Technology and Teamwork Equals Time

"… technology can make us stupid. The technology for creating things has far outstripped our understanding of them. Things that make us smart also make us dumb" (Norman, 2014)

All of us have experienced ships bridges and equipment that drive us to distraction and thus takes us away from our primary objective as members of the Bridge Team or us as pilots (in my case) which is to successfully manage a high-risk operation. I think it is sometimes forgotten that "the primary purpose of having a bridge on a ship is to provide a suitable place from which to safely navigate the ship (Barratt, 1990)" which in turn helps the ship stay in the correct safety space. In helping to cope with this it has become necessary to consider the bridge as one total design concept (Barratt, 1990).

There is much ongoing discussion at the moment dealing with the possibilities of using technology to help make automation part of the Bridge team and amongst all of the points being made, which range from reducing workload to the formation of better teamwork, a very important one is being missed and that is to do with time. Time is after all a keystone in what we all do and if used wisely will aid us in all our endeavours. In this case the use of technology in the automation process to assist in teamwork should allow extra time to become available to help us complete our tasks in the dynamic and sometimes rapidly changing situations in which we find ourselves. Time to make more informed decisions and possibly time to even sit back and enjoy what you are doing.

Ships over time, have become complex socio-technical systems which have required the use of a systems based approach that considers the interaction of all the components of the system relative to the overall system goal which in a Marine Pilots case is to safely pilot the ship (Czaja & Nair, 2006). The use of technology in this system has led to highly automated working processes that make high demands on human information processing which if exceeded can lead to problems that affect for example decision-making. System performance then is critically important to help gain time as it's through the proper performance of the system that everything should flow.

System Performance:

A nexus exists between safe bridge operations and total system performance in that the total bridge system consists of two primary parts: (1) the human operator(s) and (2) the technical system and two secondary parts which are of equal importance: (1) the human / machine interface which makes the two primary parts an integrated system; and (2) the procedures which ensure that the whole system in its entirety performs as it should under different operating conditions i.e. the system must be capable of assisting in high stress situation as well as low ones (Lutzhoft, 2004). Synergy is the key here as total system reliability demands that the whole system is greater than the sum of the parts (Czaja & Nair, 2006) because after all it does not matter which part of the system fails if the consequences are the same (Larsen, 1990).

Perrow (1999) has noted that there can be a distinct lack of good judgement shown when accidents have been caused by the improper use of technology and Lee and Sanquist (2000) have suggested that ship safety can actually be placed in jeopardy if poorly designed and improperly used technology is used.

Achieving proper system performance then, lies in part with the human / machine interface and it is here that the technology and hence automation needs to become part of the team if the required synergies are to be put in place to help in allowing the acquisition of the proper amount of time to enable the system to work as it should. The system should therefore be designed so that the human as well as the machine become team members on the same team (Christofferson & Woods, 2002) as humans "remain a critical adaptive element in operational systems for high consequence domains" (Woods & Cook, 1991).

Teams and Teamwork:

Most would agree that a great deal of the work done onboard a ship is performed by teams and that a particularly important team is the Bridge Team as they have at certain points of the voyage the control of the ship in their hands.

What then is a team and how does it function?

Teams are formed to complete defined tasks in a structured manner usually within an agreed time frame. They have a leadership structure that is hierarchical in nature and the members of the team work within agreed parameters to help fulfill a common strategy for example a Bridge Team consisting of the Captain, an Officer and a Crew Member would use the passage plan (which has the agreed parameters set down on it) to safely navigate the ship.

Salas et al, (1992, p. 4) define a team as a "distinguishable set of two or more people who interact dynamically, interdependently, and adaptively toward a common and valued goal/objective/mission, who have each been assigned specific roles or functions to perform, and who have a limited life-span membership" These characteristics bring a team its own dynamics which may not equal the combined abilities of the individual members and therefore not allow the team to work to its full capacity. To work to its full capacity, the team therefore, must as a whole become more than the sum of its parts (Schager, 2008) or as my old football coach used to say a champion team should always beat a team of champions.

