NORTHROP GRUMMAN DEFINING THE FUTURE

Electronic Systems

"KASSPER Technology for the Advanced Strike Fighter"

KASSPER Workshop
Clearwater, FL

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KASSPER Technology for the Advanced Strike Fighter (ASF)

Outline

- Introduction
- Real and Simulated Test data
- Algorithms / Experiments
  - STAP enhancement with auxiliary processes
    - Results on synthetic data
    - Results on real data from ASF prototype
  - Heterogeneous clutter
    - Analytical experiment
    - Synthetic data validation
- Summary

GMTI in Advanced Strike Fighters

- Requires the ability to reliably detect, track, and precisely locate all-speed targets in challenging surface clutter environments:
  - Heterogeneous littoral clutter scenarios
  - Rapidly changing dynamic terrain relief
  - Concentrated regions of background traffic
  - Constrained ingress routings to minimize known threats
- Needs to maintain target tracking throughout planning and attack phases
- Requires simultaneous SAR and GMTI performance during platform and target tactical maneuvers

Additional Advanced Strike Fighter Challenges

- Significant MDV and geolocation challenges under off-boresight conditions with forward-facing up-tilted arrays
- Optimal utilization of available on-board and intra-sensor information sources needed due to:
  - Limited on-board database capacity
  - Bandwidth-limited access to off-board knowledge
  - Weight/volume constrained signal processor

The Northrop Grumman Electronic Systems KASSPER Program Effort Focuses On:

- **Enhancing GMTI Performance for Advanced Strike Fighters by evaluating the benefits of:**
  - **Using on-board sensor knowledge (INS, RF waveform)**
  - **Recognizing and excising dense moving target clusters from sample background statistics**
  - **Using SAR-based prescreening of heterogeneous clutter containing large stationary discretes**
- **Leveraging the library of GMTI scans collected by our multi-channel 4th Gen AESA prototype radar**
- **Documenting the resultant knowledge-aided signal processing architecture by:**
  - **Analyzing and quantifying KASSPER benefits under realistic and challenging RF conditions**

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Northrop Grumman Electronic Systems is Actively Involved in the Design & Development of High Performance GMTI Systems for Many Applications

Program	Sponsor	Description
Joint STARS AN/APY-7	US Air Force	Design, develop and produce long-range MTI and SAR radar utilizing adaptive processing technology
F-35 Joint Strike Fighter (JSF)	US Air Force, Navy &Marines	System development and demonstration phase of next generation fighter radar
MP-RTIP	US Air Force	Next generation multiple-platform GMTI/SAR surveillance system
F/A-22 Raptor	US Air Force	Production radar system on premier air-superiority fighter; P^3I adding advanced GMTI capabilities
SBR ESA/OBP Concept Development	US Air Force & NRO	Design and analyze SAR and MTI modes for implementation on SBR systems

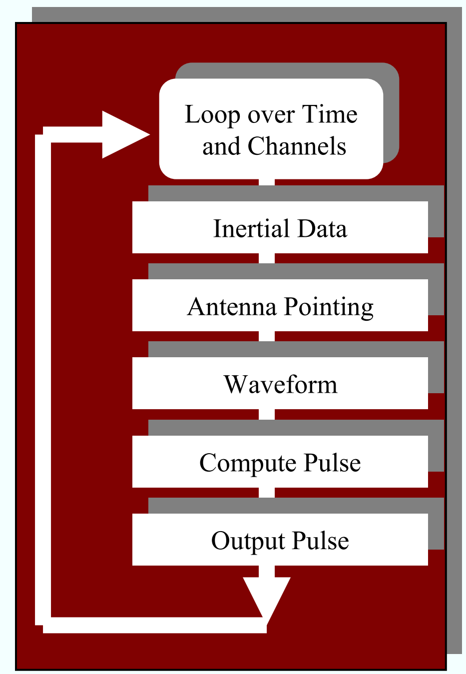
Northrop Grumman Electronic Systems has the optimal blend of GMTI experience to successfully perform the KASSPER program activities and to apply our results to many sensor configurations

IQ Data Generator . . .

- Generate IQ data for testing and evaluating algorithms
  - real-time with closed loop control
  - off-line processing
- Customizable
  - accommodates a variety of waveform timelines
  - noise jammers
  - stretch and non-stretch waveforms
- Written in C for speed, although a MATLAB re-hosting may be useful
- Wide Program Application:
  - MMRS Digital Subsystem Lab
  - JSF Demo - Digital Target Simulator
  - APTI / FOPEN / JSF / SBR / MP-RTIP

- User Inputs:
  - aircraft geometry
  - radar parameters
  - clutter and moving target arrangement
  - dynamic waveform parameters
- Outputs:
  - Binary files, one per receiver channel
  - Data arranged in pulse sequence order
  - Time tag, AGC, A/D start time, ...
  - 32 bit I/Q samples

- Process:



. . . allows high fidelity testing of KASSPER algorithms

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DEFINING THE FUTURE

IQ Data Generator . . .

