Applications of Unmanned Marine Vehicles

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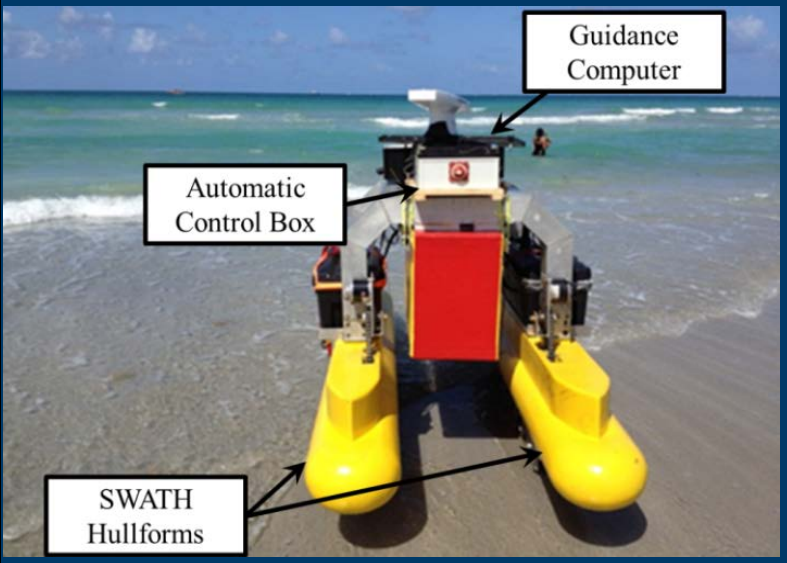
Florida Automated Vehicles Summit
3rd Annual Florida Automated Vehicles Summit
Session 5: Applications for Unmanned Systems
December 1, 2015 Jacksonville, FL

FAU SeaTech Institute for Ocean Systems Engineering


Guidance Computer
Automatic Control Box
SWATH Hullforms

Automatic Control Box
Guidance Computer
Inflatable Pontoons
Motor Pods

Unmanned Marine Vehicles

Classes of UMVs:

1) U/W Remotely Operated Vehicles (ROVs) – continuously teleoperated
2) Autonomous/Unmanned Underwater Vehicles (AUVs/UUVs), preprogrammed to perform without human intervention, and
3) Unmanned Surface Vehicles (USVs) – robotic boats that can be teleoperated or operated autonomously without human input.

Remotely Operated Vehicles (ROVs)

Applications:

- subsea inspection
- pipeline installation
- trench digging
- maintenance
- construction

Control: remote teleoperation (may be semi-autonomous)

Sensors/Instrumentation: video cameras, lights.

Advantages: Data transfer/power use umbilical – virtually unlimited power for propulsion/tooling; Human operators can perform more complex tooling motions.

Disadvantages: Limited range; need constant human supervision; need complex mooring systems to decouple wave-induced motions and prevent entanglement.

Oceaneering Nexxus ROV

Future: Hybrid AUV/ROV.

- Transit untethered (automatic control).
- Deployable from many platforms.
- Travel ~8 hours at speeds of ~3-4 knots

Saab Double Eagle SAROV

Autonomous Underwater Vehicles (AUVs)

Hydroid (Kongsberg) Remus AUV

Applications:

- Ship hull inspection
- Underwater survey
- Oceanographic sensing
- Plume tracking
- Vehicle/Animal Detection or Tracking

Bluefin AUV with B.O.S.S.

Control: Preprogrammed automatic control

Sensors/Instrumentation: Sonar (mapping), USBL (localization), Water Column (CTD, CDOM, O_2, etc.).

Advantages: Deployable from many platforms; can travel ~8 hours at speeds of ~3-4 knots; can perform many missions without human intervention.

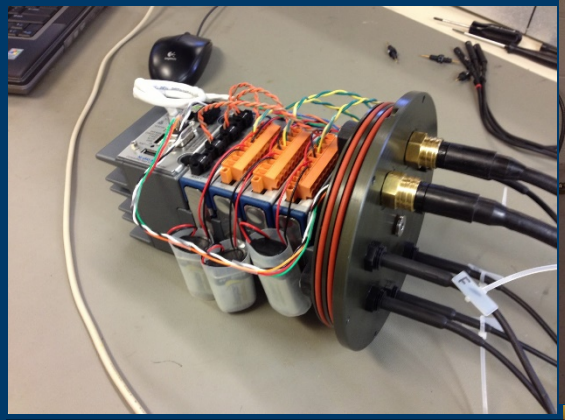
Disadvantages: Onboard power restricts range – glider technologies can circumvent; limited tooling capabilities.

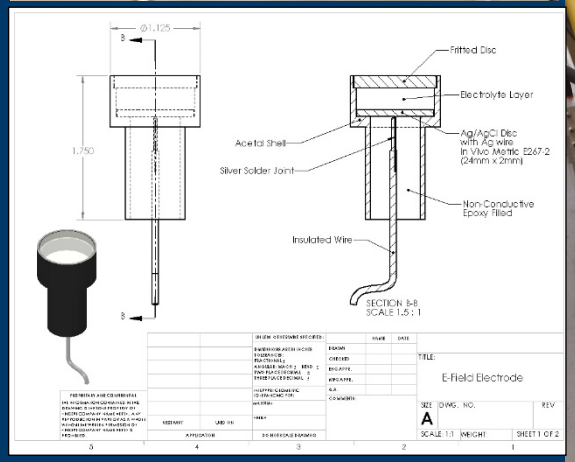
AUV Docking Station

Slocum Glider

Autonomous Underwater Vehicles (AUVs)

E-Field Sensor Development





Autonomous Underwater Vehicles (AUVs)

