From Pixels to Information: Remote Sensing for Planning

May 2008

Matthew Bobo
Remote Sensing Specialist
National Operations Center

What is Remote Sensing?

- Science and Art of measuring an object, area, or phenomena without direct contact with that object

Context

The Ideal Remote Sensing System

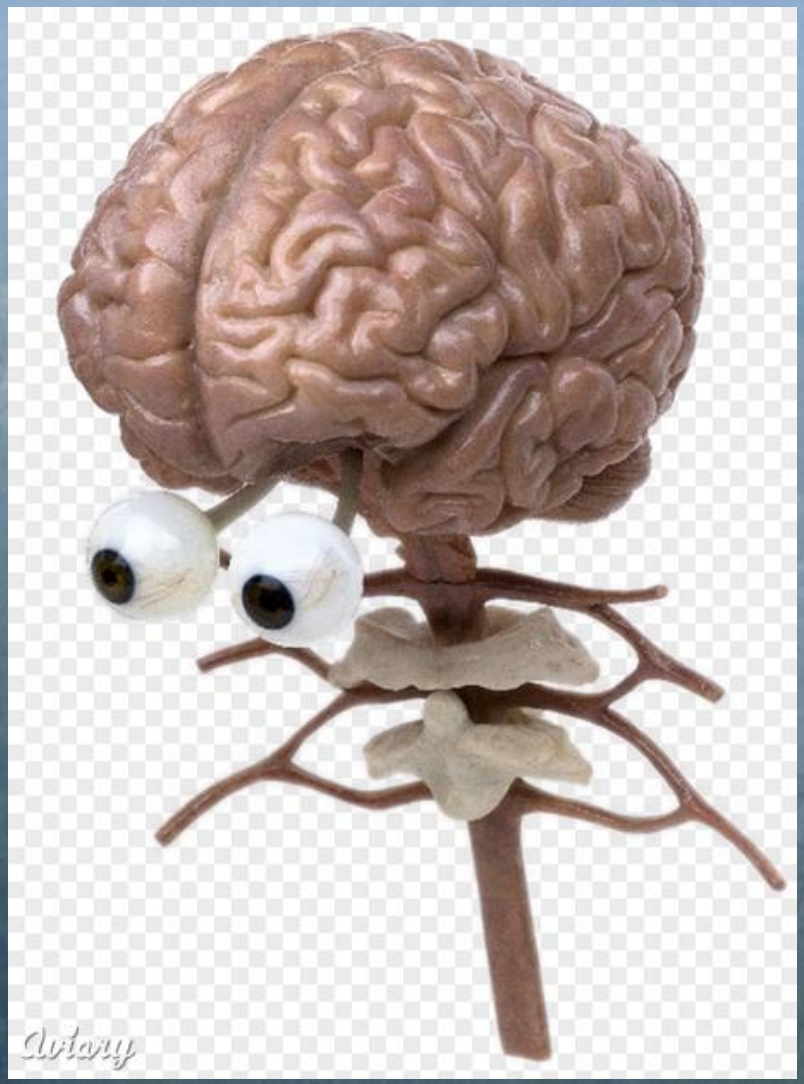


Image Interpretation Elements

- Size
- Shape
- **Tone/Color**
- Texture
- Shadow
- Association
- Pattern

We use each of these image attributes, often subconsciously, to derive information about features in an image, i.e., Photo Interpretation…

Traditional classifiers only use Tone/Color to extract features from imagery.

New technologies use some form of Size, Shape, Tone/Color, and Texture for image feature extraction…

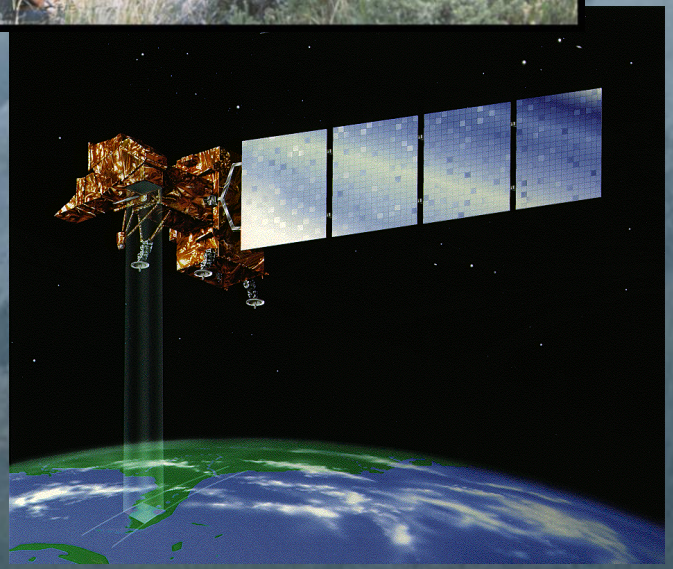
Source: USFS RSAC

How does it help planning?

- Baseline Data
  - Vegetation Mapping
  - Update Vector Layers
- Monitoring / Change Detection
- Decision Support Tool
  - Treatment Effectiveness
- Support for Cumulative Effects Analyzes
- Visual Documentation
- Climate Change

Monitoring change over time

- Traditionally the majority of BLM's monitoring activities have been field-based.
  - Provides great site-specific data
  - Difficult to extrapolate these data to coarser scales
  - Monitoring sites are infrequently visited
  - Driven by permitting not ecology
- Need to develop sampling strategies that allow BLM to effectively monitor multiple scales.
- Remote sensing provides data to fill-in the gaps both spatially and temporally

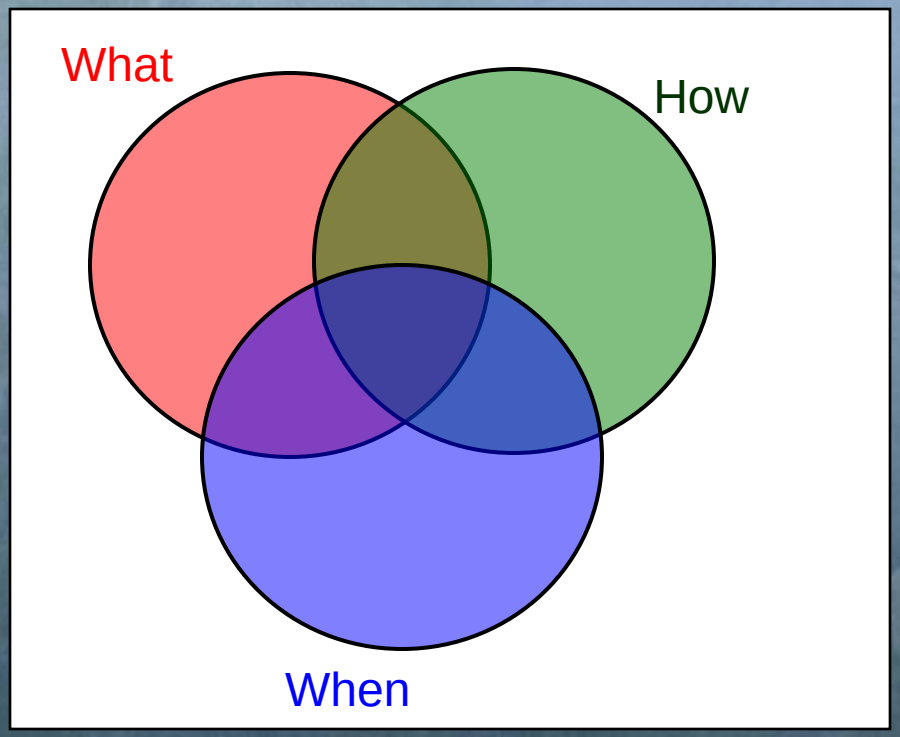


Remote Sensing Project Requirements

- Tripartisan Perspectives
  - Resource Specialist
  - Manager
  - Remote Sensing Geek
- Balance needs to be found
- Define expectations

Requirement Considerations

The Resource Specialist Perspective



What to measure

- What are the issues to be addressed
- What resources are involved
- Extent of resource
- Goals/Objectives

How to measure

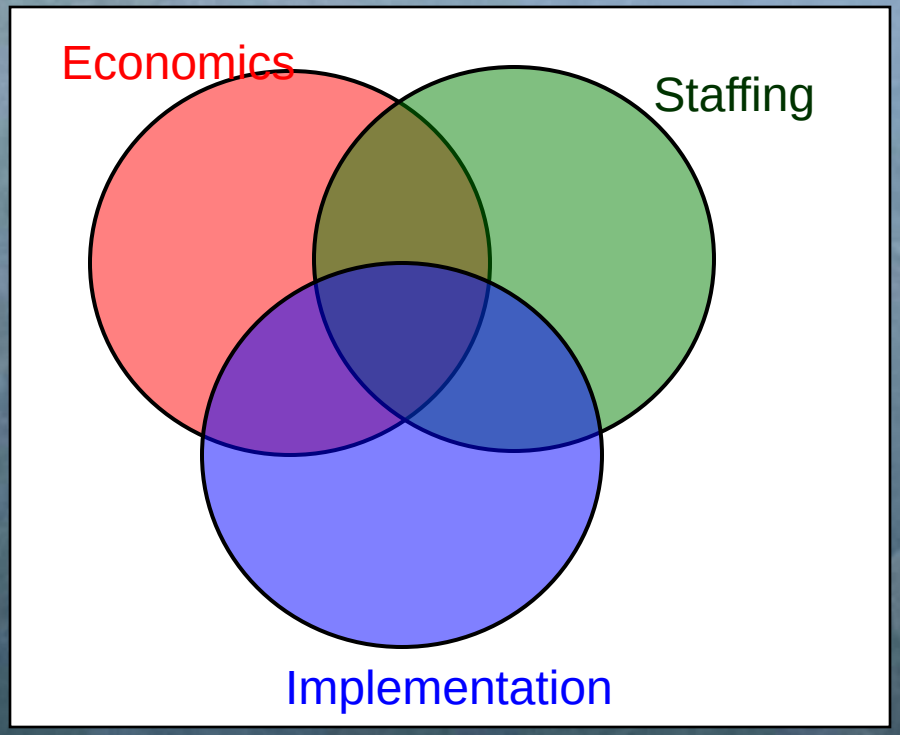
- Indicators
- Mapping verses Sampling
- Accuracy/Detail Requirements
- Scale

When to measure

- Phenology
- Triggers

Requirement Considerations

The Manager Perspective



Economics

- Costs
- Benefits
- Long-term verses Short-term
- Risk tolerance

Staffing

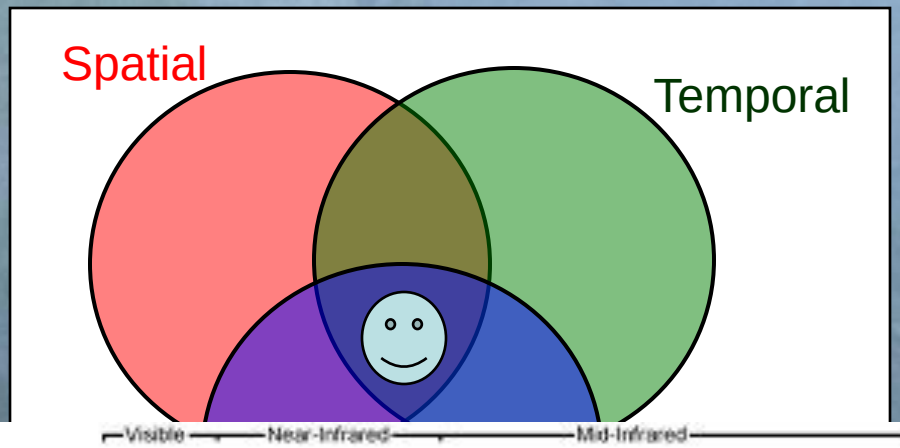
- Training
- Availability
- Commitment
- Partnerships

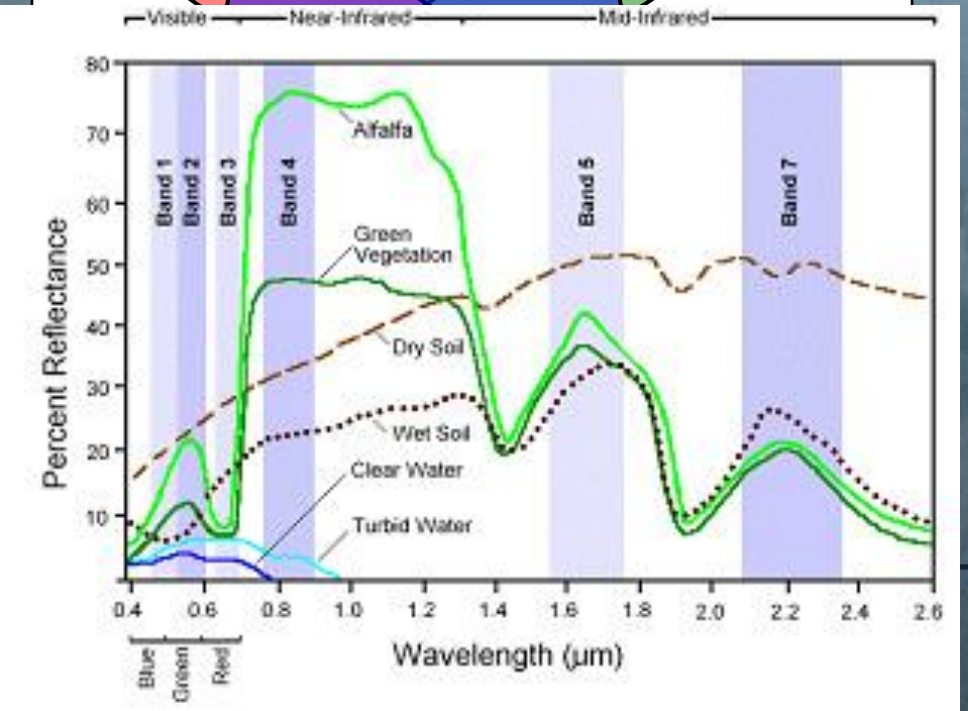
Implementation

- Single Inventory v. Monitoring
- Action Thresholds
- Existing Data

Requirement Considerations

The Remote Sensing Geek Perspective





Spatial

- Pixel Resolution
- Swath Width
- Data Volume

Temporal

- Return Interval
- Seasonality
- Imaging Frequency

Spectral

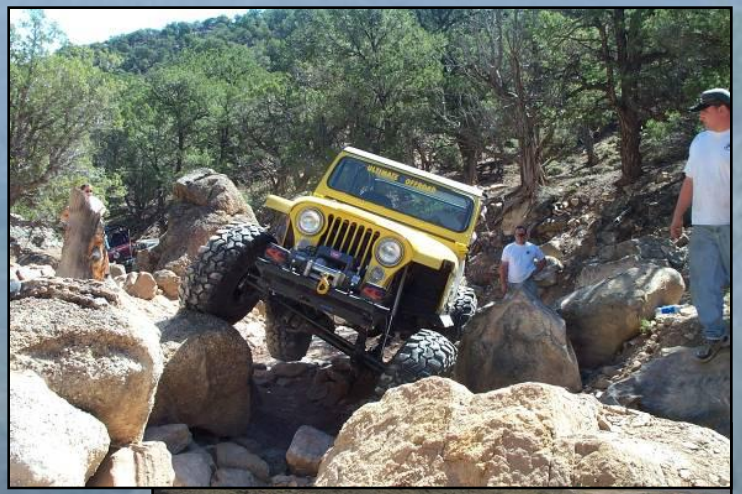
- Number of bands
- Bandwidth

National Operations Center
Division of Resource Services

NATIONAL SYSTEM OF PUBLIC LANDS

Mapping Surface Disturbance

- Inventory of disturbance at multiple resolutions
- Habitat fragmentation
- Cumulative impact
- Monitor to detect change
- Numerous field offices are exploring remote sensing options
  - WO, NOC, SO, FO need to ensure consistency

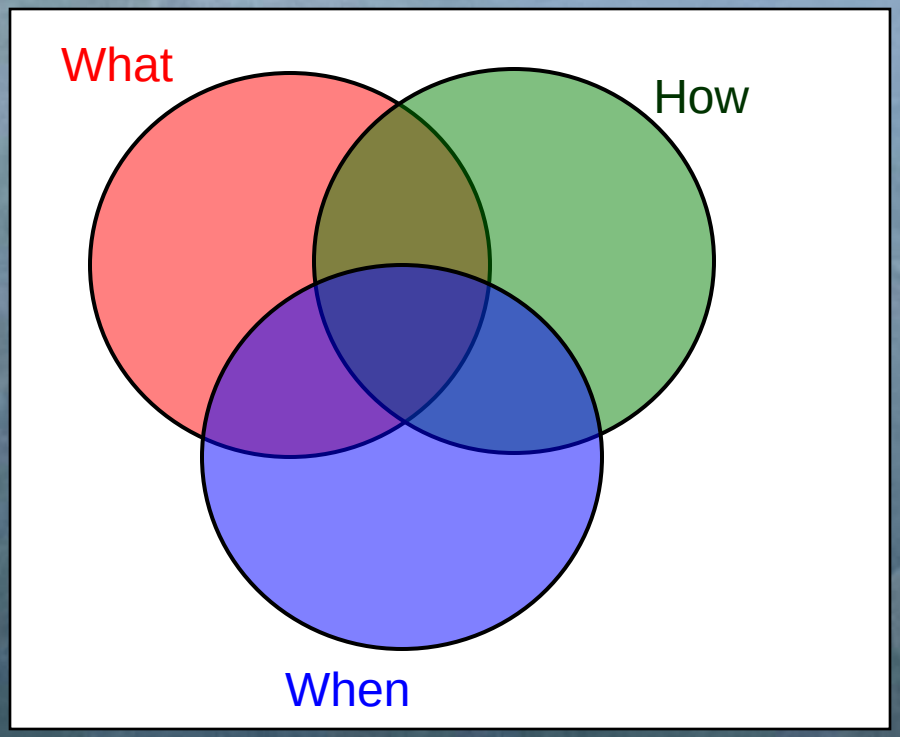


White River Field Office

- Developing Plan Amendment to Monitor Oil/Gas Development
- Need to quantify acres of disturbance per year
- Want to track reclamation progress
- 600,000 acres
- Working with AIM, NOC, and 3rd Parties to develop a scientifically sound and defensible monitoring protocol

