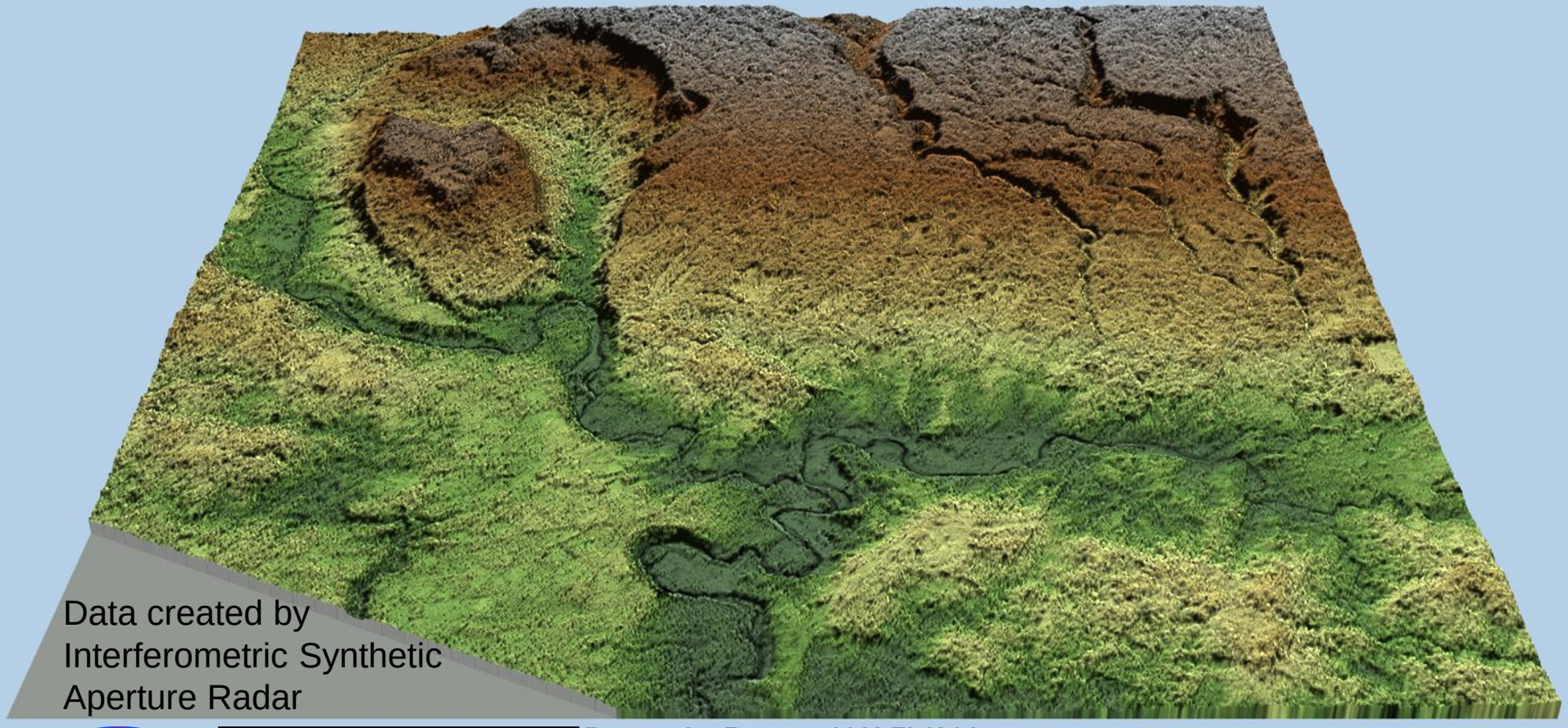
Imaging Using Microwaves

Delivering Exceptional Service in the National Interest



Data created by Interferometric Synthetic Aperture Radar

Rio Napo, Ecuador

Unclassified Unlimited Release

Name/Org: _Judith A. Ruffner, _ Date: 1/15/16_

Guidance: Multiple

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Sandia National Laboratories

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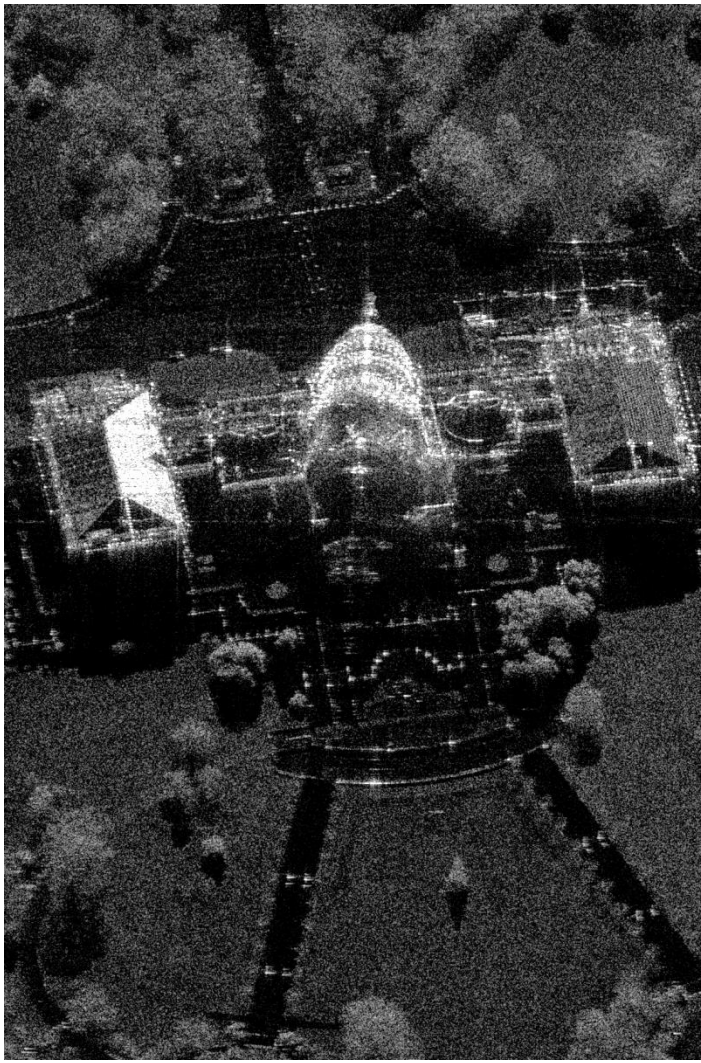
Outline

- Synthetic Aperture Radar (SAR) Overview
- Example Images
- Example Applications
- Aircraft
- Customer Comment
- Summary
- References

Capital Building Washington, DC



1 ft resolution

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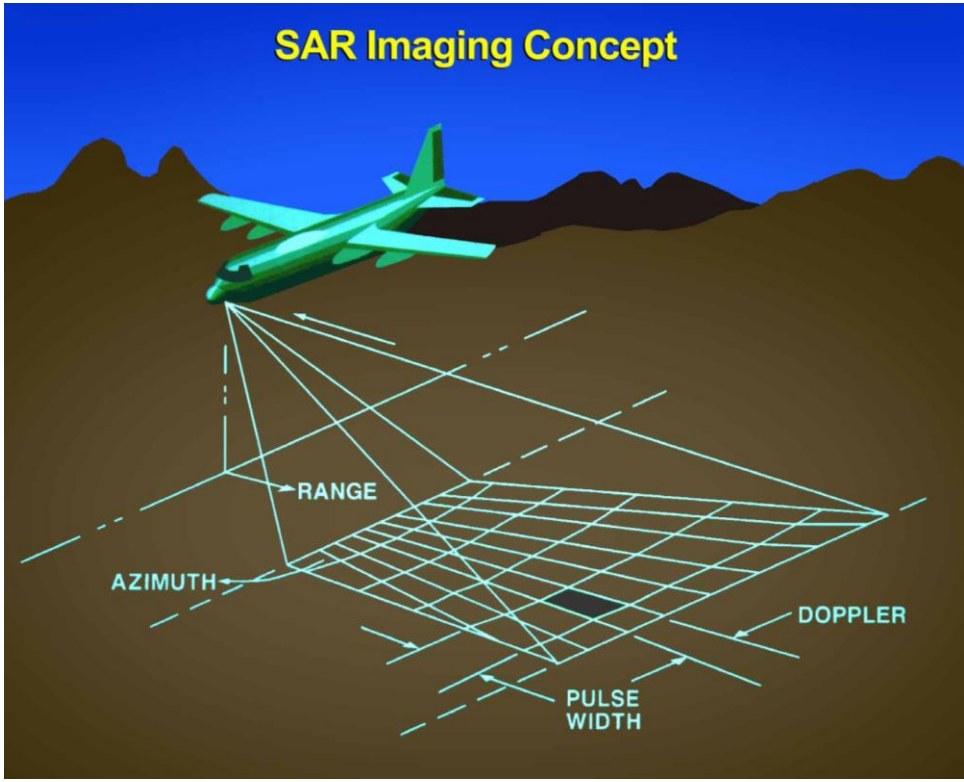
Synthetic Aperture Radar Has Unique Characteristics

