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Minefield Search Tactic Evaluation using 4 Autonomous Manta UUVs

Brutzman, Don

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NPS Undersea Warfare Academic Group IX71

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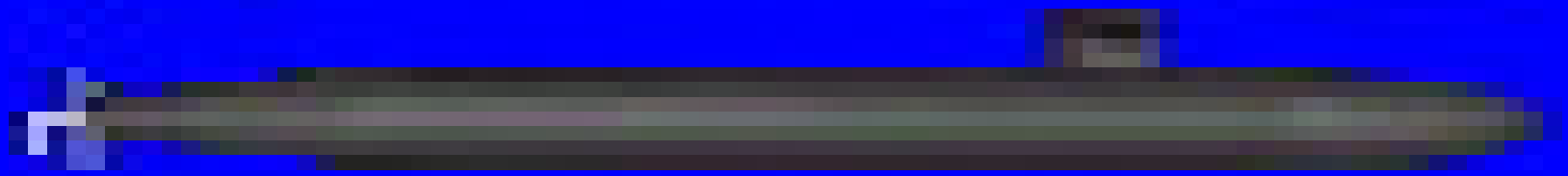
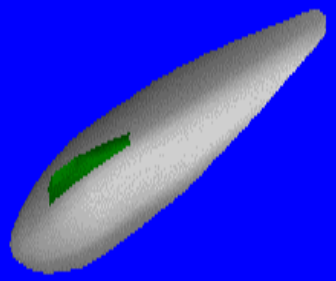
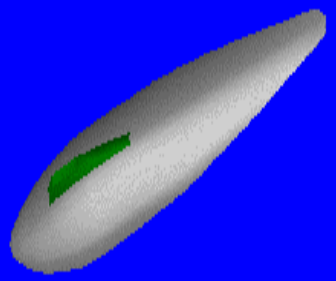
Sponsor: Naval Undersea Warfare Center, Newport Rhode Island





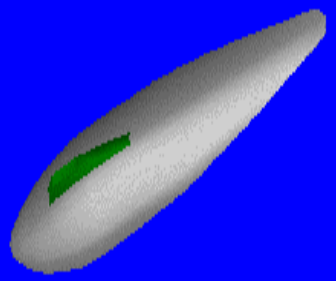
Manta Minefield Search

- Operational Scenario
- Tactics development and objectives
- Assumptions
- Minefield patterns, search tactics
- Analysis of tactical effectiveness
- 3D graphics and tactical visualization
- Conclusions and recommendations



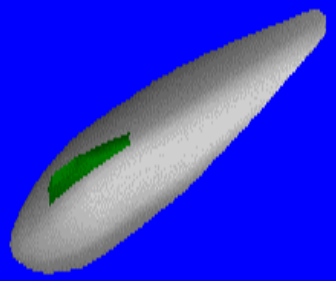
Robot objectives

- Experiment with new, larger-scale tactics
- Replay & rehearse robot mission
- Show robot functionality available today using NPS *Phoenix* AUV software
  - Current program creates mission scripts
  - Any of the tactics algorithm software can be ported to run adaptively inside the robots



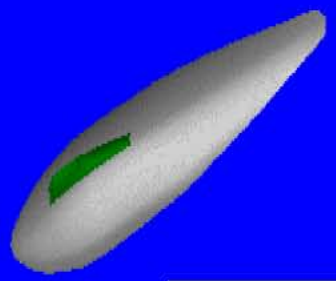
Operational Scenario

- Search enemy harbor for mines and subs
- Precede amphibious invasion
- Covert, rapid, detection sensors *in situ*
- Situated agents with local perspectives
- Realistic military scenario that cannot be performed by ships in today's fleet
- Well-suited to multiple Manta search

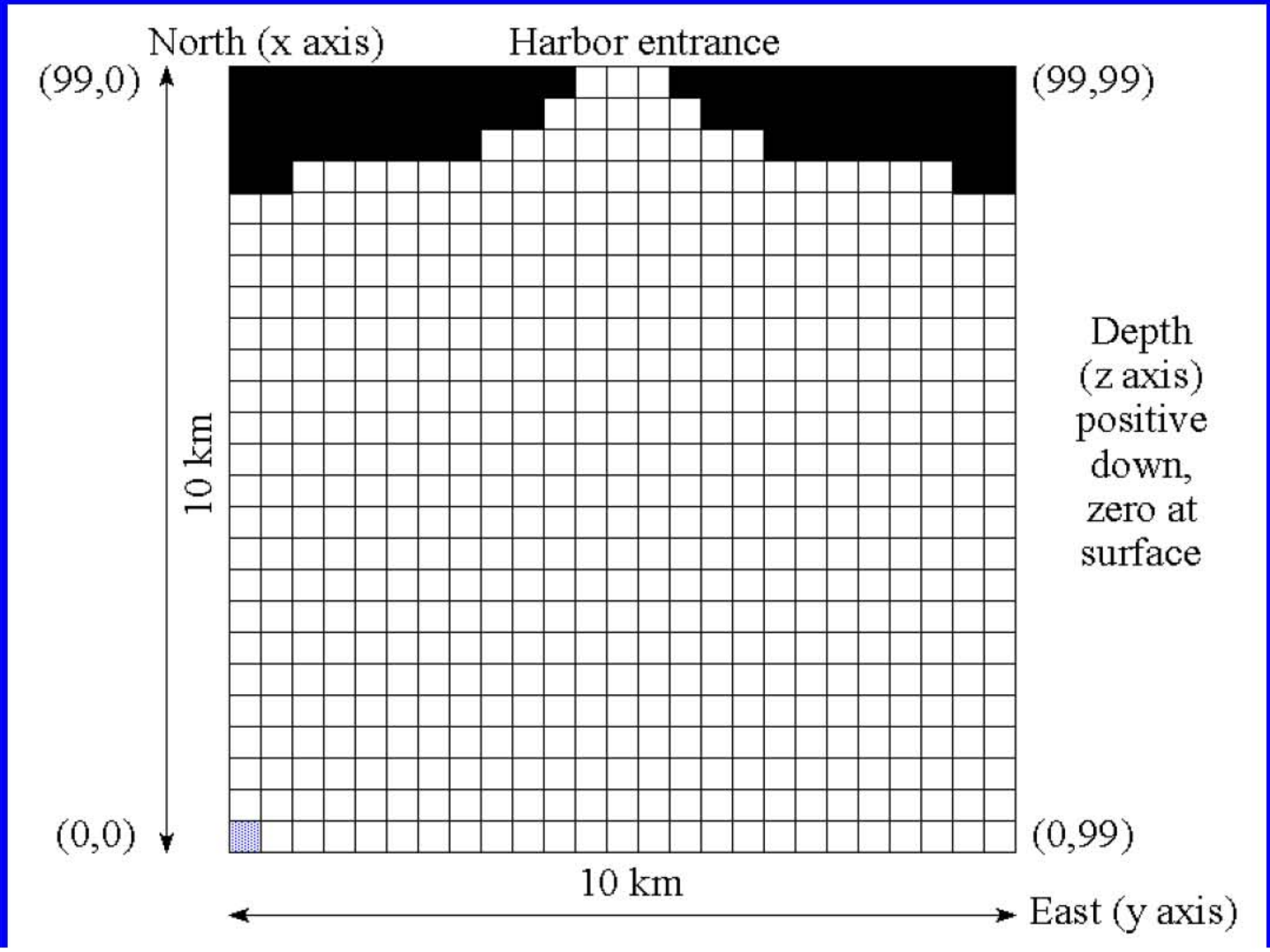


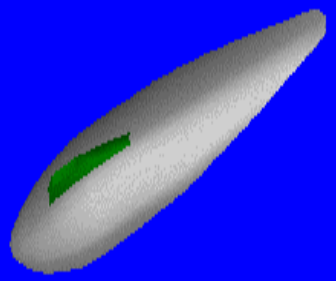
Intelligence report

- Hostile harbor guarded by mines, diesel sub
- Now targeted for an amphibious landing
- 10 km by 10 km square area
- Top 10% of box is land, harbor entrance
- 100 mines laid in random pattern
- 1 hostile diesel waiting for landing force



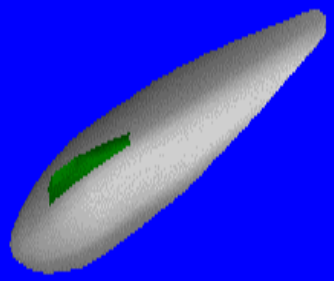
Minefield geography





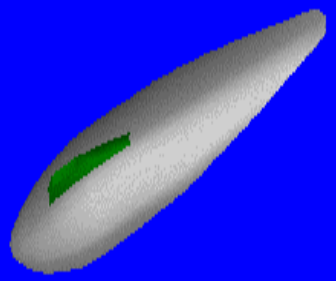
Tactics Development

- Multiple-robot search is a new twist on a challenging problem: coordinated search
- Nine scenarios simulated:
  - 3 cooperative search patterns, versus
  - 3 hostile minefield/diesel sub distributions
- Both strengths and weaknesses noted
- VRML visualizations provided separately



