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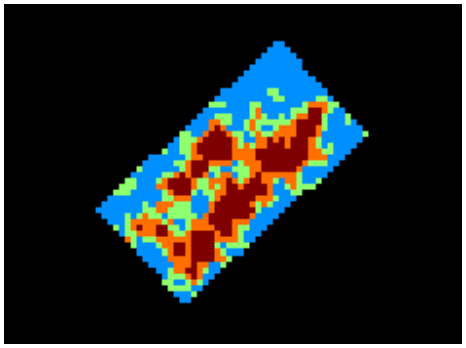

(U) Next-Gen SAR ATR

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Sandia National Laboratories

U.S. DEPARTMENT OF ENERGY | NNSA National Nuclear Security Administration

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(U) Sandia Radar ATR Timeline

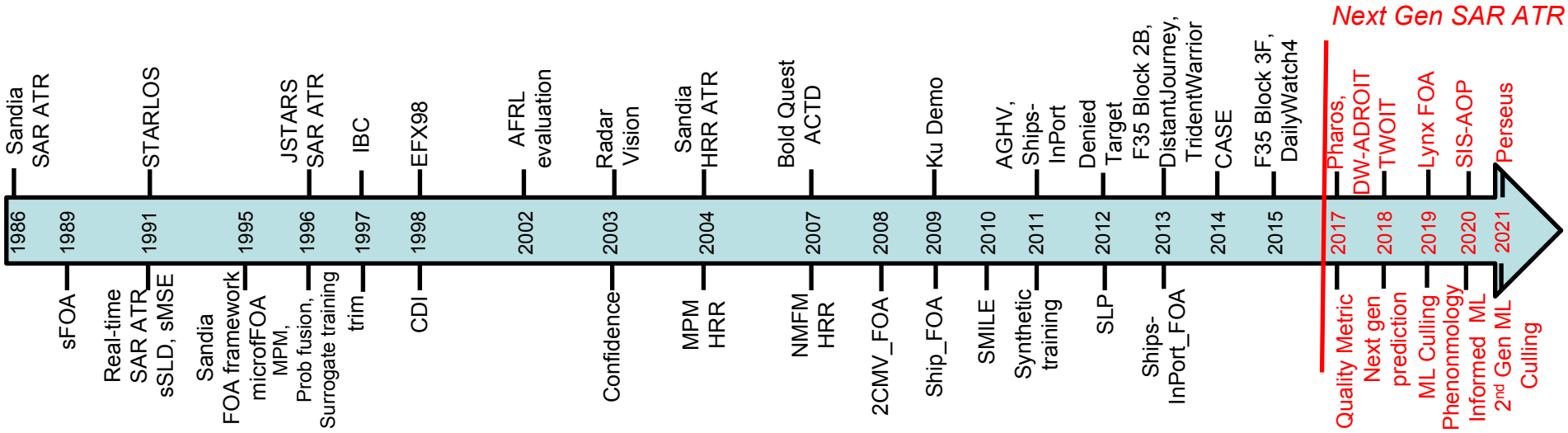
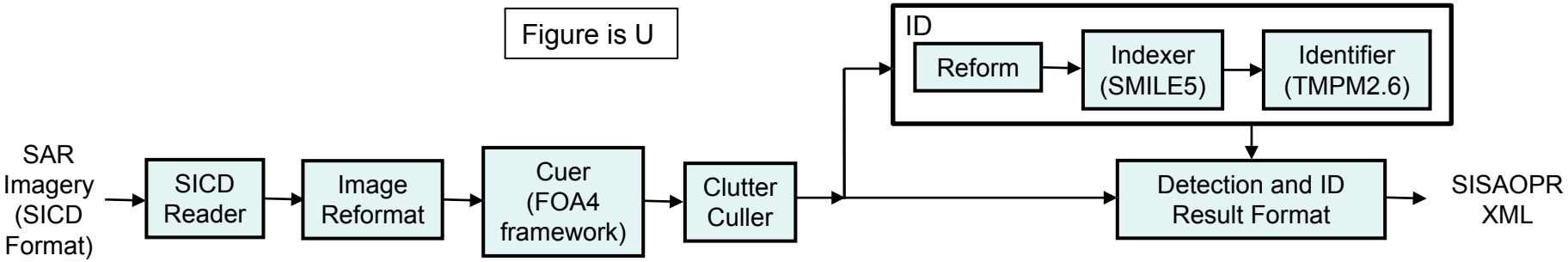


