Human-centred maritime autonomy -
An ethnography of the future

M Lutzhof1, A Hynnekleiv1, J V Earthy1,2 and E S Petersen1
1Western Norway University of Applied Sciences, Norway
2Lloyds Register, UK
mhl@hv1.no

Abstract. To date, autonomous shipping appears to primarily have been about a technology push rather than considering and providing sociotechnical solutions including re-design of work, capturing knowledge and addressing human factors in modern shipping. Autonomous shipping is frequently claimed to reduce human error, whereas in reality, any issue connected to humans will arguably move with the people from ship to shore in that different people will make different mistakes; with possibly more severe consequences. Furthermore, autonomous shipping is likely to require changes to regulation and increased attention to cyber security and other IT human-centred quality factors if it is to succeed. What the HUMANE project is interested in is how (in certain scenarios) the human collaborates with, hands over to, or takes over from the technology/automation to achieve an overall safe state of the system. The aim is to map and investigate a potential gap between current human skills, training and education and an autonomous maritime future, and to provide insight to enable mitigating change. The main project method is expert workshops, performed in a focus group style. Four workshops are planned and to date (mid 2019), two have been performed. The topic of the first was technology, and the second was legal, class and insurance implications. For this paper, we have analysed the data relevant to future skills. Results show that not only is the skill set imagined to be needed very different from that of today, it also contains many contradictory elements and, occasionally, demands for abilities that humans do not possess, and are unlikely to evolve.

1. Introduction
There are many technology-focused projects in progress in the area of maritime automation and autonomy. The concern that the HUMANE project addresses is the almost exclusive engineering/science focus of the ongoing initiatives, which nevertheless all appear to depend on human intervention under some conditions or circumstances, but do not seem to take to take due account of the feasibility of such intervention from a human factors perspective. The approach of HUMANE is to establish a set of methods for forecasting, and a series of alternative scenarios regarding, use of autonomy/advanced ICT in a perceived future. We are setting the stage for understanding the skills, training needs and, indeed, the likelihood of successful human support for autonomous systems. Having established such scenarios, we will perform a broad, human-centred evaluation of implications and required changes; in particular to work organisation, education, and training. What we are interested in here is how (in such credible scenarios) the human collaborates with, hands over to, or takes over from the technology/automation to achieve a safe system state. Therefore, we are performing an ethnography of the future, whilst accepting the possibility of observing ‘past’ problems.

There are political dimensions of pursuing this relatively recent phenomenon. If we go back, say, 6 years, there were no mentions of “autonomous ships” and now we are again changing our minds very fast about what will be automated. Many industries are back-peddalling, including shipping. Timelines are being adjusted and the view of humans as the backup (whether in a vehicle or on shore) is being revised. Volvo’s head of safety and driver assist technologies Coelingh says: “A car with any level of autonomy that relies upon a human to save the day in an emergency poses almost insurmountable engineering, design, and safety challenges, simply because humans are for the most part horrible
backups. They are inattentive, easily distracted, and slow to respond. “That problem's just too difficult” [1]. This indicates that any technology design must either be inclusive of humans or, so safe and redundant from the start that humans do not need to step in. The design philosophy of nuclear power plants is that humans should be able to do nothing for 30 minutes in order to get a full picture of what is going on. Thus, a 30-minute latency should be designed into a system. The MUNIN project concluded that, for shipping, it would mean that the machine must be always in control – which would be the engineers’ challenge [2].

There are standby ships offshore which can be remote operated from a rig, which is progress for the cause of remote operations, but does not exactly provide independent safety. Another development that may impact more than we can imagine today is the push for sustainability. More than 100 shipowners, including some big Greek and German charter businesses, have signed a letter to the International Maritime Organization (the arm of the United Nations that addresses marine issues) calling for slower sailing speeds to cut greenhouse gas emissions. This could have a detrimental effect on crew on board, even more so if they are only a few. Slow steaming will be boring, conducive to fatigue and reduced attention. This may drive increased autonomy forward, but, again, may miss the challenges involved in novel man-machine-organization systems.

