Autonomous Systems in Air, Land and Sea:
Risks & Reliability

1. Scope

As the use of autonomous systems gathers pace how do we judge the level of risk and reliability associated with them? Especially as they begin to undertake more complex tasks and become adaptive to novel or unexpected situations?
As the technology behind autonomy gathers pace it is vital that we have a good understanding of the risks and reliability associated with these systems.
This workshop looks at areas such as:

- Testing and Standards
- Safety
- Probability of mission success
- Fault analysis and diagnosis
- Maintenance

This event, the third in the South Coast Marine Cluster's Year of Autonomy series, and brings together key experts from different sectors in air, land and sea to:

- Explore the interaction between the art of the possible and the practicalities of what should be achieved
- Identify common challenges and establish where opportunities lie for shared learning and best practice.

2. Presentations and Speakers

Paradox of autonomy, Dr William McNeill, University of Southampton
Abstract: There is a well-known paradox of automation. The more automated a system, the less skilled become those who make use of that system. And the less skilled we become the
less able we are to respond to, interact with or take over from those systems in atypical situations. In high-risk industries the result is greater reliability in standard operating conditions but an increased risk of catastrophic failure in non-standard situations.
One response is to add further automation. But we are increasingly in a position to make automation *better* – more flexible, adaptive and responsive – i.e. more *skilled*. This holds the potential to greatly increase the parameter space within which an autonomous system is reliable, hence greatly decrease risk.
However current progress suggests that the more adaptive a system, the less transparent it is – non-linear neural networks are effectively 'black boxes'. This generates two further paradoxes of automation.
(1) The *paradox of autonomous risk* is that even if autonomous systems are more reliable than human operators we may be less prepared to tolerate the risks inherent in their operation. We are more comfortable with familiar as opposed to unfamiliar risks. And we are more comfortable with voluntary as opposed to involuntary risks. If a system is

autonomous then it poses an involuntary risk. And if it is a ‘black box’ then its nature is unfamiliar.

(2) The *paradox of autonomous testimony* is that the more adaptive the system the less able we are to explain why exactly we should trust its testimony. 3 **Bio**: Dr Will McNeill is a lecturer in Philosophy at the University of Southampton. He has researched problems concerning our knowledge of each other’s mental states and the epistemology of perception. His current research concerns the natures and epistemic roles of natural and artificial perceptual systems - specifically non-linear supervised and unsupervised deep learning neural networks. What lessons can be learnt from the study of natural perceptual systems in implementing more reliable and sophisticated artificial equivalents? Can current best practice in the design and implementation of artificial perceptual systems help us to understand the nature and status of their natural equivalents? What is the epistemological status of the outputs of mature non-linear neural networks, and in what sense can they further human knowledge and understanding?

Presentation summary: William McNeill introduced us to the Philosophy of Autonomy: reliability and risk, saying that in familiar standard circumstances we understand the rules of the system, and can therefore judge the reliability of what we are being told, trust that authority, and assess and explain the risk. As automation becomes more complex the use of machine learning and in particular artificial neural networks (ANNs) become standard. However, William considers ANNs to be black boxes that react benignly to unexpected and novel situations to solve complexity; but we cannot explain how they do that. So how do we know on what basis they have made their judgement, and how do we understand (perceive and respond to) the risk that autonomous systems pose?

Risk and Reliability Analysis for Autonomous Surface Vehicles, Carolina Dopico Gonzalez, ASV Global

Abstract: Risk management and system reliability are absolutely key to the successful operation of autonomous surface vehicles, underpinning safety and likelihood of mission success.

One of ASV Global’s core business objectives is to achieve market leading reliability in its product and service offering to the defence, science and offshore energy industries. This involves implementing data collection protocols and processes during design, manufacture, testing and commissioning, and operations.

Data is analysed with tailor made statistical methods, such as fault tree analysis, survival plots, or sensitivity analysis. Faults are recorded efficiently to feedback into the reliability data and analyses.

