UDT 2019 – How low can you go? Lessons learned from attempting to reduce submarine manning

A. Felstead. BAE Systems Submarines, UK

1 Background

From experience it has been difficult to reduce submarine crew numbers. This paper reflects on the reasons why and what needs to occur in the future for a more successful outcome.

Looking forward to a future class of submarine, with a combination of technology advancement and changes to policy and practices, a lean crew concept is proposed as a target to aim towards.

2 Why bother?

Why bother trying to reduce submarine crew numbers? The reasons usually given are to reduce the cost associated with the crew and also because it should result in a reduced accommodation requirement and hence smaller submarine. Although it may seem a natural progression, a move towards a lean manned submarine option is not necessarily the cheapest one to take when weighed against the cost of the technology required to achieve it and this is the first consideration.

3 The technology exists so why not use it?

There is definitely technology that could lead to the reduction in submarine crew numbers. In particular technology associated with automation and remote sensing, indication and control. However the take up is not as great as it could be and that is generally due to the cost associated with developing the technology and demonstrating its reliability and integrity. Submarine class design programmes are often over a decade apart and although there are technology development programmes in-between, these do not necessarily provide sufficient confidence for the customer to agree their use on the next submarine class. To overcome this problem the ability to demonstrate technology advancement on current platforms is required so that our customers and navy users can see clear benefits in its adoption. In other words the current classes of submarines should be progressively upgraded and hence their systems need to be designed to allow for upgrades or to be replaceable by more advanced systems. In this way submarines can progressively evolve over time and potentially have their life extended as a result.

Care needs to be taken to ensure technological advancement does not place even greater demands on the crew, for example due to information overload. As systems become more autonomous and intelligent then the role of the submarine crew will change. There will be less direct interaction with equipment by the crew and more supervision of systems and equipment The impact on both the crew role's and the crew's interface with the submarine should not be underestimated. As Cook [1] argues 'human factors are even more important when advanced technology is embedded in system design, not less'. Rather than using the terms 'automation' and 'autonomy' the term 'human machine teaming' is becoming popular to reflect the growing importance of understanding the changing role of the human in the loop. The traditional allocation of function approach based on 'humans are better at….' and 'machines are better at…' is over 50 years old but there are new methodologies being developed to assist interface design in more intelligent systems. Research is being conducted into how both the customer and crew can gain trust in automation and in ensuring that the human and machine share the same understanding and mental models. Interfaces may be improved by adopting some approaches used by IT industries, especially mobile phones and tablets. These techniques are often referred to as 'User Experience' or UX and they consider the enjoyment of the person interfacing with the device and so improve their experience and performance of operating it as a result. Technology is now at a stage whereby direct brain-computer interfacing is becoming a possibility and such rapidly emerging advancements need to be understood and developed before they can be considered to be safely adopted into future submarines. This leads us to the next question.

4 Is it safe?

Safety cases traditionally rely on the crew to intervene in the event of equipment failure. Therefore attempts to reduce crew numbers are often thwarted by demands placed on the crew to fight fires, control damage and on increased manual intervention as a reversionary mode. To reduce crew numbers systems need to be of sufficient reliability and integrity so as to not rely on manual intervention in the traditional way. Unfortunately there is probably no way to get around the significant cost of developing such solutions but without this investment it is unlikely that significant crew reductions will be achievable.

The way that humans interact with more intelligent systems is also a safety consideration. Concerns associated with increased automation and increased system complexity leading to disengagement and deskilling of the crew may not be so straightforward as first thought. Factors such as the submarine systems and the crew having different situational models and hence different, potentially conflicting, responses also need to be considered. This points to the need for an increased consideration of human factors in safety analysis. Leveson [2], for example, proposes an approach to safety cases through the consideration of scenarios that focus on accident causation other than system failure. Organisational and cultural factors may be just as important as system failure in accident events.

5 Does the Navy need to change?

The ways in which navies crew submarines can be just as big a factor in terms of the continuation of existing branch structures and roles, which in turn resist the ability to merge or eliminate roles, or even whole branches. When determining crew roles for future submarine platforms it is recommended to start with a clean slate rather than deriving from existing classes and established schemes of complement. Engagement with the navy community can then focus on how this new crew can be developed and existing roles transition rather than trying to retain current branch structures and associated ranks and rates.

Current submarines often rely on seagoing experience to qualify their crew resulting in the need to take trainees to sea. The result is additional crew that have to be accommodated at sea who are not required to operate but merely to learn. A change to introduce high integrity alongside training solutions would solve this problem. The goal is for all submariners to fully qualify ashore so that seagoing trainee billets are eliminated. It is recognised that newly qualified submariners may still require some extra supervision on their first patrols but overall seagoing numbers will significantly reduce if trainees don't need to be carried.