- RF or Microwave illumination
- All weather
- Day and Night
- Coherent imaging system
- Images are displayed in two dimensions
  - Range, distance from the radar
  - Azimuth, proportional to Doppler frequency
- Invented about 1950-1951



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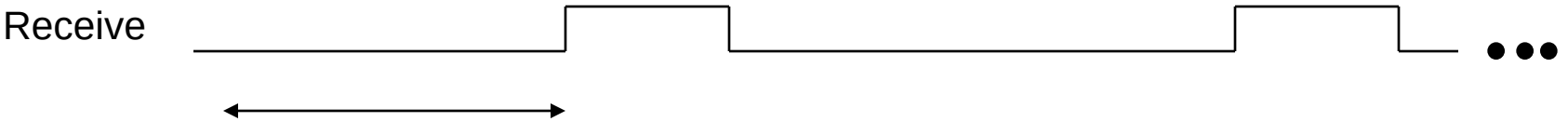
SAR Is Based On The Same Principle as Other Radars

Transmitter

Antenna/Gimbal

SARs transmit pulses

and receive echoes

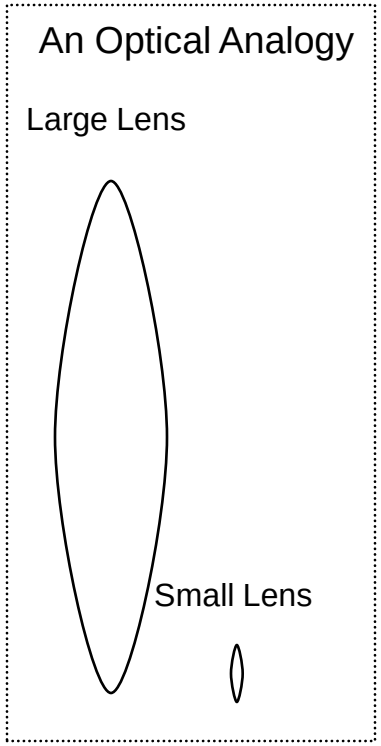


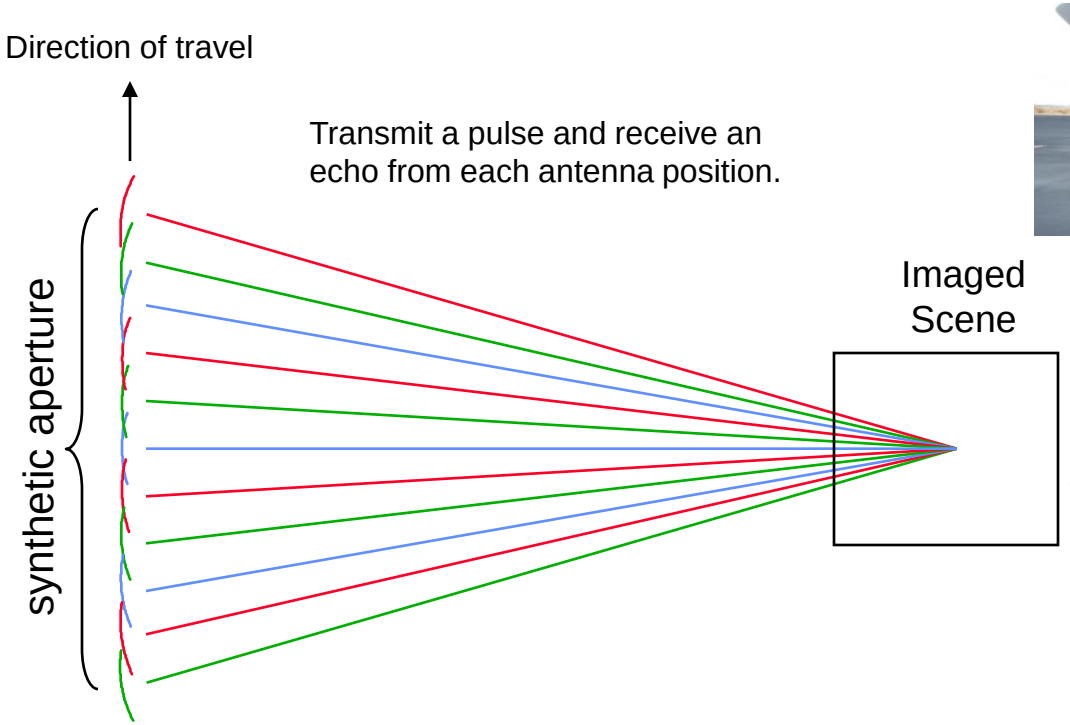
The time delay of the echo is proportional to the distance to the reflecting object.

Range resolution is inversely proportional to the bandwidth of the transmitted pulse.

For example: 1 foot resolution requires ~ 500 MHz bandwidth.

A Small Antenna Creates A Large Synthetic Aperture





7” X 15” antenna

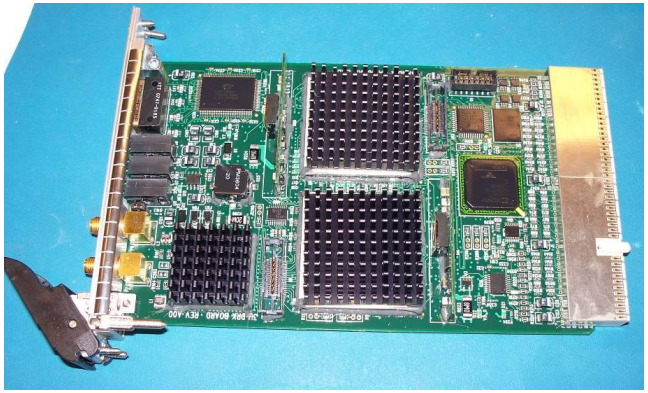
By coherently combining the information from a relatively small antenna at locations along a distance, we achieve finer resolution than a single, large antenna.

Azimuth resolution is inversely proportional to synthetic aperture length.