Views are changing rapidly, reports of progress are frequent, and the academic pace of analysing, validating, writing and publishing is hard pressed to keep up. We appear to be getting closer to autonomous vehicles and ships, there are drones at sea, but as yet no comprehensive and integrated approach for the human element has been presented, tested and validated. We, for our part, do not claim comprehensiveness, but we do assert a view of inclusiveness.

2. Background

When discussing the future of shipping, stakeholders offer different predictions regarding the timeline, the extent of changes and the resulting influence on the maritime industry. Digitalization brings about more possibilities for automation and shapes an environment for introducing autonomy. These changes are described as disruptive or revolutionary [3], [4]. Others suggest that the process of change will be seamless, and we should define the changes as digital transformation rather than digital disruption [6]. Nevertheless, interested parties seem to agree that a change is coming.

It is important to note that autonomy does not necessarily mean removing humans from the ships. According to the IMO working definition and degrees of autonomy [5], autonomous systems can be dynamic and shift between levels of autonomy. They can be temporarily supported by humans (located on or off board), remotely operated or fully autonomous, all in one voyage. Dynamically shifting systems imply different roles and sets of tasks performed by humans. The correspondingly required skills are inseparable from the job tasks and should be considered within the context. Moving people across the system challenges the existing definition of a crew (a particular structure of suitably certified staff physically located on board of the ship). This paper focuses on humans in on-board roles and in shore control centres, but also includes views on the automation/AI component.

3. Method

The main method is expert workshops, performed in a focus group style. Four workshops are planned; to date (mid-2019) two have been completed. The topic of the first was future maritime technology, including cyber security, and the second legal, class and insurance implications. A follow-up set of meetings were performed in Southampton, UK for those who could not attend the second workshop.

3.1. Participants

The experts were selected based on expertise and experience, and invited via email. Approximately 65 experts have participated so far, from the maritime domain, including regulators, classification societies, shipping companies, technology manufacturers and universities/ research organisations.
3.2. Performance

Participants were grouped before workshops (WS). Each group contained 5-6 experts, a moderator and a note-taker. The discussions were recorded at each table, and notes were taken. All moderators have academic backgrounds (maritime and human factors) and are part of the HUMANE research team. A set of thematic prompts were used to guide the discussion in WS 1:

1. Unmanned bridge
2. Unmanned engine room
3. Ultra-low manning
4. Shore monitoring/ support centre
5. Remote control
6. Fully autonomous

The themes for WS 2 were adapted to the topic and framed more like questions:

a) Is it possible to keep to conventional regulations, and adapt the autonomous solutions?
b) What type of regulations are difficult to change, what is important to change?
c) What are the challenges in achieving change?
d) What can we do to address or mitigate them?
e) How does the future influence a perception of: (a) responsibility, (b) liability, (c) control and (d) authority?
f) Who benefits the most from a goal-based approach to regulations?

3.3. Analysis

After transcription, all text was anonymised, in total 400 pages. The text was imported into NVivo analysis software. The first set of concepts used to analyse were the thematic prompts shown above and they turned out to overlap considerably. As the analysis progressed, the concepts changed, and grew out of the data, much like actual in vivo coding which allows participants’ voices to give meaning to the data [7]. The text was also manually coded using thematic grouping and regrouping, in a mind map format, which allowed for additional marking and noting contradictions and relationships. The example in Figure 1 shows the further subdivision into common themes, the start of the analysis of situations, and the further growth of the scenario emergency.

A large amount of information related to skills and knowledge began to emerge from the analysis, although that was not the explicit theme of the workshops. This was organised into the ethnography of the future, which shows the views of the stakeholders including areas of agreement and contradictions.

