

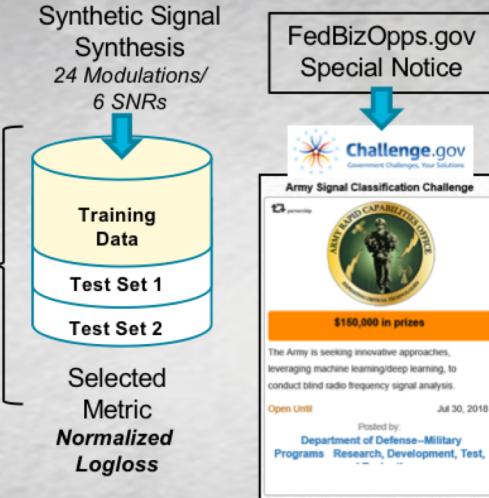


Army Signal Classification Challenge



September 2018

Modulations
BPSK
QPSK
8PSK
16PSK
QAM16
QAM64
2FSK_75KHz
2FSK_5KHz
CPFSK_75KHz
CPFSK_5KHz
MSK
GFSK_75Khz
GFSK_5Khz
GMSK
FM_NB
FM_WB
AM_SSB
AM_DSB
APSK16_c34
APSK32_c34
QAM32
OQPSK
PI4QPSK
*Noise



Dataset Generation

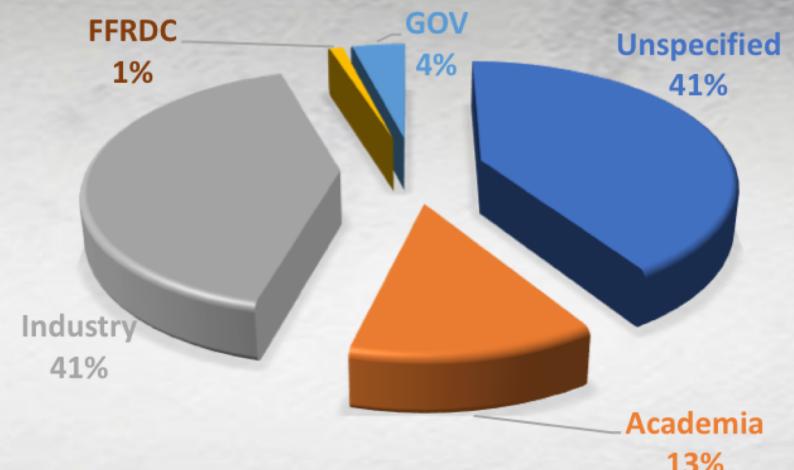
Advertising

Built Site and Data Handling

Leaderboard

Team Breakdown

Rank	Team	Test 1 Score	Test 2 Score	Total Score
1	Platypus Aerospace	54.8	71.34	66.38
2	TeamAu	55.68	68.77	64.84
3	Deep Dreamers	51.93	66.56	62.17
4	THUNDERINGPANDA	52.69	65.37	61.57
5	idle_speculation	51.45	63.85	60.13
6	KachiO	46.4	64.54	59.1
7	FirstTry	49.68	62.58	58.71
8	POCKETBEETLE	51.63	61.4	58.47
9	VTARC	53.13	60.43	58.24
10	The Cooper Union	43.3	61.7	56.18
11	DoubleDownData	49.03	56.95	54.58
12	radio quiet	32.44	63.55	54.22
13	LGS Innovations	52.81	54.74	54.16
14	AlionML and IAI	50.96	55.22	53.94
15	YellowJackets	40.97	59.49	53.93
16	TEAM TCD	35.98	61.03	53.52
17	Spectral Savant	37.98	59.45	53.01
18	Trent	50	54.11	52.88
19	Hauser	46.81	50.15	49.15
20	PhysicistForHire.com	47.24	49.9	49.1