SAR Processing

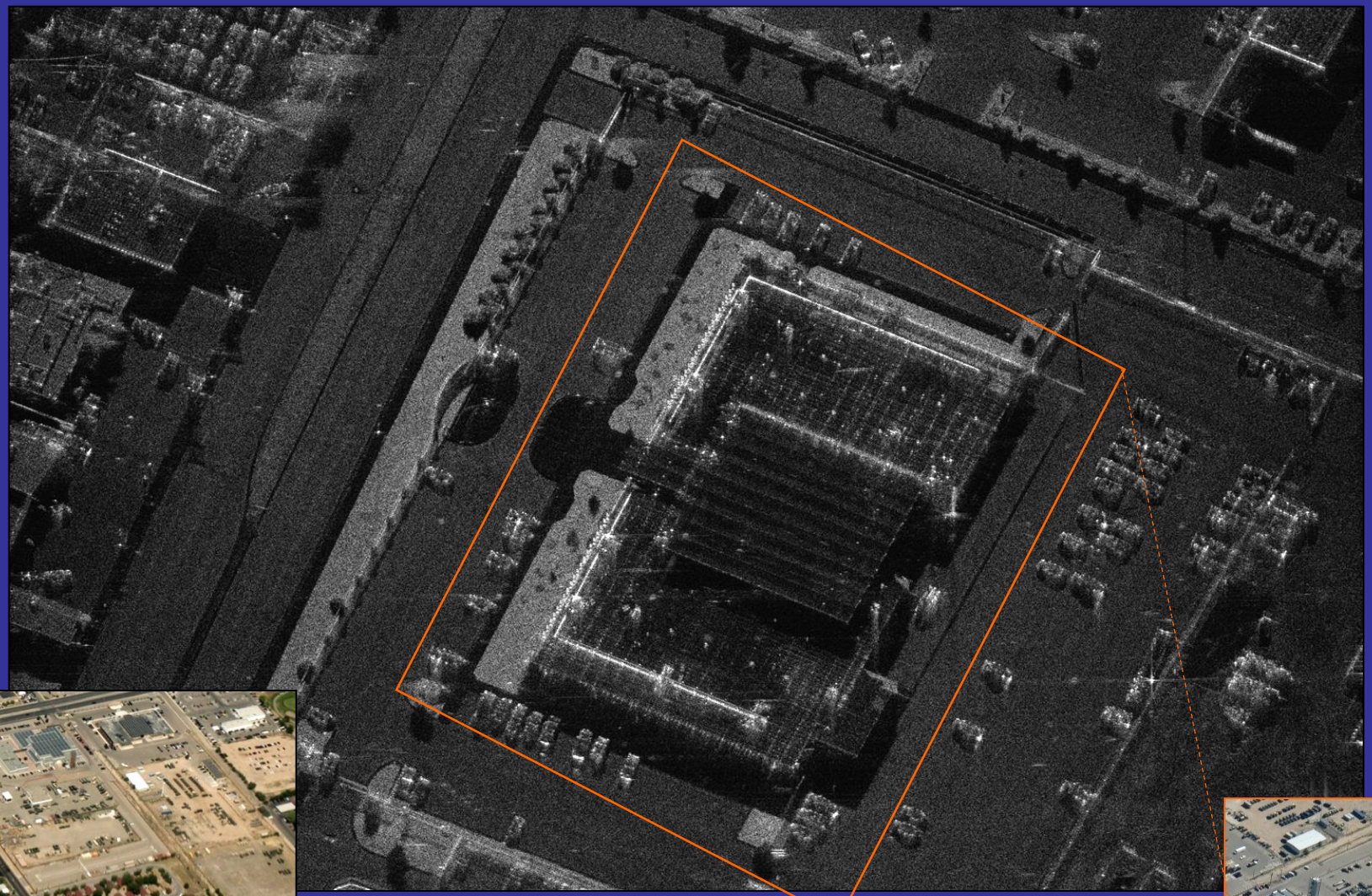
- **Originally done using optical techniques**
  - **Lenses**
  - **Prisms**
  - **Film to capture imagery (poor dynamic range)**
  - **Processing took months**
- **Now processing is done on digital computers**
  - **Commercial and Custom**
  - **Digital filtering**
  - **Interpolations**
  - **Fast Fourier Transforms**
  - **Complex convolutions**
  - **High dynamic range**

Custom Digital Receiver



Custom Digital Waveform Synthesizer

National Guard Armory, NM



4-inch Resolution

Tijeras Arroyo Golf Course

4-inch Resolution


Finer Resolution Improves Ability to Recognize Objects
T-62 tank
4-inch resolution
SS-21
gravel and tumbleweeds
scud
6-inch resolution
artillery pieces
point targets
1-foot resolution
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GSAT-000245-1

DC3 and Helicopter Static Display - KAFB

4-inch Resolution

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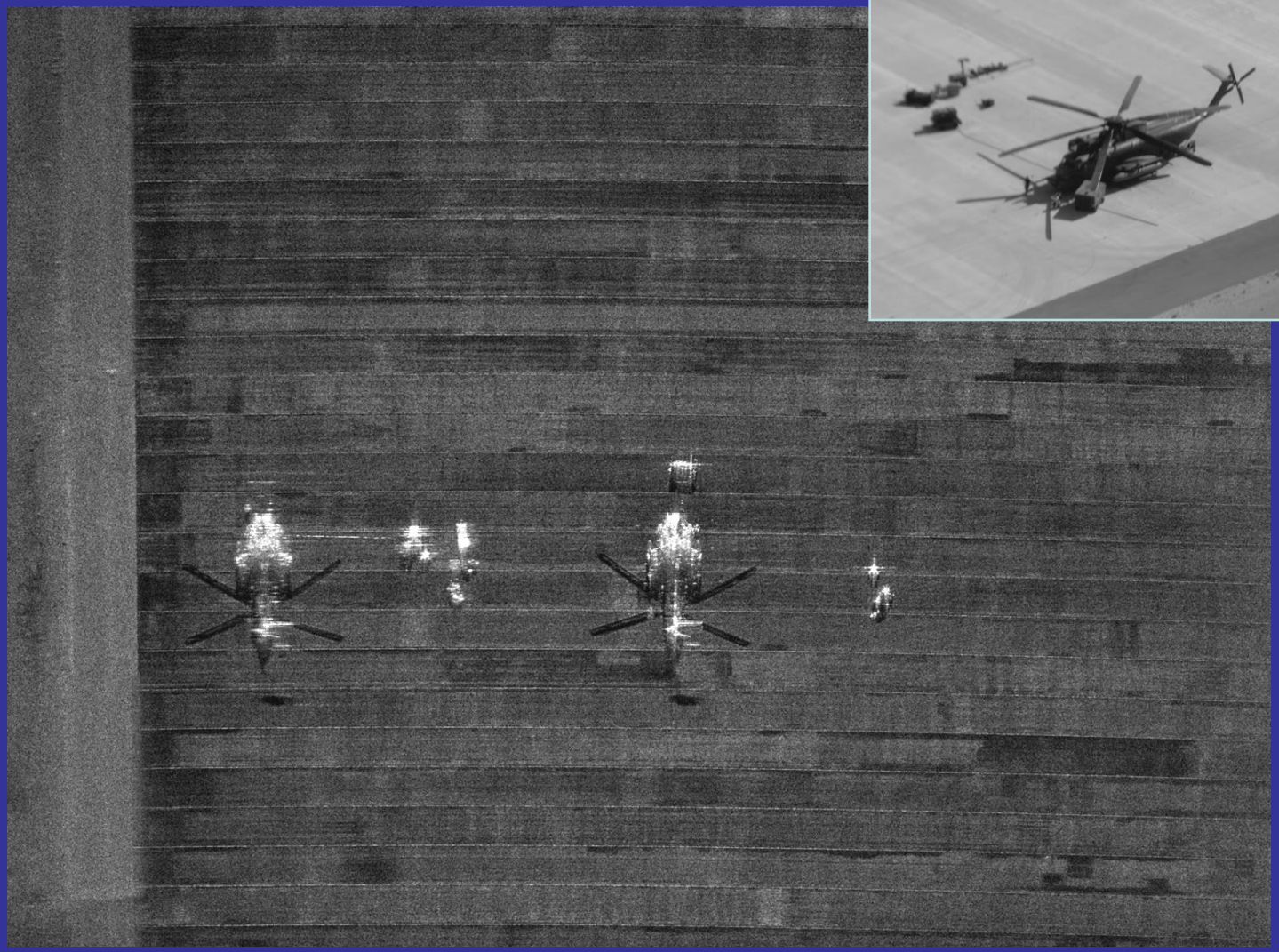
HELICOPTER ON RAMP



4-inch Resolution, Ka-Band

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Aircraft On Ramp - Albuquerque

4-inch Resolution, Ka-Band

4” Fine Resolution Strip Map Single Pass, Contiguous

Sandia First (Sep 2005): Contiguous 4” stripmap

Made from three consecutive apertures collected on a single pass
A stripmap of ~ 13800 pixels
Range ~ 3300 meters,
Grazing angle ~ 30 degrees
Swath ~ 300 meters
Range curvature is corrected (roads are straight)

