R-Pilot

Phase 2 Report - Technology Readiness Assessment

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Executive Summary

The TRA is the second deliverable of the International Study on Remote Pilotage. Its purpose is to quality assess, through desktop analysis, the extent to which proposed candidate remote pilotage solutions can enable safe remote pilotage practices and outcomes in mandatory or compulsory pilotage waters worldwide.

The intent of the Study is not to promote or denigrate remote pilotage. Consequently, the TRA served two purposes. The first and primary purpose is to identify candidate remote pilotage solutions which can be deployed to enable the trials in phases 3 to 5 of the Study. The second is an opportunity to use a combined top-down (what maritime pilots need to do their job) and bottom-up (what is already being trialled in specific scenarios) approach to describe a minimum viable remote pilotage technology solution. For manufacturers and system integrators, it provided an opportunity for international rather than local expertise in pilotage to assess the maturity of their solutions in the context of remote pilotage in mandatory pilotage waters.

In November 2024, IMPA issued an RFI to attract manufacturers and system integrators developing or trialling technological solutions to enable remote pilotage. The proposed candidate remote pilotage solutions were then assessed in terms of their maturity across four assessment criteria: operational readiness; compatibility; scalability; and security.

The RFI process was intentionally designed in a non-prescriptive manner to encourage broad participation from manufacturers and system integrators, particularly those with innovative solutions. To that end, the RFI included high-level specifications based on the fundamentals of safe pilotage but did not seek solutions that met specific requirements.

Experienced maritime pilots described in fine detail every step they take in today's world to conduct an act of pilotage, and their information, data and system needs were identified. This input resulted in the workflows of maritime pilotage used for the operational readiness component of the assessment. Ultimately, for any remote pilotage system, these needs will form the substantive basis of functional engineering requirements for remote pilotage systems.

The capabilities of the two candidate remote pilotage solutions submitted in response to the RFI were assessed to fully understand how the proposed solutions enabled maritime pilots to achieve those workflows, and to articulate the opportunities and risks for using the solutions in phases 4 and 5 of the Study. It is, however, difficult to distinguish between the opportunities and risks identified in the assessment in the context of the Study and in the broader concept of remote pilotage in mandatory pilotage waters. The articulation of risks and opportunities is presented in a colour-coded form in the technical appendices of the report. At this stage, the focus is on the impact on safe pilotage.

The candidate remote pilotage solution from AD Navigation has strong credentials in terms of line-of-sight manoeuvring decision support based on their PPU offering. Still, it is currently not able to support over-the-horizon applications.

The candidate remote pilotage solution from DanPilot/Danelec utilises existing shipboard VDR and ship sensor infrastructure in combination with proprietary Danelec cloud and software solutions to share data, and an innovative ship-shore-ship communications tool developed by DanPilot. Nevertheless, the system was unable to provide a day/night optical solution, and there were limitations on the use of radar and communication with third parties, including tugs.

This conclusion aligns with the position of DanPilot/Danelec, who would prefer their solution not be trialled independently by the Study in the mandatory pilotage areas of the St. Lawrence River.

While the assessment did not find a candidate remote pilotage solution which is sufficiently mature to take forward to phases 3 to 5 of the Study, it was nonetheless encouraging to see that manufacturers and system integrators are looking at innovative ways to support maritime pilots in doing their work in particular situations: SPM; FPSO; and transit pilotage applications.

With this conclusion and the experience gained from the TRA, the Study will issue a second RFI in Q4 2025, which will contain more detailed high-level specifications, utilising the top-down and bottom-up learnings thus far, to elicit enhanced participation from manufacturers and system integrators.

The Study recognises that whilst there is a risk that more detailed specifications may discourage some manufacturers and system integrators from responding to the second RFI, for others it may demonstrate that remote pilotage is a concept that IMPA and its partners are obliged to explore in depth and that there is value for them in participating in an unbiased, rigorous and authoritative Study designed to enable informed decisions by maritime pilots' organisations and competent authorities.

Abbreviations

AIS	Automatic Identification System
AtoN	Aids to Navigation
CCG	Canadian Coast Guard
CIRM	Comité International Radio-Maritime
COG	Course Over Ground
COLREG	1972 Convention on the International Regulations for Preventing Collisions at Sea
CPA	Closest Point of Approach
EBL	Electronic Bearing Line
ECDIS	Electronic Chart Display and Information System
EPFS	Electronic Position Fixing System
FPSO	Floating Production, Storage and Offloading
GNSS	Global Navigation Satellite System
ICS	International Chamber of Shipping
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IMO	International Maritime Organization
IMPA	International Maritime Pilots' Association
ISO	International Organization for Standardization
MASS	Maritime Autonomous Surface Ships
MPX	Master-Pilot Information Exchange
NAS	Navigation Assistance Service
NCC	Navigation Control Centre
NCEMP	National Centre of Expertise on Maritime Pilotage
OOW	Officer of the Watch
PEC	Pilotage Exemption Certificate
PI	Parallel Indices
PNT	Position, Navigation and Timing
PPU	Portable Pilot Unit
RAI	Rudder Angle Indicator
RFI	Request for Information
ROC	Remote Operations Centre
ROT	Rate of Turn
ROTI	Rate of Turn Indicator
RPM	Revolutions per Minute
RTK	Real-Time Kinematics
SDME	Speed and Distance Measuring Equipment
SOG	Speed Over Ground
SOLAS	The International Convention on Safety of Life at Sea
SPM	Single Point Mooring
STW	Speed Through Water
TCPA	Time to Closest Point of Approach
THD	Transmitting Heading Device
TRA	Technology Readiness Assessment
TRL	Technology Readiness Level
UHF	Ultra-High Frequency
UR	Unified Requirement
VDR	Voyage Data Recorder
VHF	Very-High Frequency
VRM	Variable Range Marker
VRS	Vessel Remote Server
VTS	Vessel Traffic Services
WLAN	Wireless Local Area Network

Introduction

1. Overview of the R-Pilot Project

.1 Purpose and motivation

The purpose of the International Study on Remote Pilotage (R-Pilot, the Study) is to rigorously explore remote pilotage, ground-truthing its feasibility, readiness, and impacts on safe navigation practices and systems in mandatory pilotage waters.

R-Pilot is designed to provide authoritative insights into the current and potential use of remote pilotage on conventional ships and those that might be navigated remotely or by software with autonomy in the future.

The Study is undertaken to enable competent authorities and maritime pilots' organisations to make informed decisions about the evolution of their pilotage services, in response to the number and variety of organisations promoting remote pilotage in both mandatory and recommendatory pilotage waters.

.2 What is pilotage?

IMO recommends that governments organise pilotage services in areas where such services would contribute to the safety of navigation more effectively than other possible measures, and should, where applicable, define the ships or classes of ships for which the employment of a pilot would be mandatory.[1]

Pilotage is the risk avoidance option of last resort, which delivers at least a x528 reduction in risk[2] and which has an incident rate (very serious maritime casualties) of less than 1 for every 10 million acts of pilotage.[3] It is a public service which ensures the safety of navigation, the prevention of pollution and the efficient movement of cargo and passengers.

Mandatory pilotage areas are locations including ports, harbours, canals, rivers, lakes, and their approaches, where a coastal State requires ships to comply with a requirement to have their navigation directed by a suitably trained, experienced, and licensed maritime pilot.

Recommendatory pilotage or transit pilotage areas are bodies of water where the IMO recommends that ships have their navigation directed by a suitably trained, experienced, and licensed maritime pilot.[4]

.3 What is remote pilotage?

Remote pilotage is a concept where the direction of the navigation of a ship by a suitably qualified and licensed maritime pilot from ashore is a mutually exclusive alternative to the presence of a suitably qualified and licensed maritime pilot on the bridge of a ship.

A distinction is drawn between existing shore-based pilotage protocols and remote pilotage. Shore-based pilotage is a service provided in certain ports (e.g., Rotterdam) that allows the efficient positioning of ships and the safe embarkation of maritime pilots

[1] IMO resolution A.159 (ES.IV), Recommendation on Pilotage
[2] TEMS (2022), Quantifying the value of maritime pilotage
[3] Based on port call data provided available from UNCTAD, maritime casualty data available in the MCI module of IMO GISIS and IGP&I (2020), Report on P&I claims involving vessels under pilotage
[4] Refer to IMO resolution A.1081(28), A.1080(28), MSC.138(76), A.827(19), A.710(17) and A.668(16).

in adverse weather conditions. It is not a mutually exclusive alternative to embarking a maritime pilot during the most challenging phases of a voyage (e.g., port entry, (un)berthing).

A further distinction is drawn between remote pilotage and VTS. VTS refers to services implemented by a government in accordance with SOLAS regulation V/12. While VTS is a shore-based service, and remote pilotage may be a shore-based service, there are fundamental differences in legal frameworks, obligations on personnel, and operational protocols, which mean that a NAS provided by a VTS is not equivalent to pilotage.

Finally, it is essential to distinguish between remote navigation and remote pilotage. Confusion often arises due to the use of the word “pilot” in the context of the control of remotely operated vehicles, unmanned surface vehicles and MASS. Remote navigation is the appraisal, planning, execution and monitoring of a MASS voyage by remote operators in an ROC. Remote pilotage is the direction of navigation of a ship, regardless of how it is controlled, in a mandatory or recommendatory pilotage area by a maritime pilot who is qualified and licensed for the task.

.4 Collaborators

- The International Maritime Pilots’ Association (IMPA)
- The National Centre of Expertise on Maritime Pilotage (NCEMP)
- The Canadian Coast Guard (CCG)

.5 Technical Advisers

Phase 2 of R-Pilot has been supported by risk, software engineering and technical expertise from Lloyd’s Register.

.6 Project Governance

R-Pilot was commissioned by the Executive Committee of IMPA and is overseen by a Project Board constituted of experienced maritime pilots from Australia, Brazil, Canada, Germany, the Netherlands and the United States.

2. Purpose of the Phase 2 Technology Readiness Assessment

Phase 2 of the Study aims to determine the technology readiness level of candidate remote pilotage solutions, assessing their theoretical maturity to enable safe and effective maritime pilotage.

At this stage, the determination process involves identifying candidate remote pilotage solutions that can be advanced into phases 3 to 5 of the Study.

The purpose of phases 3 to 5 of the Study is to generate, through quantitative and qualitative analysis, a rich data set providing information about:

- The necessary capabilities of any technical solution for remote pilotage.
- The pre-requisites of remote pilotage from the perspectives of the operational practices of maritime pilots, and of Master and Bridge teams.
- Human factors aspects and operational protocols of remote pilotage, from the perspective of maritime pilots, and of Master and Bridge teams.

The maturity of candidate remote pilotage solutions in the context of mandatory pilotage is therefore essential. Without mature candidate remote pilotage solutions for trials, the ability of phases 3 to 5 of the Study to deliver their purpose is compromised. This is because the output data set from the Study would be artificially limited or skewed by the technical capabilities of the candidate remote pilotage system(s).

Candidate Remote Pilotage Solutions

3. Identification

To attract the best possible candidates for remote pilotage solutions to R-Pilot, IMPA issued a public RFI targeting manufacturers and system integrators.

An RFI is a formal process for collecting information about the capabilities, products, and services primarily in the context of procurement. The choice of a public and open RFI was made to ensure the credibility of the Study by giving as many potential manufacturers and system integrators as possible the opportunity to propose candidate remote pilotage solutions.

The RFI was issued on 6 November 2024 via IMPA's media channels and through CIRM, which promotes electronic technology for maritime safety and efficient vessel operations. The deadline for responses was 31 December 2024, and reminders were issued before the deadline.

The RFI clearly articulated the objectives of the remote pilotage study and the expectations of manufacturers and system integrators proposing candidate remote pilotage solutions, including that the proponent would initially bear the costs of participation.

The RFI is available on the IMPA website.

4. High-level specifications

The RFI includes the following high-level specifications for candidate remote pilotage solutions. These specifications were deliberately set to allow a wide variety of potential solutions to be proposed for consideration and to avoid prematurely deselecting candidate solutions before the more detailed assessment was complete.

The high-level specifications were:

1. **HLSpec 1:** Deliver secure, low-latency ship-shore, shore-ship exchange of data and information required by a qualified, licensed maritime pilot to direct the navigation of a ship throughout an act of pilotage, including berthing, unberthing, and manoeuvring in a port, port approach, harbour, canal or river.

2. **HLSpec 2:** Deliver secure, low-latency ship-shore, shore-ship exchange of data and information required by a Master and Bridge Team to discharge their responsibility for the safety of a ship during an act of pilotage.

3. **HLSpec 3:** Deliver secure, low-latency shore-shore, ship-shore, and shore-ship exchange of data and information required for reporting and coordination of services in both normal and emergency situations.

4. **HLSpec 4:** Support a Master and bridge team and a pilot ashore by establishing, maintaining, and sharing situational awareness before and during an act of pilotage.

5. Proponents of candidate remote pilotage solutions

.1 AD Navigation

Founded in 2002, in Sarpsborg, Norway, by Lorentz Ryan, AD Navigation is a privately owned company headquartered near the harbour in Tønsberg, Norway. It develops and supplies what it describes as state-of-the-art products, mainly within hydrography and dredging positioning applications, as well as for portable navigation systems used by maritime pilots.[5]

The proposed solution from AD Navigation is outlined as follows:

- It is based on an existing solution that provides mooring services for tankers and gas carriers to FPSO vessels and SPM.
- It enables a mooring Master not on-board the tanker to direct the mooring of the ship to an FPSO or SPM without being onboard the tanker or gas carrier being moored.
- The technology solution consists of three (XR2) sensors and a UHF transmitter/receiver or an SPU-100 fixed installation onboard a tanker, and a portable remote pilotage workstation installed on another vessel or structure in the vicinity of the ship being remotely piloted.
- All equipment is connected via UHF radio, with a range of up to 500 metres.
- All voice interactions between parties are conducted via VHF/UHF radio, mobile network, or satellite.