Figure is U

(U)Significant IC Program investment

(U) SIS-AOP: Next-Gen Sandia SAR ATR



- (U) SIS-AOP: **Complete upgrade** of classic Sandia SAR ATR
  - SICD image front-end reader to support multiple SAR sensor systems
  - Image reformatting and FOA 4.0 framework to accommodate a wide range of system collection parameters and very large image sizes from varied SAR systems
  - Supports automated detection of ground "vehicle-like"* objects through new FOA_SIS-AOP detection and Phenomenology Informed Machine Learning Clutter Culling to significantly lower system false alarm rate
  - ID performance improved for a wide range of collection parameters enabled by
    - Significantly improved prediction of target signatures from CAD models (for ID training)
    - Significantly improved ID template generation process
  - XML output format to provide human readable and easily ingested result output
  - Modular software architecture for easy module upgrade or replacement
  - SIS-AOP Team: Ireena Erteza (System Architect and Technical Lead 6331); Brian Bray (5349); Kelsie Larson (5346); Chris Walker (6362)

* (U) ground "vehicle-like": not necessarily a ground vehicle but more like a vehicle than a building or natural clutter

(U) Perseus 2021 SAR ATR: Army demonstrator

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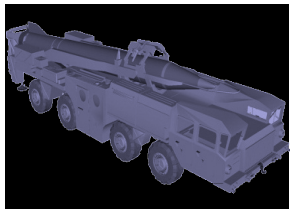
- (U) Embedded, customized solution
- (U) Based on SIS-AOP (Single Image SICD Automatic Object Processing) which is based on the ADROIT (Automatic Distant Radar Object Identification Technologies) and the TWOIT (Tactical Warning Object Identification Technologies) code base and tools
- (U) Near real-time, on-board in image formation radar electronic assembly
- (U) Currently supports ID of 34 military ground vehicles
  - target set is demonstration like in composition to be unclassified
  - Perseus ATR Team: Brian Bray (Technical Lead 5349); Ireena Erteza (6331); Mindi Koudelka (5346); Kelsie Larson (5346); Victor Sandoval (5346); Chris Walker (6362); Jason Wertz (5346)

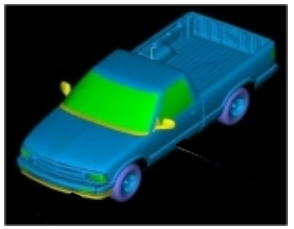
* (U) ground “vehicle-like”: not necessarily a ground vehicle but more like a vehicle than a building or natural clutter

(U) Sandia SAR Identifier Overview

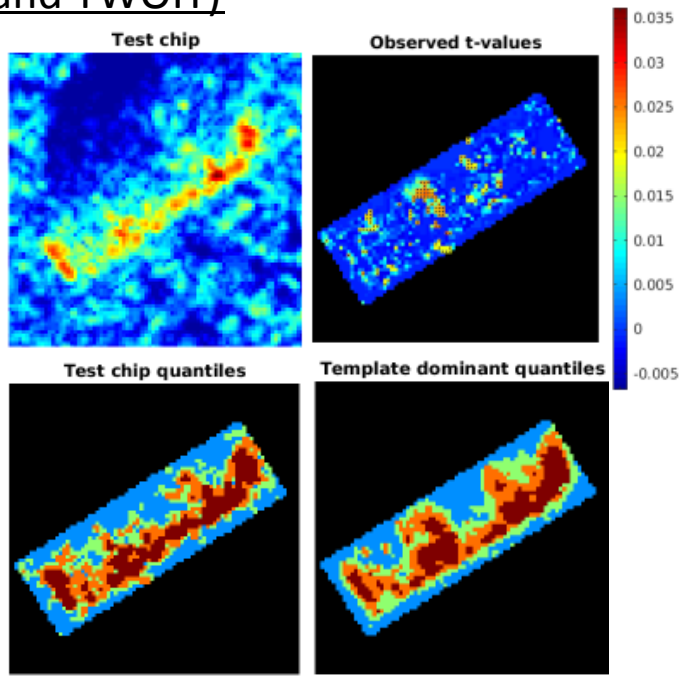
- (U) Fully synthetic training
  - No real data required for training
  - Enables rapid, low-cost development of target ID capability
  - Uses CAD models
  - Xpatch EM simulation software to generate synthetic signatures
    - From 2017-2020 significantly improved fidelity through pre- and post- processing and improved modeling (ADROIT and TWOIT)