Albuquerque, NM - 2002

30-inch resolution

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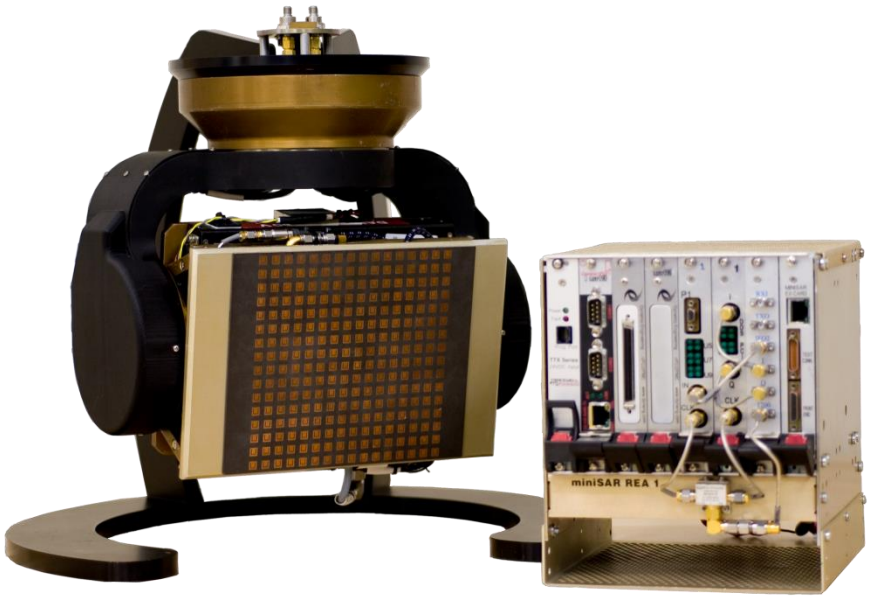
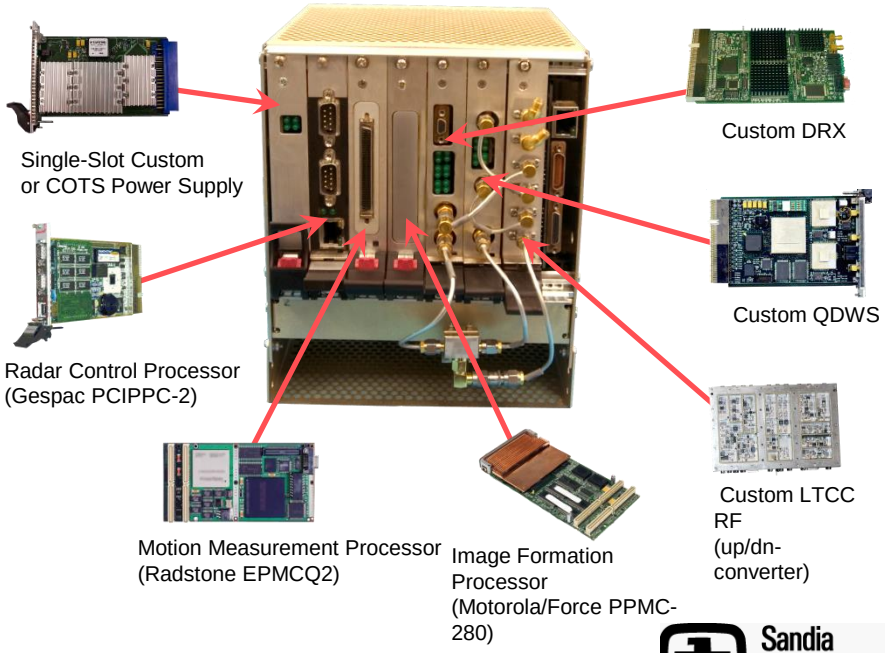
Example Applications





NYANG LC130 Stuck in Crevasse

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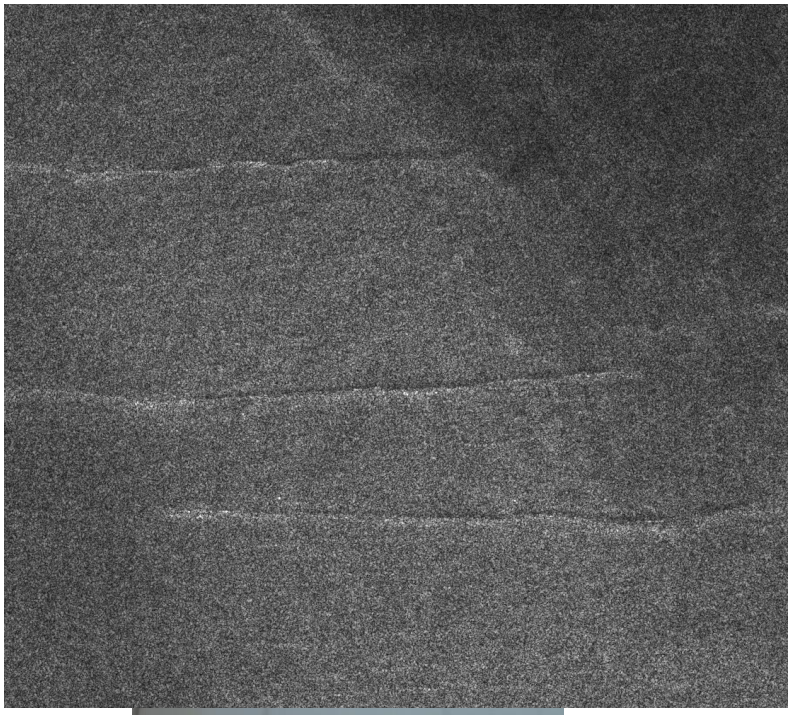
Tres Hermanas Crevasses