6 What are the types of technology that support submarine crew reduction?

The areas of technology that support submarine crew reduction can be broadly grouped into the following.

Technology that will remove the need for Fire Fighting and Damage Control Teams. Examples include fixed firefighting systems; fire resistant materials; use of cameras and other sensing devices to improve situation awareness; diagnostic tools and advise on course of remedial action; automated fail safe mechanisms, e.g. shutting of hull valves in the event of floods.

Technology that will allow for unmanned machinery spaces. Examples include remote control and indication for all normal routine operations; condition based monitoring; detect and replace approach to allow for deskilling of crew maintenance.

Technology that does not require additional manual intervention in the event of failure. High integrity systems; systems that gracefully degrade rather than fall back into a reversionary mode.

Systems that will reduce Control Room Manning. Automatic interpretation of sensor information and compilation into a tactical picture, for both mission and navigation purposes; improved communication systems to promote situation awareness; automated weapon handling and launch systems.

Systems that will replace the requirement for logistics and medical crew. Examples include naval and provision stores management and accounting systems; automated reporting systems; health monitoring and treatment diagnostic systems.

7 So how low can you go?

With technology advancements and the fore mentioned issues overcome then there is certainly an ability to reduce submarine crew numbers. The size of crew will naturally depend on many factors, not least the type of submarine and the role it is performing. As an example, to illustrate the potential for reduction, let us consider a future Attack Submarine SSN equivalent. Whether it is nuclear powered, or another air independent propulsion system, does not make very much difference as the same principles apply. This example of a minimal crew is based on the following assumptions.

1. The crew are all qualified and sufficiently experienced to conduct their roles without additional supervision.
2. There are no constraints regarding organisation, for example existing branch structures, ranks and rates.
3. Engineers have been divided into two distinct types: power & mechanical and systems / network. Precise differences between the two types are not important, this is just to recognise that a single, generic 'one size fits all' engineer is unlikely to be achievable.
4. Machinery spaces are not routinely manned, i.e. do not require dedicated watch keepers.
5. The majority of the crew will be in a watch system so the type of watch will have a significant impact on overall crew size. A 'one in three' watch has been chosen as a minimum sustainable pattern that allows sufficient time off watch to rest/relax and also to conduct extraneous duties.

6. There is no heightened watch state. The crew are either on a 1-in-3 watch pattern or all at stations, e.g. diving, attack or emergency.

Given the types of technology advancement indicated and the above assumptions then an absolute minimum crew number for an Attack Submarine could look like this.

1 x Commanding Officer
3 x Officer Of the Watch (1 per watch)
3 x Sensors (1 per watch)
3 x Tactical Picture (1 per watch)
3 x Communications (1 per watch)
3 x Navigator (1 per watch)
3 x Submarine Controller (1 per watch)
6 x Engineer (2 per watch)
2 x Chef
Total = 27

It should be noted that the above roles tend to relate to the crew's watch keeping duty and there are many other duties that need to be performed, such as weapon handling and launching. However these other duties are performed at stations (action stations, diving stations, emergency stations, etc.) when the entire crew are on duty and therefore the crew that are not on watch are available to perform them.

8 Is such a reduction in crew credible?

A crew number of 27 is an extremely lean manned platform and it is questionable whether it would cope with a prolonged heightened manning state, e.g. following an emergency. The assumption that all submariners are qualified and experienced is also unrealistic since on any given patrol some of the crew are likely to be newly qualified and very inexperienced. For this reason additional crew will need to be carried to ensure adequate supervision until the new crew gain adequate experience.

It is highly unlikely that a future SSN equivalent would be able to achieve a crew as low as 27. However since current SSNs carry over 100 submariners then it is reasonable to state that very significant reductions in crew size can be made with the adoption of suitable trusted technology and changes to other aspects relating to organisation and human factors.

References

[1] M. Cook. Martini Solutions: Automation and Manning in Future Underwater Systems, UDT 2018

[2] N. Leveson. Engineering a Safer World, MIT Press (2012)

Author Biography

Alan Felstead is the Head of BAE Systems Submarines Human Factors Department. Alan has worked on human factors in defence engineering programmes for over 25 years, including the development of their manning requirements and detailed crew roles.

Alan is a BAE Systems Global Engineering Fellow; a Fellow of the Chartered Institute of Ergonomics and Human Factors and a Chartered Member of the Institute of Engineering and Technology.