ORDA Science Webinar Series:
Small UAS for Scientific Research

Jeff Sloan
USGS National Unmanned Aircraft Systems Project Office

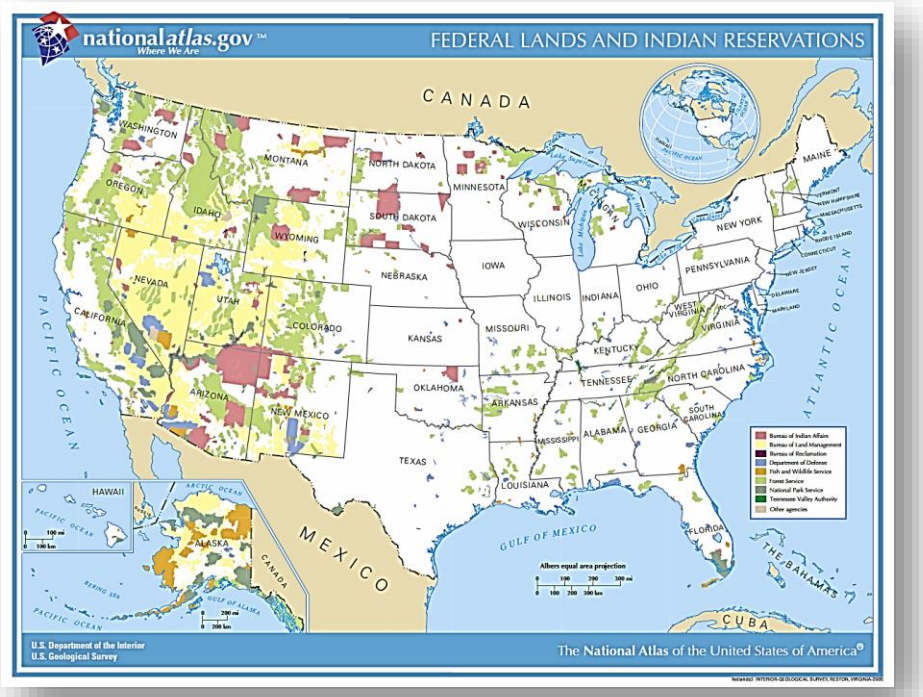
Conference Line:
DOI participants: 703-648-4848
Non-DOI participants: 855-547-8255

Passcode: 41701001

There will be NO audio through the web.
Please mute your phone during the presentation.

This presentation will be made available soon on the USGS NRDAR webpage:
https://www.usgs.gov/centers/cerc/science/natural-resource-damage-assessment-and-restoration-nrdar

USGS Mission



The USGS is the science agency for the Department of the Interior

Provides reliable scientific information to describe and understand the Earth; minimize loss of life and property from natural disasters; manage water, biological, energy, and mineral resources; and enhance and protect our quality of life

USGS science for a changing world

USGS National Unmanned Aircraft Systems Project Office

USGS UAS Implementation Timeline

- Emerging Technology Investigations……2004-2008
- USGS UAS National Project Office Created……May 2008
- First Systems (Raven) Acquired……Dec. 2009
- First Operator Training……2009-2010
- Operations in the National Airspace……March 2011

USGS UAS Strategy

Mission Statement: *The USGS National Unmanned Aircraft Systems Project Office will lead the safe, efficient, cost-effective and leading-edge investigation of the potential uses for UAS technology in scientific research activities for the USGS and the Department of the Interior.*

Goal: ***Implement UAS as a common tool for scientific research and operational activities***

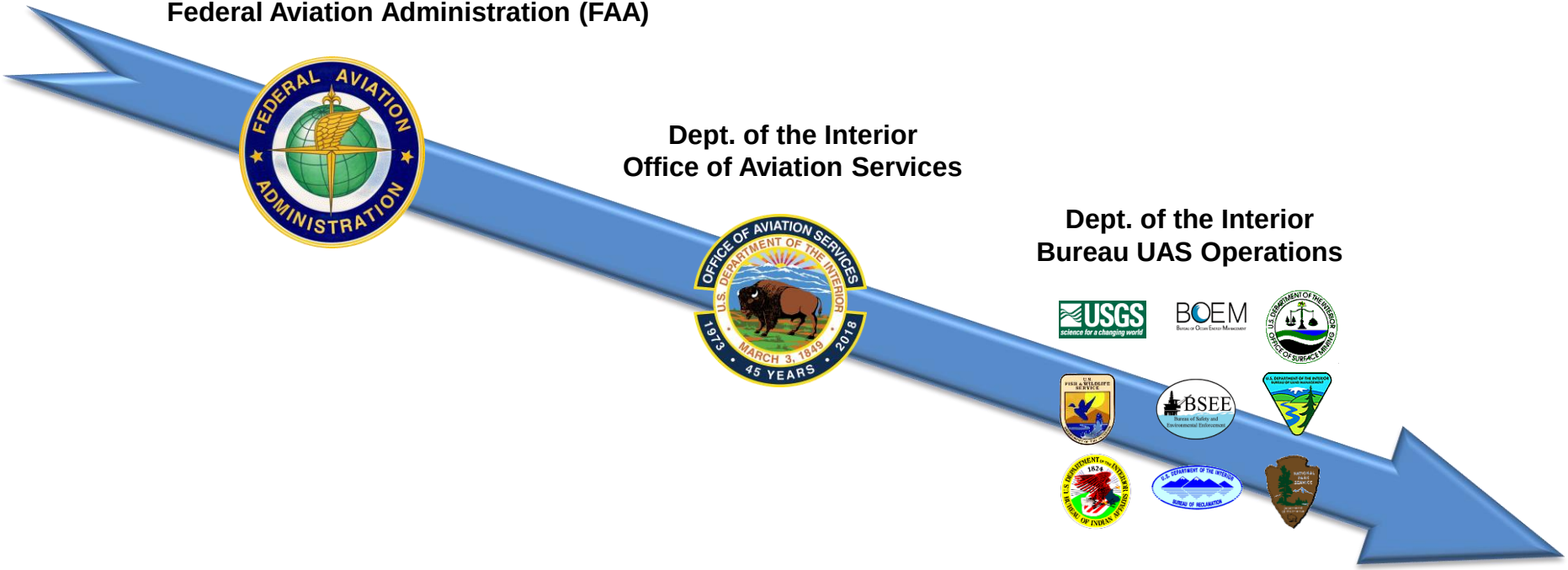
- ✓ UAS Operator Training for the USGS
- ✓ Sensor Integration, Testing and Approval
- ✓ Develop Data Processing Techniques & Best Practices
- ✓ Perform Proof-of-Concept Missions
- ✓ Inventory and Operator Qualifications Management

Department of the Interior – UAS Implementation

Federal Aviation Administration (FAA)

