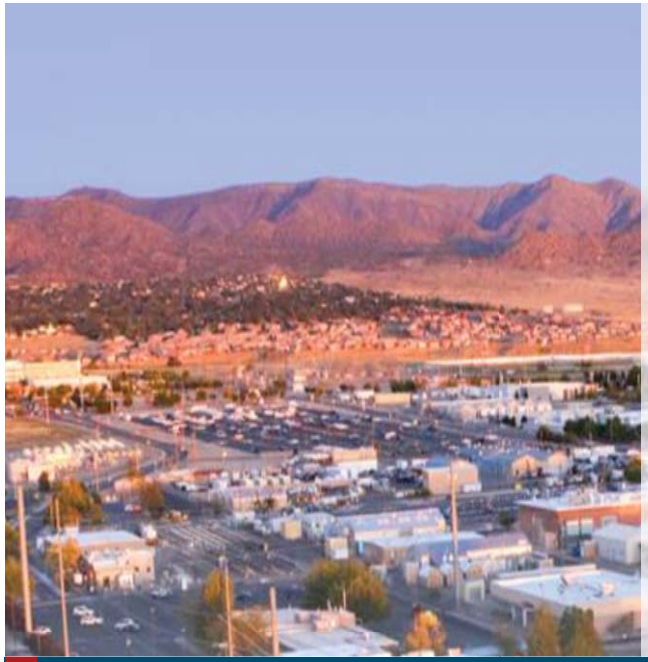

(U) SIS-AOP: Developing a Revolutionary Multi-Source SAR Automated Object Processing System (a Tactical Defense Space Reconnaissance Program)

(U) Ireena A. Erteza, Ph.D

DMTS

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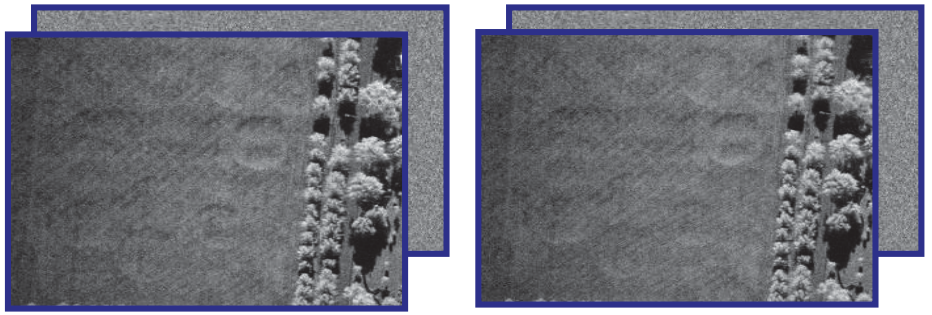
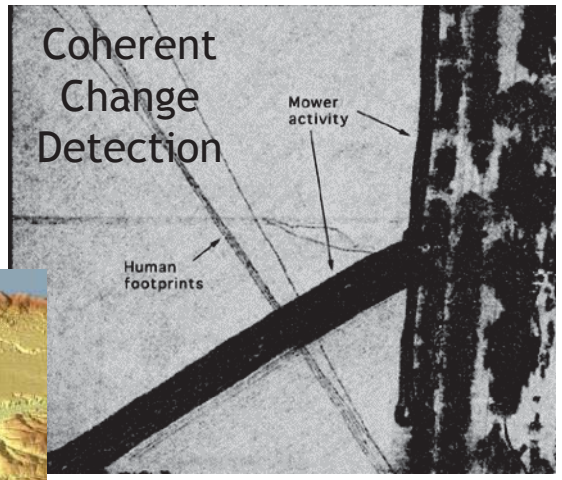
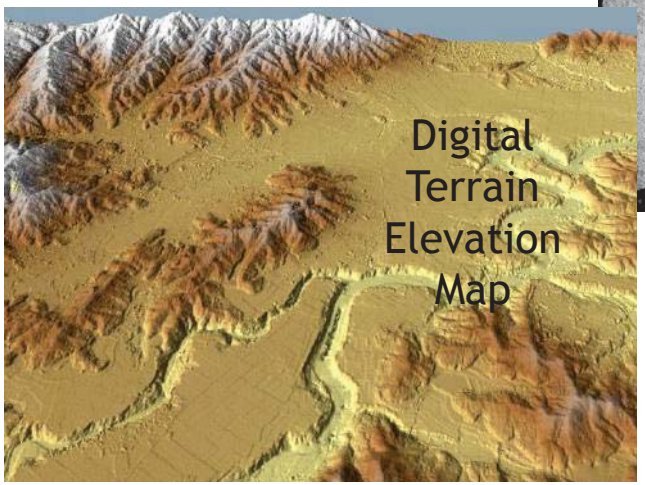
(U) Snapshot of Synthetic Aperture Radar (SAR) Research at Sandia

- (U) SAR provides day/night, all-weather high-resolution images.
- (U) SAR is a computed imaging technique.
- (U) The coherent, complex nature of SAR offers much more than just imagery.