.2 DanPilot and Danelec

DanPilot is an independent public enterprise. The company states that it contributes to maritime safety and marine environmental protection by offering pilotage services throughout Denmark and Greenland. DanPilot operates 16 pilot stations and employs 430 people. The head office is located in Svendborg.[6]

Danelec is part of the GTT Group and is a global maritime technology company with 30 years of experience of what it states as delivering digital solutions for safer, more efficient, and more sustainable ship operations. The company states it is a leader in ship data collection and AI-based analysis, with installations on more than 15,500 vessels worldwide. Danelec has 14 global offices and 180 employees. The headquarters is located in Farum, Denmark.[7]

The proposed solution from DanPilot/Danelec is outlined as follows:

[5] https://www.adnavigation.com/company-contact-info/
[6] https://danpilot.dk/news/denmark-first-to-launch-data-driven-remote-pilotage/
[7] https://danpilot.dk/news/denmark-first-to-launch-data-driven-remote-pilotage/

- A Vessel Remote Server (VRS) provided by Danelec, is a proprietary one-way gateway for streaming the data collected by a Voyage Data Recorder (VDR) and its associated remote data interfaces onboard a ship.

- The data collected by a VDR is streamed to workstations in a DanPilot Navigation Control Centre (NCC) ashore using satellite communications (although communications using 4G/5G is also possible) and via Danelec's proprietary cloud server.

- The streamed data/information is accessed by the remote pilot using Danelec's proprietary software, VDR Explorer. The data that can be streamed is the data required to be collected by a VDR, as per IMO resolution MSC.333(90)[8], as amended, and the test specification in IEC 61996-1:2013[9].

- Communications between the pilot and bridge team are enabled by a two-way communication solution called NCC Communicator. This provides the pilot and bridge team with the option to use voice, chat, drawing and video to communicate with each other.

- A tablet and a combined microphone and loudspeaker are provided to the ship to be used for the NCC Communicator. The communicator is mobile and can be used where the OOW is present.

- In addition to displays for ECDIS, radar and ships' status information, the pilot ashore has access to a PPU display.

.3 Dryad Global

Dryad Global, based in the United Kingdom, is an intelligence, information, and technology company specialising in providing intelligence and cybersecurity solutions to the maritime industry. The company states that it is founded on the principles of empowering people to improve decision-making and results using software and technology.

The proposed solution from Dryad Global was stated as a partial solution for encryption and aggregation of the data to be transmitted from the ship to shore, as well as long-term endpoint protection for the critical devices onboard using a combination of three Dryad Global solutions: Dryad Cyber Voyager Endpoint Protection, Cyber Voyager End-to-End Encryption, and Secure Voyager Shipboard.

6. Limitations on the RFI approach

While the RFI process was intended to be as wide-reaching and inclusive as possible, it is recognised that it may not have reached all manufacturers and system integrators capable of delivering candidate remote pilotage solutions meeting the high-level specifications. Moreover, it is recognised that the timing of the RFI may not have aligned with the priorities of some potential manufacturers and system integrators. This was confirmed when IMPA approached several manufacturers and system integrators who were expected to respond to the RFI, given their expertise, but who decided not to.

[8] IMO resolution MSC.333(90) on Revised performance standards for shipborne voyage data recorders (VDRs)
[9] IEC 61996-1:2013 - Maritime navigation and radiocommunication equipment and systems - Shipborne voyage data recorder (VDR) - Part 1: Performance requirements, methods of testing and required test results

Consequently, it is acknowledged that the candidate solutions assessed so far may not reflect the totality of potential candidate remote pilotage solutions.

Assessment

7. Assessment of candidate remote pilotage solutions

.1 Assessment criteria

The assessment criteria used were:

.1 Operational readiness

For the trials in phases 3 to 5 of the Study to deliver rich observations about the capabilities, limitations, and prerequisites of remote pilotage in mandatory pilotage waters, it is essential to have candidate remote pilotage solutions that can deliver as many of the workflow tasks involved in an act of pilotage as possible.

Without a sufficiently mature solution, the Study would not be able to provide authoritative information, beyond a specific technical ceiling, to support informed decision-making by pilot organisations and competent authorities.

The operational readiness component was evaluated in the following areas:

Workflow	Workflow summary
Pre-requisites	• Training and familiarisation for maritime pilots • Training and familiarisation for bridge teams
Preliminaries	• Pilot assignment • Maintenance of records
Execution of pilotage	Providing the pilot with the capabilities to execute an act of pilotage, including: • Continuous MPX • Fundamentals of safe relative navigation and manoeuvring • Collision avoidance • Hazard identification and mitigation • Operation near other ships, hazards and infrastructure and interactions • Hydrodynamic effects and interactions
Position, navigation and timing confirmation	Avoiding over-reliance on GNSS for safe navigation, direction and monitoring of manoeuvres and collision avoidance

Workflow	Workflow summary
Initial data acquisition	Providing the pilot with access to critical data required for safe navigation, direction and monitoring of manoeuvres and collision avoidance
Communications (including docking and undocking at berth or in locks)	• Providing the pilot, and the Master and the bridge team with effective means of closed-loop communications • Providing the pilot with effective means of closed-loop communications with third parties
(Un)docking (including at berth or in locks)	Providing the pilot with the capabilities to direct and monitor manoeuvres during (un)docking
Anchoring	Providing the pilot with the capabilities to direct and monitor manoeuvres during anchoring
Information, services and data	Meeting the information, service and data needs of maritime pilots

The workflows and workflow tasks were developed based on a workshop conducted by NCEMP in December 2024.

Within each area, the candidate remote pilotage solution was assessed for risk based on the following risk criteria. It is important to note that the assessment is conducted in the context of mandatory pilotage, the Study and with an open mind to opportunities and challenges that may arise during the trial phases, particularly during open trials on commercial ships (phase 5 of the Study):

Risk	Explanation
Very low	Negligible impact as no change to current operational practices.
Low	Low impact or low likelihood due to adequate alternative arrangements for current operational practices being provided.
Medium	Medium impact or alternative arrangements for current operational practices are provided, but with potential limitations identified due to technical **or** human factors.
High	Workflow task achievable under specific circumstances, or alternative arrangements for current operational practices embody limitations due to technical and human factors.
Very High	The system is not designed for the workflow task, **or** a workflow task is not achievable under all circumstances, **or** alternative arrangements result in non-conformity with IMO instruments, national legislation, or best practices.

.2 Compatibility

The candidate remote pilotage solutions must be deployable in various environments and on various types of ships, ideally including CCG ships (phase 4 of the Study). In assessing compatibility, the following sub-criteria were applied:

- The extent of reliance on proprietary hardware and interfaces in the system architecture, including those to be installed on ships.

- The use of and integration with shipboard sensors and equipment, which are a carriage requirement in accordance with SOLAS chapter V.

- Conformity of hardware with SOLAS regulation V/17 (Electromagnetic compatibility), resolution A.813(19)[10], resolution A.694(17)[11], including IEC 60533:2015[12] and IEC 60945:2002[13] and/or IACS UR E10[14], as appropriate.

- Conformity with current standards for data exchange, including those addressed in the IEC 61162-450[15], as appropriate.

.3 Scalability

The candidate remote pilotage solution must be capable of being deployed in any mandatory pilotage area and allow the navigation of multiple ships to be directed simultaneously by their assigned maritime pilots.

.4 Security

The candidate remote pilotage solution must demonstrate a level of cyber resilience commensurate with the role of pilotage in mandatory pilotage waters. At this stage, this includes, as appropriate, conformity with IEC 61162-460[16] or IACS UR E27[17].

.2 Data collection steps

.1 Initial self-evaluation

An assessment guide was sent to proponents to help them prepare for the face-to-face assessment discussions. This also served the purpose of allowing proponents to assess whether further involvement in the Study was appropriate for them.

Withdrawal of Dryad Global

At this stage, Dryad Global withdrew from the process. This decision was based on their own conclusions that their expertise and capabilities in secure data acquisition and exchange meant they had only a partial candidate remote pilotage solution.

[10] General requirements for electromagnetic compatibility for all electrical and electronic ship's equipment (IMO resolution A.813(19)).
[11] Recommendation on general requirements for shipborne radio equipment forming part of the GMDSS and for electronic navigational aids (IMO resolution A.694(17))
[12] IEC 60533:2015 - Electrical and electronic installations in ships - Electromagnetic compatibility (EMC) - Ships with a metallic hull
[13] IEC 60945:2002 - Maritime navigation and radiocommunication equipment and systems - General requirements - Methods of testing and required test results
[14] IACS UR E10 – Test specification for type approval, Rev.9
[15] IEC 61162-450:2024 - Maritime navigation and radiocommunication equipment and systems - Digital interfaces - Part 450: Multiple talkers and multiple listeners – Ethernet interconnection
[16] IEC 61162-460:2024 - Maritime navigation and radiocommunication equipment and systems - Digital interfaces - Part 460: Multiple talkers and multiple listeners - Ethernet interconnection - Safety and security
[17] UR E27 Cyber resilience of on-board systems and equipment – Rev.1 Sep 2023

.2 Assessment interviews

The proponents were invited to a day-long interview session to review the candidate remote pilotage solutions comprehensively. The interviews were conducted in London on 29 April 2025 (DanPilot/Danelec) and 1 May 2025 (AD Navigation).

The interviews were convened with expertise from IMPA, NCEMP, CCG and Lloyd's Register.

The purpose of the interviews was to conduct a deep dive into the candidates' remote pilotage solutions with the proponents, guided by the evaluation criteria.

.3 Validation with proponents of candidate remote pilotage solutions

Following the assessment, columns 1–4 of the technical appendices were shared with the proponents for validation, with comments incorporated before finalisation of the technical appendices and this report. Commentary on this is provided in sections 8.6 and 9.6 of this report.

Results of the Phase 2 Technology Readiness Assessment

The assessments in sections 8 and 9 are independent and should not be read as comparator assessments.

Each candidate remote pilotage solution was assessed independently against the criteria outlined in section 7.1 of this report.

8. AD Navigation Assessment

.1 High-Level Specifications

This assessment pertains to the high-level specifications outlined in section 4 of this report, as described in the RFI.

HLSpec	Initial conformity indicator[18]
1	🟡
2	🔴
3	🟡
4	🔴

The initial assessment indicated that the candidate solution had not achieved sufficient conformity with the high-level specifications to justify a more detailed assessment.

Nevertheless, considering the contrasting architectural differences between the proposed candidate remote pilotage solutions, a more detailed assessment was deemed to be a valuable and justified exercise.

.2 Operational readiness

[18] Green – HLSpec met. Amber – HLSpec partially met. Red – HLSpec not met

The information provided in the summary SWOT analysis below is derived from the more detailed assessment reported in Technical Appendix 1.

Strengths	**Weaknesses**
• Simplicity of the system and utilisation of proven PPU sensors, providing RTK • Demonstrably effective in single SPM and FPSO applications • Resilience to jamming and spoofing provided by the XR2 PPU • UHF, WLAN and 4G/5G support for data exchange • Not reliant on shore-based infrastructure	• Supports voice-only communications for the continuous MPX • Pilot has no access to radar for relative navigation and collision avoidance • Reliant on AIS for collision avoidance • Reliant on predicted rather than actual depth beneath the keel • Pilot unable to immediately verify the execution of helm and telegraph orders • Capabilities are limited to those tasks where the pilot requires PPU decision support only
Opportunities	**Threats**
• Line-of-sight applications for maritime pilots leading ships from another vessel in mandatory pilotage areas in accordance with national legislation	• Not designed to support over-the-horizon applications where the PPU is more than a decision support tool • Pilot is compromised in their ability to demonstrate compliance with the COLREGs (lookout by radar, reliance on AIS) • Does not support shared situational awareness between the Master and bridge team (using shipboard sensors and ECDIS), and the pilot (using PPU sensors and software) • The pilot's instructions are not recorded by the ship's VDR

.3 Compatibility

- The candidate solution relies on the AD Navigation XR2 PPU sensors, integrated with third-party pilot software. The solution does not integrate with ship systems or equipment required by SOLAS Chapter V; therefore, conformity with IEC 61162-450:2024 is not appropriate.

- The candidate solution falls within the scope of the provisions for portable electrical and electronic equipment in SOLAS regulation V/17.2, and therefore, conformity of hardware with resolution A.813(19), resolution A.694(17), including IEC 60533:2015 and IEC 60945:2002 and/or IACS UR E10 is not appropriate.

.4 Scalability

- The candidate solution can be deployed on any ship permanently or temporarily fitted with AD Navigation XR2 PPU sensors. For applications where the pilot does not board the ship, the sensors would need to be permanently installed.[19]

- The candidate solution can be deployed in any environment provided that the pilot remains within 500m of the ship and, therefore, it is not capable of supporting over-the-horizon applications.

[19] A practice already adopted in the Panama Canal. Refer to Advisory to Shipping No. A 32-2022 for New Positioning System Requirements for Transiting Neo-Panamax Vessels

.5 Security

- Evidence was provided of strong resilience to GNSS jamming and spoofing.[20]
- The solution does not integrate with ship systems or equipment required by SOLAS chapter V, and therefore conformity with IEC 61162-460 or IACS UR E27 does not apply.

.6 Comments received by proponents after validation

AD Navigation requested an amendment to the description of their system. This update was made and is reflected in section 5.1 of this report. No further comments were received on the content of columns 1 to 4 of Technical Appendix 1.

.7 Outcome

The AD Navigation candidate remote pilotage solution is based on an existing proven solution for SPM and FPSO applications. The conclusions reached in this report do not reflect on the system in its current applications.

The operating assumption of the solution is that the pilot is onboard or in the immediate vicinity of the ship being piloted and that the pilot only needs RTK manoeuvring decision support information provided by a PPU to execute a safe pilotage.

The exclusive use of the XR2 PPU sensors in combination with third-party piloting software means that information necessary for the safe conduct of pilotage beyond RTK manoeuvring information is not provided. This has implications, particularly in the context of COLREGs. Furthermore, the communications between the pilot, Master, and bridge team are voice-only, which may have implications for the effectiveness of the continuous MPX, shared situational awareness, and resolving differing perceptions of risk.

Consequently, the solution does not enable over-the-horizon remote pilotage. It therefore cannot be used by R-Pilot for this purpose in phases 3 to 5 of the Study.

9. DanPilot/Danelec Assessment

.1 High-Level Specifications

This assessment pertains to the high-level specifications outlined in Section 4 of this report, as described in the RFI.

