Distributed MCM Simulation with MOOS-IvP

David Battle
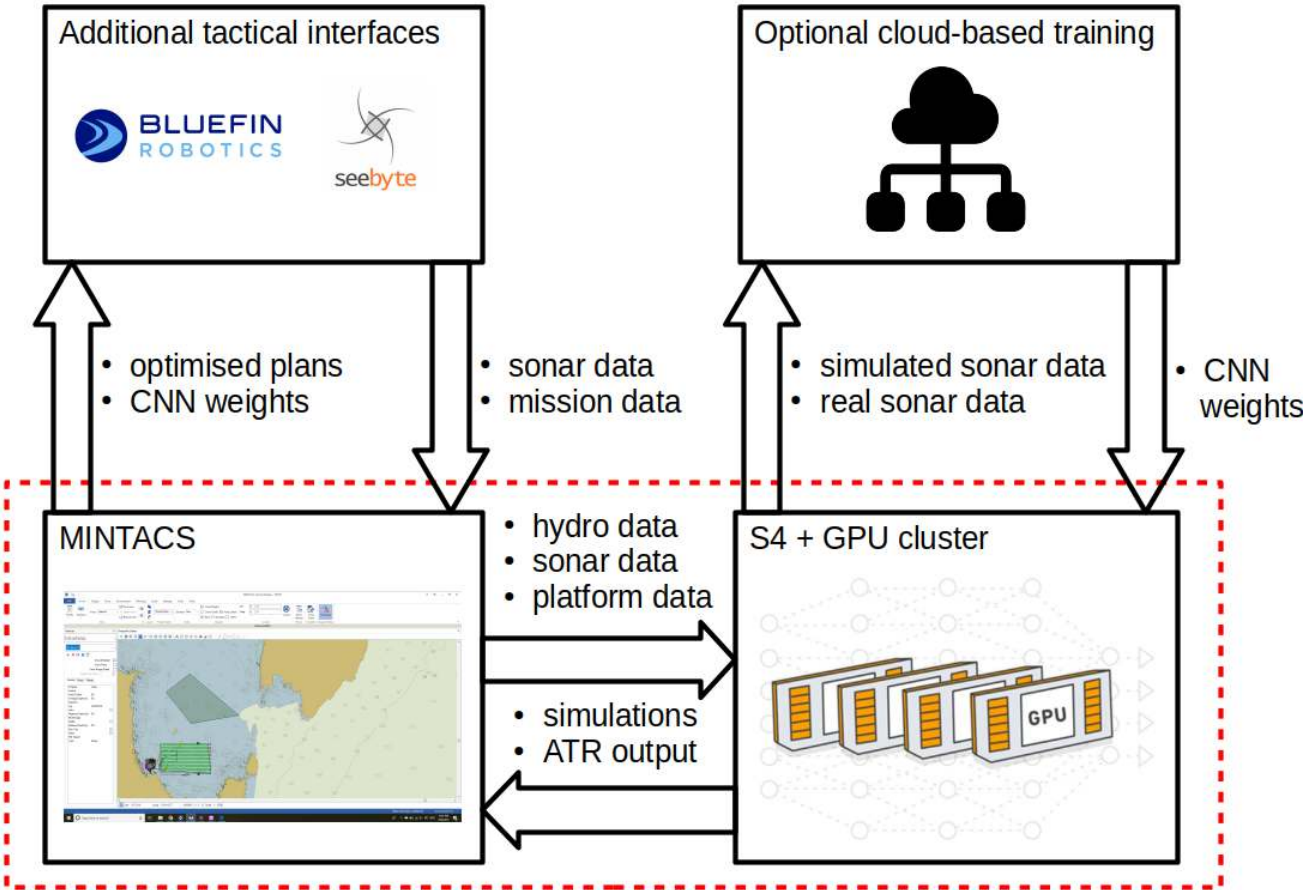
(david.battle@missionsystems.com.au)

10th Aug 2022

What is S4?

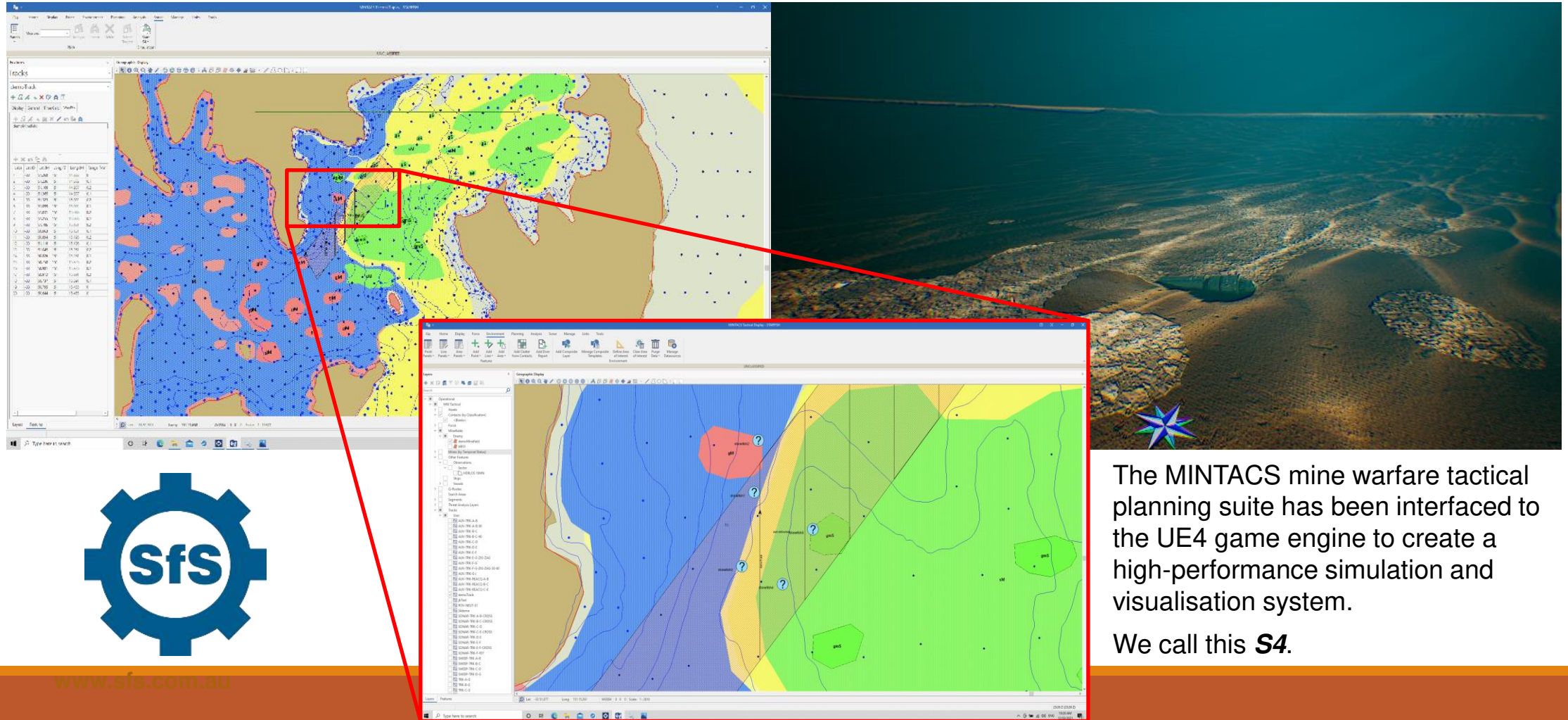*S4* is a simulation system tailored to the requirements of autonomous mine countermeasures.

Introduction

MINTACS user interface
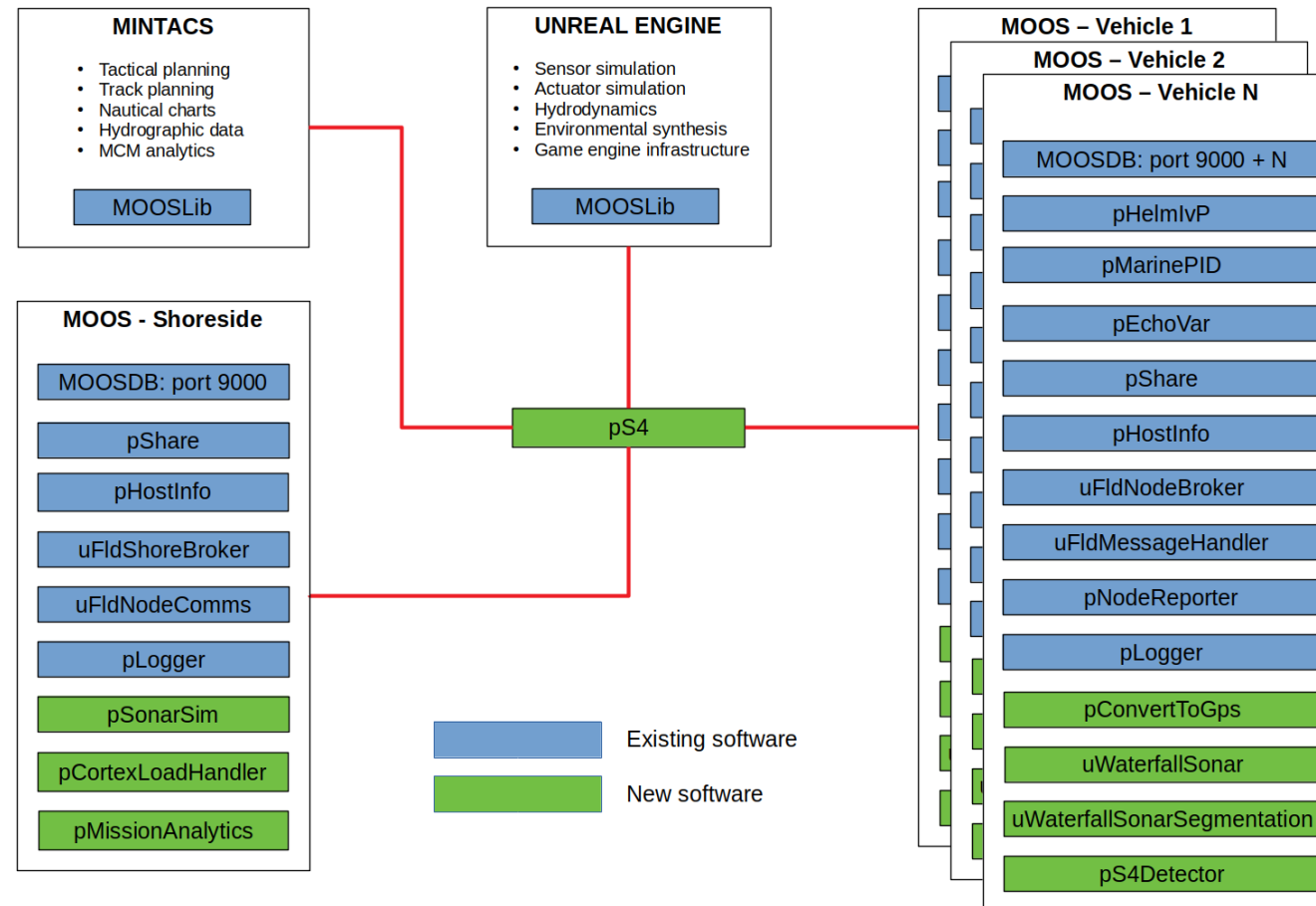
Constructs a synthetic environment within UE4