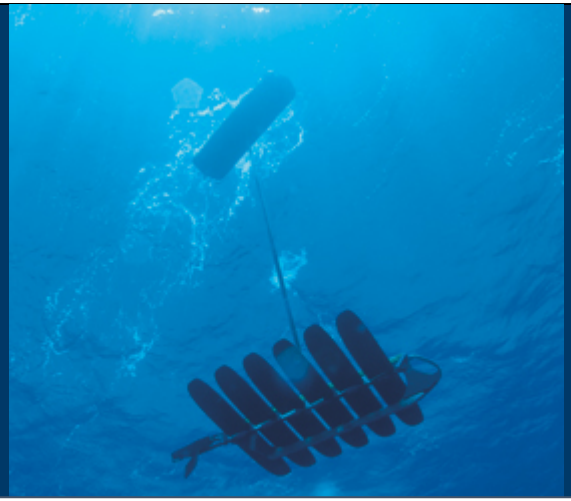
E-Field Sensor Development

Unmanned Surface Vehicles (USVs)

Applications:

- Ocean sampling
- Maritime search and rescue
- Hydrologic surveys
- Harbor surveillance
- Underwater Inspection
- Defense

Saildrone USV



Liquid Robotics Wave Glider

Control: Automatic control or teleoperated

Sensors/Instrumentation: Stereo cameras, LiDAR, Radar, GPS.

Advantages: Deployable from many platforms; can perform many missions without human intervention.

Disadvantages: Onboard power restricts range; Can be susceptible to wave, current & wind; interaction with civilian vessels.

Marine Advanced Research WAM-V

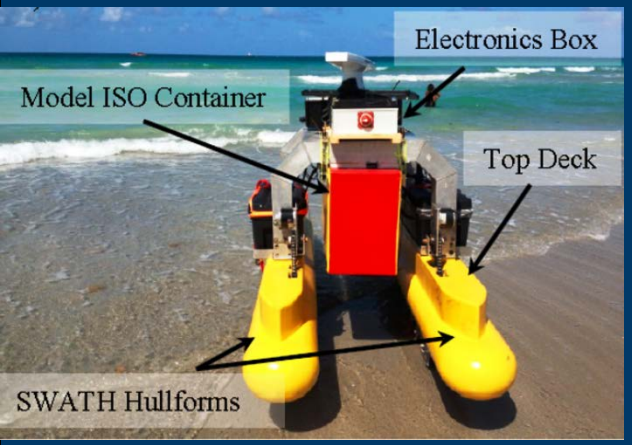
USV Challenges: Disturbance Rejection

USV Design: Hullform

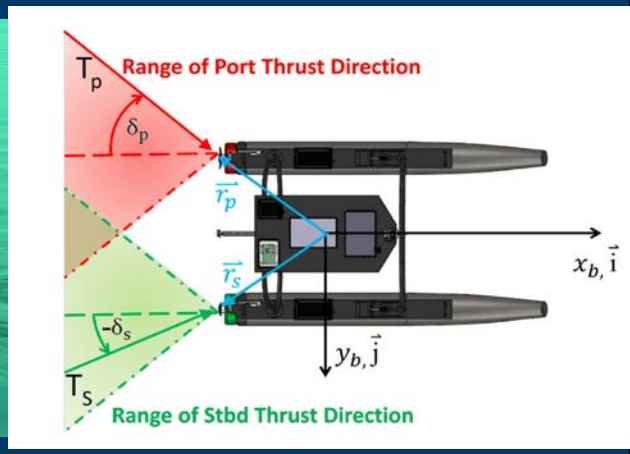
Do not need to accommodate human operators – design more optimized for sensing, maneuvering or deployment requirements.

Expected operating conditions suggest semi-displacement vessels:

1. SWATH (e.g. Marquardt et al. 2014; Kitts et al. 2012)
2. Catamarans (e.g. Sarda et al. 2015)



SWATH USV



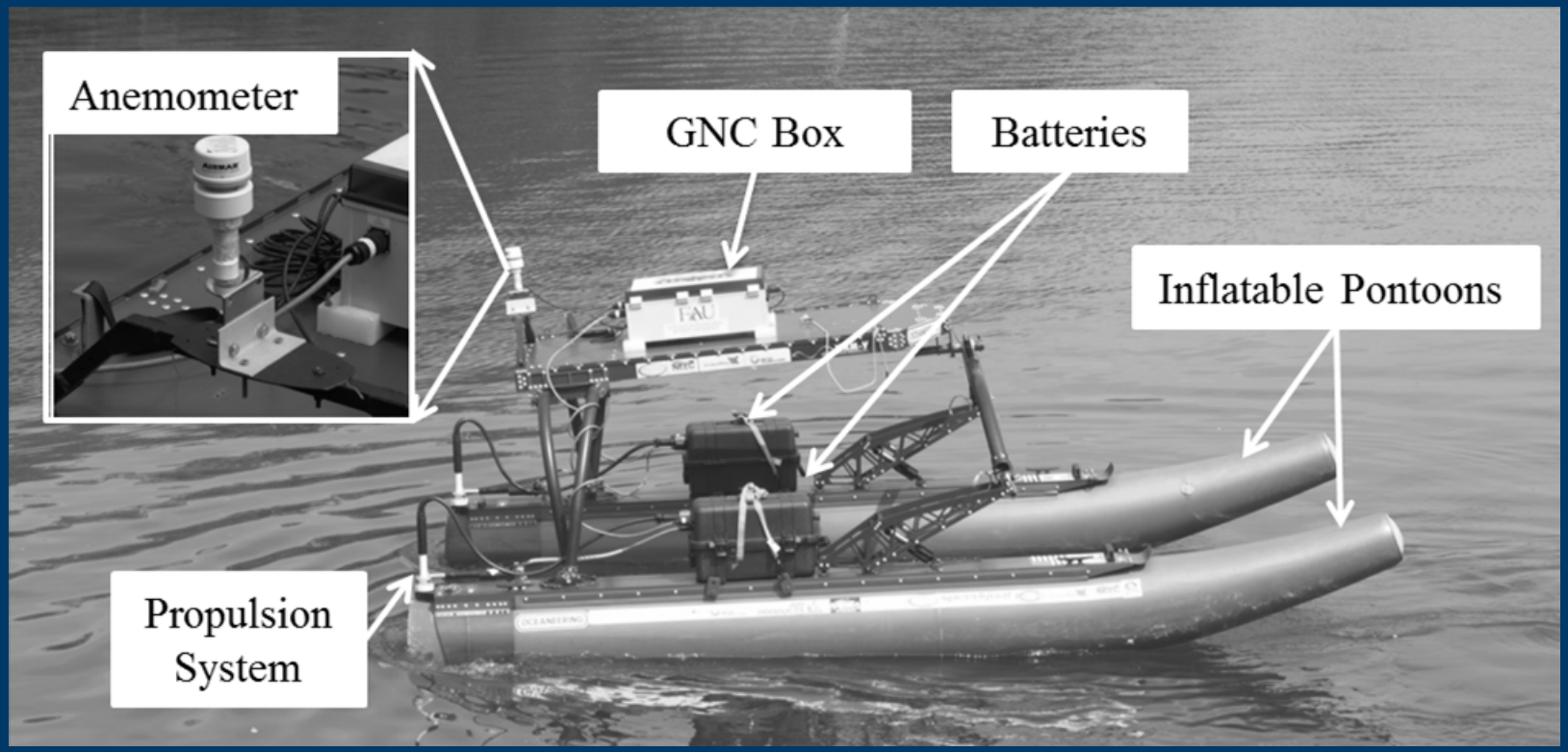
Catamaran USV configured with thrust vectoring for station-keeping