HLSpec	Initial conformity indicator[21]
1	🟡
2	🟢
3	🟡
4	🟢

[20] AD Navigation (2025), White Paper - Battling GPS/GNSS Hamming & Spoofing
[21] 21 Green – HLSpec met. Amber – HLSpec partially met. Red – HLSpec not met

The initial assessment indicated that the candidate solution achieved a reasonable degree of conformity with the high-level specifications, justifying a more detailed assessment.

.2 Operational readiness

The information provided in the summary SWOT analysis below is derived from the more detailed assessment reported in Technical Appendix 2.

Strengths • NCC Communicator as a means of conducting a continuous MPX • Under trial as an over-the-horizon remote pilotage solution in recommended pilotage areas in the entrance to the Baltic • The pilot is provided with a wide range of data and information necessary for pilotage, and there are opportunities for maritime pilots and Masters and bridge teams to develop and maintain situation awareness	**Weaknesses** • No day/night optical component • Encourages significant reliance on GNSS • Pilot is reliant solely on a VDR and the data it collects from shipboard sensors • Pilot is reliant on radar images captured by the VDR with no ability to use it independently for navigation or collision avoidance. • No RTK data for manoeuvring large vessels and to provide an independent PNT source • Requires Masters and bridge teams to be vetted to be able to use the system, where vetting is a standard below a PEC • Only communications made using the chat are recorded by NCC Communicator • Use of VHF as a redundancy measure for communications requires a coastal station radio licence
Opportunities • Utilisation of existing onboard data collection infrastructure • Enables remote pilotage use cases in mandatory pilotage waters where a pilot or PEC holder is on board the ship	**Threats** • Not designed to support port pilotage with gaps in the ability to conduct closed-loop communications with tugs and mooring personnel • Single points of failure in communications and data exchange (VDR, VRS), presenting a risk of ships navigating in mandatory pilotage areas without a pilot or PEC holder directing the navigation • Pilot is compromised in their ability to demonstrate compliance with the COLREGs (lookout by sight and radar) • Potential bridge manning implications in mandatory pilotage waters where there is a high volume of communications between the pilot and the bridge team

.3 Compatibility

- The system architecture relies on proprietary Danelec hardware (VDR and VRS), cloud server, and software (VDR Explorer).

- Danelec states vessel remote service (VRS) as conforming to IEC 61162-460 and IEC 60945.

- Danelec states data acquisition unit (DPU) as conforming to IEC 61162-1, 61162-2, 61162-450.

.4 Scalability

- The trials of the solution in recommendatory pilotage in the entrance to the Baltic indicate that the solution is scalable.

- Additional hardware is required if Danelec or JRC does not manufacture the VDR onboard the ship.

.5 Security

- Danelec states vessel remote service (VRS) as conforming to IEC 61162-460 and IACS UR E27.

- VDR Explorer is stated by Danelec as supporting encryption when communicating with the VRS and enabling use of VDR Explorer whilst maintaining conformity of the system with IACS UR E27.

.6 Comments received by proponents after validation

DanPilot and Danelec offered comments on columns 1 to 4 of Technical Appendix 2 relating to:

- Systems descriptions and clarifications relating to the Danelec hardware and infrastructure.

- Arrangements for pilot assignments as well as for bridge team and ship vetting.

- Clarifications on the recording of chat by NCC Communicator, and the use of VHF and mobile phones as a redundancy for NCC Communicator.

- Highlighting that the system is designed for transit pilotage, not port pilotage.

- Comments specific to DanPilot’s experience of use under trials in the entrance to the Baltic.

Amendments to technical descriptions of the system and clarifications have been reflected in section 5.2 of the report and Technical Appendix 2. Other matters have been addressed, as appropriate, in Technical Appendix 2, and where necessary, the assessment outcome has also been updated accordingly.

.7 Outcome

The DanPilot/Danelec candidate remote pilotage solution is undergoing trials in the entrance to the Baltic for transit pilotage in recommended pilotage areas. Remote pilotage in recommendatory pilotage areas is outside the scope of R-Pilot, and the conclusions reached in this report do not reflect on the system in its current application. Based on the assessment, it is concluded that the candidate remote pilotage solution, while promising in terms of the high-level specification in section 4 of this report, is not designed for or capable of being used for trials in mandatory pilotage areas without significant risk being carried by the study, its partners, and participating ships and maritime pilots. In this regard, DanPilot has indicated that they would prefer that the solution not be trialled independently by the Study in the mandatory pilotage areas of the St. Lawrence River.

Nevertheless, the NCC Communicator component of the system is a potentially powerful tool for shore-to-ship and ship-to-shore communications. This capability is considered a minimum viable solution in terms of the Study and for the concept of remote pilotage in general. The capabilities of the system are anticipated to be a foundation for ensuring that the human factors components of remote pilotage relating to the continuous MPX can be fully explored.

Implications for the R-Pilot Study

10. Candidate solutions for phases 3 to 5

The outcome of phase 2 of the Study demonstrates evidence of progress in the development of potentially viable remote pilotage solutions for mandatory pilotage areas. However, based on the outcome of the assessments of candidate remote pilotage solutions in sections 8 and 9, a suitable solution to enable phases 3 to 5 of the Study has not been identified.

While both candidate remote pilotage solutions may be suitable for the purposes for which they were designed, the limitations identified with both candidate remote pilotage solutions prevent the Study from designing and executing trials which allow the capabilities and limitations of remote pilotage in mandatory pilotage waters to be revealed.

If the Study were to progress with either of the candidate remote pilotage solutions, then their limitations, as described in this report, would skew the planning and execution of phases 3 to 5. In other words, the Study would only be able to find the limits of what the technology can enable, rather than the limits of remote pilotage as an operational protocol. Ultimately, this would erode the potential of the Study to provide an unbiased and thorough exploration of remote pilotage in mandatory pilotage waters.

Consequently, the Study has determined that to identify a suitable minimum viable remote pilotage solution for phases 3 to 5, a second RFI should be issued containing more detailed goal-based high-level specifications for candidate remote pilotage solutions. The objective is to give manufacturers and system integrators more direction on what a minimum viable remote pilotage solution looks like. This approach may also help address some of the limitations of the RFI process outlined in Section 6 of this report by creating a further opportunity for manufacturers and system integrators to engage with the Study.

11. Revised High-Level Specifications for phases 3 to 5

The assessment process described in this report, and the outcomes provided in sections 8 and 9, have provided the Study with insights into the capabilities of a technical solution which could enable the development of a minimum viable remote pilotage solution which could support phases 3 to 5 of the Study. Those insights are as follows:

- A communications system with the ability to support closed-loop non-verbal, verbal, and video communications between the pilot and the Master and bridge team is an essential capability for building trust, rapport, conducting the continuous MPX and providing unambiguous directions.

- Pilotage as a service is resilient because maritime pilots are not reliant on a single source of information for executing and monitoring an act of pilotage. There is a risk that remote pilotage solutions may drive maritime pilots towards over-reliance on GNSS, particularly in the absence of day/night optical solutions and the ability to independently interrogate radar. Both day/night optical solutions and the ability to independently interrogate radar are essential for maritime pilots to utilise AtoN and other navigational features to direct ship navigation.

- A VDR is designed for and required to be carried on ships for a specific purpose.[22] Whilst this duality may be an efficient use of existing shipboard infrastructure, the safety-critical role of maritime pilotage means that the re-use of equipment not specifically designed for the task of aggregation and sharing of data for pilotage is a factor that candidate remote pilotage solutions will need to consider. Dedicated solutions providing the pilot with access to information and data, as if they were on the bridge, may be necessary.

- Redundancy and resilience in communications, including data communications, have an essential role in preventing ships piloted remotely from navigating in a mandatory pilotage area without the navigation being directed by a qualified and licensed pilot or a PEC holder. This is both a legal matter for the ship and a risk management matter for the coastal State and other users of the mandatory pilotage area. An architecture with single points of failure in communications and data exchange presents an unacceptable risk.

- Communications with third parties including VTS, tugs, and mooring personnel, are necessary to ensure that maritime pilots can discharge their responsibilities throughout every phase of an act of pilotage in mandatory pilotage waters. Solutions focused purely on a continuous MPX with the Master and bridge team are insufficient for the more complex tasks involved in an act of pilotage, including (un)docking and emergency situations.

- Where the characteristics of the ship and the pilotage area dictate, maritime pilots will need access to RTK information, making pure reliance on shipboard sensors required by SOLAS chapter V a partial rather than a complete solution.

As a result of the above, the next step for the project is to revise the high-level specifications described in section 4 of this report, to provide more granularity on the functional requirements, expected performances and specific requirements of a candidate remote pilotage solution capable of enabling phases 3 to 5 of the Study.

[22] IMO resolution MSC.333(90), Recommendation on performance standards for VDRs, section 1, and IMO resolution MSC.255(84), Code of the international standards and recommended practices for a safety investigation into a marine casualty or marine incident, paragraph 2.15 and chapter 22

12. Request for Information (RFI) - Second Round

In Q4 2025, IMPA will issue a second RFI, which will request information on candidate remote pilotage solutions meeting the revised high-level specifications from manufacturers and system integrators by the end of Q1 2026. Technology readiness assessments of candidate remote pilotage solutions will take place in Q2 2026, with the aim of identifying candidate remote pilotage solutions that can be trialled with a tolerable risk being carried by the Study, its partners, and participating ships and maritime pilots.

Technical Appendix 1 – AD Navigation Solution Operational Readiness Assessment

PART 1: TRAINING AND FAMILIARISATION

	1	2	3	4	5
	Prerequisites for system users	**How the pre-requisites would be achieved from the perspective of the manufacturer or system integrators**	***Intentionally blank***	**Assessment comments**	**Assessment outcome**
1	What training and familiarisation with the system would be required for maritime pilots to achieve error-free operation, and how is this delivered?	Not part of the AD Navigation proposal	*Intentionally blank*	Unassessed	Unassessed
2	What training and familiarisation with the system would be required for the Master and bridge team to achieve error-free operation, and how is this delivered?	Not part of the AD Navigation proposal	*Intentionally blank*	Unassessed	Unassessed

PART 2: PRELIMINARIES

	1	2	3	4	5
	Pilotage workflow tasks	**Key functionality and capabilities for pilotage workflow tasks provided by the proposed solution**	**Information, services or data[23]**	**Assessment comments**	**Assessment outcome**
3	Pilot is assigned to the correct ship, and the ship is assigned to the right pilot.	None.	N/A	Pilot assignment relies on current operational practices.	**Very Low** Current operational practices would apply
4	Establish voice and data connections to and communications between the ship and the pilot.	Refer to Part 6 (Communications)			**Medium** Refer to Part 6 (Communications)
5	Maintain records of bridge communications, including interactions between the Master, bridge team, and pilot.	None.	N/A	The AD Navigation solution relies on current practices for recording bridge communications using a shipboard VDR installed per SOLAS regulation V/20 and conforming to IMO performance standards[24] and IEC 61996-1:2013.[25]	**Very High** • Incomplete records of information and directions exchanged between the Master and bridge team and pilot are kept, which would not be in the interests of maritime pilots or shipowners/operators in the event of a maritime safety or pollution incident.

[23] Information, services or data that the system uses for the workflow task, including those referred to in Annex A, and any applicable international or industry standards with which the system conforms.
[24] IMO Resolution MSC.333(90)
[25] IEC 61996-1:2013 - Maritime navigation and radiocommunication equipment and systems - Shipborne voyage data recorder (VDR) - Part 1: Performance requirements, methods of testing and required test results

PART 3: EXECUTION OF PILOTAGE

	1	2	3	4	5
	Pilotage workflow tasks	**Key functionality and capabilities for pilotage workflow tasks provided by the proposed solution**	**Information, services or data[1]**	**Assessment comments**	**Assessment outcome**
6	Conduct the MPX, considering IMPA guidance and the ICS Bridge Procedures Guide, 6th edition.	Pre-pilotage: Current operational practices would apply for exchange of the following information between the ship and the pilotage service provider: • Manoeuvring information.[26] • Ship's Particulars. • Machinery and control defects related to power, propulsion, steering and manoeuvring. • Navigation and communication equipment defects. • Route information and intentions for the pilotage. During pilotage: VHF voice communications between the Master and the pilot.	31	• The continuous MPX would be by voice only. • In some circumstances, the ability of the Master and pilot to rapidly build trust may be compromised by an inability to engage face-to-face. • The pilot is reliant on the Master providing accurate information about the characteristics of the ship, and in particular, defects affecting its operation. • Reduced ability for the pilot to use alternative cues, non-verbal indications and other information to evaluate the capabilities of the Master and bridge team and the circumstances onboard the ship. • Route information is exchanged by email rather than an interface conforming to SECOM[27]. The compatibility of this approach with IACS UR26[28] should be further explored, but it is not unique to remote pilotage systems.	**Very High** • Non-voice means of communication, which may be necessary to share situational awareness and intentions, are not available with elevated risk of misunderstandings or different perspectives between the pilot and the Master and bridge team. • Potential for gaps in situational awareness and ship controllability arising from incomplete information about defects with steering, propulsion and manoeuvring systems. This is not unique to this solution. • Explanations may be protracted, which will have opportunity costs in terms of cognitive capacity and time. • Route information is exchanged by email rather than an interface conforming to SECOM, which may compromise operational technology onboard the ship. This is not unique to this solution. • Implications for bridge manning need to be further explored. • Pilot can embark, should this be necessary, for example, in the event of a loss of communication between the Master and the pilot.
7	Direct the navigation of the ship by giving or advising helm and engine orders required to ensure safe progress through the mandatory pilotage area.	VHF voice communications between the Master and the pilot.	31	• Helm and engine orders can be provided by voice only via VHF. • The execution of helm and engine orders by the Master and the bridge team can be indirectly monitored by the pilot using ROT and speed information provided to the third-party PPU software.	**Medium** • Elevated risk of misunderstandings between the pilot and the Master and bridge team. • Potential for delays in remedial action in the event of incorrect helm or engine orders being executed by the Master and bridge team.

