Unmanned Aircraft Systems, Machine Learning and Polarimetric Imaging for Enhanced Marine Debris Detection and Removal

Presentation to the NOAA UAS Program Office
Mission Concept Review

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Principle Investigator(s)

Tim Battista
NOAA Marine Spatial Ecology Division (MSE)

Amy V. Uhrin
NOAA Marine Debris Program (MDP)

Co-Investigators

Chris Parrish & Richie Slocum
Oregon State University

Peter Murphy
NOAA Marine Debris Program

Mission Concept Review

Overall Objectives

- ID suitable UAS system/payload for Marine Debris Program.
- Determine optimal data acquisition parameters.
- Automate detection & material type classification.
- Develop and implement operationally-efficient workflows & deployable algorithms.

Mission Goals & Objectives

- Two study sites: 1) controlled testing & training site and 2) validation site with persistent high density marine debris.
- Compare sensors & platforms including polarimetric imaging.
- Develop operational procedures.
- Develop auto-detection & material-type identification via machine learning
- Evaluate concentration & material type products
- Training and initial Transition to MDP & partners.

Heatmaps Representing Concentrations of Marine Debris

** Proof-of-concept: mock-up created through hand digitization*

Focus on macro-debris (>1 m size) which is most typical debris for MDP-supported cleanup

Level of accumulation informs removal /remediation decisions

Machine Learning

- Goal: auto detection and classification of marine debris
  - Hierarchical classification
    - Binary: belongs at beach vs. doesn’t belong at beach
    - Material type classification: plastic, wood, foam, metal
    - Identification: bottle, fishing net, nylon line, buoy/float, crab trap, flipflop, etc.

- Not inventing new ML algorithms
  - Utilize existing ML frameworks
    - Tensorflow, Pytorch

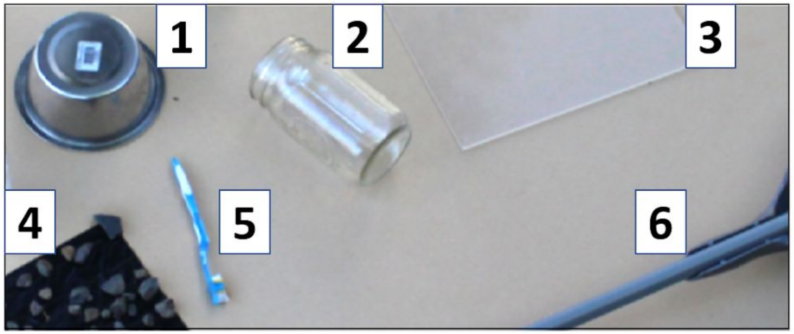
- Research focus areas
  - Size of training database
  - Performance of various models
    - Performance metrics: precision, recall, and receiver operating characteristic (ROC) curves

- Potential collaboration with Ross Winans, NOAA OCM and University of Hawai‘i at Mānoa MS student

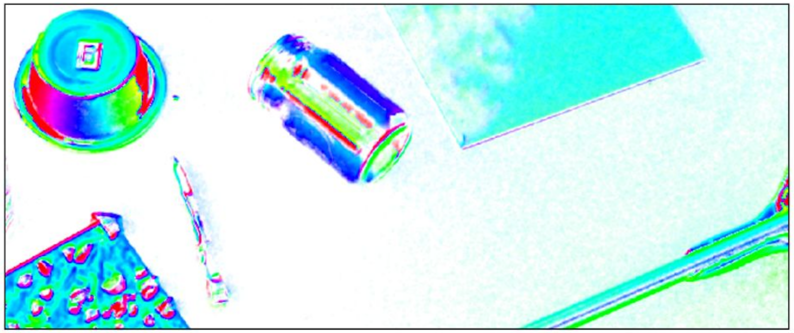
Polarimetric Imaging

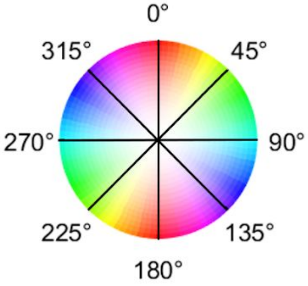
- Polarimetry = measurement and interpretation of the polarization state of transverse light waves reflected by object
- Useful for identification of human-made objects within a scene

