TRUSTED AUTONOMOUS SYSTEMS

TAS Maritime Showcase Report

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TAS Maritime Project Showcase Report

Executive summary

The Trusted Autonomous Systems (TAS) Maritime Showcase event was held on 28 September 2022 at ReefWorks at the Australian Institute for Marine Science (AIMS) in Townsville, Queensland. The event demonstrated how the TAS COLREGs Operator Guidance Framework could be used to inform live trials of autonomous and remotely operated vessels. The event also showcased Australian autonomous vessel operators, and the capabilities available at ReefWorks. The event was attended by approximately 65 people from across government, defence, industry, and academia.

This report describes the event and sets out the lessons learned to inform future events and future approaches to assurance of autonomous vessels in Australia.

Key findings were:

- When designing assurance activities, it is critical to consider the specific characteristics and capabilities of each vessel. There is vast difference in operational capability and needs between different types of vessels, and generic scenarios are unlikely to work for diverse groups.

- Translating intent is very easy for a remotely operated vessel, where the demo organiser can explain verbally and through pointing at environmental characteristics etc. their intent to an operator, who then operates the vessel accordingly. However, for vessels using autonomous operating systems, the demo organiser and operator need a strong understanding of how the system works, to ensure scenarios can be designed appropriately for the system, and to ensure the right distances and prompts are used.

- Building in wet run throughs with all parties and environmental requirements present is critical to success. Building a shared understanding of what success looks like, and ensuring scenarios are realistic and appropriate, and all parties understand exactly how they will work and what is expected of them, is critical, and it also helps to build trust in the team.

- Ensuring the requisite internet connections and associated infrastructure are available to support command and control and communications forms a critical part of live trials, and enlisting expert support is key to success.

- The regulatory requirements for operating vessels are complex and applications to the regulator can take many months to be processed. Start the process early and continue to follow up regularly. Inviting representatives from regulators is also highly recommended to build familiarity with the technology and comfort with the activities being undertaken.

- The TAS Demonstration Canvas was important for prompting a range of preparations and activities that ensured observers were well catered for and understood the activities they were observing.

- There is generally a low level of awareness and understanding regarding the use of autonomous technology in the Australian maritime domain, and demonstrations play an important role in spreading awareness and gradually building trust in this technology.

Compilation of images taken during TAS Maritime Showcase, captured by Jawahar Bhalla

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Event summary

Aim

The aims for the Showcase were to:

- Demonstrate how live trials can be used to assure participating vessels' compliance with the COLREGs Operator Guidance Framework
- Showcase leading operators of autonomous vessels in Australia
- Showcase the facilities available at ReefWorks

Intended Outcomes

- (1): A live event at ReefWorks at AIMS with key stakeholders (QLD State Government, Federal Government, Regulators, Defence, trial industry partners, industry)
- (2): A demonstrated process for using live trials to assure against the COLREGs Operator Guidance Framework
- (3): A Report reviewing Outcomes (1) and (2) and documenting the process and lessons learned that were highlighted.

Participants

- **Organising and support team:** TAS, ReefWorks, macroData, Shoal, BMT
- **Vessel Operators/Participants:** AIMS, AMC Search, BTB Marine, James Cook University, Unique Group, L3 Harris, Ocius, EdgeROV, and Australian Droid + Robot.[1]
- **Observers:** QLD State and Federal Government, Regulators, Defence, Industry, and Academia

Vessels

- **Live:**
  - BTB Marine, Indigo, 9m survey vessel
  - James Cook University, WAM-V, 6m robotics test platform
  - Unique Group, Unipact, 3m survey vessel
  - AIMS, Surfbee, 1-2m marine science vessel
- **Remote via pre-recorded video**
  - AMC Search, Microcat, training vessel
- **Static display**
  - L3 Harris, IVER, survey vessel
  - Ocius, Bluebottle, 6m persistent surveillance vessel
  - Edge ROV, ROV, multi-use vessel
  - AIMS, CoralAUV 1, scientific research vessel
  - AIMS, CoralAUV 2, scientific research vessel

