ISART™ 2026

BOULDER, CO | AUGUST 11-13, 2026

Training Aggregate Receiver-Transmitter Interference Classifiers

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8/12/2026

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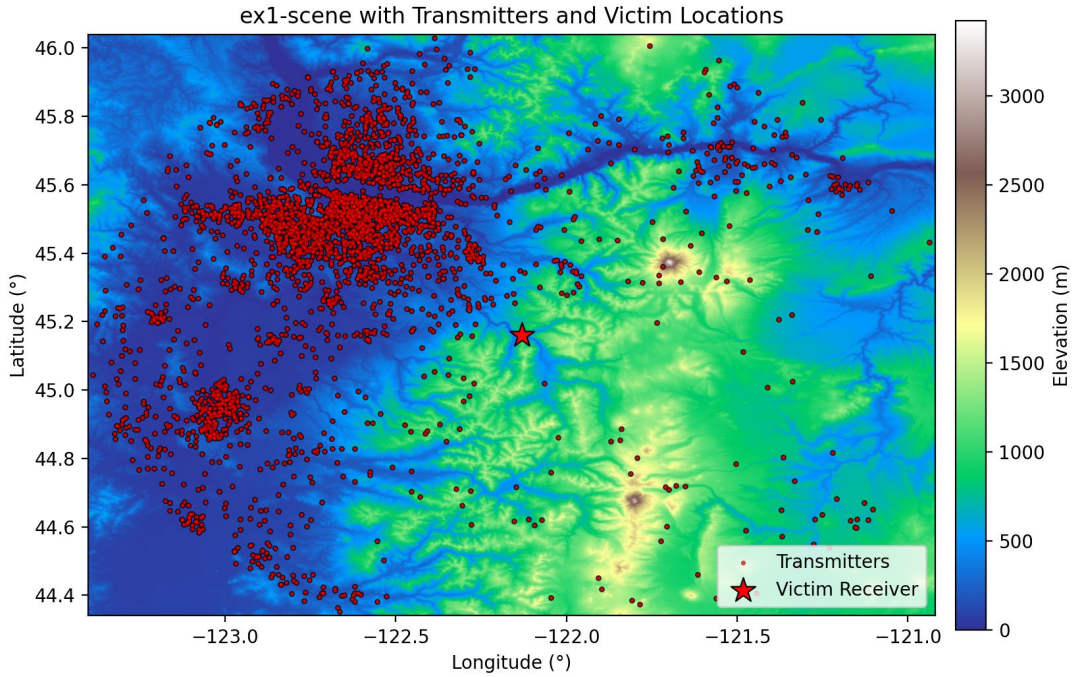
Agenda/Outline

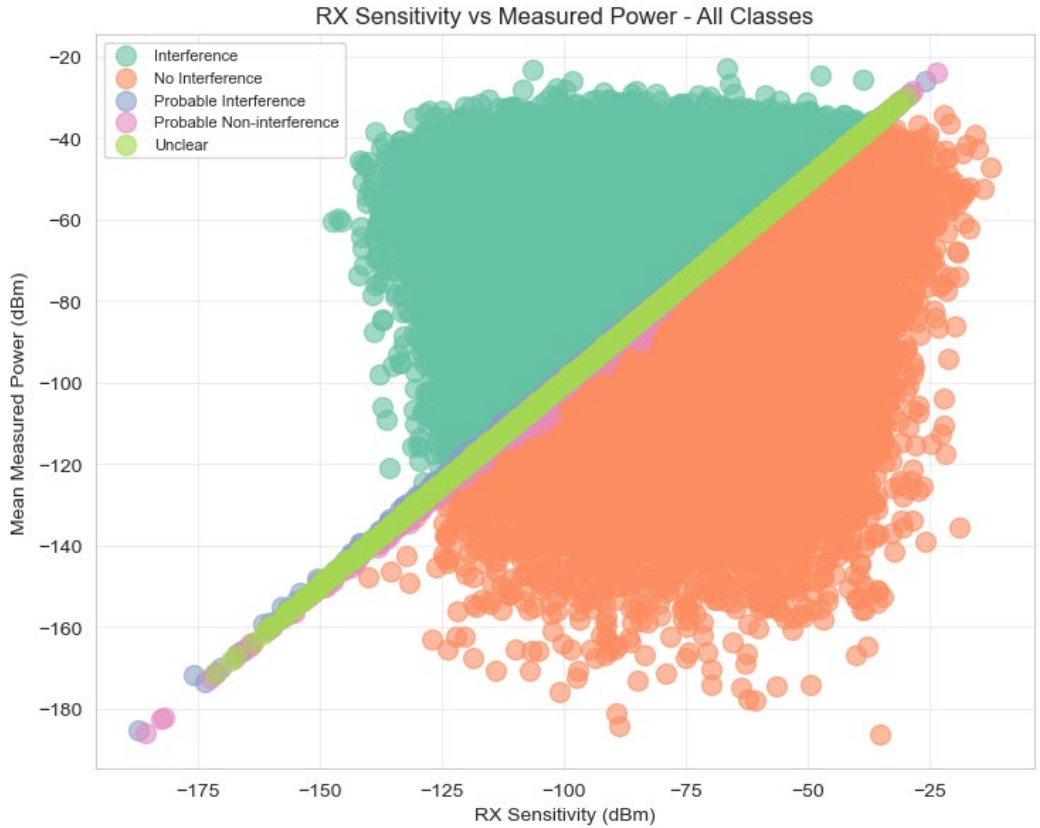
- Problem Statement
- Dataset
- Model
- Results
- Next Steps

