Geospatial Research at the Idaho National Laboratory

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3/27/2008

Idaho National Laboratory - Programs

Nuclear Energy

- GNEP
- NGNP
- Space Nuclear

•National Reactor and Fuel Cycle Laboratory and an International Leader

National & Homeland Security

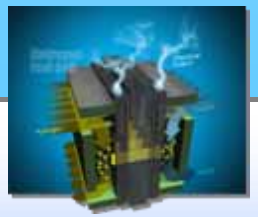
- SCADA
- Grid Reliability
- Wireless Communications

A leader in critical infrastructure protection in key areas and homeland security

Energy & Environment

- Biofuels
- Synfuels
- Hydrogen

Multi-program science base supporting NE, DoD and DHS missions; regional clean energy leadership



Center for Advanced Energy Studies

- IUC Integration
- NUC Collaboration
- Education Programs

New facility and program to promote a diversified energy portfolio and energy training

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INL's Current and Future Capabilities – Energy & Environment

- Energy Security
  - Synthetic fuels production
    - Coal to liquids
    - Biofuels
    - Unconventional oil
  - Hydrogen production
- Science
  - Biotechnology
  - Advanced artificial intelligence in robotics
  - Actinide chemistry
- Environmental Sciences
  - Subsurface fate and transport
  - Long-term stewardship
  - Radioactive waste treatment and management

- Future
  - Energy water nexus
  - Oil shale
  - CO_2 capture and sequestration

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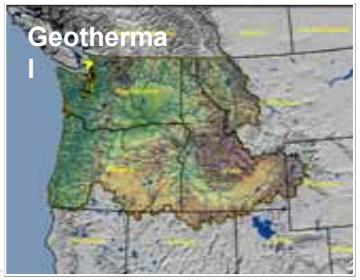
Clean Energy/Regional Resource

- Our region contains world-class conventional and unconventional fossil energy reserves complemented by significant renewable resources and energy infrastructure
- Carbon-neutral, clean energy approaches must be applied
- Integration of energy supply, infrastructure, markets, indeed an "Energy Systems Approach" is critical



INL - A leader in the development of clean energy technologies in the Rocky Mountain region, internationally

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Geospatial Science

More than GIS and maps – The Science behind the technology

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Unmanned Vehicle Systems Program

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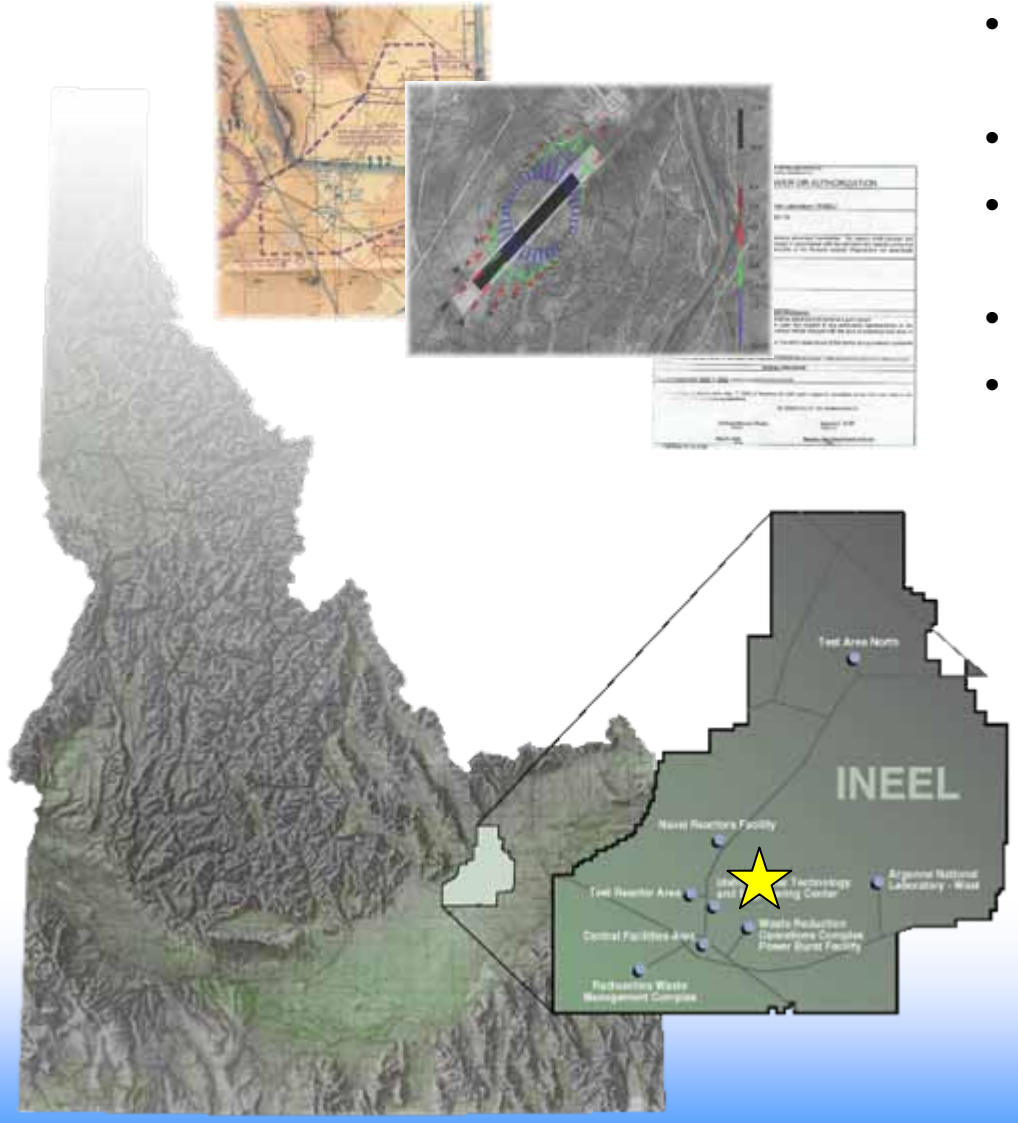
UAV Research Park

…ideal for small UAV operations



- *Isolated controlled access boundaries for testing*
- *NTIA 'Red Book' Spectrum Authority*
- *Airfield located ~45 minutes drive from Idaho Falls airport*
- *High Desert Environment (~5000 ft MSL)*
- *Air space utilization through FAA 'Certificate of Authorization (COA)' for unmanned 'Remotely Operated Aircraft (ROA)'.*

Small UAV-acquired, High-resolution, Georeferenced Still Imagery

- Platforms
- Georeferenced Still Imagery Workflow
  - *Planning / Tasking*
  - *Systems Integration*
  - *Image Pre-Processing*
  - *Image Analysis*

Arcturus T-15 Airframe

- *Composite Structure.*
- *10 ft wing span.*
- *10 - 15 lb payload.*
- *Catapult launch capable with skid (belly) landing.*
- *2- and 4-cycle interchangeable engines.*
- *4 – 8+ hour duration (engine dependent).*
- *50 – 90 kts cruise (engine dependent).*

