TWENTY YEARS ON THE WRONG HEADING DEAD AHEAD

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SUMMARY
“A wise man learns by the mistakes of others, a fool by his own.” Latin Proverb

The aviation community is undergoing a reappraisal of progress made in automated cockpits. This gives the shipping community the opportunity to learn from someone else’s mistakes and successes. Aviation has invested more heavily in automation than shipping, and in some respects can be considered to be ‘ahead’. The reappraisal has identified issues at a number of levels, ranging from decision making by the operator to the structure of the industry. It is recognised that there are numerous differences between shipping and aviation, and these are taken into account.

This paper identifies potential problems and opportunities for shipping, based on an examination of the state of aviation. The technical topics considered include equipment design and the design of automation, considering the allocation of function between the operator and the machine. Similarities in the design and development process are examined, with lessons for future automation identified. Some aspects related to the human element arise from problems with aviation or shipping as a system, and require a systems approach for their resolution. These are discussed in the light of recent aviation findings.

1. INTRODUCTION

The Human Element has long been recognised as important to marine safety. The work performed by Lloyd’s Register to address the Human Element has been described previously [1]. This paper discusses aspects of the Human Element in relation to the design and operation of automated bridges. It examines activity in the aviation sector for relevance to the maritime sector on two topics: system level issues, or Human System Integration aspects, and issues associated with automation and human error potential.

The NTSB Report on the grounding of the ROYAL MAJESTY [2] stated “Thus, while human engineering is a known concept in the marine industry, there have not been any unifying efforts to integrate this concept into the marine engineering and manufacturing sector. Additionally, human engineering in the broader context of Human System Integration has been given little or no consideration. Consequently, the potential for error causing behaviour related to these [automated] systems has not been adequately addressed by the marine industry”. This incident was a major stimulus for recent changes to the Safety of Life at Sea (SOLAS) Regulations [3] that have been introduced for ships with extensive automation, in particular SOLAS Regulation V/15 ‘Principles relating to bridge design, design and arrangement of navigational systems and equipment and bridge procedures.’

It is recognised that there are significant differences between the aviation and marine sectors, and that these differences will affect the respective evolution of the Human Element. The differences of note are:

- The investment cycle in aviation promotes greater R&D than that in shipping. It is from this that shipping can learn Human Element lessons from aviation.
- The regulatory structure in aviation is simpler and perhaps more oriented to rich countries with large aviation industries.
- Pilots receive more training per head than bridge watchkeepers.

However, the similarities between the sectors are also striking. On the basis of personal experience the following are important and form the basis of this paper:

- The difficulty in integrating different aspects of the Human Element such as changes to automation, manning levels, training provision, procedures development, and operating limits. This appears to be related to divisions in the regulatory structure and the structure for financial decision making.
- The power of ‘technology push’ – the extent to which more equipment and automation is promoted and adopted as the simplest answer to problems of all sorts. This approach to introducing automation leads to problems of ‘supervisory control’ where the human has much responsibility but little to do.

In summary, the evolution in aviation that would appear to offer lessons for the maritime sector began with a major review of the interfaces between flightcrews and modern flight deck systems [4]. This produced extended conclusions and recommendations. The summary point was the following: “Based on our investigations and examination of the evidence, these concerns represent more than a series of individual problems with individual, independent solutions. These concerns are highly interrelated, and are evidence of aviation system problems, not just isolated human or machine errors. Therefore, we need system solutions, not just point solutions to individual problems. To treat one issue (or underlying cause) in isolation will ultimately fail to fundamentally increase the safety of airplane operations, and may even decrease safety.” Not so very different from the NTSB quote at around the same time.
2. HUMAN SYSTEM INTEGRATION

The HF task force report [4] found a number of interrelated deficiencies in the current aviation system:

- Insufficient communication and coordination
- Processes used for design, training, and regulatory functions inadequately address human performance issues.
- Insufficient criteria, methods, and tools for design, training, and evaluation.
- Insufficient knowledge and skills.
- Insufficient understanding and consideration of cultural differences in design, training, operations, and evaluation.

The report made very extensive recommendations for change for all of these deficiencies.

Since [4], there has been regulatory activity at a cockpit and equipment level to address some of the problems of automated cockpits [5, 6]. The JAA Interim Policy [5] is part of the certification basis for Airbus 380, Boeing 7E7, Cessna Citation 680, Dassault EASY, Dornier 728, Embraer 170/190, Gulfstream G555. It was a major input to the ATOMIC template responses [7] to SOLAS Regulation V/15 [3].

