ORCA HUB
Offshore Robotics for Certification of Assets
Remote Safety and Integrity

Virtual Engineering Techniques to Validate and Verify UAV Offshore Asset Inspection Missions

Dr. Michael Jump, University of Liverpool
mjump1@liverpool.ac.uk
Drs. V. Page, C. Dadswell, University of Liverpool

Drones & ROVS 2021
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HERIOT WATT UNIVERSITY | THE UNIVERSITY of EDINBURGH | UNIVERSITY OF LIVERPOOL | Imperial College London | UNIVERSITY OF OXFORD | INDUSTRIAL STRATEGY | UK Research and Innovation | EDINBURGH CENTRE FOR ROBOTICS

Overview

- The ORCA Hub
- (Manned Flight) Simulation in Offshore Hazardous Environments
- Using Unmanned (Aerial) Vehicles for Offshore Inspection
- Concluding Remarks

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About the ORCA HUB (1/2)

- Launched in October 2017 with 3 other hubs as part of HMG's £93m R&D funding for 'Robotics and AI (RAI) for Extreme Environments'
- Research programme to develop RAI for the offshore sector
- Supports a long-term offshore industry vision for autonomous & semi-autonomous offshore energy fields; operated, inspected and maintained from shore
- Aim is to translate research and discovery science into commercial products and services to support the UK offshore supply chain
- Find out more at: https://orcahub.org/

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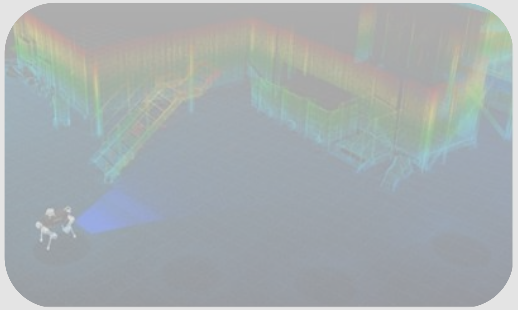
About the ORCA HUB (2/2)

The 4 Themes

Mapping, Surveying and Inspection



Planning, Control and Manipulation

Intelligent Human-Robot Interaction/XAI

Robot and Asset Self-Certification

An Observation

Robotics vs Aerospace

Goodwood drone crash: Aircraft was 'poor quality' investigation finds

A drone that crashed about 40m from peoples homes was of poor design and build quality and investigation has found.

By Joe Stack
Thursday, 18th February 2021, 11:34 am
Updated Thursday, 18th February 2021, 11:36 am

'Kill switch' failed as drone hit controlled space near Gatwick

18 February

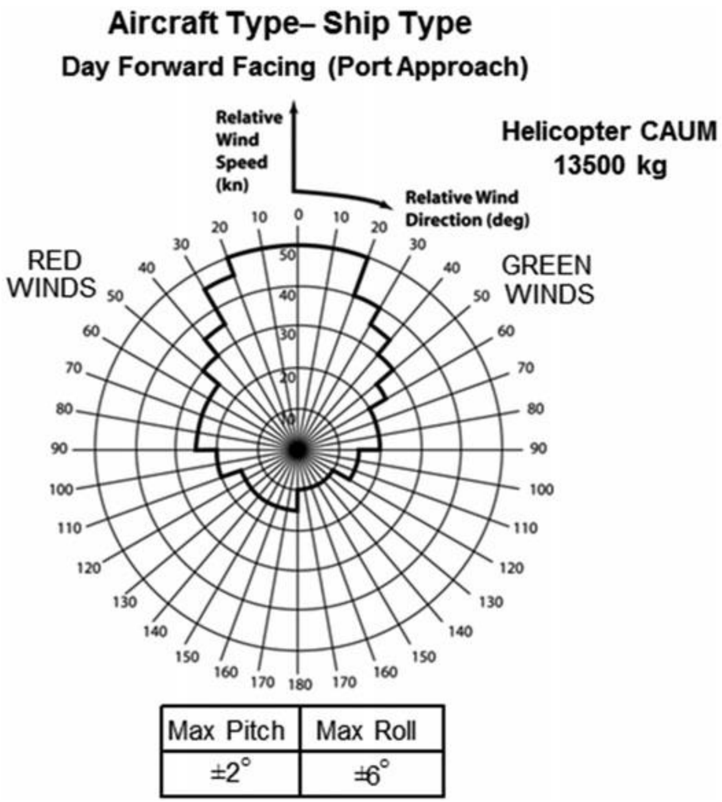
The drone crashed in a field of crops, the AAIB said

A drone went out of control and flew into airspace near Gatwick Airport before it crashed, the Air Accidents Investigation Branch (AAIB) has said.

