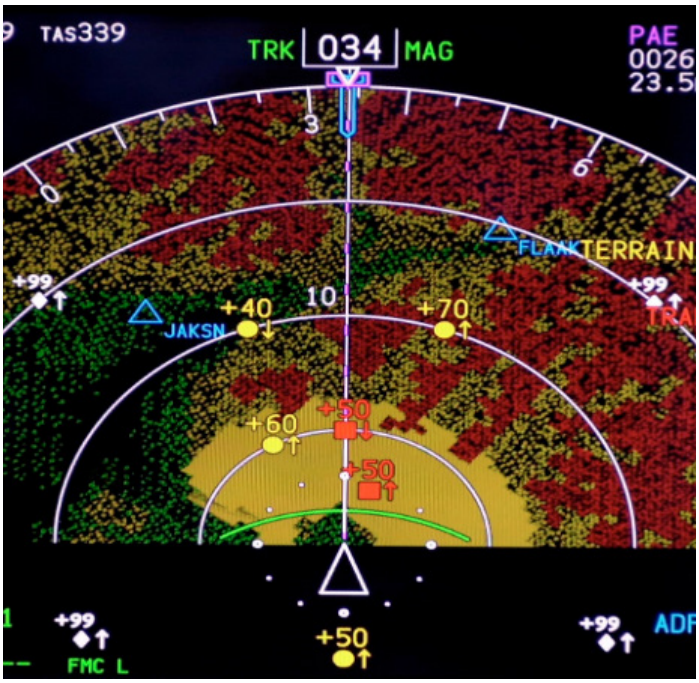
Pilot Monitoring



Summary of Research and Applied Training Tools

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Acknowledgements

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Summary

Research using current professional crews in high-level simulators has shown a consistent pattern of pilot attention following unexpected events (from serious emergencies to minor technical failures). In most cases, crews show an immediate and sustained loss of focus on the flight path (immediate as well as medium term) and unknowingly rely on expectation to maintain flight path awareness, sometimes for several minutes. This can lead to loss of control inflight (LOC-I) or Controlled Flight into Terrain (CFIT), especially where things do not happen as expected. Furthermore, the attentional pattern is contrary to how most pilots perceive they act and believe they should act. Research mitigations have shown positive results and this paper outlines information and guidance stemming from the work.

HeliOffshore has produced a video to summarise this report's findings, titled 'Unexpected Event Monitoring – Industry Research Output'. It is available to view on the HeliOffshore website (www.helioffshore.org)

Background

LOC-I and CFIT still account for half of all fatal offshore helicopter accidents (HeliOffshore research). Such issues prevail in all areas of aviation. After such events pilots are said to have been distracted, lost situation awareness, or monitored ineffectively. Whilst arguably true, greater understanding is needed to inform effective mitigations. In a move towards usable guidance, the current research (2015 to present) has been looking more deeply into the practical background of these issues, by combining a suite of techniques including the use of eye tracking technology. This research has included four major operators in two global areas (Europe and Canada), and two main types (S-92 and AW189).

Core Threat / Pattern of Attentional Displacement

The priority order of 'aviate', 'navigate', 'communicate' and/or 'systems' is firmly accepted as best practice across in aviation. The basic diagram below (Figure 1) shows the main screens associated with these areas for an S-92 helicopter. Note: only the main areas are shown; there are many references spread across the flight deck, including some that could serve multiple priorities depending on the situation. The research accounted for all.

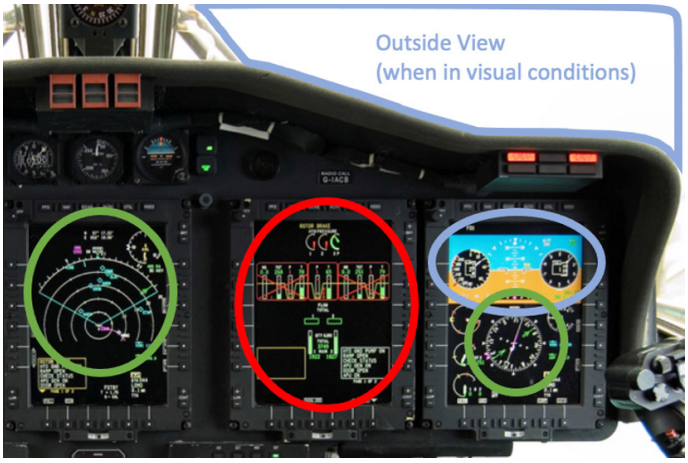

Figure 1: Simplified diagram showing the main screens for aviate, navigate and systems information in the S-92 helicopter. The research used more complex and complete mapping.