Dept. of the Interior
Office of Aviation Services

Dept. of the Interior
Bureau UAS Operations

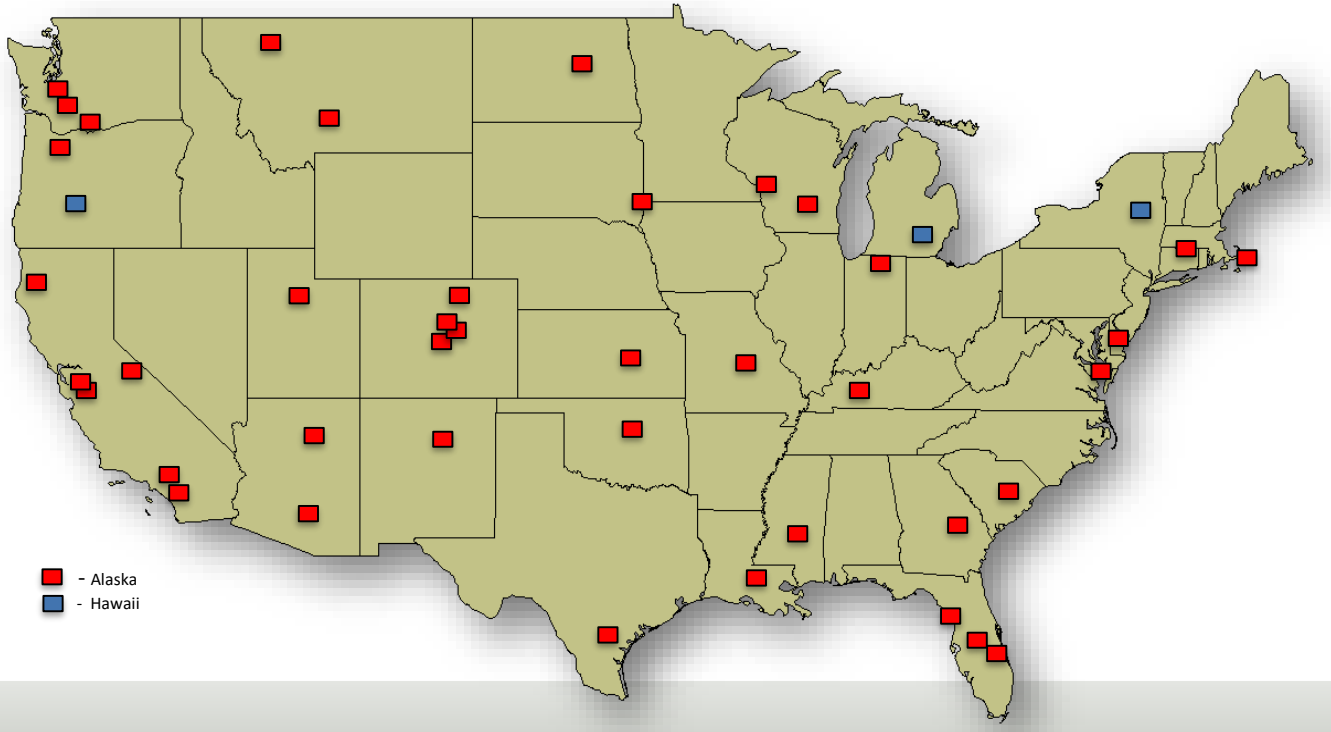


USGS (DOI) – UAS Training

- FAA - Part 107 Certification
- Procure Aircraft
- A-450 Basic Small UAS Course
- Proficiency (every 90 days)
- Currency (Refresher – 2yrs)

USGS – UAS Implementation

USGS Nationwide Trained UAS Operators



102…… USGS operators trained (*8 retired/inactive/left*)
34 …… New USGS operators to be trained in 2019

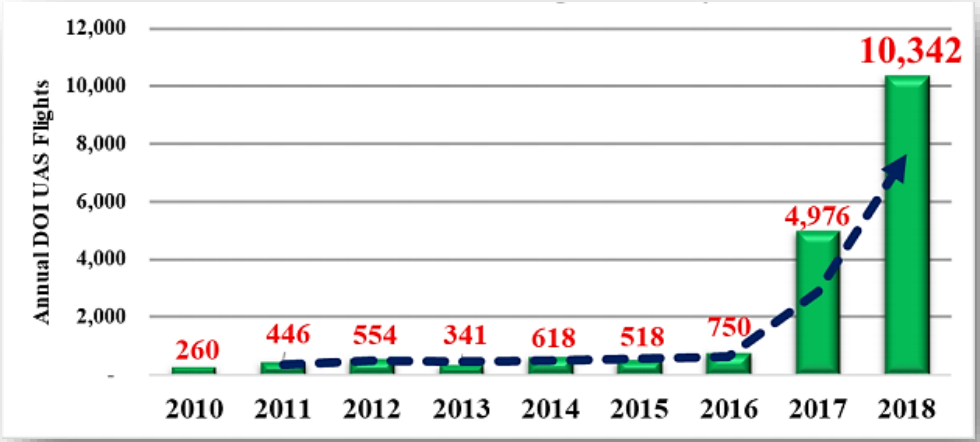
- Trained Operators
- To Be Trained 2019

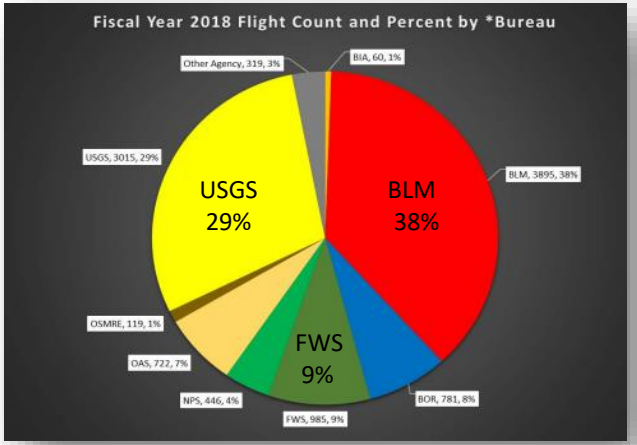
USGS
science for a changing world

Department of the Interior – Advanced Training

- Advanced Courses
- Data Processing Classes

Dept. of the Interior – Annual UAS Flight Activity





USGS = 3,015 flights (increased 178% over 2017)

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USGS – Current UAS Platforms

Pulse Vapor 55

DJI Matrice 600
(Testing)

BirdsEyeView
FireFly 6

Pulse Vapor 55	1
DJI Matrice 600	11
FireFly 6	8
3DR Solo	107
3DR Solo (Site Scan)	9
Parrot Anafi	4
Total UAS @ USGS	***151***

End of 2018:

- DOI owns 531 UAS
- DOI - 359 trained operators

3DR Solo

DJI Mavic
(Testing)

Parrot - Anafi

USGS – Current UAS Platforms

UAS Sensors Approved for DOI Use

High Definition Video

Point & Shoot Cameras

DSLR Cameras

Thermal Sensors (FLIR)

MultiSpectral (MicaSense)

Doppler RADAR

3DR Solo

- Hero 3, 4
- Ricoh GRII
- Sony UMC-R10C
- Sequoia
- Pixpro SP360 4K
- RedEdge 3, MX
- FLIR VUE Pro/Pro R/Dual Pro
- MAPIR

DJI

- Zenmuse XT2, X5, Z30
- Ronin – MX Gimbal

BirdsEyeView FireFly6

- Sony A6000, A7R, RXIRII
- Slantrange 3P
- MicaSense RedEdge M
- GoPro Hero4

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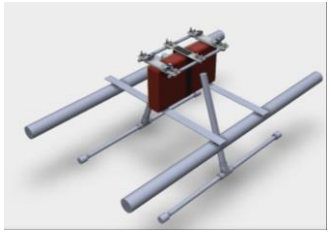
UAS Sensors Currently Being Integrated

Gas Sensors



Ground Penetrating RADAR

LiDAR

Metric Cameras

Hyperspectral

MultiSpectral

Telemetry

Methane Sensor

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USGS National UAS Project Office – Sensor Integration

Contracted Integration & Test Flight of Ground Penetrating Radar (GPR) Sensor

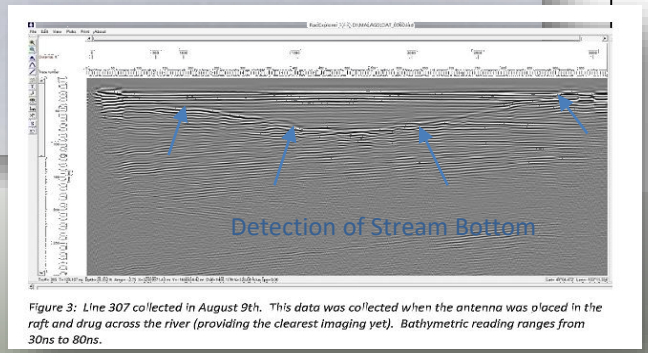
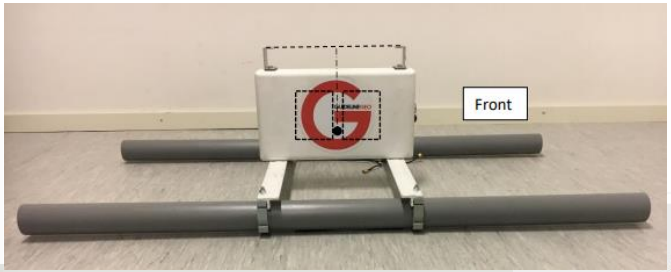
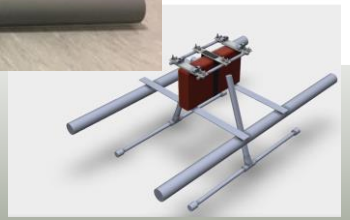


Figure 3: Line 307 collected in August 9th. This data was collected when the antenna was placed in the raft and drug across the river (providing the clearest imaging yet). Bathymetric reading ranges from 30ns to 80ns.