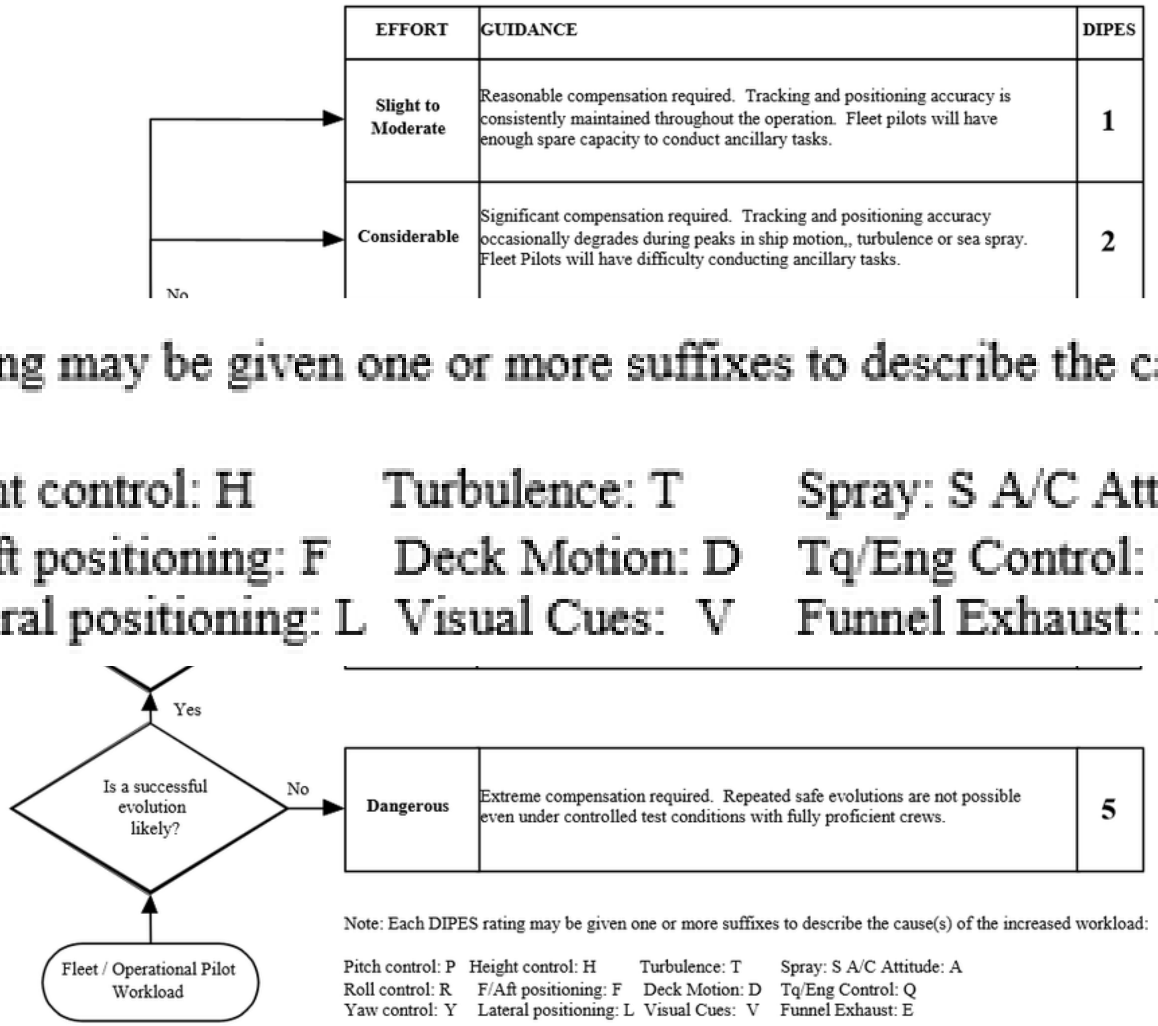
(Manned Flight) Simulation in Hazardous Offshore Environments

Helicopter-Ship Dynamic Interface (1/2)