4. The story

We describe what a range of stakeholders believe and imagine, what kind of technology is possible, and what kind of humans are needed. Our intention is to show similarities and differences in opinion. We will sail a fictitious ship, and meet personas of the imagined future maritime landscape. The personas are described as ‘she’ throughout (in honour of IMO's focus on Women in Shipping (2019)). We wish to
lay the foundation for an informed discussion of what is believed to be possible, and what is needed to make such a future possible

4.1. Where are we?
The ship is crossing the ocean. This is unusual, for a commercial vessel, as most autonomous ships are now imagined to be employed in national waters and ports, due to of applying national regulations to get around IMO. Our respondents have different views (a, b).
   a) “Sailing in the middle of the ocean … this is exactly where you need an automated system, can be very low tech, just beeping when something comes closer than 12 nautical miles”
   b) “International waters are not good for trials. There is no business case to do automation in the middle”

4.2. How many are on board?
How many people will be on board in the future? Ship-owners and shipping companies seem to be less interested in unmanned ships than was previously suggested. It is becoming more common to want to keep the crew and reduce workload. Ship-owners’ representatives say they will keep the crew and use automation to offload the crew. There is a growing concern about workload and fatigue and this is seen as a chance to manage it, by using automation to improve working conditions (c, d, e).
   c) “Our members see an opportunity to augment our trained seafarers…to preserve the ingenuity of humans. Augmentation doesn’t need regulatory change.”
   d) “It would perhaps be better to have the guy sleeping at night, just work at day time for fatigue. In chess man plus machine beats machine. That’s a good argument for having support. You can allow people to sleep at night, working dayshifts.”
   e) “If we try to keep the same number of crew … we are still already overworked. So, we would like to relax the workload. We can comply with the labour conventions and improve safety.”

There are others who focus on saving money and think that new technology can help reduce crew numbers (f, g). Others, again, state that people will be on board for many years to come, but there will also be change (h, i).
   f) “It is not requesting to remove the crew by putting a sensor on board, he can say, remove five and save money, it can sail by itself.”
   g) “For deep sea shipping, we will of course automate things more and more on board with the objective of having fewer people on board”
   h) “We will be there. And we will be needed”
   i) “If you are using duff information, it doesn’t matter if people are on the ship, people are off the ship or totally autonomous.”

Finally, there are those who want complete flexibility and believe people can easily be moved on and off the ship, anywhere and anytime (j, k). There is, however, no discussion on whether a ‘riding crew’ will be able to control the ship.
   j) “Occasionally you put people on board, you put a maintenance crew on board”
   k) “You can get additional person on board, easy”

4.3. Manning
If we did decide to go with low manning levels, what does it mean? The respondents estimated that ‘low manning could be between one and five people. Their discussion is summarized in Figure 2. There is a tendency to consider ‘what we have’ and deduct from that.

Five crew members would be no gain as that is already the range for coastal traffic, four are needed for watchkeeping, three could be captain, chief engineer and cook, two would be deck and engine, whereas one was not considered a good solution as there is no redundancy. When talking about two, three and four crew members the roles were the focus, whereas the lone seafarer was the absolute minimum – ‘someone has to be there’.
In reply to this, a respondent considered the consequences of being alone (l) whereas another was blunt on the reasons for crew on board (m) (see also Group dynamics text box).

l) “It is evil to have one person on-board.”

m) “Why the hell do we have someone standing on the bridge at 2 o’clock at night in the middle of the Pacific at ten knots? Because we need someone to blame.”

It is not only the manning numbers that are interesting, but the function or role of these few souls. There are comments on whether the new crew are even seafarers (n), but a similar number of comments concern the typical roles on board, focusing on “senior roles”, but discussing the possibility of a new “role”; a communicator or problem solver (o).

n) “It’s cheaper to add one man, not a captain”

o) “It’s hard to define what ultra-low manning will be... you would have to identify the key functions to fill. I think that would be interesting, because it doesn’t have to be a captain or a chief engineer... maybe one key function, out of, three is the guy who makes the food? So, would it be a navigator, an engineer? Or a communicator that has some role in communicating with shore... and all the other vessels on collision course to get them to go as well.”

4.4. What do they do on the ship? We meet Bo

Let us go back to our ship. The technology is in control and the people on board are not on the bridge/in the ship control room at the moment. But technology can fail, for whatever reason, and someone must be able to intervene. For now, the go-to solution seems to be a person on board to take over (or ashore, to be discussed later).

