Loss of Control Action Group

Monitoring Matters

Guidance on the Development of Pilot Monitoring Skills

CAA Paper 2013/02

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The Loss of Control Action Group is a joint Civil Aviation Authority/industry initiative supported by: British Airways, easyJet, flybe, Jet2, Thomas Cook Airlines, Thomson Airways and Virgin Atlantic Airways.

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Executive Summary

Loss of Control is prioritised as the most important of the significant seven safety issues and the application of effective pilot monitoring is identified as a key safety net in the prevention of and recovery from Loss of Control accidents and incidents. Monitoring is an essential ingredient in achieving synergy with highly automated and complex aircraft systems and effective crew co-ordination.

The Loss of Control Action Group is a joint Industry/CAA endeavour and is supported by the major airlines (British Airways, easyJet, flybe, Jet2, Thomas Cook Airlines, Thomson Airways and Virgin Atlantic Airways). The Group is addressing the following issues:

- training and assessment of pilot monitoring skills;
- use of automation;
- maintenance of manual flying skills; and
- upset recovery training.

Phase 1 of the Pilot Monitoring Skills study was carried out by ESE Associates Ltd in 2011 and included a review of:

- current practices within the airlines and training schools;
- current practices within other safety related domains (rail, road, maritime);
- research carried out globally on monitoring issues; and
- guidance material available across regulatory authorities.

As a result of this activity it was recognised that guidance material was required to promote a better understanding of the monitoring discipline and to identify potential monitoring related training and assessment practices. This constitutes Phase 2 of the study and comprises a guidance document (this report) and a training DVD.

The guidance document is structured into three main parts plus a set of annexes.

Part 1 covers the fundamental aspects of monitoring skills in terms of perception and cognition and explores the human vulnerabilities and stressors that hamper monitoring capability. Case studies are used to put the human vulnerabilities into a context. It also examines the essence of good monitoring through task management (scheduling, sharing and shedding) plus application of key

monitoring attributes (knowledge, skill, experience, attitude and communication). Intent (anticipated systems behaviour, predicted flight path, expected crew behaviour etc.) is emphasised throughout as being an essential component of the monitoring task which is why briefings play an important role. Interaction and intervention between the crew members is an important outcome of the monitoring tasks. Monitoring guidance specific to single pilot operation is provided. Part 1 finishes with a set of strategies that could be employed to enhance monitoring behaviour.

Part 2 covers selection and training aspects and includes a description of the personal traits that are relevant to monitoring competency. The monitoring behavioural markers were obtained through attendance at Airline Line Oriented Evaluations (LOEs) and these reside within 4 of the existing Non Technical Skill areas (situation awareness, leadership/teamwork/briefings, workload management and communication). Positive and negative markers are provided which could be used for assessment purposes. Different monitoring types are identified (passive, active, periodic, mutual and predictive) and a full classification is provided in Annex C at the end of the report. Generic monitoring procedures across all the phases of flight relating to the 5 monitoring types are provided in Annex D. Familiarity and compliance with the procedures/airline specific Standard Operating Procedures (SOPs) will develop good monitoring skills and the importance of compliance must be emphasised. Objective and subjective assessment methods are described for evaluating monitoring competency and it is suggested that these be used in conjunction with measurable events that effective monitoring should capture. A list of potential subtle failures is included for simulation training purposes in Annex E.

Part 3 addresses the Flight Data Monitoring (FDM) and Air Safety Reporting (ASR) classification procedures. Events that may be pre-cursive to a loss of control incident and that could relate to monitoring lapses are listed to enable trend analysis to be carried out. A set of suggested causal factors relating to monitoring lapses are provided for Air Safety Reports (ASRs) which will enable cross correlation and risk areas to be identified and mitigated through training and development. The need for the inclusion of crew monitoring procedures and principles in SOPs is emphasised particularly across all phases of flight. The importance of briefing 'intent' is stressed in order to provide monitoring goals/ triggers and guidance on briefing content is provided.

The annexes provide detailed information that would be of particular relevance for trainee pilots or cadets. Knowledge of human dynamics is as important as aerodynamics. The information processing model in Annex A provides an explanation of how monitoring is executed in terms of information retrieval and decision processing. Understanding the fundamental principles is important in order to appreciate the aspects that hamper monitoring which are detailed in the Root Cause Analysis results contained in Annex B. The procedure for carrying out the Root Cause Analysis is detailed in Part 1 and is recommended as a training activity to fully appreciate the causal factors leading to monitoring lapses and the development of mitigation strategies.

In summary therefore this document aims to provide an awareness of why monitoring matters but does not attempt to prescribe or mandate the necessary training and assessment methods and procedures.

Abbreviations

A/C	Aircraft
AAL	Above Aerodrome Level
ADAPT	Commercially available selection tool www.symbioticsltd.com/symbiotics-adapt-team.php
ADC	Air Data Computer
AFDS	Automatic Flight Director System
AMR	Action Mode Response
AP	Auto Pilot
APU	Auxiliary Power Unit
ASI	Air Speed Indicator
ASR	Air Safety Report
ATC	Air Traffic Control
BITE	Built in Test Equipment
CAS	Calibrated Air Speed
CDL	Configuration Deviation List
CFIT	Controlled Flight Into Terrain
CFP	Computer Flight Plan
COMPASS	Commercially available selection tool www.epst.nl/epst.htm
CRM	Crew Resource Management
DA	Decision Altitude
DME	Distance Measuring Equipment
EFIS	Electronic Flight Instrument System
EGT	Exhaust Gas Temperature
EHSI	Electronic Horizontal Situation Indicator
EICAS	Engine Indicator and Crew Alert System
FAF	Final Approach Fix
FD	Flight Director
FDM	Flight Data Monitoring
FEFL	Fuel, Engines, Flight Instruments, Location
FL	Flight Level
FMA	Flight Mode Annunciator
FMC	Flight Management Computer
FO	First Officer
FORCE	Flight Operations Research Centre of Excellence
FPA	Flight Path Angle
FREDA	Fuel, Radio, Engines, Direction, Altitude

GPS	Global Positioning System
GPWS	Ground Proximity Warning System
IAS	Indicated Air Speed
ILS	Instrument Landing System
IRS	Inertial Reference System
LOC	Localiser
LOE	Line Oriented Evaluation
LOFT	Line Oriented Flight Training
MCP	Mode Control Panel
MDA	Minimum Descent Altitude
MEL	Minimum Equipment List
MMO	Maximum Mach Operating
MSA	Minimum Safe Altitude
NPA	Non Precision Approach
NTSB	National Transport Safety Board
PACE	Probe, Alert, Challenge, Emergency
PF	Pilot Flying
PFD	Primary Flight Display
PILAPT	Commercially available selection tool www.pilapt.com
PM	Pilot Monitoring
PPL	Private Pilot Licence
QNH	Q code for Altitude above mean sea level
QRH	Quick Reference Handbook
RA/TA	Resolution Advisory/Traffic Advisory
SA	Situational Awareness
SOP	Standard Operating Procedure
STAR	Standard Terminal Arrival Route
T/D	Touch Down
TDODAR	Time, Diagnose, Options, Decide, Act/Assign, Review
TEM	Threat and Error Management
TOD	Top Of Descent
TOGA	Take-off/Go-around
TRE	Type Rating Examiner
VOR	VHF Omni-directional Range
VREF	Reference Speed

Contents

Monitoring Matters

Loss of Control is prioritised as the most important of the significant seven safety issues and the application of effective pilot monitoring is identified as a key safety net in the prevention of and recovery from Loss of Control accidents and incidents. Monitoring is an essential ingredient in achieving synergy with highly automated and complex aircraft systems and effective crew co-ordination.

There have been nine fatal accidents since 2000, attributed to Loss of Control, resulting in the loss of 1128 lives. Crew monitoring is frequently the last line of defence that stands between safe operation and an accident scenario. The aim of this guidance document is threefold.

1. To promote a good understanding amongst the pilot community as to why active monitoring is so important, to appreciate the human frailties that contribute to monitoring lapses and to highlight some strategies that can improve their monitoring skills. The aim is to address the needs of the full range of pilots from Private Pilot Licence (PPL) through to pilots operating commercial multi crew aircraft.
2. To place more emphasis on the Training and Assessment of monitoring competencies in terms of developing monitoring procedures, suggested assessment scenarios and additional behavioural markers.
3. To target the Commercial Air Transport Operators in terms of adopting more prescriptive monitoring procedures, maintaining monitoring focused Flight Data Monitoring/Air Safety Reporting and promoting a monitoring culture within briefing activity.

PART 1

Monitoring for Pilots

1.1 What is monitoring?

Monitoring can be analagous to plate spinning – whilst all the plates are going round evenly a cursory tap keeps them on the stick. However as soon as one starts to wobble and requires more attention than the rest you take your eye off the ball and before you know where you are others are wobbling too and eventually all are on the floor. Monitoring is not quite this dramatic but whilst you are ahead of the game, concentrating on the next event, keeping an eye on all the flight parameters,system modes etc everything runs fairly smoothly. But as soon as something draws your attention away and you become out of the loop it becomes difficult to play catch up.

The term monitoring actually comes from the Latin root 'Monere' to warn and in the context of flight operations it is defined as:

> **The observation and interpretation of the flight path data, configuration status, automation modes and on-board systems appropriate to the phase of flight. It involves a cognitive comparison against the expected values, modes and procedures. It also includes observation of the other crew member and timely intervention in the event of deviation.**

Monitoring is the name given to the extensive behavioural skill set which all pilots in the cockpit would be expected to demonstrate. The designated Pilot Flying (PF) is responsible for flying the aircraft in accordance with the operational brief and monitoring the flight path. The Pilot Monitoring (PM) will have an explicit set of activities designated by the Standard Operating Procedures (SOPs), and as such will have a specific and primary role to monitor the aircraft's flight path, communications and the activities of the PF. Both pilots will be responsible for maintaining their own big picture gained through cross checking each other's actions, communication of intent and diligent observation of the PF selections, mode activations and aircraft responses.

1.2 How do we monitor?

The mechanics of monitoring are complex and involve the selective application of mental resources to encode the sensory inputs whilst performing a goal directed task.

The senses relating to monitoring are mainly **visual** and **auditory** but **tactile** inputs from the controls can influence the monitoring task particularly in the event of a stall and similarly the **smell** and **taste** senses can alert the pilot in the event of any fumes in the cockpit and therefore also perform a monitoring stimulus.

Intent forms a very important part of monitoring and provides a baseline against which to monitor. It relates to system behaviour (what it is going to do), aircraft handling (predicted flight path/aircraft manoeuvrability) and Pilot Flying's intent (the plan).

All accurate monitoring activities result in an output following judgement and decision making and this can take the form of:

- verbalization to other pilot or self;
- non-verbalisation in the form of gesture/eye contact;
- note-taking in the case of auditory monitoring;
- reinforcement of collective Situation Awareness (SA); and
- maintenance of mental model.

There are many different forms of information processing models and Annex A contains a very simplistic single channel presentation to try and explain the sequence of flow from sensory stimulus through perception, decision making and psychomotor control.

Physical Ergonomics

It is clearly essential that the pilots are able to see and hear the information relating to the monitoring tasks.

- **The seating position** must be adjusted to the design eye position to enable the pilot to view the internal displays and controls whilst maintaining an adequate view of the external scene. This position is usually made apparent by the provision of two small balls on the central windscreen pillar which appear aligned only when the pilot's eye is at the design position.

- **Vision** is a very complex subject and relates to the ability of the eye to adapt to different lighting levels, focus on the information (normally referred to as accommodation) and for the information to be legible at the required viewing distance (visual acuity). Adaption, accommodation and acuity all vary with and are affected by age. Pilots need to be aware if they are experiencing any difficulty with focus, adaption or legibility of the displayed information as this will certainly compromise the monitoring task. Optometrists will be able to advise on corrective action if necessary.
- **Hearing** can be impaired by accumulation of wax in the outer ear (which is easily remedied), a head cold which blocks the Eustachian tube and prevents equalization of pressure or by infections in the middle ear. Hearing can be expected to deteriorate with age particularly with the higher frequencies. In addition high ambient noise environment or distractions/interruptions in the cockpit can impact the clarity of aural messages. Under all circumstances, if there is any ambiguity related to information received aurally then ask for it to be repeated.

1.3 What hampers monitoring?

There are many factors that hamper monitoring including system and ergonomic design, organisational factors and external environment. But the biggest concern relates to human vulnerabilities (complacency/inattention, distraction, low attentional resource, low arousal, disorientation, tiredness etc) and stressors (workload etc) and these are explained in the context of some relatively recent accidents and incidents.

It should be emphasised that in nearly all the case studies there are multiple causal factors including design deficiencies and pilot handling responses but for the purpose of this guidance document the case studies focus on the human vulnerabilities/stressors resulting in monitoring lapses. The case studies covered reside under the vulnerabilities/stressors that are considered to be the most dominant. Table 1 summarises the case studies.

Table 1: Case study examples where monitoring lapses were a contributory factor

Case Study Number	Where	Failure to Monitor	Dominant Causal Factor	Other Causal Factors	Fatalities
1	Bournemouth	Autothrottle disconnect	Inattention		Situation recovered
2	Everglades (CFIT)	Flight Path	Distraction	Workload	99
3	Buffalo	Low Speed Indication	Distraction	Fatigue	50
4	Cali (CFIT)	Flight Path	High Workload	Expectation Confusion/ Loss of SA Disorientation Inattention	159
5	Schiphol	Low Speed Indication Autothrottle mode	High Workload	Confirmation bias Distraction	9
6	North Atlantic Ocean	Flight Path parameters and AP selection	Startle	Distraction	Situation recovered
7	Atlantic Ocean (AF447)	Speed Inconsistencies Angle of Attack Flight path parameters	Startle	Distraction Inattention	228
8	Charles De Gaulle	Low Speed	Subtle incapacitation	Distraction Fixation/ Loss of Scan	Situation recovered
9	Indonesia	Flight path	Disorientation	Tunnel Vision	102
10	Palmerston North NZ (CFIT)	Flight path	Lack of attentional resource	Distraction Complacency Tunnel Vision	4

Inattention

Equipment failures are infrequent in modern commerical air transport operations, and humans are inherently poor at monitoring for infrequent events. High levels of trust result in a feeling of well-being in the cockpit and important cues can be missed.

A routine flight from Faro to Bournemouth had been cleared for landing when the autothrust system disconnected on approach without the knowledge of the crew. On autothrottle disconnection the visual warning, which was a flashing red annunciator, was activated for one minute before being cancelled by manually disconnecting the autothrottle. The Pilot Monitoring (PM) was focused on the Primary Flight Display (PFD) and flight instruments and did not notice the flashing warning or the associated removal of the auto-throttle mode on the PFD.