Scenarios

Scenario 1	General capability demonstration	General demonstration of the capabilities of each vessel prior to the conduct of the assurance scenarios.
Scenario 2	Safe speed and collision avoidance	Demonstrate the ability to operate at a safe speed (rule 6) and take action to avoid collision (rule 8). Requires situational awareness and reaction.
Scenario 3	Vessel avoidance actions	Demonstrate ability to react appropriately: In a head-on situation (rule 14) or As the stand-on vessel (rule 18).
Scenario 4	Restricted visibility	Demonstrate ability for extra care in restricted visibility (rule 19). The vessel to identify limited optical sensor input and slow down accordingly, and possibly utilise sound signals.

[1] Note ADR had to withdraw at the last minute, but they were intended participants

Planning and running the assurance scenarios

'Assurance' is the process of confirming that a vessel meets the requirements that apply to it. For example, you can assure against design and construction requirements through a survey. For the vessels participating in the Showcase, the process used was to identify the requirements that apply under the maritime regulatory framework, isolate the specific requirements we wanted to assure against – i.e. COLREGs (collision avoidance requirements), design and conduct the scenarios, and then collect evidence to inform the certification process.

We used the TAS COLREGs Operator Guidance Framework to identify the COLREGs rules to assure against, and the capabilities that vessels would be expected to have to be considered compliant.[2] In planning the Showcase and the scenarios, we also referred to the TAS Demonstration Canvas and the IMO Interim Guidelines for MASS Trials (MSC.1/Circ.1604 14 Jun 2019).

The workflow described above can be visualised as follows:

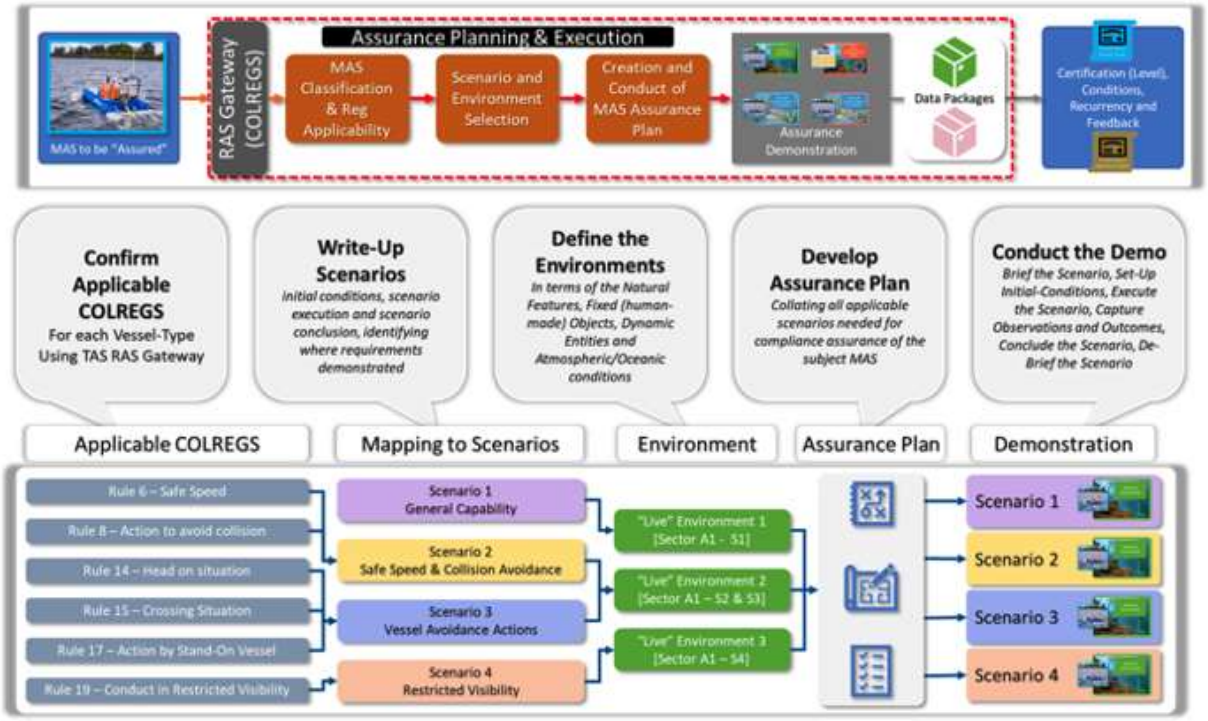


Diagram created by Jawahar Bhalla and used with permission

(1) Identify the requirements to assure against

The below content is extracted from the TAS Operator Guidance Framework. It sets out the applicable COLREGs rule, its interpretation for autonomous and remotely operated vessels, and then the capabilities that the vessel and/or a shore-based control centre (or other remote operations set up) needs to have to be compliant, split into sense and perceive, decide, and act.

[2] Note that the specific COLREGs rules chosen to assure against may not apply to the specific vessels and their usual operations, but were chosen as they supported assurance scenarios useful for the purposes of the event.

Rule	Interpretation	Capabilities: Sense & Perceive	Capabilities: Decide	Capabilities: Act
6 – Safe speed	Safe speed shall be an ongoing consideration with due regard to the state of visibility, traffic density, manoeuvrability, weather and water depth. Vessels with radar shall additionally consider radar capability, range scale, interference, the possibility of undetectable hazards.	• Range of imaging camera visibility in current environmental conditions • Wave height • Wind speed and direction • Water depth • Number, range and bearing of spotted vessels • Course and course change of spotted vessels over time • Proximity of navigational hazards	• Likelihood of undetectable hazards • Likelihood of sensor interference • Traffic density • If shallow water hazard exists • Stopping distance • Turning ability • Maximum safe speed	• Limit speed to safe speed
8 – Action to avoid collision	Actions taken to avoid a collision shall be effective and confirmed effective until clear. The most effective action is dependent on the situation and shall be proportional to the risk e.g. a minor course change or full-stop.	• Presence and characteristics of other vessels, see Rule 5	• Risk of collision exists, see Rule 7 • Stand-on or give way vessel determined IAW Part B • Safe passing distance (if give way vessel) • If stand-on vessel	When giving way: • Early and obvious course/speed changes • Bearing change favoured over speed change • Pass at least safe passing distance • Monitor effectiveness of the action until the other vessel is passed When standing-on: • Apply Rule 17
14 – Head-on situation	Where two power-driven vessels are approaching in a head-on situation, both vessels shall alter course to starboard and pass on the port side.	• Presence and characteristics of other vessels, see Rule 5 • Risk of collision, see Rule 7	• Head-on situation IAW Rule 14(a) & (b) - Encounter type • Certainty of overtaking vessel type allocation	• Alter course to starboard • Pass at safe passing distance • Line of determination - Encounter Type
15 – Crossing situation	Where two power-driven vessels are crossing, the vessel which has the other on its starboard side shall keep clear, and where feasible cross behind the other vessel. [Applies when vessel in sight of another]	• Presence and characteristics of other vessels, see Rule 5 • Risk of collision, see Rule 7	• Stand-on or give way vessel IAW Rule 15	• Apply Rule 8
17 – Action by stand on vessel	Stand-on vessels shall maintain course so as not to confuse the situation, unless the give-way vessel fails to act, in which case action should be taken by the stand-on vessel in order to avoid collision. [Applies when vessel in sight of another]	• Presence and characteristics of other vessels, see Rule 5 • Risk of collision, see Rule 7 • Stand-on vessel, see Rule 8	• If give way vessel fails to respond in time for the safe passing distance to be achieved • If collision becomes inevitable	Outside of safe passing distance: • Hold course Between safe passing distance and collision distance: • Safe speed reduction IAW Rule 6 Within collision distance: • Substantive course change