To function effectively then the team should have a hierarchical structure that is both moderate and flexible, have a capability that is able to adapt to what has happened, what is happening now and what is going to happen into the future as well being capable of catering to the individual team members skills and experience. If this is done the team will engage in a "fluent and free exchange of information" (Schager, 2008, p. 131) that will enhance teamwork.

Teamwork:

Teamwork is critical and bridge team members including the pilot must be able to coordinate action in uncertain, fast paced situations. This team in a fast paced action context, must have a clear goal i.e. safely berthing a ship, the right mix of experience and skills, adequate resources and a task that requires teamwork.

To have good teamwork, there needs to be:

1. An information exchange
2. Communication
3. Supporting behaviours
4. Team initiative / leadership

As the above applies to human teams it is logical therefore that teamwork between humans and technologically driven automation should be based on the role that it plays in the team. This automation can make important contributions to the team in one of three ways. It can (1) work independently on certain tasks allowing their human teammates to work elsewhere in the system, (2) collaborate with human teammates and support human task performance, and (3) support teamwork processes such as facilitating communication and coordination of human team members thus increasing the timeliness of the teams response to developing situations.

Technology (Automation)

Technology has allowed the increasing use of automation and brought about the creation of work environments that require the Bridge Team to work as a cohesive unit which needs to simultaneously address tasks and manage automation (Bowers, Oser, Salas, & Cannon-Bowers, 1996). One of the problems with increasing automation though is that it can change the way human members of the team communicate (Wright & Kaber, 2005) and whilst the jury is still out as to whether it helps or hinders team communication it has become apparent from studies on verbal communication and automation that when the workload is higher then there is consequent rise in team coordination efforts to ensure the system keeps running smoothly.

Technology can be used to help gain the time that will help us better operate our systems by:

1. Designing systems to participate in team play (Christofferson & Woods, 2002) and that are capable of being used by the lowest common denominator.

2. Designing in two fundamental characteristics from the beginning: (1) observability: in other words, users need to be able to see what the automated agents are doing and what they will do next relative to the state of the process, and (2) directability: users need to be able to re-direct machine activities seamlessly in instances where they recognise a need to intervene (Christofferson & Woods, 2002).

3. Following three concepts to allow feedback on what effect automation is having on the system: (1) an event based design where representations highlight changes and events, (2) be future orientated so that in addition to historical information being provided, support will be also provided for anticipatory reasoning that will reveal information about what should / will happen next and when and (3) has pattern based representations where it is possible to quickly scan displays and pick up possible or unexpected conditions at a glance rather than having to read and mentally integrate many individual pieces of data. (Christofferson & Woods, 2002)

4. Using technology to build in flexibility that can allow the human operator to easily understand what level the automation is working at and how it is achieving that. This flexibility must be used by designers if they are to provide the human with a set of tools that can be used to optimise system performance across a wide range of circumstances (Sarter & Woods, 1995).

5. The judicious use of automation to help increase human performance. This though, can be a two-edged sword as the automation can lead to new problems of automation surprises and when to intervene (Sarter, Woods, & Billings, 1997). Automation surprises are actions performed by an automation system that are unexpected by the user and can lead to the human asking the question how in the world did we ever get into that mode (Sarter & Woods, 1995).

6. Using human centred design (HCD) principles to help prevent many human - automation related problems. Research such as that done by Hutchins in his book Cognition in the Wild (1995) teaches us that if technology is to be used then it must be used in tandem with the people who must use and adapt it and the best way to do this is through the use of human centred design principles.

7. Using automation wisely by letting the automation deal with what it is good at i.e. sensing what the human cannot, performing repetitive work, perform several activities simultaneously,

maintain efficient and precise operations whilst the human part of the system is otherwise engaged (Asyali, 2003).

8. The bridge system must capable of assisting in high-stress situations as well as low stress ones (Lutzhoft, 2004).

9. "When all else fails, standardise" (Norman, 2002, p. 100)

The Importance of Time

"Thinking and acting both take time and take place in time" (Hollnagel, 2002, p. 147).

