Man-portable Bottom mobility Platform for UXO Investigations

MR-201712
PI: Arnis Mangolds
C-2 Innovations, Inc
In-Progress Review Meeting
21 February, 2018

ESTCP

MR-201712: Project Title

Performers

- **C-2 Innovations Inc. (C-2i), White River Technologies Inc (WRT)**

Technology Focus

- Create a modular man-portable, autonomous or command controlled tractor towing the marinized, size optimized Flex-EMI detector array

Demonstration Site

- A site has not yet been finalized.

Demonstration Objectives

- Conduct geophysical investigations via carried and towed instrumentation packages across a range of terrain and sea states
- Develop maneuver strategies with a tow package
- Determine mapping, coverage precision
- Show complete life cycle cost effectiveness that includes mobilization and demobilization, on-site specific vehicle modification for environment and payload support, stuck-vehicle recovery and maintenance and repair

Project Progress and Results

- Prototype Tractor (Sea Ox) and sled is under construction, Preliminary testing of navigation and communication system completed, size optimized Flex EMI constructed and bench top system tested for sensitivity and tractor noise interference

Implementation Outlook

- No implementation issues identified. Field testing next several months

Social Media Content

- ***Field experiments are beginning to test mobility and maneuverability in difficult access terrain and surf****. Researchers at C-2i, Inc and WRT Inc are starting field experiments to test the operational limits and effectiveness of the light weight autonomous Sea Ox and Flex EMI systems used for detecting UXO located in the transition zone of estuarine environments*

Project Team

- C-2 Innovations, Inc (C-2i)
  - Arnis Mangolds
    - 978-257-4820
    - amangolds@c-2iinc.com

- White River Technologies, Inc, (WRT)
  - Greg Schultz
    - 603-678-8385
    - Schultz@whitervertech.com

Problem Statement

- Get the sensor close to the target
  - Detection and localization is dramatically improved as the sensor-to-target distance diminishes so an instrumentation sled makes sense.
    - Presently most surveys are surface or mid-column
      - Sensitivity is lower
      - Localization and target reacquisition is less certain
      - Does not offer any additional information about temperature, currents, soil density, etc.
- The challenge is
  - Maneuverability around clutter, very soft ground and through the surf
  - Communications and control very difficult
- Large or heavy systems cannot access sensitive areas, and inevitable breakdowns can create unsupportable logistical costs
  - Capital, logistics, recovery and operational costs of heavy systems can dominate program costs
- Smaller systems more sensitive to environmental influence (currents, wave action)

Technical Objectives

- Assess the capabilities and limitations of a light weight Surf Zone Crawler mobility platform
- Develop maneuver strategies for turning and backing out with a tow package
- Determine coverage characteristics
- Assess positional accuracy for reliable mapping purposes and reacquisition
- Create operational procedures that include
  - mobilization and demobilization
  - on-site specific vehicle modification for environment and payload support
  - stuck vehicle recovery
  - maintenance and repair
- Show complete life cycle cost effectiveness for different project sizes and conditions

Technical Approach

- Begin testing with Sea Otter
  - Power draws, performance, navigation issues
  - Test sled interface
- Build/test prototype sleds
  - Look at drawbar loads, turning different soil types, currents
  - Test different mobility methods for the sled
    - Wheels, tweels, tracks, skids
    - Pitch, yaw and roll
    - Separation distance form the tractor
- WRT making size optimized, lower profile Flex EMI
- Design/build/test tractor (Sea Ox)
  - Assume full life cycle considerations
- Work with WRT to integrate the instrumentation into the sled/tractor
- Field test with inert’s
- Field test with live
- Demos

Advantages

- The man-portable autonomous bottom crawler’s
  - ♦ low profile minimizes drag
  - ♦ can be carried in a pickup truck
  - ♦ can be assembled by hand on site
  - ♦ minimizes logistical costs
- Low noise vehicle signature enables a short wheel base which in turn permits higher degree of maneuverability
- Short wheel base minimizes transfer error for anomaly localization
- Autonomous and optional manual control simplifies operation and provides maximum site and mission flexibility

Technical Progress

Preliminary Tests with prototype sled and Sea Otter



- Drag, lift; f(speed, turn radius, slope, ballast, ground type, motive concept)
- EM noise
- Navigation
- Conclusion:
  - Tracks, track pitch, no castor
  - Noticed lift, especially on skids
  - For large enough turn radius yaw not needed