Requirement Considerations

The Resource Specialist Perspective



What to measure

- Surface disturbance, Vegetation
- Annual grasses

How to measure

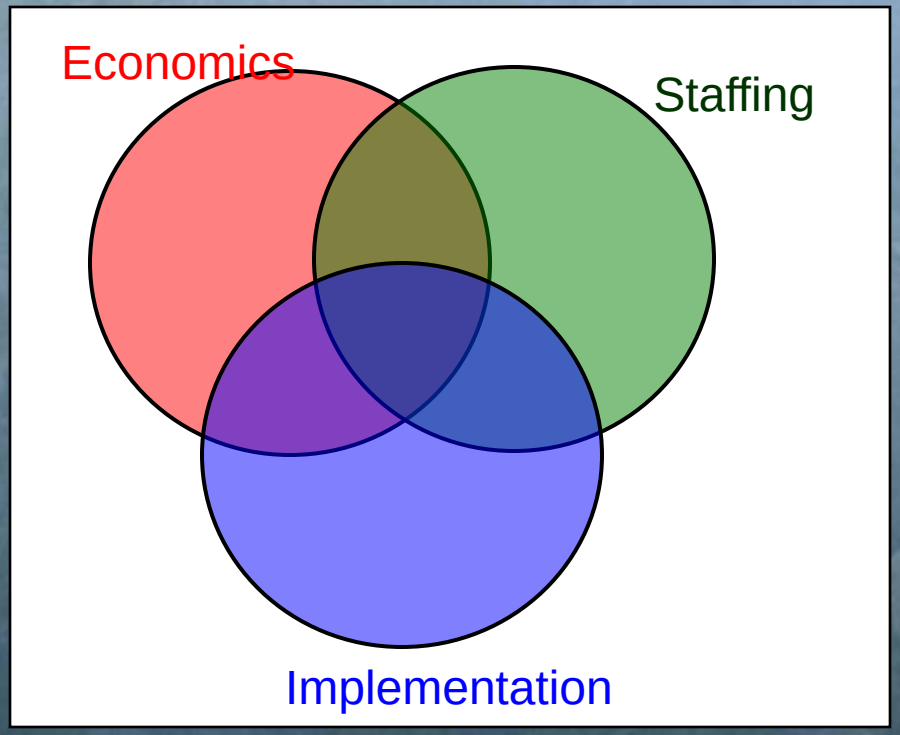
- Remote Sensing
- Wall-to-Wall Mapping
- Percent cover of indicator grasses

When to measure

- Surface Disturbance Annually
- Vegetation intra-annual

Requirement Considerations

The Manager Perspective



Economics

- Funds available from FO, AIM
- Identifying long-term funds
- Setting aside money for imagery

Staffing

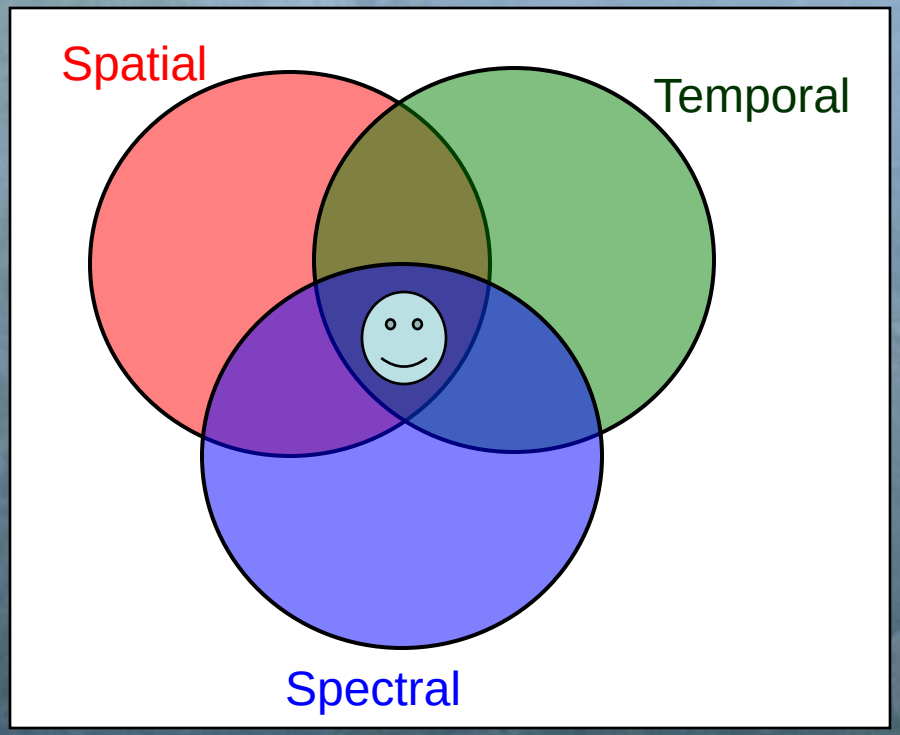
- One GIS Staff person (1 pending)
- In-house staff and partners for fieldwork
- Working with 3rd Party and NOC for plan development and training

Implementation

- Long-term Monitoring
- Tied to Plan Amendment

Requirement Considerations

The Remote Sensing Geek Perspective



Spatial

- Need to capture two-track roads
- Grasses and Shrubs

Temporal

- NAIP every 3 years
- RapidEye multiple times per year
- Capturing phenology of grasses is key

Spectral

- Vegetation requires infrared

Remote Sensing Systems

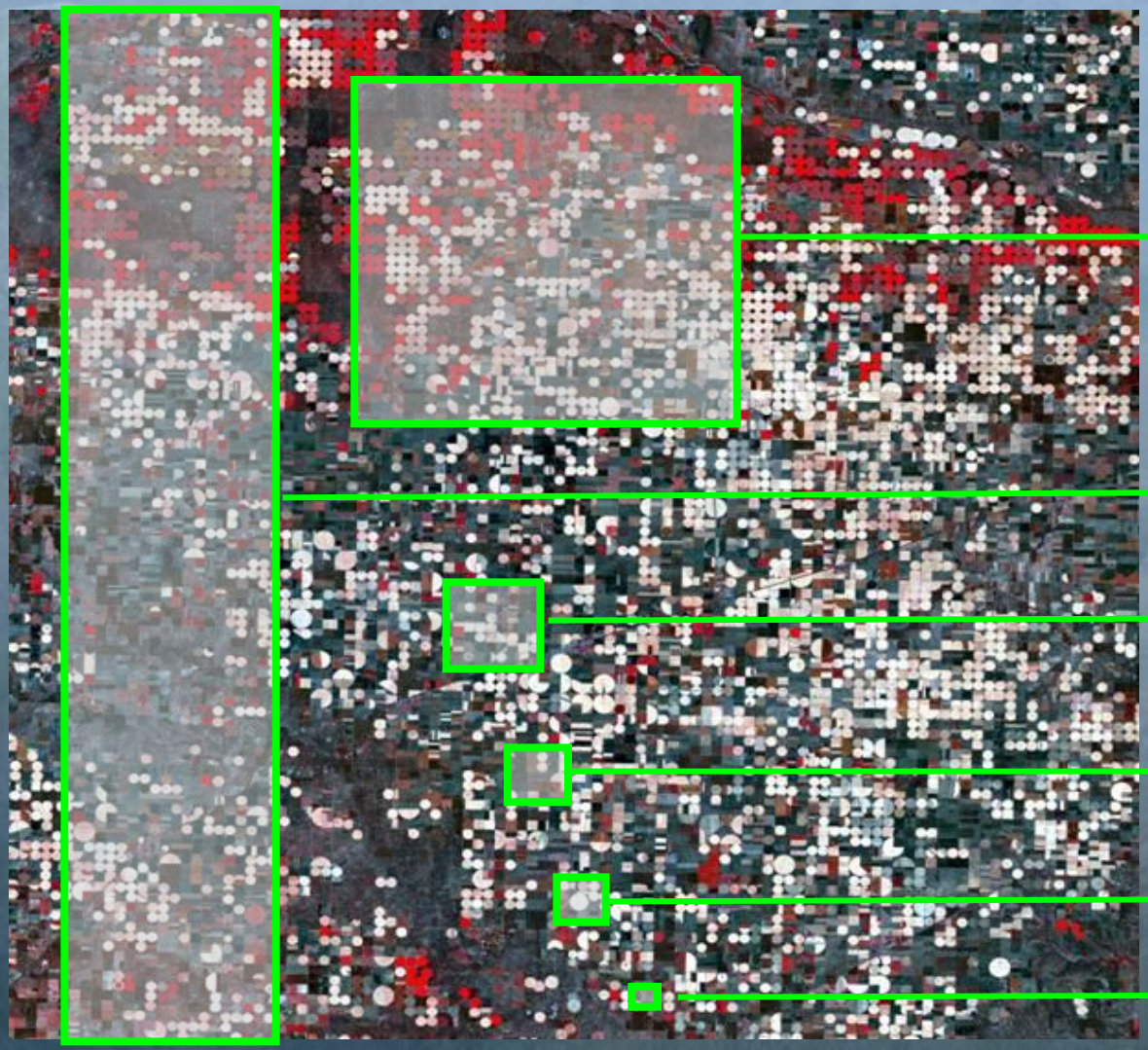
Domains:

Spatial: 0.5 m-5m
10-30m
100-500m
1k-8km

Temporal: 0.5 hr
Daily
Weekly
Bimonthly

Spectral: Panchromatic (1)
Multispectral (2-7)
Hyperspectral (10s-100s)

Imagery Comparisons



Landsat

ASTER, SPOT

EO-1 ALI

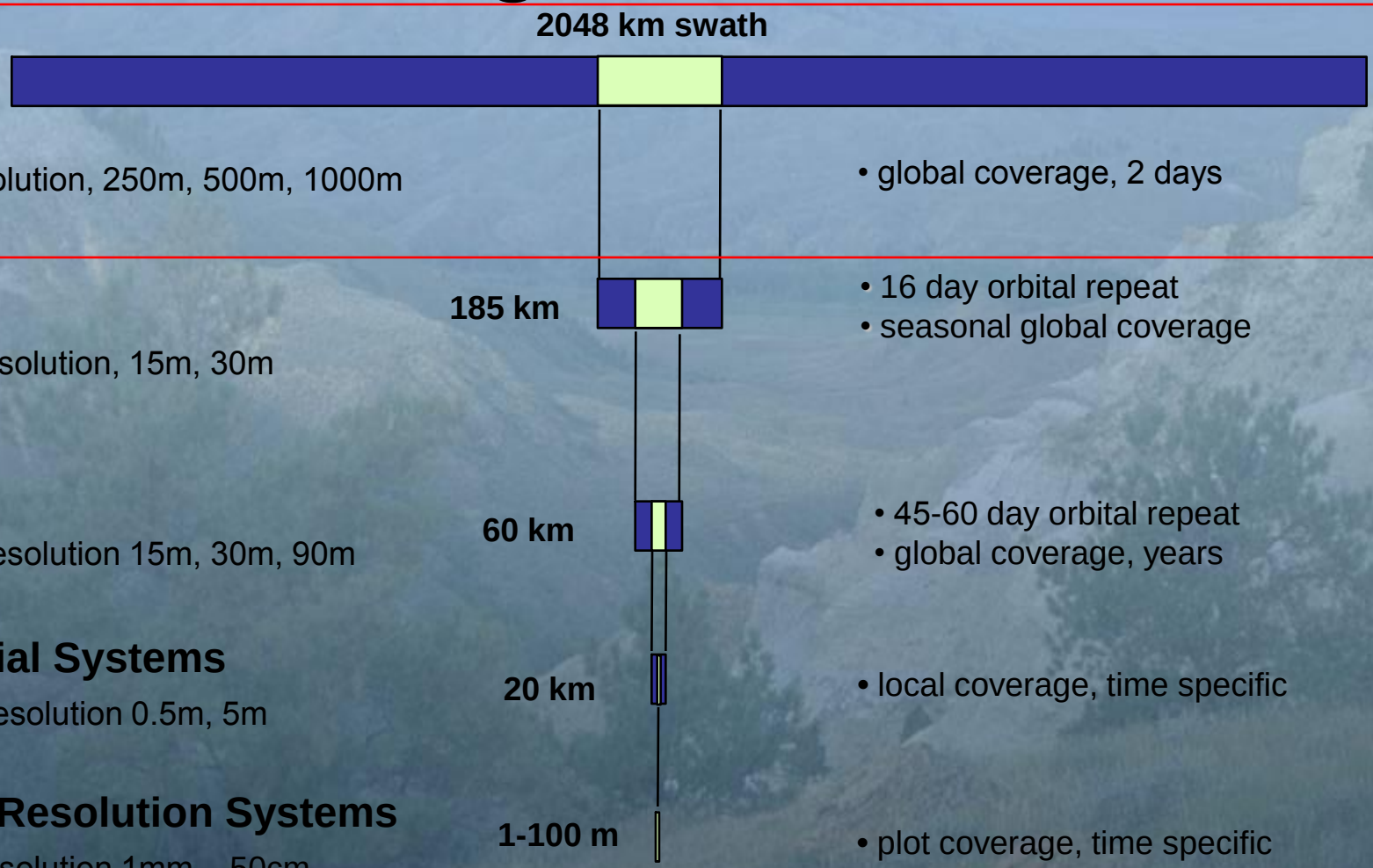
QuickBird

IKONOS

OrbView-3

Aerial

Remote Sensing Resolution



AVHRR/ MODIS

- spatial resolution, 250m, 500m, 1000m
- global coverage, 2 days

Landsat

- spatial resolution, 15m, 30m
- 16 day orbital repeat
- seasonal global coverage

ASTER

- spatial resolution 15m, 30m, 90m
- 45-60 day orbital repeat
- global coverage, years

Commercial Systems

- spatial resolution 0.5m, 5m
- local coverage, time specific

Very High Resolution Systems

- spatial resolution 1mm – 50cm
- plot coverage, time specific

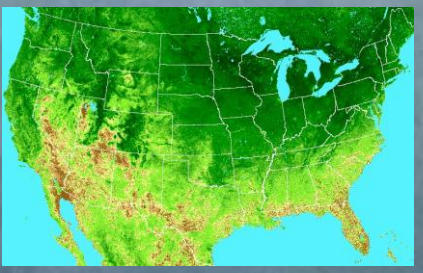
High Temporal Frequency Data

1989

1990

1991

1992


1993

1994

1995

1996

1997

1998

1999

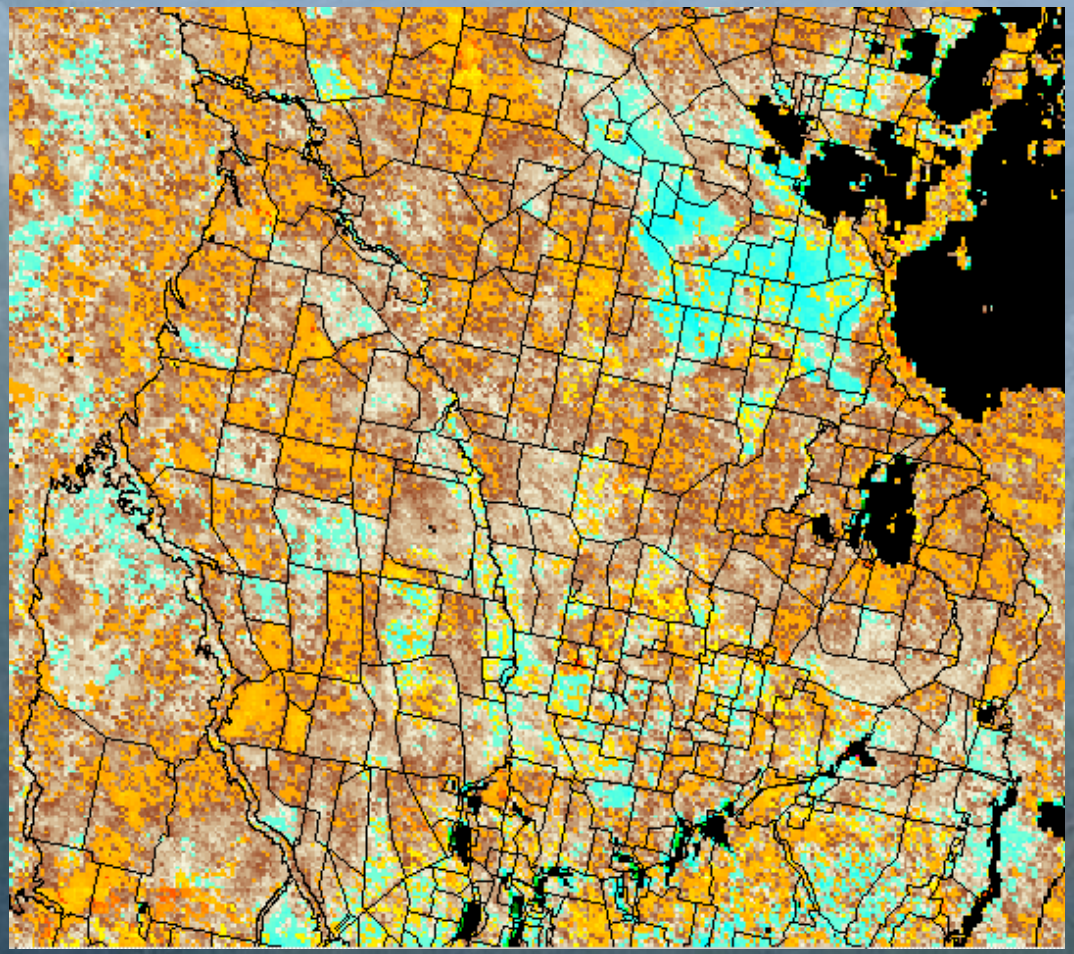
2000

Normalized Difference Vegetation Index = NIR – Red / NIR+ Red

MODIS Landscape Performance

2007 Pre-Murphy Complex Fire

Over-Performing
Normal
Under-Performing



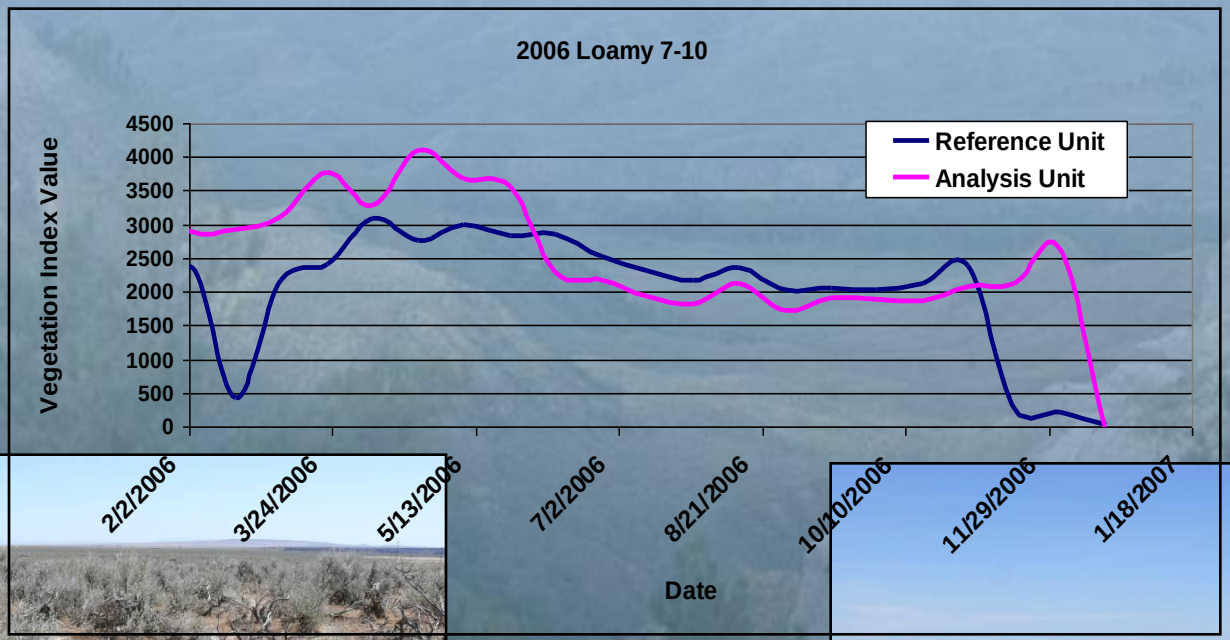
Anomalies in the Northeast Align with the Clover (7/15/05) and Sailor Cap (8/25/2006) Fires