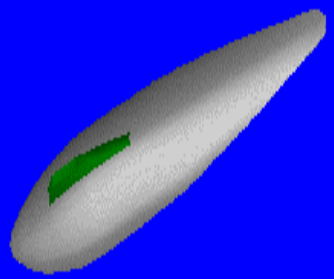
Analysis objectives

- Examine a variety of multiple-*Manta* tactics
- Compare 4-robot search effectiveness against likely minefield patterns
- Determine if hostile diesel sub presence forces revision of minefield search tactics
- Repeat analysis until statistical convergence
- Produce mission package for *Manta* ops



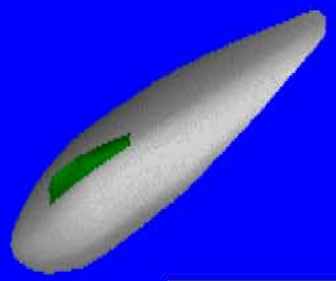
Assumptions

- Simulation limited to 10x10 km-squared grid
- Detection ranges vary, search speeds constant
  - 100 m detection at 5 knots versus mines
  - 1000 m detection at 5 knots versus submarine
- Problem can be posed as a grid box search
  - 100 x 100 x 90% = 9,000 boxes
  - 1 time step = 40 seconds = 100m at 5 knots
  - 24 hours = 2160 time steps total

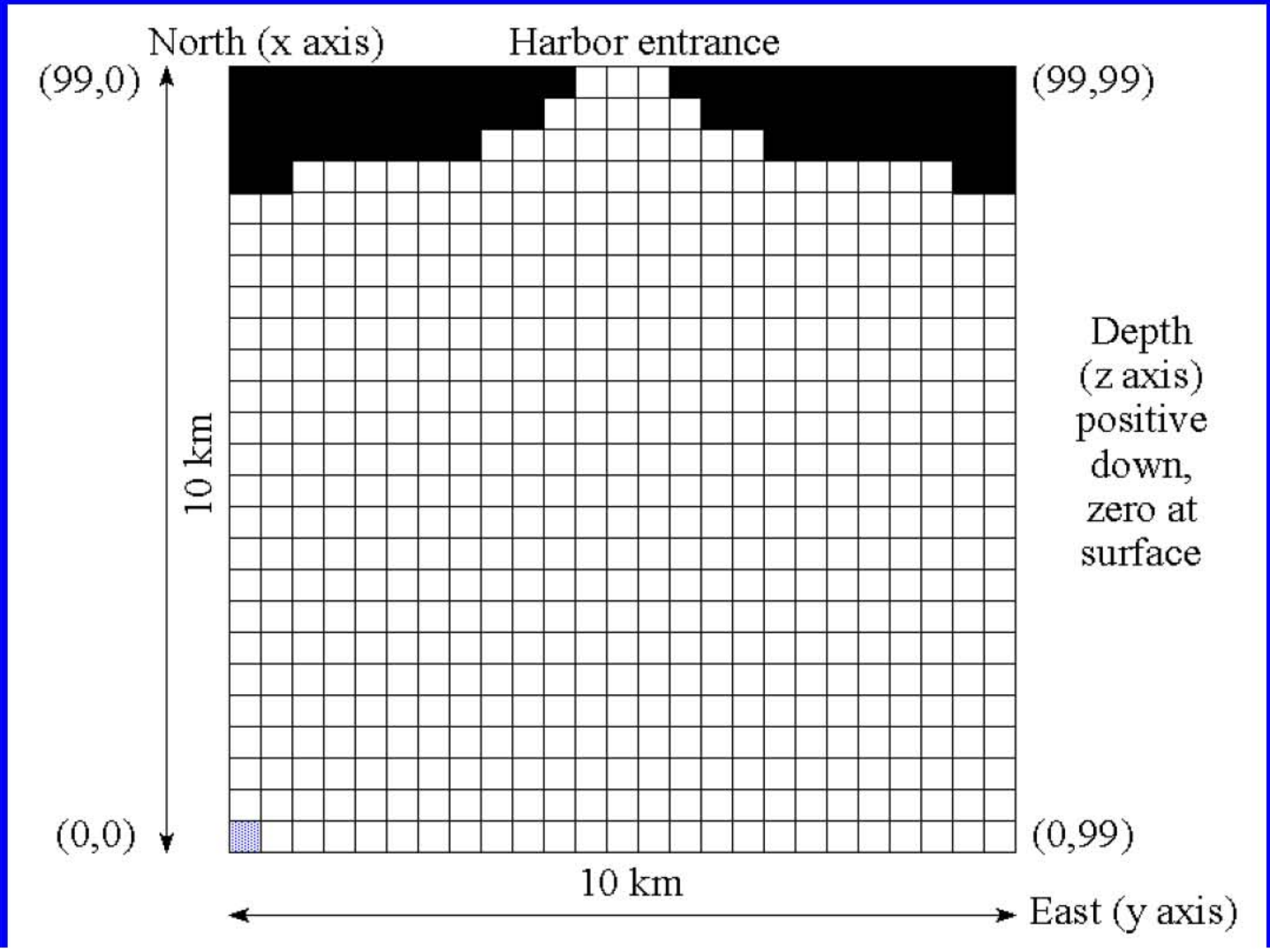


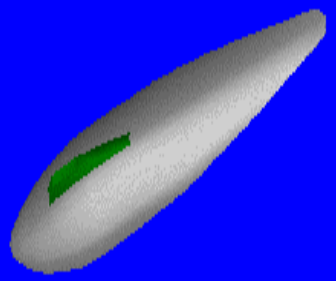
Other Assumptions

- Mapping is faster/better than neutralization
- *Manta* torpedoes permit self defense
- No delays due to detection or avoidance
- 24-hour time constraint to support landing, thus 100% search (25 hours) not possible
- 100% probability of detection (for mine or diesel) once Manta enters occupied grid box