Let’s call her Bo, she is on board. A first consideration could be: What is Bo (and possibly her colleagues) doing when they are not actively controlling/monitoring? We have data showing that some think that the crew on board would be doing unspecific maintenance, others think they would perform more important work and some even suggest “drinking coffee” (p. q).

p) “We are reducing tedious tasks, and they are transferring the focus for the person to more important items”

q) “Really positive item... that we hopefully at least get the technology to do more of the tedious tasks, one of these examples is of course the maintenance bit”
Sleep at night will be better, maintenance and paperwork will be reduced. But we still do not know what they will be doing on board or where they will be. That will influence whether Bo can quickly get to the bridge/control station.

4.5. Who is in control? We meet Alba
On our ship, technology is presently in control. Let’s call it Alba (“AI”). Alba may or may not be clever. Alba is a machine, some automation, perhaps autonomy. Some believe Alba might be a software agent, intelligent to some degree.

When discussing artificial intelligence, the participants with knowledge of AI are carefully positive, reminding us that such agents cannot (yet?) manage the whole complexity of the world (r, s).

r) “We need a world model and a controller. This is the typical design of autonomous agent. In a limited context we can design. Unlimited context, it’s very difficult to design such an agent”

s) “From my perspective the fully autonomous means that even fallback is done by the system. Then the discussion is similar to traditional AI issues…can it have common sense. So it’s an endless discussion on ethics. I can’t see the answer to solve the issue…maybe if we limit the context, a boundary, like firefighting and those cases...”

Experts from the aviation domain also warn us that it may not be achievable, and computers are not as clever as we think...yet? (t). Then again, some believe that computers are close to perfect (u). Whatever the case may be, the collaboration needs to work (w).

r) “Computers are basically dumb (bad at making decisions) - we don’t have AI yet”

u) “99% of what computer does is right”

v) “Automation is a tool, not the goal”

w) “If a manned ship has a traditional bridge and not a good lookout it doesn’t matter what you put on the autonomous ship. I don’t care from a third party if the vessel coming over there is manned or autonomous it has to act the same way - they ave got to be integrated and sail together.”

4.6. Alba is not coping
On our ship, something happens. A situation may have been building up for a while or be a sudden onset. Alba can no longer cope and in some way “realises” this and alerts Bo. The first steps of the handover/teaming are for Alba to become “aware” and to “decide” to alert someone. This is where Bo comes in. The data shows that Bo must be good at monitoring and able to step in when needed. Here, she must be made aware, move to a control station, access the system, get in the loop, and take control.

Some say that humans will be out of the loop; others believe awareness will increase. Part of our data shows that she is assumed to “acquire situation awareness in 6 seconds”. However, in a future high autonomy context it may take Bo up to 20 minutes to become fully aware and ready to go – she must assess information in a structured way and make a decision based on facts (not bias) (x). This includes a diagnosis of Alba’s correct functioning. Participants are in two minds here; some say this will be difficult, others say ‘don’t panic’ (y, z).

x) “How do you train people to react?”

y) “Imagine if they turn around and said, do you want to interact with the system itself? What is your password? I can’t remember my password from last week never mind in 6 months’ time. Imagine if you have to login to take control.”

z) “Ships don’t actually sink if software fails, they just sit there and wait for someone to press the restart button”

4.7. Alba teams with Bo
On our ship Bo has been alerted, realised that there is an issue, moved to the control station and a handover from Alba to Bo is initiated. Bo needs to understand what Alba is/has been doing (aa). Alba must show Bo what is going on and what may be expected to happen (bb, cc, dd).
aa) “Humans need to understand the machine, we need transparent technology”

bb) “We might need to put the human back in the loop, but the system has to tell the operator things, at a minimum”

cc) “The computer has to do what the second officer has to do, explain to the guy coming up, this is the situation, this is what I have observed, this is the problem I have, please tell me, I can’t handle this myself.”

dd) “No difference whether it is a second officer or a computer who adapts this explanation, but it has to be done in a way that is possible for the guy coming up to do sensible decisions.”