[26] IMO resolution A.601(15)
[27] IEC 63173-2:2022 - Maritime navigation and radiocommunication equipment and systems - Data interfaces - Part 2: Secure communication between ship and shore (SECOM)
[28] IACS UR E26 – Cyber resilience of ships

	1	2	3	4	5
	Pilotage workflow tasks	**Key functionality and capabilities for pilotage workflow tasks provided by the proposed solution**	**Information, services or data[1]**	**Assessment comments**	**Assessment outcome**
8	Perceive, comprehend and act on the position of the ship relative to the planned track and proximate navigation hazards, including channel limits.	The solution provides access to the following information: • RTK information, including position and true heading, from multi-constellation GNSS to inform the perception and comprehension of the position of the ship relative to the planned track and proximate navigation hazards. • Access to virtual Aids to Navigation information via AIS is possible within 200m (WLAN) or 100m (Bluetooth) of the ship. The remote pilot interacts with the Master and bridge team through VHF voice communications to direct navigation based on their perception of the position of the ship relative to the planned track and proximate navigation hazards, including channel limits.	2, 5, 7, 20, 26, 31	• Relative navigation by visual means is supported to the extent that it is possible when the pilot is in the vicinity of, rather than onboard, the ship. • No access to shipboard sensor information, including EPFS, THD, radar, echosounder, wind speed and direction. AIS is available within specific ranges of the ship. • Perception, understanding and action using are reliant on the specific third-party piloting software used, including whether S-57 and/or S-101 chart products are supported. • Pilots within 500m of the ship may depend on RTK data to determine the ship's position relative to the planned track and nearby navigational hazards. • Limitations are imposed by the absence of access to ECDIS. This means that the Master, the Master and bridge team, and the pilot may not have shared situational awareness. • Limitations are imposed by the absence of radar information which can be independently interrogated by the pilot to monitor the position of the ship relative to safe water and navigational hazards. • Any actions would need to be communicated to the Master and bridge team by voice only.	**High** • The Master, the Master and bridge team, and the pilot depend on different information sources as a basis for shared situational awareness and may therefore have different perceptions of risk. • Pilot is unable to independently use radar tools (e.g., VRM, PI) to execute and monitor a pilotage plan in a mandatory pilotage area. • The limitations mean that the solution may be considered unsuitable for applications in areas with unreliable GNSS or during restricted visibility.
9	Perceive, comprehend, and act on safe speed in prevailing circumstances and conditions, and in accordance with local regulations.	The solution provides RTK information, including position, SOG, COG, and heading, from multi-constellation GNSS for the perception and understanding of the ship's speed. The remote pilot interacts with the Master and the Master and bridge team through VHF voice communications to direct navigation based on their perception of the ship's speed.	2, 3, 4, 6, 7, 10, 11, 12, 19, 20, 26, 31	• A remote pilot less than 500m from the ship may be able to perceive and comprehend some, but not all factors to be considered when assessing safe speed (COLREG Rule 6 (a) (i, ii, iv)) using visual observation. • Information about the ship's own speed is provided by RTK data independent of the ship's sensor data. • A remote pilot more than 200m away from the ship would not be able to use AIS to contribute to situational awareness and assessment of safe speed. • The pilot does not have access to radar range information, which is necessary to determine the range of visibility and the associated safe speed (COLREG Rule 6 (a) and (b)(v, vi)). • Any actions to amend speed are communicated to the Master and bridge team by voice only.	**High** • The inability of the pilot to independently use radar may result in the need for the ship to proceed at a reduced safe speed (COLREG Rule 6 (b)(i)), even when vessels are navigating in sight of one another. This may result in disruption to the efficiency of ship movements if not factored into the operation of ports, rivers and canals. • The inability of the pilot to independently assess safe speed in restricted visibility may not be consistent with the obligations on pilots in many jurisdictions to ensure that ships navigate safely in mandatory pilotage waters.

	1	2	3	4	5
	Pilotage workflow tasks	**Key functionality and capabilities for pilotage workflow tasks provided by the proposed solution**	**Information, services or data[1]**	**Assessment comments**	**Assessment outcome**
10	Perceive and comprehend developing traffic situations, including arrangements for meeting and overtaking in narrow channels, and act in accordance with COLREGs or local regulations.	The system provides: • RTK information, including position, SOG, COG and heading, from multi-constellation GNSS to inform the perception and comprehension of risk of collision. • Access to AIS information, including position, course, speed, heading and CPA / TCPA, is possible within 200m (WLAN) or 100m (Bluetooth) of the ship. The remote pilot interacts with the Master and the Master and bridge team through VHF voice communications to direct navigation to avoid the risk of collision.	2, 7, 19, 20, 26, 31	• Perception, understanding and action are reliant on the specific third-party piloting software used. • Pilot reliant on the use of AIS data for collision avoidance. Access to AIS is within 200m (WLAN) or 100m (Bluetooth) of the ship. • Line-of-sight observations about the position and movement of the ship relative to other ships support perception, understanding and action. • The pilot does not have access to radar information including range, bearing, CPA/TCPA. • The pilot does not have access to a radar overlay which may be displayed on ECDIS, unless they are onboard the ship. • Any actions would need to be communicated to the Master and bridge team by voice only.	**Very High** • The pilot has a reduced ability to direct the navigation of a ship in accordance with the COLREGs or local regulations in mandatory pilotage waters. This will need to be compensated for by the Master and bridge team. • Potential for increased reliance by pilots on AIS for collision avoidance in mandatory pilotage waters which is inconsistent with IMO Resolution A.1106(29)[29]. • This outcome may not be consistent with the obligations on pilots in many jurisdictions to ensure that ships navigate safely in mandatory pilotage waters.
11	Perceive, comprehend and act on the weather at or in the vicinity of the ship.	The system does not provide weather information at or in the vicinity of the ship. The remote pilot can interact with the Master and the Master and bridge team through VHF/UHF to obtain this information.	31	• A remote pilot less than 500m from the ship should be able to perceive and understand the weather at or in the vicinity of the ship can be done by visual observation. • Pilot cannot assess visibility using radar and would be reliant on assessments provided by the Master and the Master and bridge team in restricted visibility. • The Master and bridge team should be able to communicate weather information using VHF voice.	**Low** Equivalent arrangements are sufficient to assess the weather.
12	Perceive, comprehend and act on the wake being generated by the ship and its impact on other ships and the environment, including compliance with local regulations.	The system does not provide any information regarding the ship's wake. Any change in speed to reduce wake would need to be communicated by VHF voice.	31	• A remote pilot less than 500m from the ship may be able to perceive, comprehend and act on the wake being generated by the ship. • The Master and bridge team should be able to communicate wake information using VHF voice.	**Very Low** Current operational practice would apply.
13	Perceive, comprehend and act on under-keel clearance, including at the berth, and compliance with local regulations.	The system does not provide depth beneath the keel information.	None	• The remote pilot is reliant on calculated predictions, not actual under-keel clearance for perception and comprehension. • Under-keel clearance management requires active participation of the Master and bridge team in communicating the depth beneath the keel to the pilot.	**Medium** • No echosounder information available to the pilot. • Pilotage practice changes. The pilot has a reduced ability to direct the navigation of a ship, taking into account under-keel clearance. This will need to be compensated for by the Master and bridge team.
14	Perceive, comprehend and act on the interaction between ships passing at close quarters and maintain safe distances from other ships and infrastructure.	The system provides RTK information, including bow and stern speeds, to inform the perception and comprehension of the interaction between ships. The remote pilot interacts with the Master and the Master and bridge team through VHF voice communications to respond to interactions between ships.	2, 20, 26, 31	• Remote pilots less than 500m from the ship may be able to perceive and comprehend the effects of interactions by visual observation and changes in bow and stern speed. • The ability to assess interactions based on changes in bow and stern speeds would depend on the third-party piloting software used. • The Master and bridge team need to be able to communicate observations regarding interactions between passing ships. • Any actions would need to be communicated to the Master and bridge team by voice only.	**Medium** • Pilots less than 500m from the ship may be able to assess the effects of interaction but are reliant on RTK data to perceive early indications of unexpected interaction or the scale of any interaction from a remote location.
15	Perceive, comprehend and act on shallow water and bank effects in narrow channels, canals and locks.	Refer to lines 14 (bank effect) and 15 (other effects)	None	Refer to lines 14 (bank effect) and 15 (other effects)	**Medium** Refer to lines 14 (bank effect) and 15 (other effects)

[29] Revised Guidelines for the onboard operational use of shipborne automatic identification systems (AIS) (Resolution A.1106(29))

	1	2	3	4	5
	Pilotage workflow tasks	**Key functionality and capabilities for pilotage workflow tasks provided by the proposed solution**	**Information, services or data[1]**	**Assessment comments**	**Assessment outcome**
16	Perceive, comprehend and act on the effects of wind and/or tide on the set and drift of the ship.	Refer to line 8	2, 3, 4, 5, 6, 7, 20, 26, 31	Refer to line 8	**Low** Equivalent arrangements are provided, although specifics are dependent on the third-party software used by the pilot.
17	Perceive, comprehend and act on the position of other ships and ships relative to planned or anticipated wheel over points.	Refer to lines 8,10	2, 3, 4, 5, 6, 7, 20, 26, 31	Refer to lines 8,10	**Very High** Refer to lines 8 and 10
18	Perceive, comprehend and act on any increase in draft due to heeling in a turn.	Refer to line 13	Nil	Refer to line 13	**Medium** Refer to line 13
19	Perceive, comprehend and act on the progress of a turn and heading leaving a turn using: • Rudder angle indicator • ROT data, including vectors and predictors • Visual reference points • Radar ranges.	The system provides ROT via RTK to inform the perception and comprehension of a ship's rate of turn. The remote pilot interacts with the Master and the Master and bridge team through VHF voice communications to manage the progress of a turn.	2, 3, 4, 5, 6, 7, 10, 11, 20, 26, 31	• Remote pilots less than 500m from the ship may be able to perceive and comprehend the rate of turn from RTK data. • The ability to perceive and act on the rate of turn data depends on the third-party piloting software used. • Line-of-sight observations about the progress of a ship through a turn may support perception, understanding and action. • Limitations are imposed by absence of radar which can be independently interrogated by the pilot to monitor the progress of a turn using VRM and PI. • Pilot does not have access to the shipboard RAI to be able to confirm rudder position, or the onboard ROTI to cross-check RTK ROT. • Any actions would need to be communicated to the Master and bridge team by voice only.	**High** • Pilots less than 500m from the ship may be reliant on RTK data to assess the progress of a turn. • Pilotage practice changes. Pilot unable to use radar to assess the progress of a turn. • Unsuitable for applications in areas with unreliable GNSS or restricted visibility. • Limitations on the ability of the pilot to manage turns and similar manoeuvres may not be consistent with the obligations of pilots in many jurisdictions to ensure that ships navigate safely in mandatory pilotage waters.
20	Determine and verify the position of lifting bridges and lock gates.	Unassessed	26, 31	Unassessed	Unassessed
21	Perceive, comprehend lock sequencing and act to contribute to decisions about lock sequencing.	Unassessed	26, 31	Unassessed	Unassessed

PART 4: POSITION, NAVIGATION AND TIMING CONFIRMATION

	1	2	3	4	5
	Pilotage workflow tasks	**Key functionality and capabilities for pilotage workflow tasks provided by the proposed solution**	**Information, services or data**	**Assessment comments**	**Assessment outcome**
22	Acquire the ship's position.	The system provides RTK information, including positions, from a multi-constellation GNSS to inform the perception and comprehension of the ship's speed.	2, 7, 20	• Remote pilots less than 500m from the ship can acquire the ship's position, provided the ship has PPU sensors set up and operational. • Position is displayed on a device using third-party PPU software compatible with the XR2 sensors. • There is no access to an alternative GNSS position, but multi-frequency multi-constellation GNSS is supported.	**Medium** • Current operational practice applies to pilots within 500m of the ship. • Reliant on the ship having PPU sensors set up correctly and operational. • No redundancy in the event of PPU sensor failure or loss of connection but this is mitigated by the pilot being able to embark the ship.

	1	2	3	4	5
	Pilotage workflow tasks	**Key functionality and capabilities for pilotage workflow tasks provided by the proposed solution**	**Information, services or data**	**Assessment comments**	**Assessment outcome**
23	Use visual AtoN to confirm position (e.g., when no GNSS is available or to confirm accuracy of GNSS position).	Pilot remains within line of sight of the ship.	31	• A pilot within line of sight of the ship will be able to use AtoN, local knowledge and PPU information to confirm the position of the ship. • The Master and bridge team can undertake the task and report the accuracy of the ship's position to the pilot via VHF.	**Very Low** Current practices can be used to achieve this workflow task.
24	Use X-band and / or S-band radar to determine the position of the ship relative to land, aids to navigation, other ships, and wheel-over positions.	None	None	It is not possible for a pilot who is not onboard a ship to confirm the accuracy of the ship's position by using radar ranges.	**High** • Pilot unable to independently interrogate radar. • This workflow task requires the Master and bridge team to independently and accurately assess the ship's position by radar.
25	Assess GNSS smoothing impact on position data provided by the ship.	Not applicable. The ship's position from the ship's GNSS is not used.	N/A	Unassessed	Unassessed

PART 5: INITIAL DATA ACQUISITION

	1	2	3	4	5
	Pilotage workflow tasks	**Key functionality and capabilities for pilotage workflow tasks provided by the proposed solution**	**Information, services or data**	**Assessment comments**	**Assessment outcome**
26	Access and use RTK provided by portable pilot unit sensors, which are independent of ship sensors required by SOLAS chapter V.	The system uses independent sensors to provide RTK data, including position, heading, bow and stern speeds, and rate of turn, from a multi-constellation GNSS.	2, 10	Pilots within 500m of the ship can access the necessary RTK data.	**Very Low** Current operational practice applies.
27	Acquire the ship's true heading and determine or verify gyro error.	The ship's heading from the ship's own sensors is not available. The system provides RTK information, including heading.	7	• True heading is available to the pilot less than 500m from the ship. • Gyro error would need to be determined and communicated to the pilot by the Master and bridge team using VHF.	**Low** Pilot is reliant on the Master and bridge team's accurate assessment of gyro error.
28	Acquire and verify ship's COG.	The system provides RTK information, including COG.	3	The remote pilot can access RTK sensor information, providing COG, when located within range of UHF and WLAN.	**Medium** Where the pilot is located less than 500m from the ship.
29	Acquire and verify ship's STW, SOG.	The system provides SOG information through sensors independent from the ship, but not STW information.	4	The remote pilot can access RTK sensor information, providing SOG, when located within range of UHF and WLAN.	**Medium** Where the pilot is located less than 500m from the ship.
30	Acquire and verify depth at the ship's position.	None	None	The remote pilot cannot acquire and verify depth at the ship's position.	**Medium** • No echosounder information available to the pilot. • Reliant on clear and accurate information from the Master and bridge team.
31	Acquire and verify the ship's rudder, or equivalent steering arrangement, position.	None	None	• The remote pilot cannot acquire and verify the rudder position or the position of equivalent steering arrangements. This may result in a delay in confirming and/or correcting the execution of the helm order by the Master and bridge team. • Position of rudder or equivalent steering arrangement would need to be communicated by the Master and bridge team.	**High** • No RAI or equivalent information available to the pilot. • Reliant on clear and accurate information from the Master and bridge team.