- (U) Goal: To develop innovative techniques for exploitation of synthetic aperture radar imagery, as applied specifically to problems in nuclear non-proliferation, arms control and national security.





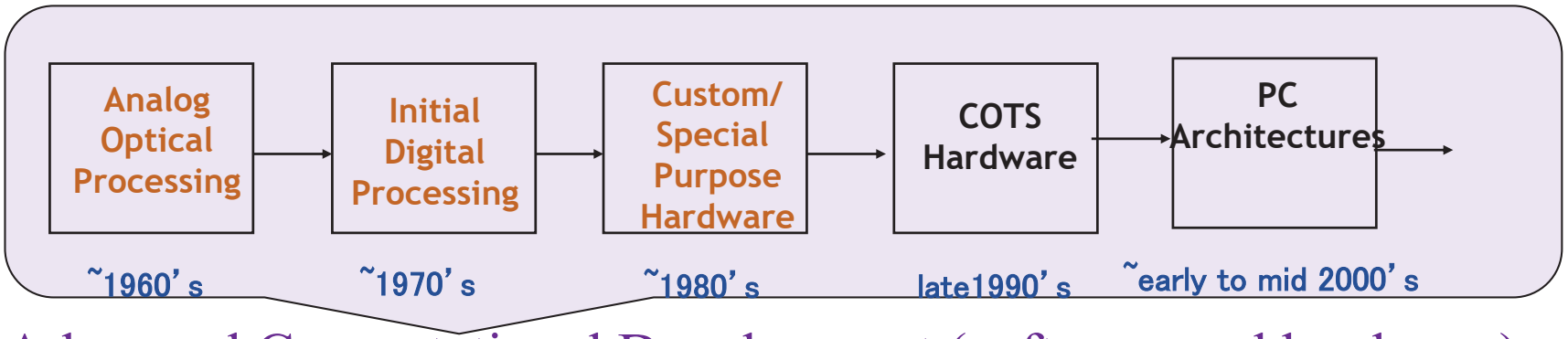
Graphics are (U)

(U) Impact on the National SAR Community

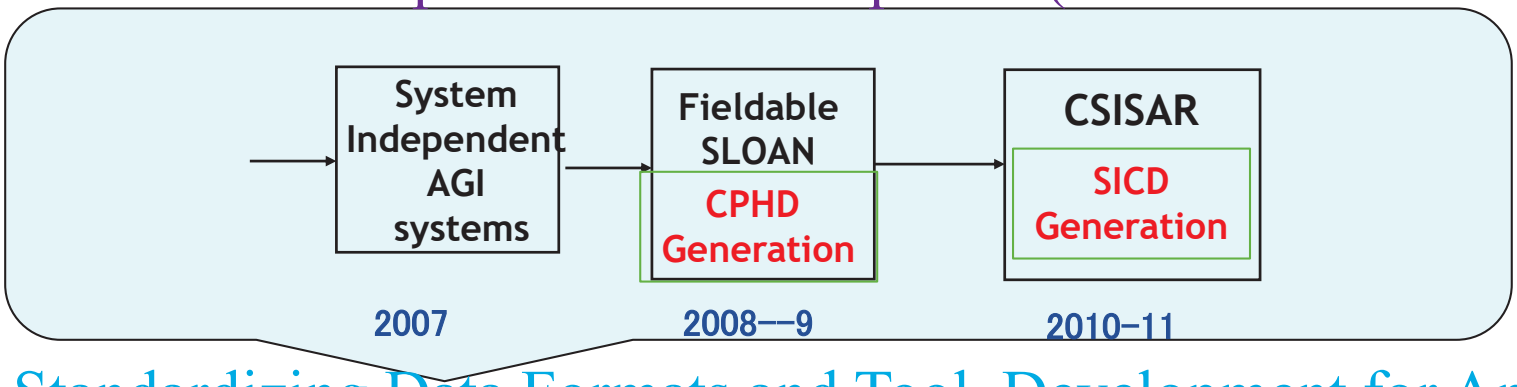
- (U) You probably have heard about some other significant ways Sandia's IC SAR group has impacted the entire National SAR community and changed conventional thinking in the community since 1998 to the present.
  - Advanced Computational Development (software and hardware)
  - Standardizing Data Formats and Tool Development for Analysts
  - Automated Processing for the National Community (current thrust)

(U) We have influenced what types of products are made and how they are made.