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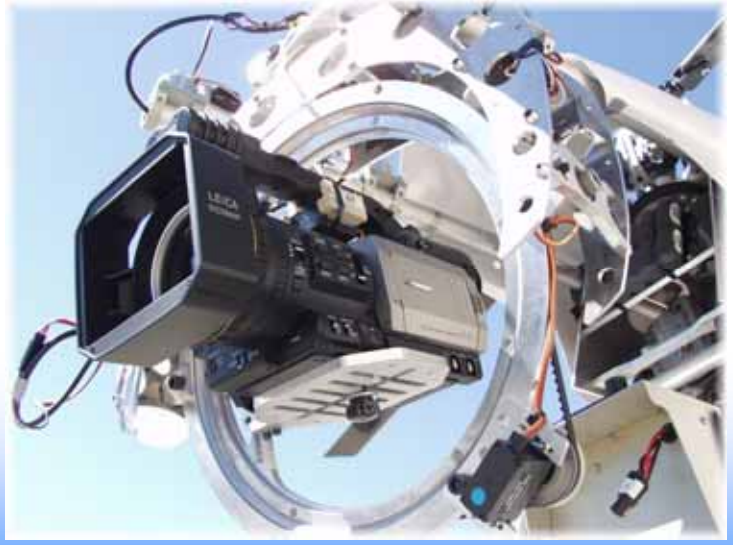
NRI Autocopter

- *72” main rotor diameter.*
- *86” total length.*
- *15 lb payload.*
- *2-stroke, air-cooled, 5.75 hp engine.*
- *30 minute fuel capacity.*
- *Manual and autonomous flight.*
- *Autorotational & parachute failsafe mechanisms.*



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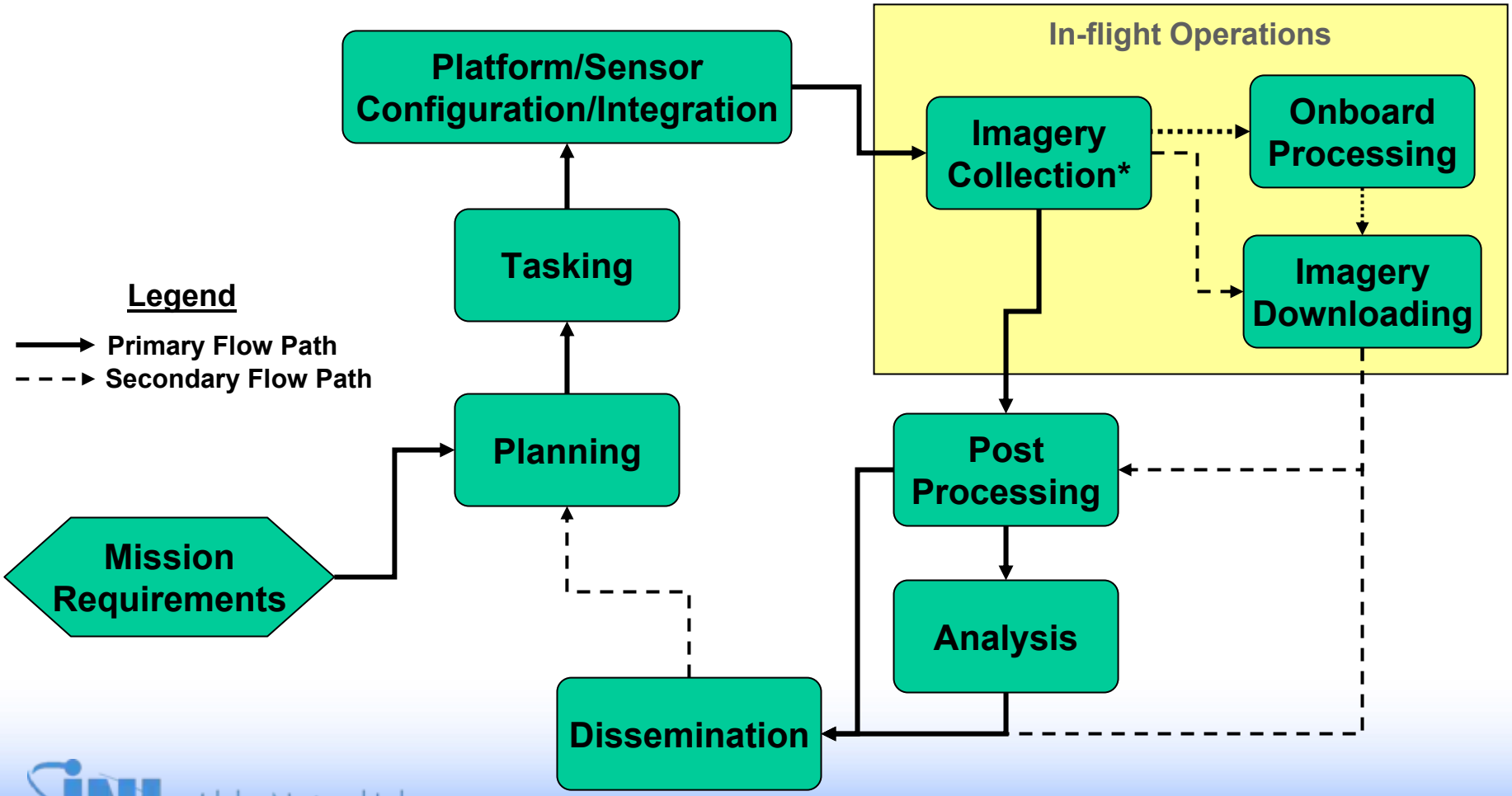
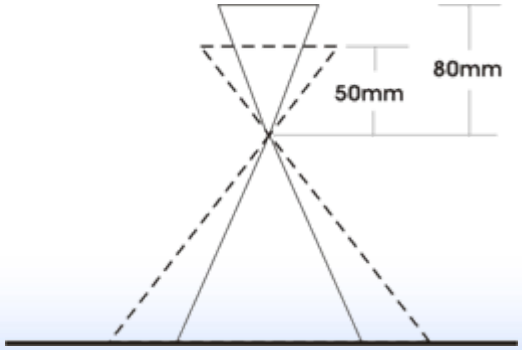
Georeferenced Still Imagery Workflow

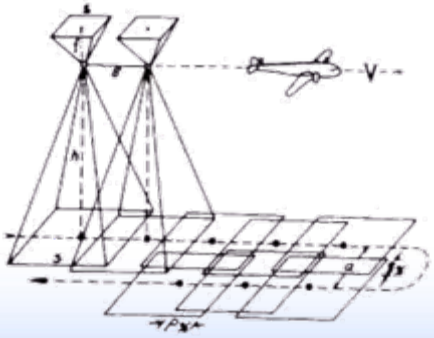
Small UAV-collected, High-resolution, Georeferenced, Still Imagery Workflow



Mission Requirements and Planning

- *Technical Specifications:*
  - *Focal Length (Digital Camera: Focal Length Magnification)*
  - *Flight Altitude*
  - *Resolving Power (Photo Scale)*
  - *Overlap and Sidelap*
  - *Number of Flightlines*