Problem Statement

- How do you know if a certain receiver will be interfered with?
- How much information do you need to decide?
- Can you explain the result? With what confidence?



Problem Statement



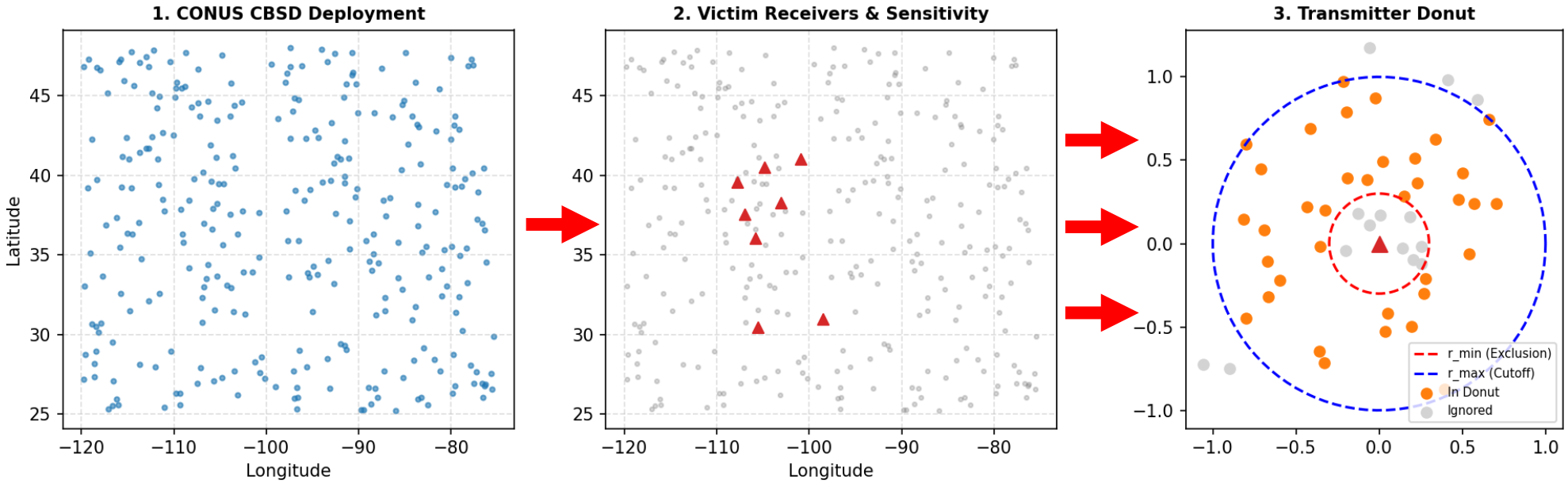
- Knowing whether the model thinks this is an interfering or non-interfering scenario → now you can search for thresholds when the classification changes
- An explicit classification can be more useful than comparing a quantitative comparison against a reference value

Proposed Solution

- Two key components:
  - A dataset that demonstrates this problem
  - A trained model reliably classifying when the victim is interfered with
- Intended outcome:
  - Develop a proof-of-concept against a gap in interference modeling
  - Learn strengths/weaknesses of the dataset, models, and approach

Dataset Concept

- Best case would be real-world data, but it doesn't exist at scale
- Therefore, we use a synthetic technique:



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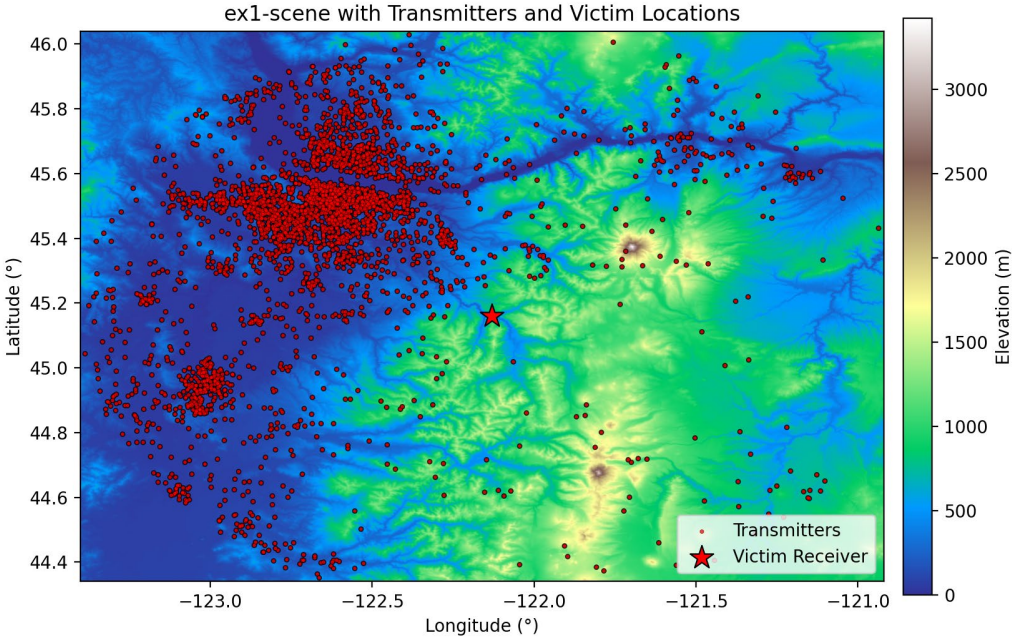