Linking science and industrial robotics shows how serious commercial companies like ASV Global are about understanding and continually improving the reliability of their systems. The more data and backup analyses that exist about these systems, the more trust will be built among stakeholders. This synergy brings the critical intellectual approach of science methods to business and ensures a high level of confidence in ASV Global’s products.

This presentation will focus on testing and standards, safety, probability of mission success, methodology of data analysis including fault analysis and diagnosis and maintenance. It will also present the challenges that arise around the development and operation of autonomous systems for the marine sector and how risk and reliability analysis can help predict and minimise these. 4

Bio: Carolina Dopico-Gonzalez is the Knowledge Transfer Partnership Associate in Risk and Reliability Management at ASV Global. Responsible for implementing the risk and reliability management process to ensure good industry practice for ASV Global with regards to standards compliance and clients' satisfaction. She joined the company in 2015 through a Knowledge Transfer Partnership (KTP) with the University of Southampton. Carolina has over 5 years experience in the marine sector, drawing on core research and engineering skills from a range of industries.
Presentation summary: Carolina Gonzalez (ASV Global) outlined the work she had been doing with ASV Global to put in place a risk and reliability analysis for autonomous surface vessels. She started from the IEC 61508 standard which describes functional safety as relying on system or equipment operating correctly in response to its inputs. So from a risk management and system reliability perspective it is important to measure and analyse the reliability of components, incidence of faults and issues, and analyse causes. Carolina noted that key to this is the collection of data so one can undertake various analyses to inform decision making.

Flying High: Autonomous Drone Systems in Cities, Olivier Usher, Nesta

Abstract: Drone technology has come on in leaps and bounds, with uses in infrastructure, inspection, logistics and even leisure. So far these have almost exclusively been piloted by remote control, from nearby. But many foresee a future in which autonomously and remotely piloted drones are widespread in urban areas. This throws up technical challenges for the manufacturers - but also broader issues for how these systems will work. How will traffic be managed? How will safety be ensured? How will different systems work together? And will there be meaningful democratic oversight of what drones are used for and how?
Nesta's Challenge Prize Centre has been gathering views on drones from experts and stakeholders as part of two projects - Flying High, a project to help cities shape the rollout of drone systems; and Safety Grand Challenges, an expert engagement exercise (for Lloyd's Register Foundation) on major safety challenges around the world. I will highlight some of the key issues facing the future of drones we have learned as part of these.
Bio: Oli is Research Manager at the Challenge Prize Centre. The Challenge Prize Centre (part of Nesta, the UK's innovation foundation) researches, designs and runs prizes to accelerate technological and social innovation for the good of society.
He has participated in the development of a range of prizes, from driving innovation in aquaculture in India to the Open Up Challenge for small business fintech solutions in the UK. He leads the Challenge Prize Centre's work to identify and scope out new topics, and has worked on projects ranging from the safety of infrastructure to assistive technology for people with paralysis to the introduction of drones in cities. As part of this horizon scanning role, he oversees the Centre's 'Challenges of our Era' research events series.
He previously worked as a science writer, and is the author of a popular science book, *The Universe through the Eyes of Hubble*.
He holds a first class degree from UCL and a Master's from Cambridge, both in History and Philosophy of Science.

Presentation summary: Olivier Usher (NESTA) talked about the “Flying High” safety grand challenge of unmanned aircraft systems (commonly referred to as drones) in cities. This presents a number of use challenges.

- Given limited airspace, how do you manage and control drones in that airspace, and do it safely?
- How do you control and monitor for noise levels, privacy, priority of use, among other things?
- Also to look at issues around certification, mechanical failure, GPS reliability and cybersecurity.

Olivier posed the questions what are drones to be used for? Who are they for? Who decides priorities? He mentioned that a Foresight Review: Safety Grand Challenge Report is due in the near future. In the meantime NESTA is working to convene a consortium of pioneering cities in order to create an expansive and interconnected series of outcome-based funding opportunities. This will culminate in live, large-scale and complex urban drones system demonstration projects in 2019/20.