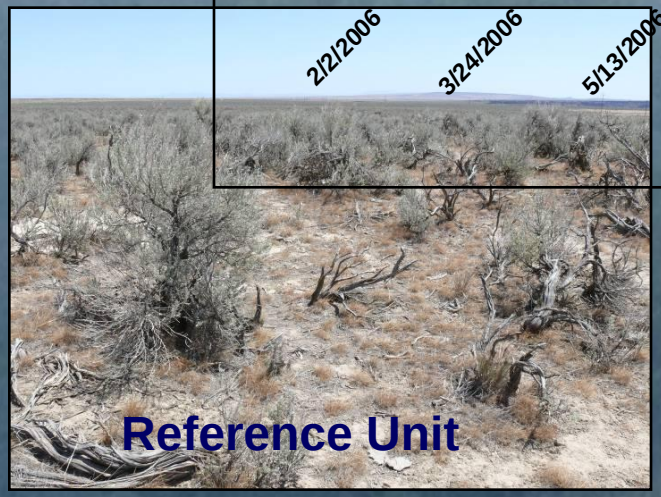
Most anomalies align with fence lines

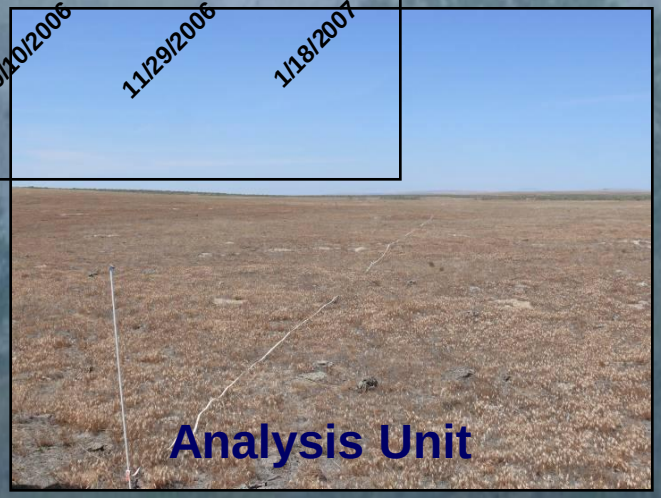
USGS

Phenological Signatures

Comparison Between Two Sites







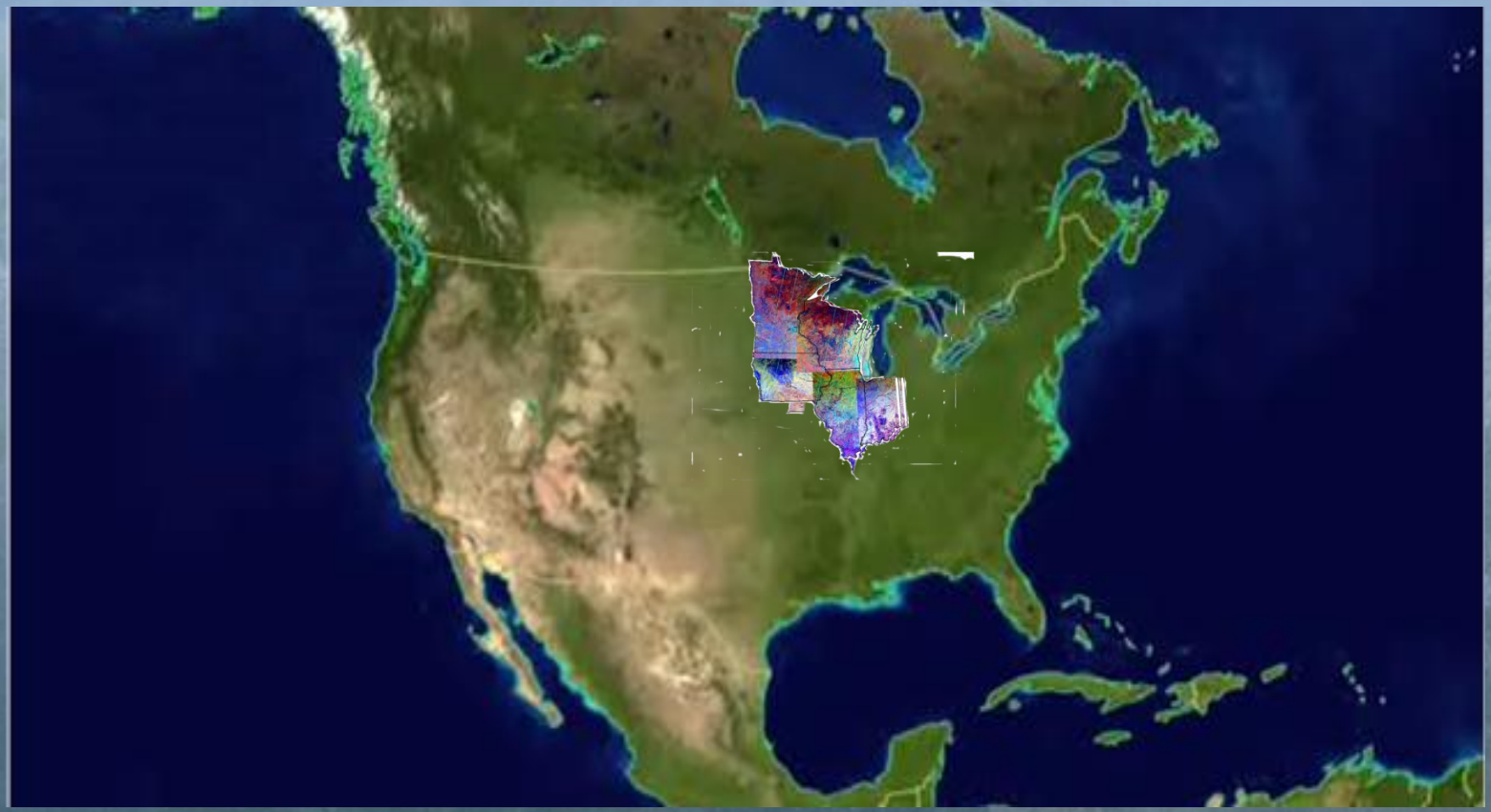
Source: J. Tagestad – Pacific Northwest National Laboratory

RapidEye
geo facts
turned into knowledge

Spectral Bands	• Blue 440 – 510 nm • Green 520 – 590 nm • Red 630 – 685 nm • Red Edge 690 – 730 nm • NIR 760 – 850 nm
Satellite Altitude	• 630 km
Camera Angle	• +/- 25 degrees
Pixel Size, (orthorectified)	• 5 m
Tile Size (scence)	• 25 x 25 km
Swath Width / Length	• 77 km x 1500 km
Revisit Time	• Daily
Equator Crossing Time	• 11:00 am
Image Capture Capacity	• 4 Million sq.km daily

Satellite Specifications

Price = ~$1.25/km2



RapidEye
geo facts
turned into knowledge

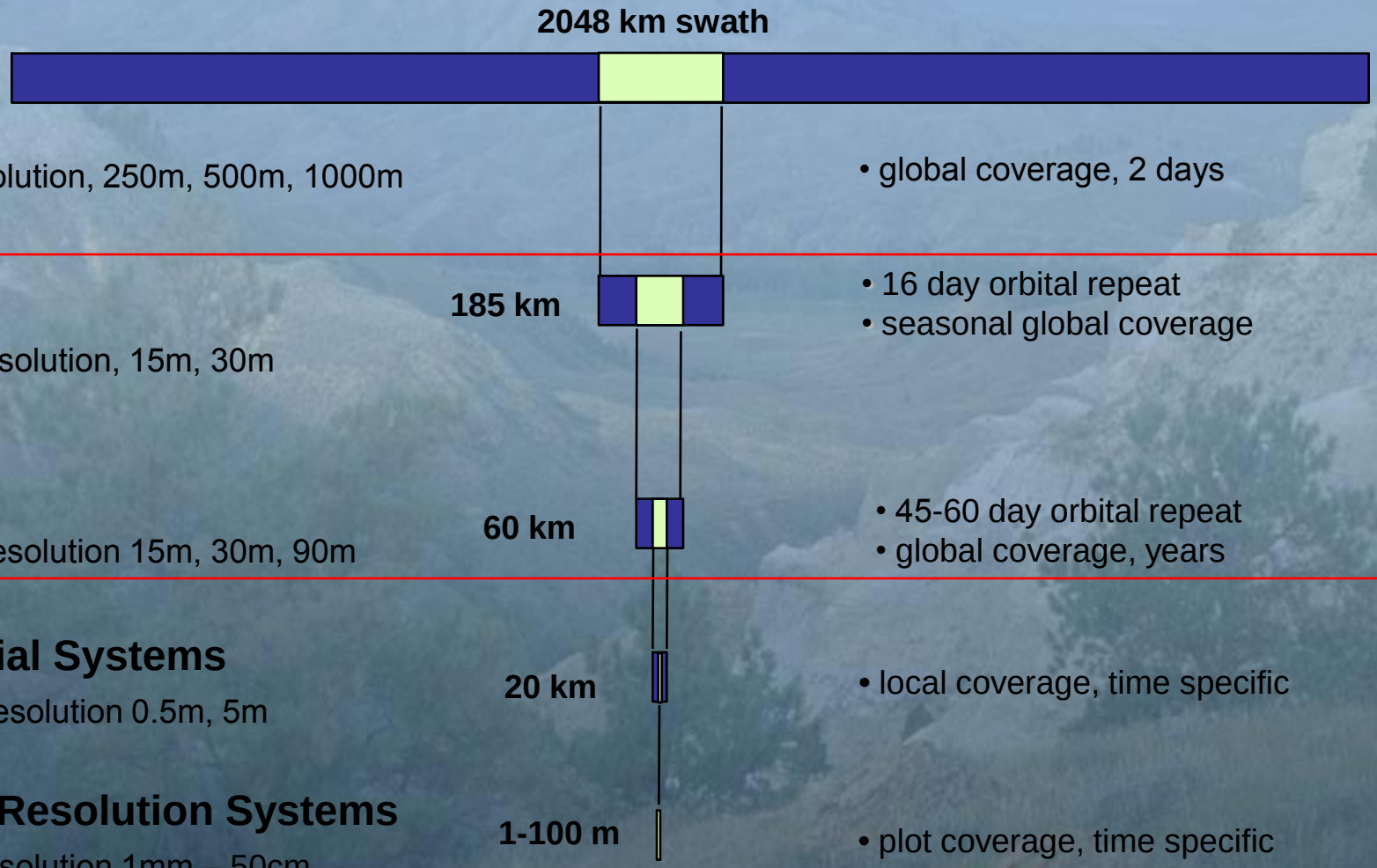
CAPABILITIES

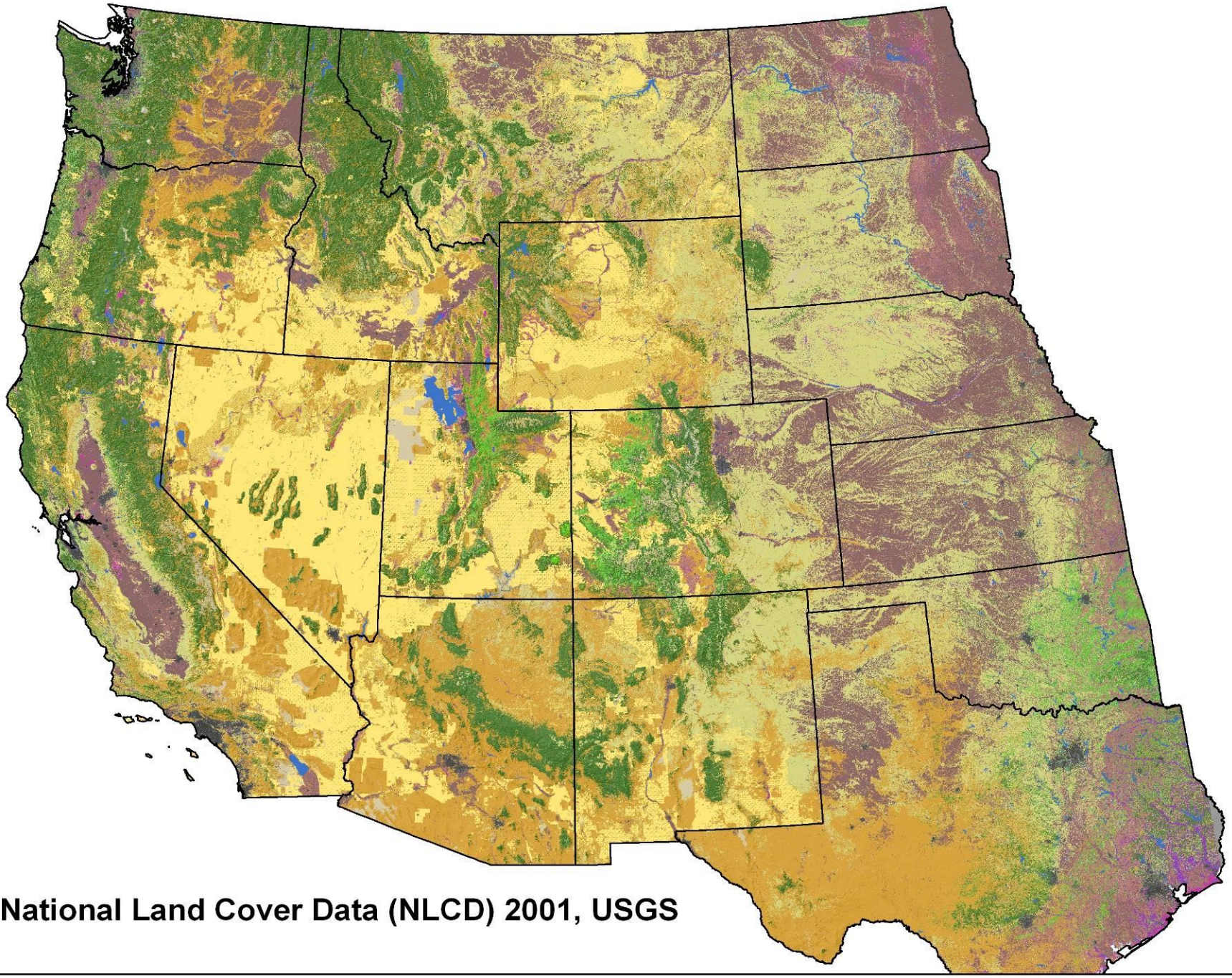
National Planning Conference
March 2009

National Operations Center
Division of Resource Services

NATIONAL SYSTEM OF PUBLIC LANDS

Remote Sensing Resolution

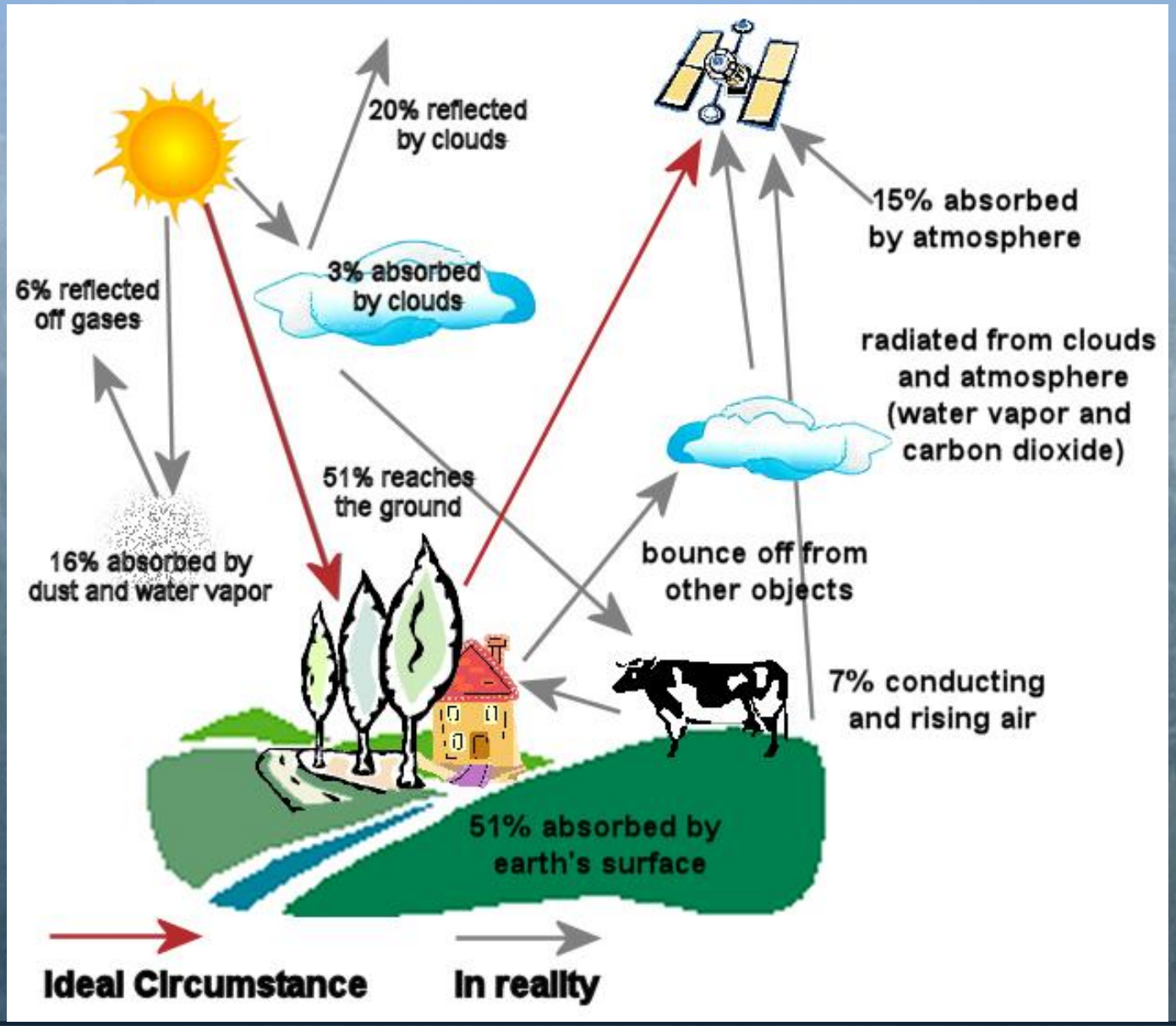




National Land Cover Data (NLCD) 2001, USGS

Vegetation Datasets

- National Land Cover Dataset (NLCD)
  - www.mrlc.gov
  - Overall: 38-70% @ Anderson Lv 2
  - Anderson Lv 1 74-85%
- LANDFIRE
  - www.landfire.gov
  - Great Basin – 50% Overall; 67% using SAF/SRM
- ReGAP – Northwest & Southwest
- SAGEMAP
  - Combines a sticthed product of multiple vegetation classification efforts


