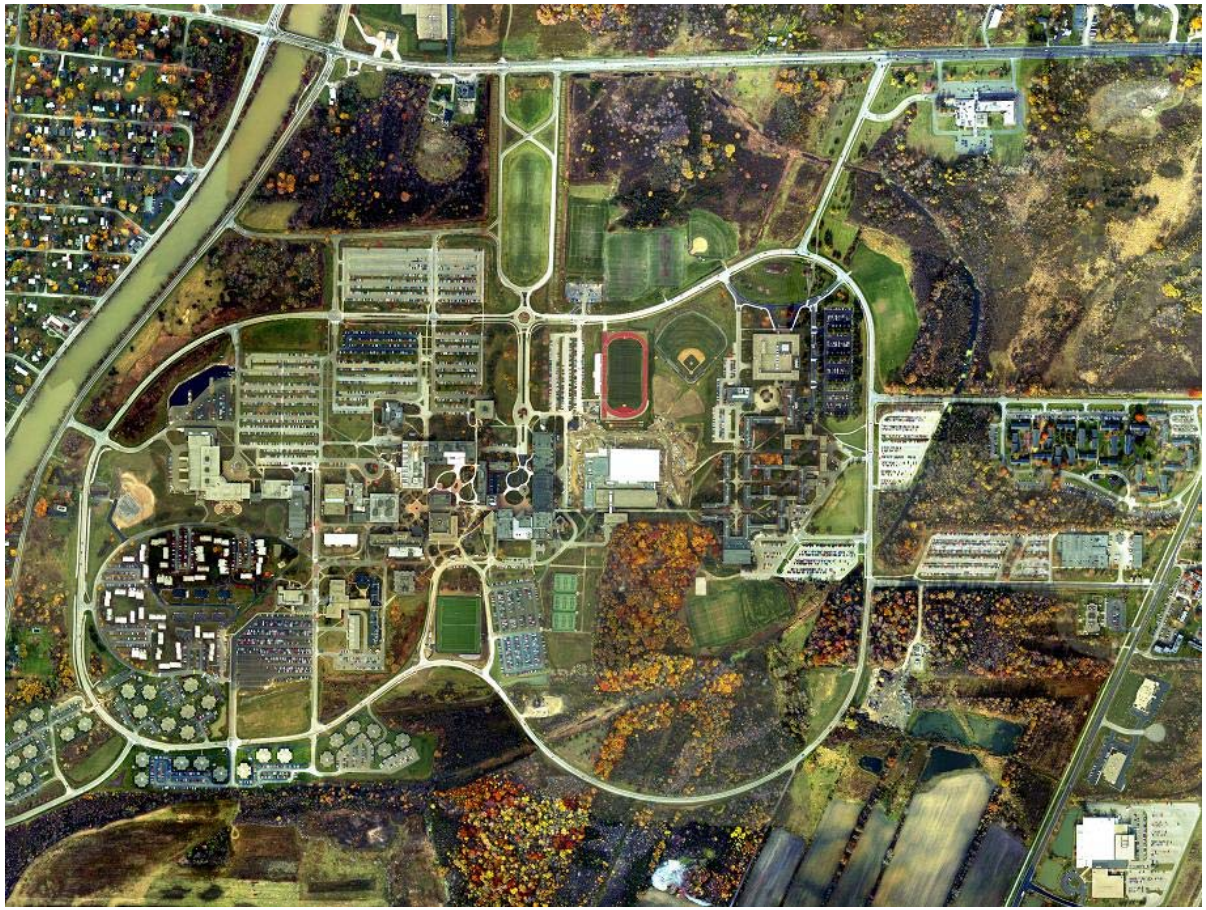
Overview of the Digital Imaging and Remote Sensing Laboratory

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

R·I·T

Who We Are

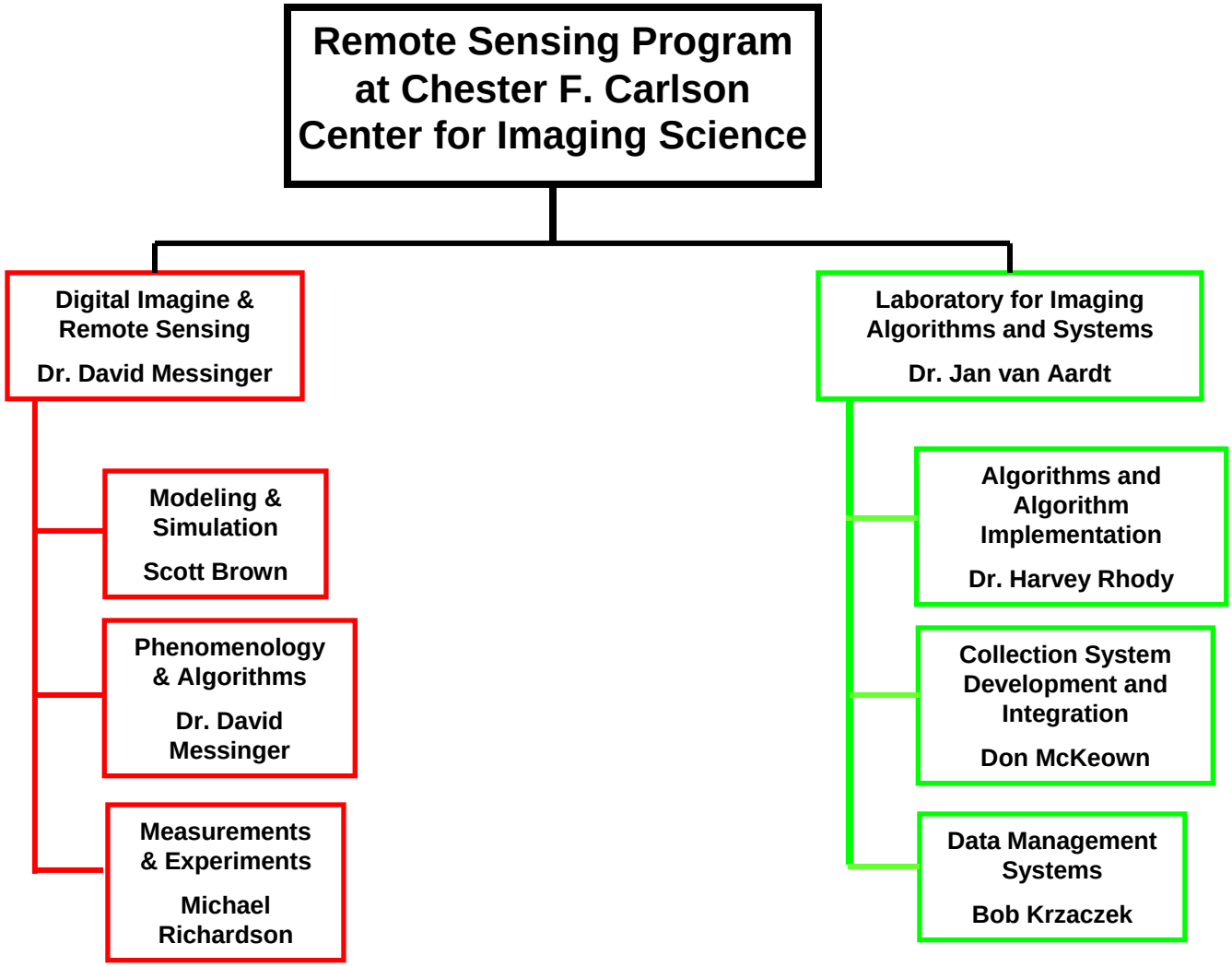


WASP Image
Of the RIT Campus

Chester F. Carlson CENTER for IMAGING SCIENCE

DIRS

Remote Sensing Organization



DIRS Faculty

- Dr. John Schott
  - hyperspectral algorithm development, multi- and hyperspectral instrument development, synthetic scene simulation and modeling

- Dr. Tony Vodacek
  - environmental applications of remote sensing; forest fire detection and monitoring; active and passive sensing of water quality

- Dr. Carl Salvaggio
  - new techniques and devices for optical property measurement; applied image processing and algorithm development

- Dr. John Kerekes
  - image processing and algorithm development; image chain modeling and parametric analysis

- Dr. David Messinger
  - multi- and hyperspectral algorithm development; advanced mathematical approaches to spectral image processing

- Dr. Emmett Ientilucci
  - multi- and hyperspectral algorithm development; physics-based signature detection in HSI; low SNR imaging systems

DIRS Research Programs

- DIRS consists of
  - 6 full time faculty
  - 7 full time research staff
  - 2 postdoctoral researcher
  - 1 administrative assistant
  - 5 undergrad research assistants
  - 9 MS candidates
  - 18 Ph.D. candidates

- Current research program
  - 25 funded projects
  - annual research revenue ~ $2.5M

- Sponsors from government and industry

DIRS Current Undergraduate and Graduate Students

USAF Officer in Training Program (fall 2008)

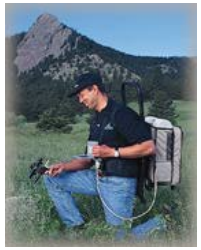
DIRS Research Focus

Measurements and Phenomenology

- Significant capabilities to characterize material optical properties over a wide spectral regime

Field Measurement

0.4 to 20µm coverage
- ASD Field Spec Pro
- SOC 400T (IR)
- D&P Model 102



Laboratory Measurement

0.4 to 20µm coverage
- Varian Cary (Vis/VNIR)
- SOC 100 (IR)

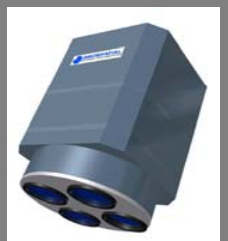
Sensor System Development

RIT builds and operates several airborne sensing systems covering the full EO-IR spectrum

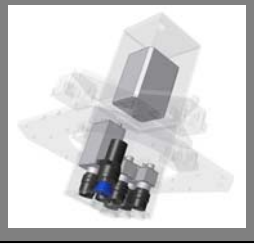
Modular Imaging Spectrometer Instrument (MISI)

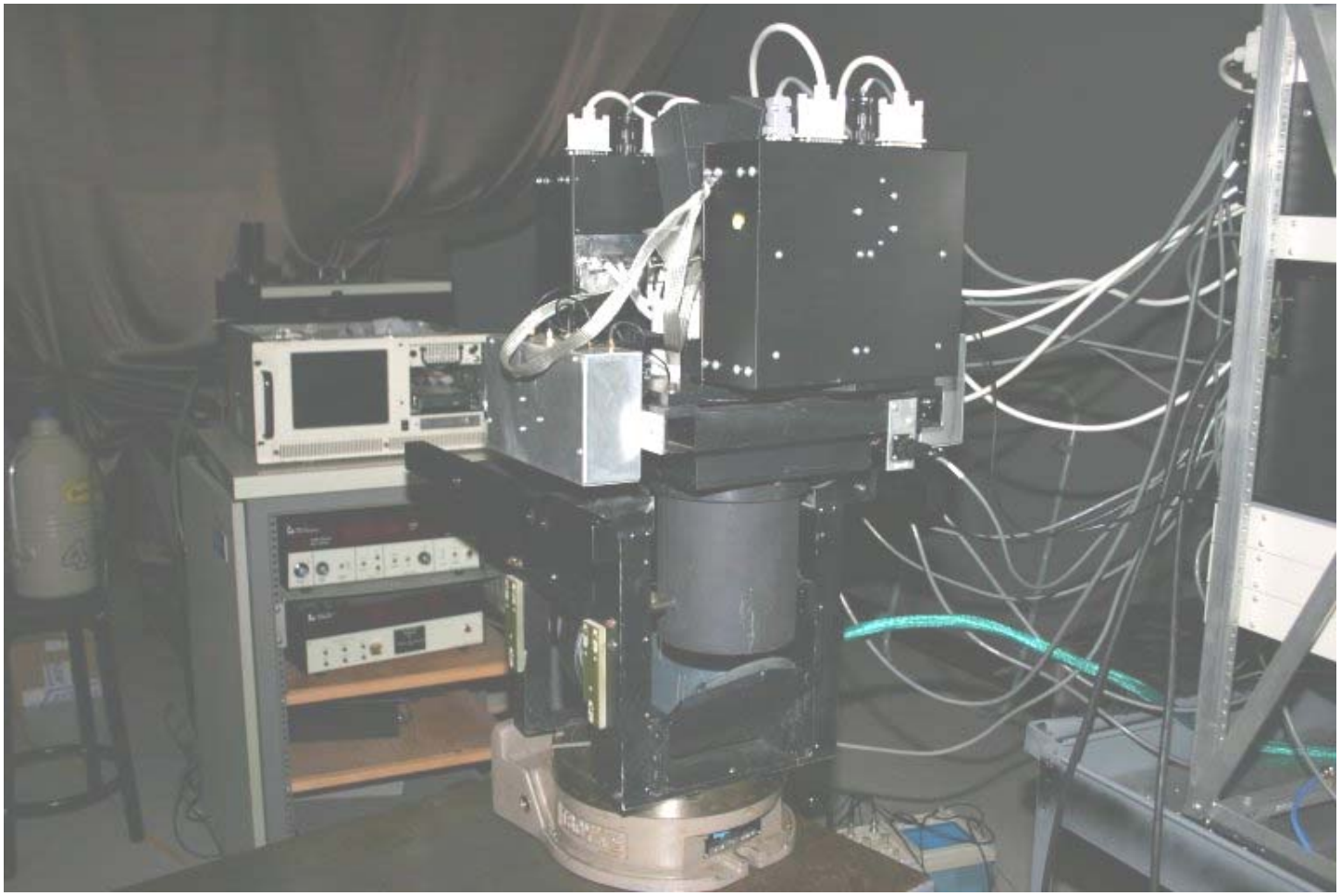
Wildfire Airborne Sensor Program (WASP)