19 – Conduct of vessels in restricted visibility	Extra care is to be taken in poor visibility, considering that not all other vessels have radar and not all hazards are detectable by radar. Sound signals become more important. [applies at night or in poor visibility]	• Sound signals, type and duration • Light signals, type and duration • Interpret meaning of signal	When signalling intent • Decide the type of signal that needs to be produced to convey intent, see Rules 33-35 When a sound or light signal has been perceived • Determine the form of response required for the perceived signal and meaning	• Produce sound or light signals IAW Rules and COLREGS Annexes

(2) Write up scenarios

Scenario 1	General capability demonstration	General demonstration of the capabilities of each vessel prior to the conduct of the assurance scenarios.
Scenario 2	Safe speed and collision avoidance	Demonstrate the ability to operate at a safe speed (rule 6) and take action to avoid collision (rule 8). Requires situational awareness and reaction.
Scenario 3	Vessel avoidance actions	Demonstrate ability to react appropriately: 1. In a head-on situation (rule 14) or 2. As the stand-on vessel (rule 18).
Scenario 4	Restricted visibility	Demonstrate ability for extra care in restricted visibility (rule 19). The vessel to identify limited optical sensor input and slow down accordingly, and possibly utilise sound signals.

(3) Define the environment

When conducting testing it can be done in virtual, constructive or live environments, or combinations. For the Showcase a live environment was used. It was necessary to consider whether the assurance scenarios required environmental factors to be present or introduced such as atmospheric or oceanic conditions, natural features, fixed or moving objects, or dynamic entities.

The live environment used, ReefWorks Marine Operations Facility, had a fixed jetty, and that was used in the scenarios together with buoys, a small anchored vessel, and a small crewed moving vessel.

(4) Develop assurance plan

To test against the selected COLREGs rules, in the environment available, and for the vessels participating, the following scenarios were identified:

- **Scenario 1: General capability demonstration**
  - Intent: To allow a general demonstration of the capabilities of the vessel prior to the conduct of the assurance scenarios.
  - Mission: Introduce vessel operators and the vessel and show it off
  - Actions: From the vessel's starting point, conduct capability demonstration of the vessel, however the operator chooses, with narration to explain to the audience them, their company, the vessel, its statistics, common uses etc. Return to a safe holding location on conclusion.
  - Timings: <5min per vessel

- **Scenario 2: Safe Speed & Collision Avoidance**
  - Intent: This will demonstrate ability to operate at a safe speed (Rule 6) and take action to avoid collision (Rule 8). area for the following scenario.
  - "Mission": Transit to survey location
  - Actions: From a starting point on the inside of the jetty (i.e. in front of the audience), transit the vessel around the jetty past the rock wall and the yellow buoy. Operator/vessel will identify the anchored yellow Aries vessel, take action to move around it, and then return to the original course. On conclusion return to the designated holding area
  - Notes:
    - Order: Unipact, Indigo, Surfbee, WAM-V
    - Final location to move to when you finish the scenario: off to the right of the buoy
  - Timings: < 5min per vessel
  - Metric (practically): Did the vessel:
    - Detect the object
    - Slow down to a safe speed
    - Go around the object safely
    - Move away at slow speed then increase speed

- **Scenario 3: Vessel Avoidance Actions**
  - Intent: Demonstrate ability to react appropriately in a head-on situation (rule 14) or as the stand-on vessel (rule 17). This will require vessel detection, identification and taking of appropriate action. This will be tested by putting the vessel in a position where there is a vessel on its path approaching it, and it must slow down and take the required action
  - "Mission": Transit to survey location
  - Actions: From the starting position
    - Unipact and Surfbee: to the right of the yellow and red buoys
    - Indigo and WAM-V: inside the jetty

