A multi-modal approach for coral reef data collection

Gregory Dudek,
Natasha Dudek, Katrine Turgeon
Junaed Sattar, Florian Shkurti,
Chris Prahacs, Anqi Xu, Yiannis Rekleitis,
Malika Meghjani.

McGill University

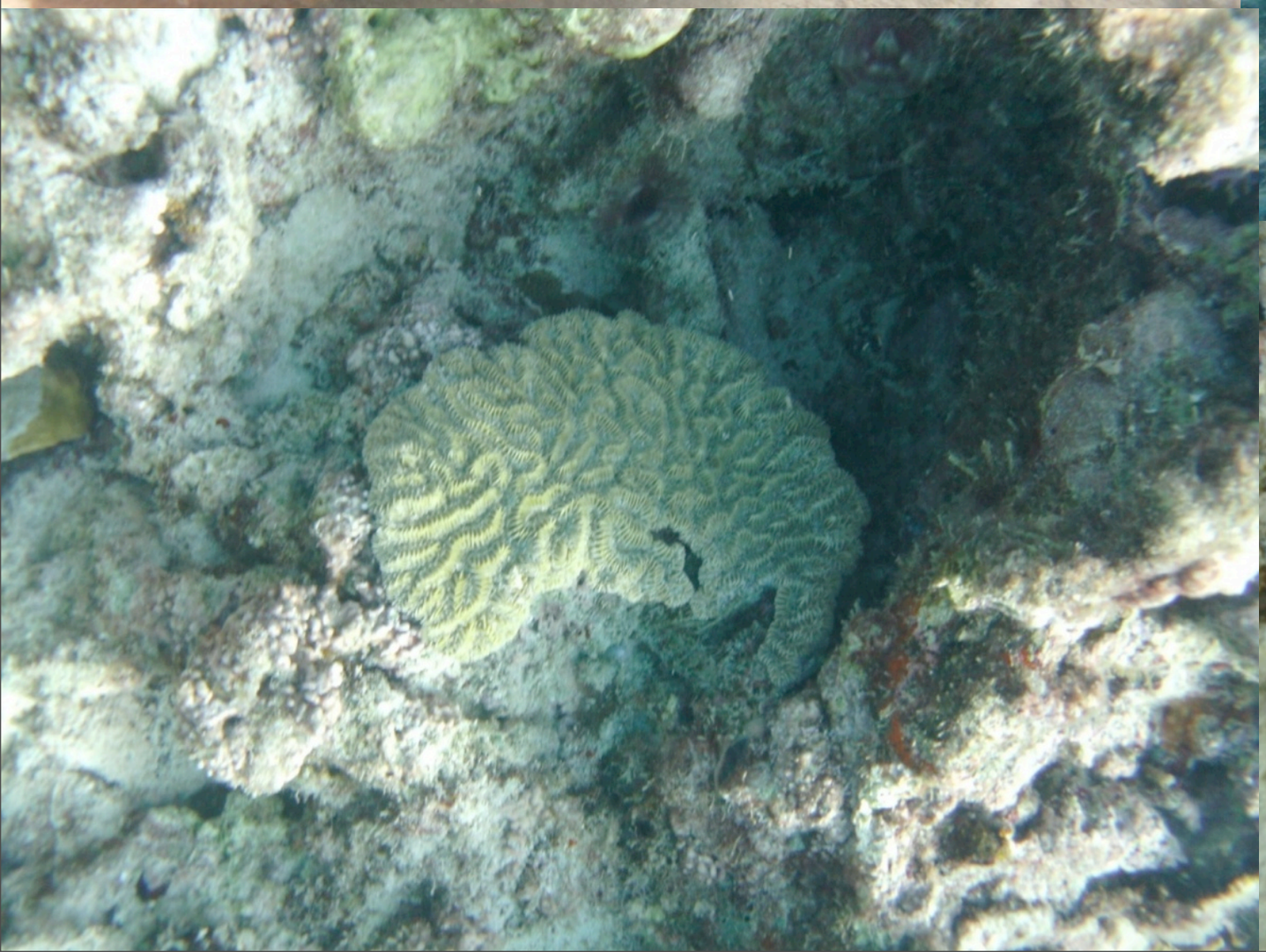
Acknowledgements to many participants.

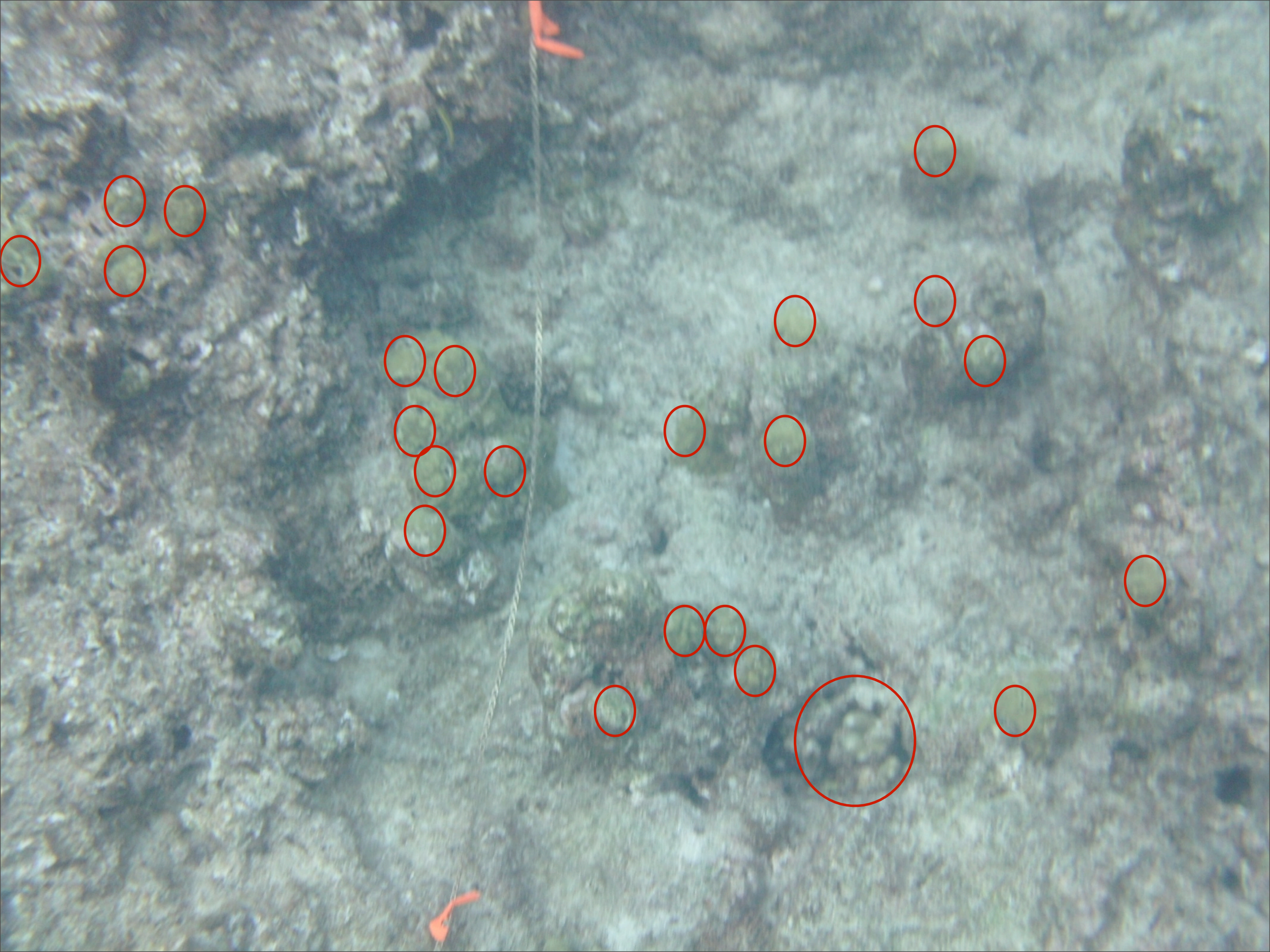
Outline

- Project overview
- Human-robot interaction underwater
- Robot-UAV coordination
- Robot-boat & boat-UAV interaction
- Conclusion