	1	2	3	4	5
	Pilotage workflow tasks	**Key functionality and capabilities for pilotage workflow tasks provided by the proposed solution**	**Information, services or data**	**Assessment comments**	**Assessment outcome**
32	Acquire and verify the ship's telegraph, or equivalent engine control, setting.	None	None	• The remote pilot cannot acquire and verify the telegraph or equivalent engine control settings. This may result in a delay in confirming and/or correcting the execution of the engine order by the Master and bridge team. • Position of rudder or equivalent steering arrangement would need to be communicated by the Master and bridge team.	**Medium** • No telegraph or equivalent engine control setting information is available to the pilot. • Reliant on clear and accurate information from the Master and bridge team.
33	Acquire ship's X- and S-band radar data, including information about motion, trails, offsets, and range.	None	None	The remote pilot does not have access to radar or control of radar.	**Very High** The pilot has no access to radar.
34	If radar data is not raw data which can be manipulated by the pilot, acquire and verify the settings of motion, trails, offsets, range, gain and clutter controls, pulse	Refer to line 33	None	Refer to line 33	**Very High** Refer to line 33
35	Determine or verify the index error, heading alignment error.	Refer to line 33	None	Refer to line 33	**Very High** Refer to line 33
36	Acquire the ship's AIS feed (equivalent to a pilot plug onboard the ship).	ADQ-2 pilot plug	20	Pilots within 200m (WLAN) or 100m (Bluetooth) of the ship can receive AIS from the ship.	**Medium** Current operational practice applies, but the risk of signal loss is considered high and requires further exploration.
37	Determine or verify the AIS antenna offset.	Unassessed	20	Unassessed	Unassessed

PART 6: COMMUNICATIONS (INCLUDING DOCKING AND UNDOCKING AT BERTH OR IN LOCKS)

	1	2	3	4	5
	Pilotage workflow tasks	**Key functionality and capabilities for pilotage workflow tasks provided by the proposed solution**	**Information, services or data**	**Assessment outcome**	**Assessment outcome**
38	Establish connectivity with the ship (primary and reversionary).	UHF, WLAN, Bluetooth data exchange	19	• UHF RTK available up to 500m • WLAN RTK and AIS available up to 200m • Bluetooth AIS available up to 100m. • VHF/UHF voice communications • Redundancy is provided by embarking on the ship.	**Medium** Current operational practice applies, but the risk of signal loss is considered high and requires further exploration.
39	Establish communications with the ship (primary and reversionary).	VHF voice	30	• Connectivity is determined by the real-world range of VHF in the area. • Redundancy is provided by embarking on the ship.	**Very Low** Current operational practice applies.
40	Conduct closed-loop communications with the Master and bridge team throughout the act of pilotage in the agreed working language.	VHF voice	30	Closed-loop communications by voice only	**Medium** • The pilot and the Master and bridge team are reliant on voice-only communications. • This is considered to carry a high risk of misunderstanding / miscommunication and requires further exploration.
41	Establish pilot-VTS communications (primary and reversionary).	VHF voice, cellular	30	Pilot-VTS communications can be established via VHF or cellular.	**Very Low** Current operational practice applies.

	1	2	3	4	5
	Pilotage workflow tasks	**Key functionality and capabilities for pilotage workflow tasks provided by the proposed solution**	**Information, services or data**	**Assessment outcome**	**Assessment outcome**
42	Comply with reporting obligations under local regulation in the mandatory pilotage area throughout the act of pilotage.	VHF voice, cellular	30	Reporting obligations would be conducted via VHF or cellular.	**Very Low** Current operational practice applies.
43	Establish communications with tugs required for escorting or manoeuvring the ship throughout the act of pilotage.	VHF voice	30	Communications with tugs required for escorting or manoeuvring the ship throughout the act of pilotage would be done via VHF.	**Very Low** Current operational practice applies.
44	Conduct closed-loop communications with the Masters of escort or harbour tugs throughout the act of pilotage.	VHF voice	30	Communications with the Masters of escort or harbour tugs throughout the act of pilotage would be done via VHF.	**Very Low** Current operational practice applies.
45	Establish communications with other ships (including to coordinate collision avoidance and ships meeting) and other waterway users, as required, throughout the act of pilotage.	VHF voice	30	Communications with other ships would be done via VHF.	**Very Low** Current operational practice applies.
46	Establish communications with mooring personnel during docking and undocking.	VHF voice, cellular	30	Communications with mooring personnel would be done via VHF or cellular.	**Very Low** Current operational practice applies.
47	Conduct closed-loop communications with mooring personnel during docking and undocking operations.	VHF voice	30	Communications with mooring personnel would be done via VHF.	**Very Low** Current operational practice applies.

PART 7: EXECUTION OF DOCKING AND UNDOCKING (INCLUDING AT BERTH OR IN LOCKS)[30]

	1	2	3	4	5
	Pilotage workflow tasks	**Key functionality and capabilities for pilotage workflow tasks provided by the proposed solution**	**Information, services or data**	**Assessment comments**	**Assessment outcome**
48	Communicate the line cast off sequence and instructions to the ship.	VHF voice	30	The pilot communicates the cast-off sequence to the Master and bridge team, and they inform the various parts of the ship.	**Low** VHF voice provides an equivalent means of communicating the instructions.
49	Communicate the line cast off sequence and instructions to the mooring personnel.	VHF voice	30	Communications with mooring personnel would be done via VHF.	**Very Low** Current operational practice applies.
50	Communicate propeller and thruster clearance.	VHF voice	30	Information is communicated from various parts of the ship to the Master and bridge team and then to the pilot.	**Low** VHF voice provides an equivalent means of communicating the instructions.
51	Direct (un)docking manoeuvres by providing helm, engine and thruster orders to the Master and bridge team.	The system provides RTK information, including position, true heading, bow and stern speed, from multi-constellation GNSS to inform the perception and comprehension of the ship's motion during (un)docking. The remote pilot interacts with the Master and the Master and bridge team through VHF voice communications to direct navigation based on their perception of the position of the ship relative to the berth.	2, 5, 7, 20, 26, 31	• Perception, understanding and action are reliant on the specific third-party piloting software used, including whether S-57 and/or S-101 chart products are supported. • Perception, understanding and action use RTK data independent of the ship's own sensor data, and line-of-sight observations about the position and movement of the ship. • Any actions would need to be communicated to the Master and bridge team by voice only.	**Medium** • Pilots within 500m of the ship may use a combination of RTK data and visual observations to direct (un)docking manoeuvres. • The pilot may lose the benefit of being able to see the position and motion of tugs from a bridge wing.

[30] Tasks are in chronological order for undocking and may be in a different order for docking

	1	2	3	4	5
	Pilotage workflow tasks	**Key functionality and capabilities for pilotage workflow tasks provided by the proposed solution**	**Information, services or data**	**Assessment comments**	**Assessment outcome**
52	Coordinate tugs to enable (un)docking manoeuvres.	Refer to line 44	30	Refer to line 44	**Very Low** Current operational practice applies.
53	Verify that the helm, engine and thruster orders are executed correctly.	Refer to lines 32 and 33	2, 3, 4, 5, 6, 7, 10, 11, 20, 26, 31	• Refer to lines 32 and 33 • No RAI available	**Medium** Refer to line 32 and 33
54	Assess and act on the position of the ship relative to the berth and the final position of the bridge.	The system provides RTK information, including position, from a multi-constellation GNSS to inform the ship's positioning at berth. The remote pilot communicates with the Master and the Master and bridge team via VHF/UHF voice channels to direct berthing operations.	2, 5, 7, 20, 26, 40, 31	• Assessing and acting on position at berth are reliant on the specific third-party piloting software used, including whether S-57 and/or S-101 chart products are supported. • Perception, understanding and action use RTK data independent of the ship's own sensor data, and line-of-sight observations about the position and movement of the ship. • Any actions would need to be communicated to the Master and bridge team by voice only.	**Very Low** Current operational practices would apply.
55	Perceive, comprehend and act on the presence of obstructions, including overhangs, dock cranes.	Pilot able to perceive and comprehend using line of sight observations, in conjunction with information displayed on PPU. The remote pilot interacts with the Master and the Master and bridge team through VHF voice communications.	26, 30, 31	• Assessing and acting on presence of obstructions relies on the specific third-party piloting software used, including whether S-57 and/or S-101 chart products are supported. • Perception, understanding and action use RTK data independent of the ship's own sensor data, and line-of-sight observations about the position and movement of the ship. • Any actions would need to be communicated to the Master and bridge team by voice only.	**Low** A combination of current operational practices and equivalent means of assessing obstructions is provided.
56	Determine and verify which side of the ship is berthed.	Pilots can use line-of-sight observation in conjunction with information displayed on the PPU.	26	The remote pilot can determine and verify which side of the ship is berthed using RTK information and visual observations.	**Very Low** Current operational practices would apply.

PART 8: EXECUTION OF ARRIVAL AND DEPARTURE AT ANCHORAGE

	1	2	3	4	5
	Pilotage workflow tasks	**Key functionality and capabilities for pilotage workflow tasks provided by the proposed solution**	**Information, services or data**	**Assessment comments**	**Assessment outcome**
57	Perceive, comprehend and act on the lead of the anchor chain.	VHF voice	30	The pilot communicates the cast-off sequence to the Master and bridge team, and the Master and bridge team informs the various parts of the ship.	**Low** VHF voice provides an equivalent means of communicating the instructions.
58	Perceive, comprehend and act on the manoeuvres required to bring the anchor chain up and down.	The system provides RTK information, including position, true heading, bow and stern speeds, from a multi-constellation GNSS to inform perception and comprehension during anchoring operations. The remote pilot interacts with the Master and the Master and bridge team through VHF voice communications to direct navigation during anchoring operations.	2, 5, 7, 20, 26, 30, 31	• Perception, understanding and action are reliant on the specific third-party piloting software used, including whether S-57 and/or S-101 chart products are supported. • Perception, understanding and action use RTK data independent of the ship's own sensor data, and line-of-sight observations about the position and movement of the ship. • Any actions would need to be communicated to the Master and bridge team by voice only.	**Low** Pilots within 500m of the ship may use a combination of RTK data and visual observations to direct anchoring manoeuvres.
59	Determine and verify the length of the anchor chain.	VHF voice	30	The pilot communicates the cast-off sequence to the Master and bridge team, and the Master and bridge team informs the various parts of the ship.	**Low** VHF voice provides an equivalent means of communicating the instructions.

PART 9: INFORMATION, SERVICES AND DATA

This appendix outlines the information / services / data that maritime pilots use to deliver safe and efficient maritime pilotage. Each requirement is ranked by importance, as follows:

Importance of information / services / data	Explanation	Weighting
Critical	Without this information / service / data an act of pilotage would result in a maritime safety incident	10
High	Without this information / service / data an act of pilotage would be likely to result in a maritime safety incident	5
Medium	This information / service / data is required for safe and efficient pilotage.	3
Low	This information / service / data is not required for safe and efficient pilotage.	1

The importance of information / service / data is complemented by expected latency levels:

Description	Maximum Latency	Identifier
Ultra Low Latency	200 milliseconds	U
Low Latency	5 seconds	L
Acceptable Latency	30 seconds	A

For this candidate solution, the extent to which the information / service / data needs of maritime pilotage are met is as follows:

	Information / Services / Data	Weighting	Latency Identifier	Needs met?
1	Echosounder	3	L	No
2	GNSS	10	U	Yes (<1 sec)
3	COG	10	U	Yes (<1 sec)
4	SOG	10	U	Yes (<1 sec)
5	Heading	10	U	Yes (<1 sec)
6	Lateral Displacement	3	U	Yes
7	Gyro Compass	10	U	Yes
8	Magnetic Compass	1	L	No
9	Wind Speed & Direction	5	L	No
10	ROT	10	U	Yes (<1 sec)
11	RAI	10	U	No
12	Engine RPM / propellor pitch	10	L	No
13	Visual of the Telegraph	3	L	No
14	Water Levels Log	1	A	No
15	Status of Thruster(s)	5	U	No

	Information / Services / Data	Weighting	Latency Identifier	Needs met?
16	Radar Images	5	U	No
17	Radar Raw Data and Control	10	U	No
18	ECDIS	1	U	No
19	PPU providing RTK	10	U	Yes (<1 sec)
20	AIS	10	L	Yes (<1 sec)
21	Inclinometer	1	L	No
22	Day/night optics with zooming capabilities	5	U	No
23	Daylight signalling (ALDIS)	1	U	No
24	Whistle Control	1	U	No
25	Search lights (bridge wing)	1	L	No
26	Visibility from the bridge equivalent to that required by SOLAS regulation V/22	10	U	Yes (depending on the position of the pilot)
27	Capabilities to hear noise from outside the bridge	3	U	No
28	Capabilities to hear inside the bridge	10	U	No
29	External data Availability (Cameras, Weather Stations, Water Levels, etc.)	5	L	No
30	External communications (VHF, Cellular, Satellite)	10	U	No
31	Two-way communications with the Master and the Master and bridge team	10	U	Yes

Technical Appendix 2 – DanPilot/Danelec Solution Operational Readiness Assessment