USV Challenges: Disturbance Rejection

USV Design: Autonomy (Station Keeping)

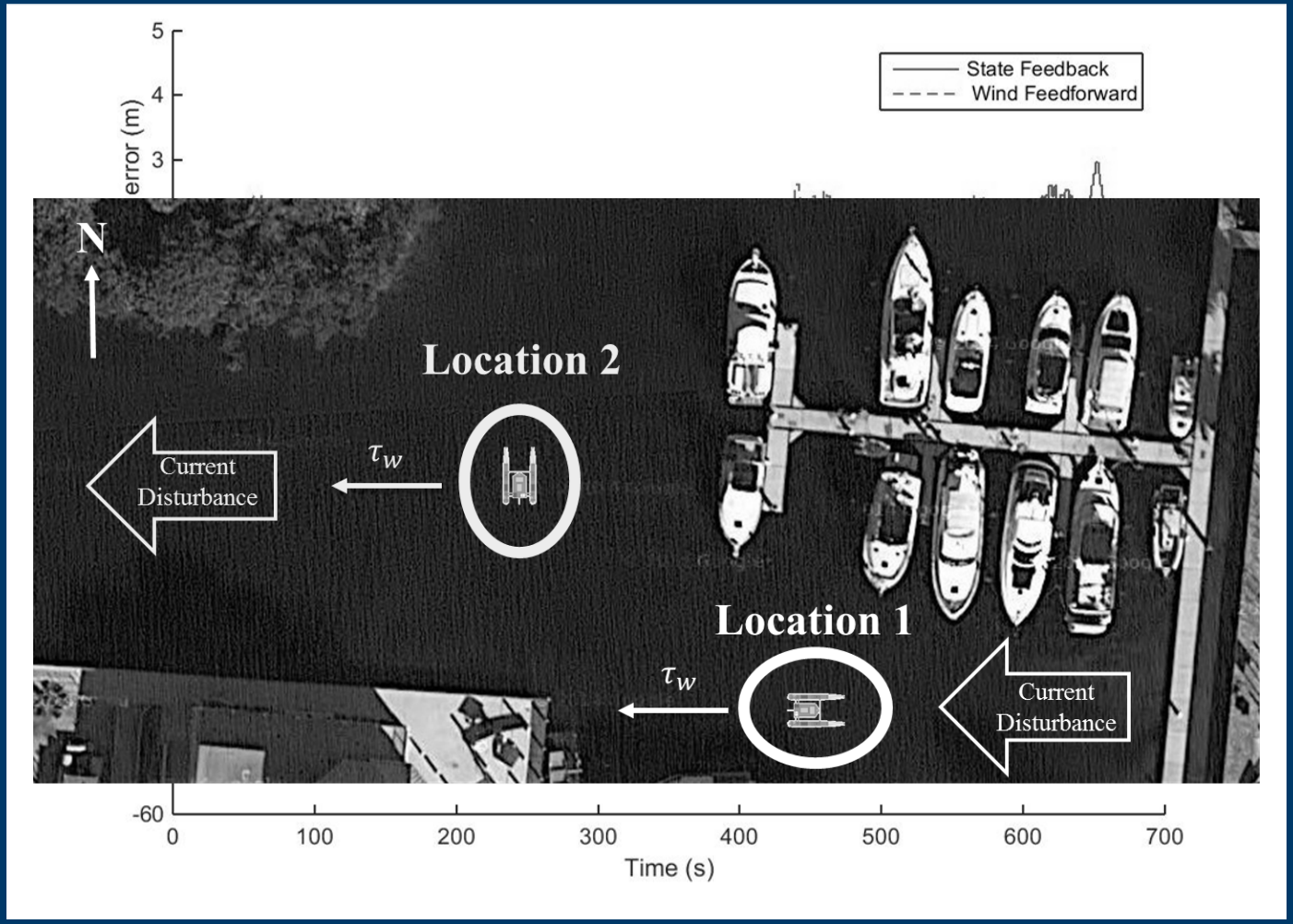
1. Inspections may require object localization, feature imaging and the launch and recovery of smaller subsystems – stationkeeping essential.
2. Winds, tides and waves – can vary substantially, in time and space, as a USV maneuvers around a bridge structure → robust stationkeeping.
3. Typical low weight and high windage of USVs can make this challenging.
4. Nonlinear MIMO and Backstepping stationkeeping controllers (Sarda et al. 2015)
5. Wind Feedforward Control – wind models, sensor number and placement (Qu & von Ellenrieder 2015).

