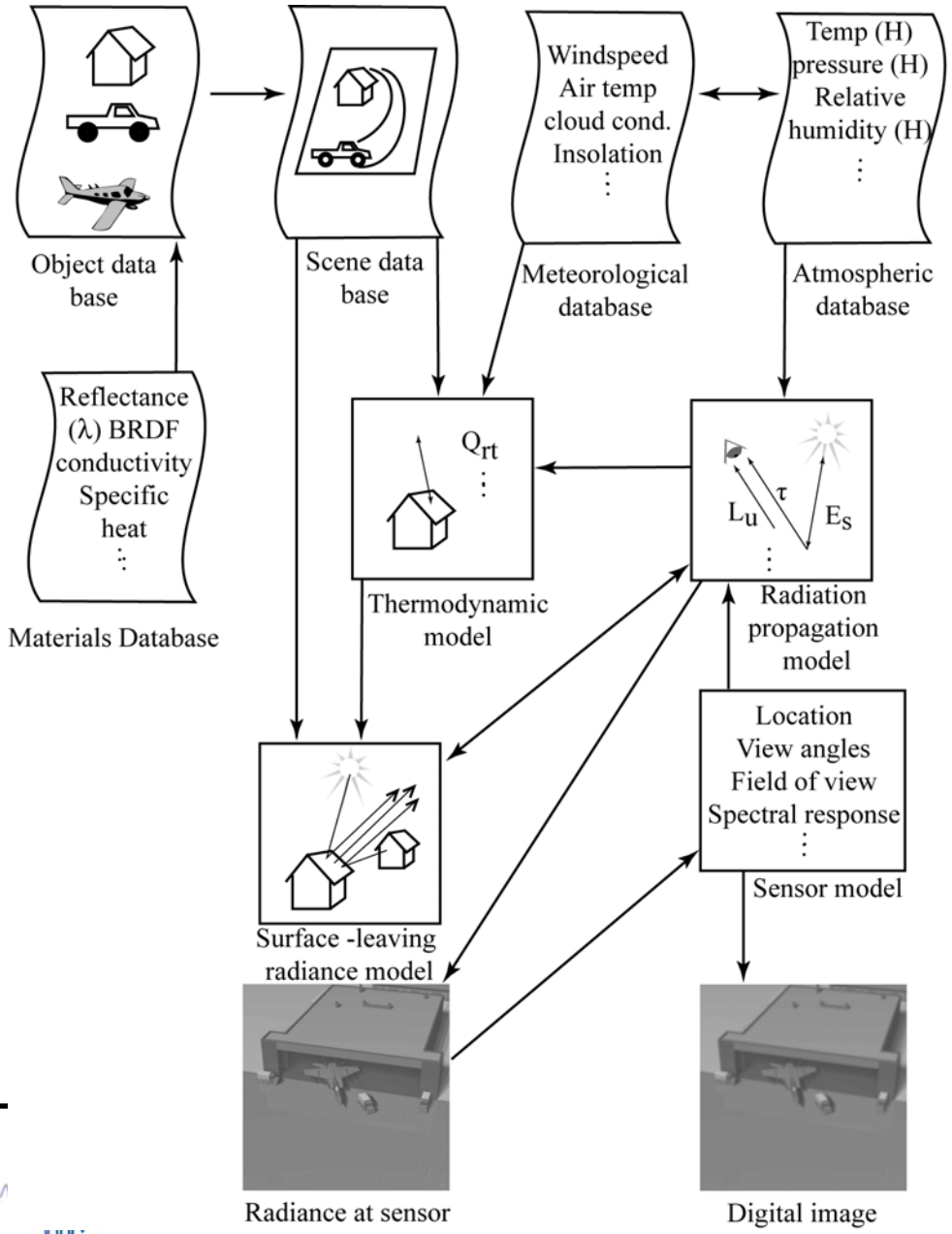


Figure 14.2

Diagram of conceptual data flow and interaction mechanisms in a generic SIG model.

Section 14.3 A Modeling Example

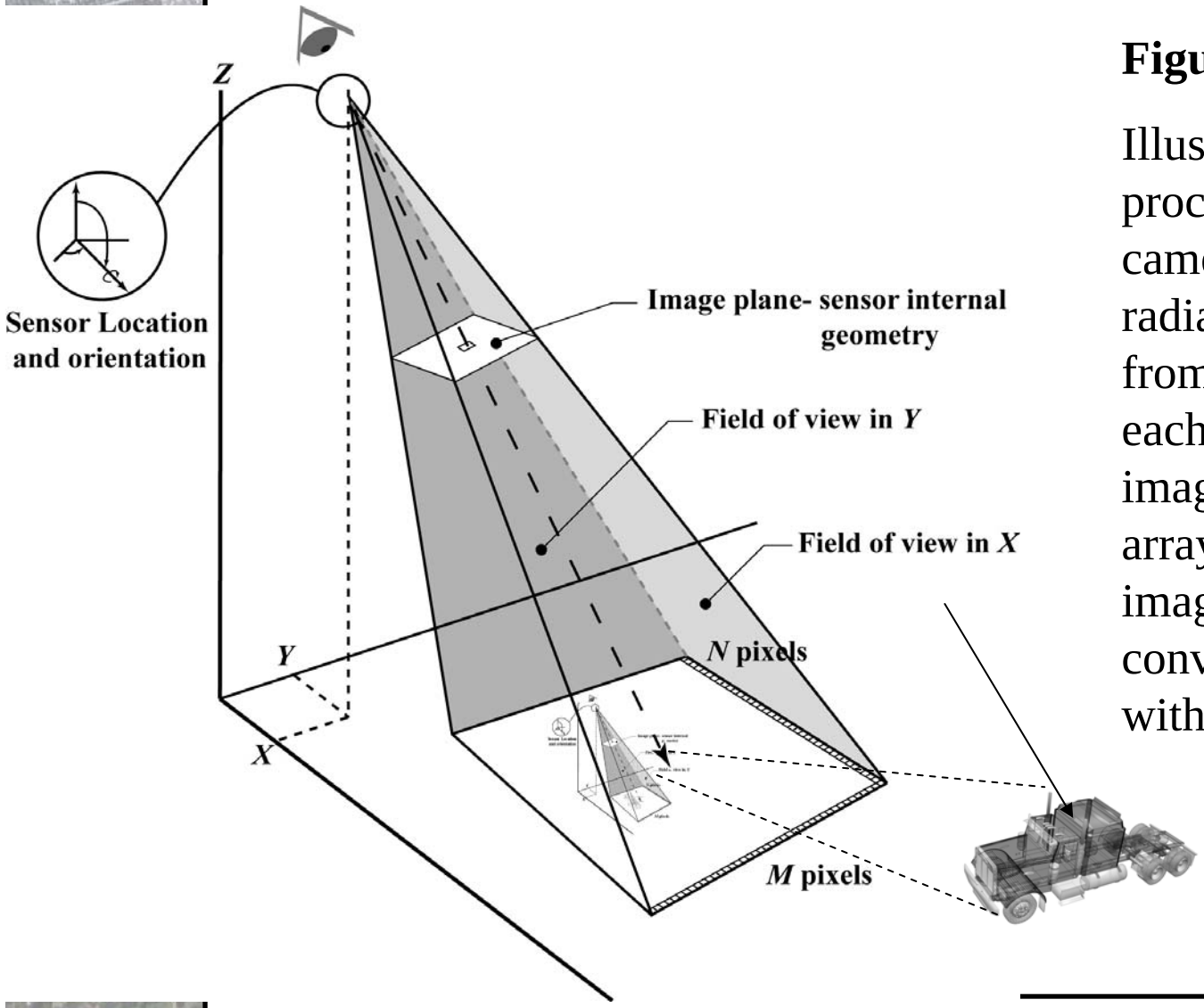
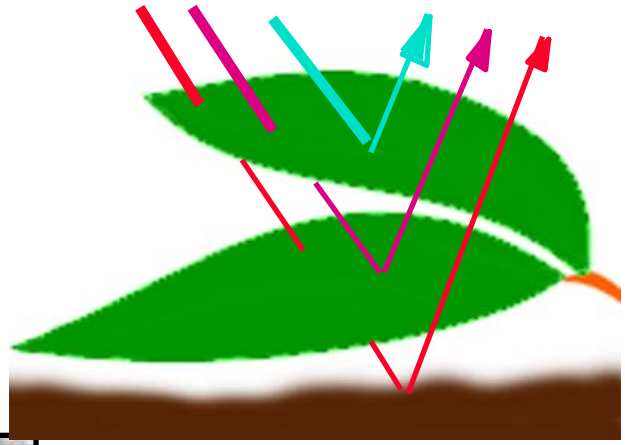


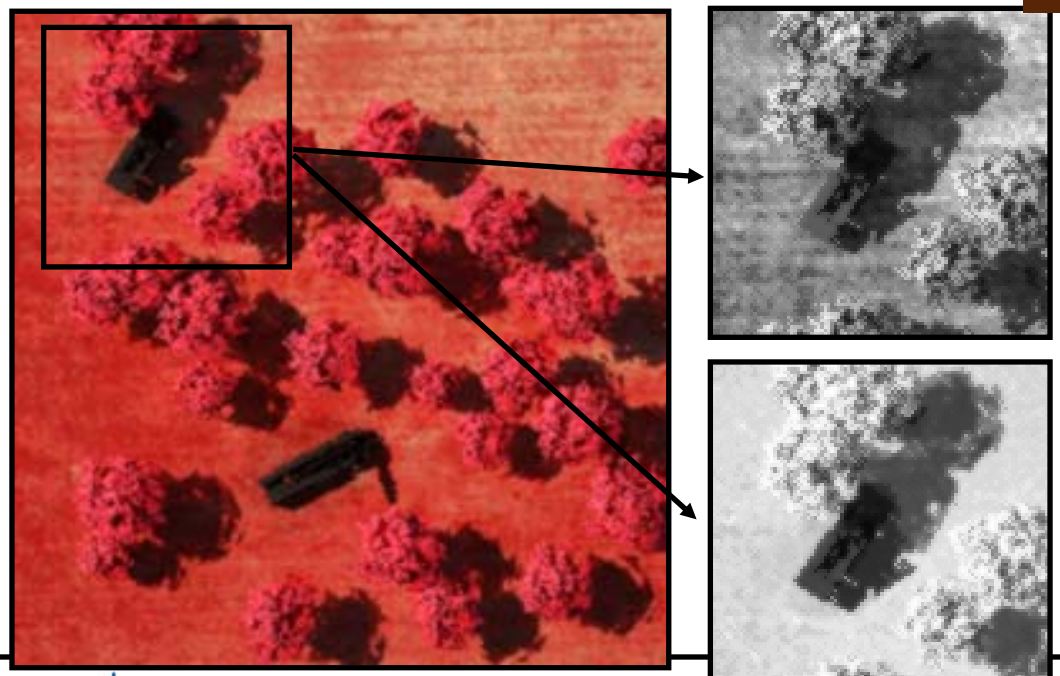
Figure 14.9

Illustration of the ray-tracing process for a simple framing camera. To generate an *N* x *M* radiance array, rays are traced from the focal point through each pixel center in an *N* x *M* image plane. Note the N x M array is denser than the final image array to allow convolution and resampling with the instrument PSF.

Forestry

- The model includes the transmission of leaves to reproduce the complex energy exchange in tree canopies.