Aircraft Parameter	
Altitude	8 km
Slant Range	37 km
Speed	109 m/s

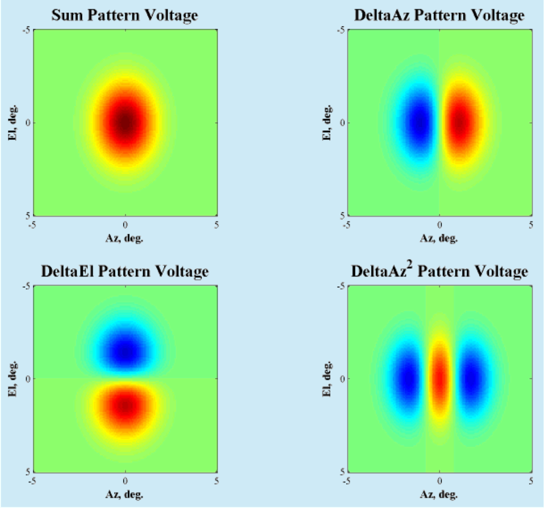
Radar Parameter	
f	9.7 GHz
P_T	8 kW
Duty	.4%

Waveform Parameter	
PRF	1.428 kHz
Tc	100 ms
Range resol.	~ 1 m

Antenna Parameter	
Transmit	
G_{XMT}	37 dB
BW_3dB_AZ	1.3 deg
BW_3dB_EL	1.7 deg
Receive	
G_{REC}	37 dB
BW_3dB_AZ	1.3 deg
BW_3dB_EL	1.7 deg

Clutter Parameter
Discrete Clutter Model

ASF Antenna Patterns

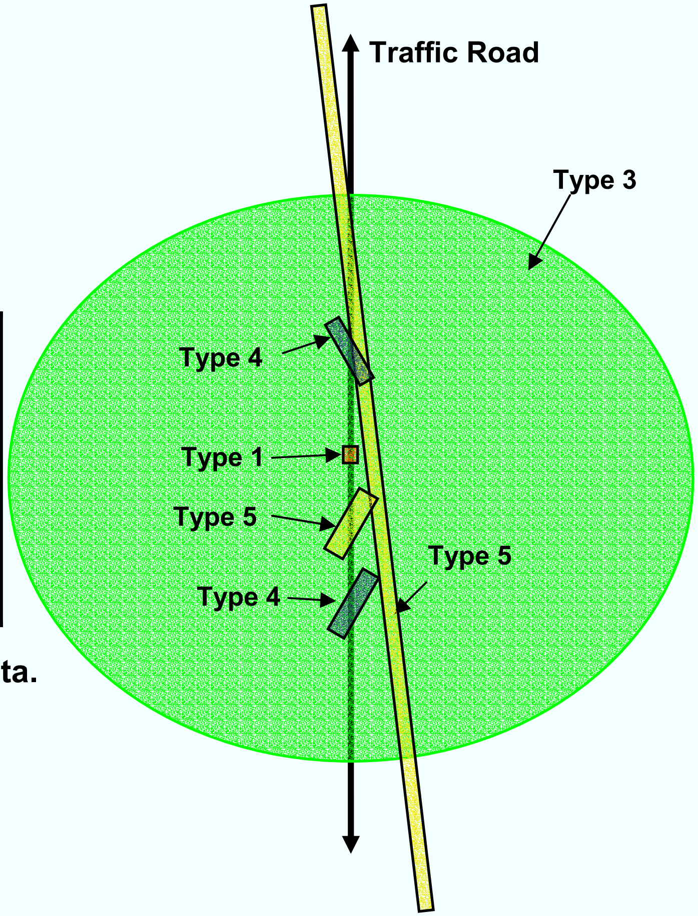


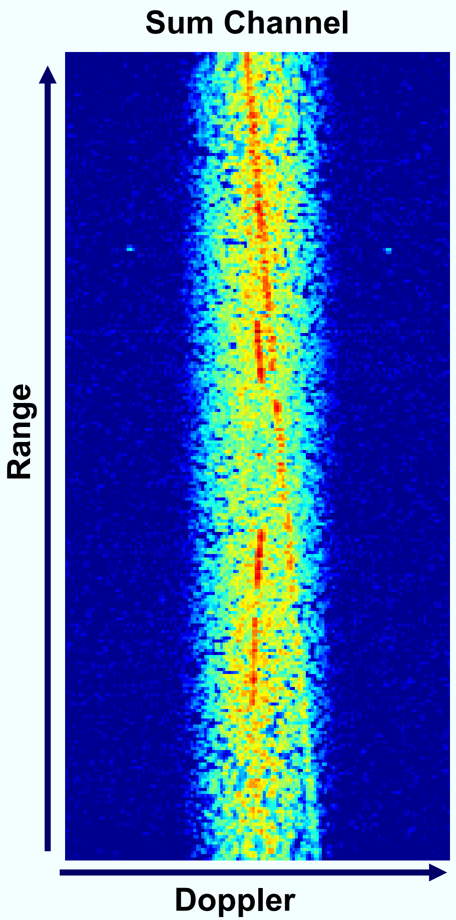
. . . emulates ASF environment, beam patterns and waveforms

Typical Output from the IQ Generator

Clutter Type	Amplitude	Distribution
1	Constant	Uniform
3	Rayleigh	Gaussian
4	Rayleigh	Uniform
5	Gamma	Uniform

*Type 2 clutter: Based on real SAR image data.