The MINTACS mine warfare tactical planning suite has been interfaced to the UE4 game engine to create a high-performance simulation and visualisation system.
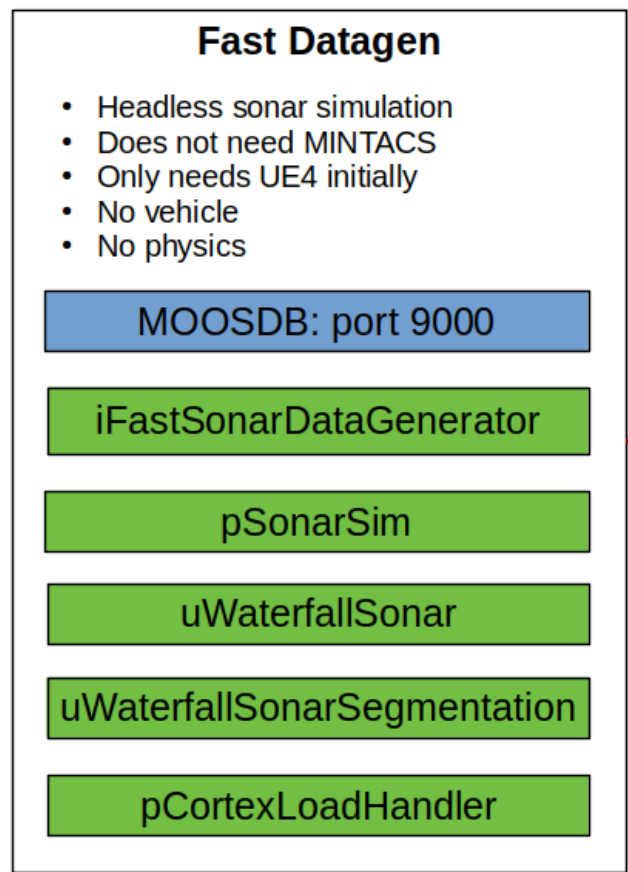
We call this **S4**.
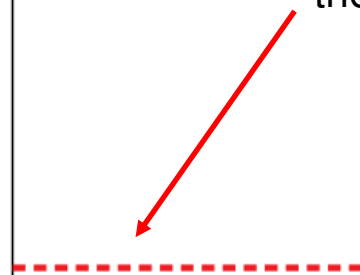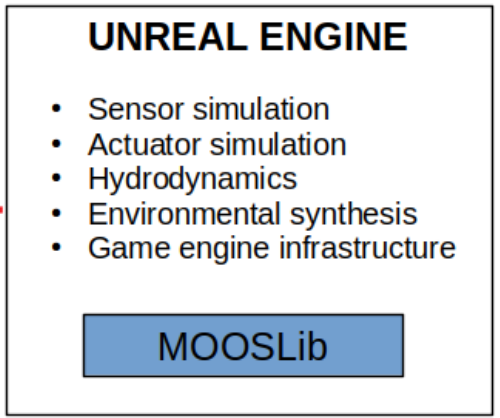
S4 Simulator architecture
Full prototype

MINTACS
- Tactical planning
- Track planning
- Nautical charts
- Hydrographic data
- MCM analytics

MOOSLib

UNREAL ENGINE
- Sensor simulation
- Actuator simulation
- Hydrodynamics
- Environmental synthesis
- Game engine infrastructure

MOOSLib

MOOS - Shoreside

MOOSDB: port 9000

pShare

pHostInfo

uFldShoreBroker

uFldNodeComms

pLogger

pSonarSim

pCortexLoadHandler

pMissionAnalytics

pS4

MOOS – Vehicle 1
MOOS – Vehicle 2
MOOS – Vehicle N

MOOSDB: port 9000 + N

pHelmIvP

pMarinePID

pEchoVar

pShare

pHostInfo

uFldNodeBroker

uFldMessageHandler

pNodeReporter

pLogger

pConvertToGps

uWaterfallSonar

uWaterfallSonarSegmentation

pS4Detector

Existing software

New software

S4 Simulator architecture
Fast-data generation subset

Fast Datagen

- Headless sonar simulation
- Does not need MINTACS
- Only needs UE4 initially
- No vehicle
- No physics

MOOSDB: port 9000

iFastSonarDataGenerator

pSonarSim

uWaterfallSonar

uWaterfallSonarSegmentation

pCortexLoadHandler

UE4 only required to initialise the environment and can run headless or be shutdown thereafter.

UNREAL ENGINE

- Sensor simulation
- Actuator simulation
- Hydrodynamics
- Environmental synthesis
- Game engine infrastructure

MOOSLib

Mission Time: 03:01
Warp: 1.00
Robot: 0
Speed: 1.50m/s
Altitude: 2.91m
Depth: 8.83m
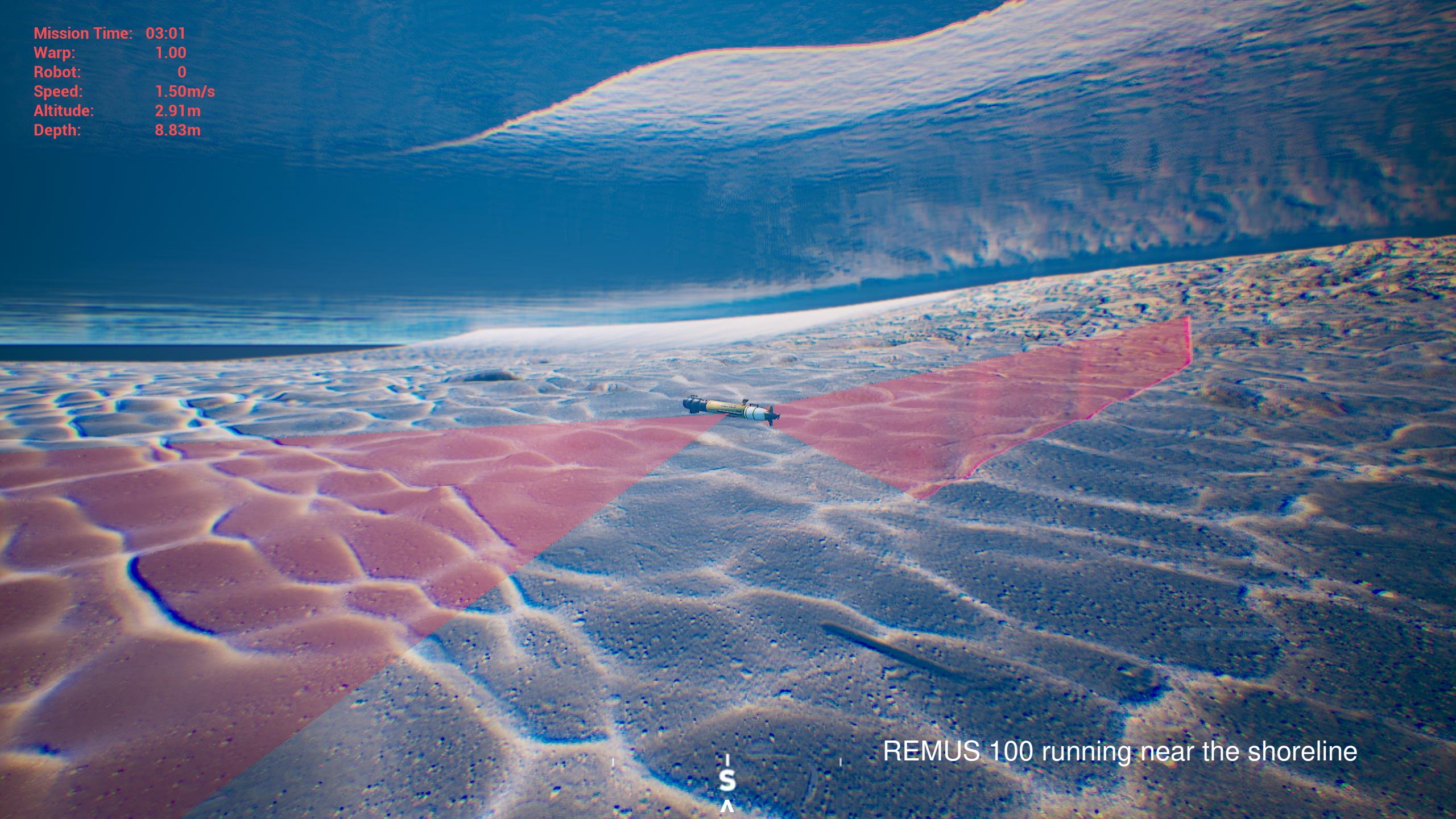
REMUS 100 running near the shoreline