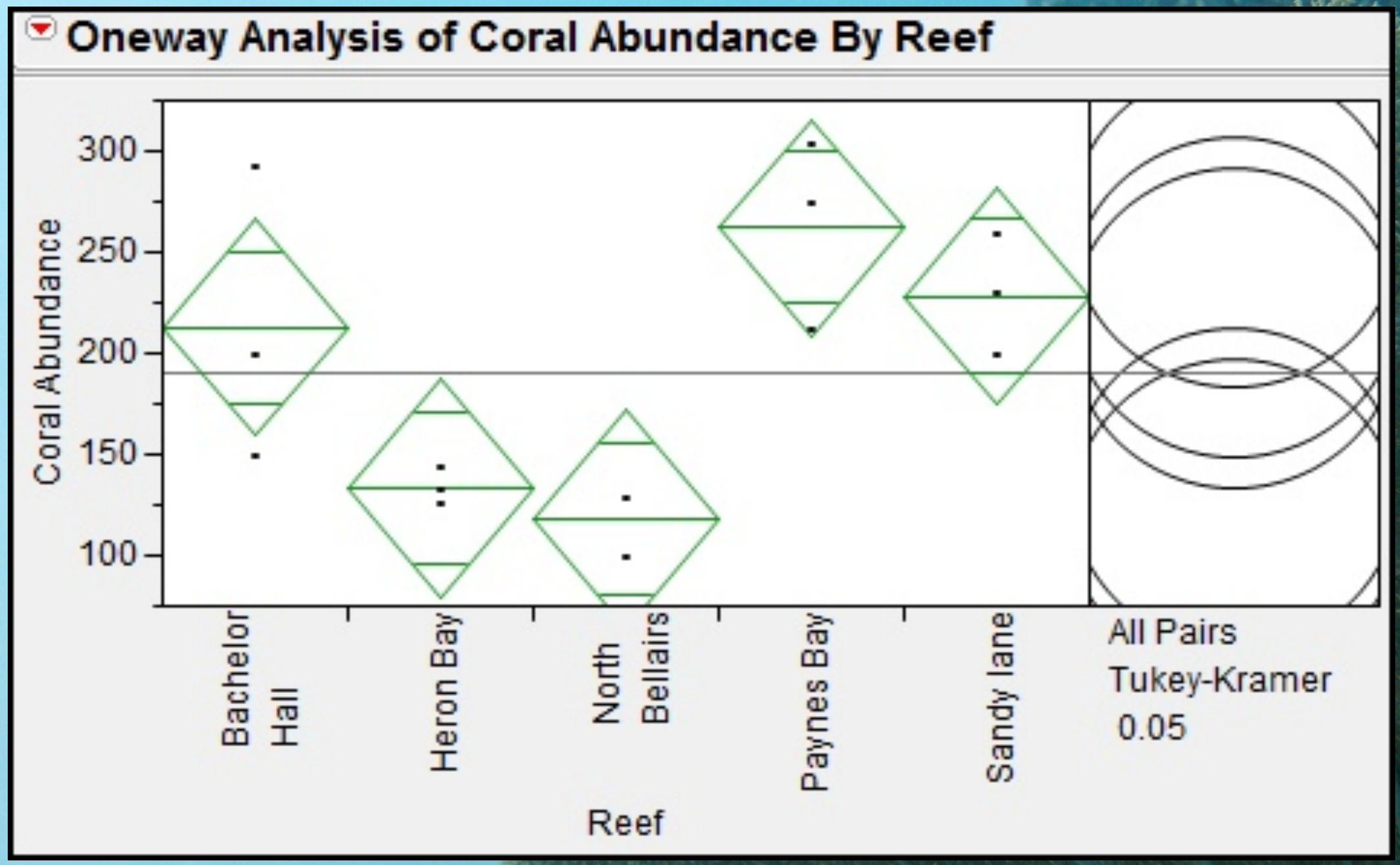
Typical data collection objective

- 5 Reefs, multiple transects per reef
- 20x1m transects
- Transects 20 m apart
- Count every colony in all transects
- Track depth and location
- Transects typically located in the spur and groove zone of fringing reefs





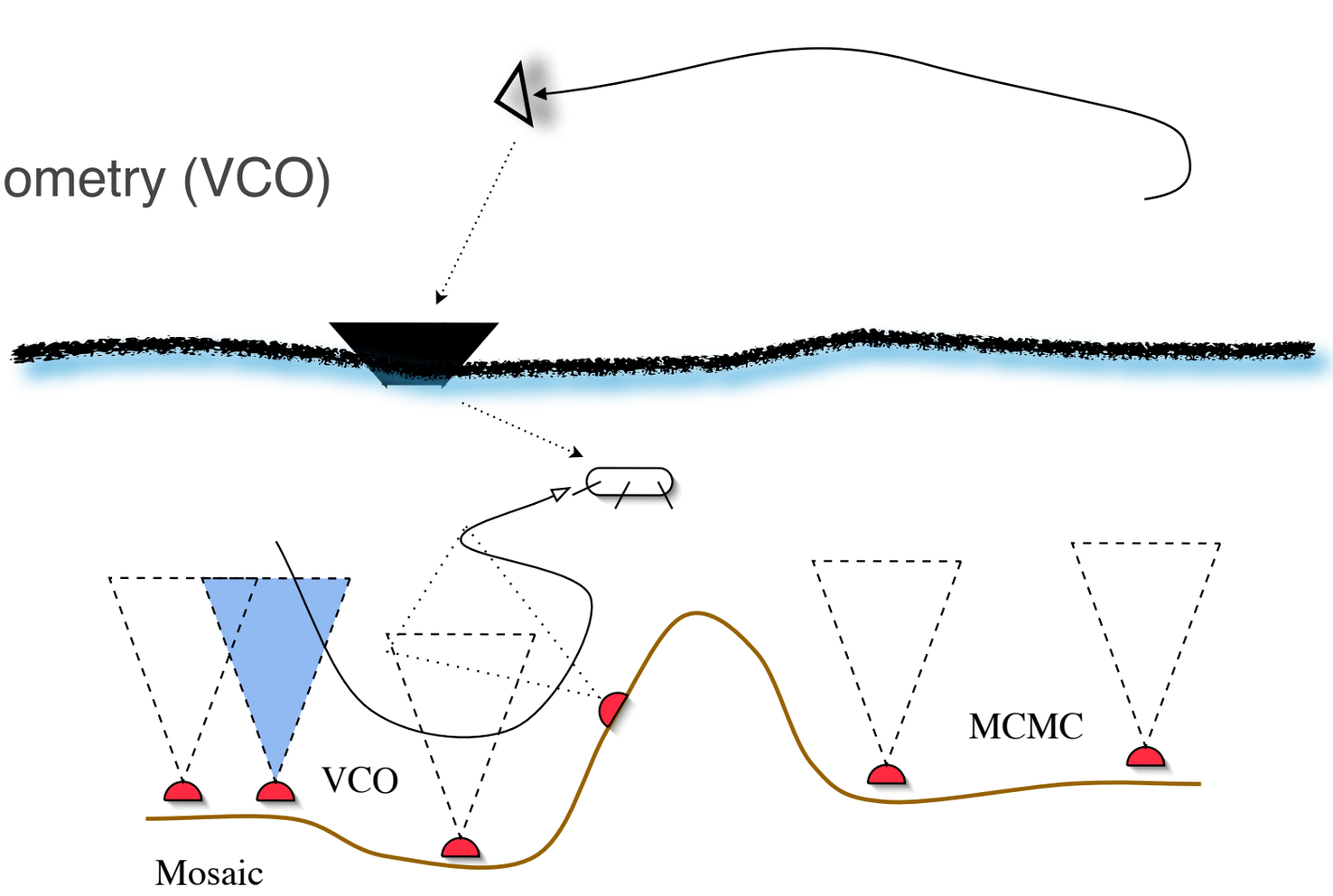
Coral Abundance by Reef



P=0.0067

Vehicle/Node network

- Sessile sensor nodes
  - Some close to one another (metric relations)
  - Some well separated (metric or topological relations)
- Moving vehicle(s)
  - Vehicle-carried odometry (VCO)



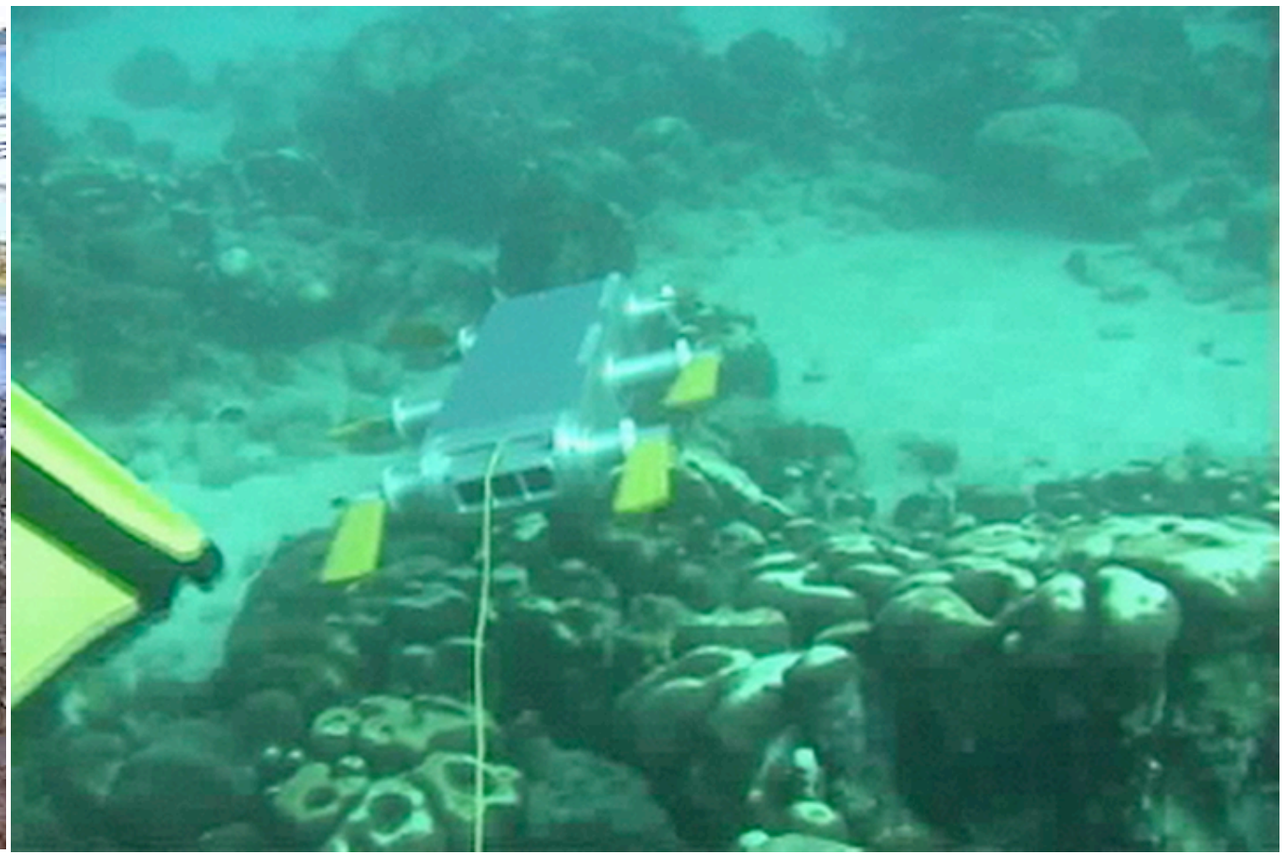
Aqua Vehicle

High-mobility amphibious capability

(descendant of RHEX).