USV Challenges: Disturbance Rejection



WAM-V USV16 during on-water station-keeping tests in the Intracoastal Waterway

USV Challenges: Disturbance Rejection

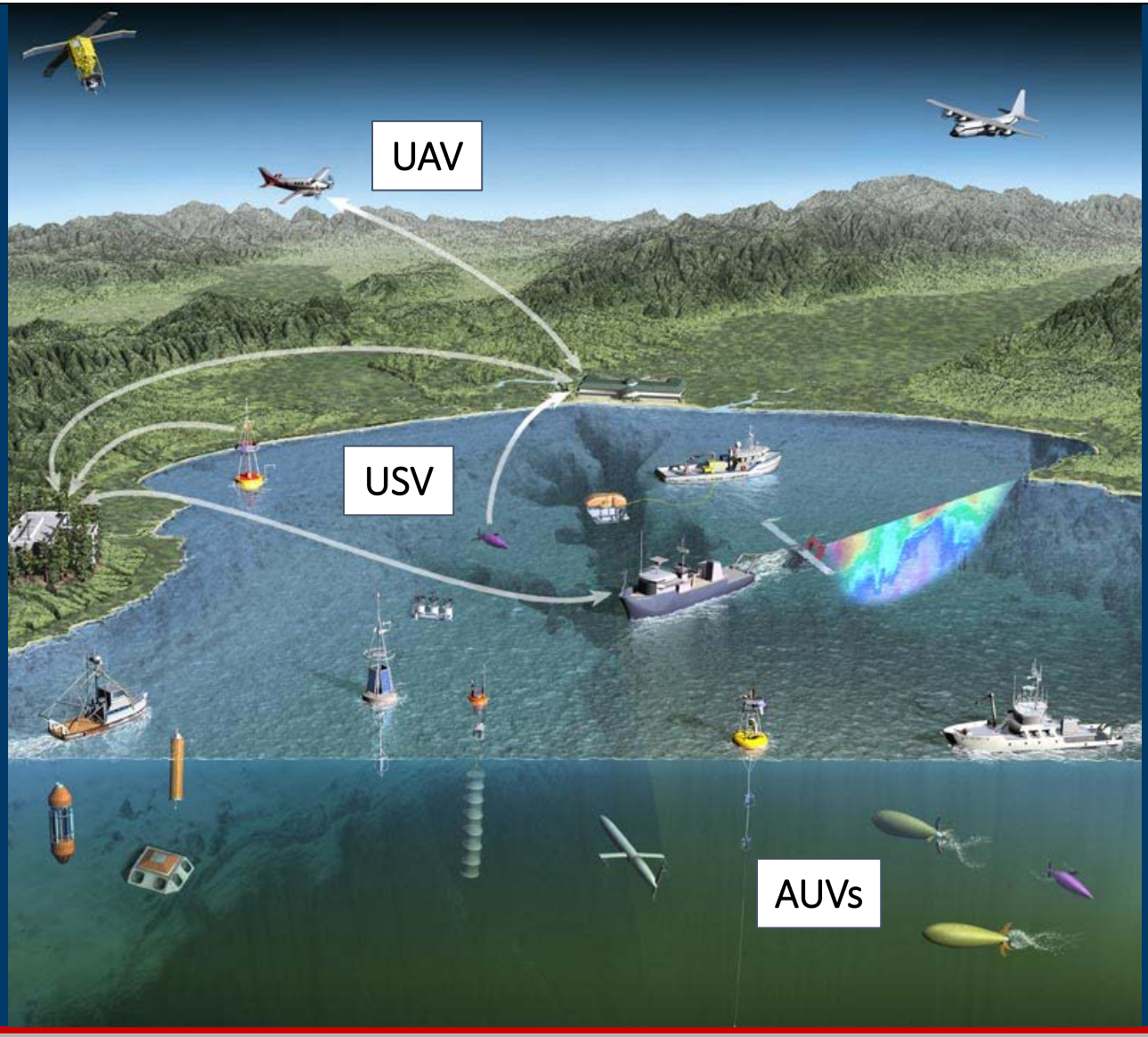


Position and heading errors for sliding mode station-keeping controller with/without wind feedforward control at Location 1.

