PART 1.4 – FINDINGS

Notes:

Extended references to Cabin Safety analysis in report AO-2008-070 (Dec 11) made with the kind permission of the Australian Transport Safety Bureau.

Illustrations of the Digital Flight Data Recorder are adapted from raw data traces provided by QinetiQ.

Illustration of aircraft route: Map data © 2014 Google, Basarsoft.

Photographs provided by the Military Air Accident Investigation Branch (MilAAIB) and by 1710 Naval Air Squadron.

In this section, organizational references to 'Airbus,' refer to Airbus SAS, based in Toulouse, France.

Executive Summary of Findings

1.4.1 The incident involving Voyager KC Mk 3 (ZZ333) on 9 Feb 14 occurred when the aircraft suddenly pitched down while in the cruise at FL330 (33,000 ft). The pitch-down command persisted for a total of 33 seconds, during which time the aircraft lost 4,400 ft in height. The aircraft's self-protection measures initiated a recovery from the dive.

1.4.2 Evidence gathered from the aircraft's Digital Flight Data Recorder (DFDR) showed that a full pitch-down command had been initiated from the Captain's side-stick, which caused the autopilot to disconnect and the aircraft to enter a dive. The evidence also showed that the pitch-down command was not the result of a technical malfunctioning of the side-stick, the control surfaces, the autopilot, the flight control computers, or the aircraft's weight and balance. Neither was the pitch-down command the result of turbulence. A detailed examination of the aircraft indicated that there were no pertinent technical faults throughout the flight.

1.4.3 The Inquiry established conclusive evidence that the pitch-down command was actually the result of an inadvertent physical input to the Captain's side-stick. Specifically:

> a. Two or three minutes before the event, a Digital Single Lens Reflex (D-SLR) camera was placed directly behind the side-stick, in the space between the side-stick and the Captain's left armrest.
>
> b. At one minute and 44 seconds before the event, the Captain's seat was moved forward, creating a slight physical jam of the camera between the front of the armrest and the rear base of the side-stick.
>
> c. At the onset of the event, the Captain's seat was moved forward again, forcing the side-stick fully forward and initiating the pitch-down command.
>
> d. With the Captain's side-stick jammed fully forward, the pitch-down command could not be counteracted initially, as the Captain was the only person present on the flight deck.
>
> e. The resulting forces were sufficient for a considerable number of passengers and crew to be thrown to the ceiling, resulting in a number of injuries.

1.4.4 The Panel found that the factors which led to the pitch-down command were influenced principally by the prevailing safety culture with respect to loose articles on the flight deck of RAF air transport aircraft. The small amount of guidance regarding the treatment of loose articles on flight decks was overwhelmed by an organizational requirement to take large amounts of equipment and documentation onto the flight deck to support missions, and to store it in ad hoc locations. As a result, the carriage, use and ad hoc storage of a small number of personal items had become normal practice. The recovery from the pitch-down command was initiated by the aircraft's own protection laws which prevented the incident from being far worse. In the opinion of the Panel, the evidence suggests strongly that the clearing of the obstruction from behind the side-stick was achieved by means of a physical manipulation of the camera itself.

1.4.5 The situation in the passenger cabin was managed effectively and had no adverse bearing on the injuries which were sustained by either the passengers or members of the Cabin Crew. The actions of the Purser were particularly noteworthy in bringing the situation under control. Physical injuries were mostly minor; however a number of personnel were admitted to hospital in the days or weeks following the incident suffering from acute stress.

1.4.6 The practical response in the immediate aftermath of the incident was fast, thorough and highly effective. There was a sense in some areas however, of command, control and support being conducted in an improvised fashion. A lack of continuity in information flow led to a lack of pre-preparedness in Theatre for the volume of medical cases which followed amongst those passengers who subsequently deployed. There Panel found no evidence that this had an adverse effect on the quality of individuals' treatment.