Minefield geography

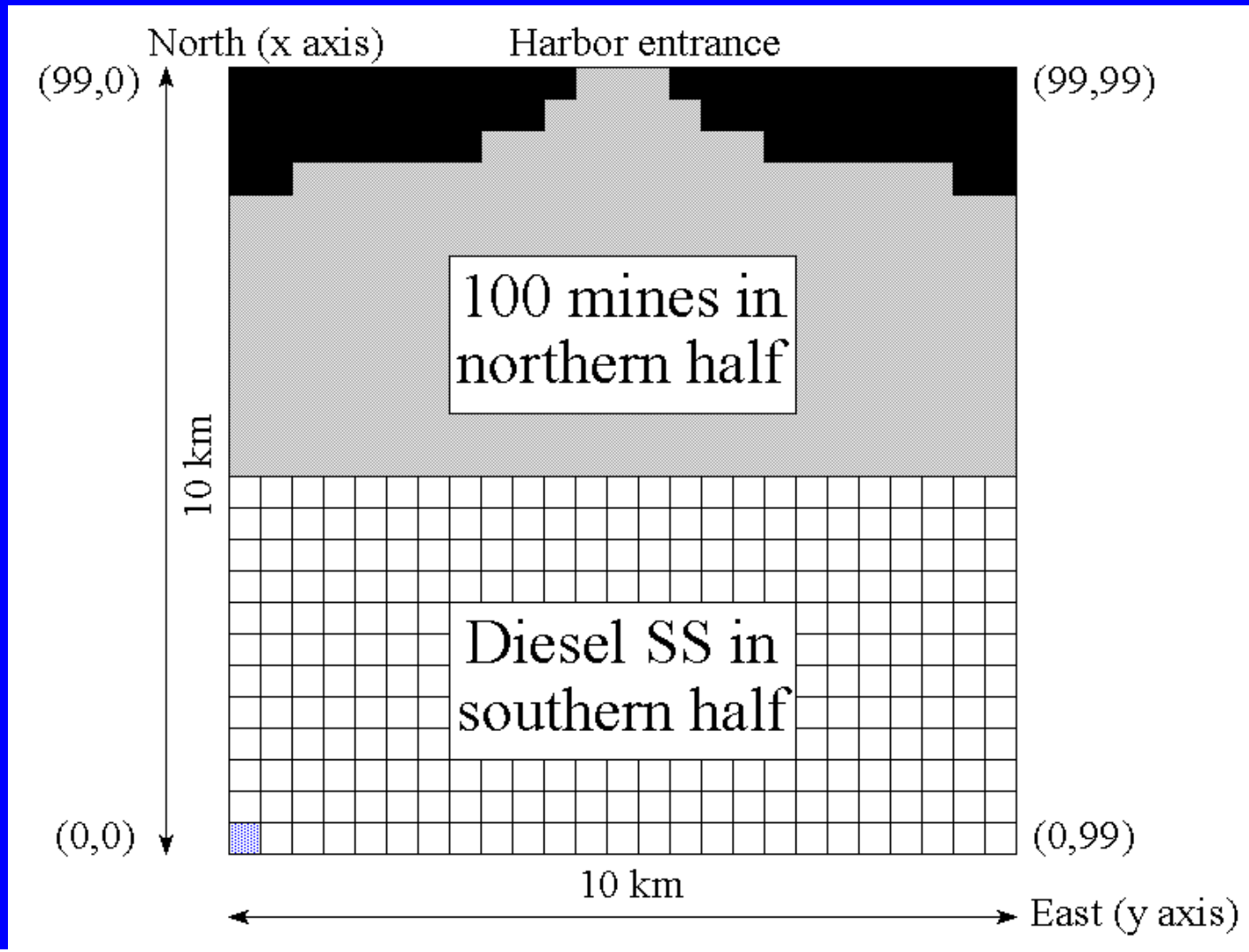


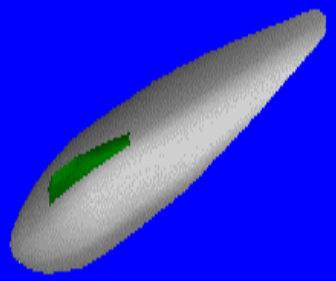


Three Defensive Tactics

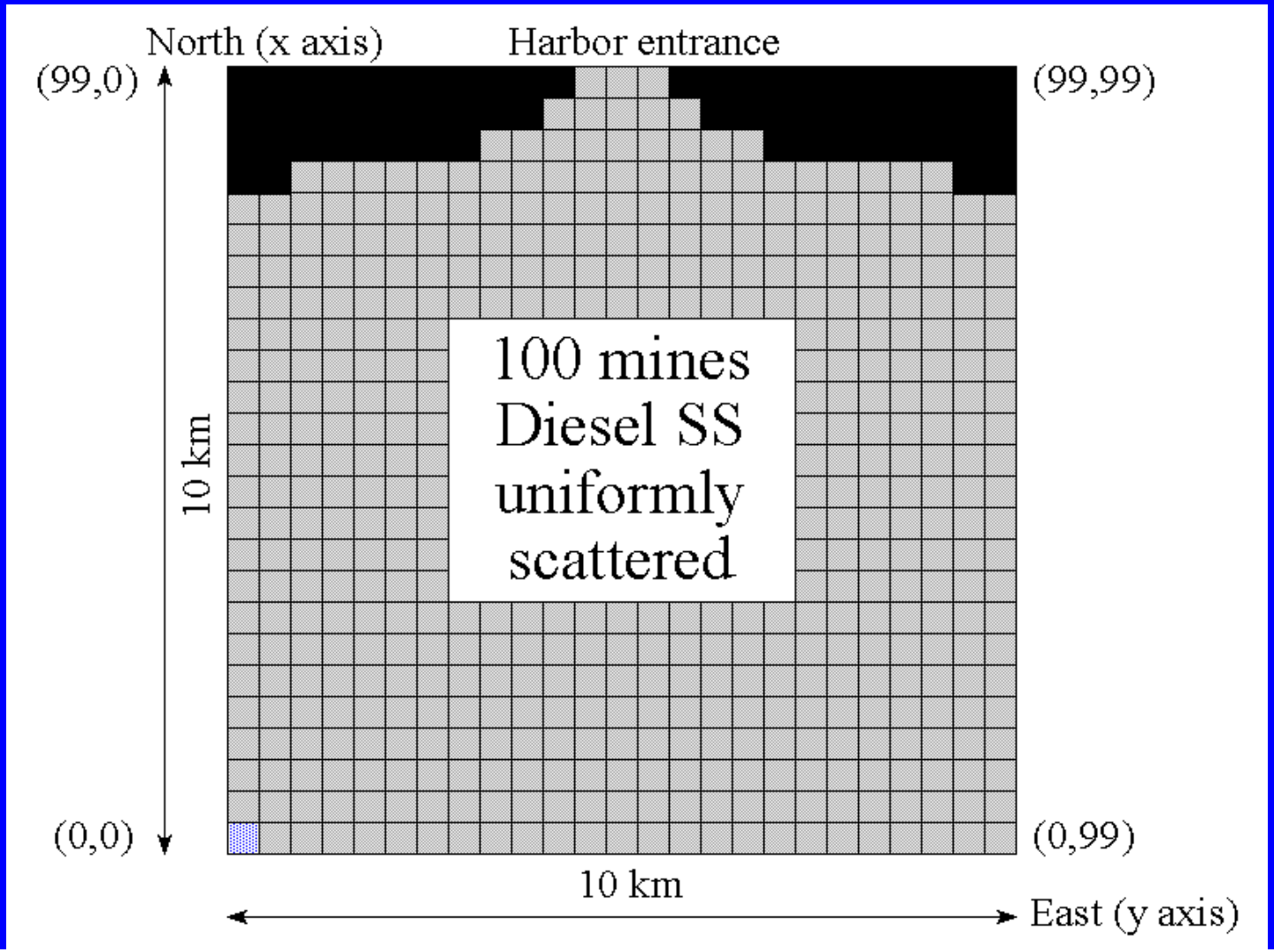
- **North-South Minefield**
- **Scattered Minefield**
- **Diesel Channel Minefield**