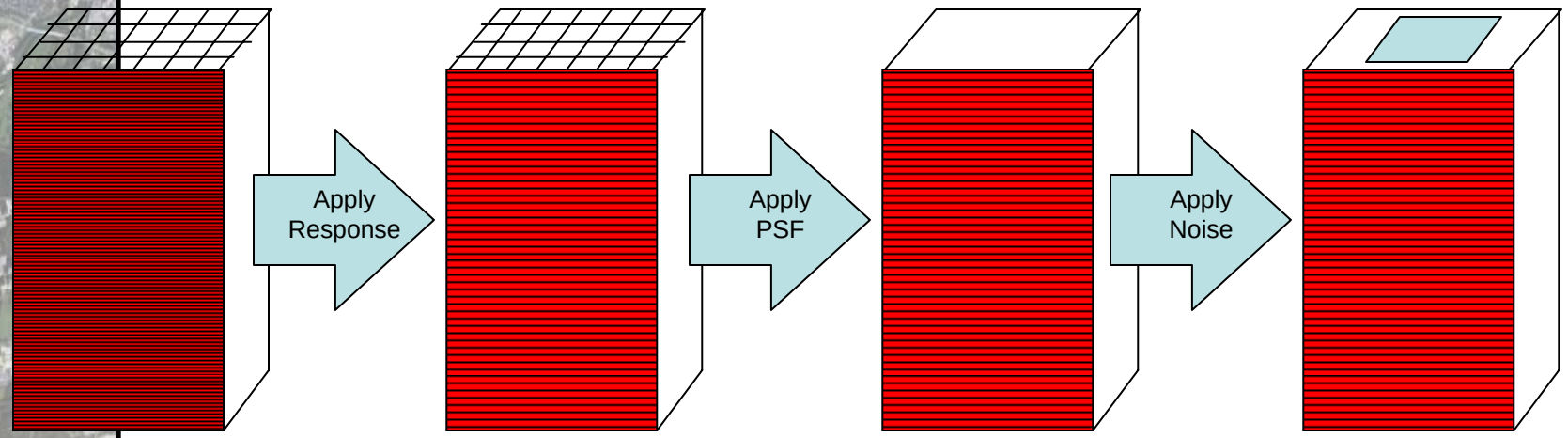




Green Band

NIR Band

Internal Data Flow

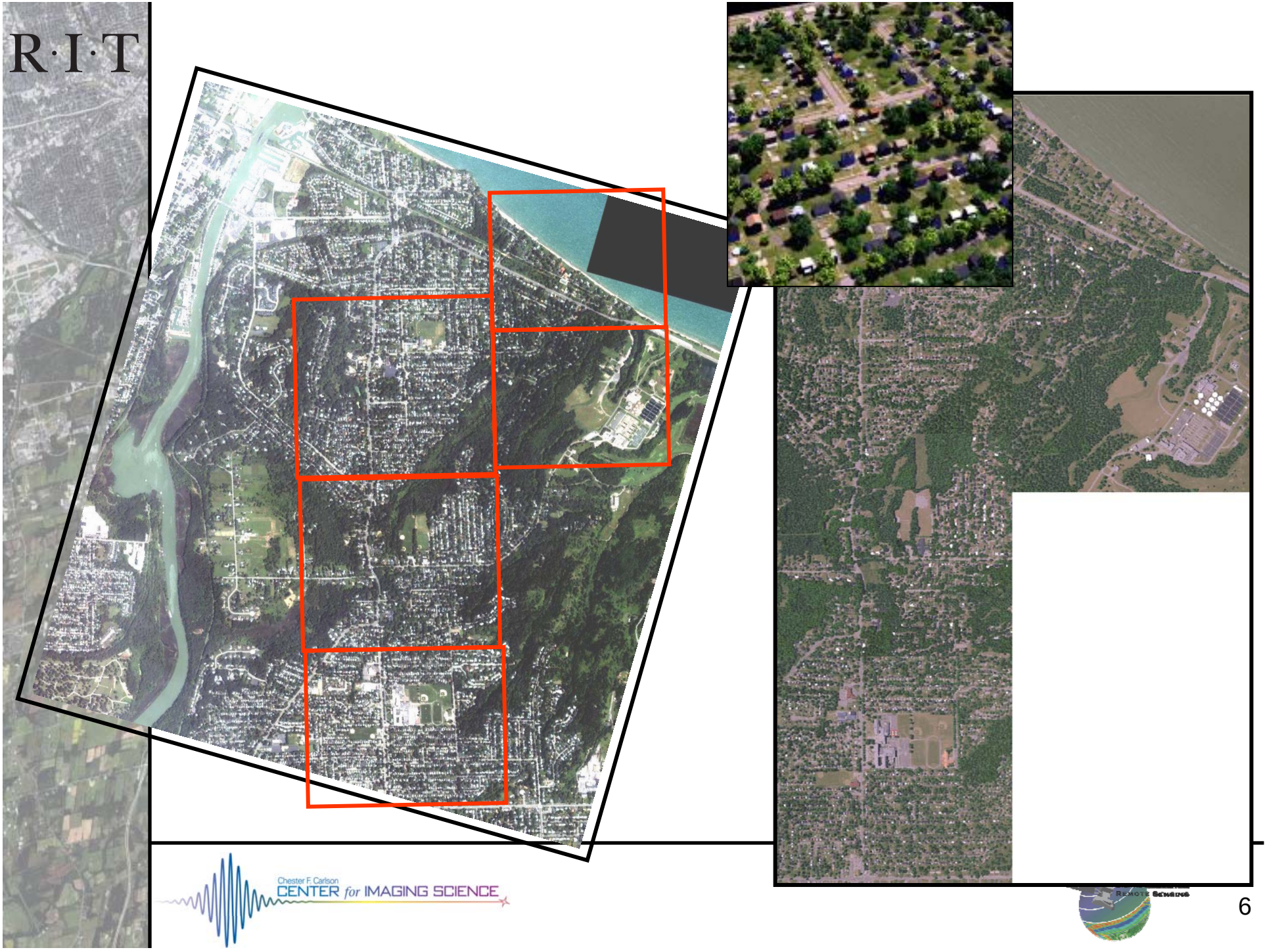


N Spatial Samples
"Many" Spectral Samples
Without Noise

N Spatial Samples
M Spectral Samples
Without Noise

1 Spatial Sample
M Spectral Samples
Without Noise

1 Spatial Sample
M Spectral Samples
With Noise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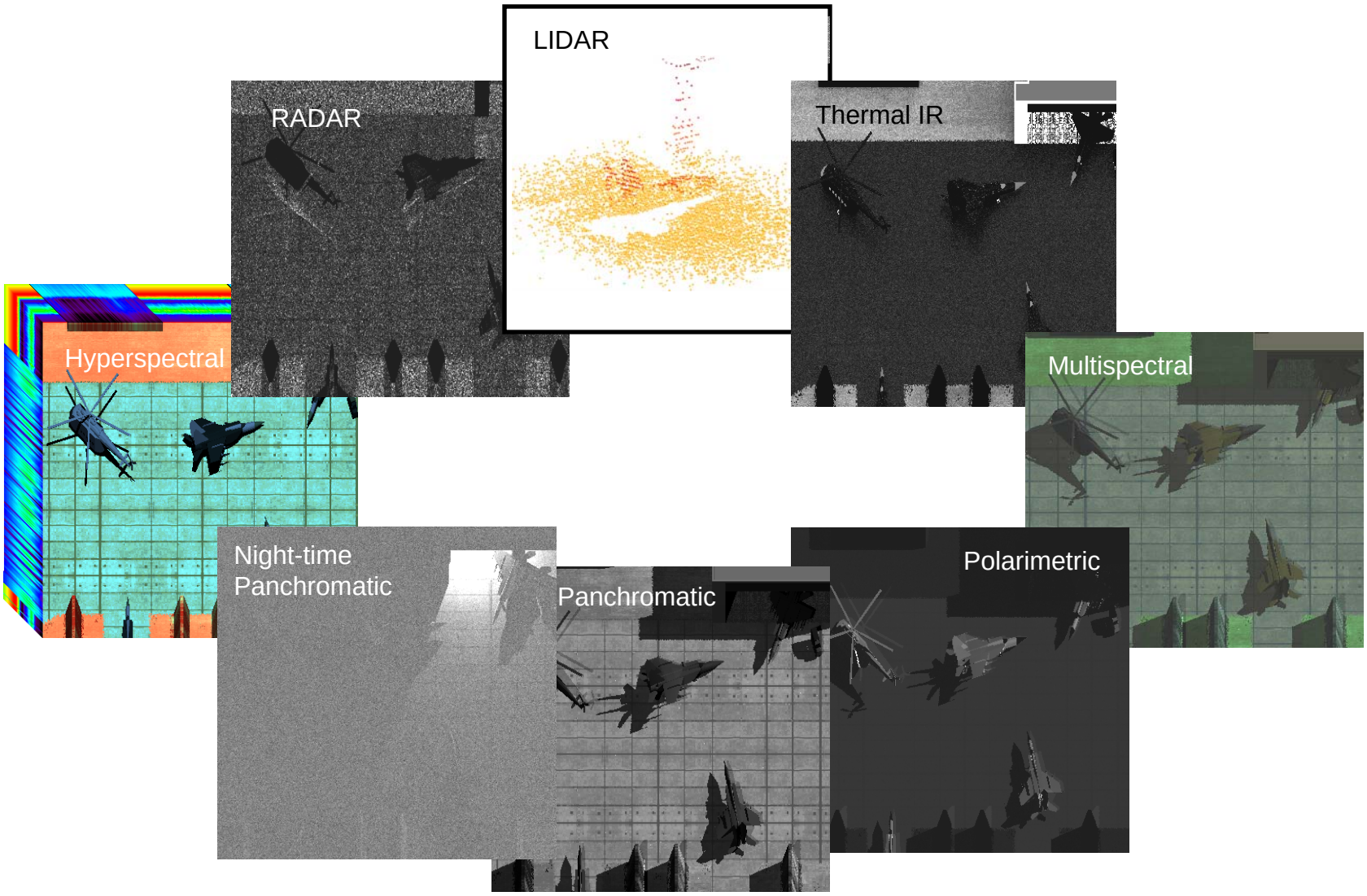
Megascene 1, Tile 1

- 5,000+ objects
- 500+ million facets
- 1.6 km^2 (0.6 mi^2)

One model, many modalities

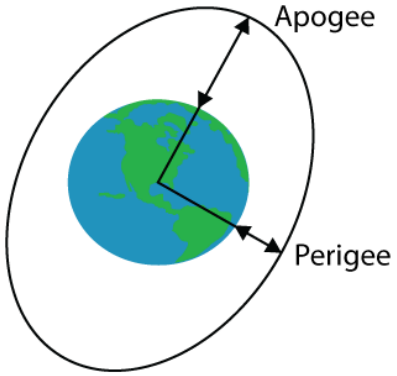


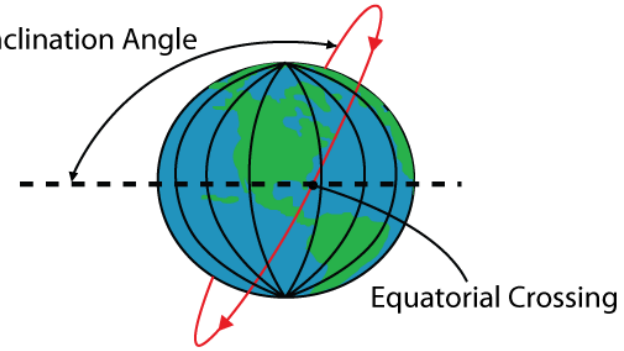
Approach

- Use DIRSIG to model OLI/TIRS imaging capabilities
  - Geometric effects top priority
  - Radiometry in future revisions
- Use fused data sets to establish **virtual truth**
  - Digital Globe
  - Hyperion
  - LANDSAT
  - DEMs
  - ASTER emissivity maps

TLE → Orbital Discriptors → SGP4 Translator → TEME → TEME to ECEF Translator → ECEF

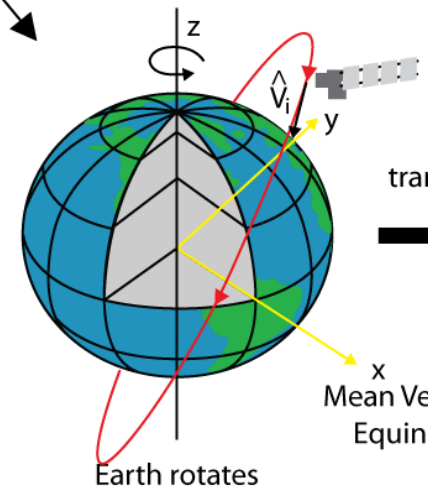
TLE Describes Orbit



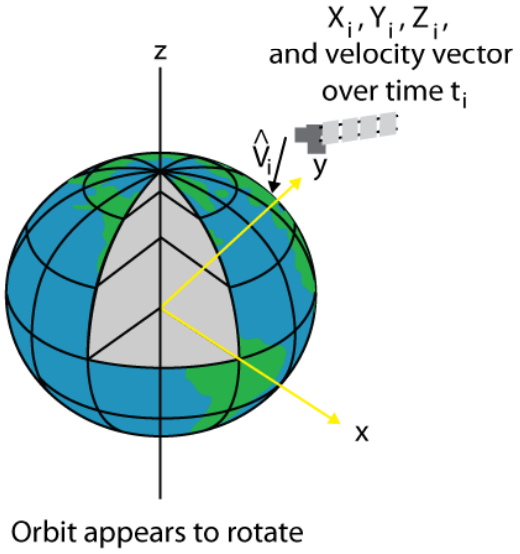


SGP4

Translator yields location and velocity vector for time t_i

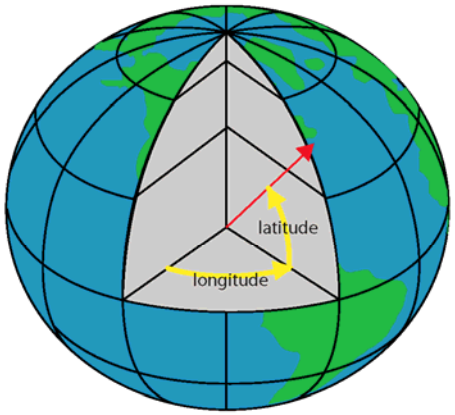


translator

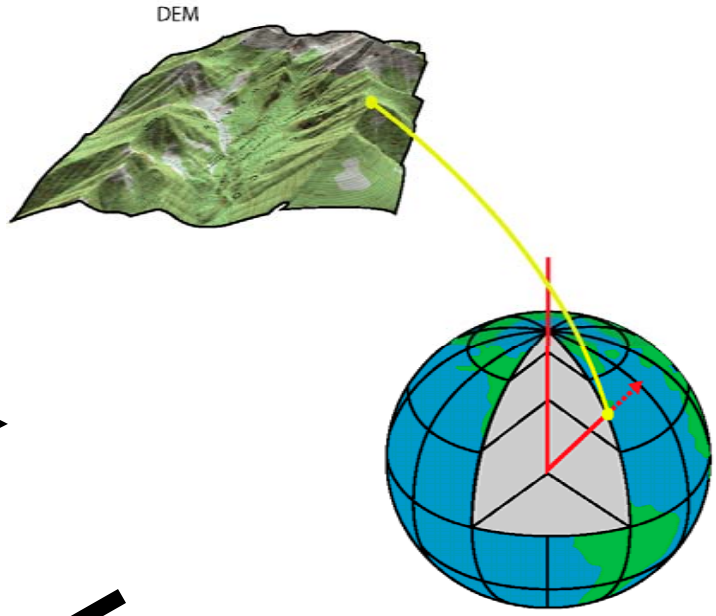


TEME Coordinate System
(True Equator Mean Equinox)

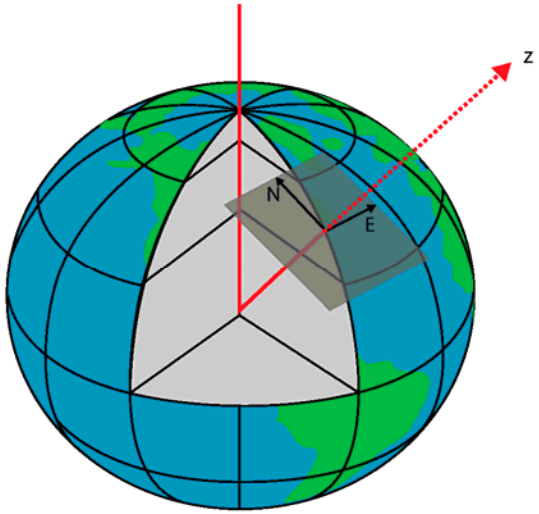
ECEF Coordinate System
(Earth Centered Earth Fixed)



Angle, angle, distance describes any point on the surface.



DEM is height above or below WGS 84.



DIRSIG NATIVE Format is Euclidian with x,y plane tangent to Earth.

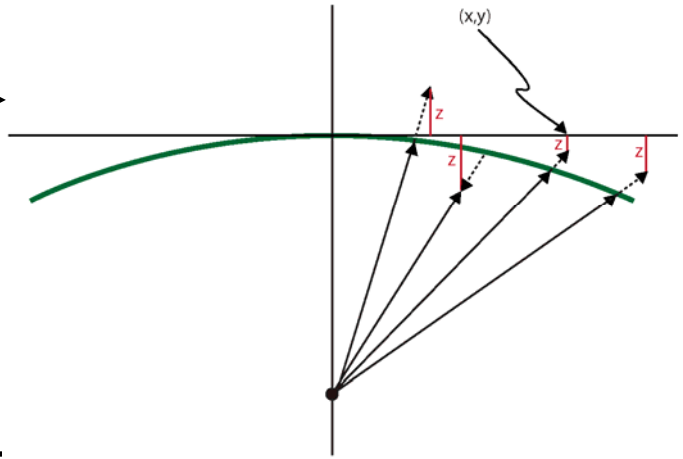


Illustration of how angle, angle, distance (DEM) is converted to NATIVE DIRSIG geometry.

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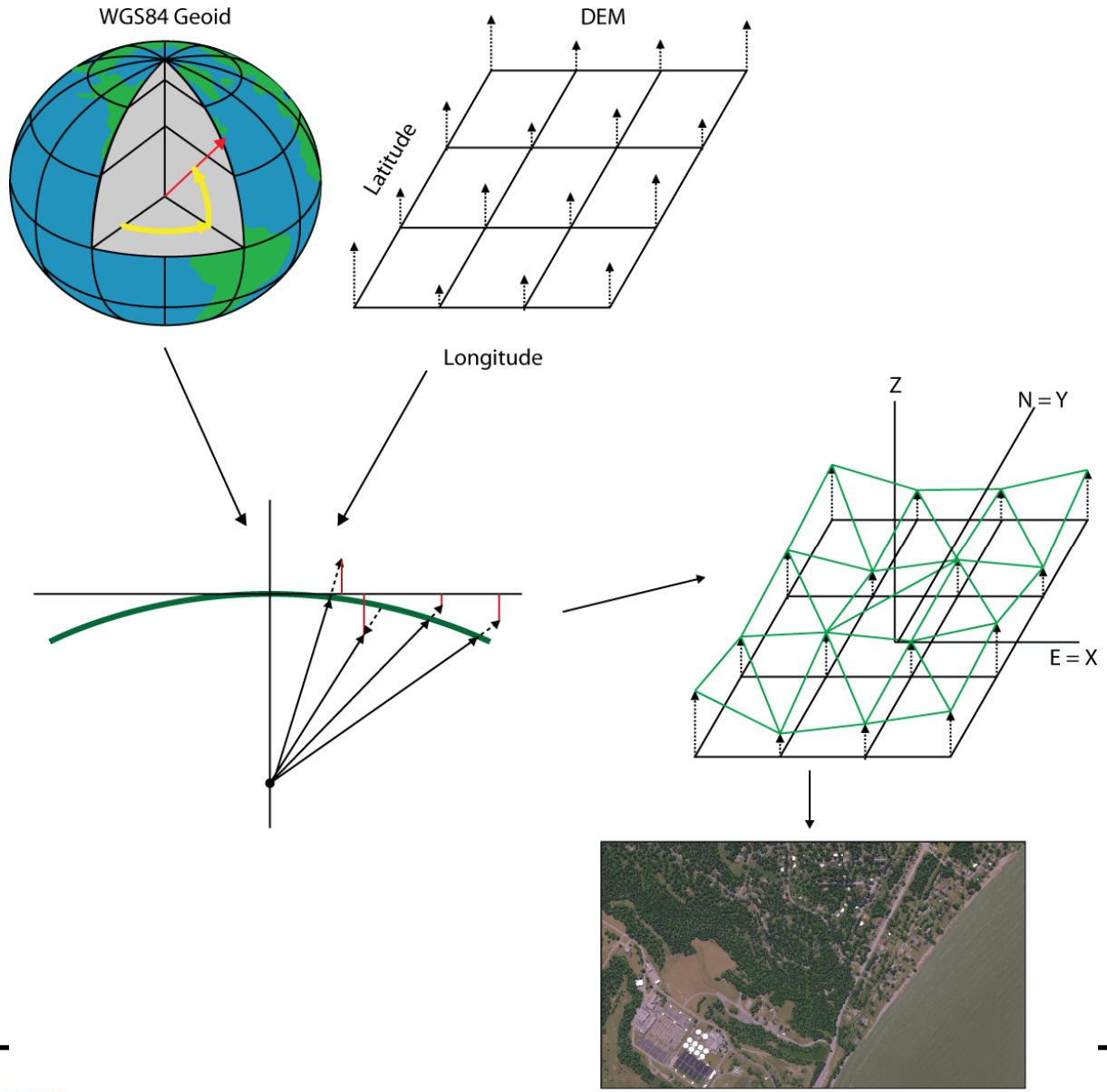
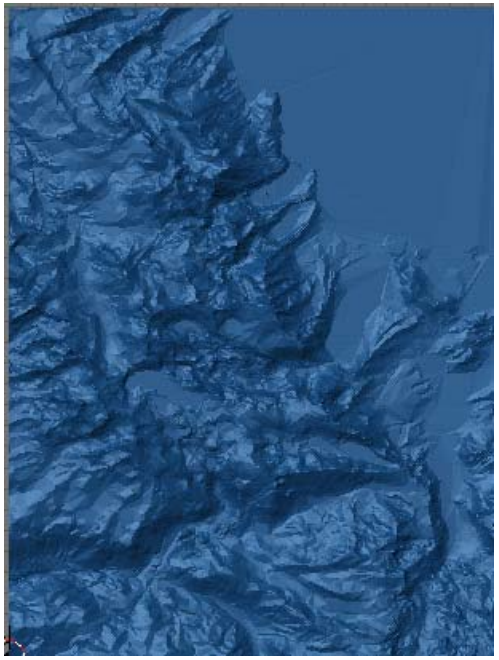

WGS84 Geoid
DEM
Latitude
Longitude
Z
N = Y
E = X

Orbitology Path Forward

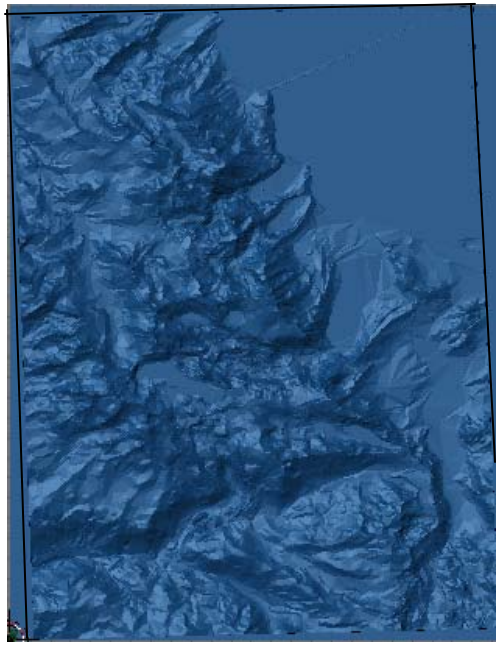
- We are building the translators and will be writing code to format the data into DIRSIG standard format and then testing in DIRSIG.

- At some point, the DIRSIG user interface could be adjusted to facilitate use of this approach. E.g., select satellite, date and time and the code would go out on WEB and get TLE and run code for that satellite.