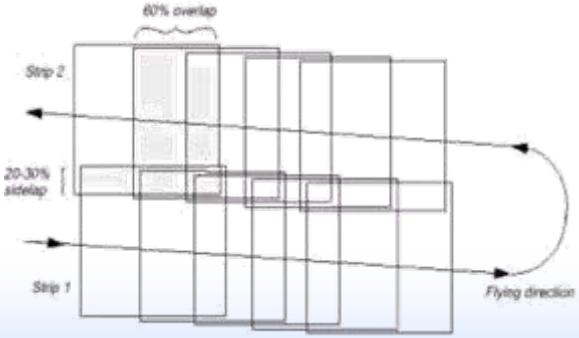


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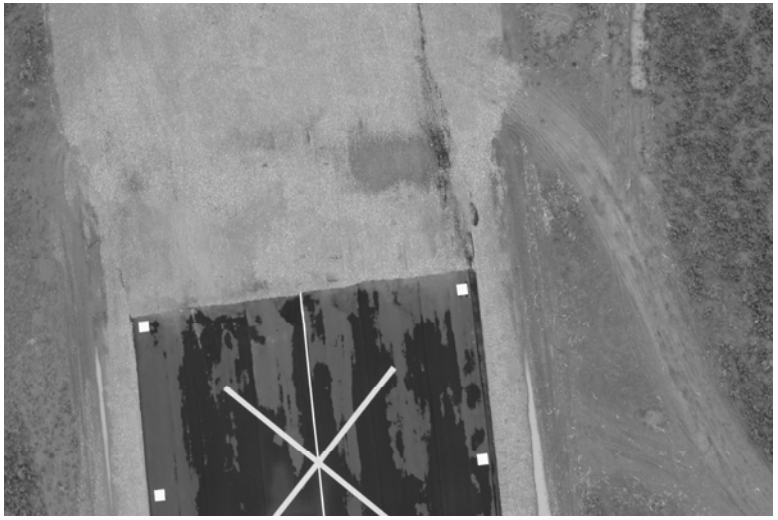
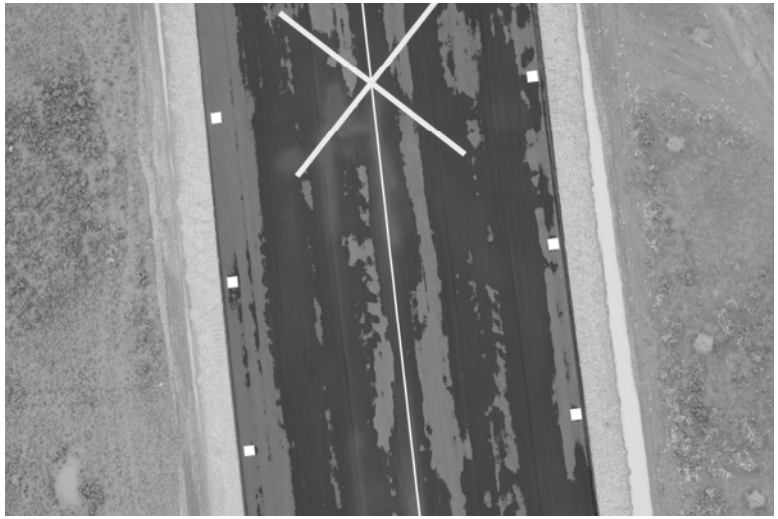
Image Acquisition

- A still frame camera is used to acquire high resolution imagery.
- Shown above are two sequential images of the test area, a 1000ft runway.



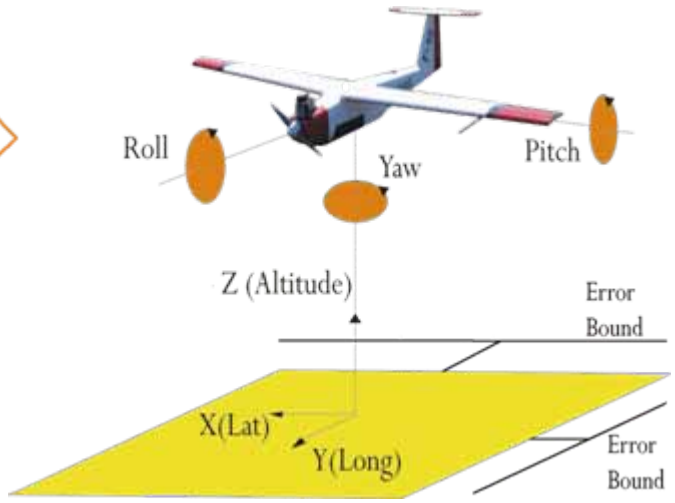


Georeferencing Process

- Traditional Methods (All Require Ground Control Points (GCPs)):
  - Image-to-Map
  - Image-to-Image
  - Aerial Triangulation
- Issues with using GCPs for UAV-acquired, low altitude, High Resolution Imagery
  - High cost
  - To dangerous to obtain GCPs
  - Small footprint (single photo)
  - No distinguishable GCPs
- Direct Georeferencing

Direct Georeferencing

- The process of registering an image frame to a map coordinate system through direct measurement of the sensor interior and exterior orientation parameters at the moment of exposure



Feature Matching

- Shown is the correspondence of SURF features between two sequential images.
- The Hessian Detector Matrix forms the basis of the SURF algorithm.

Hessian Detector Matrix

$$\mathcal{H}(\mathbf{x}, \sigma) = \begin{bmatrix} L_{xx}(\mathbf{x}, \sigma) & L_{xy}(\mathbf{x}, \sigma) \\ L_{xy}(\mathbf{x}, \sigma) & L_{yy}(\mathbf{x}, \sigma) \end{bmatrix}$$