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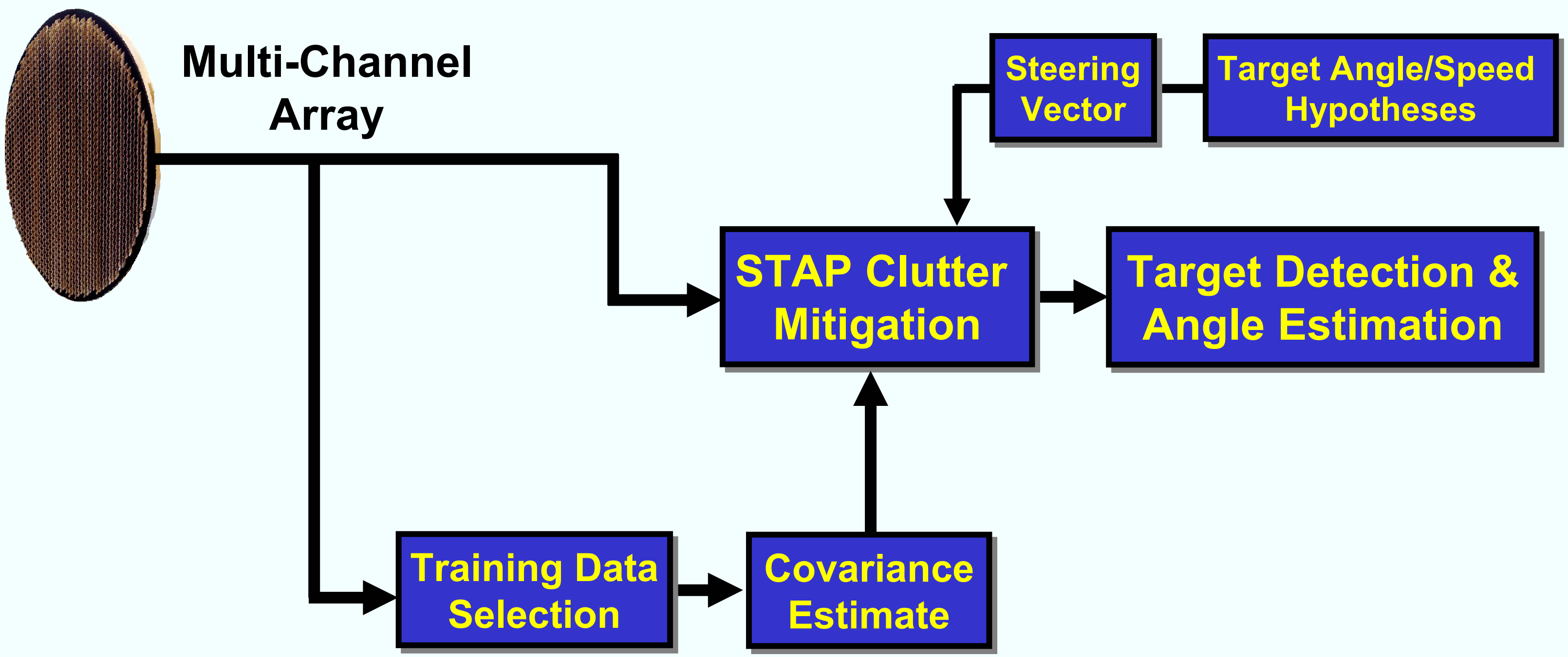
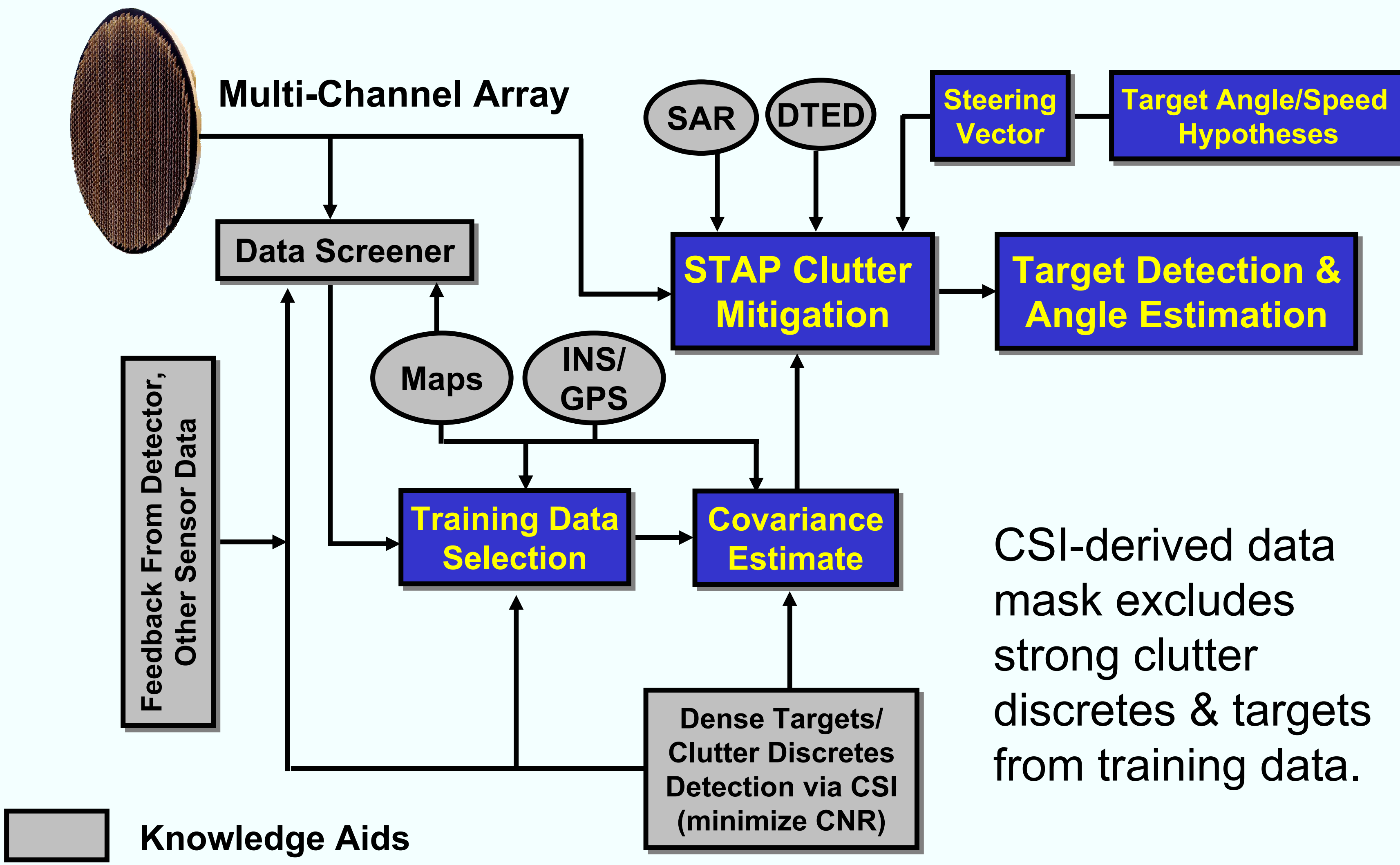
Traditional STAP Architecture

