



KASSPER Signal Processing

7 April 2004

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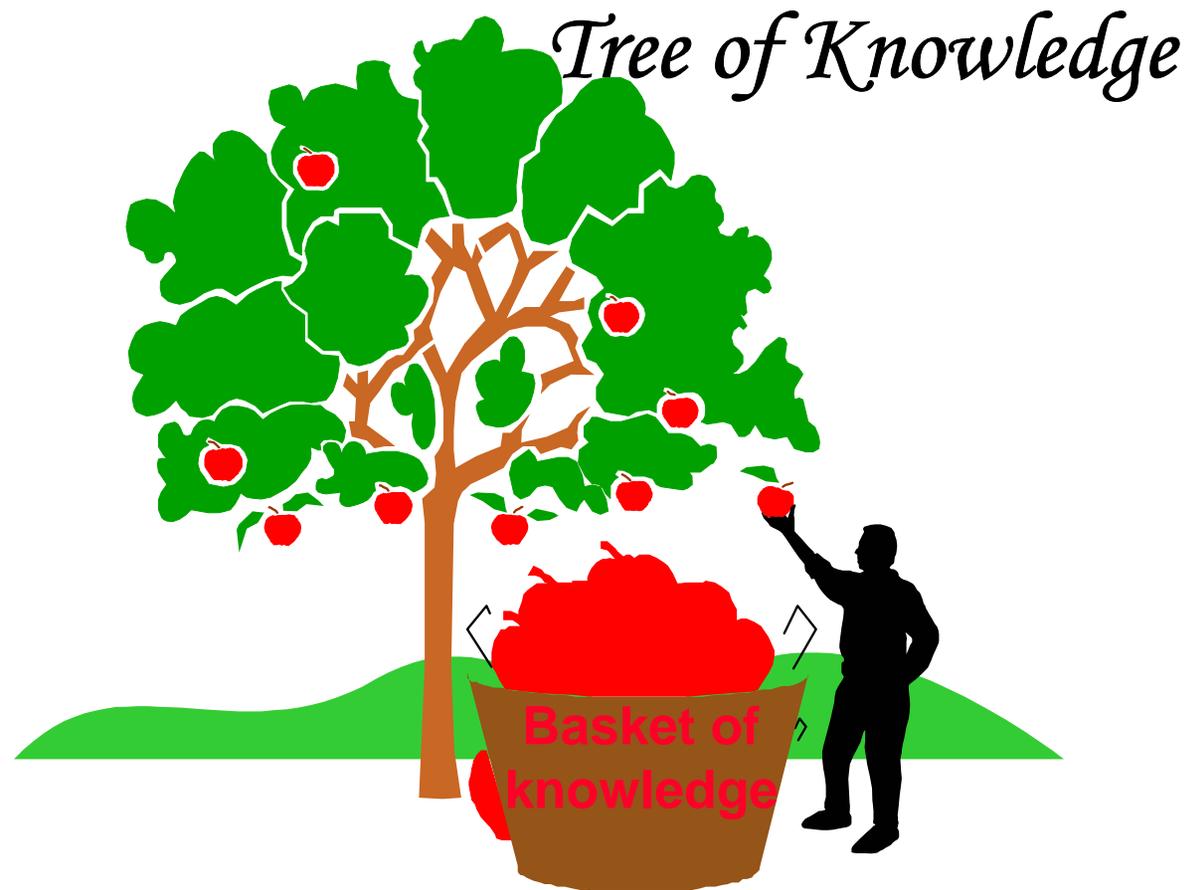
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KASSPER challenge is to integrate this “**basket of knowledge**” into cohesive algorithms and a processor



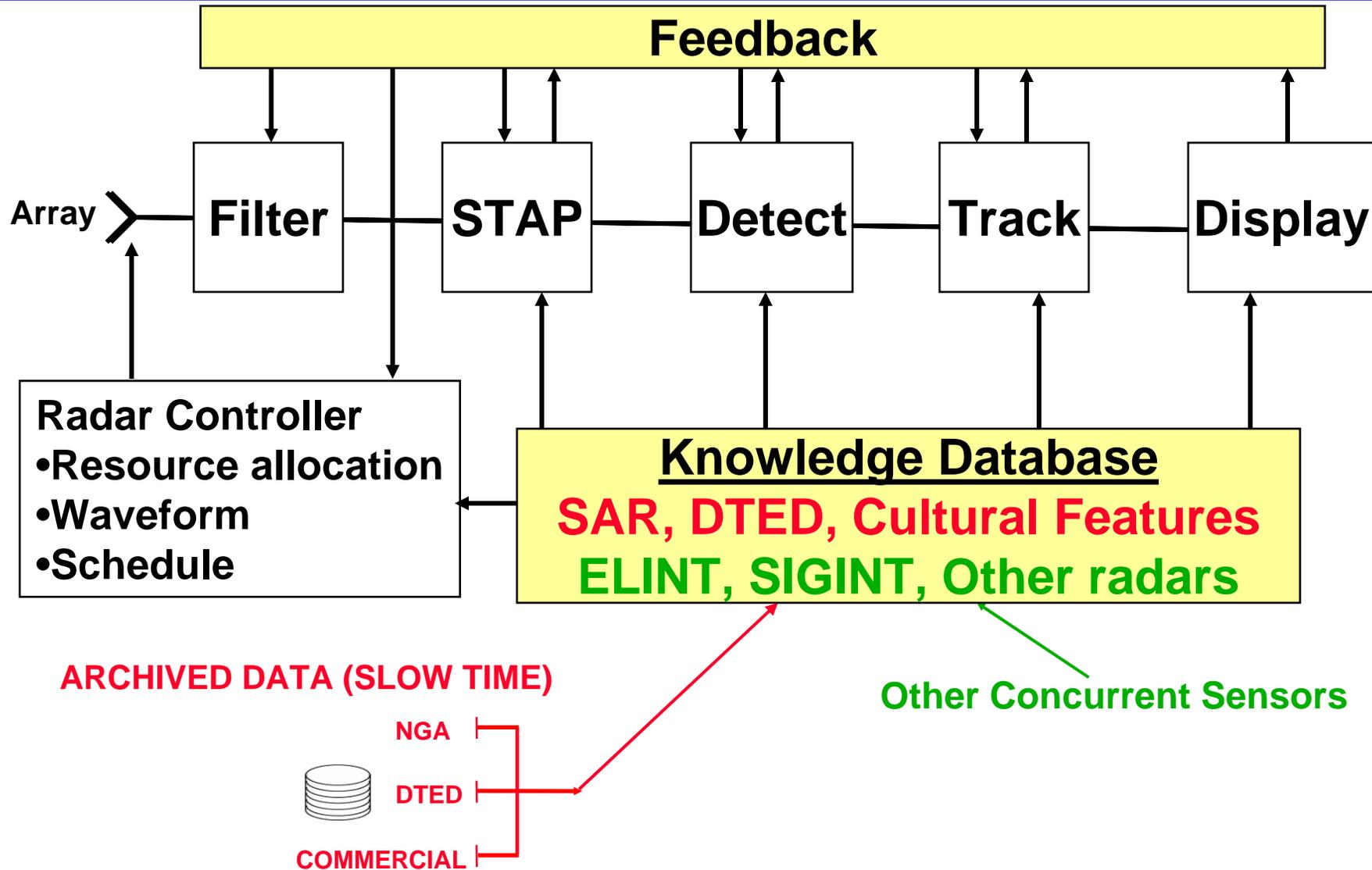
Outline



- **Incorporating knowledge into algorithms**
- **Results with Tuxedo data**
- **Long CPI for enhanced MDV**
- **Radar modes and time critical targets**
- **Summary**

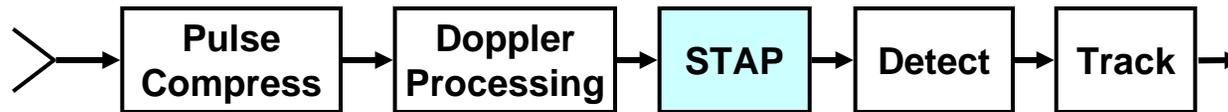


Representative GMTI Processing (with knowledge)