Autonomous Navigation in GPS Limited Environments, Hongjie Ma, University of Portsmouth

Presentation summary: Hongjie Ma (University of Portsmouth) outlined research he had been undertaking on autonomous navigation in environments where GPS was limited or unreliable. His work fuses the existing navigational technique of dead reckoning with radar and camera outputs as a means of automating navigational and positioning activities.

3. Round table discussions on challenges and solutions

Chair: Ian Stock, Knowledge Transfer Network (KTN)
The aim of the Year of Autonomy is to share learning, and to understand and address challenges across land, sea and air.
In the workshop session attendees were grouped and asked to consider “what are the main challenges / risks associated with autonomous systems (vehicles and vessels)?“ in relation to the following:

- Testing and Standards
- Safety
- Mission success / Reliability
- Fault analysis and diagnosis
- Maintenance

A wide range of challenges and risks were mentioned and discussed within the groups. In summary, each group was asked to nominate their top three, with the main ones being: 6

1. Accountability, as regards who owns the operational risk, insurance aspects, what is good practice and can it be standardised, and where are the manual vs autonomous

control boundaries. What level of proof would be required to demonstrate that one was operating in a compliant, or even legal and moral manner?
This challenge could be met in a number of ways:

- Establishment of standardised regulations to control the boundaries around the interaction of manned and autonomous systems.
- some evidence of rule sets or a basic logic, by looking at the testing scenarios being used, and the length of time the system was being tested
- by some qualification assessment process, such as a 'driving test' that is widely accepted and consistent, or has equivalency to the manned system
- transparency and auditability of component parts and assembly process, such as was said to exist in the aviation industry
- if "accidents" happen then an independent, trusted, investigation branch to find out the cause

2. Cyber security, which needs to be built in by design, from the beginning.

This requires a fail-safe capability with end-to-end encryption, and limited cloud computing back-ups.
To improve security the system would need to

- autonomously recognize threats
- prevent malicious adaption
- stop an accumulation of threats

An additional layer of security could be added by have to enter into agreements when (e.g. the drone) was purchased

3. Data, in terms of a lack of data and evidence base, as well as data collection itself.

It is important to understand what data we need to gather, for what purpose, and then how to process it.
A question was whether the historical data actually existed – had the right data been collected in the first place?
Data sharing in order to make decisions was seen as important. This may require (or create a role for) an honest broker in order to extract value from the sanitized data and make it open access.

4. Societal acceptance of risk and public trust, what are the acceptance criteria and the role of regulation in this?

One challenge is the time it takes for changes to go through 'regulatory bodies' such as IMO. How can this time lag be reduced
Societal acceptance would be increased through:

- Incremental introduction of the autonomous system – safe, slow steps
- Openness in the way they were integrated
- Effective external communications, e.g. positive media and social benefits
- Endorsement by Government or an accredited body; any regulation should not be too constrictive

- Strategic work stream to manage societal change

5. Skills, an additional challenge was around skills. There was seen to be a need for education, and suitable qualifications of the operators. How do we integrate complex systems into the skills and training agenda? What licensing of personnel is required

4. Conclusion

To sum up, the event attracted 70 delegates of which 48 were present on the day including 10 academics. The majority of business delegates were from a marine background. The event was an excellent opportunity for both the research and business communities to come together to identify and discuss the challenges about risks and reliability in autonomous systems, and potential innovative solutions to address them. The challenges will be passed on to Innovate UK with the support of the KTN team to consider them in the future Innovate UK calls on autonomy.

In conclusion, the event was very successful, and we have since received excellent feedback from the delegates about the quality of the presentations, table discussions, networking opportunities, venue, and even the food.

I would like to thank the National Oceanography Centre, speakers, delegates, and in particular the KTN team in contributing to the success of the event.