Mission Time: 01:42
Warp: 2.00
Robot: 0
Speed: 1.51m/s
Altitude: 7.57m
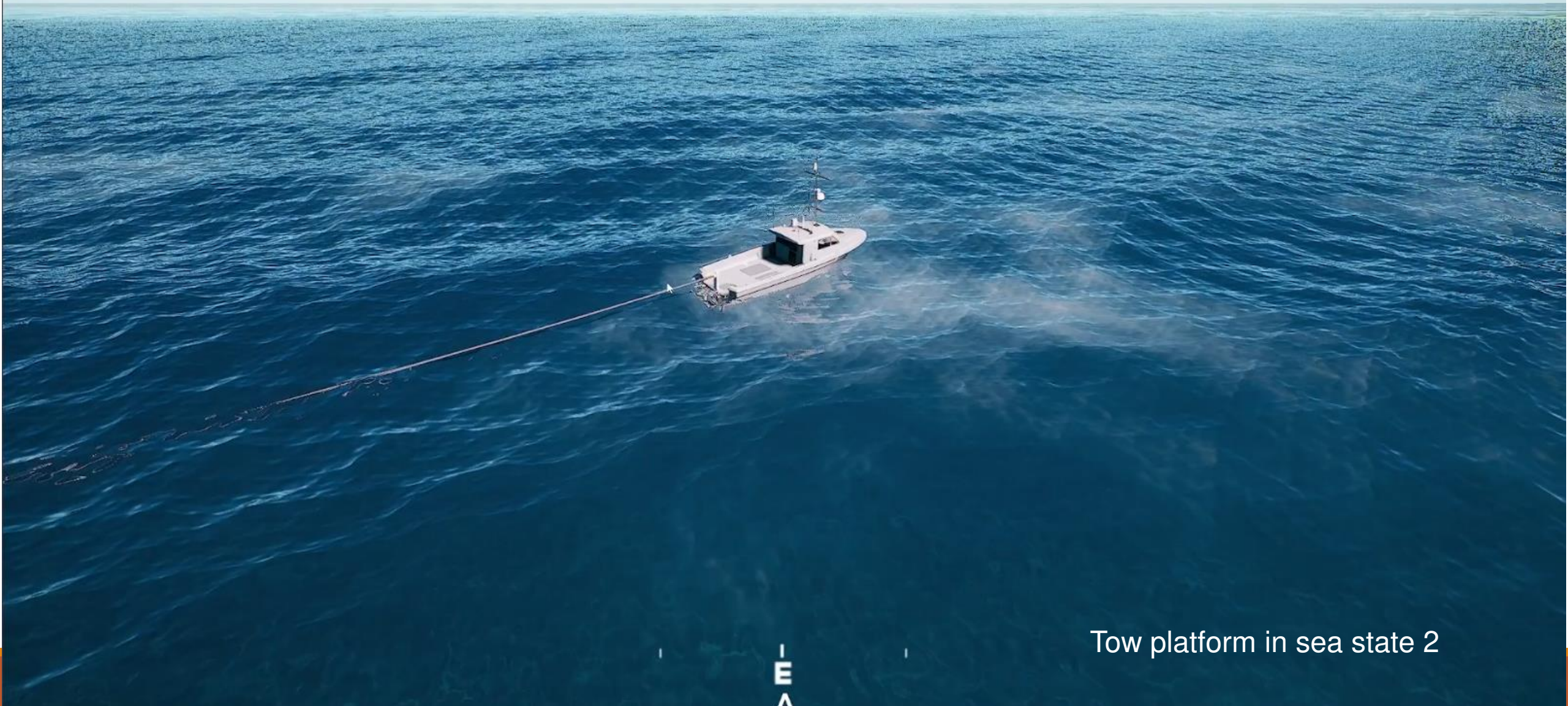Depth: 20.41m
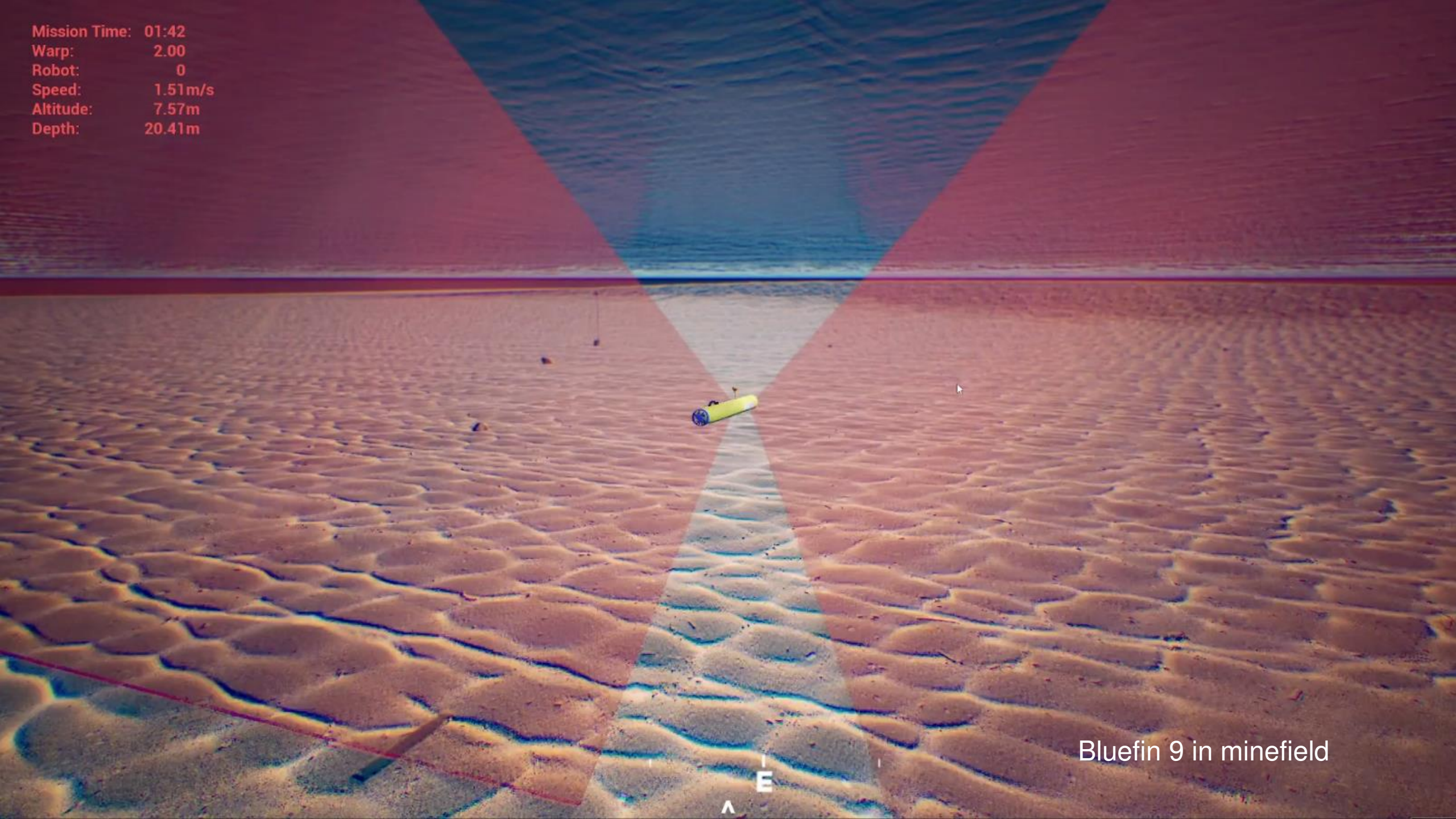
Bluefin 9 in minefield

Mission Time: 07:49
Warp: 1.00
Robot: 0
Speed: 3.88m/s
Altitude: 7.77m
Depth: 7.40m

SE

AQS-24 towbody during a turn

Mission Time: 00:44
Warp: 1.00
Robot: 0
Speed: 6.94m/s
Altitude: 7.71m
Depth: 7.42m

Tow platform in sea state 2

S4 Prototype:
Modes and use cases

Use cases

1. Automatic Target Recognition (ATR) Training
2. Operational Mission Planning
3. Operational Mission Analytics
4. Mine Warfare Personnel Training

These have now been broken down into four distinct modes of simulation:

- **Mission-Mode** (previously *time-warp*), in which platform dynamics are applied in an accelerated manner along a specific mission-track in a selected region of interest.

- **REA-Mode** experimental mode in which region of interest is evaluated for the detectability of specific mine threats using a specific sonar.

- **RMA-Mode** Another experimental mode in which a particular vehicle track is evaluated for the detectability of specific mine threats in a specific environment.