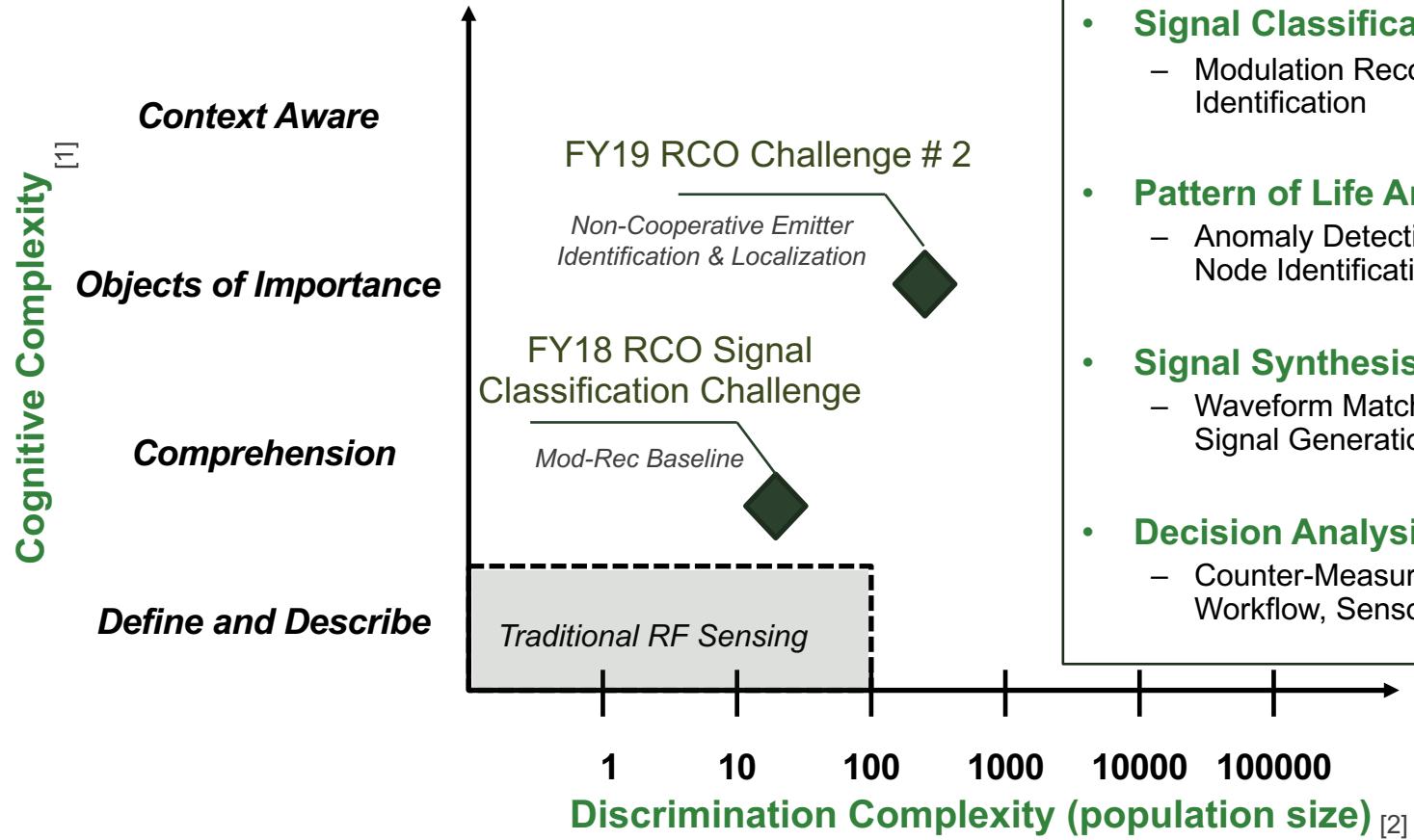


Participation

- 161 Teams Registered
 - 270 total participants registered
 - 43 Team submitted for both Test Set 1 and 2



RF Spectrum Sensing



Application Areas

- Signal Classification**
 - Modulation Recognition, RF-Fingerprinting, Signal/Protocol Identification
- Pattern of Life Analysis**
 - Anomaly Detection, Network Mapping, Net Association, Critical Node Identification, Traffic/Burst Time Pattern Analysis
- Signal Synthesis**
 - Waveform Matching, Signal Feature Reconstruction, Adversarial Signal Generation
- Decision Analysis**
 - Counter-Measure Prioritization, Signal Analysis Automated Workflow, Sensor Hardware Control