Initial sled design

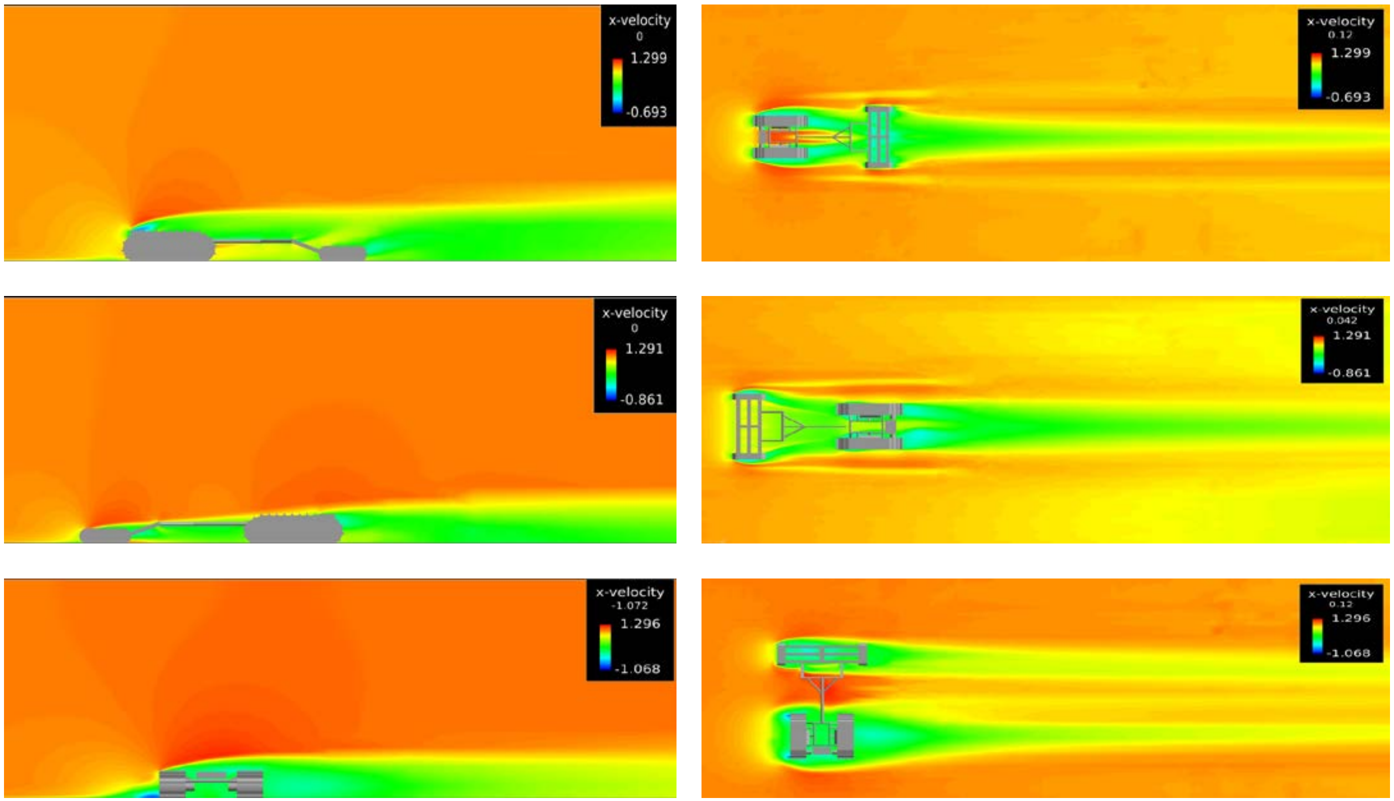
Tested various sled systems:

- Tweel
- Wheel
- Tracked
- Skid
- Castor

Prototype Ox

- 250-lb vehicle (dry)
- Can carry 350-lbs (dry)
- 4-ft x 4-ft x 1 ft
- Drawbar normal operating
  - 750N normal (167-lb)
  - 1500N Max continuous (337-lb)
  - 3600N Peak (809-lb)
- Estimated range
  - 10- miles
  - Extendable to 40-miles
    - No sled
    - Extra batteries
- Operating speed 0.5m/s
- Motors are stackable