20% reflected by clouds
15% absorbed by atmosphere
3% absorbed by clouds
6% reflected off gases
radiated from clouds and atmosphere (water vapor and carbon dioxide)
51% reaches the ground
16% absorbed by dust and water vapor
bounce off from other objects
7% conducting and rising air
51% absorbed by earth's surface
Ideal Circumstance
In reality

NLCD 2001 Land Cover Classes

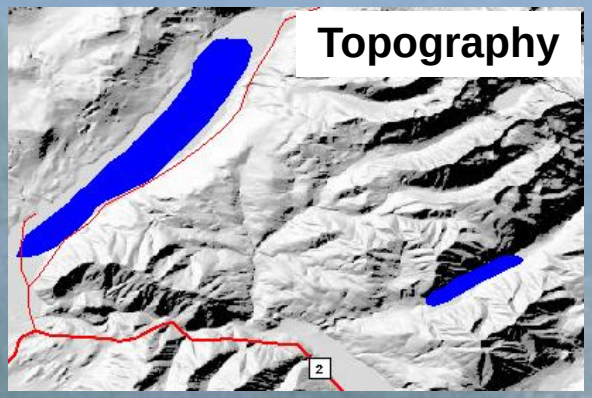
- Water
  - Open Water
  - Perennial Ice/Snow
- Developed
  - Developed, Open Space
  - Low Intensity
  - Medium Intensity
  - High Intensity
- Forests
  - Deciduous
  - Evergreen
  - Mixed
- Barren(Rock/Sand/Clay)
- Non-Vascular
  - Lichens*
  - Moss*
- Shrubland
  - Dwarf Shrub*
  - Shrub
- Grasslands/Herbaceous
  - Herbaceous
  - Sedge Herbaceous*
- Agriculture
  - Pasture/Hay
  - Cultivated Crops
- Wetlands
  - Woody Wetlands
  - Emergent Herbaceous Wetlands

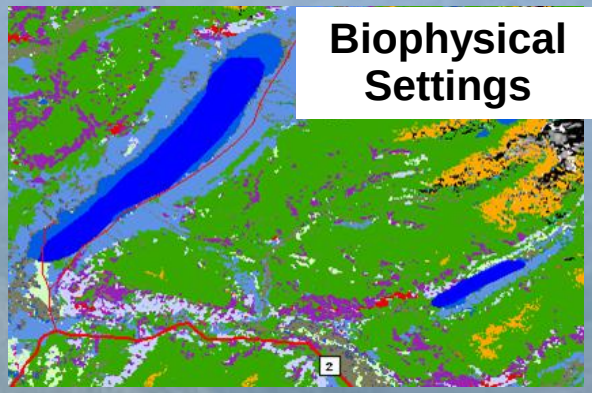
* Alaska only

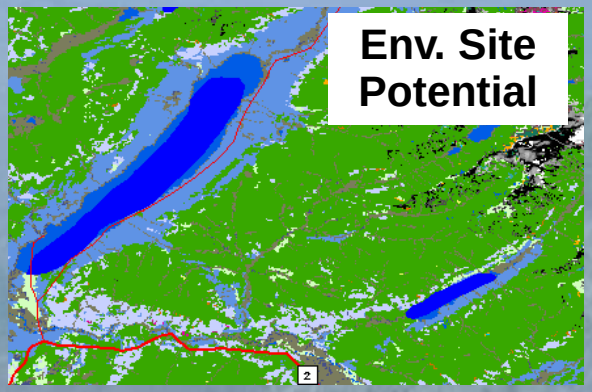
What is LANDFIRE?

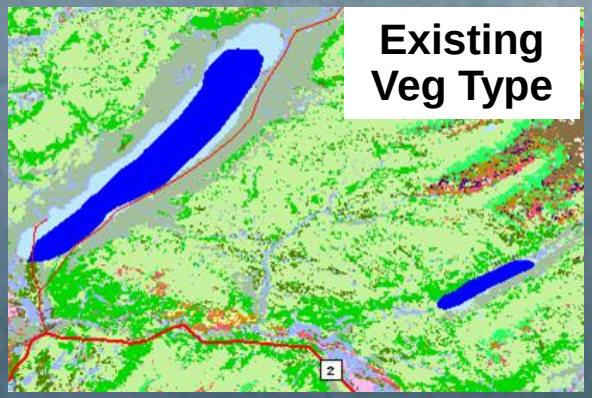
- National Effort/Multi-Agency
- Primary Focus: Develop consistent fuels and vegetation data across the nation
- Uses data from MRLC
  - Landsat-based
- Not intended for local level analysis
- Develop nationally consistent 30m map data of vegetation, wildland fuels, and ecosystem fire regime conditions

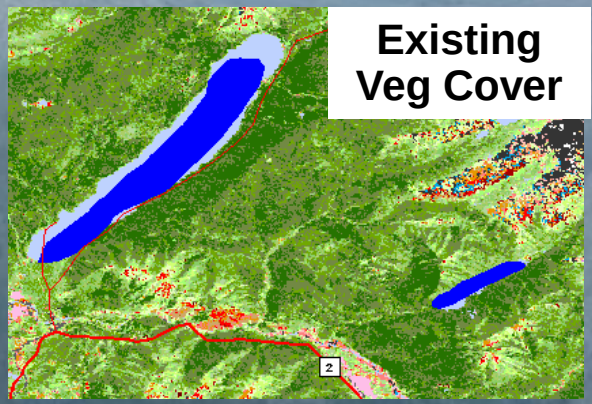
LANDFIRE – Products

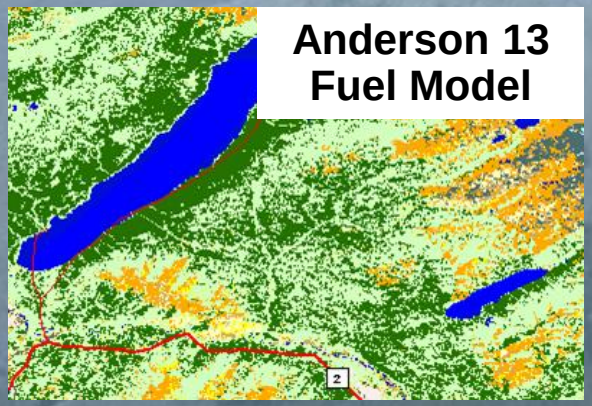


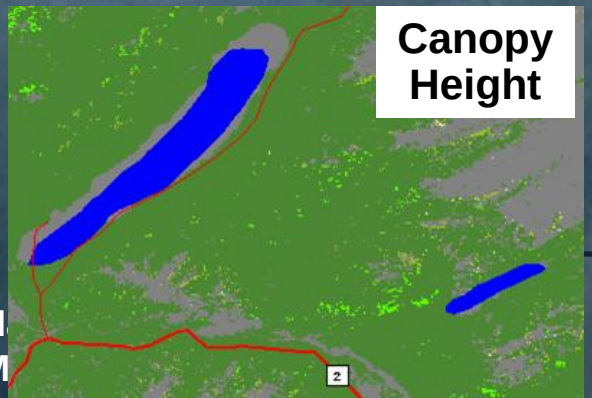


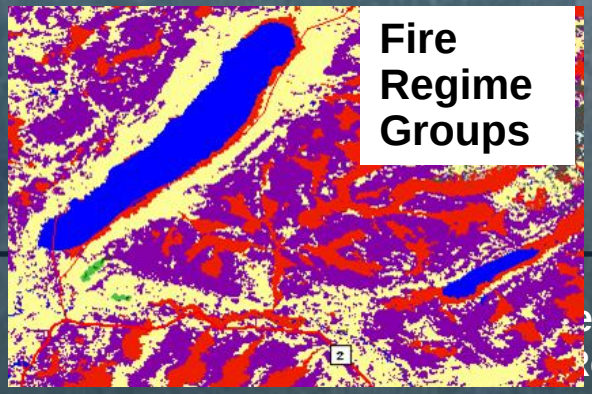


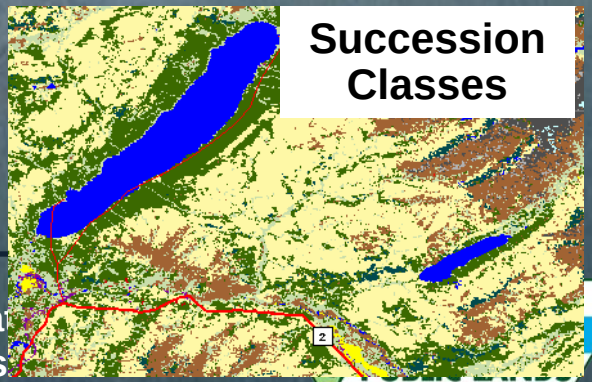












LANDFIRE Vegetation Classification System: Ecological Systems

Ecological Systems: an additional floristic level in the US-NVC hierarchy

Formation Class	Woodland
Formation Subclass	Evergreen Woodland
Formation Group	Temperate or Subpolar needle-leaved…
Formation Subgroup	Natural vs. Cultural
Formation	Rounded-crowned…
Ecological Systems	
Alliance	Pinus palustris / Quercus spp. Woodland Alliance
Association	Pinus palustris - Pinus taeda / Quercus geminata - Quercus hemisphaerica - Osmanthus americanus var. americanus / Aristida stricta Woodland

USGS science for a changing world

LANDFIRE Vegetation Classification System

NatureServe's Ecological Systems

Designed for mid-scale mapping of existing vegetation

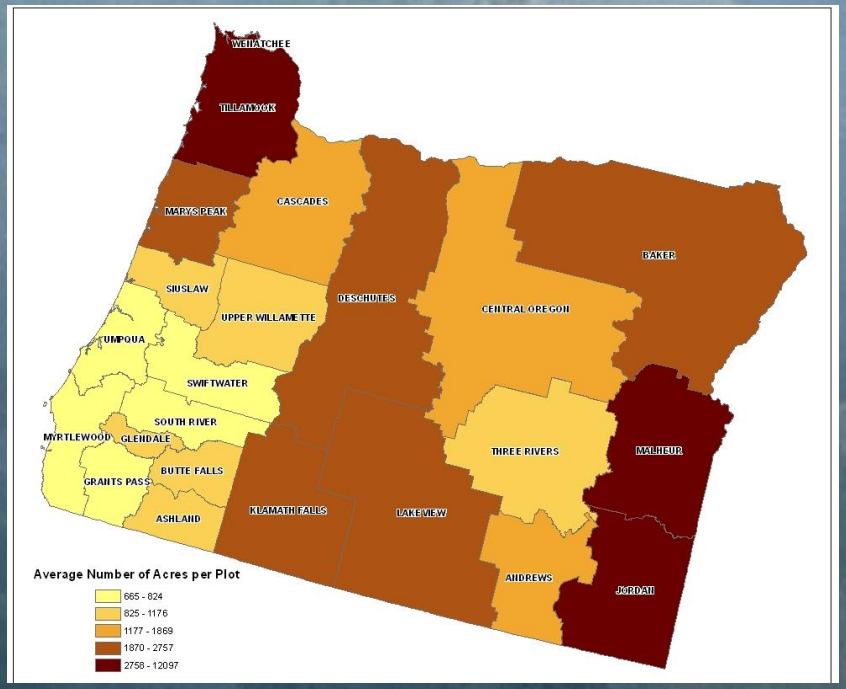
Nationally consistent and can be applied nationwide

Provided a template which could be adapted to for mapping potential vegetation

Links to National Vegetation Classification System

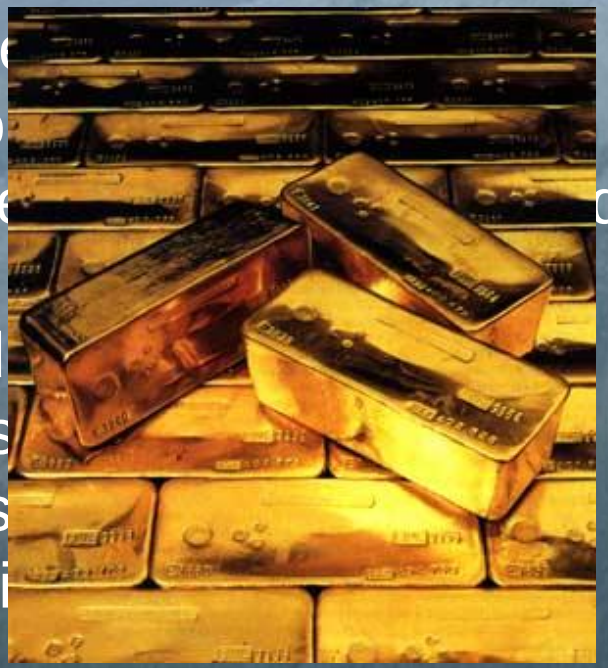
LANDFIRE Accuracy

Super Zone	Ecological System Agreement (%)	# of EVT Classes	Similarity Class Agreement (%)	# of EVT Similarity Classes Assessed	SAF/SRM Agreement (%)	# of SAF/SRM Classes Assessed
Great Basin	50	56	63	22	67	36



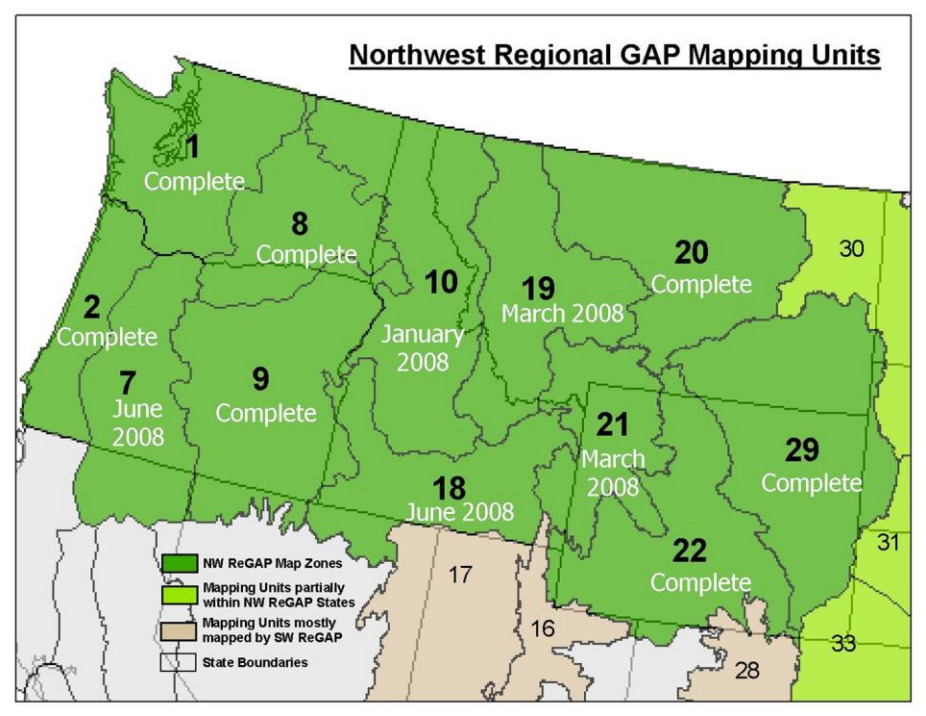
Remote Sensing and Fieldwork

- Not a re
  fieldwo
- Remote d
  data is
- Extend
- Increas
- Access
- Good fi



ReGap

Northwest



Southwest

http://gapanalysis.nbii.gov/portal/server.pt

Use the Best Information Available…

Idaho BLM Land Cover Data Standard

- Develop Idaho BLM land cover classification system consistent with NVCS
- Provide a glossary of terms.
- Define mapping standards for RMPs consistent with national standards.
  - Accuracy, minimum map units, etc.
- Provide directions for land cover classification use for RMPs.
  - Define appropriate classification thematic scale for RMP map.
  - Explain how to handle “special” fine-scale vegetation communities (e.g., aspen communities).

Why develop a standard?

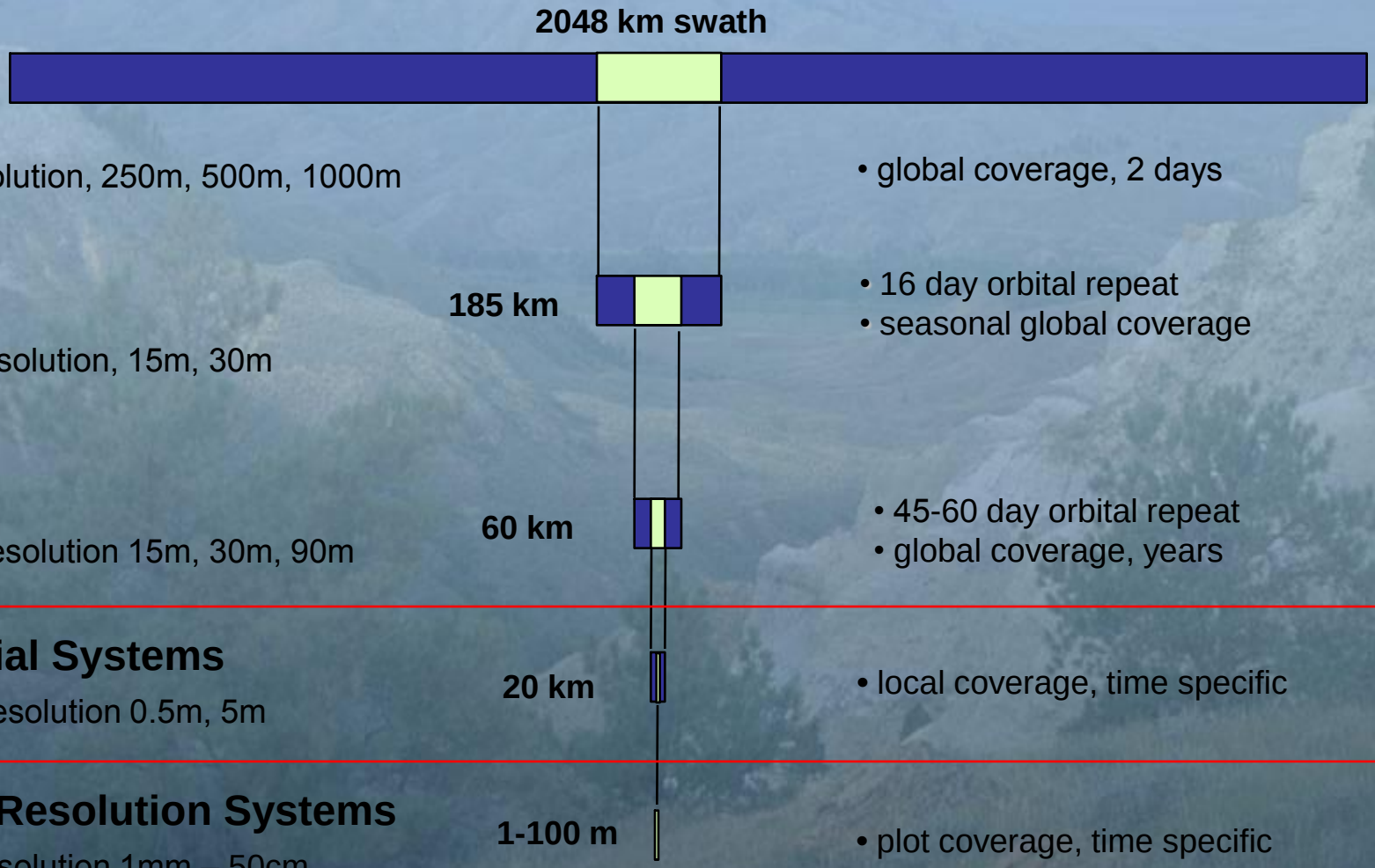
- Communication: internal and external
- Inventory: point-in-time description
- Monitoring: measuring changes over time
- Aggregating information across admin. boundaries