In essence, control and immediate flight path management *(aviate)* is a crew's highest monitoring priority, followed by the extended flight path *(navigate)* and then other areas such as systems and communication. Pilots have confirmed this in surveys and debriefs. After an unexpected event, most pilots believe the Pilot-Flying (PF) should prioritise *aviate* and *navigate*, and the Pilot-Monitoring (PM) may give some priority to managing the *systems*. However, the pattern of results in the research programme, supported by findings from fixed-wing Jarvis Bagshaw research, shows this is not what usually happens.

Across domains, types, and countries, it has been found that after an unexpected event (technical failure, emergency, unexpected situation, etc) both pilots drop their monitoring of the immediate flight path *(aviate drop-off)* and experience a sustained decay on extended flight path monitoring *(navigate drop-off)*. A distracting event does require prompt pilot scrutiny, the problem is the immediate and prolonged nature of both PF and PM drop-offs. This pattern is consistent and common, yet the aircraft usually behaves as expected and so there is often no negative outcome. However, if changes occur to control and flight path (such as a mode change, trim change, autopilot uncoupling, erroneous action, etc) then pilots can fail to notice. Even where nothing goes wrong this monitoring pattern has two negative consequences:

1. Pilots unintentionally develop the habit of de-prioritising flight path monitoring after distractions or during event management, without any overt consequence, and therefore without realising it has happened. Such habits can then work against the crew in real world situations.

2. The threat is not visible to safety management systems, safety data, or reporting, and does not lend itself to pilot recall. Hence, despite being consistent, threatening, and probably contributing to many serious accidents, it has remained hidden.

For the research, pilots flew scenarios with unexpected events of varying criticality and ambiguity. The eye-trackers showed exactly where pilots were looking, and whether they were monitoring the *aviate*, *navigate* or *systems* tasks (to a greater depth than shown in Figure 1).

The graph below (Figure 2) shows that *systems* monitoring increases substantially when the unexpected issue occurs (combined PF and PM). This is accompanied by a large drop in *aviate*-related monitoring that partially recovers within about 20 seconds, and a sustained drop in *navigate* monitoring that can last minutes. Both lead to crews relying largely on expectation for their situation awareness. Such *aviate* and *navigate* drop-offs can lead to LOC-I and CFIT respectively.

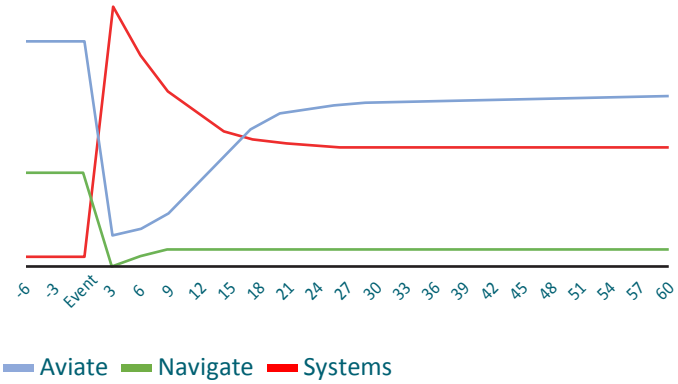

Figure 2. Chart of pilot visual attention to aviate (Av), navigate (Nav) or systems (Sys) related tasking. Time is on the horizontal axis (seconds) and average amount of looking time on the vertical axis; either aviate, navigate or systems. Both pilots' monitoring is combined, so this is a crew average. This figure is illustrative only (representing the general pattern across research).