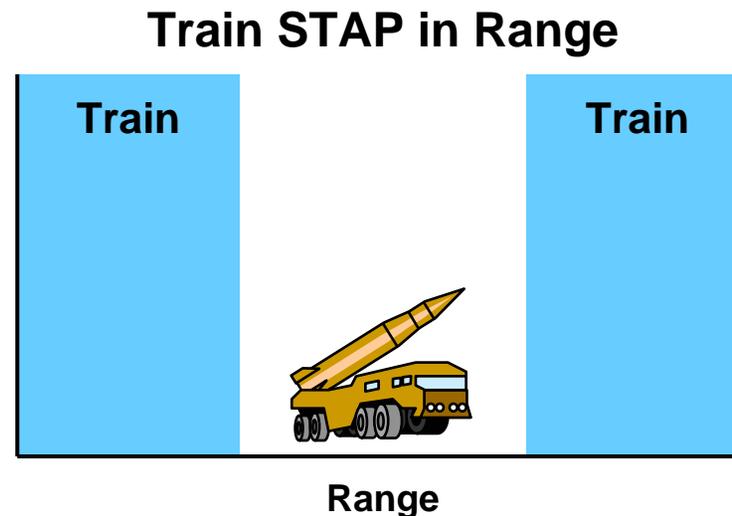




Desirable Features for STAP Training

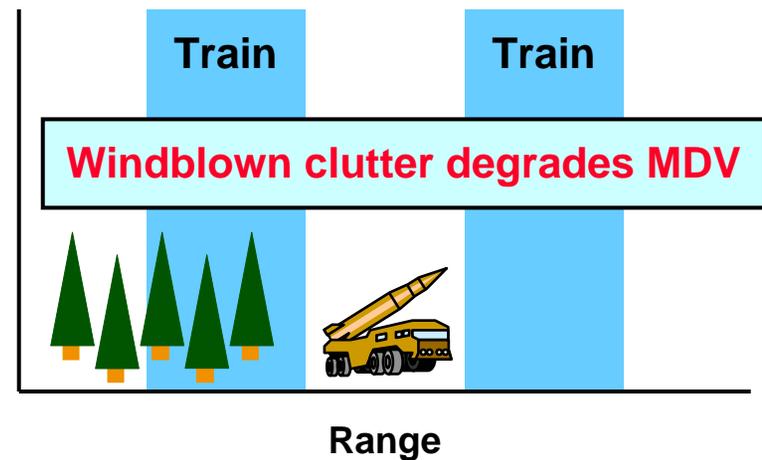
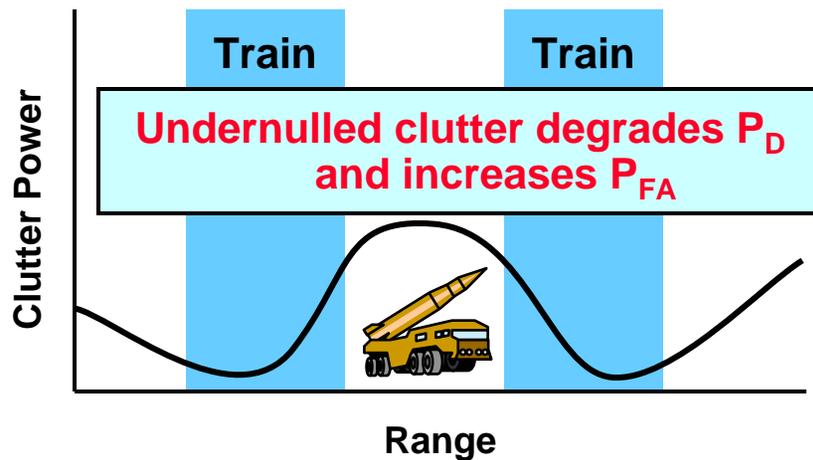
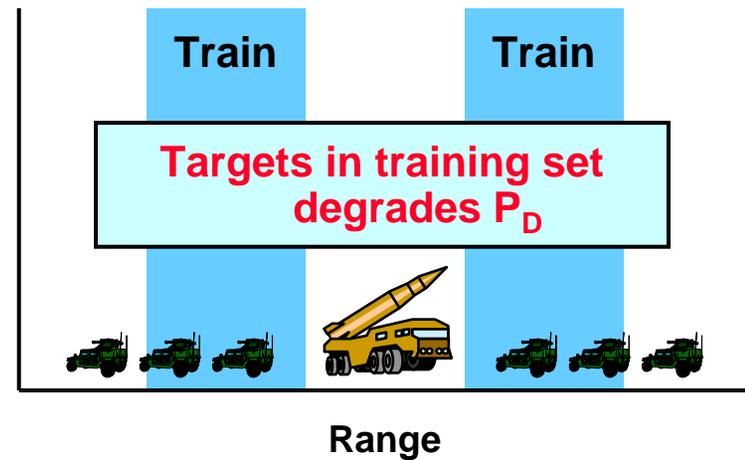
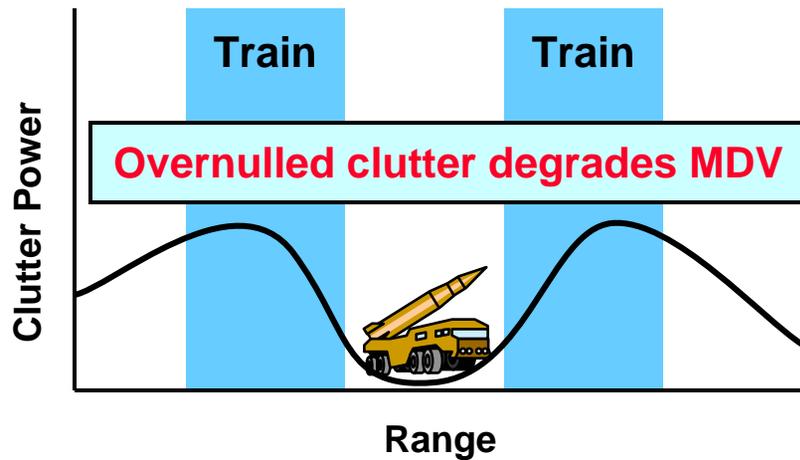


- **Training statistics must match the cell under test**
 - Angle/Doppler relationship
 - Clutter type (vegetation / mountain / desert)
 - Power
- **No targets in training**





Localized Training Impact





SINR Loss in 50% Wind-Blown Clutter



Target in the clear (no foliage)
Train with 50% wind blown clutter from foliage

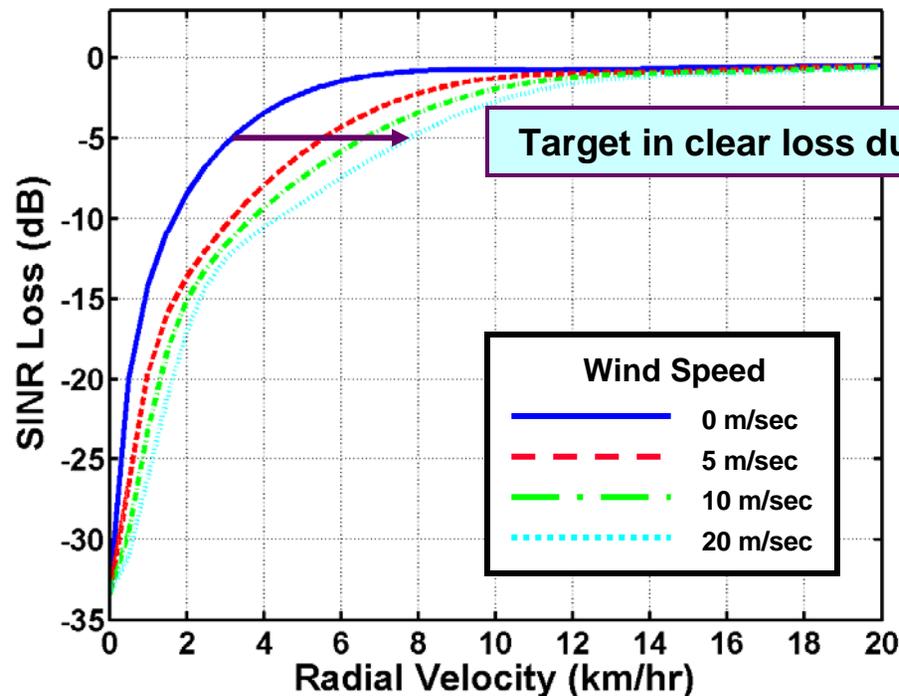
Train



Train



Aperture = 10 feet



Target in clear loss due to foliage training

Platform velocity = 150 m/sec
Altitude = 10 km
CNR = 35 dB
 $f_0 = 10$ GHz
PRF = 2 kHz
50% mixture (wind-blown & stationary)

Wind blown foliage training degrades performance in clear

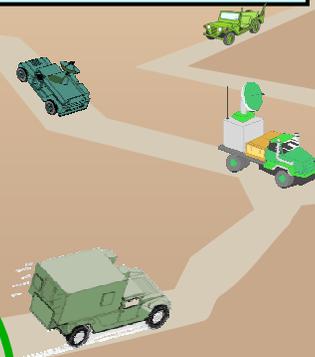


Regionalized Training

(No windblown clutter for targets in clear)

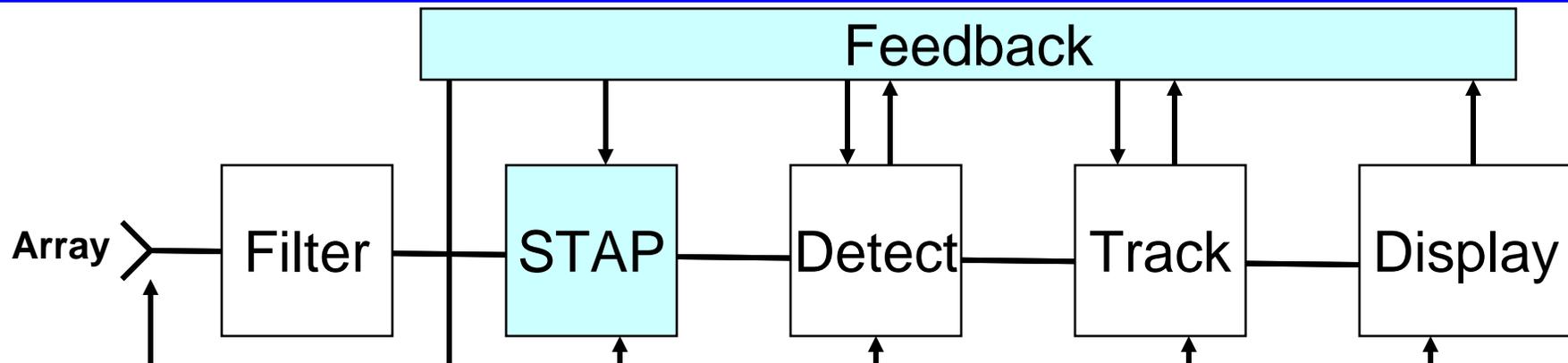


- Classify ground swath regions from NGA database
 - Foliage
 - No foliage
 - Urban
- *Train and apply* STAP separately for each region





STAP Ideas



Correct statistics for clutter cells in training set

- Power variable training with target excision (**reasoning***)
- Deterministic covariance matrix loading or pre-whitening (**knowledge**)
- Train separately in foliage, non-foliage, urban, etc. regions (**knowledge**)

Removal of targets from the training set

- Feedback from tracker (**knowledge**)
- Avoid roads from training set when possible (**knowledge**)

Training cells based upon VMAP, SAR, clutter from previous GMTI passes, or DTED (**knowledge**)

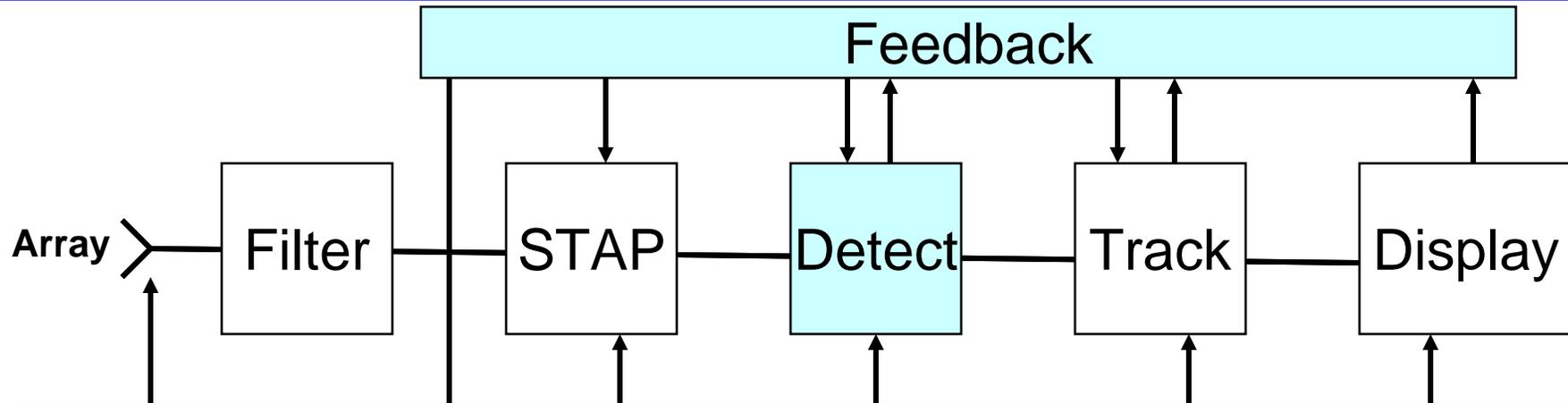
Avoid anomalous clutter discretely from training (Ex: flash, saturation, etc.) (**knowledge**)