Status: Most Component tools in test

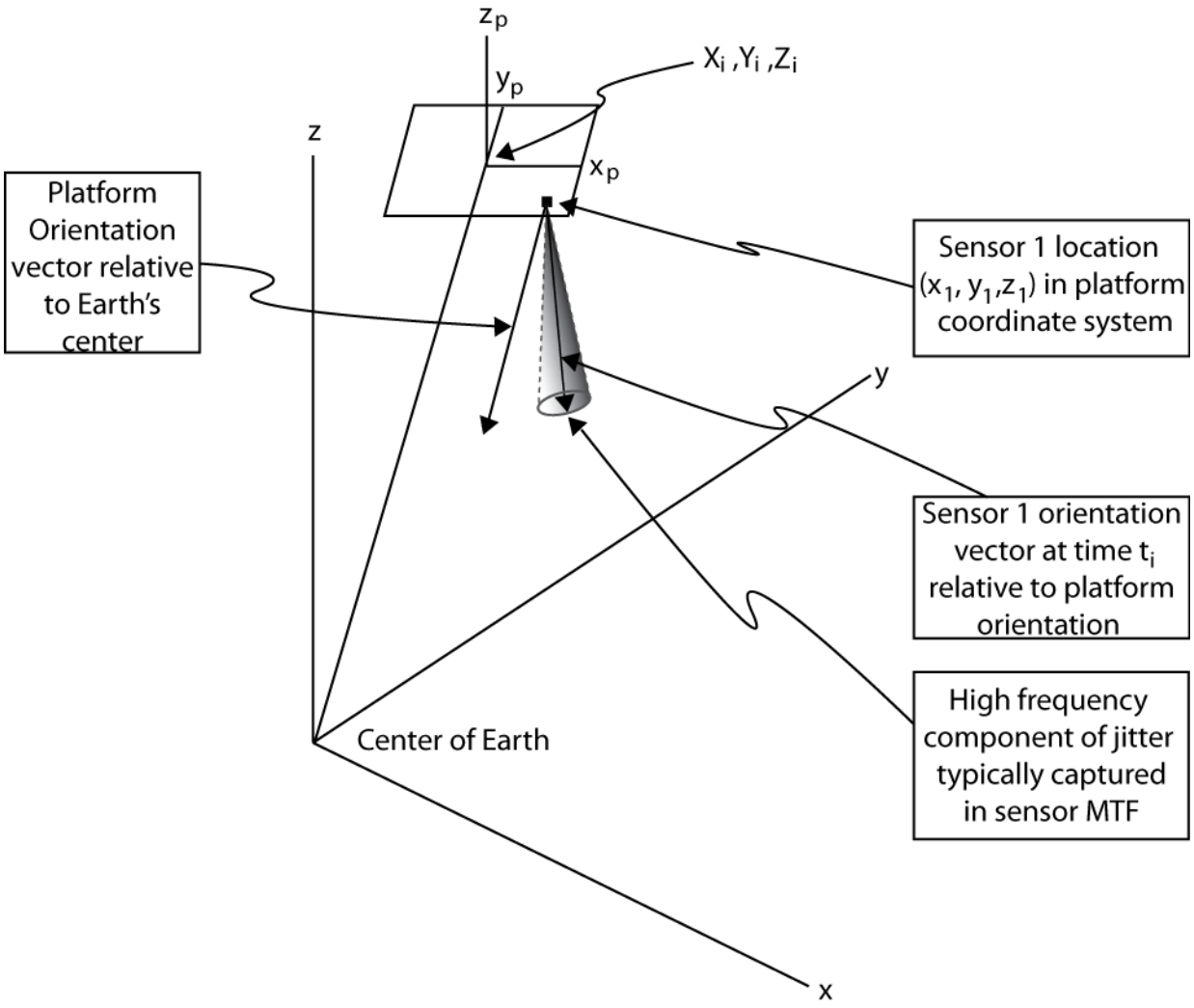


DEM in Lat. Long
In Bulldozer

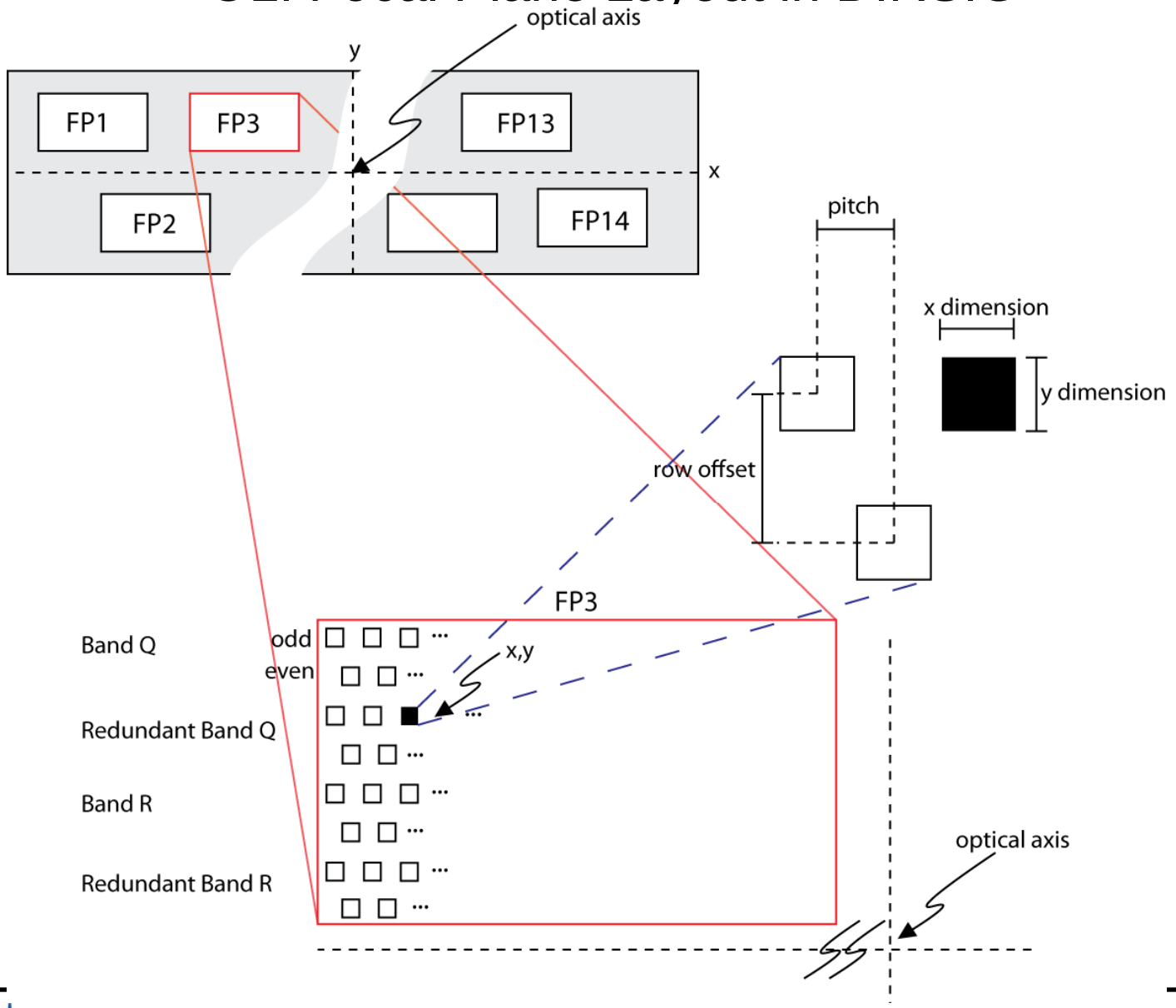


DEM in UTM

DIRSIG Platform/Sensor Model



OLI Focal Plane Layout in DIRSIG



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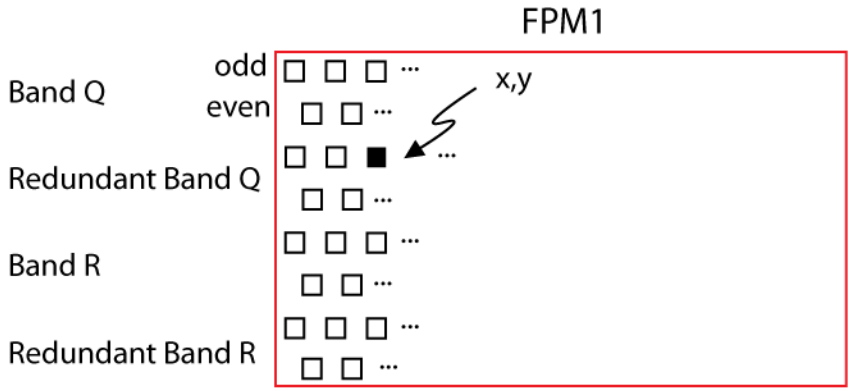
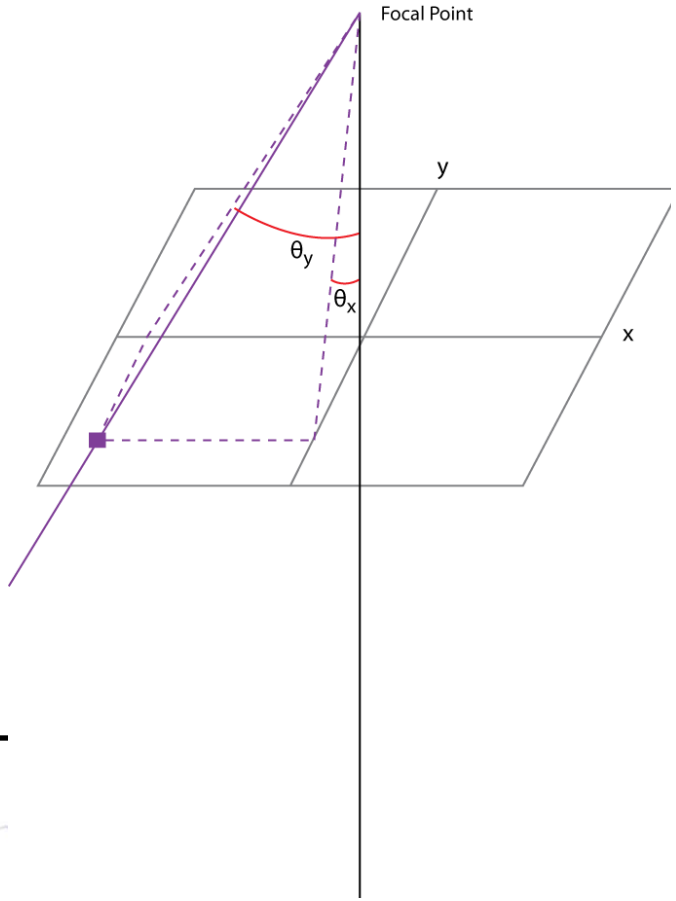
Pixel locations are designated by angle pairs accessed by a user controlled look-up-table





Focal Plane Module	Band	Primary/ Redundant	Odd/Even	Detector
1	1	Primary	Odd	1
1	1	Redundant	Even	1
1	1	Primary	Odd	2

Look Up Table

Designator	θ_x	θ_y
11P01	0.0071	0.0072
11P02	0.0076	0.0076
11P03	0.0072	0.0074

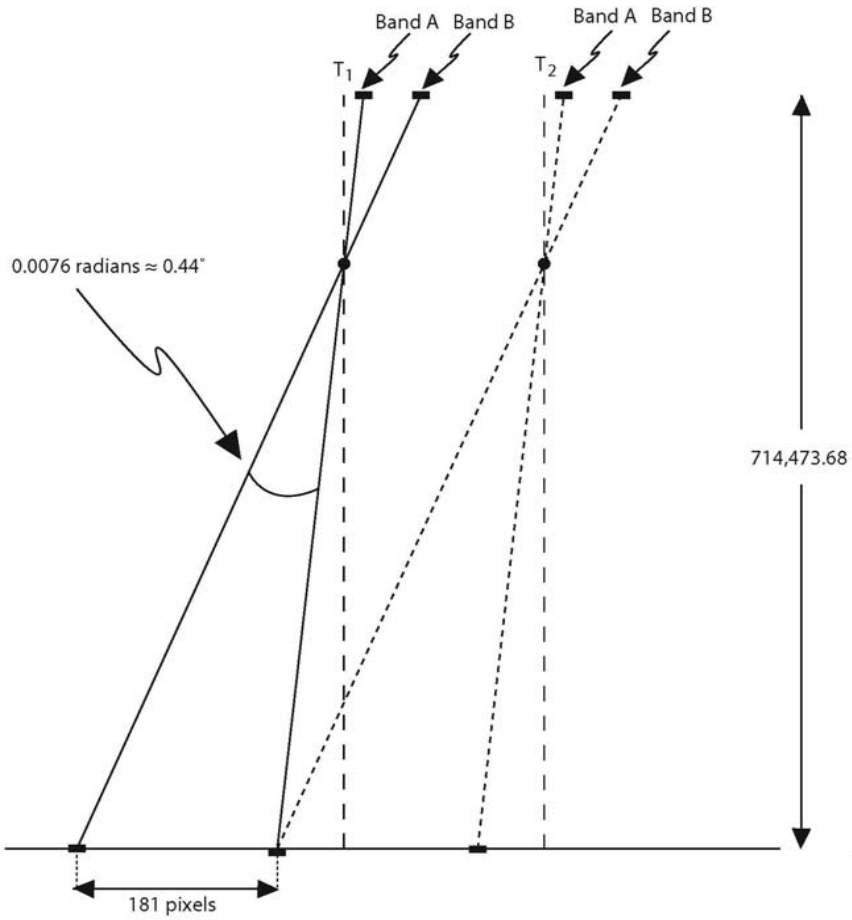


Figure 1: At nominal flying height (AGL) Bands A and B require 181.0 pixels of offset to exactly register A to B.

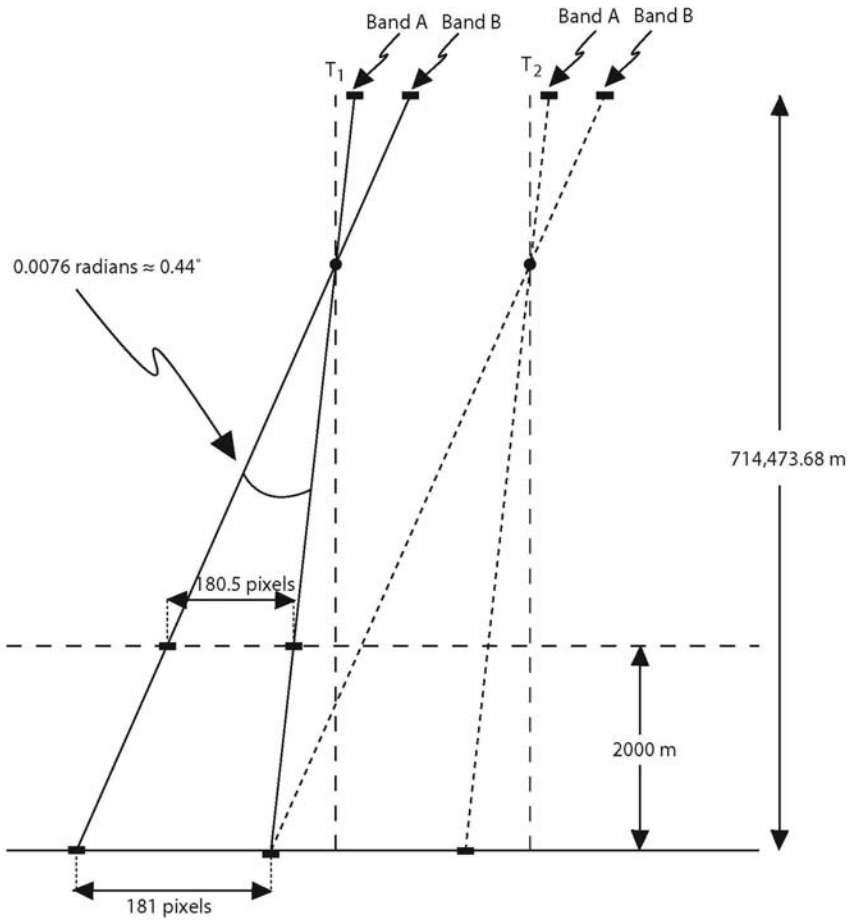
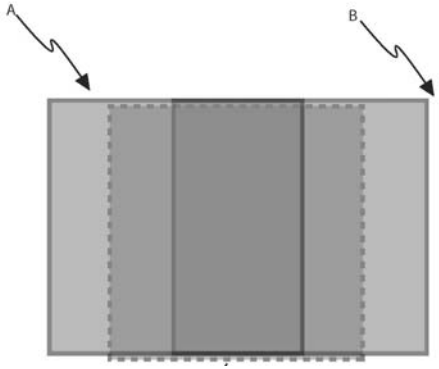
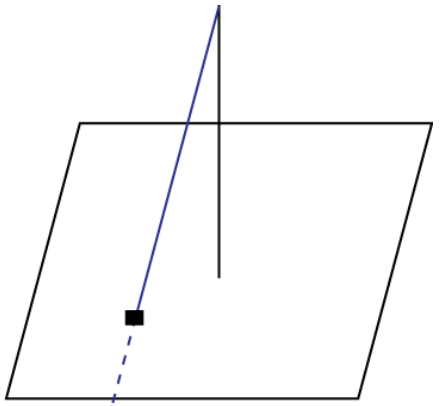


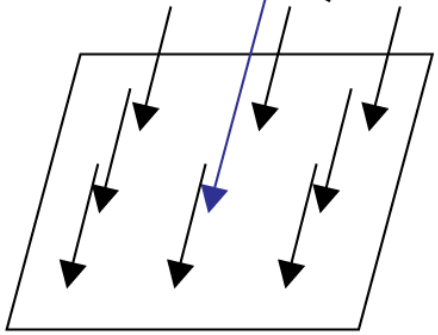
Figure 2: For a target at 2000m AGL Bands A and B are offset by 180.5 pixels



Primary ray defined by detector element angle-angle designation

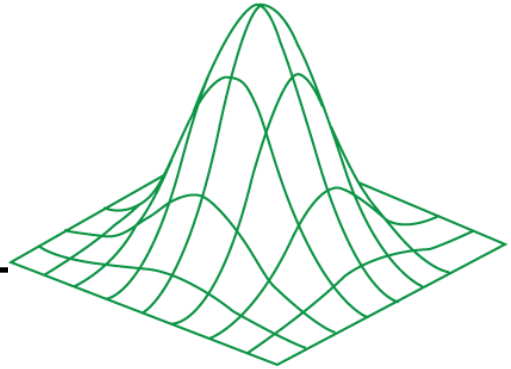


User defined level of oversampling about primary ray



*

Convolution of oversampled radiance values with band specific or focal plane array specific instrument PSF