LC130

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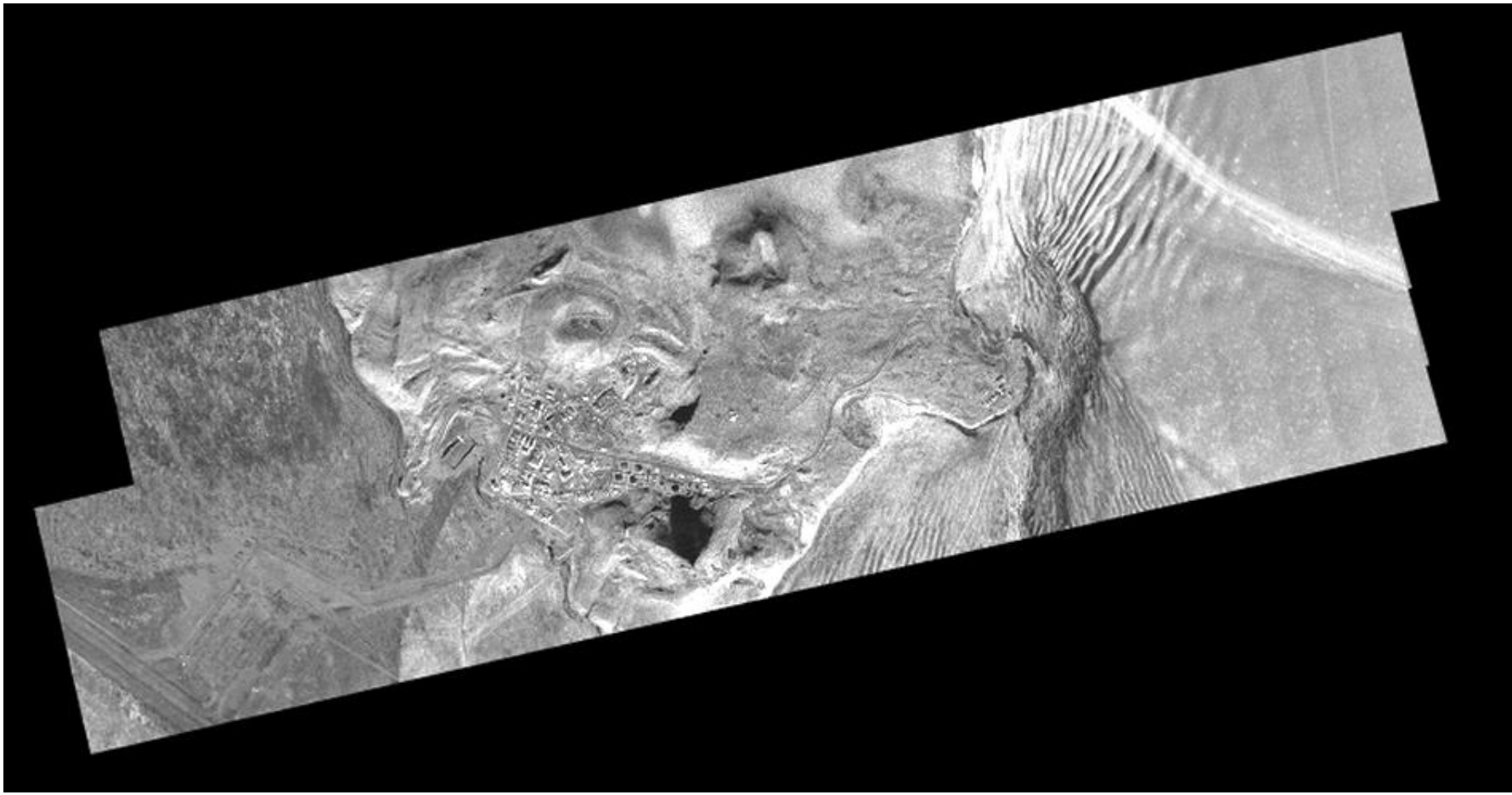
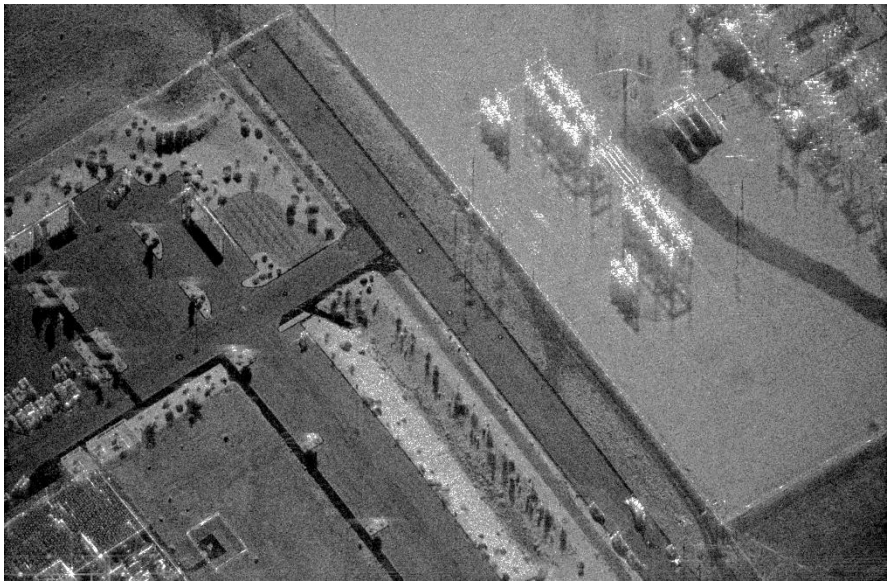
1ft resolution SAR Image of McMurdo Station



Exploitation of SAR Imagery

Getting information from the imagery

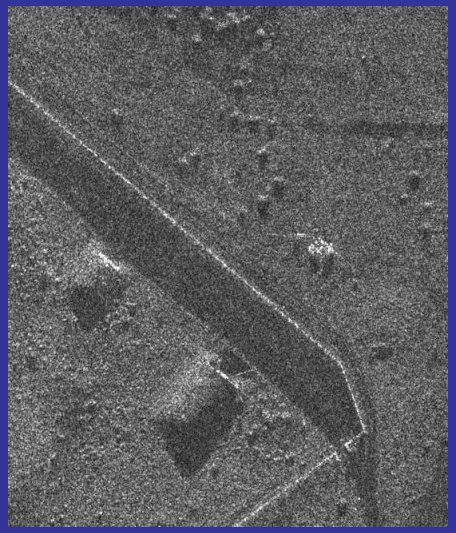
C130 and V22 - KAFB

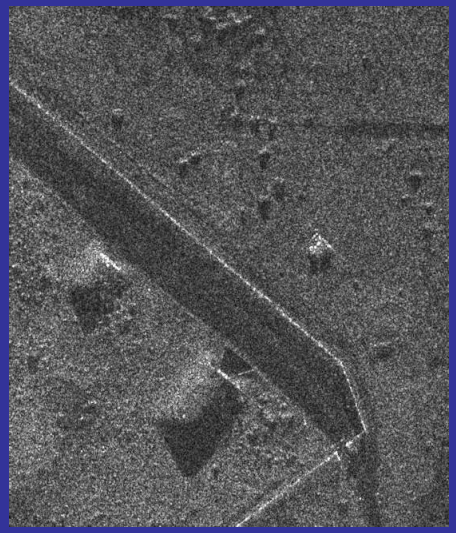


Power Substation

Coherent Change Detection Senses Millimeter-Level Changes

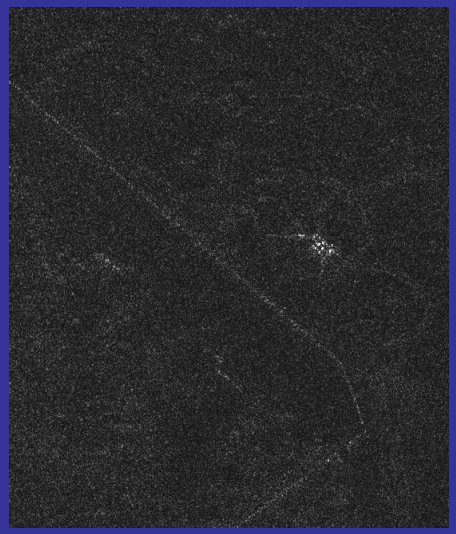
Reference image taken earlier





Current image

Coherent Change Detection



Magnitude Change Detection

Image 1

RMabry_NS_1-TO-FL_6500_001\Data\M20090401F1C5\Disturbance\Patch003

Image 1: Created: 4/1/2009 9:47:13 AM (local) //mdet.exe/&fp=dsM20090401F1.xml&c=5&rs=RMabry_NS_1-TO-FL_6500_001&z=6.674&ll=30.313924,-97.758353&p=NCP
Image 2: Created: 4/1/2009 10:04:35 AM (local)
Image 3: Created: 4/1/2009 10:12:48 AM (local)

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Image 2

RMabry_NS_1-TO-FL_6500_001\Data\M20090401F1C5\Disturbance\Patch003

Image 1: Created: 4/1/2009 9:47:13 AM (local)
Image 2: Created: 4/1/2009 10:04:35 AM (local)
Image 3: Created: 4/1/2009 10:12:48 AM (local)

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CCD12

RMabry_NS_1-TO-FL_6500_001\Data\M20090401F1C5\Disturbance\Patch003

Image 1: Created: 4/1/2009 9:47:13 AM (local)
Image 2: Created: 4/1/2009 10:04:35 AM (local)
Image 3: Created: 4/1/2009 10:12:48 AM (local)

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Image 3

RMabry_NS_1-TO-FL_6500_001\Data\M20090401F1C5\Disturbance\Patch003

Image 1: Created: 4/1/2009 9:47:13 AM (local)
Image 2: Created: 4/1/2009 10:04:35 AM (local)
Image 3: Created: 4/1/2009 10:12:48 AM (local)

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CCD13

RMabry_NS_1-TO-FL_6500_001\Data\M20090401F1C5\Disturbance\Patch003

Image 1: Created: 4/1/2009 9:47:13 AM (local)
Image 2: Created: 4/1/2009 10:04:35 AM (local)
Image 3: Created: 4/1/2009 10:12:48 AM (local)