- The 'invisible enemy'
- Qualifying helicopters to safely operate from ships is expensive, time-consuming and dangerous → to establish a Ship-Helicopter Operating Limit (SHOL)
- DIPES rating provides more information on reason for the limit…



(Manned Flight) Simulation in Hazardous Offshore Environments



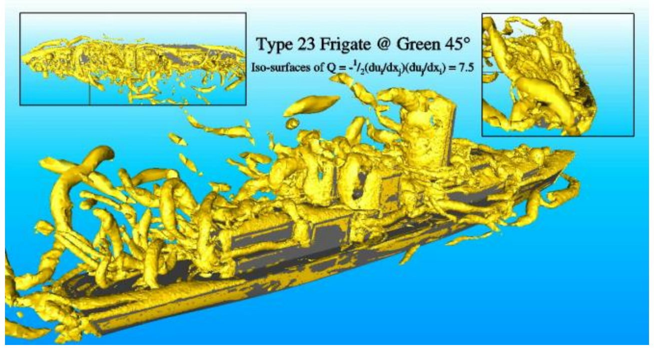
Note: Each DIPES rating may be given one or more suffixes to describe the cause(s) of the increased workload:

Pitch control: P Height control: H Turbulence: T Spray: S A/C Attitude: A
Roll control: R F/Aft positioning: F Deck Motion: D Tq/Eng Control: Q
Yaw control: Y Lateral positioning: L Visual Cues: V Funnel Exhaust: E

(Manned Flight) Simulation in Hazardous Offshore Environments

Helicopter-Ship Dynamic Interface (2/2)

- A requirement therefore exists to try to use simulation and virtual tools to reduce costs and elapsed time to generate a SHOL
- Technique developed at University of Liverpool



Using Autonomous (Aerial) Robots for Offshore Inspection

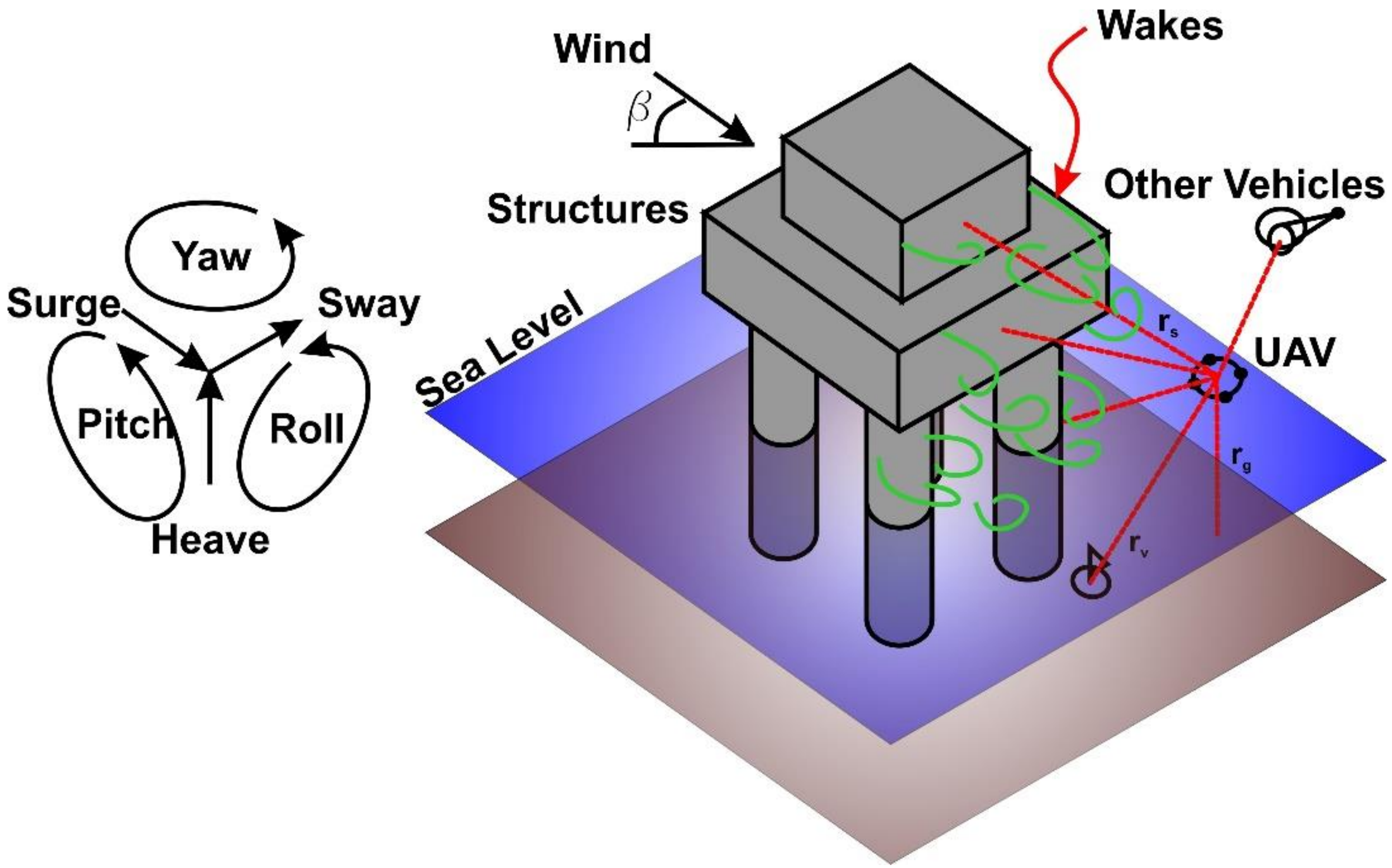
Use these ideas for unmanned aviation?