Idaho BLM Land Cover Classification Scheme

Scale	Planning Use	Idaho BLM Land Cover Categories
Broad-Scale	State-wide Plans	Group
	State-wide Plans / RMP	Class
	RMP	Division
	RMP / Activity Plans / Project Plans	Sub-Division
	Activity Plans / Project Plans	Ecological System
	Project Plans	Alliance
Fine Scale	Site Plans	Association

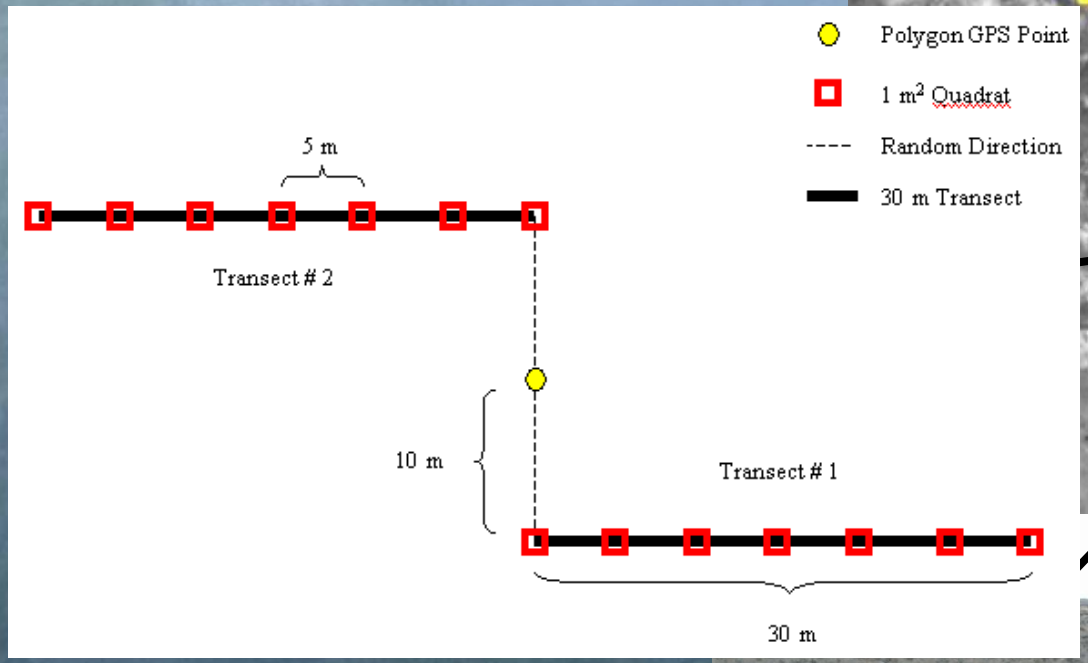
More than one way to skin a cat…
mapping vegetation isn't just about classification.

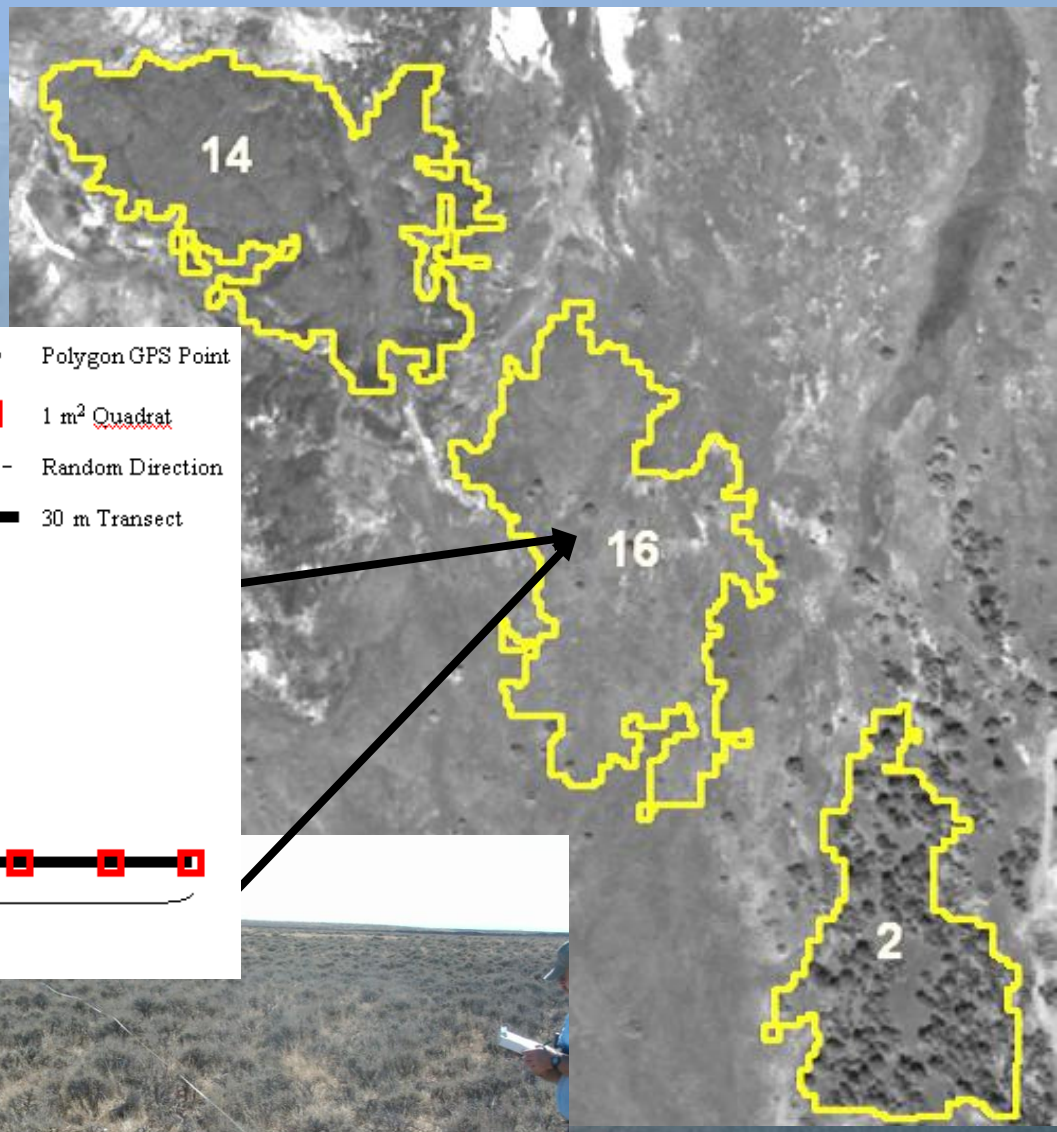
Remote Sensing Resolution

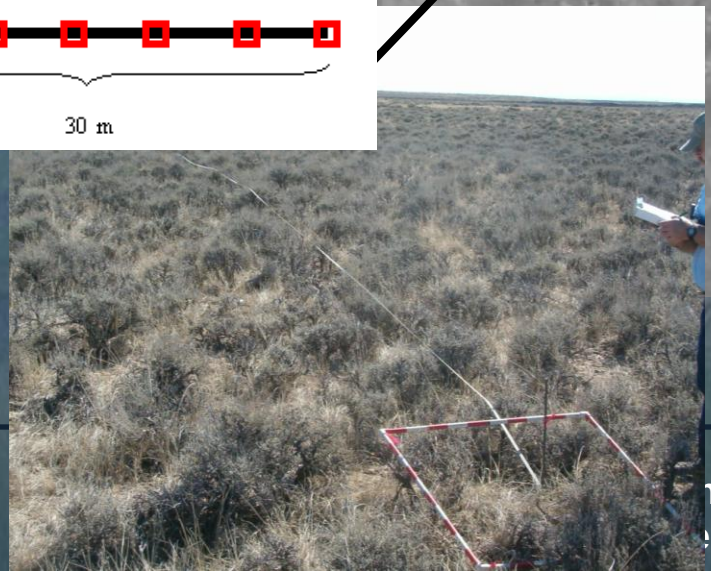


Continuous Field Mapping (CFM)

- Variation on the traditional classification mapping typically done using remote sensing data.
- Mapping variables based on their percent cover.
- Enables the ability to monitor within class vegetative changes.
  - Percent shrub, bare ground, litter, herbaceous, etc.
- Multi-scale by design





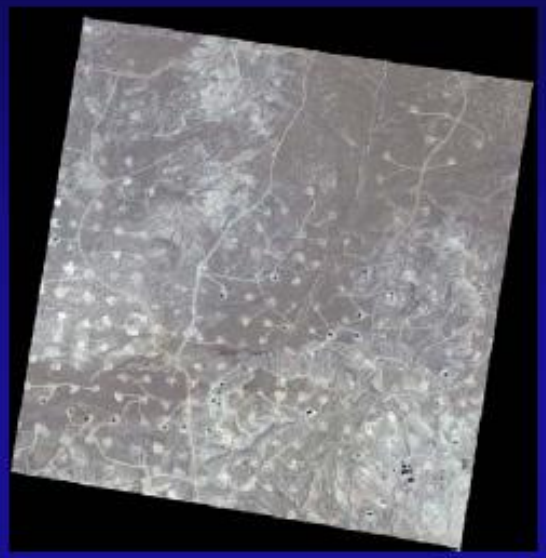


USGS

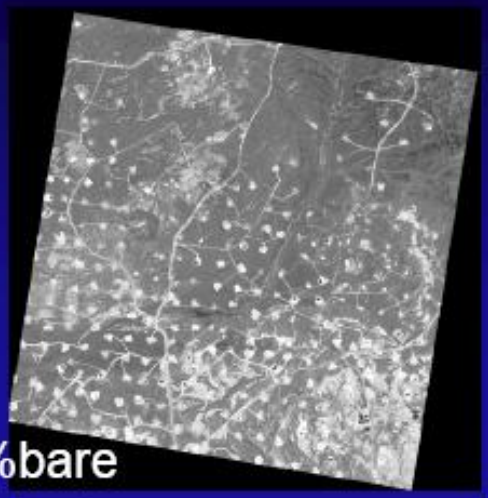
National Planning Conference
March 2009

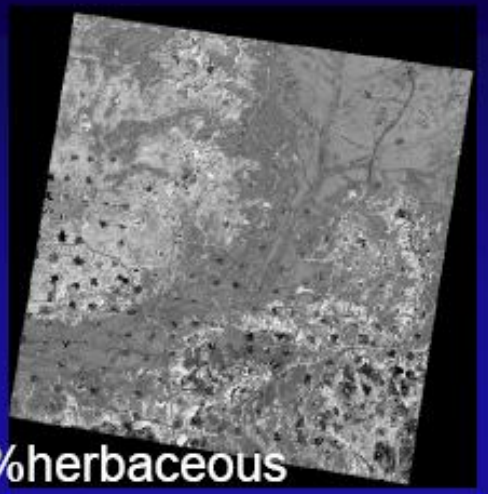
nter
ervices

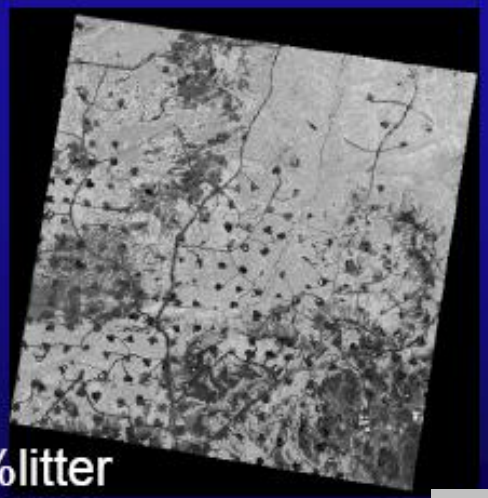
NATIONAL SYSTEM OF PUBLIC LANDS

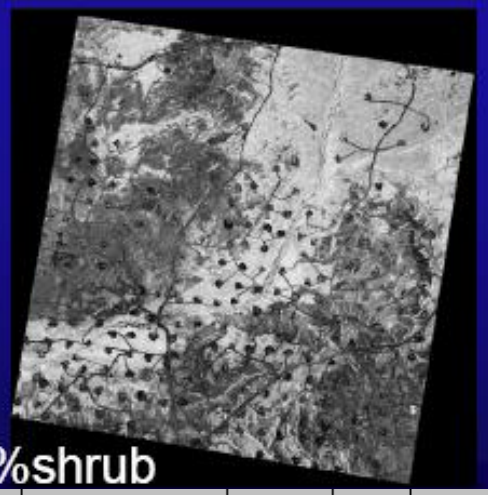


2.4m R-G-B-Nir
Quickbird Scene







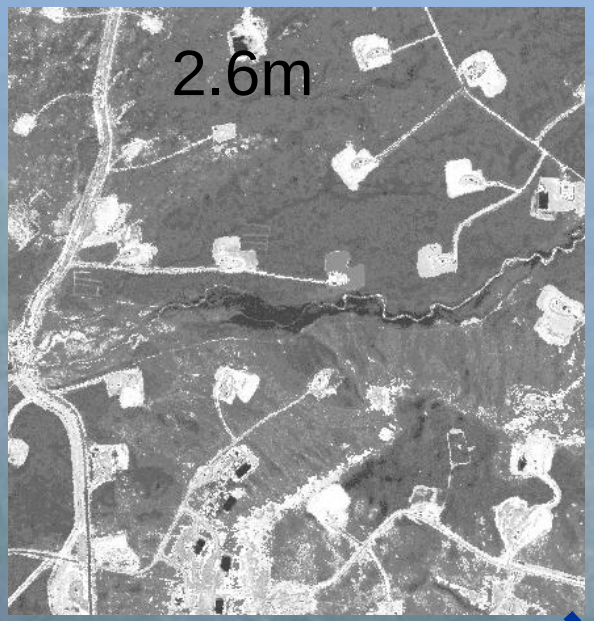


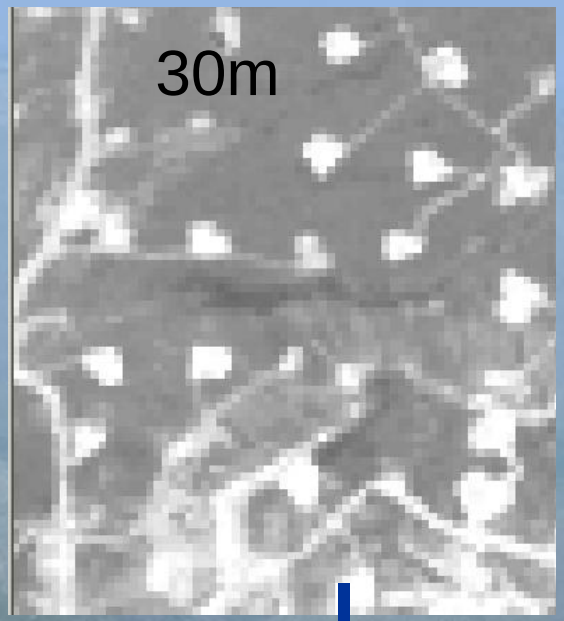
Prediction accuracies at The Quickbird scale

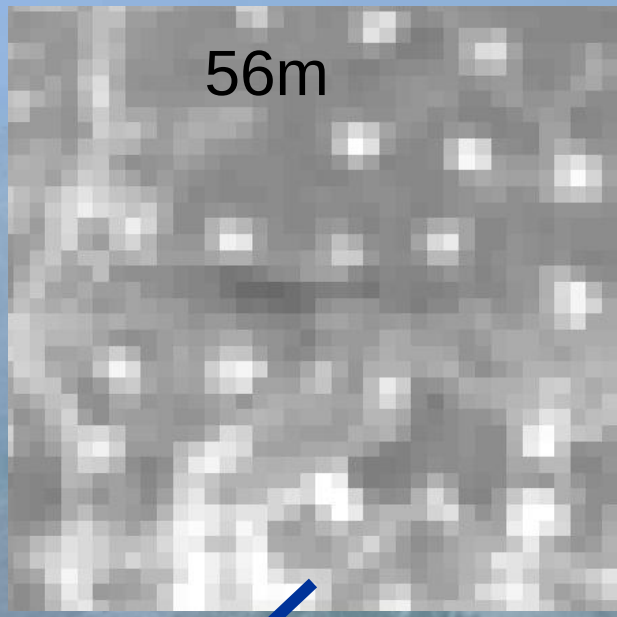
Sensor	Variable	Model R	N	R	R^2	RMSE
Quickbird	sage	0.90	61	0.92	0.85	2.99
Quickbird	shrub	0.89	61	0.91	0.82	2.95
Quickbird	bare	0.91	61	0.94	0.89	6.38
Quickbird	herbaceous	0.80	61	0.88	0.77	5.02
Quickbird	litter	0.86	61	0.90	0.82	4.36
Quickbird	big sage	0.89	61	0.9	0.84	3.04
Quickbird	wyomingensis	0.85	61	0.9	0.75	3.71
Quickbird	h_shrub	0.85	61	0.9	0.79	5.07

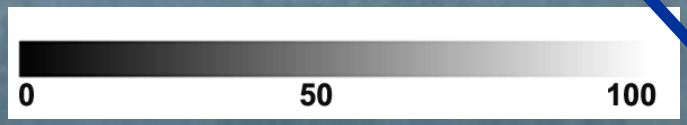
Digital Globe

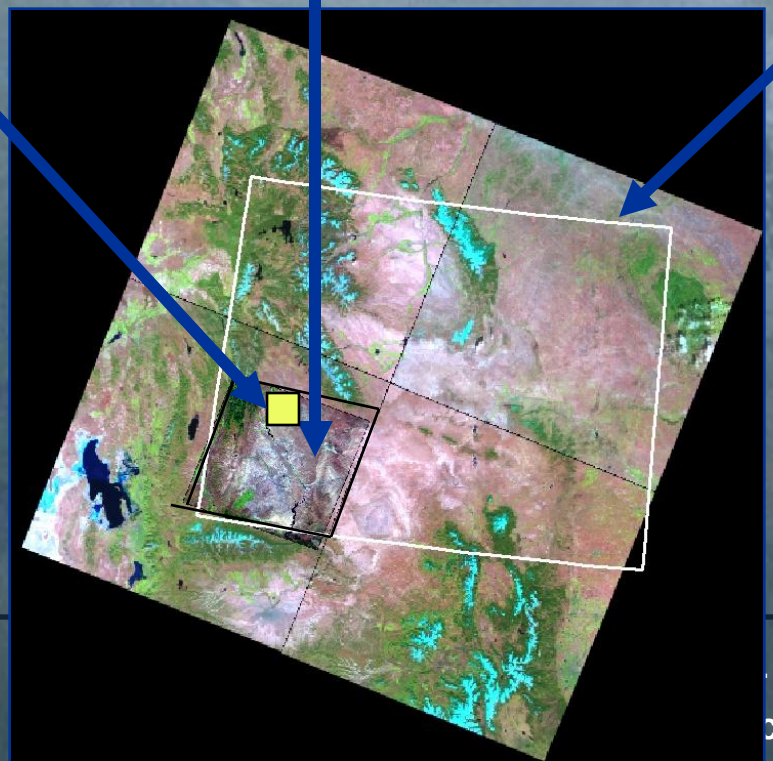
- Quickbird (2001)
  - 60 cm Pan; 2.4 m Multispectral (VISNIR)
  - 4 Bands
  - 23 m CE90
- WorldView-1 (2008)
  - 50 cm Pan
  - Stereo Capability
  - 6.5 m CE90
- WorldView-2 (2009)
  - 46 cm Pan; 1.8 m Multispectral
  - 8 Bands
  - 12 m CE90
- Cost = ~25/km^2