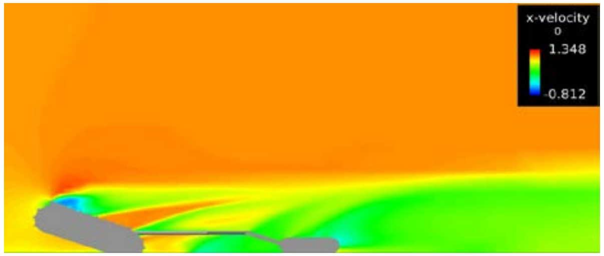
CFD: Forward, Back wash and side

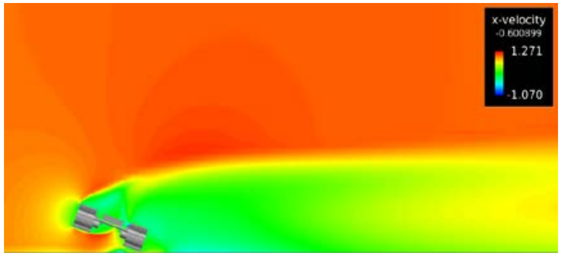


Case	Flow speed (m/s)	OX drag (N)	OX lift (N)	Sled drag (N)	Sled lift (N)
Forward	1.0	140	-1	67	-43
Reverse	1.0	70	-31	96	-51
Cross	1.0	185	31	75	13