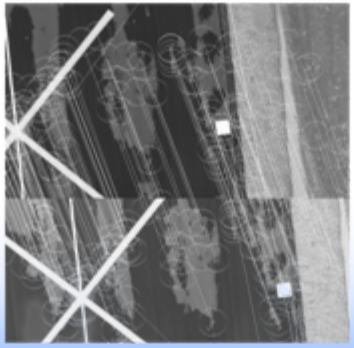
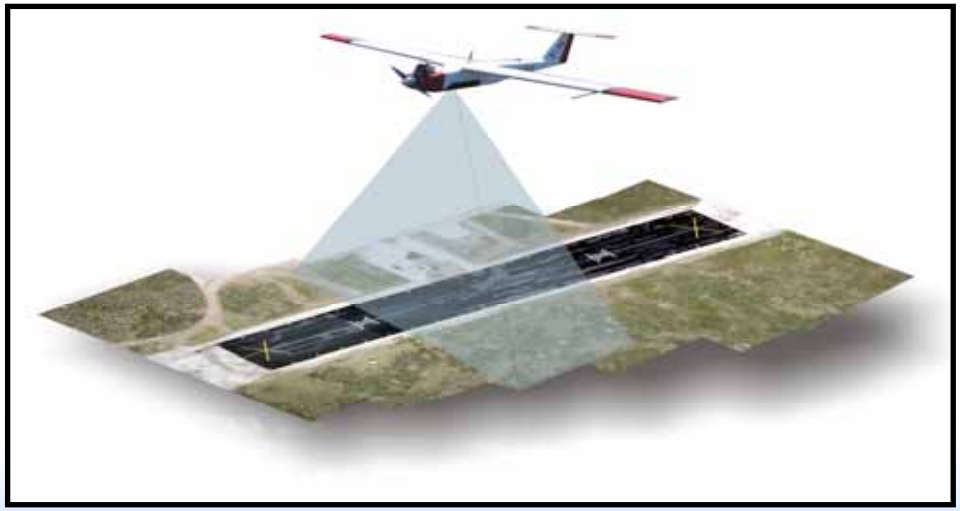
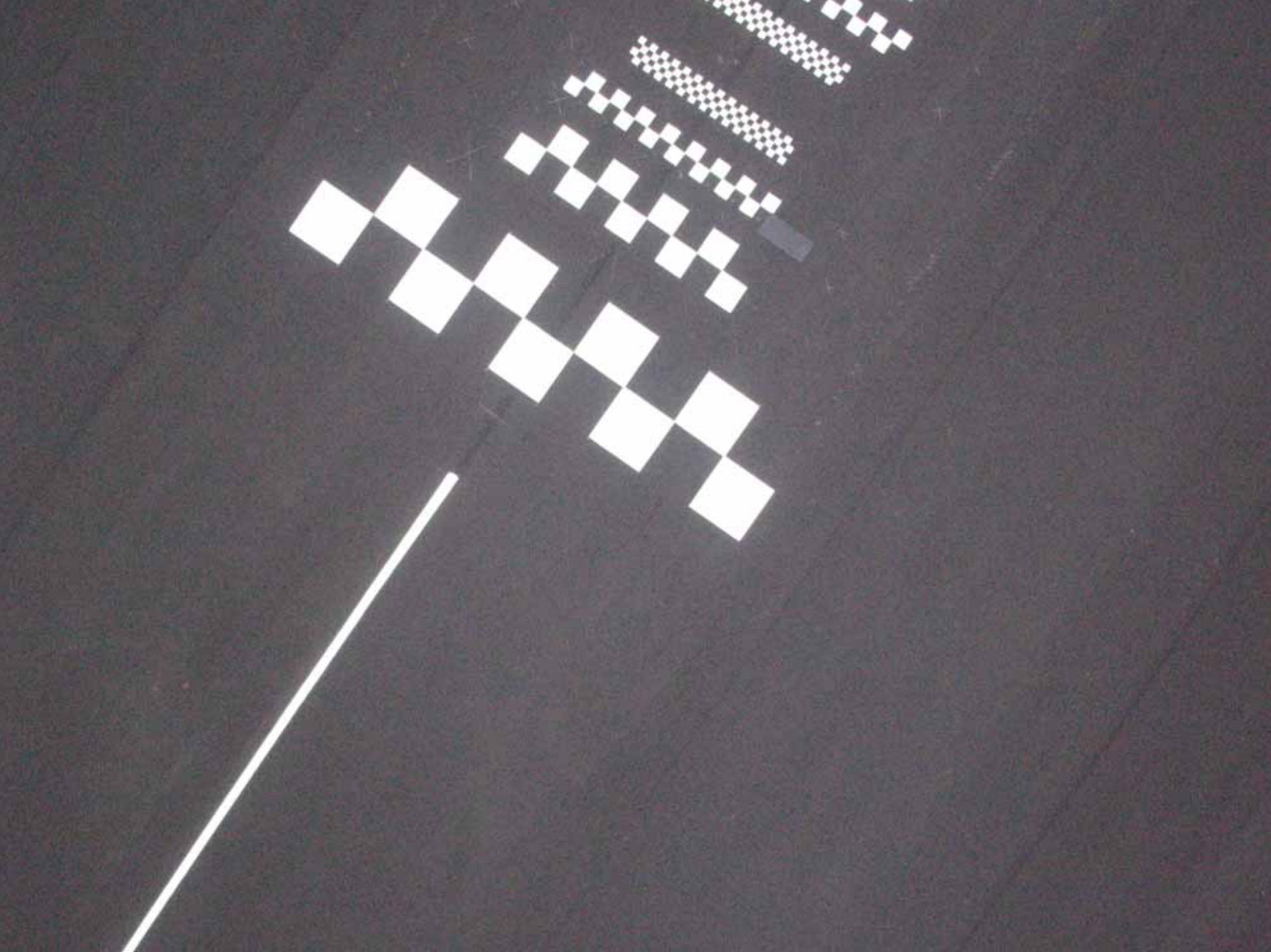


Image Stitching

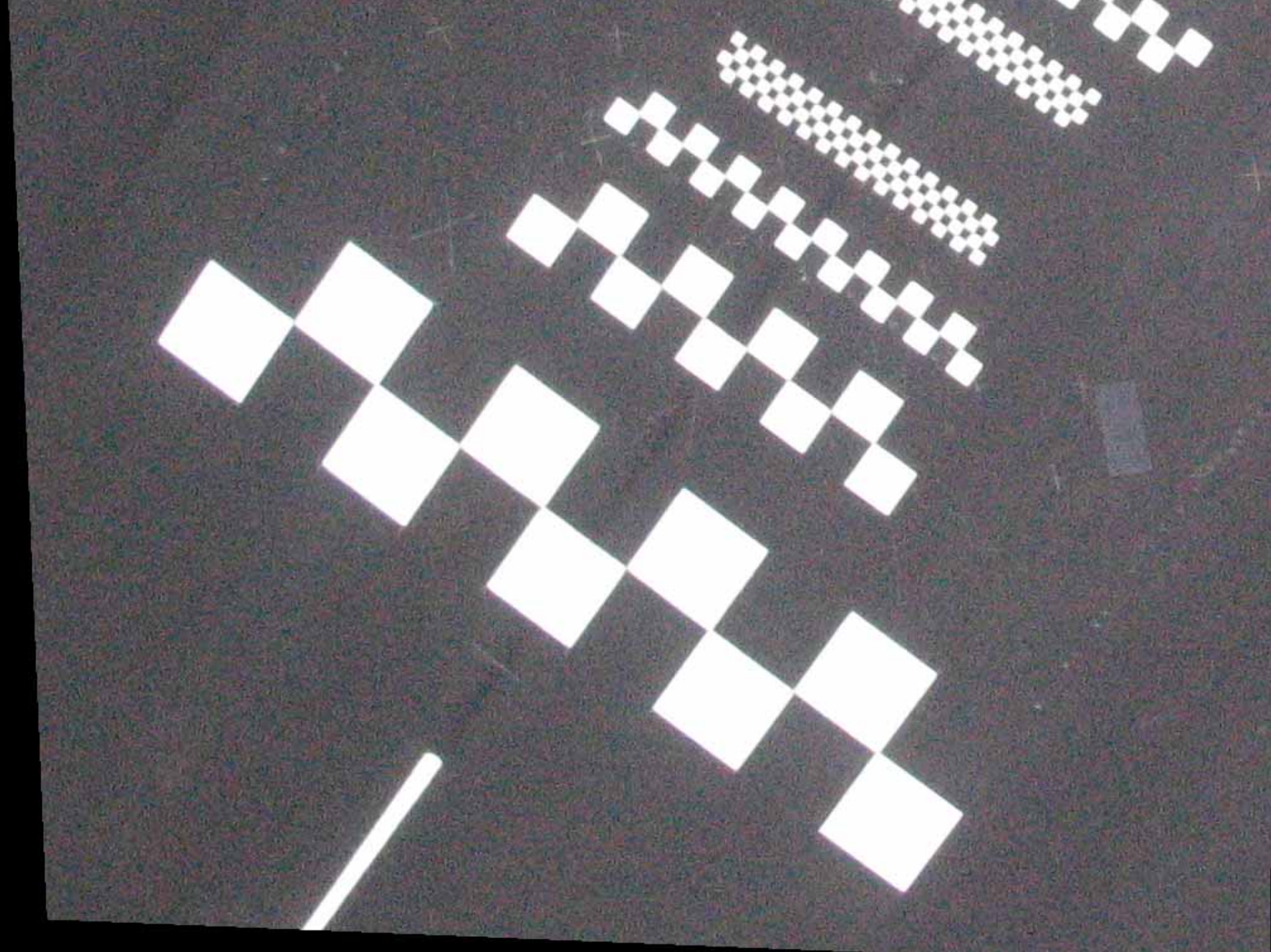
- A highly accurate match is made, and the two images are stitched together to form one image.
- Images are overlaid in the most accurate configuration available using the RANdom SAmple Consensus (RANSAC) algorithm.