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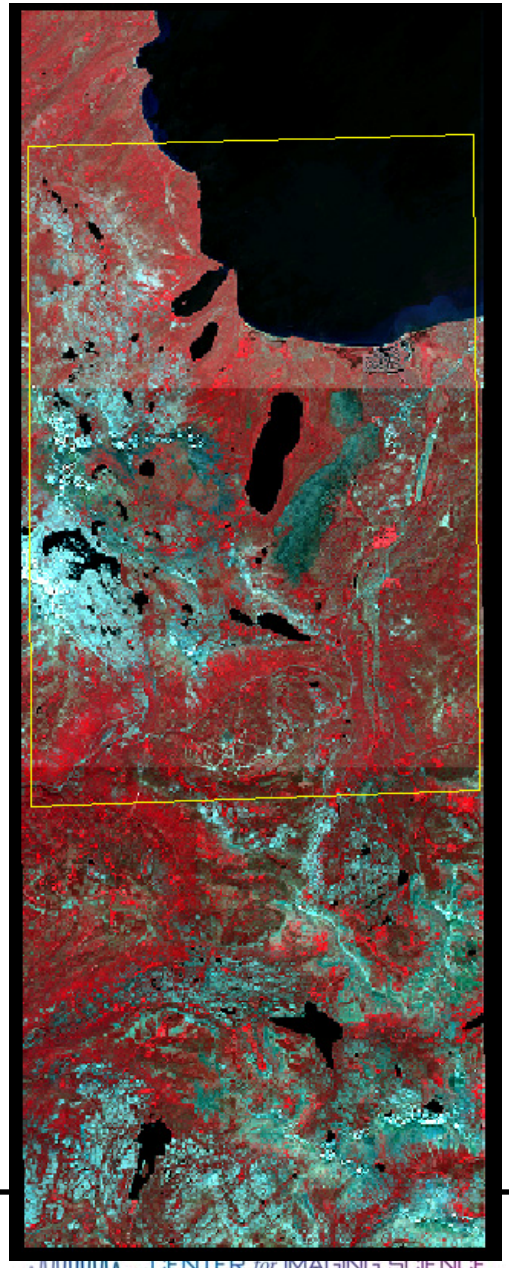

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Quickbird 4 band MSI

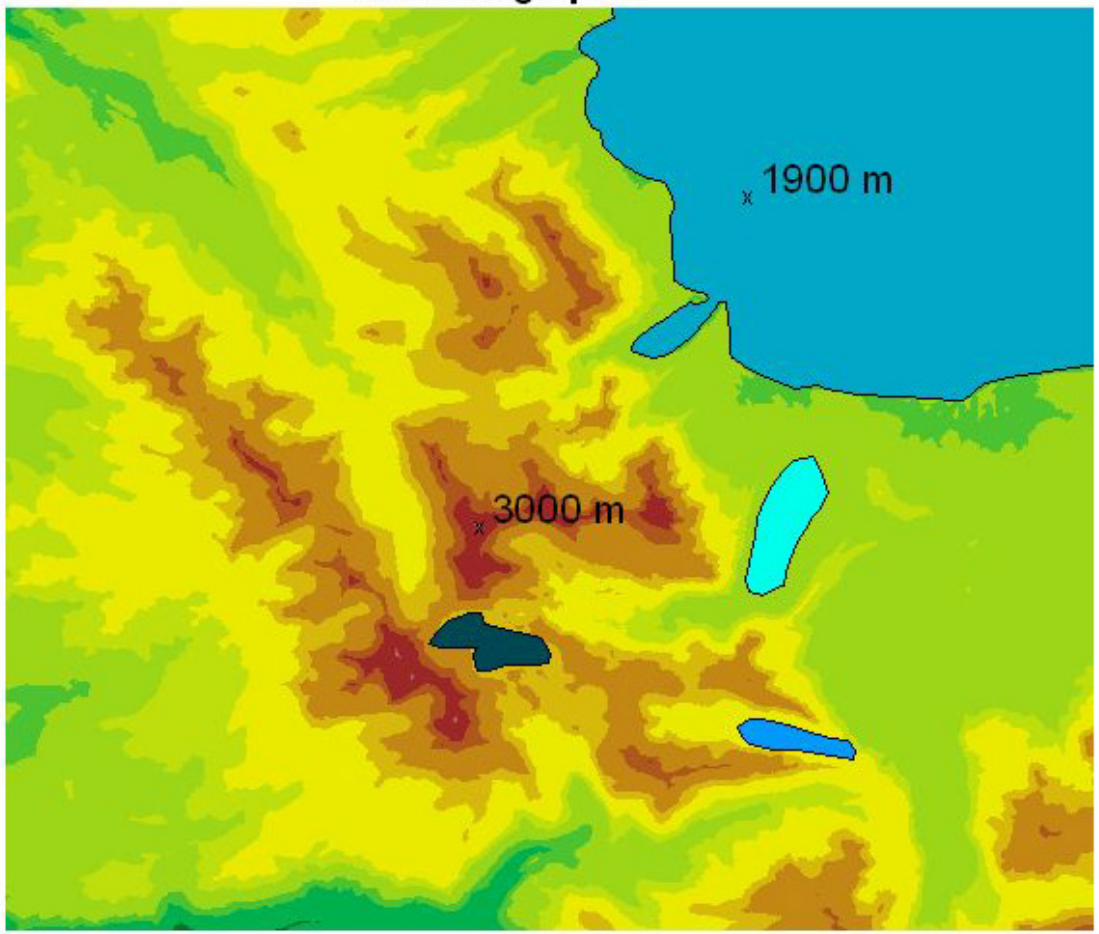
Sensor: Tahoe Area
AcqDate: Jun 28, 2007 Sensor: QB02
Format: NITF
Geo-spatial:Geographic WGS84

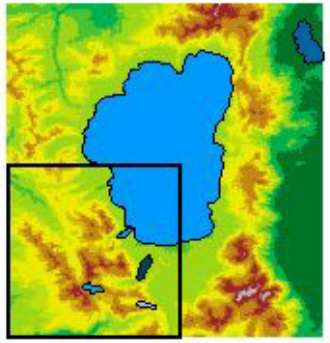
QB Dimensions: 17km x 47km compared to 30m pixel * 500 detectors = 15km

DIRS

Lake Tahoe Area Elevation [meters]

National Elevation Dataset (NED) 1/3 Arc Second
X Ycell size ~10 meters or 0.00009 Degrees
NAD Geographic





Waterbodies
- Fallen Leaf Lake
- Lake Aloha
- Lake Tahoe
- Lower Echo Lake

Elevation [meters]
- 1400 - 1500
- 1500 - 1600
- 1600 - 1700
- 1700 - 1800
- 1800 - 1900
- 1900 - 2000
- 2000 - 2100
- 2100 - 2200
- 2200 - 2300
- 2300 - 2400
- 2400 - 2500
- 2500 - 2600
- 2600 - 2700
- 2700 - 2800
- 2800 - 2900
- 2900 - 3000
- 3000 - 3100
- 3100 - 3200
- 3200 - 3300
- 3300 - 3400
- No Data

10 0 10 Miles

N W E S

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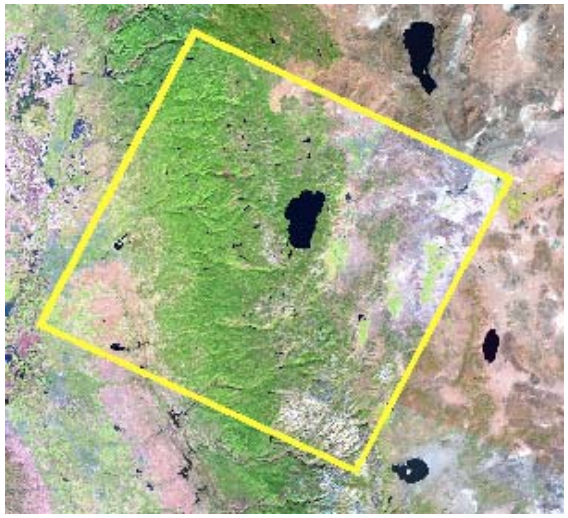
EO1 Hyperion Scene



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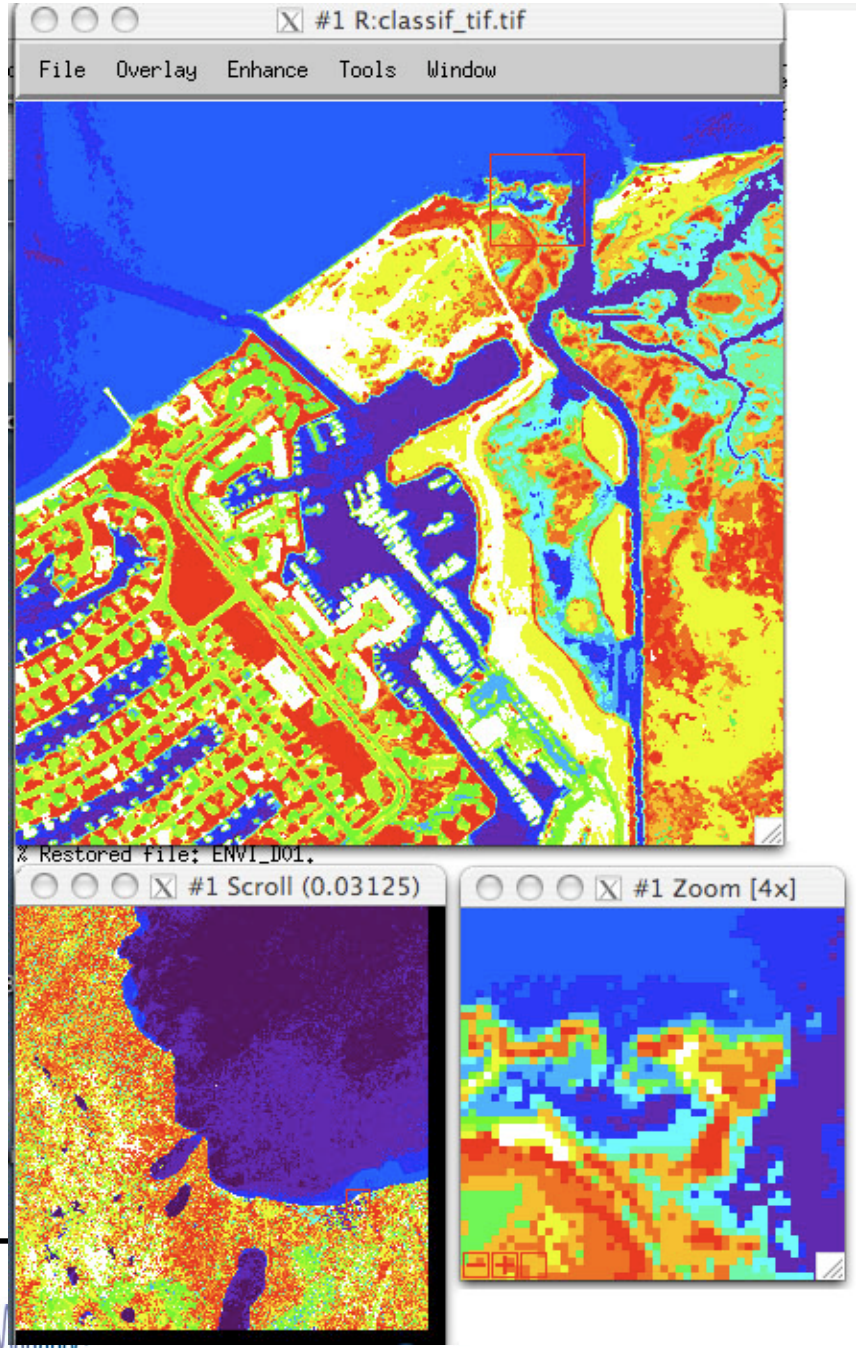
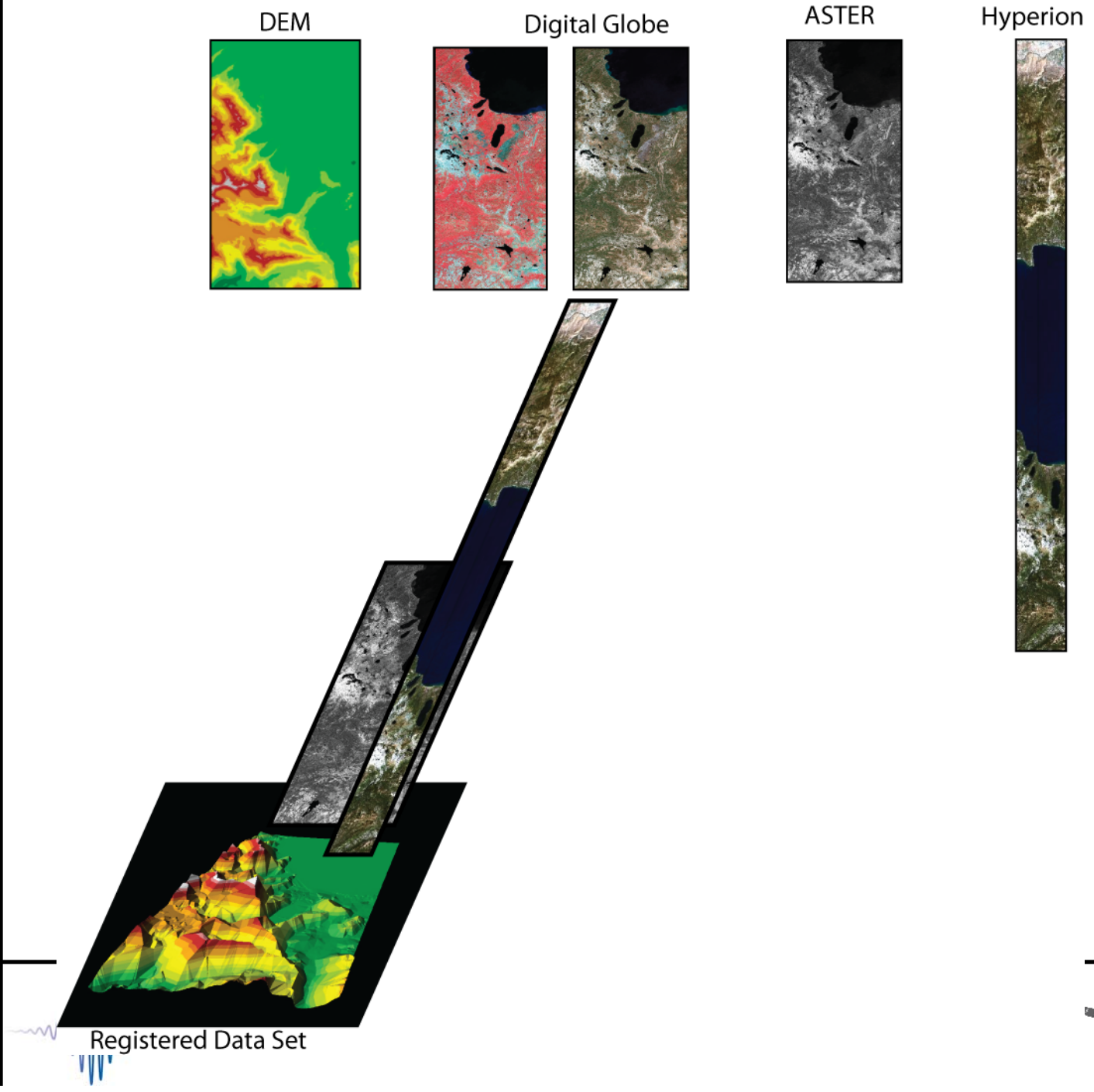
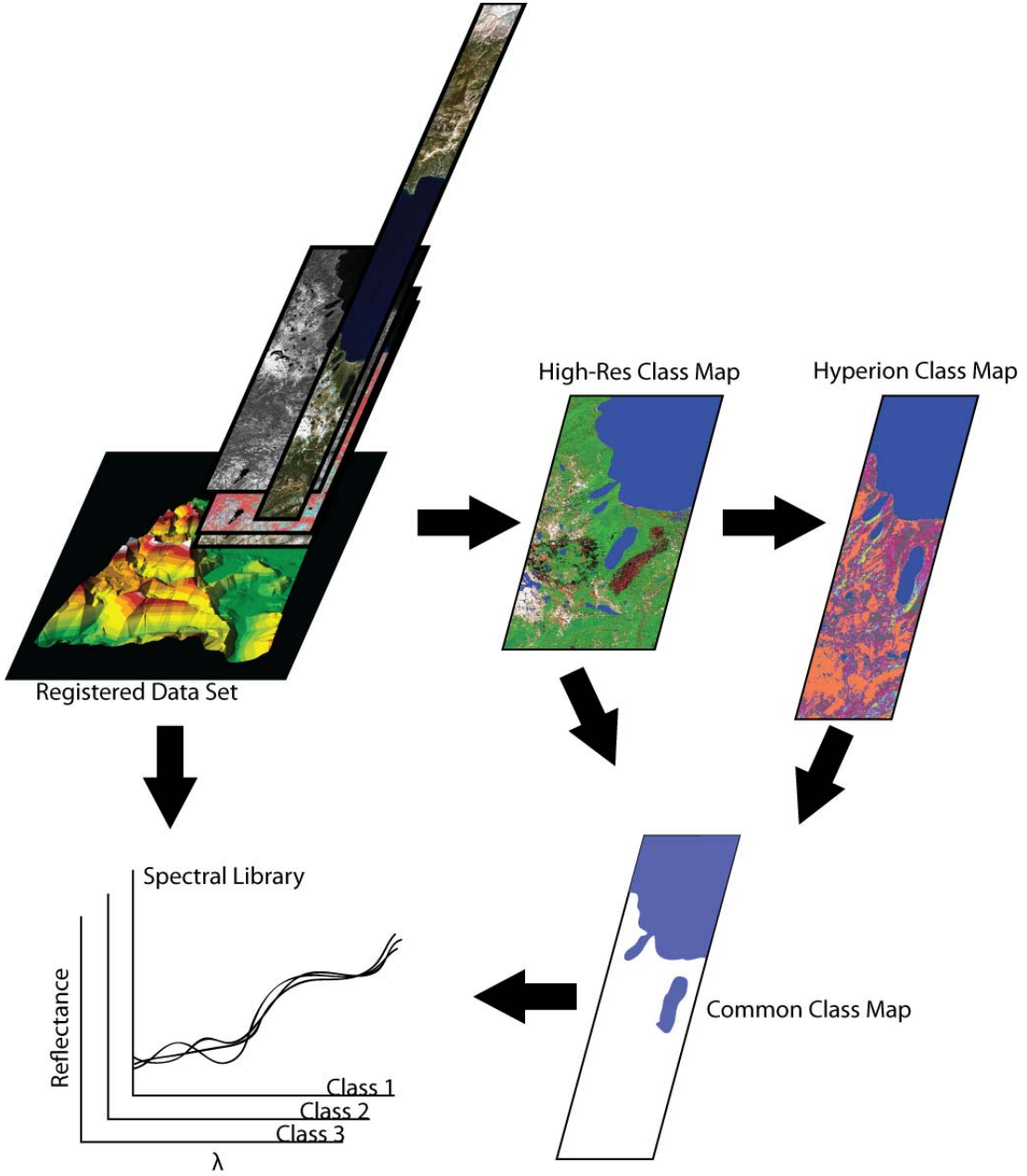
Path43Row33

