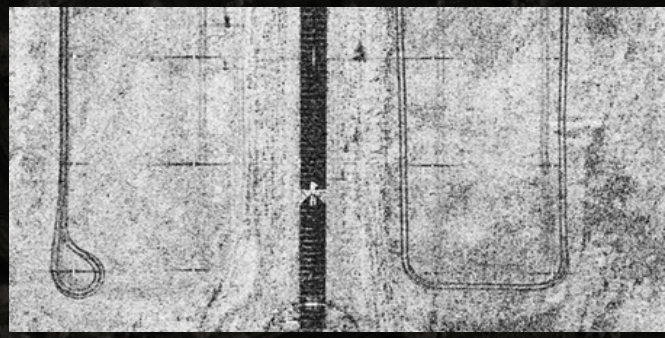
SAND2016-4588C

Exceptional service in the national interest

Sandia National Laboratories





Pathfinder GEOINT/ISR Development at Sandia National Laboratories

Bert Tise, Airborne ISR Systems
Sandia National Laboratories
bltise@sandia.gov

Sandia Airborne ISR: www.sandia.gov/radar/

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000. SAND NO. 2014-XXXXP

U.S. DEPARTMENT OF ENERGY | NNSA

Overview

Sandia National Laboratories

- General Introduction
- RADAR Capabilities
- Advanced SAR Testbed R&D Capability
- Advanced Exploitation and Automation
- Human Factors
- Future Radar Directions

Governance of Sandia Laboratories

Sandia National Laboratories

Sandia Corporation

- AT&T: 1949–1993
- Martin Marietta: 1993–1995
- Lockheed Martin: 1995–present
- Existing contract expires: April 30, 2016, with a one-year contract extension option
- Government owned, contractor operated

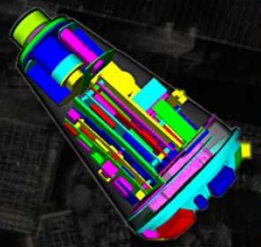
Federally Funded Research and Development Center (FFRDC)
Unique nonprofit entities sponsored and funded by the U.S. government to meet some special long-term research or development need

Sandia is 1 of 39 recognized FFRDCs

NW Mission & Sandia SAR Evolution

Sandia National Laboratories

NW Radar Fuze Tech Base



Advanced radar fuzing technology

Radar tech base originated with Nuclear Weapons

Strengthened through SAR development

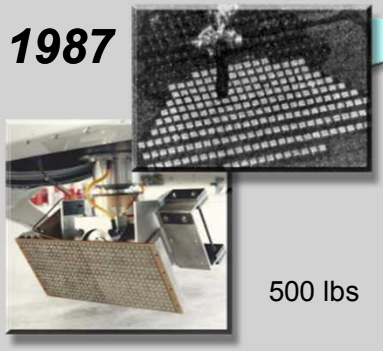
Applied advanced technology to NW systems

Synthetic Aperture Radar

Sandia SAR Evolution

Sandia National Laboratories

1987



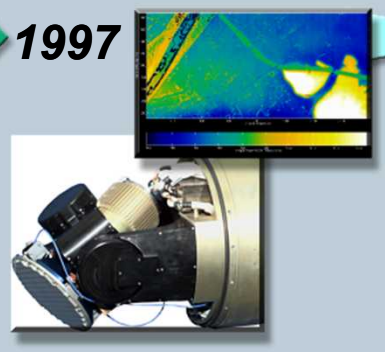
500 lbs

Terminal Fix System (TFS) SAR

1991

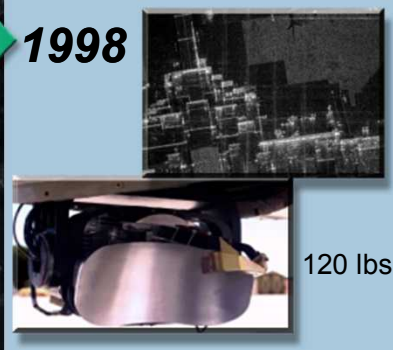
SAR Target Recognition & Location System (STARLOS)

1997



Inertial Terrain Aided Guidance (ITAG)

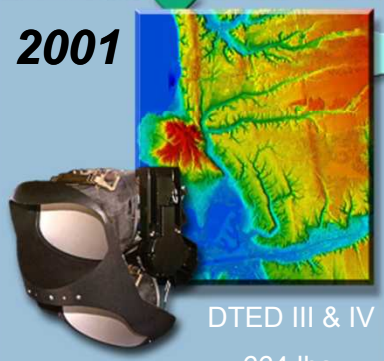
1998



120 lbs

Lynx Multi-Mode Radar CCD & GMTI

2001

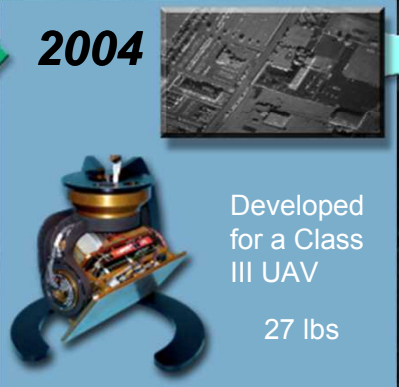


DTED III & IV

664 lbs

Rapid Terrain Visualization (RTV)