Since then, EASA has developed draft material for the Airworthiness Code and an Acceptable Means of Compliance for Human Factors [6]. This sets out requirements and Acceptable Means of Compliance so that installed equipment can be shown, individually and in combination with other such equipment, to be designed so that qualified flight crewmembers trained in its use can safely perform their tasks associated with its intended function.

Most of the technical material is directly applicable to a maritime setting. Of regulatory interest is the extensive Regulatory Impact Assessment, which examines a number of options (including a ‘do nothing’ option). The pros and cons of the selected option can be summarised as follows:

Pros:
- It addresses design characteristics that lead to error rather than error itself.
- It allows focused discussion on certain aspects of design characteristics.
- It has explicit ties to the flight crew tasks.
- It is potentially easier to tie to methods of compliance.
- It allows a more direct basis in the requirements such as integration and systems behaviour.

Cons:
- The list of characteristics may not be complete, thus leaving “holes” that an error based requirement would cover.
- Being based on design characteristics may not result in applicant taking a better, more structured, approach to the design process.

The split in regulation and standards-setting between bridge layout and bridge equipment design is more severe both in structure and in practice than the comparable split in aviation. Achieving technical integration from an operator point of view is hindered by this split. The investment cycle in aviation makes it possible to do some integration at a cockpit level, but this is difficult in shipping during design and build. It may be more readily achieved if the bridge and its topside (including the antenna farm) is contracted out as a module, and including a system engineering/integration role.

Finally, it should be noted that there is a significant rider to the last point of difference between sectors noted in the introduction; the aviation industry has yet to come to terms with training for automation. Indeed, this is a nice example of a problem at an aviation system level, as shown in the quote from Wood [8].

“...So at the end of the Type Rating training the pilot is competent to manage the system in a normal situation based on declarative knowledge but has little experience or procedural knowledge of normal operation and even less in the case of failure, i.e. non-normal situations.”

3. AUTOMATION AND HUMAN ERROR POTENTIAL

Reising [9] has pointed out the increasing mental distance between the operator input and the system output, illustrated in Figure 1.

![Figure 1: (From Reising [9])](image)

In older aircraft, there was a direct connection between the pilot’s movement of the control yoke, through the connecting cables, to the control surfaces. Later as autopilots came in to the aircraft, the pilots indirectly controlled the surfaces through these devices. Further, with the introduction of flight management systems,
more technology was placed between the pilot and control surfaces. The pilot’s mental model of how the system worked became severely strained and resulted in a lack of understanding of the relationship between the automation and the control output. Some of these cockpit problems were undoubtedly due to the automation philosophy which drove the task sharing between the crew and the automation.

The problems of aviation automation are well-documented, and have been summarised by Sarter et al [10] as:

- Workload - Unevenly Distributed, Not Reduced.
- New Attentional and Knowledge Demands.
- Breakdowns in Mode Awareness and "Automation Surprises".
- New Coordination Demands.
- The Need for New Approaches to Training.
- New Opportunities for New Kinds of Error.
- Complacency and Trust in Automation.

Recent research by Wood [8] has “indicated that there was much evidence to support the concern that crews were becoming dependent on flight deck automation. Furthermore, the new human task of system monitoring was made worse by the high reliability of the automation itself. Little research exists to provide a structured basis for determination of whether crews of highly automated aircraft might lose their manual flying skills. However, anecdotal evidence ... indicates that this is a concern amongst practitioners. Finally, several MOR incidents revealed that crews do respond inappropriately having made an incorrect diagnosis of their situation in which the automation fails.”

There is a body of guidance on solutions – not all of it readily usable by practical engineers. “It is relatively easy to get agreement that automation should be human-centered, or that potentially hazardous situations should be avoided; it is much more difficult to get agreement on how to achieve these objectives”. [4]

The general intent is to have a human-machine team, as described in Lützhöft [11], and having a coherent crew-centred design philosophy [12].

4. CONCLUSIONS

The aviation industry has successful experience to offer shipping as regards:

- Recognition of Human-Systems Integration and developing a regulatory response to system-level issues.
- Guidance on the design of automated cockpits and systems that would translate to automated bridges and their systems.

The aviation sector appears to offer shipping the opportunity to learn from its mistakes as regards the design of ‘strong and silent’ automation leading to difficulties in teamworking, situation awareness and mode awareness. Increasing the ‘distance’ between the user and the platform and increasing the numbers of modes should be viewed with considerable caution.

5. RECOMMENDATIONS

Attempts to achieve human-system integration can be made through-life e.g. by making use of the ATOMOS templates [7]. Monitoring the aircraft programmes using the JAA Interim Policy [5] may offer lessons for shipping regulation.

Changing contractual boundaries may facilitate the integration of equipment and structural design.

The guidance and research on automation sponsored by the aviation sector is tailored and applied to shipping.

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