1.4.7 As of 25 Feb 14, it was estimated that out of 198 personnel on-board ZZ333, a minimum of 32 (16%) and a maximum of 48 (24%) were, for varying reasons and periods of time, rendered unfit for duty as a result of the incident. The overall medical outcome of the incident however, was not being tracked.

1.4.8 The Service Inquiry (SI) was convened officially on 13 Feb 14 to investigate the circumstances which led to the incident, to determine the cause and to make recommendations to enhance air safety. The following analysis examines the cause of the incident and its associated factors, and makes a number of other observations which the Panel has deemed pertinent.

Methodology

Definitions

1.4.9 The following definitions were used to classify the various factors which were pertinent to the incident:

a. **Cause**. An event which led directly to the incident.

b. **Contributory Factor**. A factor which made the incident more likely.

c. **Aggravating Factor**. A factor which made the outcome worse.

d. **Other Factor**. A factor which was none of the above, but was noteworthy in that it may cause or contribute to future incidents or accidents.

e. **Observations**. An issue that was not relevant to the incident but worthy of consideration to promote better working practices.

Incident modelling

1.4.10 In assessing the evidence, the Panel adopted an epidemiological model first proposed by Professor James Reason of Manchester University in 1990. The model broadens the scope of an investigation beyond individual acts, to include an examination of the latent conditions and organizational factors which may also lie behind an incident. As such, the following categories were used to inform the Panel's analysis:

a. **Unsafe acts**. Unsafe acts are those committed by those at the 'sharp end' of a system, in close proximity to the incident. Fact-based, non-judgemental statements are used to categorize the potentially unsafe acts of an individual or a group, whether those acts have been intentional or not:

(1) **Unintentional acts**.

(a) **Slips**. A slip is defined as an error by commission; where a well-practised skill, requiring little cognition, has been carried out incorrectly.

(b) **Lapses**. A lapse is defined as an error by omission; where a well-practised skill, requiring little cognition, has not been carried out.

(2) **Intentional acts**.

(a) **Mistakes**. A mistake is defined as a deficiency in judgement and/or a failure to formulate the right plan based on flawed knowledge, and/or an incorrect comprehension of rules.

(b) **Violations**. A violation is defined as a deliberate and conscious departure from established rules or procedures, even if there has been no intent to cause harm.

b. **Error promoting condition (EPC)**. Error promoting conditions refer to those psychological, physical/mental limitations and physiological factors that can influence human performance; for example, pressure, weather or fatigue.

c. **Organizational influences**. Organizational influences refer to the broader, and often latent, influences that an organization brings to bear on those involved in an incident. These will inevitably be beyond those individuals' control and could, for example, relate to equipment design, operational culture or organizational policy.

d. **Breached or failed defences**. Breached or failed defences refer to those rules, orders, practices and procedures which are designed to ensure the safe operation of aircraft, but which failed or were breached in the course of the incident.

Available evidence

1.4.11 The Panel had access to the following evidence:

a. Interviews with the crew of ZZ333 and other witnesses.

b. Written statements and correspondence from witnesses.

c. DFDR data from the flight.

d. A Cockpit Voice Recorder (CVR) from the flight.

e. Photography from various sources.

f. Relevant orders, terms of reference and documentation including flying logbooks, aircraft documentation, flight planning, briefing materials and engineering documentation.

g. Aircraft ZZ333 at Incirlik airbase.

h. An aircraft technical report by Military Air Accident Investigation Branch (MilAAIB).

i. Technical reports by 1710 Naval Air Squadron (NAS).

j. A Human Factors report provided by the RAF Centre for Aviation Medicine (RAFCAM).

k. Flight Simulator assistance from AirTanker Services Ltd and Airbus.

l. Flight safety-related material, including previous MOD accident and incident reports and Mandatory Occurrence Reports from the Civil Aviation Authority (CAA).