2004



Developed for a Class III UAV

27 lbs

MiniSAR

2008

IED Detection

65 lbs

Copperhead

2010

FARAD

Multi-mode

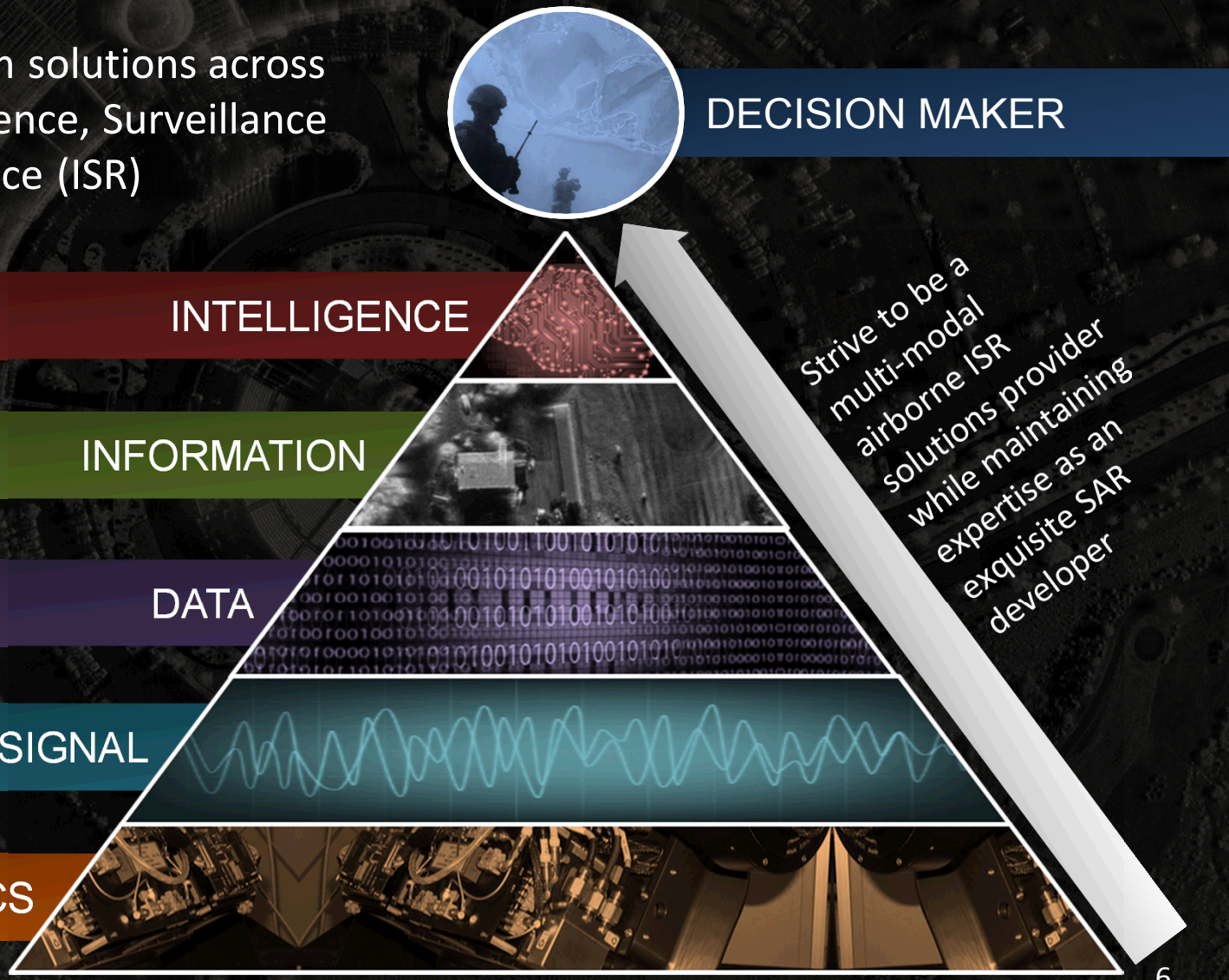
Variable Resolution & SWAP

Improving radar performance & reducing SWAP for three decades

Airborne ISR at Sandia

Sandia National Laboratories

Provider of system solutions across the entire Intelligence, Surveillance and Reconnaissance (ISR) architecture

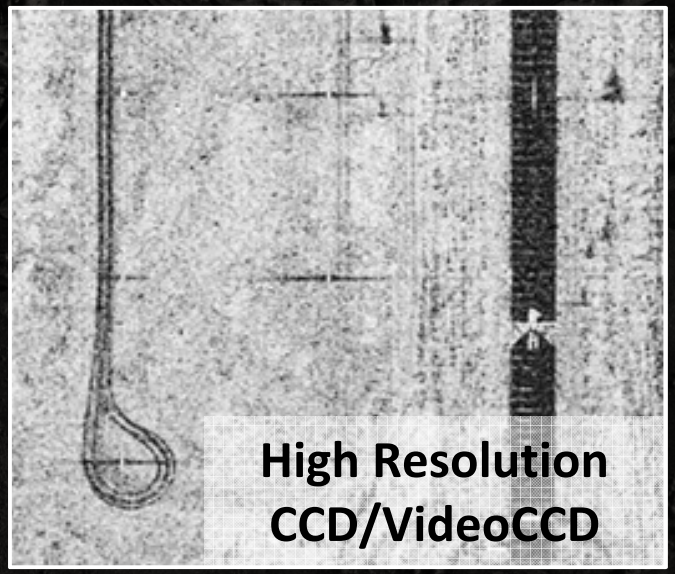


Pathfinder Airborne ISR Solutions

Sandia National Laboratories

3+ decades of experience delivering pathfinder ISR solutions for complex, critical and urgent national security problems (FFRDC)

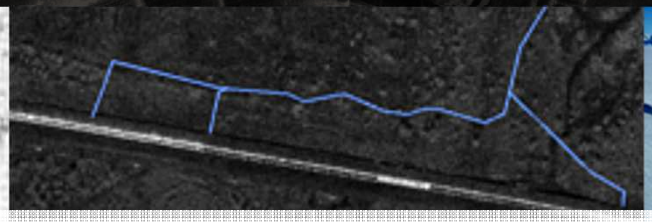
- All Weather, Day or Night
- High Resolution, Optical-like
- On-board and Real-time Processing
- Flexible platform and TPED configuration