Percent Bare Ground estimate @ 3 scales

USGS

NATIONAL SYSTEM OF PUBLIC LANDS

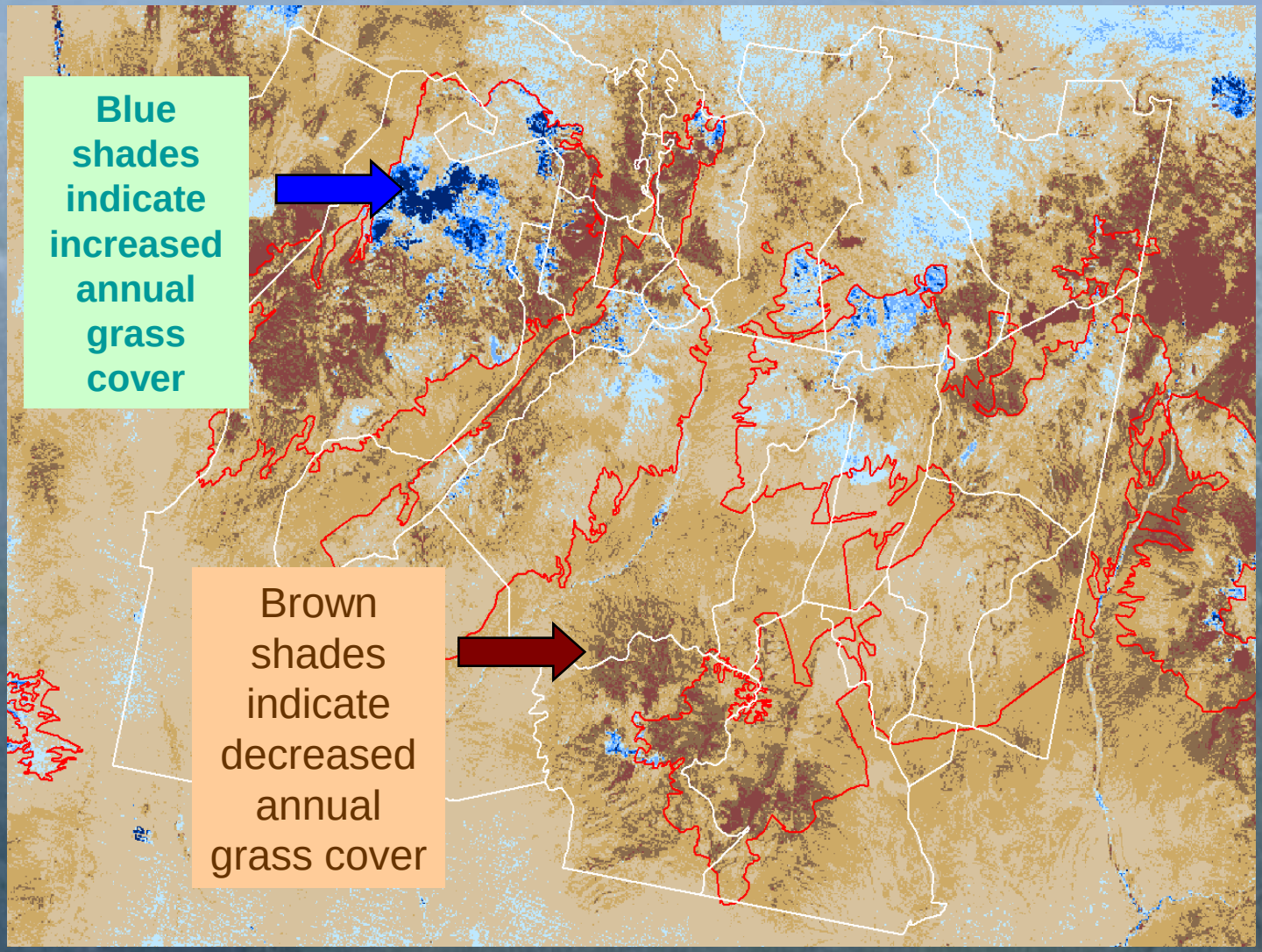
Billings Field Office

- In the midst of their RMP
- Contracted with USGS to develop CFMs for majority of planning area
- Will use to provide baseline vegetation data
- Primarily intended as a monitoring tool – process will be repeated periodically to provide data for quantifying if vegetation goals are being met.

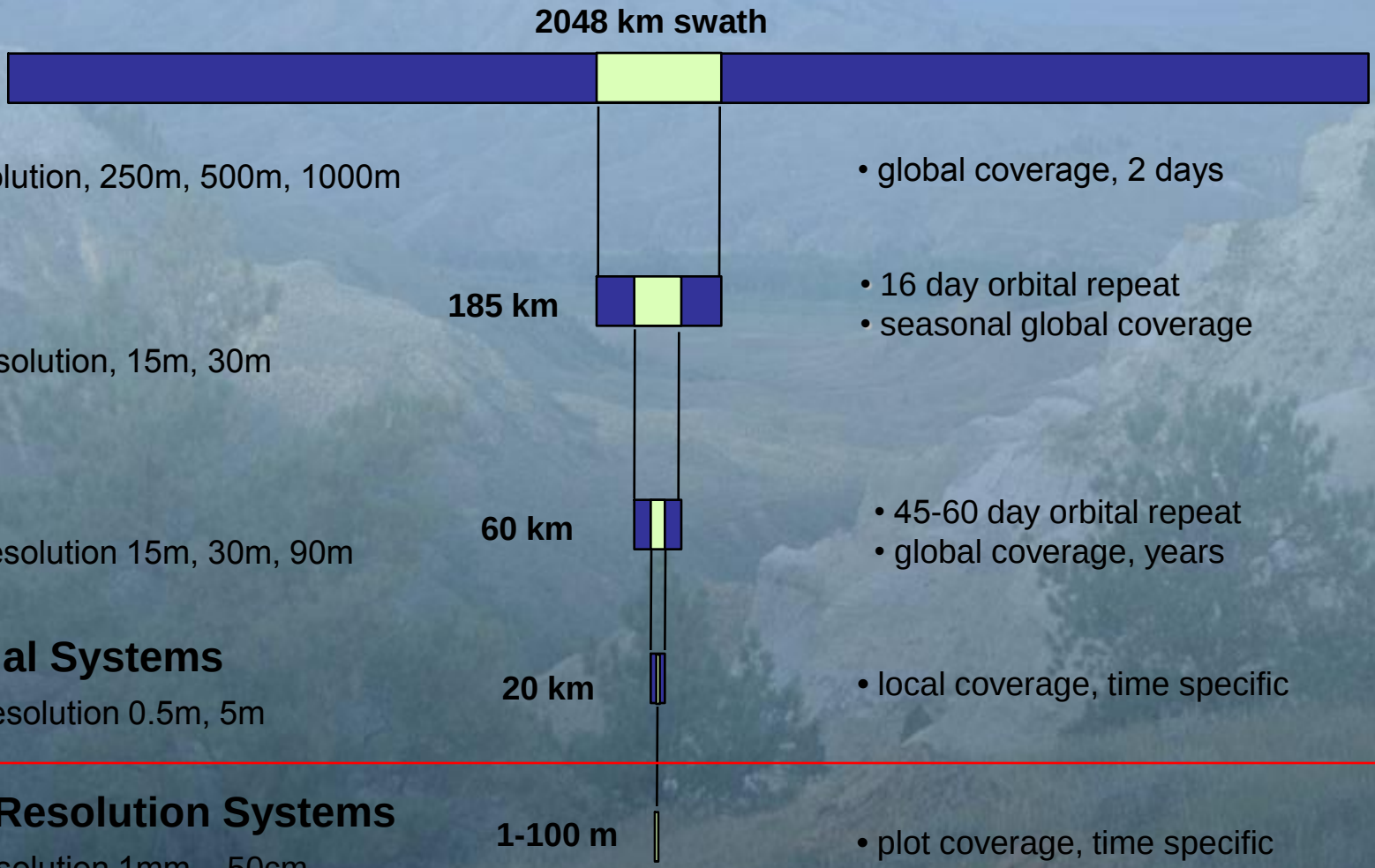
Effectiveness of Treatments

- Map past treatments (i.e. prescribed fire, seeding)
- Cumulative effect of disturbance (i.e. invasives, fragmentation)
- Cumulative effect of treatments (i.e. connectivity, fire regime)

Detecting Annual Grasses



Remote Sensing Resolution



AVHRR/ MODIS

- spatial resolution, 250m, 500m, 1000m
- global coverage, 2 days

Landsat

- spatial resolution, 15m, 30m
- 16 day orbital repeat
- seasonal global coverage

ASTER

- spatial resolution 15m, 30m, 90m
- 45-60 day orbital repeat
- global coverage, years

Commercial Systems

- spatial resolution 0.5m, 5m
- local coverage, time specific

Very High Resolution Systems

- spatial resolution 1mm – 50cm
- plot coverage, time specific

VLSA for Natural Resource Management

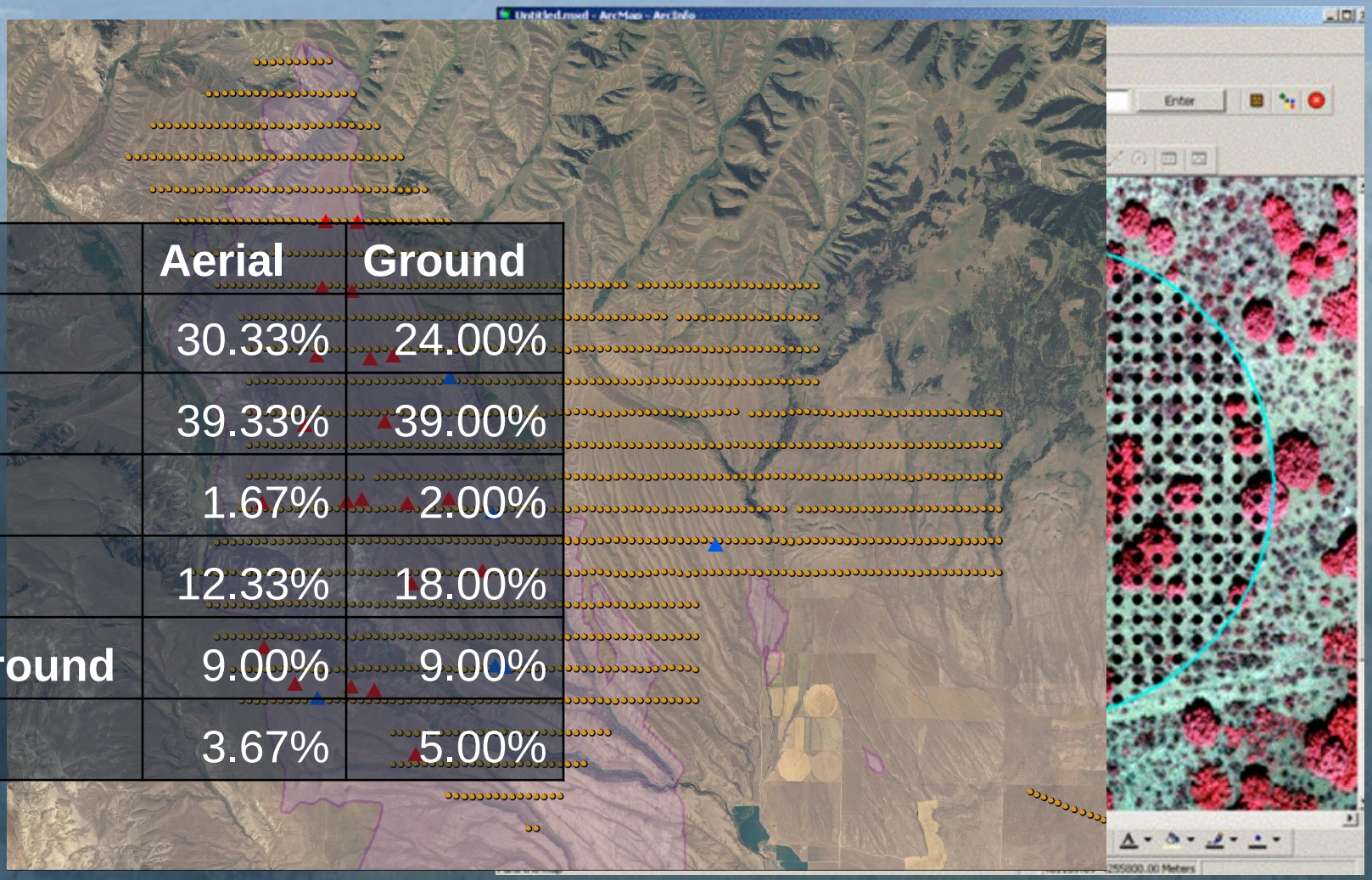
National Planning Conference
March 2009

National Operations Center
Division of Resource Services

NATIONAL SYSTEM OF PUBLIC LANDS

Remote Sensing as Sampling

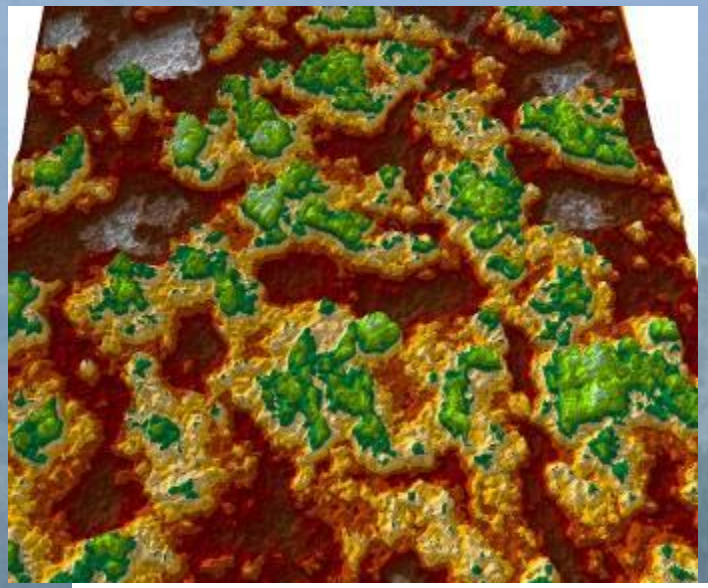
	Aerial	Ground
Grass	30.33%	24.00%
Forb	39.33%	39.00%
Shrub	1.67%	2.00%
Litter	12.33%	18.00%
Bare ground	9.00%	9.00%
Rock	3.67%	5.00%

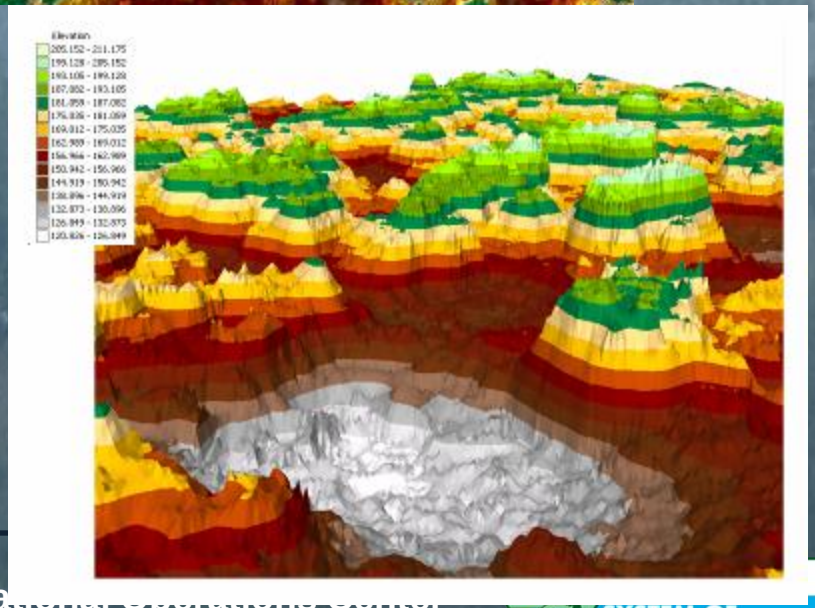


Cost Comparison:

- Traditional Monitoring
  - 27 plots in 50,000 acre project area (Medicine Lodge)
  - Most allotments have 1 study plot per pasture
  - 2-3 plots per day
  - 4 hours per plot site including travel time and post processing
  - Typically 15 – 20 sites visited yearly
  - $74.80 / site (GS-8, monitoring tech)
- Aerial Monitoring
  - One time funded monitoring project (Medicine Lodge) – $25K
    - 1500 (3000 photos) photographic locations per 50,000 Acres
    - Flight Time = 6 hours
    - Analysis using existing software and verified with traditional data
    - $16.67 / site (preflight planning, flight, post processing, travel and per diem)
  - UAV purchase (50,000 acres/year with 3000 photo locations)
    - 1st Year: $4.87 / site ($12,000 plus ½ WM preflight planning, flight, post processing)
    - 2nd Year: $2.87 / site ($6,000 plus ½ WM preflight planning, flight, post processing)
    - 3rd Year: $1.87 / site ($3,000 plus ½ WM preflight planning, flight, post processing)