- Previous flights and passes contain a wealth of information on clutter discretely that have caused STAP training problems

— ***See ASAP 2004 and KASSPER workshop 2003 for details** —



Detection Ideas

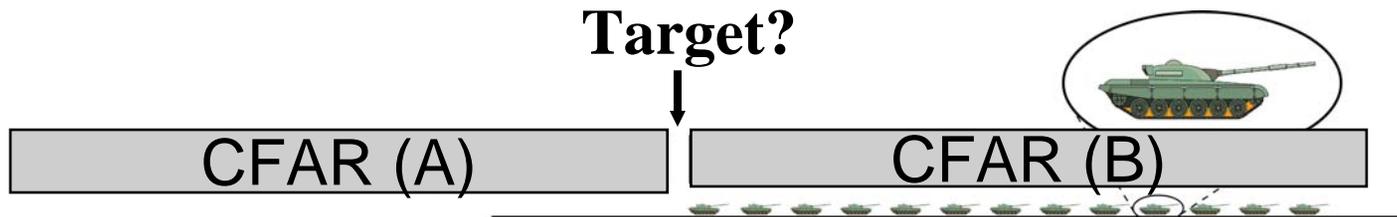


- Robust for convoys and individual vehicles* (**reasoning**)
- Reject detections near clutter discretely (**knowledge**)
- Do not include tracked targets in CFAR stencil (**knowledge**)
- Delete roads from CFAR stenciled when possible (**knowledge**)
- Adjust thresholds based upon: roads, off roads, max expected velocity, being tracked, staging area (**knowledge**)

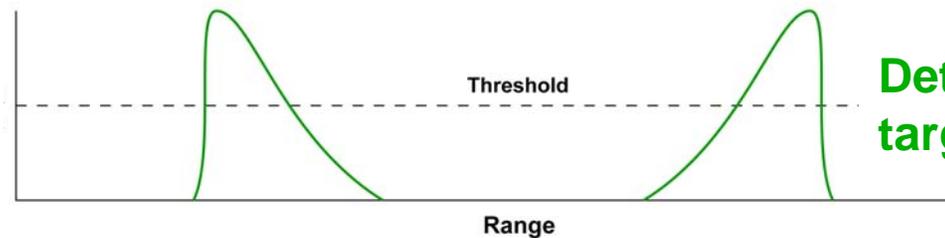
*more on next chart



Ordered Statistic CFAR



CFAR
lesser (A,B)



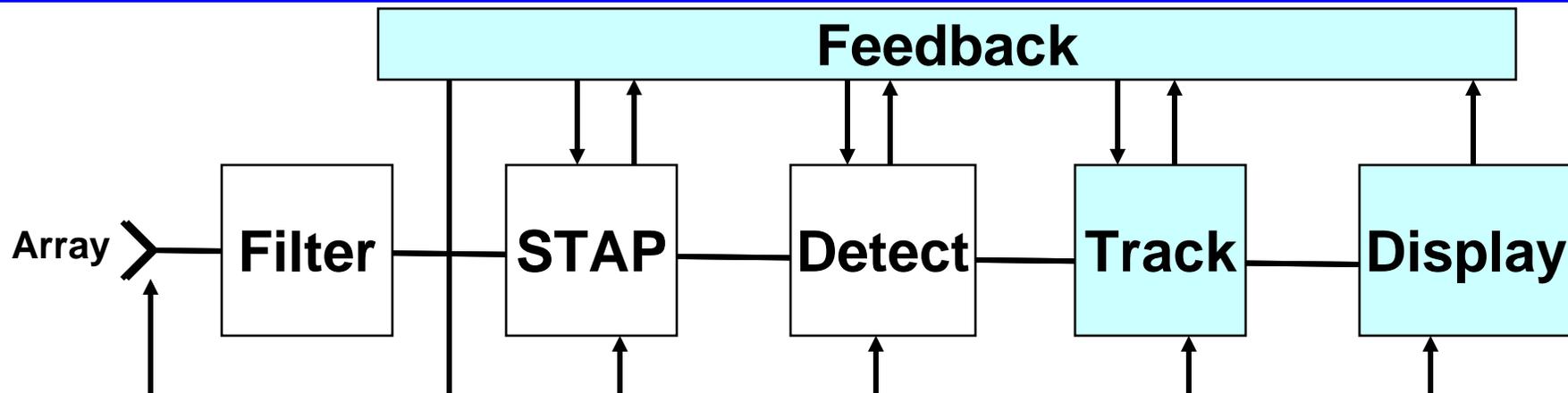
Median CFAR
(ordered statistic)



Ordered statistic (median) CFAR is robust for convoys and individual vehicles **(reasoning)**



Tracking (with knowledge)



- Track and identify clutter discretely for feedback to STAP, Detector and for future flights (**create knowledge**)
- Improve target to track association (reduce track swapping)
 - Select radar mode to resolve track ambiguity* (**reasoning**)
 - Look ahead scheduling based upon visibility (**knowledge**)
- Weed out false alarms
 - Better false alarm control by detector

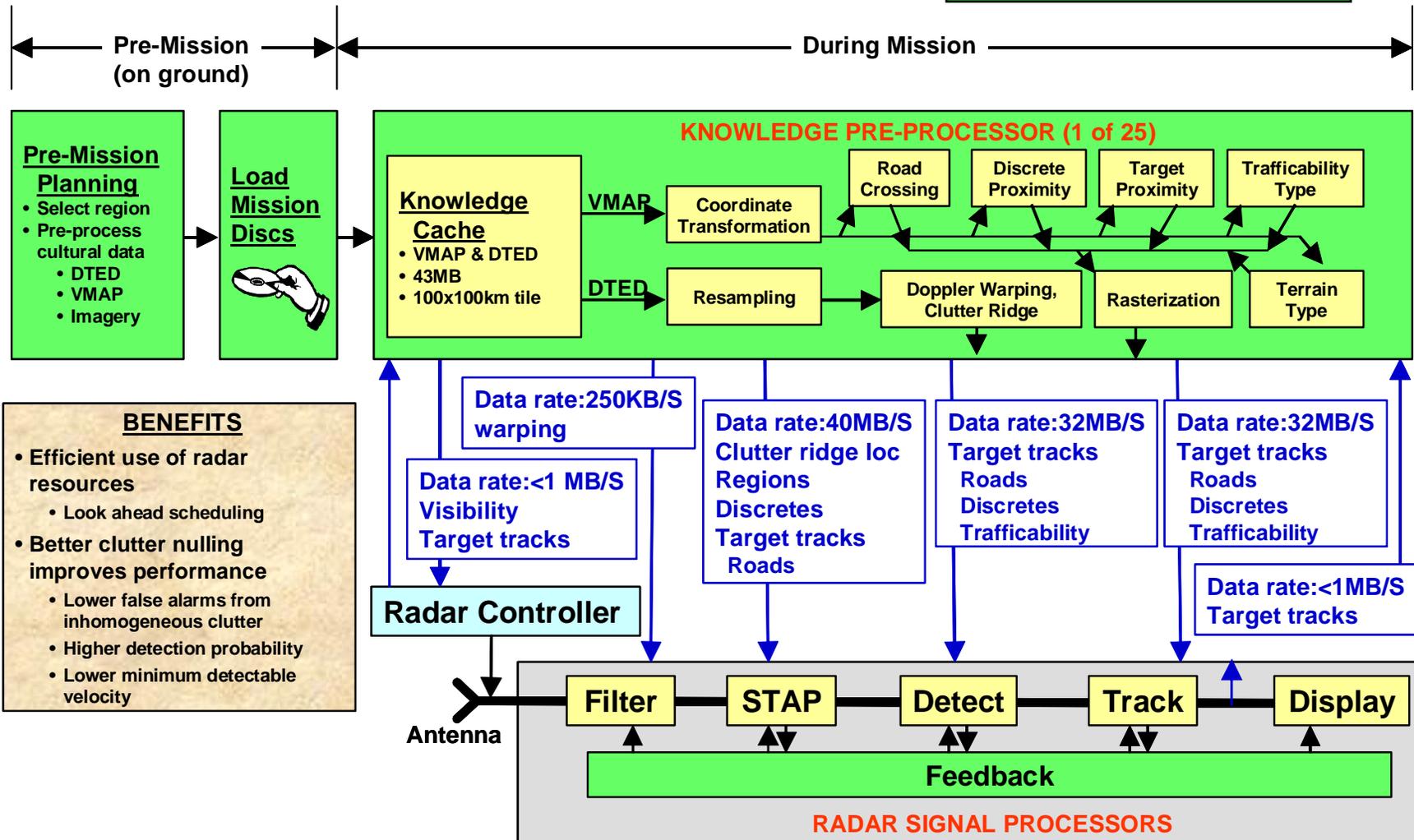
*More at end of presentation on tracking time critical targets



KASSPER GMTI Signal Processor



New with KASSPER





Outline

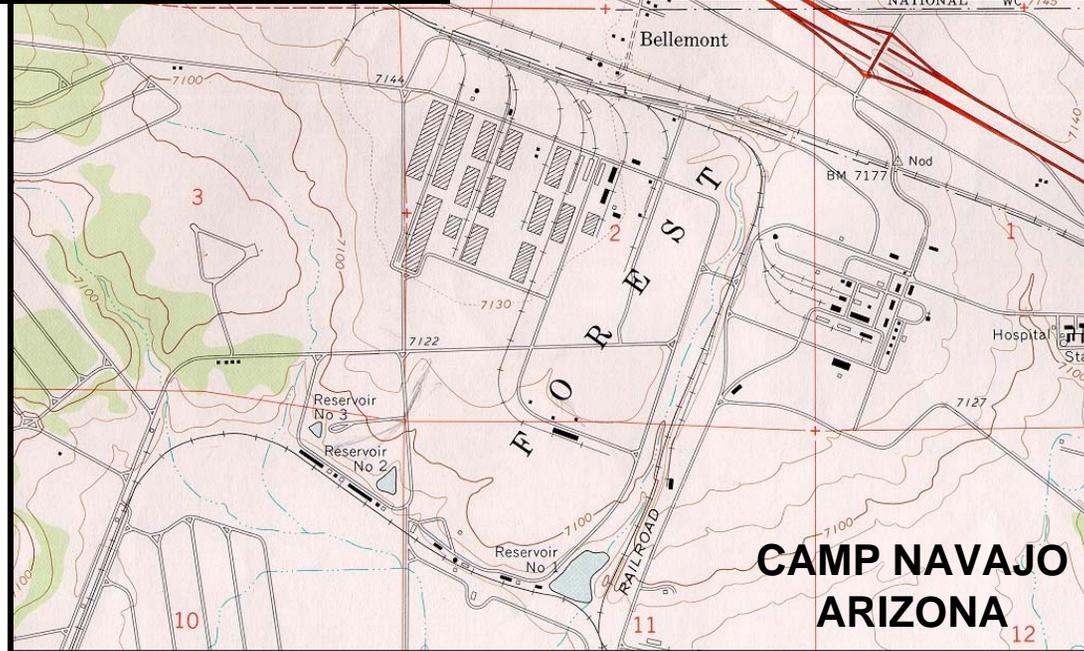


- Incorporating knowledge into algorithms
- Results with Tuxedo data
 - Jacob Griesbach et. al. - ASAP 2004
- Long CPI for enhanced MDV
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Tuxedo Data