    Transit in a straight line, (while the AIMS vessel is transiting also from the red buoy near the audience out towards the yellow buoy or back again), so that vessel is in a position where it needs to identify that the AIMS vessel is going to pass in front, slow down, and move around behind it, and then continue on original course
  - Notes:
    - Minimum distance to be maintained between vessels:
      - autonomous vessel with persons on board: 200m minimum
      - autonomous vessel with no persons on board: 100m minimum
  - Metric (practically): Did the vessel:
    - Detect the other vessel
    - Alter course to starboard and pass on the port side
    - Continue at a safe speed
    - Return to original course

- **Scenario 4: Restricted Visibility**
  - Intent: Demonstrate ability to take extra care in restricted visibility (rule 19). This will require the vessel to identify limited optical sensor input and slow down accordingly, and possibly utilise sound signals
  - "Mission": transit to survey location
  - Actions: starting inside the jetty, slowly move as if the intent was to transit out of the jetty area, but as vessel starts moving, a deluge of water will appear (via fire hose) creating restricted visibility. Vessel will need to slow down and/stop, maybe sound a horn if available, and wait for the water to recede.
  - Timing: <5min per vessel
  - Metric (practically): Did the vessel:
    - Identify it was operating in restricted visibility
    - Take extra care / stop
    - Use sound signals where necessary

During each scenario the operator and/or their offsider provided verbal commentary to help the assessor and audience understand the mission, how it was intended to be achieved, what was expected to happen, what is happening, and whether the mission went as expected. This verbal commentary helps the audience to understand what is happening and how it relates to the expected mission.

The assurance plan was to have participating vessels attempt the four scenarios outlined above, enabling an assessment of whether they demonstrated the required capabilities for each applicable COLREGs rule. Vessel operators and the assessor were briefed in advance, and were in open communication with the demo organiser throughout each serial. Debriefs occurred at the conclusion of scenarios 1 and 2, and 3 and 4.

Image of range set up, courtesy of AIMS

(5) Conduct the demo

Wet run through – 27 September 2022
All operators were on site for a full wet run through the day prior to the Showcase event. This included a safety brief, a briefing on the Showcase event and the scenarios, deploying the assets needed in the water, and then a run through of each scenario. The main tweaks made as a result of the wet run through were:

- Decision to have the largest vessel start first where possible
- Decision to have one holding area for all vessels to remain in while they were not participating in a scenario. This lowered time between scenarios and was visually impactful.
- The anchored vessel was placed between the jetty and buoy to place it in a designated path and increase the chances of it being in the way
- Emphasis on live commentary before, during and after every scenario to ensure everyone involved understood what was happening, what we were seeing, and what it meant.

Showcase event – 28 September 2022
The demo day was scheduled as follows:

- Welcome and opening remarks
- Safety brief
- AMC Search video on use of small autonomous vessels to survey a marina
- Scenarios 1 and 2
- Debrief Scenarios 1 and 2
- Presentation on use of simulation for assurance (AIMS and BMT)
- Scenarios 3 and 4
- Operators debrief on scenarios
- Concluding remarks

The environment was set up and all vessels were deployed in the water prior to observers arriving. At the commencement of the event a brief was provided on the scenarios, followed by a safety brief. Scenarios 1 and 2 occurred first, followed by Scenarios 3 and 4, with the demo organiser explaining to observers what to expect, what the vessels needed to do to be considered to successfully complete the scenario, what they were seeing, and what the result of each scenario was. Vessel operators and support also provided live narration, supported by live video feeds showing observers the HMI (human-machine interface) for some participating vessels. This combination of description, narration and live feeds immersed the observers in the experience and greatly assisted in building understanding and context.