Case Study 1: Boeing 737-300 Bournemouth September 2007

The Crew had been cleared to land on runway 26 at Bournemouth International Airport. At 7 DME the autopilot captured the glideslope at 2245 hrs and the Pilot Flying (PF) requested the landing gear to be lowered, flap 15 to be selected and the landing checklist. A lower speed was then selected on the MCP and the autothrottle set the thrust levers to idle. About 20 seconds later the autothrottle disconnect warning was triggered and the autothrottle disconnected. The Crew **failed to respond** to this event. The speed continued to decay **in line with the crews expectations** and at 150kt flap 25 was selected. The PM was **momentarily distracted** when he needed to adjust his lamplight to check the speed for Flap 40 selection. 135kt was then selected on the Mode Control Panel (MCP). When Flap 40 was in position, the speed had decayed to 130kt (5 kt below Final approach Speed). The landing checklist was carried out and by the time Commander (PM) had stowed his checklist he saw that the Indicated Air Speed (IAS) was now 125kt and called SPEED. The Commander took control and executed a Go-Around at 1540ft and Calibrated Air Speed (CAS) of 110kt. The Auto throttle was now manually deselected and the warning light stopped flashing. Within 1.5 seconds the stick shaker was activated and full thrust applied. The aircraft pitched up excessively and attempts to reduce it were largely ineffective due to authority limits being reached (due to the increased pitch trim **which also had gone unnoticed**). The stick shaker activated 3 times until, with a pitch angle of 44 degrees and speed on 82kt, the aircraft stalled. It remained stalled for 10 seconds until the PF reduced the pitch trim, gained control and climbed to 4000 ft to reposition for a 2nd approach. Both auto systems performed normally throughout the second approach. The autopilot and autothrottle were manually disengaged at 1,200 ft and 800 ft respectively and the aircraft landed at 2301 hrs.

The AAIB recommended [1] that an aural alert should accompany a visual alert of this severity.

1 AAIB 3/2009 Report on the serious incident to Boeing 737-3Q8, registration G-THOF on approach to Runway 26 Bournemouth Airport, Hampshire on 23 September 2007

Distraction

Distraction is one of the major factors which underlie most incidents and accidents and this can be either physical or mental. Physical distractions occur due to unexpected problems in the cockpit or interruptions from cabin crew, Air Traffic Control (ATC), etc. Humans are capable of attending to more than one task utilising selective attention techniques but have limited cognitive capacity. Therefore if one of the tasks consumes the entire pilot's mental capacity then task shedding will occur. Two accidents are described where distraction was a contributory factor.

The first one is a Controlled Flight into Terrain (CFIT) related to landing gear malfunctions. The crew were distracted for 4 minutes whilst the First Officer (FO) became preoccupied with his attempts to remove a jammed light assembly and the captain divided his attention between helping the FO and discussions with other crewmembers.

Case Study 2: Tristar crash Everglades December 1972

The flight had just begun its approach to Miami international when one of the green lights failed to illuminate on selection of landing gear. The captain aborted the approach and was cleared to 2000ft circling over the Everglades. The 2nd Officer was despatched to the avionics bay, followed by the jump seat occupant to check whether the landing gear was in place. The 1st Officer selected the Auto Pilot (AP) but the mode was inadvertently switched from Altitude Hold mode to Control Wheel Steering mode in pitch. Thus each time the captain leaned on the yoke a pitch command was activated. **No-one noticed** the reducing altitude or **responded to** the altitude deviation warning. The aircraft eventually impacted the ground with the loss of 99 lives.

The National Transport Safety Board (NTSB) report cited [2]'the failure of the flight crew to monitor the flight instruments during the final four minutes of flight, and to detect an unexpected descent soon enough to prevent impact with the ground. Preoccupation with a malfunction of the nose landing gear position indicating system distracted the crew's attention from the instruments and allowed the descent to go unnoticed'.

In the second example, at Buffalo, distraction came in the form of social chat in the cockpit during the descent phase. Clearly this was in violation of the sterile cockpit procedure and was a factor in the lack of monitoring of the developing low speed situation.

2 NTSB 1-0016 Eastern Airlines Inc E-1011,N 310EA Miami Florida, 29 December 1972

Case Study 3: Bombardier DHC8-400 February 2009[3]

The aircraft had been cleared for final approach to Buffalo-Niagara International Airport when they encountered icing conditions. The captain (PF) was **distracted** by talking to the FO about various non-flight related issues throughout the approach and as a result the descent and the approach checklist were **carried out late**. The Reference speed had been set to INCR to provide an earlier warning of stall as a safety precaution under icing conditions and they were required to fly the descent faster which they failed to do. **They did not notic**e the IAS speed display as it changed to red to indicate the approach to the stick shaker activation speed. When the stick shaker activated and the AP disconnected the pilot's inappropriate aft input to the control column (possibly **startled** by the shaker) induced an aerodynamic stall. The aircraft's stall protection system was activated with nose down inputs but the captain, **confused by the situation**, made repeated counter inputs and the aircraft eventually crashed claiming the lives of all onboard (49) and 1 person on the ground.

High Workload

When under high workload conditions, particularly those associated with descent, approach and landing checklists, ground communication and approach charts the attention capacity reduces significantly. The automation is there to reduce and balance the workload but accidents have occurred where management of the Flight Management System (FMS) at critical phases of flight increases the workload resulting in errors going un-noticed.

In the situation at Alfonso Bonilla Aragon International Airport at Cali, Colombia terrorist activity had resulted in the ground radar system being blown up. Therefore the Ground Controllers had no means of monitoring flight AA 965 from the ground and relied totally on positional radio reports. The FMS was pre-programmed with all the en-route waypoints but due to a miscommunication with the Ground Controllers the route was deleted as the Crew were under the misconception that they were flying directly to Cali. The resultant **workload** associated with re-programming the FMS and the critical error that was made sealed their fate. In this example, time pressure was a factor as they were 2 hours behind schedule and were commercially driven to make decisions that reduced the time available resulting in a high workload/error prone descent and approach.

3 NTSB/AAR 10/01 Loss of Control on Approach Colgan Airline Inc, operating as continental connection flight 3407 Bombardier DHC-8-400 N200WQ Clarence Centre New York, 12 February 2009

Case Study 4: Boeing 757 December 1995

The Boeing 757 was transiting from Miami to Cali, Colombia and was in radio contact with Cali Controllers at around 60 DME from Cali. They were offered a direct approach to runway 19 rather than circling round to runway 01. They were commercially driven to make up some of their time and selected Cali as a direct waypoint (this action deleted the programmed flight plan). They now needed to get the approach plates out for runway 19 and increase their descent through deployment of the speed brakes. The Ground Controller then requested that they report their DME from Tulua which was one of the waypoints that they had just deleted. In trying to establish their position with respect to Tulua they became **very confused** and realised eventually that they had already overflown it. They then requested clearance to Rozo which was the final waypoint before Cali. This was confirmed but when they entered R into the Flight Management Computer they **expected** Rozo, as the closest beacon, to be on the top of the computer generated list. When they selected the waypoint at the top of the list they **failed to check** the position on the Nav display and **failed to monitor the path of the aircraft** as it veered off in a wide semi-circle toward Romeo Non- Directional Beacon (NDB) near Bogata some distance off track. They were completely **pre-occupied** with the landing charts and by the time they realised their error they were on collision course with a mountain. The Ground Proximity Warning System (GPWS) alarm activated but they failed to retract the speed brakes in order to achieve the required climb rate to clear the mountain. It crashed near the summit claiming the loss of 159 lives.

The crash investigation report [4]cited several causal factors including:

- the failure of the crew to revert to basic radio navigation at the time when FMS-assisted navigation became confusing and demanded an excessive workload in a critical phase of flight;
- the failure of the crew to discontinue the approach despite numerous cues alerting them of the inadvisability of continuing the approach; and
- the lack of situation awareness of the flight crew regarding vertical navigation, proximity to terrain and the relative location of critical radio aids.

Time pressure was also an issue for the crew who were conducting a line training sector under supervision flight into Schiphol Airport. Additional training tasks were placed upon the captain (PM) to instruct the FO (PF) and this would have impacted his workload and reduced his capacity to monitor the flight path

4 Aeronautica Civil of the Republic of Columbia Santafe de Bogata DC Columbia Controlled Flight into Terrain AA 965 Boeing 757-223 N651AA near Cali, Columbia, 20 December 1995

and speed particularly during the final approach phase. As it was an instructional flight the communication workload was higher than it would normally have been and therefore was an impedance to effective monitoring. The time required to complete the landing checks correctly was significantly greater than the time available and an overload situation existed. In these situations tasks are inevitably shed and in this case it was the monitoring tasks.

Case Study 5: Boeing 737-800 Crash February 2009[5]

There were three crew members in the cockpit of the Flight transiting from Istanbul Atarturk Airport in Turkey to Schiphol Airport in Amsterdam; namely the captain, who was also acting as instructor, the FO who had to gain experience on the route of the flight and who was accordingly flying under supervision, and a safety pilot who was observing the flight. Whilst in the descent at around 8000 ft the landing gear configuration horn sounded **to alert the crew** that the system was in a landing mode but the landing gear had not been lowered. The captain **responded by cancelling the warning** stating that it was due to the radar altimeter which was erroneously reading -8. The landing gear warning sounded several more times during the descent and each time was cancelled by the captain. The approach vectoring provided by the Ground Controller meant that they would be capturing the glideslope from above which requires a faster descent. A vertical speed of 1400 ft/min was selected and shortly after this the autothrottle mode changed to RETARD which **went unnoticed**. They finally captured the glideslope at 1300 ft. The FO, who was PF, was late in instigating the landing checklist which should have been completed by 1000 ft and it wasn't started until 800ft.

Whilst the crew were carrying out the checklist the airspeed fell below the selected Final Approach Speed and **they failed to notice and react to** the flashing of the airspeed box and to the increase in aircraft pitch. Problems with arming the speed brake during the checklist **distracted** the crew. The safety pilot was also **distracted** by the task of informing the cabin crew of the imminent landing. The 500 ft call was made and shortly after, at 460 ft, the stick shaker activated indicating an impending stall. The captain applied thrust but **failed to recognize** that the Auto Thrust mode was still active and in a landing mode. The auto throttle and auto pilot were disconnected and the correct pitch and power inputs applied but too late to avoid the crash which claimed the lives of 9 people.

5 Dutch Safety Board M2009LV0225-01 Crashed during approach, Boeing 737-800 near Amsterdam Schiphol Airport, 25 February 2009

There were system design issues which confounded the situation – the left hand radar altimeter had erroneously sent a value (-8ft) to the auto thrust system which in conjunction with other preconditions (gear down and flaps set for landing) activated the landing mode (the aircraft had been dispatched with a fault that was allowable according to the Minimum Equipment List (MEL) manual. The autopilot was still tracking the glideslope so the pitch angle increased.

Confirmation bias came into play in that the speed was decaying in line with their expectations. Confirmation bias is a type of selective thinking whereby one tends to notice and look for what confirms one's belief and disregard any conflicting indication (the under carriage warning alert)

However it is unclear as to why they did not conduct a Go-Around given that they were not stabilised by 1000ft which is the company agreed procedure. Particularly as this was a training flight.

Low Arousal

Mental distractions normally accompany boredom and a lower vigilant state and whilst monitoring may still continue, the pilot's reaction time to any deviation will be slower and more error prone. During long haul flights there are long periods of routine flight management and weather surveillance. In this calm environment if you are confronted with sudden unexpected aural stimuli the brain invariably responds with an instinctive reflex psychomotor action (**startle**). If this is accompanied by a mismatch in the pilot's mental model of the system state/ aircraft behaviour with the reality of the actual situation, then the outcome is loss of situation awareness and subsequent inappropriate action.

There are 2 examples of **startle reflex** where the results of instinctive but erroneous control inputs should have been recognised and corrected by attentive monitoring of the flight path parameters and system modes.

Case Study 6: A340 July 2011

The aircraft was cruising at Flight Level (FL) 350 when it encountered turbulence and exceeded the target speed limit. The over speed alarm went off and the PM **startled by the aural stimuli** instinctively pulled back on the side stick for 6 seconds causing the AP to disconnect and to climb to FL 380. It took the crew 90s before they realized that the AP had disconnected (the over speed alarm had masked the AP disconnect alarm) and the FL had increased. The crew were **distracted with the turbulence issue and no-one monitored the flight instruments. Important cues were missed** (nose-up pitch of 12 degrees, high climb rate, excessive altitude, position of the FD bars, FMA indications, ECAM 'AP off' message and AP light extinguished).

The accident report[6] cited that the serious incident was due to inadequate monitoring of the flight parameters which led to the failure to notice AP disengagement and the level bust following a reflex action on the controls.

In the second example (AF 447) immediately prior to the system malfunction (pitot blockage resulting in loss of speed data and AP disconnect) the crew were dealing with impending turbulence and icing associated with a tropical storm. They had not anticipated the risk of pitot blockage and subsequent loss of speed information. When the AP disconnect warning occurred the instinctive reflex action was a lateral roll input followed by an excessive nose up input by the PF. At no time was an action plan discussed and agreed to deal with the encountered problem.

Case Study 7: AF447 Airbus A330-203 June 2009

AF447 was in the cruise at FL350 flying at 467 kt over the Atlantic Ocean en-route to Charles De Gaulle Paris . At just less than 4 hours into the flight the captain **woke** the 2nd pilot to inform that he, the captain, was taking a break and the other pilot would be PF. After a short briefing the captain left the flight deck and the crew informed the cabin that they were about to enter an area of turbulence. The PF made a slight heading change and reduced the speed to Mach 0.8. A few minutes later, as a result of inconsistent speed data the autopilot disconnected followed by the auto thrust. The PF, **possibly confused and startled by the situation**, immediately made a nose up input and the stall warning sounded briefly when the turbulence caused the angle of attack to exceed its threshold. The aircraft eventually climbed to 38000ft with an angle of attack of 16 deg. The pitch attitude started to reduce but the angle of attack continued to rise rapidly until the aircraft stalled. **During this period there were no call outs from the PM of any of the flight parameters, mention of the stall condition or the fact that the aircraft was now at its maximum permissible altitude.** The captain returned to the flight deck but despite a final nose down input the aircraft remained stalled until it crashed into the ocean following a descent lasting 3 mins 30 seconds with the loss of 228 lives.

6 BEA Report Serious incident on 22 July 2011 in cruise at FL350 North Atlantic Ocean to the Airbus A340-313, May 2012

The final report[7] cites:

- the lack of any link by the crew between the loss of indicated speeds called out and the appropriate procedure;
- the late identification by the Pilot Monitoring (PM) of the deviation from the flight path and the insufficient correction applied by the PF;
- the crew not identifying the approach to stall, their lack of immediate response and the exit from the flight envelope; and
- the crew's failure to diagnose the stall situation and consequently a lack of inputs that would have made it possible to recover from it.
- System design issues were also highlighted which could have supported the monitoring task:
- the lack of a clear display in the cockpit of the airspeed inconsistencies identified by the computers; and
- the lack of a clear angle of attack presentation.