As pointed out in the opening paragraphs time is a keystone in everything we do. Hollnagel (2004) states that "one of the most fundamental characteristic of human actions is … that they take place in time". Actions therefore take time and if these action "take place relative to some process or set of events that develops over time, i.e., in a dynamic system, time is also a limited resource". It goes without saying then that if more time is spent on planning and carrying out required actions than is available then a loss of situation control will eventuate (Hollnagel, 2002).

Time therefore is an intrinsic part of the dynamic process of systems operation and this fact leads us to two conclusions: "First that there is limited time available to evaluate events, to plan what to do, and to do it. Secondly, that the information that is used needs to be updated and verified regularly because the world is changing" (Hollnagel, 2002, p. 152).

In marine piloting or certain shipboard operations, some tasks are considered to be at a level that requires a forced pace. This forced pace brings about limitations in the amount of available time and if the time needed for evaluation plus the time needed for action selection exceeds the available time then constraints on evaluation and action selection are introduced and these constraints may lead to human error. To maintain control of the situation therefore, the operators of the system need time to review the current situation and also be able to plan before acting. Slowing down the process will achieve this but difficulties achieving this have led to a more common approach which is to improve evaluation and action times by making improvements to the system and interface design (Hollnagel, 2002).

It should be obvious therefore that a team's functionality is highly dependent on the amount of time that is allowed for them to perform their tasks. This time is in certain cases limited and if teams are to be expected to cope with this limited time then they must be able to understand not only what use time is as a resource but also as a demand and how that affects what they do. If the technology / teamwork interface is as shown in figure 1 then the synergies that result will allow extra time to be gained and if it is not then no extra time will result as shown in figure 2.

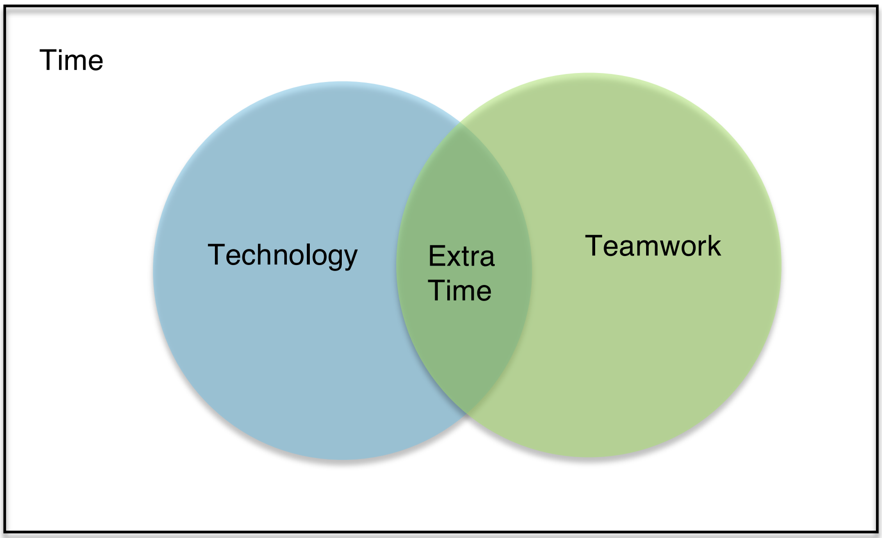

Figure 1: The extra time benefit given by synergies between technology and teamwork