References

[1] Cognitive Complexity adopted from Anderson & Krathwohl (2001) Bloom's Taxonomy

[2] Chart concept adapted from Paul Tilghman, DARPA RFMLS GRCON17 Presentation (2017)

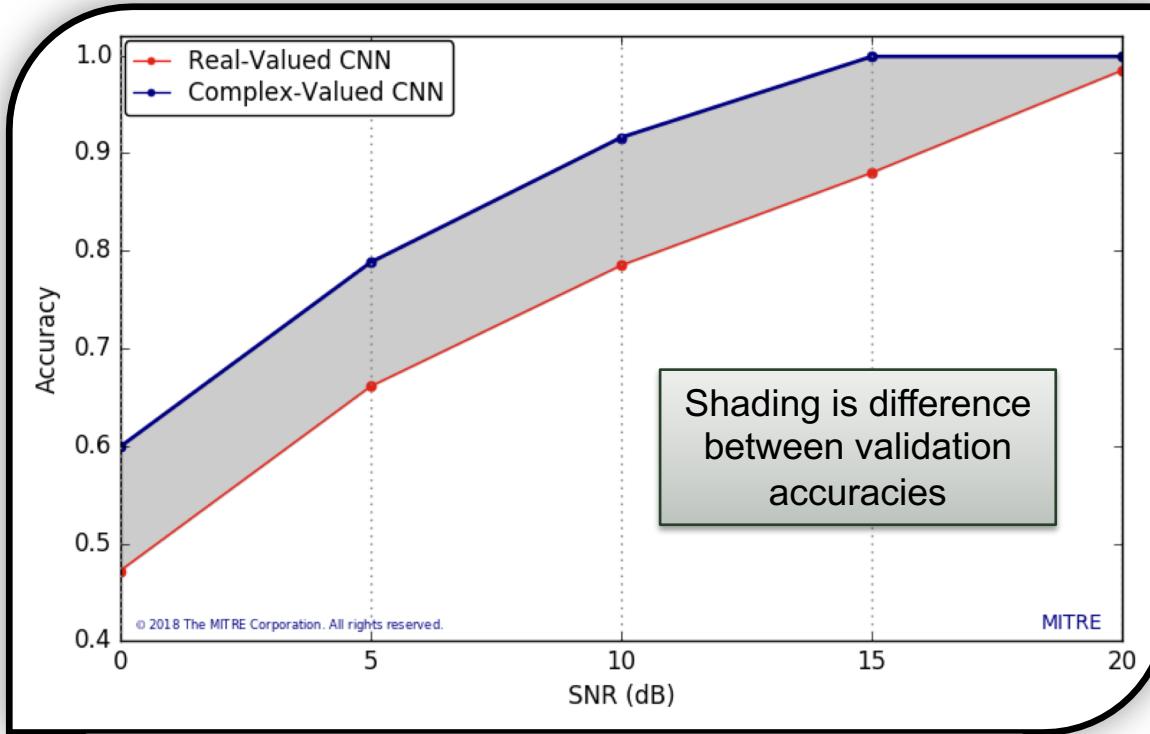


Exploring Alternative Approaches for Modulation Recognition



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Complex Valued CNNs vs Real Valued CNNs



Loss Function

$$L(z) = - \sum p_i \log |z_i|$$

Complex Backpropagation

$$\frac{\partial L}{\partial z} = \frac{\partial L}{\partial x} + i \frac{\partial L}{\partial y}$$