North-South Minefield

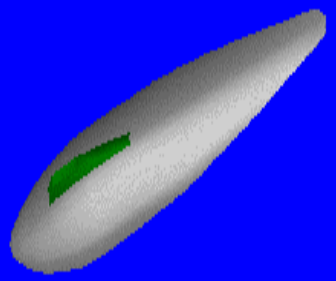


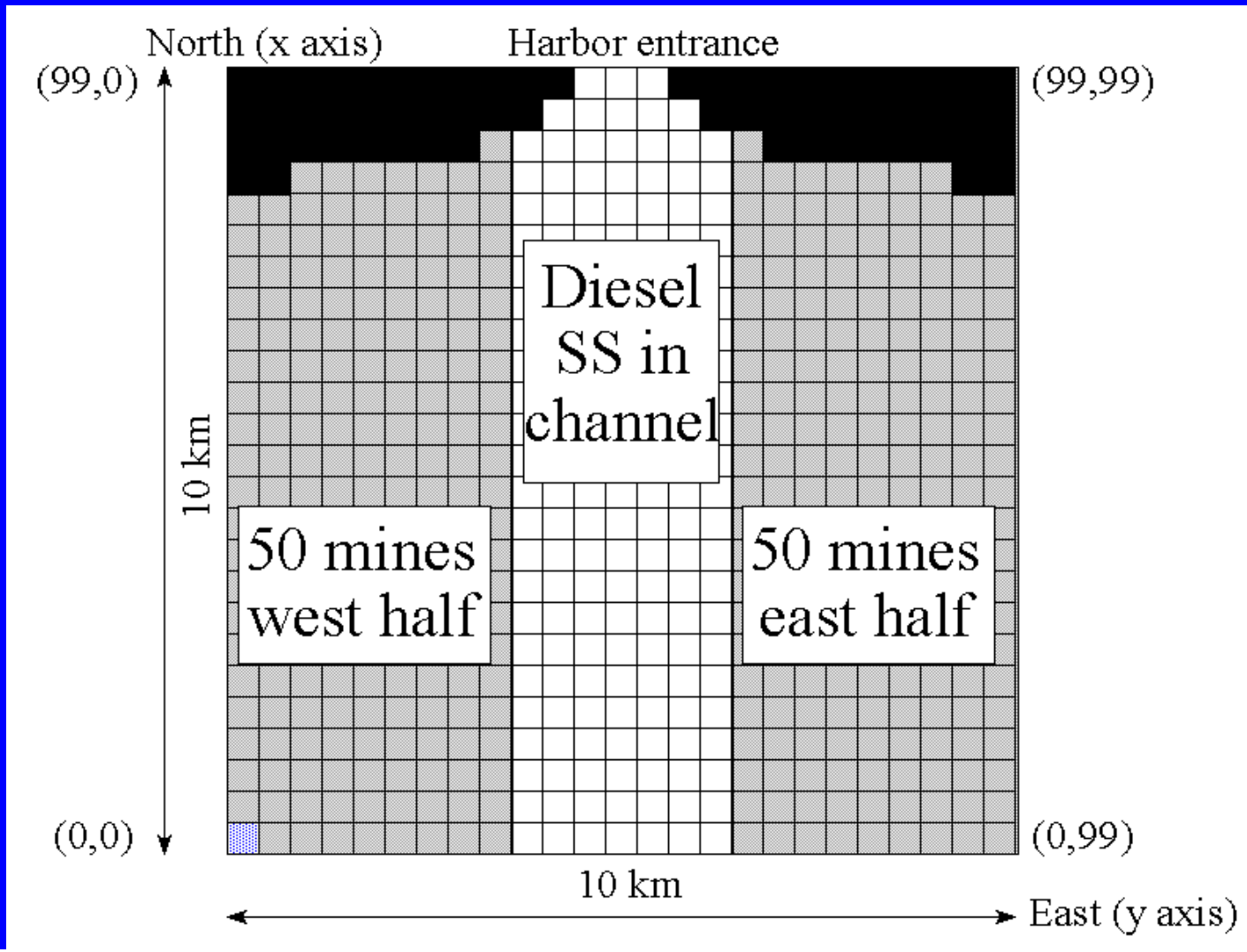


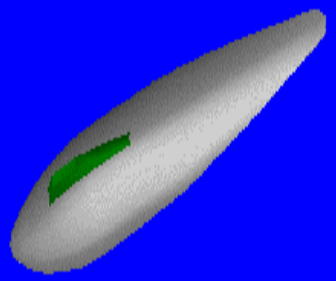
Scattered Minefield



Diesel Channel Minefield

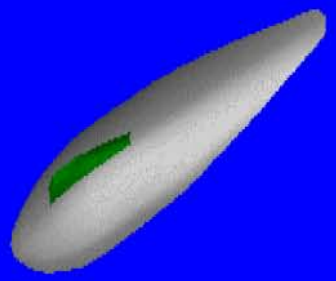




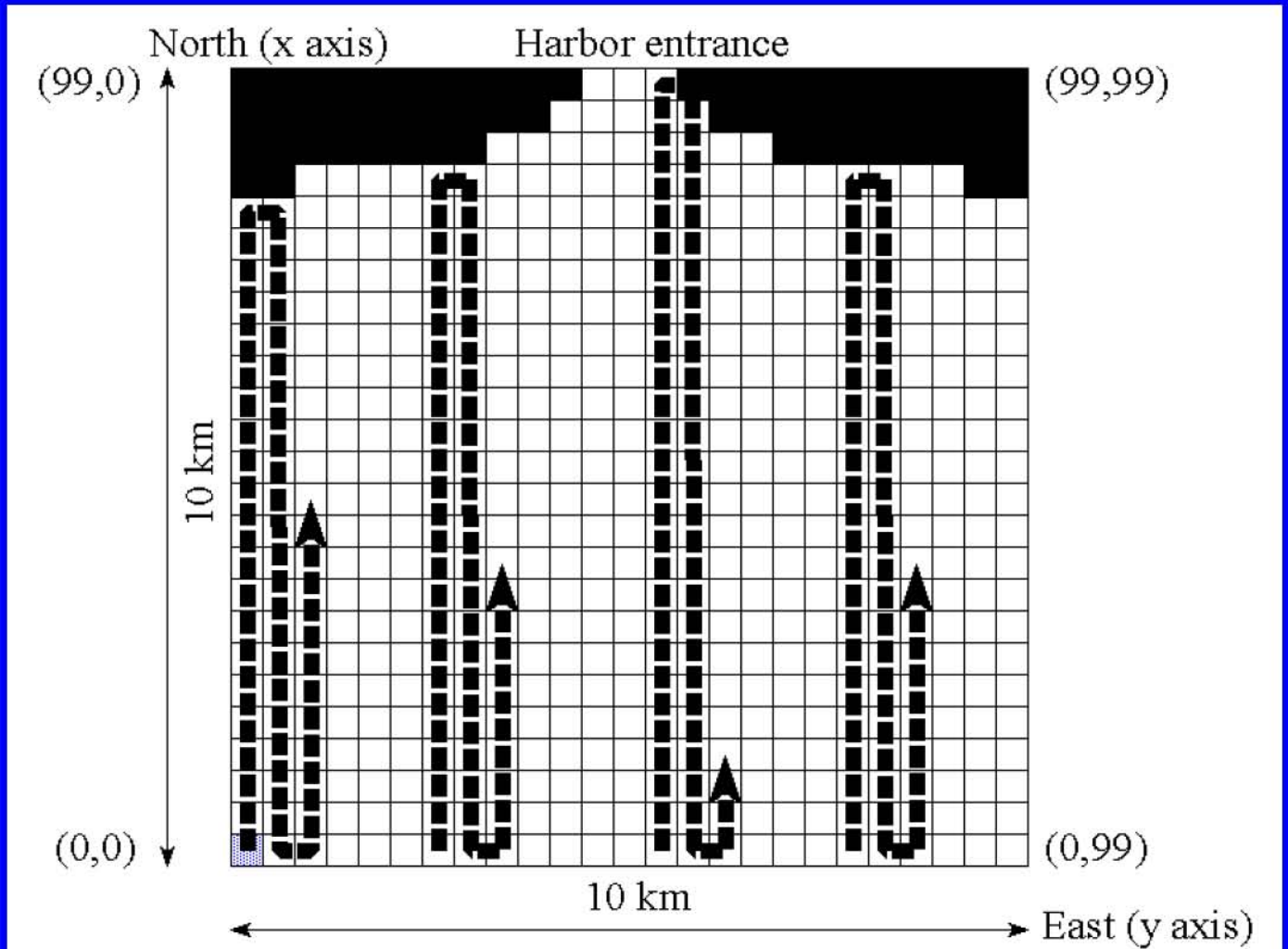


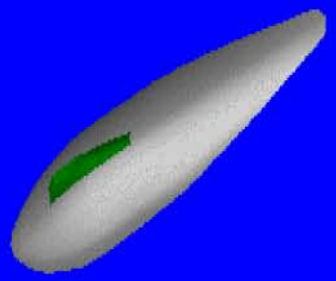
Three Search Tactics

- **North-South Lawnmower**
  - each searches simple pattern for mines, diesel
- **Collapsing Box** for one Manta vs. diesel, 3-Manta North-South Lawnmower vs. mines
  - dedicate one Manta to sub detection
- **Combination** Collapsing Box+Lawnmower
  - combined tactic for each Manta