We assume that Alba has been able to tell Bo what is going on, and Bo competently can take over. This “teaming” is imagined to be simple and straightforward, aided by the assumption/fact that machines have no shame, do not argue and there are no power gradients – but you cannot discuss with them (ee, ff).

ee) “...Computer cannot have an argument or have a discussion, but allows you to look into the future by spotting issues”

ff) “If things go wrong in the future where systems are integrated, one thing that will be more positive is the transparency of what has actually happened. And the absence of shame as the machines don’t have that problem. And cultural difficulties to question your superior or whatever. The machines will be super clear on what has happened and why of course.”

Humans have capabilities and limitations – it is essential to understand what stakeholders think the future ship crew/seafarers need to know. This is a summary of future skills: according to our data, Bo understands all the bridge and other electronics (gg). She also retains the classic seamanship (hh). But there is more.

gg) “you don’t need to have a deep understanding of all the systems, but you need to be able to deal with the mechanics, electronics and the software.”

hh) “need seamanship”

She is IT literate, a software expert and knows about cyber security (ii, jj).

ii) “Future skills for seafarers must be IT literacy”

jj) “And then you need cyber security skills”

She can handle tools, but we prefer she does not touch the systems (kk, ll, mm). She is well trained and multi-skilled (nn), with basic skills in many areas (a seafarer!) and specific expertise, which will be needed only now and then – she knows more and less (oo, pp, qq, rr).

kk) “I mean, how to handle tool”

ll) “... that is the other problem ... people go and fix their IT systems. Not always wise.”

mm) “Now it’s tightly integrated systems! They lock cabinets and don’t give the key to crew. Do I get highly trained people or remove them?”

nn) “like planned maintenance, who is going to do the main daily tasks?... that means they have to be well-trained, multi-skilled.”

oo) “basic skill set in many different areas”

pp) “Know more about all systems”

qq) “you need to know the most important troubleshooting when things go wrong”

rr) “You need less skills on board.”

Furthermore, Bo must be fluent in English (ss). She has Master’s papers, and is a certified mariner, but there may be no need to navigate (tt). Some are not convinced these super humans exist (uu).

ss) “They need to understand and speak English.”

tt) “...don’t necessarily need a navigator, but the sea demands certain insight and skills to handle.”

uu) “You’ll never get a master that will be an expert in IT in addition to everything else. Then we’re talking about super humans...”
The story can now develop in two ways;
Alba is in control, and Bo is on board (4.8)
Alba is not in control, no human on board (4.9)

4.8. Alba is in control and Bo is on board
Alba is in control again and has taken over. The ship is getting closer to restricted waters and we can
expect complex situations involving many ships. It was found that there was an imagined change in the
way ships interact with other. The relationship between human and machine would be different, because
the machine would be ‘learning’ or ‘intelligent’ – a ‘robot’.

The COLREGs were written with the assumption that a human is making decisions (vv). Humans
collaborate and sometimes agree to circumvent the rules – because it is practical or efficient (ww). An
AI is assumed to follow rules to the letter and would therefore not
consider negotiations. This influences
the way a manned ship would interact with an ‘unmanned’ ship; rules would be followed but efficiency
may be sacrificed (xx).

vv) “COLREGS needs human interpretation, difficult for computer to do”
ww) “Humans have to waylay COLREGS to keep the schedule, they do it every day efficiently.”
xx) “it would be double the time travelled if they had artificial intelligence follow COLREGS”

In approaches to a port, a need for more smart systems was expressed. Humans are described as not
being able to cope with manoeuvring and docking, often crashing into infrastructure and incurring costs
and damage (yy, zz).

yy) “People cannot cope and are hitting quayside”
zz) “We need auto-docking and undocking because they are 80% of minor accidents”

In contrast, other experts claim that, for seafarers today, the ‘fun part’ is going in and out of port, and
manoeuvring the ship (aaa, bbb).

aaa) “humans would still have the fun part of just going in and out of port”
bbb) “Automation made navigating less exciting, we become squashed into a corner with all these
burdens that are less exciting”

Humans will also be used as the trainer for the ‘Alba’. The humans will be asked to train the systems
(ccc), and when the technology is good enough it will take over – and be as good as the best (ddd, eee).

ccc) “How to quality assure it, you said training but 80% of dockings had a mistake. So it will take
long to get good data to train.”

ddd) “It is not that hard, the system is as good as the best captains, far better than the average, so
what you do is lift the level to that of the best.”

eee) “align the ferry and transfer it to automatic system, the computer will do the same.
The computer will be as good as the best.”

