TEAMS OF ROBOTIC BOATS

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PLATYPUS

THE ROBOTICS INSTITUTE

CHALLENGE: MAXIMIZE THE AMOUNT OF USEFUL KNOWLEDGE IN THE AVAILABLE TIME *USING ROBOTS*

INFORMATION COLLECTION

- Take noisy, temporal samples
  - Go to a location for sampling
  - Create a model
  - Use model to decide where to sample next
- Robots can achieve:
  - Intelligent sampling
  - Spatial, temporal density
  - Vigilance
  - Repetition
  - (i.e., dull, dirty, dangerous)

DO IT WITH REAL ROBOTS

- World has interesting, complex structure that can be exploited
  - Hard to capture real distributions
  - The "real" problems are sometimes not the ones we study
    - E.g., communications patterns
- Absolutely a role for simulation, highly constrained environments

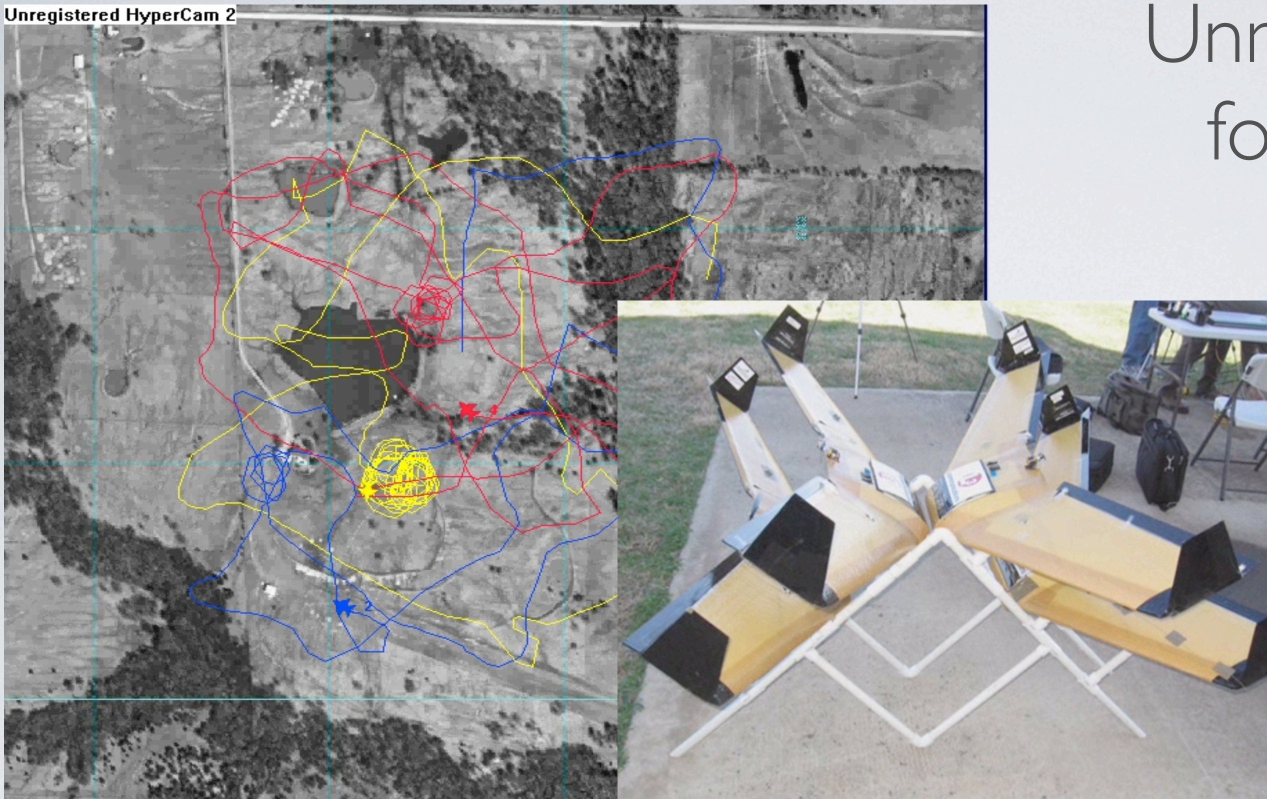
GO INTO THE FIELD

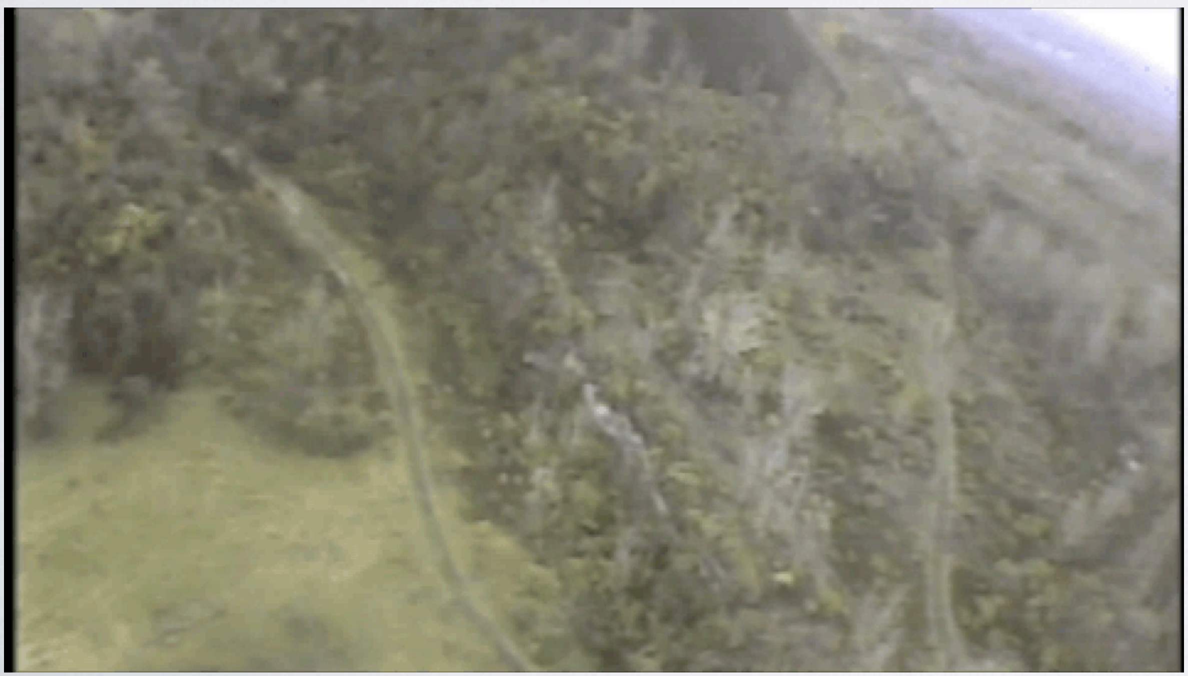
- Take the robots into real environments, let them loose!
  - Prioritize research challenges
- Field is not necessarily harder
  - Sometimes it lets you throw away overly broad assumptions
  - Design something that works in at least one place

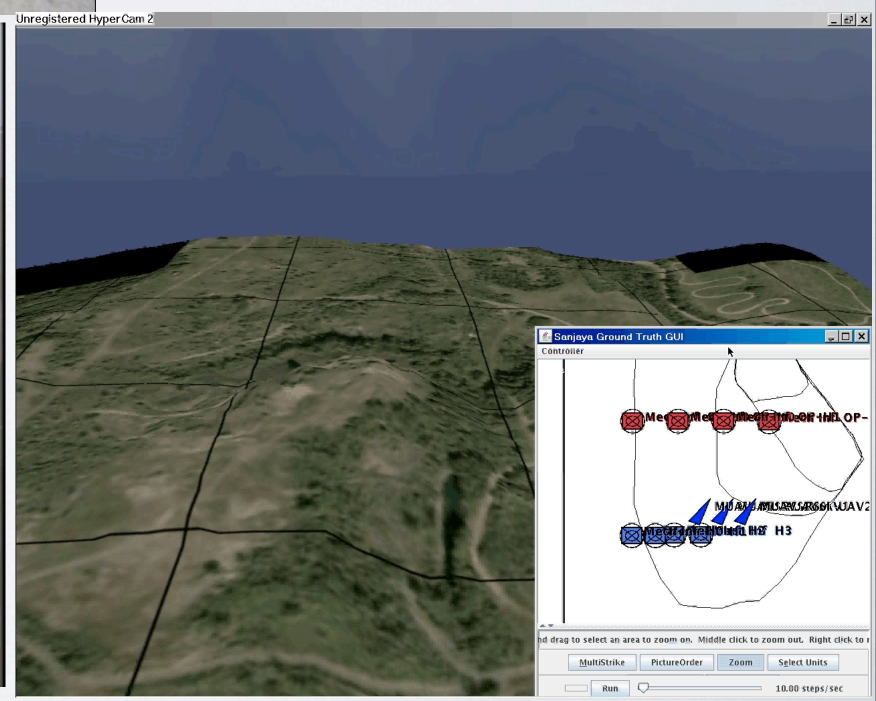
BIG TEAMS

- Once we have one reliable robot, having many is easily possible
  - Prices will fall precipitously
- Allow: Temporal, spatial, vigilance, redundancy, reactive
- Not swarms
  - Not necessary, not obviously useful for information collection

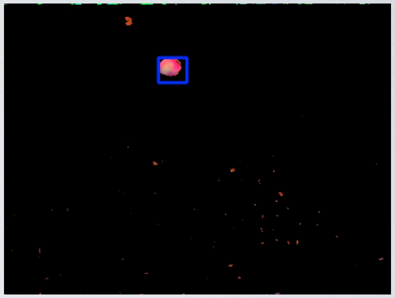
Unmanned aircraft looking for radio signals or lost hikers or cows