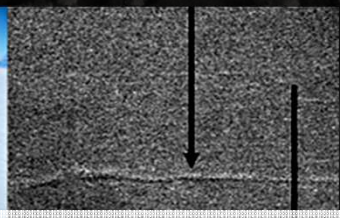
Real World Applications

Sandia National Laboratories

Coherent Change Detection

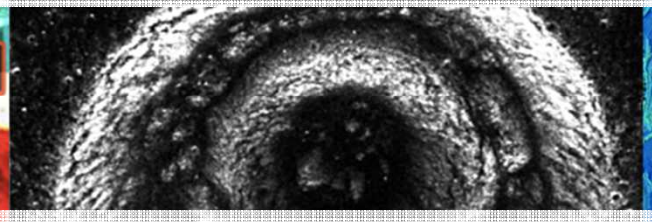


Facilities and Border Protection

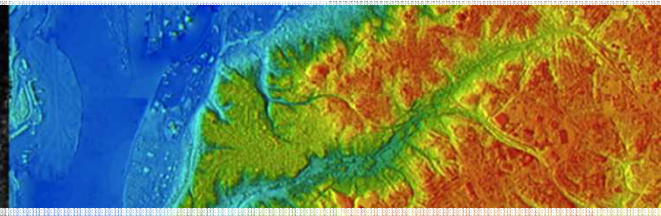


Crevasse Detection

Environmental Monitoring



Earth Sciences

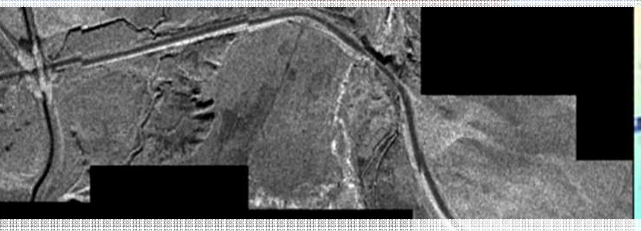


High Res. Terrain Elevation Mapping

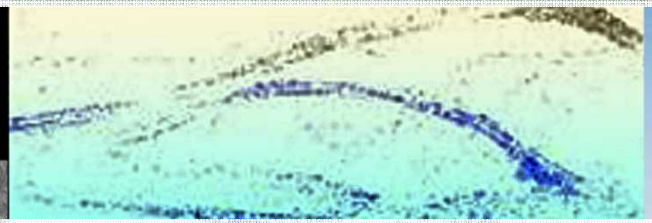
Maritime & Littoral

Tracking

S&R and Targeting



C-IED & Route Reconnaissance



Patterns of Life

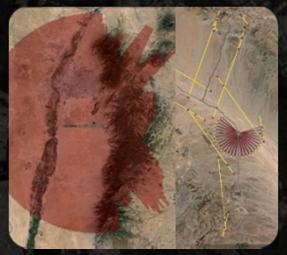
Precision Guidance

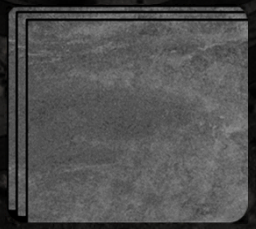
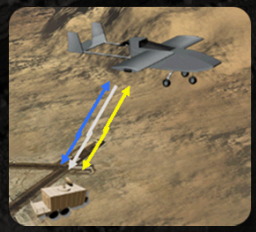
Since 1997, Sandia radars have been used to address critical problems in all geographic areas

Complete Mission Solutions

Sandia National Laboratories

- Provider of end-to-end solutions that leverage physics, engineering, and data and information science to support national security decision making
  - **Mission Engineering**
    - Pre-Mission Analysis & Flight Planning
    - Highly customized TTPs and CONOPs
    - Continuous performance assessments
    - Analyst Training in SAR phenomenology
  - **Real-time Processing**
    - Real-time Delivery of Multiple Image Products to Analysts
    - Image Formation
    - Change Detection Products
    - Transmission of Real-time Products
  - **Advanced Sensor Exploitation**
    - Predictive Intelligence
    - Human Factors
    - Advanced Exploitation Techniques
  - Analyst Training



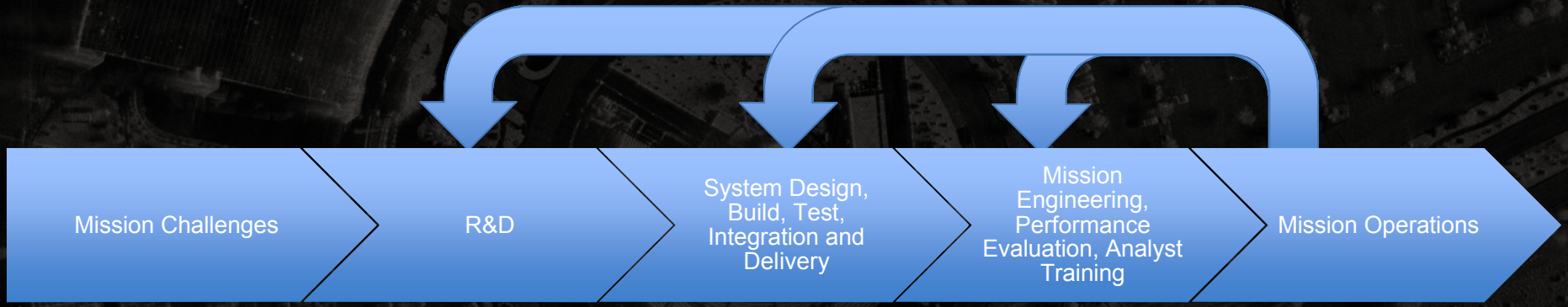



SAR imagery integration into PED cycle is difficult at best.

Full Cycle Solutions

Sandia National Laboratories

Multiple current missions requiring high performance capabilities



Fully understanding the mission challenges allows for the successful development and deployment of the mission solution!