Recorded Data



System Parameters for GMTI Mode

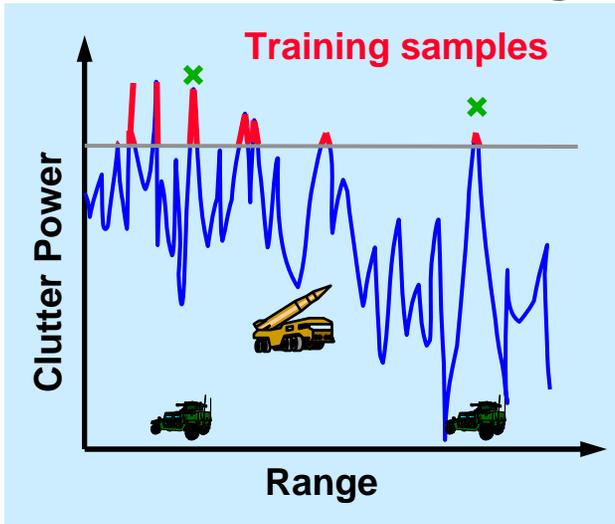
Center Freq.	9.6 GHz
Bandwidth	66 MHz
PRF	1,400 Hz
Tx Apertures	1
Rx Apertures	3
Horiz. Aperture	1.83 m
Vert. Aperture	0.18 m
Az BW	3.6 deg
EI BW	9.1 deg
Polarization	HH
A/C Heading	290 deg
Depr. Angle	15 deg
Recorded Time	40-60 sec



Power Variable Training (ASAP 2004 and KASSPER 2003)

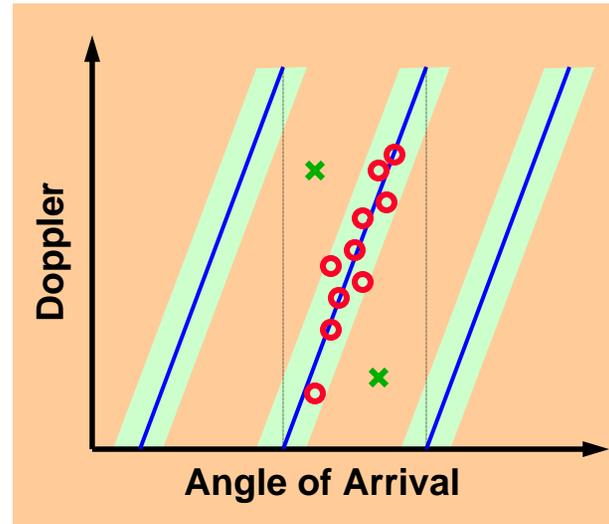


Power Selective Training



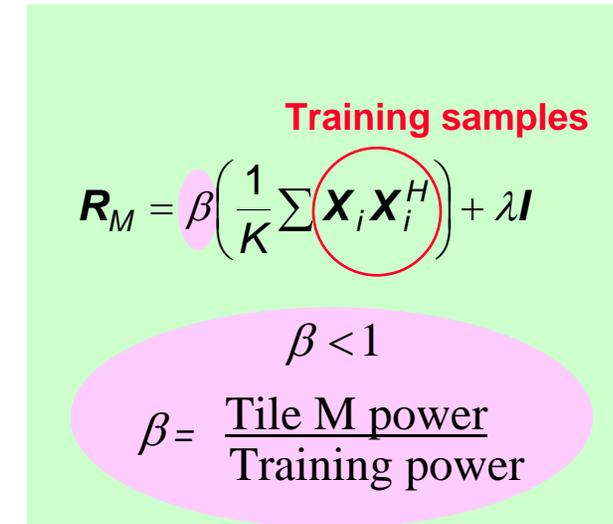
Select strongest clutter returns as candidate training samples

Excision



Excise samples away from clutter ridge (potential targets)

Adjust Clutter Power



$$R_M = \beta \left(\frac{1}{K} \sum \mathbf{x}_i \mathbf{x}_i^H \right) + \lambda I$$

$$\beta < 1$$

$$\beta = \frac{\text{Tile M power}}{\text{Training power}}$$

Scale training samples to estimated CNR for Tile

TRAINING SAMPLES

- No windblown clutter for targets in clear
- Right angle-Doppler relationship for clutter
- Eliminate targets from training data
- Correct clutter power



Included in Tuxedo Results



STAP

Correct statistics for clutter cells in training set

- Power variable training with excision (reasoning*)
- Deterministic covariance matrix loading or pre-whitening (knowledge)
- Train separately in foliage, non-foliage, urban, etc. regions (knowledge)

Removal of targets from the training set

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Training cells based upon VMAP, SAR, clutter from previous GMTI passes, or DTED (knowledge)

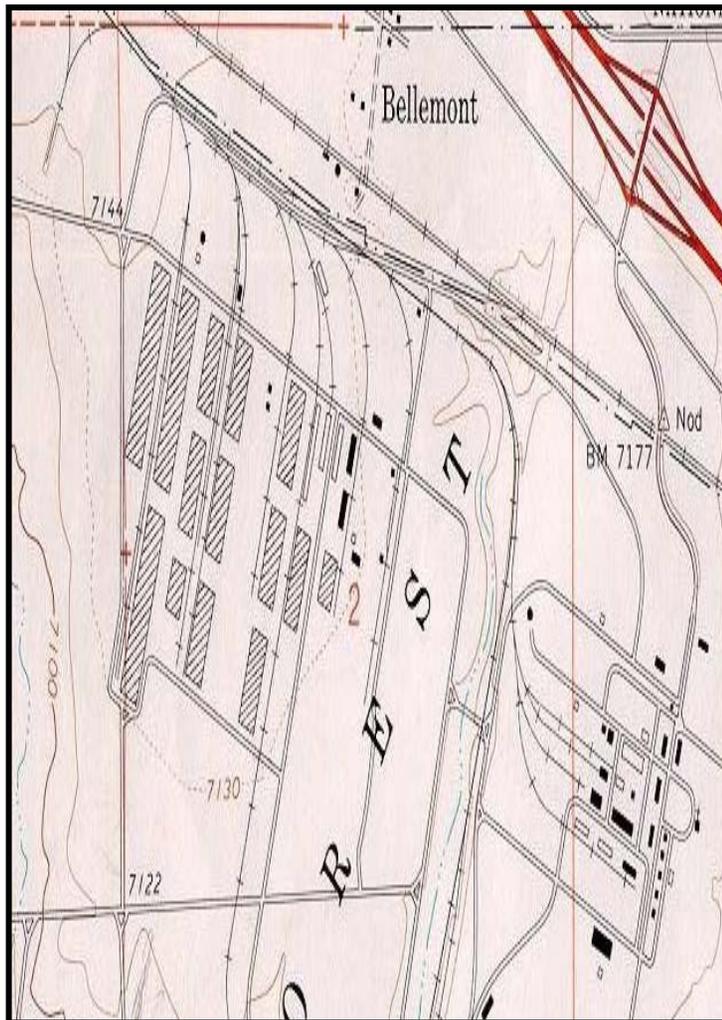
Avoid anomalous clutter discretely from training (Ex: flash, saturation, etc.) (knowledge)

Detector

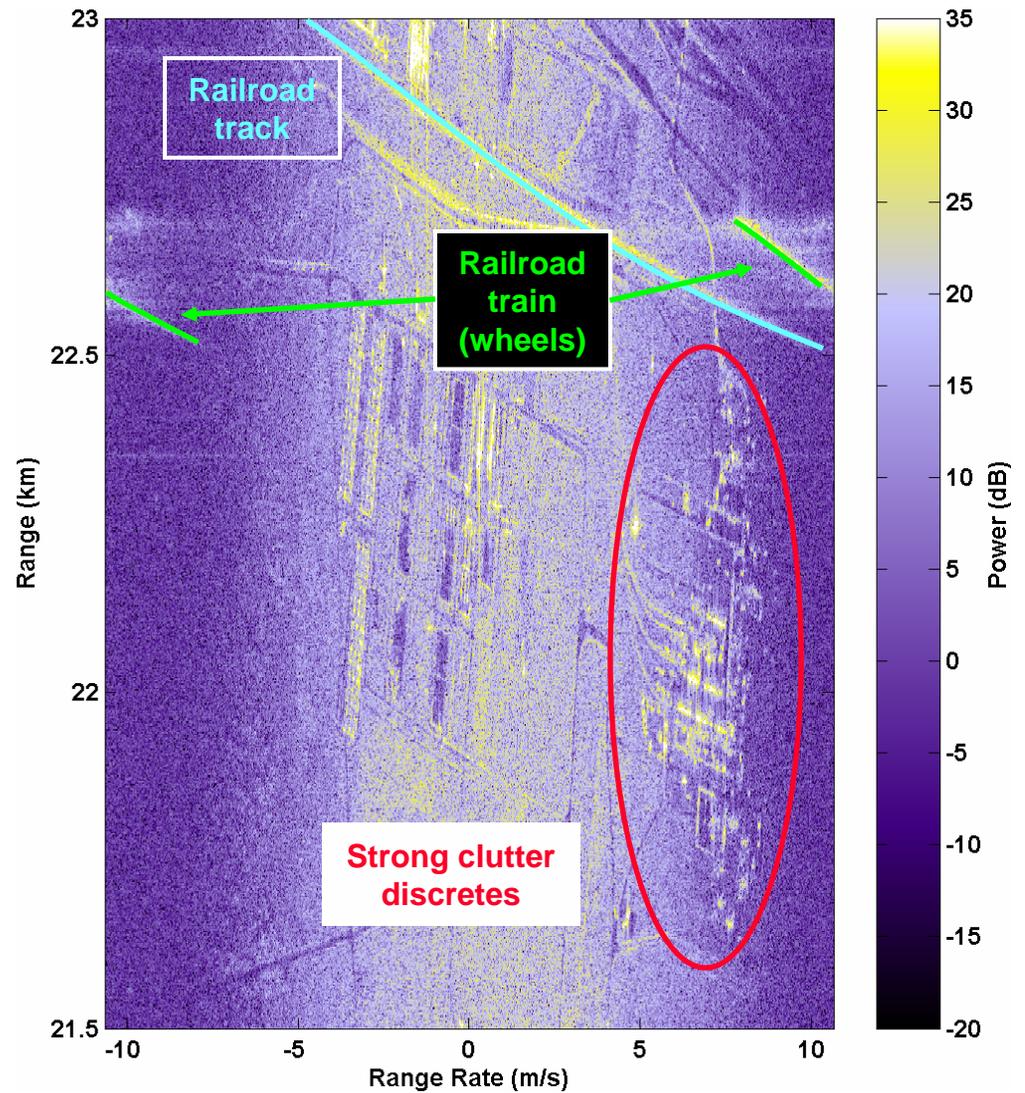
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Range-Doppler Image