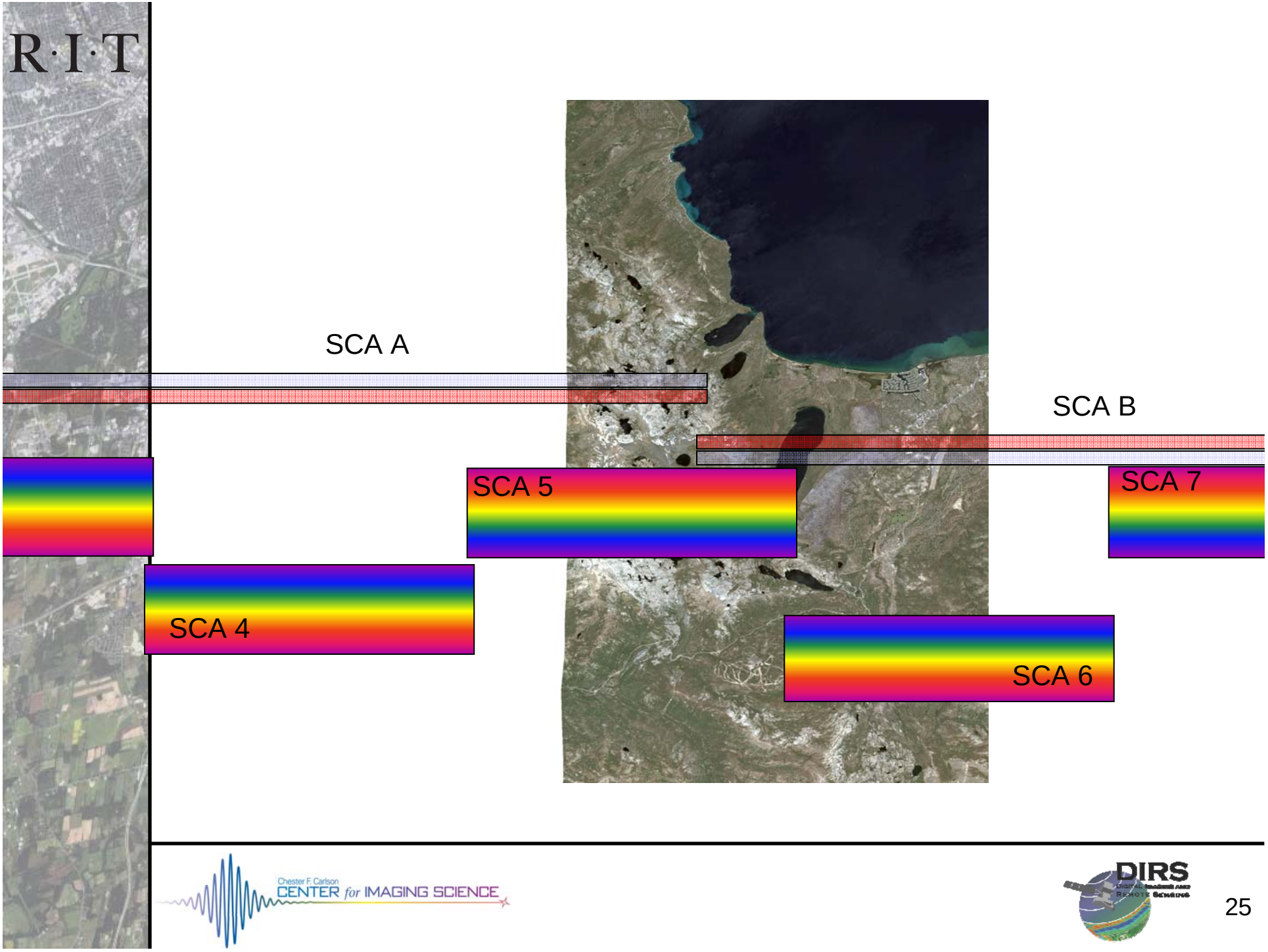
DIRS



Example Quickbird
Unsupervised Classification
(Isodata)
15 bands


DEM
Digital Globe
ASTER
Hyperion
Registered Data Set


High-Res Class Map
Hyperion Class Map
Registered Data Set
Spectral Library
Reflectance
Class 1
Class 2
Class 3
λ
Common Class Map



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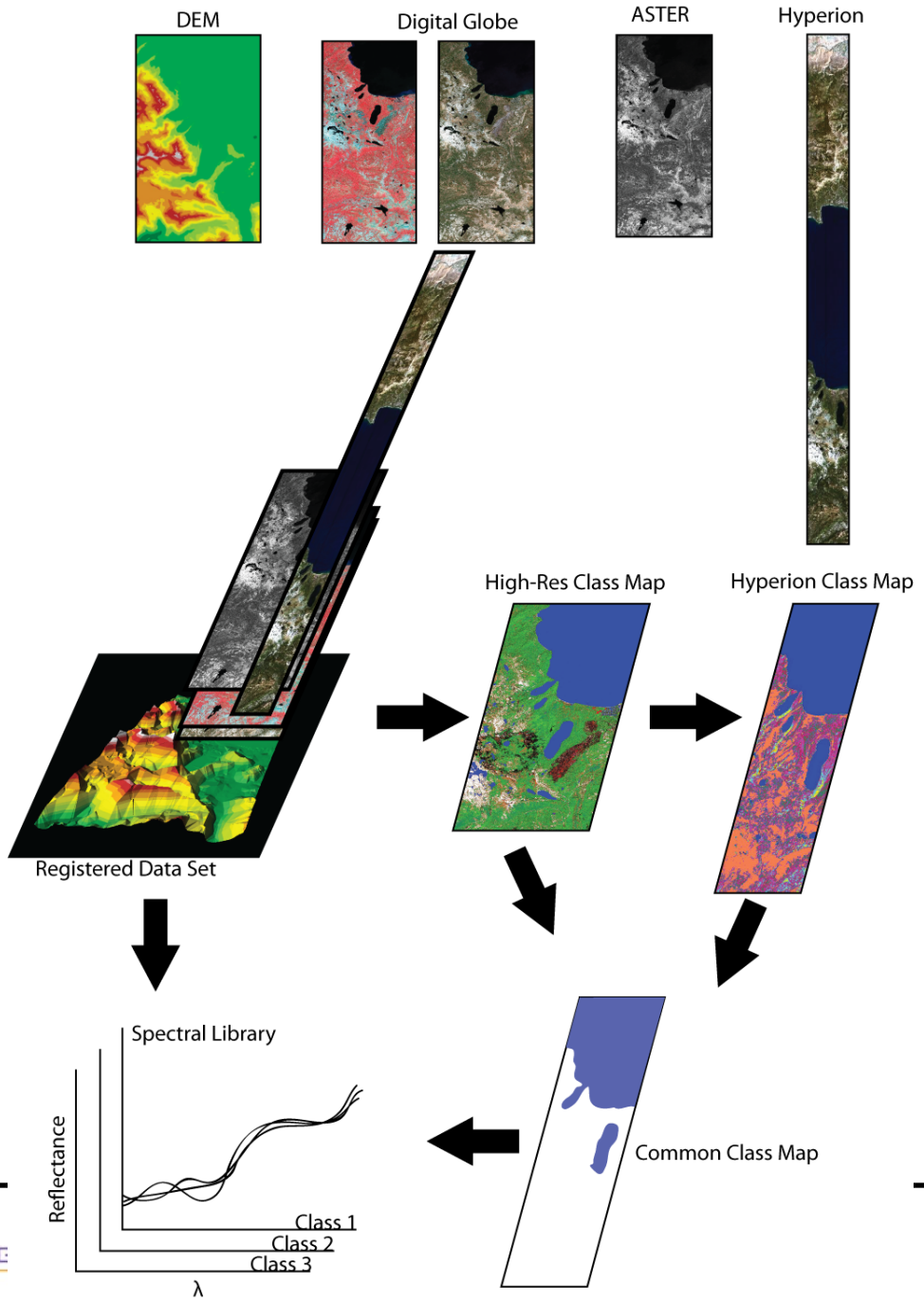
DIRS Digital Imaging and Remote Sensing

SPIRAL 1

- Internal goal is first release at six months: End Feb 2010
  - First OLI image
  - Orbital Geometry
  - Angular detector location
- Plan to release first TIRS image approximately six weeks later
  - Per class bulk properties

Spiral development approach will allow updates on a regular basis (roughly every six months). Each release will improve sensor and scene fidelity.

- http://dirsig.cis.rit.edu


DEM
Digital Globe
ASTER
Hyperion
High-Res Class Map
Hyperion Class Map
Registered Data Set
Spectral Library
Reflectance
λ
Class 1
Class 2
Class 3
Common Class Map

Scene Creation

- Status: Quickbird data registered to DEM and Initial Class Map Generated
- Working on EO-1 Registration
- Soon!!! ELM calibration of EO-1.Later!!!Per Pixel Atmospheric Compensation and Class Attribution.

Path Forward (Post rev 1)

- Convert Hyperion images to reflectance using ELM fits to reflectance estimates of multiple photo interpreted targets
- Reprocess radiance spectral databases to reflectance
- Allow DIRSIG to model atmosphere and illumination
- Develop methods to incorporate thermal effects

Short Term Thermal

- Assign thermal materials properties by class based on photo interpretation of class type and thermodynamic databases
  - Emissivity spectra (ASTER maps?)
  - Specific heat
  - Conductivity
  - Density
  - Thickness

Short Term Thermal

- Assign absorption, slope, aspect from DIRSIG knowledge of r(λ) and DEM
- Tune bulk properties by class using Therm estimates of mean behavior compared to Landsat ETM+ derived temperatures for a range of dates

Long Term Thermal

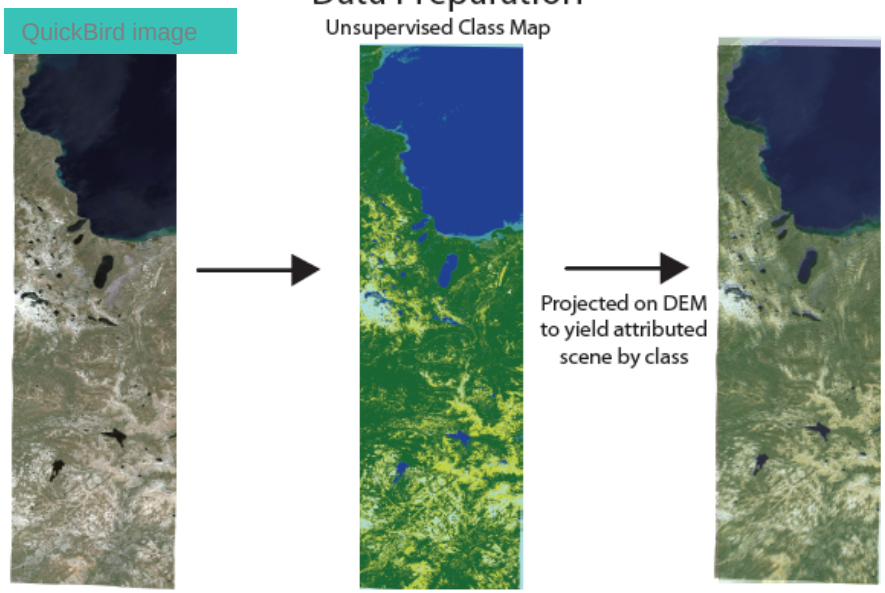
- Input weather to Therm for 24 hours before Landsat acquisition
- Get absorption from Hyperion spectra
- Slope and aspect from DEM
- from material type (Note this requires manual determination of class name of unsupervised classes and assignment of emissivity spectra)
  - Alternately, does ASTER have viable emissivity product?

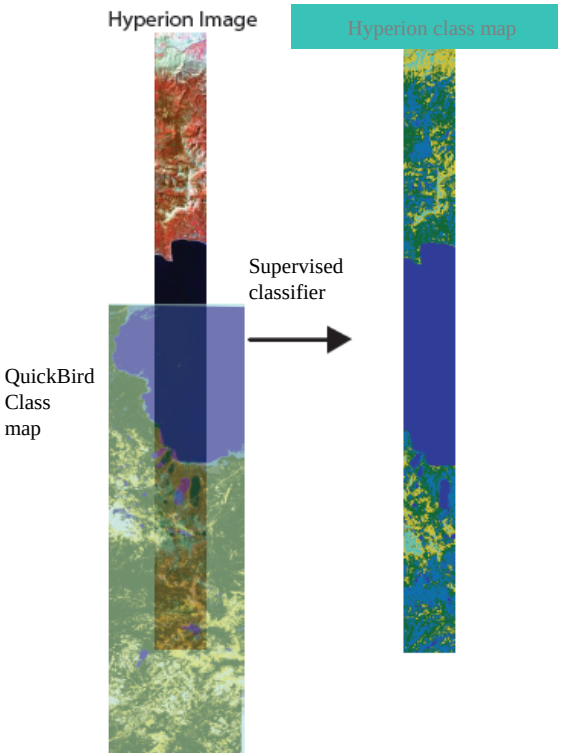
$\mathcal{E}$

Long Term Thermal

- For registered pixels in study region at ETM+ resolution calculate surface leaving radiance and apparent temperature for 5 or more days
- With inputs described above – vary remaining 2 free parameters in Therm to obtain best estimate of these parameters on a per pixel basis

Data Preparation





Section 14.3 A Modeling Example

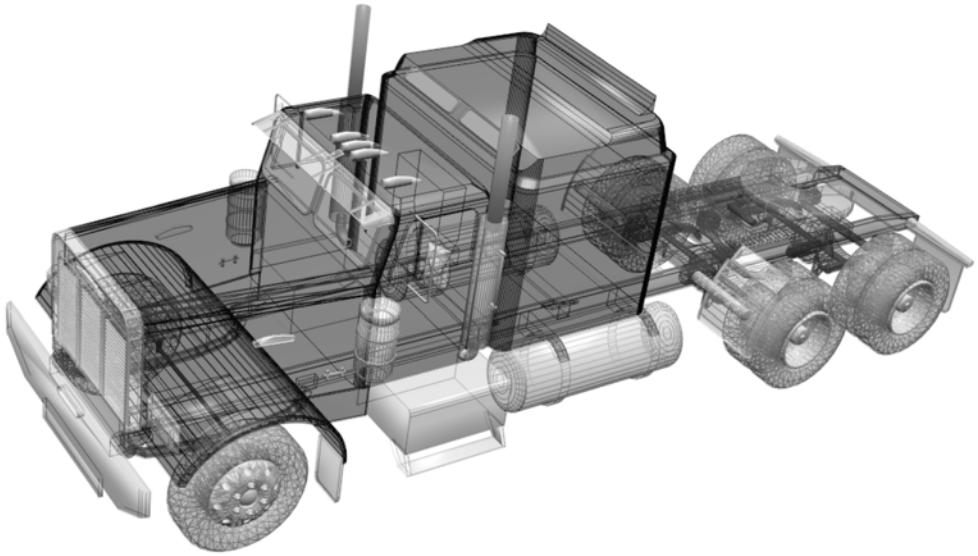
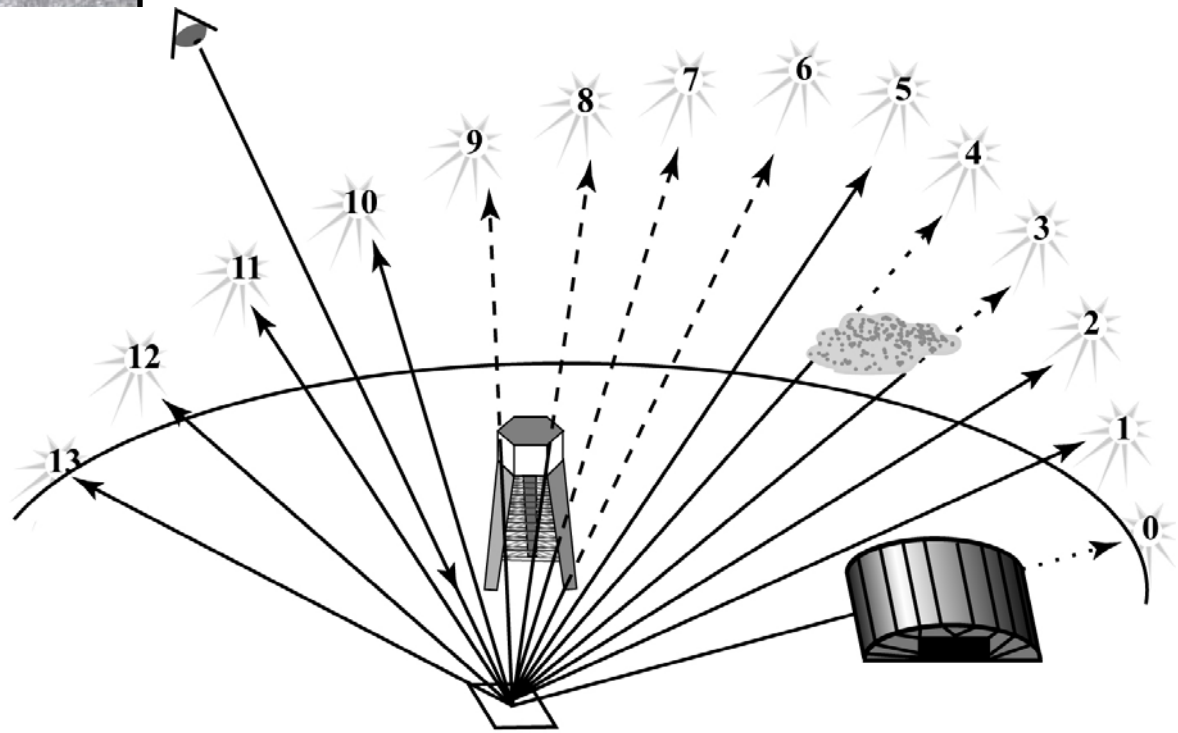


Figure 14.7

Wire frame of an object used in the SIG process. The object is produced using CAD software and material types are assigned to each facet during the construction process.