Compact Airborne Modular Mapping System (CAMMS)



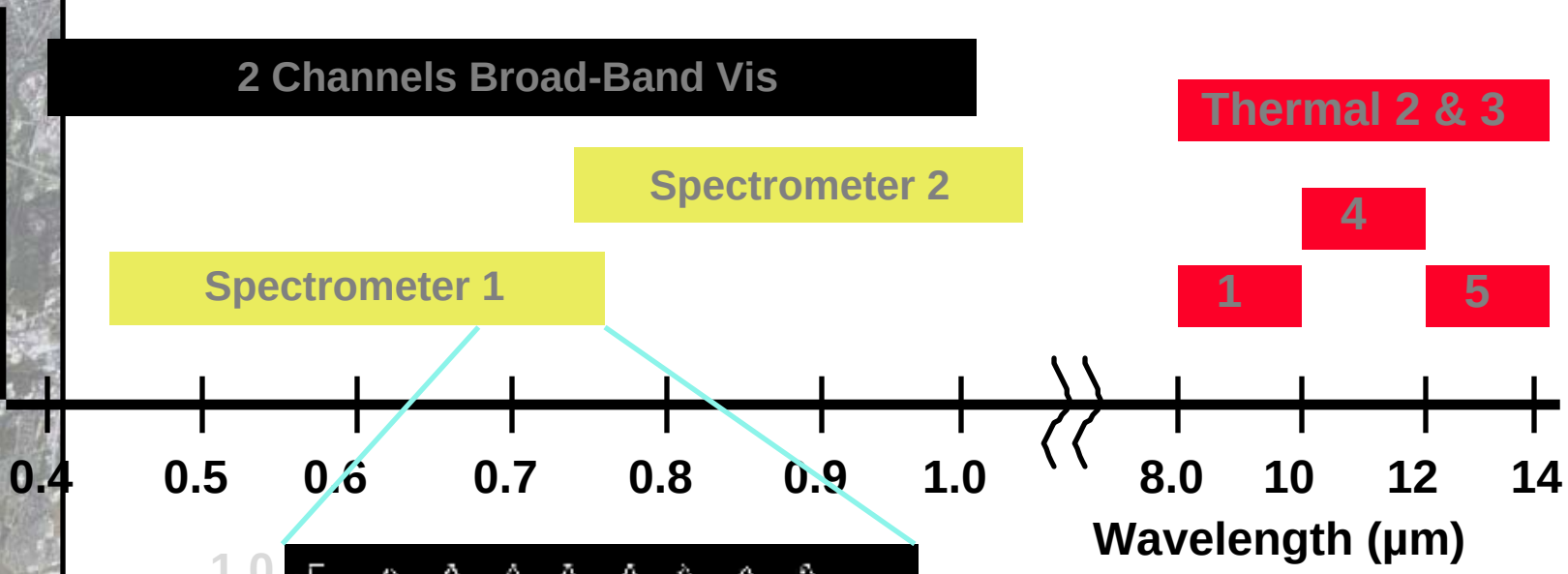
WASP-lite

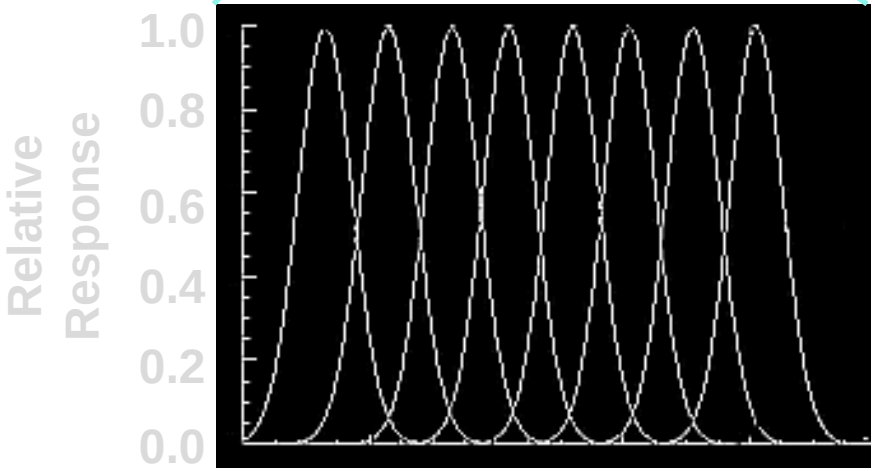




The MISI Sensor:
70 band Vis/NIR Hyperspectral
8 band SWIR / MWIR / LWIR Multispectral

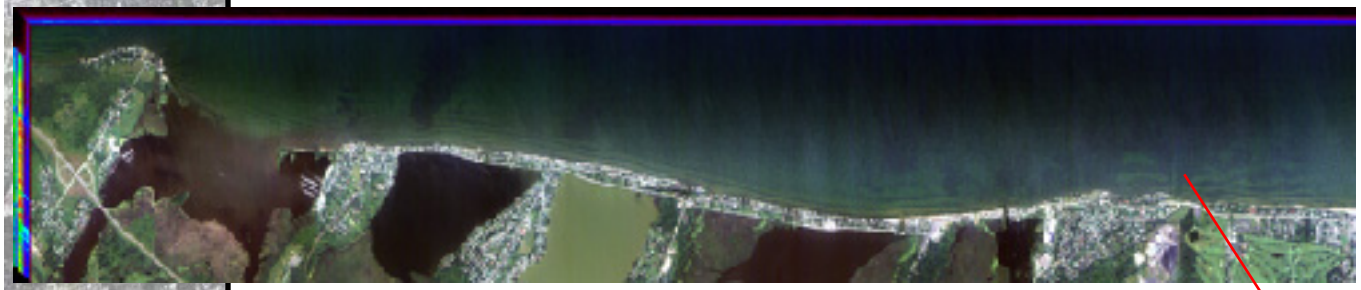
MISI Spectral Responses



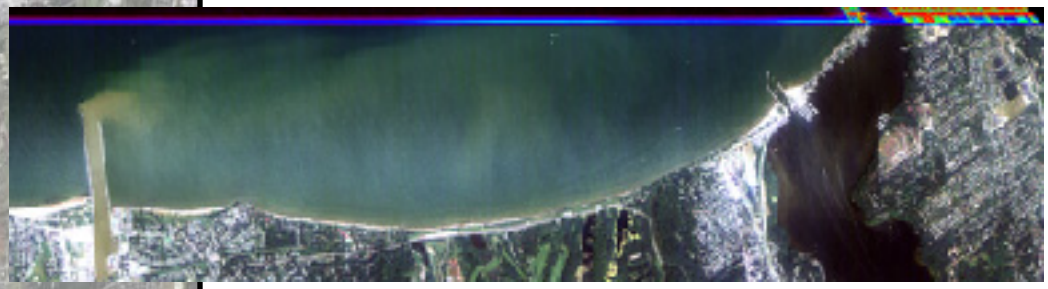


MISI

RIT's Modular Imaging Spectrometer Instrument



West Roch Embayment
Russell Power Plant
July 5, 2000
Altitude=4000ft



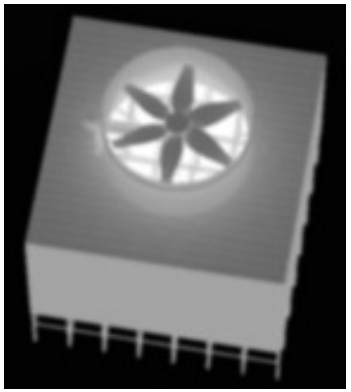
East Roch Embayment
Genesee River Plume
July 5, 2000
Altitude=4000ft

MISI thermal image of Russell Power Plant Effluent

WASP thermal image of Ginna Nuclear Power Plant

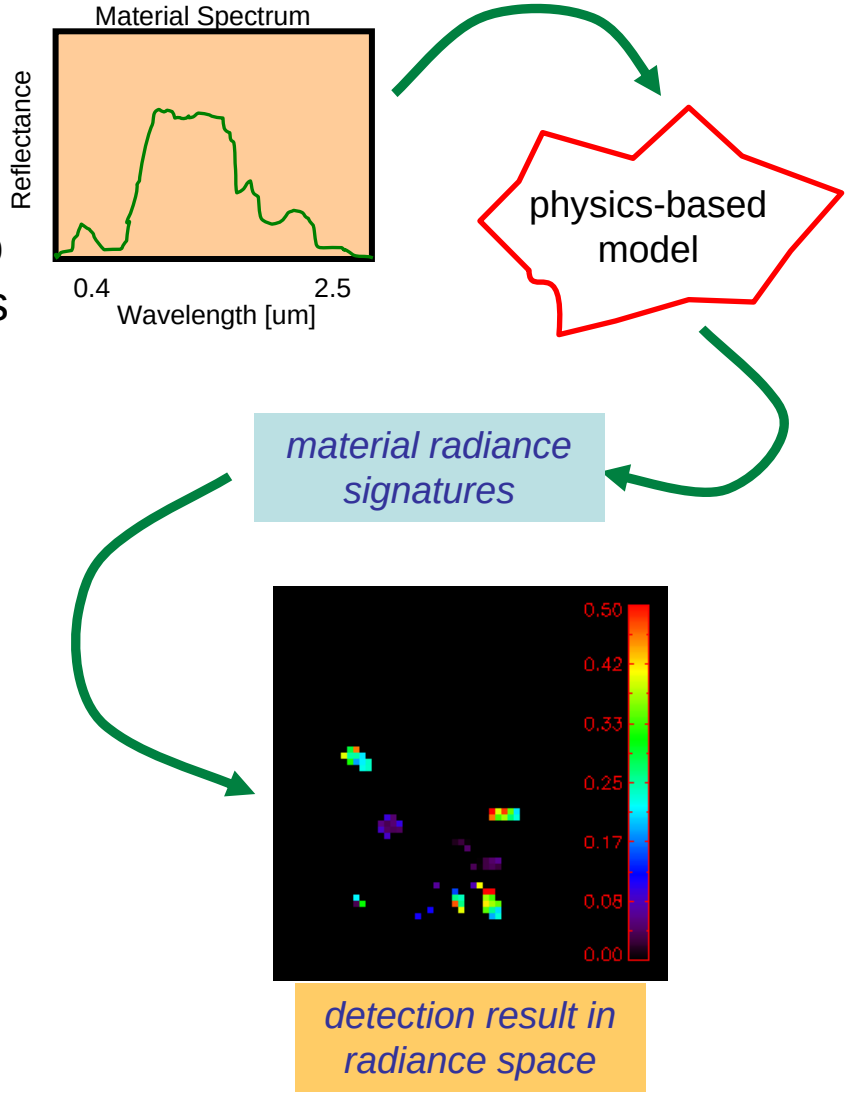
Algorithms and Phenomenology

- Involved in the development and testing of exploitation algorithms
  - spectrally driven with a physics-based philosophy
  - multi- & hyperspectral applications
- Projects spanning reflective through emissive spectral regimes
- Developing advanced capabilities
  - exploitation using multi-modal data
  - advanced mathematical techniques
- Current DIRS personnel involved in exploitation algorithms:
  - 2 or 3 faculty
  - 2 full time research staff
  - ~20 MS and PhD students



Advanced Algorithm Development Examples

- Physics-based signature exploitation
  - use of physics-based models to predict signature manifestations
  - applied to target detection and spectral unmixing
- Applied to reflective, thermal, and LIDAR imagery
- Shown to improve results in challenging situations