Subtle Incapacitations

There are certain human states which can be transitory in nature whereby the pilot becomes traumatised and unable to function normally. They are insidious conditions because the pilot may appear to be functioning normally but only have a partially functioning brain. Mental incapacitations will always affect the monitoring task and may manifest itself in either a complete freeze or tunnel vision. Case study 8 exemplifies this condition which fortunately was recognised by good monitoring by the captain.

Case Study 8

This was a line training sector with an experienced line training captain in the left hand seat and a newly type rated FO in the right hand seat. The FO was flying the aircraft and they were making the final approach to Charles De Gaulle Airport. The Glideslope had been captured, after a little instability, and the landing checks had been completed. The aircraft was stabilised by the required position. The captain looked away momentarily to check correct GA Altitude set in MCP window and when he looked back his attention was immediately drawn to speed 5 knots below bugged speed and decreasing. Also Flight Mode Annunciator (FMA) revealed Autothrottle was disconnected but no audible warning had been heard. Captain called

7 BEA Final Report on the accident on 1 June 2009 to the Airbus A330-203 AF 447 Rio de Janeiro – Paris, July 2012

> 'SPEED' but to no avail. He called again and assumed control, bringing the aircraft back to a stable position. The PF had frozen and was completely out of the loop. The captain took control and safely landed the aircraft.

This case study emphasises why it is so important to continually monitor any performance degradation of the other crew member.

Disorientation

The human visual and vestibular systems are prone to illusionary inputs related to depth, height speed and distance. This can seriously challenge the perception channels and result in incorrect decisions being made in, for example, fast taxi speeds (effect of high level cockpits and perceived velocity). There are at least four illusionary situations when making a visual approach:

- the first involves either sloping terrain or sloping runway which could result in a low approach;
- the second illusion is the 'black hole phenomenon' where the lack of illuminations, other than runway lights, gives the impression of extra height;
- the third illusion is the 'whiteout phenomenon' where the homogenous external environment fails to provide the important depth perception cues; and
- the fourth illusion is encountered with the perceived runway size. For example if the runway is narrower than expected this could be interpreted as increased range. Therefore the touchdown point occurs too early.

Severe disorientation can occur if the aircraft is rolling and the pilot moves his or her head out of the plane of rotation which may have been the case in Adamair Flight 574 Indonesia.

Case Study 9: Boeing 737 – 4Q8 January 2007[8]

> The aircraft was en-route from Surabaya, East Java to Manado, Sulawesi and was in the cruise at FL350 with the autopilot engaged. The aircraft developed a problem with the Inertial Reference System and both pilots became so **engrossed** in sorting out the problem that they failed to respond to the increasing descent and bank angle. The pilots became **disoriented** and did **not detect** and appropriately arrest the descent soon enough to prevent the loss of control. The aircraft crashed with the loss of 102 lives.

8 National Transportation Safety Committee Republic of Indonesia KNKT/07.01/08.01/36 Boeing 737-4Q8 Makassar Strait Sulawesi Republic of Indonesia, 1 January 2007

Lack of Attentional Resource

There have been many aircraft accidents and incidents where both crew members focus all their attention on dealing with a system malfunction to the detriment of other tasks (**attention-tunnelling**). Case study 9 is one such example and the flight to Palmerston North in case study 10 is another when the crew encountered problems with the gear down mechanism and failed to monitor the flight path.

When dealing with an emergency situation the company procedures allowed three options:

1. The captain flies the aircraft and acts as a single pilot while the FO concentrates on the Quick Reference Handbook (QRH), each acting without any monitoring from the other.
2. The captain flies the aircraft but the FO is still responsible for checking the safety of the aircraft and giving check altitude calls while completing the QRH.
3. The captain flies the aircraft but keeps a check on the FO's conduct of the QRH checklist while the FO in turn still cross checks the captain's conduct of the flight.

This was a Non-Precision Approach onto a runway that the captain was unfamiliar with and surrounded by high ground. They had elected to select the gear down early which negated activation of the GPWS Modes 2 and 4.The decision was taken to continue the approach and the FO was assigned the task of carrying out the drill (option 1).

Case Study 10: De Havilland DHC8 June 1995[9]

The aircraft was transiting from Auckland to Palmerston North at 0915 hours and making a VOR/DME approach. They were told to stop their descent at 6000 ft and intercept the 14 DME arc for the VOR/DME approach to runway 25 instead of the expected approach to runway 07 which was being used by departing traffic. The profile monitoring continued until 12 DME when they were at 4000ft. At this point the captain called for the gear to be extended (early gear extensions were common practice at that time to reduce the likelihood of nuisance GPWS warnings) and selection of Flap 15. The landing gear failed to lock and the captain instructed the FO to get the QRH for the Landing Gear Malfunction Alternate Gear Extension stating "I'll keep an eye on the aeroplane while you're doing that". There were no further altitude calls. The FO started to go through the procedures but was **interrupted** by the captain who told him to skip through some of the tests. He missed a step out and tried to insert the gear handle too early. The captain was **distracted** from flying the aircraft and tried to help the FO sort the problem out. The GPWS warning went off 4 seconds before the aircraft hit the ground killing three passengers and one crew member.

Clearly the approach should have been aborted to give the crew time and space to sort out the problem. It must be emphasised that **someone must fly the aircraft.**

Fatigue

In addition to the vulnerabilities highlighted in the Buffalo disaster (Case Study 3) there were 2 other key stressors – **tiredness** and **fitness**. The FO had commuted overnight from Seattle arriving at Memphis International Airport at 6:30am and was suffering from a heavy cold. The captain had completed a 2 day trip sequence the day before the accident. Although not cited as a causal factor, **sleep debt** and **extended periods of wakefulness** will impair the vigilance required under demanding flight conditions. The NTSB report[10] cites that the captain failed to monitor the instruments and the FO failed to provide back-up and corrective input. They both failed to follow the stall procedures with the appropriate call outs and actions.

Sleep inertia which occurs when you have just woken up can hamper the monitoring task. Sleep inertia can last between 1 minute and 1 hour but typically is between 15 to 30 minutes (dependent upon the length and depth of sleep).

9 Transport Accident Investigation Report 95_011 de Havilland DHC-8, ZK-NEY Controlled Flight into Terrain near Palmerston North, 9 June 1995

10 NTSB/AAR-10/01 PB2010-910401

During this period you are operating at a lower capacity and reactions are likely to be slower.

Other potential factors

In addition to the vulnerabilities relating to the air incidents described above there are others that could hamper the monitoring task:

- the pilot may become habituated in carrying out the instrument and display scanning task and fail to accurately process the information which is a phenomenon described as 'looking but not seeing';
- the pilot could also become fixated on a particular display or instrument and fail to complete the scanning process;
- when the workload is high or poorly managed, monitoring can be treated as a low priority task; and
- authority gradients in the cockpit can impair monitoring if the PM is intimidated by the PF and is unwilling to question their judgement.

1.4 What are the root causes?

In order to identify the root causes it is necessary to examine contributory factors that relate to the effects and conditions shown in the outer (yellow) circle in figure 1. The effects cannot always be taken in isolation and they often inter relate or are causal factors in their own right – for example:

- complacency, boredom, low arousal level;
- lack of knowledge, poor Situational Awareness (SA), confusion;
- limited attentional resource, tiredness;
- attention tunneling, disorientation; and
- distraction, poor SA.

The root cause analysis process, which is similar to Threat and Error Management (TEM), is carried out in 3 steps:

Step 1 – Consider the human vulnerabilities which could accompany a monitoring lapse.

Step 2 – Take each of the vulnerabilities and consider causal factors from 4 different perspectives:

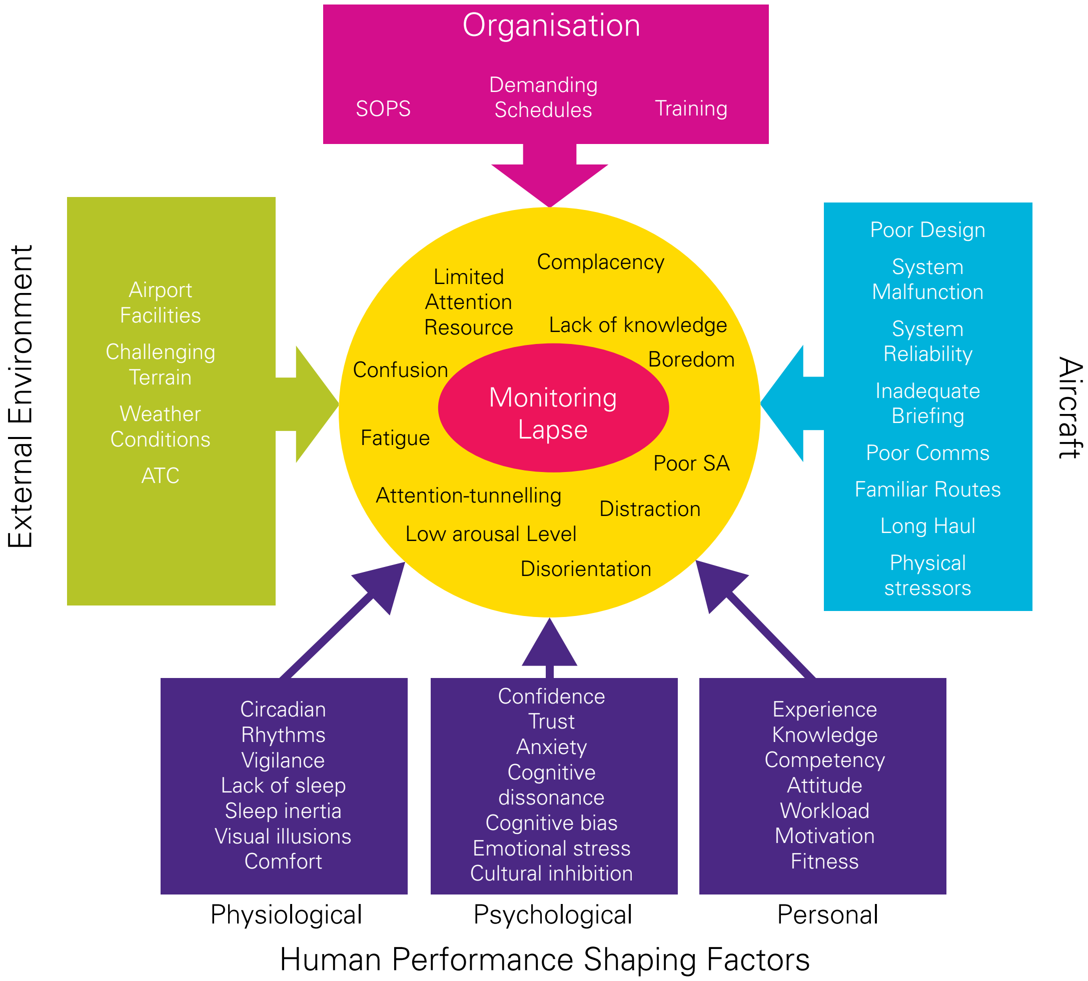
- self (physiological, psychological and personal);
- work place (cockpit);
- organisation (commercial air transport operators); and
- environment (geographical, meteorological, airport facilities, ATC).

Step 3 – List the root causes and consider mitigation strategies.

A completed table is shown in Annex B. However it should be stressed that this is not necessarily the only solution and the benefit in fully appreciating the broad range of circumstances leading to monitoring lapses will be gained in developing one's own table.

The completed figure 1 represents all the root causes and as might be expected is very broad. It represents the set of threats that need to be mitigated against.

Figure 1: Factors affecting monitoring lapses

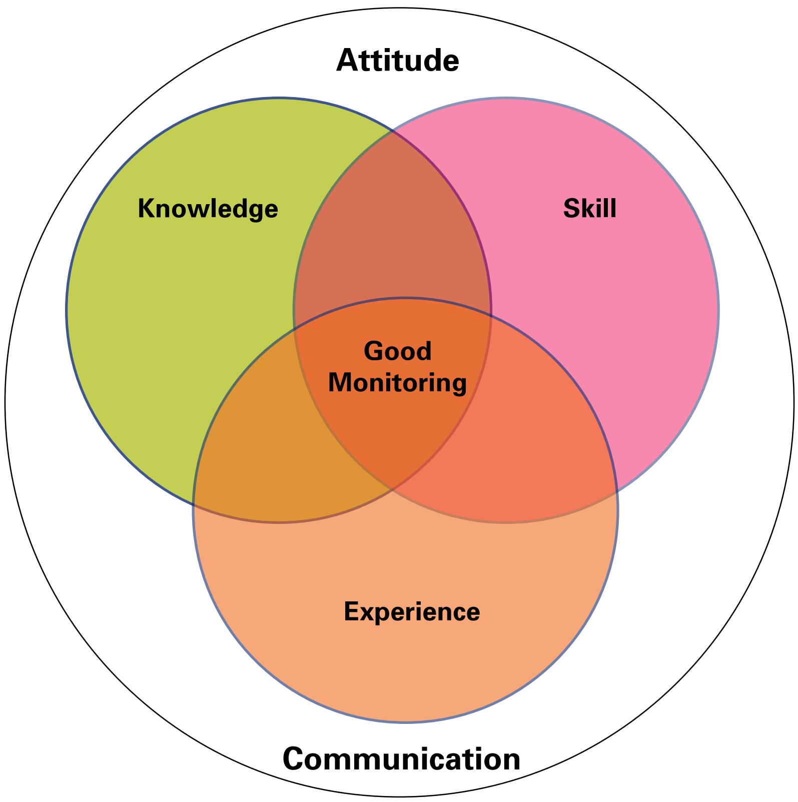


1.5 What promotes good monitoring?

Good monitoring relies upon effective **task management** and 'making time for monitoring'. It is evident from nearly all of the case studies that carrying out tasks associated with landing checklist (Bournemouth, Buffalo, Schiphol), emergency drills (Everglades, Indonesia, Palmerston North), landing charts (Cali) and handling FMS (AF447, Cali) took priority over monitoring tasks. Flight path monitoring/ selective radial instrument scan must be a priority task that is not compromised by other priority tasks. **Task scheduling** (e.g. carrying out normal checklist), **sharing** (e.g. balancing the monitoring workload and being aware when the PM has very limited capacity) and **shedding** (e.g. prioritising tasks) must be considered as strategies to achieve a good monitoring practice.

Good monitoring requires knowledge, skill, experience, attitude and communication. None of these can be taken in isolation. **Knowledge** is provided through training, **Experience** is the application of the knowledge and **Skill** is the product of both knowledge and experience. **Attitude** is a personal trait that can be shaped and developed. **Communication** is fundamental to monitoring as both an output and input.