Commonly as the event occurred, both PF and PM switched attention immediately from flight path monitoring to the distraction (systems). The PF regained flight path monitoring quickest (usually between about 5 and 20 seconds) and after recovering, tended to prioritise the *aviate* task while sharing some attention with systems. PM's *aviate drop-off* was much more sustained than PFs. PMs tended to look mostly at systems after the event (depending on the failure) with some back-up of the *aviate* monitoring, but not usually until a little later. The overall result of this pattern is that after the initial *aviate* drop-off (approx. 5 to 20 seconds) the PF is left monitoring *aviate* followed by *systems*, and the PM monitors *systems* followed by *aviate*. Neither pilot prioritises the navigate task (monitoring the extended flight path) and it appears that neither has the intuitive feeling that navigational monitoring is the priority at the time. This makes navigational monitoring very vulnerable to task-load (as was demonstrated) because it is treated by both pilots (unconsciously) as dispensable when under high workload on their main priority (*aviate* for PF and *systems* for PM).

This 'falling between the gaps' of the PF and PM can be termed '*navigate ownership ambiguity*' and it appears to be the primary cause of unnoticed loss of tactical flight path awareness by crews. It is worth noting that most research scenarios were at lower altitude with critical navigational (tactical) threats, such as terrain, restricted airspace and obstacles.

Experienced trainers involved in one experiment predicted that crews would pay a lot of attention to the navigational situation because of this, but they did not. There were many resulting events that would have been serious incidents in a real operation. Below is a representative heat map of the first 15 seconds after an unexpected event, clearly showing navigate drop-off.

Figure 3. Heatmap showing the amount of looking in the first 15 seconds following an event onset (in this case a master caution for a non-emergency technical failure). PF is on the left, PM is on the right. The red, yellow and green areas show the amount of looking at each point. Aviate drop-off is particularly clear on this heat map.

These effects are further confounded by '*parallel monitoring*', which is also clear in Figure 3. This is a phenomenon first researched in airlines (Jarvis 2017) and is the tendency for the PF and PM to monitor the same areas as each other (in parallel) even where protocol would not predict it. One reason is vocalisation, where one pilot talking draws the other's attention to that same information. In the experiment, PMs vocalising non-flight-path issues (e.g. *systems* or other distractors) often inadvertently drew the PF's attention away from flight path references, increasing drop-offs on flight path monitoring. Another reason for parallel monitoring is common pilot skill sets being applied by both pilots to the situation confronting them at the time.

Tests found that just a minute after an unexpected event, pilot awareness of their situation had degraded significantly. Perception of heading was inaccurate by an average of 37 degrees (over 100 degrees in several cases) and two pilots in the same crew can perceive the heading to be more than 100 degrees apart. Similar findings were seen for other parameters including airspeed, vertical speed (VS), altitude, radio altitude, and overall position. In one experiment, nearly half of all 14 pilots incorrectly thought the aircraft was over sea instead of land (or vice-versa) just one minute after the unexpected event.

The research is so consistent (across many pilots, experience levels, types, and countries) that it suggests this issue (in various forms) may have been responsible for many past accidents.

Mitigation

A mitigation process was developed, informed by sister research in fixed-wing, and in place with an international airline since 2019.

The aim was to move towards the best compromise of attentional prioritisation. The mitigation gives pilots a framework to practice re-distributing attention in a way that maintains coverage of flight path. Slightly different experimental mitigations were used for different operators (in order to fit with SOPs, screen layout, etc) but the core points were the same. For the final experiment, the mitigation was merged into the operator's SOPs for the tests, and training given.

Research was carried out by comparing pilots when trained and untrained in the mitigation. Trained mitigation led to the results illustrated in Figures 4 and 5 (below), which can be compared to untrained as seen in Figure 2 and 3 (above). The trained group showed very little *aviate drop-off*, and the modest *navigation drop-off* initially recovers to higher than pre-event. The latter was mainly driven by the PM who, after backing up the *aviate* monitoring, assesses the tactical threat. Systems monitoring increases initially as expected (and as needed for an initial assessment of the distraction), then drops back as pilots re-assess flight path, and finally increases again as the pilots begin emergency management about 25 seconds after the event. Crucially, *systems* monitoring never overwhelms flight path monitoring in the way seen in Figure 2.