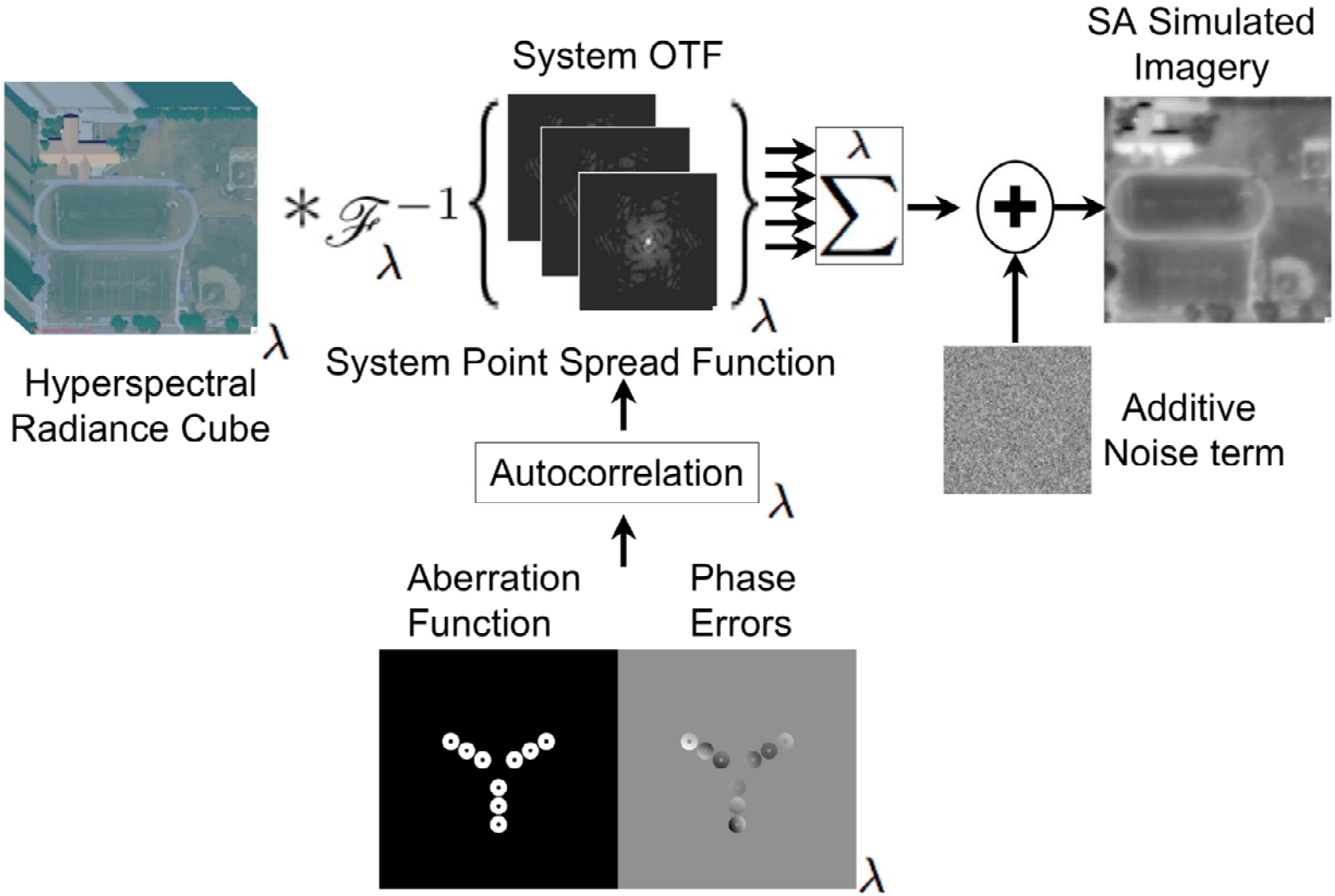


Modeling and Simulation

- Modeling and Simulation involves the precise radiometric representation of remote sensing scenes over a wide spectral regime
- RIT developed DIRSIG is leading tool for scene and image chain simulations
- Common uses include:
  - Sensor/system performance evaluation
  - Algorithm training and evaluation
  - Rapid parametric analysis

Tile #1 Specifications:
- 5,000+ objects
- 500+ million facets
- 1.6 km^2 (0.6 mi^2)

Impact of Sparse Aperture Phase Retrieval on Image Quality



DIRSIG Multi-modal Simulation Capability

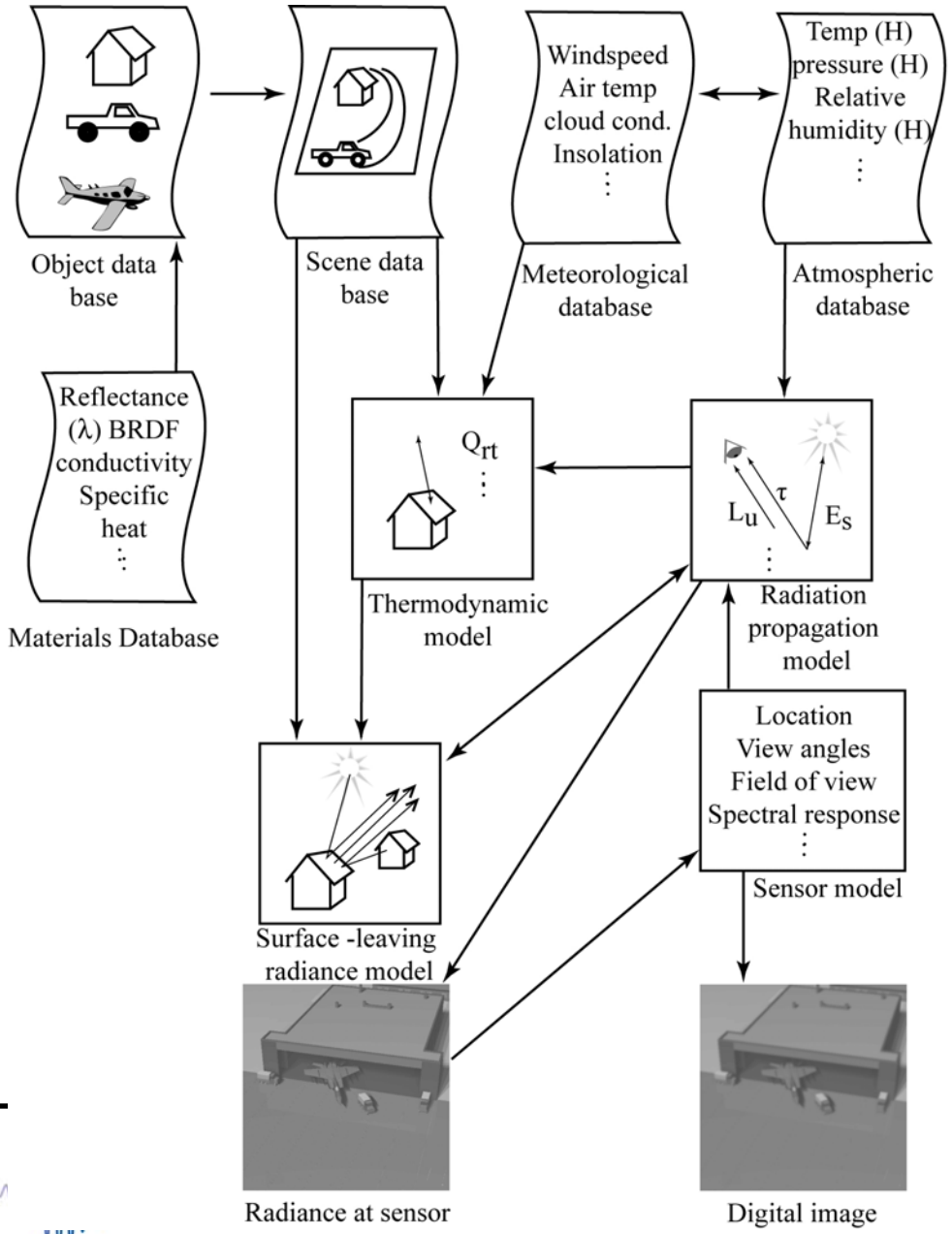


Figure 14.2

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

Section 14.3 A Modeling Example

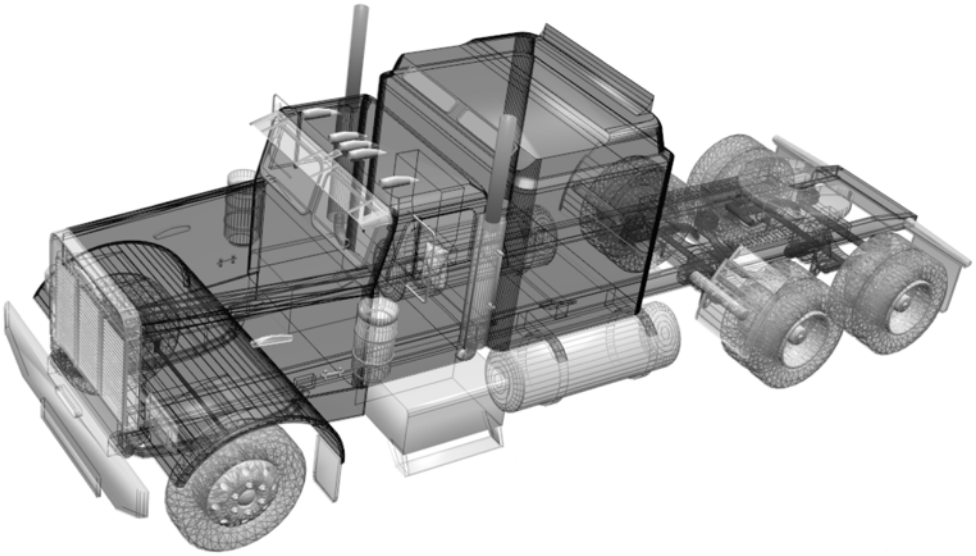


Figure 14.7

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

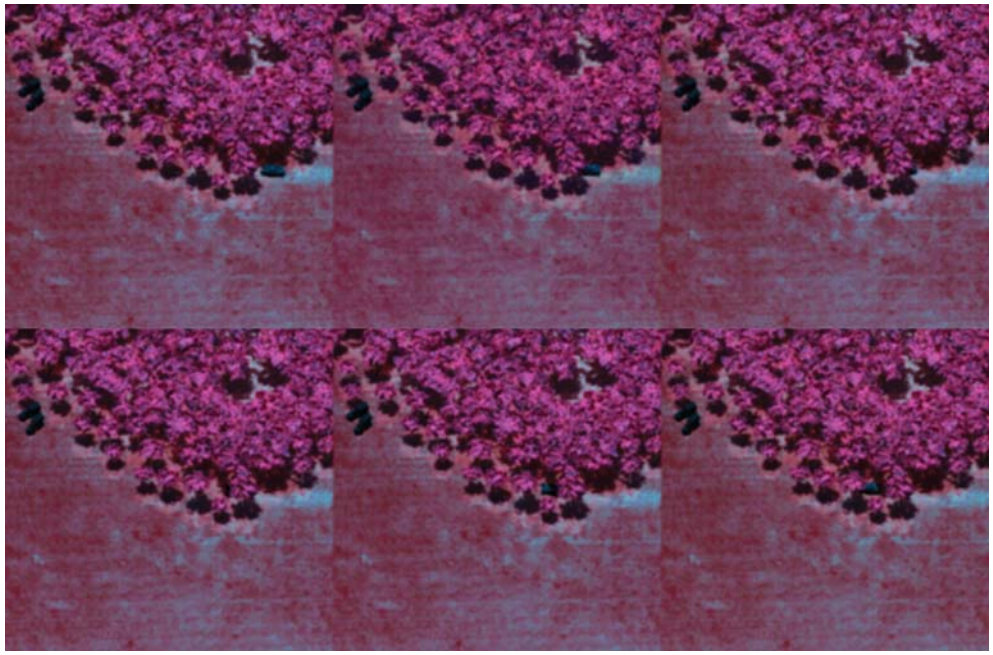


Figure 14.8

DIRSIG false color infrared image sequence showing a vehicle passing under overhanging trees. These images could be used to predict the vehicle signature under a range of adjacency and obscuration conditions.