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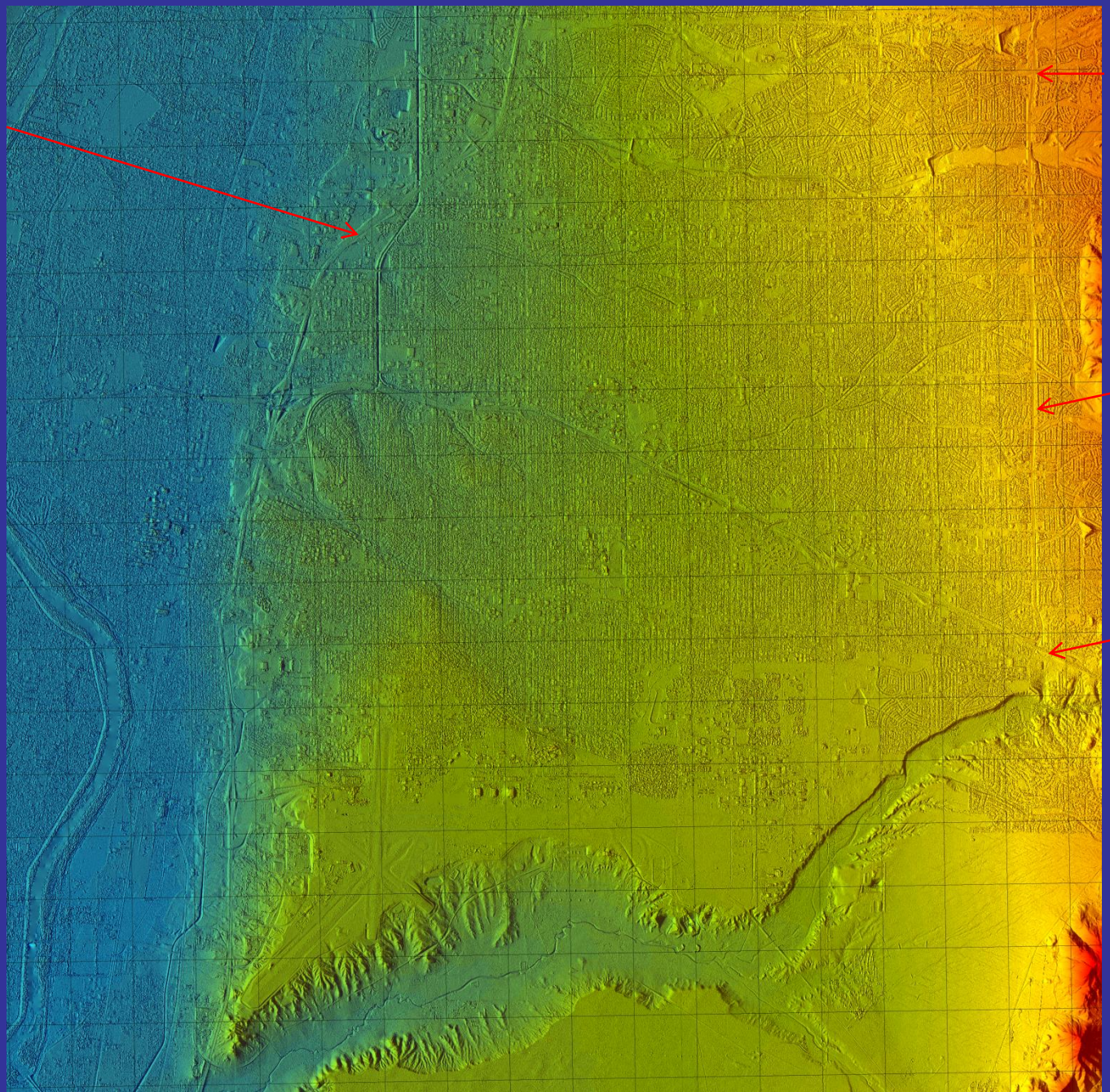
Terrain Elevation Measurement



2002
Terrain Elevation
Albuquerque, NM

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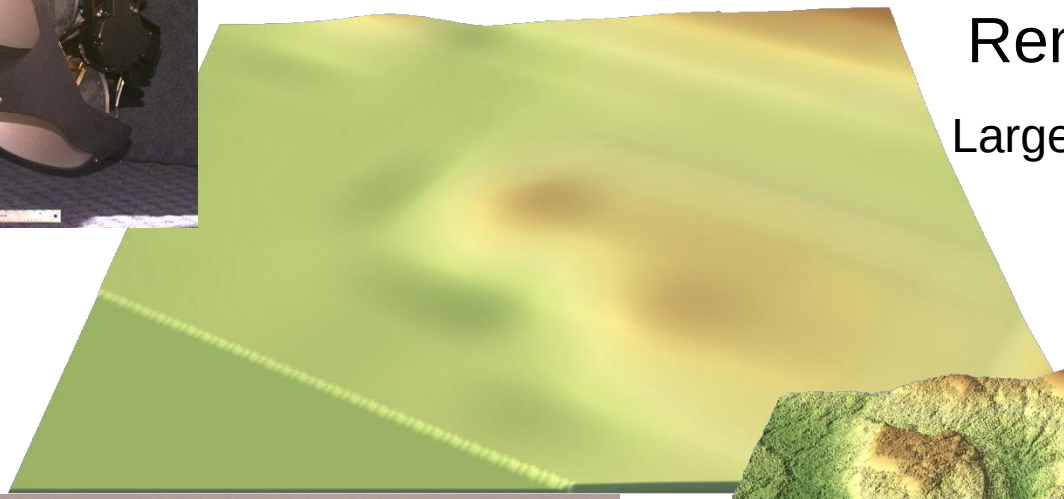
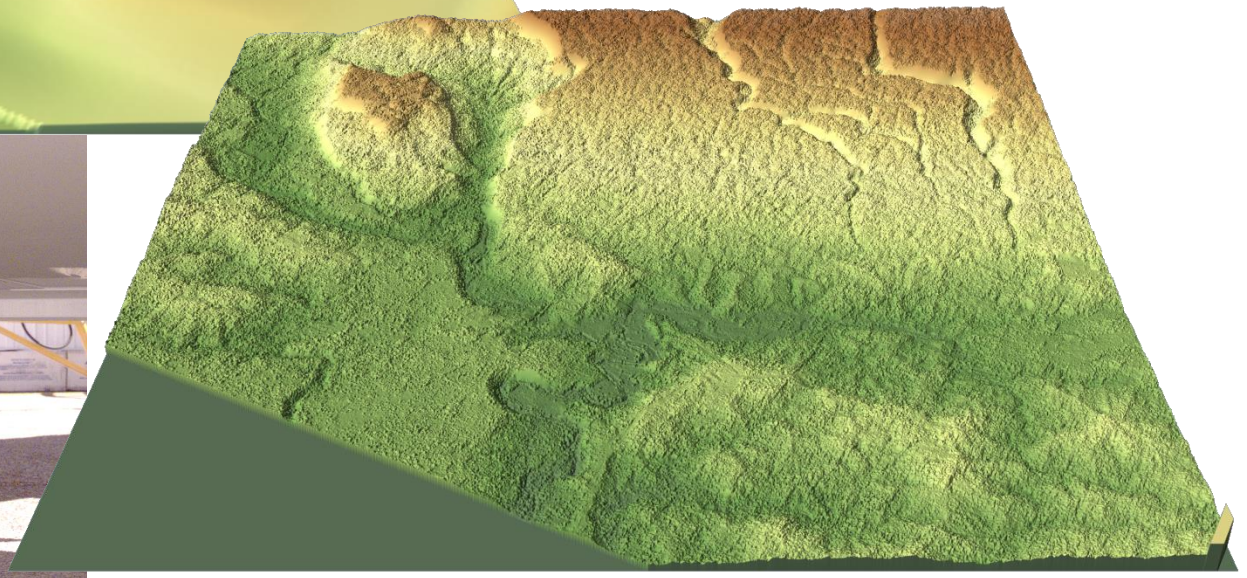
SAR Data Dramatically Improved Terrain Elevation Data in Ecuador



Rendering from NIMA Data

Large areas in Northern Ecuador only data of this quality.