USGS UAS Sensor Integration

LiDAR – YellowScan/Velodyne… USGS, Univ. of FL, Contract
Ground Penetrating RADAR……..Mississippi State Univ.
Telemetry ……NASA Ames
Doppler RADAR……..USGS
Hyperspectral ……USGS/Nano Headwall/Resonon
Thermal ……Contracted Project
Geomagnetic Sensor……Contracted Project
Green LiDAR ……Contracted Project
GPR……Contracted Project
Pulsed RADAR……Contracted Project
UltraSonic Sensor ……Contracted Project





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SUAS GPR TESTING
GOLDEN, CO, APRIL 9, 2019
USGS
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USGS National UAS Project Office – Sensor Integration

Test Flight of YellowScan LiDAR Sensor

USGS UAS Sensor Integration

LiDAR – YellowScan/Velodyne… USGS, Univ. of FL, Contract
Ground Penetrating RADAR……..Mississippi State Univ.
Telemetry ……..NASA Ames
Doppler RADAR……..USGS
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Geomagnetic Sensor……..Contracted Project
Green LiDAR ……..Contracted Project
GPR……..Contracted Project
Pulsed RADAR……..Contracted Project
UltraSonic Sensor ……..Contracted Project

USGS National UAS Project Office – Sensor Integration

Contracted Test Flight of GeoMagnetic Sensor

USGS UAS Sensor Integration

LiDAR – YellowScan/Velodyne… USGS, Univ. of FL, Contract
Ground Penetrating RADAR……..Mississippi State Univ.
Telemetry ……..NASA Ames
Doppler RADAR……..USGS
Hyperspectral ……..USGS/Nano Headwall/Resonon
Thermal ……..Contracted Project
Geomagnetic Sensor……..Contracted Project
Green LiDAR ……..Contracted Project
GPR……..Contracted Project
Pulsed RADAR……..Contracted Project
UltraSonic Sensor ……..Contracted Project

USGS National UAS Project Office – Sensor Integration

Contracted Test Flight of AstraLite Green LiDAR (swath) Sensor

USGS UAS Sensor Integration

LiDAR – YellowScan/Veledyne… USGS, Univ. of FL
Ground Penetrating RADAR……..Mississippi State Univ.
Telemetry ……NASA Ames
Doppler RADAR……USGS
Hyperspectral ……USGS/Nano Headwall
Thermal ……Contracted Project
Geomagnetic Sensor……Contracted Project
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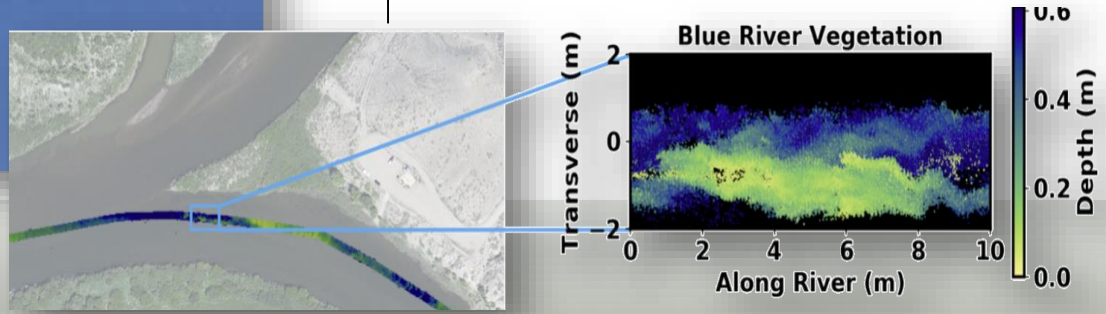
GPR……Contracted Project
Pulsed RADAR……Contracted Project
UltraSonic Sensor ……Contracted Project



Courtesy: Paul Kinzel, USGS

USGS
FRONT

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USGS – UAS HyperSpectral Sensor Testing

Nano Headwall - Hyperspec

- Visible Near InfraRed
- Note: USGS lost the UAS and Sensor during test flights

Nano-Hyperspec®	
Wavelength range	400-1000 nm
Spatial bands	640
Spectral bands	270
Dispersion/Pixel (nm/pixel)	2.2
FWHM Slit Image	6 nm
Integrated 2nd order filter	Yes
f/#	2.5
Layout	Aberration-corrected concentric
Entrance Slit width	20 µm
Camera technology	CMOS
Bit depth	12-bit
Max Frame Rate (Hz)	350
Detector pixel pitch	7.4 µm
Max Power (W)	13
Storage capacity	480GB (~130 minutes at 100 fps)
Weight without lens, GPS (lb / kg)	1.2 / 0.5
Operating Temperature	0˚C to 50˚C

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USGS – UAS HyperSpectral Sensor Testing

Resonon Pika XC2 Hyperspectral

- Visible Near InfraRed
- Note: USGS Just Acquired the Sensors
  – will begin to integrate onto DJI Matrice 600 UAS System

Spectral Range (*nm*)	400 – 1000
Spectral Resolution (*nm*)	1.3
Spectral Channels	447
Spatial Channels	1600
Max Frame Rate (*fps*)	165
Bit Depth	12
Weight (*lb/kg*)	4.9 / 2.2
Dimensions (*cm*)	10.1 x 27.5 x 7.4
Connection Type	USB 3.0
Operating Temperature (°F/C)	41-104, 5-40
f/#	2.4
Pixel size (*µm*)	5.86
Avg. RMS Spot Radius (*µm*)	6
Smile (peak-to-peak) (*µm*)	4
Keystone (peak-to-peak) (*µm*)	5

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USGS – UAS HyperSpectral Sensor Testing

HySpex Mjolnir VS-620

HySpex Demonstration

Demo: June 4, 2019 - Denver

- Visible ShortWave InfraRed
- Integrated UAV System
- Note: USGS Does Not have this UAS System or Sensor

Main Specifications:

	HySpex Mjolnir VS-620
Spectral range (nm)	400-2500
Spectral sampl. (nm)	3.0 | 5.1
Spatial pixels	620
Spectral channels	490
Field of view (deg)	20
Pixel FOV (mrad)	0.54/0.54
Bit resolution (raw data)	16
Noise floor (e-)	2.34| 80
Dynamic range	4400 | 10000
Peak SNR	<180 | <900
Max speed (fps)	100
Power cons. (W)	50 (with DAU/INS)
Dimensions (cm)	37.4 - 20 - 17.8