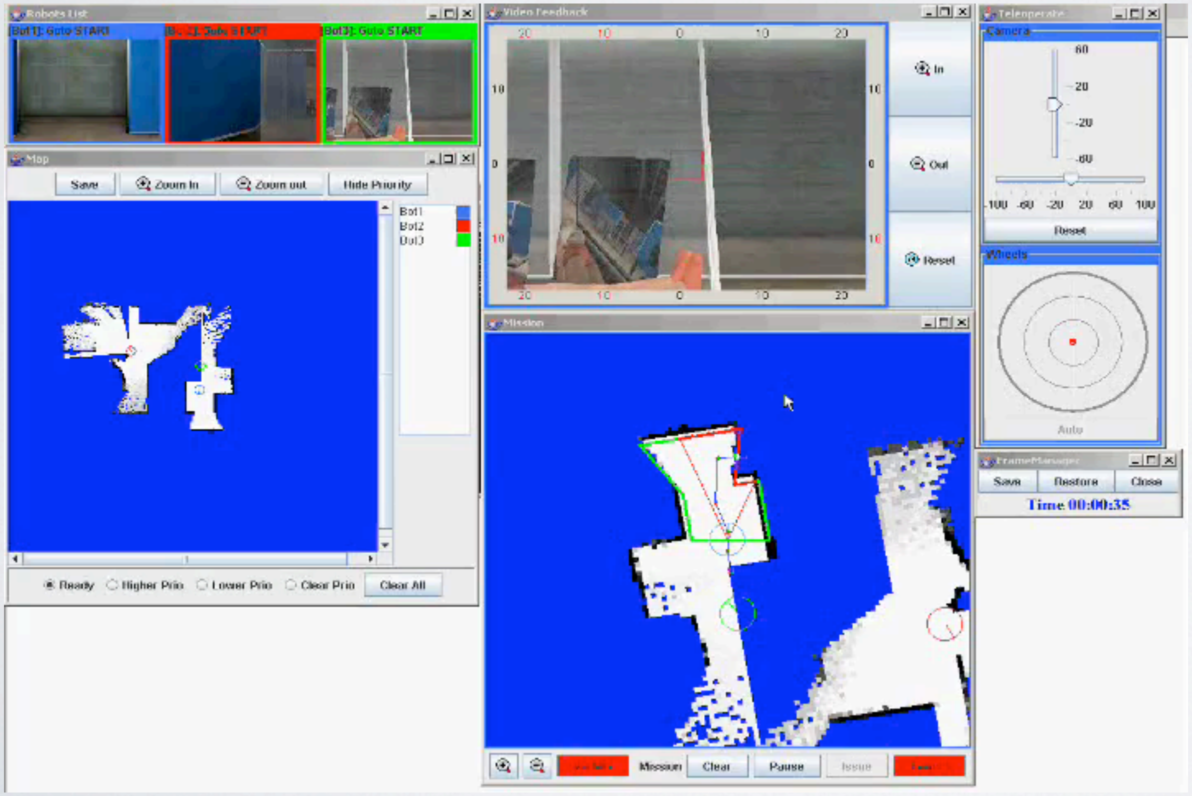






Robot looking for a dog toy





TOO MUCH TIME SPENT MAKING ROBOTS WORK

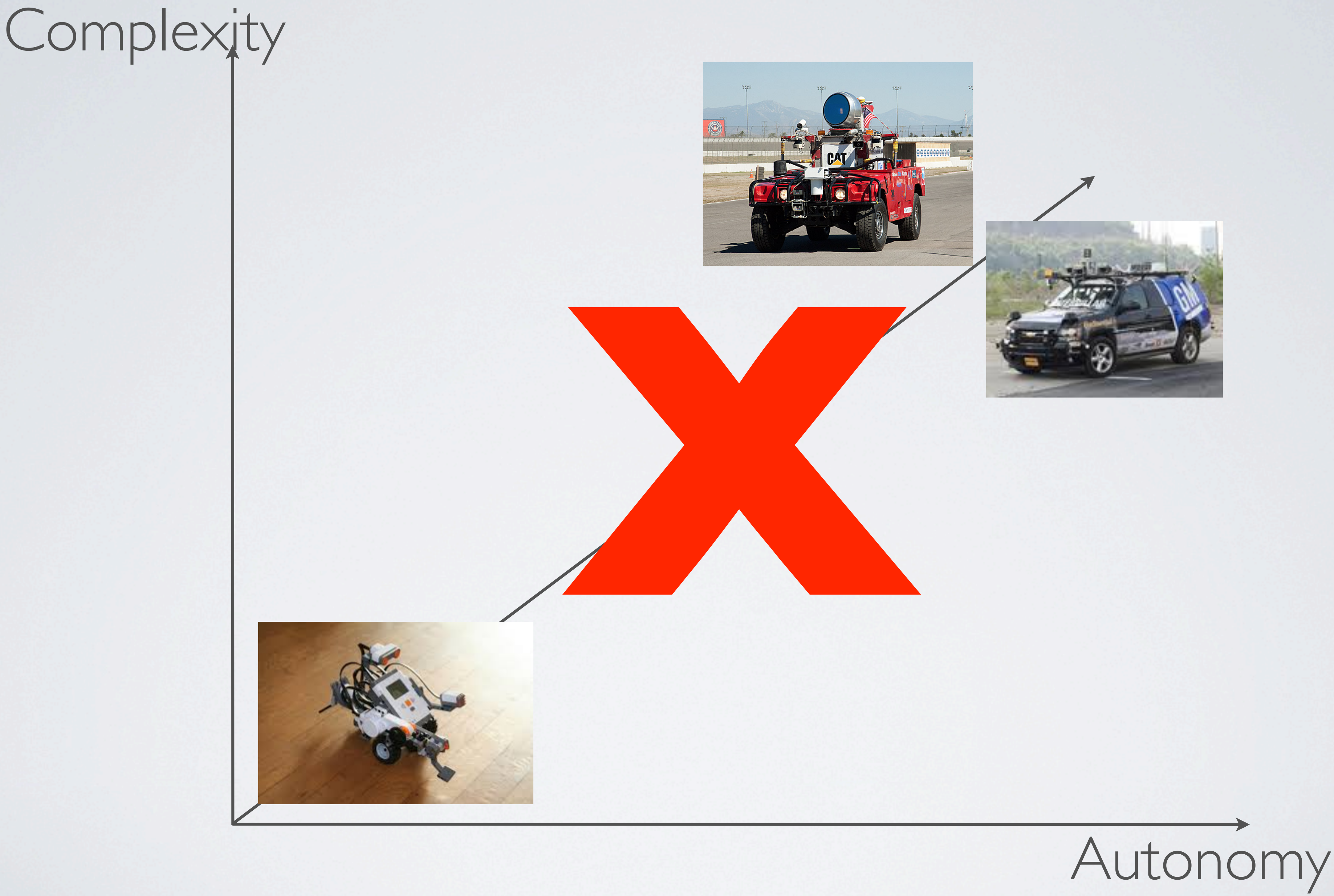
NOT ENOUGH TIME ON APPLICATION AND COORDINATION ISSUES

NEED TO BE TOO CAREFUL

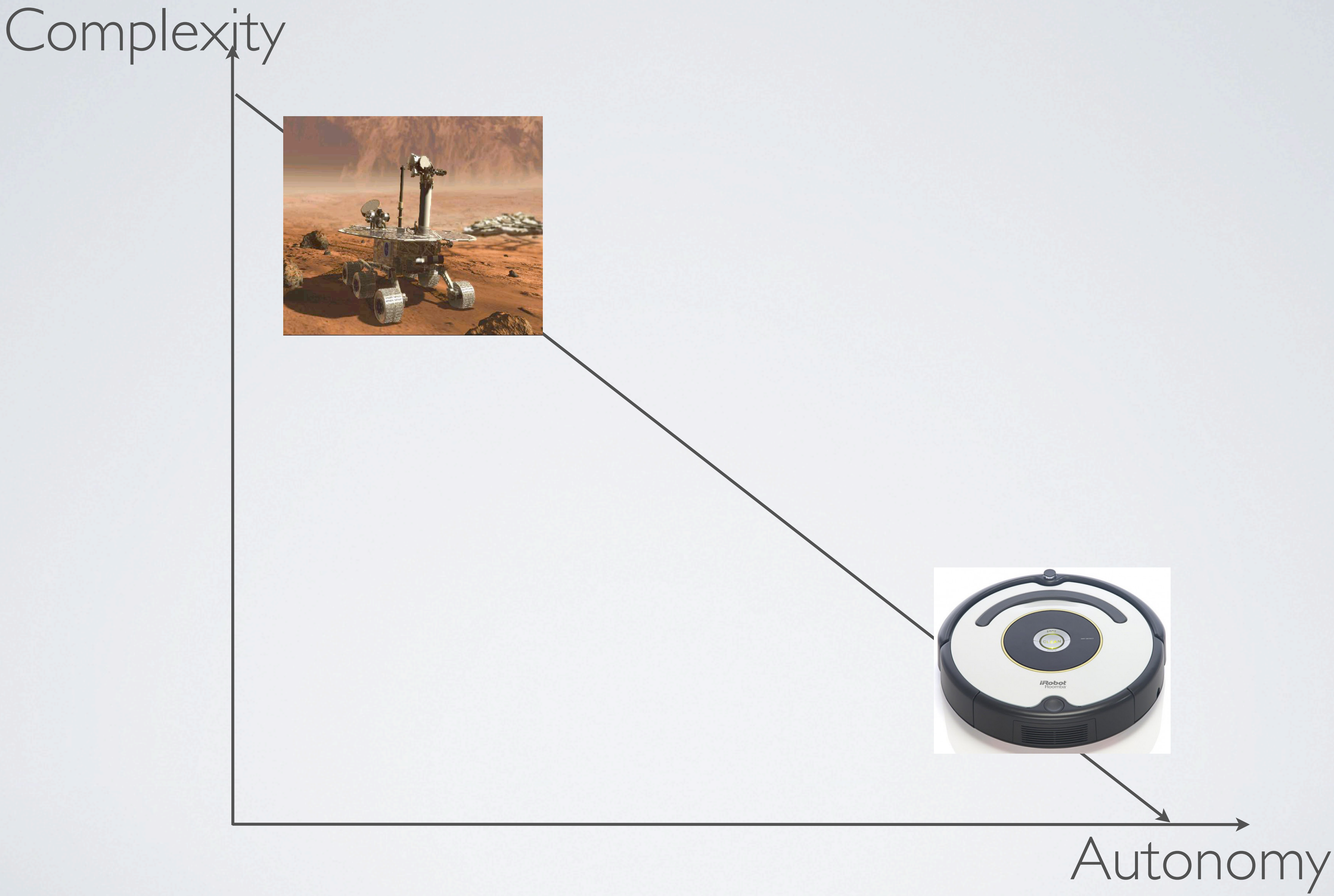
GOING INTO THE FIELD WITH A DIFFERENT ATTITUDE

- Let's lose some robots
  - Safe, unbreakable or don't care
- Let's go every day
  - One or two students
- Let's do the <u>first</u> test of an algorithm in the field

Rod Brooks



Rod Brooks




HIGH

PROBLEM

- Large areas get flooded every year
  - Often poor countries with few resources
- First responders struggle with:
  - Dirty, dangerous water difficult to get around
  - Victims spread over very large area
- AIM: Identify victims, either get help or send urgent emergency supplies

ROBOT BOATS

- Robust, safe
- Low-cost
- Easy to deploy
- Simple regulation issues
- Robotic technology is easy

- Lots of water, lots of boats make sense
  - Even densely
- Sparse knowledge of water
- Complex spatial, temporal processes
- Relatively hard and expensive for people

