Improvements to Near-Real-Time Rocket Detection Transfer Learning Model

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Introduction and Motivation

- Aggregate, curate, and annotate a dataset of rocket launch audio recordings from smartphones

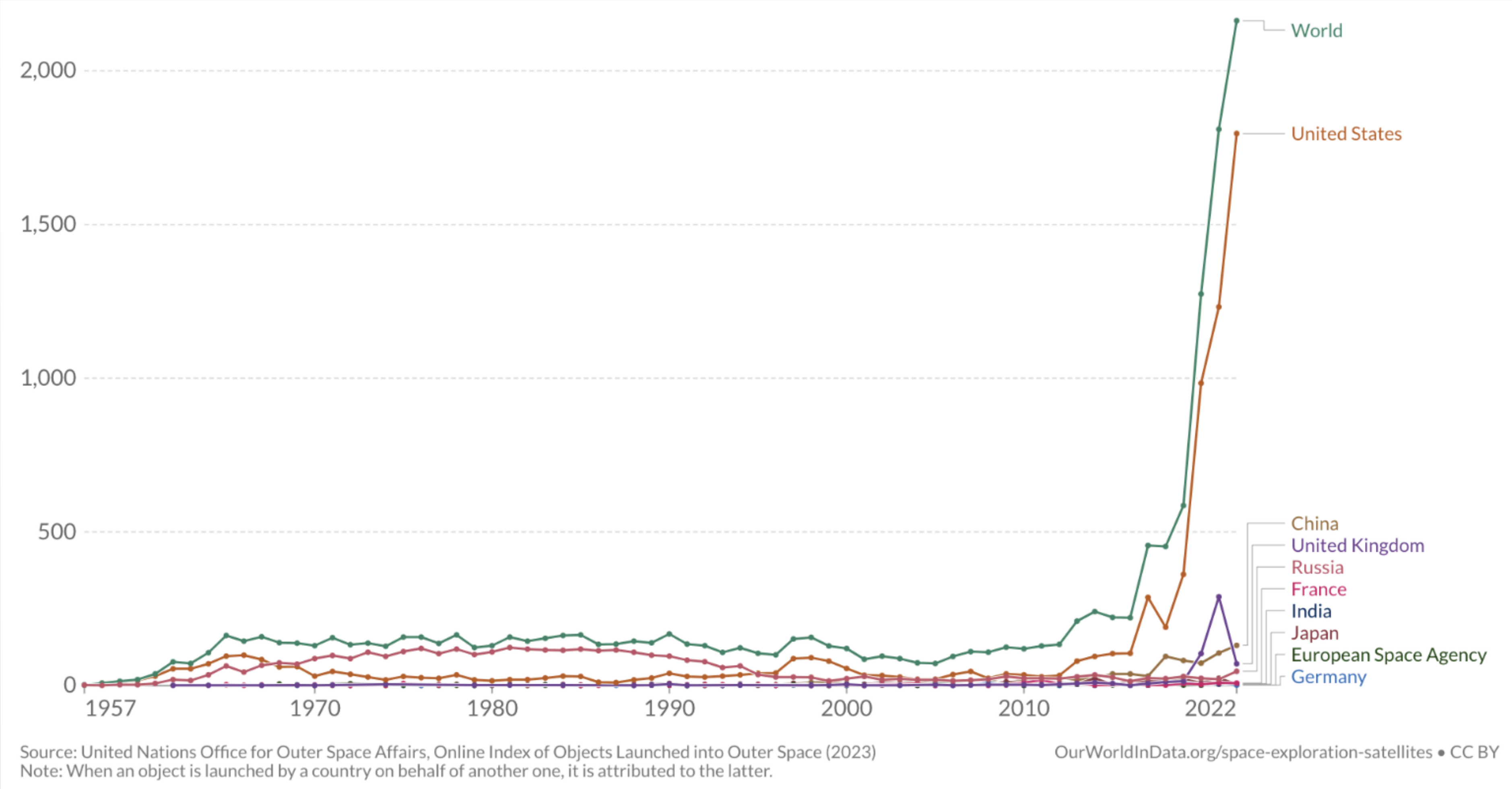
- Use the dataset to train machine learning models to detect rocket launch signatures in audio data and evaluate its performance