Walking

Swimming



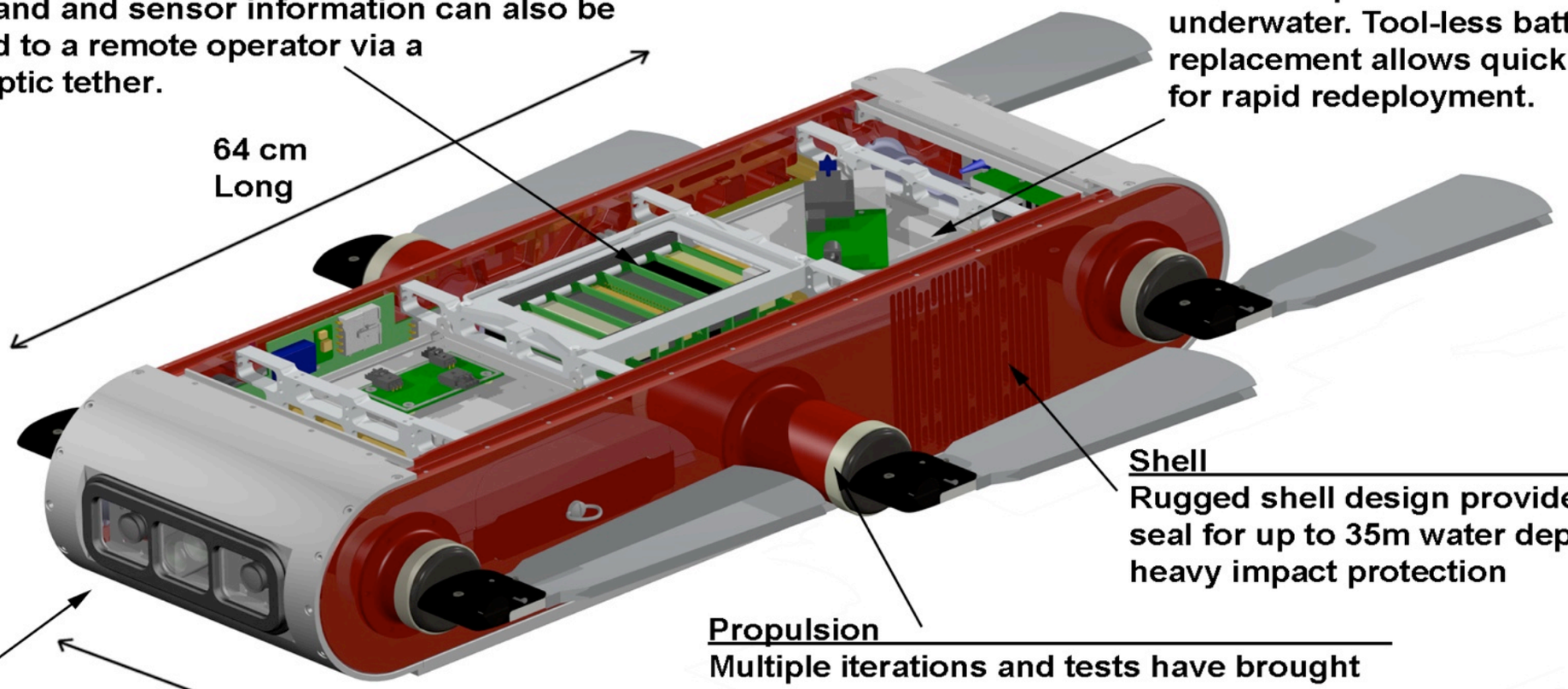
Aqua robots: Overview

Computation

AQUA operates with two Pentium CPU's, one for vision, the other to control its motion. command and sensor information can also be relayed to a remote operator via a fiber optic tether.

Power

Two MIL-spec Li-Ion batteries allow AQUA to operate for over 5 hours underwater. Tool-less battery replacement allows quick swaps for rapid redeployment.



Shell

Rugged shell design provides ample seal for up to 35m water depth and heavy impact protection

Propulsion

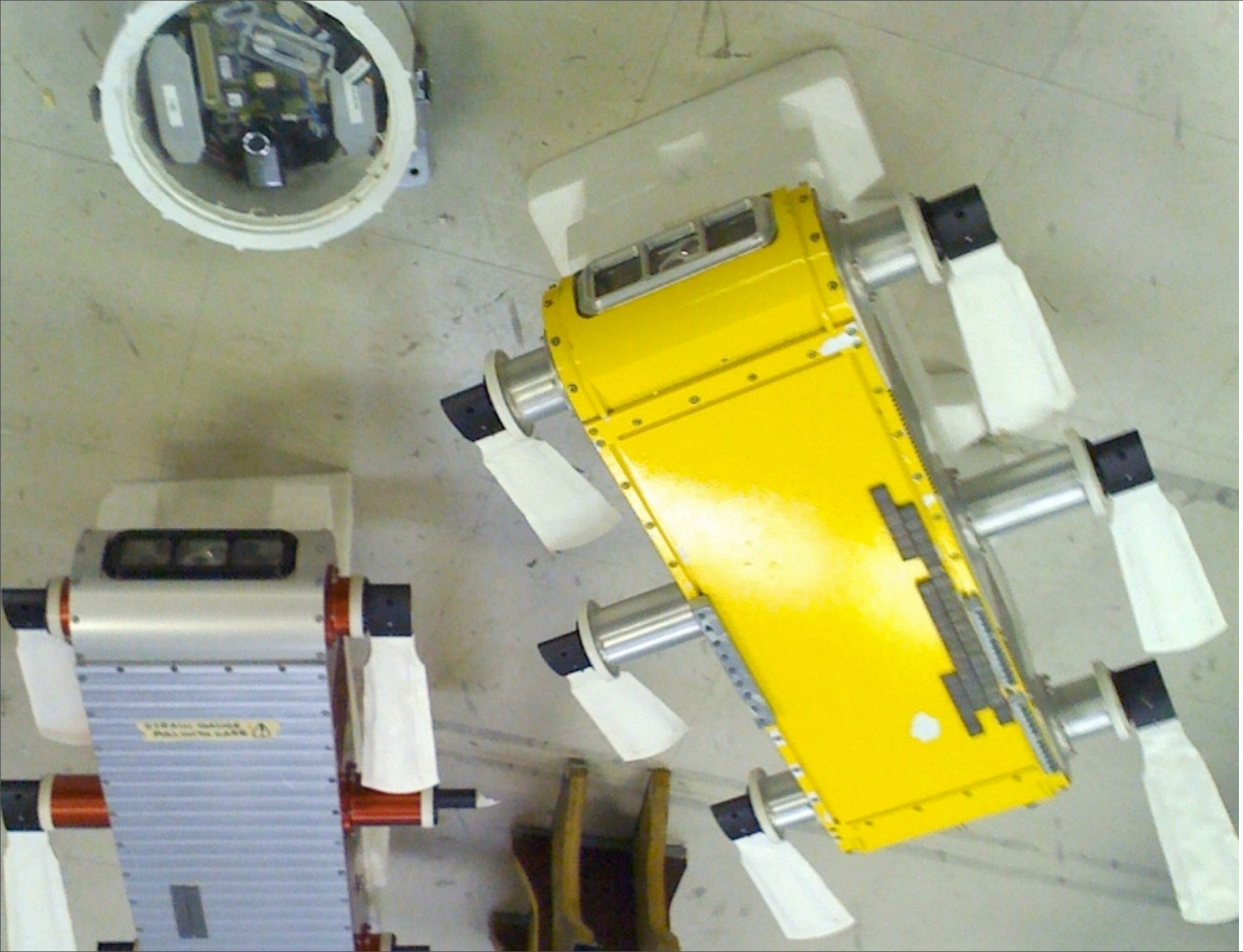
Multiple iterations and tests have brought the biologically inspired flippers to generate optimal thrust. Experimentation with new swimming gaits has allowed for further improvement of AQUA's underwater performance.

Vision

Two forward and one rear facing cameras allow for remote operation of the robot, as well as visual servoing and stereoscopic 3D terrain mapping.