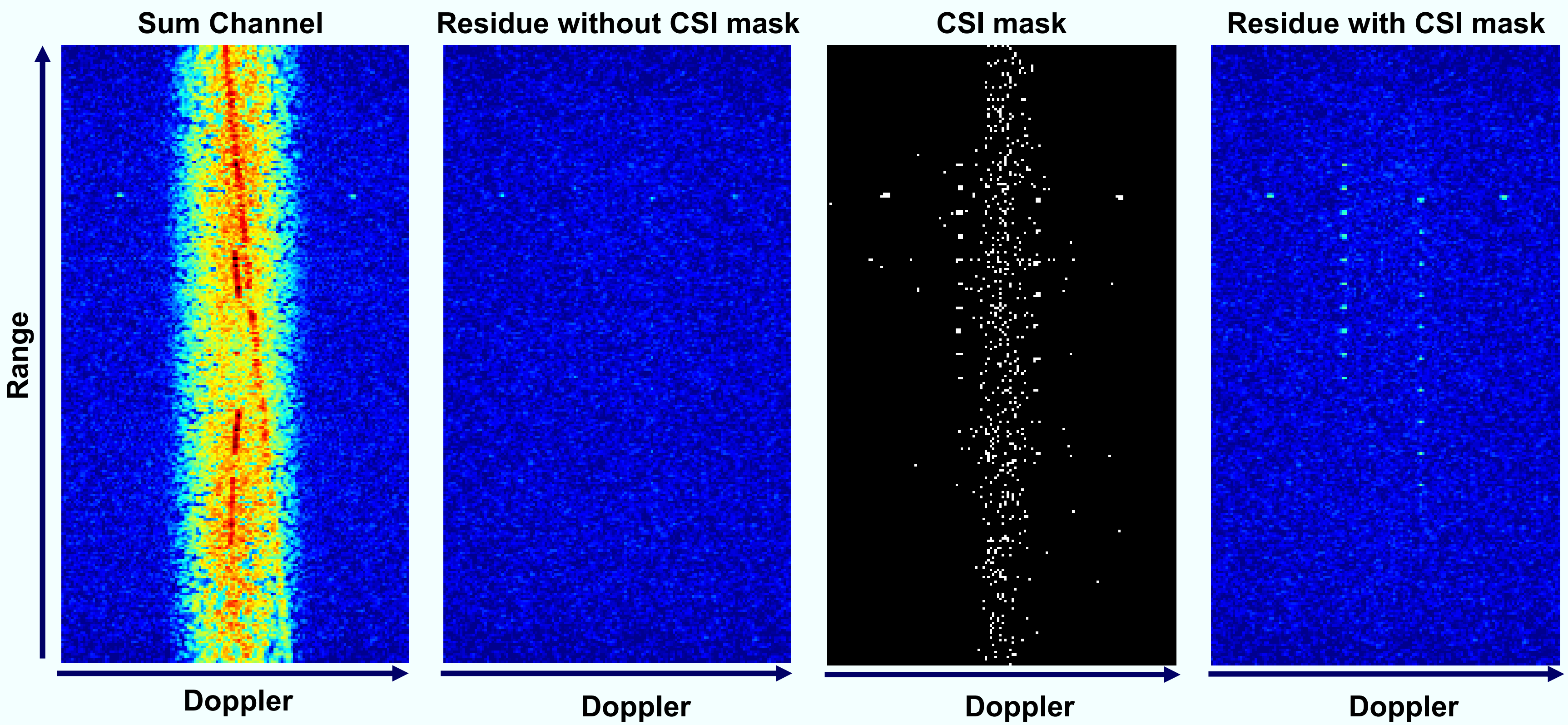


Intra-Sensor Knowledge Aids Traditional STAP Architecture

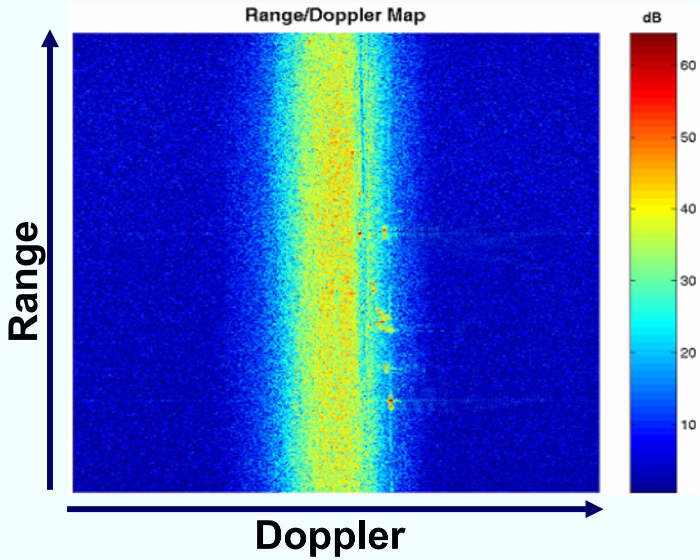


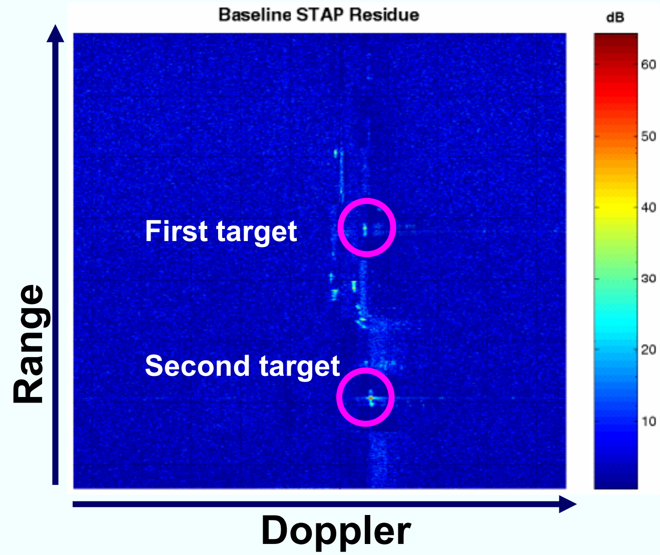
CSI-derived data mask excludes strong clutter discretes & targets from training data.