- **FastDataGen-Mode** (previously *ludicrous-mode*), in which a disembodied sonar teleports around without vehicle dynamics to generate synthetic data for ATR training

Headline use case:
Data generation for synthetic ATR training
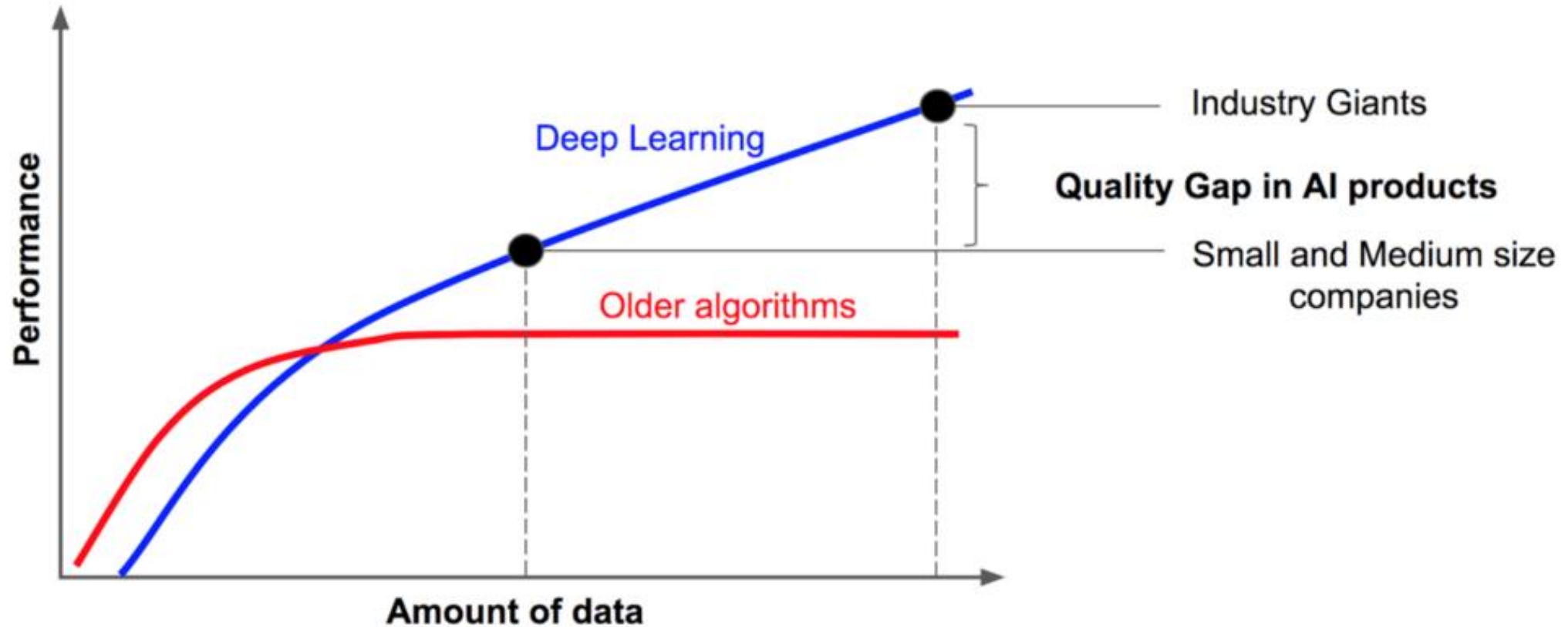
Target simulation

S4 can produce infinite amounts of synthetic sonar data!
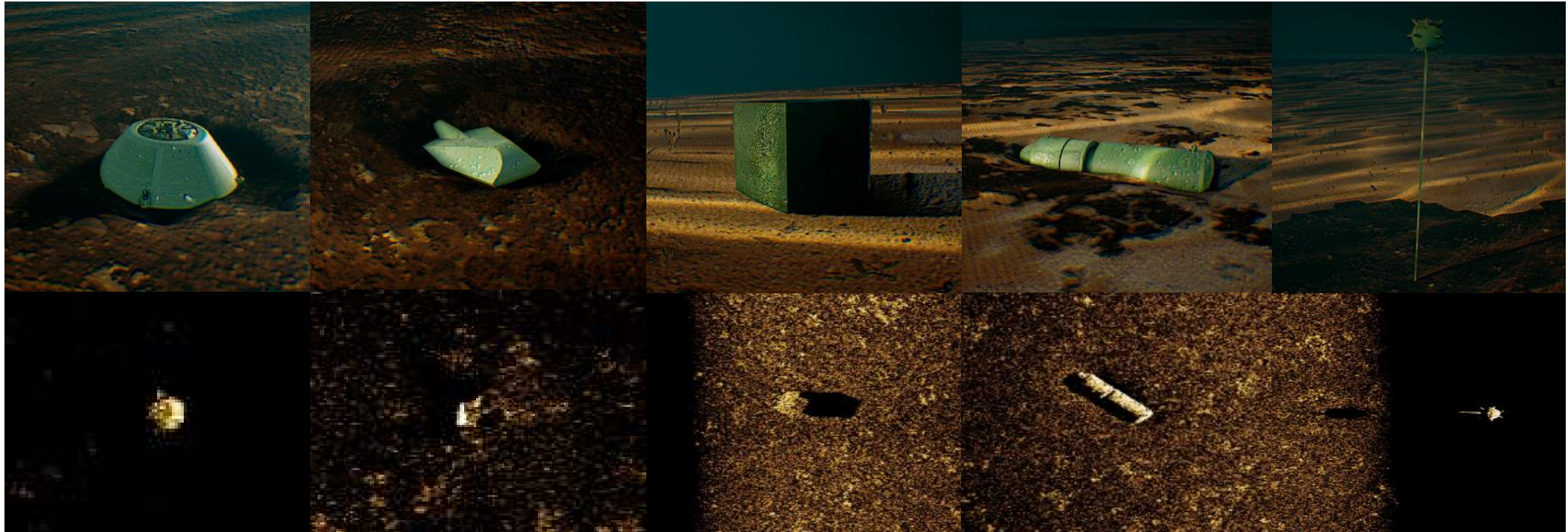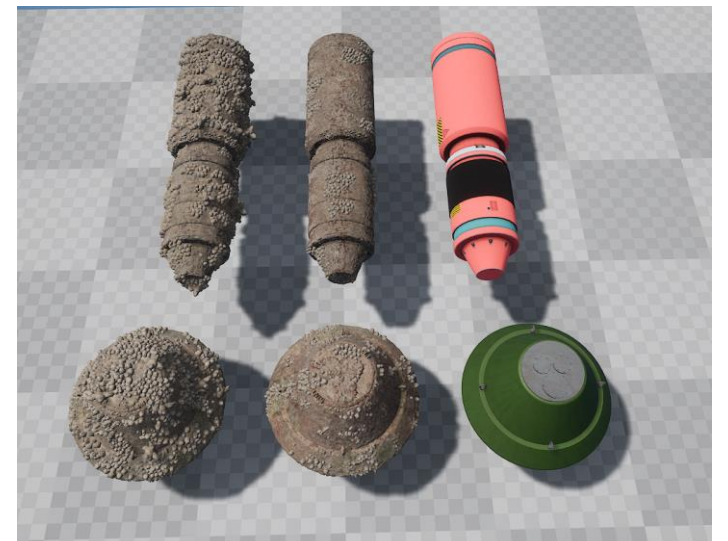