Stabile to 3m/s

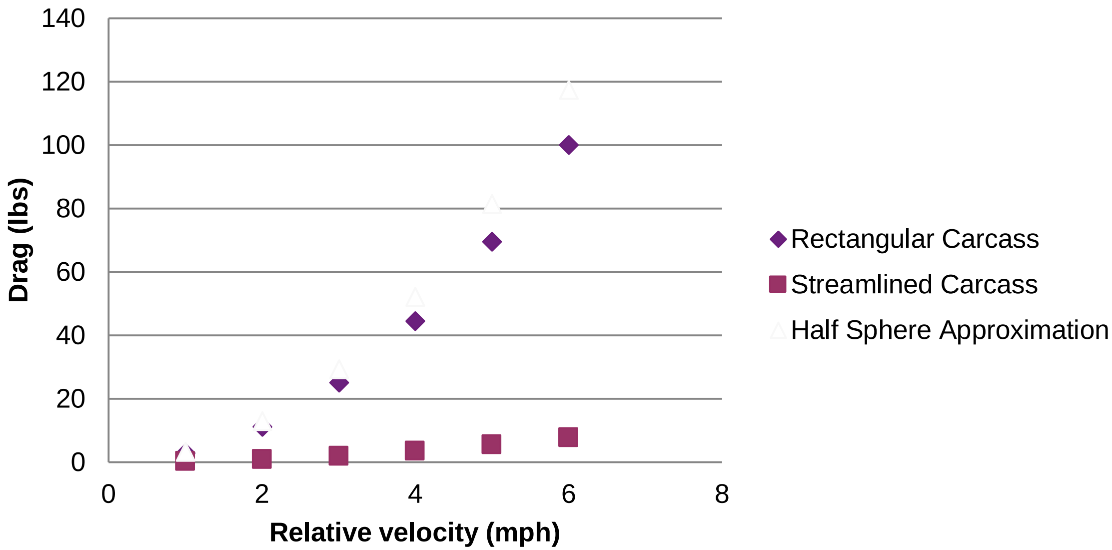
The effect of obstacles

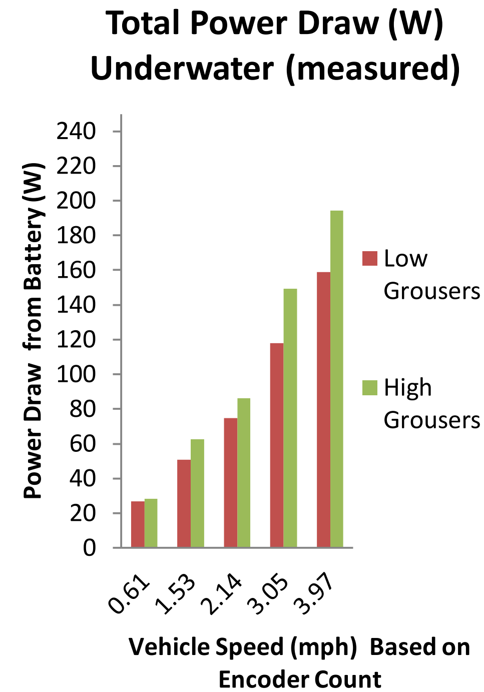


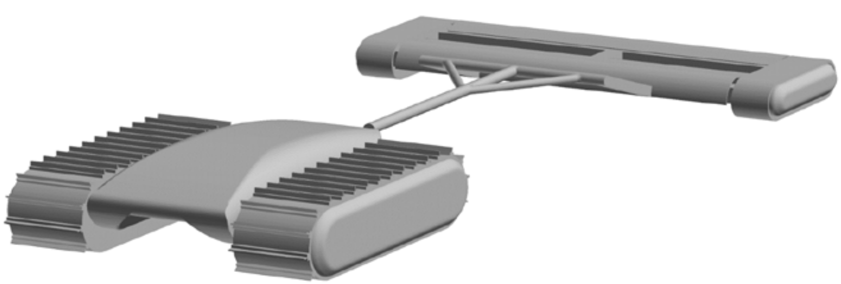


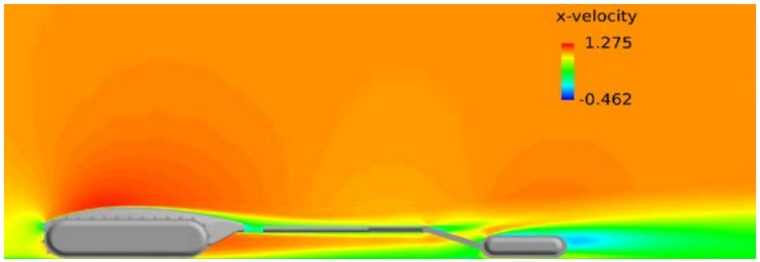
Case	Flow speed (m/s)	OX drag (N)	OX lift (N)	Sled drag (N)	Sled lift (N)
Forward flow, OX 10 deg pitch	1.0	237	197	67	-67
Forward flow, OX 20 deg pitch	1.0	281	255	68	-69
Forward flow, OX 30 deg pitch	1.0	330	282	67	-69
Forward flow, sled 10 deg pitch	1.0	N/A	N/A	221	80
Forward flow, sled 20 deg pitch	1.0	N/A	N/A	289	152
Forward flow, sled 30 deg pitch	1.0	N/A	N/A	337	182
Cross flow, OX 10 deg roll	1.0	476	25	N/A	N/A
Cross flow, OX 20 deg roll	1.0	590	65	N/A	N/A
Cross flow, OX 30 deg roll	1.0	665	79	N/A	N/A
Cross flow, sled 10 deg roll	1.0	N/A	N/A	152	19
Cross flow, sled 20 deg roll	1.0	N/A	N/A	195	59
Cross flow, sled 30 deg roll	1.0	N/A	N/A	245	98