Rendering from Radar Data

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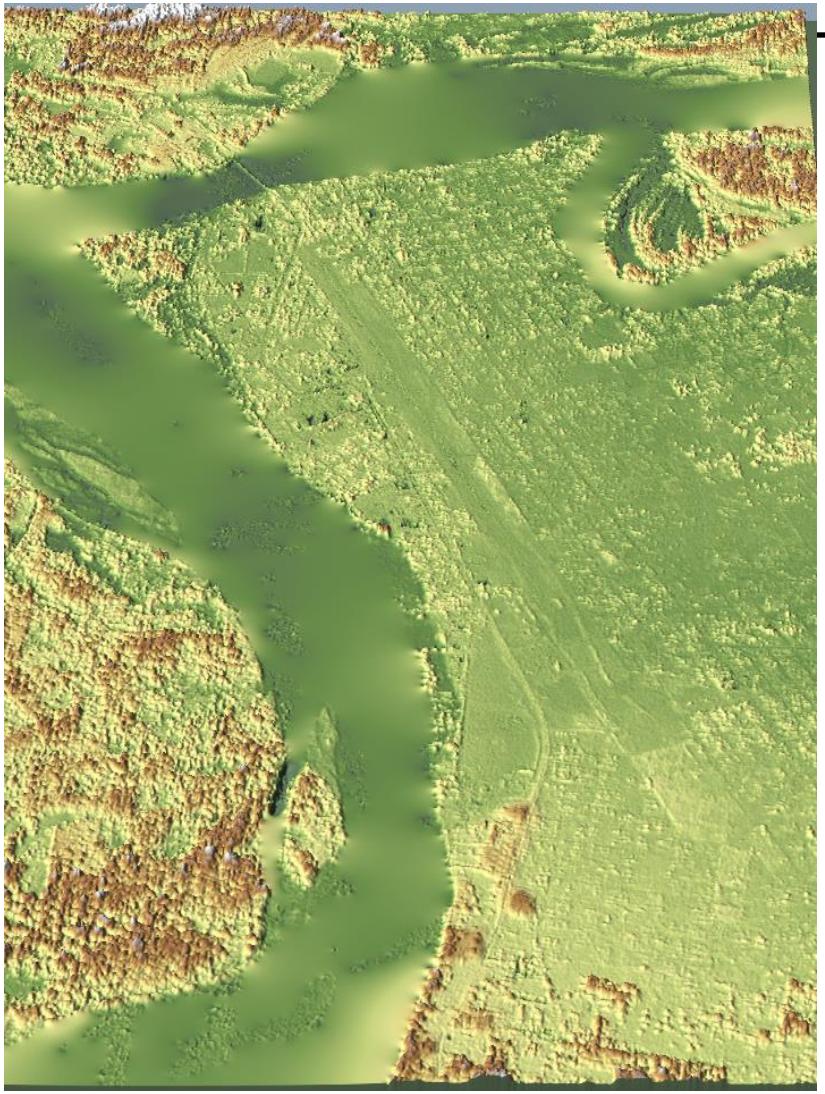
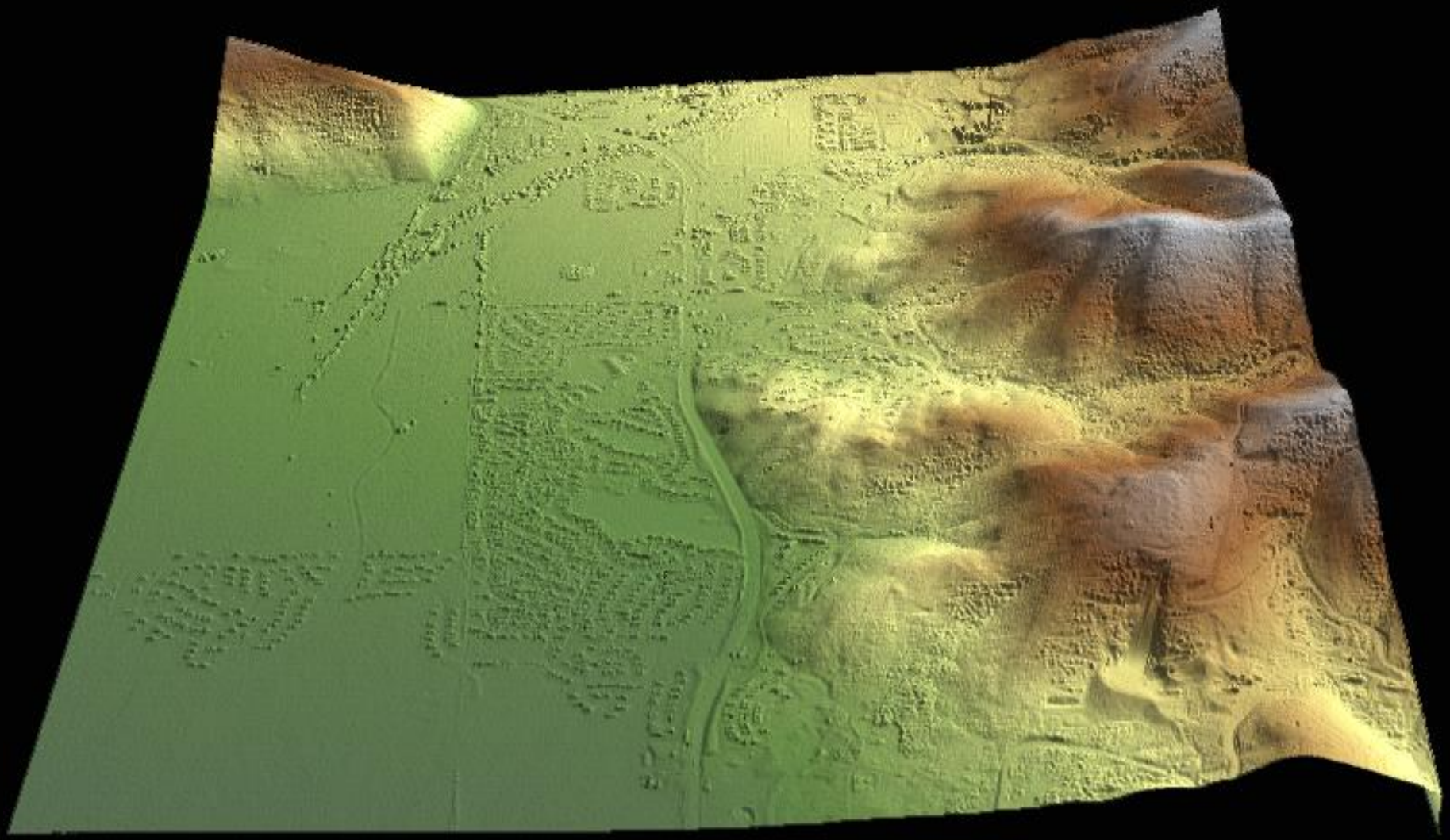
A Comparison of Radar Data and Photograph of Coca, Ecuador