PART 1: TRAINING AND FAMILIARISATION

	1	2	3	4	5
	Prerequisites for system users	**How the pre-requisites would be achieved from the perspective of the manufacturer or system integrators**	***Intentionally blank***	**Assessment comments**	**Assessment outcome**
1	What training and familiarisation with the system would be required for pilots to achieve error-free operation, and how is this delivered?	Deployment of the system is enabled by training and familiarisation, including: • One day familiarisation: Use of a simulator focusing on procedures and the use of data and hardware of the NCC Communicator. • Hands-on training consisting of five piloting acts with peer-to-peer training to gain practical experience with remote pilotage. • Four days of VTS training, including one in a VTS centre. • Hands-on training consisting of ten pilotage acts to gain practical experience with remote piloting on a stand-alone basis. Evaluation/feedback from other pilots is provided. • Three days of theoretical and practical training using a combination of ROC and simulator for advanced NCC training; and • An annual one-day course with a focus on emergency response and the use of procedures.	*Intentionally blank*	• The training and familiarisation appear to be commensurate with the intended user case for the solution and the legal framework for pilotage in Denmark. • The training is additive. Pilots continue to require training and certification per national requirements, which should be based on IMO Resolution A.960(23). Pilots continue to be required to maintain on-water currency, in addition to remote-specific initial and periodic training. • Pilots who do not complete the training are unable to use the system. • Implementation of the system requires a risk-based and iterative capacity development process, including trials with pilots and without pilots onboard.	**High** • It is unclear whether the amount and level of practical training would be sufficient for workflow tasks in mandatory pilotage waters, especially those related to navigation in restricted visibility, manoeuvring ships close to port infrastructures and other vessels, and (un)berthing using tugs. • No supplementary Bridge Resource Management training specifically tailored for pilots is included, even though the system requires changes in the working relationship between the Master and bridge team. • Training does not address remote coordination of tugs and mooring personnel because the system is not used for pilotage in mandatory pilotage waters and tug-assisted manoeuvres and (un)docking. Nevertheless, this is a critical capability in the context of mandatory pilotage in ports, rivers and canals.
2	What training and familiarisation with the system would be required for the Master and bridge team to achieve error-free operation, and how is this delivered?	• Only pre-qualified ships and bridge teams can use remote pilotage services. • To qualify, the Master and the Master and bridge team must attend an awareness session and undergo a computer-based training assessment (e-learning). • Before being able to use the system, bridge team members also conduct an assessed remote pilotage with a pilot assessor onboard. • Only ships with at least one vetted bridge team member can opt for remote pilotage. That vetted bridge team member must be on the bridge during remote pilotage.	*Intentionally blank*	• The deployment of the system is predicated on a vetting process for bridge teams, which embodies a standard below that which would be required for a PEC. A PEC is required for a ship to be able to navigate in a mandatory pilotage area without a pilot onboard. • Implementation of the system requires a risk-based and iterative capacity development process, including trials with pilots and without pilots on board. • The vetting of ships and bridge teams means the service would not be available to all ships required to comply with mandatory pilotage requirements.	**High** • The legal and liability implications of vetting crews by pilotage service providers rather than using a more inclusive mechanism established by the competent authority need to be understood in the context of national legislation. • Applying a minimum standard for shipboard personnel in mandatory pilotage waters, which is below that required for a PEC, means that the Master and bridge team would be unable to provide redundancy of expertise in the event of communications or data exchange with a remote pilot being lost. • The process of establishing the system requires a risk-based and iterative capacity development process in which relevant risks are identified and managed by competent authorities, pilotage service providers, technology solution providers, and shipowners / operators / charterers. • This means that any operational or environmental benefit for the pilotage service provider and shipowners / operators / charterers could be limited.

PART 2: PRELIMINARIES

	1	2	3	4	5
	Pilotage workflow tasks	**Key functionality and capabilities for pilotage workflow tasks provided by the proposed solution**	**Information, services or data[31]**	**Assessment comments**	**Assessment outcome**
3	Pilot is assigned to the correct ship, and the ship is assigned to the right pilot.	The solution is reported to use secure login functionality on the proprietary cloud-based infrastructure provided by Danelec to establish connectivity between a ship (VRS) and a pilot (VDR Explorer at NCC workstation). The computers at the NCC are preconfigured to open the VDR Explorer for all the vessels that that can use the remote pilotage protocol using a configuration file that is delivered by Danelec. The initialisation is done via the web interface where access is granted to the NCC. Login to NCC Communicator is achieved using a password and an individual order number to confirm that the pilot is connected to the correct ship.	30	• The system has protections which should prevent pilots from being assigned to the wrong ships, and vice versa. • NCC Communicator provides a full-service information exchange tool which should enable an effective MPX, where any potential mismatch could be identified and resolved. • Danelec VRS 003 is a gateway approved to IEC 61162-460 (Ed.3.0)[32] covering the security capabilities of DNV security profiles 0 and 1 (the minimum standards for merchant ships, including advanced ships and cruise passenger ships).	**Low** The system has arrangements which should support correct and efficient pilot assignment.
4	Establish voice and data connections to and communications between the ship and the pilot.	Refer to Part 6 (Communications)			**Very High** Refer to Part 6 (Communications)
5	Maintain records of bridge communications, including interactions between the Master, bridge team, and pilot.	Danelec or third-party shipboard VDR installed per SOLAS regulation V/20 and conforming to IMO resolution MSC.333(90) and IEC 61996-1:2013.[33] The NCC Communicator records and stores information exchanged through the chat function, including advice provided using message markers. Advice has to be acknowledged by the bridge team.	N/A	• The system is intended to ensure that information provided to the ship's VDR is not affected by the streaming of that data to a pilot using VDR Explorer at an NCC workstation). • All verbal communications between the pilot and the Master and bridge team using NCC Communicator may not be recorded by the bridge microphones and stored on the ship's VDR. • Non-verbal communications between the pilot and bridge team including navigation directions using NCC Communicator, are not recorded by the ship's VDR. • NCC Communicator only records information and directions exchanged using the chat function.	**High** • Incomplete records of information and directions exchanged between the Master and bridge team and pilot are kept, which would not be in the interests of maritime pilots or shipowners / operators in the event of a maritime safety or pollution incident. • The implication for pilots and pilotage service providers of an architecture which uses data explicitly collected for maritime safety incident investigation is unclear. This includes the implications in the event of VDR data being corrupted or not recorded in the event of a serious or very serious maritime safety incident during an act of pilotage.

[31] Information, services or data that the system uses for the workflow task, including those referred to in Annex A, and any applicable international or industry standards with which the system conforms
[32] IEC 61162-460 Ed. 3.0 (2024-04) - Maritime Navigation and radiocommunication equipment and systems – Digital interfaces – Part 460: Multiple talkers and multiple listeners – Ethernet interconnection – Safety and security
[33] IEC 61996-1:2013 - Maritime navigation and radiocommunication equipment and systems - Shipborne voyage data recorder (VDR) - Part 1: Performance requirements, methods of testing and required test results

PART 3: EXECUTION OF PILOTAGE

	1	2	3	4	5
	Pilotage workflow tasks	**Key functionality and capabilities for pilotage workflow tasks provided by the proposed solution**	**Information, services or data**	**Assessment comments**	**Assessment outcome**
6	Conduct the MPX, considering IMPA guidance and the ICS Bridge Procedures Guide, 6th edition.	Pre-pilotage: The following information is exchanged in advance between the ship and the pilotage service provider: • Pilot card and manoeuvring information.[34] • Ship's Particulars. • Machinery and control defects related to power, propulsion, steering and manoeuvring. • Navigation and communication equipment defects. • Route information and intentions for the pilotage. During pilotage: NCC Communicator provides the MPX platform.	30, 31	• NCC Communicator provides a potentially effective MPX tool during an act of pilotage. • In some circumstances, the ability of the Master and pilot to rapidly build trust may be compromised by an inability to engage face-to-face. This is not unique to remote pilotage but is likely to be more challenging when the pilot and bridge team are not co-located. • The pilot is reliant on the Master providing accurate information about the characteristics of the ship, and in particular, defects affecting its operation. This is not unique to remote pilotage but is likely to be more challenging when the pilot and bridge team are not co-located. • Reduced ability for the pilot to use alternative cues, non-verbal indications and other information to evaluate the capabilities of the Master and bridge team and the circumstances onboard the ship. • NCC Communicator has no redundancy, which provides an equivalent level of functionality. Redundancy is voice-only VHF (if licensed to transmit from shore) or mobile phone. • Route information is exchanged by email rather than an interface conforming to SECOM[35]. The compatibility of this approach with IACS UR26[36] should be further explored, but it is not unique to remote pilotage systems. • It is unclear whether an effective MPX during pilotage would require additional bridge personnel to monitor NCC Communicator and respond to incoming communications from the pilot.	**Very High** • NCC Communicator provides an effective MPX tool during an act of pilotage; however, redundancy is provided by VHF or mobile phone which does not provide an equivalent level of functionality. • Potential for gaps in situational awareness and ship controllability arising from incomplete information about defects with steering, propulsion and manoeuvring systems. This is not unique to this solution. • Route information is exchanged by email rather than an interface conforming to SECOM, which may compromise operational technology onboard the ship. This is not unique to this solution. • Risk that ships that lose connectivity will be navigating in a mandatory pilotage area without a pilot or a PEC holder if connectivity is lost. This situation would be contrary to national legislation regarding mandatory pilotage and would pose an unacceptable risk to the safety of navigation, the environment and the efficient movement of ships. • Implications for bridge manning in the context of mandatory pilotage environments need to be further explored.
7	Direct the navigation of the ship with helm and engine orders required to ensure safe progress through the mandatory pilotage area.	NCC Communicator exchanges with the Master and bridge team, including the use of predefined action phrases.	30, 31	• NCC Communicator provides a potentially effective tool for providing helm and engine orders. • Non-verbal control directions are highlighted until actioned and acknowledged by the Master and bridge team. • The execution of helm and engine orders by the Master and the Master and bridge team can be monitored by the pilot at the NCC workstation using VDR Explorer. • NCC Communicator has no redundancy, which provides an equivalent level of functionality. Redundancy is voice-only VHF (if licensed to transmit from shore) or mobile phone.	**Medium** NCC Communicator provides an equivalent means of providing helm and engine orders to the Master and bridge team; however, redundancy is provided by VHF or mobile phone which does not provide an equivalent level of functionality.

[34] IMO resolution A.601(15)
[35] IEC 63173-2:2022 - Maritime navigation and radiocommunication equipment and systems - Data interfaces - Part 2: Secure communication between ship and shore (SECOM)
[36] IACS UR E26 – Cyber resilience of ships

	1	2	3	4	5
	Pilotage workflow tasks	**Key functionality and capabilities for pilotage workflow tasks provided by the proposed solution**	**Information, services or data**	**Assessment comments**	**Assessment outcome**
8	Perceive, comprehend and act on the position of the ship relative to the planned track and proximate navigation hazards, including channel limits.	The solution provides access to the following data from the ship's sensors: • Position (provided by shipboard EPFS) • Heading (provided by an onboard gyro and / or THD • STW (ship's log) • SOG and COG (provided by EPFS) • Radar (replicated images only recorded every 15 seconds, no live data or control) • Echosounder • Wind speed and direction • AIS (provided by onboard AIS transponder, not pilot plug). The remote pilot interacts with the Master and the Master and bridge team through NCC Communicator to direct navigation based on their perception of the position of the ship relative to the planned track and proximate navigation hazards, including channel limits.	2, 5, 7, 16, 18, 20, 31	• Limitations are imposed by the absence of day/night optical solution for conducting visual, relative navigation. The pilot can use virtual but not physical AtoN. • Unless the shipboard EPFS is a multi-frequency and multi-constellation receiver[37] the system has limited resilience to spoofing and jamming. • Pilot has access to ECDIS information based PNT data streamed from the ship. This means that the Master, the Master and bridge team, and the pilot can have shared situational awareness, provided that the ECDIS onboard the ship is correctly set up for navigation in pilotage waters. • Limitations are imposed by reliance on radar image recordings (15-second delay) rather than live-streamed radar data, which can be independently interrogated by the pilot to monitor the position of the ship relative to safe water and navigational hazards using EBL, VRM and PI. • Limitations are imposed by the absence of an independent source of RTK data, which may be required for safe manoeuvring of ships of particular sizes and types near other vessels and shore-based infrastructure.	**Very High** • Pilotage practice changes. The pilot is reliant on GNSS sensors for directing navigation, rather than supplementing visual navigation and navigation using radar in a mandatory pilotage area. This outcome may not be consistent with the obligations on pilots in many jurisdictions to ensure that ships navigate safely in mandatory pilotage waters. • No equivalent provision for bridge visibility in accordance with SOLAS regulation V/22 for the pilot is provided. The remote pilot's ability to maintain situational awareness is severely compromised by the absence of direct bridge visibility and the inherent data transmission latency of 5 or 15 seconds. These latencies are far beyond the acceptable threshold of 200ms for some data defined by pilots. • Pilot is unable to independently use radar tools (e.g., VRM, PI) to execute and monitor a pilotage plan in a mandatory pilotage area. They rely on the bridge team. • Limitations imposed by the absence of RTK information mean the solution is expected to be unsuitable for directing ships where the availability of RTK data is part of the risk management strategy for a particular type or size of ship.
9	Perceive, comprehend and act on safe speed in prevailing circumstances and conditions, and per local regulations.	The solution provides access to the following information from the ship's sensors:[38] • Position (provided by shipboard EPFS) • Heading (provided by an onboard gyro and / or THD) • STW (ship's log) • SOG and COG (provided by EPFS) • Radar (replicated images only recorded every 15 seconds, no live data or control) • AIS (provided by onboard AIS transponder, not pilot plug) The remote pilot interacts with the Master and the Master and bridge team through NCC Communicator to assess and act on safe speed in the prevailing circumstances and conditions.	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 12, 17, 18, 20, 31	• Limitations are imposed by the absence of day / night optical solution for assessing the factors to be considered when assessing safe speed (COLREG Rule 6(a) (i, ii, iv)). • Potential limitations are imposed by reliance on radar image recordings (15-second delay) rather than live-streamed radar data, which can be independently interrogated by the pilot when complying with COLREG Rule 6(b). • The pilot would be reliant on the assessment of visibility by the Master and bridge team (COLREG Rule 6(b) (ii – vi)).	**High** • The inability of the pilot to independently use radar may result in the need for the ship to proceed at a reduced safe speed (COLREG Rule 6 (b)(i)), even when vessels are navigating in sight of one another. This may result in disruption to the efficiency of ship movements if not factored into the operation of ports, rivers and canals. • The inability of the pilot to independently assess safe speed in restricted visibility may not be consistent with the obligations on pilots in many jurisdictions to ensure that ships navigate safely in mandatory pilotage waters.