- As part of the ORCA Hub activity, we are building a virtual environment that combines these two ideas
    - test environment plus unsteady environmental conditions
- This is to be used as a proof-of-concept to:
    - Establish likely vehicle performance limits
    - Mission rehearsal/training
- Progress…

Using Autonomous (Aerial) Robots for Offshore Inspection

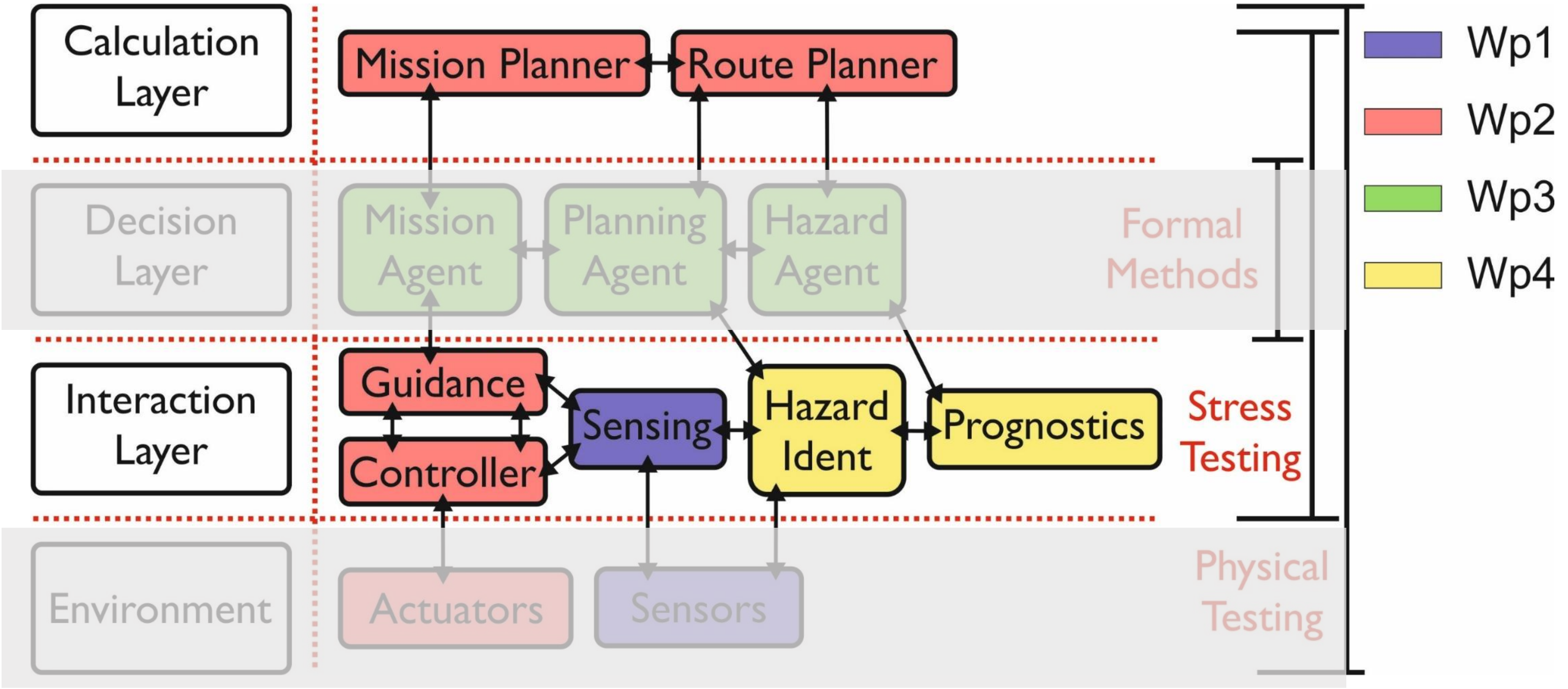
Scenario

- Inspection mission around offshore asset using an unmanned aerial system
- Challenge – operate safely in an unsteady wake that cannot be 'seen'
- Can we ascertain the operating limits to inform operational safety?



Using Autonomous (Aerial) Robots for Offshore Inspection

Architecture



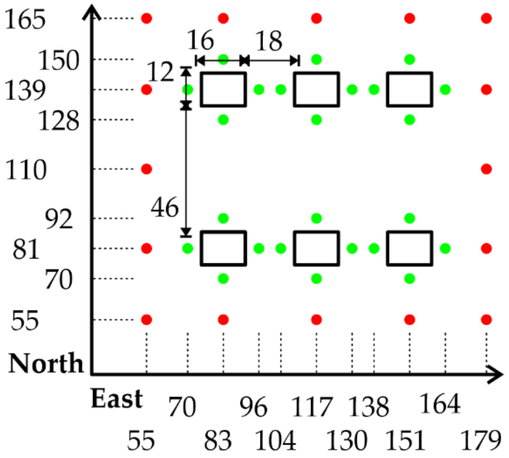
Using Autonomous (Aerial) Robots for Offshore Inspection