Section 14.3 A Modeling Example

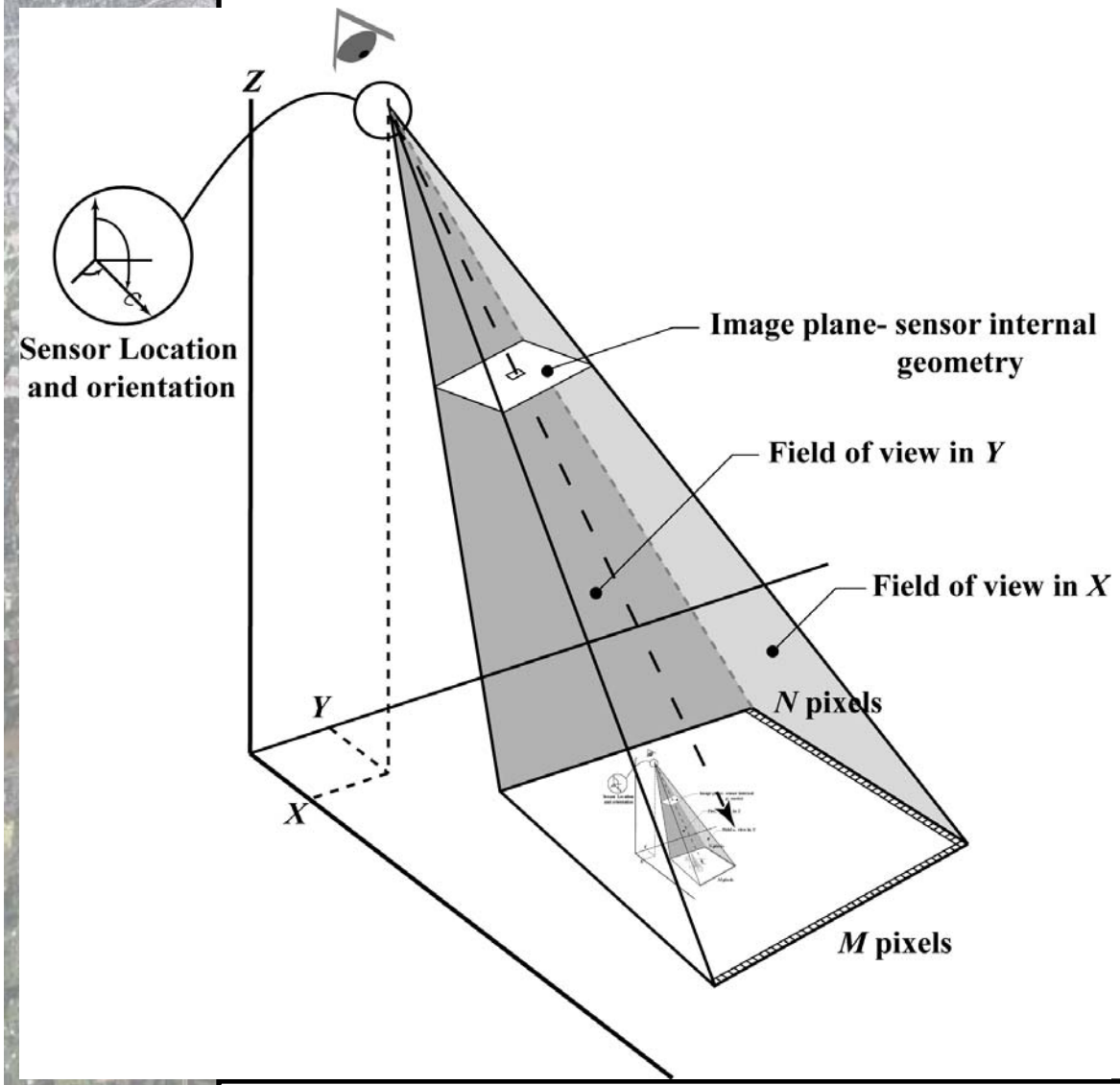
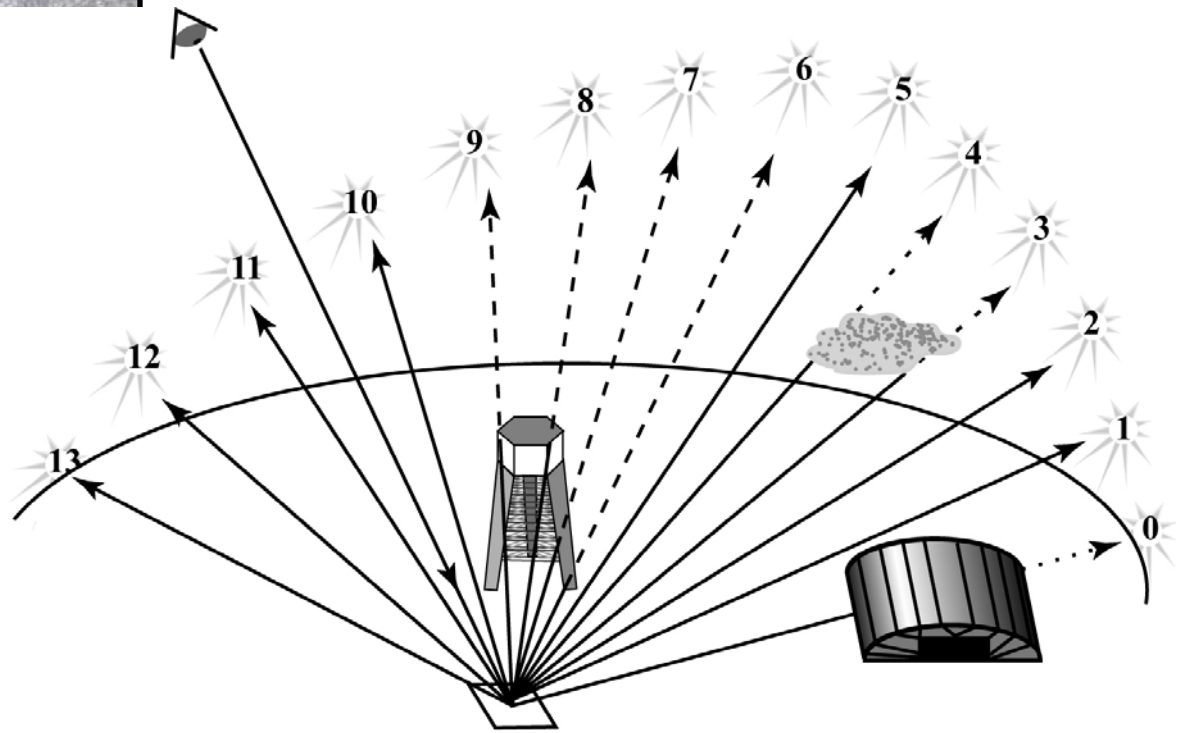


Figure 14.9

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.

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

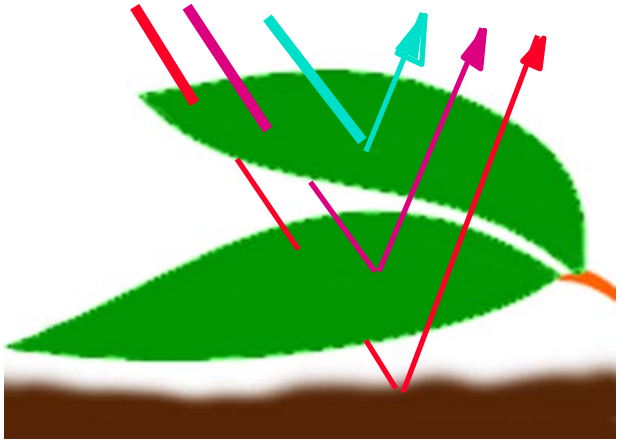
(total shadow) 0.0 < direct insolation modifier < 1.0 (total sunlight)

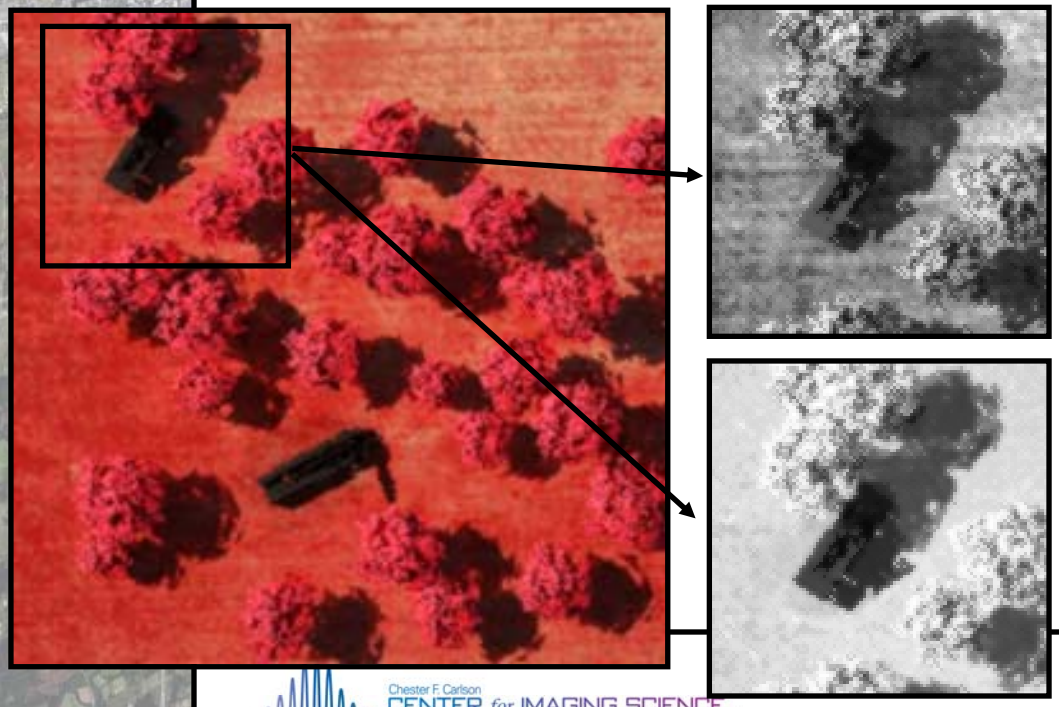
Figure 14.10

Sun shadow history, including partial obscuration by transmissive objects.

Forestry

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

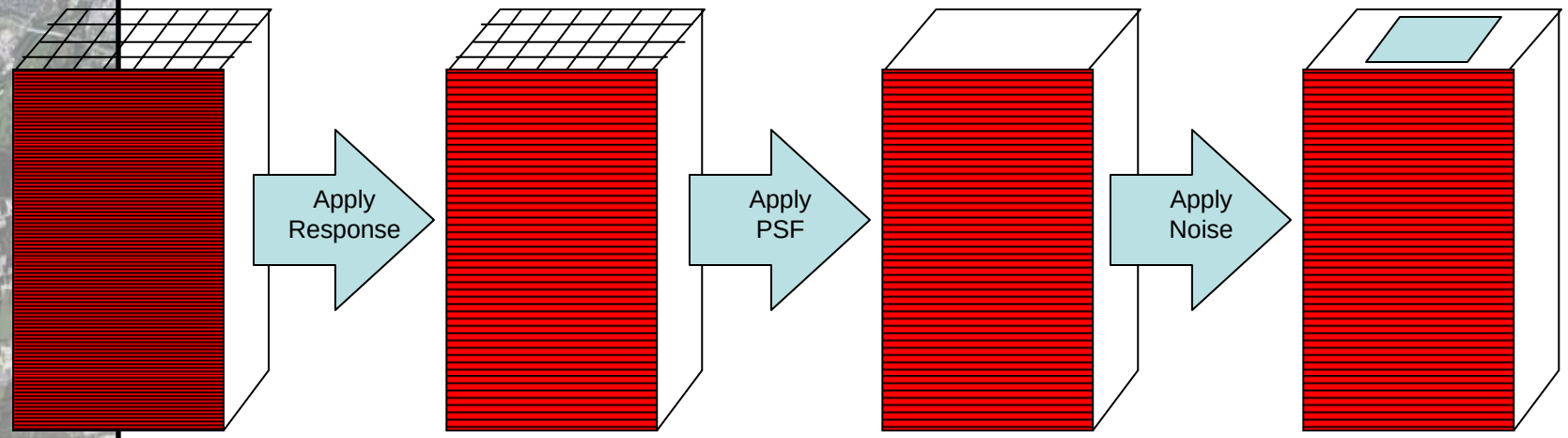




Green Band

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

Section 14.3 A Modeling Example

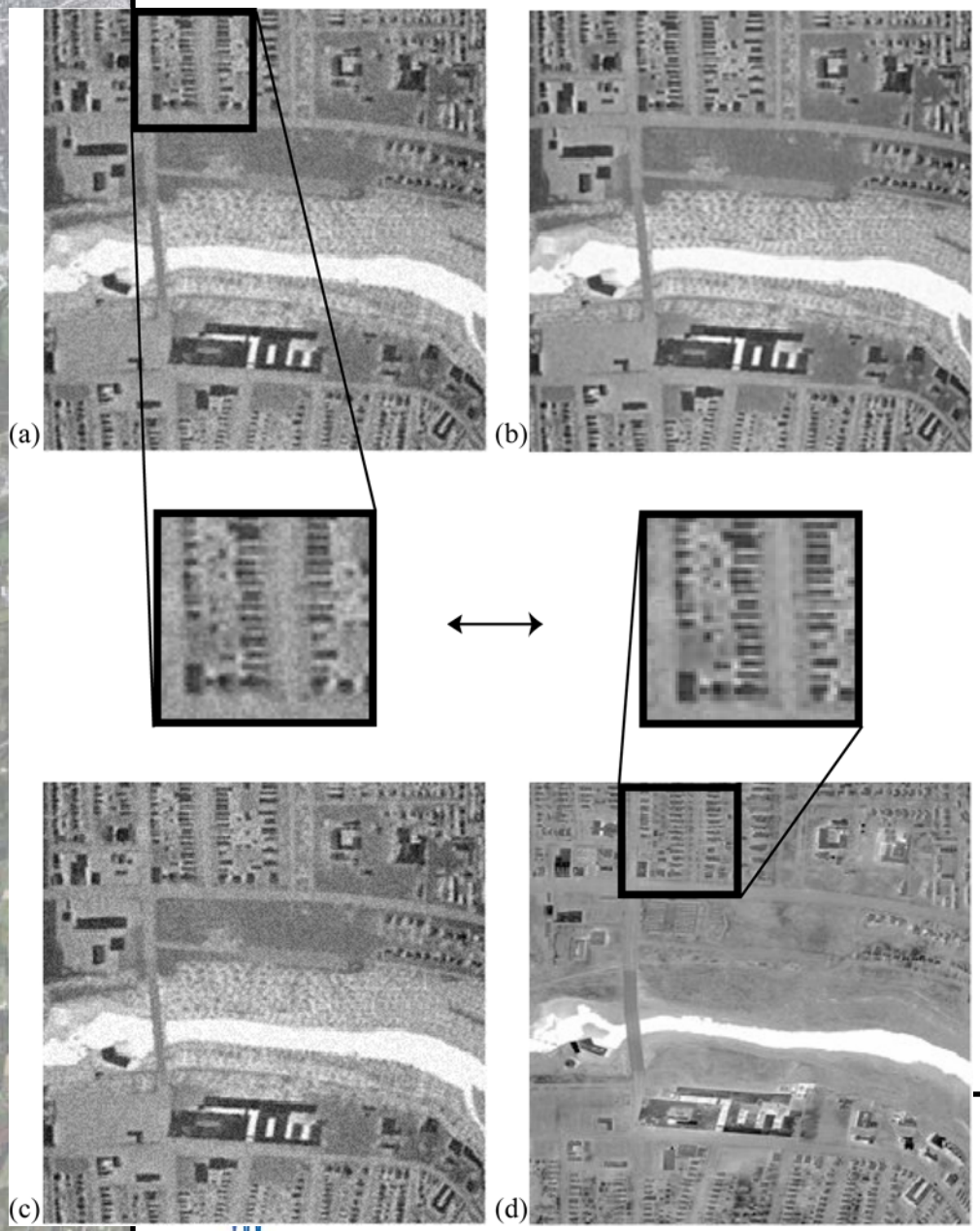
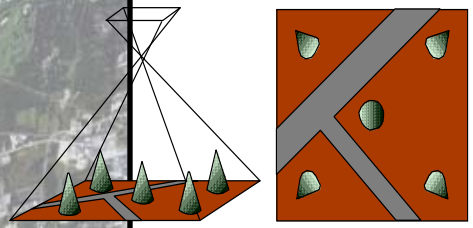