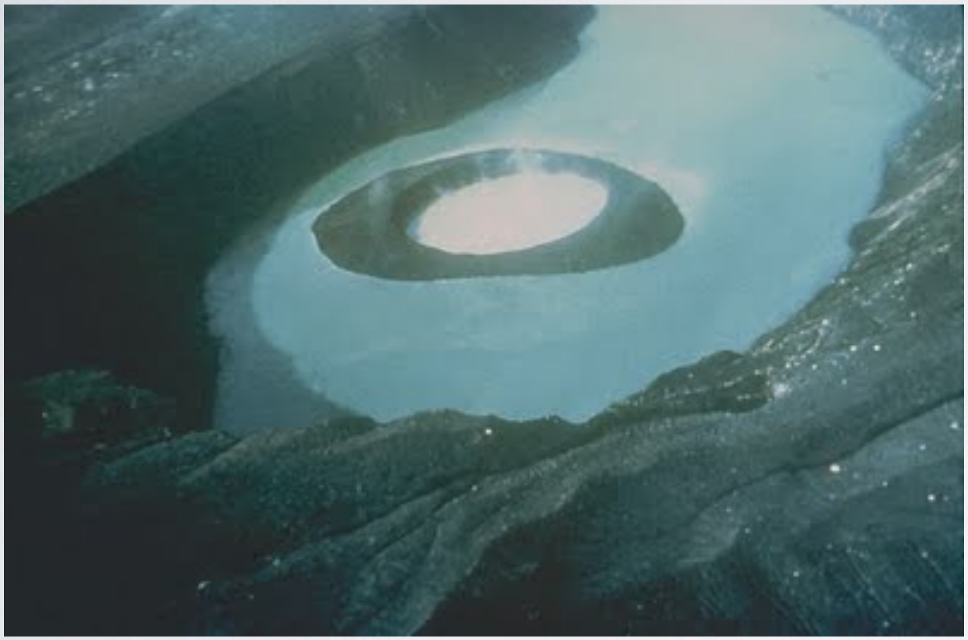
ROBOTIC BOATS: BEEN DONE ... NOT HARD


THE
ROBOTICS
INSTITUTE

PHILIPPINES

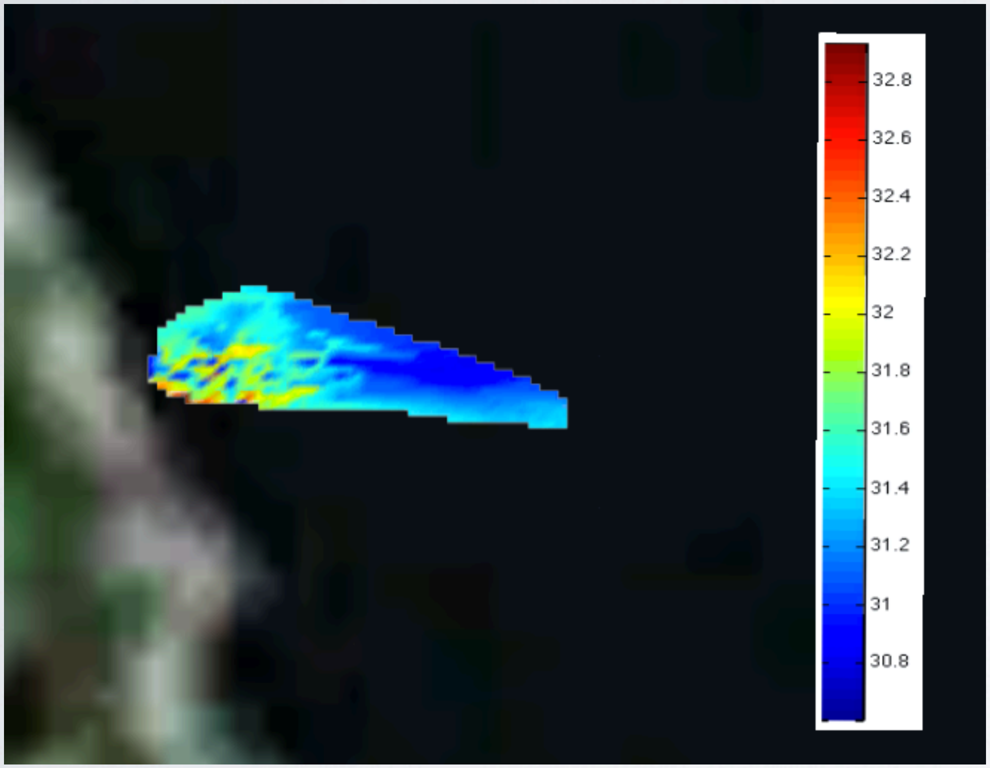
Taken from boat

LAKE TAAL FISH FARM

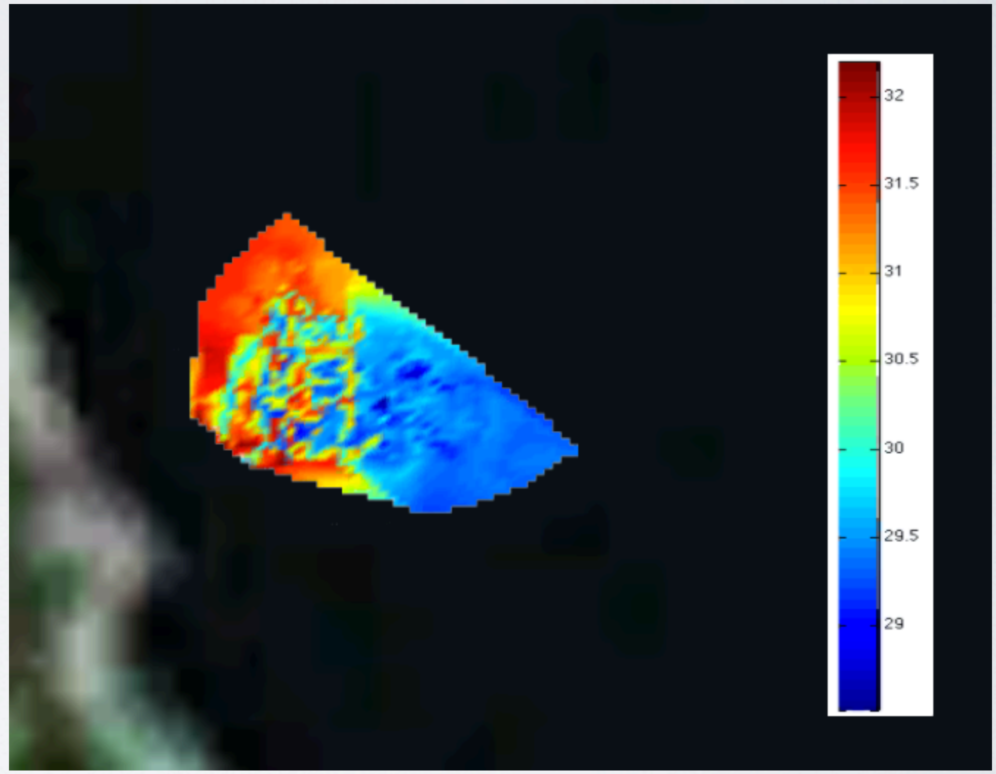


$1.5M dead fish, due to an unanticipated drop in oxygen levels (the fish drowned)

WATER TEMPERATURE IN LAKE TAAL



Before rain



After rain


Vegetation mapping
Education
Archeology
Nursery
Fish farm
Large area monitoring
Shrimp
Sea cucumbers
Pollution
Buoy monitoring
Research
Floods
Oil well monitoring
Hippos
Logging
Estuary monitoring
Fishing
Mine water
ARCTIC OCEAN
Greenland
Svalbard (Nor.)
Russia
Iceland
Norway
Sweden
Finland
Estonia
China
Algeria
Libya
Egypt
Western Sahara
Saudi Arabia
Iran
Brazil
Paraguay
Uruguay
Argentina
French Guiana
ATLANTIC
OCEAN
Australia
Madagascar
South Africa
Philippines
Papua New Guinea

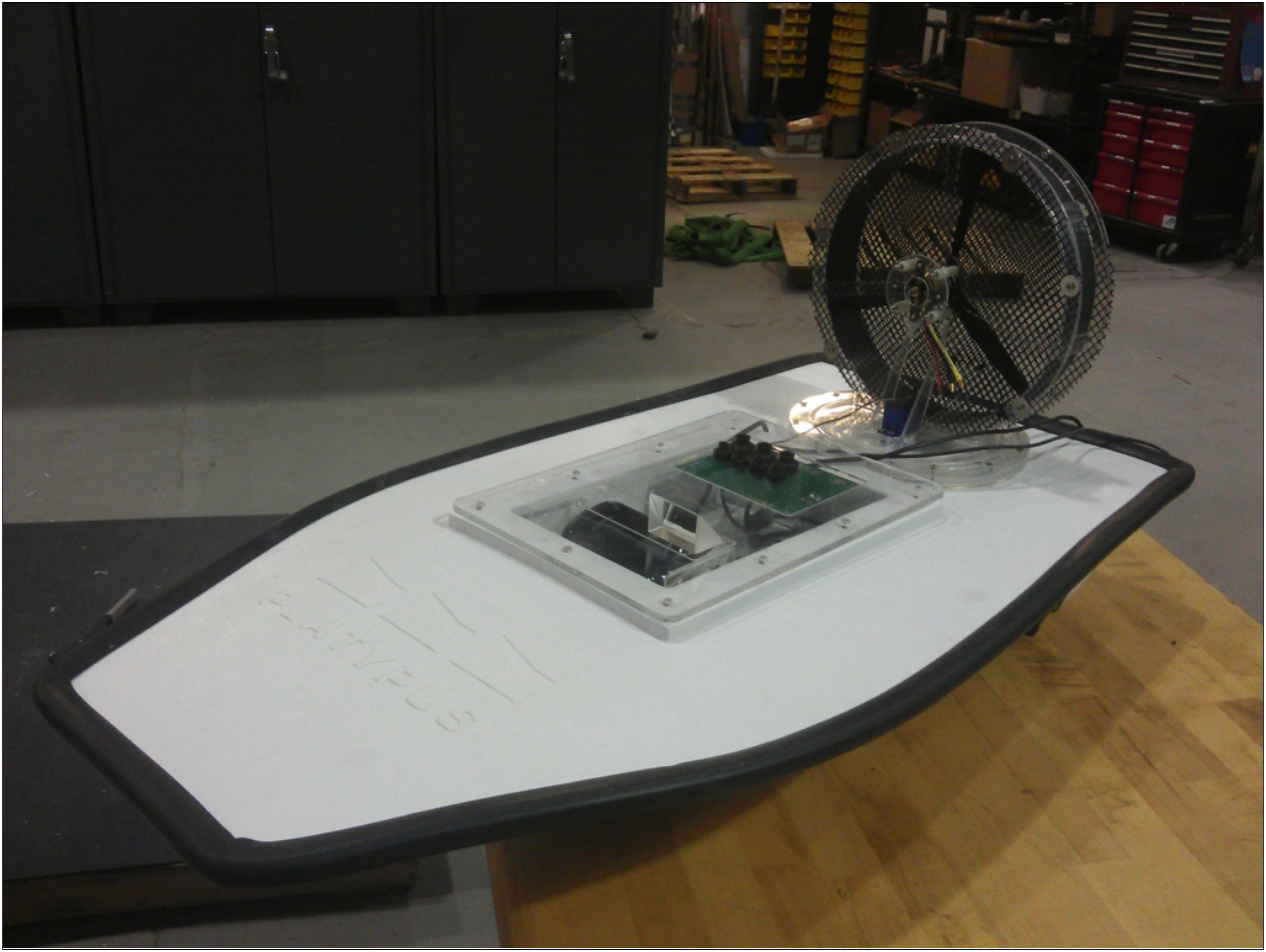
TEAMS OF ROBOT BOATS:

- INTERESTING DOMAIN
- GOOD PLATFORM FOR RESEARCH

✔

HARDWARE CHALLENGES

- Reliability, simplicity
- Stock components
- Extensibility, flexibility and usability
    - Iterative architecture design
- Transportability
- Very low cost
- "Deployability"
- Safety
- Manufacturability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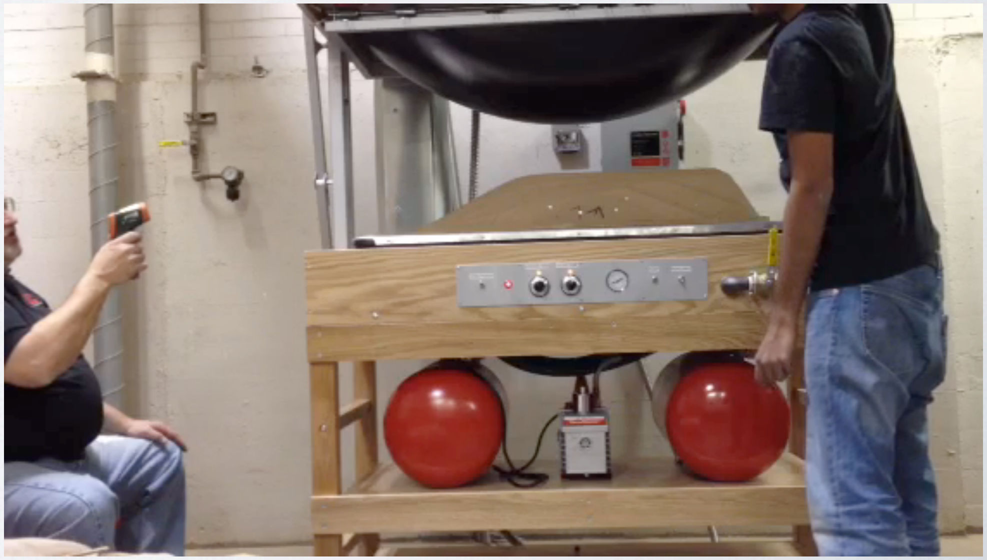
HARDWARE DESIGN

- Airboat design for shallow water, debris
- Two moving parts
- < $2000
- ~10 hours to construct