- End goal of reliable, accurate **near-real-time detection** of ignition and launch signatures on mobile platforms

- Since UPR 2023, we've been focusing on improving and automating alignment in the dataset due to the increasing resource cost of manual alignment checks as the dataset grows

Mission Relevance

- The ability to detect rocket launches quickly and accurately is valuable for monitoring and nonproliferation efforts
- Opportunity to collect data in much larger quantities than in the past due to increasing prevalence of launches



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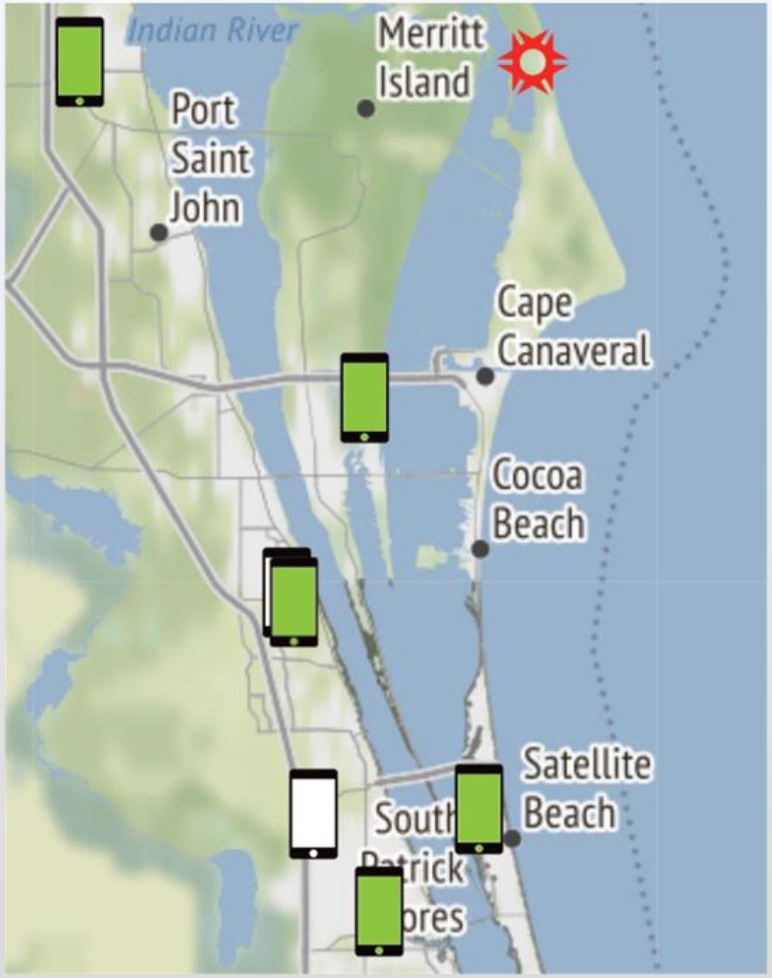
Data Collection

	2022 dataset	2024 dataset
Make of phones:	All Android	All Android
Sampling rate:	800Hz	800Hz
Number of launches:	66	**180**
Number of recordings:	212	**801**
Most common type of rocket:	SpaceX Falcon 9	SpaceX Falcon 9
Other rocket types:	ULA Atlas V, SpaceX Falcon Heavy	ULA Atlas V, SpaceX Falcon Heavy, SLS B1 (Artemis), Terran 1, ULA Delta Heavy