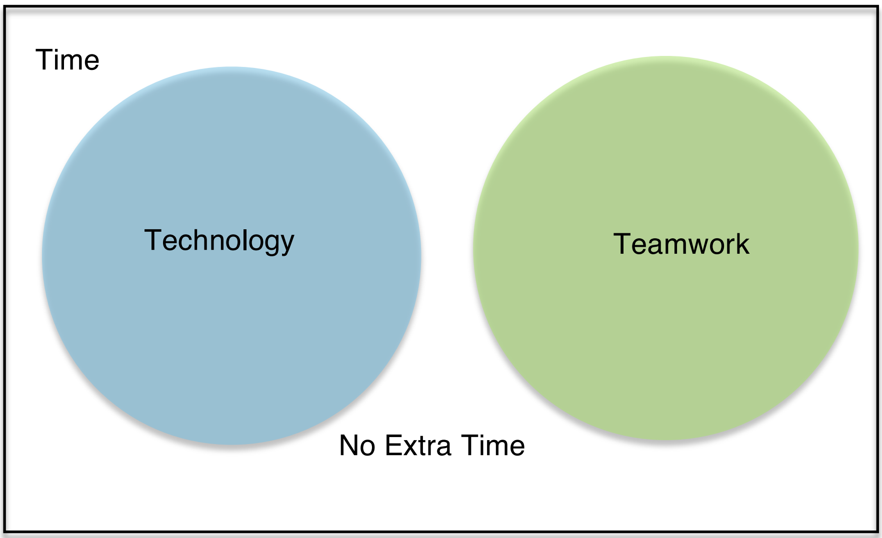

Figure 2: No extra time benefit as no synergies between technology and teamwork

Examples of Ship Teamwork and Technology Failures

Ship Incident	Human Team Error	Technology Error	Outcomes
Collision of Big Orange XVIII with water injection facility Ekofisk 2/4-W The duty officer activated the vessel's autopilot mode	A bridge culture existed that allowed for deviation from established	With the autopilot activated, the azimuth thrusters are locked in place	The technology and team in this case were not operating as they should. Alarms were ignored which could have given more time to

and leaves steering position to answer a phone call. On return the autopilot was not deactivated so manual steering is not in use. This leads to a period of the ship being under no control even when the emergency steering is activated as the ship is still being steered by the autopilot. The vessels speed also increases as a result of increased fuel supply.	procedures. The Ekofisk platform did not contact the vessel after it had entered the safety zone whilst exceeding the maximum speed even though the speed alarm had sounded.	and will not respond to attempts in changing direction.	assess the situation. There was no alarm on the propulsion system to give an alert about what mode the system was in when the Captain tried to put the engines astern. Thus the technology was not helping and in fact made the situation worse by increasing speed thus lessening the amount of time needed to effectively manage the situation.
Heeling Accident on M/V Crown Princess After experiencing problems steering a steady course with the trackpilot (autopilot) the rudder limit was increased to allow the vessel to settle onto a course. Initially this was successful but after a short period the heading again became unsteady and the rate of turn began to increase rapidly shifting from side to side at the same time. Shortly after this manual steering was re-engaged and the helm moved repeatedly from side to side to try and regain control. A wrong helm direction occurred and the ship took an even sharper turn which caused the vessel to list to a maximum angle of about 24°.	There was a lack of training in regards to the operation of the trackpilot in auto in shallow water at high speeds. There was a lack of knowledge of the steering system in that no account was taken of the possibility of helm lag when operating in manual mode	The technology assumed that the steering was being done in rough seas and deep water as no alarms had been fitted to indicate this to the user. The steering lag in manual made the situation worse as the helm was being put over before the rudder had completed the previous order.	The team and technology were not able to work together due to a lack of understanding on the human team of what the steering system was actually doing. This lack of understanding led to misperceptions of the situation, which in turn led to miscomprehension of the situation, which in turn led to incorrect projections being formulated. This led to rapid decisions being made that did not allow time to fully assess the situation.
Frank W / Lilly Collision Whilst approaching the port of Skagen the Frank W collided with the fishing vessel Lilly even though the two vessels observed each other shortly before the	The bridge team on the Frank W assumed that detected radar echoes were in fact false echoes of an approaching buoy instead of the	The difference between Type A and B AIS equipment led to the cargo vessel not detecting the fishing vessel that had Type B	If the data from the Type B AIS equipment onboard the Lilly had been available on the Frank W's radar then there would have been less chance of the observed radar echoes being misinterpreted and allowed