Section 14.3 A Modeling Example

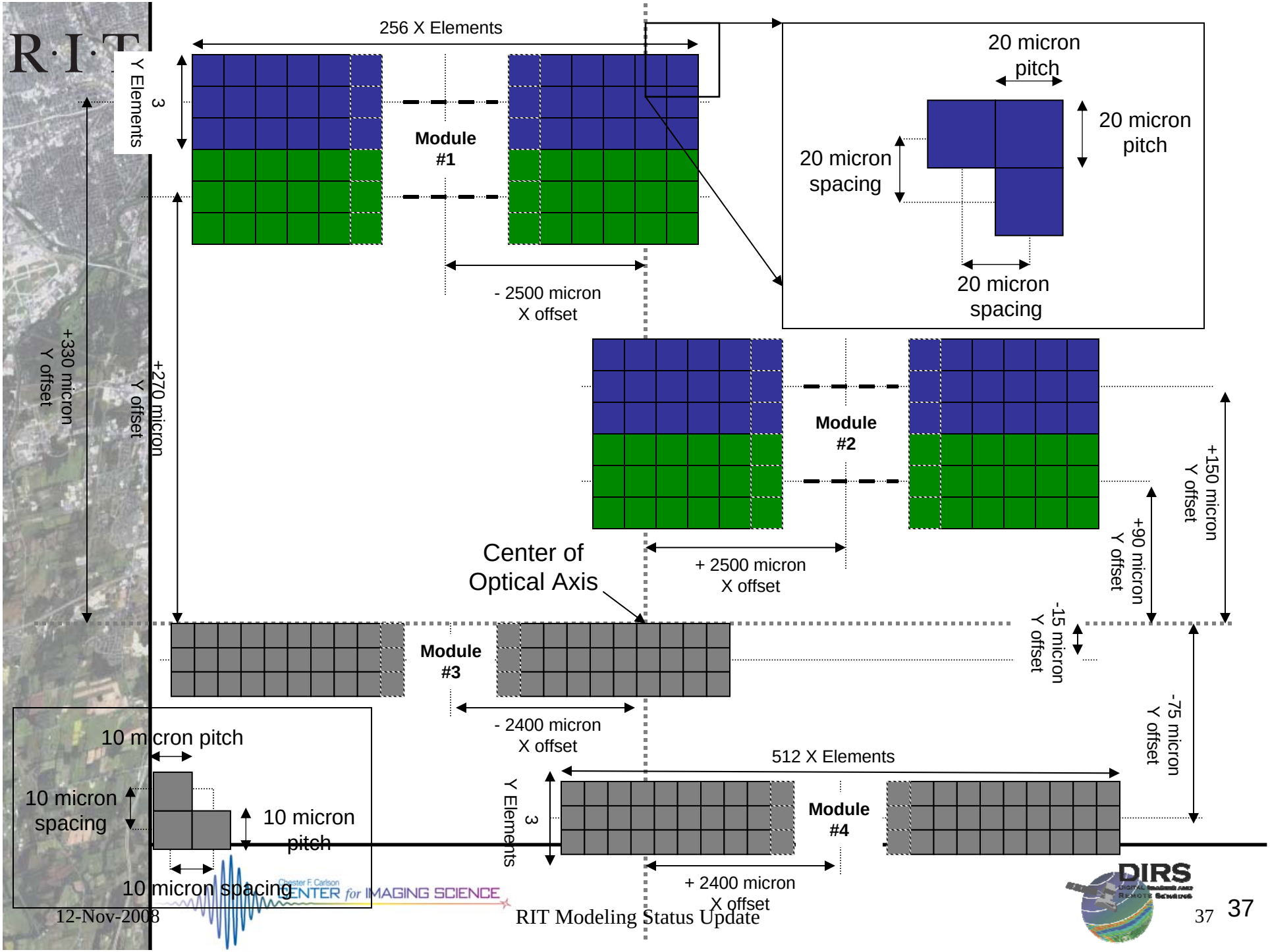


0.0	1.0	1.0	0.4	0.?3	1.0	0.0	0.0	0.0	0.0	1.0	1.0	1.0	1.0
0	1	2	3	4	5	6	7	8	9	10	11	12	13

(total shadow) 0.0 < direct insolation modifier < 1.0 (total sunlight)

Figure 14.10

Sun shadow history, including partial obscuration by transmissive objects.


256 X Elements
3 Y Elements
Module #1
- 2500 micron X offset
20 micron pitch
20 micron pitch
20 micron spacing
20 micron spacing
+330 micron Y offset
+270 micron Y offset
Module #2
+ 2500 micron X offset
+150 micron Y offset
+90 micron Y offset
Center of Optical Axis
-15 micron Y offset
-75 micron Y offset
Module #3
- 2400 micron X offset
10 micron pitch
10 micron spacing
10 micron pitch
10 micron spacing
512 X Elements
3 Y Elements
Module #4
+ 2400 micron X offset

Megascene 1
Thermal Infrared

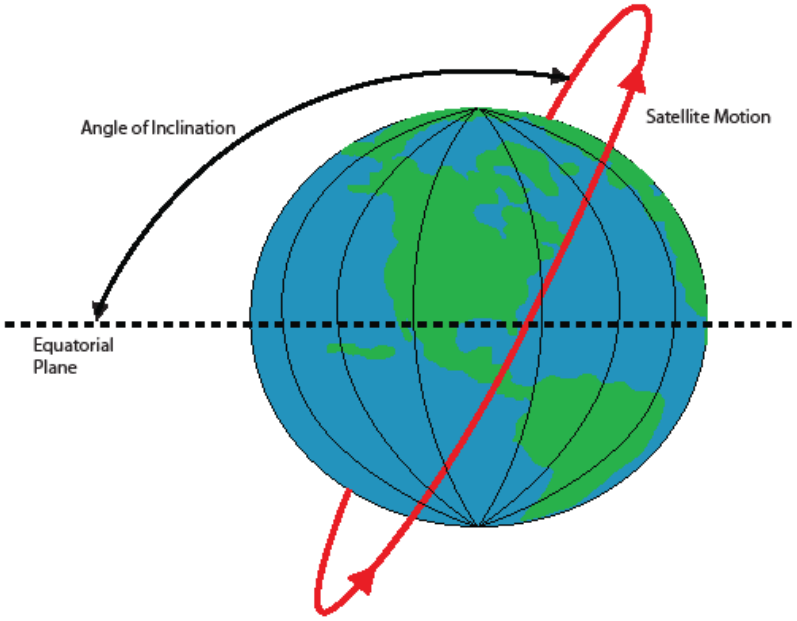
- Complete VIS-NIR coverage
- MWIR coverage
  - RIT lab measurements for hard objects
  - Database for natural objects
- LWIR coverage for most objects
  - RIT measured and available databases
  - Updating and expanding

Orbitology Path Forward

- Uses the NORAD Two-Line Element (TLE) format for describing the Orbit (Keplerian Elements). This is information on Inclination, Eccentricity, Drag, etc.). TLE are readily available for all NASA satellites (Note they are updated regularly (e.g., weekly) to adjust for orbital perturbations.

- Feed DIRSIG satellite TLE, start time, end time and sample clock rate.

- Use SpaceCom's Simplified General Perturbations version 4 (SGP4) orbital propagator to convert to position and velocit for any given time (we use SGP4-Celestrak).
- Output is in True Equator and mean Equinox (TEME) format . We need to convert to Eart Centered-Earth Fixed (ECEF) format. (North =z, sun at Noon on vernal Equinox is x and right hand rule yields y). Note that the vecto from the location x, y, z to the origin (Earth's center) is the nominal line of sight (LoS) of the instrument. Finally we convert to DIRSIG's native East North Up (ENU) format.



Sensor Design

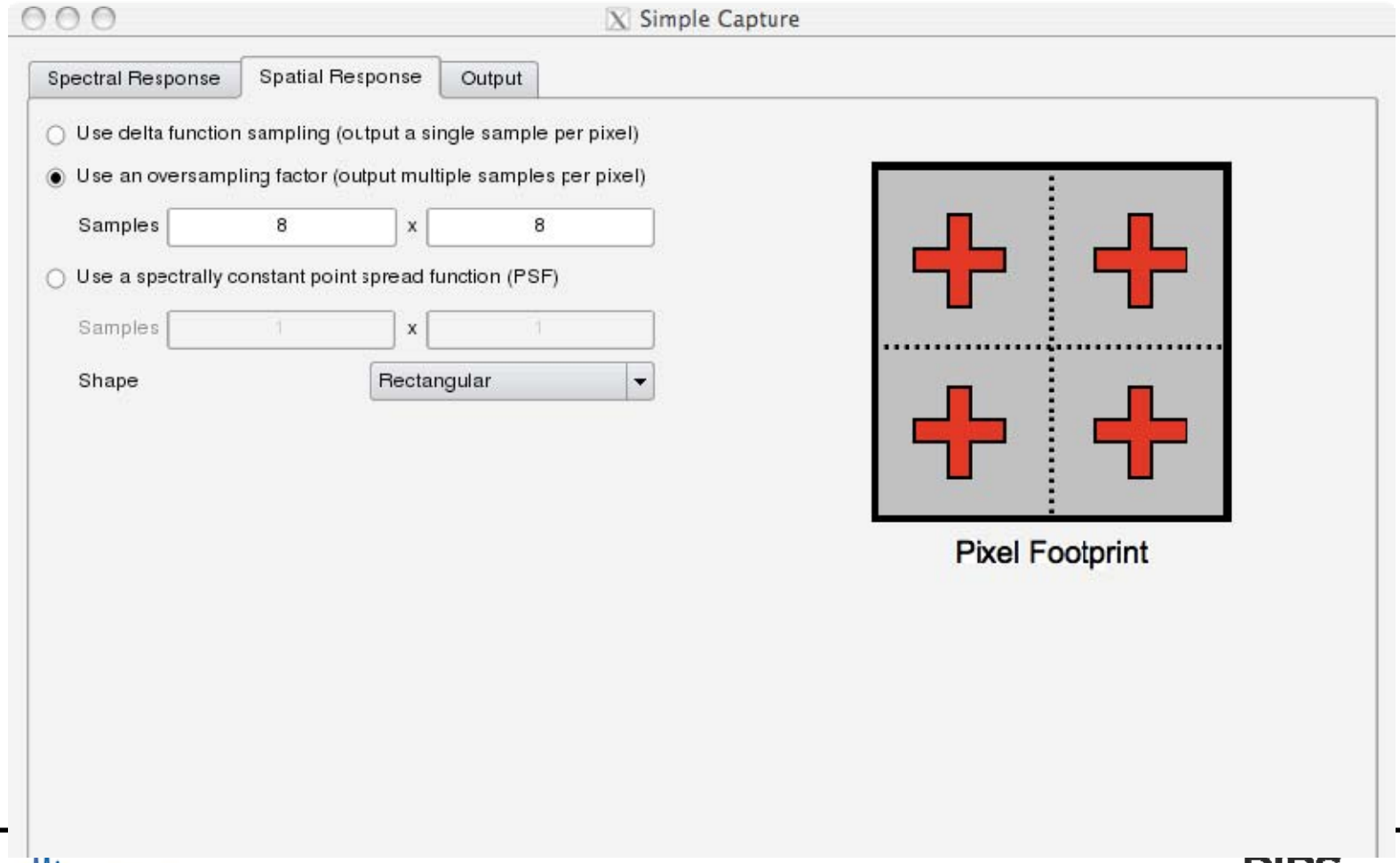
Implementation Plan is to Use Actual Sensor Angle-Angle descriptors of Detector Element Effective Focal Plane Location and a LUT to Relate Active Detectors and Sample Order to Tabulated Angle-Angle Data (Status: Scripts are in place and under test)

Angle-Angle Detector Locations

SCA	Band	Set	Detector	X	Y
1	1	1	1	0.0064828	0.1345405
1	1	1	2	0.0065670	0.1344997
1	1	1	3	0.0064800	0.1344587
1	1	1	4	0.0065641	0.1344179
1	1	1	5	0.0064771	0.1343768
1	1	1	6	0.0065612	0.1343360
1	1	1	7	0.0064743	0.1342950
1	1	1	8	0.0065584	0.1342542
1	1	1	9	0.0064714	0.1342131
1	1	1	10	0.0065555	0.1341723
1	1	1	11	0.0064686	0.1341312