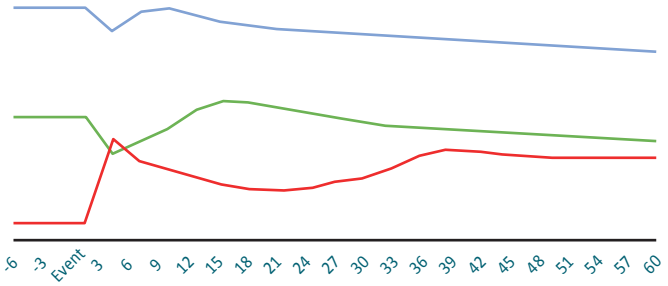

Figure 4. Chart of pilot visual attention to aviate (Av), navigate (Nav) or systems (Sys) for pilots trained in the mitigation. Time is on the horizontal axis (seconds) and average amount of looking time on the vertical axis; either aviate, navigate or systems. Both pilots' monitoring is combined, so this is a crew average. This figure is illustrative only (representing the general pattern across research).

Figure 5. Heatmap showing the amount of looking in the first 15 seconds following an event onset (in this case a non-emergency technical failure). PF is on the left, PM is on the right. This is representative of a crew using the experimental mitigation. The attention to the aviate task is clear, as is the extra navigational monitoring by each pilot.

The pattern seen in the trained group is partly due to a lengthened 'assessment period' in which pilots (particularly the PF) assure the flight path before committing to any event management. The average time before actioning emergency checklists (ECLs) in such scenarios was 41 seconds, compared to 28 seconds in the untrained group. Pilots commented favourably on this aspect, several mentioning that the situation felt more under control, and that they had time to properly assess the flight path.

In the trained group the crews' flight path situation awareness was generally good about 20 seconds after the distraction, and the situation stable before they switched more attention to the systems issue. Hence if the crew did then inadvertently rely on expectation while dealing with the systems issue, their situation awareness would have a better chance of staying high. The situation awareness measures showed this very strongly, being significantly better overall. Also, no pilot using the experimental mitigation wrongly thought they were over land instead of water (or vice-versa). In addition, mean pilot performance (as perceived) was significantly higher when using the mitigation, and perceived workload was unaffected.

Mitigation Tool used in Main Experiment

The mitigation tool developed for the main experiment (HeliOffshore research Phase 3; conducted on S-92) was briefed as follows:

An event happens (master caution, loud bang, distraction, fire alarm, etc), and then:

1. Initial short statement to be made by the first pilot to notice the problem/issue (e.g. "*master caution*" or even just "*something's wrong here*"), followed by "*I have control*" (if PF) or "*you have control*" (if PM), with confirmation from the other pilot
2. PF action and PM identifying:
   - PF assesses *Aviate/Navigate* (with no talking about any other issues unless urgent)
   - PM states "*identifying*". No other talking unless urgent. When clear, PM makes high-level, clear statement of what they see, and the need for *immediate actions**. For example "*AC bus caption, no immediate actions**"). PM then switches to monitoring the *aviate* task (to complement PF).
3. PF confirms and returns to *aviate/navigate* monitoring
4. Crew perform immediate actions* if required and reset master caution
5. *Aviate/Navigate* assessment; crew update their situation awareness (SA) and make flight path safe…
   - This is the main part of the 'assessment period'
   - PF can use "*standby*" (optional) to remind PM to avoid interrupting or distracting through thinking aloud (avoiding parallel monitoring threat)
   - PM says nothing unless urgent; can re-check *aviate/navigate* then consider issue
6. Diagnosis/emergency management when PF is ready
   - When ready, PF can ask for diagnosis/ECLs etc (they may preface this with a comment on the flight path state, such as "*flight path safe*").
   - If PM sees that PF is ready, they might make a passive prompt such as "*ready to diagnose*", but must take care not to rush the PF away from flight path monitoring / management until the PF has assured the flight path.
7. Perform abnormal/emergency management, make decisions, etc. Try to remember to return periodically to flight path monitoring (and particularly the tactical navigational threat) during situational management.