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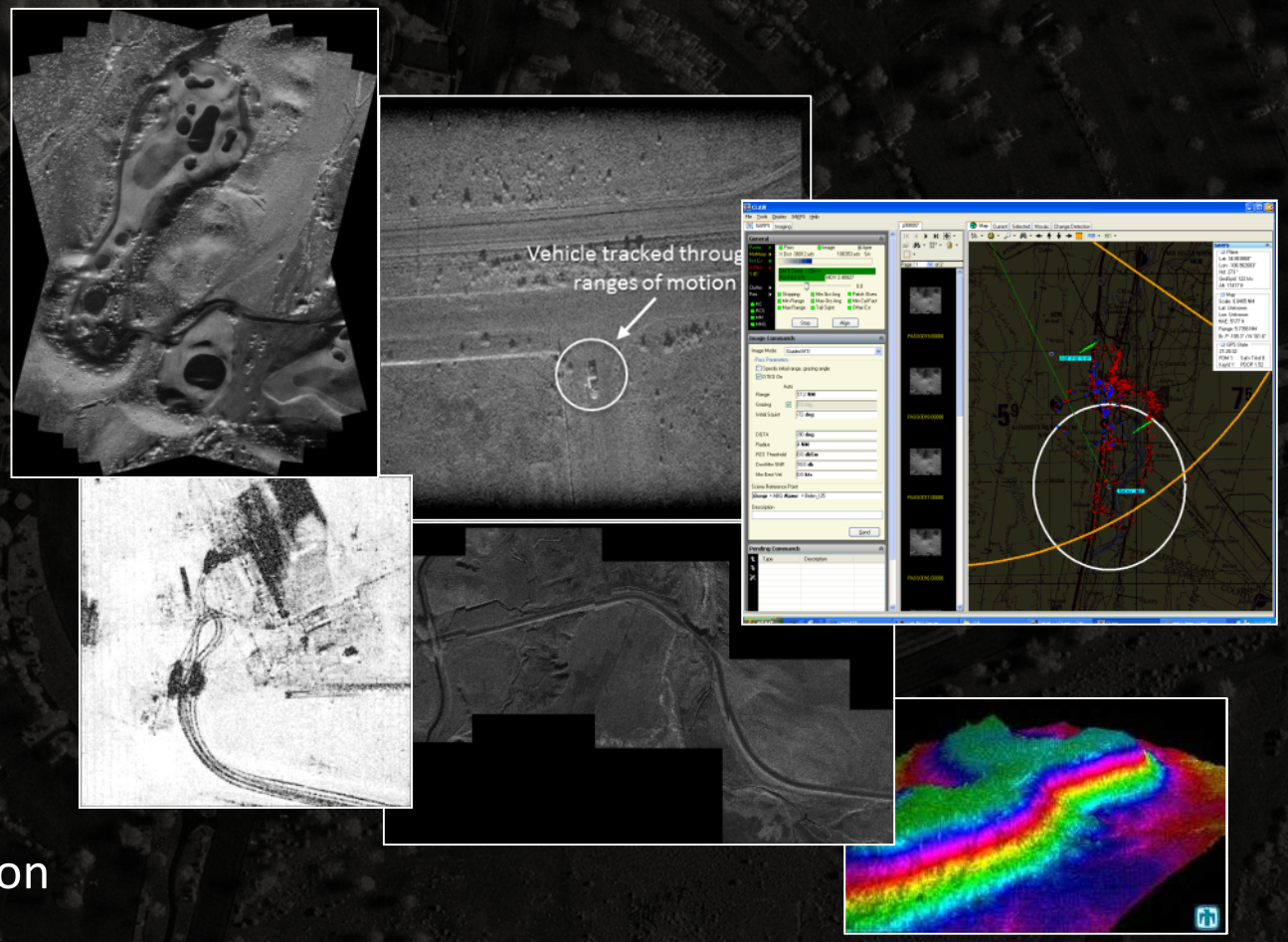
Multi-Mode Functionality

- Spotlight
- SpotDwell
- Circle
- Stripmap
- Arbitrary Stripmap
- CCD/NCP
- IFSAR
- VideoSAR/VICTR
- GMTI/DMTI
- Wide Area Search
- High Range Resolution

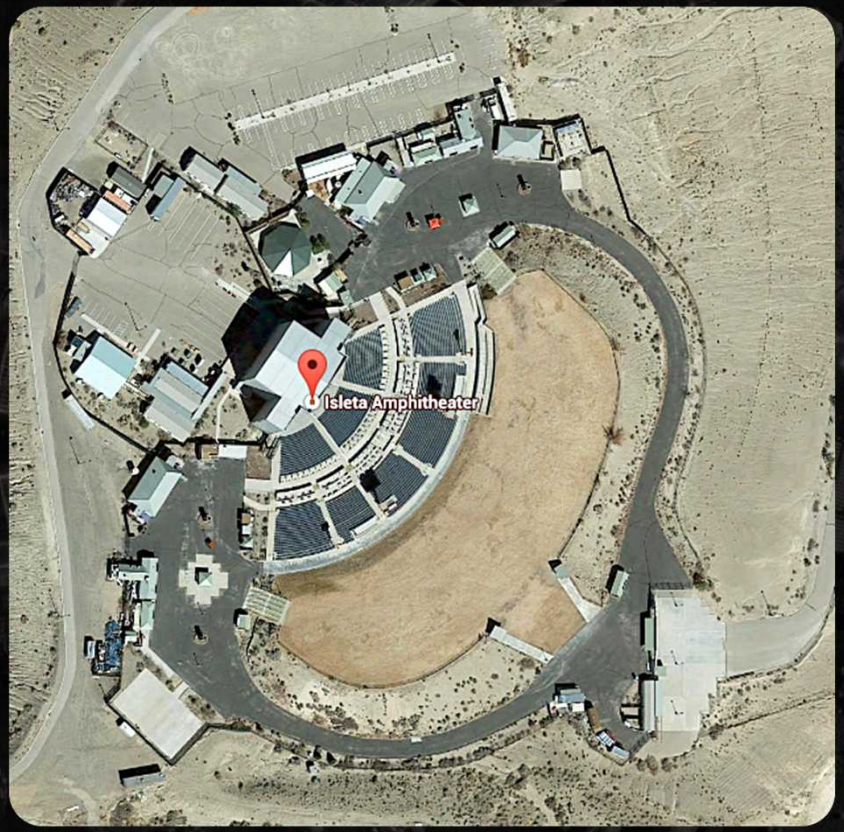


As new radar modes are developed they can be integrated into existing Sandia radars during product improvement phases without redeveloping the entire system

VideoSAR Vehicles Example

This is VideoSAR footage of a gate at a facility. The video shows vehicle traffic moving through the gate. As the vehicles are in motion their location is indicated by a shadow. As the vehicles stop the reflected energy of the vehicles fall on top of the shadow. Once the vehicle continues in motion the shadow is again visible. The lines moving across the screen are Doppler shifts caused by the moving vehicles.