SNR Improvement with CSI Knowledge Using Simulated data

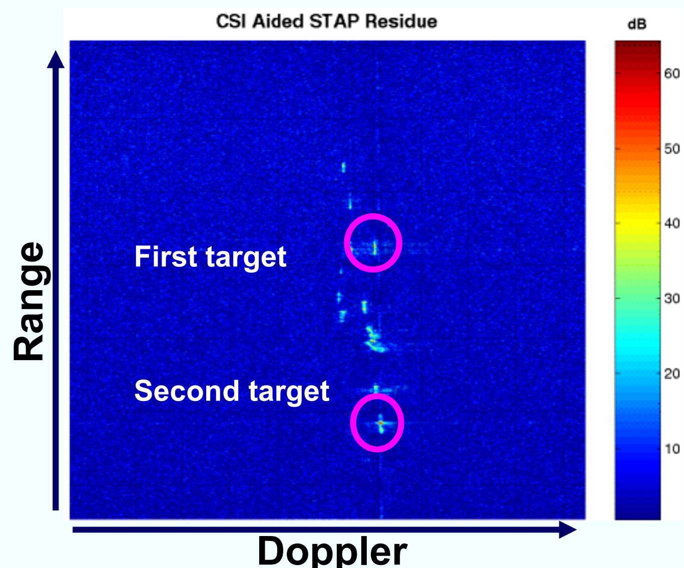


SNR Improvement with CSI Knowledge Using Real Data

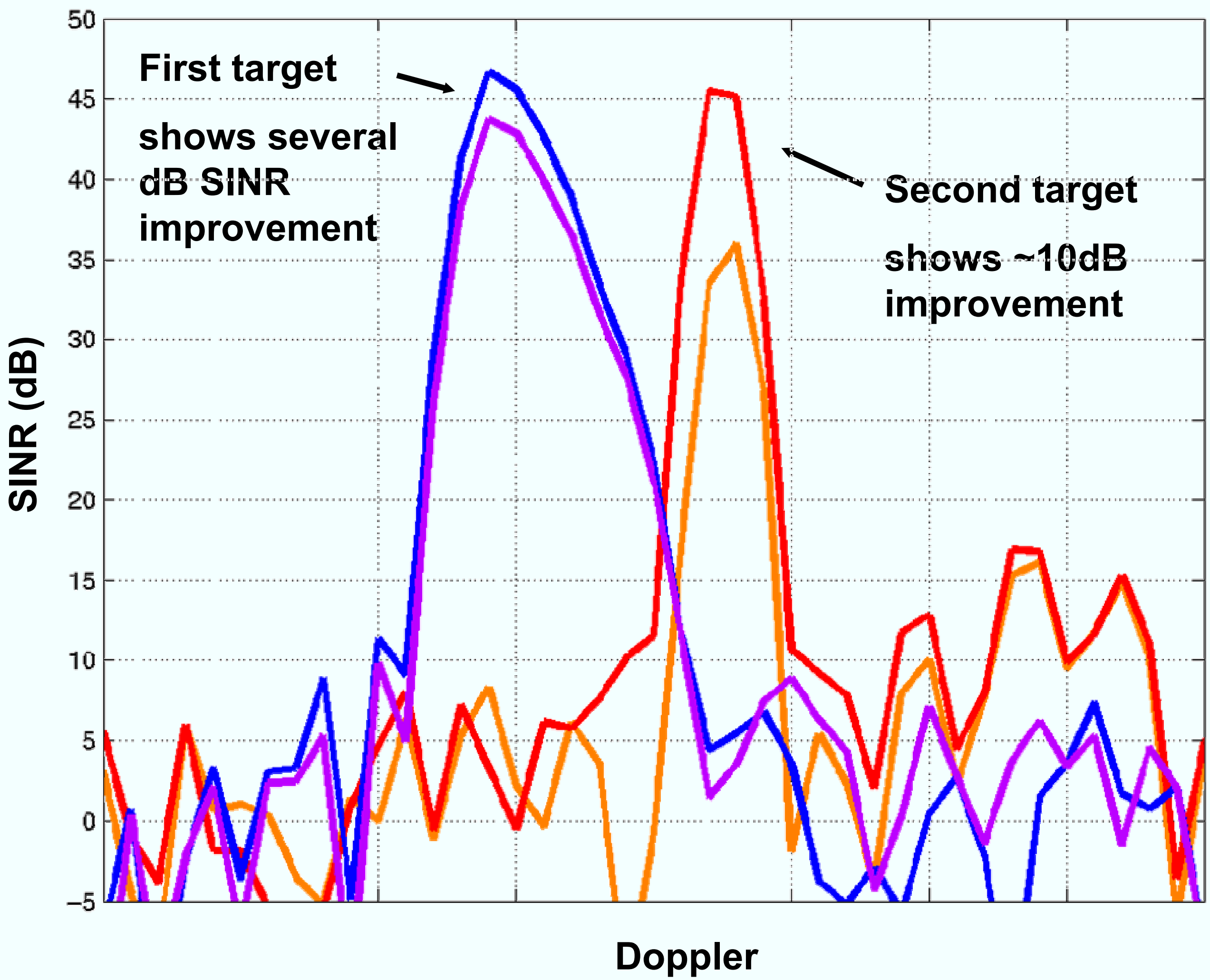




- Input Data: Σ, Δ_{az}, and Δ^2_{az}
- Process:
  - Post Doppler, Single Bin STAP
- Output:
  - Top left: Range/Doppler Map of Sum Channel
  - Top right: STAP residue without CSI knowledge
  - Bottom right: STAP residue with CSI knowledge



CSI-Aided STAP Residue Shows Improved SINR



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Effect of Non-Homogeneous (NH) Clutter