Combination of spectral and polarimetric imaging info can facilitate both detection and recognition



(1) Aluminum bowl
(2) Glass mason jar
(3) Acrylic panel
(4) Plastic trash bag
(5) Toothbrush
(6) Plastic broom handle





Investigation of PI Cameras

- Will be conducting market research for procurement
- Key specs
  - Cost
  - Resolution
  - Chip size (pixels and microns)
  - Lens
  - Frame rate
  - Spectral bands
  - Polarimetric info
  - Size, weight, power requirements

FLIR Blackfly S USB3:
https://www.flir.com/products/blackfly-s-usb3/?model=BFS-U3-51S5PC-C

PolarCam G5:
https://www.4dtechnology.com/products/imaging-polarimeters/

sUAS Platforms

3DR Solo

DJI S900 + Pixhawk

DJI P4P - RTK

- 3 OSU owned airframes operated by OSU team members

- Solo : Lightweight custom mapping system
- S900 : Heavy lift custom mapping system
- P4P : COTS mapping system

- Algorithms and research aims to be platform agnostic

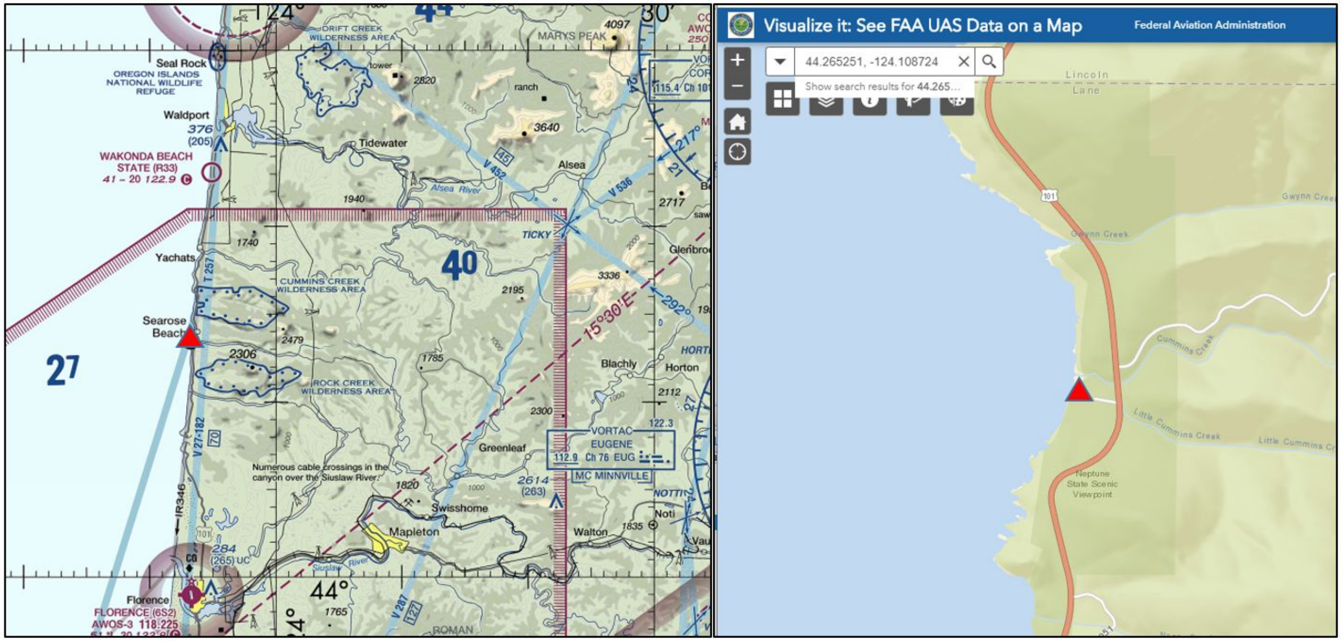
CONOPS

Two study sites:

1. Controlled testing and training site
   - Debris items will be placed, accurately surveyed, and flown with range of parameter settings
   - Identified location: Neptune State Scenic Viewpoint, south of Yachats, Oregon
     - Encompasses range of shoreline types/features: rock outcrop, sand, vegetation, cliff, and creek outflow
2. Validation site
   - Test procedures operationally in site known to have persistently high densities of macrodebris
3. *Opportunistic data collection opportunity @ Netarts Bay, OR

CONOPS Florence, OR Testing Site

- Neptune State Park in Class-G airspace. OPRD Scientific Research Permit Required
- Flights: surface to 400 ft AGL, operations 150-400 ft
- Flights under Part 107, OSU UAS policies and procedures, NOAA UAS Handbook, & AOC-approved

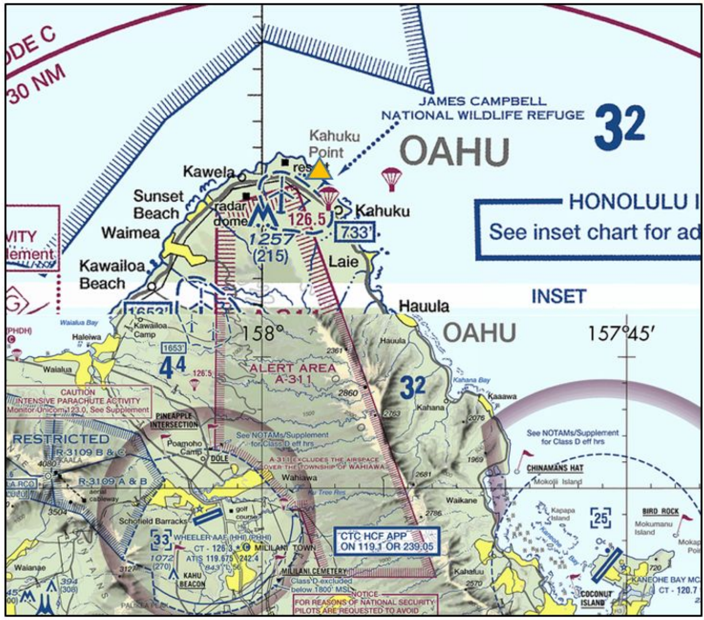


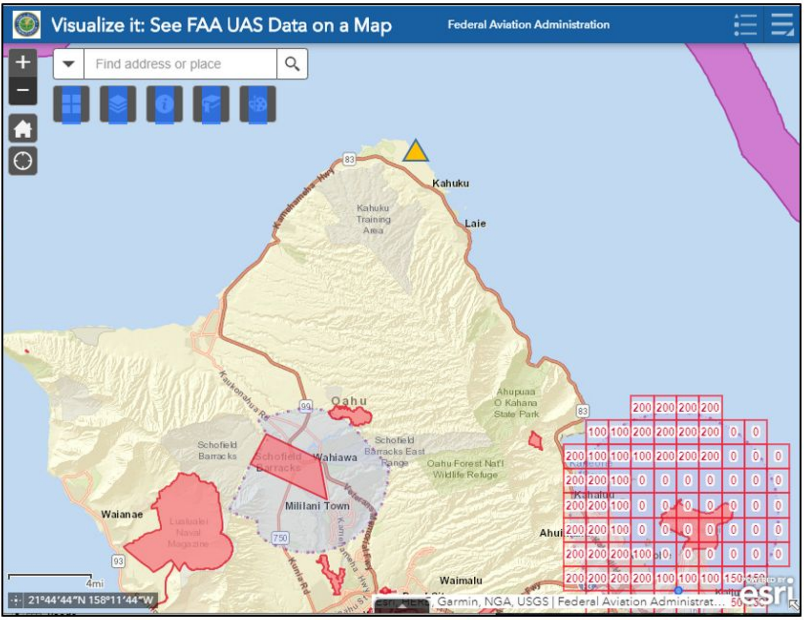
▲ = Neptune State Scenic Viewpoint test site