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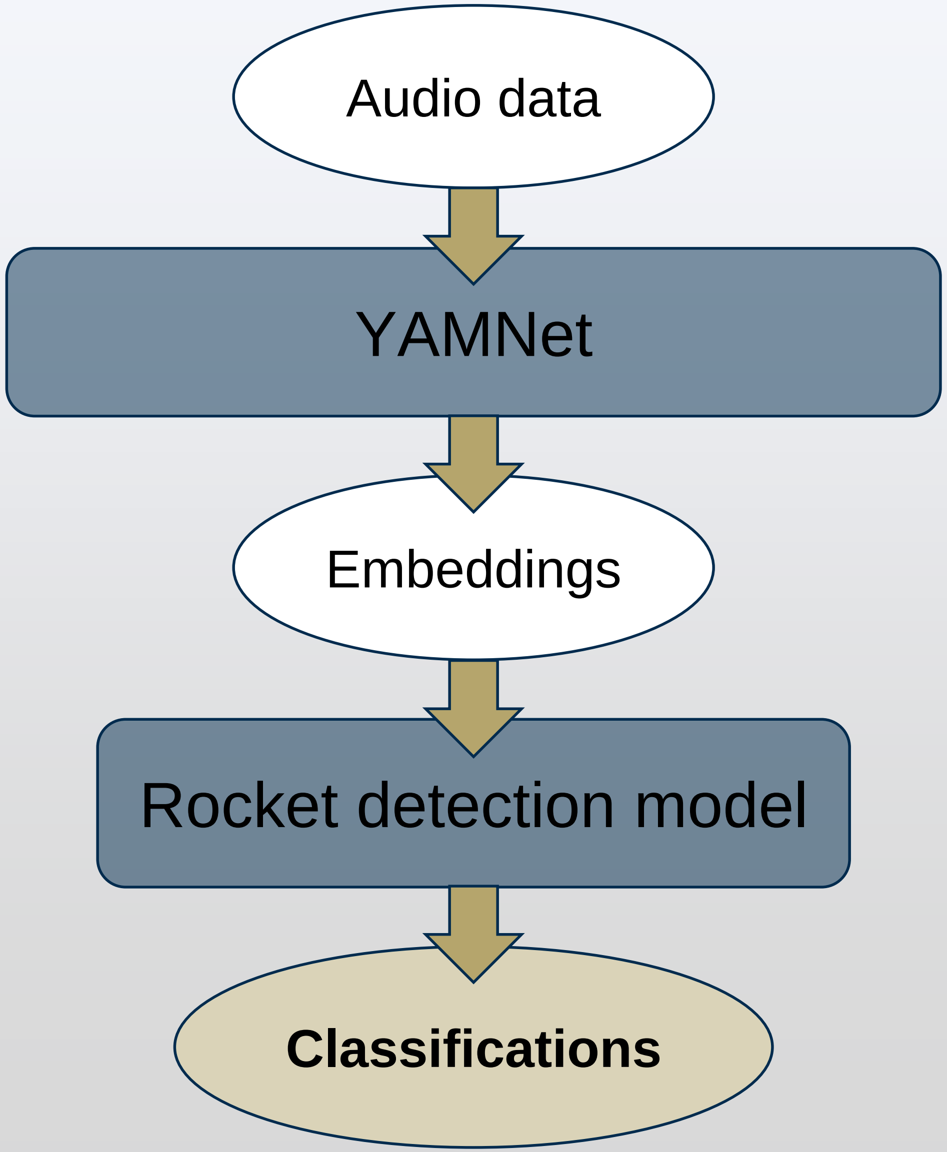