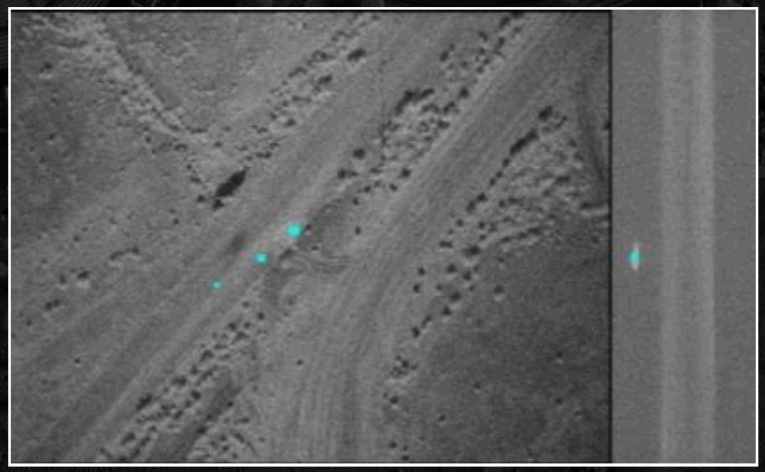
VideoSAR Facility Example



Advanced Capabilities

Sandia National Laboratories

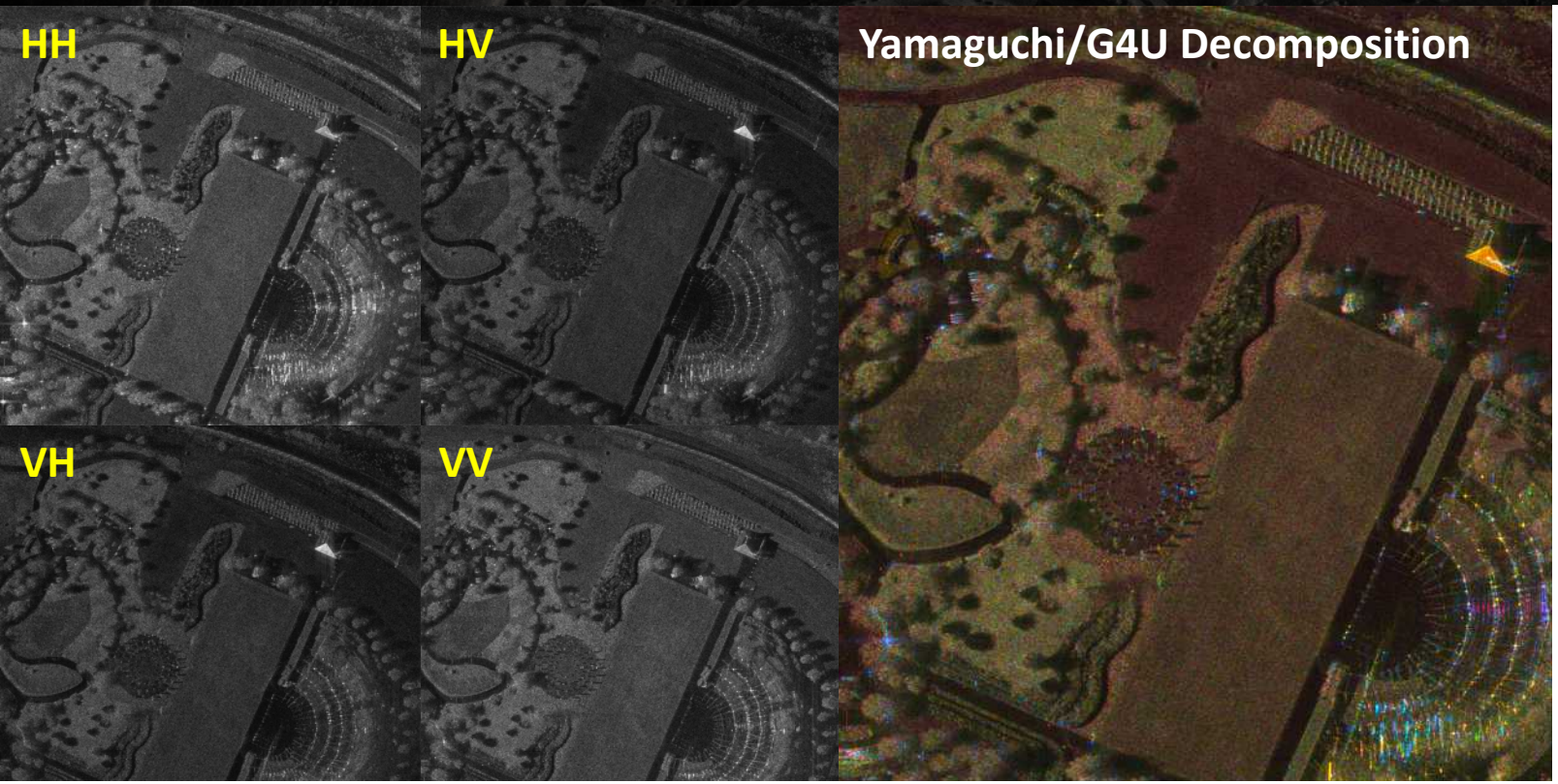
- Multiple channels with the same instantaneous bandwidth.
- Multiple phase centers – sum and difference yield clutter suppression and increased ability to track targets.
- Polarimetric (HH, VV, HV, VH) yields additional information around scattering phenomena.