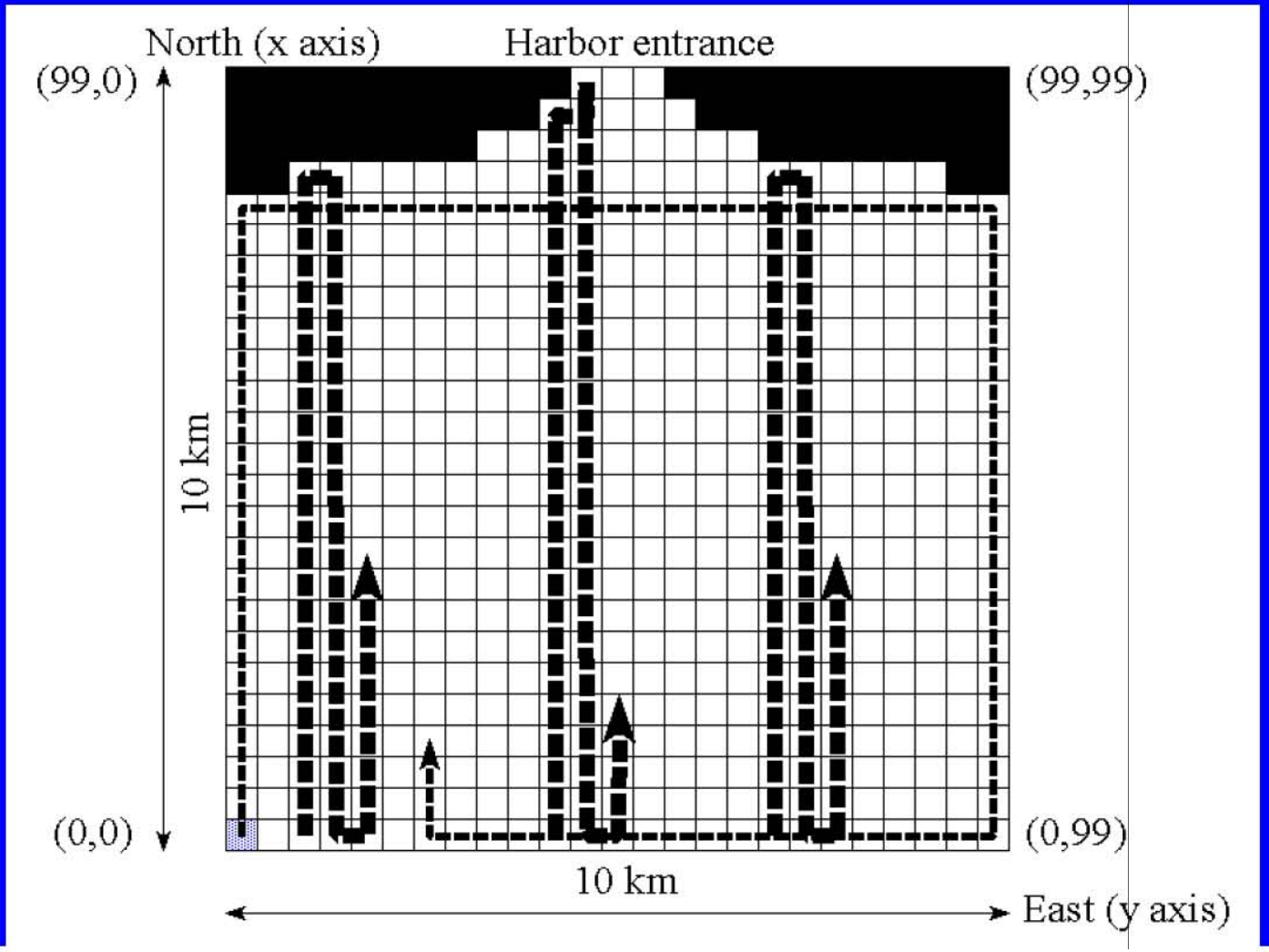


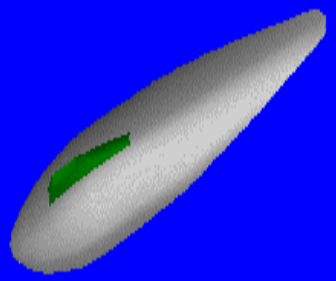
North-South Lawnmower





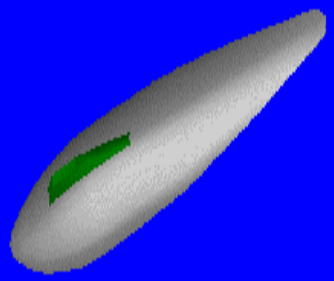
Collapsing Box Search





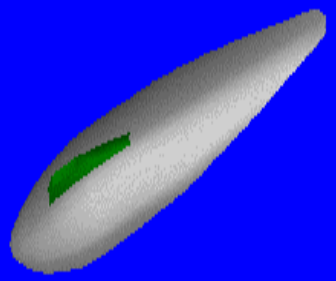
Combination Search

- Combine Collapsing Box with Lawnmower (hard to draw clearly)
- All four Manta columns identical:
- first Collapsing Box tracks at 20-box spacing for rapid detection of diesel sub
- then revert to Lawnmower North-South for dense coverage of minefield