- **Compare the effects of sensed (observed) versus actual Clutter to Noise Ratio (CNR) which differ by some CNR error**

$$\hat{\alpha}_{\mathrm{dB}} = \alpha_{\mathrm{dB}} + (\text{CNR error})_{\mathrm{dB}}$$

$$\text{SINR}_{\text{ACTUAL}} = \frac{\mathcal{G}(\theta_{\mathrm{s}})}{\alpha_{\mathrm{V/V}}\mathcal{G}(\theta_{\mathrm{RFI}})+N}$$

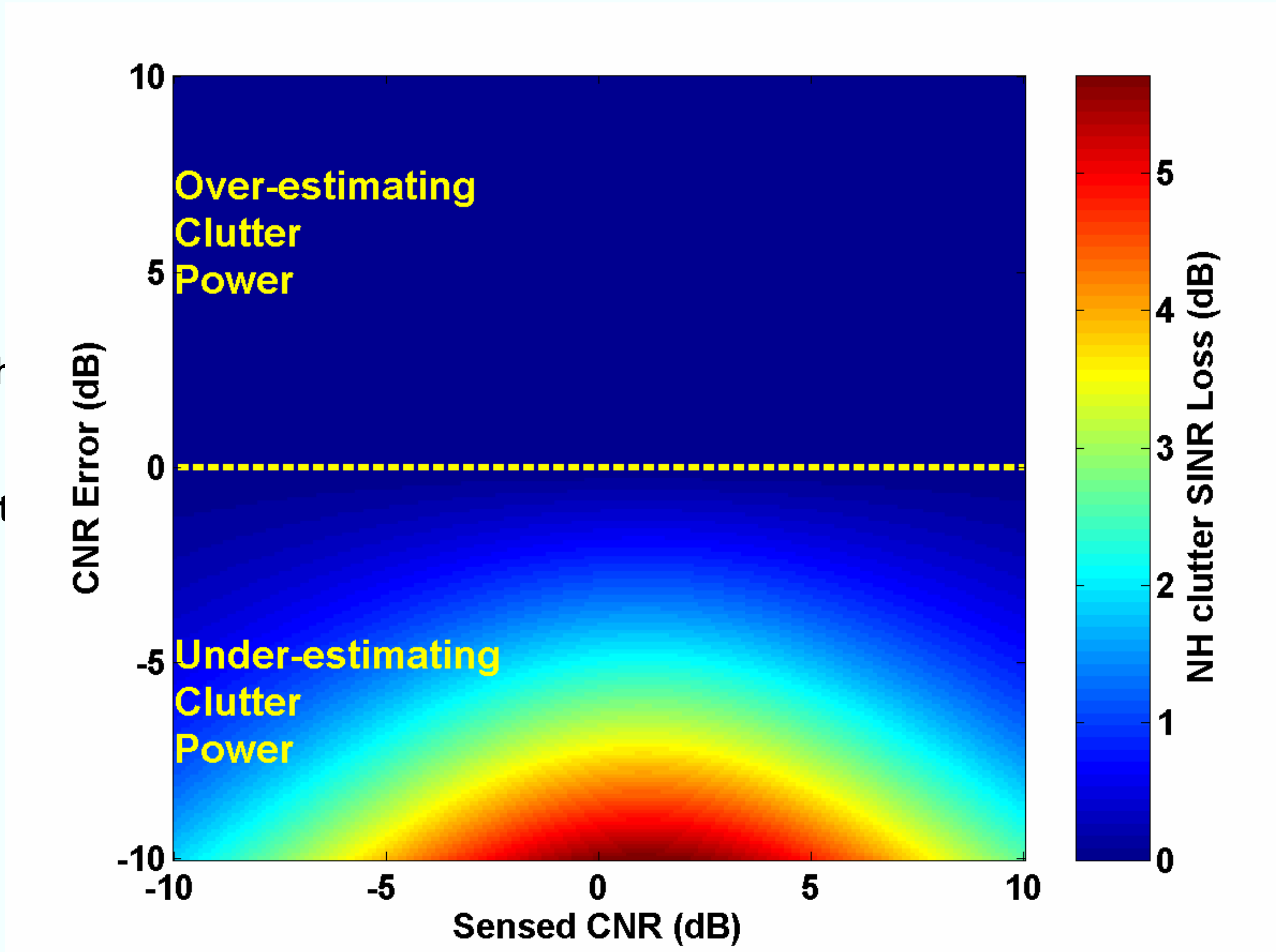
$$\text{SINR}_{\text{SENSED}} = \frac{\mathcal{G}(\theta_{\mathrm{s}})}{\hat{\alpha}_{\mathrm{V/V}}\mathcal{G}(\theta_{\mathrm{RFI}})+N}$$