High Resolution Polarimetric SAR

Sandia National Laboratories

Value in polarimetric SAR is not in visual comparison of individual channel (HH, VV, HV) backscatter intensity maps, but rather in the inference of underlying scattering mechanisms from these independent phase coherent measures



SNL FARAD, X Band, 0.2m Full-Pol Imagery of New Mexico Veterans Memorial, Model Based Decomposition Example

Velocity Independent Continuous Tracking Radar (VICTR)

Simultaneous VideoSAR/GMTI with automated tracking

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FARAD – SAR R&D Testbed

Sandia National Laboratories

- An in-house, high-performance, multi-mode airborne radar capability for the continued advancement of SAR ISR capabilities
- FARAD works in accord with R&D efforts, both internal and external, to provide advanced radar airborne data collection and exploitation assets to facilitate specific research goals
- FARAD provides a “testbed laboratory”/research tool set that can be widely utilized in support of internal R&D, new program development, and collection of nationally-important data products.

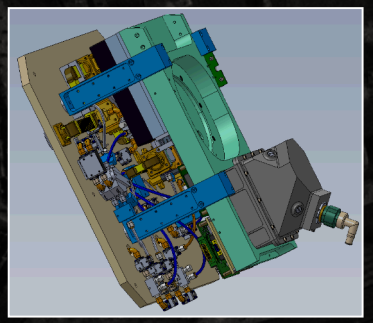
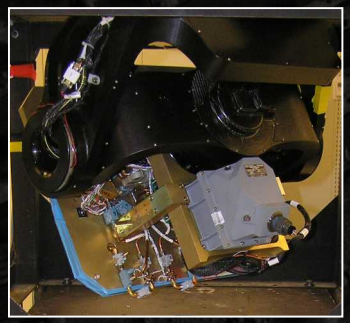
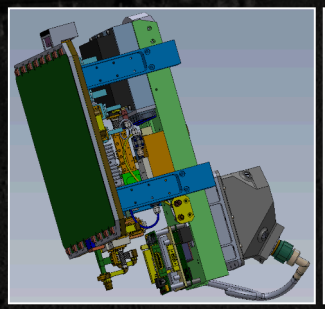
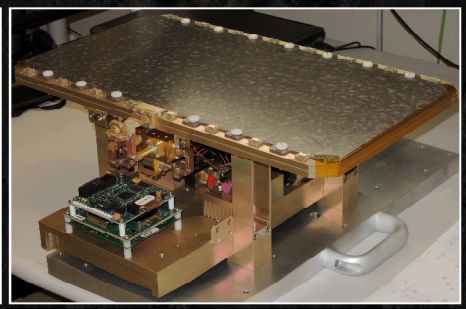
DeHavilland DHC-6 “Twin Otter” research aircraft operated for Sandia by Twin Otter International

FARAD Systems

Sandia National Laboratories

- **PhoeniX**
  - X-Band
  - Fully polarimetric
- **Ku-Band**
  - Quad-phase-center planar antenna
- **Ka-Band**
  - Dual-phase-center planar antenna



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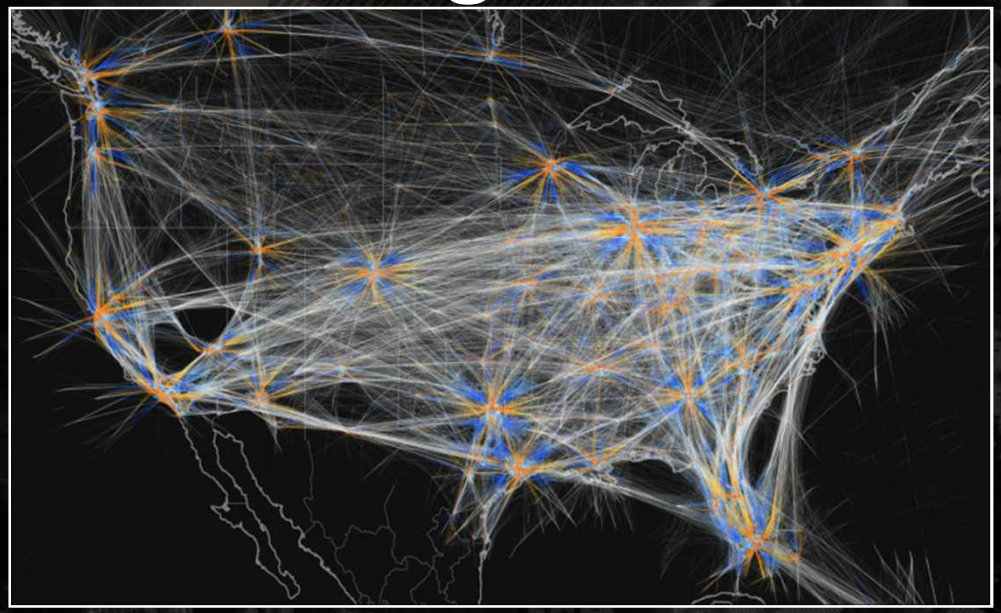
Rethinking Search

Sandia National Laboratories

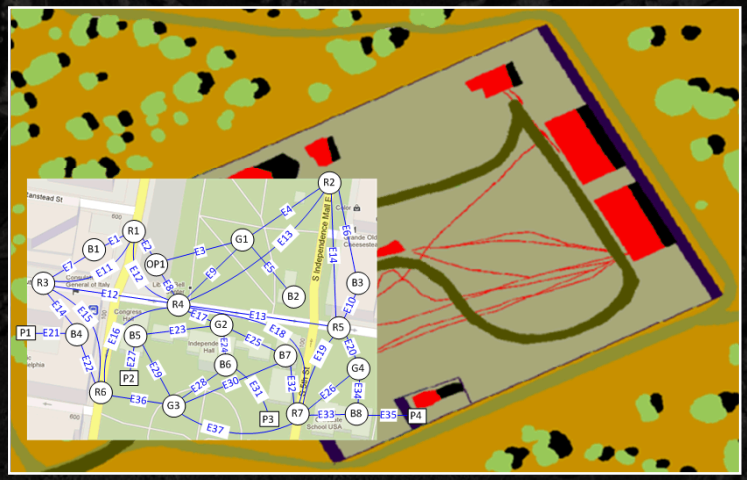


Rethinking traditional GIS and geospatial search.