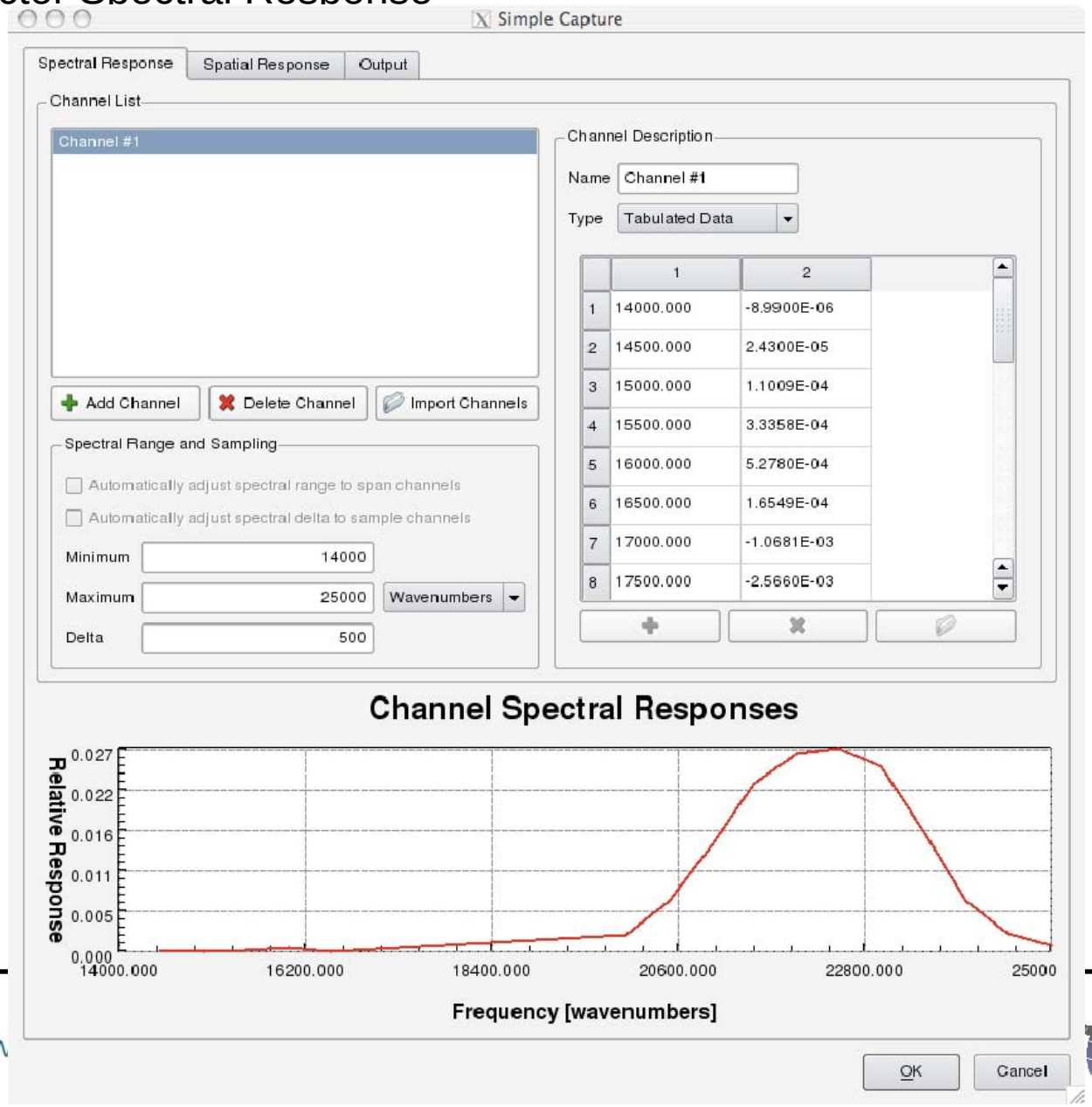
Sensor Design

Detector Element Spatial Sampling



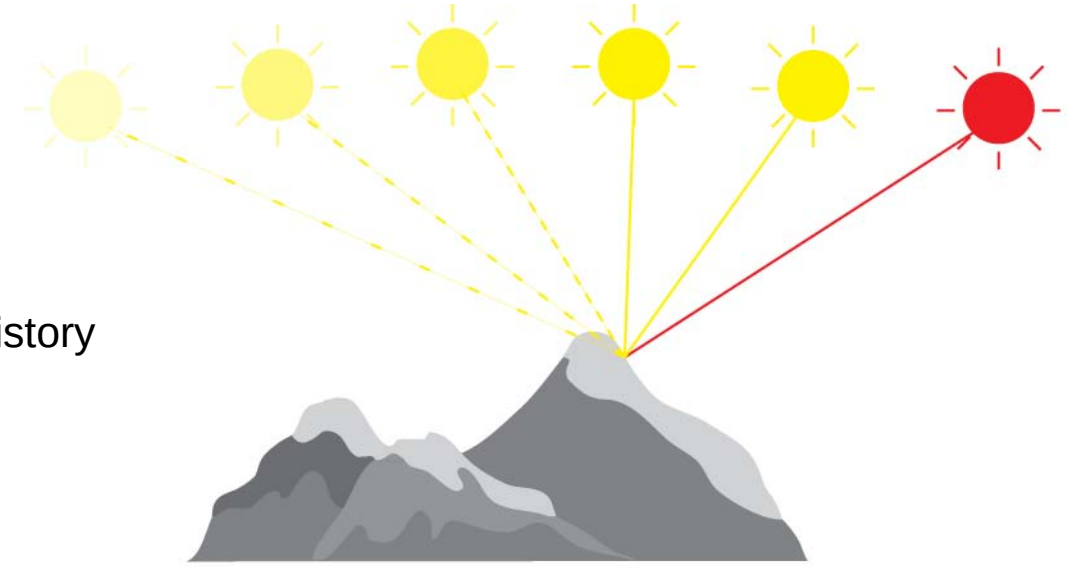
Sensor Design

Detector Spectral Response

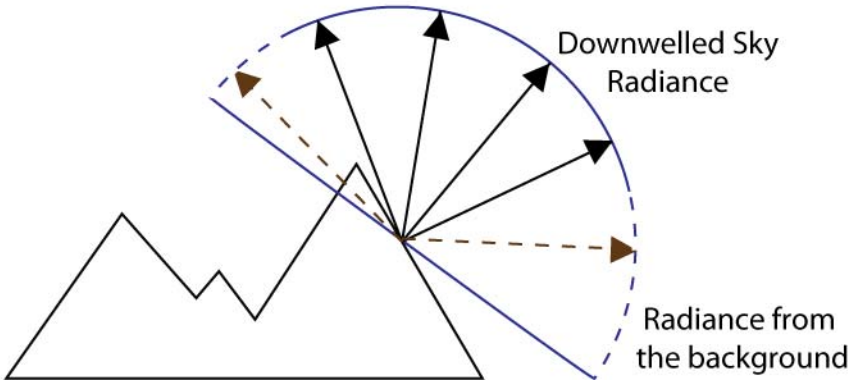


Ray Tracer Gathers Information for the Thermal and Radiometry Models

Sun Shadow History



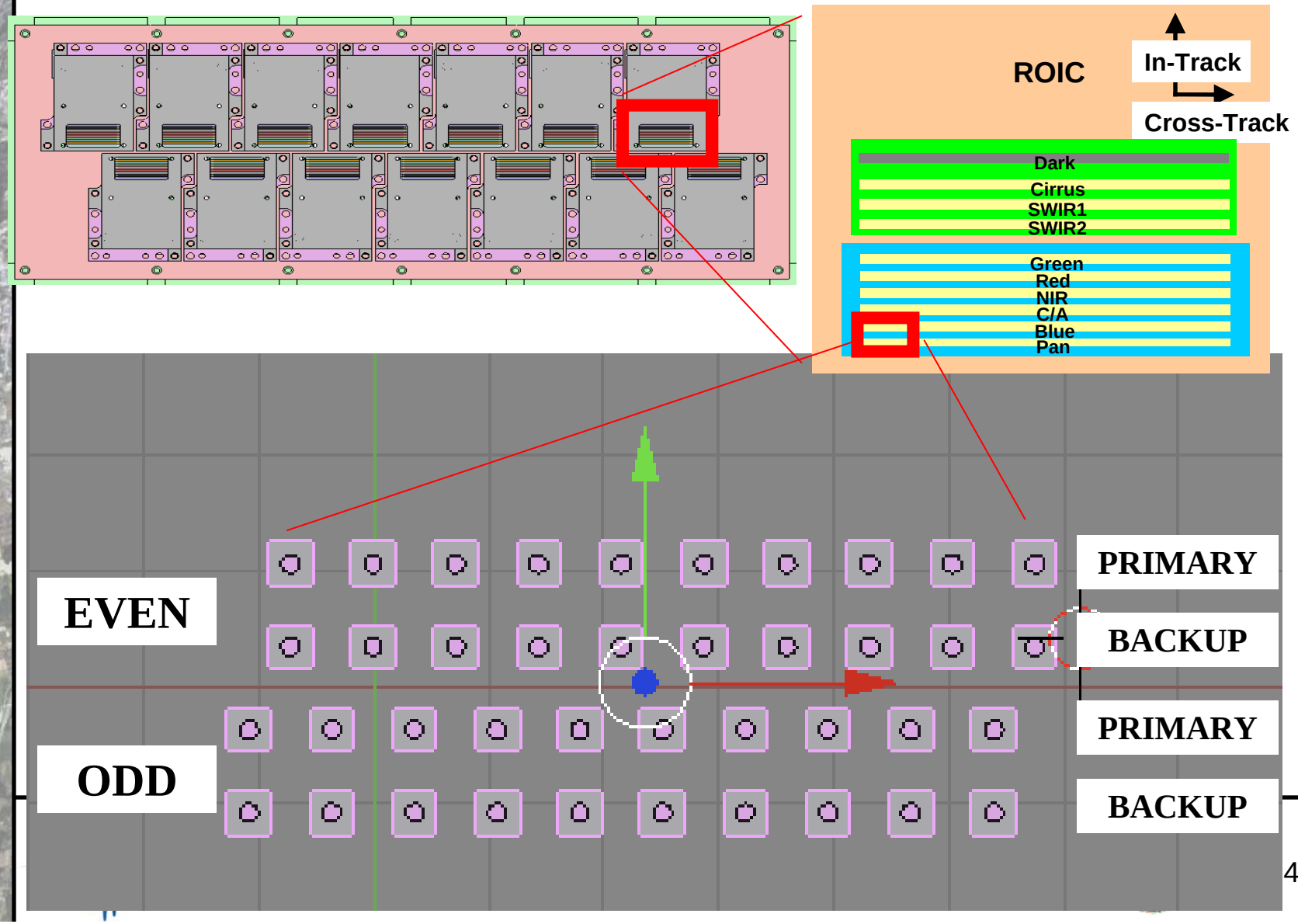
Radiance from Surround



R·I·T

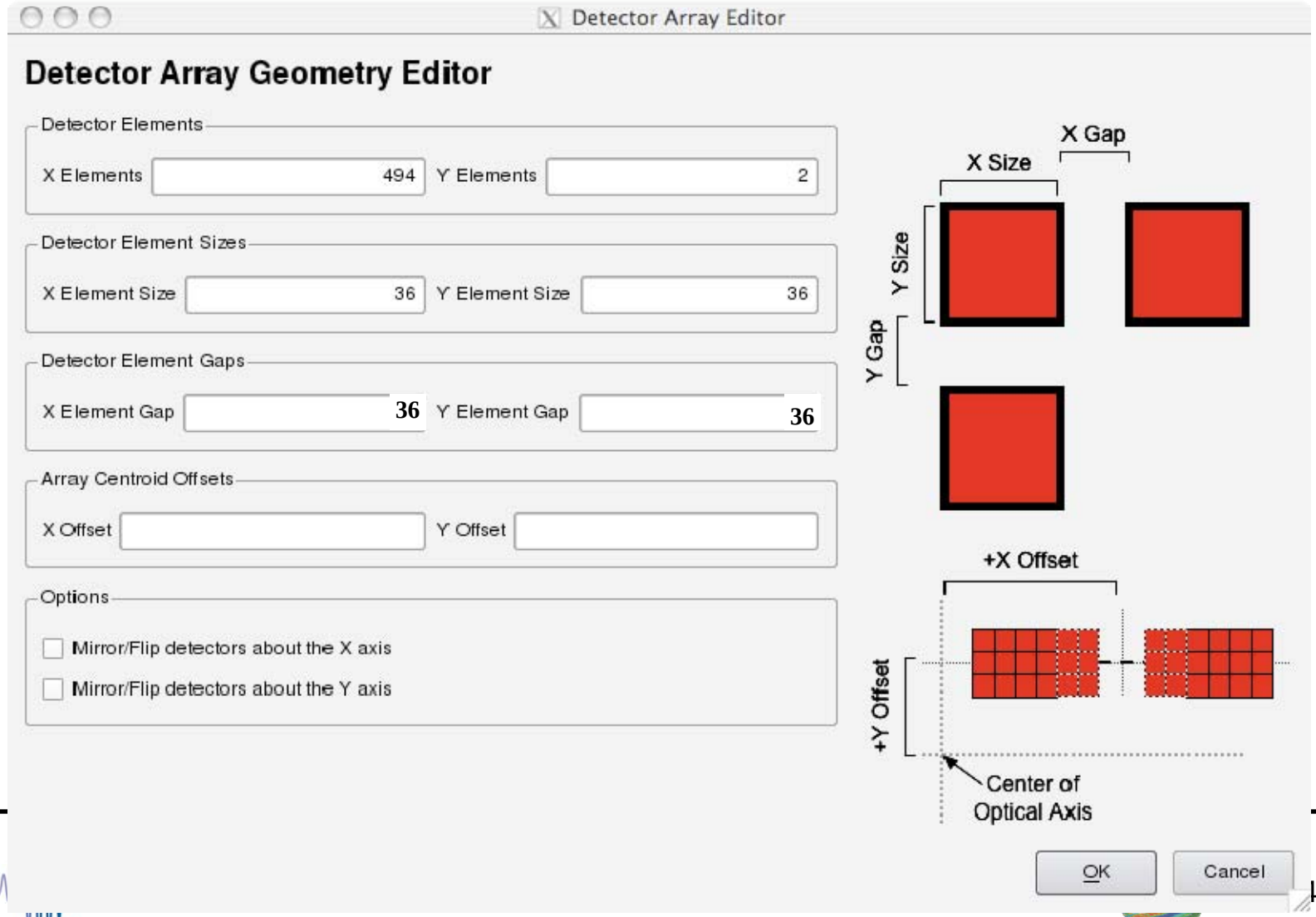
Sensor Design

Blue Array Pixels Arrangement 36 um detectors, 72 um pitch (xy)



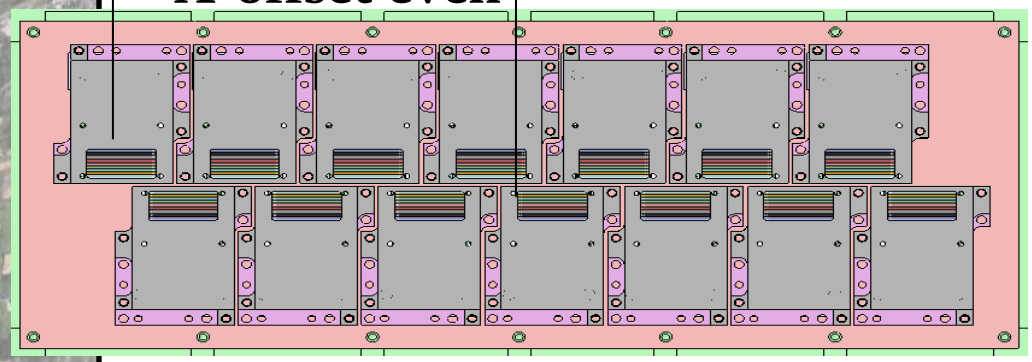
Sensor Design

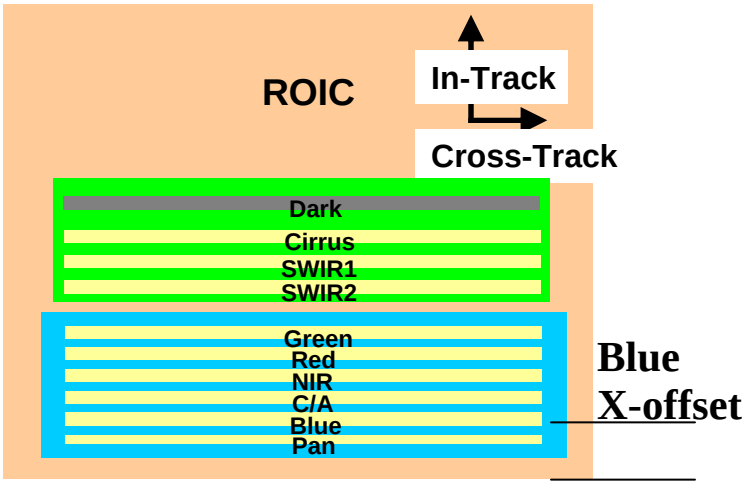
Specifying Positions of Blue Odd Pixels Focal Plane 1