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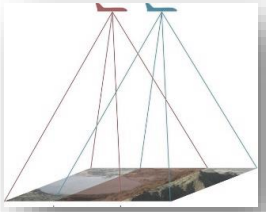
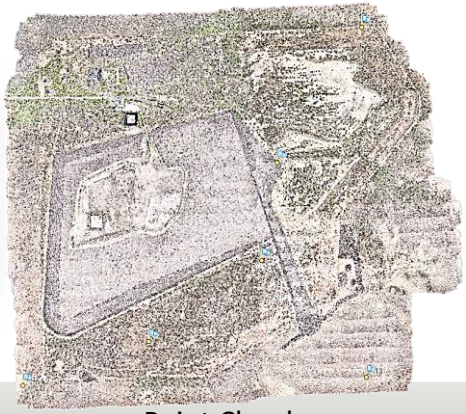
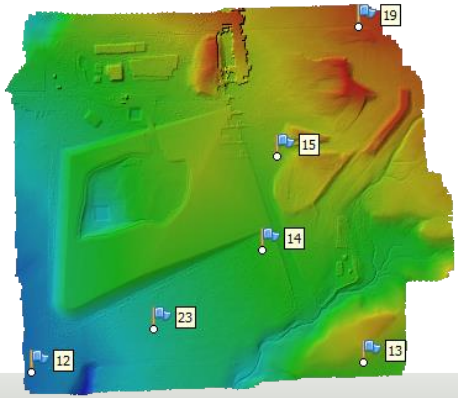
Structure-from-Motion (Photogrammetry)



Stereo Overlapping Images



Point Cloud

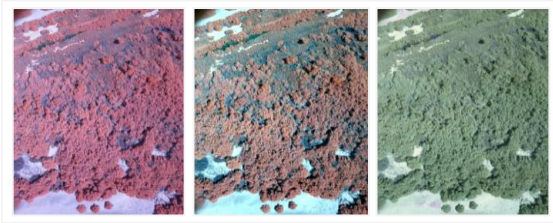


Elevation Model

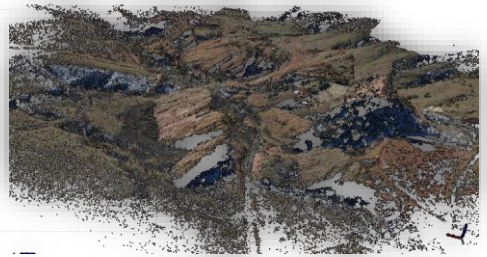
Ortho-Mosaic

Derived Geospatial Products

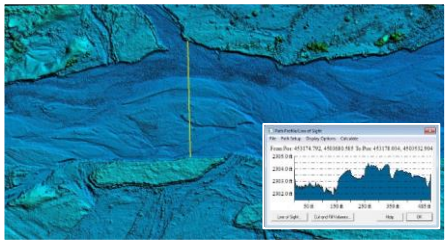
Primary Goal:
GIS Data Layers



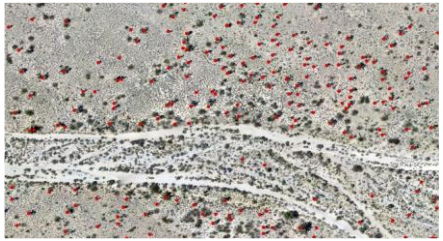
Color Infrared - NDVI



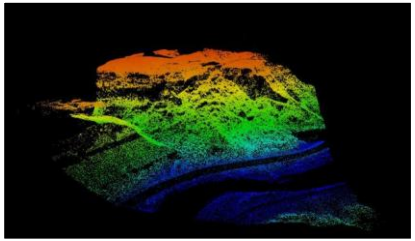
Point Cloud Generation



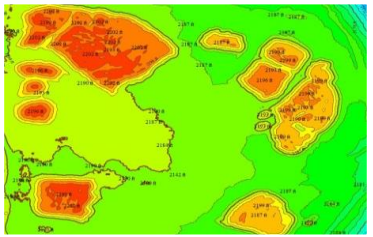
Elevation Models



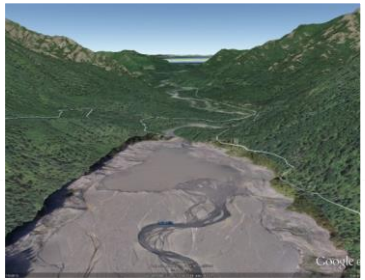
Feature Extraction



Point Cloud Classification



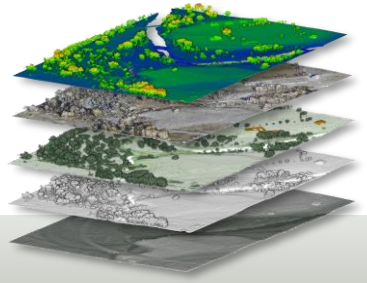
Contour Generation



KML – 3D Modeling

Orthophotography

Volumetric Measurements



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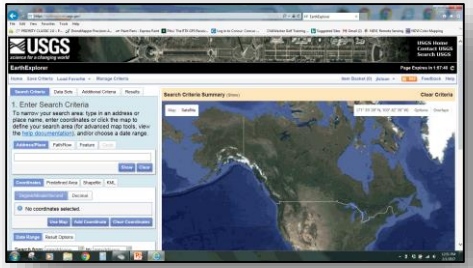
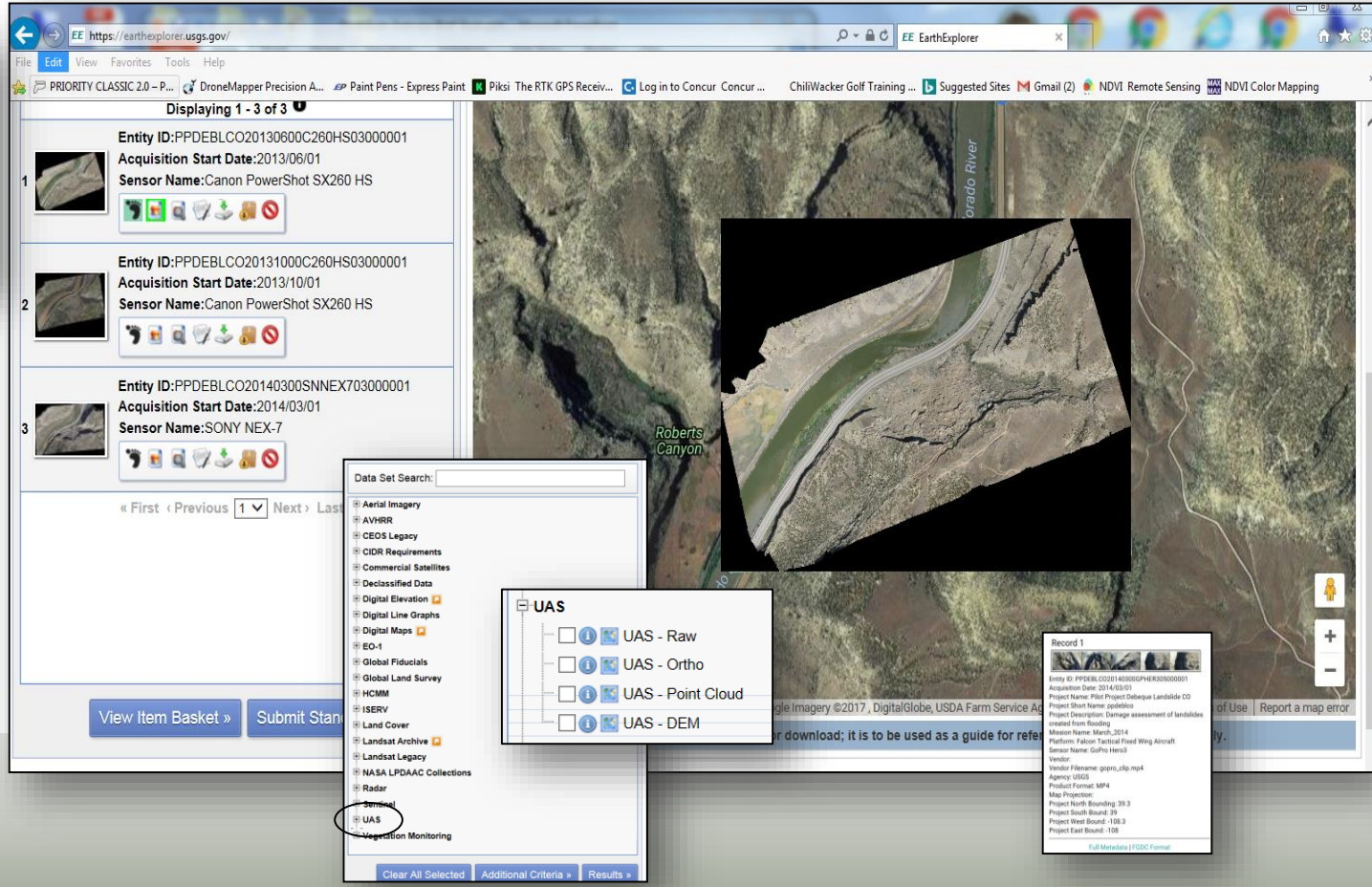
Metadata, Archiving and Distribution