[37] IMO resolution MSC.401(95), as amended
[38] SOLAS regulation V/19

	1	2	3	4	5
	Pilotage workflow tasks	**Key functionality and capabilities for pilotage workflow tasks provided by the proposed solution**	**Information, services or data**	**Assessment comments**	**Assessment outcome**
10	Perceive and comprehend developing traffic situations, including arrangements for meeting and overtaking in narrow channels, and act in accordance with COLREGs or local regulations.	The solution provides access to the following information from the ship's sensors:[39] • Position (provided by shipboard EPFS) • Heading (provided by an onboard gyro and/or THD) • STW (ship's log) • SOG and COG (provided by EPFS) • Radar (replicated images only recorded every 15 seconds, no live data or control) • AIS (provided by onboard AIS transponder, not pilot plug) The remote pilot interacts with the Master and the Master and bridge team through NCC Communicator to take actions which comply with the COLREGs or local regulations.	2, 7, 16, 18, 20, 31	• Limitations are imposed by the absence of day / night optical solution enabling the maintenance of a proper lookout (COLREG Rule 5) and the other actions required by COLREG Part B to avoid collision. • Potential limitations are imposed by reliance on radar image recordings (15-second delay) rather than live-streamed radar data, which can be independently interrogated by the pilot when complying with COLREG Rule 2 and Part B. • Depending on the configuration of the radar onboard and the traffic situation, the pilot may become reliant on AIS data when complying with COLREG Rule 2 and Part B.	**Very High** • Pilotage practice changes. The pilot has a reduced ability to direct the navigation of a ship in accordance with the COLREGs or local regulations in mandatory pilotage waters. This will need to be compensated for by the Master and bridge team. • The pilot cannot independently maintain a proper lookout by sight, hearing, and all other means, including radar, to direct navigation per COLREGs in mandatory pilotage waters. • Potential for increased reliance by pilots on AIS for collision avoidance in mandatory pilotage waters which is inconsistent with IMO Resolution A.1106(29)[40]. • This outcome may not be consistent with the obligations on pilots in many jurisdictions to ensure that ships navigate safely in mandatory pilotage waters.
11	Perceive, comprehend and act on the weather at or in the vicinity of the ship.	Information about weather conditions can be exchanged between the Master and the bridge team and the pilot using NCC Communicator. DanPilot uses a dynamic weather forecast.	31	• Limitations are imposed by the absence of day / night optical solution for observing the weather. • Pilot is reliant on third-party sources and actuals and visibility information provided by the Master and bridge team via NCC Communicator.	**Low** Equivalent arrangements are sufficient to assess weather.
12	Perceive, comprehend and act on the wake being generated by the ship and its impact on other ships and the environment, including compliance with local regulations.	Information about wake and its impact can be exchanged between the Master and bridge team and the pilot using NCC Communicator.	31	• Limitations are imposed by the absence of day / night optical solution for monitoring wake. • The Master and bridge team need to be able to communicate information regarding wake to the pilot using NCC Communicator.	**Low** Equivalent arrangements are sufficient to assess wake.
13	Perceive, comprehend and act on under-keel clearance, including at the berth, and compliance with local regulations.	The solution provides access to the following information from the ship's sensors: • Position (provided by shipboard EPFS) • Echosounder Actions would be communicated using NCC Communicator.	1, 2, 31	The pilot has access to depth below the keel, which, in combination with position information provided by the ship's EPFS, can be used to manage under-keel clearance.	**Low** The pilot has access to depth below the keel at the NCC workstation that is required for UKC management.
14	Perceive, comprehend and act on the interaction between ships passing at close quarters and maintain safe distances from other ships and infrastructure.	The Master and bridge team would need to actively monitor interaction and communicate this information to the pilot using NCC Communicator. Actions would be communicated using NCC Communicator.	2, 16, 18, 20, 26, 31	• Limitations are imposed by the absence of day / night optics for observing any interaction between ships passing at close quarters. • Limitations are imposed by the absence of RTK information providing leading indications of actual interaction resulting from changes in bow and stern speed. • The Master and bridge team may need to manage interactions independently of the pilot, or operational measures may need to be implemented in ports, rivers and canals to prevent ships from being exposed to a risk of interaction. • Any actions need to be communicated to the Master and bridge team by NCC Communicator.	**Very High** • Pilotage practice changes. The pilot has a reduced ability to direct the navigation of a ship to manage high-risk interactions between passing ships. This will need to be compensated for by the Master and bridge team. This may not be consistent with the obligations on pilots in many jurisdictions to ensure that ships navigate safely in mandatory pilotage waters. • The solution may not be suitable for mandatory pilotage areas where the physical environment and/or operational needs of ports, rivers and canals mean that the risk of interaction between ships is high.
15	Perceive, comprehend and act on shallow water and bank effects in narrow channels, canals and locks.	Refer to lines 13 (bank effect) and 14 (other effects)	1, 2, 3, 4, 5, 6, 7, 9, 16, 18, 20, 31	Refer to lines 13 (bank effect) and 14 (other effects)	**High** Refer to lines 13 (bank effect) and 14 (other effects)

[39] SOLAS regulation V/19
[40] Revised Guidelines for the onboard operational use of shipborne automatic identification systems (AIS) (Resolution A.1106(29))

	1	2	3	4	5
	Pilotage workflow tasks	**Key functionality and capabilities for pilotage workflow tasks provided by the proposed solution**	**Information, services or data**	**Assessment comments**	**Assessment outcome**
16	Perceive, comprehend and act on the effects of wind and/or tide on the set and drift of the ship.	Refer to line 8	2, 5, 7, 16, 18, 20, 31	Refer to line 8	**Low** The pilot has access to wind speed and direction information, and CMG on ECDIS at the NCC workstation.
17	Perceive, comprehend and act on the position of other ships and ships relative to planned or anticipated wheel over points.	Refer to lines 8, 10	1, 2, 3, 4, 5, 6, 7, 9, 10, 16, 18, 20, 31	Refer to lines 8, 10	**Very High** Refer to lines 8, 10
18	Perceive, comprehend and act on any increase in draft due to heeling in a turn.	The solution provides access to the following data from the ship's sensors: • Position (provided by shipboard EPFS) • Heading (provided by an onboard gyro and/or THD) • SOG and COG (provided by EPFS) • Echosounder Actions would be communicated by NCC Communicator.	2, 3, 4, 5, 6, 7, 10, 16, 18, 20, 31	The pilot can monitor changes in draft due to the angle of heel during a turn.	**Low** The pilot can monitor changes in draft due to the angle of heel during a turn at the NCC workstation.
19	Perceive, comprehend and act on the progress of a turn and heading leaving a turn using: • Rudder angle indicator • ROT data, including vectors and predictors • Visual reference points • Radar ranges	The solution provides access to the following data from the ship's sensors: • Position (provided by shipboard EPFS) • Heading (provided by an onboard gyro and/or THD) • SOG and COG (provided by EPFS) • RAI • ROT Actions would be communicated by NCC Communicator.	2, 3, 4, 5, 6, 7, 10, 11, 16, 18, 20, 26, 31	• Limitations are imposed by the absence of day / night optics for visual assessments of the progress of a turn, using either bearings or physical aids to navigation. • Limitations are imposed by reliance on radar image recordings (15-second delay) rather than live-streamed radar data, which can be independently interrogated by the pilot to monitor the progress of a turn using VRM and PI. • Rate of turn data from a dedicated ROTI may only be available on ships of 50,000gt and above.[41] • Limitations are imposed by the absence of RTK information which would allow precise assessment of the rate of turn when directing the navigation of large ships, or in confined areas. • A pilot can use ECDIS at the NCC workstation to assess the progress of a turn, but the validity of the assessment depends on the pilot's inputting the correct dimensions / turning characteristics of the ship and this being reflected in the wheel-over point on ECDIS.	**Very High** • Pilotage practice changes. Pilots are now reliant on GNSS sensors for assessing the progress of a turn, rather than GNSS supplementing visual navigation and navigation using radar in a mandatory pilotage area. • No equivalent provision for bridge visibility in accordance with SOLAS regulation V/22 for the pilot is provided. This means the pilot is unable to use visual information to monitor the progress of a turn. • Pilot is unable to independently use radar tools (e.g., VRM, PI) to monitor the progress of a turn. • Limitations on the ability of the pilot to manage turns and similar manoeuvres may not be consistent with the obligations of pilots in many jurisdictions to ensure that ships navigate safely in mandatory pilotage waters. • Limitations imposed by the absence of RTK information mean the solution is expected to be unsuitable for directing ships where the availability of RTK data is part of the risk management strategy for a particular type or size of ship.
20	Determine and verify the position of lifting bridges and lock gates.	Unassessed	None	Unassessed	Unassessed
21	Perceive, comprehend lock sequencing and act to contribute to decisions about lock sequencing.	Unassessed	None	Unassessed	Unassessed

[41] SOLAS regulation V/19.2.9

PART 4: POSITION, NAVIGATION AND TIMING CONFIRMATION

	1	2	3	4	5
	Pilotage workflow tasks	**Key functionality and capabilities for pilotage workflow tasks provided by the proposed solution**	**Information, services or data**	**Assessment comments**	**Assessment outcome**
22	Acquire the ship's position.	The solution provides ship position from a shipboard EPFS via the VRS and proprietary cloud to the NCC workstation, where it can be displayed on an ECDIS and other user interface displays through VDR Explorer.	2, 7, 16, 18, 20	• Pilot has access to position data from a ship's EPFS, which can be plotted on an ECDIS at the NCC workstation. • There is no access to an independent GNSS position. • Multi-frequency multi-constellation GNSS receivers are not mandated, and therefore, the solution is susceptible to GNSS jamming, spoofing and other interference.	**High** • The pilot has access to position data, but the accuracy of the data is determined by the configuration of EPFS on the ship. • No EPFS redundancy or independent source of position data is available. • Not suitable for applications in areas where GNSS jamming, spoofing and other interference are a risk.
23	Use visual AtoN to confirm position (e.g., when no GNSS is available or to confirm accuracy of GNSS position).	None.	26, 31	• Limitations are imposed by the absence of day/night optics and alternative means available for the pilot to independently confirm the accuracy of the ship's EPFS. • The Master and bridge team can undertake the task and report the accuracy of the ship's position to the pilot using NCC Communicator.	**High** • The workflow task relies on the Master and bridge team to independently and accurately be able to determine ship's position using visual marks and AtoN. • Limitations on the ability of the pilot to use AtoN may not be consistent with the obligations of pilots in many jurisdictions to ensure that ships navigate safely in mandatory pilotage waters.
24	Use X-band and / or S-band radar to determine the position of the ship relative to land, aids to navigation, other ships, and wheel-over positions.	The solution provided radar screen images recorded in accordance with IMO resolution MSC.333(90) and IEC 61996-1:2013.[42]	16	• The latency of the radar images (15 seconds) provided at the NCC workstation and the inability of the pilot to independently use VRM controls mean the pilot cannot independently confirm the ship's position using radar. • The Master and bridge team need to undertake the task and report the accuracy of the ship's position to the pilot using NCC Communicator. • This information is not available from ships configured to use an S-VDR, which is not required to store radar images.	**Medium** This workflow task requires the Master and bridge team to independently and accurately assess the accuracy of the ship's position by radar.
25	Assess GNSS smoothing impact on position data provided by the ship.	Unassessed	N/A	Unassessed	Unassessed

PART 5: INITIAL DATA ACQUISITION

[42] IEC 61996-1:2013 - Maritime navigation and radiocommunication equipment and systems - Shipborne voyage data recorder (VDR) - Part 1: Performance requirements, methods of testing and required test results

	1	2	3	4	5
	Pilotage workflow tasks	**Key functionality and capabilities for pilotage workflow tasks provided by the proposed solution**	**Information, services or data**	**Assessment comments**	**Assessment outcome**
26	Access and use RTK provided by portable pilot unit sensors, which are independent of ship sensors required by SOLAS chapter V.	None	None	• Pilots would not have access to RTK information, including position, heading, bow and stern speeds, rate of turn, for manoeuvring very large ships, or ships in confined waters close to infrastructure. • The solution provides no sensor information which is independent of the ship's sensors.	**Very High** • Limitations are imposed by the absence of RTK information which would allow precise assessment of the rate of turn when directing the navigation of large ships, or in confined areas. • No sensing redundancy provided. • This outcome may not be consistent with the obligations on pilots in many jurisdictions to ensure that ships navigate safely in mandatory pilotage waters.
27	Acquire the ship's true heading and determine or verify gyro error.	The solution provides heading information from either a gyro or THD installed to comply with SOLAS regulation V/19 and transmitted to the ship's VDR.	5, 7	• Pilot can view heading information from ship's THD at the NCC workstation, including on ECDIS and radar. • Accuracy would be limited to that available from a gyro compass (0.2 – 0.4 degrees[43]) rather than RTK (0.01 degrees). • Pilot does not have access to an independent heading source. • Gyro error would need to be determined and communicated to the pilot by the Master and bridge team using NCC Communicator.	**High** • The workflow task is achievable but limited to the information provided by the ship's sensors. • Limitations are imposed by the absence of RTK information which would allow precise assessment of the rate of turn when directing the navigation of large ships, or in confined areas. • No sensing redundancy provided.
28	Acquire and verify ship's COG.	The solution provides COG from the shipboard EPFS, and this is available on the NCC workstation via VDR Explorer and the ECDIS.	3	• Pilot can view course information provided by ship's sensors. • Pilot does not have access to an independent course information source.	**High** • The workflow task is achievable but limited to the information provided by the ship's sensors. • Limitations are imposed by the absence of RTK information which would allow precise assessment of the movement of the ship when directing the navigation of large ships, or in confined areas. • No sensing redundancy provided.
29	Acquire and verify ship's STW, SOG.	The solution provides SOG from GNSS and STW from the ship's SDME.	4	• Pilot can view speed information provided by ship's sensors. • Accuracy would be limited to that available from a ship's SDME (0.2 – 0.4 degrees[44]) rather than RTK (0.01 degrees). • Pilot does not have access to an independent heading source.	**High** • The workflow task is achievable but limited to the information provided by the ship's sensors. • Limitations are imposed by the absence of RTK information which would allow precise assessment of the rate of turn when directing the navigation of large ships, or in confined areas. • No sensing redundancy provided.
30	Acquire and verify depth at the ship's position.	The system provides echosounder data as collected by the VDR in a format that meets the requirements of IMO Resolution MSC.333(90) and IEC 61996-1.[45]	1	Depth beneath the keel information is available to the pilot via the NCC workstation.	**Low** Echosounder data is available to the pilot.
31	Acquire and verify the ship's rudder, or equivalent steering arrangement, position.	The system provides rudder order and response that the VDR collects in a format that meets the requirements of IMO Resolution MSC.333(90) and IEC 61996-1.[46]	11	The pilot has access to information on the ship's rudder order and response information at the NCC workstation.	**Low** Rudder order and response are available to the pilot.
32	Acquire and verify the ship's telegraph, or equivalent engine control, setting.	The system provides engine and thruster order and response that the VDR collects in a format that meets the requirements of IMO Resolution MSC.333(90) and IEC 61996-1.[47]	12	The pilot has access to information on the ship's telegraph and thruster order and response information at the NCC workstation.	**Low** Engine and thruster order and response are available to the pilot.