The ship has arrived. It is docked, moored and ready for the next part of the voyage. Before signing
off, let us look at what may happen in the parallel, other, possible future where no one is on board (no
human, that is).

4.9. The shore control centre, we meet Ash
What if no one is on board, and Alba cannot control the ship? There needs to be another actor in the
system. The consensus is that a shore control centre will exist because the alternative is ‘unthinkable’. With
no one on board, there is no redundancy. Who can detect problems, and be in the loop? Let’s call
her Ash.

The control centre will provide redundancy and backup, because values must be protected (fff, ggg).
Another assumption is that human error will decrease, somewhat surprising as humans are assumed to
be in the control centre as well (hhh).

fff) “safety related systems have tough standards, for example redundancy, but 4-5 times
redundancy to replace humans doesn’t make sense”

ggg) “multi-million-dollar assets, an autonomous ship would have someone in a control room”
“We want to take away human errors or more precisely human operational errors, all errors are human by system design or operational, it is human error, you can remove some of it”

Who is Ash? What does she know, what does she do, what can she perceive? She may be a monitoring operator, but most respondents imagine she can also remotely control vessels. The views are divided, some think it is a different and difficult role to take (iii, jjj), others believe situation awareness will be better or at least the same.

iii) “The role cannot be the same, maybe, but the action of the control centre is not necessarily the same as on board a ship. Imagine you must suddenly take over, you don’t have situation awareness, it would be really difficult.”

jjj) “Just look at it and try to understand what the technology is doing and when to intervene or predict what it is doing, it is impossible.”

What does Ash know? Cybersecurity skills are mentioned, but not much else. Some assume it’s completely different from seafarer skills, others think navigation will be needed (kkk). Almost nothing is mentioned about how the shore operator is educated and trained, apart from the lack of a baseline (lll). High-level concepts are discussed such as situation awareness, trust and complexity (mmm).

kkk) We can’t just put an ordinary seafarer there. It is a completely different environment

lll) “What would they need to do for certification? SOLAS doesn’t work for shore-based work. STCW gives no baseline for shore personnel.”

mmm) “…if you have a ship and a shore-control-centre and the master is in the control centre and you lose track of your ship and it goes on automation, can you blame the master? And if the master in a situation is able to intervene will he do it because if the ship goes on automation it might be the people that design the ship and algorithms, but they shifted the blame. And then you got this human trust, over-trust, under-trust problems and everything – yeah”

Ash is assumed to have responsibility (nnn), constantly following what is going on, monitoring, and ‘on watch’ on several bridges/ships at once. When needed, Ash must identify objects correctly, in the same way as on board, close by and far away. It is claimed we need better sensors, preferably with human abilities (ooo). The focus is on seeing and having the same perspective as on a ship, even though supplying sound is mentioned. The discussion centres on providing what we can, and the assumption is that having the same information as on board is the same as being on board. This is a real issue as the discussion moves to the technology available in the shore centre (ppp).

nnn) “I think it is moving the responsibility; it will be the man in the control room.”

ooo) “Need better sensors, like humans, need vision, sound, all that a human does it’s a challenge to see stuff on the horizon.”

ppp) “And whereas you can see visually some of the marks and navigation marks it is much more difficult to imagine an autonomous vessel or a remote control vessel seeing those in the same perspective.”

We must have multiple sensors, which are assumed be intelligently integrated and presented. Benefits from using a smart system that can manage a lot of data include getting early warnings and trends to better manage upcoming issues, but this is not exclusive to the shore – it would be just as useful for an on-board operator. The technical system is assumed to always be alert, have access to more data, perform faster analytics, and pick up weak signals. The focus is on visual information. What about the other human senses?

Ash now has theoretical access to the information it is assumed that she needs. What about transmission of the information? Can we support seeing with video or image transfer? There is a fundamental agreement that a much higher bandwidth than we have today is needed (qqq). Some suggestions are provided on how to work around the bandwidth–perhaps you don’t need all the information all the time and being close to shore works better (rrr).

qqq) “We need communication cost. We need high bandwidth to achieve the similar situation awareness.”
"Do you need to communicate constantly? No, just when the ship has made its own assessment that something is wrong, and it does a procedure and contacts [someone]."