Services

1.4.12 The Panel was assisted by expertise within the following organizations:

a. Air Accident Investigation Branch (AAIB).

b. Airbus (including Airbus Defence and Space).

c. AirTanker Services Ltd.

d. Military Aviation Authority (MAA).

e. MilAAIB.

f. QinetiQ.

g. RAF Brize Norton.

h. RAFCAM.

i. Rolls Royce.

j. 1710 NAS.

k. 206(R) Squadron.

Factors considered by the Panel

1.4.13 With respect to the pitch-down command, the Panel analysed the following key factors:

a. Possible triggers.

b. The relevance of individual acts.

c. The prevailing conditions at the time of the event.

d. Regulations and safety culture.

e. Aircraft design.

1.4.14 The Panel also analysed the following areas:

a. The recovery from the pitch-down command.

b. Cabin safety, including the handling of injuries.

c. Post Occurrence Management, including the handling of injuries.

d. Other areas pertinent to the Panel's terms of reference.

Determining the cause of the pitch-down command

Context

1.4.15 Aware that flying on the Voyager fleet had been paused and that the incident was attracting considerable international interest, the Panel's initial efforts were focussed entirely on determining the cause of the pitch-down command. [redacted] Comprehensive interviews with the pilots conducted in Incirlik by MilAAIB had already established a strong theme that pointed towards a technical malfunction on the aircraft, specifically associated with the side-sticks and the autopilot. By contrast, initial analysis of the DFDR and CVR had revealed no evidence of any pertinent technical malfunctions, particularly in respect to the side-sticks and the autopilot. Exhibit 20 Exhibit 2 Witnesses 1 & 2

1.4.16 [redacted], a number of concurrent lines of inquiry became necessary in order to rule out a variety of possible causes. Such was the [redacted] nature of interview evidence taken by MilAAIB and the Panel, these lines of inquiry were necessarily broad and time consuming. They included early engagement with Airbus, from whom the Panel would have lengthy and close co-operation over the course of the Inquiry. They also included extensive work carried out for the Panel by independent parties to help isolate the cause of the pitch-down command.

Possible causes

1.4.17 The range of possible causes considered by the Panel included:

a. A Human Factors related deliberate act.

b. A Human Factors related inadvertent act.

c. A side-stick malfunction, including:

(1) A mechanical or electrical failure of a side-stick transducer.

(2) A mechanical or electrical failure of a side-stick solenoid.

(3) A failure of side-stick damper rods & linkages.

(4) A mechanical failure of Artificial Feel Spring and Dampening System.

(5) A loose article blockage in the side-stick pitch rods.

(6) Cross-talk or electromagnetic interference inducing a pitch-down command.

d. A Single Event Effect (atmospheric particles from a solar flare event) causing a pitch-down command in the Flight Control Computers.

e. An autopilot fault.

f. Any other avionics hardware or software design fault or 'bug.'

g. A weight and balance related issue.

h. A control surface malfunction.

i. Turbulence.

Analysis

1.4.18 The DFDR showed no indication of system failures that could have led the aircraft to pitch down. Throughout the flight, there were no annunciations to the crew of pertinent faults, nor were any relevant fault codes generated that would help explain the incident. The Panel found no evidence of unresolved comparable incidents across any A330 aircraft variants. The Panel assessed this incident to be unique.

Exhibit 20
Exhibit 17
Exhibit 29

1.4.19 At 1548:13 UTC, one minute and 44 seconds prior to the event, the DFDR (Figure 1) detected a low frequency fluctuating pitch-down command of 0.5 to 0.9 degrees from the Captain's side-stick. This input endured until the onset of the full pitch-down command. This initial forward input was pure in pitch with no discernible lateral input. The force and displacement of the side-stick during this command did not disengage the autopilot, because a five deca-Newton force and five degree displacement of the side-stick (in pitch) is required before the autopilot will disengage. All side-stick movements, including those below the threshold for autopilot disconnection are recorded by the DFDR. Therefore, the aircraft remained initially in level flight with the autopilot engaged. At 1549:57 UTC, a fully-forward input was made by the Captain's side-stick. This input was also pure in pitch and at constant rate. It had no discernible lateral input and was held initially for approximately four seconds at a fully forward deflection. It was this input which initiated the pitch-down event.