Figure 2: Good monitoring attributes



Knowledge

An essential component of the monitoring task is knowledge .The monitoring task becomes easier when you are familiar with displays and controls functionality and layout, system responses and handling manoeuvres. The application of knowledge equates with **intent** which is fundamental to the monitoring task. If you do not know how the system is going to behave or how the aircraft is going to respond then you will not be in a position to make a judgement on correct operation (monitoring task). Similarly if you are unaware of the other crew member's intent then this will also impair the monitoring task.

Skill

Monitoring the flight path is simply flying with your eyes, observing cockpit displays and indications to ensure that the aircraft response matches mode selections and guidance target entries. Monitoring skill therefore can be considered, in part, to be the ability to judge whether the aircraft attitude, speed and trajectory matches your expectations.

Monitoring skill relates to the ability of the pilot to:

- recognise and respond to any deviations from the plan in a timely and effective manner;
- recognise and advise on deviations in appropriate configuration states;
- recognise and advise on abnormal conditions;
- alert changes in automation modes (in accordance with SOP);
- advise on achievement of approaching clearance heights;
- advise on external threats (weather, terrain, traffic); and
- recognise and advise on any errors by Crew Member.

Experience

Good monitoring correlates highly with mental capacity which in turn may be factored by the pilot's amount of flying experience. The more familiar you are with a set of procedures/system operation, the greater the ability to operate effectively on mental autopilot. Therefore carrying out some of the operational tasks utilising lower levels of concentration can release more capacity for the monitoring task. However this doesn't necessarily mean that pilots with a lot of flying hours are good monitors.

Attitude

A good monitor will possess a healthy scepticism on the integrity of the systems and will cross check the autopilot performance against the raw flight path parameters. They will also be aware of and also possibly be a little suspicious about the capability of other crew members thereby cross checking actions judiciously. They will act dutifully in the execution of their monitoring task and be assertive when necessary.

Communication

Effective communication is intrinsically linked to monitoring skills. It involves communications between; flight crew and controller; flight crew members; flight crew and cabin crew. Communication allows sharing goals and intentions to enhance crew's situational awareness and monitoring.

1.6 Further monitoring strategies for single pilot operation

When the role of PF and PM are combined as in the case of a single pilot it presents a different set of monitoring disciplines. The processes and procedures will be equivalent to multi crew operation except there will only be one person in the cockpit and the systems may be less automated. Hence the need to monitor the flight profile, flight instruments, fuel state, engines, radio, etc. diligently. The instrument scan must be carried out very frequently, especially during departure and approach in order to monitor the aircraft state and planned profile.

The light aircraft environment operating in uncontrolled airspace requires additional internal and external monitoring as illustrated in figure 3 below.

Figure 3: Typical monitoring environment

The following is an extract from an AAIB report[11] of a fatal accident involving a solo pilot flying a Bolkow 208C light aircraft from Long Marston Airfield to Peterborough Sibson Airfield. It serves to emphasise the importance of planning and monitoring particularly in unfamiliar territory

> The aircraft was on final approach to land at Sibson Airfield when it struck the uppermost cable of a set of power transmission lines situated approximately 0.5 nm from the airfield. The runway in use had a significantly displaced threshold to provide aircraft on approach with adequate clearance from the transmission lines. Evidence suggested that the pilot made an approach to the start of the prepared runway surface, rather than the displaced threshold. The pilot's unfamiliarity with the airfield, distraction due to a departing aircraft in front and inadequacies in the briefing material available to him may have been contributory factors to the accident.

There is still the requirement to carry out the checklist drills and emergency briefings.

11 AAIB EW/C2011/09/01 D-EGFU

- Resist the temptation to take short cuts and avoid repeating the well-known checklists from memory. Although it may be embarrassing, there are times when just saying a drill out loud will re-enforce the actions and ensure nothing is missed. Departure and approach briefings or reviews are an essential element of safe operations. An update of the airfield procedures or approach plates would highlight restrictions, terrain or limitations, even for a well-known airfield.
- Emergency briefings become a self-disciplined action. However, completing a briefing (to yourself) re-enforces the thought process –'Have I thought of everything'. Similarly, have a 'what if plan'. Consider, any airfield restrictions, surrounding terrain, weather, temperature, aircraft weight and payload. What are you going to do if the engine fails?
  - On the runway.
  - Just after take-off, below 1000ft.
  - Above 1000 ft. and just beginning the departure.
  - Is the weather/terrain acceptable for a forced landing ahead, or
  - Does the weather/terrain allow for a return to the runway?
  - What is my decision point/speed required?
- Always carry out an independent check of fuel contents with respect to flight plan before take-off.

It is a good practice to review the engine failure or major emergency actions by self-briefing and accomplishing a touch drill of all the relevant switches and levers. The touch drill improves the memory for actions required under stress and is an accepted training method. For example, in martial arts training, students practice a move against an imaginary opponent some hundreds of time to become proficient.

Ensure that emergency checklists are accessible and can be executed whilst still flying the aircraft. Consider having the major critical emergency drills on a knee board type check list, which is always available and won't fall off. The relevant checklist may then be completed once the situation is under control prior to the approach.

In most emergencies, the best strategy is to land as soon as possible. Therefore, have a plan.

Self monitoring, to detect lapses becomes important. In a single pilot situation taking a break is not an option so ensure that you are well rested and fit to fly.

1.7 Tips and hints for good monitoring

Good monitoring can make a difference as shown in one of the incidents abstracted from the Dutch Safety Board Report[12]

> A Boeing 737-700 made an approach for runway 16 at Calgary airport in Canada on 12 July 2009. The first officer was pilot flying. The first officer disengaged the autopilot when passing a height of 1000 ft to perform a manual approach; the autothrottle, however remained engaged. He kept his hand on the throttles. He felt the throttles move aft at an altitude of approximately 150 ft. He also noticed that the speed dropped below the selected speed of 133 knots. It was noted that the autothrottle 'retard flare' mode was activated. This could be seen on the flight mode annunciation, which indicated RETARD. The first officer disengaged the autothrottle, manually selected thrust and made a safe landing.

These are a few strategies that could be employed to enhance good monitoring behaviour:

- Stay in the loop by mentally flying the aircraft even when the autopilot or other pilot is flying the aircraft.
- When you have been distracted ensure that you always check the FMAs and your flight instruments to get back in the loop as soon as possible.
- Monitor the flight instruments just as you would when you are manually flying the aircraft.
- Be diligent in monitoring all flight path changes – pilot ACTIONS, system MODES, aircraft RESPONSES.
  - Always make monitoring of the PF a priority task when flight path changes are being made.
  - Always check the FMA after a change has been selected on the autopilot mode control panel.
- During briefings include 'monitor me' type comments to encourage intervention – 'remind me if I haven't asked for the after take-off checks'.
- Provide the occasional monitoring reminders e.g. – 'make sure that the tail wind doesn't exceed 10 kt'.
- During flight the captain should ensure that the shared mental model remains intact this can be achieved through:

12 Turkish Airlines Crash Investigation Report Appendix N

  - application of TDODAR (Time, Diagnose, Options, Decide, Act/Assign, Review) (agree the plan);
  - expression of intent (I will be flying the descent at 200kt); and
  - providing a situation update to the PM when he/she has been carrying out a non-monitoring task.
- Manage the workload:
  - when the workload gets too high, prioritise which parameters to monitor – don't multi-task for too long;
  - when dealing with emergency situations ensure adequate time and space to enable the continuation of the monitoring tasks; and
  - avoid programming the FMS at critical phases of flight.
- Don't rely on memory when receiving aural communications – write it down or request it again.
- Mentally rehearse during low periods of workload, monitoring tasks that will occur in the next phase of flight.
- Make cross checking achievement of the autopilot targets a force of habit.
- Verbalise your observations or checklists (especially if single pilot).
- At the end of the flight discuss how well the monitoring was carried out – did you both share the same plan.
- When the aircraft is carrying defects that are acceptable in the MELs consider the impact on the monitoring task – make a note (mental or otherwise) of the affected flight parameters, modes or systems that will require more attentive monitoring (discuss this during briefing).
- Judicious use of acronyms are a good way of remembering monitoring tasks or techniques:
  - FREDA (Fuel, Radio, Engines, Direction, Altitude)
  - FEFL (Fuel, Engines, Flight Instruments, Location)
  - CAMI (Confirm FMS, Activate Mode, Monitor, Intervene)
  - PACE (Probe, Alert, Challenge, Emergency) (Structured intervention)
  - AMR (Action, Mode, Response)

- When referring to charts/checklists/QRH hold them in a position that facilitates the scanning of flight parameters
- The PF can put the A/C into a situation where it is unsafe but PM can stop it 'Never whisper when you know it's time to shout'.

PART 2

Monitoring for Trainers

2.1 What are the personal traits associated with monitoring competencies?

The traits and their characteristics relevant to good monitoring are:

- Conscientiousness
  - Disciplined approach
  - Rigorous
  - Reliable
  - Compliant with SOPs
  - Responsible
  - Judicious
  - Act dutifully in the execution of their task
- Vigilance
  - Sceptical
  - Distrustful
  - Suspicious
  - Alert
  - Watchful
  - Accurate
  - Conduct repetitive tasks effectively
- Assertiveness
  - Challenge
  - Probe
  - Intervene

2.2 Can selection tools discriminate a monitoring competency?

There are two main tools that are used by the airlines currently – PILAPT and COMPASS. They both have tests that focus on the ability of the candidate pilot to monitor and respond to stimuli under high workload conditions. They both relate to concurrent task management but PILAPT Deviation Indicator task (DI4) is more difficult than the COMPASS Task Manager. To a certain extent they should both be able to discriminate the potential to monitor under high workload conditions. However they do not cover vigilance and the ability to maintain the monitoring tasks during periods of low workload

ADAPT is another tool which is used to select pilots at all levels from ab-initio to TRE. It is different from PILAPT and COMPASS in that it is an immersive scenario based tool which includes all the usual metrics (spatial awareness, numeric reasoning, perceptual speed and accuracy etc). However it also includes specific monitoring skill related tests that examine selected and divided attention, scan pattern behaviour under pressure, concentration and focus, visual/auditory dominance and reaction to stimuli (looking without seeing and listening without hearing).

2.3 What observable behaviours relate to good monitoring?

There are different types of monitoring in the cockpit:

- Passive Monitoring (keep an eye on, maintain regular surveillance, listen to) e.g. maintaining selective radial scan;
- Active Monitoring (cross check, oversee, report on) – relates to all monitoring tasks where a call out is required;
- Periodic Monitoring (check over a period of time) – e.g. fuel consumption check;
- Mutual Monitoring (watch over) – where an action is carried out by one crew member and cross checked by the other; and
- Predictive Monitoring (advise, urge)- mentally flying the aircraft and predicting deviations.

A comprehensive classification is contained in Annex C.

The monitoring behavioural markers reside within four of the existing and widely accepted non technical skills (NOTECHS) as follows.

Situation Awareness

- Active monitoring behaviour (equivalent to SA level of noting):
  - Making the calls as required by the SOPs;
    - e.g. V1,ROTATE, POSITIVE CLIMB, FLAP Checks, 1 to go etc
  - Cross checking other crew member's actions.
  - Risk aware – heightened alertness in hazardous situations and verbalising observations (e.g. traffic, terrain or weather); and
  - Checking state of other crew member (expression of concern).
- Mutual monitoring behaviour (equivalent to SA level of understanding):
  - Pointing to changes of flight path parameters on autopilot control panel prior to selection (speed, heading height, vertical speed);
  - Cross checking altimeters; and
  - Cross checking charts.
- Predictive monitoring behaviour (equivalent to SA level of predicting);
  - Advising on deviations from flight path, flight path parameters etc.

Leadership/Teamwork/Briefings

- 'Monitor me' type requests from captain to promote good monitoring and interventions.
- Identification of risk and provision of intent in the briefing in terms of aspects of the plan that need to be actively monitored.
- Shared mental model – agreeing changes to the plan.
- Mental model repairs – noticing when the PM has been pre-occupied and providing a sit rep, advising if not going to plan and outline resolutions.
- Requests for monitoring – 'remind me if I haven't carried out the After Take Off checklist' or ' Remind me of the MSA'.
- Encourage shared vulnerabilities that may hamper monitoring – tiredness, stress, illness e.g. I am feeling tired.

Workload Management

- Inform PF when completely focused on one task and no longer monitoring (e.g. when completing QRH drill).
- Manages distractions (e.g. ATC calls).
- Maintains concentration and scan(e.g. repetitive checklists, periods of inactivity).
- Ability to switch attention between multiple sources of information (e.g. take-off, engine parameters, speed, acceleration).
- Ability to prioritise and shed non-essential monitoring tasks.

Communication

- Requests clarification to support monitoring task (e.g. when distracted or reduced spare capacity).
- Verbalises observations in a calm and concise manner (avoid startling or distracting PF).
- Listens and follows instructions.

2.4 How do you train monitoring skills?

Impart monitoring knowledge

Part 1 of this guidance material is intended to provide a foundation of knowledge relating to monitoring in terms of what it is, why it is so important and how human vulnerabilities/stressors can impact upon monitoring lapses. Therefore the intention would be for this guidance material to form part of the reference material used during ab-initio training and reinforced throughout recurrent training.

Through CRM training

During the CRM training, emphasis should be placed on how behaviours that reflect good monitoring are integrated within existing NOTECHS as described previously in section 2.3. Table 2 summarises the respective skills and behavioural markers.

Table 2: Behavioural markers pertinent to monitoring ability

Non-Technical Skill	Positive Markers	Negative Markers
Situation Awareness Ability to use monitoring skills to maintain high levels of situation awareness at all times	Actively monitors the flight path, configuration, system states and external environment and responds in accordance with SOPs. Advises the PF of any deviations from the agreed plan Cross checks the other crew member's actions. Is risk aware and maintains heightened levels of alertness in hazardous situations	Unaware of system state, poor at adherence to SOPs, inability to recognise or predict deviations from the agreed flight path, lack of appreciation of hazardous external environment or implications of system malfunctions
Leadership/Teamwork/ Briefings Ability to promote good monitoring culture in the cockpit and maintain high levels of shared situation awareness	Pro-active in the encouragement of monitoring, identifies risks and hazards and specific monitoring countermeasures. Ensures a common understanding of the sector goals, is aware when the shared intent is flawed and takes steps to redress it. Encourages vulnerabilities that may impact monitoring to be shared	Briefings fail to compare or share mental models, do not consider the 'what if's. Fails to provide intent when deviating from plan

Non-Technical Skill	Positive Markers	Negative Markers
Workload Management Ability to ensure that monitoring performance is managed and effective at all times	Ability to manage interruptions and distractions and focus on monitoring tasks, prioritise and shed lower priority tasks. Be aware when monitoring is not taking place and advise PF. Sustain concentration levels and maintain scan	Easily distracted and has difficulty staying focused. Does not maintain attention/ vigilance during low workload periods. Cannot prioritise tasks and fails to recognise time implications. Unable to maintain scan, becomes fixated on particular instrument or display
Communication Ability to ensure that monitoring performance is not compromised by poor communication	Listens to instructions and requests clarification when required. Verbalises observations in a calm and concise manner	Does not listen carefully and commits erroneous instructions to memory. Uses inappropriate tone of voice in response to emergency situation

Through TEM training

Monitoring plays a powerful role as a countermeasure in TEM. Good monitoring will enable a pilot error (handling, procedural or communication) to be detected before it leads to an undesired aircraft state and to a potential unsafe outcome.