Virtual Environment Inputs

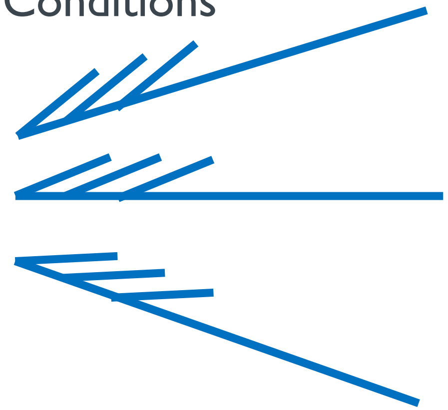
1. Stitched Linear Vehicle Model (plus stabilisation and guidance controllers)

$$\boldsymbol{A}_{ij} = f\left(U_q, V_{w_q}, \psi_{w_q}, \bar{U}, \bar{V}_w, \bar{\psi}_w, \boldsymbol{A_{base}}_{ij}\right) \; for\ i = 1{:}9\ and\ j = 1{:}9$$
$$\boldsymbol{B}_{ij} = f\left(U_q, V_{w_q}, \psi_{w_q}, \bar{U}, \bar{V}_w, \bar{\psi}_w, \boldsymbol{B_{base}}_{ij}\right) \; for\ i = 1{:}9\ and\ j = 1{:}4$$
$$\boldsymbol{k}_{ij} = f\left(U_q, V_{w_q}, \psi_{w_q}, \bar{U}, \bar{V}_w, \bar{\psi}_w, \boldsymbol{k_{base}}_{ij}\right) \; for\ i = 1{:}4\ and\ j = 1{:}13$$
$$\overline{trim}_i = f\left(U_q, V_{w_q}, \psi_{w_q}, \bar{U}, \bar{V}_w, \bar{\psi}_w, \boldsymbol{trim_{base}}_i\right) \; for\ i = 1{:}6$$