Exhibit 30
Annex C
Exhibit 30

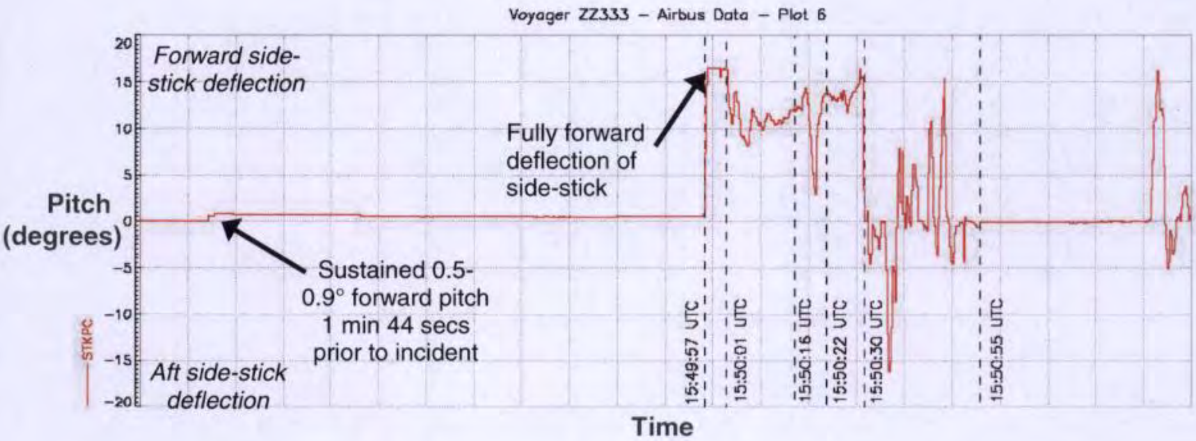

Figure 1: DFDR extract showing Captain's side-stick pitch commands.

1.4.20 The Panel examined the possibility that the input had been made deliberately. Neither the Captain's most recent training report, nor his flying

Exhibit 7
Witness 4

records, nor his supervisory chain, nor his medical history, gave the Panel reason to suspect that the input was the result of a deliberate act. Furthermore, analysis of the CVR indicated that the Captain seemed genuinely surprised by the pitch-down event. The Captain did not press his autopilot disconnect button on the side-stick until four seconds after the pitch-down was initiated. UK Defence Standards indicated that a normal reaction time to an unexpected in-flight event would be in the region of three to five seconds[1]. Thus, the evidence indicated strongly that the pitch-down was unexpected and not deliberate. Exhibit 31 Exhibit 2 Exhibit 20

1.4.21 Early analysis of the CVR identified a distinctive noise on the flight deck at one minute and 44 seconds prior to the event, and at the onset of the event itself. Spectral analysis of the noise identified it as the electrical motor used to adjust the flight deck crew seats (identified by its frequency of 1900-2000 Hz). The seats are adjustable by means of a switch which is located on the base of the seat itself. The Captain's seat is on the left-hand side of the flight deck and his adjustment switch is on the bottom right-hand side of the seat (Figure 2). In the two minutes leading up to the event the Captain was the only person present on the flight deck, indicating that the motor noise came from the Captain's seat. There was no evidence that the seat had malfunctioned in flight and functional tests carried out after the event showed that the seat was fully serviceable. It was quite normal for the seat to be adjusted several times during the flight, either for reasons of comfort or for the performing of a specific task. The Captain confirmed that his seat may have moved forward at this time, although he could not specifically recall it. Exhibit 2 Exhibit 32 Witness 1, Panel Interview 1 Annex A, 1.2.6 Witness 1, Panel Interview 3 Witness 1, Panel Interview 2