(map cropped and stretched to match data)



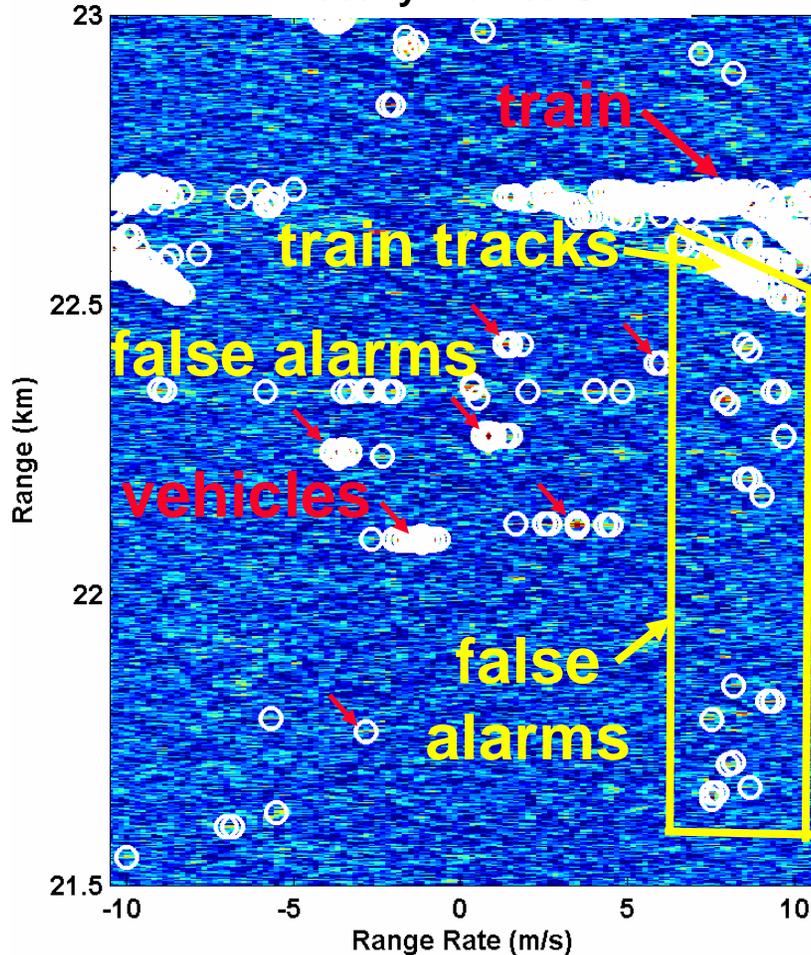


Power Variable Training Comparison (detector output)

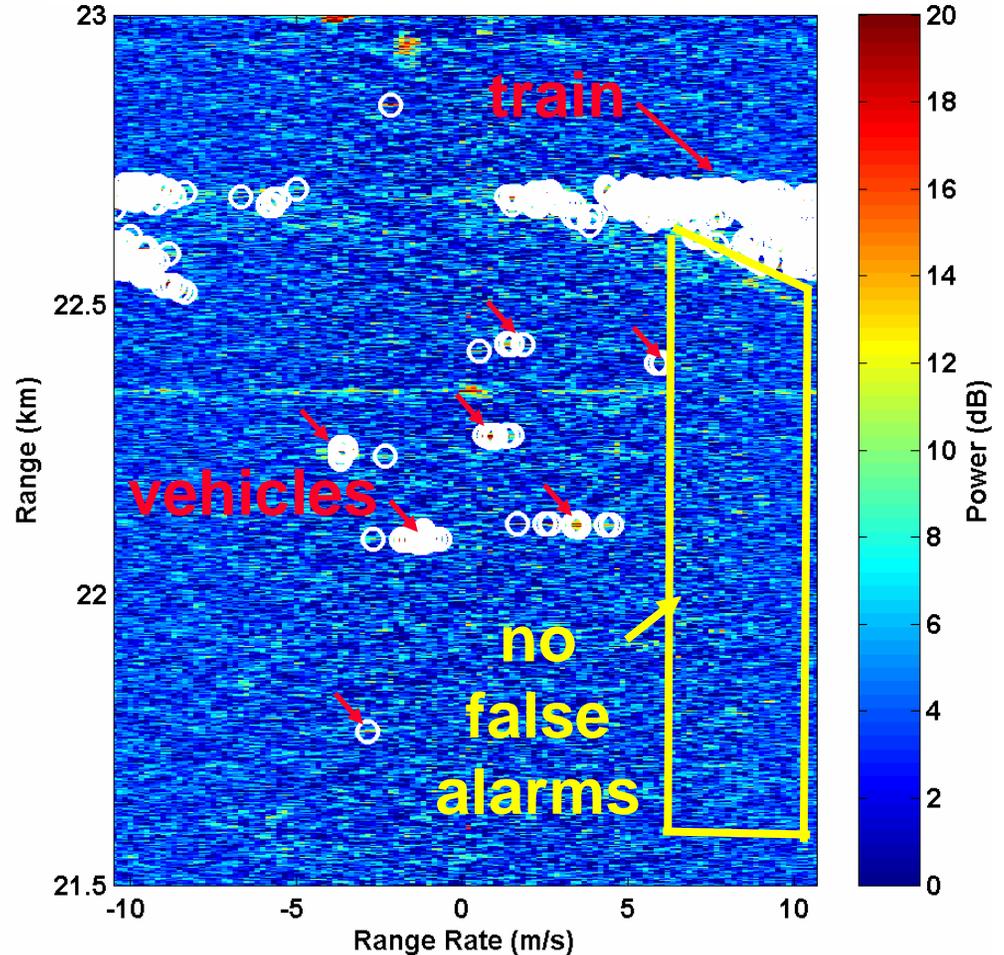


Range: 30 3  3 30

Locally Trained STAP



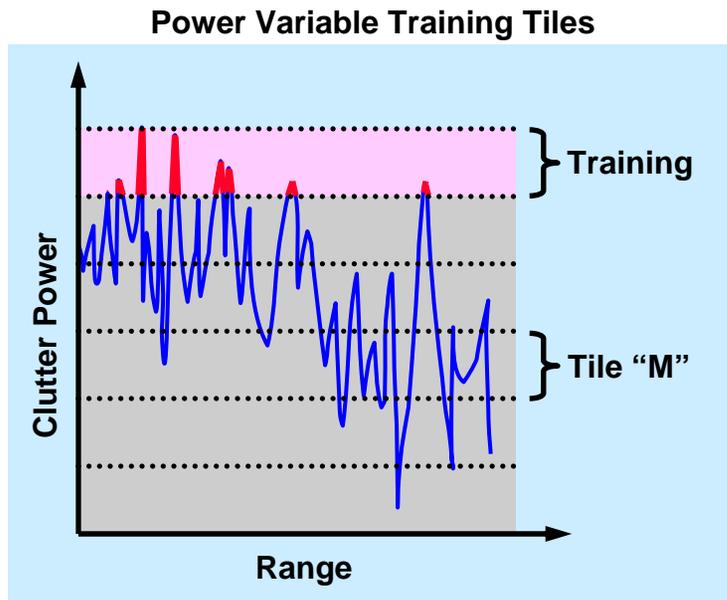
Knowledge Aided Power Variable Training



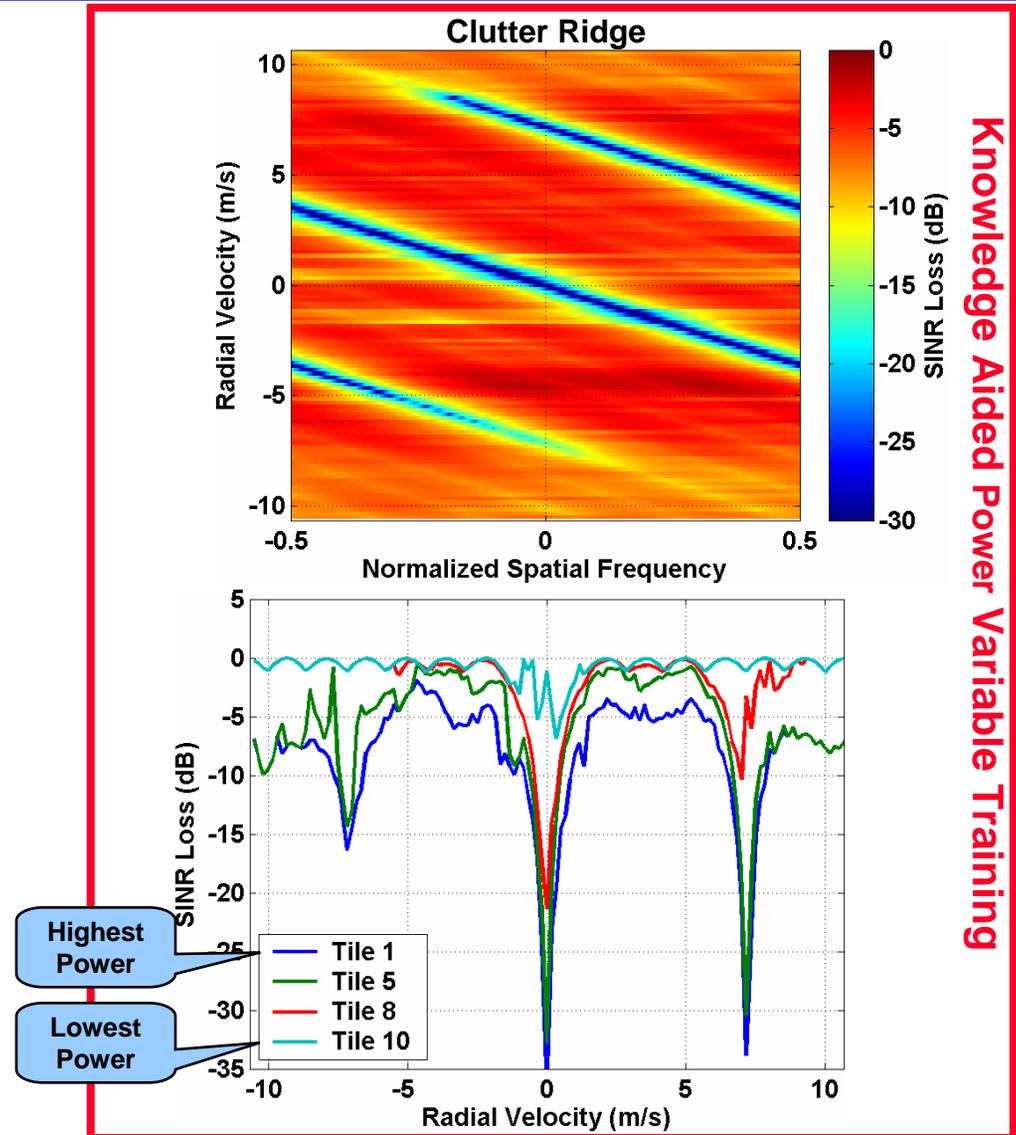
Power variable training dramatically reduces false alarm rate