What is the work environment like in the control room? Arguably, it should be fit for purpose. Many of the limitations and flaws of the on-board work environment can now be fixed. Perhaps even must now be fixed, because land-based regulations will apply. Distractions should be minimised, for example phones and alarms – or even eliminated (sss).

"Today you have a captain as a barrier so it’s your problem as a captain to be on the ship and handle [everything]. If you don’t have the captain as a barrier someone else needs to experience this problem. I think that if is going to be pushed to a shore control centre handling managed vessels you can’t get 2000 alarms going off constantly because it would be impossible so you force system integration in a way. Maybe not liable as to what you have but they will be more responsible for having good system integration, maybe it is more interest for it."

Work and shift hours need regulating, and perhaps even time “on” and “off” monitoring tasks (ttt), and issues hereto ignored on board such as video display unit regulations and alarm overload. Flexibility in the design, for example the control position, is suggested (uuu).

"different work dynamics - how to regulate? Can you work 1 hour on, 1 hour off?"

The verification of the control centre appears unsolved – particularly verifying the whole. We do not know what competence is needed, who will have it, and who will be trusted to verify. The system should work under all conditions, in all types of weather.

If we consider the larger socio-technical system, we realise that numerous centres would exist. How does one hand over from one to another, how does one transfer awareness by distance? How can we assure that time zones and languages do not cause issues? Considering we already have communication issues in the maritime – they will not go away.

What is it like when nothing is happening? Comments include the need for activity and not just looking at screens, monitoring, and the demotivating effect of nothing happening (vvv).

"As long as you have got some activity and not staring at the screens waiting for something to move actually you are running a complex part of a control room."

The other end of the workload spectrum is overload (see Multitasking text box). The eternal question is: how many ships can one person reasonably keep track of? There is no definite answer, but standby staff are always mentioned; the upside to a shore centre is that specialists could be available for issues that happen infrequently. No one knows where the standby staff will be and how they can be called in at a moment’s notice. Where are they when not needed? What is their latency time to being available and fully updated?

4.10. Ash takes control

What happens when Ash takes control of the ship? How will she know it is time, and how long can the ship manage on its own (www, xxx)? Is there a possible lag in communications with shore? (see Remote operators text box)

"If you have an operator in a remote control centre that doesn’t understand the automation functions and intervenes when they shouldn’t"

"How long can the system keep within a safe state before some other party has to step in, but what is permissible break in communications?"

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### Multitasking

The common understanding of multitasking refers to performing more than one task at the same time. However, it appears that the human mind quickly switches between multiple tasks rather than performing many simultaneously. Switching between tasks creates a cognitive demand that goes beyond performing each task separately [9].

### Remote operators for cars

Waymo is still working through some trickier situations that might result in vehicles "calling home" to a remote operator who will determine the proper course of action. Due to issues with operator availability, situations might result in a several-minute wait for the vehicle, even if there’s a passenger inside [10].
There are very few comments on how to interact with the ship. Turning it or taking ‘physical’ control, by remote control; did we focus so much on seeing that we forgot about feeling? This raises questions in need of answers, potentially in need of research: Will we be using a joystick, or a copy of the bridge controls? What happens with the endless variations in bridge design and differences in ship behaviour (yyy)?

yyy) "Remote control operators has two sister ships, they behave differently and you expect them to behave similarly"

Will manual control be transferrable to other centres?

When taking remote control of a vessel, who is available to take over the other vessels? (see Southampton text box)

5. Discussion

How far away from autonomous shipping are we? Based on the data available, timelines shift and most are moved forward. Whenever it happens, it is clear that for a period of time there will be mixed traffic. The replacement rate for commercial ships is usually quoted at 3–4% per year, and is likely to be less for autonomy as not all owners see a reason to make this change. It seems some people subscribe to a level system where we move from manned or remote controlled to more automation or autonomy. However, in discussion it becomes apparent that these distinctions do not exist in most stakeholders’ minds, neither as steps, nor as final state descriptors.