Mass = 16.5kg (ballasted for salt water)

Now available commercially as Aqua2




select gait

Offboard GPS

- Porpoising for GPS localization
- Scheduling issue

Software View

- QNX
  - RoboDevel
- Linux (Vizibuntu)
  - Vision Sandbox
  - ROS
- RoboDevel OCU
- GSSP

Key problems

- Human-robot interaction [Junaed Sattar]
    - Underwater robot control
- Pose estimation and localization [Florian Shkurti]
    - Combination for vision and IMU data
- Data summarization: what were the key “finds”
- Near-optimal coverage (2D, 3D, 6D)
- Network localization
    - MCMC methods for joint localization
- Multi-vehicle planning & coordination
- Robot rendezvous planning

Problem setting

Marine biologists are conducting coral reef bio-assays and behavioral studies.

e.g. How does fish prevalence and mobility relate to rugosity, reef geometry and spacing [K Turgeon]? How does coral abundance and diversity vary with location and reef properties [N Dudek]?

Phase 1: single robot

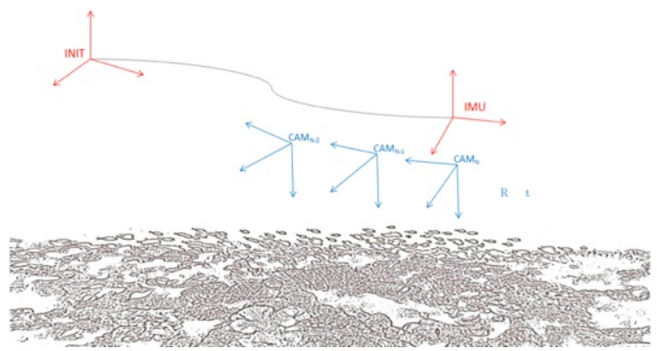
- Develop a robotic system that can survey the reef.
  - Collect image and video.
  - Discreet footprint (small, quiet, small shadow).
  - Perform transects, hover, land with minimal disturbance.

Phase 1 *requirements*

- Human-in-the-loop when *underwater*.
- High mobility: transects, hovering.
- Technical challenges:
  - Localization; state.
  - Servo-after human.
  - Human-robot interaction.
  - Mission planning.

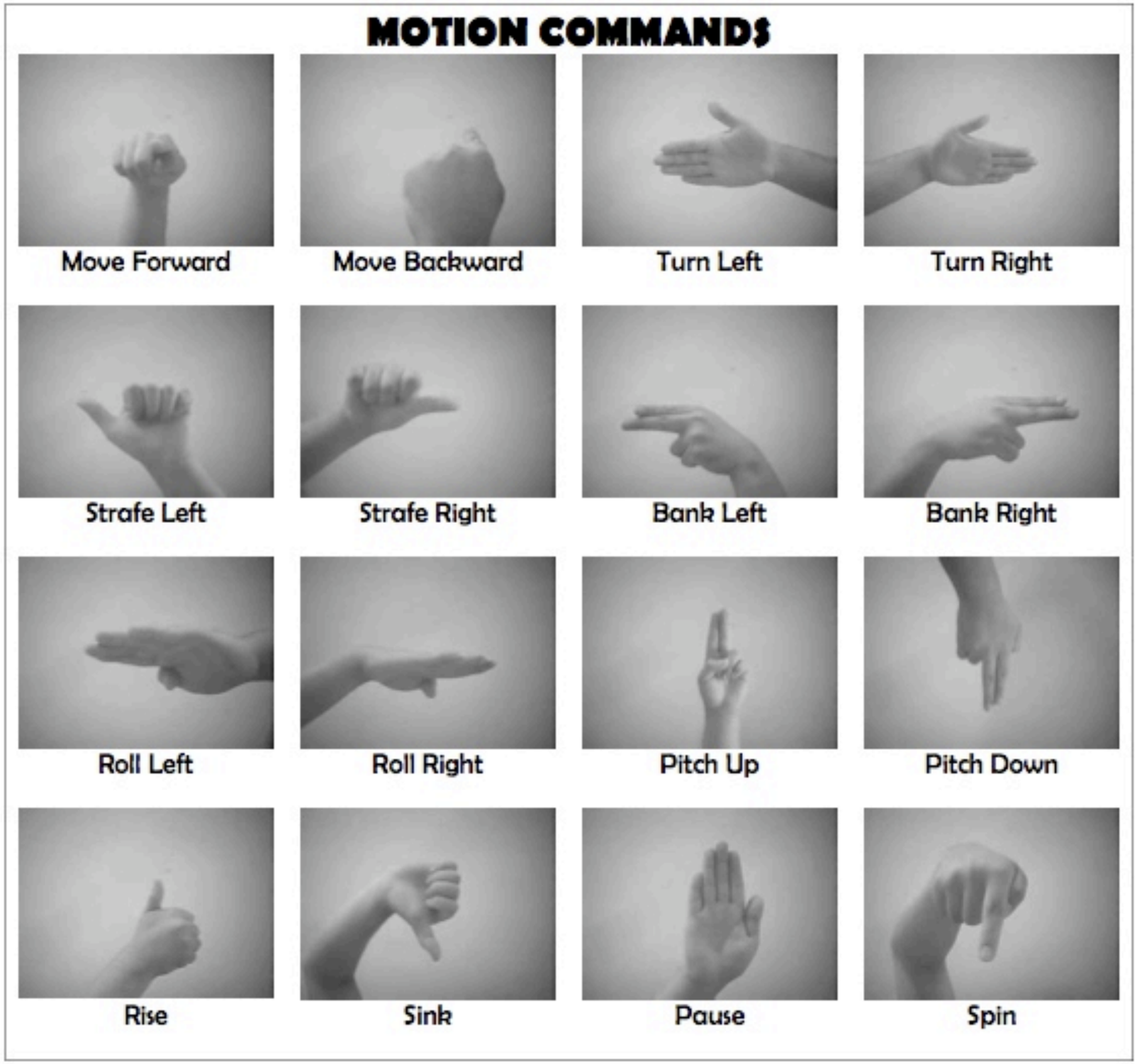
Related talks

Extended Kalman Filter integrates IMU and camera measurements.