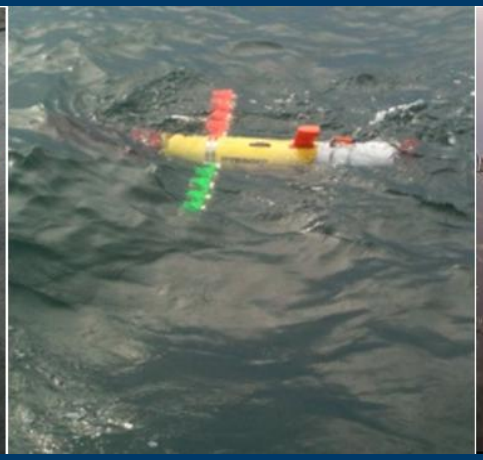
USV Challenges: Positioning

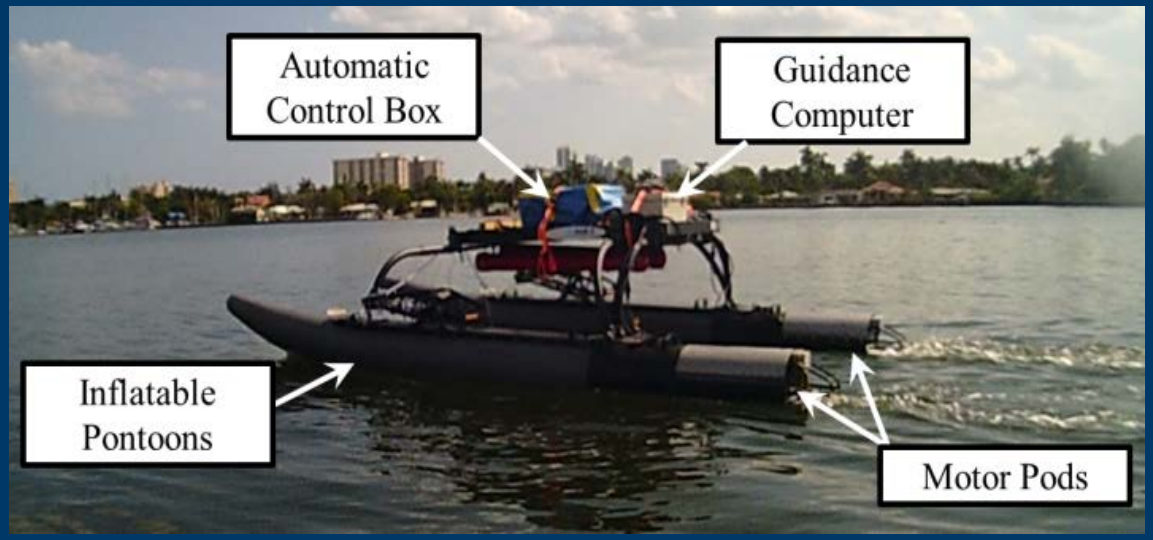
1. Operating near a large structures can affect precise positioning:
   a) GPS line of sight to overhead satellites blocked
      i. Kalman-filter sensor fusion combining dead-reckoning and GPS
      ii. Real Time Kinematic (RTK) GPS positioning technology
   b) System Localization and Mapping (SLAM)
2. Large bridge structures can affect compasses (flux-gate)
3. Cooperative sensing/Multi-session Mapping
   a) Use of SLAM to capture changes in bridge structures using maps obtained over repeated bridge inspections.
   b) Can increase efficiency and quality of maps using informative path planning for active mapping in SLAM (Kim & Eustice 2015)

UxV Multi-domain Systems



USV Challenges: ALR





USV Challenges: ALR

Variable mass and drag during ALR

USV Challenges: Multiple Vehicle Interaction

Field Testing of Dynamics-Aware COLREGs-Compliant Behaviors for USVs

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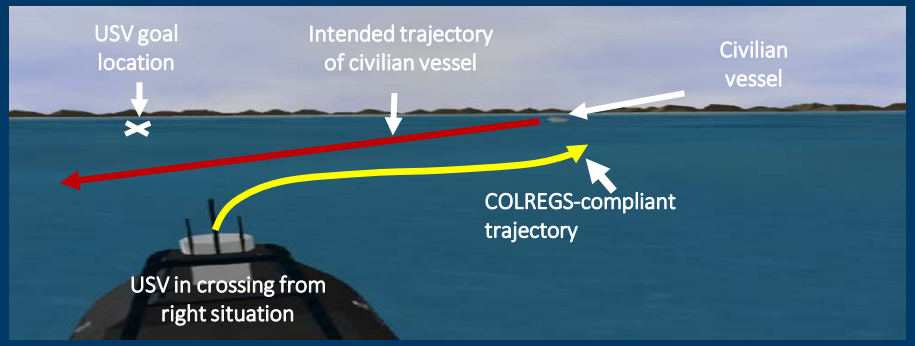
MOTIVATION: NON-TRIVIAL TRAJECTORY PLANNING AND TRACKING CHALLENGES

Congested harbor scenario
(Source: Map data ©2013 Google)



USV encountering COLREGS "crossing from right" situation

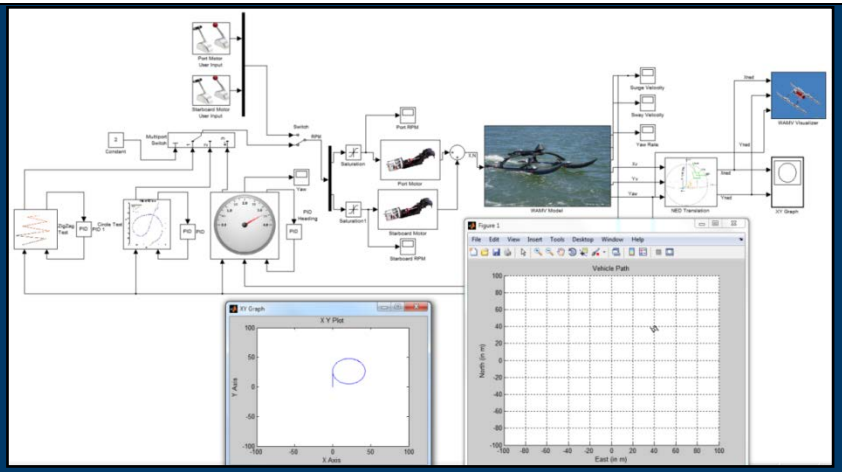
USV Challenges: Multiple Vehicle Interaction

Not possible to anticipate the infinite number of possible situations a USV might encounter – combination of advanced deliberative/reactive task and trajectory planning is needed.

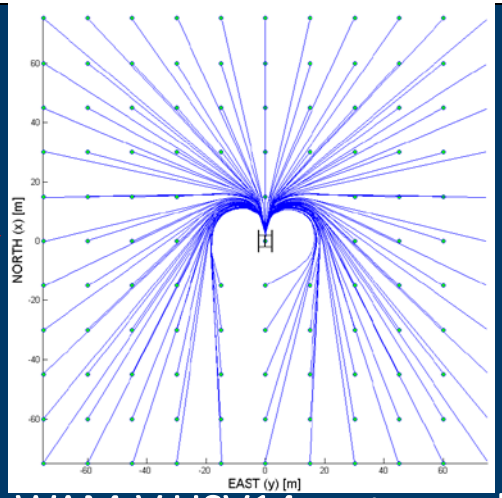
a) "Automatically-generated" behaviors that allow planner to consider classes of situations in pre-programmed ways, while accounting for limitations of the vehicle's dynamic response (Bertaska et al. 2015).