Figure 14.15

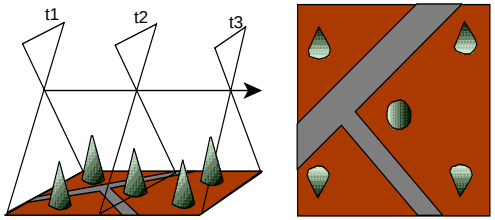
A final DIRSIG image (a) and "truth" images showing later stages of the image chain, (b) radiance image, (c) radiance image with noise effects, and (d) actual image from an infrared line scanner. Final image includes noise, MTF, and sampling effects.

DIRSIG Sensor Model

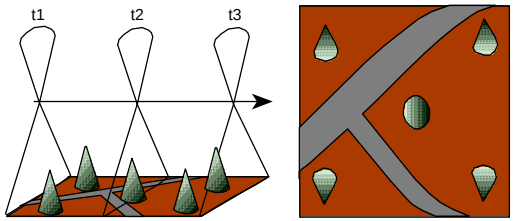
- Variety of sensors



frame camera

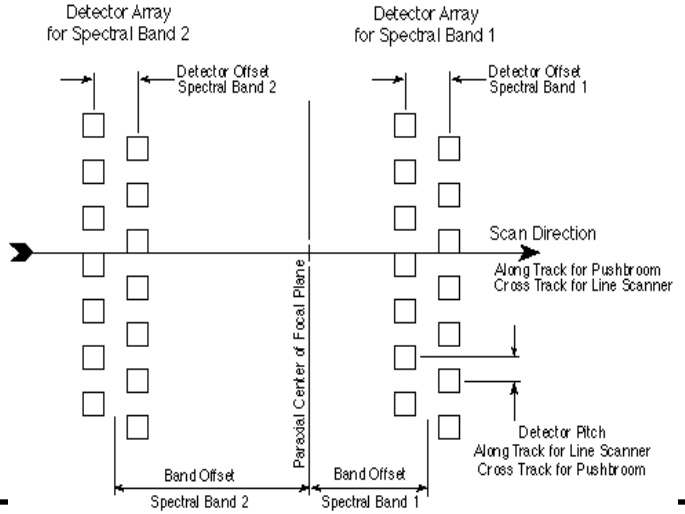


pushbroom scanner



line scanner

- Focal plane effects
  - TDI
  - MS band misregistration



Section 14.4 Application of Sig Models

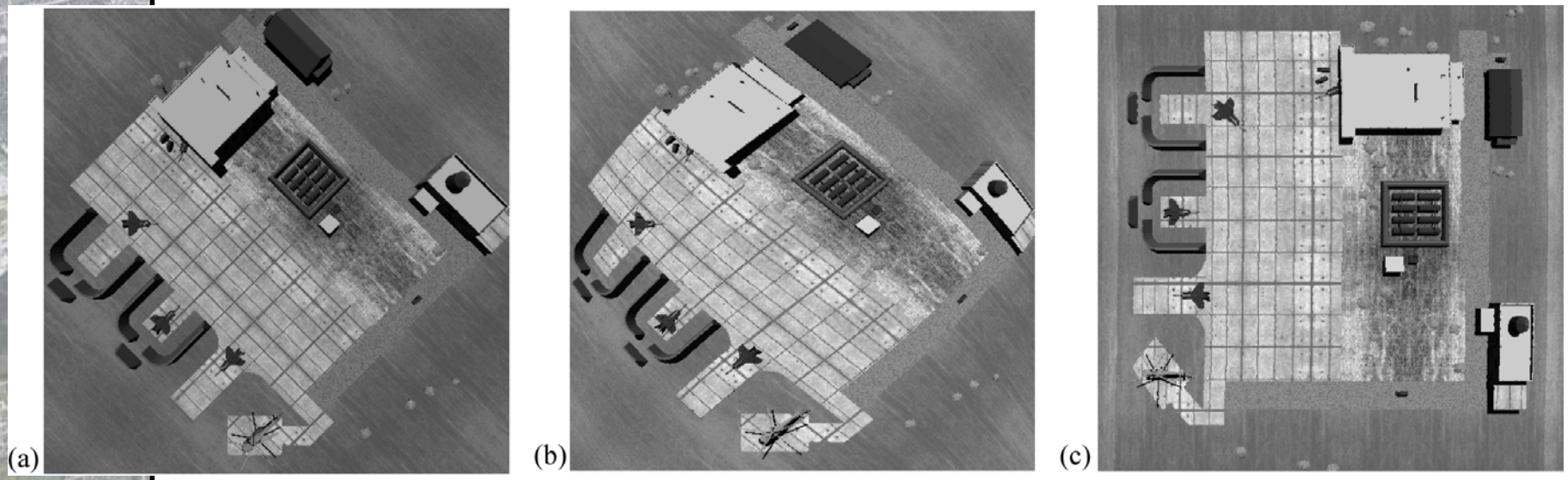


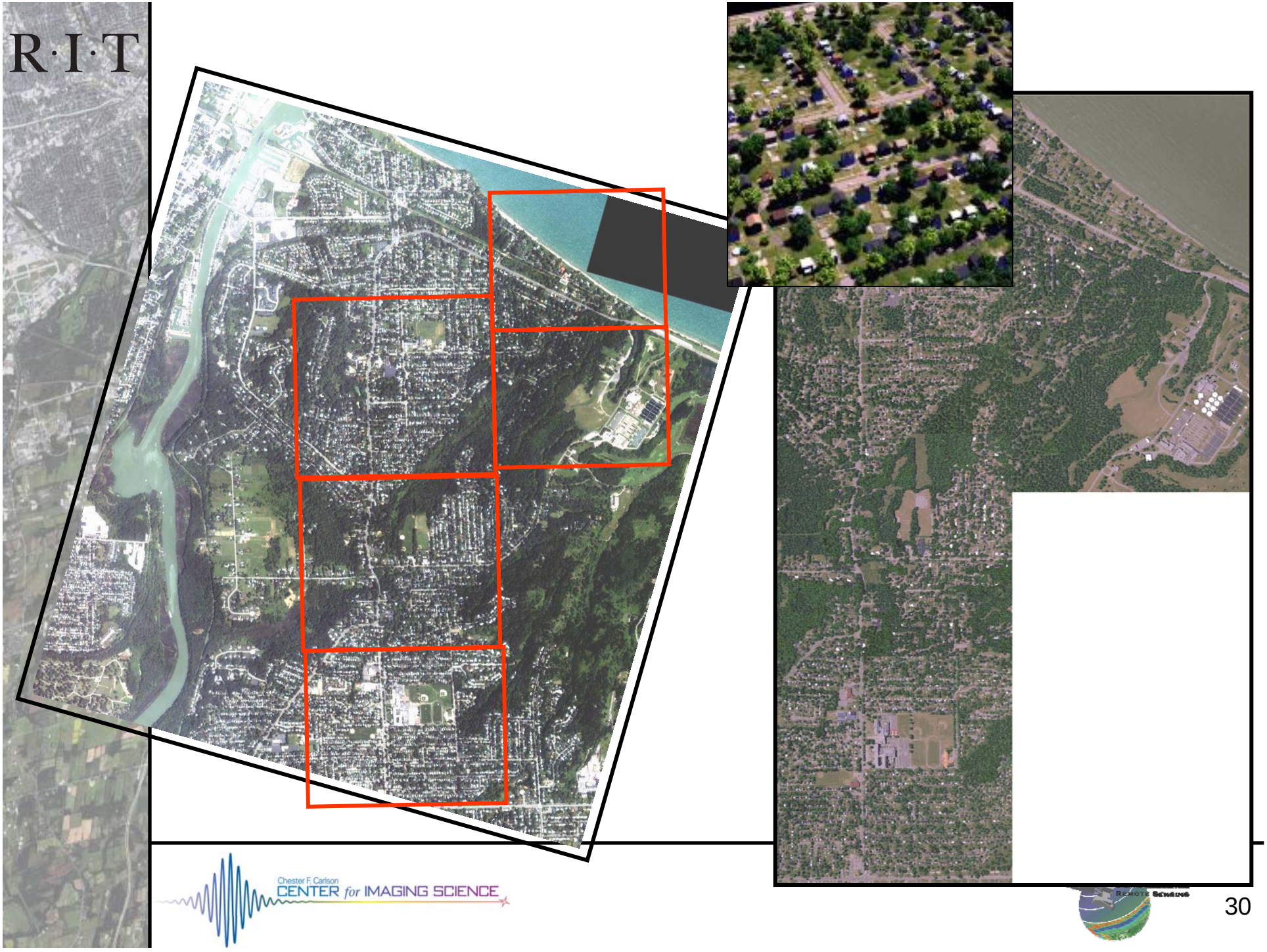
Figure 14.22

DIRSIG images showing sensor modeling:

(a) frame camera,

(b) line scanner model including V/H and tangent errors, and

(c) line scanner model with platform motion (roll, pitch, yaw) included.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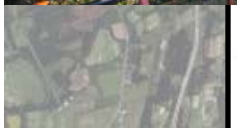
Megascene 1, Tile 1

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

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



Chester F. Carlson CENTER for IMAGING SCIENCE

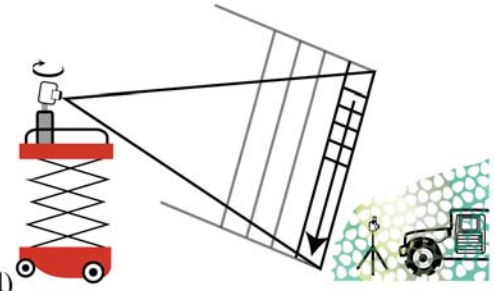
DIRS Digital Imaging and Remote Sensing

Application of Sig Models

a)

b)

c)



d)

e)

f)

Illustration of one band from a real

(a) and synthetic and

(b) hyperspectral line scanner image used for algorithm development,

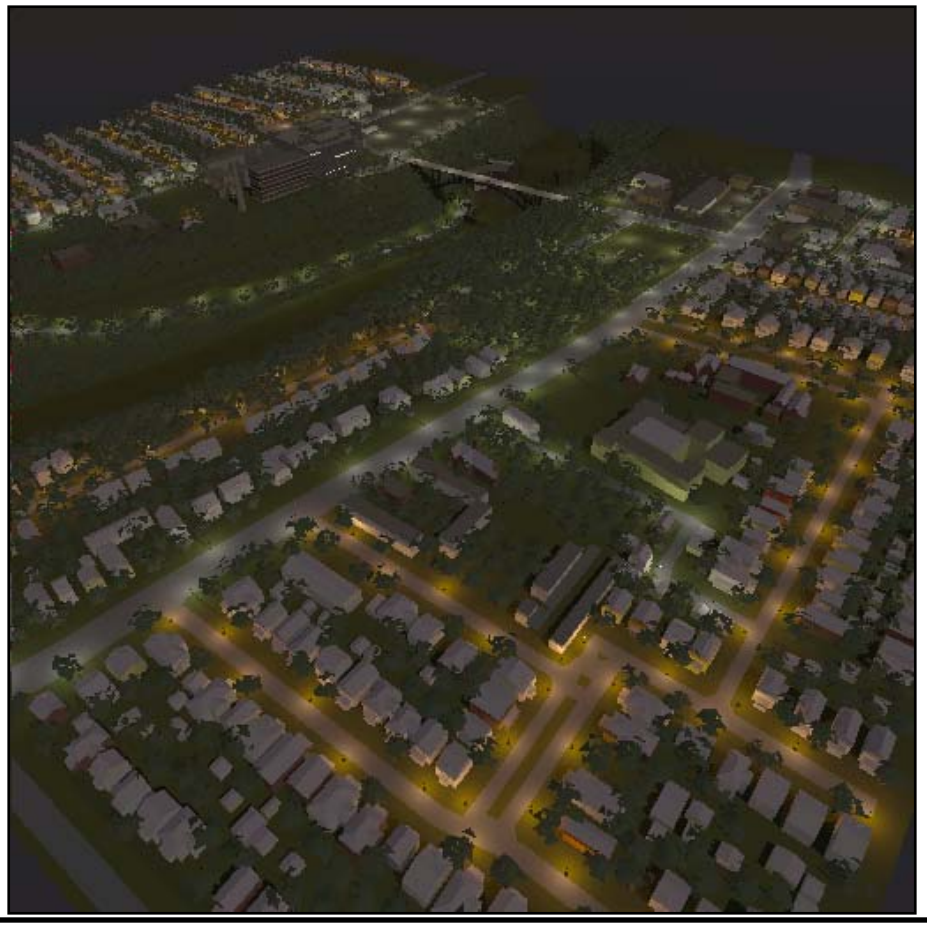
(c) shows RIT's MISI line scanner used to acquire the real image operating from a rotating table on the scissor truck as illustrated in (d).