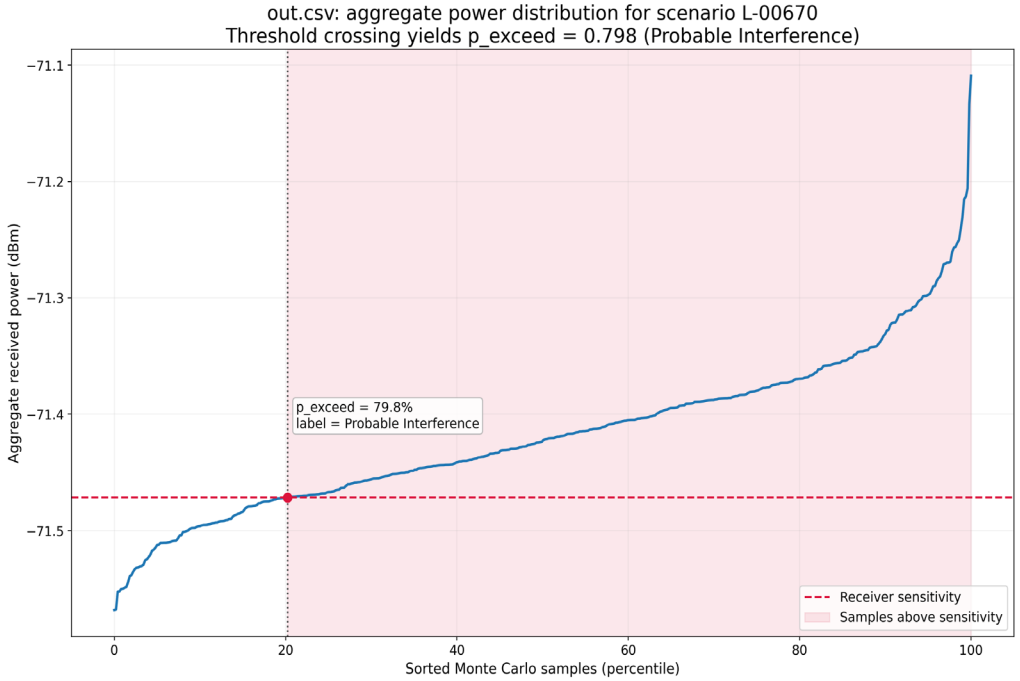
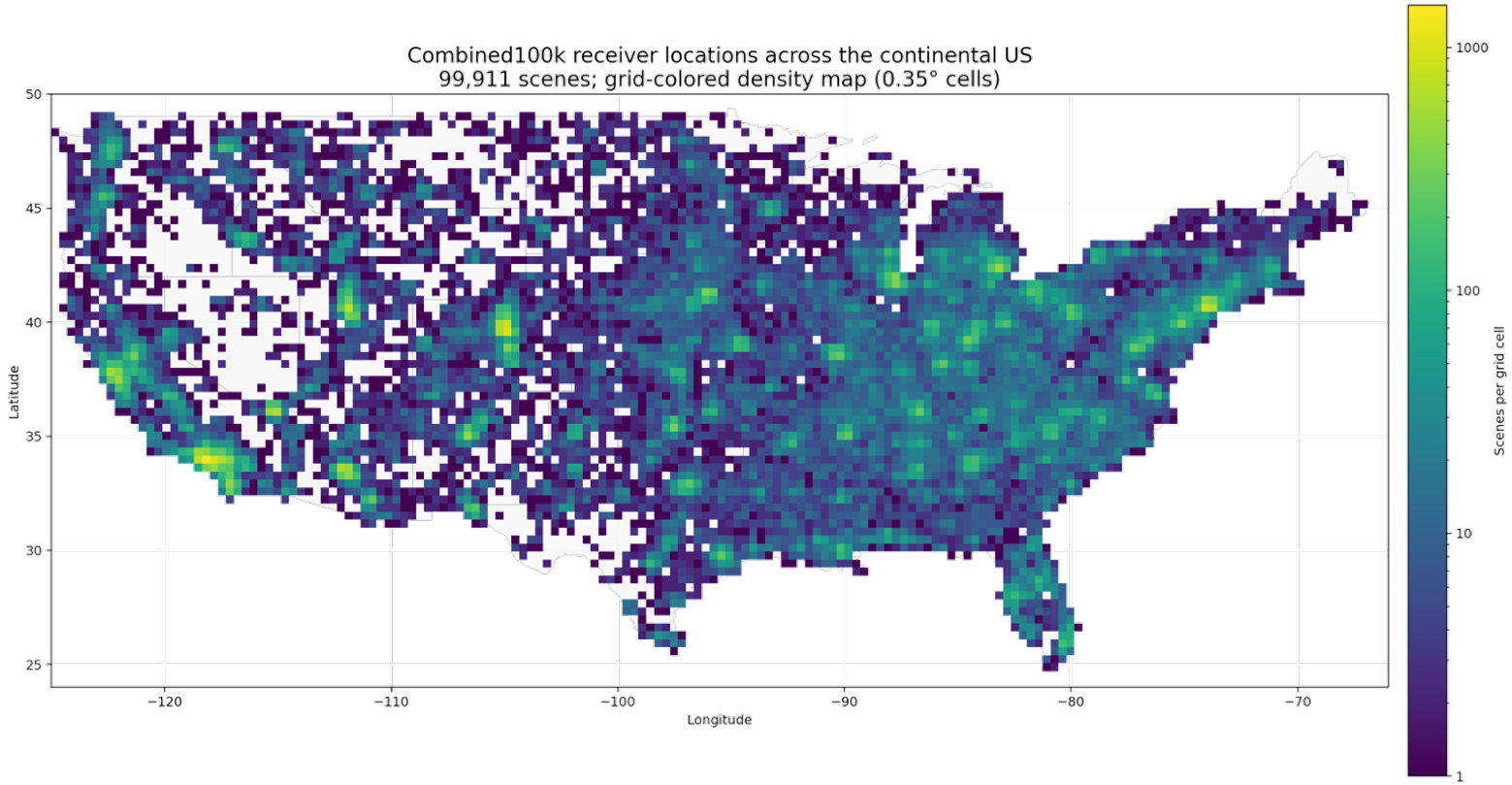