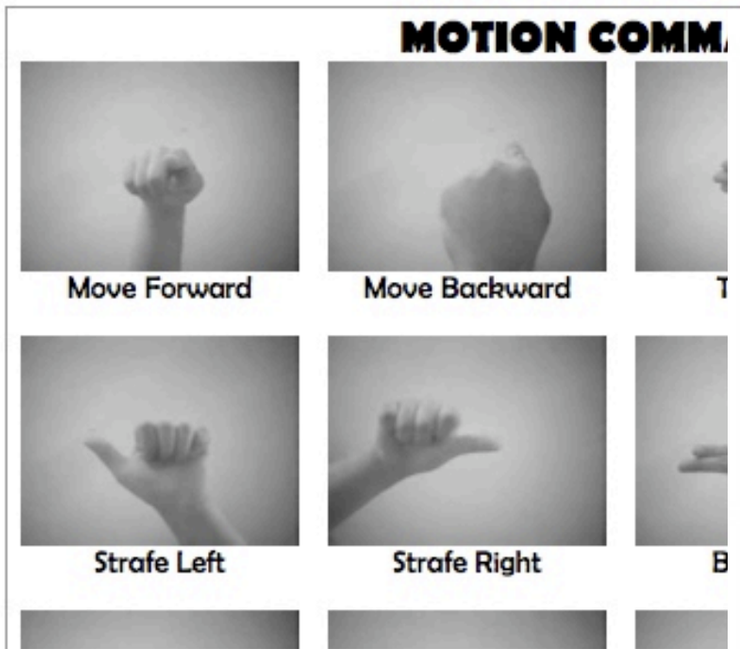
McGill
Centre for
Intelligent Machines

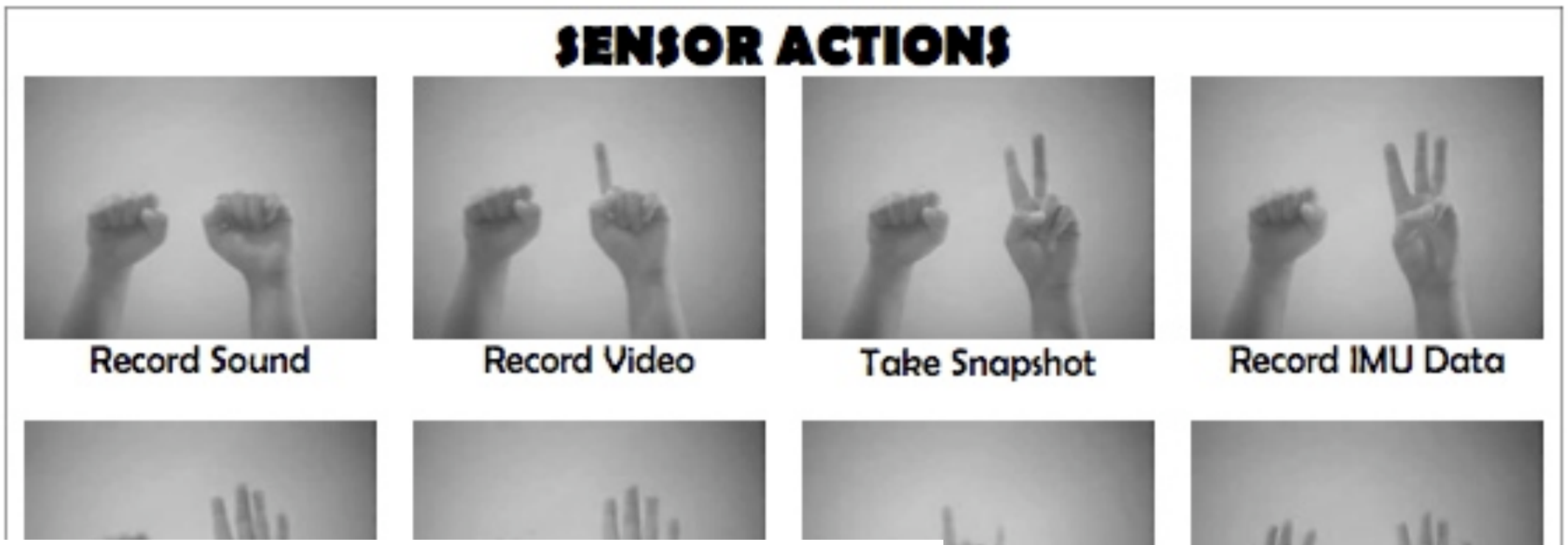
Diver-Operator Gesture Language

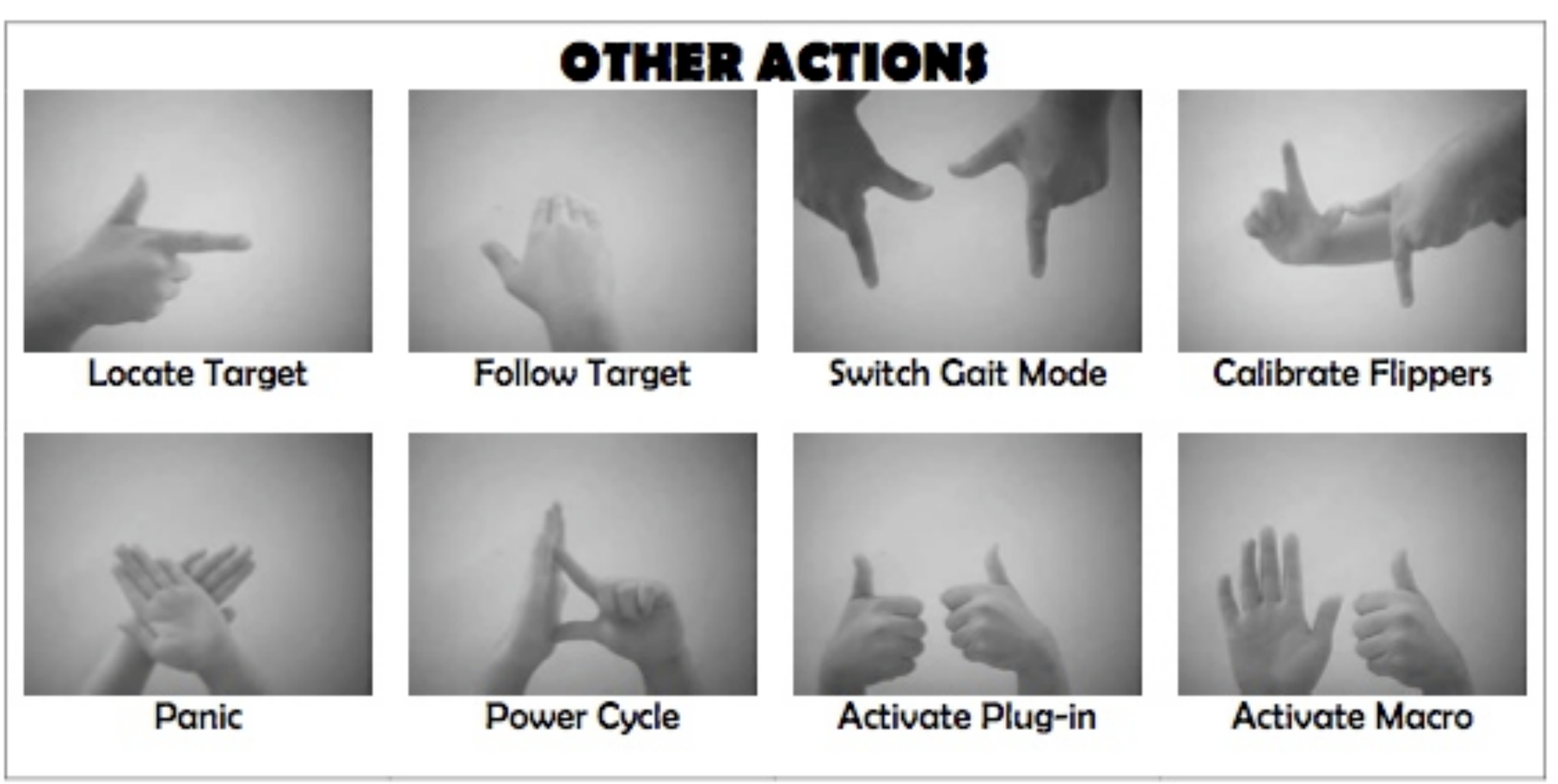


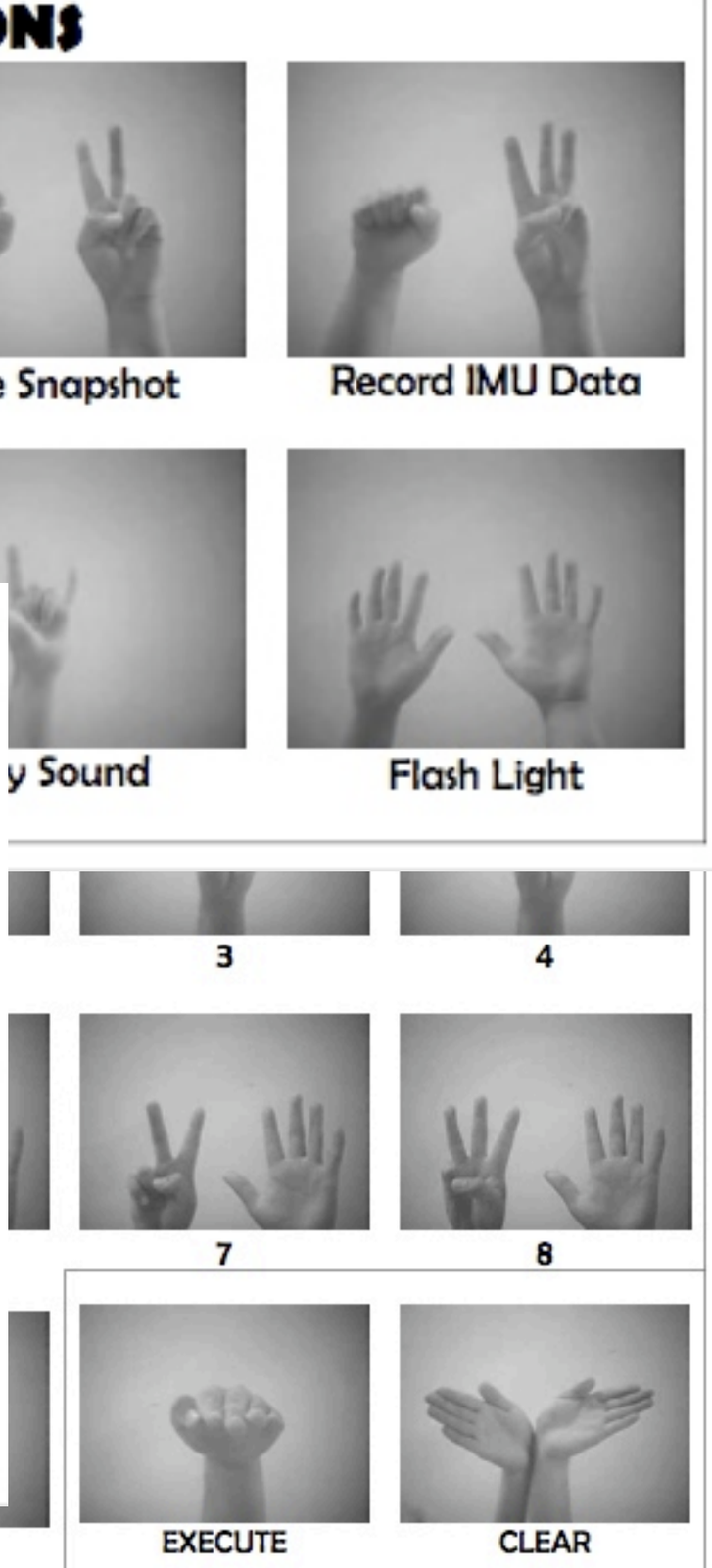
McGill
Centre for
Intelligent Machines

Diverse Command Set





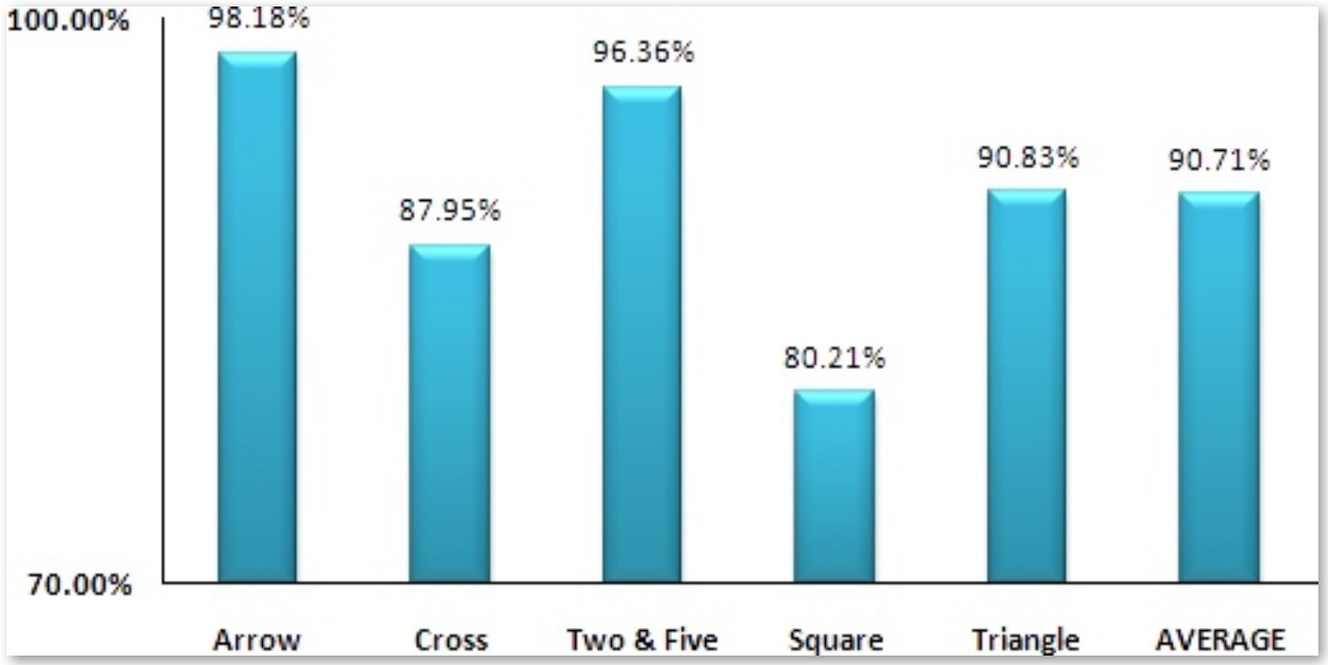




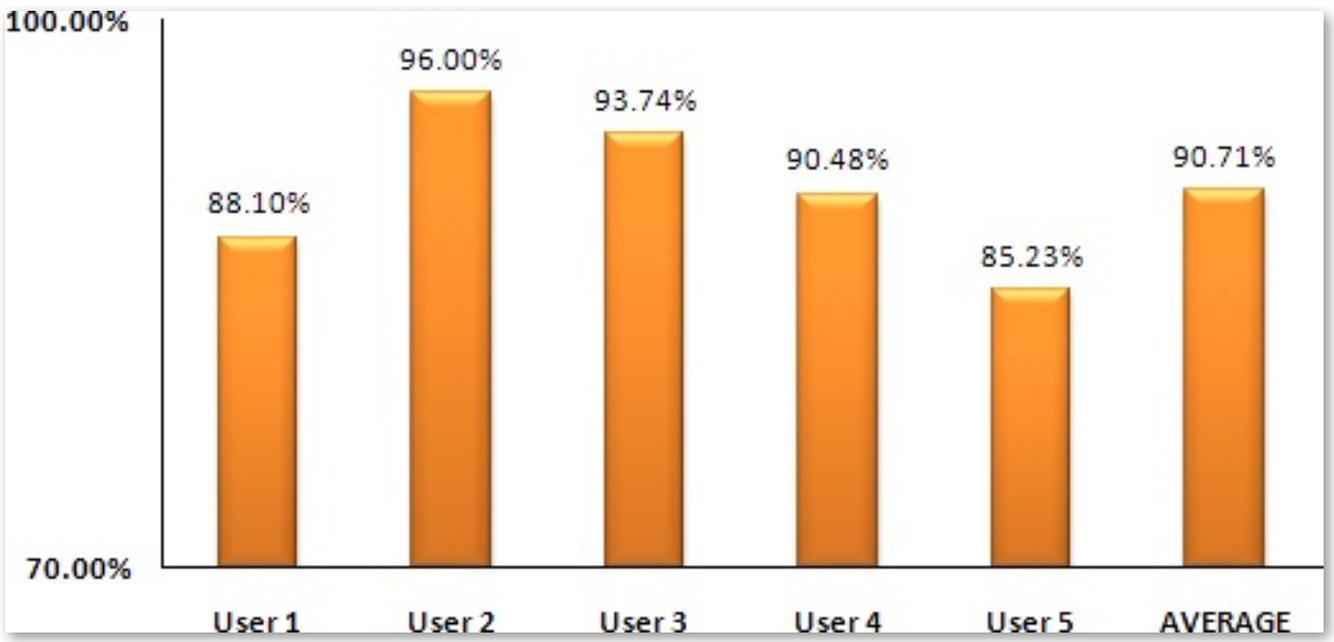
Human Interface Studies

- Goal: comparing RoboChat to manual person-to-person communication system.