Power Variable SINR Loss Effects (adjusts to local clutter power)

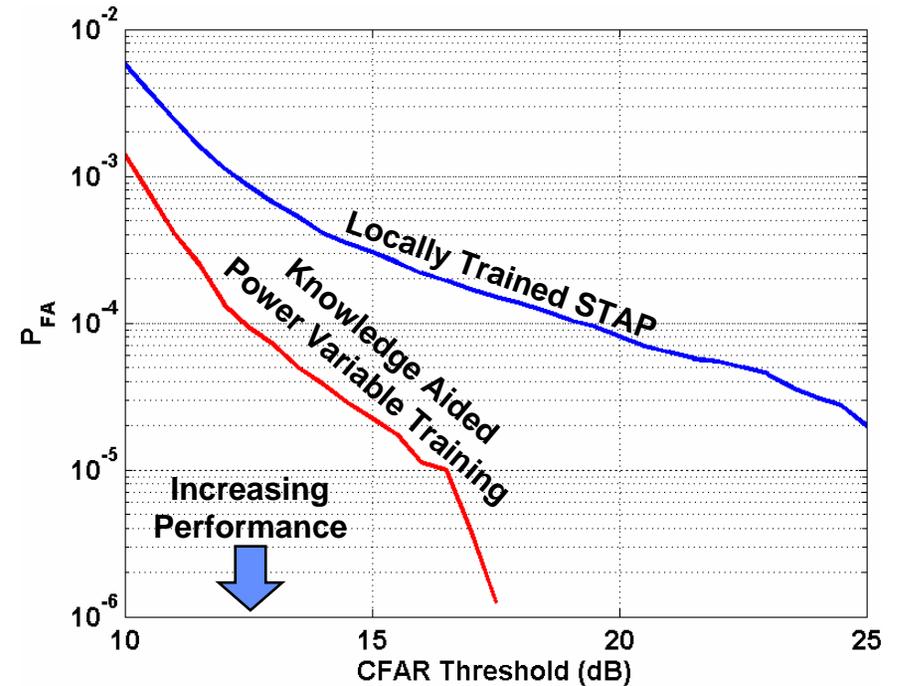
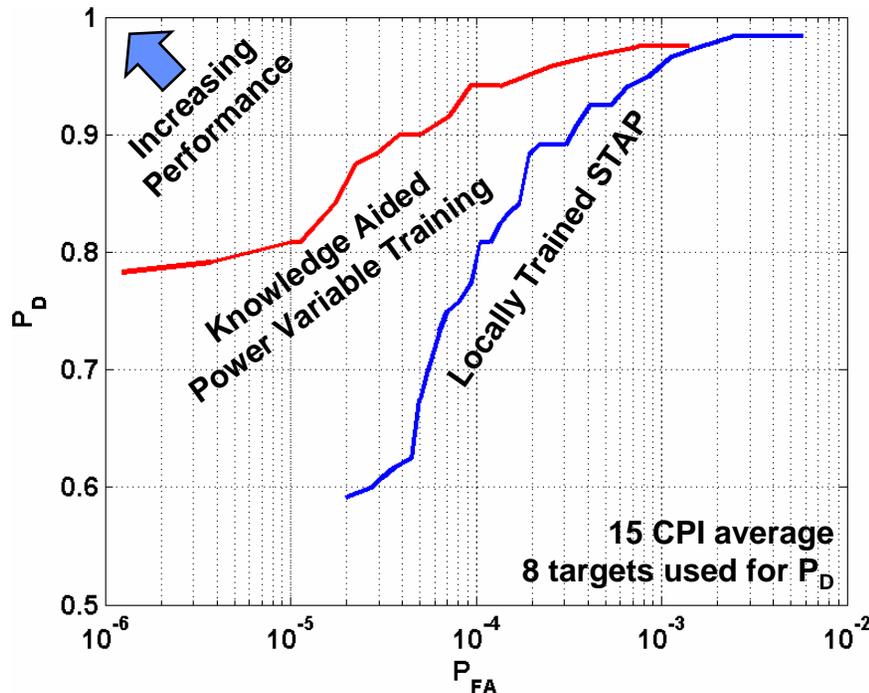


- Tile SINR loss approaches 0 dB as tile power decreases
- Significantly improved MDV for with small clutter power range





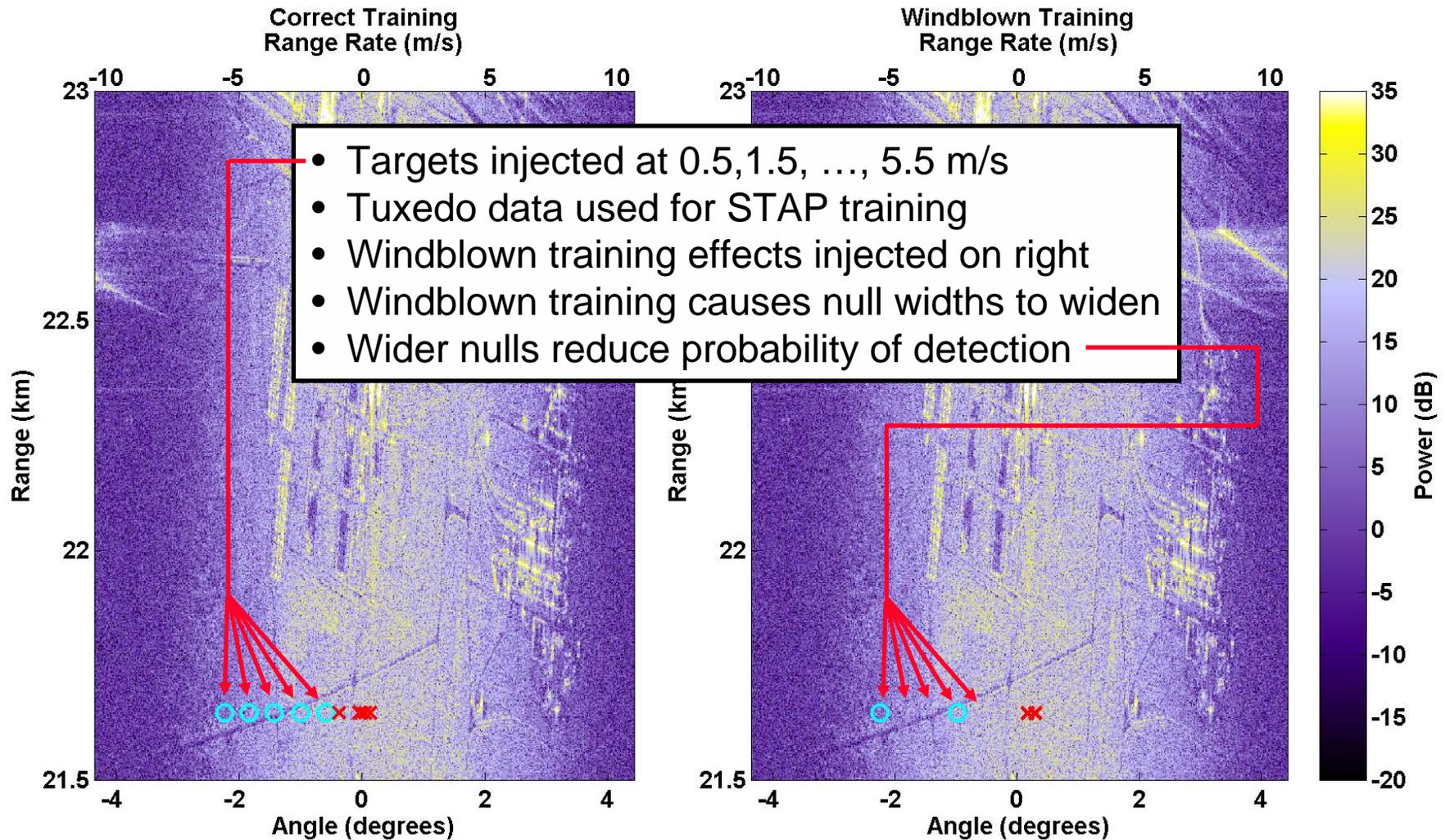
ROC Comparison



- Overall ROC curve illustrates performance increase
- Significant P_{FA} benefits demonstrated
- Performance gain primarily from P_{FA}