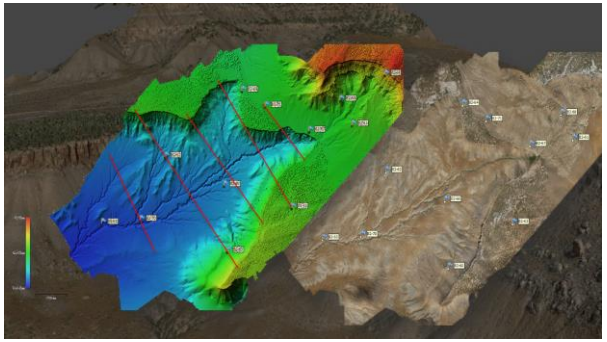




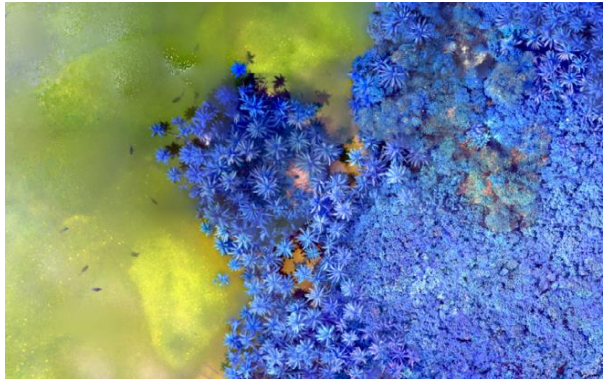
USGS Past Projects

Hawaii – Kiauea Volcano Eruption

Wyoming – Devil's Tower NM 3D Modeling

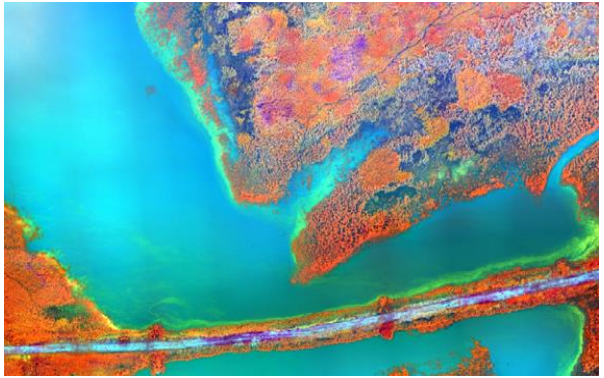


Colorado Hydro Basin – Photogrammetry



Palmyra Atoll – MSI Collection

Ft. Laramie NHS - LiDAR



Kansas – Algal Bloom – MSI Collection

3D Modeling – Devil's Tower National Monument

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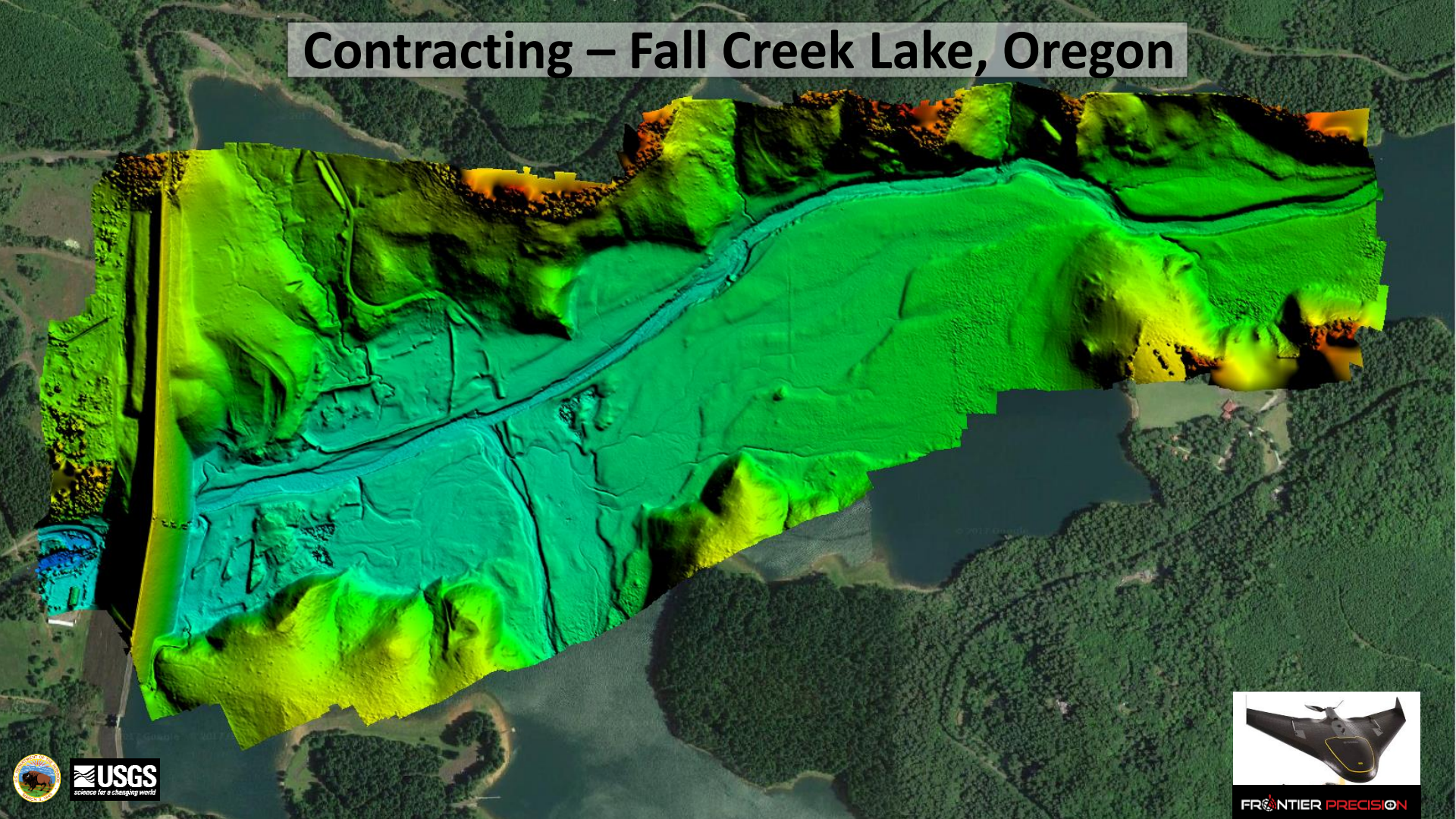
Contracting – Fall Creek Lake, Oregon