- Cognitive loading akin to underwater.
- Criteria: speed, accuracy, rate of improvement.

Results: accuracy



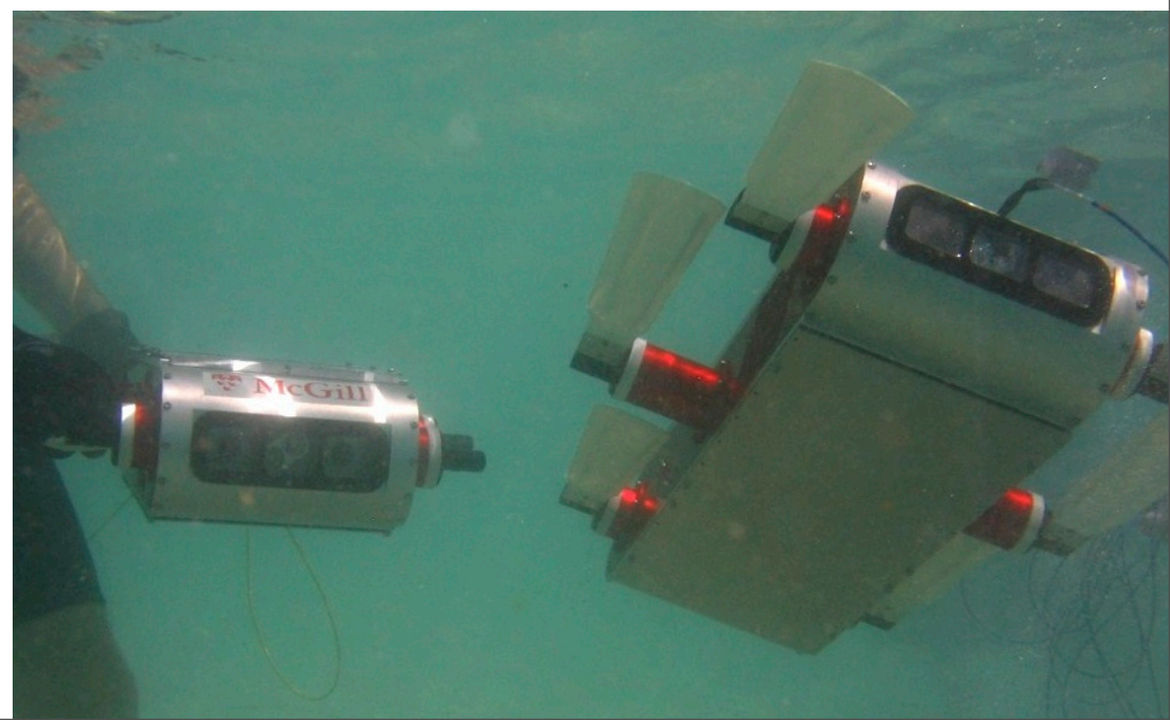
All users/gesture



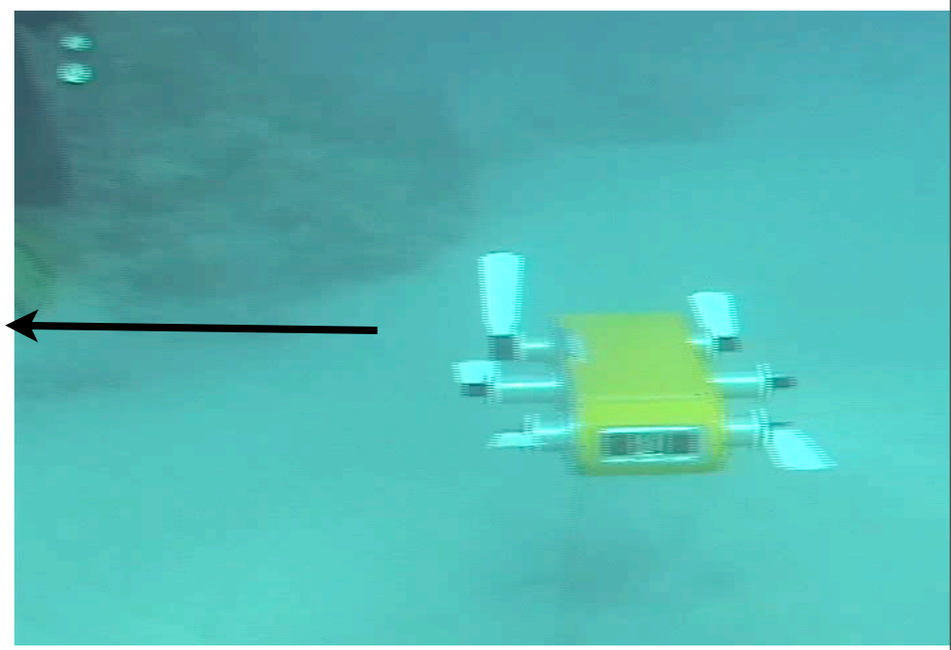
All gestures/user

Phase 2: multi-vehicle

- Detect reefs of interest from the air
  - Deploy the swimming vehicle/team to selected target coral heads.
- Work collaboratively to visit sessile nodes *(future work)*.