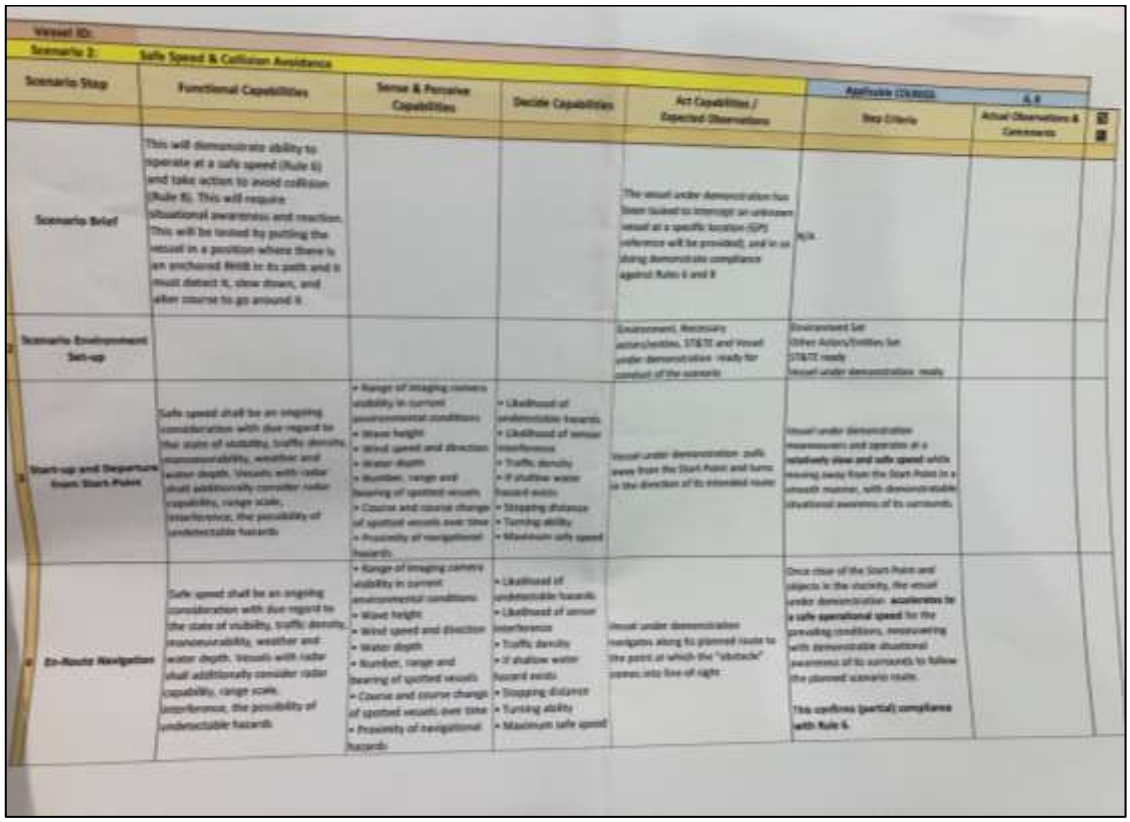
The majority of vessels successfully completed each scenario attempted. It became evident that the scenarios planned were more suitable for the smaller vessels, with the larger vessel not being provided enough time and water space to successfully engage the autonomous operating system and display the required behaviour. One vessel also had technical difficulties and needed to retire from the trials early.

The video by AMC Search showing the use of a small autonomous vessels to survey a marina was a great prelude to the live scenarios, providing observers with an understanding of a common use of these vessels and how they operate. The presentations by AIMS and BMT highlighted the role of simulation in assuring autonomous and remotely operated vessels, including in relation to COLREGs compliance.

Assessing vessels participating in scenarios

An important element of assurance activities such as live trials is having a professional observe and identify whether participating vessels are demonstrating the expected capabilities or not. As part of the Showcase event we had a person act as an “assessor” – he observed each scenario and used the assessment table (Figure 1) to record commentary on the performance of each vessel against the expected outcomes. The spreadsheet was created collaboratively to ensure it met the needs of the activity and could easily capture what the assessor should be expecting to see. As the assessor’s role was for demonstration purposes only no formal assessments were made, but participants were debriefed.