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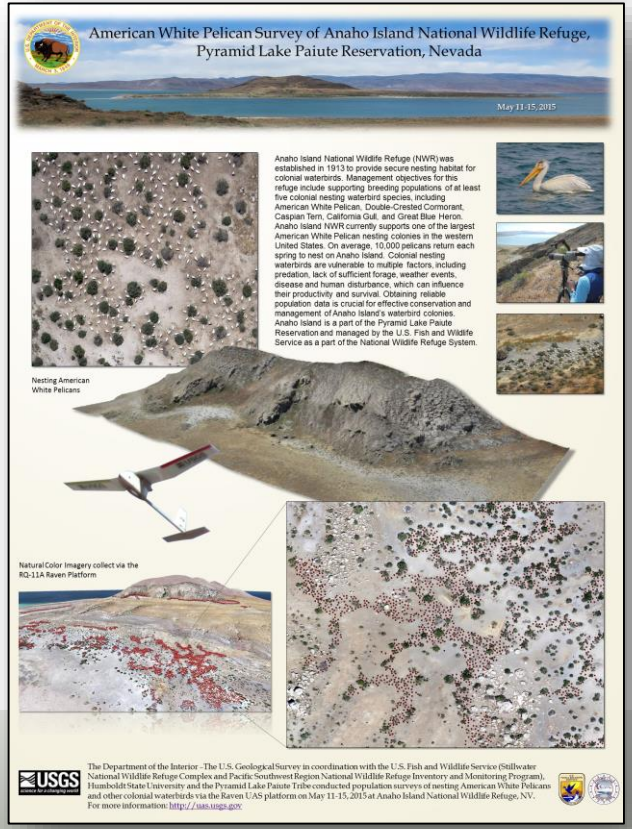
FRONTIER PRECISION

Biology Applications

Elk

White Pelicans

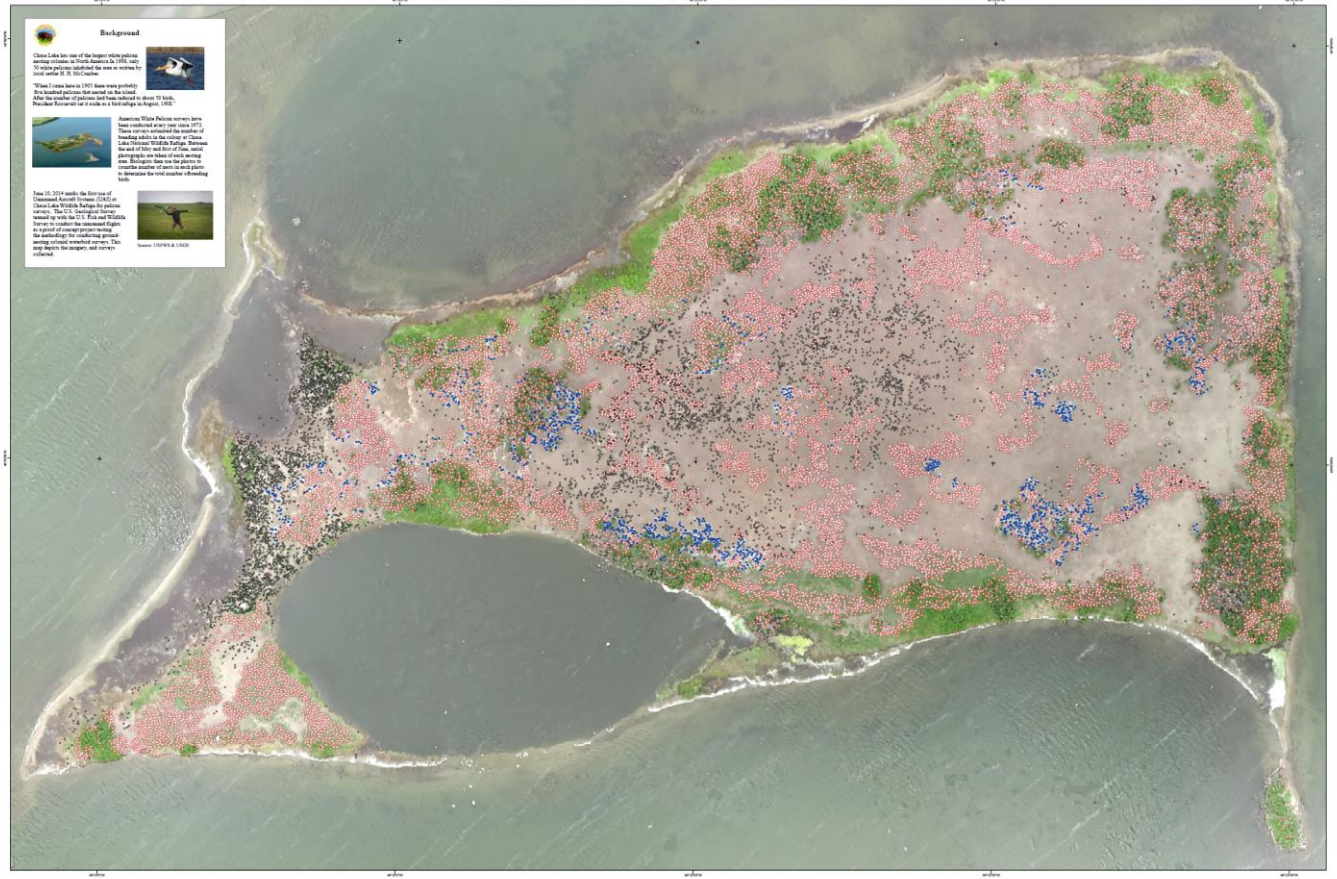


Mallard Ducks

USGS science for a changing world

Chase Lake National Wildlife Refuge Pelican Survey, North Dakota

June 10, 2014

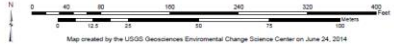


RQ-11A Raven UAS

The Raven small unmanned aerial vehicle (SUAV) is a hand-launched reconnaissance and surveillance tool. The system transmits live airborne video images, compass headings and location information to a ground control unit (GCU) and receives video terminal (RVT). The Raven aircraft is hand launched without the need of special equipment or landing area required. The system employs a self-stabilizing aircraft configuration with orbiting augmentation avionics and provides ease of control and steady video imagery.

The Raven's optics package includes an electro-optical (EO) color camera nose payload (side, forward, and nadir orientation) and two infrared (IR) thermal nose payloads (a side look payload or a forward looking payload). The Raven system is typically operated by a two person team consisting of a pilot and mission controller.