Anticipation of likely threats enables cross monitoring mitigation strategies to be put in place:

- weather (thunderstorms, turbulence, icing, wind shear, cross/tail winds etc.);
- ATC (traffic congestion etc.);
- airport (contaminated/short runway, contaminated taxiway etc);
- terrain (high ground, slope, etc);
- aircraft (MEL/Configuration Deviation List (CDL), system malfunction etc); and
- crew member error (misheard an instruction, misperceived an indication etc).

Thus these would form briefing topics both pre and during flight.

A recommended training exercise is to consider a monitoring lapse as the threat as shown in section 1.4. By considering all of the factors that contribute to a monitoring lapse the pilot can develop his/her own mitigation strategy.

Through practice

It goes without saying that the only effective way of developing monitoring skills is through flight exposure during simulator training and line flying. The monitoring is far more demanding for the PM when the PF is manually flying the aircraft mainly due to the likelihood of flight path and speed excursion compared with when the AP is managing the flight (assuming all the flight plan inputs have been cross monitored previously). Therefore manual flying is the best way to develop the predictive monitoring skills. The other monitoring skills (passive, active, periodic and mutual) relate mainly to SOP adherence which will improve with practice and feedback.

The instructors must ensure that:

- all monitoring/cross checking SOPs are followed;
- they are cross monitoring each other (ideally this will become a force of habit);
- there is a gap between the challenge and response to make sure that they have actually checked it (encourage them to say what they see);
- they are holding any checklist/chart/QRH in a position that facilitates continued monitoring (alternatively recognise when there is no spare capacity to carry on monitoring and encourage them to focus attention on QRH); and
- they have their seat at the design eye position so that they are able to monitor the required instruments, panels, displays and controls.

The old adage 'we all learn from our mistakes' is true and events which introduce failures that good monitoring should capture should be considered – see section 2.6.

2.5 How do you measure monitoring skills?

Having identified the observable behaviours it is possible to measure achievement of these either objectively or subjectively.

Objective measures

Objective metrics are generally

- reaction time;
- accuracy; and
- error rate.

There are some aspects of the monitoring skill that can be measured objectively particularly in the event of specific failures that good monitoring should capture.

Observation of their **active and mutual monitoring** will be possible and it will be evident when the following are carried out (or not carried out) by the PF/PM:

- significant changes in system status;
- changes in aircraft configuration;
- changes in automation modes;
- confirmed automation status and performance;
- modification to the autopilot and FMS;
- cross check QNH settings; and
- cross check charts.

Eye Tracking devices can be used to measure where the pilot is focusing his/her attention and gathering information. Dwell time and position can infer whether the pilot is monitoring instruments and displays appropriate to the task in hand (looking in the right place). But what it cannot do is ascertain how/whether the information is being processed and this can only be established by an outcome as discussed in 1.2 (How we monitor). However this is a very good training method to appreciate how, when and where monitoring breaks down.

Subjective measures

Subjective measures can be self rated (did he/she know what was going on) and can be captured during a detail by freezing the simulator in a timely manner (after the fault situation has developed and whilst it is still recoverable) and asking leading questions – some of these will be directly related to monitoring or lack of it and some will be related to systems knowledge e.g.:

- what has led to this situation;
- what has failed;
- what are the implications; and
- what are you going to do next (e.g. what are the required pitch/attitude and thrust settings).

Probing questions can be asked during debrief e.g.:

- What was the thrust EPR when additional thrust was requested?
- What was the final thrust EPR?
- What trim setting did you have on take-off?
- What was the wind speed and direction on landing?

Subjective assessment can also be carried out using the behavioural markers:

- Were they cross checking each other's actions?
- Did they verbalise observations under hazardous situations?
- Did PM advise on deviations from flight path?
- Did PF encourage monitoring during briefings (give examples)?
- Did PM manage interruptions and distractions (give examples)?
- Did PM routinely check the system status?

2.6 Which scenarios would be suitable to assess monitoring skills?

In order to establish whether the pilot is actively monitoring the flight path, systems and each other, it is suggested that deviations, excursions, errors or malfunctions that they should respond to be stimulated. This can be achieved by internal failures or external factors (e.g. tail wind, turbulence etc). Ideally the internal failures would be **subtle** i.e. are not announced by the internal warning systems.

The Line Oriented Flight Training (LOFT) sessions provide a good platform to exercise monitoring competencies and Annex E lists some suitable events.

The Flight Operations Research Centre of Excellence (FORCE) at Cranfield University investigated the application of auto flight failures that could only be identified by cross checking the flight path parameters against the automation modes (Human Factors Malfunctions 2009). The simulators would need to be modified to accommodate these types of failures but their application is effective in testing how diligently the pilots are monitoring the flight path. The failures were as follows:

- a failure to capture altitude (climb and descent);
- a failure to control to indicated speed target;
- a failure that presents an incorrect flight mode annunciation following autopilot mode selection;
- a failure to capture ILS LOC and/or Glideslope beams;
- a failure to engage pitch control on selection of TOGA on go-around i.e. power applied but no pitch-up;
- failure of thrust reduction to climb power on selection after take-off;
- autopilot drops out without warning;
- autothrust drops out without warning; and
- an instantaneous (over 1 second) speed gain of 10-30 kt due to wind shear.

Distractions and interruptions are important shaping factors and should be designed into the scenarios. **Distractions** would come in the form of changes to plan (diversions), use of complicated drills, traffic, terrain, weather etc. **Interruptions** would include interaction with Cabin Crew, ATC, ground control and Dispatchers.

PART 3

Monitoring for Aircraft Operators

3.1 How can FDM reporting support monitoring development?

The value of Flight Data Monitoring (FDM) is the continuous monitoring of the pilot workforce and for any deviations on normal flight parameters during normal operations. The main points can be found in simple listings of FDM data sets, such as flap over-speed events. (For further details see CAP 731[13]) These may be across the fleet or limited to airports with difficult terrain etc. The FDM monthly or quarterly output could be grouped for both levels of events and the basis for the criteria. Has something changed? Is there a new event or new major event that warrants action or consideration? Another example is high rates of descent that may or may not trigger the EGPWS but are demonstrating a trend or problem at a particular airport. (Geneva, Chambery, Innsbruck).

Establishing whether the training input and SOPs have adequately addressed the risk has always depended largely on an effective routine assessment of flight exceedances. However, the widespread adoption of FDM now provides an opportunity to configure data analysis software for a range of lesser 'precursor' events in which there has been an abnormal deviation from the expected. This ensures that the risk management is effective and modified if necessary. Design issues may become apparent and highlight areas of design which are error prone and where more focused training is required (e.g. low speed alert, issues with digital readouts, understanding of automation, etc.).

Sample FDM data listing related to monitoring lapses:

1. High Speed/ Low Speed and Unstable Approaches

- Approach Speed High (<1500ft <1000ft)
- MMO Exceeded
- High rate of descent (1000 to 500ft, 1500 to 1000ft, below 500ft)
- Speed Low at Touch Down, Approach Speed Low (<1000ft) (<500ft)
- Climb out speed low

13 CAA Publication: Approval, Operational Serviceability and Readout of Flight Data Recorder Systems and Cockpit Voice Recorders

2. Excess Pitch Rate or Bank Incidents
   - Abnormal Pitch (High) (Low)
   - Bank Angle on Approach (100 – 500ft) (below 100ft)
   - Bank Angle on Take Off (100 – 500ft) (below 100ft)
   - Excessive Bank on landing (below Flare Ht)
   - Excessive Bank on takeoff (<1000ft) (<500ft) (<50ft)
   - Excessive bank on approach (<500ft) (<50ft)
3. Gear Down Speed incidents
   - Gear Down Excess Speed, Gear Extension Speed Exceeded
4. Configuration Warnings and Flap Placard Speed Exceeded
   - Flap before gear
   - Late gear, below 1000ft
   - Early configuration change after take-off (height) (time)
   - Leading edge/trailing edge slats asymmetry, Disagree
   - Landing Configuration Gear Warning
   - Late Gear Retraction
   - Late land flap (height above Above Aerodrome Level (AAL))
5. Displacement from runway centreline,
   - Displacement of 20ft and 50ft from below 100ft to touchdown.
   - Excess deviation, set to a company limit(e.g. > 50ft) below 500ft
6. Altitude Bust
7. Engine or Propeller Thrust and minimum thrust levels on approach
8. GPWS Activations
   - GPWS (DONT SINK), GPWS (SINK RATE)
   - GPWS (GLIDESLOPE)
   - GPWS (PULL UP), (TERRAIN PULL UP)
   - GPWS (TERRAIN)

- GPWS (TOO LOW FLAPS), (TOO LOW GEAR)
- GPWS (TOO LOW TERRAIN)
- GPWS (WINDSHEAR)

9. Fuel contents or settings

- Minimum departure fuel, or final shut down fuel
- Maximum pitch angle with low fuel states

3.2 What classification is recommended for ASR monitoring capture?

A company attitude with a just culture is essential to obtain timely and adequate reporting. In this way Air Safety Reports (ASR) would demonstrate possible lapses or operating issues before the situation could develop into a flight safety risk. In the real world, all humans may err but by working together and honestly reporting latent problems, Flight Safety is increased. Consider the following from CAP 719[14].

Failures to monitor the profile or latent failures. As aircraft systems are so completely reliable and double or triple redundant, complacency is a consequence. However, crew diligence is still needed to confirm that the profile is actually achieved. "Crew co-ordination is the advantage of team work over a collection of highly skilled individuals." (CAP 719 Chapter 3.3.4).

ASR publicity for pilot awareness

In incidents involving a lack of monitoring, comparisons may be drawn from normal operations. Then Company prompts may be issued, to obtain ASR feedback on some areas, thus raising pilot awareness of the pitfalls, before they happen. For example:

- inappropriate response to an un-commanded autopilot disconnect at high altitudes;
- indicated airspeed is unintentionally allowed to deviate from the target;
- approach weather hazards, e.g. frozen deposits on the wings;
- mishandling during a go around;

14 CAA Publication: Fundamental Human Factors Concepts

- insufficient understanding of automation flight envelope protection systems; and
- improper slats/flaps configuration.

As discussed in previous sections, monitoring lapses have many latent causes. This may be addressed by improved training and promoting an awareness campaign from the feedback and details of the ASR data, which could include a classification of causal factors.

ASR monitoring causal factor classification

- Inadequate knowledge of or failure to understand the rule, procedure or action.
- Insufficient emphasis on strict adherence to SOPs during transition and recurrent training.
- Insufficient vigilance (i.e., tiredness).
- Distractions (e.g., due to intra-cockpit activity).
- Interruptions (e.g., due to ATC communication).
- Task saturation (i.e., degraded multi-tasking ability or task overload).
- Incorrect management of priorities.
- Reduced attention (tunnel vision) in abnormal or high-workload conditions.
- Incorrect Crew Resource management (CRM) techniques (e.g., absence of cross-checking, crew co-ordination or effective backup).
- Inattention.
- Overconfidence.

3.3 What SOP attributes would promote good monitoring?

The setting and maintenance of good safe operating polices should be at the heart of every operation. Therefore the review and crew allegiance to company SOP's is essential. With modern operating procedures almost all aspects of SOP constraints have a direct relationship with the utilization of the aircraft and crew behaviour.

"The need for standardisation and simplification of all aspects of operation of two-person crew automated aircraft should be given a high priority. Standardisation is one of the foundations of safety, and its importance has been accentuated by the appearance of aircraft leasing organisations, airline mergers, consolidations, etc. Flight crews may be faced with different names for the same item, different procedures to operate the same systems, different symbology to display the same information, and all of this often under demanding conditions." (Cap 737[15]).

In normal operations, technical mitigations include stall warning devices and highly reliable flight envelope protection systems. However, the reduction of risk from unwanted flight conditions, such as a stall, generally lie in the area of flight training – in both the classroom and the full flight simulator – and in the application of appropriate SOPs. Therefore, the consideration of good SOP's should contain the basic elements for crew action. Such as:

- **triggers**: Events or actions initiating groups of actions (called action-blocks);
- **action blocks**: Groups of actions being accomplished in sequence as a group;
- **action patterns**: Cockpit panel scanning sequences or patterns supporting the flow and sequence of action blocks; and
- **standard calls**: Standard phraseology and terms used for effective intra-crew communication.

(CAP 737 Appendix 8)

However triggers are only effective if they are consistently present as you may become reliant upon them to initiate other actions. For example if the trigger to carry out the approach checklist is receipt of QNH from ATC (which in turn is a trigger to set and check QNH altimeters) then lack of ATC communication could result in the checklist not being carried out and the subsequent failure to update QNH (which is one of the checks within the Approach Checklist).

The company SOPs should accurately define the options and strategies selected by the commerical air transport operator for the various flight phases and for the various types of approaches. Subsequently the SOP should include the required monitoring aspects of each phase of flight operations, including:

- departure;
- en-route climb/cruise/descent;
- terminal area; and
- approach and landing.

15 CAA Publication: Crew Resource Management (CRM) Training

Therefore, for each phase or check points where an SOP is required, the following list of essentials should be included:

- task sharing (i.e., who-should-do-what);
- standards calls (i.e., what-to-expect, what-to-observe);
- use of normal checklists;
- approach and go-around briefings;
- altimeter setting and cross-check procedures;
- use of radio altimeter;
- profile management and energy management;
- threats and hazards awareness;
- terrain awareness;
- elements of a stabilised approach and approach gates;
- approach procedures and techniques for various types of approaches;
- landing and braking techniques for various types of runway and wind conditions; and
- readiness and commitment to go-around (e.g. GPWS warning, un-stabilised approach, bounce recovery).