b) Model-predictive trajectory planning for operations in civilian traffic (Shah et al. 2014) – contingency maneuvers; COLREGs

USV Challenges: Multiple Vehicle Interaction



WAM-V USV14 simulation model



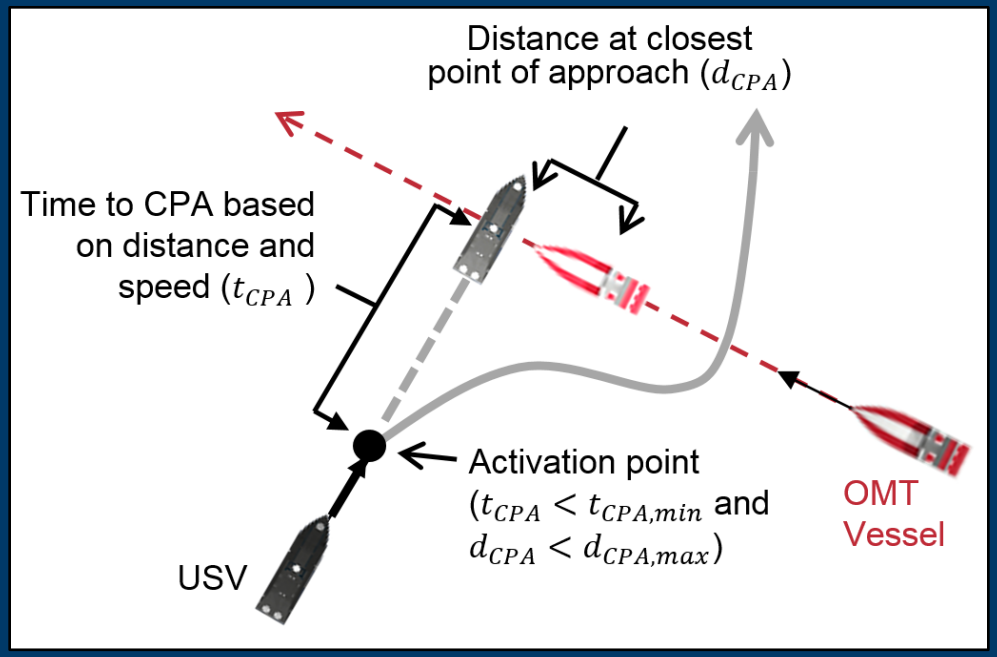
WAM-V USV14 meta-model

- Lattice-based global trajectory planner
  - USV control action space discretized into a set of dynamically feasible motion commands
    Planner utilizes A* search to find a collision-free, dynamically-feasible trajectory $\tau = \{w_i \mid w_i = [x, y, \theta, t]^T\}$ between the current USV's state and motion goal

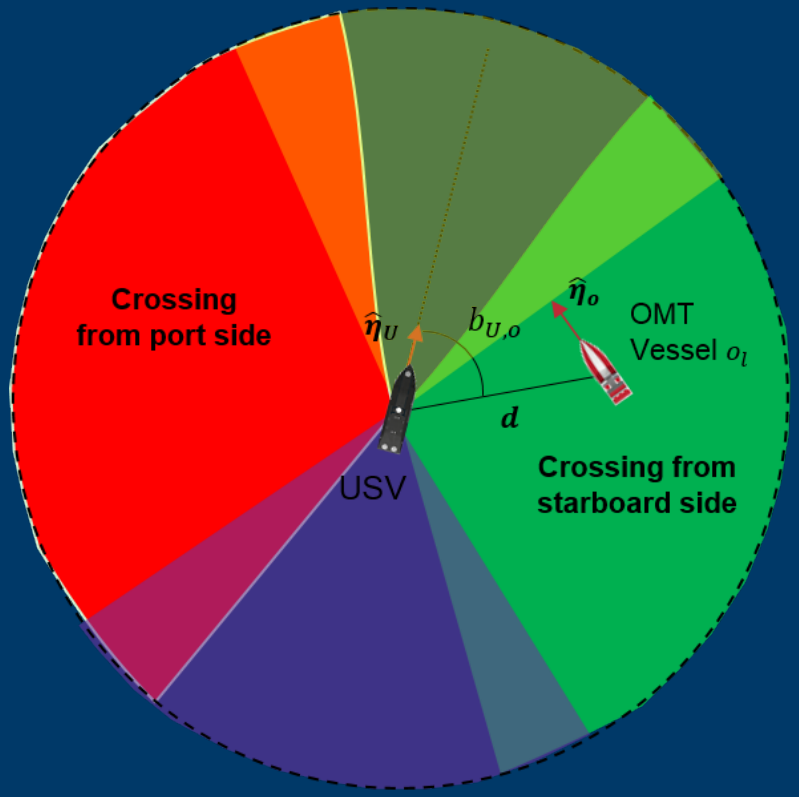
- **Meta-model of WAM-V USV14's dynamics and control**

- COLREGs-compliant local trajectory planner
  - Adaptively samples space of reachable motion goals based on temporal-spatial distribution of obstacle vessels and history of detected collisions during the search:
    a) prioritized sampling of entire set of state space trajectories in each sampling cycle
    b) sampling of individual state space trajectories for collision detection