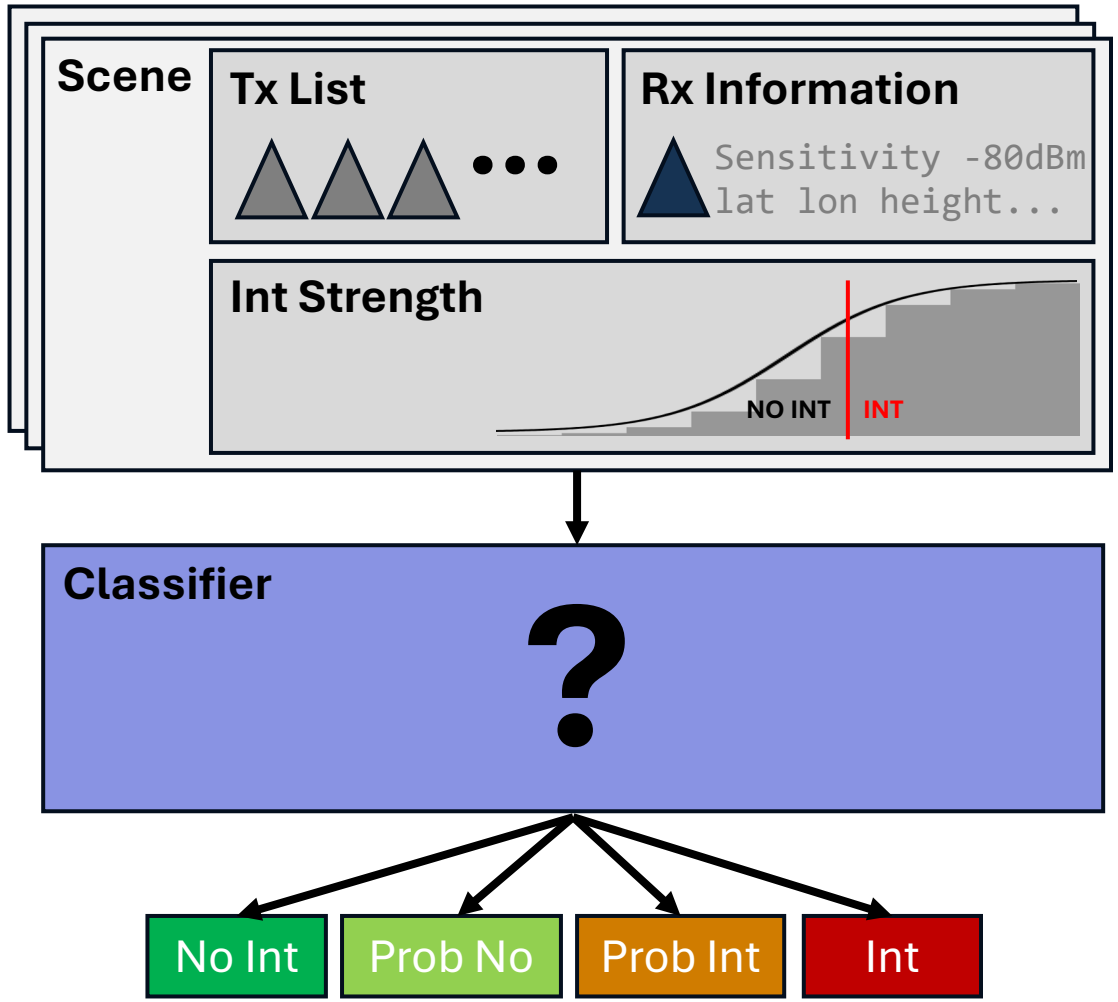
Dataset Result

- ~100k unique labeled scenes across the continental US
- 10s to 1000s of transmitters across rural and urban scenarios