$$\text{NH CLUTTER LOSS} = \text{SINR}_{\text{ACTUAL}} - \text{SINR}_{\text{SENSED}}$$

for pattern gain adapted to sensed RFI power

Non-Homogeneous Clutter Loss

This shows th
it's better to
overestimate
the power of t
RFI source.



α_{dB}

esultant SINR
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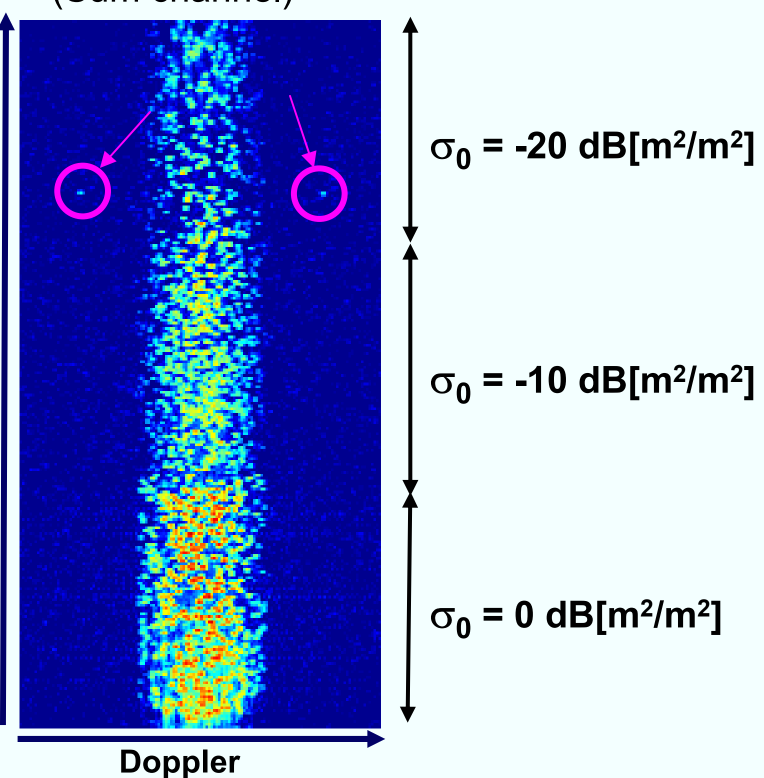
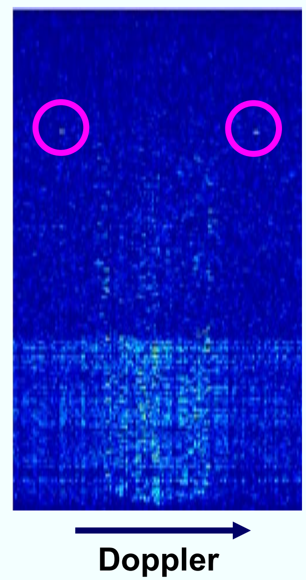
nderestimating
lutter power

Training in Heterogeneous Clutter Environment Demonstrates Effects of Power-Weighted Training

Heterogeneous Clutter Scenario For STAP Data Training Selection (Sum channel)

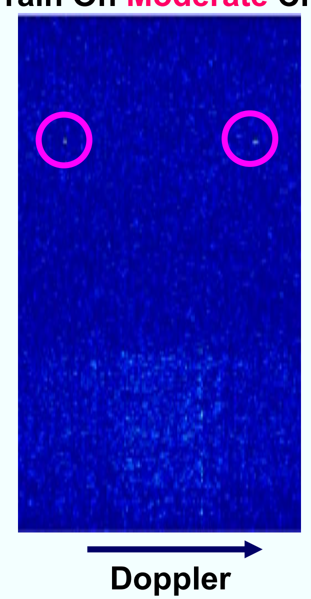


Train On Weak Clutter



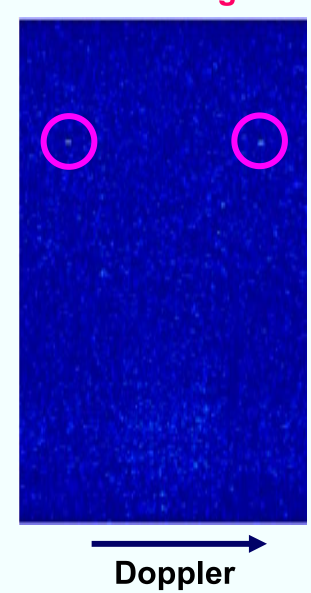
Bad to under-estimate clutter power.