ANDROID PHONES

GPS

IMU

Computer

Powerful IDEs

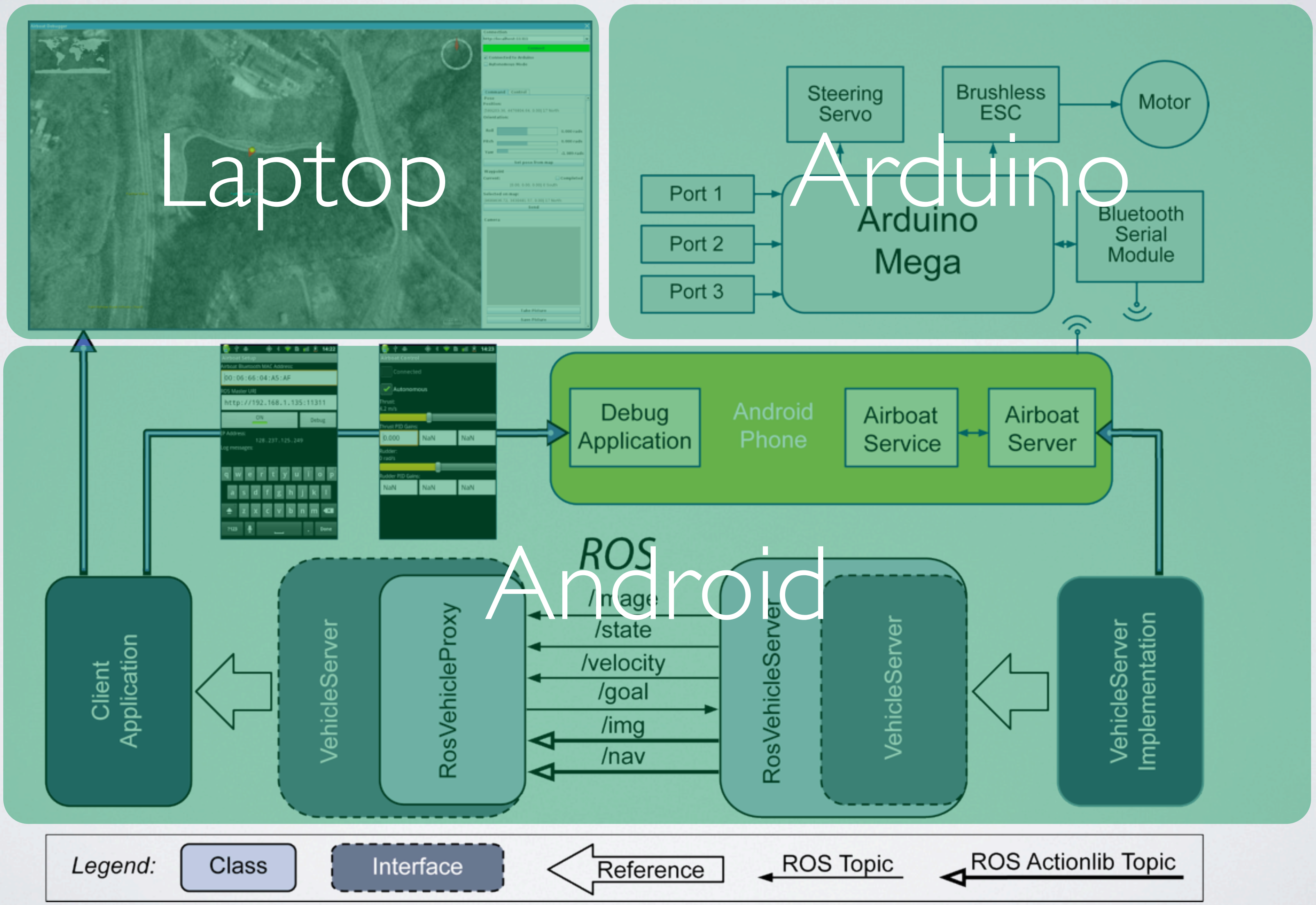
Wireless, 3G

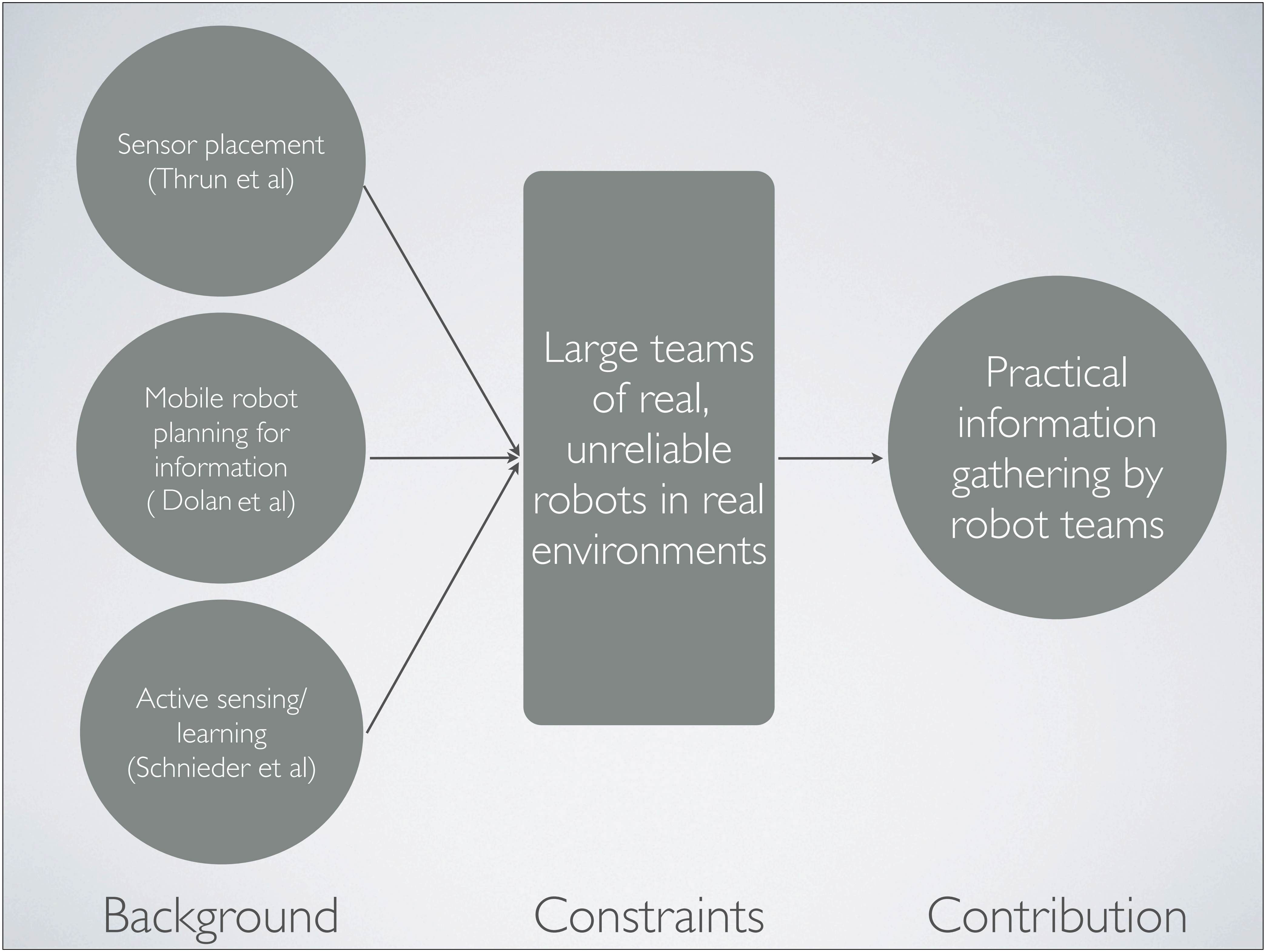
Battery life

Robust

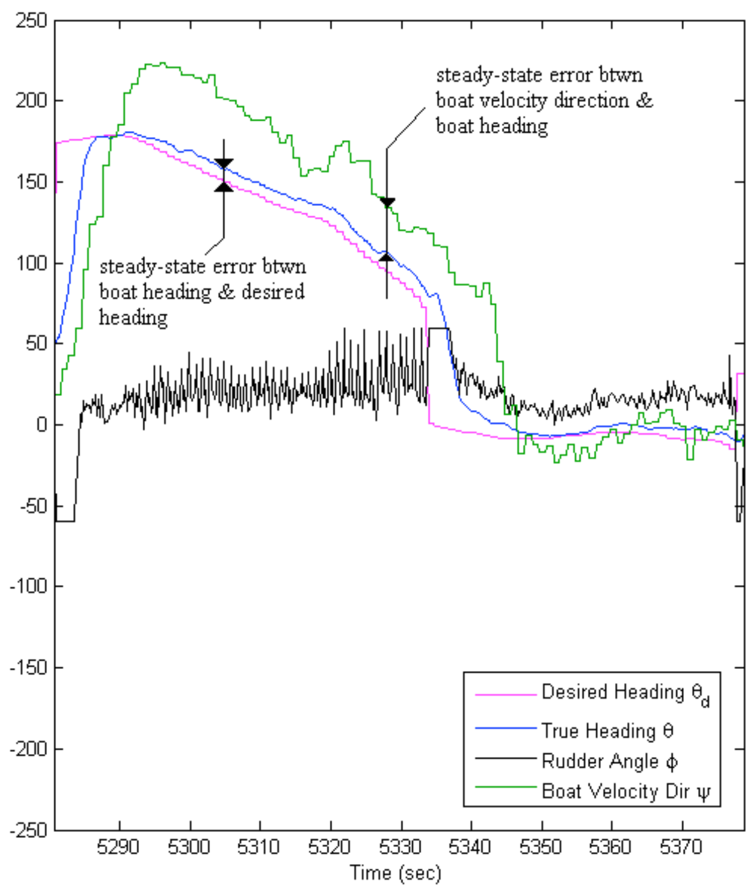
Very low cost

SOFTWARE DESIGN

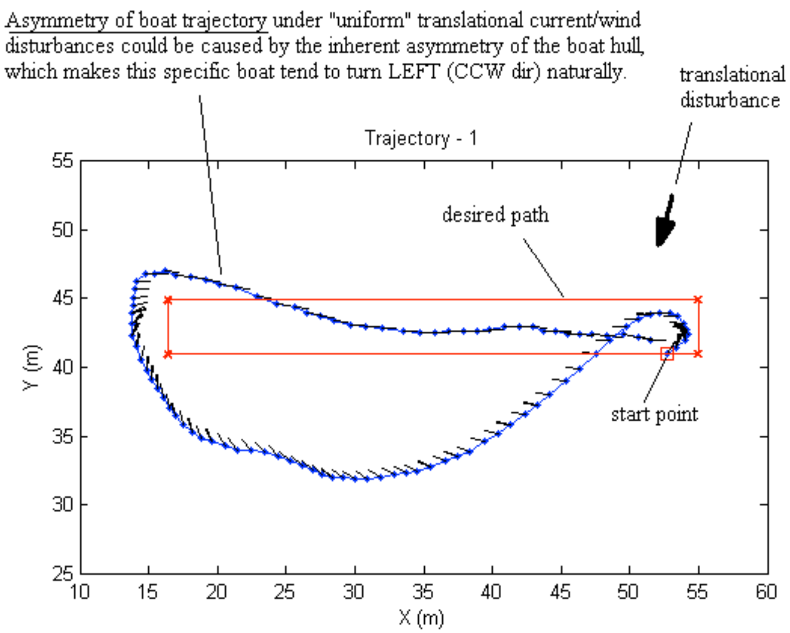



Sensor placement (Thrun et al)
Mobile robot planning for information (Dolan et al)
Active sensing/ learning (Schnieder et al)
Large teams of real, unreliable robots in real environments
Practical information gathering by robot teams
Background
Constraints
Contribution

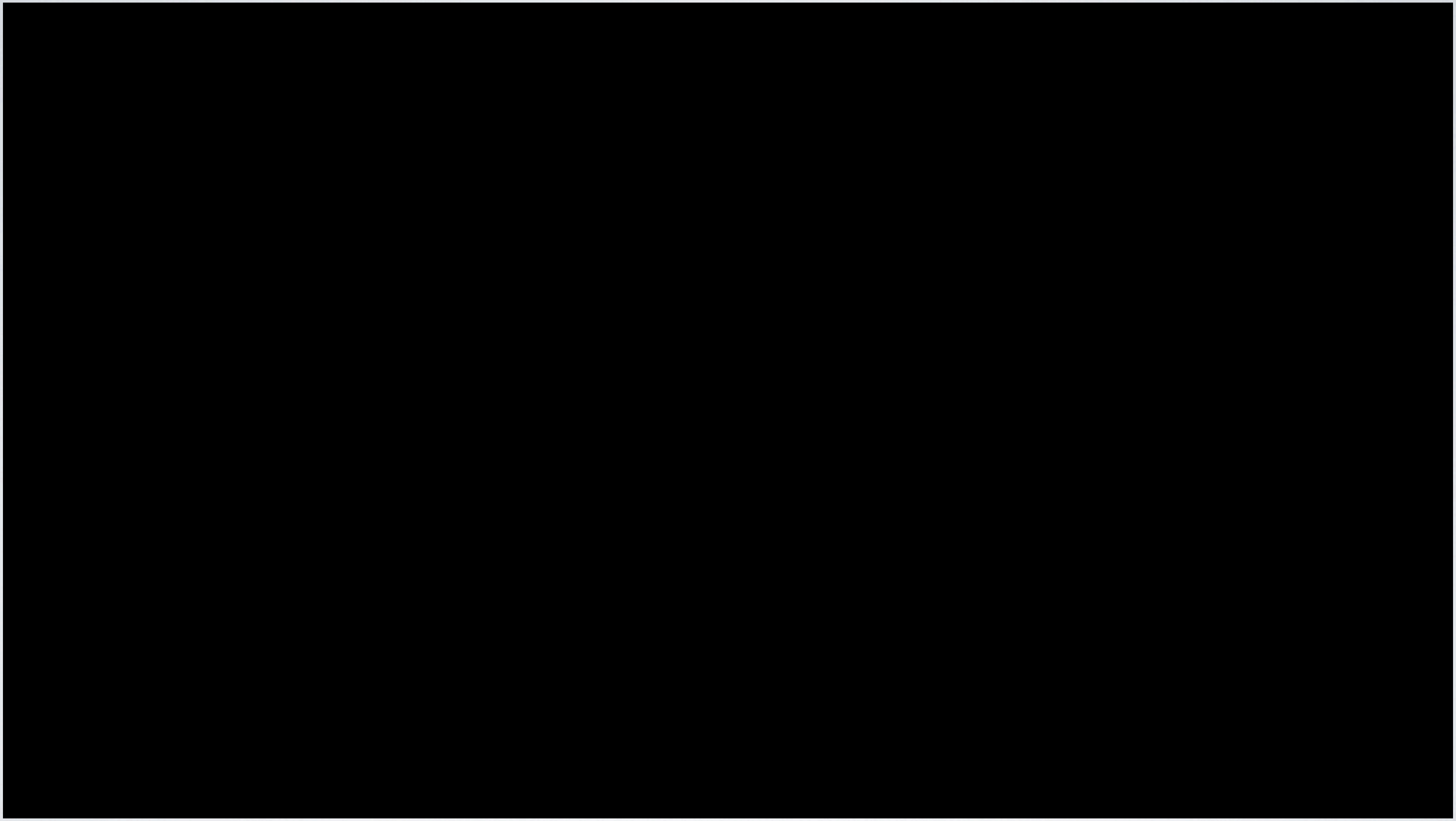
CONTROL



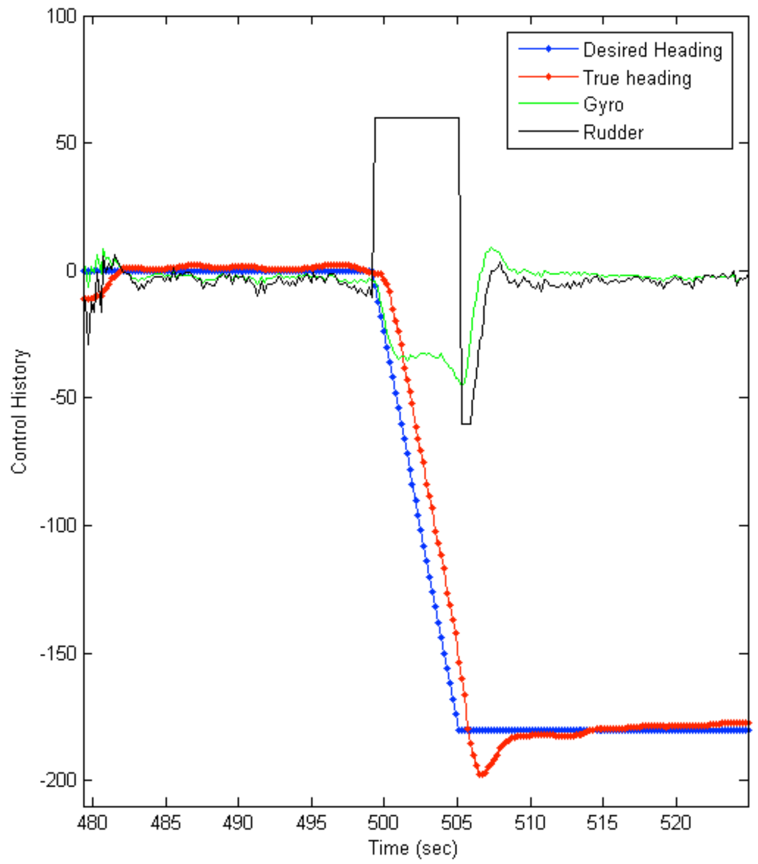
250
200
150
100
50
0
-50
-100
-150
-200
-250
5290
5300
5310
5320
5330
5340
5350
5360
5370
Time (sec)
steady-state error btwn boat velocity direction & boat heading
steady-state error btwn boat heading & desired heading
Desired Heading θd
True Heading θ
Rudder Angle ϕ
Boat Velocity Dir ψ

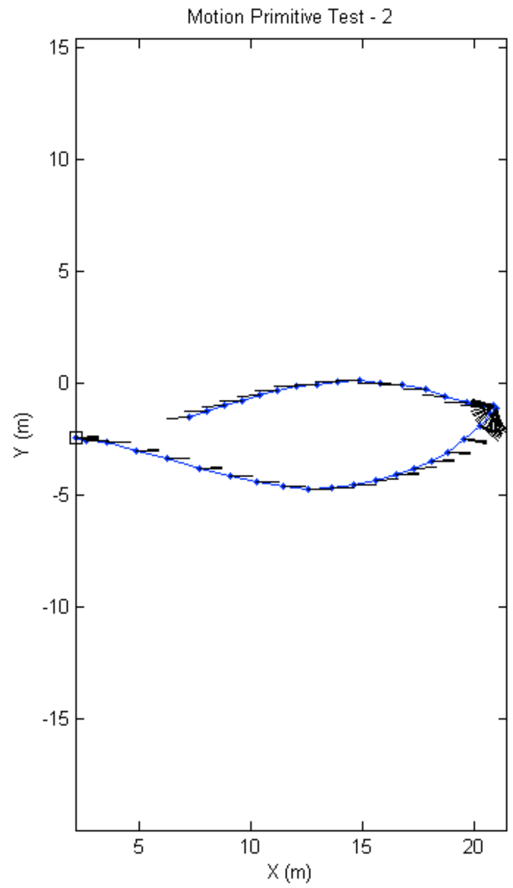


Asymmetry of boat trajectory under "uniform" translational current/wind disturbances could be caused by the inherent asymmetry of the boat hull, which makes this specific boat tend to turn LEFT (CCW dir) naturally.
translational disturbance
Trajectory - 1
desired path
start point
55
50
45
40
35
30
25
10
15
20
25
30
35
40
45
50
55
60
Y (m)
X (m)