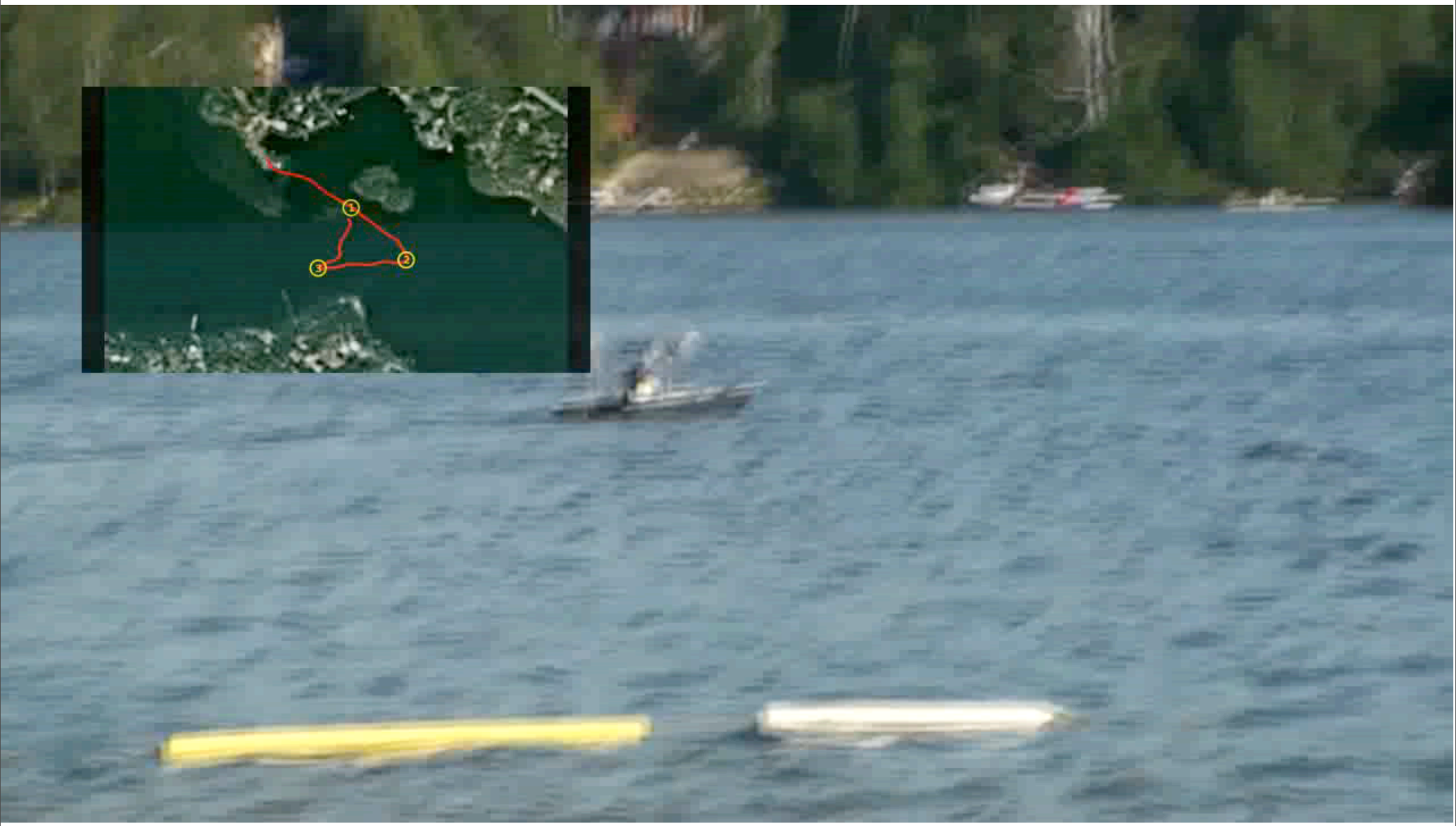


Phase 2 *requirements*



- AUV-UAV coordination.
- High mobility: transects, hovering.
- Additional Technical challenges:
  - Automatic reef-head detection, coral ID.
  - Rendezvous scheduling and planning.
  - Communication and coordination.
  - High-level mission planning.


Gymbal-mounted
look-down camera

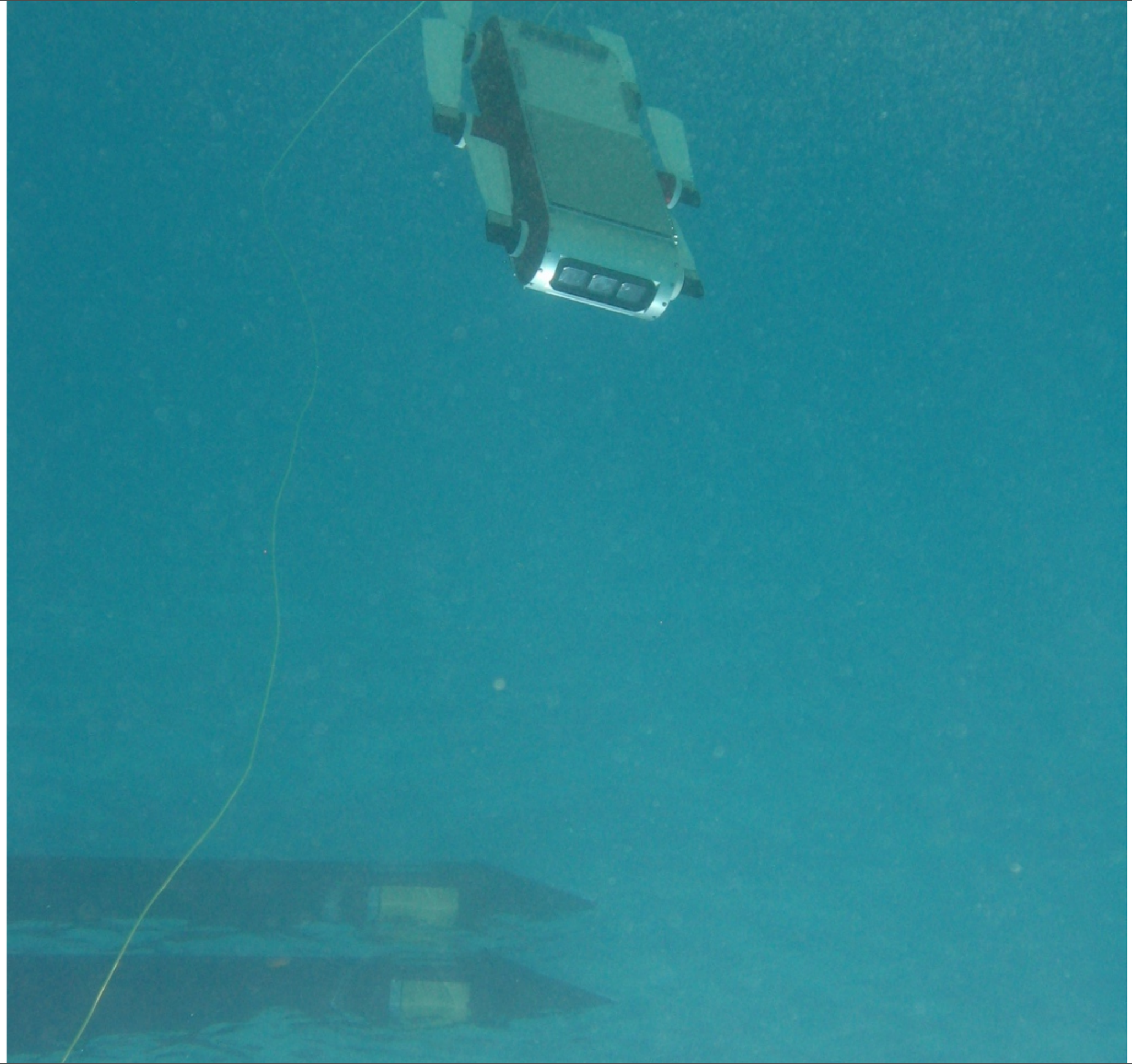

1
2
3

Data flow (phase 2)

- Human mission planning using GSSP [ICRA 2011]
- UAV collects images
- Ground station processes them to define targets

  [analog video modem]
  on-board OMAP3 processor coming soon

- Overflight of boat
- Downlink data via 802.11x
- Boat coordinates with underwater vehicle (at surface)
- Data transfer via Zigbee



A Vision-Based Boundary Following Framework for Aerial Vehicles

Anqi Xu and Gregory Dudek
Centre for Intelligent Machines
McGill University, Canada

This project is funded by the National Science and Engineering Council (NSERC) of Canada.