Other influences



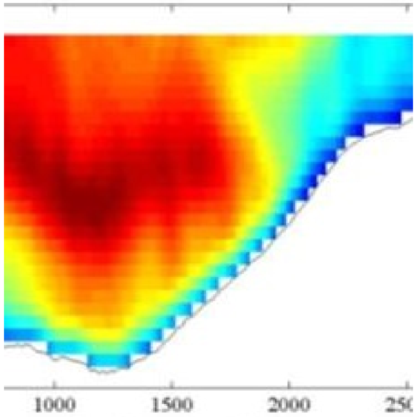




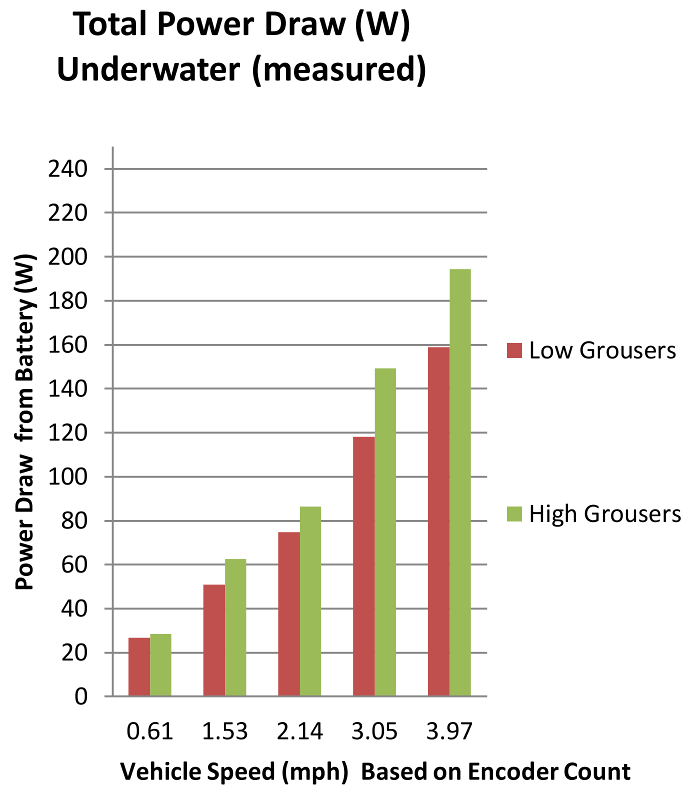


CFD Conclusions:

- Stay low
- Go slower 0.5m/s
- Ballast
- Fairings on the sides
- No fairings on top
- Encourage porosity
- Maybe a spoiler
- Drag is not a killer
- Sled as a wheelie bar
- Keep sled close in
- Minimize pitch and yaw separation

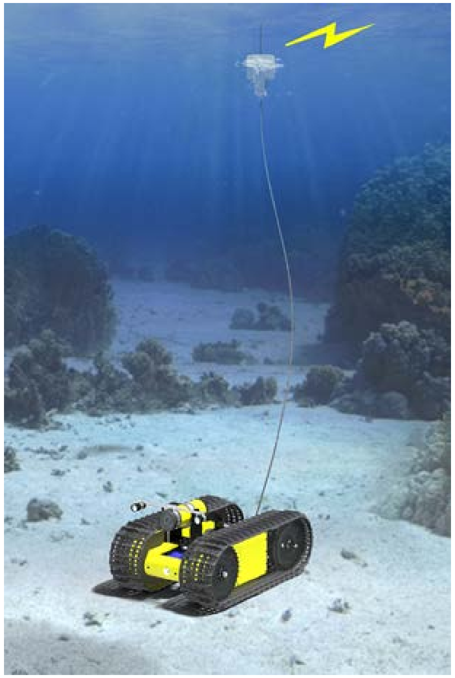


- Tested comms



Comms

- Just beginning
- Tested 1 mile range with ethernet system transmitting at 900mHz

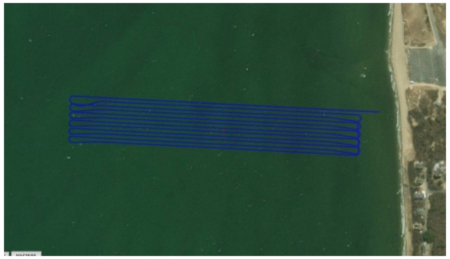


Ox Nav Options

Nav Option	% Error*	10 Mile Angle Error Distance	Raw Cost	Advantage	Liability
Sparton AHRS-M2	3.5	1840'	$2K	Low Cost, all in one package.	Relies on Magnetometers
KVH-1750 FOG	1.4	735'	$4K	Immune to magnetic environment changes.	Manual Initial Heading required
Vector NAV 310 Dual	0.9	459'	$5K	Seamless Retrofit to KVH-1750 FOG Good performance/cost ratio.	1 meter GPS baseline required
GEOFOG 3D Dual INS	0.3	166'	$32K	Expandable to USBL, Odometry, DVL	1 meter GPS baseline required Limited USBL upgrade options
iXBlue Phins C3	0.5	276'	$65K	Expandable, widely proven in UAV industry	42% power draw increase over GEOFOG 3D, 1% range penalty.
iXBlue Phins C5	0.2	92'	$110K	Higher precision	65% power draw increase, 2% Range penalty
iXBlue Phins C7	0.03	18.5'	$116K	Highest precision offering.	Cost 2% Range penalty