collision.	approaching fishing vessel.	AIS equipment onboard.	for more time to assess the situation.
Maria M Grounding Whilst approaching a bunkering anchorage the Master made a number of rudder and main engine control movements that caused the ship to be in the wrong position on the course line. This put an approach buoy opposite to where it should have been. This was not noticed and the ship grounded.	The Master was unfamiliar with the ships instrumentation and decided to try various manoeuvres to see how the ship handled. During these manoeuvres the Ships Master may have mixed up the indicators for rudder position and turning rate.	The two indicators for rudder position and rate of turn (ROT) were located at a distance of about one metre from one another. The rudder position was shown by an arrow which pointed in whatever direction the helm was put. The ROT was shown by a deflection of the arrow. The turning rate indicator could thus show turning to port although the rudder was to starboard, and vice versa.	The design of the rudder and ROT indicators led to possible confusion on the Masters part as he may have interpreted the deflection on the turning rate indicator as showing the rudder position. This led to problems with determining what was happening with the vessels manoeuvrability and took away time that could have been used to keep an eye the vessels position.
Royal Majesty Grounding Whilst approaching Boston the Royal Majesty grounded on Rose and Crown Shoal	The watch officers on the Royal Majesty had an over reliance on the automated features of the integrated bridge system (in this case the GPS).	There were deficiencies in the design of the integrated bridge system as well as inadequate international standards for the design, installation, and testing of integrated bridge systems	The poor interface design of the GPS meant that the symbols indicating the DR and SOL were not only small but misleading. The alarm that would have indicated that there was a problem was such that it would only have been heard if someone had been standing close to the GPS unit. The ignoring of other

		aboard ship.	technology robbed the crew of the required time to correct the situation.

Conclusion

The inadequate understanding of teamwork, technical knowledge, ship systems as well as poor automation has led to many unfortunate accidents such as the Torre Canyon disaster and the Royal Majesty grounding. The grounding and loss of the Costa Concordia was in part due to an incorrect use of technology and poor teamwork (Di Lieto, 2015) . Rothblum (2000) in a paper on Human Error and Marine Safety states that “mariners often do not understand how the automation works or under what set of operating conditions it was designed to work effectively”.

Wiener (1989) states that the three most commonly asked questions on the highly automated flight deck are what is it doing, why is it doing that, and what will it do next. Answering these questions takes up valuable time that may be required to attend to an emerging problem that may lead to disastrous consequences.

These questions could just as easily be asked of technology driven bridge systems (or any shipboard technology system) and this trend towards using technology to increase the levels of automation on ships generally as well as in the marine pilots tasks (i.e. the increasing use of Portable Pilotage Units) has led to breakdowns in the interaction of operators and computer-based automated systems that have become common place on modern ships bridges.

Decisions that are made by the Bridge Team need to be based on adequate information given in a timely fashion and too often we as Mariners on whatever side of the profession we are from are forced by technology or breakdowns in teamwork to rely on either a single piece of equipment or our memory. Today Marine Piloting is far more complex and involves constraints that test not only the pilot but also the Bridge team to the maximum as they strive to achieve the numerous complex and at times competing tasks to achieve a safe outcome. Technology and automation go hand in hand and if it is used wisely can greatly assist in allowing everyone the time to achieve a self-outcome.

Di Lieto (2015, p. 289) points out that “it is often an excessive faith in technology that feeds the illusion of total control “ and then goes onto discuss defensive redundancy where there are backup components that will allow control when the first fails and also functional redundancy where function are carried out by two components that are independent of each other. An example of this would be an (ideal) bridge setup where the active monitoring of navigation is performed by each operator using different navigation displays (functional redundancy) and also by at least two operators with the same level of skill (defensive redundancy). Teamwork and Technology in this case are working as one and allowing us the time to possibly enjoy what we are doing or at least enjoy a little less stress (of course being at all times cognisant of the consequences of complacency, but that is another topic for another time).

References

Asyali, E. (2003). Impact of Man-Machine Interfacve on Maritime Casulaties. Paper presented at the 4th IAMU General Assembly, Alexandria.

Barratt, M. (1990). Key Factors in Bridge Design for Trading Vessels. In T. N. I. P. W. Group (Ed.), The Nautical Institute on Pilotage and Shiphandling (pp. 363-366). London: The Nautical Institute.