(e) and

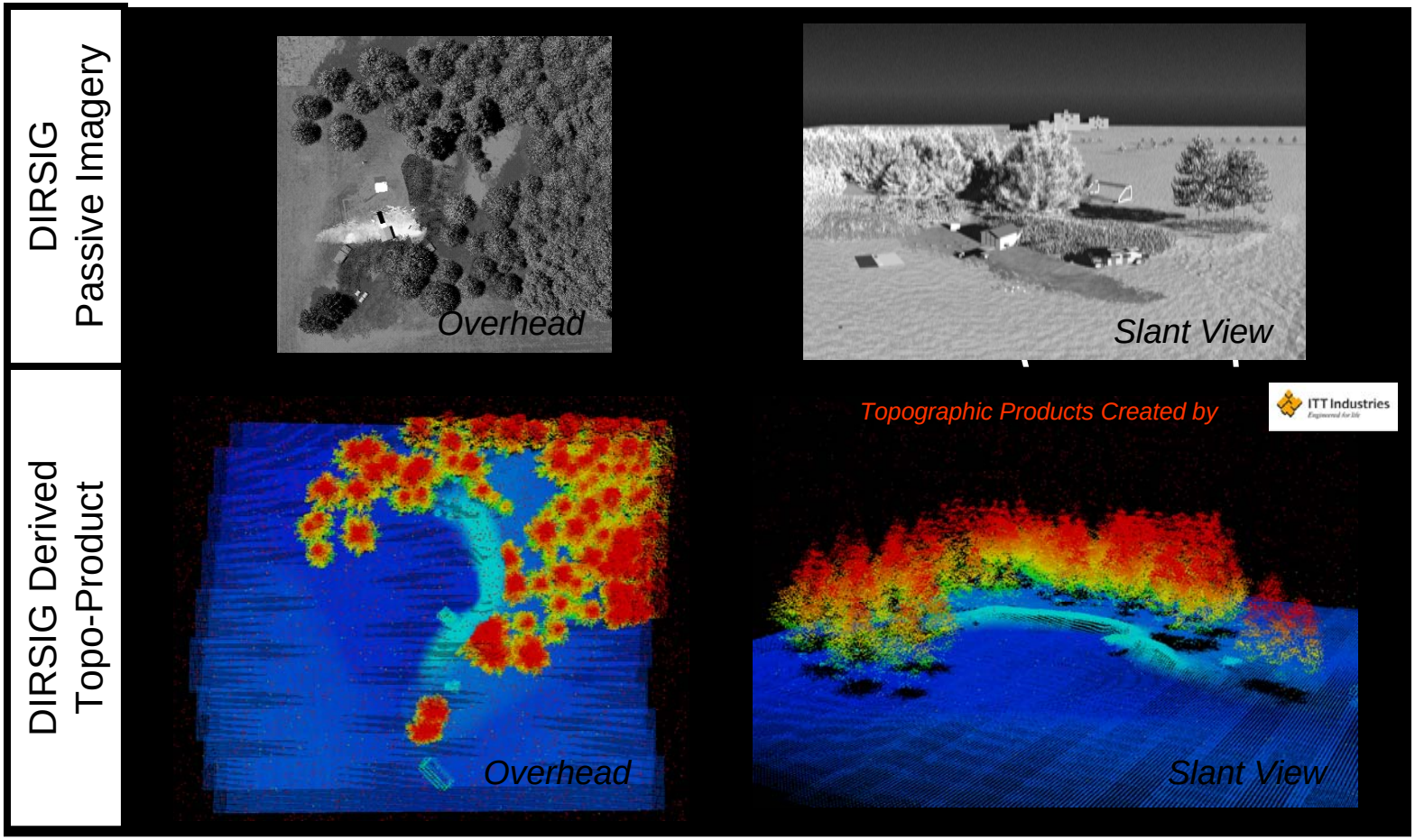
(f) show real and synthetic images from a framing camera on a tripod under the net as illustrated in (d).

Low-Light Simulation:

Urban Example



Topographical LADAR



- Study the impact of system design, energy budgets, scan patterns and collection design on end-user data products.

Reflective Polarized Imaging (PI)

Panchromatic: 0.4-0.9um with sensor response similar to Kodak KAI-4021

Added polarimetric signatures to grass, asphalt and roofing only

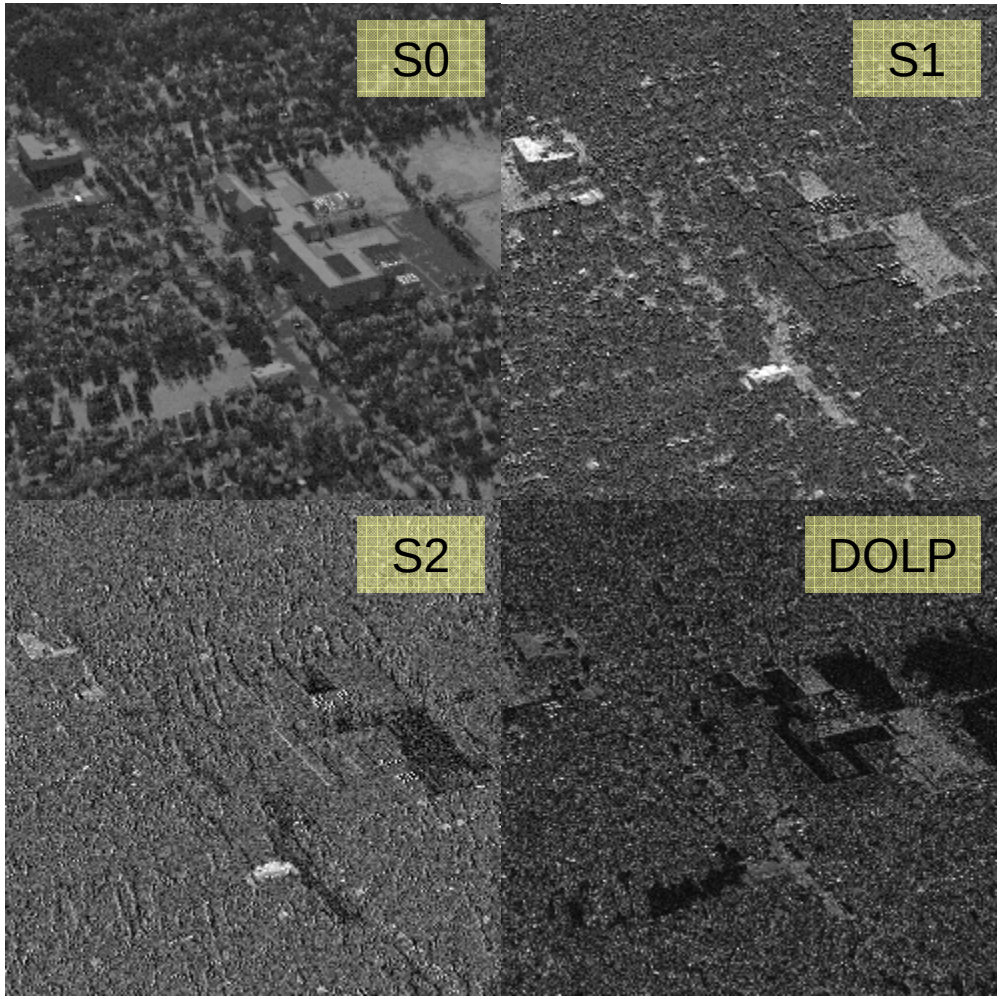
Unpolarized skydome

GSD = 2.5 meters

Added ½ pixel vertical misregistration between I0/I90 and ½ pixel horizontal misregistration between I45/I135

Add some gaussian distribution sensor noise to intensity bands

About 20 degrees azimuth out of solar specular plane and 10 degrees zenith from solar zenith



Platform Tasking

- Integrates with collection design tools.
  - Latest releases support fully geo-located scenes and platform data which simplifies data import.
- Working on integration with powerful collection design and visualization tools such as Satellite Toolkit (STK).

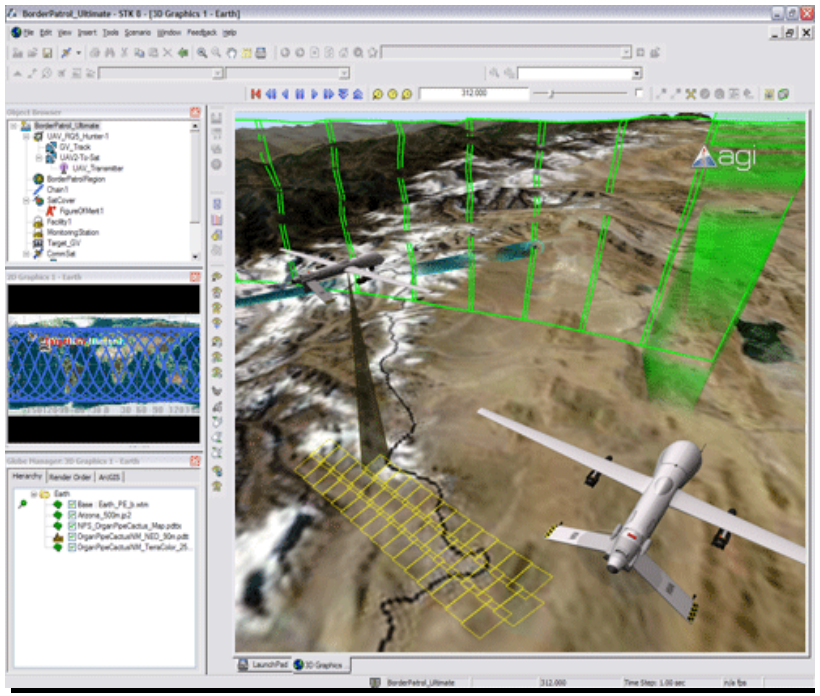
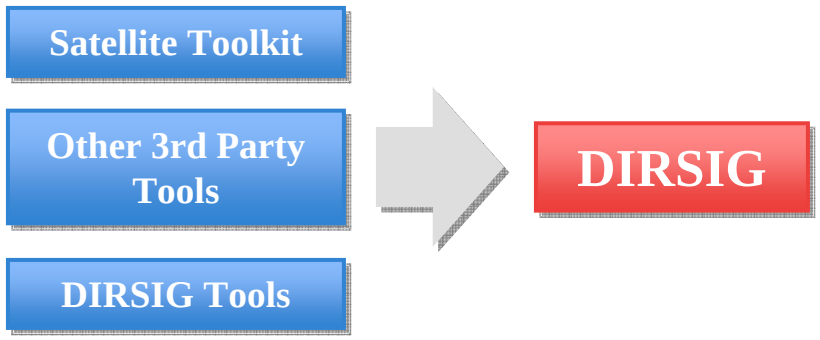


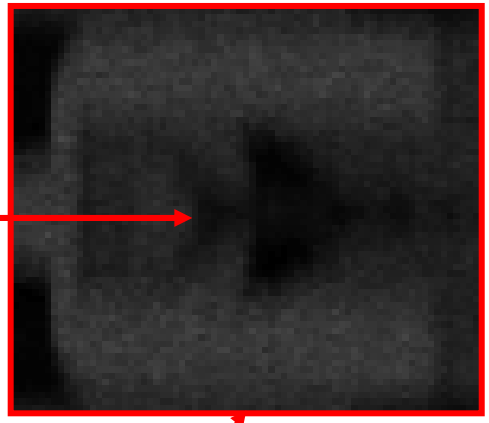
Image courtesy of Analytical Graphics, Inc.
©2008