*Error % based on 10 miles straight line assumption, worst case two sigma (95%) heading accuracies

Navigation tests (Sea Otter)

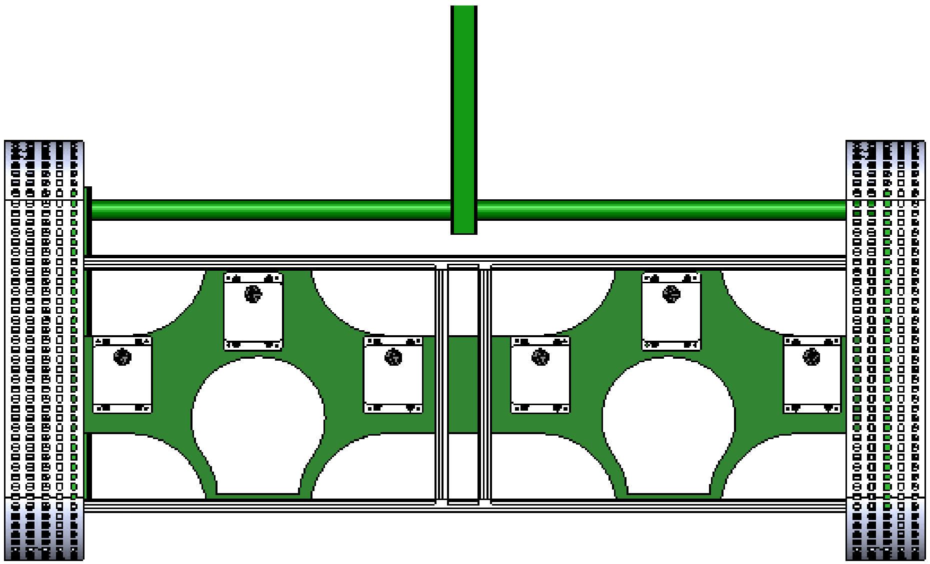


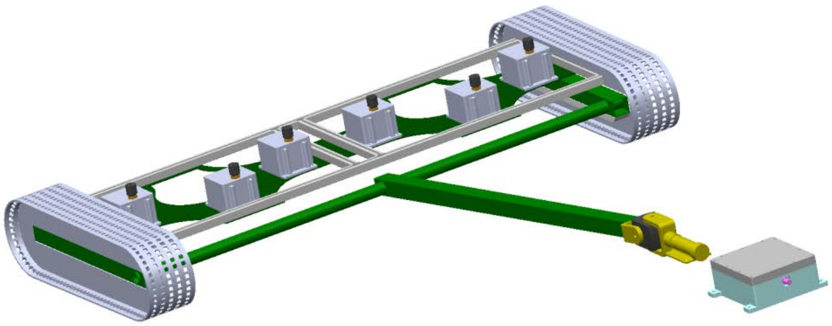
Right-sized Crawler-EM Array

- Doing more with less: a smaller EM array with better performance in power and fidelity
- Greatly reduced size receiver cube pressure vessels – improved hydrodynamic performance
- Smaller, more powerful transmitter driver leveraged from NMR and ROV-EM work
- Improved noise robustness using physically separated Rx and Tx modules, improved pre-amplifier and receiver signal conditioning