Complex Activation Function

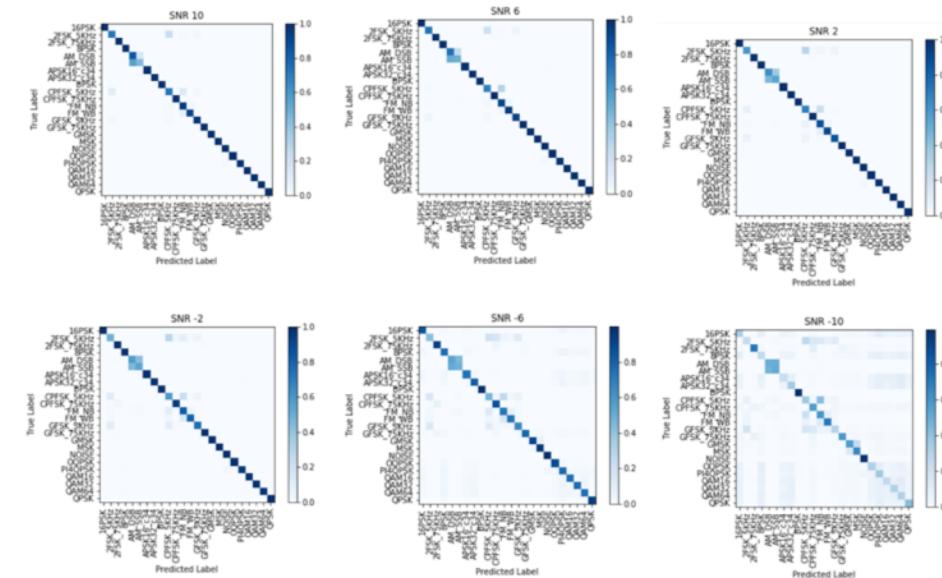
$$\text{crelu}(z) = \text{relu}(x) + i \cdot \text{relu}(y)$$

Real Valued CNNs vs Capsule Networks

	10 dB SNR	6 dB SNR	2 dB SNR	-2 dB SNR	-6 dB SNR	-10 dB SNR	Total
CNN	92.3%	92.0%	90.4%	87.7%	74.2%	46.6%	80.5%
Caps Net	92.7%	92.4%	90.3%	87.0%	71.4%	43.9%	79.6%

CNN + CapsNet Ensemble:

- Accuracy: 82.09% overall
- 94% on 10 dB SNR; 48% on -10 dB SNR

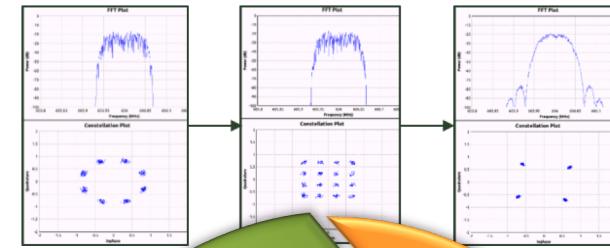




GNU Radio Data Generation

Signal Generation Requirements

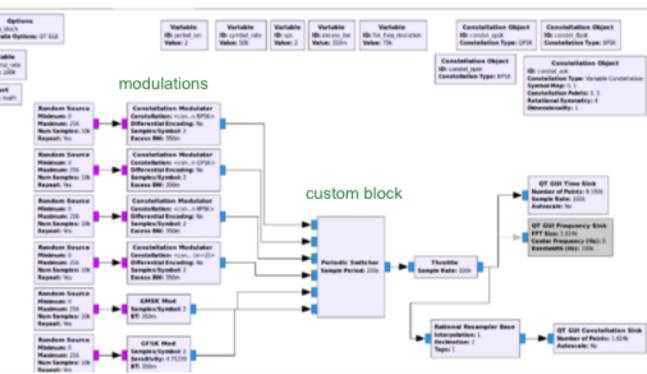
- ❖ Comms, Radars, Jammers
- ❖ Impairments
- ❖ Anomalies