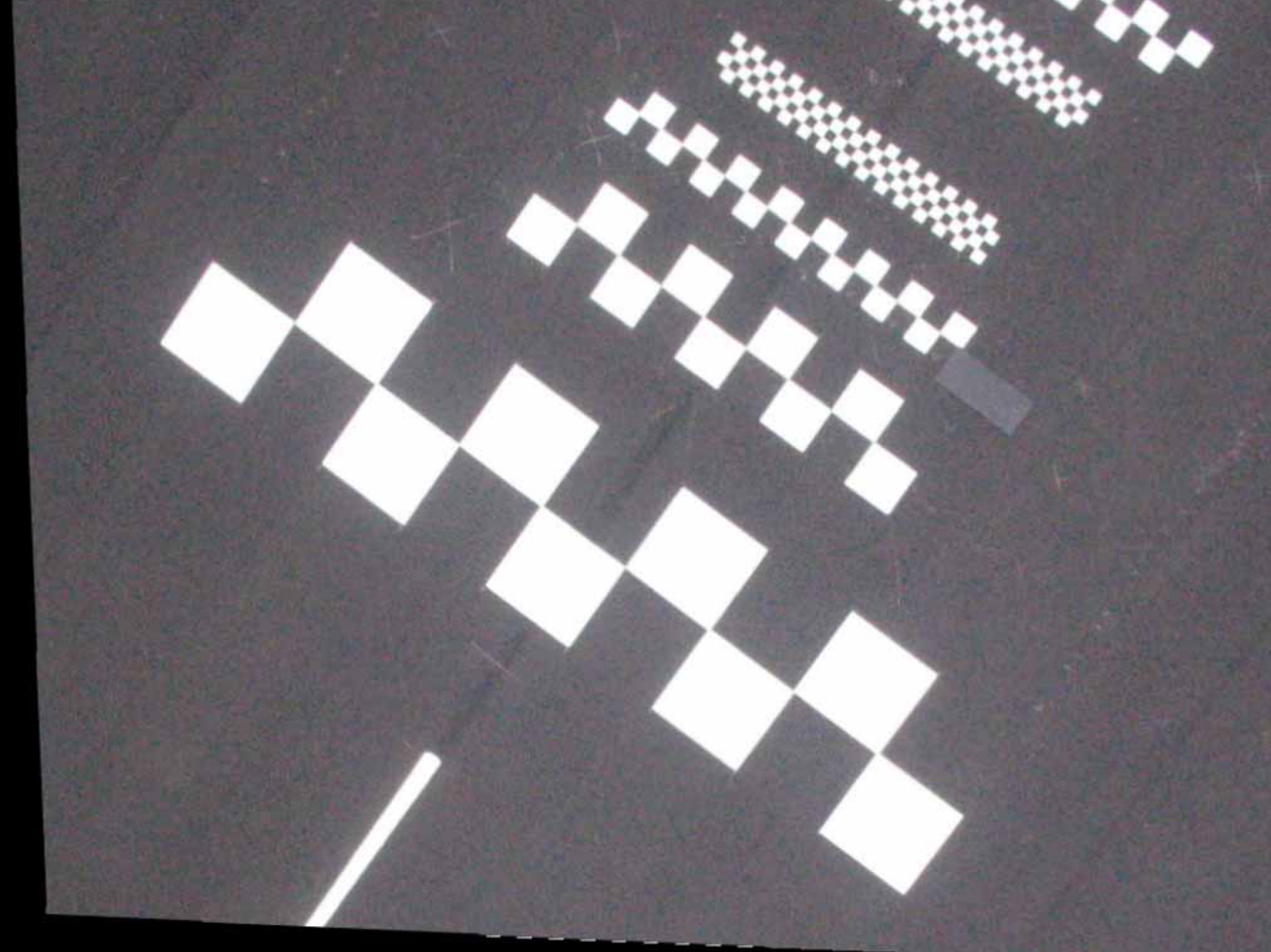


Unregistered



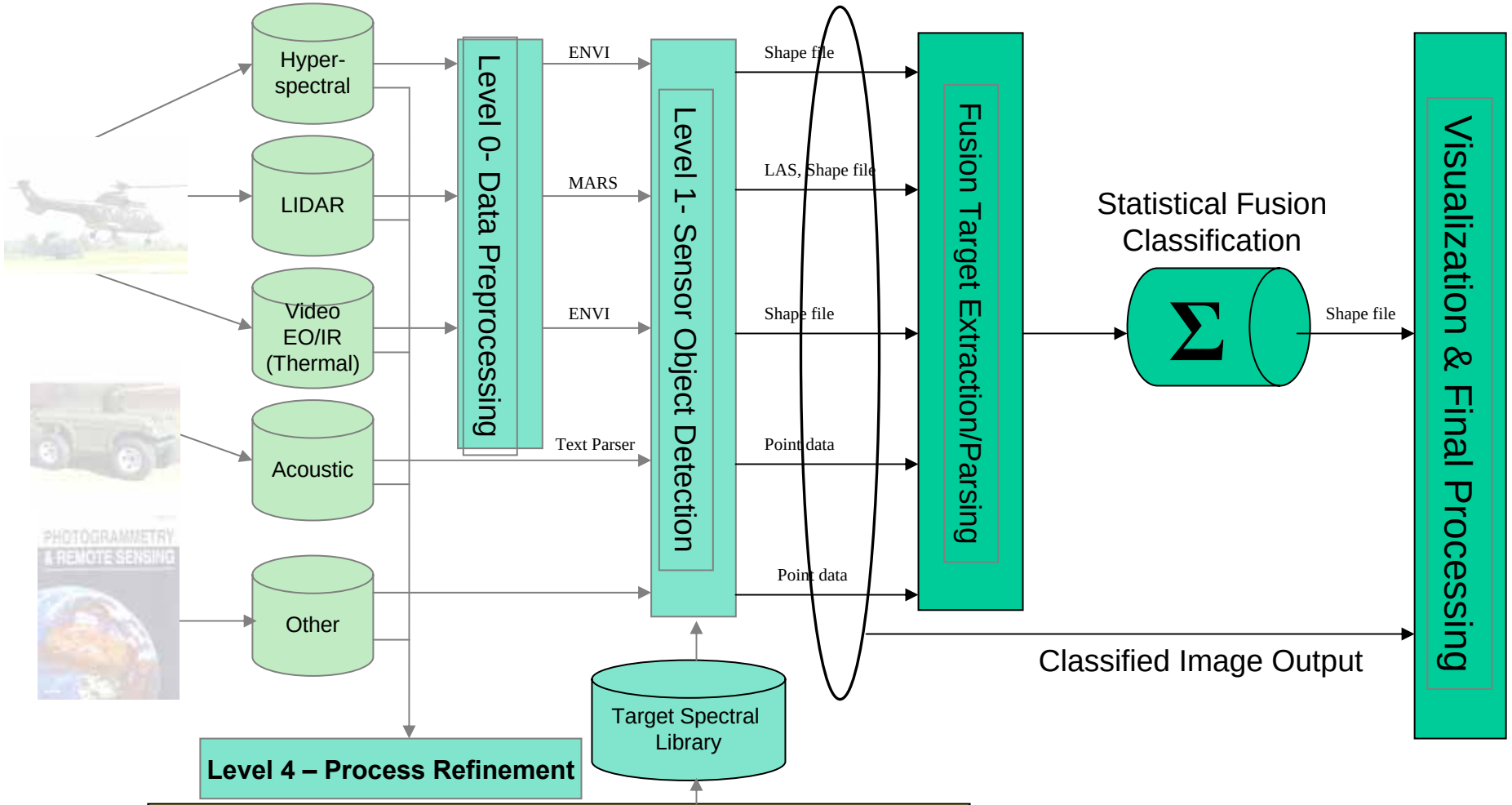
Registered





Sensor Fusion

Sensor Data Processing



Manual Discovery for "Signature" Development

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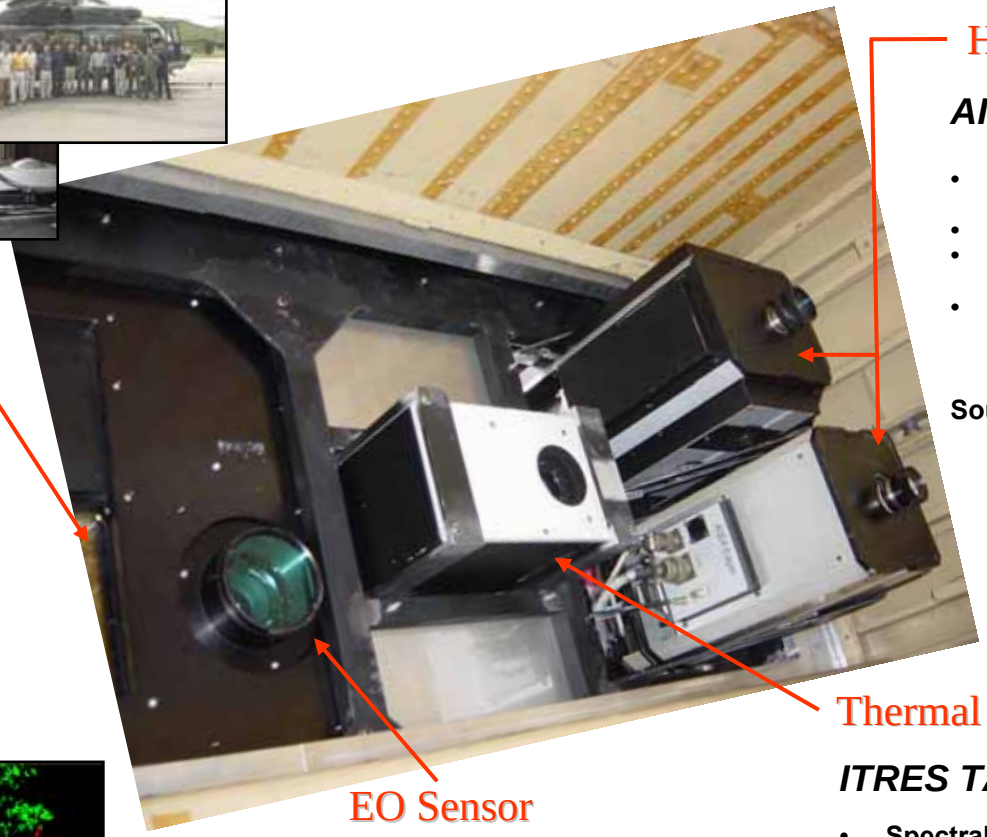
Sensors

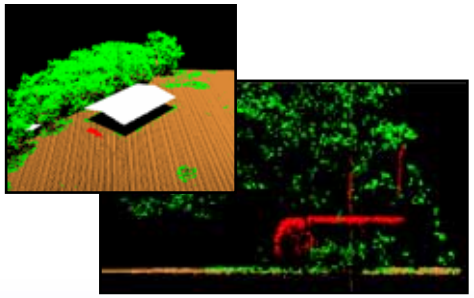


LIDAR Sensor

Leica ALS-50

- Ground Resolution @ 2500ft AGL: 1.31 m
- Scan Angle Range: 45 deg
- Scan Rate: 5 – 160 scans/sec
- Eye safe operation above 200m

Source: Switzerland

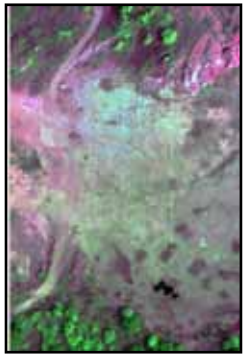


SWIR/ VNIR Hyperspectral Sensors

AISA Eagle, Hawk