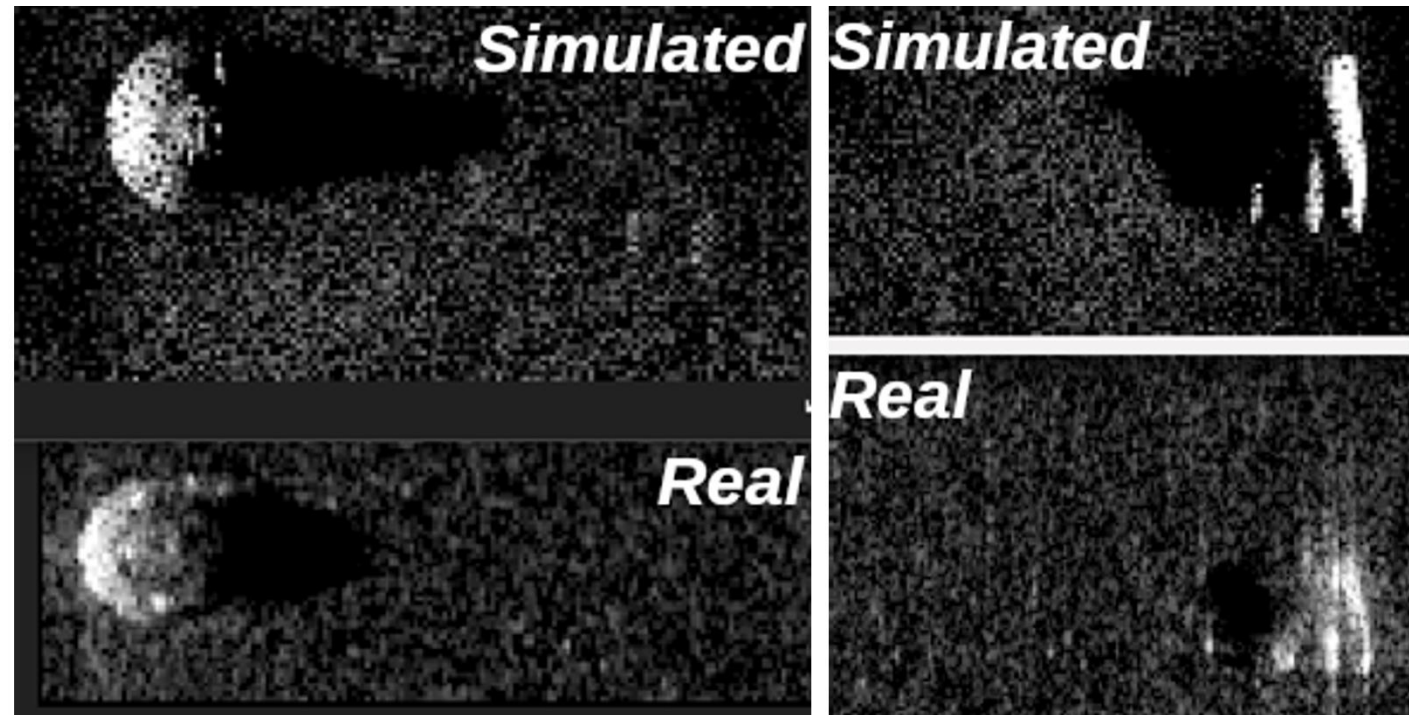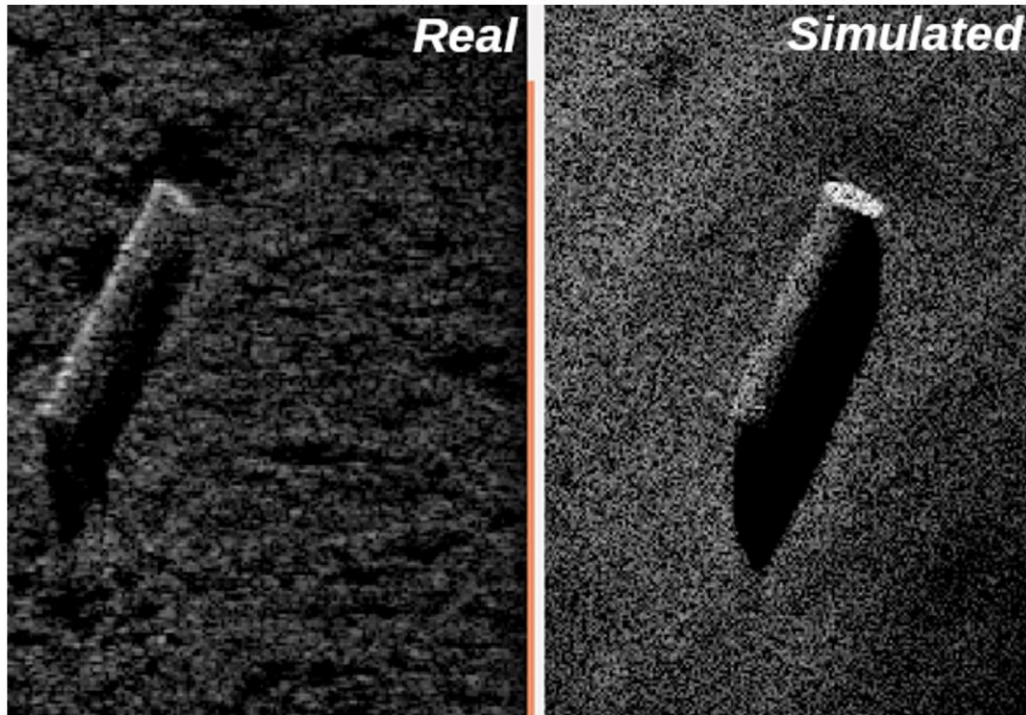| Manta mine | Rockan mine | IHO cube | Stonefish mine | Buoyant mine |

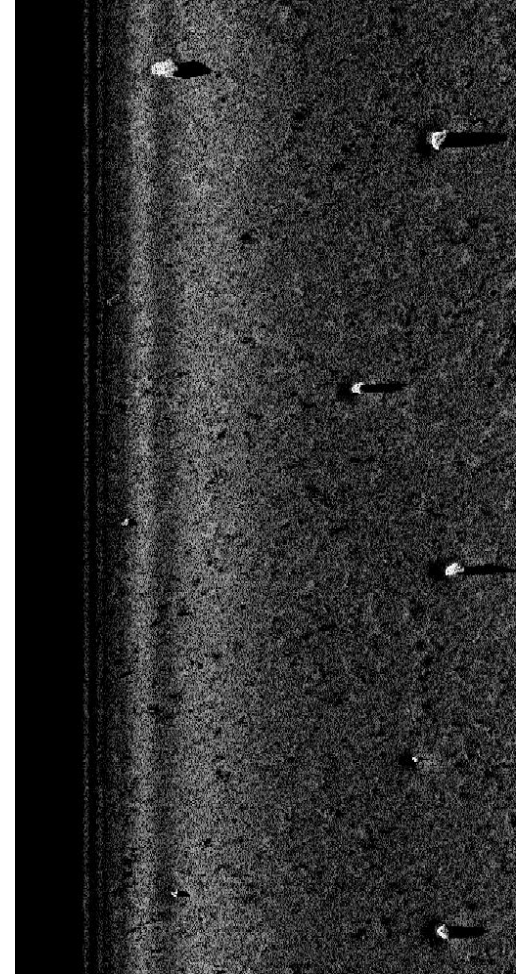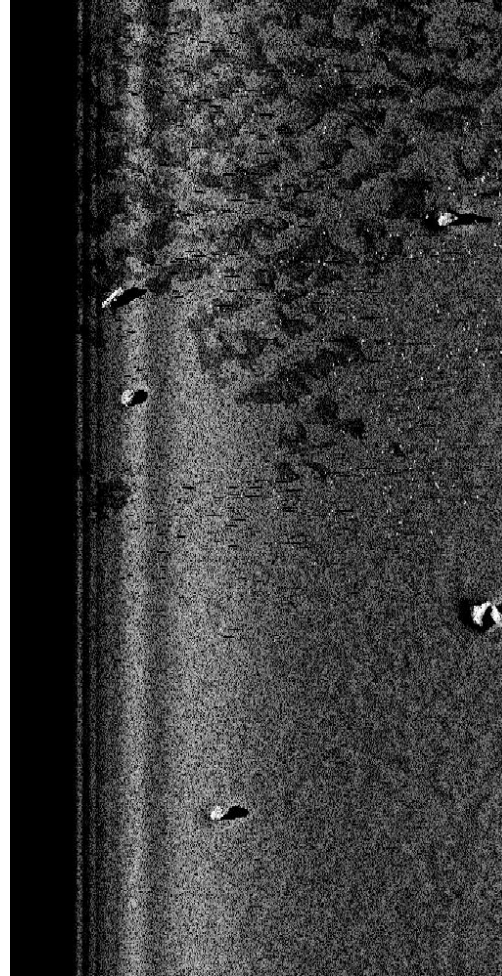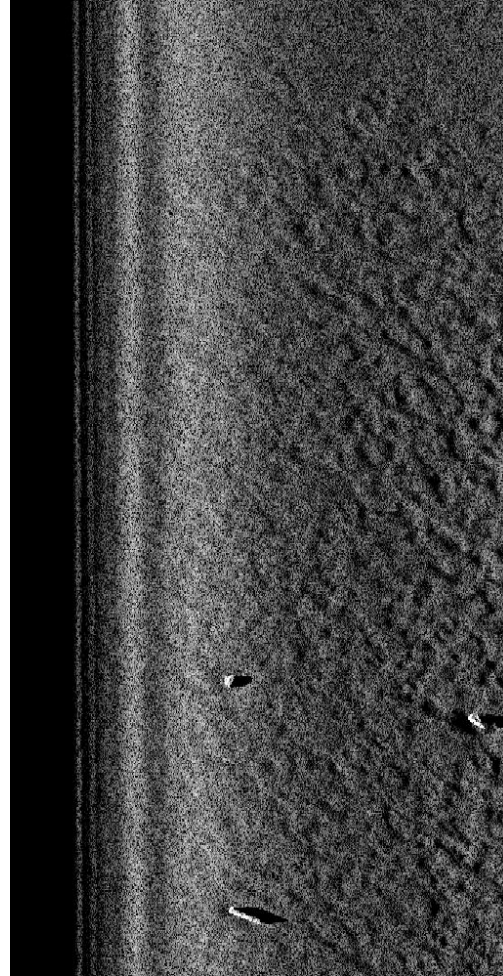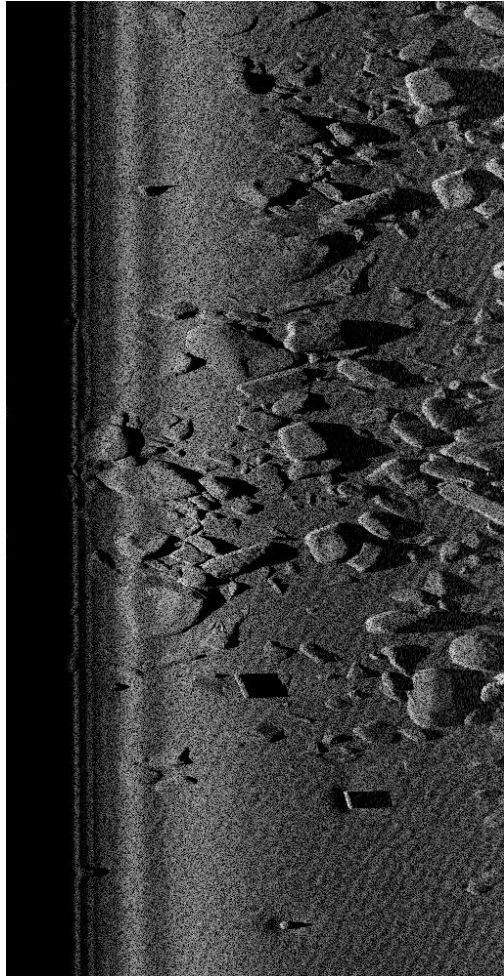# Target simulation cont'd
Mine burial and accretion simulation