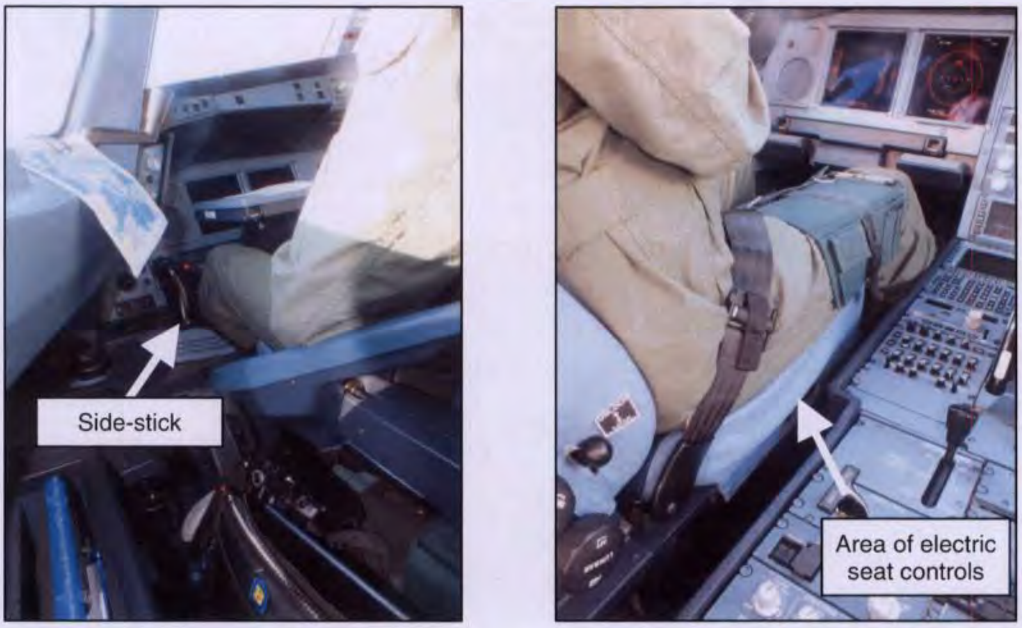

Figure 2: Captain's seat position.

1.4.22 There was an obvious and strong temporal and directional correlation between the seat motor movement and the side-stick movement. The Panel examined the possibility that the movement of the Captain's seat and the Captain's side-stick were connected. For there to have been a direct relationship, the seat and the stick would have to be physically connected, either by the occupant of the seat or by an object (other methods of interference are dealt with in a separate

[1] DEF-STAN 00-97- Part 1, Section 4, Leaflet 36.

paragraph). The pitch input from one minute and 44 seconds until the onset of the event remained around a datum of between 0.5 and 0.9 degrees, in a manner inconsistent with a human input. It would be extremely difficult for a pilot to hold and maintain the small forward elevator deflection manually on the side-stick for nearly two minutes. The side-stick would have a tendency to return to the neutral position under spring loading. Even extremely light atmospheric turbulence or airframe vibration would tend to move the pilot, which in turn would be expected to translate into movement of the side-stick. The movements of the pilot's body would be expected to create changes in side-stick pitch input that were not visible on the DFDR plot. Annex A, 2.1 & Exhibit 30; Annex C Exhibit 30

1.4.23 The Captain was certain that he was not touching the controls prior to the event, and the persistence of the subsequent pitch-down command (lasting in total around 33 seconds) indicated that it was not the product of an inadvertent human input. Multiple attempts to recreate the pitch-down event were carried out in the simulator. Hand flying a fully forward deflection of the side-stick resulted on each occasion in some roll input inadvertently being applied. The lack of roll input on the DFDR trace during the initial pitch-down of the aircraft meant that a hand flown pitch-down command was unlikely. The Panel concluded that the Captain was not in physical contact with the side-stick either immediately prior to, or during the onset of the event. Witness 1, Panel Interview 1; Annex C; Exhibit 33; Exhibit 34; Annex C; Exhibit 35