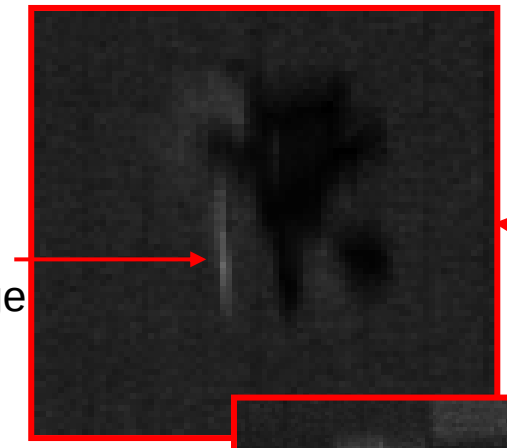
Real Aperture Radar (RAR) Simulation

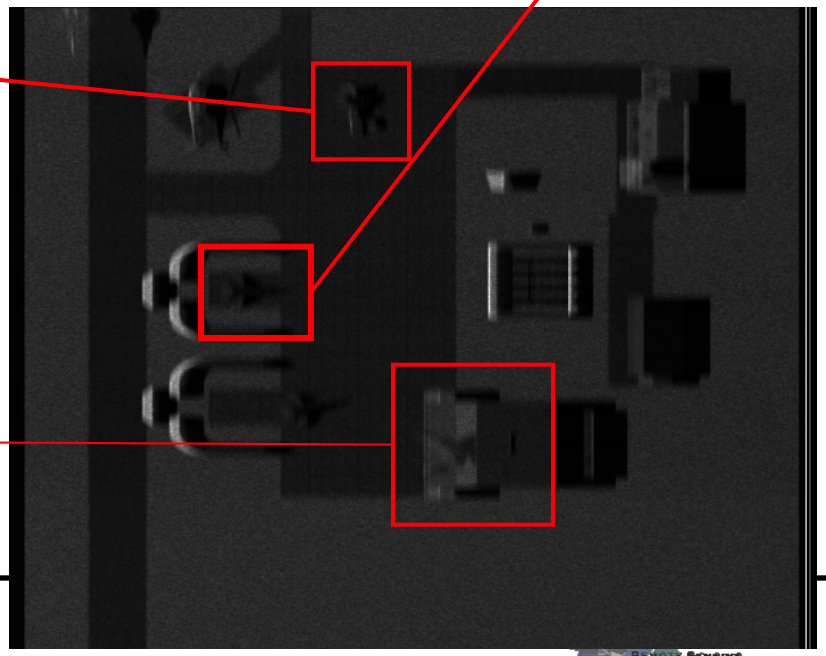
To achieve 0.5m azimuth resolution requires a 150m antenna, which is 10x the length of a Twin Otter aircraft

Shadow of plane

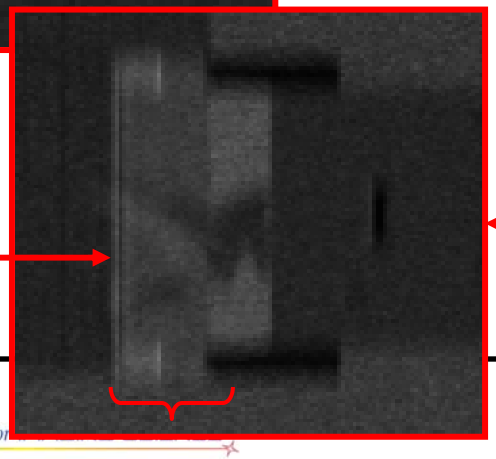


Glints on plane fuselage





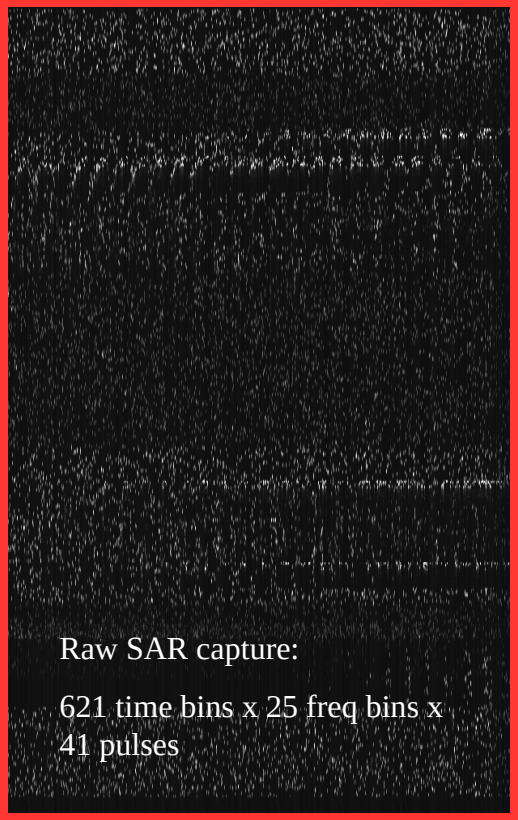
Plane in hanger



Synthetic Aperture Radar (SAR) Simulation

Data Simulation

25 freq bins per pulse



Raw SAR capture:

621 time bins x 25 freq bins x 41 pulses

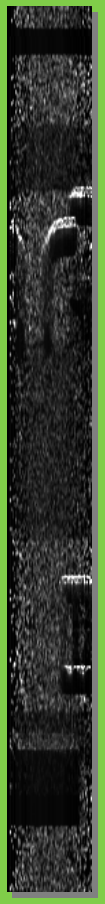
Data Processing

Synthetic Aperture Systems

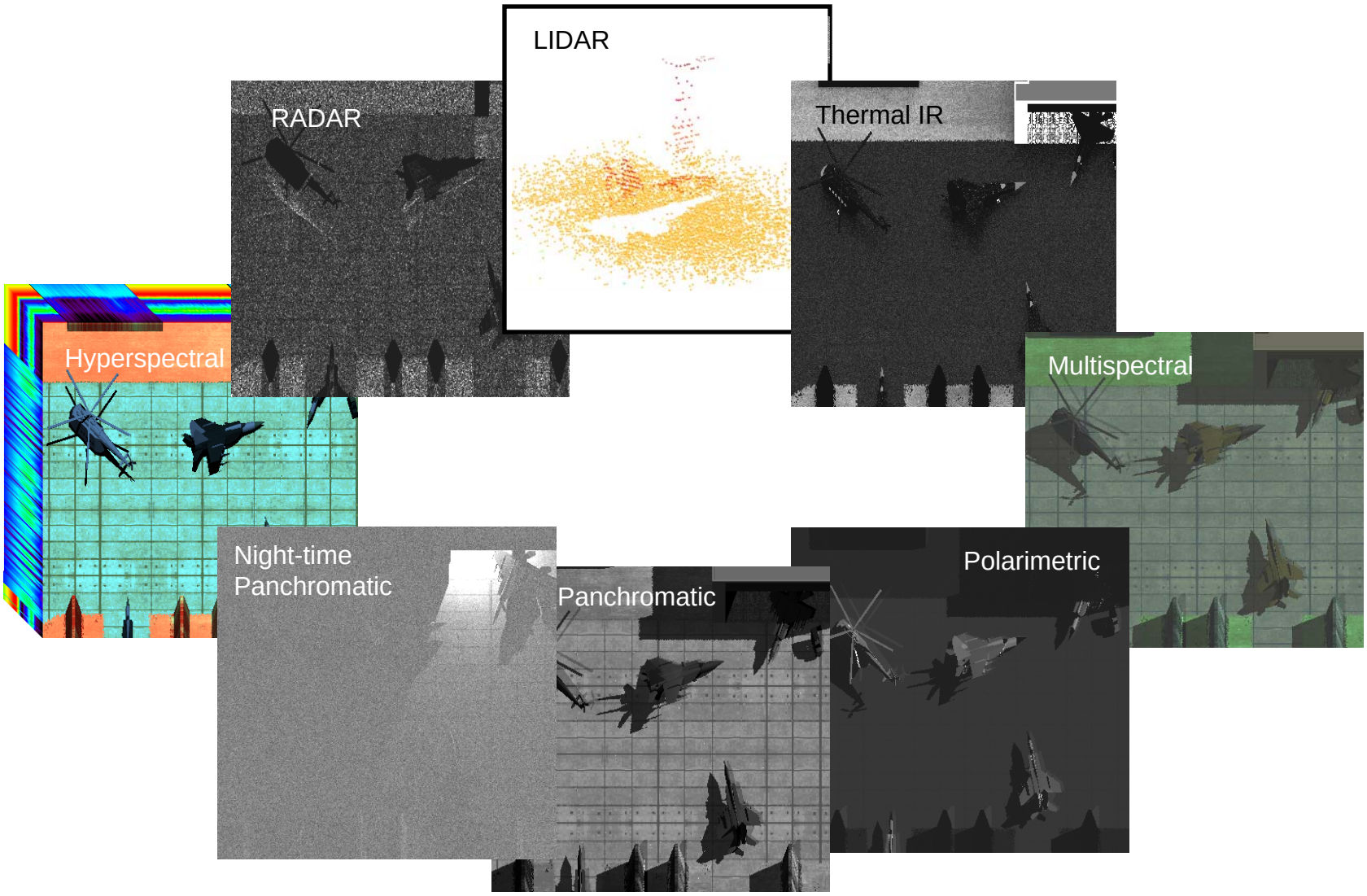
- Receiver Model
- Range Decompression
- Doppler Processing

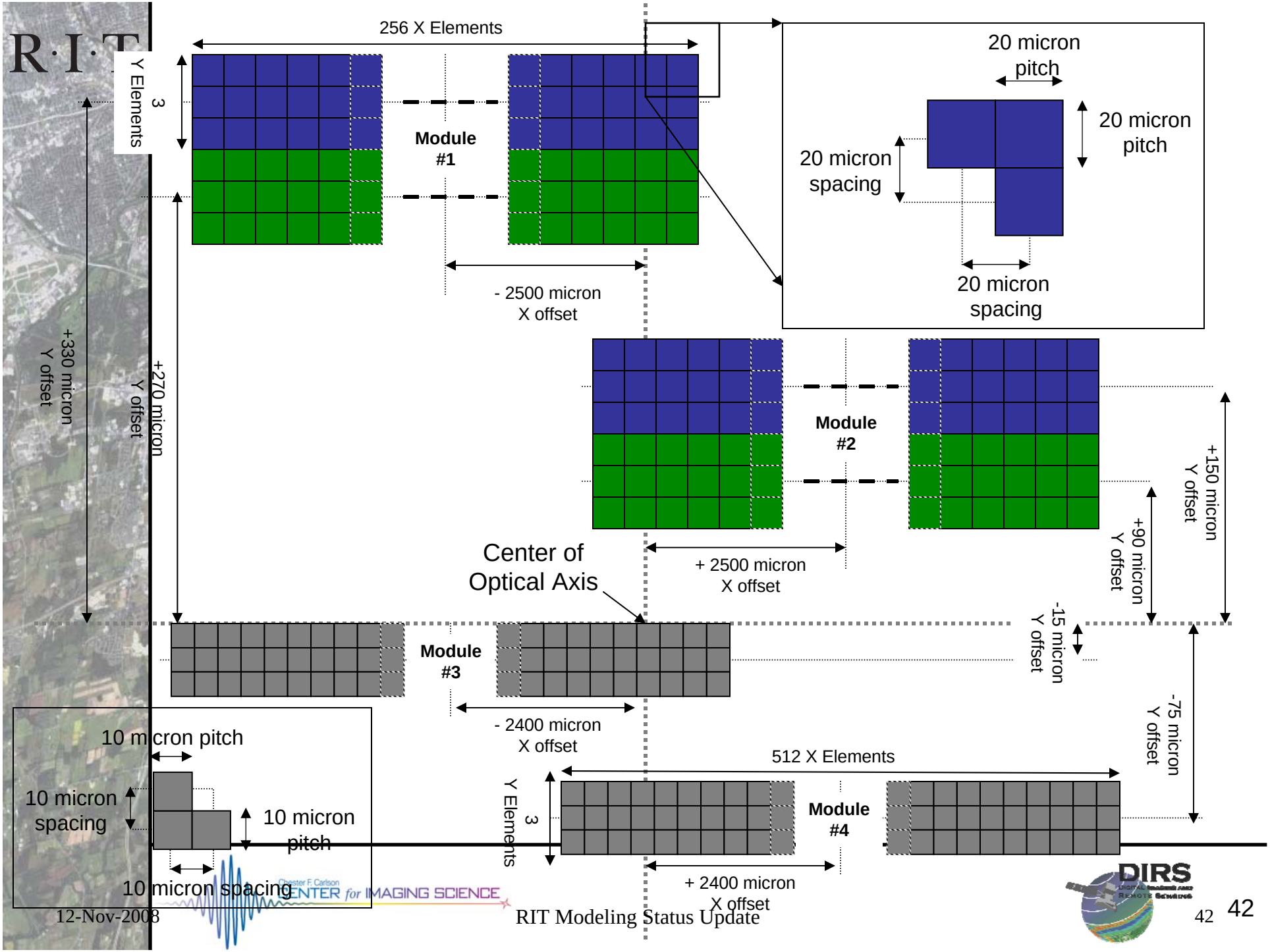
Post processing to map frequency bins to range bins for each pulse

Typical Products



One model, many modalities



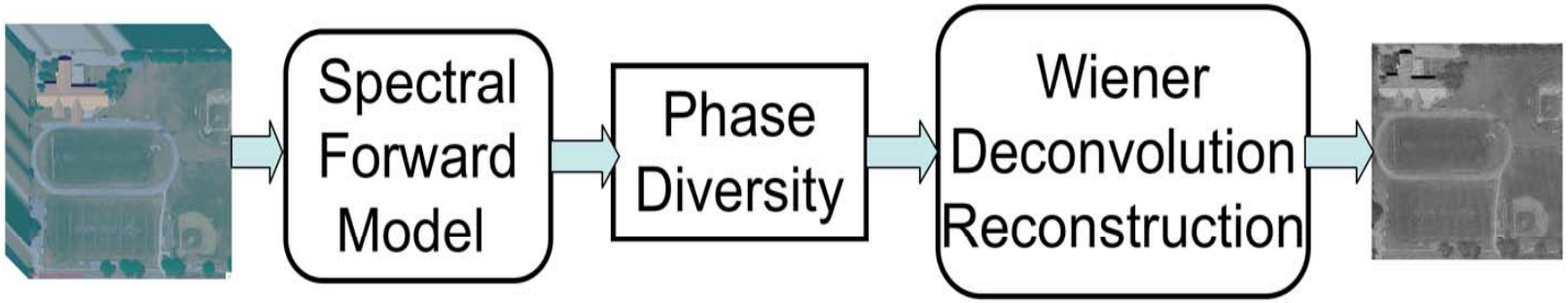

256 X Elements
3 Y Elements
Module #1
- 2500 micron X offset
20 micron pitch
20 micron pitch
20 micron spacing
20 micron spacing
+330 micron Y offset
+270 micron Y offset
Module #2
+ 2500 micron X offset
+150 micron Y offset
+90 micron Y offset
Center of Optical Axis
-15 micron Y offset
-75 micron Y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

Night Imaging Scenario Example

Single visible band taken at night over a simulated industrial facility with embedded light sources.