Target simulation cont'd
Real vs synthesized data

Synthetic sonar data
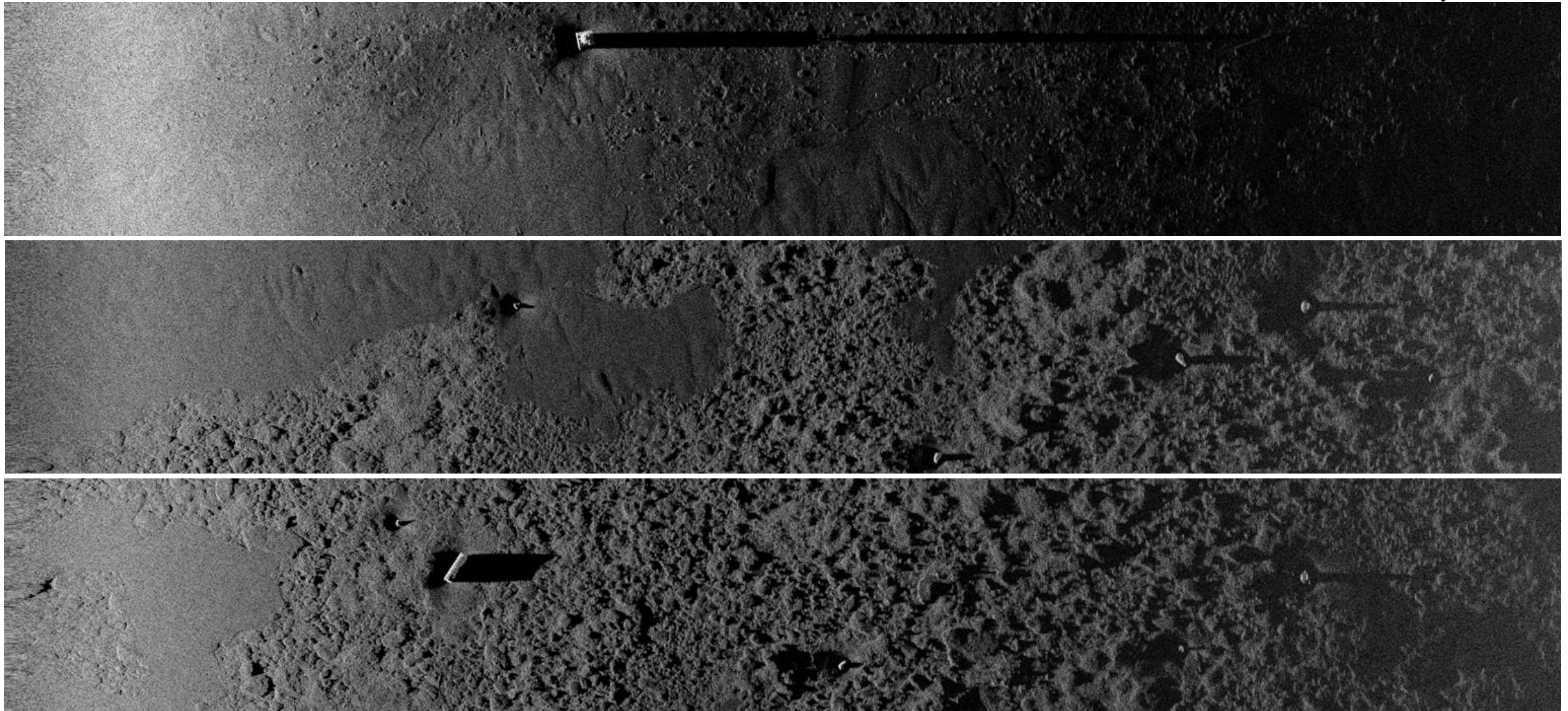*(Marine Sonics 900 kHz – one side)*

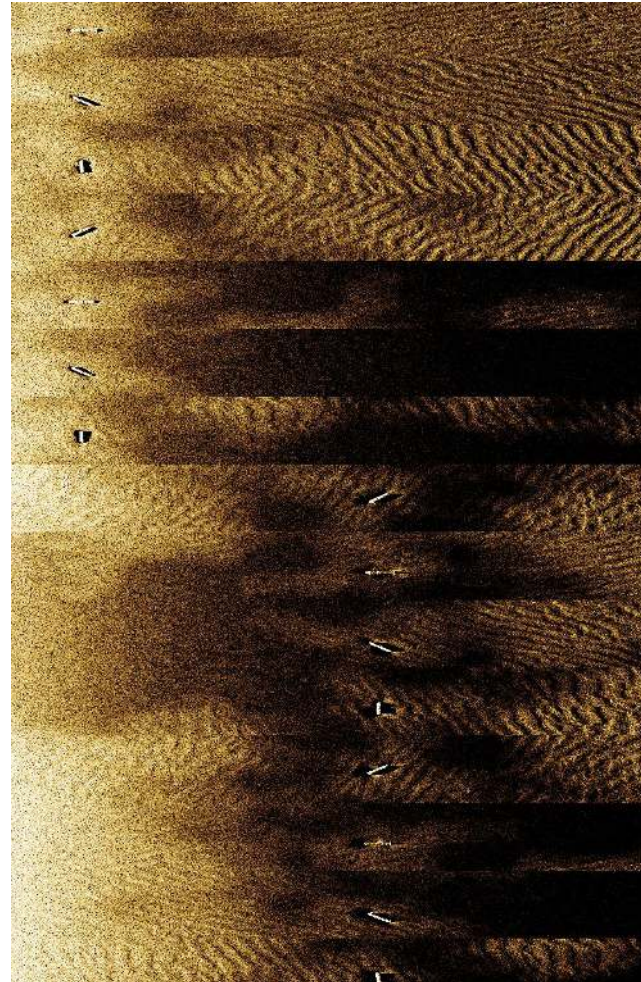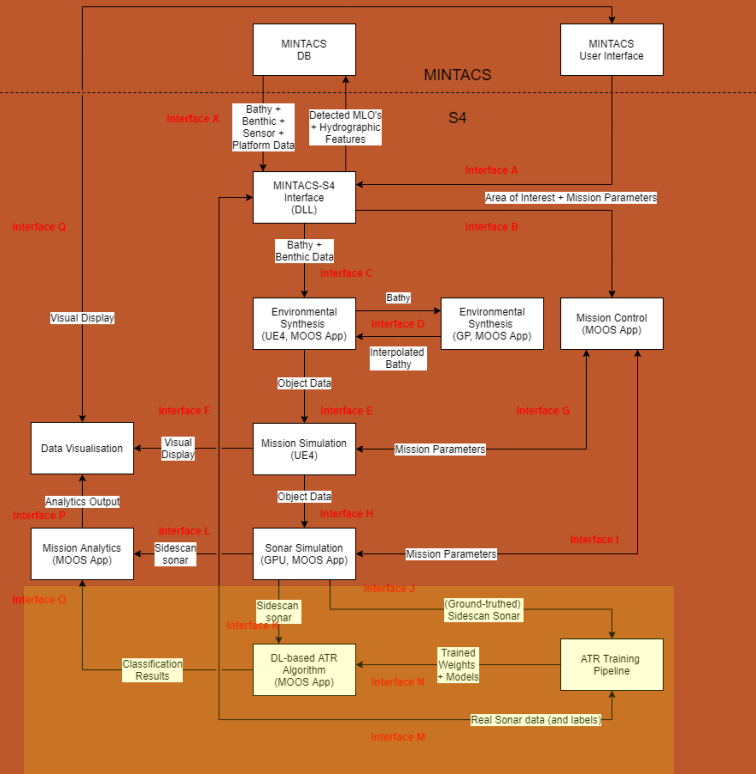# Synthetic sonar data
(Sonardyne SOLSTICE 750 kHz – one side)

Headline Achievements:

ATR Training Pipeline

Fast data generation
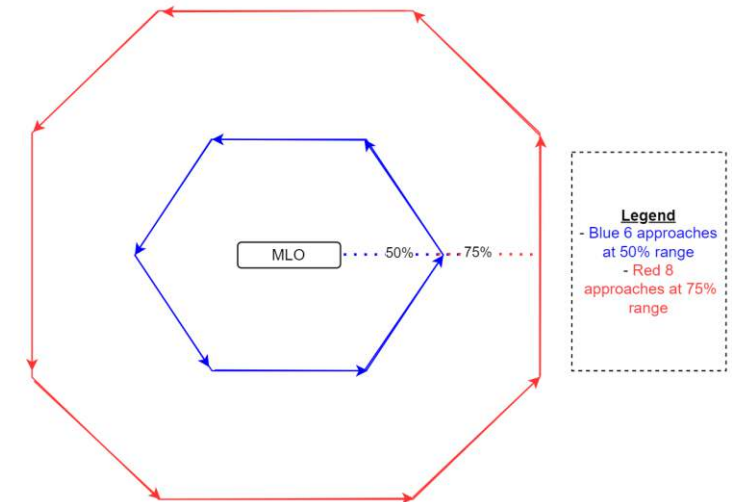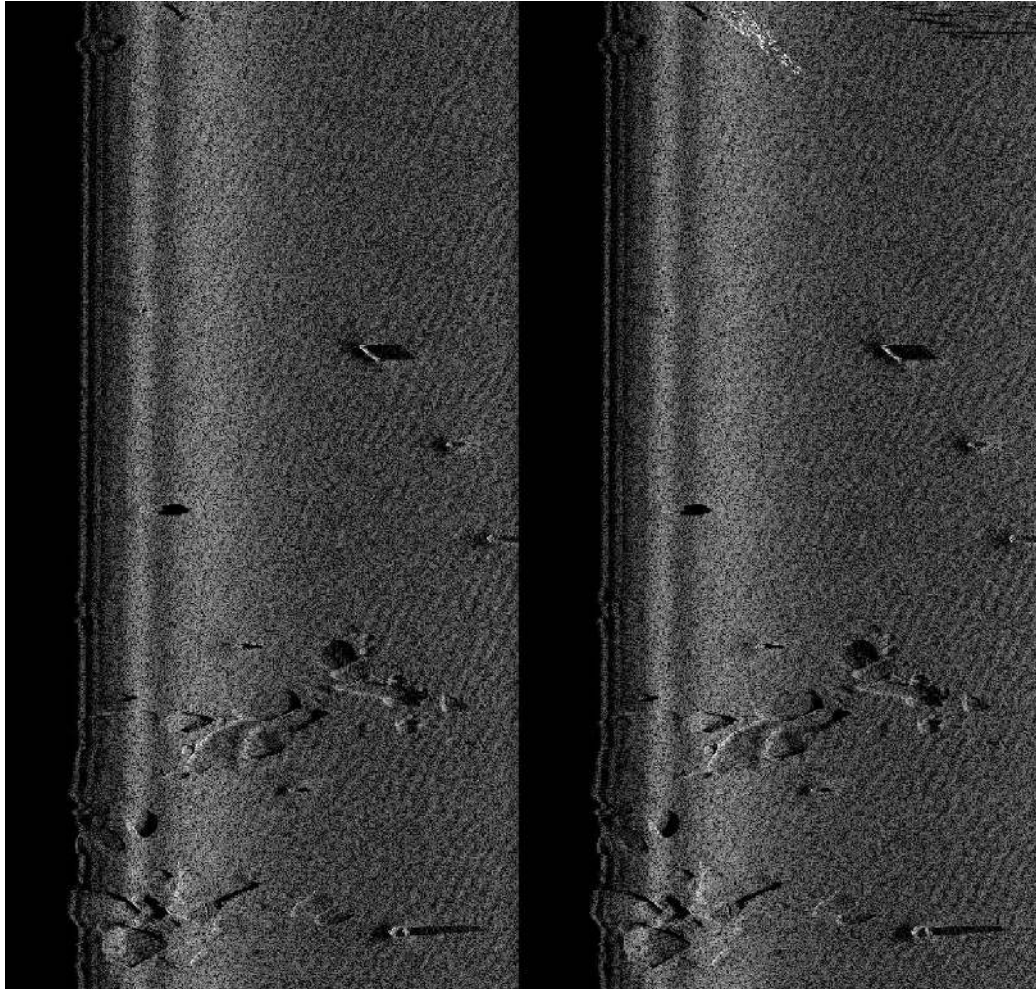*The ATR training workhorse*

- Place any mine type on any sediment

- Add any clutter from the real world

- Create any approach vector desired

- Generate 10,000+ mine images over night (on a single 3090 GPU)

- Operates independently of MINTACS

ATR Training Pipeline
Adding synthetic clutter to reduce false alarms

- The central thesis of this project was that optimal ATR detection performance requires training in virtual environments with statistics as similar to reality as possible.

- As a corollary, the addition of clutter objects to the training data which are rejected as targets should then reduce the false alarm rate.

- In trials to date, we have seen false alarms drop from over 300 in real mission data to under 100 simply by adding schools of fish into the simulated training data!
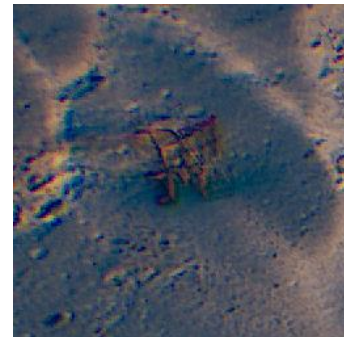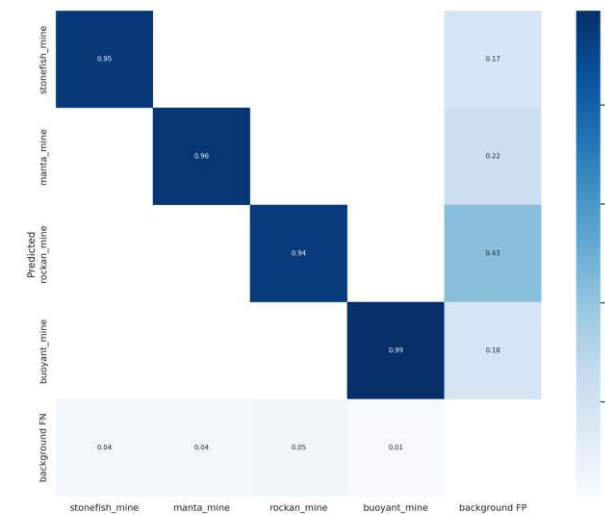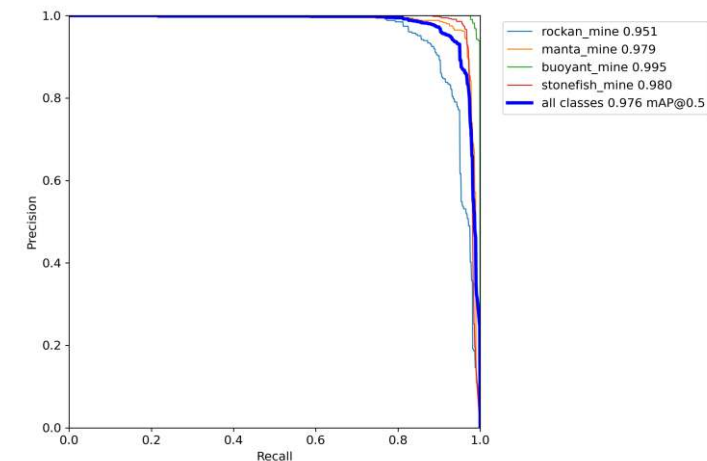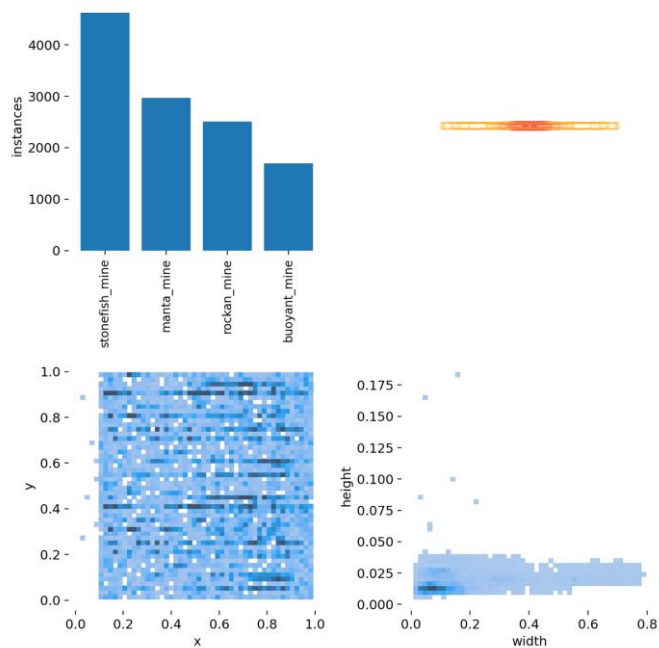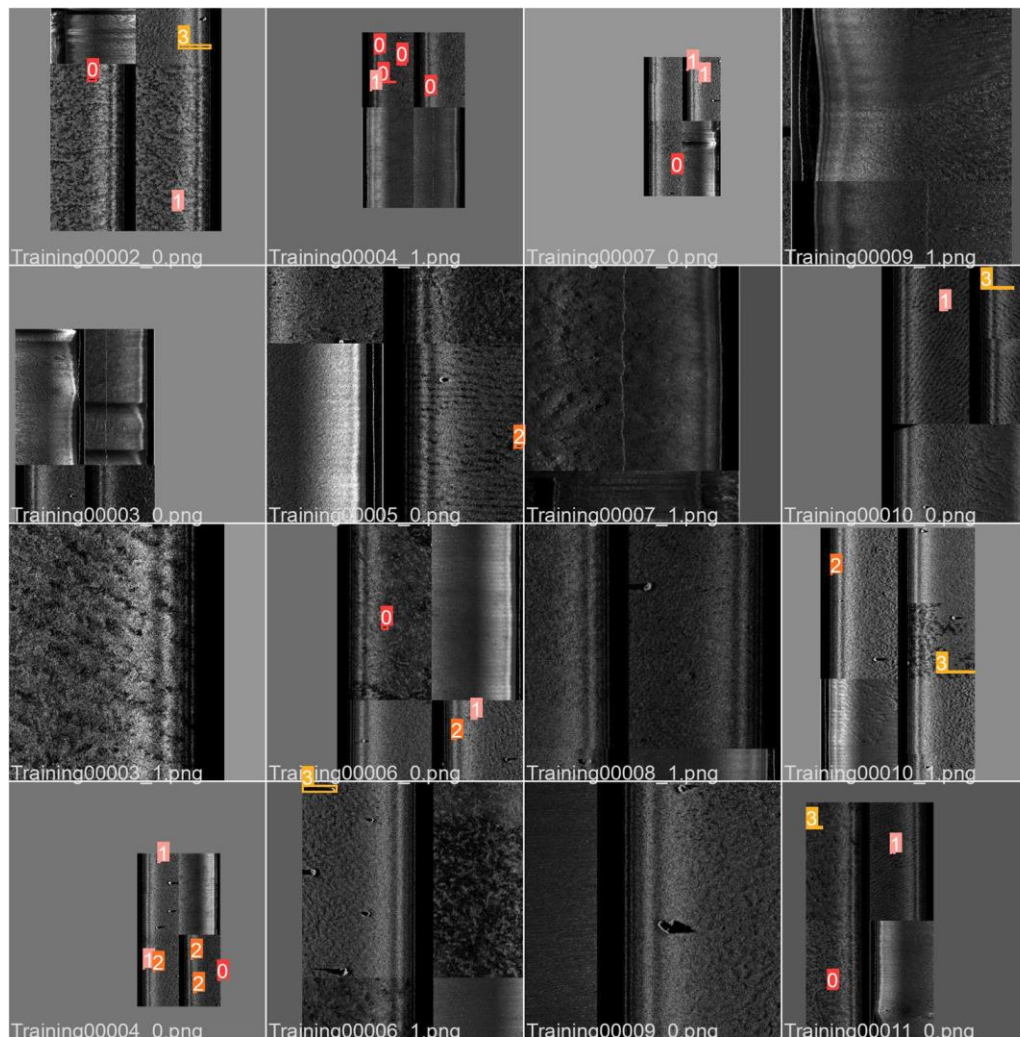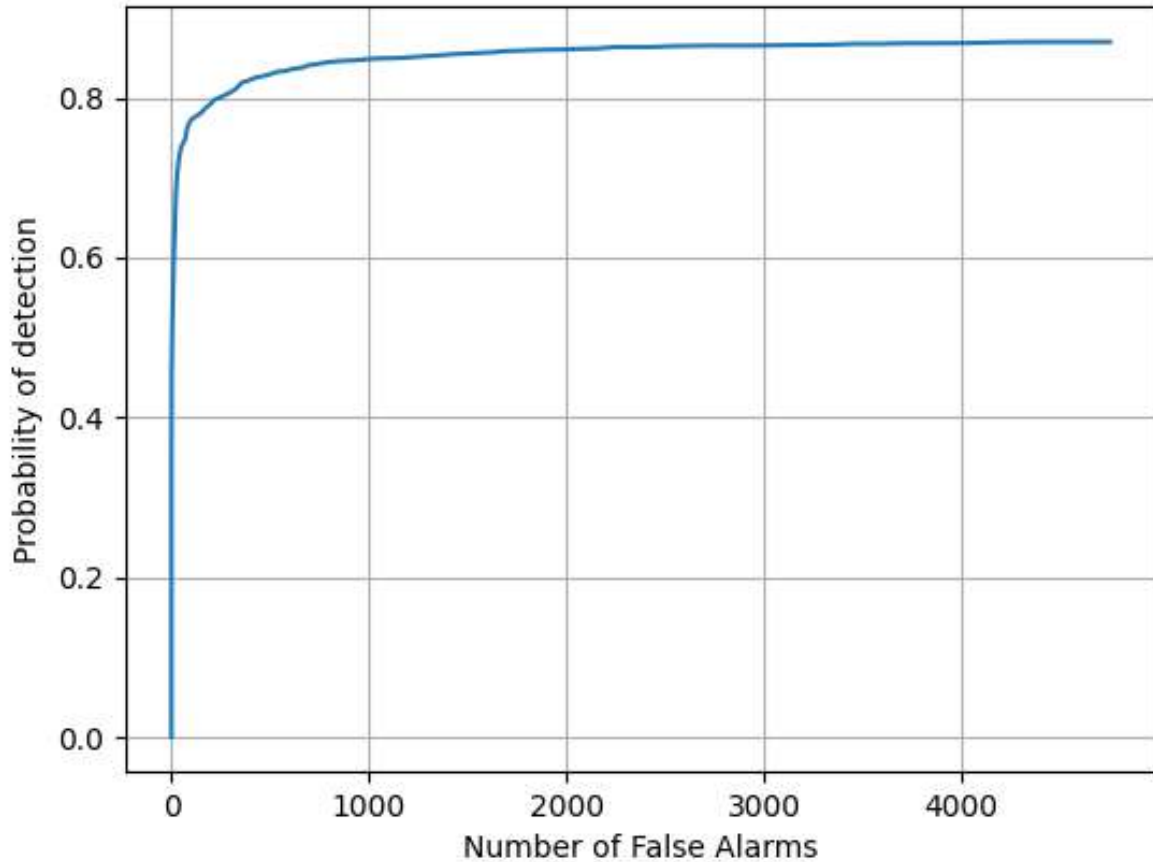
Synthetic data: 8221 Images:
4654 stonefish, 3034 manta,
2609 rockan, 1786 buoyant
mines