Bowers, C., Oser, R., Salas, E., & Cannon-Bowers, J. (1996). Team Performance in Automated Systems. In R. Parasuraman & M. Mouloua (Eds.), Automation and Human Performance: Theory and Applications (pp. 243-263). Mahwah, NJ: Erlbaum.

Christofferson, K., & Woods, D. (2002). How to Make Automated Systems Team Players. In E. Salas (Ed.), Advances in Human Performance and Cognitive Engineering Research (Vol. 2). Bingley, UK: Emerald Group Publishing Limited.

Czaja, S., & Nair, S. (2006). Human Factors Engineering and Systems Design. In G. Salvendy (Ed.), Handbook of Human Factors and Ergonomics (Third ed., pp. 32-49). Hoboken, New Jersey: John Wiley & Sons.

Di Lieto, A. (2015). Bridge Resource Management: From the Costa Concordia to Navigation in the Digital Age. Brisbane, Australia: Hydreas Pty Ltd.

Hollnagel, E. (2002). Time and time again. 3(2), 143- 158. Theoretical Issues in Ergonomics Science, 3(2), 143-158.

Hollnagel, E. (2004). Time to Think and Time to Do? I can fail, and so can you! Human Factors and Aerospace Safety, 4(3), 169-180.

Hutchins, E. (1995). Cognition in the Wild. Cambridge, Massachusetts: The MIT Press.

Larsen, P. (1990). Classification of Ship Bridges: A systematic approach to improve operational safety at sea. In The Nautical Institute Pilotage Working Group (Ed.), The Nautical Institute on Pilotage and Shiphandling (pp. 357-362). London: The Nautical Institute.

Lee, J., & Sanquist, T. (2000). Augmenting the Operator Function Model with Cognitive Operations: Assessing the Cognitive Demands of Technological Innovation in Ship Navigation. IEEE Transactions on Systems, Man, and Cybernetics - Part A: Systems and Humans, 30(3), 273-285.

Lutzhoft, M. (2004). The technology is great when it works: Maritime Technology and Human Integration on the Ship's Bridge. Linkoping, Sweden.

Norman, D. (2002). The Design of Everyday Things. New York: Basic Books.

Norman, D. (2014). Things That Make Us Smart: Defending Human Attributes in the Age of Machines (pp. 231).

Perrow. (1999). Normal Accidents: Living with High Risk Technology. Princeton, New Jersey: The Princeton University Press.

Rothblum, A. (2000). Human Error and Marine Safety. Paper presented at the National Safety Council Congress and Expo, Orlando, FL.

Salas, E., Dickenson, T., Converse, S., & Tannenbaum, S. I. (1992). Toward an Understanding of Team Performance and Training. In R. Swezey & E. Salas (Eds.), Teams: Their Training and Performance (pp. 3-29). Norwood, New Jersey: Ablex.

Sarter, N., & Woods, D. (1995). How in the World Did We Ever Get into That Mode? Mode Error and Awareness in Supervisory Control. Human Factors, 37(1), 5-19.

Sarter, N., Woods, D., & Billings, C. (1997). Automation Surprises. In G. Salvendy (Ed.), Handbook of Human Factors & Ergonomics (Second ed.). Hoboken, New Jersey: John Wiley and Sons.

Schager, B. (2008). Human Error in the Maritime Industry: How to Understand, Detect and Cope. Halmstad, Sweden: Halmstad Tryckeri AB.

Weiner, E. (1989). Human Factors of Advanced Technoloy ("Glass Cockpit") Transport Aircraft. Moffett Field, CA: NASA Ames Research Center.

Woods, D., & Cook, R. P. p. a. t. (1991). Nosocomial Automation: Technology-Induced Complexity and Human Performance. Paper presented at the IEEE International Conference on Systems, Man, and Cybernetics: Decision Aiding for Complex Systems, Charlottesville, Virginia.

Wright, M., & Kaber, D. (2005). Effects of Automation of Information-Processing Functions on Teamwork. Human Factors, 47(1), 50-66.