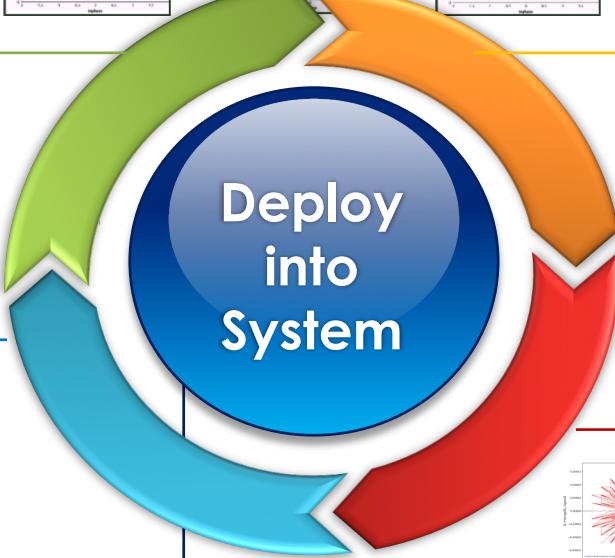
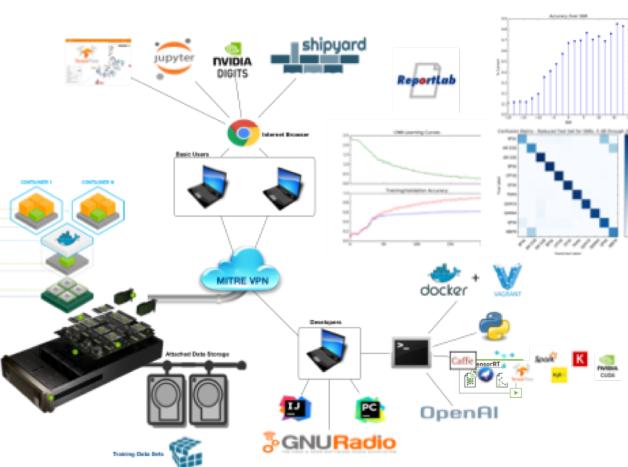
GNURadio
THE FREE & OPEN SOFTWARE RADIO ECOSYSTEM

Signal Data Generation and Collection

- ❖ Synthesized
- ❖ Open-Air Collected on Army SDRs

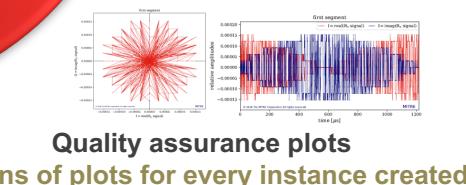


Develop & Train AI Models



5 Deployment

- ❖ Quantization for Real Time
- ❖ Standard Validation Metrics
- ❖ Reference I&T Platform



Quality assurance plots
Dozens of plots for every instance created

Dataset Building



- ❖ CV/NLP Conventions
- ❖ Adopt Open-Source
- ❖ Promote Community Interest in DSP RF-ML