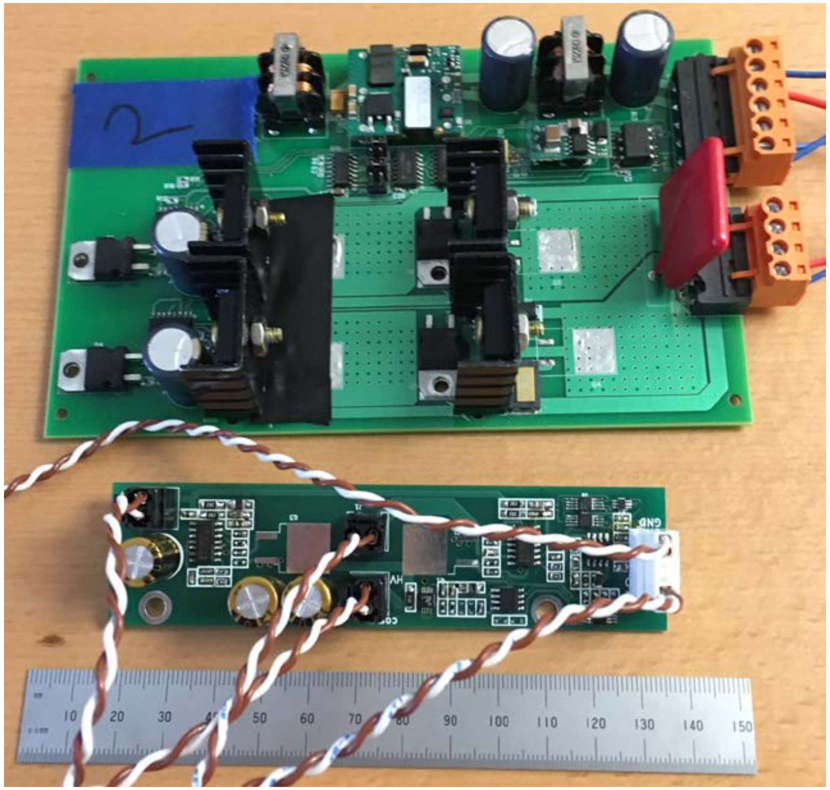
1.6 meter-wide SeaOx EM Array

- 2 Tx, 6 Triaxial Rx Array
- Scaled-down from 1422
- Smaller marine receiver pressure vessels with wet-mateable connectors
- Small overlap between adjacent coils yields null zone for DC sensor