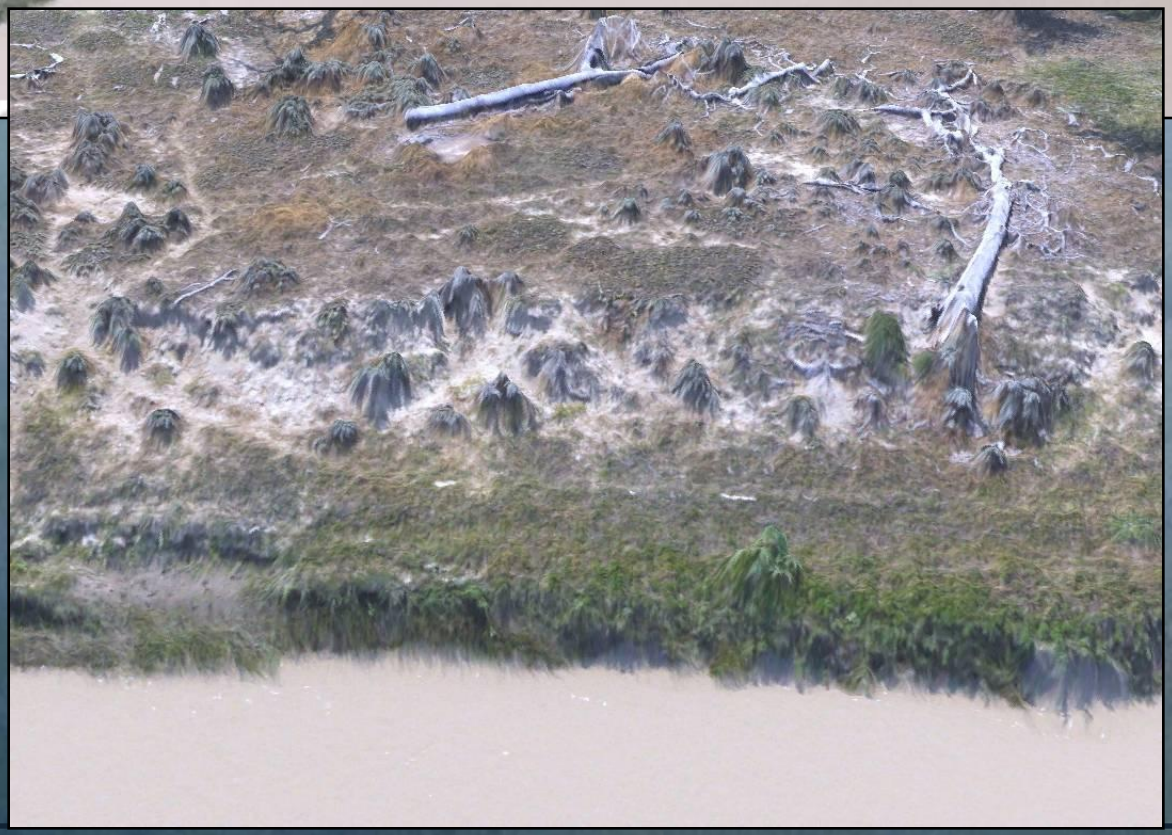
Soil Monitoring





Powder River Basin Remote Sensing

- Multi-Agency effort to study the impacts of Coalbed Methane Development on the aquatic/riparian habitats
- Quantify in-stream habitats
  - Mapping verses Sampling
- Monitor in-stream habitats under different flow rates
  - Intra-annual and Inter-annual
- Derived measurements of channel properties
- Map riparian vegetation and invasive species
- Test new methods for developing stereo models from Very Large Scale Aerial (VLSA) photography



Derived Data

1. Vegetation Heights
2. Bank Erosion, Slope
3. Water Depth (need baseline of empty stream channel elevation)
4. Vegetative cover/Bare Ground

Uses

1. Training coarser resolution imagery
2. Monitoring invasive species
3. Change detection
4. Guide sampling
5. Visualization tool

Need

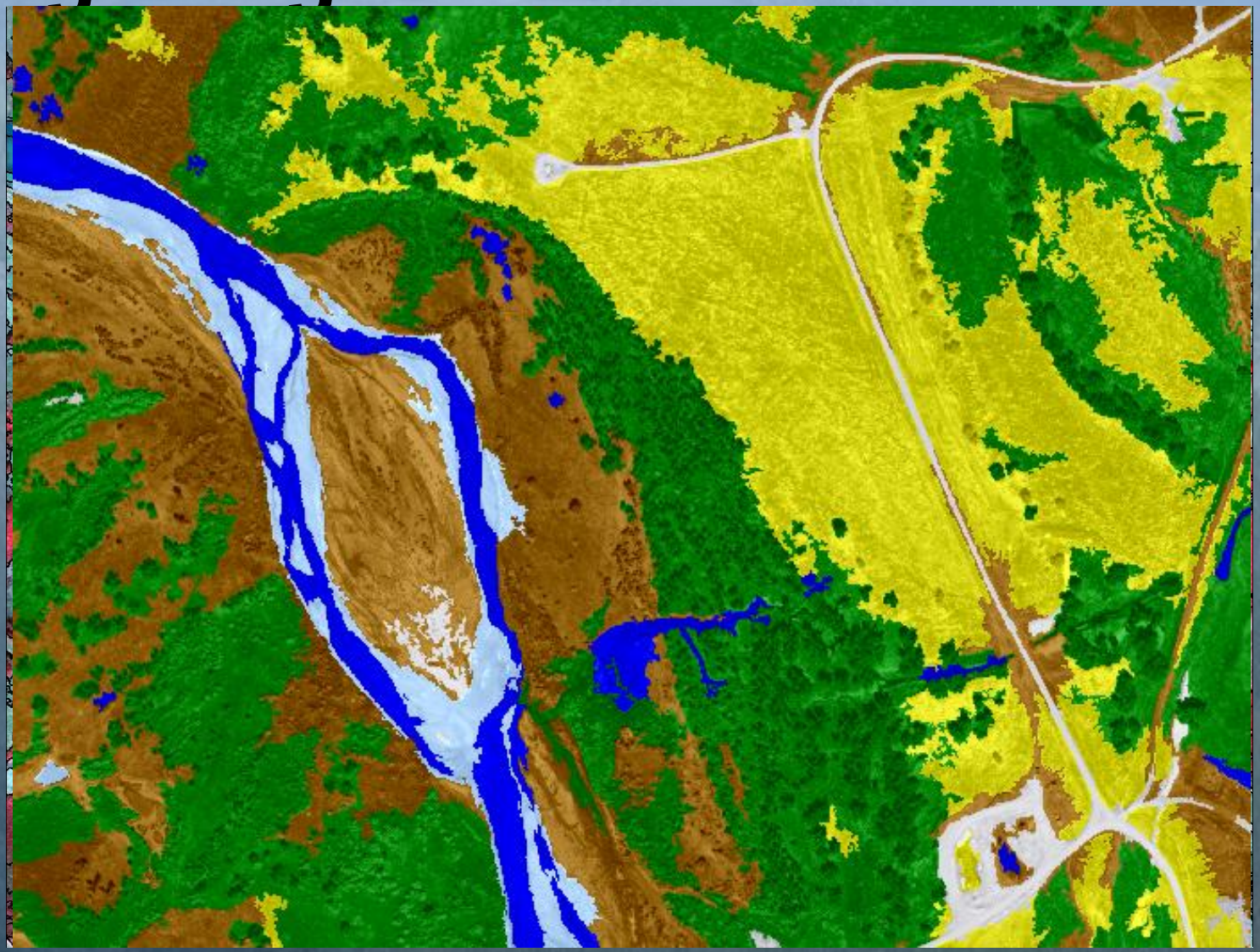
Accurate, Low-cost, multi-temporal, co-registered imagery

Some Available Resources

IP Software Tools

- Imagine 9.1 Available; 9.2 in testing
- Feature Analyst 4.1 (4 ArcGIS; 1 Imagine)
- Image Analysis for ArcGIS 9.2
- ENVI 4.5 (2 licenses)
- Definiens Developer 7 (1 license)
- Image Server
- Leica Photogrammetry Suite 9.2
- Stereo Analyst for ArcGIS 9.2 in testing
- ILMNIRM3AP9

Image Segmentation

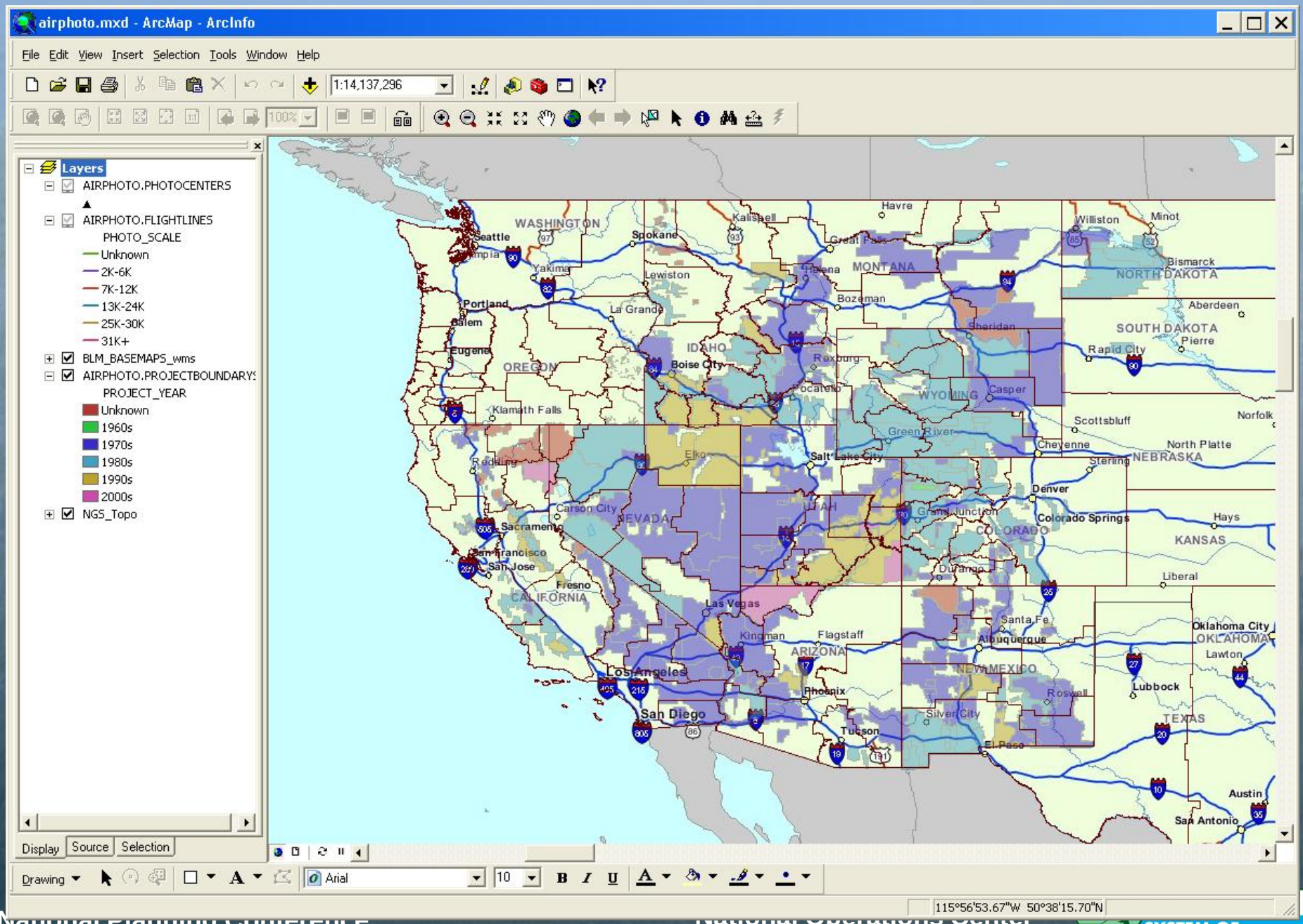


Remote Sensing Applications Center (RSAC)

- US Forest Service Research Center
- http://fsweb.rsac.fs.fed.us/
- Great resource for remote sensing information
- Seamless 1-meter orthophotography for the US
- Requires client installed in ArcMap
- 166.2.126.235

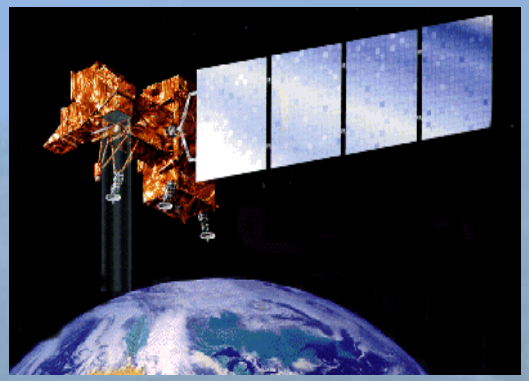
Aerial Photography Spatial Index (APSI)

- Citrix Application – Need to be added to permissions list
  - **https://citrixnr.blm.doi.net**.
- ArcMap document to search for historical aerial photography collected by the BLM
- Approximately 600,000 frames
- Public Access: GeoCommunicator
- Internal: Translated into ArcGIS Server


airphoto.mxd - ArcMap - ArcInfo
File Edit View Insert Selection Tools Window Help
1:14,137,296
Layers
AIRPHOTO.PHOTOCENTERS
AIRPHOTO.FLIGHTLINES
PHOTO_SCALE
Unknown
2K-6K
7K-12K
13K-24K
25K-30K
31K+
BLM_BASEMAPS_wms
AIRPHOTO.PROJECTBOUNDARYS
PROJECT_YEAR
Unknown
1960s
1970s
1980s
1990s
2000s
NGS_Topo
Display Source Selection
Drawing
Arial
10
115°56'53.67"W 50°38'15.70"N
WASHINGTON
OREGON
CALIFORNIA
IDAHO
NEVADA
MONTANA
WYOMING
UTAH
COLORADO
ARIZONA
NEW MEXICO
NORTH DAKOTA
SOUTH DAKOTA
NEBRASKA
KANSAS
OKLAHOMA
TEXAS
Seattle
Spokane
Portland
Salem
Eugene
Yakima
Lewiston
La Grande
Boise City
Klamath Falls
Redding
Sacramento
San Francisco
San Jose
Fresno
Carson City
Elko
Salt Lake City
Las Vegas
Los Angeles
San Diego
Phoenix
Tucson
Flagstaff
Kingman
Albuquerque
Santa Fe
Roswell
Silver City
El Paso
Denver
Colorado Springs
Grand Junction
Durango
Cheyenne
Casper
Rawlins
Rock Springs
Green River
Rexburg
Pocatello
Sheridan
Billings
Bozeman
Great Falls
Havre
Kalispell
Williston
Minot
Bismarck
Aberdeen
Pierre
Rapid City
Scottsbluff
Sterling
North Platte
Norfolk
Hays
Liberal
Lubbock
Oklahoma City
Lawton
Austin
San Antonio

Our Changing Landscape

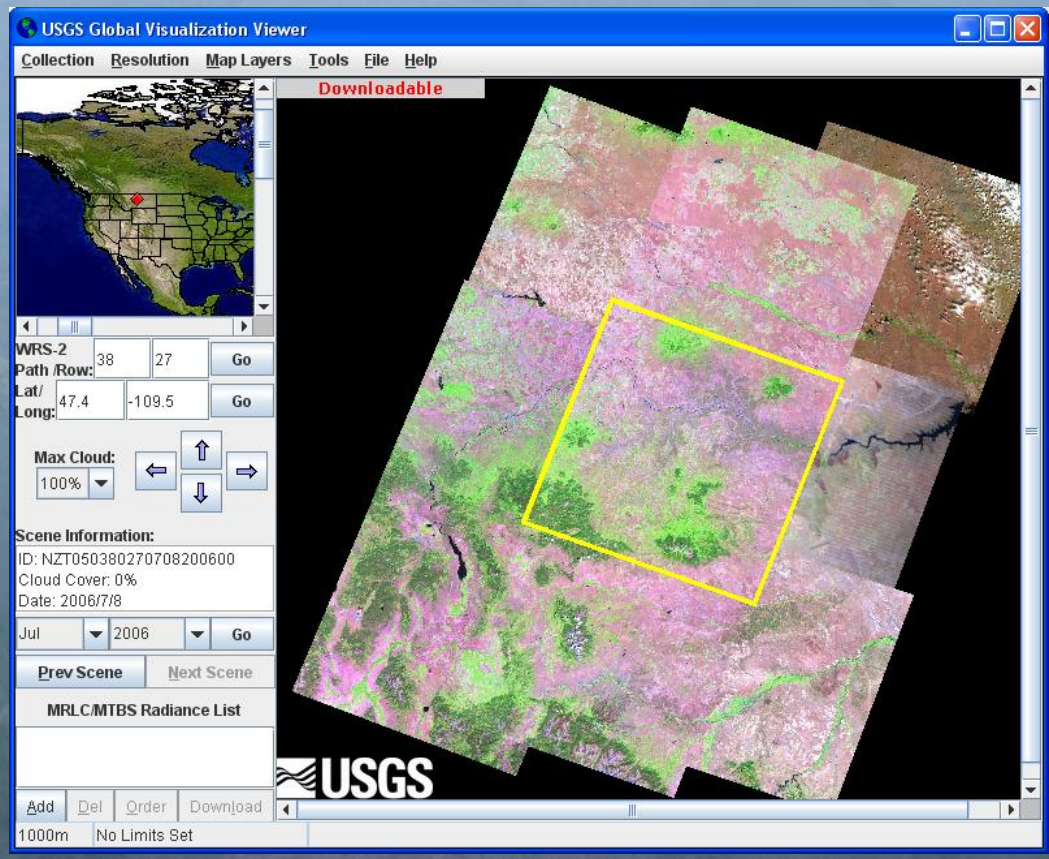
Landsat



- Landsat 1, 2, and 3 MultiSpectral Scanner (MSS) – 4 bands, 80 meter spatial resolution (1972-1983).
- Landsat 3, 4, and 5 carried both MSS and Thematic Mapper (TM) sensors (Landsat 4 1982-1992, Landsat 5 1984-present).
- Landsat 6 occupies a sub-aqueous orbit
- Landsat 7 carries the Enhanced Thematic Mapper Plus (ETM+), with 30m visible and IR bands, a 60m thermal band, and a 15m panchromatic band (185 km swath width) (1998).
- Landsat 8 (LCDM) planned for 2011