Figure 1: The assessment document – Scenario 2



Vessel ID:

Scenario 2: Safe Speed & Collision Avoidance

Scenario Step	Functional Capabilities	Sense & Perceive Capabilities	Decide Capabilities	Act Capabilities / Expected Observations	Applicable (Criteria)	A, B
					Pass Criteria	Actual Observations & Comments
Scenario Brief	This will demonstrate ability to operate at a safe speed (Rule 6) and take action to avoid collision (Rule 8). This will require situational awareness and reaction. This will be tested by putting the vessel in a position where there is an anchored MMB in its path and it must detect it, slow down, and alter course to go around it			The vessel under demonstration has been tasked to intercept an unknown vessel at a specific location (GPS reference will be provided), and in so doing demonstrate compliance against Rules 6 and 8	N/A	
Scenario Environment Set-up				Environment, Necessary actors/entities, ST&TE and Vessel under demonstration ready for conduct of the scenario	Environment Set Other Actors/Entities Set ST&TE ready Vessel under demonstration ready	
Start-up and Departure from Start-Point	Safe speed shall be an ongoing consideration with due regard to the state of visibility, traffic density, manoeuvrability, weather and water depth. Vessels with radar shall additionally consider radar capability, range scale, interference, the possibility of undetectable hazards	• Range of imaging camera visibility in current environmental conditions • Wave height • Wind speed and direction • Water depth • Number, range and bearing of spotted vessels • Course and course change of spotted vessels over time • Proximity of navigational hazards	• Likelihood of undetectable hazards • Likelihood of sensor interference • Traffic density • If shallow water hazard exists • Stopping distance • Turning ability • Maximum safe speed	Vessel under demonstration pulls away from the Start-Point and turns in the direction of its intended route	Vessel under demonstration manoeuvres and operates at a **relatively slow and safe speed** while moving away from the Start-Point in a smooth manner, with demonstrable situational awareness of its surrounds.	
En-Route Navigation	Safe speed shall be an ongoing consideration with due regard to the state of visibility, traffic density, manoeuvrability, weather and water depth. Vessels with radar shall additionally consider radar capability, range scale, interference, the possibility of undetectable hazards	• Range of imaging camera visibility in current environmental conditions • Wave height • Wind speed and direction • Water depth • Number, range and bearing of spotted vessels • Course and course change of spotted vessels over time • Proximity of navigational hazards	• Likelihood of undetectable hazards • Likelihood of sensor interference • Traffic density • If shallow water hazard exists • Stopping distance • Turning ability • Maximum safe speed	Vessel under demonstration navigates along its planned route to the point at which the "obstacle" comes into line-of-sight	Once clear of the Start-Point and objects in the vicinity, the vessel under demonstration **accelerates to a safe operational speed** for the prevailing conditions, manoeuvring with demonstrable situational awareness of its surrounds to follow the planned scenario route. **This confirms (partial) compliance with Rule 6.**	

Images from the event

Compilation of images, courtesy of AIMS

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Key findings and reflections

Key findings

- When designing assurance activities, it is critical to consider the specific characteristics and capabilities of each vessel. There is vast difference in operational capability and needs between different types of vessels, and generic scenarios are unlikely to work for diverse groups.

- Translating intent is very easy for a remotely operated vessel, where the demo organiser can explain verbally and through pointing at environmental characteristics etc. their intent to an operator, who then operates the vessel accordingly. However, for vessels using autonomous operating systems, the demo organiser and operator need a strong understanding of how the system works, to ensure scenarios can be designed appropriately for the system, and to ensure the right distances and prompts are used.