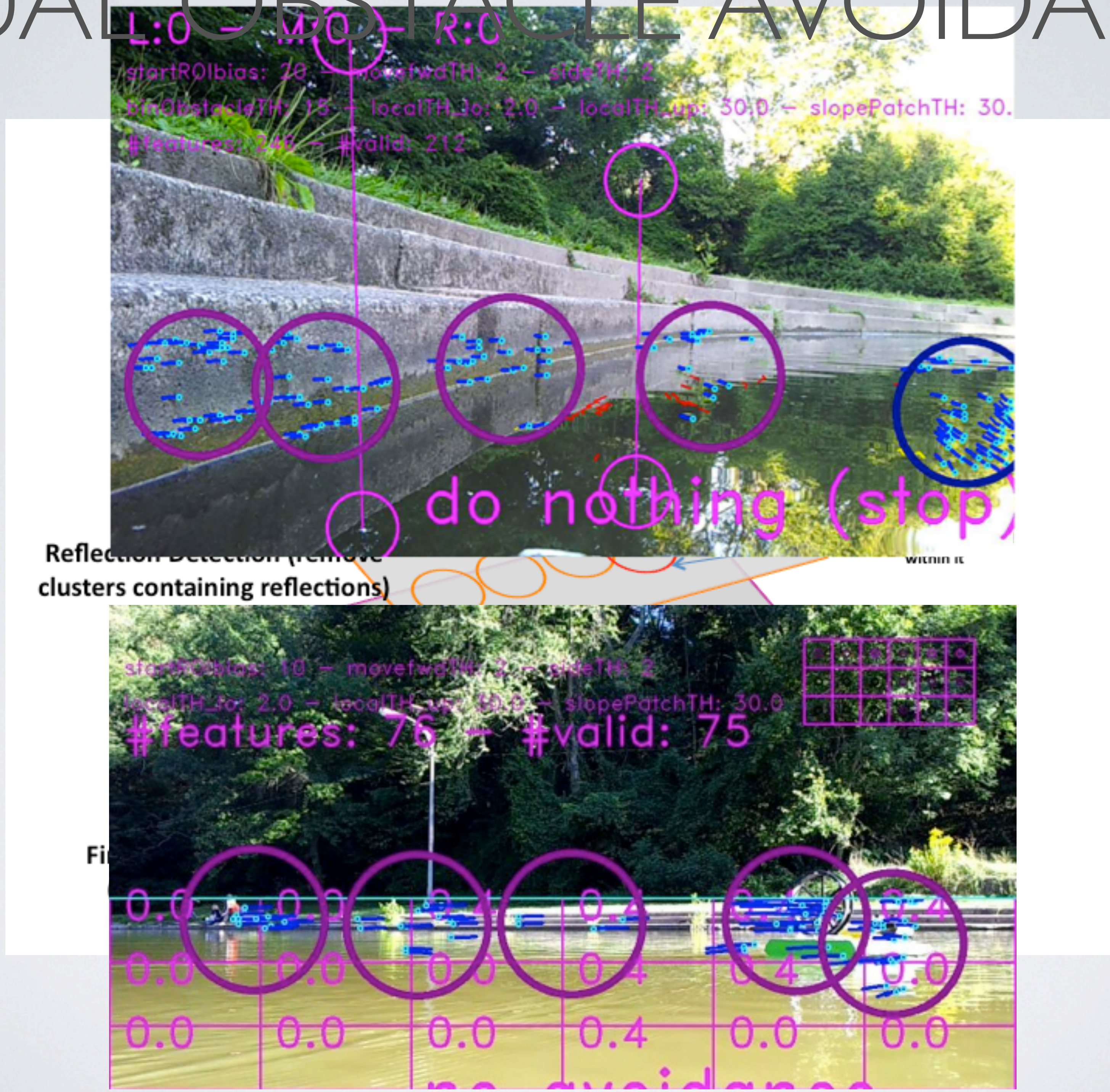


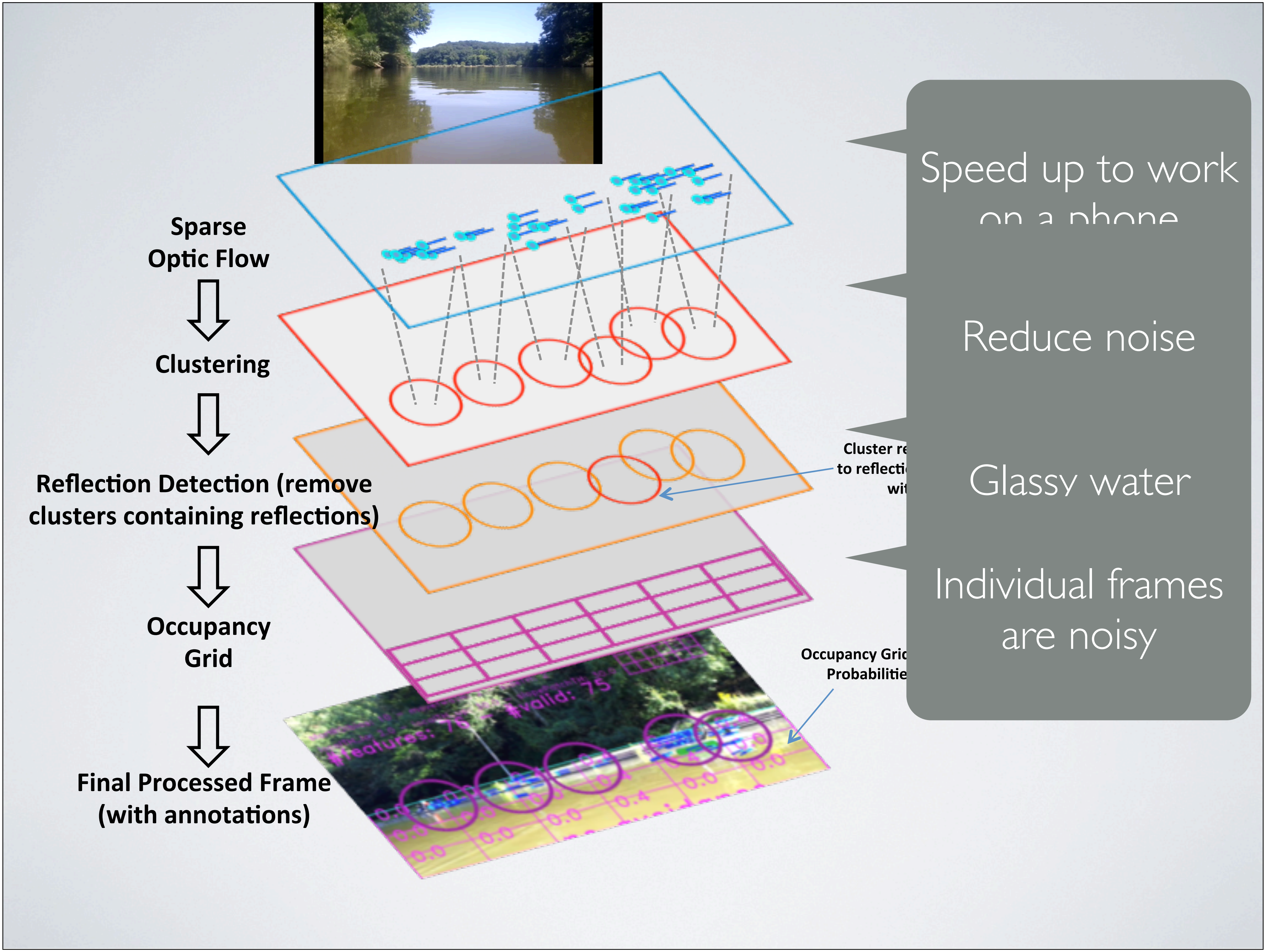
MOTION PRIMITIVES





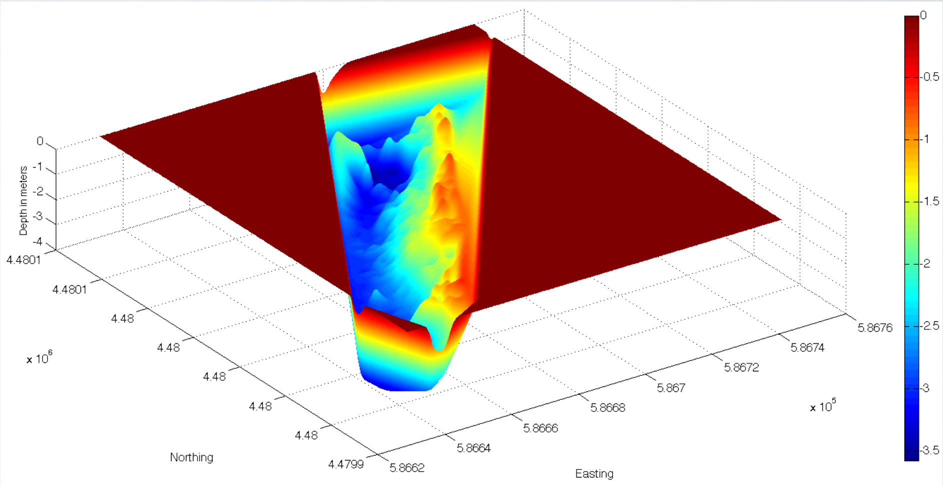
VISUAL OBSTACLE AVOIDANCE

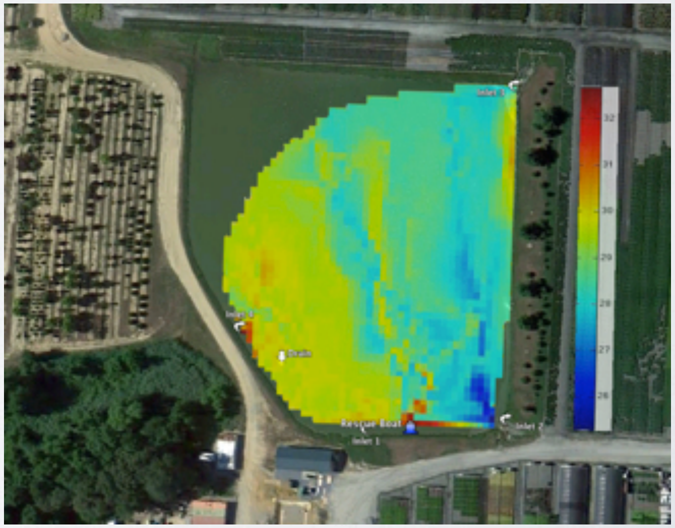



Sparse
Optic Flow
Clustering
Reflection Detection (remove clusters containing reflections)
Occupancy
Grid
Final Processed Frame
(with annotations)
Speed up to work
Reduce noise
Glassy water
Individual frames
are noisy