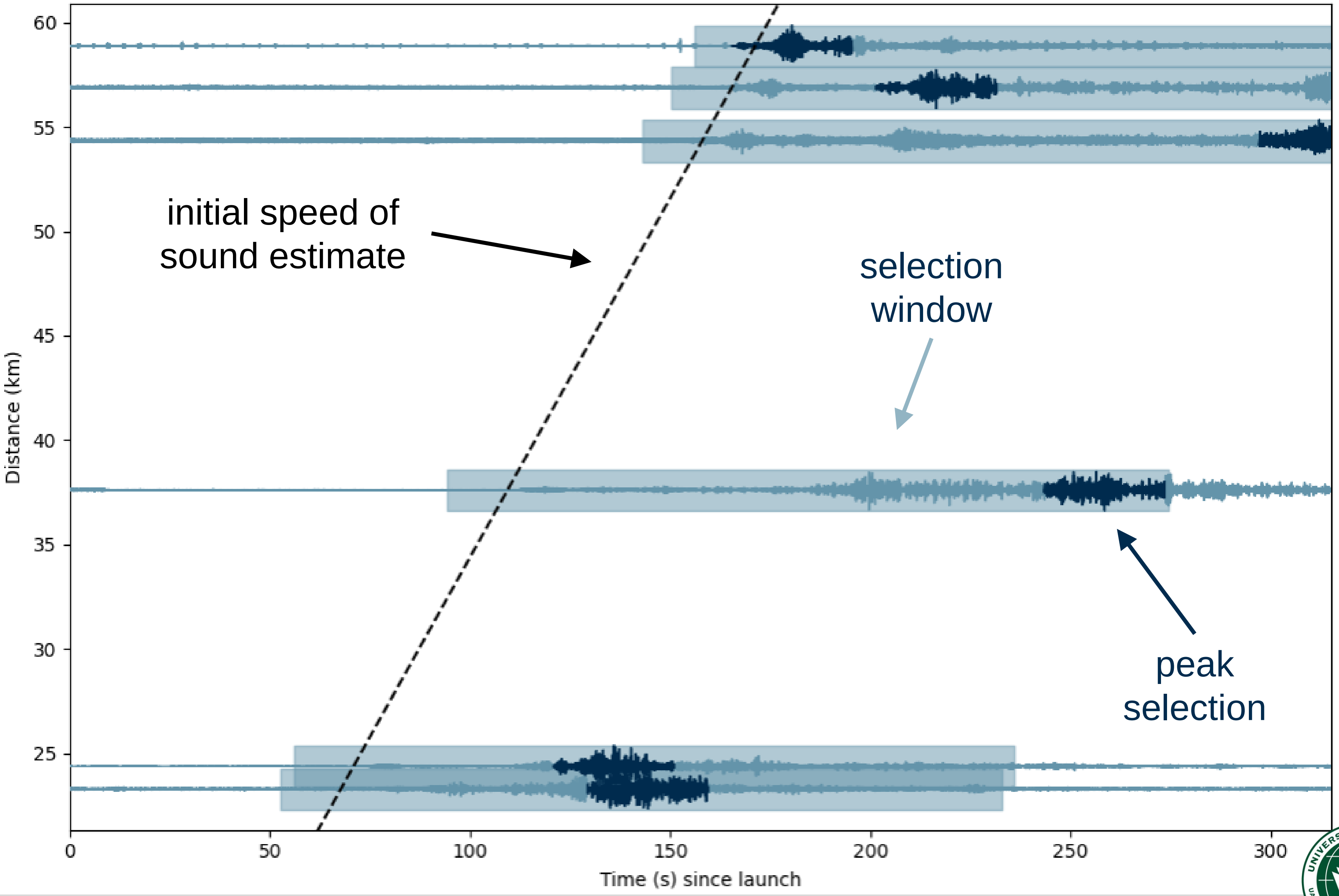
Transfer Learning with YAMNet