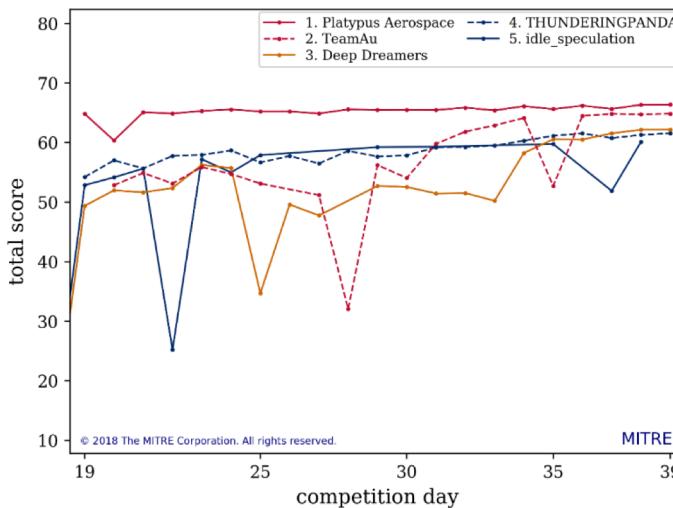


Top 5 Scoring Teams

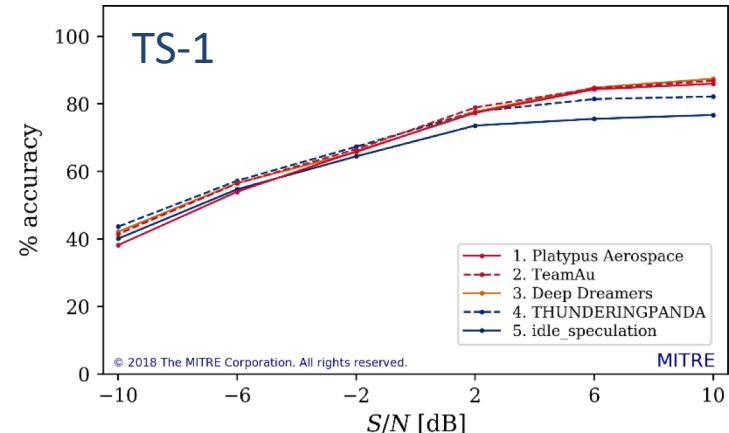
Top 5 overall accuracies

	TS-1	TS-2	final score
1. Platypus Aerospace	67.5%	87.3%	66.4
2. TeamAu	69.0%	85.2%	64.8
3. Deep Dreamers	69.0%	84.4%	62.2
4. THUNDERINGPANDA	68.2%	80.7%	61.6
5. idle_speculation	64.1%	82.0%	60.1

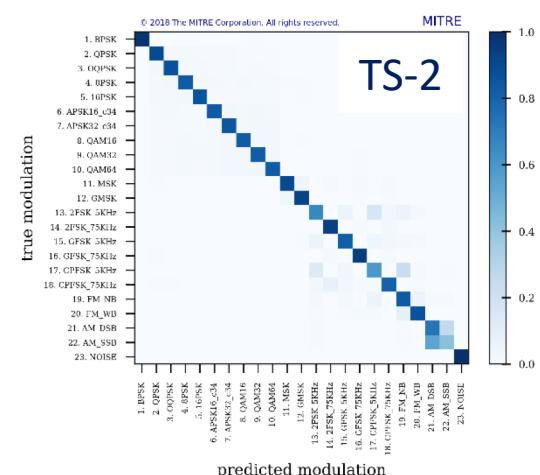
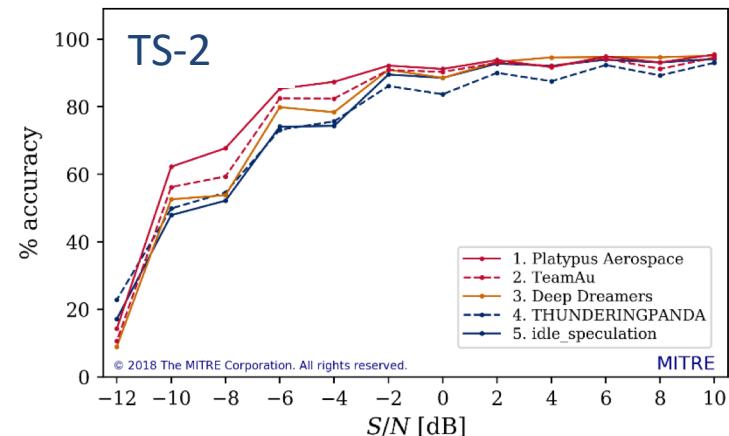
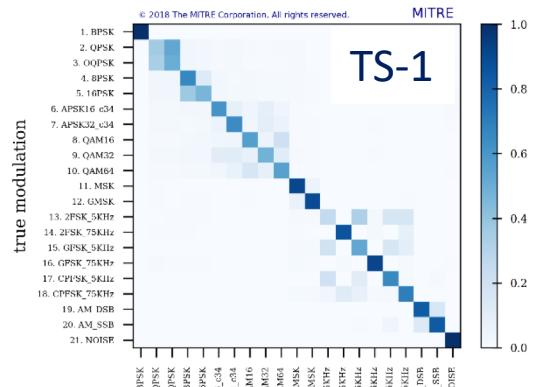
Top 5 – scores over time