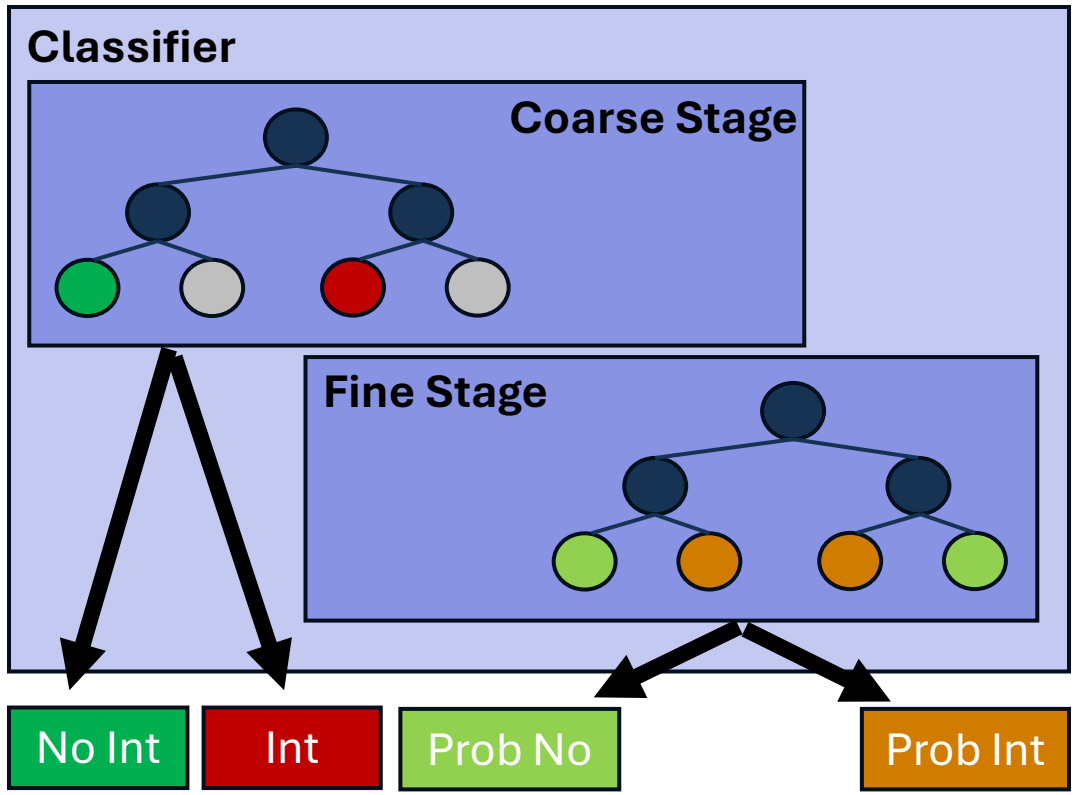


Model Concept

- Aggregate Receiver-Transmitter Interference Classifier (ARTIC)
- Train against the corpus of scenes and determine how well it predicts an interference class
- No Interference ↔ Interference



Classifier Architecture



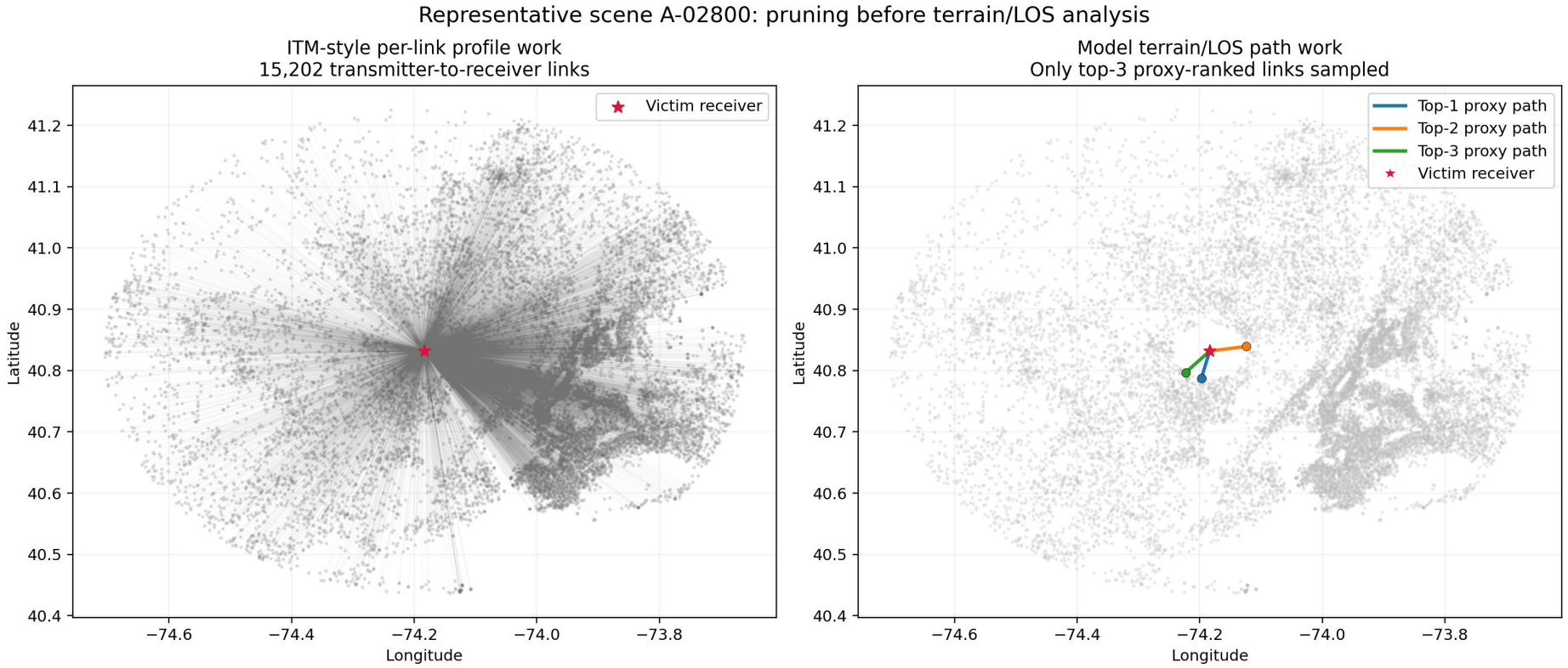
- Many architectures considered
- Strongest builds separate endpoint cases from close calls into multiple stages
- Main frontrunning technologies
  - gradient-boosted machines (GBMs)
  - graph neural networks (GNNs)