Once the essentials of the SOP framework are established, then the crew monitoring procedures and principles would be included as the CRM and monitoring needs of the crew. Both pilots should be advised to "back each other up", monitor the aircraft's flight path, with encouragement to "communicate". Therefore the SOP would be elaborated to include the following principles:

- monitoring the PF to provide effective cross-check and backup, as required (i.e. standard calls and excessive deviation callouts e.g. SPEED MINUS 15);
- the PM-pilot should inquire about all actions that are not understood or considered inappropriate;
- monitor the AP/FD/ATHR modes and engagement status on the FMA;
- monitor the result of any target selection performed on the autopilot control panel, on the related scales of the PFD;
- monitor the AP/FD/ATHR resulting guidance, on the basic flight instrument scales of the PFD; and

- monitor Minimum Safe Altitude (MSA) or minimum vectoring altitude.

Data entry pre-flight and flight profile adjustments or route changes should be cross monitored as part of the SOP process and awareness made of the possible errors. Many FMS/Autopilot systems require a set order of input in order to follow the required profile. It is essential that these inputs are not rushed and are monitored by PM and PF in order to verify the response.

A set of generic monitoring procedures that have been derived from various type specific SOPs are contained in Annex D.

3.4 How can briefings promote good monitoring?

A structured and interactive briefing fulfils two important goals:

1. It provides the crew with an opportunity to:
    - share a common action plan; and
    - set priorities and share tasks – possibly mentally rehearse forthcoming monitoring tasks.
2. It helps achieve effective teamwork – requiring the optimum use of:
    - communication skills; and
    - monitoring skills.

When briefing, the brief should both confirm the intentions for the phase of flight and provide questioning in order to confirm that the proposed plan is adequately understood. Make the briefing interesting, informative and concentrate on the salient points and use aide memoires.

Suggested good briefing attributes:

- brief and succinct;
- understand information overload, not too many numbers – especially if printed on the plates;
- normal or emergency actions keep to the facts, emphasise slowly and clearly;
- emergency briefs may benefit from a touch drill;
- be aware of crew status and level of concentration which can lead to poor monitoring, for example – low workload/boredom, complacency, tiredness, distraction, high workload, etc;

- routine and formal repetition of the same facts may become counterproductive. Adapt by highlighting the priorities and/or the actual weather conditions and possible problems (good TEM);
- consider what is different today and encourage interaction and questions; and
- brief the plan for energy management with altitudes and minimum approach gates.

During the approach profile, be aware of any degraded situation awareness due to re programming the FMS and the posibility of 'Monitoring Lapses' (both pilots head down). Good monitoring includes maintaining an awareness of overload, not only in yourself but notice it in the other crewmember. The predominant cues are concentration for long periods on one task, lack of speech, possible slowness to respond etc. If re-planning is required, plan and accept whether it is a long term or short term change or is more time and attention required:

- short-term task (i.e., tactical choice, short and head-up action(s) on autopilot panel, immediate aircraft response); or
- long-term task (i.e., strategic choice, longer and head-down action(s) on FMS, longer term aircraft response).

Be aware of any lapses caused by excess re-programming.

- **Degraded situational awareness due to excess re-programming.** This could be due to distractions such as changes to plan, requests from ATC, runway change, especially below 10,000 ft. in the approach. Clear communication is required so that someone is monitoring the aircraft. Additionally, clear direction is required to confirm whether the PM is re-programming followed by a clear statement that PF is flying the aircraft. (CAP 719 Ch2. Paragraph 2.1-g, h).
- **Insufficient monitoring and communication**. It is essential that entries are not only cross-checked between the crewmembers but are correctly set into the systems. Similarly, the autopilot and FMS systems may have similar selections but different responses. Thus all selections for autopilot and FMC must be cross-checked and then re-check from the response that the desired input was actually achieved (CAP 719 Ch 3. Para 3.3.3).

Finally, briefings should attract the attention of the PM. They should help both the PF (giving the briefing) and the PM (receiving and acknowledging the briefing) to understand the sequence of events and actions, the safety key points, specific threats/hazards. So brief what is pertinent.

Further Reading

The following list of books and papers contain material that are pertinent to monitoring issues and were consulted in the production of this guidance material.

Papers

Title	Author	Year
Checklists and Monitoring in the Cockpit: Why crucial defenses sometimes fail http://humanfactors.arc.nasa.gov/ihs/flightcognition/Publications/NASA-TM-2010-216396.pdf	Dr R Key Dismukes NASA Ames Research Centre Ben Berman San Jose state University Foundation	2010
Workload – Summary paper presented at CAA RETRE Seminar http://www.caa.co.uk/docs/33/srg_l&ts_RETRESeminar5_6Oct10_.pdf	Dr Steve Jarvis	2010
Aeroplane Upset Recovery Training	Specialist Paper RAES	2009
A study to develop a new methodology for automation training for a modern highly automated transport aircraft	Captain Simon Wood CAA Flight Operations Research Centre of Excellence	2005
TEM in Flight Operations http://www.skybrary.aero/index.php/TEM_in_Flight_Operations	Captain Dan Maurino	2003
Concurrent Demands in the cockpit Challenges and vulnerabilities in routine flight operations http://www.interruptions.net/literature/Loukopoulos-ISAP03.pdf	Dr Loukia D Loukopoulos NASA Ames Research Centre Dr R Key Dismukes NASA Ames Research Centre Dr Immanuel Barshi NASA Ames Research Centre	2002

Title	Author	Year
Enhancing Crew Monitoring Skills can increase Flight Safety http://human-factors.arc.nasa.gov/flightcognition/Publications/Holbrookcopy.pdf	Captain Robert L Sumwalt Airline Pilots Association Captain Ronald J Thomas US Airways Key Dismukes NASA Ames Research Centre	2001
Analysis of Pilots' Monitoring and Performance on an automated Flight Deck http://www.humanfactors.illinois.edu/Reports%26PapersPDFs/isap01/starter.pdf	Dr Randall Mumaw Boeing Commercial Airplanes Dr Nadine B Starter, Ohio State University Dr Christopher Wickens University of Illinois	

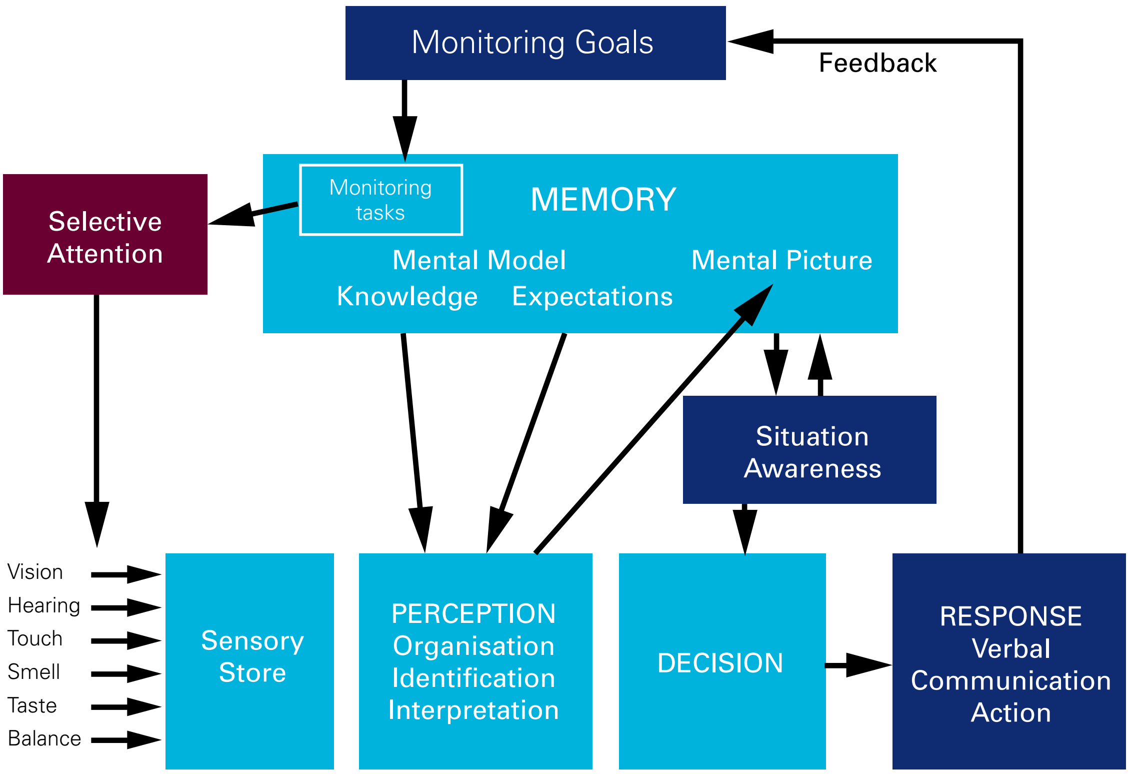
Reference Books

Title	Author	Year
Cockpit Engineering	D.N Jarrett	2005
Human Factors in Multi-Crew Flight Operations	Harry W. Orlady Linda M Orlady	1999
Human Factors for Pilots	Roger G Green, Helen Muir, Melanie James, David Gradwell, Roger L green,	1996
Human Performance and Limitations	Trevor Thom	1992
Engineering Psychology and Human Performance	Christopher D Wickens	1992
Human Performance and Limitations in Aviation	R D Cambell M Bagshaw	1991
Human factors in Aviation	Earl L Wiener, David C Nagal	1988
Human Factors in Flight	Frank Hawkins	1987

ANNEX A

How we monitor – Information Processing Model

Figure 4: Information processing model relating to monitoring process



The trigger for monitoring will always be purpose driven by the need to satisfy an information/decision requirement (e.g. height requirement on Non Precision Approach). **Monitoring Goals** as shown in the figure relate to the execution of monitoring tasks contained in SOPs (e.g. Non Precision Approaches), monitoring checks against plans/basic flight operation (e.g. monitor height and speed on approach) across the phases of flight, cross monitoring other pilot's actions and monitoring communication channels.

Thus, in pursuit of the goal, the pilot will activate the relevant **monitoring tasks** that reside within the long term memory. Monitoring tasks are similar to encoded computer subroutines determining when and where to look, listen etc. When these tasks are well rehearsed and very familiar the response will be carried out subconsciously and monitoring tasks like instrument scanning should become habitual. Conscious control is more likely to occur when the monitoring task relates to a predictive activity e.g. in the NPA example 'is the vertical speed too excessive to achieve the height capture'.

The monitoring task will focus **selective attention** on the specific information source (e.g. the PFD for height readout and VOR/DME panel for distance in the NPA example) which will stimulate the respective senses to transmit the responses via the **sensory stores** (e.g. in this case a visual task). The brain **perceives** the sensory responses within the short term memory and interprets the context of the input via **knowledge** stored in **the long term memory** (e.g. NPA requirements). Within the working memory the processed input is compared against the **expected** value/mode contained within the **mental model** associated with the **knowledge** of the systems, flight plan and expected actions in the case of the other crew member. A comparison of the mental model and mental picture updates the **situation awareness** state and allows **decisions** to be made. In the NPA example this would result in advice on height deviations from required flight path. The PF will monitor the outcome of any flight path corrective action and the PM will continue to monitor PF actions and repeat the NPA monitoring task in accordance with the NPA goals as specified on the approach charts.

Invariably the decision process is not dependant on a single source of information and rapid selective attention switching (visual and/or auditory modes) can occur (e.g. on take-off engine state and speed sampling is carried out whilst monitoring communications channels). This is frequently referred to as 'multi-tasking' and can be effective over a short period of time but over a longer period the continual brain re-focus will become error prone.

When the visual and auditory channels are stimulated at the same time depending upon the type of auditory input (a system warning, intercom, or verbal communication from co-pilot/ATC) the pilot will either transfer attention to deal with the warning or divide attention between listening to the input and keeping an eye on the readout on the display or instrument. When attentional resource capacity becomes limited **prioritisation** of the monitoring task is essential which will be enabled through training and experience.

ANNEX B

Root Cause Analysis

Table 3: Root causal analysis

Condition/Effect	Causal Factors	Root Cause	Mitigation
Complacency ▪ Over familiarity/over reliance with high integrity systems that rarely fail ▪ Feeling of well being and unaware of a developing situation	Personal ▪ Experience (never failed before) ▪ Attitude (self satisfied) Psychological ▪ Trust Physical ▪ Lack of oxygen (hypoxia can result in a feeling of euphoria) Aircraft ▪ System Reliability (high) ▪ Long haul routes ▪ Route familiarity	High level of trust caused by lack of exposure to failure of high integrity systems	1. During LOFT assessments include subtle system failures that demonstrate possible areas of system weakness and encourage monitoring

Condition/Effect	Causal Factors	Root Cause	Mitigation
Limited Attentional Resource ▪ Reduced capability to carry out the monitoring tasks required	Personal ▪ Workload Pressure (time required to carry out tasks exceeds time available) ▪ Experience (novel situation to deal with – higher attentional demand) ▪ Competency (limited skill in dealing with situation in timely fashion and/or system knowledge) Psychological ▪ Anxiety ▪ Emotional stress Physical stressors ▪ In general all the physical stressors (temperature, noise, vibration, humidity, time of day, lack of oxygen) could result in performance degradation and reduced capacity Aircraft ▪ System Malfunction (increase workload to deal with problem)	High workload is the most likely root cause that reduces the mental capacity to carry out all the monitoring tasks	1. The monitoring tasks must be prioritised and the lower priority monitoring tasks need to be shared/shed. 2. SOPs could identify the highest priority monitoring tasks across the phases of flight 3. Exposure to high workload situations will be required to practice and develop monitoring task shedding strategies 4. If the non-monitoring task (e.g. QRH) takes all attention then inform the PF (ideally the PF will already be aware of high workload situation)

Condition/Effect	Causal Factors	Root Cause	Mitigation
	Commercial Air Transport Operator ▪ Lack of prioritisation guidance in SOP to deal with overload ▪ Lack of exposure during training to task overload situations to provide experience and hone multi-tasking skill External Environment ▪ Dealing with adversity in any situation e.g. low visibility, high terrain, limited navigational aids places high demands on both pilots thereby reducing their spare capacity to carry out all monitoring tasks		

Condition/Effect	Causal Factors	Root Cause	Mitigation
Confusion (Loss of Situation Awareness) ▪ Lack of understanding of what is going on ▪ Inability to predict what is going to happen (mode changes, system implications, System interactions, aircraft response) ▪ Inability to focus attention on the right information source	Physiological ▪ Sleep Inertia (difficulty in carrying out tasks immediately after waking up) ▪ Visual Conflict ▪ Disorientation Personal ▪ Workload (e.g. when attention completely focused on resolving system problem) Psychological ▪ Cultural Inhibition (to request information, intervene, inform) Aircraft ▪ Poor crew briefing (pre- flight and during flight) resulting in the situation where the co-pilot is not fully aware of the overall plan ▪ Lack of communication between pilots resulting in one of the pilots being out of the loop ▪ Poor design Organisation Training (lack of knowledge) Environment ▪ Unfamiliarity ▪ Low visibility	A monitoring lapse can cause loss of SA therefore to address the root causes of the effect of SA on the monitoring lapse it is more likely to be due to workload management and crew communication	1. Training in metacognition (knowing what you know and don't know and similarly for your crew member – what he or she knows or doesn't know) 2. Recognising loss of SA and repairing it through situation updates to bring them back into the loop again 3. Ensuring briefings are adequate to reduce the likelihood of loss of SA