* *NOTE – "immediate actions" was the term used by the operator in the final Phase 3 experiments, and is used here for that reason only. However, operators may prefer their own terms (such as "memory items")*

Briefing and Practice Used in Main Experiment

Pilot Briefings

Pilots were briefed for over an hour. Important topics were:

- Research to date, including special emphasis on
  - *Aviate* and *navigate drop-offs*
  - *Navigational ownership ambiguity*
  - Parallel monitoring background and threats (from Jarvis Bagshaw research).
- Pilot acceptance. It is common for pilots to feel that they prioritise in this way already, and that they have high levels of situation awareness before dealing with an event. However, the research shows this is not often the case. Briefings conveyed this sensitively through de-personalised research and exercises.
- The mitigation tool, and specific discussion around:
  - The initial phrase *"I/you have control"*. This is used here as a trigger for attention, not as an initiator for transferring control. This phrase is conditioned in all pilots and reliably drives the PF's attention (back) to flight path management, to avoid large *aviate drop-off* caused by the PF becoming fixated on a 'distraction'.
  - The main 'assessment period'. This should happen after pilots determine that there are no immediate/memory items (or after finishing these). The PM must not rush the PF out of this period. A longer assessment period slows down the situation in a controlled way. This is also positive for mitigating two well-documented performance-inhibiting phenomena, *startle* and *surprise*. The PF use of *"standby"* is an effective method of prompting the PM.

Practice

- Crews went through the process in a static simulator (using wording and directing attention).
- Crews then practised repeatedly (using over-learning) the initial trigger, prioritisations and wordings in a simulated event (e.g. technical failure, master caution, etc).
- Two short scenarios were then completed.

Output

The experimental mitigation described above was developed to temporarily integrate into one operator's SOPs, for research purposes. Major elements that can be considered for integration are:

- *"I/you have control"* trigger
- PF getting into the habit of returning their eyes to the *aviate* task quickly after the initial distraction, or even staying on the *aviate* task.
- PM understanding the threat of distracting the PF from the flight path by vocalising a non-urgent issue early on.
- Lengthening the assessment period (time between event and management) where there are no memory items/ immediate actions (or after they have been completed)
- Assessing *aviate* and *navigate* prior to event management
- Getting into the habit of returning periodically to flight path monitoring (and particularly the tactical navigational threat) during non-normal situations

Crew Resource Management (CRM) and technical training briefings can deliver important knowledge around areas described in this paper. These include:

- Understanding the monitoring threats found, such as *aviate* and *navigate drop-off*, and the updating of situation awareness through expectation.
- The threat of distracting the PF from the flight path by the PM talking about low priority or non-urgent issues, especially before the PF has established the flight path as safe (which can take up to 20 seconds).
- Discussion about the PM's intermediate communication after stating *"identifying"*. A slightly different approach might be required for each situation, but the overwhelming priority is to clearly determine the need for memory items, regardless of what statement is used. PMs should attempt a high-level, clear statement along with communicating the need for memory items/immediate actions. The high-level statement should be a communication as opposed to an analysis and need not be overly precise at this stage. If the issue is simple (such as a non-urgent caption appearing) the PM can simply read the caption and report *"no immediate actions"*. However, if the issue is more ambiguous or complex, attempting to read out everything the PM sees risks parallel monitoring and PF distraction. In that case it would usually be best for the PM to briefly summarise what they see and prioritise determination of immediate actions / memory items (e.g. *"multiple cautions, unsure of the exact issue, but NO memory items"*). Examples of translating various indications into clear high level informational statements could be practised to aid fluency.

Simulator training can also benefit from this research, for example:

- Introducing tactical challenges into at least some non-normal management and unexpected situation training (to help the threat of *navigate drop-off*). Tactical challenges (including altitude awareness) might include ATC/airspace restrictions, proximate terrain and low altitude, converging traffic, etc. This will help build the habit of incorporating the navigational priority into event management.
- Trainers pay some attention to when (and whether) crews are considering the flight path (both critical control and performance and tactical navigation). It is easy for trainers to miss a crew's omission of flight path consideration when upper mode automation is engaged, or when other key tasks are prioritised during event management.