Figures are U





- (U) Multinomial Pattern Matching (MPM)
  - Template-based algorithm
  - Robust to calibration
  - Quantile* mapping considers *relative* pixel values
  - Produces an interpretable match error surface
  - Improved in 2017 to now have a realistic, robust individual quality score



*(U) quantiling refers to breaking up histogram into value bins with varying population percentages

(U) Summary

- (U) 30+ years of radar exploitation and system development—
  Now expanded to varying, challenging collection geometries (including very long range)
- (U) Efficient, robust algorithms for detection and ID—
  Now expanded to include clutter rejection and phenomenologically informed machine learning (PIML)
- (U) Field-tested SAR ATR ID performance
  - SAR ATR: TRL 9
  - JointSTARS T-3 test aircraft, F-35
  - Experience with SAR ATR at low grazing angles (JointSTARS, F-35)
  - Now expanded to challenging, long-range scenarios
- (U) Real-time systems
  - Delivered RT SAR ATR systems

(U) Backup Slides

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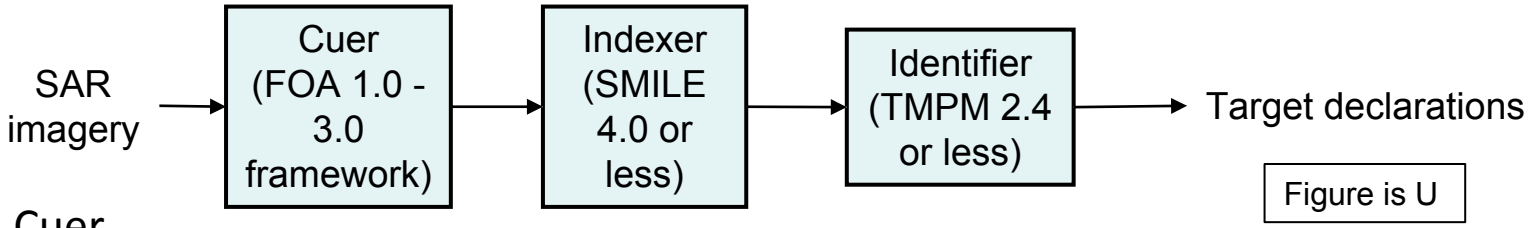
- (U) Classic (obsolete) SAR ATR
- (U) FOA (Focus of Attention)
- (U) MPM

(U) Classic Sandia SAR ATR (obsolete)



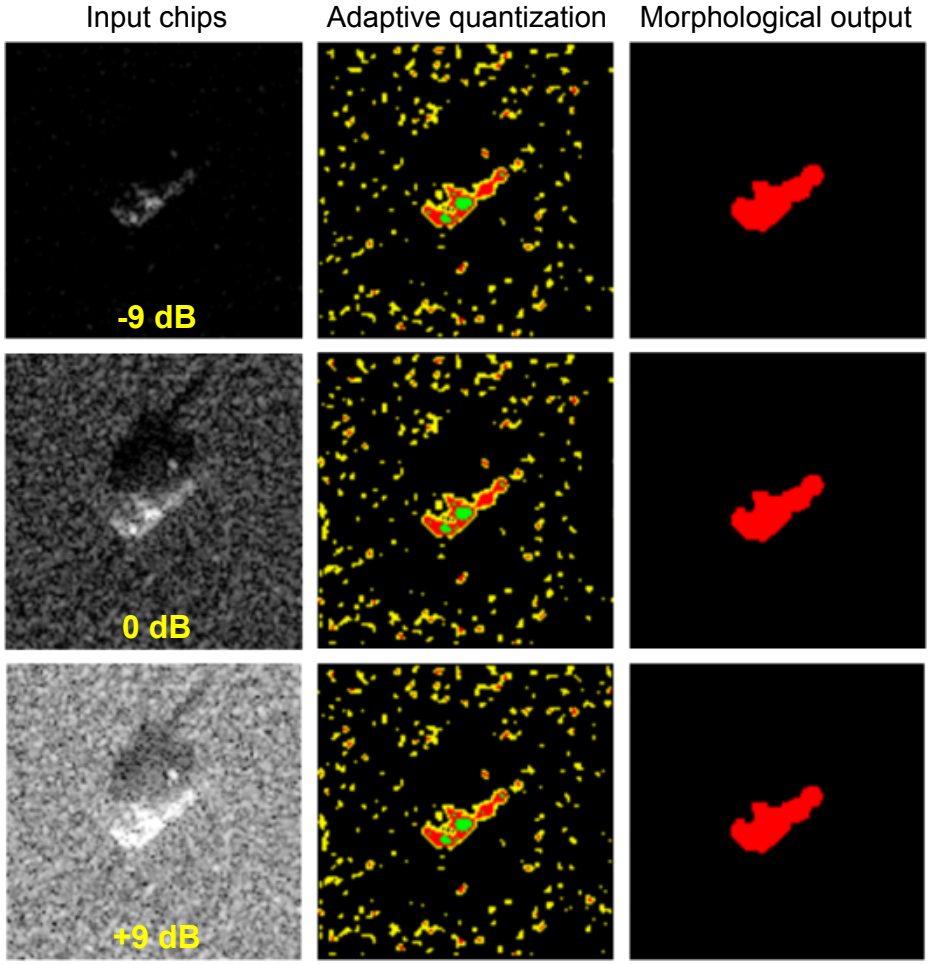
- (U) Cuer
  - Segments potential target regions from background clutter
  - Processes large amounts of imagery very quickly
  - Problem specific FOA algorithm built on Sandia FOA (1.0 – 3.0) framework
- (U) Indexer
  - Rejects obvious non-target regions falsely passed by cuer
  - Passes likely target regions to identifier with hypotheses
- (U) Identifier
  - Classifies targets of interest by type
    - Cannot calculate confidence correctly unless know target to confuser ratio
  - Rejects non-targets
- (U) Overall Performance
  - Reasonable vehicle discrimination
  - ***Clutter rejection is not good enough***