Top 5 by SNR



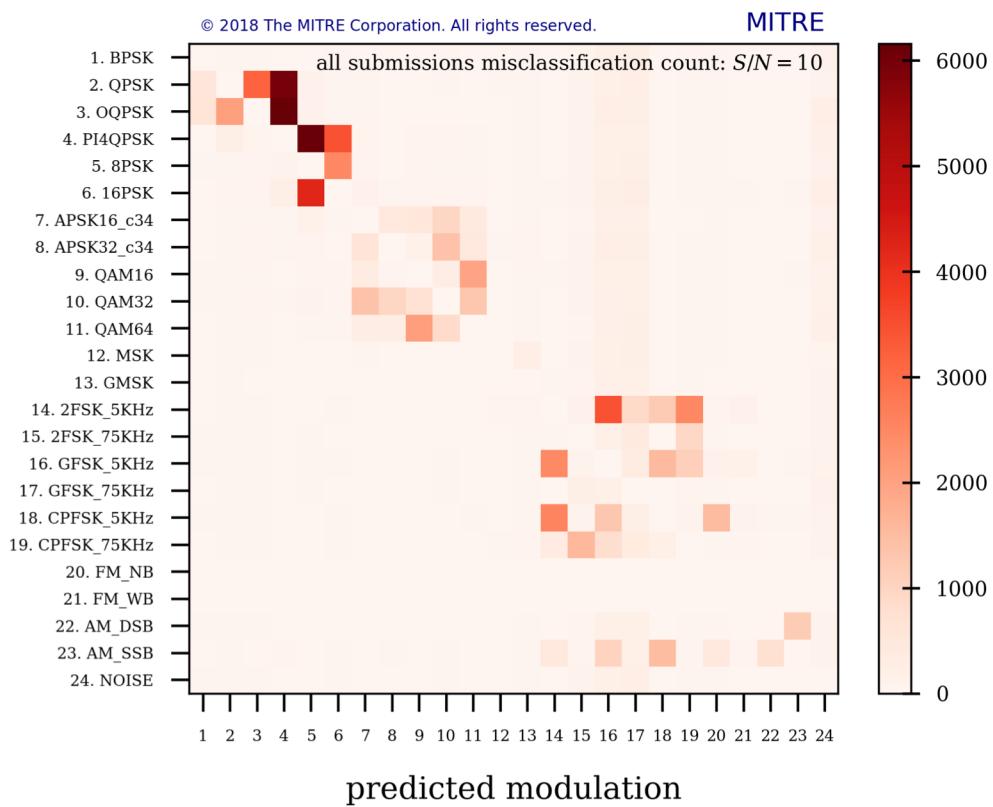
Top 5 aggregated



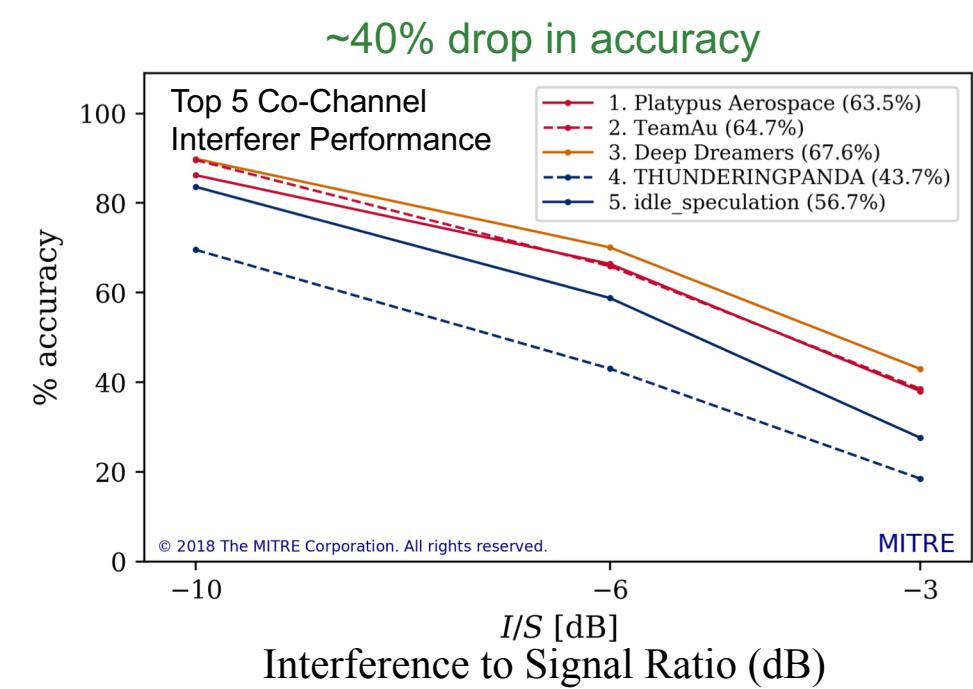
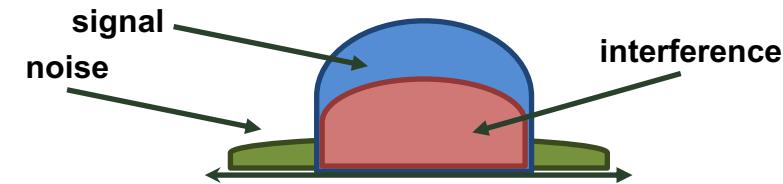
Observations