Windblown Clutter Training Effects

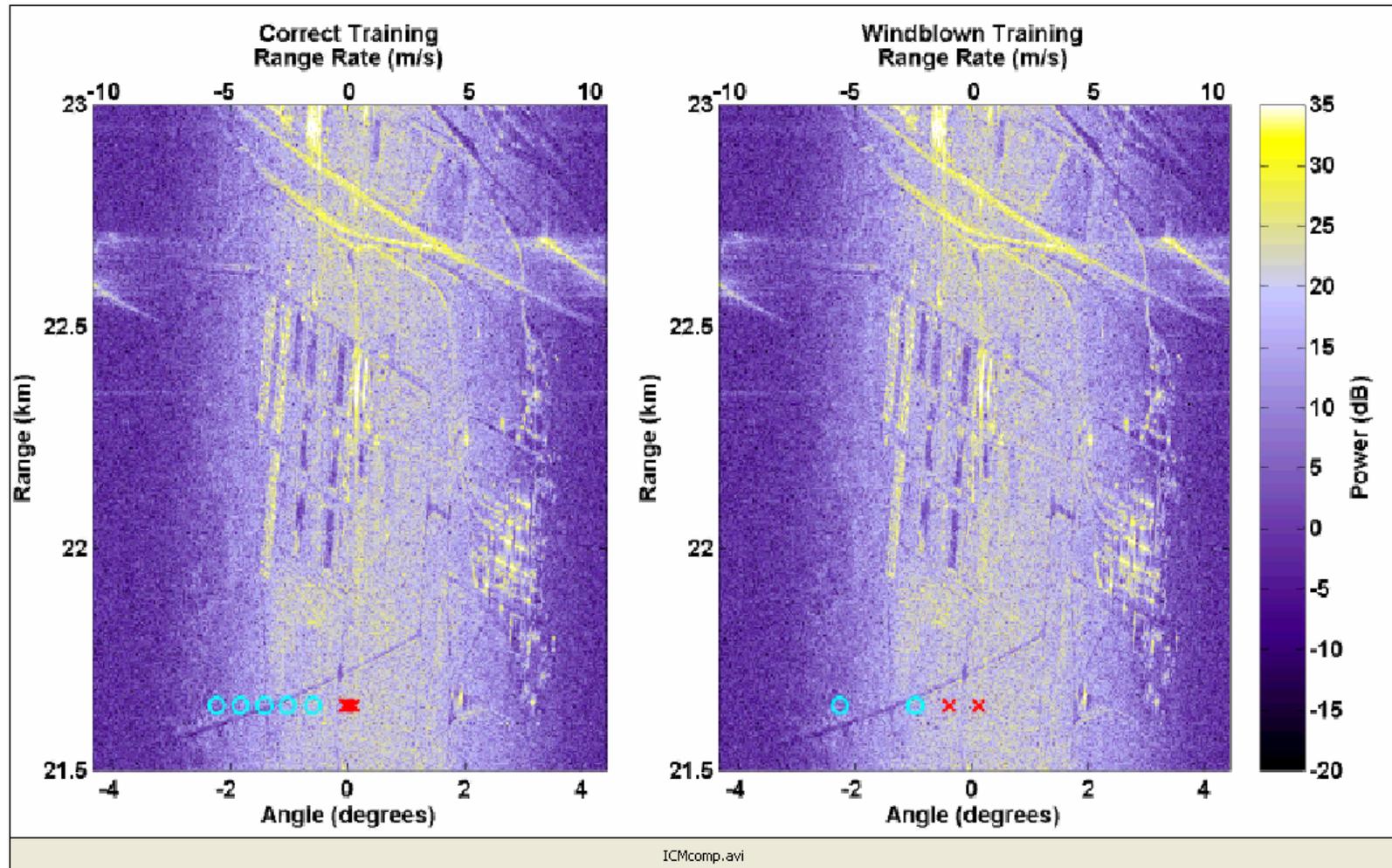




Windblown Training Effects Movie



Click for Demo



Windblown training reduces probability of detection for targets in clear



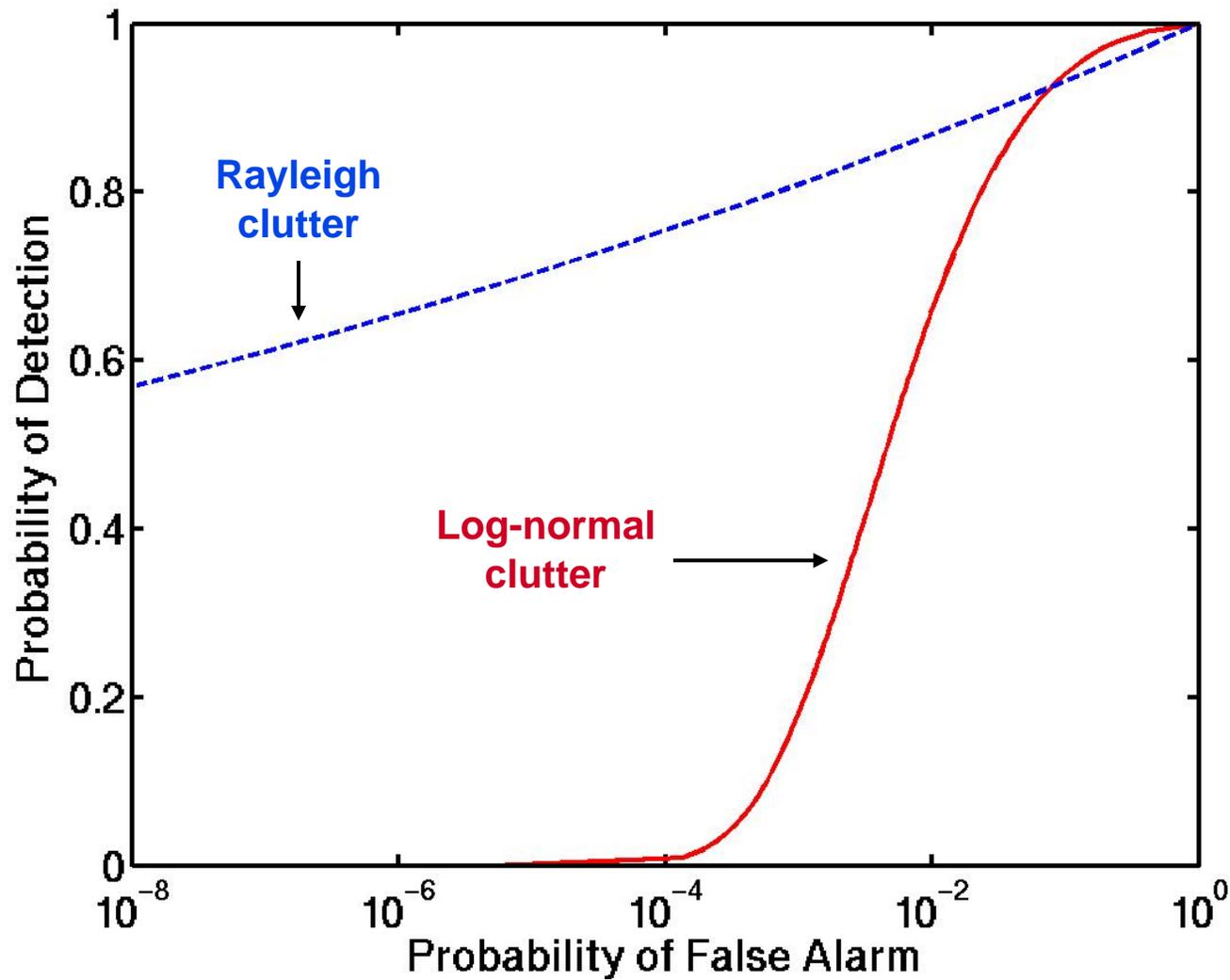
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 - Ali Yegulalp: ASAP 2004
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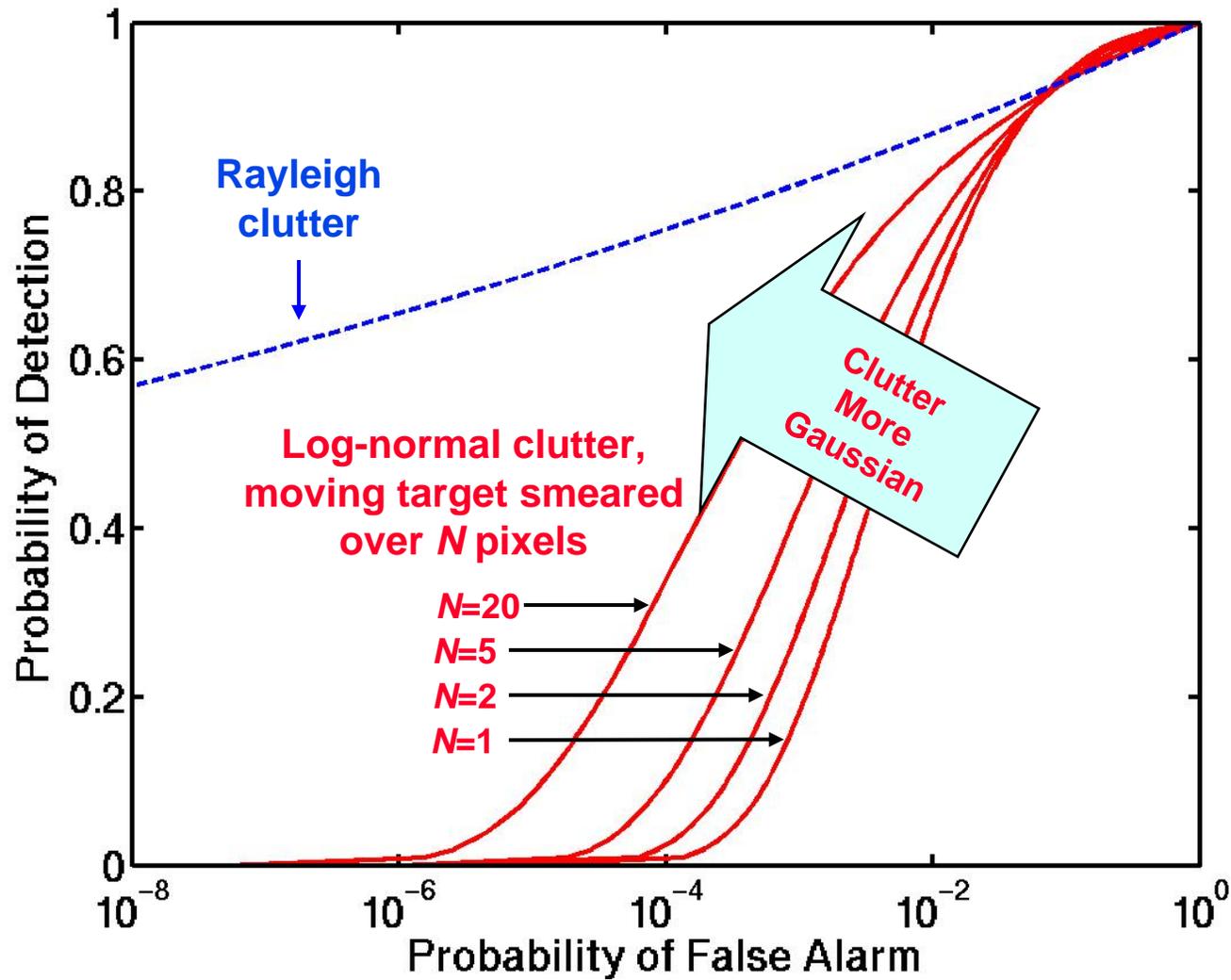