- Building in wet run throughs with all parties and environmental requirements present is critical to success. Building a shared understanding of what success looks like, and ensuring scenarios are realistic and appropriate, and all parties understand exactly how they will work and what is expected of them, is critical, and it also helps to build trust in the team.

- Ensuring the requisite internet connections and associated infrastructure are available to support command and control and communications forms a critical part of live trials, and enlisting expert support is key to success.

- The regulatory requirements for operating vessels are complex and applications to the regulator can take many months to be processed. Start the process early and continue to follow up regularly. Inviting representatives from regulators is also highly recommended to build familiarity with the technology and comfort with the activities being undertaken.

- The TAS Demonstration Canvas was important for prompting a range of preparations and activities that ensured observers were well catered for and understood the activities they were observing.

- There is generally a low level of awareness and understanding regarding the use of autonomous technology in the Australian maritime domain, and demonstrations play an important role in spreading awareness and gradually building trust in this technology.

Reflections

Planning and running the Showcase event was complex, particularly because of the range of parties involved. Good communication was critical, as was the willingness of everyone to pitch in and help wherever they could. The diversity of operators and vessels, from university researchers using robotics testing platforms to professional survey operators operating a sophisticated survey vessel, added depth to the event and provided important contrast of capabilities and operating approaches. The event provided an excellent learning opportunity for everyone involved, particularly because of the diversity of professional backgrounds involved. Having a full day set aside for a wet run through was critical, and future demonstrations would benefit from having longer time periods spread over multiple days to run through a larger number of meaningful scenarios and allow for tech issues to be resolved. The ReefWorks facility was a perfect location for the event, and the team were a pleasure to work with as always. Overall, the Showcase event was a big success, with required outcomes achieved, key findings identified that will be useful for future projects, and more experience gained for the organising team.

Feedback received
A survey was set out after the Showcase event, which provided useful data to use to assess whether the event met the expected outcomes identified. Respondees were from a spread of Defence, Regulators and industry. The data gathered indicates that the event did meet its outcomes, with reported increased understanding of COLREGs and how it applies to autonomous and remotely operated vessels, how the TAS COLREGs Operator Guidance Framework works and how it supports live trials, and reported increased awareness of the facilities available at ReefWorks. Respondees reported event highlights as including the vessel demonstrations, seeing the range of vessels in the water, the presentations that occurred in between the scenarios, and meeting people. Respondees reported that some areas for improvement would have been more breaks between activities, more interactive opportunities, and pre-recording some scenarios enabling playback later to understand what was achieved. Respondees provided suggestions for future events, including more live demonstrations, longer range trials over longer time periods, more dynamic scenarios, and including more potential customers at events.

Conclusion

The TAS Maritime Showcase event demonstrated how the TAS COLREGs Operator Guidance Framework can be used to inform live trials of autonomous and remotely operated vessels. The event also showcased Australian autonomous vessel operators, and the capabilities available at ReefWorks. The event was attended by approximately 65 people from across government, defence, industry, and academia. Overall the event was a success, with four live vessels participating in a range of scenarios testing their capabilities relevant to COLREGs, and observers gaining a stronger understanding of the technology and how live assurance against COLREGs requirements can be conducted. The key findings and feedback identified will help to shape future activities and events planned by TAS and AIMS.

TAS would like to thank all participants in this event, including the teams from:
- ReefWorks at the Australian Institute for Marine Science
- MacroData
- Shoal
- Downer Group
- Unique Group
- James Cook University
- BTB Marine
- AMC Search
- EdgeROV
- L3 Harris
- Ocius
- BMT

References:

- TAS COLREGs Operator Guidance Framework
- Australian Code of Practice for Autonomous and Remotely Operated Vessels
- TAS Demonstration Canvas (Annex 1)
- IMO Interim Guidelines for MASS Trials (MSC.1/Circ.1604 14 Jun 2019)
- AIMS Media Release: Uncrewed boats put to test in Australia