Navigation Summaries

Highlights of a robot's experience (location and sensor data).

Did anything really odd happen?

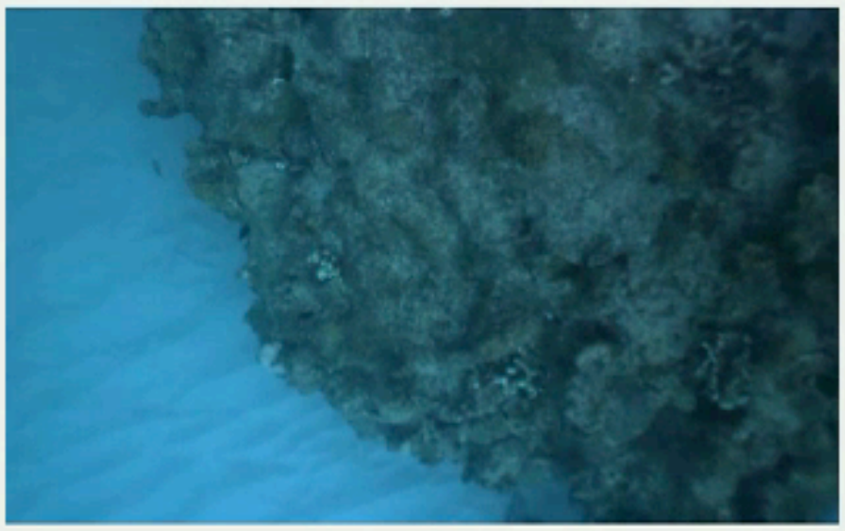
What were the most notable moments?

Not a *complete* summary.

Delivered on-line: what's interesting *so far*.

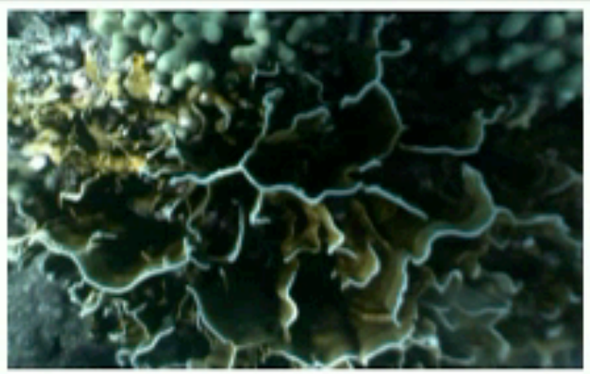
Work with Yogesh Girdhar

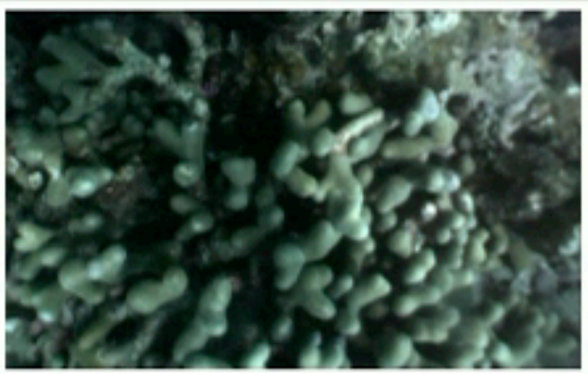
AQUA 2X

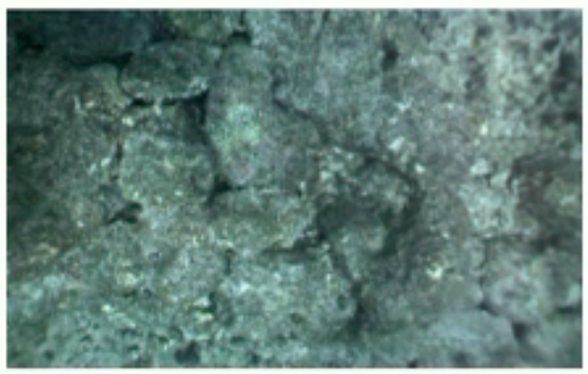



906


796

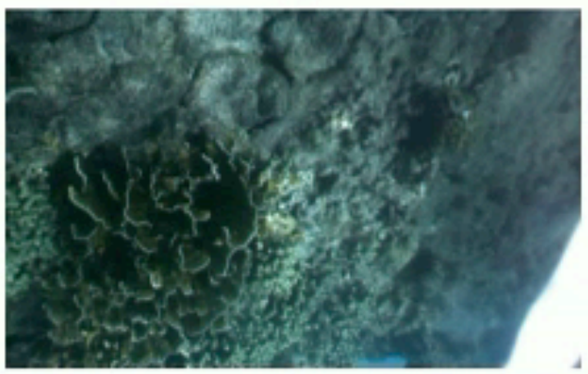

608

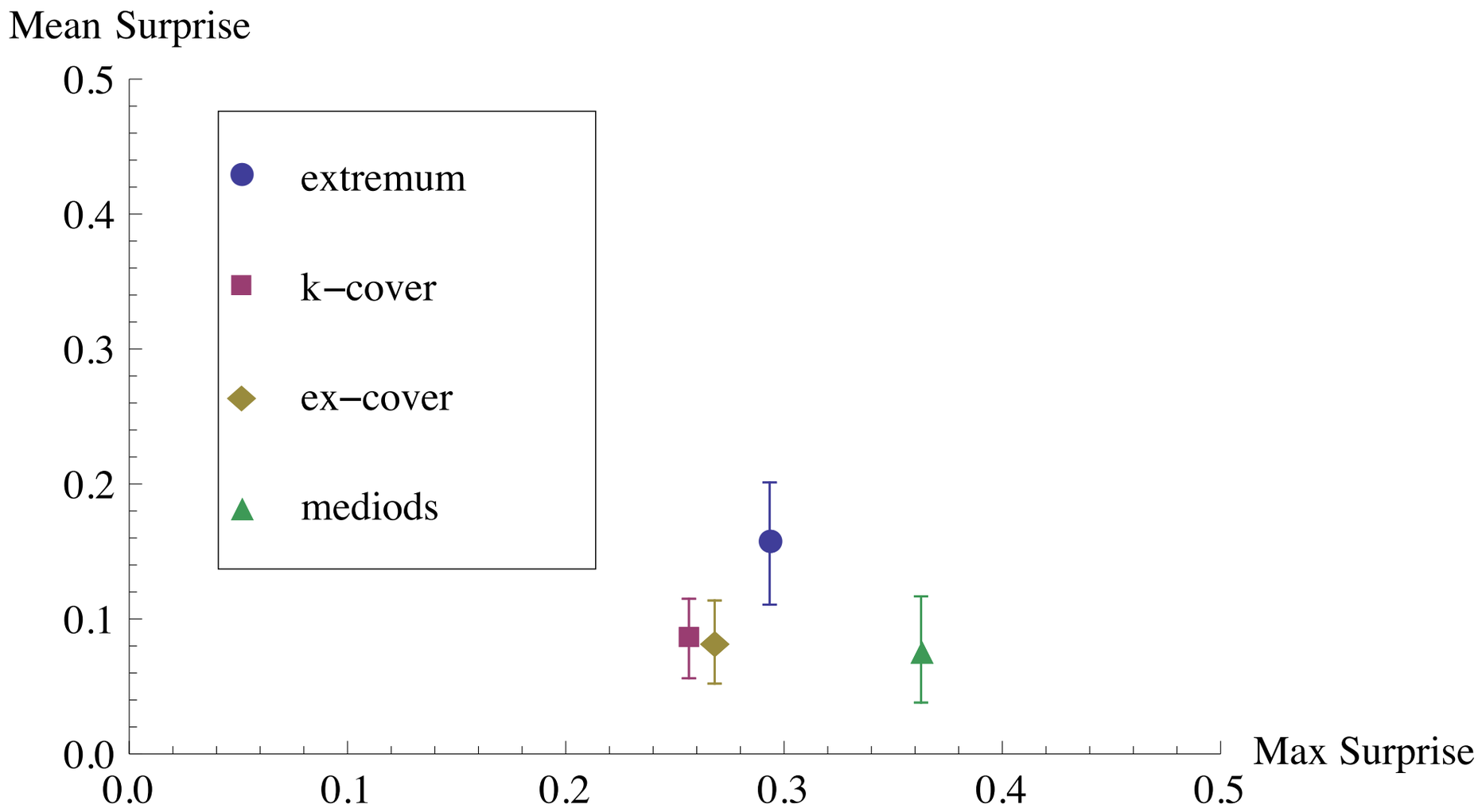

416


330


210


126


4


Mean Surprise
0.5
0.4
0.3
0.2
0.1
0.0
extremum
k–cover
ex–cover
mediods
0.0
0.1
0.2
0.3
0.4
0.5
Max Surprise

Summary

- Heterogeneous multi-vehicle project. Diverse algorithmic and logistic issues.
  - Human-robot interaction. *[Junaed Sattar, here]*
  - Pose estimation. *[Florian Shkurti, here]*
  - Robot-robot interaction. *[A Xu;Y Rekleitis; M Meghjani]*
- Mission planning is destined to become a major challenge.
  - Graphical State Space Planning tool (GSSP).
- Coordination and synchronization needs not only an effective algorithm, but a robust failure-handling mechanism.
- Future plans to incorporate data from additional vehicles.