The present focus is to get a shore control centre to work rather than the ship, its manning and equipment. These authors see this as: ‘Same problem, different place’ How do we decide on allocation of function? The question used to be ‘What do you want the seafarer to do under the various use cases and what you want the technology to do?’ Now, we are asking almost the same question, but instead of ‘what do you want the (human at) the shore centre to do and what do you want the autonomous systems on the ship to do?’ This is coupled with the uncertainty about training and education of the shore-based operator, the equipment available, and the cognitive and tactile problems associated with acting remotely. The maritime industry is still trying to automate as much as possible and assume that humans will and can monitor it remotely. The question used to be ‘What do you want the (human at) the shore centre to do and what do you want the autonomous systems on the ship to do?’ This is coupled with the uncertainty about training and education of the shore-based operator, the equipment available, and the cognitive and tactile problems associated with acting remotely. The maritime industry is still trying to automate as much as possible and assume that humans will and can monitor it remotely. To standardize what is easy, augment what is easy then get into what is difficult.

The Southampton Oceanographic centre have performed trials with a hydrographic survey boat. It was remote controlled from a safety boat standing by on the edge of the safety area, and they claim it was very difficult to judge distances, and to gain awareness. “Very hard to judge what to do when you are not on the vessel… the camera isn’t like being there… we couldn’t judge closing distances.”

The data collected so far has little discussion of teams, probably because it was not the topic. From earlier research we know that humans and technology must ‘team’, and the defense industry is doing that now (after trying autonomy) [11]. In a well-integrated system (a team), the actors can communicate and collaborate. For example, today; on many bridges and other control rooms, humans are the “glue” between more or less self-sustaining sub-systems, equipment from many manufacturers, and many technology generations. A participant says: “What we have got now is a collection of half-developed systems that really haven’t been designed to support the people, whoever they are” (see Teaming text box).
Humans have capabilities and limitations – remember what the stakeholders believed that the future maritime workers will need to know? Be good at handling tools (but not touch the systems), have basic skills in many areas and specific expertise, needed only now and then. They do not need deep knowledge (but may need a PhD), they need to be fluent in English (to communicate with?) and have Master’s papers but there will be no need to navigate. In the HUMANE project, we are asking ourselves a number of questions: Do people with these traits exist? How do we train them? Will they be seafarers? Our participants say, “You could end up with a ‘Seafarer’ of the future that may never have actually set foot on a ship” and worry that “we do not have the right educational establishment to produce these people. I haven’t seen the universities teaching these things. We need educational establishment, who teaches at much more higher levels”.

If we find them and train them – how do we keep their skills active? (This applies to Ash, and Bo as well, if she never gets to do ‘real work’). Human skills are verified by STCW today and the skills and the verification are by no means perfect, but they are built on years of experience. If we succeed with all of the above, how will we manage to retain people? Other sectors are also likely to need these rare professionals. When we get fully autonomous systems, how can we retain the skills to be the redundancy that the system will need? A large challenge is skill degradation [13]. Skills should be not only developed according to new technological solutions, but also protected from eroding. This refers to skills that are not used on daily basis, but can be vital in case of a system failure.

6. Conclusions
Our initial reaction to the data available is that it will be problematic to find these people, hard to train them, difficult to retain them. Given this, and the assumption that one person is unlikely to possess all these skills, we may have to consider an ecosystem of skills which will be addressed in forthcoming papers from HUMANE. A discussion of aspects of skills and knowledge needed for varying relationships between human and automation is found in Hynmekleiv et al., 2019, Ergoship conference paper. It is most likely that for many years conventional vessels will dominate the waters. Ships are becoming larger and less manoeuvrable, which is hard to fix with training. The world merchant fleet is continuously growing and so is the demand for people manning ships competently, whether on board or ashore. This growth is anticipated to hold. There is a strong view that future maritime workers will need seamanship and new skills, including human-autonomy teaming, maintenance, and teaching AI.

Finally, the human contribution; “Humans are also preventing a lot of incidents...so maybe we see that humans save ten times more than the automation would do”.

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