Stationary Target Detection



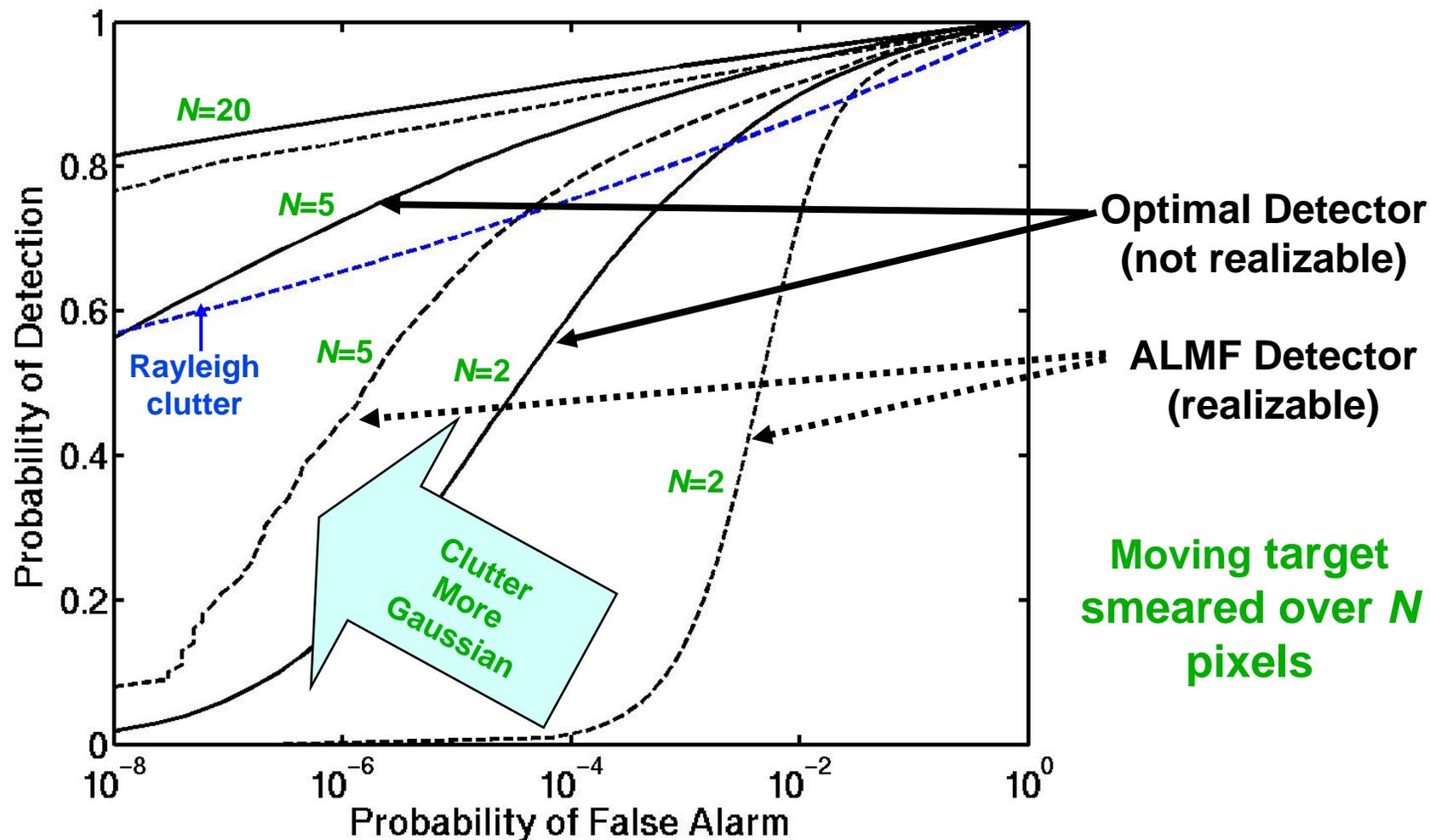


Matched Filter Detector





ALMF - Amplitude Limited Matched Filter (Sub-Optimal Detector)



Long CPI enables detection of along track targets



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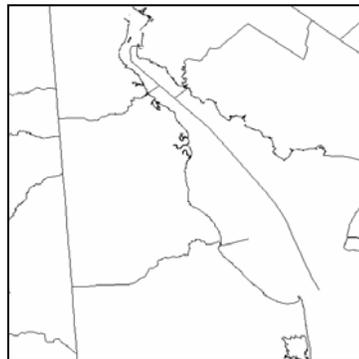
Waveforms for Time Critical Targets (Many Waveforms or Modes Needed)



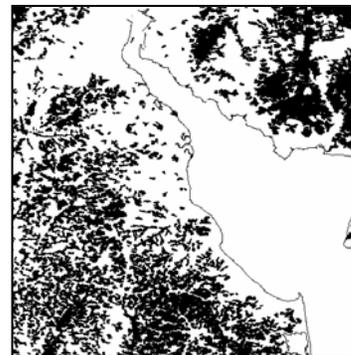
Track	Surveillance	Radar mode	Purpose
		GMTI (narrowband)	Track target while doing broad area surveillance
		GMTI (wider band)	Resolution for targets near confusers & Improve MDV.
		Low velocity, SAR like, GMTI	Further improve MDV for low radial velocity target
		HRR GMTI	ID target when near confusers
		ISAR	ID
		SAR (Strip)	Search for lost target over a wide area
		SAR (Spot)	Locate stopped target
		IFSAR	Measure height of ground for targeting

- Operator selects a target track as a “top priority” target
- Scheduler selects appropriate mode for uninterrupted tracking
- Pre-Mission planning selects the appropriate KNOWLEDGE data
 - DTED -- VMAP --Imagery --Clutter discretetes --etc.

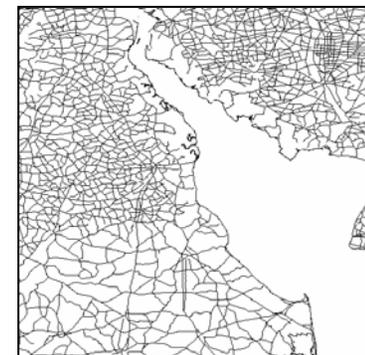
Sample
VMAP



Political (line)



Trees (area)



Roads (line)

MIT Lincoln Laboratory



Knowledge to Enhance Waveforms

		KNOWLEDGE													
Track	Surveillance	Radar mode	DTED					Political Boundary	Roads, train tracks	Trafficability	Foliage, Urban, etc.	Shadowing (buildings etc.)	Clutter discretetes (towers, etc.)	Prior SAR Images	Tracks
			1	2	3	4	5								
		GMTI (narrowband)													
		GMTI (narrowband)													
		GMTI (wider band)													
		Low velocity, SAR like, GMTI	Preliminary												
		HRR GMTI													
		ISAR													
		SAR (Strip)													
		SAR (Spot)													
		IFSAR													
		IFSAR mapping													
Dynamic Scheduler															
		Prioritize missions (targets and region)													
		Compute visibility vs time for critical targets	Preprocessed*												
		Select radar mode and beam location vs time													
		Identify utility of data for multiple modes													
* Use best DTED available but mission planning processor will dramatically reduce the required cache												disc			
												cache			

•Cache: rapid access needed

•Disc: slower access times are fine



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Summary



- **GMTI surveillance**
 - Knowledge and Reasoning incorporated into STAP, Detection, and Tracking
 - Benefits demonstrated with the Tuxedo data
 - Processor architecture identified
- **Long CPI: Practical algorithm for targets with low or no radial velocity**
 - Exploits smearing across SAR pixels
 - Solid theory developed
 - Ready to test with data
- **Time critical targets**
 - Requires many modes to maintain continuous track
 - Most of these modes will benefit from knowledge and reasoning



Kilimanjaro





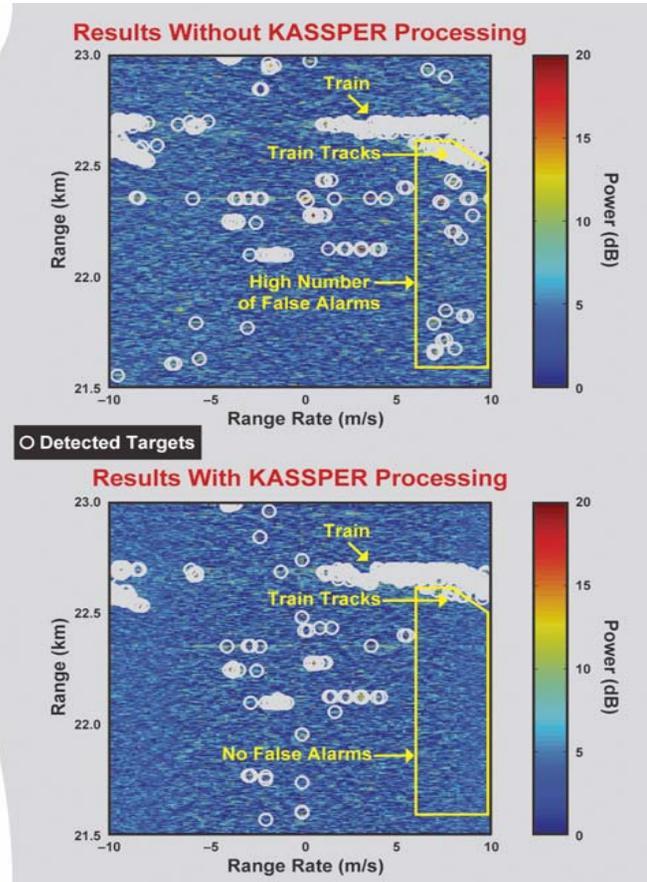
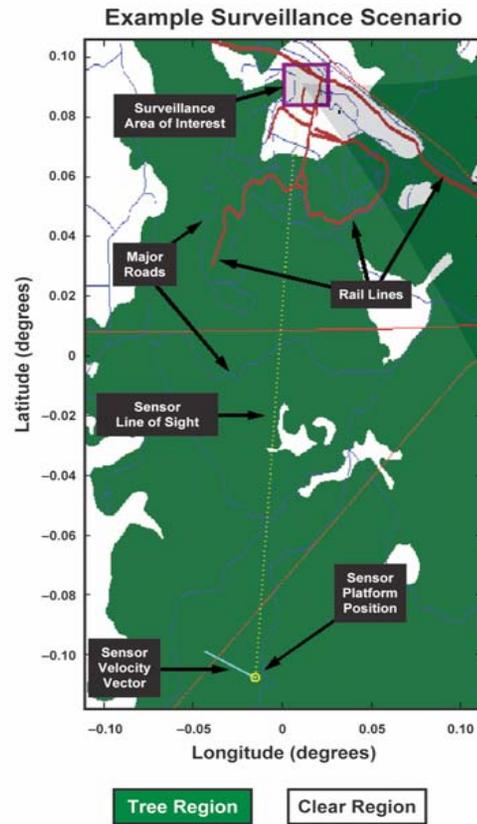
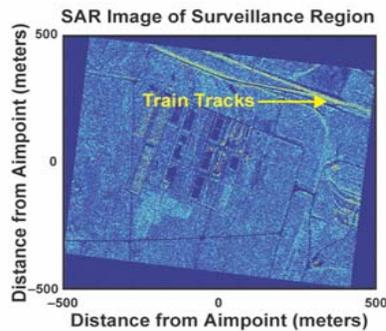
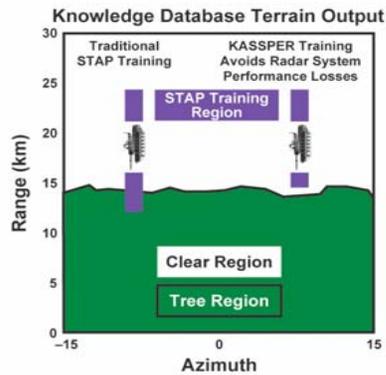
-
- **backup**



Key KASSPER Knowledge-Aided Processing Benefits



Additional Knowledge Sources for Use in KASSPER Processing





Comparison Movie – Vehicle Clusters



Click for Demo