CONOPS Oahu, HI* Validation Site

- James Campbell Wildlife Refuge in Class-G airspace.
- Site selected due to persistent high concentrations of debris.
- Same operational approval and CONOPS process as for testing site.

**Tentatively planned site*




Visualize it: See FAA UAS Data on a Map

△ = Oahu validation site

Airspace Access Plan

- All proposed operating areas are in Class G airspace and do not require special airspace access requests.

Required Assistance

- No assistance is required from AOC.

Project Personnel

Name	Affiliation	LOE (mo)	Role	Qualification(s)
Tim Battista	NOAA NCCOS	7	Project management, technical guidance	sUAS operation planning, remote sensing
Amy Uhrin	NOAA ORR	2	Project management, technical guidance	MDP expert
Chris Parrish	OSU	4.5	Pilot, system integration, sUAS field testing	sUAS pilot, system engineer
Richie Slocum	OSU	10	Pilot, system integration, sUAS field testing	sUAS pilot, system engineer
Kyle Herrera	OSU	12	Pilot, system integration, sUAS field testing	sUAS pilot*
Peter Murphy	Genwest	2	Technical guidance & evaluation, sUAS system testing	MDP Developing Technologies Expert

Project Risks

Project Management Risks and Mitigation

Risk: Project funding transferal
Probability: unlikely.
Potential Impact: moderate.
Mitigation: NCCOS will pre-initiate the contract mechanism through existing contract vendor mechanisms to ensure success.

Risk: Cost overrun
Probability: unlikely.
Potential Impact: moderate.
Mitigation: In the event that project cost estimates are inaccurate, cost overruns will be mitigated by cost trimming in other portions of the budget.

Risk: Key personnel leaving the project
Probability: unlikely.
Potential Impact: moderate.
Mitigation: In the event that key personnel (Parrish/Slocum) leave the project, the alternate pilot will conduct UAS flights, and an alternative engineer will be substituted for integration tasks.

Project Risks

Mission Operational Risks and Mitigations

Risk: Inclement Weather
Probability: low
Potential Impact: moderate.
Mitigation: Time windows specified for fieldwork include realistic-to-conservative budgets for inclement weather. Fieldwork can be suspended on a daily basis, as necessary, if short-term weather events occur.

Risk: NEPA permitting failure
Probability: unlikely.
Potential Impact: moderate.
Mitigation: Operations will be rescheduled in the event additional NEPA review/clearance is necessary. However, ample lead-time submitting documentation for NEPA approval and close coordination with the AOC oversight authorities should mitigate any delays.

Project Risks

Flight Safety Risks and Mitigations

Risk: Failure of a quadcopter UAS engine
Probability: unlikely
Potential Impact: moderate.
Mitigation: Preflight inspection of engines and props. We will not fly the drones over people or vessels.

Risk: Collision with a manned aircraft
Probability: Rare
Potential Impact: Catastrophic
Mitigation: UAS operations will conform to all FAA policies and flight restrictions..

- We will remain below 400 feet MSL at all times
- Use Flightradar24 to track aircraft to give us early alerts including distance, and altitude of nearby manned aircraft.
- Use a visual observer to monitor the UAS and visually search for nearby manned aircraft
- Maintain radio contact with nearby control tower, if available

Project Risks

Flight Safety Risks and Mitigations (contd)

Risk: Loss of Drone GPS navigation
Probability: unlikely
Potential Impact: moderate.
Mitigation: Switch pilot control mode to control the UAS to use only the augmented stability mode without GPS, and manually fly the UAS to the designated landing zone and land.