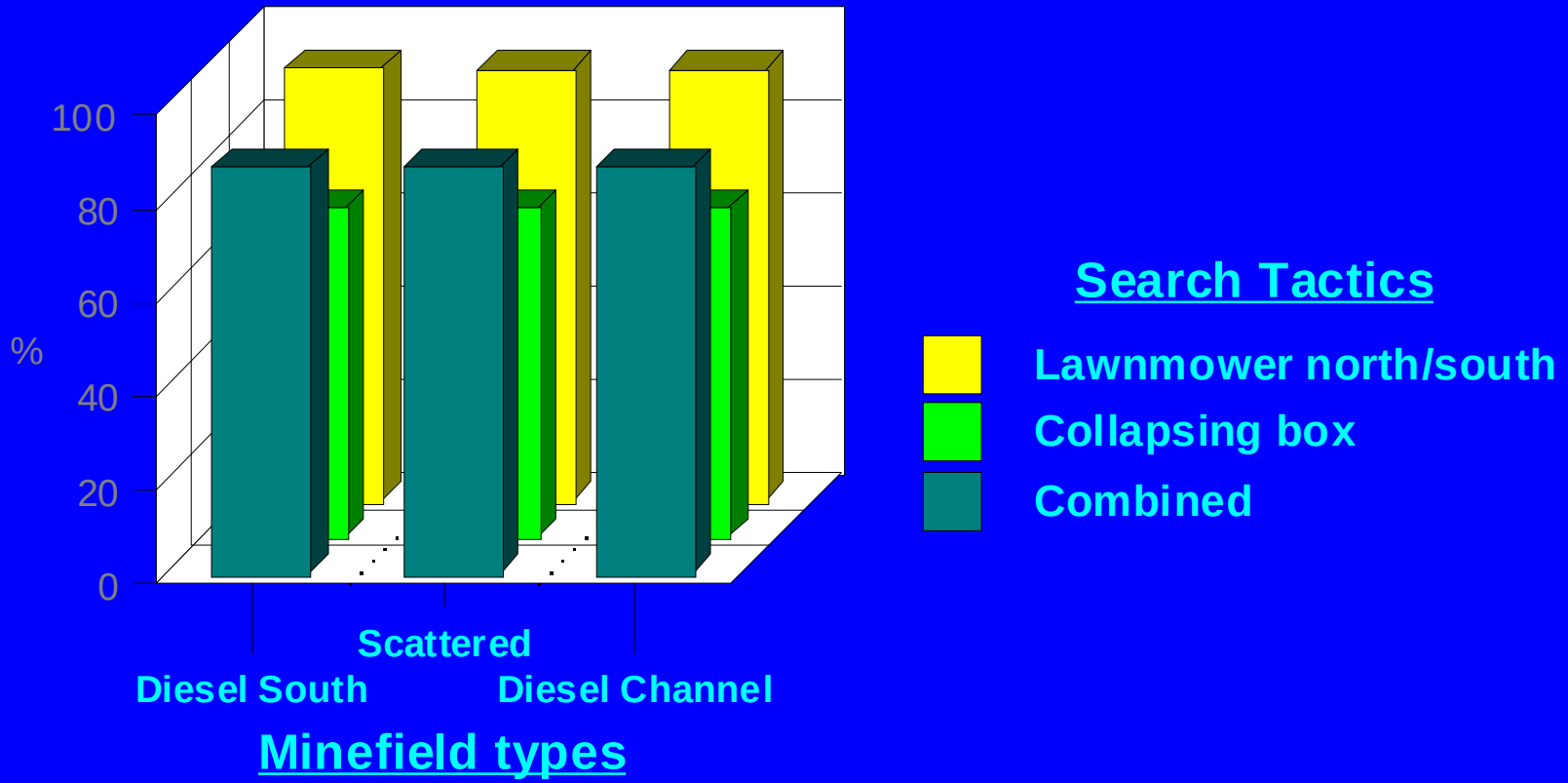


Evaluation Metrics

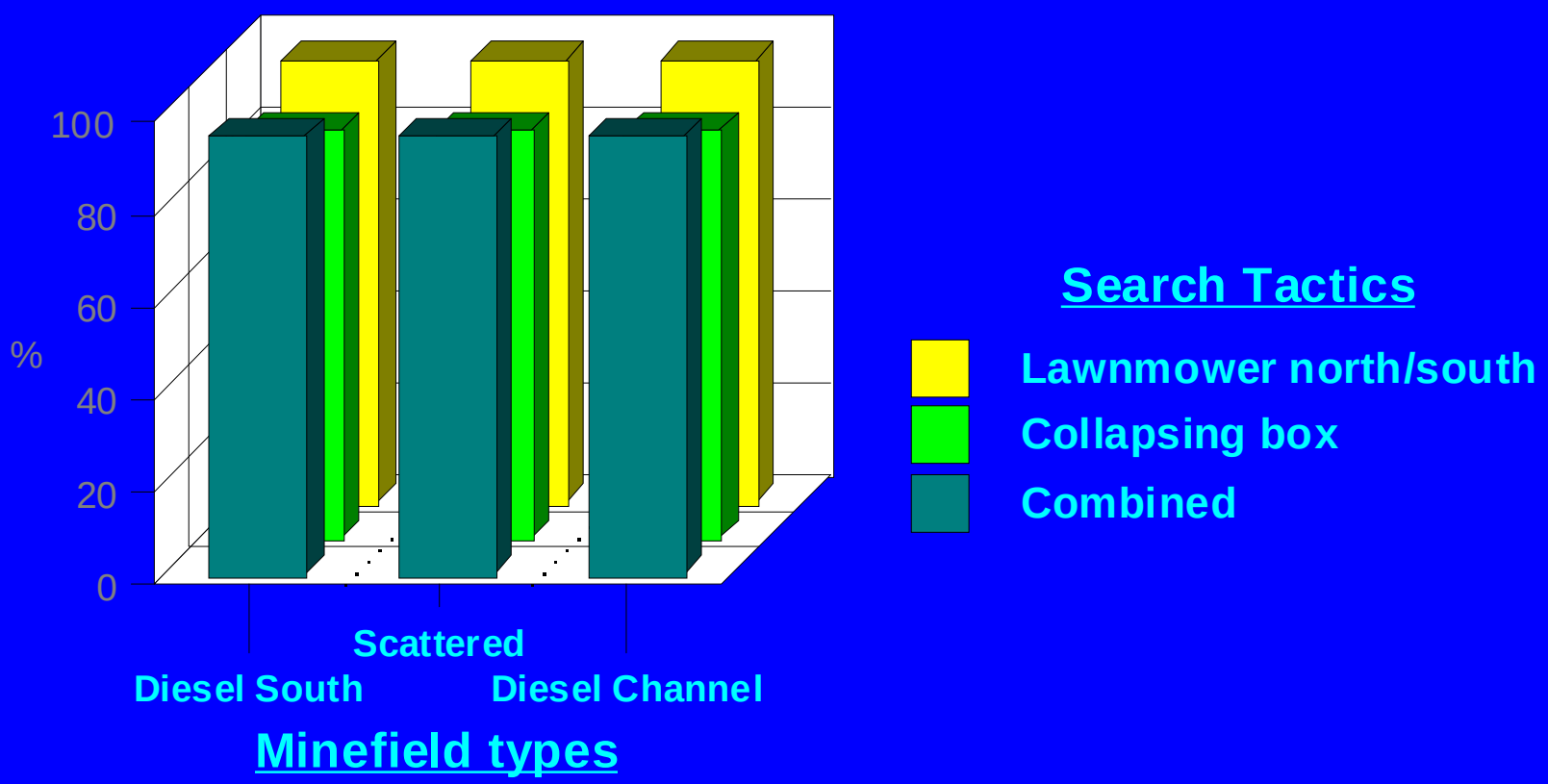
- Number of Mines Found
- Area Searched
- Time to Find Diesel Sub

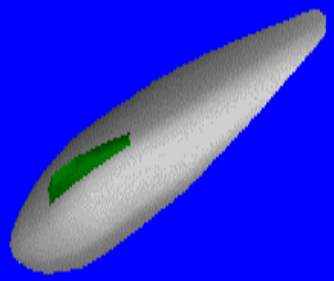


Number of Mines Found Comparison

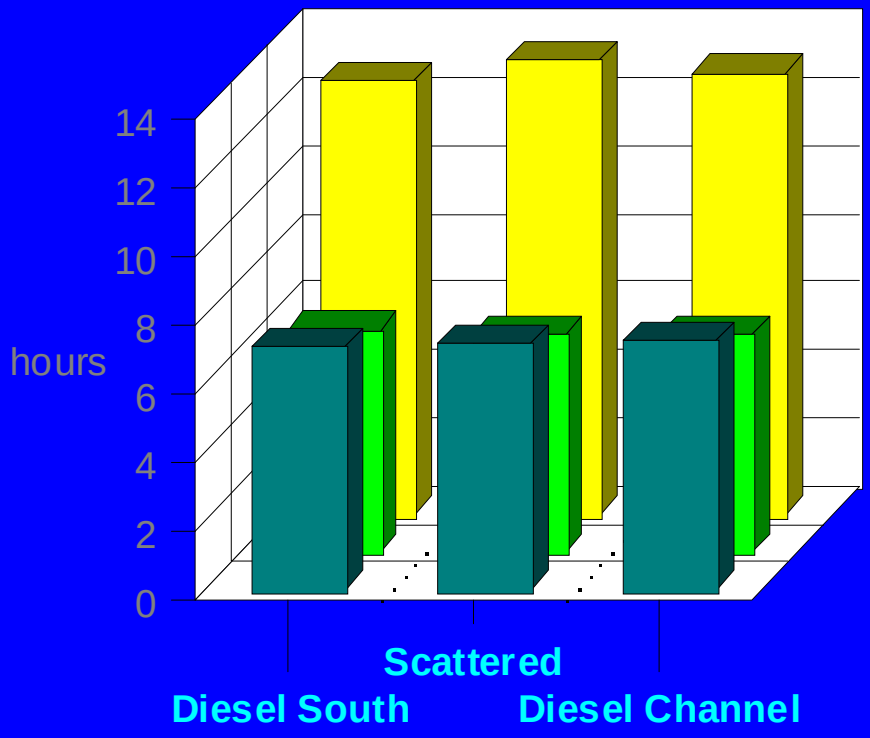


Area Searched Comparison

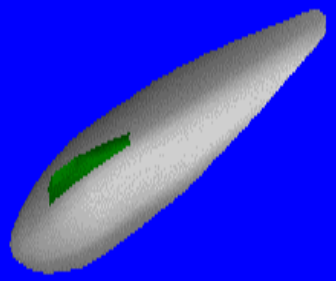




Time to Find Diesel Comparison

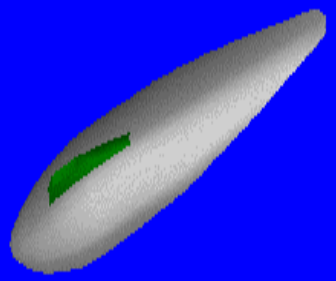


Caveat: these location times are high-variance results



Which is the Best Tactic?

	Mines found	Area Searched	Time to find diesel
Lawnmower north-south	best	best	
Collapsing box			best
Combination	best	best	best



Visualization objectives

- Visualize mission and tactical environment
- Sensor-environment interactions are critical
- Examine multiple tradeoffs in robot tactics
- Unexpected scenarios foreseen
- More intuitive risk analysis
- Scalable 3D world construction with VRML
- Consider 3D interfaces to CCS

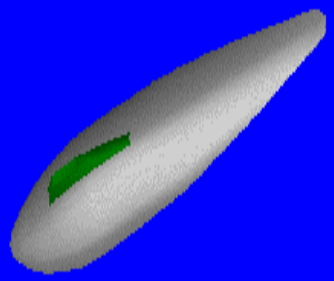
Video makes the story quickly understandable

- MPEG video clips of tactical players
- Can be stored & streamed over Internet
- Caveat: large file sizes not “radio friendly”



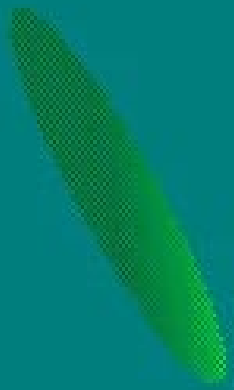


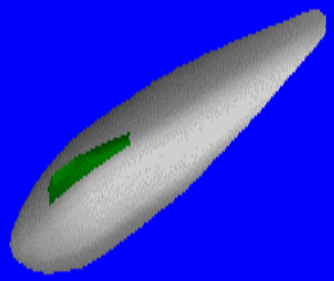




View tactical environment

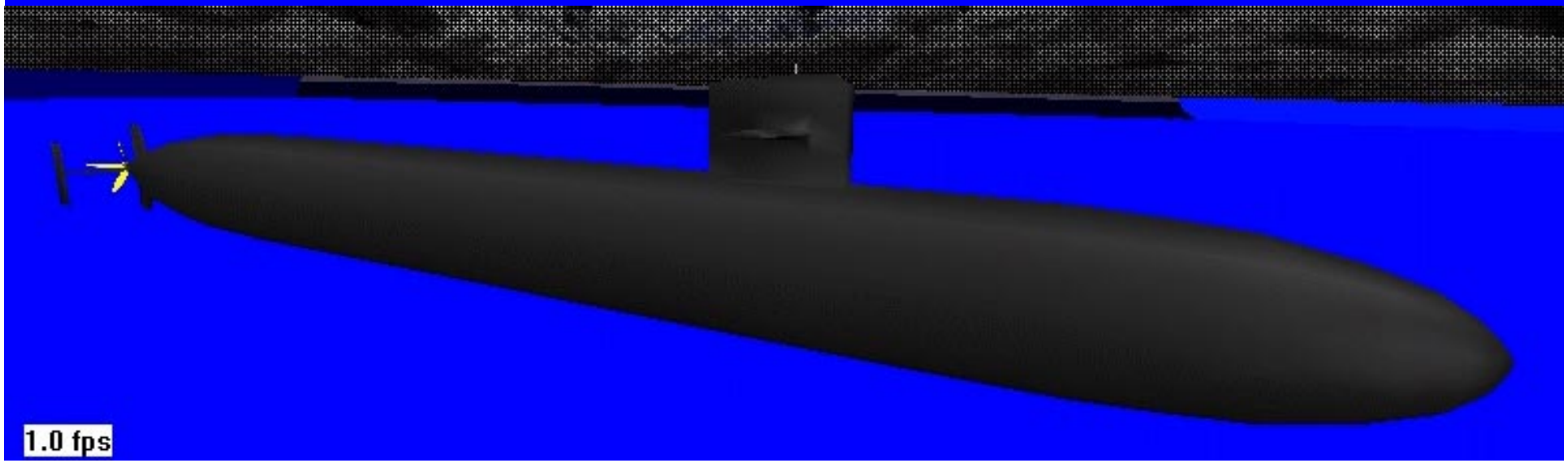
- Visualize sonar beams moving in real time: seeing the invisible, making it intuitive
- Take tactical operators out of flatland
- View sonar/entities/environment in context