Train On Moderate Clutter

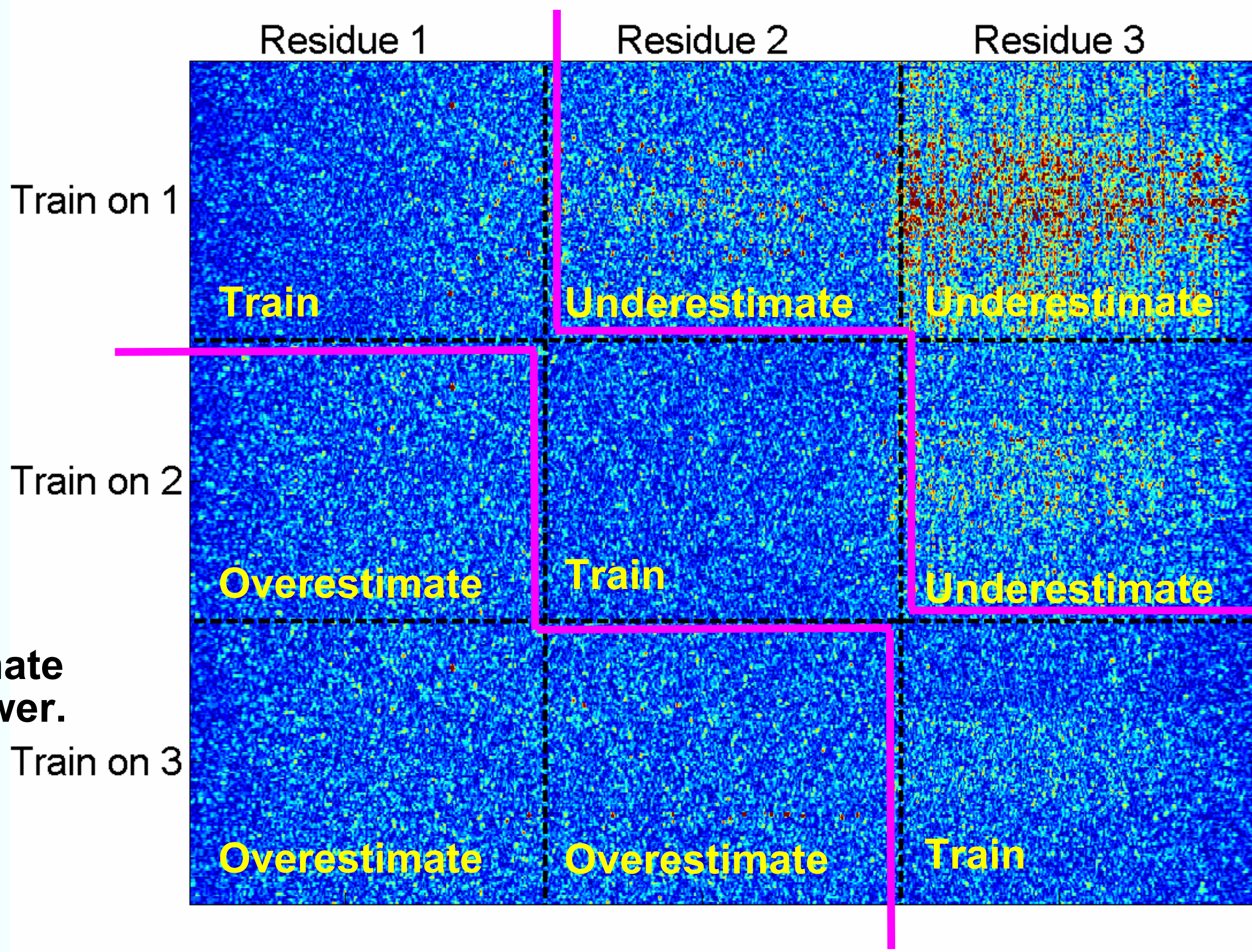


Better to over-estimate clutter power.

Train On Strongest Clutter



Training in Heterogeneous Clutter Environment Demonstrates Effects of Power-Weighted Training



Bad to under-estimate clutter power.

Better to over-estimate clutter power.

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Summary: Current Status

- **The need for knowledge aids for Advanced Multi-Mission Strike Fighters STAP/GMTI processing is well-established.**
- **I/Q simulation of synthetic data cubes for the Advanced Multi-Mission Strike Fighters includes heterogeneous clutter.**
- **Multi-pass CSI / STAP algorithm demonstrates improvement in SINR using both simulated and real radar data from ASF.**
- **Better clutter cancellation performance is attained when sensed clutter power matches actual.**

Summary: Future Work

- **Short term**
  - **Near real-time demo in JSF classified laboratory in Norwalk, CT.**
  - **Show STAP performance improvement using knowledge aids on synthetic and real data from the 4th Generation sensor.**
- **Long term**
  - **Implement KASSPER technologies into JSF GMTI architecture to enhance detection performance.**