- Compact, efficient representations of features extracted from sensor data
- Sensor agnostic capability for multi-INT feature relationships in time and space
- Predictive and forensic analysis

Rethinking patterns in motion.

- Geometric and temporal trajectory analyses – changing dots to tracks to *trajectories*.
- Geospatial-temporal relationships – i.e., identifying things like co-travelers.



Decision Makers and Analysts care about "what", "where", and "when".
Where is it going? Where has it been? What's the relationship? What's changed?

SAR in an Advanced Exploitation Environment

Context enhanced information fusion and integration

Sandia National Laboratories

EO

LIDAR

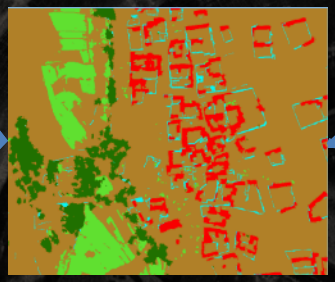
SAR
time$_0$
⋮
time$_n$

Other datasets

Point data

Type	Lat	Lon	MM	DD	YY	...

Landcover



SAR image products

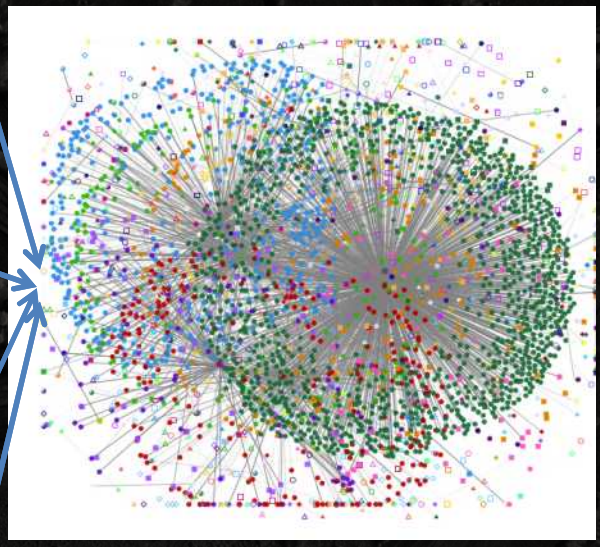
Type	Lat	Lon	MM	DD	YY	...

Static features

Transient features

Nodes

Semantic Graphs enable a higher level of reasoning by analysts.



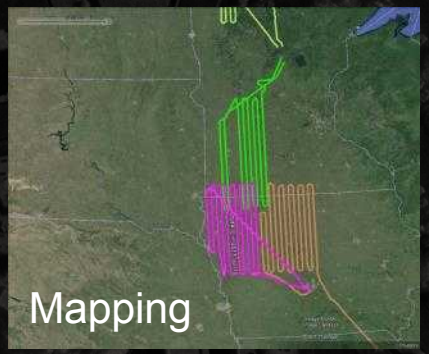
Graph of nodes and edges forming geospatial/temporal relationships

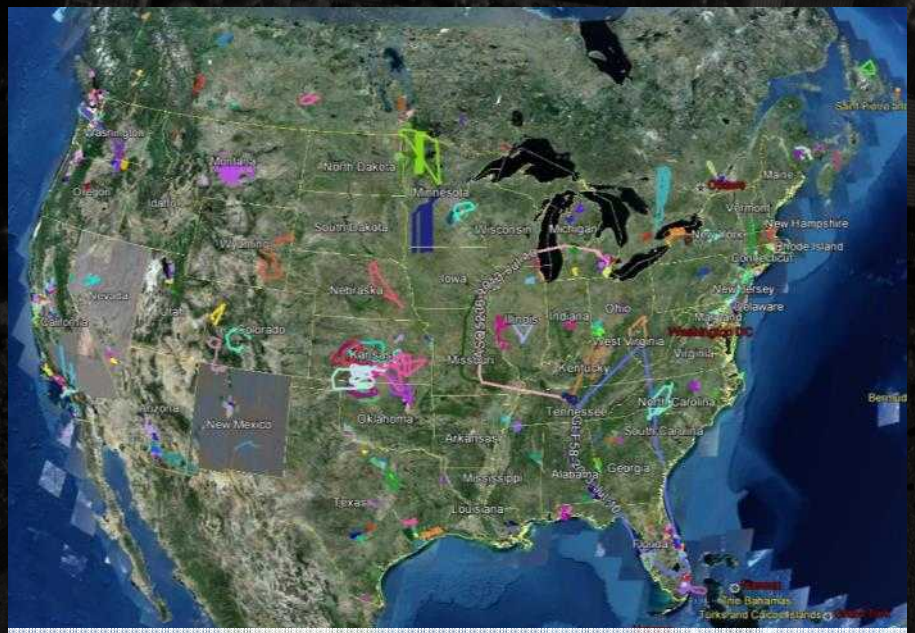
Synthesis/Analytics/Decision Tools

Discovery of Flight Patterns and anomalies

Sandia National Laboratories

Collections of geometric descriptions can describe a trajectory. Extensions: impact of time.





Represents approximately 700 out of the total 50,000 flights.

Discovery of Odd Flights based on unsupervised learning.

- Clustering done based on geometric features

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Human Factors Issues Permeate ISR

Sandia National Laboratories

- Human-system integration remains the weakest link in the analytics research-development-deployment process
  - Human factors requirements may not be adequately addressed in acquisitions process.
  - As a result, situation awareness and general ergonomics may not be optimal for the TCPED cycle
  - Sandia is investing in its understanding of the Human-Machine Interface (HMI) in efforts to deliver optimal PED solutions.