Glovis

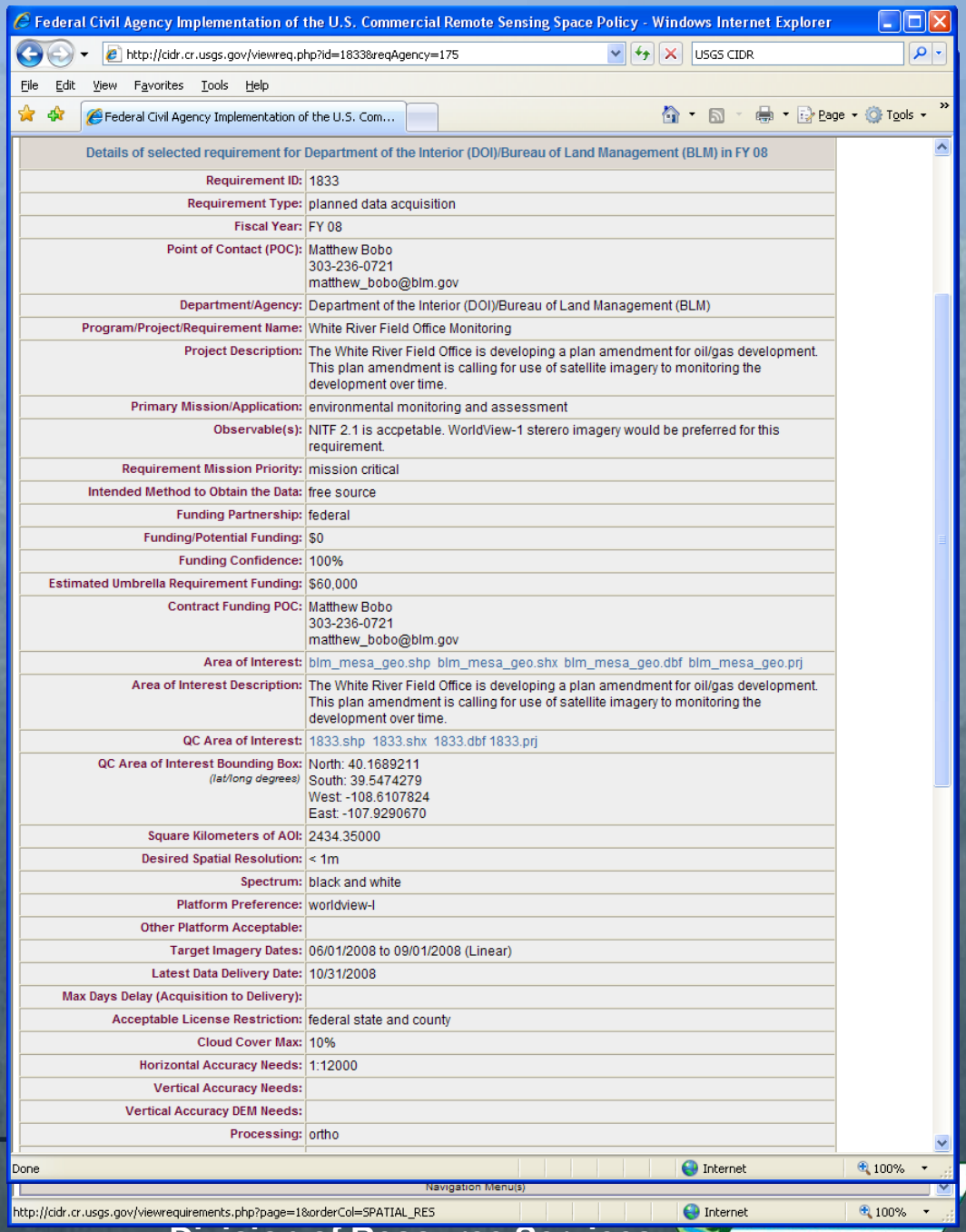
- Search variety of image datasets maintained by USGS
- Several collections are free to download
- Tool used to distribute all free Landsat data



http://glovis.usgs.gov

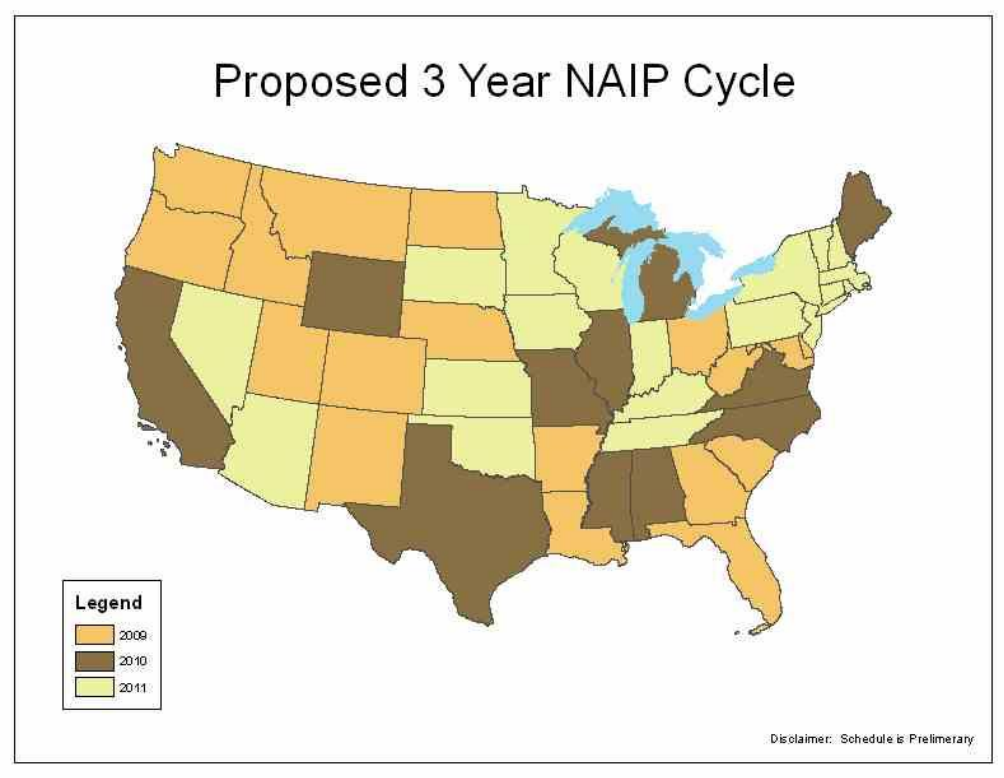
CIDR

- http://cidr.cr.usgs.gov/main.php
- Mechanism for acquiring free high resolution imagery
- NOC can assist with defining requirements

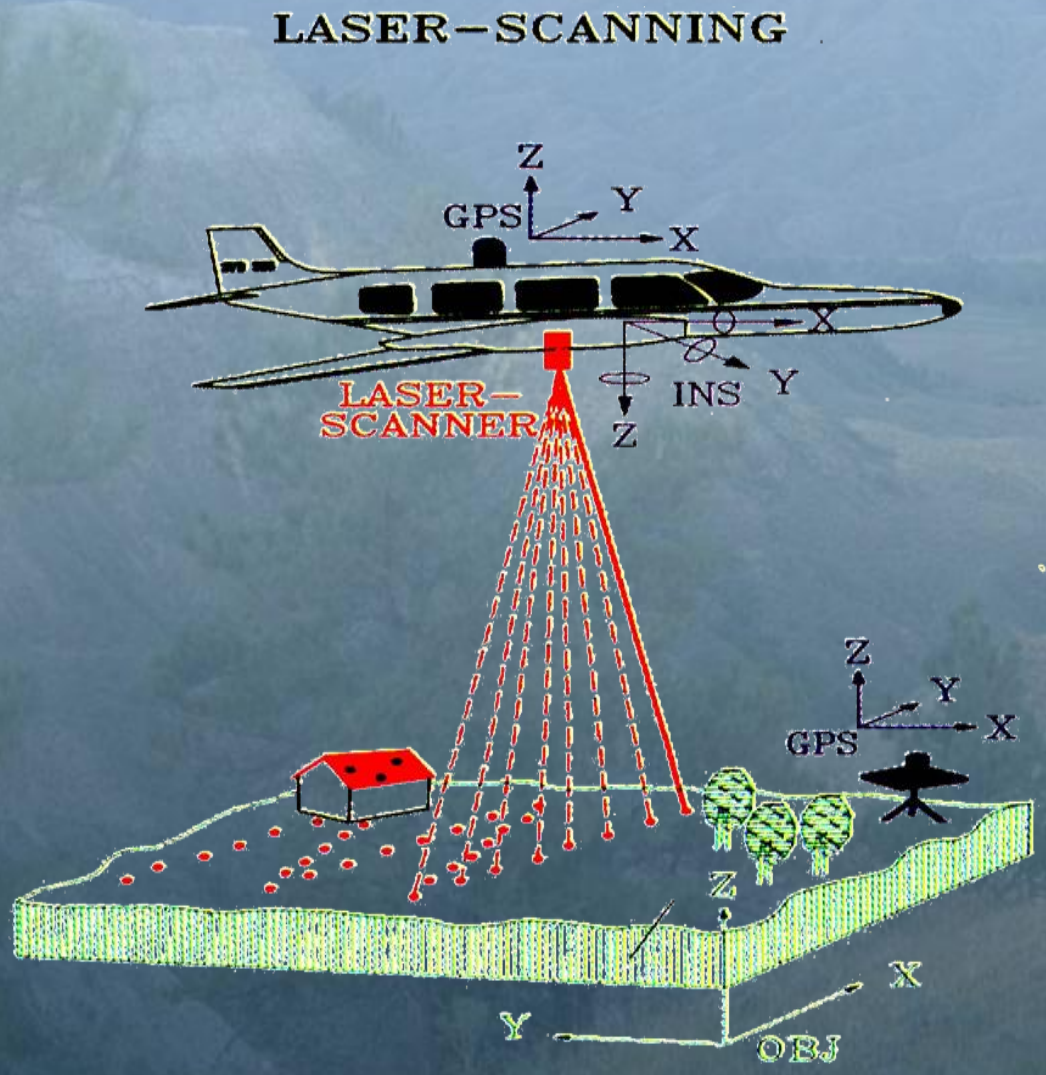


National Agricultural Imagery Program

- New Collection Schedule – Every 3 yrs
- WO secured funds for states
- Only AG lands guaranteed
- 15% premium for 4-Digital Orthos
- ~$1.4 million for Idaho
  - $215/DOQQ



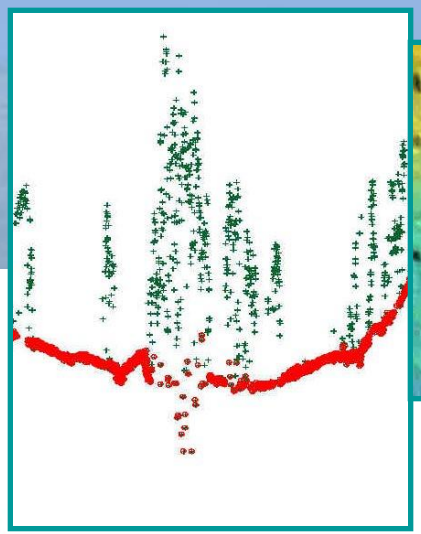
LIDAR

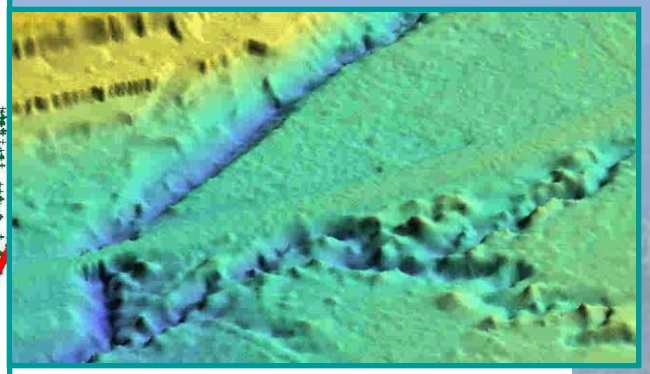


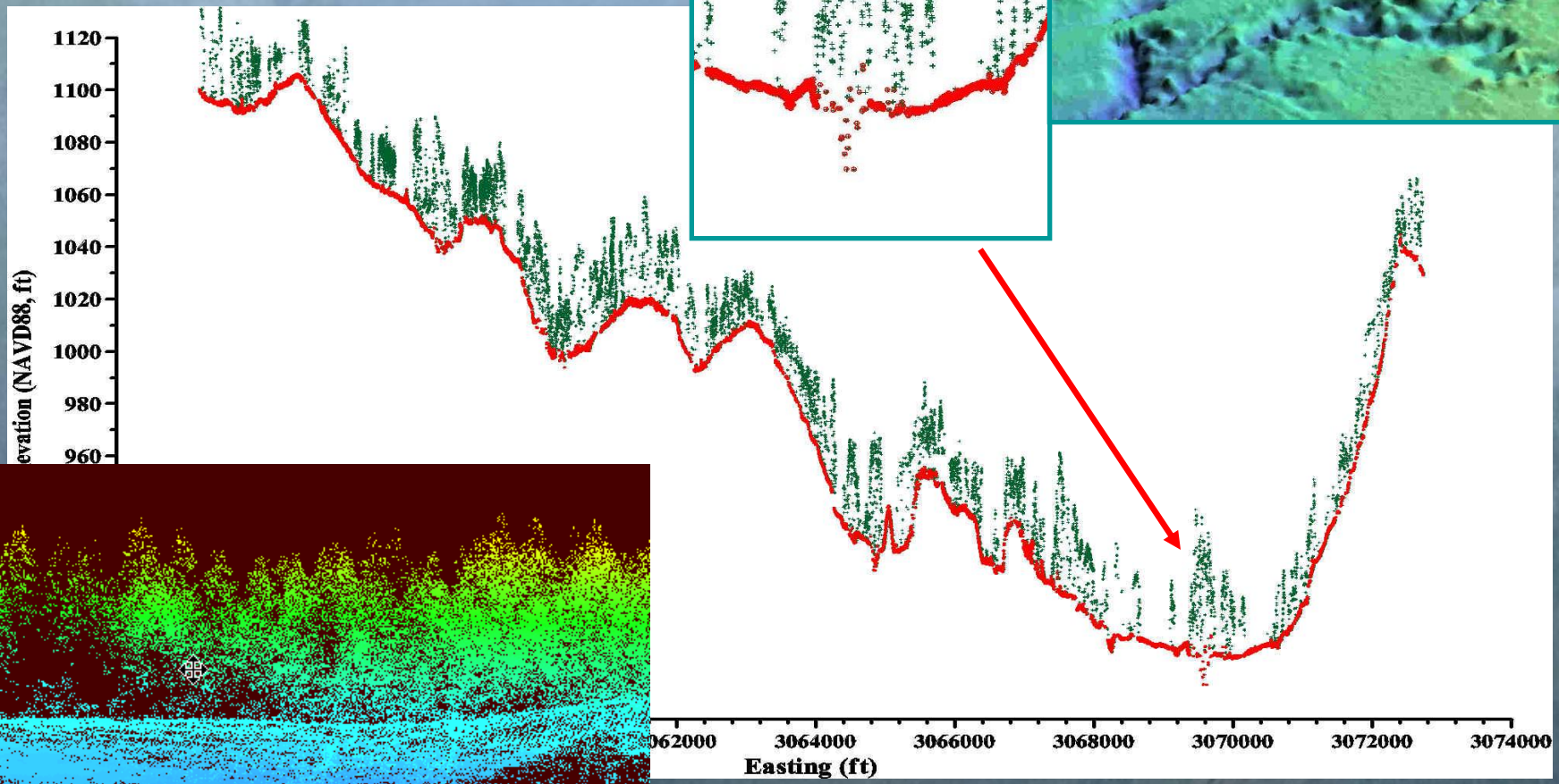
- LIDAR = Light Detection and Ranging
- Active sensing: can collect at night
- Timing of pulse gives elevation (DEM)
- Magnitude of return pulse gives intensity image (DOQ)
- Minimum of thousands of pulses per second (KhZ+)
- Multiple returns potentially from each transmitted pulse
- Costs are widely variable depending on size and complexity of project
  - Low of $0.82/acre

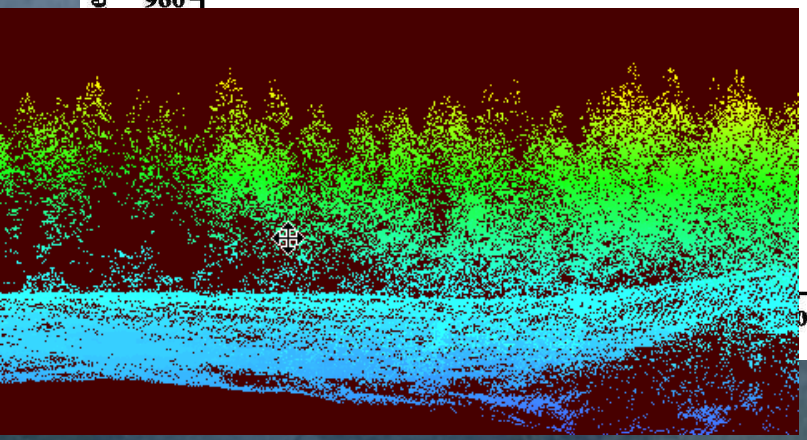
From EarthData, Inc. original

LIDAR transect



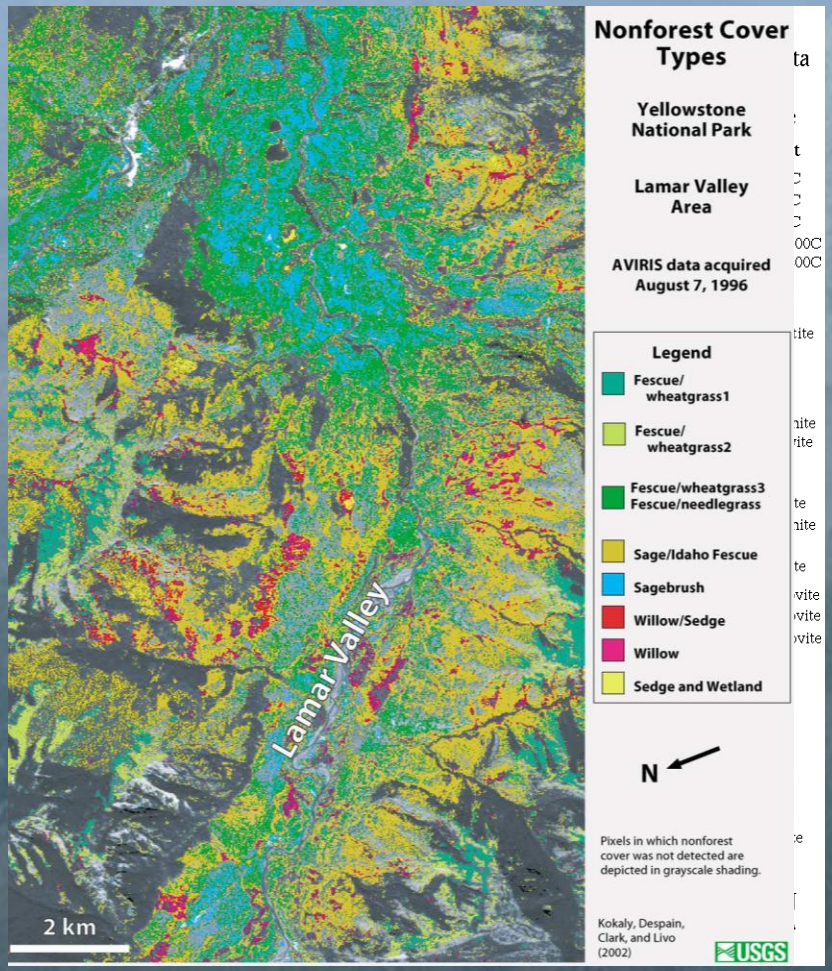






Hyperspectral Remote Sensing

- Images in 100s of very narrow wavelength
- Much finer discrimination of resources
- Examples:
  - HyMap - 126 bands across the wavelength region of 0.45 – 2.5 nm.
  - ARCHER – Run by CAP
- Typical cost $3.5k per 20 km line length with 5 m pixel size plus 5-7k for mobilization from Colorado.



We are Data Rich and Information Poor

Remote Sensing (POCs)

- Debra Dinville
  - Section Lead
- Russell Jackson
  - Leica Software Products
  - NAIP, NED
- Dave Kett
  - Aerial Photography Acquisition
  - Traditional Photogrammetric Processing
- Matthew Bobo
  - Satellite Imagery
  - Image Processing
  - Other IP Software Products
- Neffra Matthews
  - Close Range Photogrammetry
- Susan Goodman
  - Fire Related Geospatial Activities

Contact Information

Matthew Bobo

National Operations Center
Division of Resource Services (OC-534)
Denver Federal Center, Bldg. 50
P.O. Box 25047
Denver, CO 80225

Phone: 303-236-0721
Email: matthew_bobo@blm.gov