USV Challenges



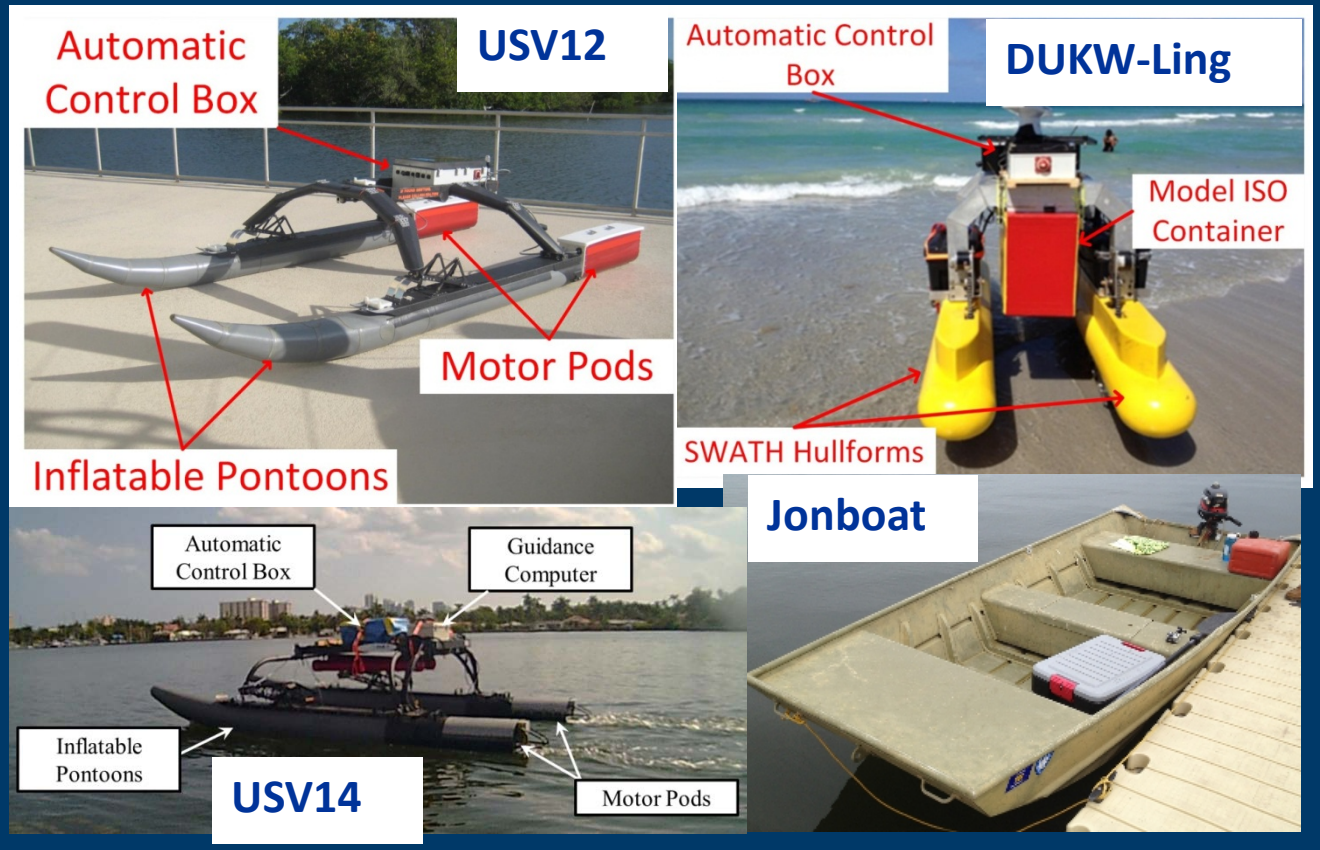
Calculation of Closest Point of Approach (CPA) distance and time for initiation of COLREGs-Compliant Maneuvers (Bertaska et al. 2015).



COLREGs rule for each OMT vessel is determined by its current position with respect to USV (Bertaska et al. 2015).

USV Challenges: Multiple Vehicle Interaction

Experimental Setup

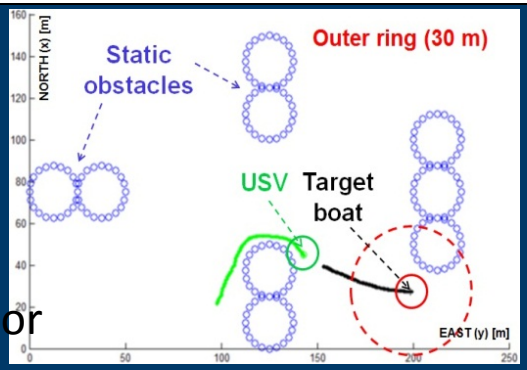


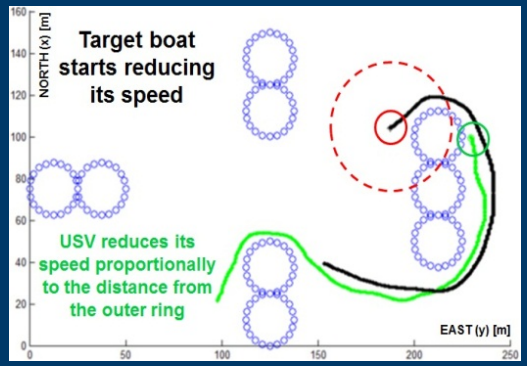
Experimental platforms

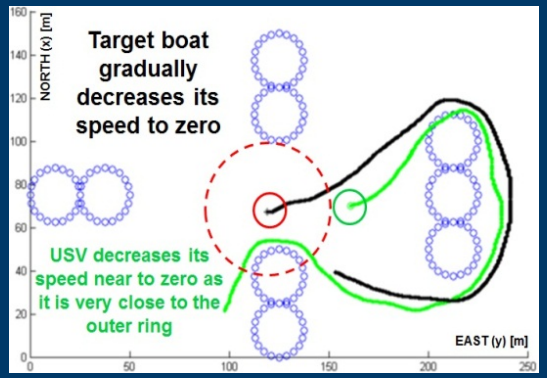
USV Challenges: Multiple Vehicle Interaction