Feature Engineering

- This system operates at a scene level, not a link level
- Therefore, features can come from scene context or from meta-model behavior

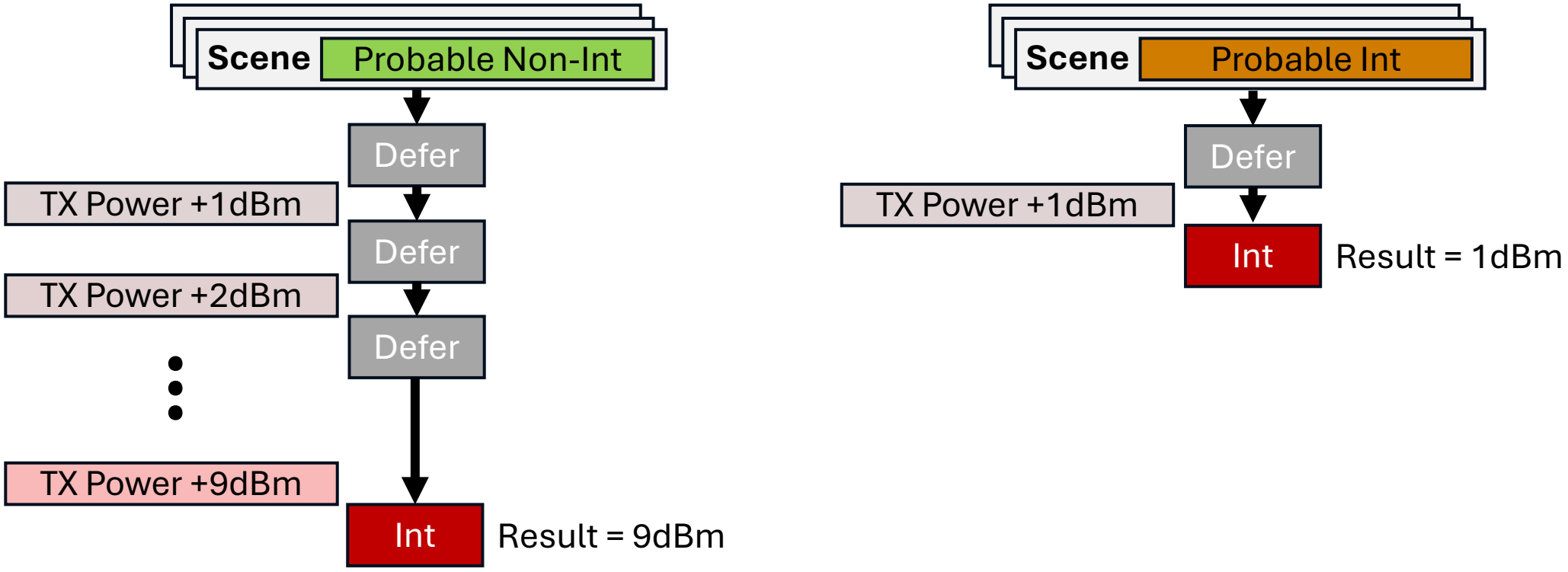
Feature Engineering

- Ex – only evaluate line-of-sight from top N links based on a free-space-like power function