[43] IMO Resolution MSC.116(73)
[44] Ibid
[45] IEC 61996-1:2013 - Maritime navigation and radiocommunication equipment and systems - Shipborne voyage data recorder (VDR) - Part 1: Performance requirements, methods of testing and required test results
[46] Ibid
[47] Ibid

	1	2	3	4	5
	Pilotage workflow tasks	**Key functionality and capabilities for pilotage workflow tasks provided by the proposed solution**	**Information, services or data**	**Assessment comments**	**Assessment outcome**
33	Acquire ship's X- and S-band radar data, including information about motion, trails, offsets, and range.	The system provides screen images that the VDR collects in a format that meets the requirements of IMO Resolution MSC.333(90) and IEC 61996-1.[48]	None	The pilot has access to screen images of radar. The pilot relies on the Master and bridge team for the setup, interrogation, and utilisation of radar.	**Very High** The lack of raw radar data and the pilot's inability to independently interrogate radar is addressed comprehensively elsewhere in this document.
34	If radar data is not raw data which can be manipulated by the pilot, acquire and verify the settings of motion, trails, offsets, range, gain and clutter controls, pulse.	None	None	• The pilot relies on the Master and bridge team to set up the radar correctly so that they receive radar image recordings (15-second delay) showing the information they expect to see, so that it can be interpreted correctly. • The pilot relies on the Master and bridge team to correctly set up radar and communicate radar settings to the pilot using the NCC Communicator.	**Medium** Pilot is reliant on the Master and bridge team for correct radar settings.
35	Determine or verify the index error, heading alignment error.	None	None	The pilot relies on the Master and bridge team to accurately determine the index, heading, and alignment error and communicate this information to the pilot using the NCC Communicator.	**Medium** Pilot is reliant on the Master and bridge team for determining radar errors.
36	Acquire the ship's AIS feed (equivalent to a pilot plug onboard the ship).	The system provides AIS data in a format that meets the requirements of IMO Resolution MSC.333(90) and IEC 61996-1, as collected by the VDR.[49]	20	The pilot has access to AIS information from the ship at the NCC workstation.	**Low** AIS is available to the pilot.
37	Determine or verify the AIS antenna offset.	Unassessed	20	Unassessed	Unassessed

PART 6: COMMUNICATIONS (INCLUDING DOCKING AND UNDOCKING AT BERTH OR IN LOCKS)

	1	2	3	4	5
	Pilotage workflow tasks	**Key functionality and capabilities for pilotage workflow tasks provided by the proposed solution**	**Information, services or data**	**Assessment comments**	**Assessment outcome**
38	Establish connectivity with the ship (primary and reversionary).	Danelec VRS. Ship's satellite communications infrastructure. Proprietary cloud-based infrastructure provided by Danelec to allow connection of the NCC workstation to VRS and use of VDR Explorer.	31	• Multiple single points of failure between ship sensors and NCC workstation (VDR, VRS). • Redundancy for data connectivity heavily depends on ship communications infrastructure. • Reliant on a proprietary infrastructure, which may not be suitable in all applications.	**Very High** • Risk that a ship that loses data connectivity will be unable to provide the information necessary for safe navigation in a mandatory pilotage area. • Risk that ships that lose connectivity will be navigating in a mandatory pilotage area without a pilot or a PEC holder onboard.
39	Establish communications with the ship (primary and reversionary).	NCC Communicator via satellite communications infrastructure.	31	• NCC Communicator is a full-service communications tool. • No secondary means of communication with the ship which provides a similar level of interaction. Reliant on voice-only VHF (if licensed to transmit from shore) and mobile phone.	**Very High** • Risk that a ship that loses communications connectivity will be unable to provide the information necessary for safe navigation in a mandatory pilotage area. • Risk that ships that lose communications will be navigating in a mandatory pilotage area without a pilot or a PEC holder onboard.
40	Conduct closed-loop communications with the Master and bridge team throughout the act of pilotage in the agreed working language.	NCC Communicator	31	• NCC Communicator is a full-service communications tool. • Managing and actioning incoming and outgoing communications between the Master and bridge team and pilot may require a dedicated officer to be present on the bridge in mandatory pilotage waters.	**Medium** In mandatory pilotage waters, it may be necessary to provide additional personnel on the bridge for effective closed-loop communications. This requires further exploration.

[48] Ibid
[49] Ibid

	1	2	3	4	5
	Pilotage workflow tasks	Key functionality and capabilities for pilotage workflow tasks provided by the proposed solution	Information, services or data	Assessment comments	Assessment outcome
41	Establish pilot-VTS communications (primary and reversionary).	Cellular	None	The pilot will need to communicate via a cellular device.	**Low** Equivalent arrangements allow the workflow task to be achieved.
42	Comply with reporting obligations under local regulation in the mandatory pilotage area throughout the act of pilotage.	Pilot is limited to the use of cellular, but the intent is for the Master and bridge team to conduct reporting in accordance with obligations under local regulations.	None	The Master and bridge team is expected to take full responsibility for reporting to VTS in mandatory pilotage waters.	**Medium** Pilotage practice changes. This will need to be compensated for by the Master and the bridge team.
43	Establish communications with tugs required for escorting or manoeuvring the ship throughout the act of pilotage.	None	None	It is unclear how a pilot will communicate with tugs required for escorting or manoeuvring.	**Very High** Workflow unachievable.
44	Conduct closed-loop communications with the Masters of escort or harbour tugs throughout the act of pilotage.	Refer to line 43	None	Refer to line 43	**Very High** Refer to line 43
45	Establish communications with other ships (including to coordinate collision avoidance and ships meeting) and other waterway users, as required, throughout the act of pilotage.	None	None	• The pilot will need to communicate with other ships via the Master and bridge team or use VHF (if licensing allows). • In certain circumstances, including collision avoidance, this will depend on the Master and bridge team being able to clearly and accurately relay information to and from the pilot.	**Medium** • Pilotage practice changes. This will need to be compensated for by the Master and the bridge team. This approach relies on the Master and bridge team relaying information clearly and accurately between the pilot and the bridge.
46	Establish communications with mooring personnel during docking and undocking.	None	None	It is unclear how a pilot will communicate with mooring personnel during (un)berthing operations.	**Very High** Workflow unachievable.
47	Conduct closed-loop communications with mooring personnel during docking and undocking operations.	Refer to line 46	None	Refer to line 46	**Very High** Refer to line 46

PART 7: EXECUTION OF DOCKING AND UNDOCKING (INCLUDING AT BERTH OR IN LOCKS)[50]

	1	2	3	4	5
	Pilotage workflow tasks	Key functionality and capabilities for pilotage workflow tasks provided by the proposed solution	Information, services or data	Assessment comments	Assessment outcome
48	Communicate the line cast off sequence and instructions to the ship.	NCC Communicator	31	The pilot communicates the cast-off sequence to the Master and bridge team using NCC Communicator, and the Master and bridge team informs the various parts of the ship.	**Low** NCC Communicator provides an equivalent means of communicating the instructions.
49	Communicate the line-casting-off sequence and instructions to the mooring personnel.	None	None	It is unclear what process would be used to enable the pilot to communicate with mooring personnel during berthing operations.	**Very High** There is no apparent arrangement for communicating with mooring personnel.
50	Communicate propeller and thruster clearance.	NCC Communicator	31	Information is communicated from various parts of the ship to the Master and bridge team, who can use NCC Communicator to relay this information to the pilot.	**Low** NCC Communicator provides an equivalent means of communicating the instructions.
51	Direct (un)docking manoeuvres by providing helm, engine and thruster orders to the Master and bridge team.	NCC Communicator	31	Refer to lines 49	**Medium** Refer to lines 49
52	Coordinate tugs to enable (un)docking manoeuvres.	None	None	It is unclear what process would be used to enable the pilot to communicate with mooring personnel during berthing operations.	**Very High** There is no apparent arrangement for communicating with mooring personnel.
53	Verify that the helm, engine and thruster orders are executed correctly.	Refer to lines 39 and 40	Refer to lines 39 and 40	Refer to lines 39 and 40	**Low** Refer to lines 39 and 40

[50] Tasks are in chronological order for undocking and may be in a different order for docking

	1	2	3	4	5
	Pilotage workflow tasks	Key functionality and capabilities for pilotage workflow tasks provided by the proposed solution	Information, services or data	Assessment comments	Assessment outcome
54	Assess and act on the position of the ship relative to the berth and the final position of the bridge.	The solution provides position and heading data to an ECDIS, and radar image recordings (15 second delay) at the NCC workstation. Additional information can be obtained from the Master and bridge team using NCC Communicator.	2, 16, 18, 20, 31	• Refer to line 10 • The position and presentation of the ship on ECDIS would depend on the dimensions of the ship being displayed on the ECDIS at the NCC workstation, and the final position of the ship also being plotted.	**Very High** Refer to line 10
55	Perceive, comprehend and act on the presence of obstructions, including overhangs, dock cranes.	The solution provides position data to ECDIS at the NCC. Additional information can be obtained from the Master and bridge team using NCC Communicator.	2	• Refer to line 10 • The Master and bridge team would need to identify and monitor obstructions, including the position of dock cranes and be able to clearly and accurately communicate this information to the pilot.	**Very High** Refer to line 10
56	Determine and verify which side of the ship is berthed.	The solution provides position and heading data to ECDIS at the NCC. Additional information can be obtained from the Master and bridge team using NCC Communicator.	2, 5	The position and presentation of the ship on ECDIS would depend on the dimensions of the ship being displayed on the ECDIS at the NCC workstation.	**Low** Multiple alternative ways of achieving this workflow task are provided.

PART 8: EXECUTION OF ARRIVAL AND DEPARTURE AT ANCHORAGE

	1	2	3	4	5
	Pilotage workflow tasks	Key functionality and capabilities for pilotage workflow tasks provided by the proposed solution	Information, services or data	Assessment outcome	Impact in the context of remote pilotage
57	Perceive, comprehend and act on the lead of the anchor chain.	NCC Communicator allows the Master and bridge team to communicate with the pilot.	31	The information can be provided to the pilot via the Master and bridge team.	**Low** The Master and bridge team can provide the lead of the anchor chain.
58	Perceive, comprehend and act on the manoeuvres required to bring the anchor chain up and down.	Refer to lines 11, 48, 59	Refer to lines 11, 48, 59	Refer to lines 11, 48, 59	**Very High** Refer to lines 11, 48, 59
59	Determine and verify the length of the anchor chain.	NCC Communicator allows the Master and bridge team to communicate with the pilot.	31	The information can be provided to the pilot via the Master and bridge team.	**Low** The Master and bridge team can provide the length of the anchor chain.

PART 9: INFORMATION, SERVICES AND DATA

This appendix outlines the information / services / data that maritime pilots use to deliver safe and efficient maritime pilotage. Each requirement is ranked by importance, as follows:

Importance of information / services / data	Explanation	Weighting
Critical	Without this information / service / data an act of pilotage would result in a maritime safety incident	10
High	Without this information / service / data an act of pilotage would be likely to result in a maritime safety incident	5
Medium	This information / service / data is required for safe and efficient pilotage.	3
Low	This information / service / data is not required for safe and efficient pilotage.	1

The importance of information / service / data is complemented by expected latency levels:

Description	Maximum Latency	Identifier
Ultra Low Latency	200 milliseconds	U
Low Latency	5 seconds	L
Acceptable Latency	30 seconds	A

For this candidate solution, the extent to which the information / service / data needs of maritime pilotage are met is as follows:

	Information / Services / Data	Weighting	Latency Identifier	Needs met?
1	Echosounder	3	L	Yes
2	GNSS	10	U	Yes
3	COG	10	U	Yes
4	SOG	10	U	Yes
5	Heading	10	U	Yes
6	Lateral Displacement	3	U	Yes
7	Gyro Compass	10	U	Yes
8	Magnetic Compass	1	L	No
9	Wind Speed & Direction	5	L	Yes
10	ROT	10	U	Yes
11	RAI	10	U	Yes
12	Engine RPM / propellor pitch	10	L	Yes
13	Visual of the Telegraph	3	L	No
14	Water Levels Log	1	A	No
15	Status of Thruster(s)	5	U	No
16	Radar Images	5	U	Yes

	Information / Services / Data	Weighting	Latency Identifier	Needs met?
17	Radar Raw Data and Control	10	U	No
18	ECDIS	1	U	Yes
19	PPU providing RTK	10	U	No
20	AIS	10	L	Yes
21	Inclinometer	1	L	No
22	Day/night optics with zooming capabilities	5	U	No
23	Daylight signalling (ALDIS)	1	U	No
24	Whistle Control	1	U	No
25	Search lights (bridge wing)	1	L	No
26	Visibility from the bridge equivalent to that required by SOLAS regulation V/22	10	U	No
27	Capabilities to hear noise from outside the bridge	3	U	Yes (if NCC Communicator outside the bridge)
28	Capabilities to hear inside the bridge	10	U	Yes (if NCC Communicator within the bridge)
29	External data Availability (Cameras, Weather Stations, Water Levels, etc.)	5	L	No
30	External communications (VHF, Cellular, Satellite)	10	U	Yes
31	Two-way communications with the Master and the Master and bridge team	10	U	Yes