QPSK and OQPSK being confused as PI4QPSK
PI4QPSK being confused as 8PSK and 16PSK

true modulation



Interested in understanding the impact on performance with co-channel interference



Note: These examples were not scored



Signal Classification Challenge Winners – Congratulations!!!!



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Rank	Team	Accuracy (%)	
		Test Set 1	Test Set 2
1	Platypus Aerospace	67.53	86.08
2	TeamAu	69.05	84.08
3	Deep Dreamers	68.96	83.24
4	THUNDERINGPANDA	68.19	79.93
5	idle_speculation	64.14	80.91
6	KachiO	59.34	80.84
7	FirstTry	64.17	80.44
8	POCKETBEETLE	64.26	77.88
9	VTARC	65.74	74.91
10	Cooper Union	57.4	80.35

Challenge Winners

Platypus Aerospace (\$100k)
TeamAU (\$30k)
THUNDERINGPANDA (\$20k)

Technical Artifacts to RCO

- Winning Software/Descriptions
- All SW-AI Details, Parameters, Etc.
- In-Person Demo @ TBD Location

Challenge Winner Engagements

Understand their models,
technical approaches, challenges,
and lessons learned

Advance AI Approaches

Provide baseline datasets to
challenge leaders to refine
algorithms

Engaging participants to evaluate their approaches



Questions/Contact the Army RCO



Website: <http://rapidcapabilitiesoffice.army.mil>

Email: rapidcapabilitiesoffice@mail.mil

Follow: <https://www.linkedin.com/company/us-army-RCO>

Submit to the Emerging Technologies Office database:
<http://rapidcapabilitiesoffice.army.mil/eto>

The diagram illustrates the submission process. On the left, a screenshot of the 'EMERGING TECHNOLOGIES OFFICE' website shows a 'Submit a Technology' button. A large green arrow points from this button to a second screenshot on the right. The second screenshot shows a black silhouette of a helicopter against a background of circuit board patterns, with the word 'VULCAN' prominently displayed in the center.

EMERGING TECHNOLOGIES OFFICE

Within the Army Rapid Capabilities Office, there is a dedicated cell called the Emerging Technologies Office (ETO). The ETO mission is to directly, and continuously, align, understand and drive academia, industry and Science & Technology solutions to near-term and emerging threats with development and demonstration of revolutionary new capabilities while leveraging innovation by other government agencies and industry partners. Industry partners and other parties who desire to share information with the Emerging Technologies Office should click the "Submit a Technology" button below.

Submit a Technology

Participants are hereby instructed NOT to submit proprietary or classified information, the government shall not be responsible for safeguarding any proprietary or liable for damages, including but not limited to any direct, indirect,

Mr. Doug V
Director, Army Rapid C
Rapidly Develop, Acquire, Integrate, and Equip

Indu
March
Seco
place.
Detail.

VULCAN

Rapidly Develop, Acquire, Integrate, and Equip