Experimental Results

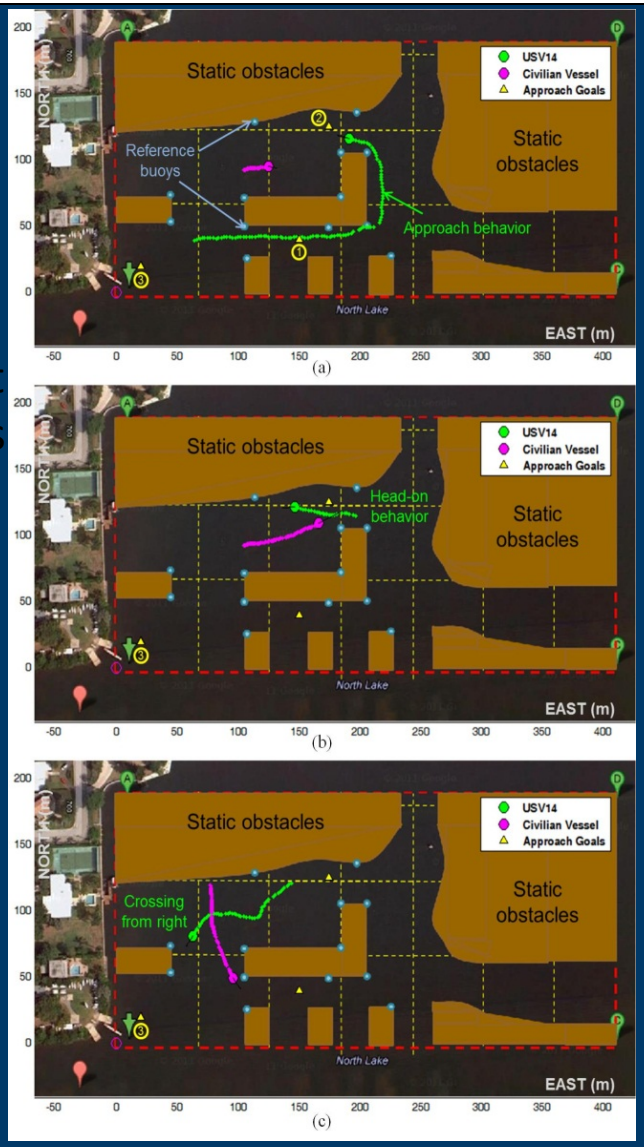
Follow-behavior







Head-on and crossing-from-right COLREGs situations



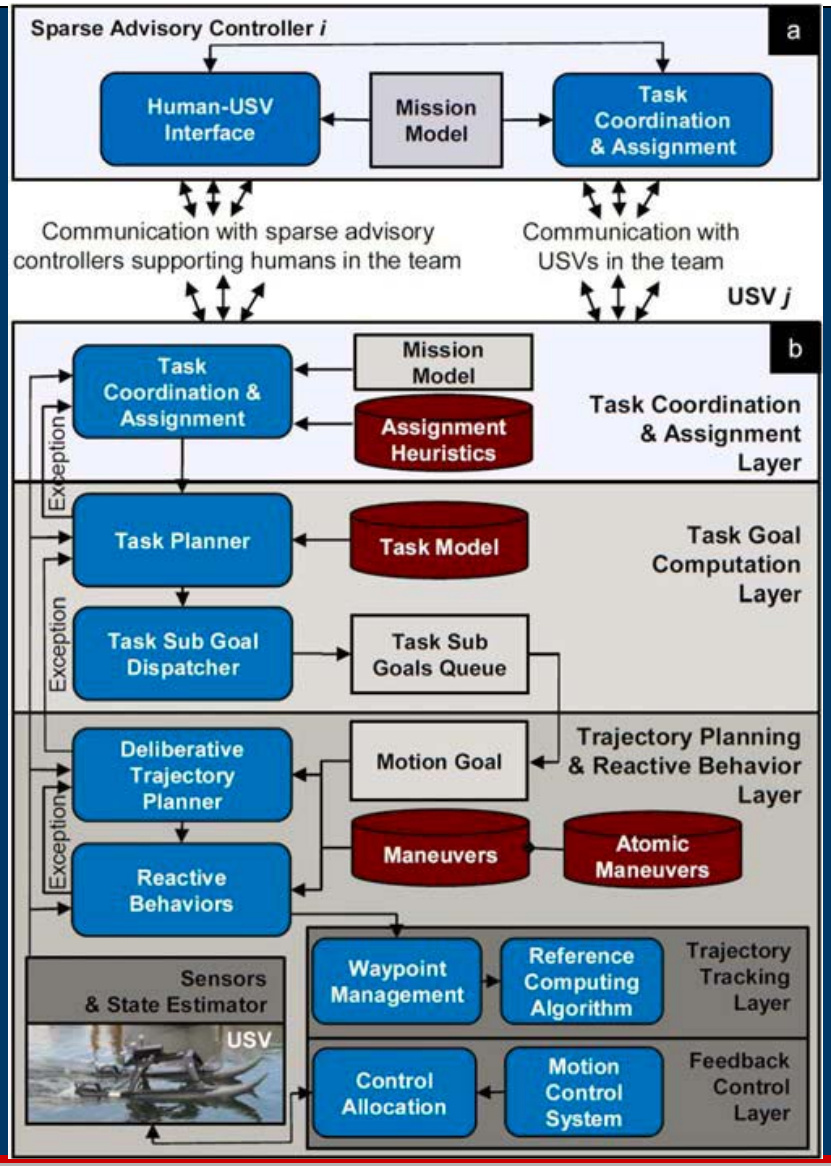
USV Challenges: Multiple Vehicle Interaction

Experimental Setup

USV Challenges: Autonomy

a) Small teams, 3-5 people, maybe with ALR
b) Some locations difficult to access – system small/light for small truck transport and tended by small boat.
c) Autonomy:
   i. Does not need continuous monitoring by human team.
   ii. Should permit teleoperation or redirection to areas of interest (RSC).
   iii. Capable of autonomously resuming normal operation after interruption (sliding autonomy).
d) Constant communications with auto reconnect.
e) GUI: near real time; bright sunlight; outdoor working conditions; balanced operator workload.
f) Other boat traffic: COLREGs; dynamic obstacle avoidance.

USV Challenges: Autonomy



Multilayered Software Architecture.

Acknowledgements

Florida DOT Grant BDV27 TWO 977-07

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