Condition/Effect	Causal Factors	Root Cause	Mitigation
Fatigue ▪ Progressive decline in attention ▪ Decreased level of consciousness	Physical Stressors ▪ In general all the physical stressors (temperature, noise, vibration, humidity, time of day, lack of oxygen) could result in tiredness Physiological ▪ Lack of sleep ▪ Circadian disruption ▪ Prolonged period of wakefulness Psychological ▪ Fear ▪ Anxiety ▪ Motivation ▪ Emotional Stress Personal ▪ Workload/effort Commercial Air Transport Operator ▪ Demanding Schedules resulting in long periods of wakefulness	The most likely root cause of tiredness will be related to rostering and sleep management. Long haul flights may pose problems due to multiple time zones and night time flights. Also long haul back to back flights may result in long rosters causing significant sleep debt.	1. Acknowledge tiredness for crew member to self manage rest periods 2. Recognise and compensate for low levels of arousal due to tiredness (self and crew member) 3. Maintain stimulation through passive, active periodic and predictive monitoring 4. Schedule rosters to minimize sleep deprivation 5. Plan pre-flight rest accordingly

Condition/Effect	Causal Factors	Root Cause	Mitigation
Low Arousal Level ▪ Low level of attention capability normally due to task inactivity ▪ Can be related to boredom and tiredness	Physical stressors ▪ Temperature, time of day Physiological ▪ Lack of sleep ▪ Circadian disruption ▪ Prolonged period of wakefulness Psychological ▪ Motivation (low) Personal ▪ Workload (low) Aircraft ▪ Long haul routes ▪ Route familiarity	Lack of stimulation due to cruise phase or over familiarity	1. Provide stimulation through passive, active periodic and predictive monitoring
Disorientation ▪ Cognitive disability whereby the senses of time, direction and recognition of situation becomes difficult to distinguish	Physiological ▪ Visual illusion caused by conflict between visual, vestibular and proprioceptive mechanism Design ▪ Principle of the moving part – a moving reference against a fixed aircraft can cause disorientation Weather Conditions ▪ Poor visibility causing loss of visual cues/reference	Eye/brain interpretation of spatial position	1. Always monitor/ cross check flight instruments 2. Conduct upset recovery and disorientation training

Condition/Effect	Causal Factors	Root Cause	Mitigation
Distraction ▪ Divided attention from the current attention focus to the distraction source ▪ Mental distraction – day dreaming	Psychological ▪ Anxiety ▪ Emotional stress Personal ▪ Motivation System Malfunction ATC interruption Cabin Crew interruption	Lack of ability to maintain focus on primary task	1. Discipline in prioritising task demands 2. Develop multi tasking ability through practice (e.g. doing drills and keeping an eye on flight parameters) or use of commercially available Selection software tools (PILAPT, ADEPT, COMPASS)

ANNEX C
Classification of Monitoring Types

Definition of Monitor

As a transitive verb it means to watch, to oversee, to police, to scan, to cross-check, to keep track of or to check usually for a special purpose.

As a noun a Monitor is defined as one that admonishes, cautions or reminds, especially with respect to matters of conduct (Merriam-Webster Dictionary), overseer, watchdog, supervisor, observer, advisor (Roget Thesuarus), a person or device that monitors something, to observe and check over a period of time, to maintain regular surveillance over, to listen to and report on (Oxford English Dictionary)

The different types of monitoring in the cockpit can be classified as follows:

Passive Monitoring (keep an eye on, maintain regular surveillance, listen to): maintaining a scan of the instruments/displays related to the aircraft attitude, power, performance and position and vary according to the phase of flight. Routine check of autopilot modes and auto throttle modes, engine display, flight progress, attending to communication requirements

Active Monitoring (cross check, oversee, report on): relates to all monitoring tasks where a call out is required and also includes cross checks of for example:

- engine instruments;
- flight parameters;
- A/C configurations (operation and confirmation of indications);
- FMA modes;
- cross check flight path parameters against selected FMS parameters;
- cross check navigation accuracies; and
- check condition of other crew member (look for signs of stress, tiredness).

Cross check other crew members actions (particularly related to guarded switches).

Periodic Monitoring (check over a period of time): carrying out a check every pre-defined time interval, such as the aircraft state for example:

- pressurization;
- anti-icing;
- engine instruments, oil temperature etc;
- hydraulic pressure/contents;
- cabin temperature;
- fuel; and
- radio/ATC checks.

Mutual Monitoring (cross check, watch over, oversee, report on): where an action is carried out by one crew member and cross-checked by the other for example:

- altimeter changes;
- use of charts;
- AP Flight modes; and
- FMS changes.

Predictive Monitoring (advise, urge): comparing flight path parameters against known tolerances – equivalent to mentally flying the aircraft and advising on deviations. Advising on confirmation of acceptable criteria (speed, bank, vertical speed, configuration).

ANNEX D

Generic Monitoring Procedures across Phases of Flight

The following table has been derived from various type specific SOPs where the monitoring tasks are implicit rather than stated.

The first 5 procedures at the beginning of the table are considered to be high priority monitoring tasks occurring across multipl e phases of flight.

The remainder of the table comprises examples of monitoring tasks across all phases of flight. It also includes their classification into type based upon the classification contained in Annex C.

Table 4: Generic monitoring procedures across flight phases

Phase of Flight	Action	Monitoring Type	Monitoring Activity
MULTIPLE PHASES OF FLIGHT – Priority monitoring procedures			
	Adherence to Minimum Safe Altitudes	Predictive	Monitor the aircraft altitude relative to the MSAs shown on PLOG or other flight plan – alert PF to any perceived hazard Advise PF when high MSAs are active and the duration of the period

Phase of Flight	Action	Monitoring Type	Monitoring Activity
	Adherence to ATC cleared altitudes/flight levels climb or descent	Predictive	The approach to cleared altitudes must be monitored and may for example be called at "1" to go when 1000 ft from the appropriate altitude If the AP fails to capture the altitude alert the PF
	AP monitoring	Active	All changes to the AP modes and auto throttle modes must be monitored on FMAs and basic flight instruments and announced The effect on the flight path must be cross monitored on basic flight instruments (heading, speed, altitude, vertical speed (VS), Flight path Angle (FPA))
	Speed and pitch monitoring	Predictive	PM should closely monitor IAS/Mach No and attitude reference and call SPEED, SPEED or PITCH, PITCH when significant sustained deviations occur

Phase of Flight	Action	Monitoring Type	Monitoring Activity
	Crew Monitoring	Active	Monitor co-pilot for any signs of tiredness or stress Adherence to SOPs Guarded switch operations
PRE-START			
Before Start Check List – Adhere to Challenge and Response			
	Select Auxiliary Power Unit (APU) Master Switch	Active	Monitor APU
	Communicate with ATC	Active	Obtain take-off time, runway and clearance etc
	Check plates and charts	Mutual	Check Plates and charts are the same
	Enter Flight Plan	Active	Cross Check Flight Plan with computer flight plan etc
	Enter cleared altitude	Active	Check Altitude setting
	Enter Performance data	Active	Gross error check – Fuel at destination is as expected, route distance etc
	Enter take-off data and configuration	Active	Cross check speed, configuration, thrust setting etc

Phase of Flight	Action	Monitoring Type	Monitoring Activity
	Start Engines and allow engines to stabilise	Active	Monitor increase in N2, oil pressure, igniter, fuel flow, Exhaust Gas Temperature (EGT), and N1. When Start accomplished, call STABLE
After Start Checklist – Adhere to Challenge and Response			
	Engine mode to NORMAL	Active	Monitor Engine Mode
	Set Trim	Active	Monitor Trim setting
	Set Flaps	Active	Monitor Flap setting
	Instrument and altimeter checks	Active/Mutual	Check V Speed correct Flight Director (FD) set to ON Cross check PFD altimeters for QNH Check selected altitude and headings Check standby altimeter for QNH, altitude and acceleration etc
	Nav Display	Active	Terrain or weather data etc
Taxi checklist – adhere to Challenge and Response			
	Obtain Taxi Clearance	Mutual	Monitor charts etc

Phase of Flight	Action	Monitoring Type	Monitoring Activity
	Taxi to departure runway	Predictive	Monitor external view for obstructions, Monitor speed and verbalises deviations, Adhere to ground control instructions
Take-off Checklist – adhere to Challenge and Response			
	Complete take-off checklist	Active/Mutual	Cross check configuration and performance for take-off. NAV required
	Select TOGA	Active	Monitor Engine display and speed – when 80kt call THRUST SET
	Initiate climb	Predictive	Monitor speed and Call V1 and ROTATE, confirm PF initiates rotation Monitor PF and in case of incapacitation take control of aircraft

Phase of Flight	Action	Monitoring Type	Monitoring Activity
	Rotate aircraft toward climb attitude	Predictive	Monitor attitude using different horizon indicator to that used by PF If pitch attitude too high call PITCH, PITCH. If bank attitude too great call BANK, BANK Monitor initial climb speed by reference to Airspeed Indicator (ASI) If speed discrepancy in accordance with SOP call SPEED,SPEED Monitor positive climb on altimeters and call POSITIVE CLIMB
	Call for GEAR UP	Active	Select GEAR UP. Monitor gear light selection for transit and then gear up doors closed etc
	Call for FLAP on speed schedule	Active	Monitor speed/flap retraction schedule

Phase of Flight	Action	Monitoring Type	Monitoring Activity
CLIMB			
	Select Climb thrust	Active	Selection and monitor activation of auto-thrust modes. Monitor and selection of thrust modes. Call FMA Monitor flight path parameters, speed trends Monitor terrain, Monitor EGPWS etc
	Select Climb mode	Active	Monitor appropriate climb mode and selection Call FMA
	Select cleared Altitude	Active	Communicate with ATC, Monitor clearance
	Select Navigation mode	Passive	Monitor Nav Display VOR, GPS etc
After Take-off Checklist – adhere to challenge and response			
	Select Cruise FL	Active	Monitor and confirm selection
	Maintain awareness of terrain and traffic	Passive	Monitor PFD for Resolution Advisory/ Traffic Advisory (RA/TA) Select weather map and monitor weather conditions ahead PF monitoring terrain

Phase of Flight	Action	Monitoring Type	Monitoring Activity
	Respond to ATC route modifications	Active	Monitor Nav Display VOR, Global Positioning System (GPS) etc
	Call for FL 100 check	Active	Monitor Pressurisation, landing lights off Cross check navigation accuracy etc
CRUISE			
	Checks pressurisation, hydraulic pressure/ quantities, Oxygen contents, Cabin temperatures etc	Periodic	Monitors/checks aircraft systems every 20 minutes
	Checks weather and facilities of en-route alternates	Active	Monitors flight path parameters whilst retrieving weather data
	Selects and maintains optimum speed	Active	Monitors and cross checks speed Monitor auto thrust mode etc
	Selects and maintains optimum cruise flight level	Active	monitors FMA Monitors and cross checks altimeters Cross checks optimum altitude etc

Phase of Flight	Action	Monitoring Type	Monitoring Activity
	Monitors and controls fuel status	Periodic	Monitors fuel Monitor Fuel Temperature Cross check fuel consumption with Computer Flight Plan (CFP) every 30 minutes Monitor fuel balance etc
	Monitor en-route weather and conditions	Active	Monitor windspeed and temperatures and cross check inputs against waypoints Monitor and adjust radar tilt Monitor weather patterns etc
	Monitor Navigation accuracy	Active	Monitor and cross check navigation sources etc
	Monitor Flight Progress	Passive	Monitor track and distance to next waypoint when overflying waypoint etc
	Monitor communications	Predictive	Monitor comms channels set on radios etc

Phase of Flight	Action	Monitoring Type	Monitoring Activity
Conduct Descent Brief			
DESCENT PREPARATION (for destination and diversion airfields)			
	Check fuel and landing weight and distances required	Active	Monitor the aircraft status compatibility with airfield etc
	Select appropriate approach/ missed approach charts	Mutual	Cross check PF and PM charts Check NOTAMS etc
	Enter STAR and final approach	Active	Monitor correct Standard Terminal arrival Route (STAR) and runway etc
	Establish Top of descent waypoint, Final Approach Fix, speed and altitude constraints	Active	Monitor correct speed and altitude gates for profile Monitor accuracy of Top of Descent (TOD) waypoint Monitor accuracy for Final Approach Fix (FAF) waypoint etc
Conduct Approach Brief			
	Set destination QNH	Mutual	Monitor correct QNH is set on standby altimeter
	Establish MSA/ DA/DH	Mutual	Monitor/check that correct altitudes have been set on route/legs etc
	tune appropriate VOR/DME	Mutual	Monitor/check correct VOR/DME etc

Phase of Flight	Action	Monitoring Type	Monitoring Activity
	Set VREF and speed bugs	Mutual	Monitor/check Reference Speed (VREF) setting etc
	Set auto brake settings	Mutual	Monitor brake setting etc
Conduct Descent Checklist – adhere to challenge and response			
DESCENT			
	Obtain ATC Flight Clearance	Active	Monitor and respond to every new altitude setting
	Select appropriate AP descent mode	Mutual	Monitor and respond to FMA selection etc
	At FL180 PF Calls for seatbelt sign ON and review MSA,	Predictive	Acknowledge MSA etc
	When directed by ATC Select appropriate AP descent speed	Mutual	Monitor descent speed etc
	When directed by ATC Select appropriate descent rate	Mutual	Monitor selected descent rate etc
	10,000 ft check	Active	Announce 10000ft, confirm pressurisation set for landing.
HOLD – if required			
	Programme and enter Holding pattern into FMS	Passive	Monitor flight path in hold etc

Phase of Flight	Action	Monitoring Type	Monitoring Activity
	Select Speed and configuration	Passive	Monitor speed etc
	Review fuel situation	Passive	Monitor/check fuel and predict time available in hold etc
	Establish diversion options	Passive	Review fuel required to land at specified diversion airfield etc
	Periodically and on leaving hold Monitor Systems	Passive	Monitor Fuel asymmetry Check fuel transfer switch set as required. Check fuel pumps Check hydraulics Check warning light panel Check icing conditions etc
APPROACH			
	Confirm QNH setting	Mutual	Monitor QNH setting Call Baro Ref, passing altitude, Autopilot Control Panel selected altitude and decision height etc
	Position command speed according to approach schedule	Mutual	Monitor speed and configuration setting etc