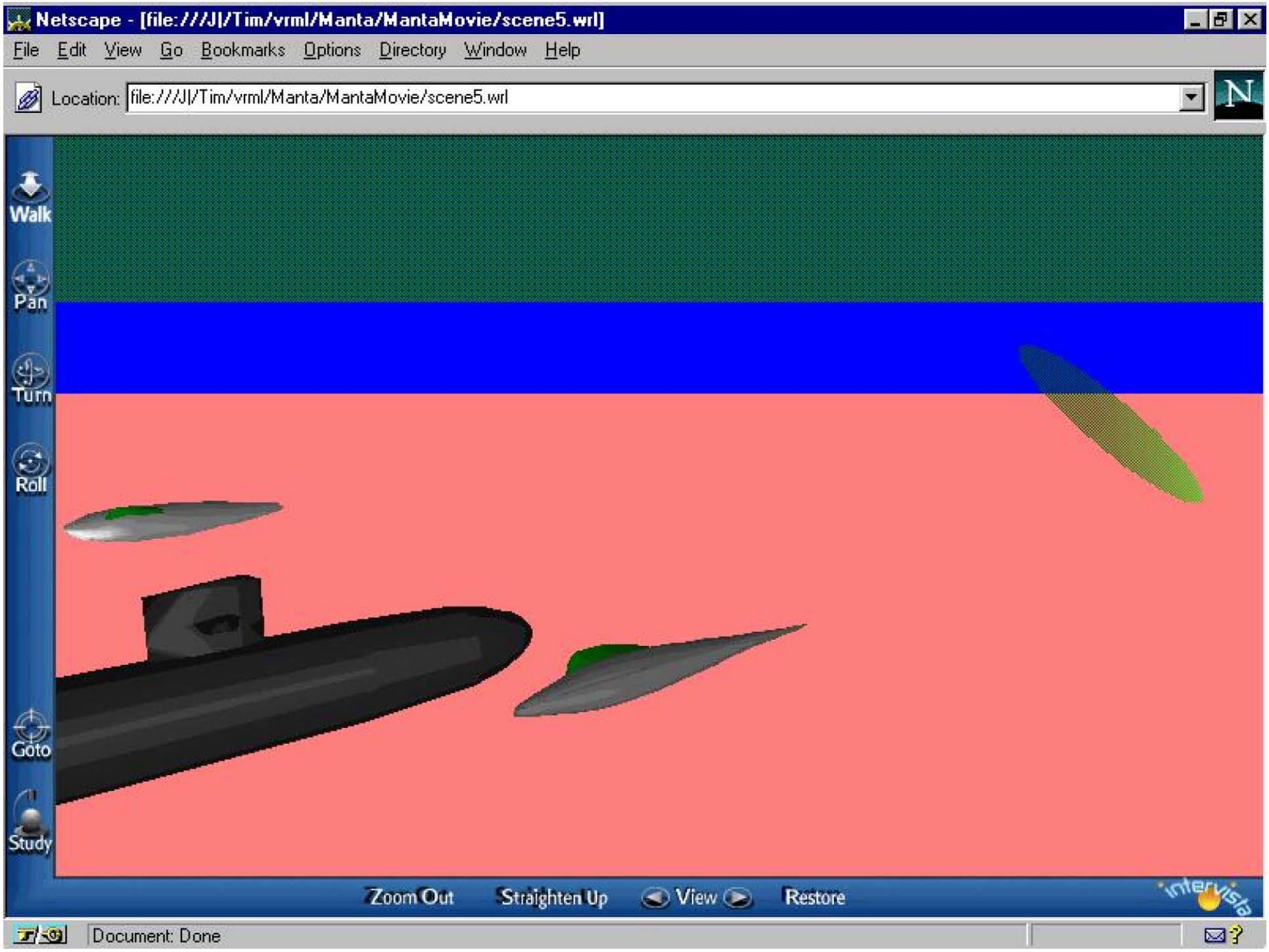




View tactical environment

- Visualize vehicles and sensors in context
- Real physics (hydrodynamics) in real time
- Networked: multiple participants, viewers