1:550

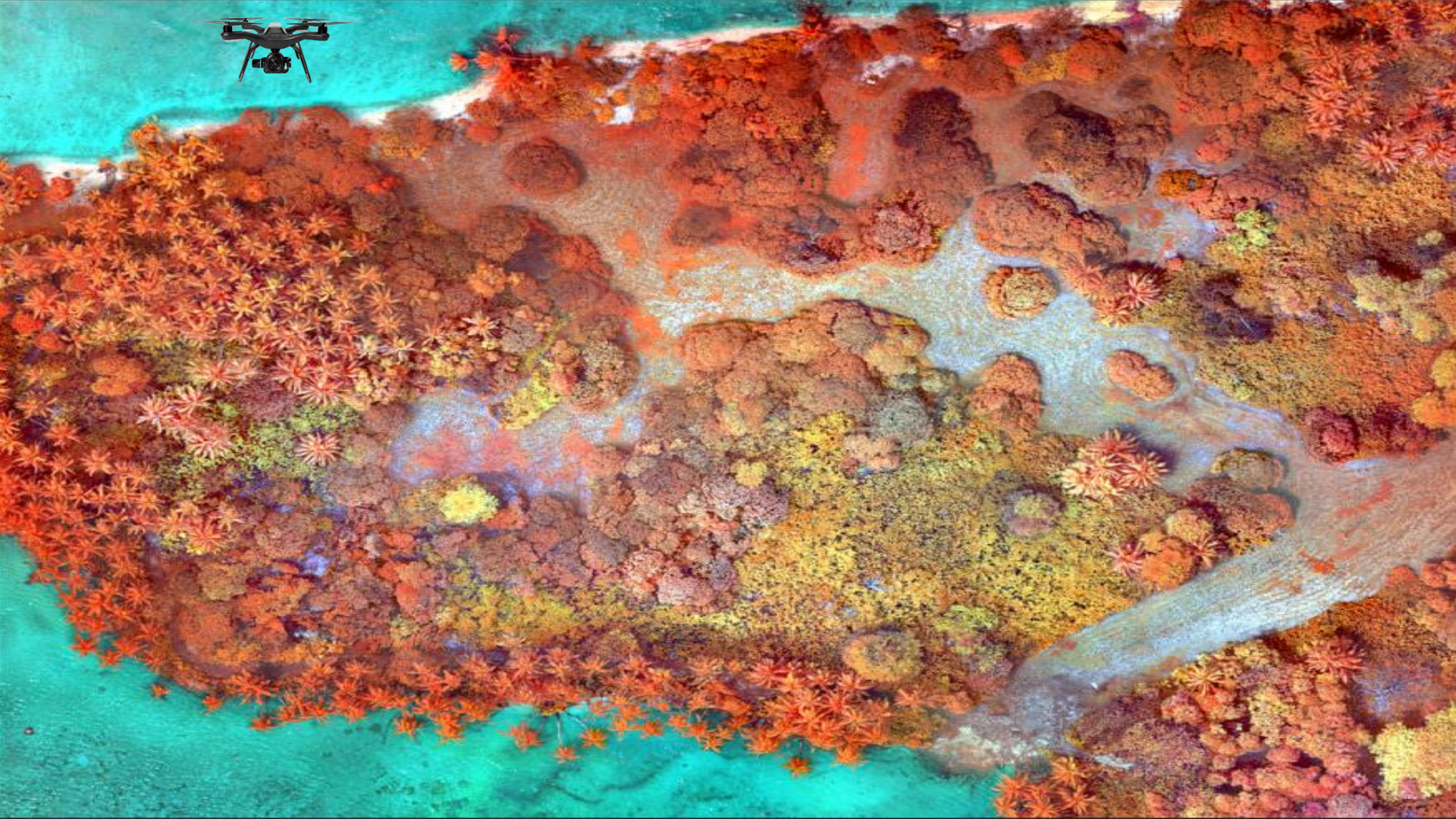


Map created by the USGS Geosciences Environmental Change Science Center on June 24, 2014

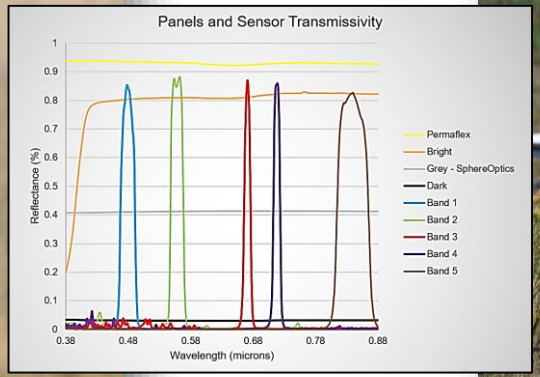
Legend

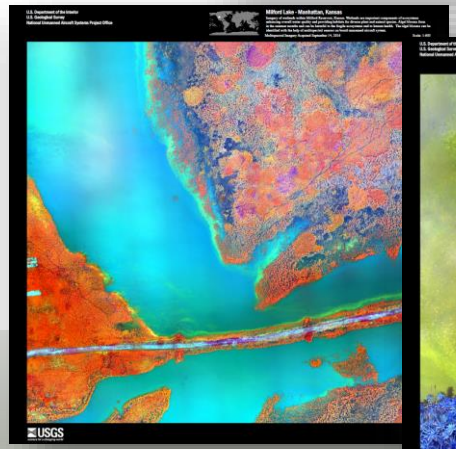
- Gulls, Egrets, and Other
- Cormorant Nests
- American White Pelicans

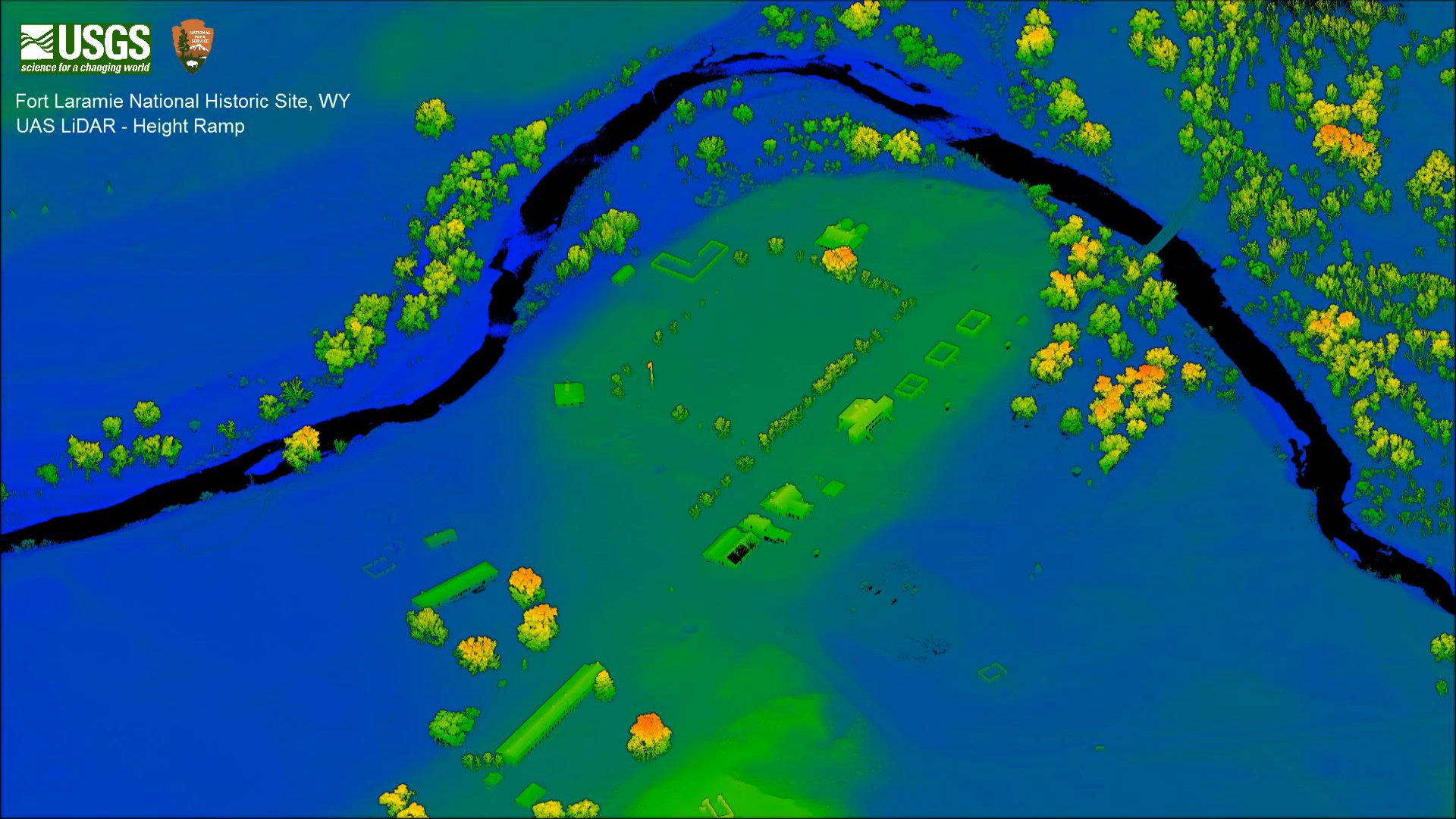
Imagery collected by the the RQ-11A UAS Raven on June 10, 2014.