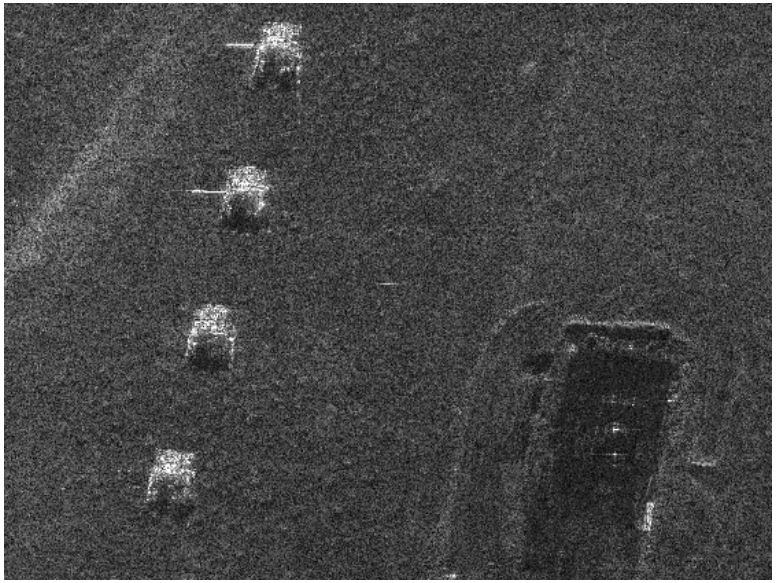
RTV IFSAR

30 Meter Terrain – Park City, Utah



Video SAR

Wyoming Gate KAFB



M-47 Tanks KAFB

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Eubank Gate
Kirtland
Air Force Base

Aircraft

Washington, DC

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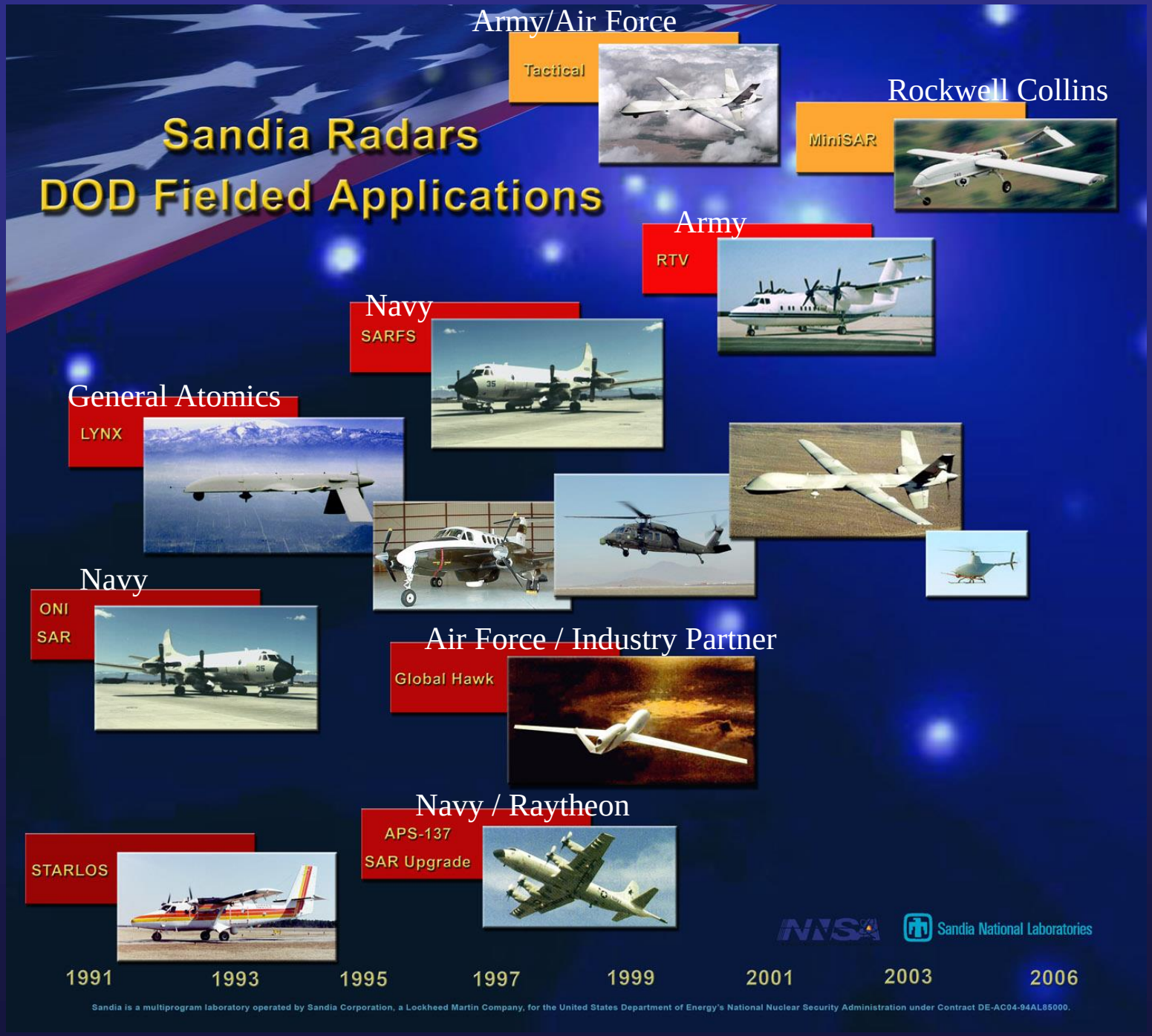
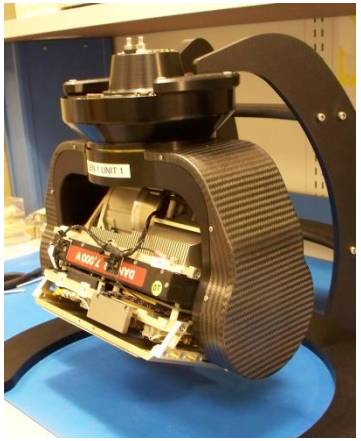

Army/Air Force
Tactical
Rockwell Collins
MiniSAR
Sandia Radars
DOD Fielded Applications
Army
RTV
Navy
SARFS
General Atomics
LYNX
Navy
ONI
SAR
Air Force / Industry Partner
Global Hawk
Navy / Raytheon
APS-137
SAR Upgrade
STARLOS
NNSA
Sandia National Laboratories
1991
1993
1995
1997
1999
2001
2003
2006
Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under Contract DE-AC04-94AL85000.

Utilization of This Technology Requires System Level Thinking

- **Radar Modes**
  - SAR (Spotlight, Stripmap, Circle, Tracking)
  - Real-time digital terrain
  - Ground Moving Target Indication
- **System Design**
  - Architectures
  - Concept of Operations
  - Solving Customer Problems
- **Algorithms**
  - Image Formation
  - Autofocus
  - Image exploitation
    - Coherent Change Detection
    - Moving target indication
- **Hardware**
  - Advanced radar architectures
  - Miniaturized hardware to reduce size, weight, and cost
- **Advanced Radar Modes**
  - Video SAR
  - Route Following Stripmap



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Sandia Directly Supports the Warfighter

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Sandia, working with government partners, is providing technologies to the Warfighter which locate and help defeat improvised explosive devices (IEDs). These technologies are directly linked to saving the lives of many service men and women.

- Sandia's history of developing radars for Nuclear Weapons led to the development of advanced Synthetic Aperture Radars (SARs) that are today fielded on small unmanned aerial vehicles (UAVs) to locate and help defeat IEDs.
- This Counter IED system has been determined by the Department of Defense to significantly exceed all performance requirements and was unanimously recommended as a Proven Counter IED system.

- A Class III UAV outfitted with a Sandia developed SAR.

- Words from the Warfighter:

  "That thing is amazing, I wish we had it from the beginning a lot of people would still be around right now ….. I have witnessed 2 occasions in the passed few weeks where things could have turned out bad and you all saved the day."

Summary

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- Imaging using microwaves can be done using Synthetic Aperture Radar (SAR).
- SAR radars have many similarities to other traditional radar systems.
- Images produced appear similar to other imaging techniques such as an optical camera; however, there are important differences
  - Range dimension
  - Azimuth dimension
- Many types of objects are easily identified in SAR imagery: roads, rivers, trees, natural vegetation, ...
- Interpretation of some objects requires understanding of backscatter phenomenology: man-made objects such as vehicles, bridges, buildings, …
- Exploitation of the SAR imagery has been frequently utilized for
  - Terrain elevation measurement
  - Change detection

References

References

- Sandia SAR web site
  - http://www.sandia.gov/radar/
- Amateur built SAR
  - https://www.youtube.com/watch?v=MViVyocQhVw