- Transfer learning uses the output of one model (**YAMNet**) as the input of another model (**rocket detection model**)
- YAMNet:
  - Deep neural network
  - Pre-trained for 521 classes of audio events
  - Classifies 16kHz audio in 0.96s increments
  - Outputs **embeddings**, which are then used by the rocket detection model to make **classifications**



Pre-2024 Alignment Process

- Estimate the earliest possible time of arrival, then peak select from the following 3 minutes
- **Problems:**
  - Reported launch time isn't always accurate
  - Results are sometimes unrealistic
  - Manual verification is necessary
- Varying peak selection method (cross-correlation, etc.) has minimal effects



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New Alignment Process

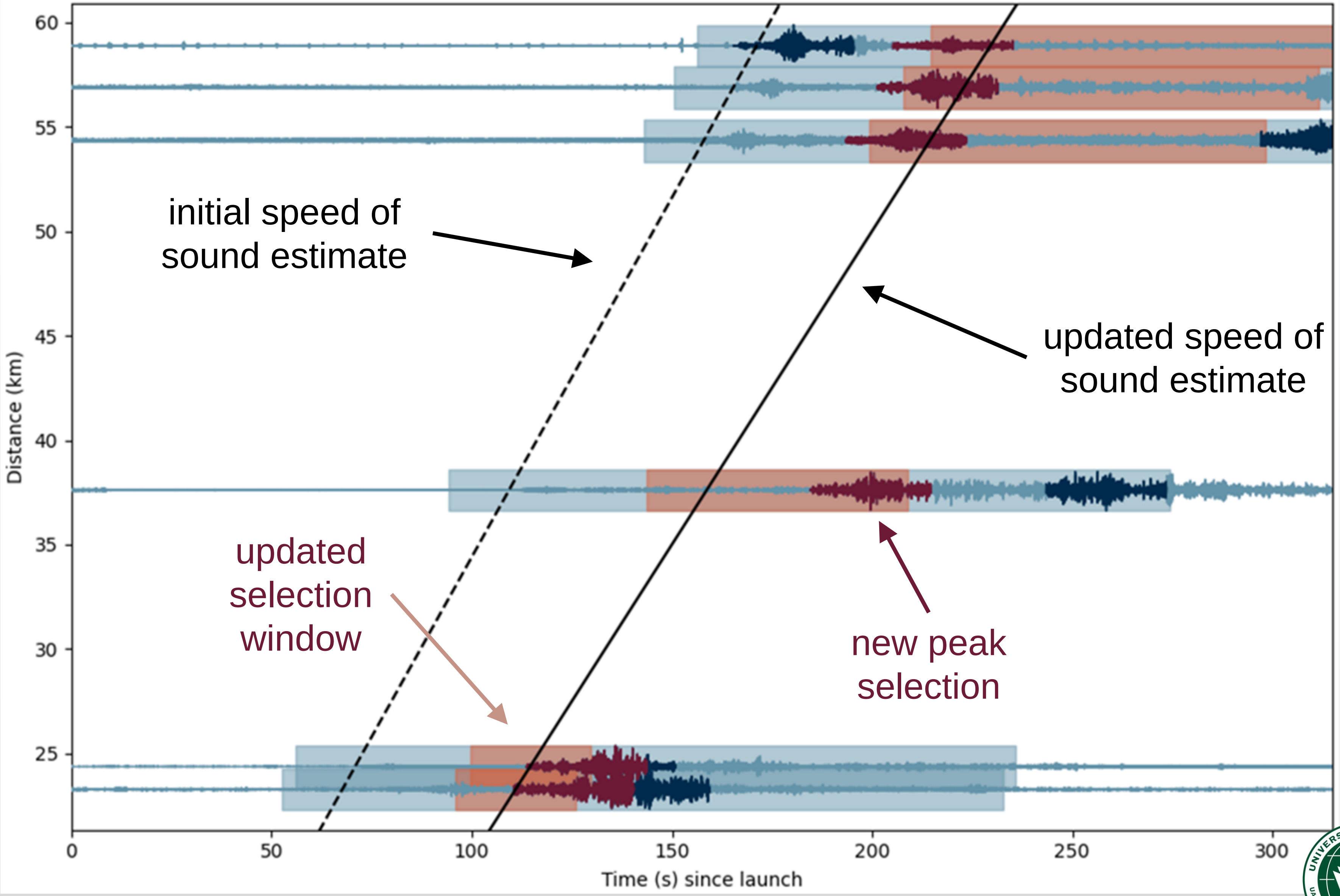
Pre-2024 alignment

Constrained linear fit (est. sound speed)