- Spectral Range: 400-2400nm (2.9 nm FWHM)
- Field-of-view: 40 deg
- Ground Resolution @ 2500ft AGL: .60 m
- Includes algorithms to facilitate target detection and identification

Source: Finland

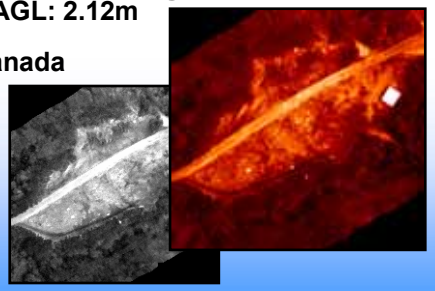


Thermal Sensor

ITRES TABI 320

- Spectral Range: 8-12µm
- Field-of-view: 48 deg
- Ground Resolution @ 2500ft AGL: 2.12m

Source: Canada



EO Sensor

Merrick DACS2

- 7216x5472 pixel array, Visible
- Field-of-view: 34 deg
- Ground Resolution @ 2500ft AGL: .07m

Source: USA

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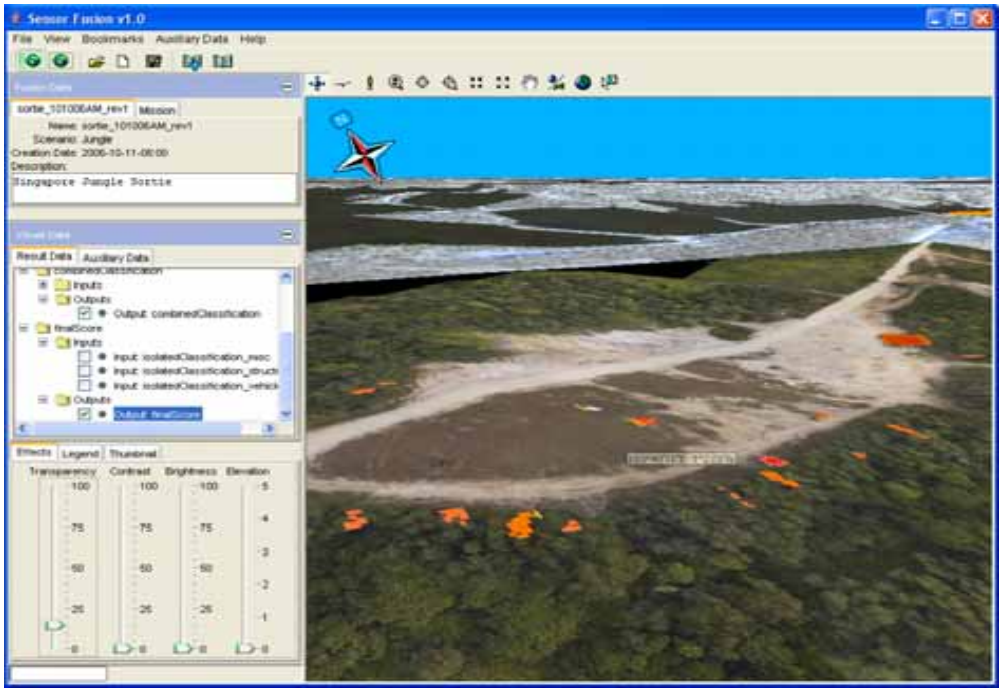
Fusion Process and Interface