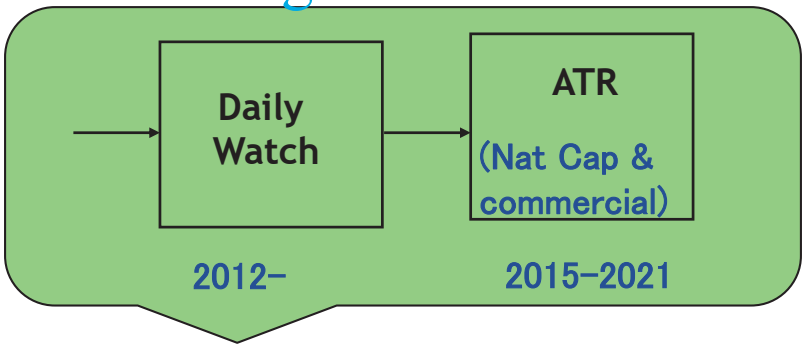
(U) Significant Impacts to National Processing Systems & Beyond



Advanced Computational Development (software and hardware)



Standardizing Data Formats and Tool Development for Analysts



Automated SAR Processing

This graphic is (U)

(U) SIS-AOP BLUF (Bottom Line Up Front)
Single Image SICD-Based Automated Object Processing

- (U) SIS-AOP fills a huge void that has existed in SAR exploitation:

  Persistent and effective automated vehicle-like detection in strategic imagery with good performance (Pd, FA rate)

- (U) Key Enablers
  - Using **data standards** (System Independent Complex Data-SICD) to increase persistence
  - Very fast and capable first-stage cueing, using the **improved Sandia FOA4.0 Framework**, that enables consistent performance even with data from systems with vastly different performance
    - Adaptive quantization
    - Morphological processing
    - Feature-based back-end processing
  - **Revolutionary PIML Clutter Culling Module to dramatically reduce false alarm rate**
    - Phenomenologically Informed Machine Learning (PIML): smartly using knowledge of SAR physics to develop machine learning techniques that encourage the neural networks to key in on pertinent features of objects
    - Enables good performance on data from widely different SAR systems
  - **Modular system architecture** allowing easy insertions of modules to get better performance or to tune to more specific objectives.

(U) TacDSR (Tactical Defense Space Reconnaissance Program)

- (U) TacDSR is a Congressionally-mandated, NRO Military Intelligence Program to "develop, mature and integrate technologies that facilitate the dissemination of National Systems Data to the warfighter in the field"
  - Very competitive, open to industry, govt agencies, FFRDC and academia
  - ~ 25-30 projects annually between CSI and MERIT
  - Each project: 1-2 years, up to ~1.75M funding

- (U) Sandia's IC/National Capabilities-Focused SAR Group's related TacDSR Programs
  - SLOAN (2008-2009)
  - CSISAR (2010-2011)
  - DailyWatch (2015)
  - TWOIT (2018-2019)
  - SIS-AOP (2020-2021)

(U) Problem Differentiation: Strategic Alerting or Screening in National Capability Strategic-Size Single Images

- (U) **Strategic screening** (looking for a general vehicle-like object in any type of background at any orientation in a large scene) is a very difficult problem.
  - SAR imagery is not easy to interpret
  - Many objects can look like vehicles (buildings, bushes, dirt mounds, rock edges)
  - In large scenes, there is no consistent background
  - Screeners using change detection imagery can use change to cut down on the number of cues (help focus in on items that moved between two collects).

  It is extremely difficult to get enough labeled examples to cover many different types of vehicles (in different orientations and configurations) in many different background areas in order to train and tests systems ➔ must develop a general type of cuer

- (U) Contrast this with **tactical ATR problems** (looking for a specific vehicle type at specific sites in imagery)

(U) In the tactical ATR situation, you can narrow the scope of the problem (to look for specific vehicle types only at specific sites), and gather enough labeled examples to train and test for this specific set of vehicles at these locations. The system is then looking for a fixed number of very specific items, not something as broad as a ground military vehicle.