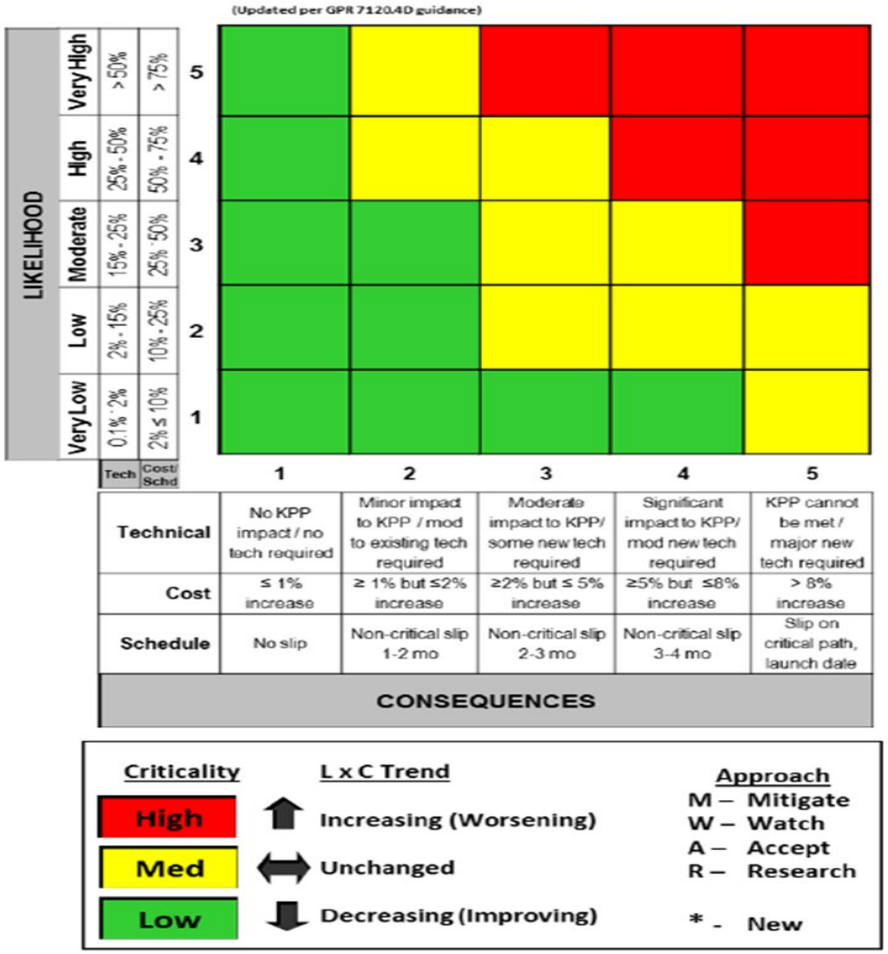
Risk: Loss of Drone ground control signals
Probability: unlikely
Potential Impact: moderate.
Mitigation: Each drone will be configured to “Return to Home” in the event of a loss of control signals. The Return to Home location will be updated and verified as part of the preflight checklist before each takeoff. We will advise the nearest control tower of the loss of control.

Risk: Interference with UAS control signals causing loss of control.
Probability: Rare
Potential Impact: moderate.
Mitigation: When onsite, examine the radio frequency (RF) spectrum used by each UAS for interference by using an RF spectrum analyzer to insure clear channel operation.