(U) Focus Of Attention (FOA) Framework Backup Slides

(U) Focus of attention (FOA) Frameworks

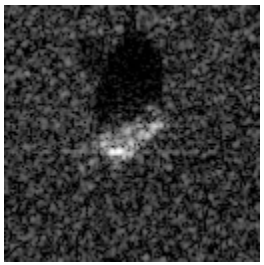
- (U) Problem-specific FOA algorithms are built upon the Sandia FOA frameworks
- (U) Rapidly scans full images, rejecting uninteresting regions while preserving target regions
- (U) Morphological front-end
  - Uses adaptive quantization
  - Produces target-shape mask
- (U) Feature-based back-end
  - Reject clutter
  - Assigns target hypotheses
- (U) Adaptive to variations in image calibration/attenuation

Figure is U



(U) Clutter Culler using Machine Learning*

- (U) GOAL: Use modern machine learning techniques in the detection stage of SAR imagery to reduce the amount of clutter passed to reduce image analyst workload and improve follow-on automated processing
- (U) CHALLENGES: Vehicles of interest usually have only a few hundred target pixels. The small number of pixels, the specular nature of SAR imagery, and how radically an objects SAR signature changes with orientation and imaging geometry are major challenges



**(U) Initial results from another project, this preliminary version is not used by SIS-AOP*

(U) Target Class vs Natural Clutter

(U) Simple experiment to see if we can use deep learning to separate targets from natural clutter; even a target vehicle that we did not train for

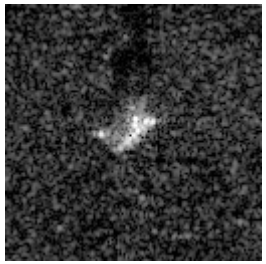
Table is U

Predicted Class

Actual Class		Target	Clutter	Accuracy
	Target (Not including D7)	2912	17	99.47%
	D7	274	0	
	Clutter	5	20320	99.98%

(U) Trained with 9 MSTAR targets plus clutter
(U) Added the 10th MSTAR target (D7) in only for testing
(U) Training data and test data are different
(U) Overall Accuracy: 99.91%

(U) D7



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(U) MPM Backup Slides

(U) Multinomial pattern matching (MPM) identifier module (1-D HRR example)

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- (U) Produces declaration-quality match scores representing similarity between observed signatures and target models
- (U) Employs multinomial transform
  - Maps amplitudes to quantiles
  - Discards absolute pixel amplitudes in favor of relative pixel amplitudes
- (U) Represents targets with statistical models of multinomial distributions at each pixel
  - Models attributes of each target type, not differences between types
  - Accommodates real-world signature variation
- (U) Match scores separate targets, nontargets
  - Can be thresholded to yield declarations
  - Can be fused with other identifiers
  - Can be used to calculate quality

Figures are U

(U) Example: MPM four-quantile transform applied to Vehicle HRR profiles