USGS National UAS Project Office – Sensor Calibration & Best Practices



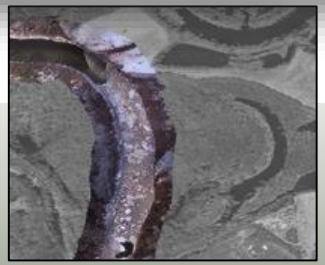



USGS
science for a changing world
Fort Laramie National Historic Site, WY
UAS LiDAR - Height Ramp

Contracting - Emergency (Rapid) Response

AIRSHARK

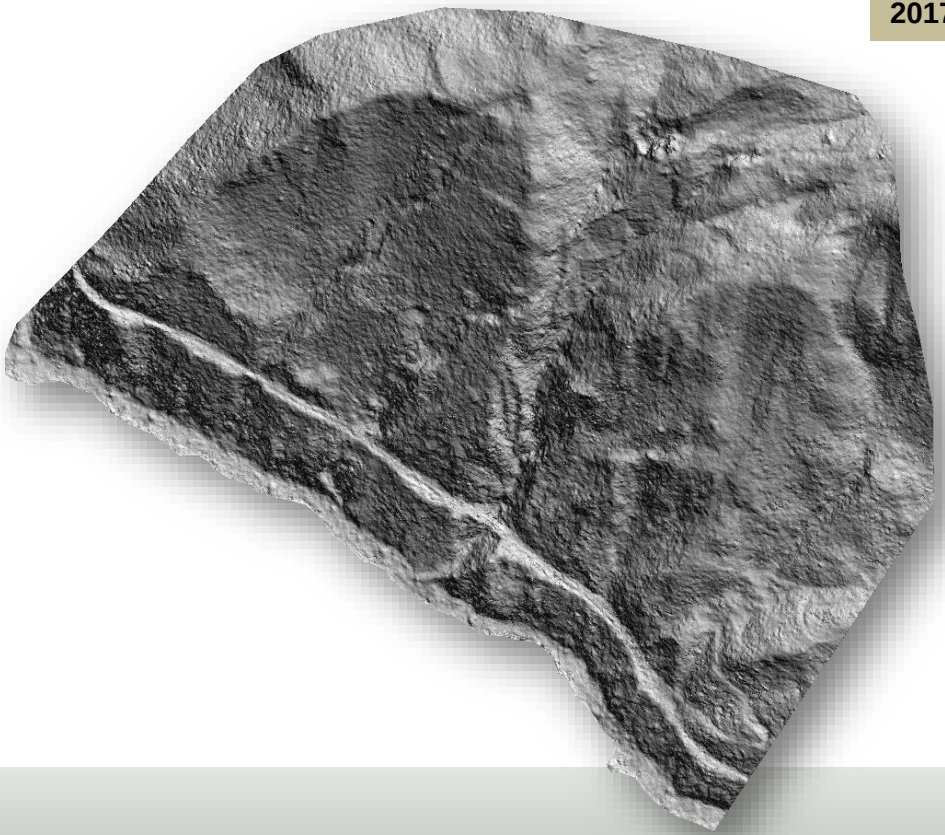
Officials meet, assess damage to Plymouth area after ice jam causes NH river to flood



USGS science for a changing world

Natural Hazards – Landslide Analysis (over time)

2017 Mud Creek Landslide, California



1967

SfM

Courtesy: USGS, J. Warrick, et. al 2019

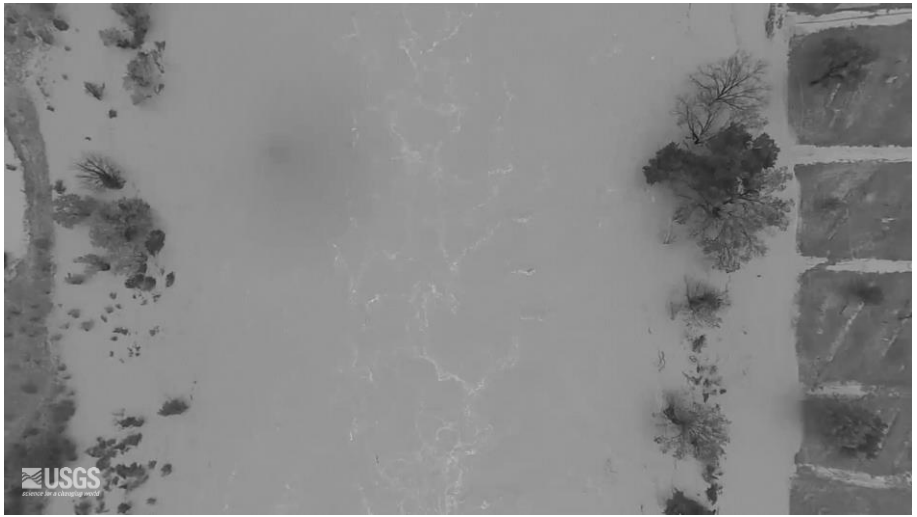
Natural Hazards – Water Related Emergencies

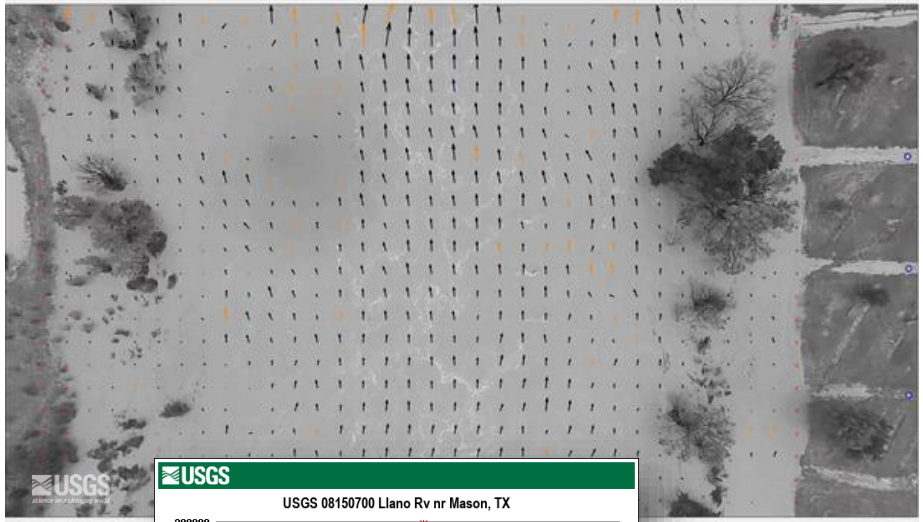
GoPro video

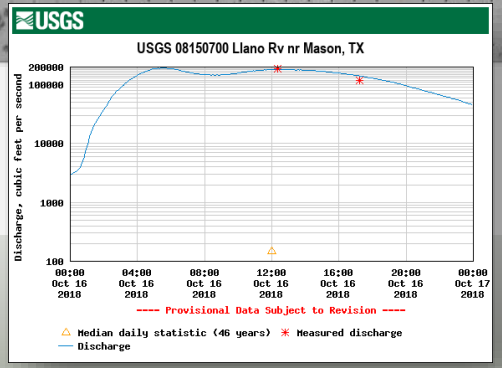
Courtesy: USGS, F. Engel - 2019

Natural Hazards – Water Related Emergencies

LSPIV – Large-Scale Particle Image Velocimetry







Computer vision used to:

- **Stabilize video**
- **Remove lens distortion**
- **Image velocimetry**

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Courtesy: USGS, F. Engel - 2019

Hawaii – Kilauea Volcano Eruption - 2018

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Preliminary Information-Subject to Revision. Not for Citation or Distribution.
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USGS UAS Implementation – Challenges

- Working at the speed at which USGS Scientists want operational platforms & sensors
- Sensor Integration always has hurdles
- Access to the DJI Equipment
- Batteries
- Sensor Weights
- Best Practices – ensure USGS is creating and using accurate data
- Data archive, management and release
- Lack of high-resolution Data Standards
- Support for a dedicated Hazards response team

USGS National UAS Project Office

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