Risk Assessment

<u>X,Y</u>

Technical:	2,2
Cost:	1,1
Schedule:	3,4



(Updated per GPR 7120.4D guidance)

LIKELIHOOD	Tech	Cost/ Schd						
Very High	> 50%	> 75%	5	🟩	🟨	🟥	🟥	🟥
High	25% - 50%	50% - 75%	4	🟩	🟨	🟨	🟥	🟥
Moderate	15% - 25%	25% - 50%	3	🟩	🟩	🟨	🟨	🟥
Low	2% - 15%	10% - 25%	2	🟩	🟩	🟨	🟨	🟨
Very Low	0.1% - 2%	2% ≤ 10%	1	🟩	🟩	🟩	🟩	🟨
				1	2	3	4	5

	1	2	3	4	5
Technical	No KPP impact / no tech required	Minor impact to KPP / mod to existing tech required	Moderate impact to KPP/ some new tech required	Significant impact to KPP/ mod new tech required	KPP cannot be met / major new tech required
Cost	≤ 1% increase	≥ 1% but ≤2% increase	≥2% but ≤ 5% increase	≥5% but ≤8% increase	> 8% increase
Schedule	No slip	Non-critical slip 1-2 mo	Non-critical slip 2-3 mo	Non-critical slip 3-4 mo	Slip on critical path, launch date

CONSEQUENCES

<u>Criticality</u>	<u>L x C Trend</u>	
🟥 High	⬆ Increasing (Worsening)	
🟨 Med	⬌ Unchanged	
🟩 Low	⬇ Decreasing (Improving)	

<u>Approach</u>
M – Mitigate
W – Watch
A – Accept
R – Research

* - New

Milestones

Period of Performance: 01 June 2020 – 31 May 2022

#	Deliverables (D) & Milestones (M)	Estimated Completion Date	Success Criteria
1	(D) Quarterly Project Report Briefings	Quarterly	Completion
2	(D) Initial Technical Review with UASPO	2 months from date of award (est. August, 2020)	Completion
3	(M) NEPA documentation	7 months from date of award (est. January, 2021)	Signed document
4	(M) Procure or fabricate sensors and platforms	4 months from date of award (est. October, 2020)	Proof of purchase
5	(D) Development of Transition Plan	6 months from date of award (est. December, 2020)	Completion
6	(M) Conduct flight tests at OSU UAS test facility	7 months from date of award (est. January, 2021)	Written Documentation
7	(M) Conduct tests of PI at OSU testing facility	7 months from date of award (est. January, 2021)	Written Documentation
8	(M) Train machine learning (ML) algorithm and develop beta version of workflow	11 months from date of award (est. May, 2021)	Written Documentation

Milestones

Period of Performance: 01 June 2020 – 31 May 2022

#	Deliverables (D) & Milestones (M)	Estimated Completion Date	Success Criteria
9	(M) Conduct flights at testing & training site Neptune State Scenic Area, OR	12 months from date of award (est. June, 2021)	Trip Report
10	(M) Refine ML algorithms and workflows	14 months from date of award (est. August, 2021)	Completion
11	(M) Conduct validation tests in HI	15 months from date of award (est. September, 2021)	Trip Report
12	(M) Develop SOPs	22 months from date of award (est. April, 2022)	Written Documentation
13	(D) Conduct training for MDP staff	22 months from date of award (est. April, 2022)	Written Documentation
14	(D) Complete system performance and technology transfer document	23 months from date of award (est. May, 2022)	N/A
15	(D) Deliver Final Project Report	23 months from date of award (est. May, 2022)	Completion
16	(M) End of Project Technical Review	23 months from date of award (est. May, 2022)	Completion

Technical Readiness

Project Component	Current RL	Anticipated Final RL
Observing System Application (Platform + Sensor Combination	RL 5 (Concept Demonstrated in Relevant Environment)	RL 8 (Final System Demonstrated in Operational Environment)
Machine learning approach to auto-detection of debris	RL 3 (Proof of Concept Developed)	RL 7-8
Polarimetric imaging (PI)	RL 2	RL 6-7, pending findings of this portion of project

Questions?