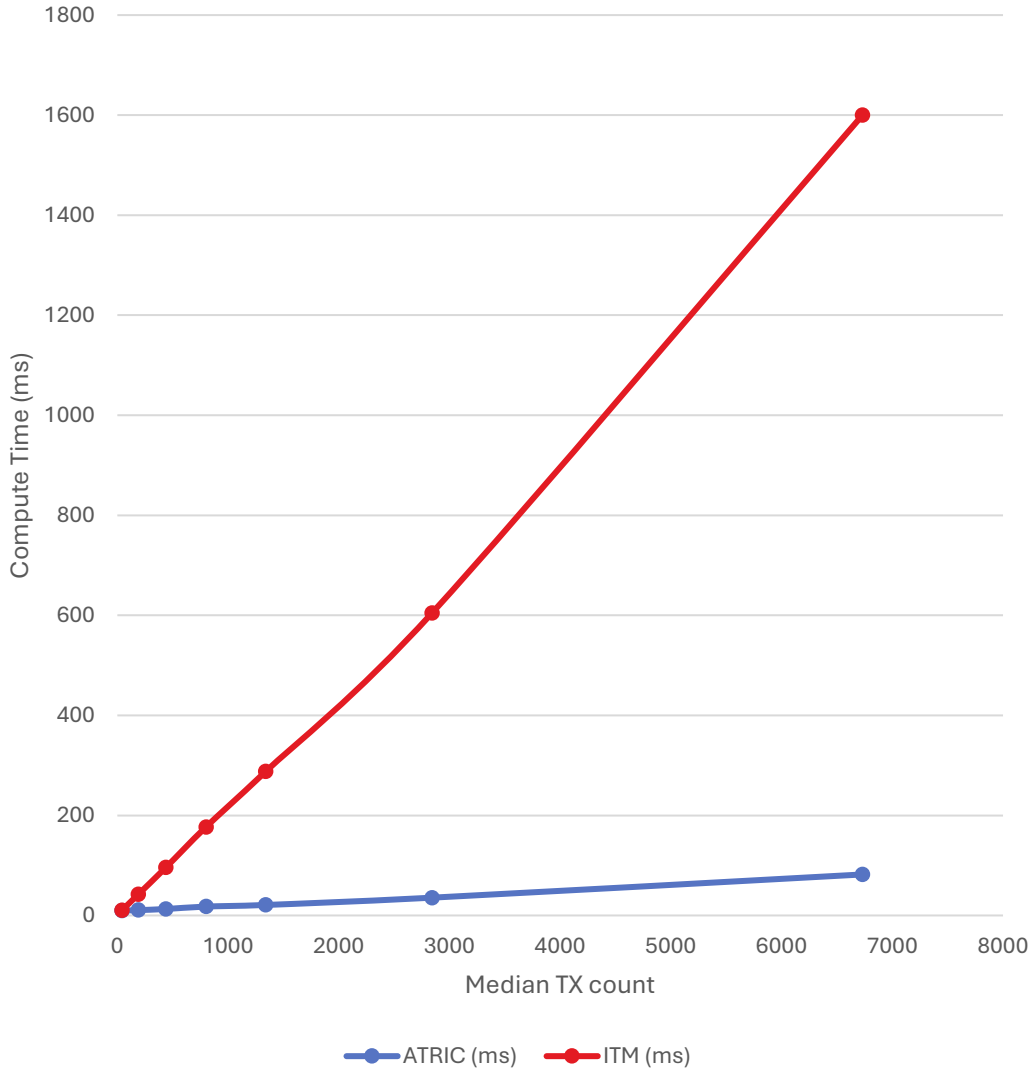
Feature Engineering

- Ex – informing fine sieve by varying coarse sieve TX power to see when it changes its prediction



Results - Speed

- Tested vs running ITM once against every link in a scene, both with cold cache
- ITM linearly adds about ~240µs each TX
- ARTIC optimizes as TX count increases
  - ~240µs/TX like ITM early on, ~10µs/TX at >5k TXs



Results - Accuracy

- ~81% accuracy vs ITM predictions using a 5,000-scene validation set
- ~86% accuracy allowing for near-correct predictions (e.g., Int ↔ Prob Int)
- ~2% catastrophic misprediction (Int ↔ No Int)
  - ~0.3% when limited to only high-confidence scenarios

n=5000	No Int	Prob No	Prob Int	Int (Pred)
No Int	**810**	139	29	**19**
Prob No	39	**791**	54	45
Prob Int	31	199	**258**	27
Int (Real)	**77**	247	63	**2172**
Precision	85%	57%	64%	96%
Recall	81%	85%	50%	85%

Strengths/Weaknesses

Core strengths

- **Functional** – proof-of-concept typically accurate
- **Fast** – soundly beats ITM when there's lots of TXs
- **Flexible** – can be retrained to different scenarios, and architectures can be mix and matched

Core weaknesses

- **Limited data** – synthetic, terrestrial-only, purely isotropic antennae, no near-band, purely proof-of-concept
- **Risky** – 2% catastrophic misprediction is too high for a real-world deployment

Next Steps

- Soon: data + software + paper release
- Future potential directions:
  - Feature analysis → what does this mean for ITM?
  - Feature performance/explainability
  - Incorporating features used in band studies/spectrum assignment
  - Temporal scenes (e.g., a transmitter on a schedule)
  - Validation against limited real-world datasets
  - …

Q&A

Thank you

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- Bradley Eales, beales@ntia.gov