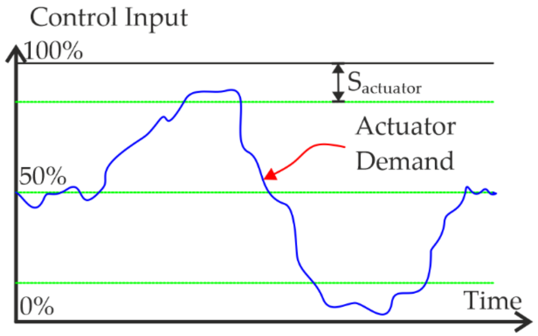
2. Mission Definition



3. (Un)Steady Variable Wind Conditions

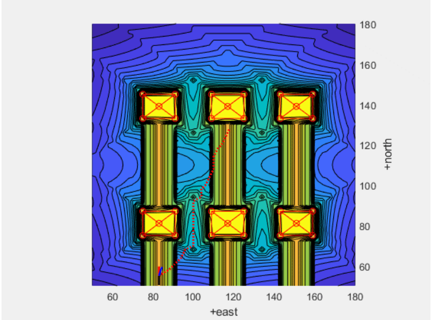


4. Cost function definitions for safety-critical systems of interest



$$F(\bar{\theta}) = F_A = \frac{1}{n_A}\sum_{1}^{i=n_A} \frac{1}{t_m}\int_0^{t_m} \sqrt{\frac{\left(\bar{x}_{actuator_i} - 0.5\right)^2}{0.5 - \bar{S}_{actuator_i}}}\, dt$$

5. 'Risk' Map for Wake Severity



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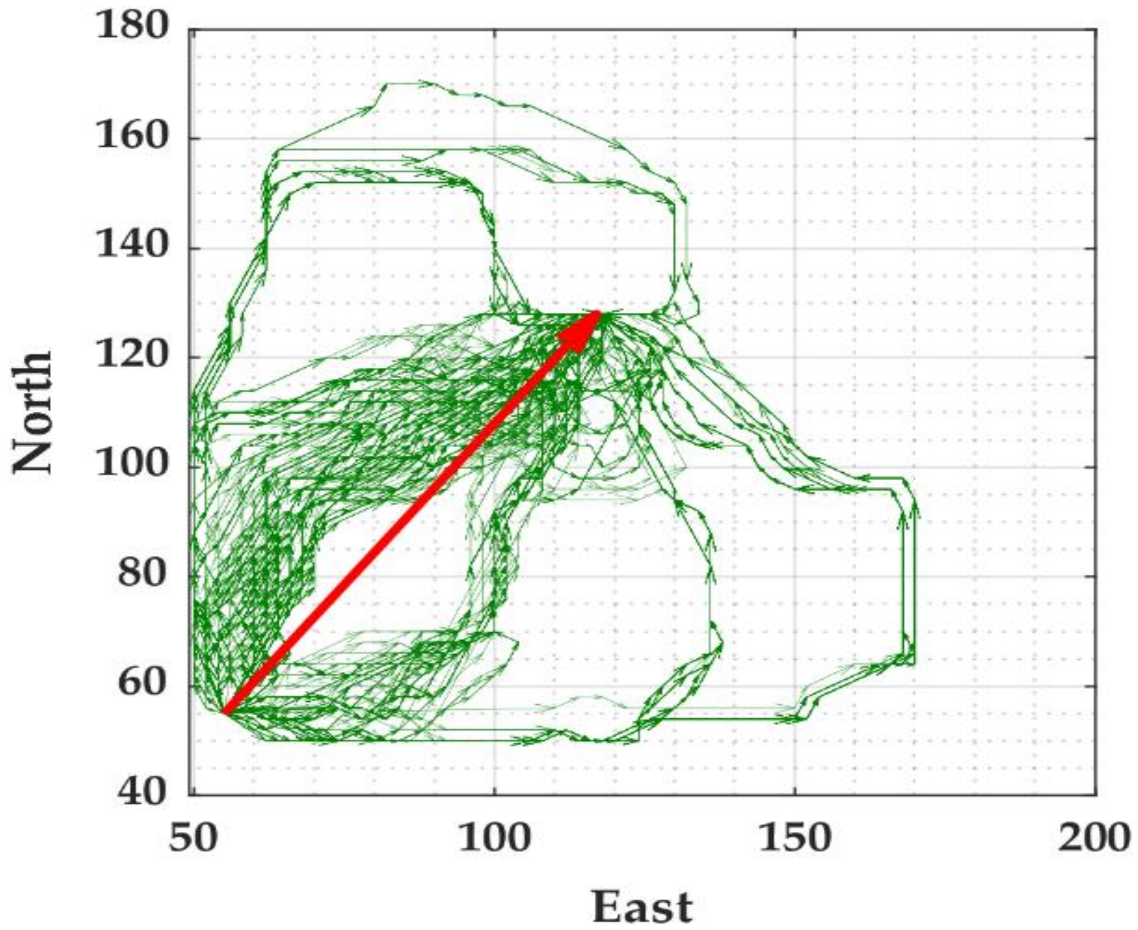
Using Autonomous (Aerial) Robots for Offshore Inspection