Update time of arrival estimates

Update selection windows

Select new peaks



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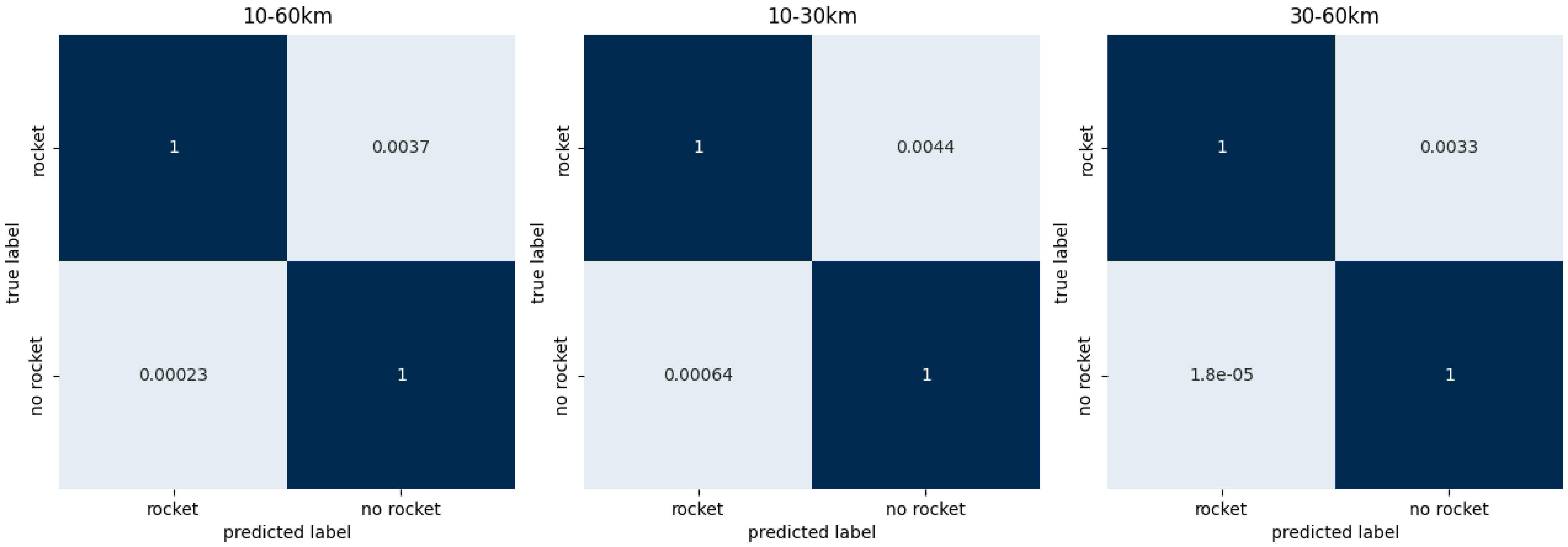
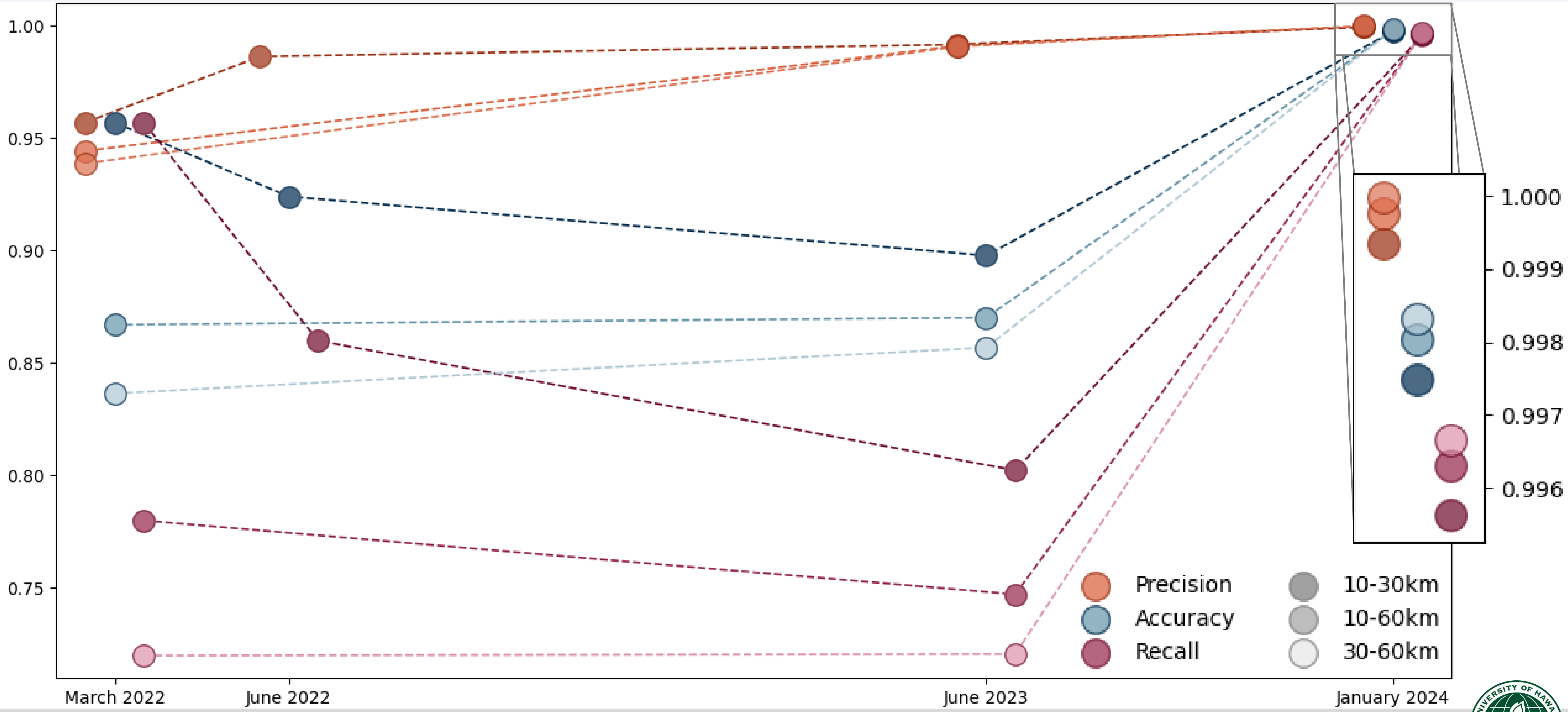
Results

Mean metrics over 25 random training set/test set splits

All data | Short-range data only | Long-range data only



Results



Mean metrics over 25 iterations: 99.80% accuracy, 99.98% precision, and 99.63% recall

Conclusion

- Issue with accuracy decreasing with distance appears to be entirely negated by improved alignment, supporting our hypothesis that many of the long-range samples were previously mislabeled

- The model's already very low false positive rate decreased even further, from **0.7% to 0.023%**

- The combination of the rapid growth of the dataset and the new alignment strategy significantly improved long-range detection, resulting in **a dramatic decrease in the overall false negative rate (25% → 0.37%)**

- **99.63% mean true positive rate over 25 iterations**

Next Steps & ETI Impact

- Near future:
  - Continued collection, aggregation, and curation of the dataset
  - Training against other infrasound signals using data collected in collaboration with INL and NNSS
  - Deployment of updated model on phones near Cape Canaveral
- Further out:
  - Narrowing in on the ignition signature
  - Investigating feasibility of trajectory modeling, rocket type classification, etc.
- ETI Impact:
  - Continued collaboration with LANL on propagation modeling
  - Internship with INL last summer

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