SENSING WATER

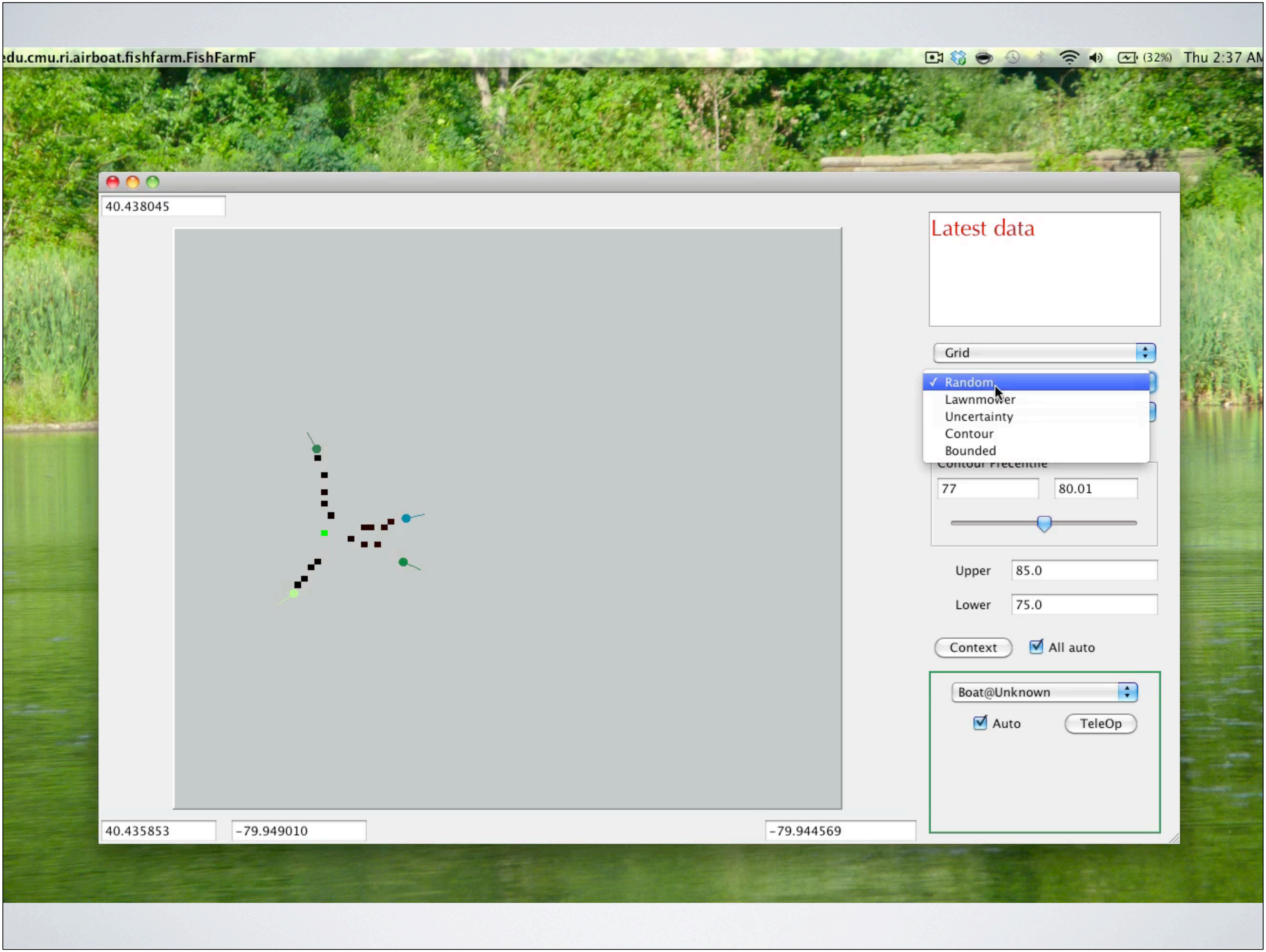
- Complete map
- Level set
- Event
- Maximum/minimum



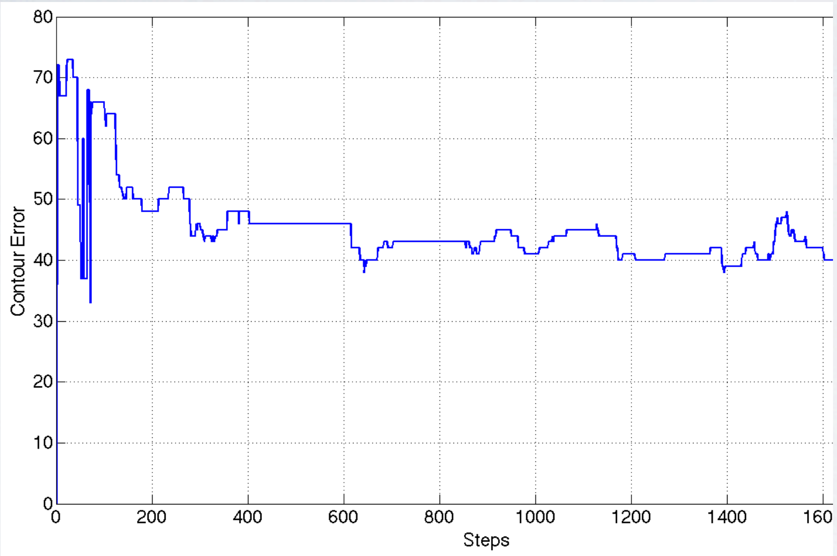


WHAT SENSORS?

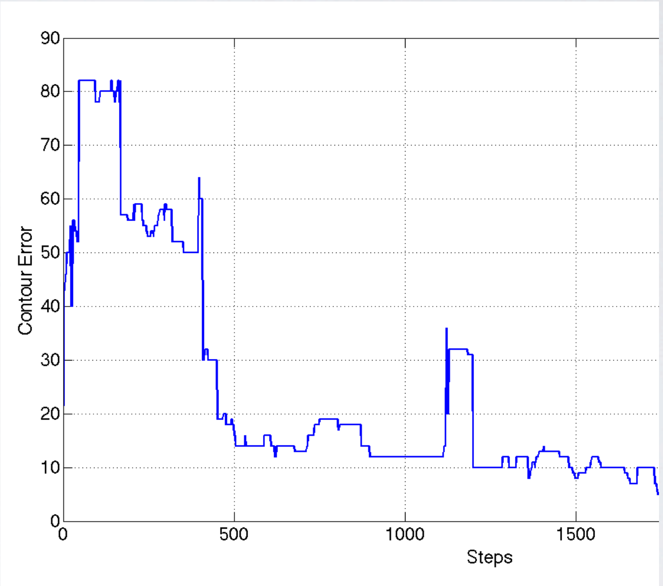
- Camera
- Ph, temperature, oxygen, dissolved solids, bromide
- Depth, currents, vegetation


edu.cmu.ri.airboat.fishfarm.FishFarmF
(32%) Thu 2:37 AM
40.438045
Latest data
Grid
✓ Random
Lawnmower
Uncertainty
Contour
Bounded
77
80.01
Upper
85.0
Lower
75.0
Context
All auto
Boat@Unknown
Auto
TeleOp
40.435853
-79.949010
-79.944569