Software Framework

Extensible architecture for registering and fusing multi-source data

Loosely couples Scenarios, Mission Data, Fusion Engine Decision Trees, and Final Fused Data

Fusion Algorithm

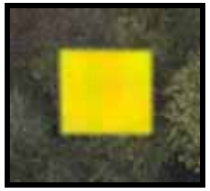
Adapted Scoring Model

$$S(\gamma_i) = [1/c]\sum_{j=1}^{M} w_i \gamma_{ji}$$

M **= total number of sensors**
W_i **= a priori weight assigned to the *j*th hypothesis**
γ_{ji} **= the score assigned to the *j*th hypothesis by the *i*th sensor**
c **= a normalization constant**
$S(\gamma_i)$ **denotes the total score assigned to the *i*th hypothesis by M sensors**

Interface

Based on ArcGIS Globe control and interfaces with C/JMTK v9.1

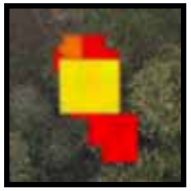


Thermal Anomaly

+

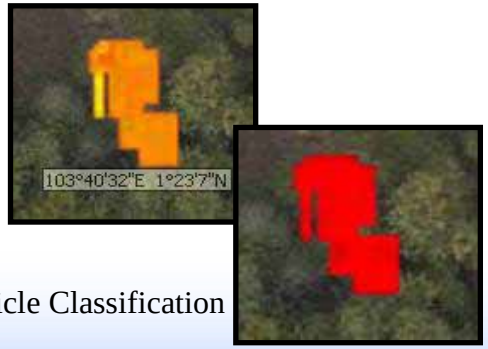
Paint Signature

+



LIDAR Anomaly

→



Vehicle Classification

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Integrated Basin Modeling

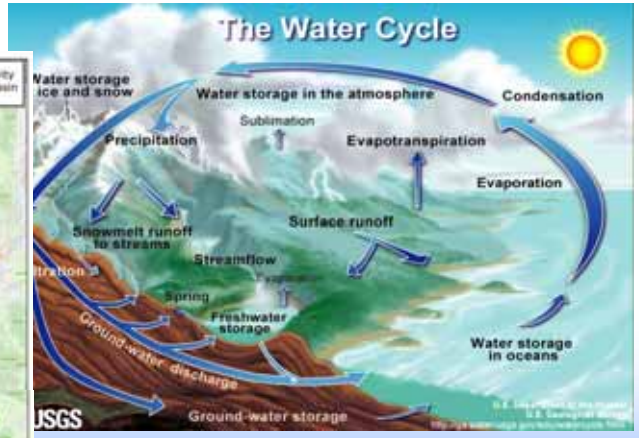
Integrated Basin Management:

The primary objective of this effort is to provide a scalable modeling framework for integrated basin management to enable resources managers to design the unconventional fuel industry in the intermountain west.

• Development of a modeling and simulation tool to assess potential impacts of developing the develop energy industry, model the interdependencies between natural and human systems and evaluate potential management options.

•Integrate multiple existing modeling capabilities that will allow a user to spatially visualize and interact in a time-based simulation.

• Focused on water availability under different management and climate scenarios



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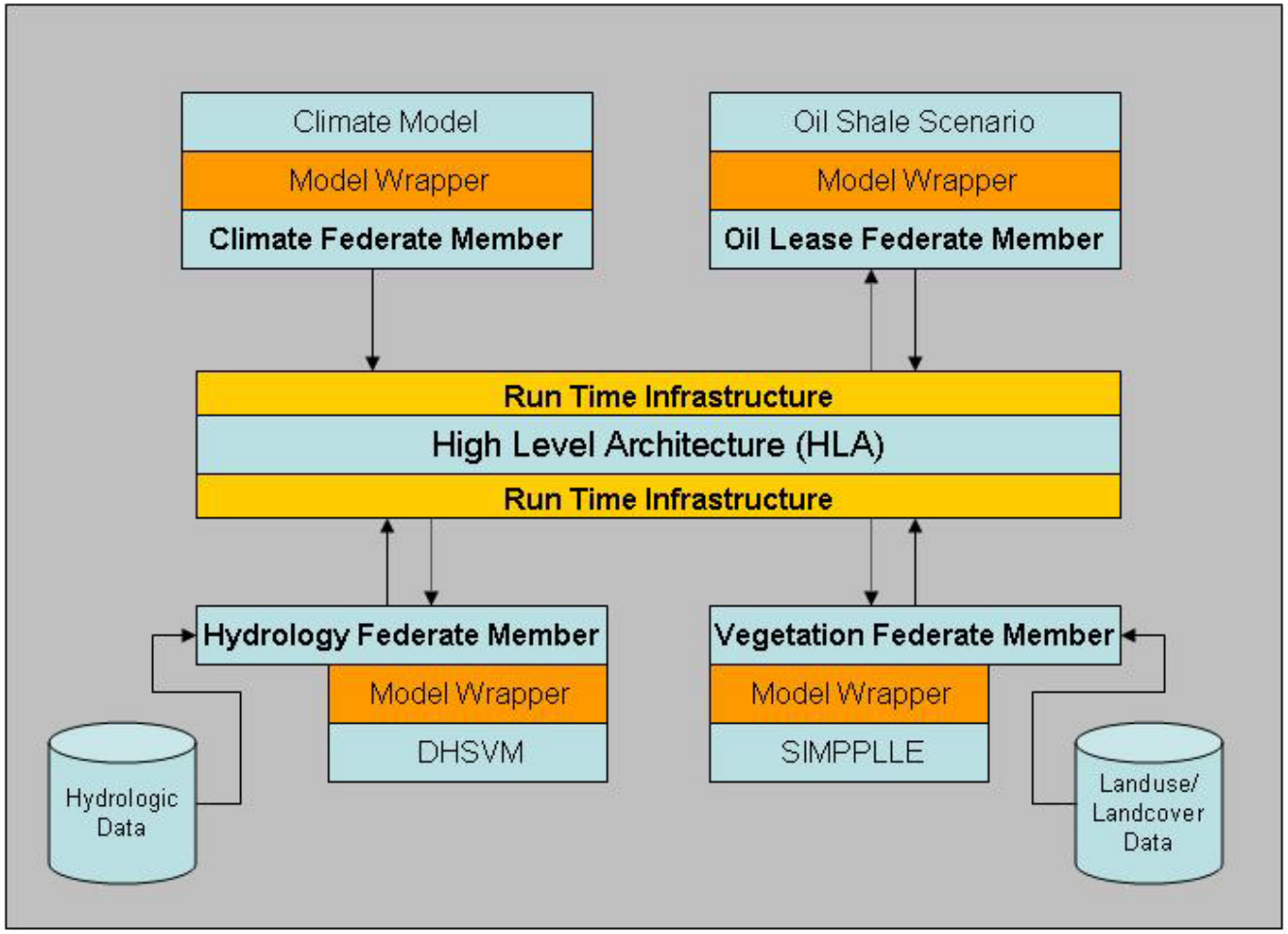
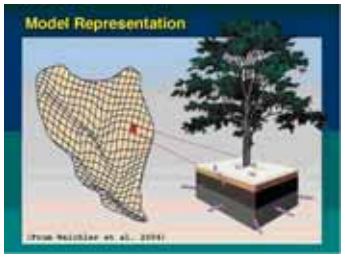
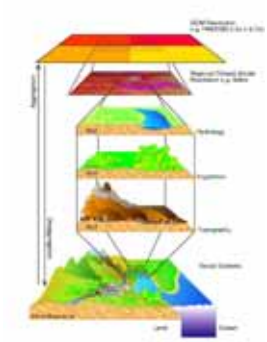
Conceptual Design