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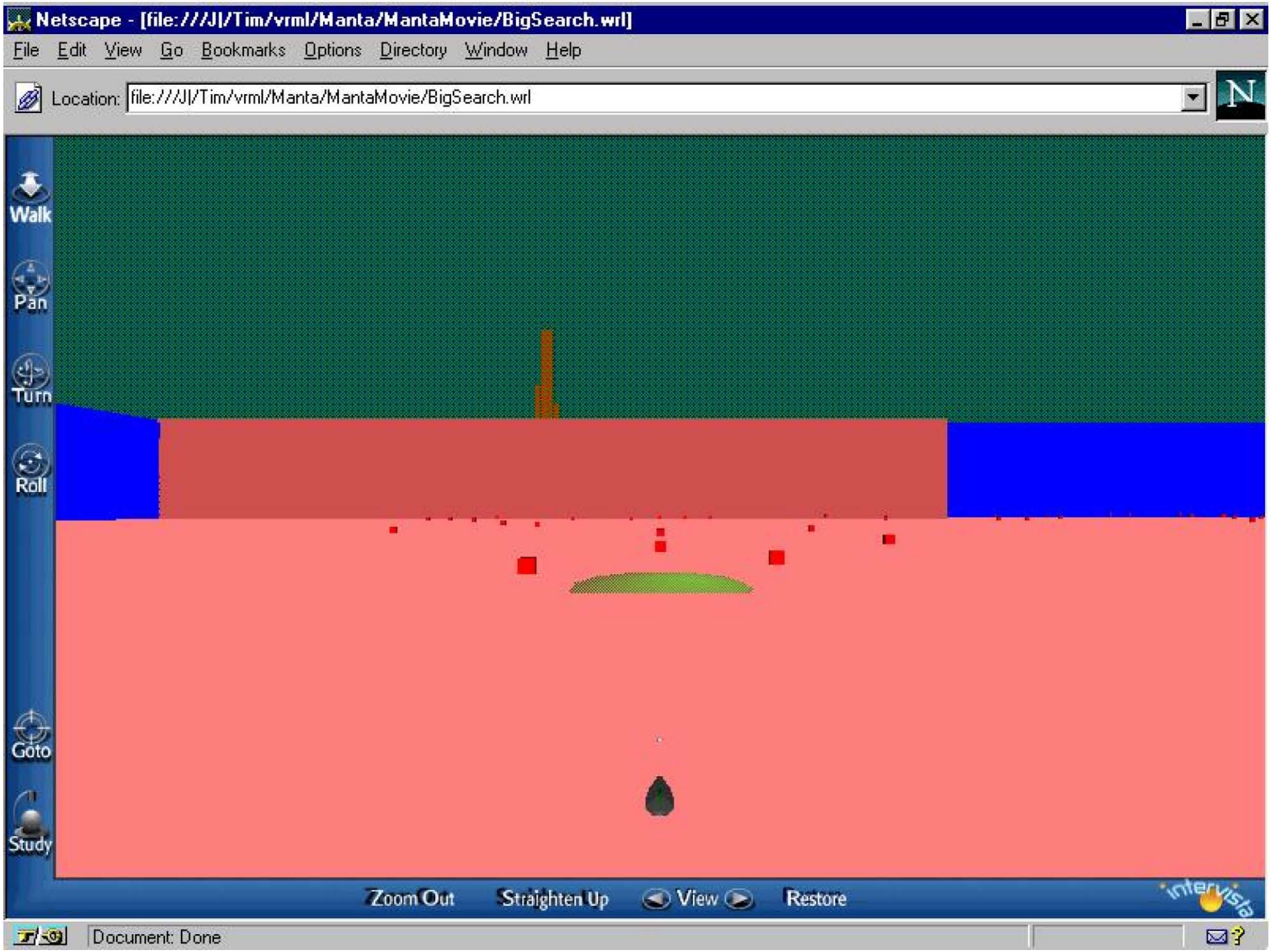
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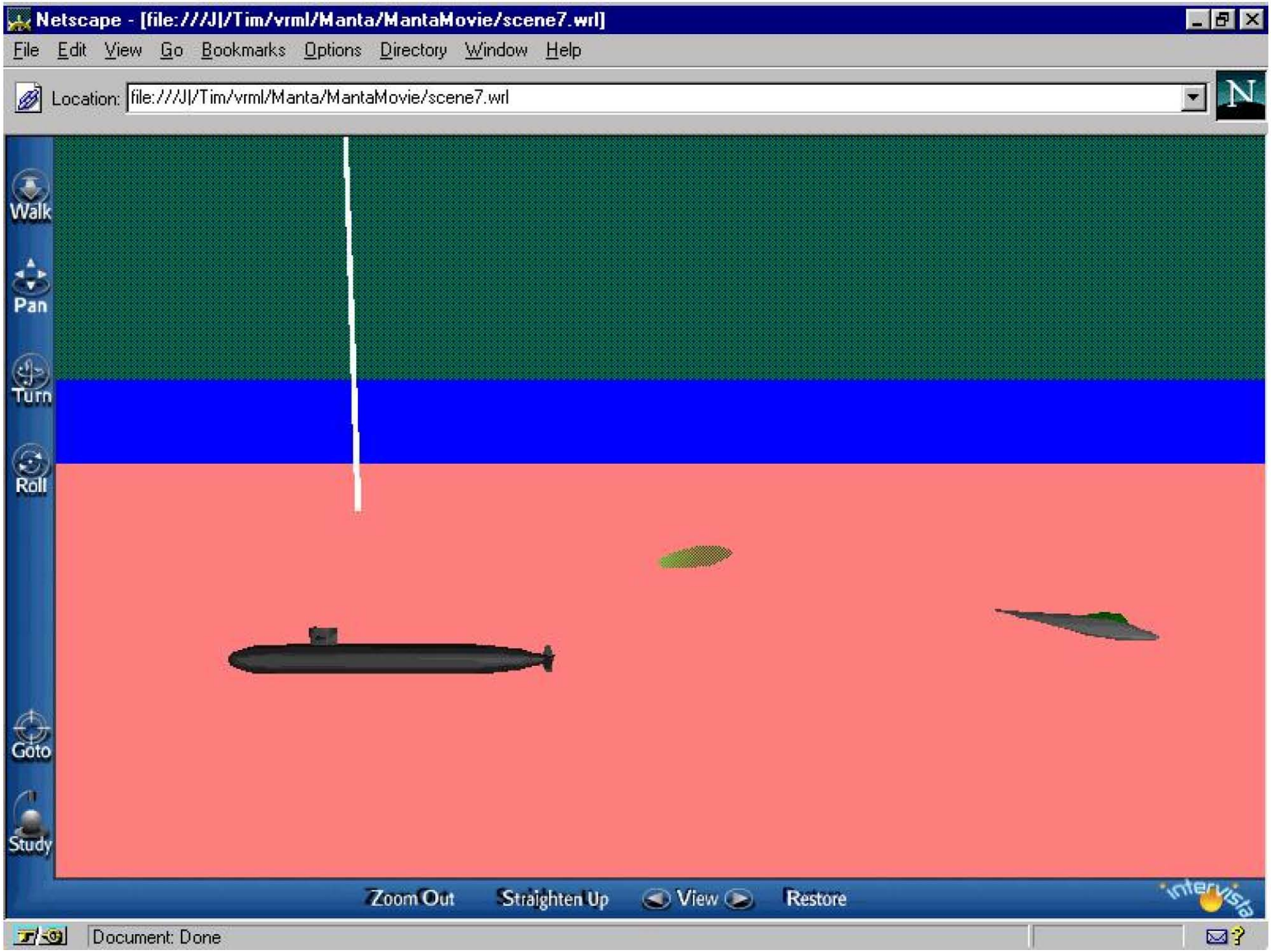
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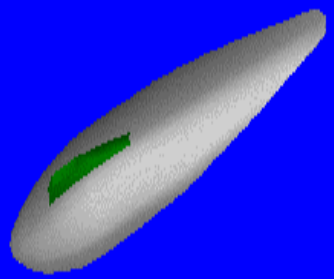
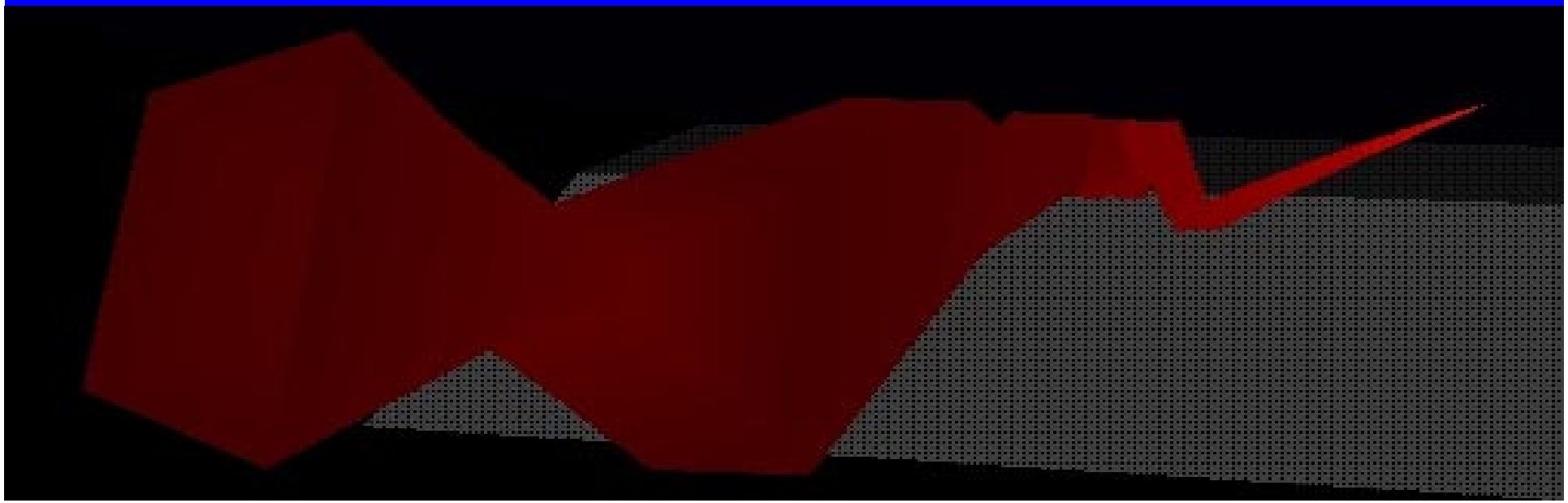
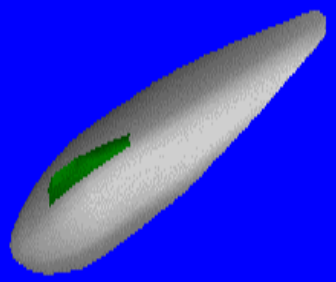


Sonar visualization

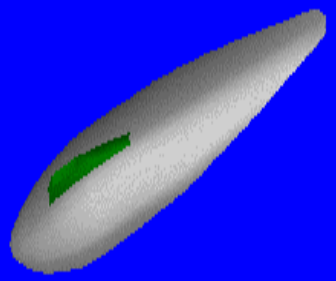
- Again: real physics in real time
- Visualize the unseen, passive or active
- Share same 3D scene database using VRML





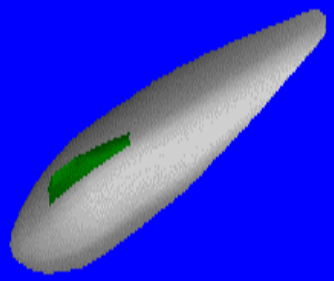
Recommendations

- Tactical visualization of environment
  - Big wins: scalability, integration, presence
  - More work needed: sonar visualization, connections to combat control systems, addition of hydrodynamics modeling, etc.
- Develop more tactical scenarios using 3D
- Build more 3D entities using VRML with embedded behaviors, physics, networking



Please remember!

- NPS faculty & students solve real problems
- Real-time 3D visualization has arrived



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