Virtual Environment Outputs



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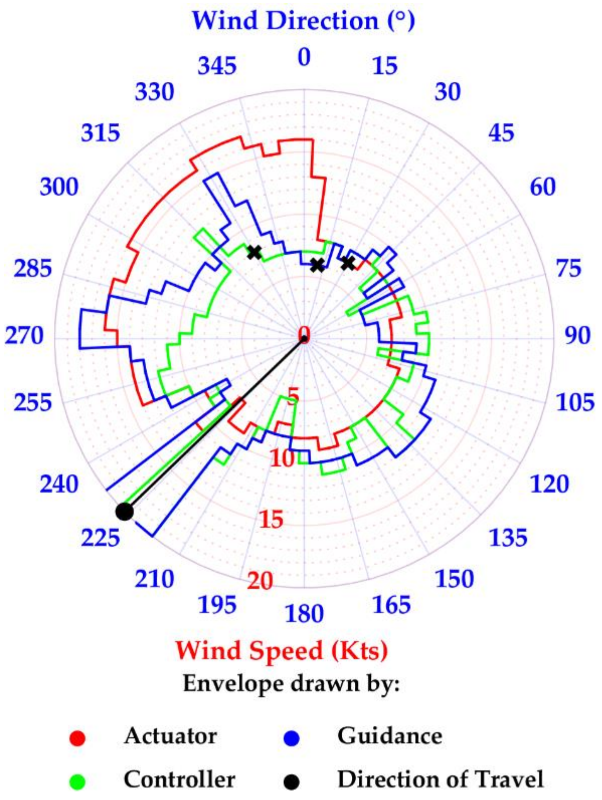
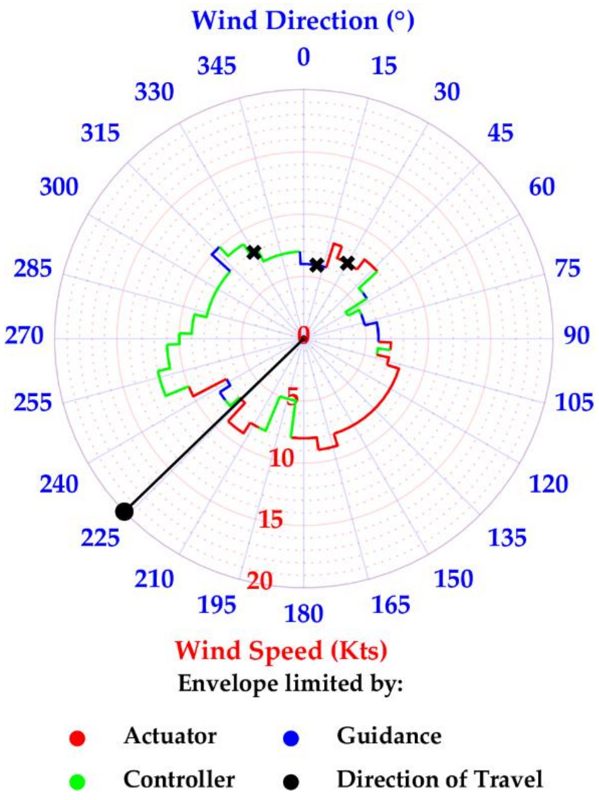
Virtual Environment Outputs