EXAMPLE MODEL ERROR

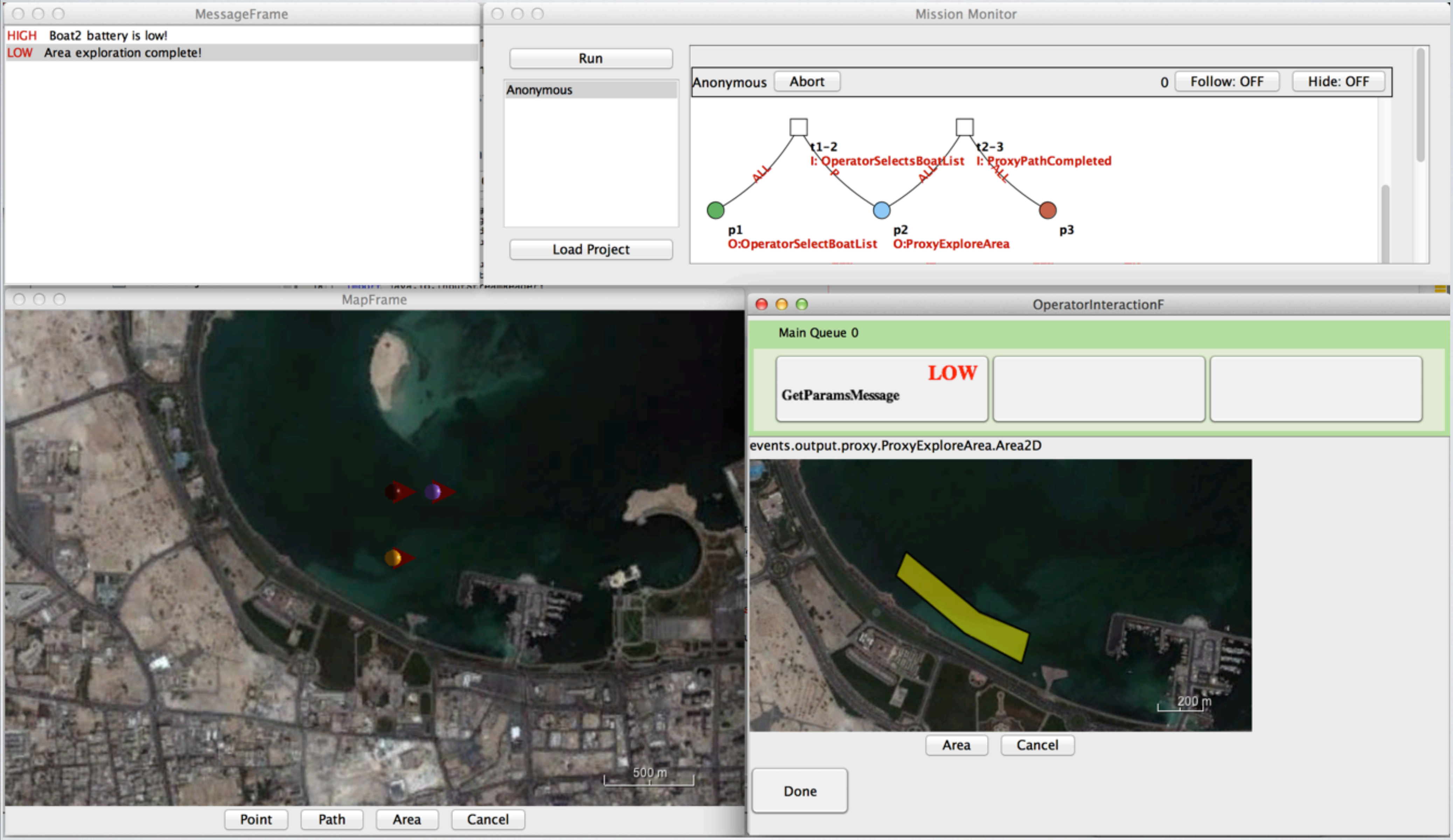


One boat



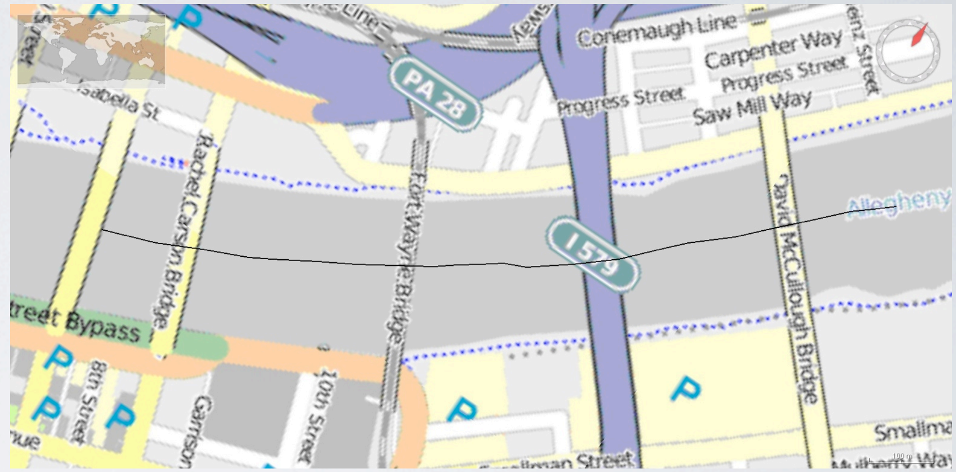
Four boats

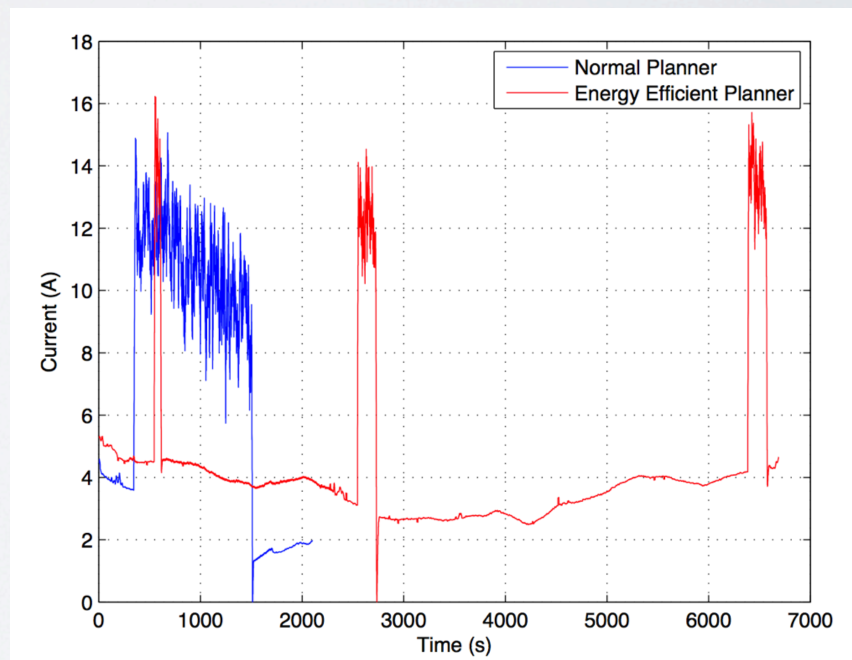
User Interaction



GOING FORWARD:
LONG TERM OPERATION

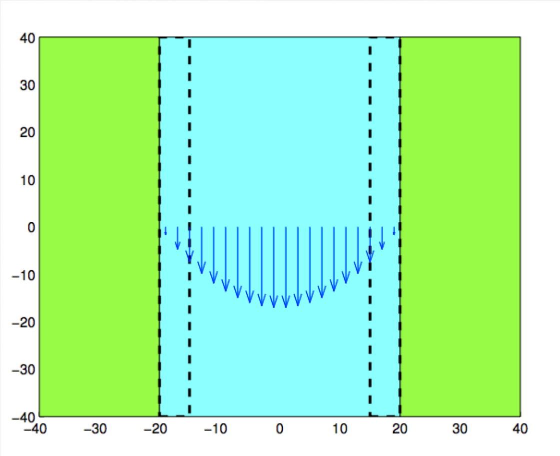
USING CURRENTS



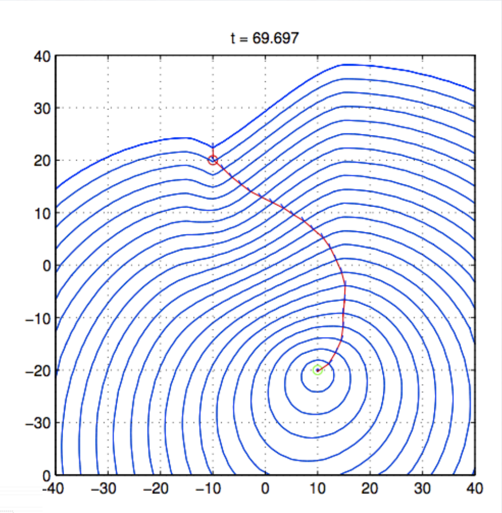


- Travel long distances by using the current, not the engine
- 1. Find river on map
- 2. Go to middle of river
- 3. Turn off motor

PLAN TO AVOID CURRENTS

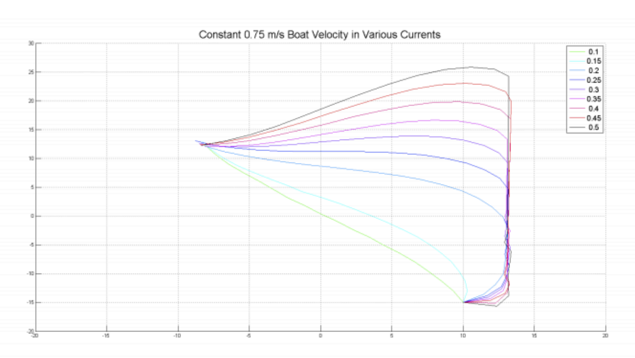


- May plan to avoid currents when going against



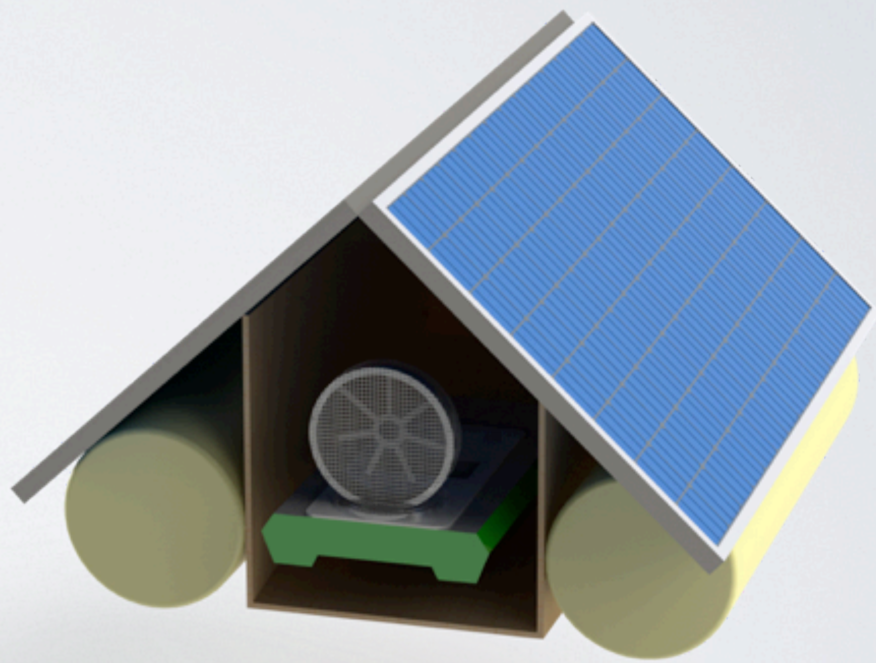
- Straight line might not be the most efficient

- Use level set expansion to plan



RECHARGE STATION

- Allow long-term deployment, daily monitoring
- Two stations near locations impacted by storm water runoff
  - Soon!
- Great AI challenges
  - (with Mel Siegel)



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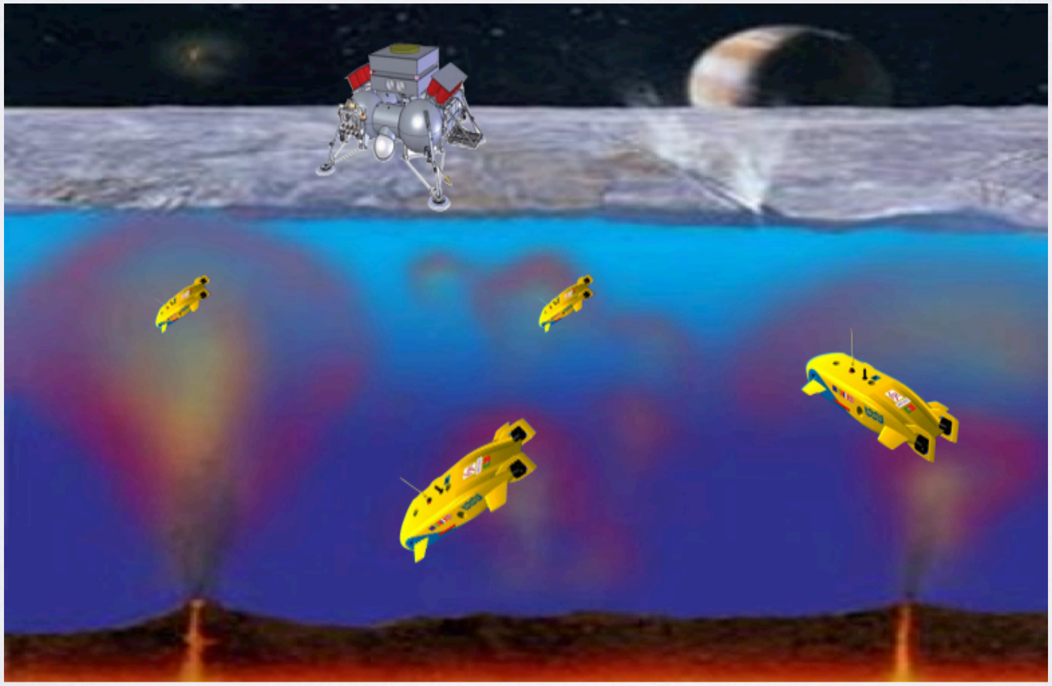
WHAT HAVE WE LEARNED?

- Current technology is useful
  - I.e., Alex's "Remaining Years R&D for Essential Capabilities" is misleading
- We don't know the killer apps
- Business pressures are different (should we care?)
- Design, build, test, transport, train, use, repair, repurpose
  - We typically only care about first two, is that right?

CONCLUSIONS

- Robotic boats are a great platform for multi-robot research
- Information collection is a high-complexity AI challenge
  - Just scratching the surface



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