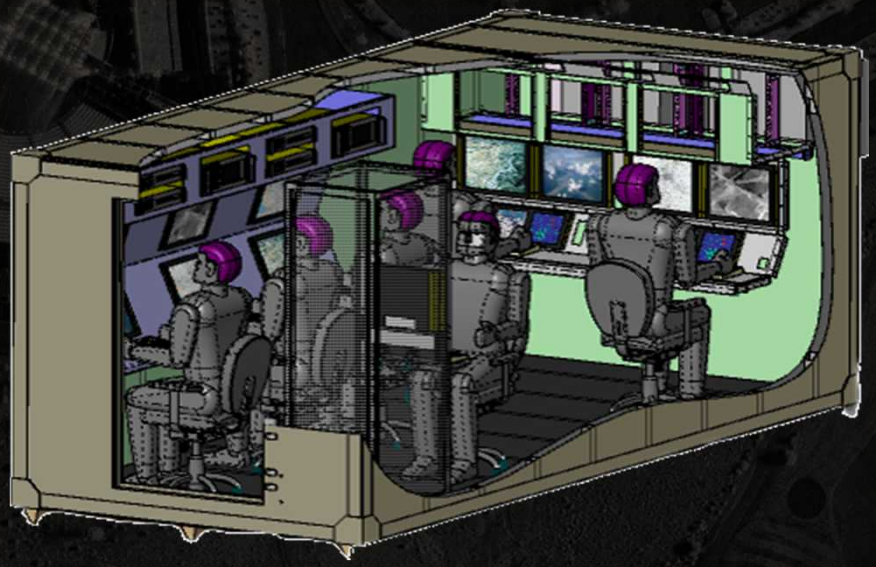
Opportunities for Improved Work-flows

Sandia National Laboratories

- System Opportunities:
  - Platforms and Sensors
  - Control Stations
  - Communications
  - Crew
- Mission specifics are developed after system development and deployment, rather than as a concurrent effort in an "incremental development" program

Excerpted from *Operating Next Generation Remotely Piloted Aircraft for Irregular Warfare* - USAF Strategic Advisory Board, 2010.

Sandia is currently evaluating HMI environments for ground stations



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Radar Modernization

Sandia National Laboratories

- VPX Multi-Channel for All Sandia Designed, Delivered and Deployed Radars
  - More physics – more information
  - Drive down costs
- Enables collection of a broader set of physics:
  - Enhanced Coherent Change Detection
  - Maritime Situational Awareness
  - Mover Detection
  - Tracking Capabilities
  - Other
- Common hardware and software base
  - Encompassing various SWAP configurations
- In progress

Next Generation + 1 Radar Concept

Sandia National Laboratories

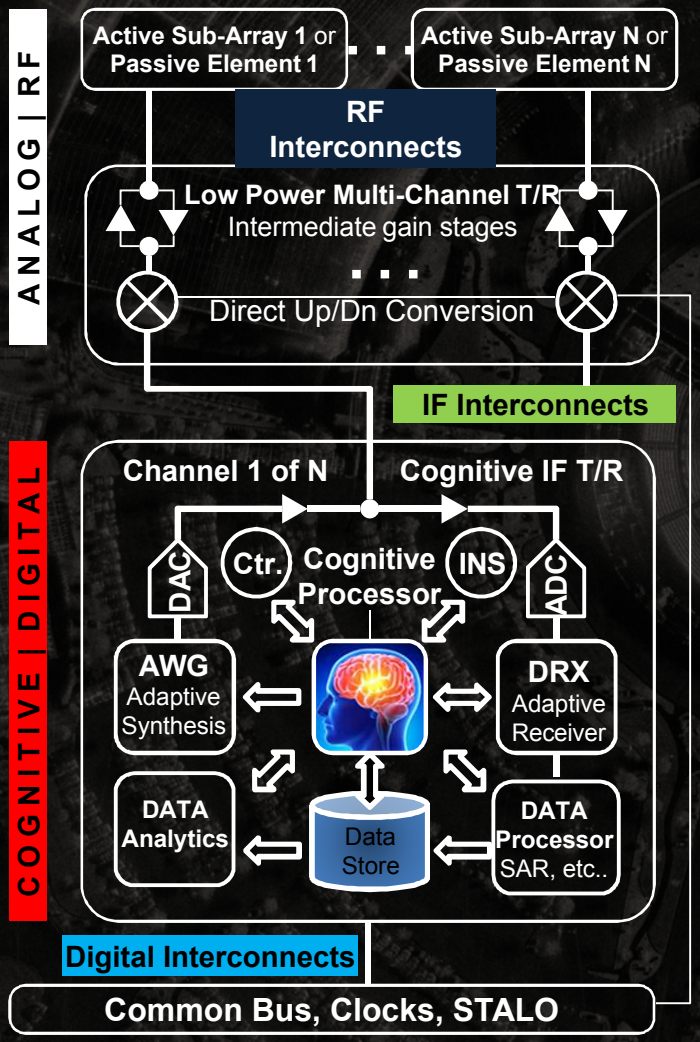
- Cognitive Digital Radar
  - Flexible operations in complex electronic environments
  - Multi-Channel Depending on Application
  - Simplified RF Frontend
  - Digital processing at full instantaneous bandwidth of radar
- Applications in Addition to Radar:
  - COMMS
  - A2AD (sense, analyze, respond)
- Emerging high-speed digital COTS hardware
  - Decreased hardware costs
  - High-performance, real-time processing for multiple missions will be required.

Cognitive Agile Tactical SAR (CATSAR) Concept

A multi-mission broadband digital radar

H. Loui - PI

Sandia National Laboratories



(Guerci, Joseph R. , Cognitive Radar, 2010)

Cognitive Agilities:

- **Waveform agility** (Full RF bandwidth)
  - Arbitrary waveform generation on Tx → Tx-STAP
  - Digital-matched filtering on Rx → Rx-STAP
- **Channel agility** (supports additional DOFs such as polarimetry)
  - Modular/Scalable architecture
  - Simultaneous/selective multi-channel
- **Beam agility** (MIMO/AESA)
  - Multiple phase centers, no TTD or phase shifters
  - Monolithic power combining (Active Array)

Digital Subsystems - COTS

Tactical Advantages:

- **Operate in complex electronic environment**
- **Multi-mission software configurable: SAR, GMTI, EW, etc…**

Real-time Challenges:

- **Large data throughput requirements:** Wideband radar will require large data rates for each channel.
- **Large processing requirements:** Cognitive processing aside, simple matched filter operation utilizing FFT and complex multiplication requires high capacity floating-point capabilities for real-time processing.