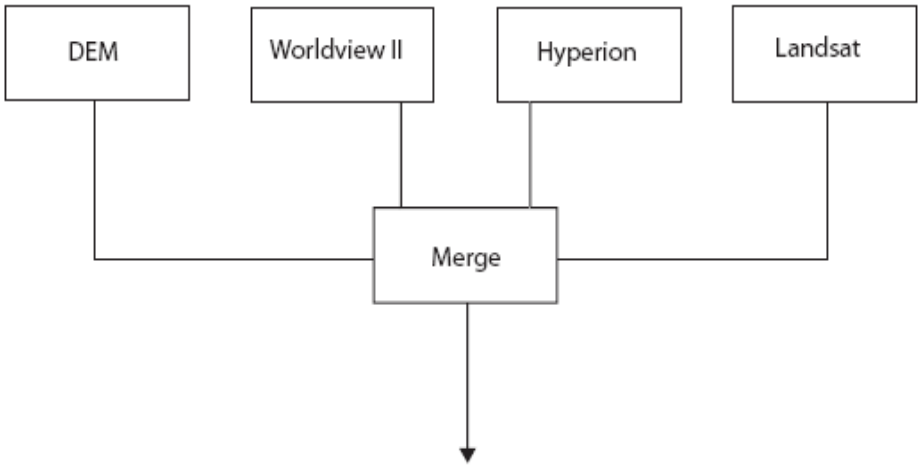
Sensor Design

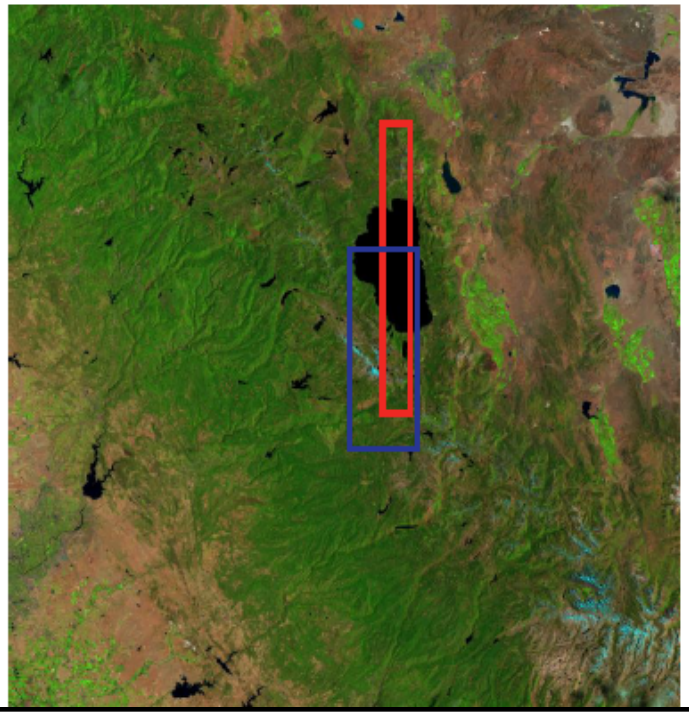
Array Centroid Offsets



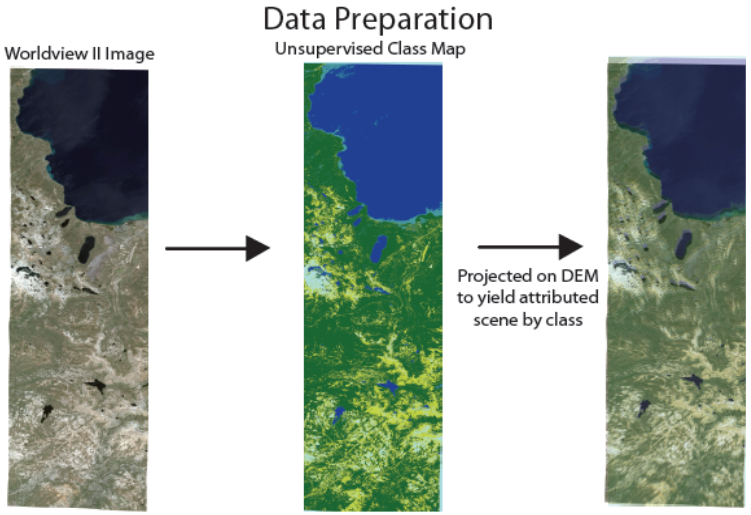


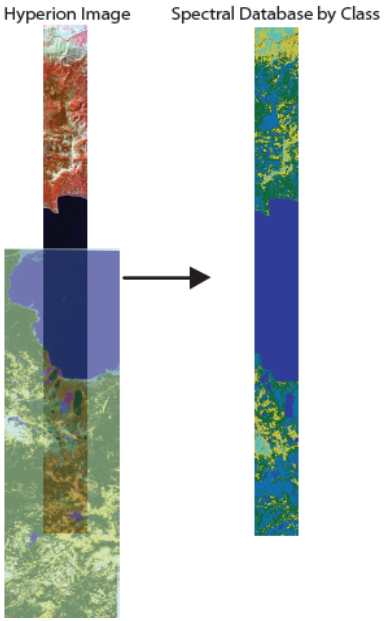
Virtual Scene Creation Approach





DIRSIG Scene Generation

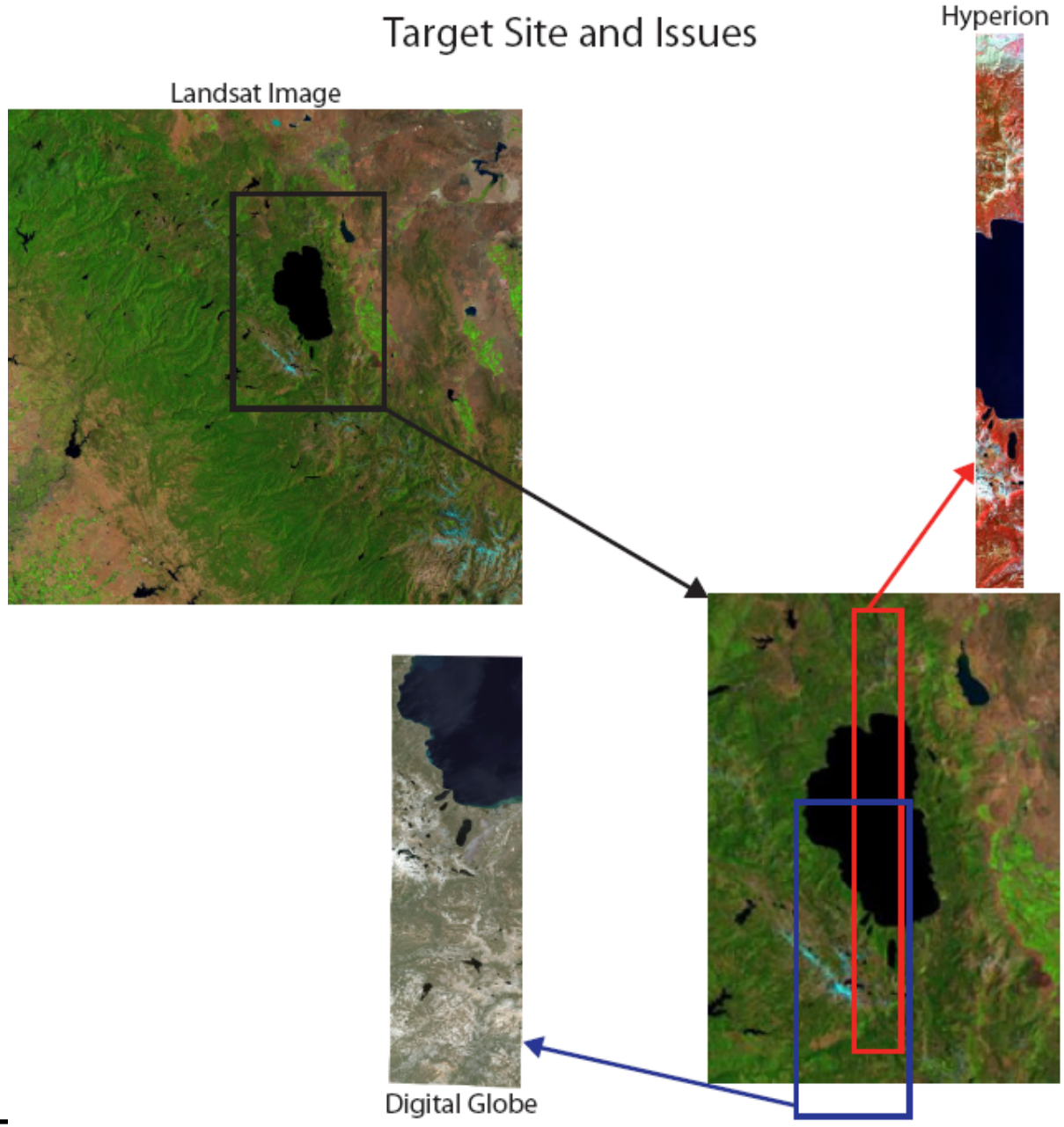


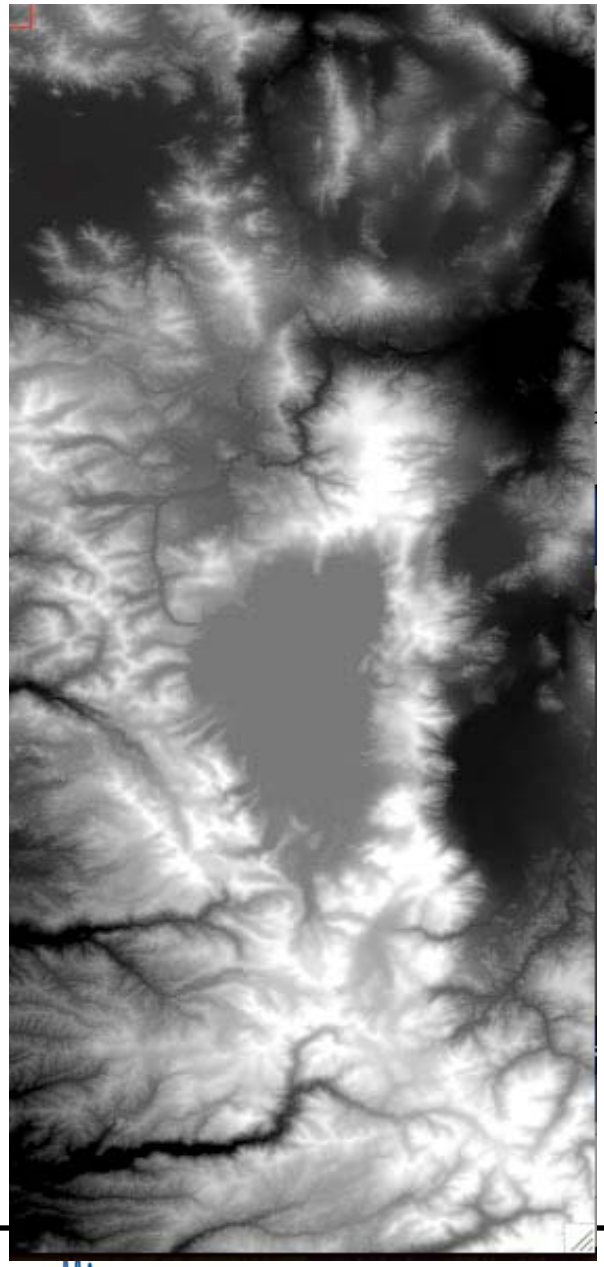


- Use fused data sets to establish a **virtual truth**
  - DEMs: scene geometry
  - Quickbird: MSI high spatial resolution Initial Landcover Class.
  - Hyperion: Spectral Resolution 196 bands 357 - 2576 nm
  - LANDSAT thermal texture
  - ASTER emissivity map

- Register QuickBird image to DEM
- Register Hyperion and ASTER to QB
- TIN DEM and format for use in DIRSIG

Target Site and Issues





NED National Elevation Dataset Product

For Tahoe area 1/3 arc second is available which corresponds to ~10m pixel or x,y cell size =0.00009 degrees

Geographic properties:

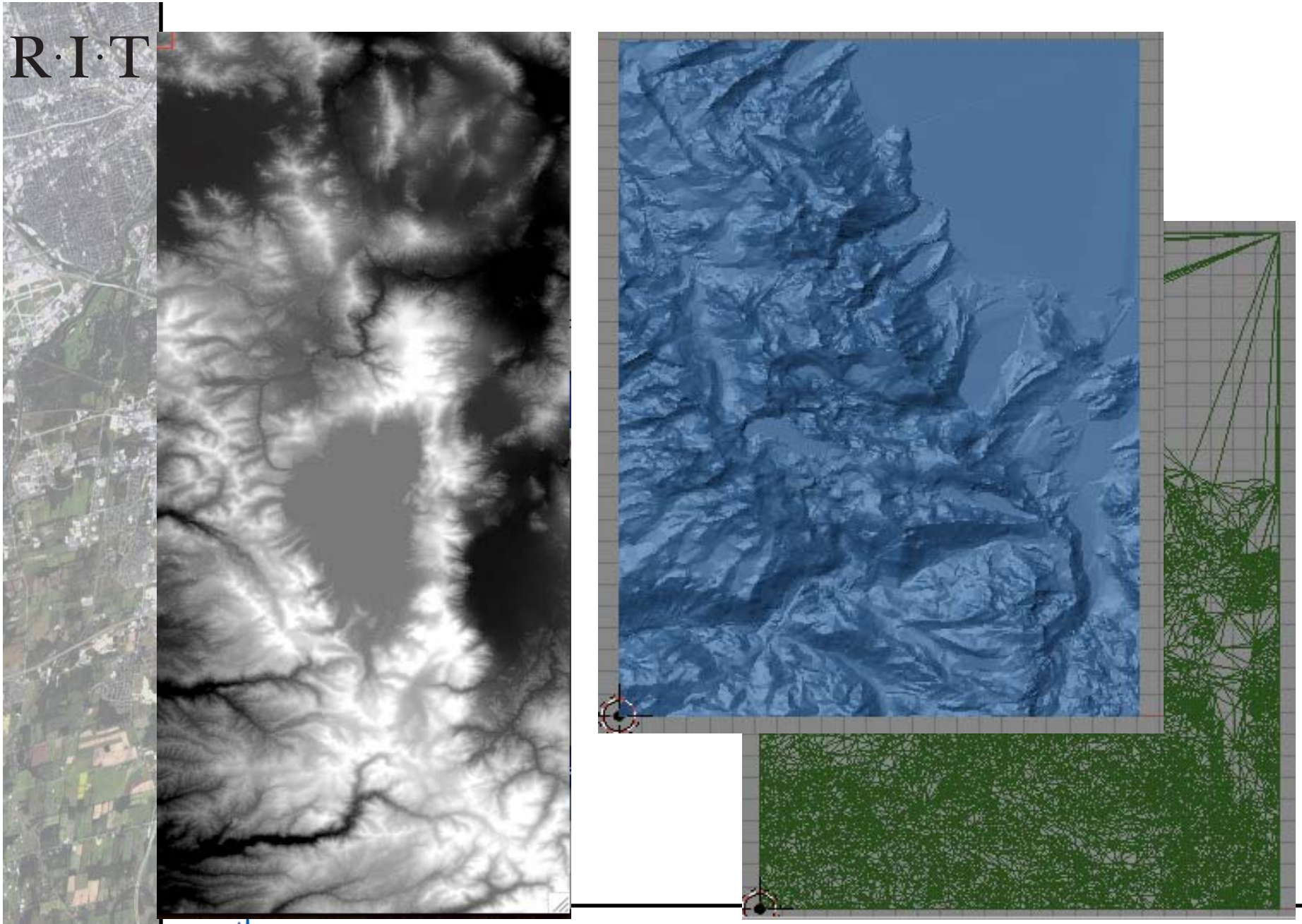
-Geographic Lat/Long

-Horiz Datum NAD83

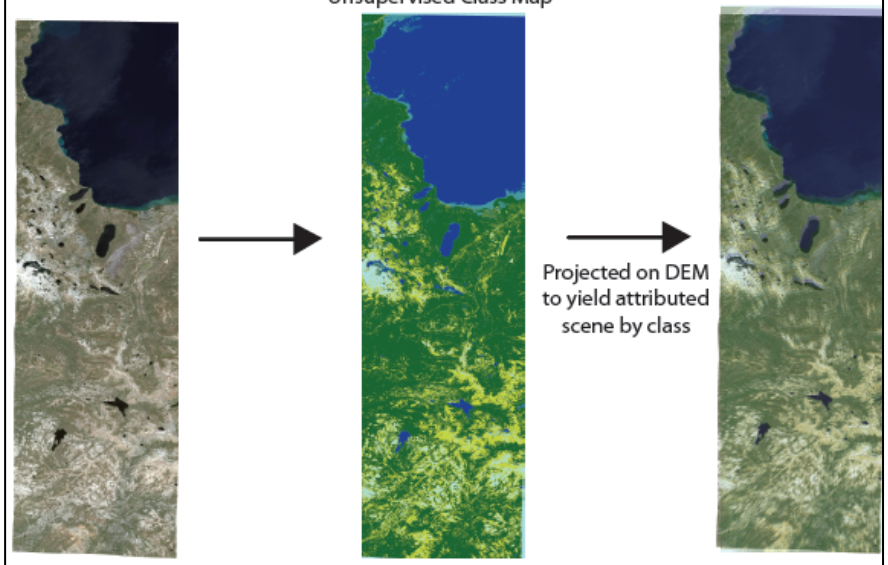
-Vert Datum NADV88 convert to WGS84

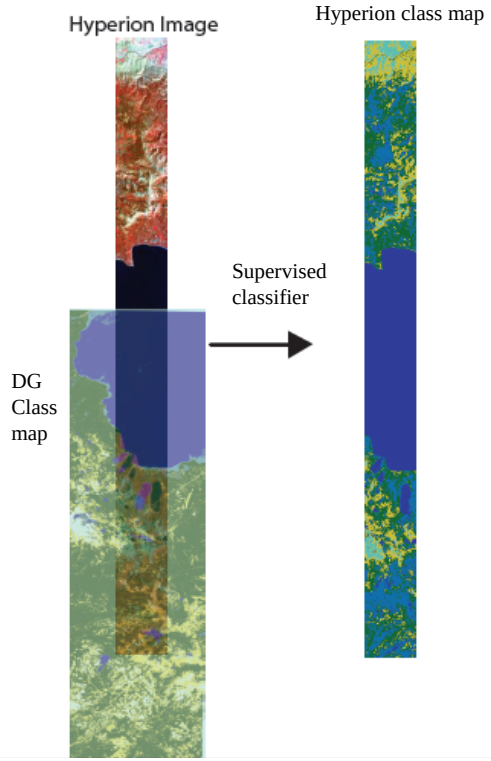
-Vert Units -meters

-Vert Accuracy - +/-7meters

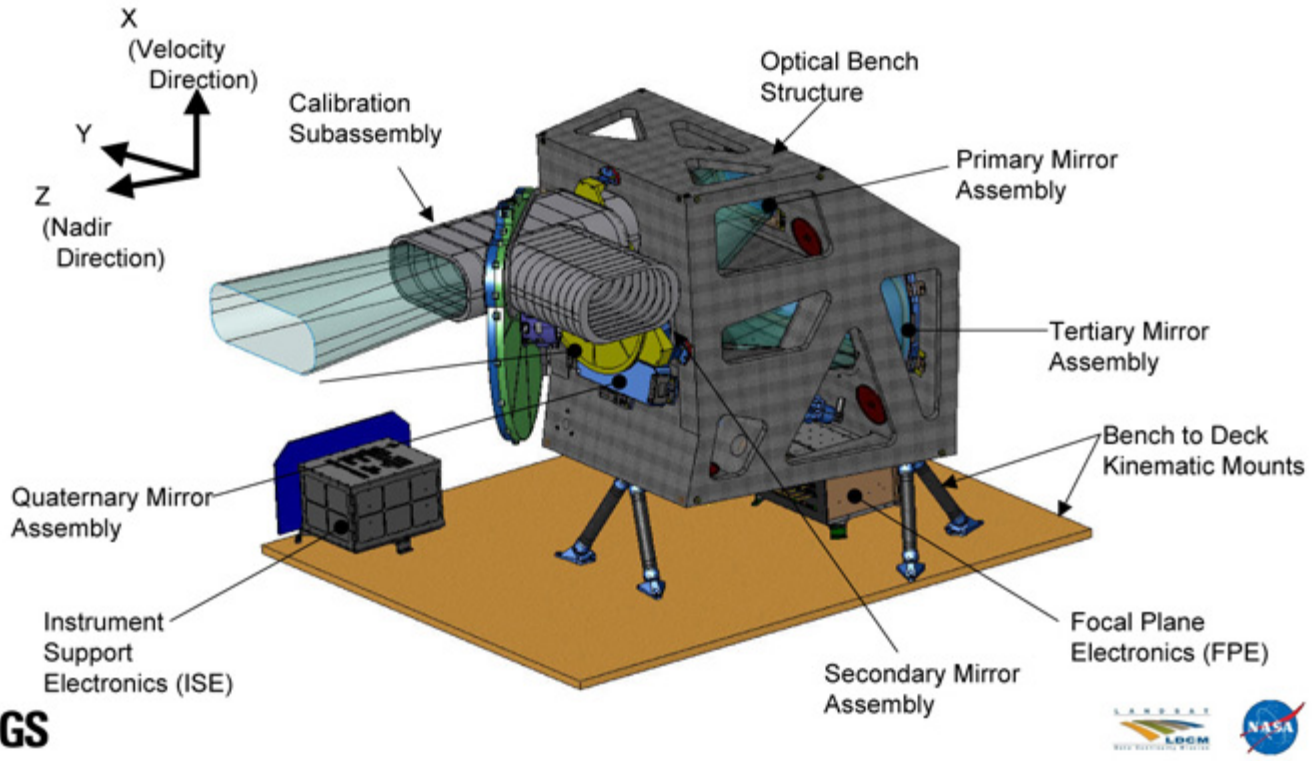


Data Preparation

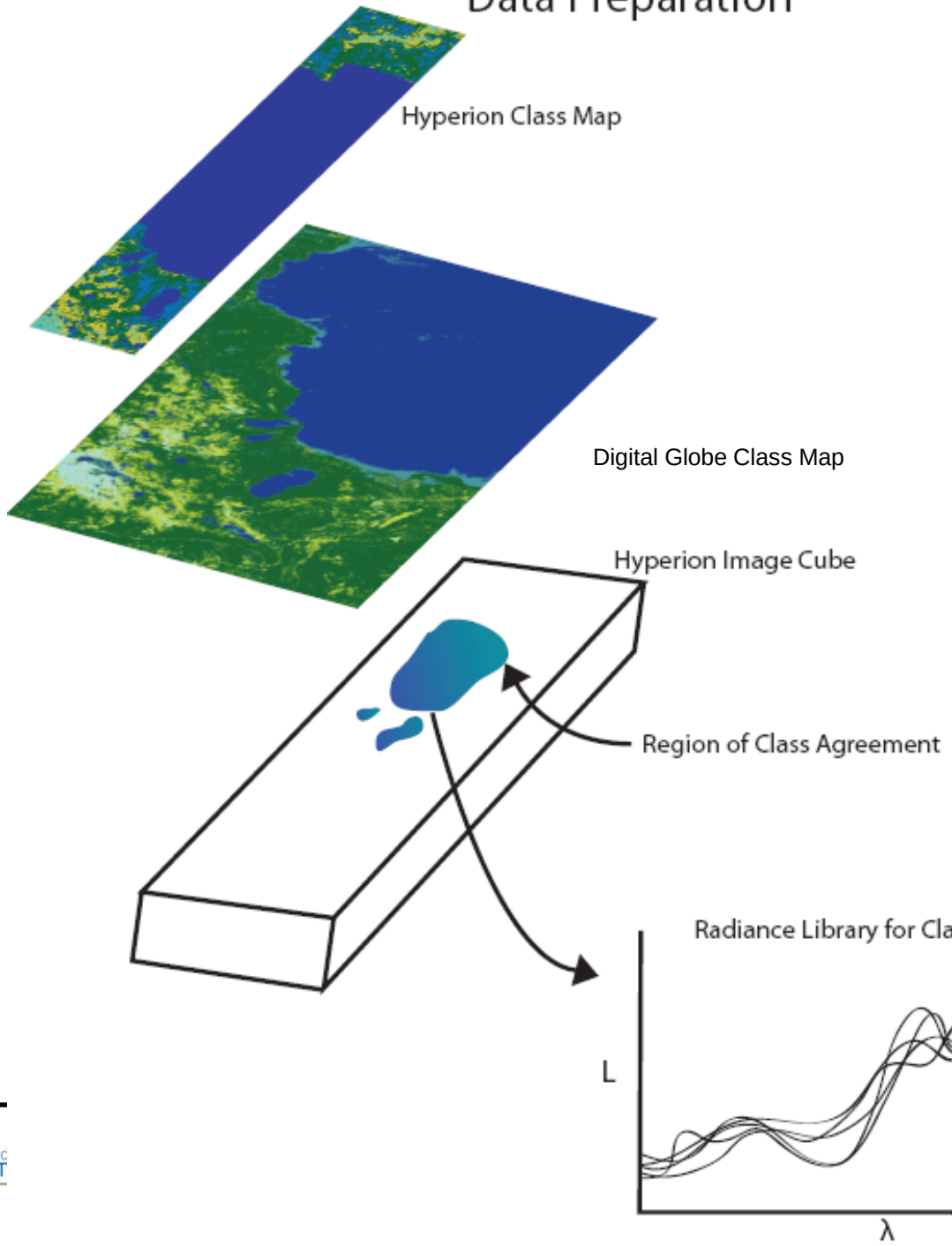




OLI Instrument Overview



Data Preparation



Build DIRSIG Inputs

- Run unsupervised classifier on QuickBird image to form large number of classes (e.g., 10's of classes)
- Project class map on DEM to generate attributed scene
- Project 4 band Quickbird image on class map to form texture image for spectral curve selection

Conceptual Implementation