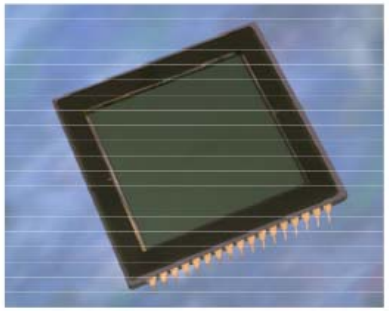
- spatially oversampled without a PSF

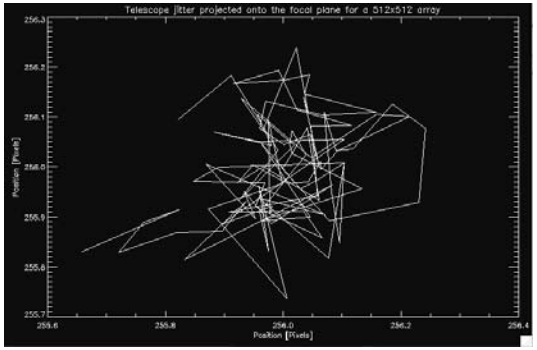
Analysis Model

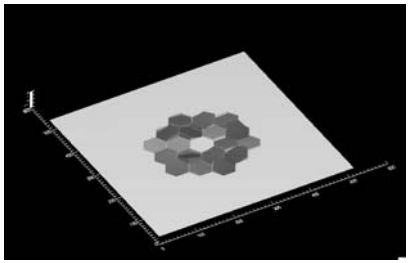


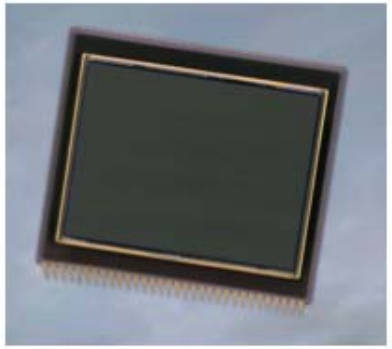
Mike Zelinski – End to end Simulation Tool

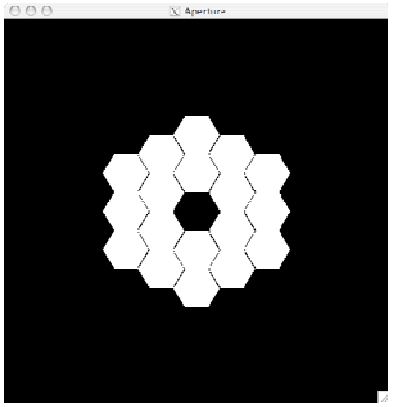
Build a space telescope imaging simulation tool that will allow a user to specify pupil type, detector type, platform stability, optical aberrations, and test imagery.

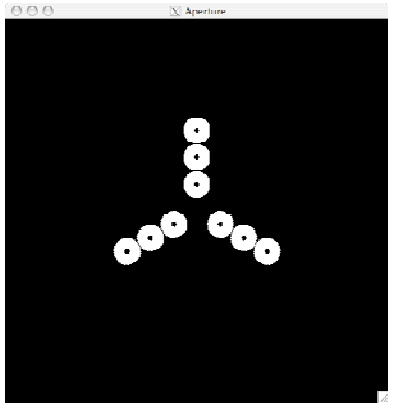












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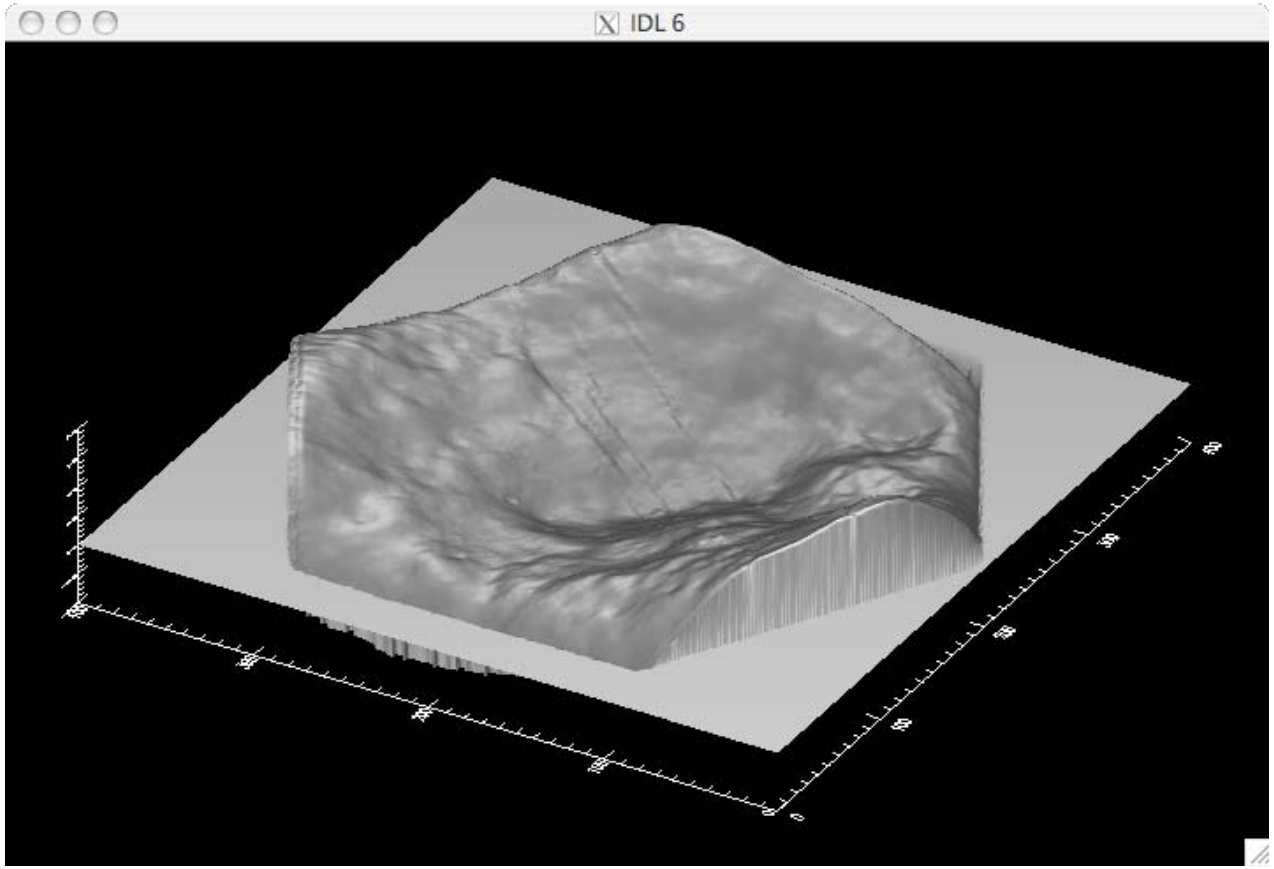
DIRS Digital Imaging and Remote Sensing

R·I·T

Incorporate lightweight elements with higher OPD within the segment

- More complex aberrations

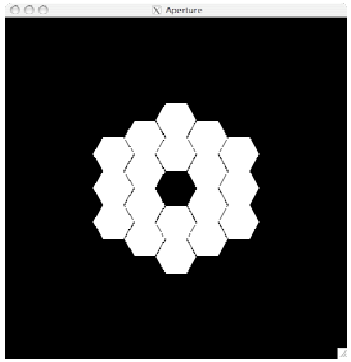


Telescope Jitter Example

σ_{Jitter} = .1 [pixel]

σ_{Jitter} = 1 [pixel]

σ_{Jitter} = 10 [pixel]



R·I·T

Andy Adams - Persistent Surveillance

Consider a Large Area of Responsibility (AOR)
(Can't cover entire area with a single FOV…)

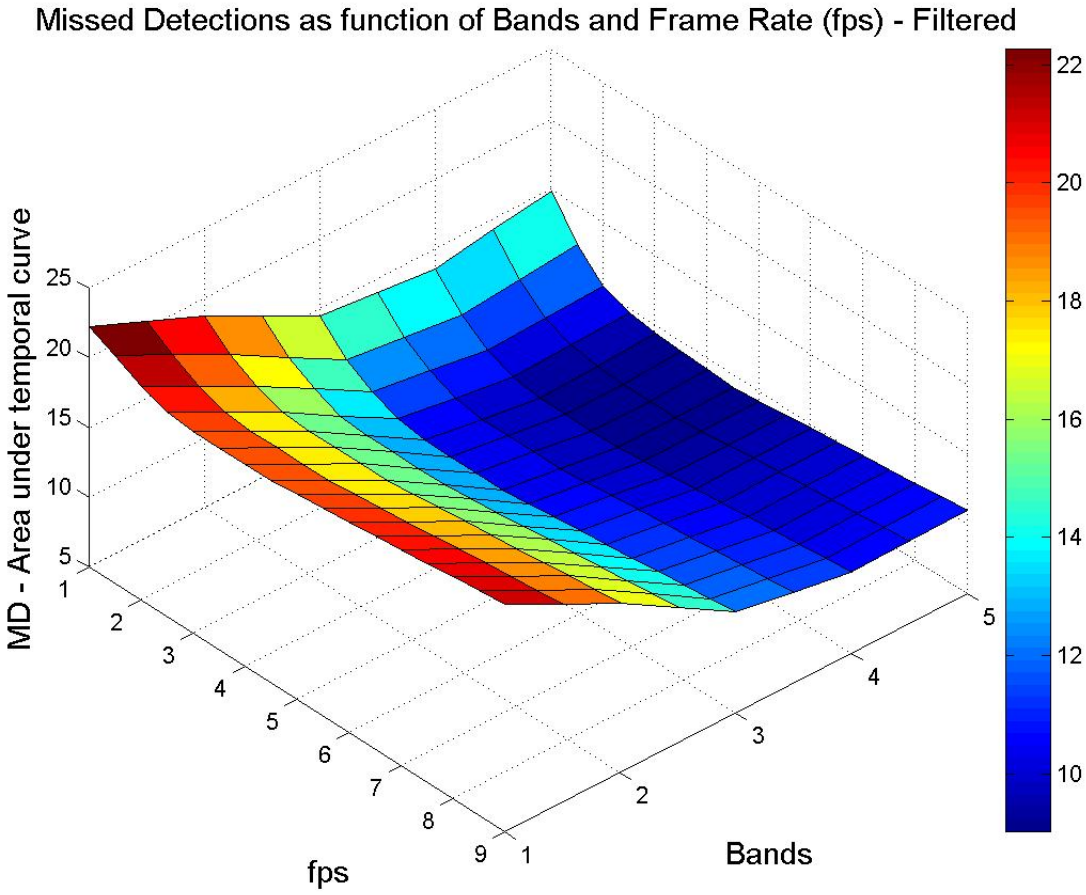
Alternative : Use one sensor with a rotating mirror over four Areas of Interest (AOI)

Resource Allocation: Want satisfactory tracking performance at ***reduced frame rate*** (~7 fps per AOI) due to sensor "sharing" over four AOI
Can Multispectral Help??

Motivation

Motion Detection Results

MD vs. Frame Rate (fps) and Number of Bands



MT = 62

FILTERED

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