Phase of Flight	Action	Monitoring Type	Monitoring Activity
Conduct Approach checklist – adhere to Challenge and Response			
	When clearance height has been given by ATC activate Approach mode (if not activated automatically)	Mutual	Monitor approach mode selected Monitor Navigation accuracy and position Monitor altitude calling out thousands of ft to go to the selected clearance Monitor speed etc
	Select ILS	Mutual	Monitor selection made Verify ILS is tuned and identified etc
	Call LOCALISER ALIVE when appropriate	Mutual	Monitor FMA for localiser indication etc
	Verify LOC on FMA when localiser is captured	Active	Monitor FMA for localiser indication Monitor the ILS by reference of PFD raw data Monitor for deviation of 1 dot in the localiser or glideslope indication (Call LOCALISER or GLIDESLOPE) etc
	Call GLIDESLOPE ALIVE when appropriate	Active	Monitor FMA for Glideslope Monitor descent rate and if greater than 1500ft/min call SINK SINK

Phase of Flight	Action	Monitoring Type	Monitoring Activity
	Select Flaps	Mutual	Monitor speeds prior to flap selection
	Select Gear Down	Mutual	Monitor speed and call GEAR DOWN 3 GREENS when gear is down and locked
Complete Landing checklist – adhere to challenge and response			
	Achieve stabilised approach at 1000ft or 500ft	Predictive	Call SPEED if target IAS is +15kt or -5kt Call SINK RATE if V/S > 1000ft/min Call PITCH if pitch +10 deg/-2.5 deg Call BANK ANGLE if bank >7 deg
	Descend to Decision Altitude	Mutual	Call 100 feet to go to Decision Altitude (DA)
NON PRECISION APPROACH			
Brief lateral and vertical FPLAN against approach plates			
	Check Navigational accuracy	Predictive	Monitor GPS and VOR/DME etc.
	Check limitations	Mutual	Check any aircraft or approach limitations etc.
	Select lateral and vertical guidance mode	Predictive	Monitor NAV AID raw data Monitor FMA Monitor the FMS predictions for final approach point Monitor colour of arrow (airbus) etc

Phase of Flight	Action	Monitoring Type	Monitoring Activity
	Set speed constraint at FAF	Predictive	Monitor flight plan sequencing Monitor FMA etc
	Monitor descent	Predictive	Monitor altitude and distance etc
	Select HDG or TRK mode	Predictive	Monitor FMA and call selection monitor VDEV etc
	Select Flaps	Mutual	Monitor speeds prior to flap selection
	Select GEAR DOWN	Mutual	Monitor speed and call GEAR DOWN 3 GREENS when gear is down and locked
Complete Landing checklist – adhere to challenge and response			
	When MDA is reached monitor visual cues	Predictive	Continue to monitor visual cues and call MINIMUM at Minimum Descent Altitude (MDA) Monitor altitude etc
	Check Navigational accuracy	Predictive	Monitor GPS and VOR/DME
	Disconnect AP and set FD off BIRD on (Airbus)	Predictive	Monitor PFD etc
GO AROUND			
	PF announce GO-AROUND FLAP and sets thrust lever to TOGA	Mutual	Check speed and altitude and select Go-Around Flap. Monitor correct flap setting achieved
	Rotate aircraft to Go-Around attitude	Mutual	Monitor attitude angle etc

Phase of Flight	Action	Monitoring Type	Monitoring Activity
	Request GEAR UP when positive climb is achieved	Mutual	Monitor climb angle and call POSITIVE CLIMB Select GEAR UP on request
	Monitor FMA – TOGA, SRS, GA TRK	Predictive	Monitor FMA – modes Call GOING AROUND to ATC etc
	At acceleration altitude Select CLIMB THRUST	Predictive	Monitor that Climb Thrust is set Monitor agreed climb rate achieved etc
	Activate required navigation mode	Predictive	Monitor NAV, HDG or TRK on FMA etc
	As required by ATC re-activate approach phase	Predictive	Monitor ATC request monitor Approach selection etc
LANDING			
	FLARE	Predictive	Monitor pitch attitude and call PITCH PITCH Monitor bank angle and call BANK BANK Monitor rate of decent and call SINK RATE when constraints are exceeded

Phase of Flight	Action	Monitoring Type	Monitoring Activity
	After touchdown check ground spoilers and autobrake	Predictive	Monitor deployment of ground spoilers – call NO SPOILERS Monitor Auto brakes and call MANUAL Brakes if autobrake light extinguishes Monitor Engine instruments and advise of any abnormalities etc
	Reduce reverse thrust to be in reverse idle by 60 kt	Predictive	Monitor speed and call 70 KNOTS and 50 KNOTS
	Vacates runway with taxi speed (20kt)	Predictive	Monitor speed below 20kt etc
TAXI IN			
	Cross check safe route from ATC	Predictive	Monitor taxi route, traffic etc
Complete After Landing checklist – adhere to Challenge and response			
PARK ON GATE			
	Cross check stand clearance	Predictive	Monitor stand clearance etc
Complete Shut down checklist – adhere to Challenge and Response			

ANNEX E

Subtle LOFT events suitable for assessing monitoring competency

Section 2.5 discusses methods of objectively measuring monitoring skills by utilising subtle events that good monitoring should capture. The following tables contain malfunctions which are not declared by the internal warning systems and would be suitable events for inclusion in LOFT/LOE exercises. They have been abstracted from specific Boeing 737 and Airbus A320 simulation rig specifications and the intention is to provide example failures. It is considered that the failures detailed in tables 5 and 6 are readily transferable to other aircraft types although the responses may vary.

Table 5: Suggested Boeing events suitable for assessing monitoring skills

AUTOFLIGHT	
MACH/AIRSPEED FAIL	Mode control fail autothrottle. A/C does not hold speed or track any changes.
LOC FAIL TO CAPTURE	Beam capture inhibited FCC, left and right fail to capture Localiser (LOC). No fail indication.
AFDS COMM FAIL	All Automatic Flight Director System/Electronic Flight Instrument System (AFDS/EFIS) comm fails. EFIS fails to display flight mode info. Heading bug disappears from screens.
FUEL	
FUEL MAIN FUEL QTY	Indicator shows less fuel +/-1360 kg. Indicated fuel error then config/ imbalance.config light/ warning.
MAIN FUEL QTY FAIL	Main fuel quantity fail. Corresponding indicators blank Engine Indicator and Crew Alert System (EICAS) fuel quantity Built in Test Equipment (BITE).
ICE AND RAIN PROTECTION	
PITOT HEAT FAIL	Heater fails, loss of indications due to ice, in weather.
CAPT/FO STATIC BLOCKED	Static block indicator errors. With ALT change MACH/ inc/dec, speed inc/dec. ALT,VMO,VSI freeze.

NAVIGATION	
DME FAIL	DME fails indicator blanks,
VOR FAIL	VOR fail pointers freeze Electronic Horizontal Situation Indicator (EHSI) fail flag.
VOR COURSE FAIL	Course select fails, info lost from screen.
LOC RCVR FAIL	LOC fails signals, DEV removed from display, LOC fail flag.
ILS CONTROL PANEL FAIL	Loss of selection for Instrument Landing System (ILS) Panel inoperative.
ILS COURSE SELECT FAIL	Course info lost no ILS course info displayed.
GS RECVR FAIL	Glideslope (GS) receiver fails. EHSI scale and pointer removed. GS flag in view.
FLIGHT INSTRUMENTS	
ADC TOTAL PRESSURE SENSOR	Sensor calibration error ASI.MACH, TAS, SAT all in error.
AIRSPEED ERROR	ASI error 1 knot for every 5kt above 150kt comparison required.
ADC PROBE ERROR	Static pressure drifts MACH,ASI ALT all drift and increase, VMO decrease,s comparison required.
FLIGHT MANAGEMENT SYSTEM	
LFMC SYNC FAIL	Flight management Computer (FMC) outputs do not agree, neither indicates failure.
ADC INPUT FAIL	Inertial Reference System (IRS) wind speed direction, baro alt, vert speed outputs invalid.
THRUST MANAGEMENT SYSTEM	
THRUST LIMIT INVALID	Thrust Management System (TMS) sets improper thrust limit. Does not show correct limits, no fail indication.
AT MOTOR FAIL	Throttle drive fail. EADI shows THR hold mode.
AUTO GA SWITCH FAILS	TMS GA fails, does not respond. No failure indications.
AT DISCONNECT SW FAIL	At disconnect switch fails. No failure indication.
FMC THR COMMAND FAIL	TMC improper thrust settings. Does not respond to thrust targets, no failure indication.

Table 6: Suggested Airbus events suitable for assessing monitoring skills

AUTOFLIGHT	
AP LOC CAPTURE FAIL 1 or 2	If AP1/2 was engaged and AP1/2 not engaged or FD1/2 engaged without AP1/2 and FD1/2 engaged, LOC CAPT MODE can be engaged but AP1/2 doesn't follow LOC beam.
AP GLIDE CAPTURE FAIL 1 or 2	If G/S MODE (G/S * green on FMA) wasn't engaged: § IF AP1/2 was engaged and AP1/2 not engaged or FD1/2 engaged without AP1/2 and FD1/2 engaged, GLIDE MODE doesn't engage in FMGC1/2 while conditions are satisfied. AP1/2 or FD1/2 remains in G/S ARM (G/S blue on FMA). If G/S MODE was engaged: § it remains engaged but AP1/2 doesn't follow the Glide beam.
FLIGHT CONTROLS	
ERRONEOUS PITCH UP ORDER CAPT or F/O	§ The CAPT or F/O side stick Pitch order is blocked to up deflection. § The elevators move up on the F/CTL SYS page. § No message on the ENGINES WARNINGS display.
ERRONEOUS PITCH DOWN ORDER CAPT or F/O	§ The CAPT or F/O side stick Pitch order is blocked to down deflection. § The elevators move down on the F/CTL SYS page. § No message on the ENGINES WARNINGS display.
ERRONEOUS ROLL LEFT ORDER CAPT or F/O	§ The CAPTor F/O side stick roll order is blocked to left deflection. § No message on the ENGINES WARNINGS display.
ERRONEOUS ROLL RIGHT ORDER CAPT or F/O	§ The CAPT side stick roll order is blocked to right deflection. § No message on the ENGINES WARNINGS display.

FUEL	
WING QUANTITY PROBE FAILED RIGHT	§ Right outer cell Fuel quantity and total fuel quantity displayed by ECAM are downgraded (the two least significant digits of the indication are amber cross lined).If REFUEL is in progress:Refuel operation aborts § Indicator light AUTO REFUEL "END" flashes on the refuelling control panel
FUEL QUANTITY INDICATION FAIL	Fuel quantities, fuel temperature, transfer valves and FOB indications displayed by ECAM are replaced by amber XX. On MCDUs, on FUEL PRED page, cyan FQ indication disappears (FOBnn/FF+FQ indication becomes FOBnn/FF).
ICE & RAIN PROTECTION	
PITOT PROBE FAULT F/O or CAPT	When the probes/window P/B OFF and ENG running the aircraft is in climb or hold no local warning but after a delay: § single chime sounds § master caution lights on § associated anti–ice messages appear on E/W CRT (30110) Then after successive "CLR", STATUS page appears with appropriate anti–ice messages
INDICATION FAILURE	
FWC 1+2	Loss of both flight warning computers in flight
DMC FAULT	The display units driven by DMC1 or 2 (captain or F/O) PFD and ND and upper ECAM DU) display a diagonal line. The Engine/Warning image is automatically displayed on the lower ECAM DU instead of the system page or status message ("Mono" display configuration).
PFD FAULT (CAPT or F/O)	Appropriate (Capt or F/O) PFD screen blank. There is an automatic transfer of the PFD image to the unit normally showing an ND image.

NAVIGATION	
AIRSPEED CHANNEL ADR FAULT 2	If AIR DATA switching is in neutral position on right PFD Airspeed scale is not displayed and red flag SPD appears. On right ND TAS is displayed. No warning on ECAM.
ALTITUDE CHANNEL ADR FAULT 2	If AIR DATA switching is in neutral position:On F/O PFD ALTITUDE FLAG appears No warning on ECAM.
DME RECEIVER FAIL 1 (Capt) or 2 (F/O)	On VOR/DME RMI, DME 1 or 2 displayed data is cleared. DME 1 or 2 call signs are no longer received. In the case of ILS/DME on the appropriate PFD screen, if the ILS push button of the appropriate EFIS control panel is pressed, a DME1 or DME2 (as appropriate) red message is displayed. In the case of VOR/DME or DME alone, of the appropriate ADF–OFF–VOR switch is in VOR position, a DME1 or DME2 red message is displayed in the RH lower corner of the CAPT and F/O ND screens.
ILS RECEIVER FAIL 1(Capt) or 2 (F/O)	On the appropriate PFD screen, if the ILS push–button of the appropriate EFIS control panel is pressed, all the respective ILS information disappears and an ILS 1 or 2 red message is displayed. On the appropriate ND screen, in ROSE–ILS mode, all the ILS information will disappear and ILS G/S and LOC red messages are displayed. ILS call signs are no longer received when both ILS receivers are failed. On the PFD, in the FMA part, the message CAT 1 is displayed. If the aircraft is in flight phase 1, 6 or 7, and if an upper level landing capability is engaged (i.e. CAT3 dual or CAT3 single or CAT2 or LAND green), 3 clicks sound to announce the change of category.

VOR RECEIVER FAIL 1(Capt) or 2 (F/O)	If the aircraft is equipped with a VOR/DME RMI . VOR 2 flag appears . VOR 2 bearing needle shows a bearing of 90 deg. If the CAPT and F/O ADF1/OFF/ VOR1 switches are on VOR 1 position, on both ND screens, in ROSE–ILS, ROSE–VOR, ROSE–NAV or ARC mode, the VOR 1 information displayed in the left lower corner and the associated pointers disappear and a VOR 1 red message is showing. On the CAPT ND screen, in ROSE–VOR mode, all the VOR 1 information disappears and a VOR red message is overlaying the A/C symbol.
STANDBY ASI FAIL	The airspeed indication is frozen on standby airspeed indicator.
STANDBY HORIZON FAIL	Red flag on the standby horizon.
STANDBY ALTI FAIL	The altitude indication is frozen on standby altimeter.
ENGINE PARAMETERS	
OIL QUANTITY INC/DEC	Oil quantity indication lashes (green) on the "ENGINE" page. Oil pressure decreases, Oil temperature increases.
N1 INDICATION FAULT	Engine 1 N1 analogue indications are replaced by amber circles on the E/W CRT – Engine 1 N1 numerical indication is replaced by amber crosses on the E/W CRT.
N2 INDICATION FAULT	Engine 2 N2 numerical indication is replaced by two amber crosses on the E/W CRT.
EPR INDICATION FAULT 2	Engine 2 EPR analogue indications are replaced by amber circle on the E/WCRT.