Synthetic + real data: 8221
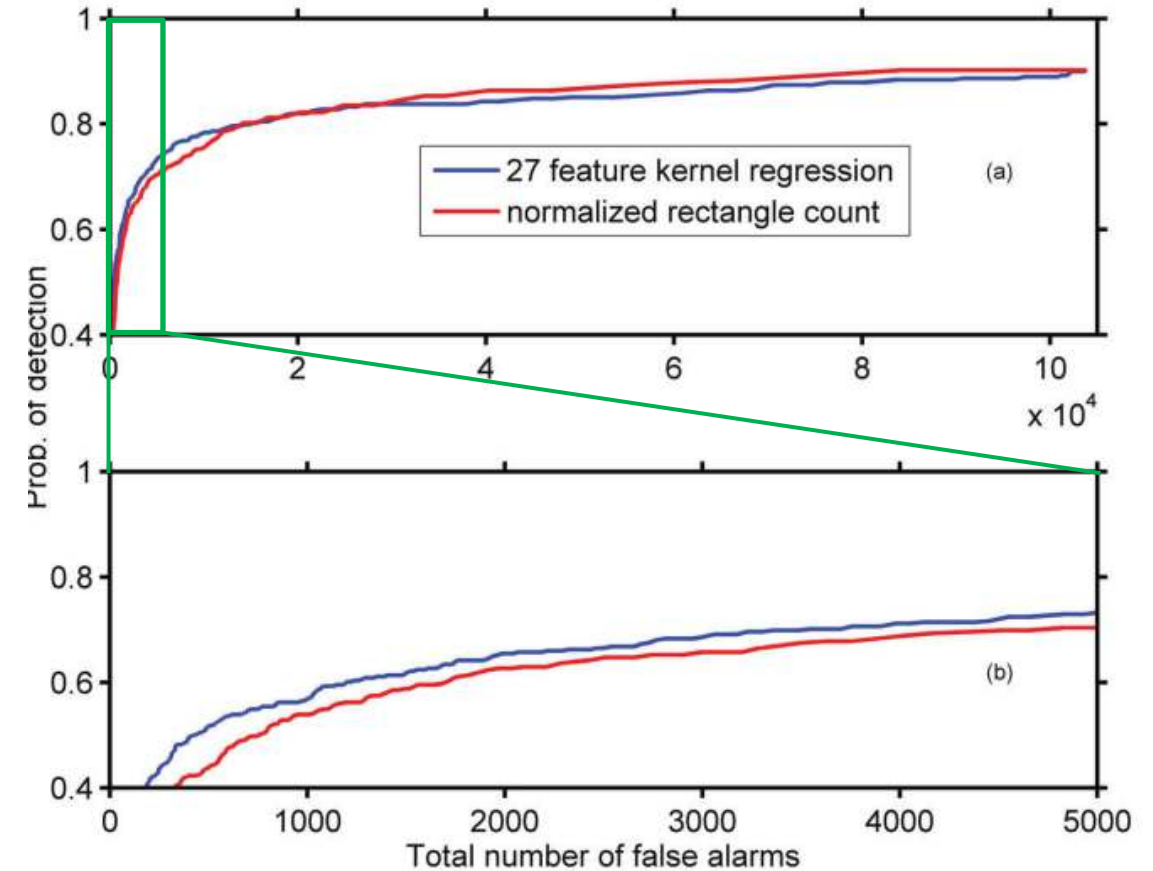Images + 654 with 154 MLOs

ATR Training Pipeline cont'd
ATR Challenge ROC Curves (Marine Sonics 900 kHz)

YoloV5 trained by S4 with ATR Challenge + synthetic data
86.9% TPR with 4751 False Alarms

Haar Cascade Detector trained with ATR Challenge data
70% with 3500 False alarms and 14,000 False alarms for 80% TPR

MOOS-IvP feature wish list
Things that might make life easier[*]

- Runtime warp control

- Better shutdown control

- Configurable message queue depth

- Services

- Name spaces

- Encryption and access control

- Config syntax highlighting

- MOOSDB reset

* Some of these suggestions were the result of a survey of our programmers, some of whom have not been using MOOS for very long. Some, however come from experienced MOOS practitioners.

Conclusions:

- We have demonstrated a functioning prototype of the S4 MCM simulation system

- S4 is based on MOOS-IvP because of its small codebase and limited dependencies, which simplified its integration into MINTACS

- In the course of demonstrating S4, we have pushed MOOS-IvP to the limit and it didn't break!

- We have demonstrated that synthetic sonar data can be used to train ML-based ATR systems

- The next version of S4 will be demonstrated at Euronaval later this year.

Questions?