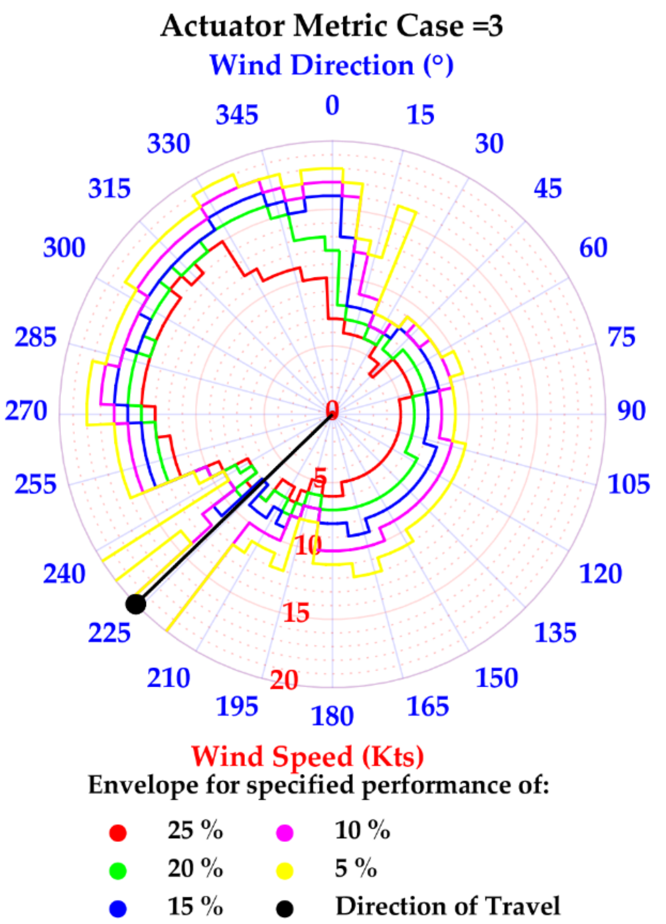


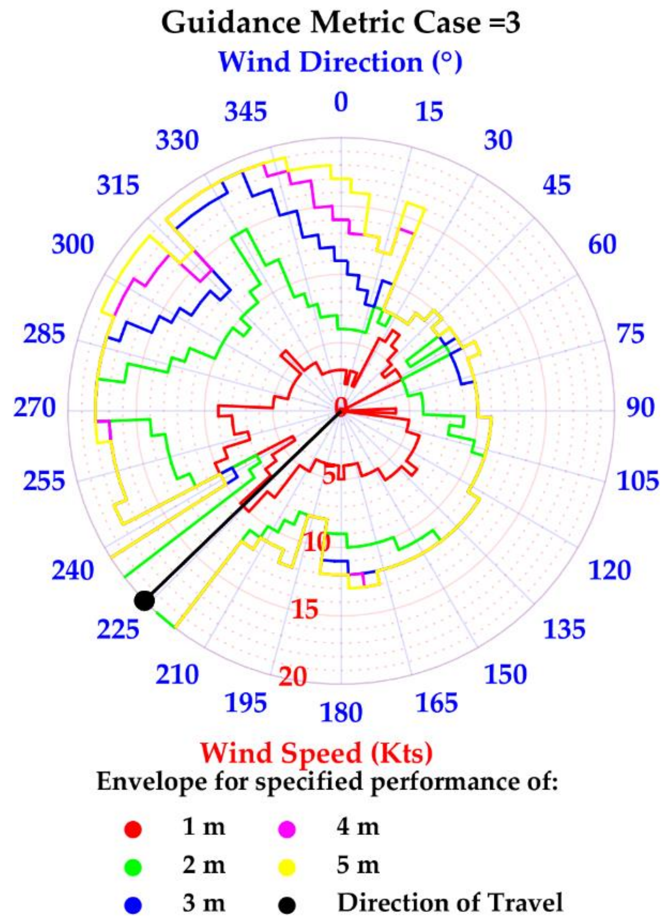
Take the most severe limitation per radial



Using Autonomous (Aerial) Robots for Offshore Inspection

Virtual Environment Outputs – Sanity Check





Concluding Remarks

- More complex unmanned air system operations will need to be certified as airworthy. This process could be helped via "traditional" aerospace techniques
- Simulation and virtual engineering are key current techniques
- A set of tools and workflow has been created to generate explainable safe operating envelopes for unmanned aerial system inspection missions
- This technique is a suggested means to provide (some) evidence that will provide confidence in a mission systems capabilities prior to actual flight (testing)

Further Work

- All models are wrong, some are useful
- Replace stitched linear model with a non-linear model
- Replace steady wind with an unsteady wake
- Integrate the Virtual Engineering techniques with those from Computer Science
- Integrate a means to try to eliminate having to test all wind speed/directions
- Validation of the operating envelopes

Further Reading

- Page, V., Webster, M. P., Fisher, M., & Jump, M. (2019). Towards a Methodology to Test UAVs in Hazardous Environments. In ICAS 2019, The Fifteenth International Conference on Autonomic and Autonomous Systems
- Webster, M., Cameron, N., Fisher, M., & Jump, M. (2014). Generating Certification Evidence for Autonomous Unmanned Aircraft Using Model Checking and Simulation. JOURNAL OF AEROSPACE INFORMATION SYSTEMS, 11(5), 258-278. doi:10.2514/1.I010096

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Thank you for listening.
Any Questions?

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