The specificity helps cut down on the number of cues.

(U) SIS-AOP Involves Six Fundamental Processing Parts

1. (U) Ingest of SAR data in a widely accepted standard format (SICD)
2. (U) Preprocessing of the images
3. (U) Automatic detection of vehicle-like objects, also known as "cueing"
4. (U) A **revolutionary** "culling" step to further refine candidate cued objects, reducing system false alarms (based on Phenomenologically Informed Machine Learning)
5. (U) Automatic object identification (when the quality of the call supports it)
6. (U) Forming an output product with labels, locations and other features of cued items in XML format which can be used by users directly or ingested into other tools and then disseminated for users or analytics.

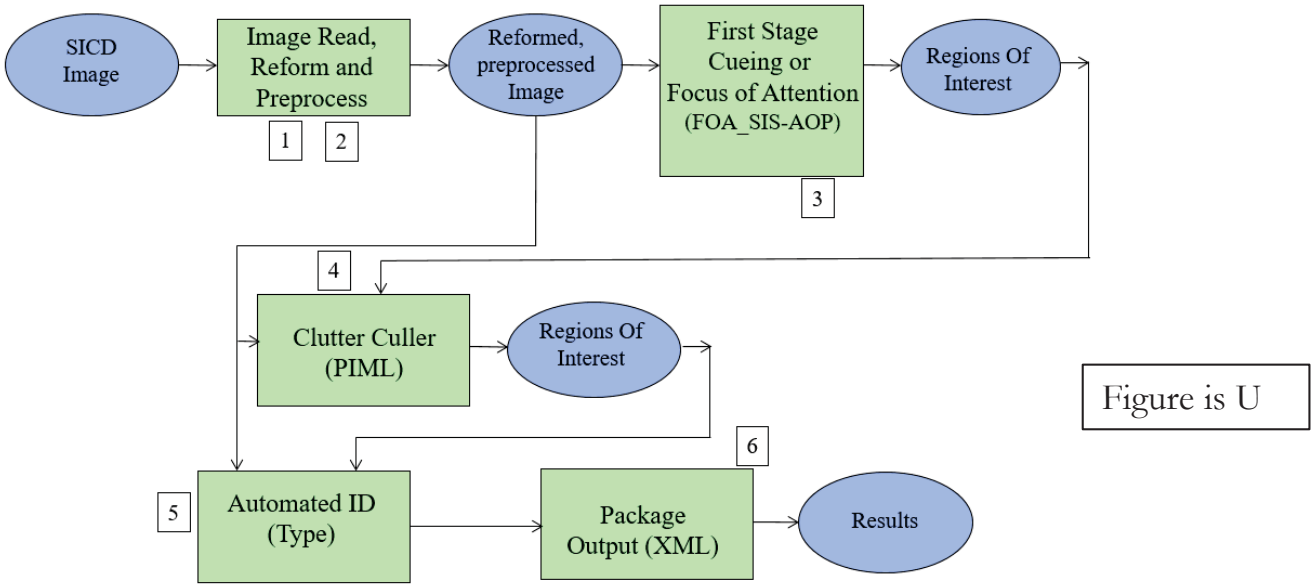


Figure is U

(U) Conclusions

- (U) June 24, 2021 closed out the MERIT SIS-AOP project
- (U) SIS-AOP is a software system providing automated vehicle-like object cueing and identification on a single complex SAR image in SICD (System Independent Complex Data) format.
- (U) The idea is to provide **automated vehicle-like cueing (with ID calls when warranted) in single SAR images**, ultimately easing the workload for analysts by prioritizing interesting imagery and providing information for other downstream data analytics.
- (U) Using the SICD standard **provides increased persistence** by processing images from any system (commercial, government).
- (U) Key to SIS-AOP is a **revolutionary ML culling stage**, designed to help to reduce system false alarms.
- (U) Demonstrated a dramatic decrease in false alarm rate for vehicle-like detection (10x in extremely benign environments to 100X in worst-case example)
- (U) An additional unique feature of SIS-AOP is the **modular system architecture** and its use of defined interfaces between different modules.
  - The SIS-AOP architecture **can be updated** with module improvements or insertions of completely different modules to get better performance or to tune to more specific objectives.