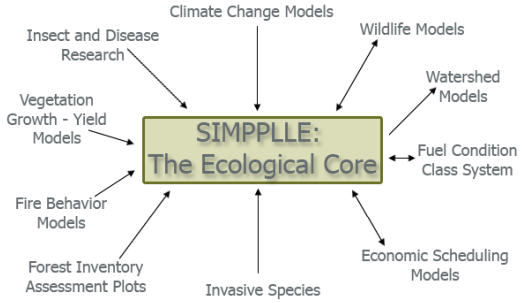


Models: Spatially and Temporally Explicit

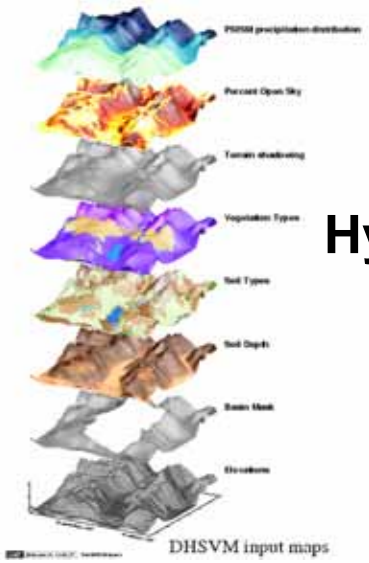




Climate Model

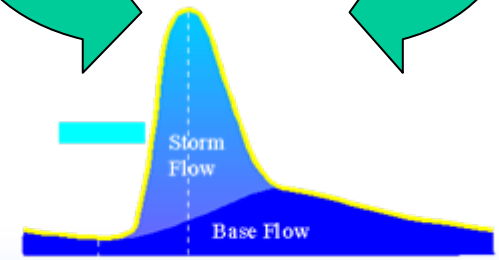


Landscape Model

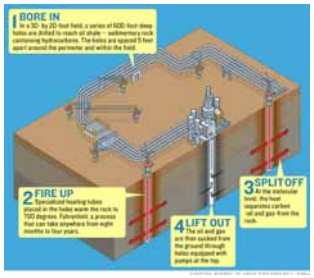


Hydrology Model

Distributed Simulation Architecture



Water Availability



Scenario Generator

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Web Based Information Systems

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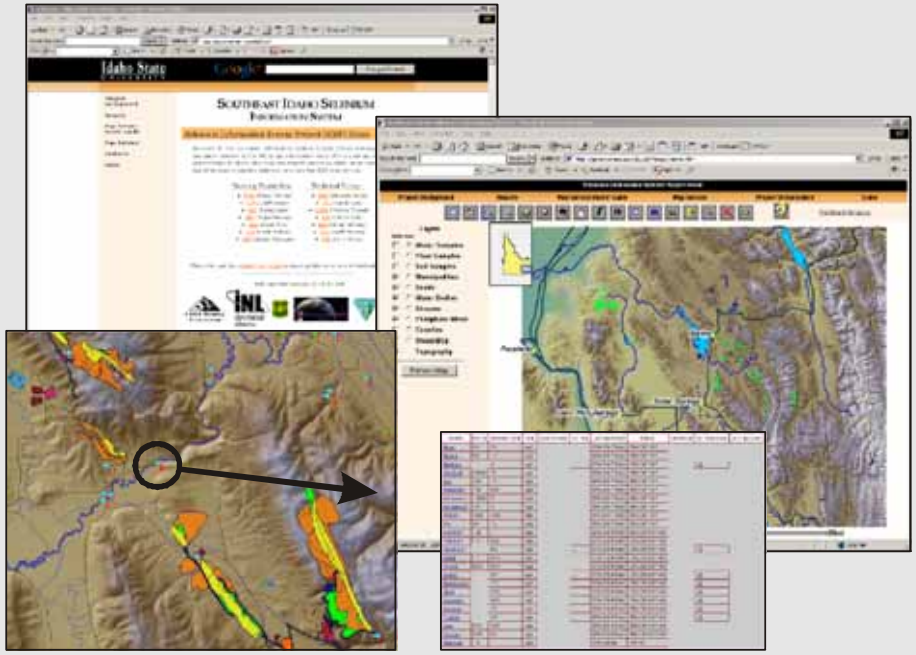
Web Based GIS Applications

- Single location for disparate data
- Multi-agency (BLM, USFS, EPA, Tribes) agreement
- Data download available for researchers and public in Excel format
- Query by location, sample, or analyte

Selenium Information System



This information system is a centralized data repository that combines previously inaccessible information from area-wide investigations of Selenium contamination from phosphate mining operations in S.E Idaho within a web-based GIS user interface.

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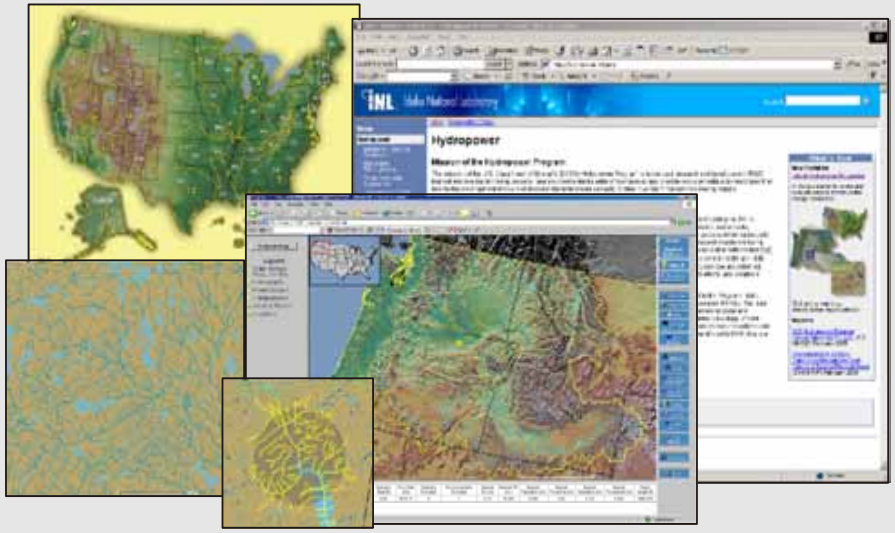
Web Based GIS Applications

- **Single access point for very large datasets**
- **Rapidly query by location, power level, or proximity**
- **Available via a web browser**

Virtual Hydropower Prospector



A Web-based GIS application to locate and evaluate natural stream water energy resources giving end-users a first cut evaluation of potential hyropower resource sites for the United States.

Thank You