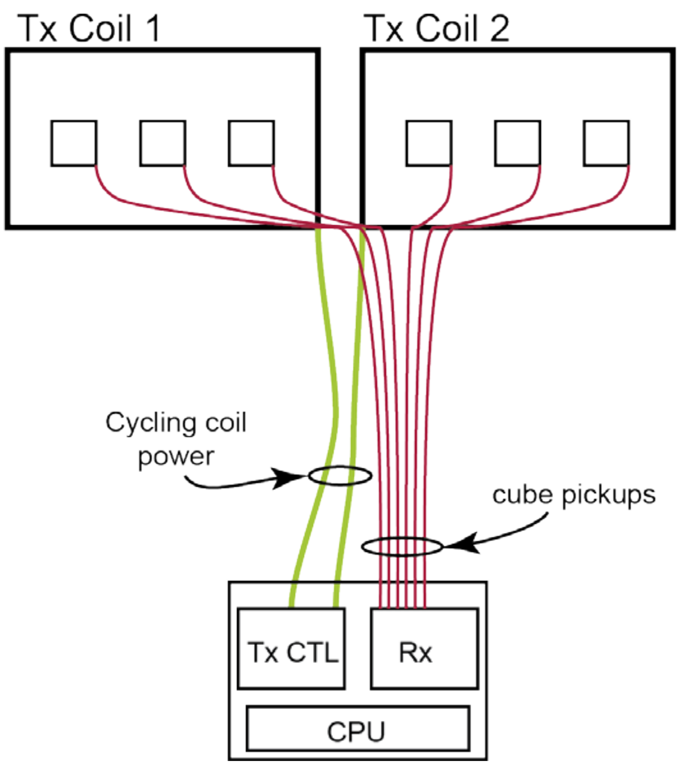
Transmitter Driver Boards



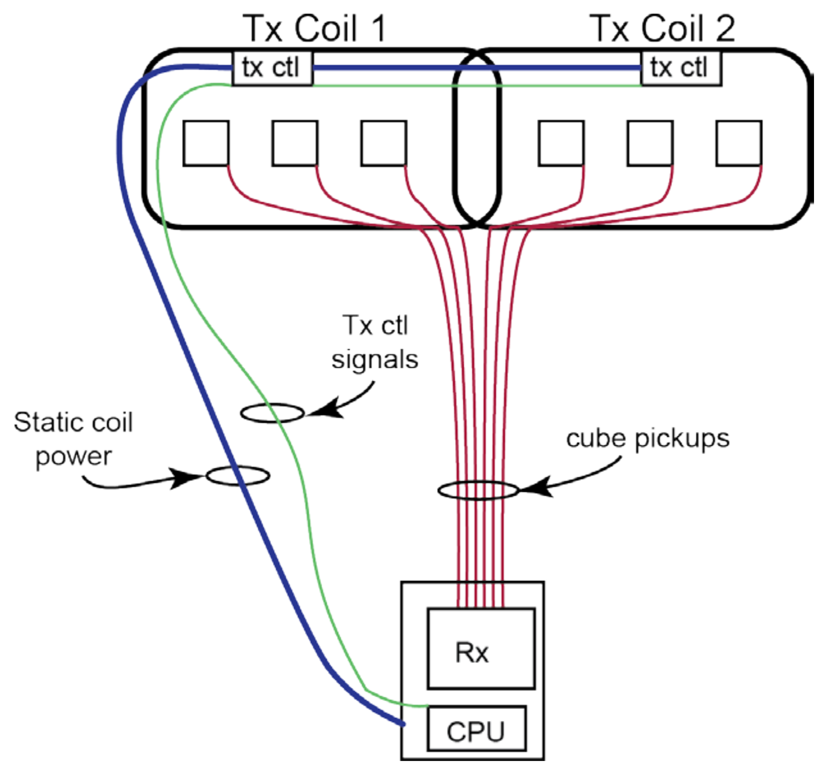
- Decrease in size with an increase in current.
- Coil mounting coil driver board.
- Coil heath monitoring through current and voltage measurement

Transmitter Board Locations

Crawler Array (from MR-201422)



Improved*, small-form SeaOx Array



**2017 improvements to EM Array leveraged from Army (A142-091) and Navy (N17A-T015) SBIR/STTR projects*

	Program Year 2017												Program Year 2018											
	FY 2017					FY 2018												FY 2019						
Task	CY 2017								CY 2018												CY 2019			
	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A
1. Survey and Kickoff																								
Sensor review, reuriements development																								
Vehicle review																								
KO meeting, Washington DC																								
Test site & plan discussions																								
System Design Document, Go/No-go decision																								
2. Baseline																								
Develop instrumentation package																								
Collect OSZC signal noise @ WRT																								
Build Gen 1 trailer w/ sled and track																								
Prep Gen1 OSZC (pintal, extended bracket, track, bridge)																								
Confirm signal fidelity with OSZC																								
Test @ 5 sites for load histories																								
Analyize data, spec changes																								
3. Design, Build Modified OSZC																								
Design Transmission, track change out, track, pintal																								
Changes to comms, navpac																								
Build modifications																								
4 Design, build trailer																								
Low signature, low drag trailer																								
Mount instrumentation and test																								
System Test Report, Go/No-go																								
Task 5 Integrated Mobility, Maneuverability																								
Open field																								
Sand/bay, hard, soft, slope																								
Mud flats																								
obstcle testing, backup maneuvers																								
Analysis,																								
Task 6 Navigation and Operational Run times																								
Autonomous runs 5 sites																								
Commanded (RF) runs 5 sites																								
Target density tests																								
Task 7 Demo 1																								
Demo plan																								
Demo																								
Demo Analysis and report																								
Demo Analysis and Report Go/no-go																								
Task 8 Demo 2																								
Demo plan																								
Demo																								
Demo Analysis and Report																								
Task 9 Data Compliation and Reporting	Po, Ep		T,Q			Q		Ep	Q		T	QT		Dp	Q			Dp,(	Dr	Ep,	Q		Dr	F
Task 10 Commercial technology Transition																								

Po = Project overview; Ep = Execution Plan; T = Task reports; D = demonstration plan; Q =Quarterly Progress Report; F = final report

Technology Transfer

- Demos:
  - Pilgrim Lake seep mapping: CCS Provincetown MA (Oct 2017)
- Shows/presentations:
  - Coastal Estuarine Research Foundation (CERF, booth)
  - World Oceans Congress, Shenzhen China (Nov 2017, talk)
  - China University of Petroleum (Beijing China Nov 2017, talk)
  - Environmental and Engineering Geophysical Society (poster - SAGEEP, Mar 2018)
  - Clean Rivers (April, 2018)
  - NEERS (April 2018)
- Publications:
  - Marine Reporter (summer 2018)
- Cut sheets:
  - UMST (January 2018)
  - USMC (Feb 2018)

Technology Transfer

- Presentations:
  - Schlumberger
  - NOAA
  - Nav-O
  - USMC
- Marketing help
  - SBANE
  - Babson Strategic Analysis Consulting Program
  - Mass Venture

Issues

- Lots of challenges, no issues