1.4.24 As a result, the Panel's focus turned to the possibility of an object connecting the seat and the side-stick. The Panel collected the official items and personal effects which had been on the flight deck at the time, in order to ascertain which of them could have interfered with the side-stick. In an interview with the Co-pilot, it became evident that a Nikon Digital Single Lens Reflex (D-SLR) D5300 Camera (Figure 3) belonging to the Captain had been present on the flight deck in the minutes leading up to the pitch-down event. Specifically, the camera had been seen by the Co-pilot on the surface area near the base of the Captain's side-stick shortly before the event. He had also seen the Captain using the camera during the flight. Exhibit 18; Witness 2, Panel Interview 1

Figure 3: Nikon D5300 D-SLR camera as received.

1.4.25 [redacted] Witness 1, MilAAIB interview & Panel interview 1 [redacted] Analysis of [redacted] photographs submitted subsequently by the Captain indicated that 28 photographs were taken during a period of darkness between around eight minutes and three minutes prior to the incident (Figure 4). It was established that, in all, 77 photographs were taken during the flight. In one photograph, the GPS digital clock on the flight deck could be seen, allowing a comparison to be made between the aircraft's internal time measurement and that of the camera.

Witness 1, Panel interview 2
Exhibit 36
Exhibit 123

Figure 4: Sample of 28 photographs taken on flight deck shortly before incident.

1.4.26 As such, the Panel established that the last photograph taken with the camera was at 15:46:38 UTC; one minute 35 seconds before the initial pitch event, and three minutes and 20 seconds before the full pitch-down event. Analysis of the CVR indicated that approximately four seconds after the last photograph was taken, the Purser came onto the flight deck to have a short conversation with the Captain, before returning to the passenger cabin (Figure 5).

Exhibit 18
Exhibit 2
Exhibit 18
Witness 3, Panel Interview 2

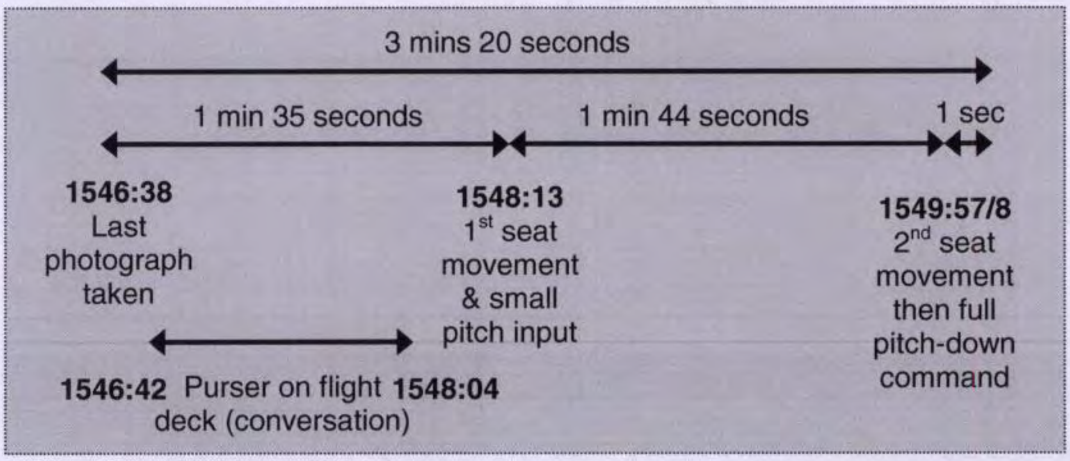

Figure 5: Timeline immediately prior to incident (all times UTC).

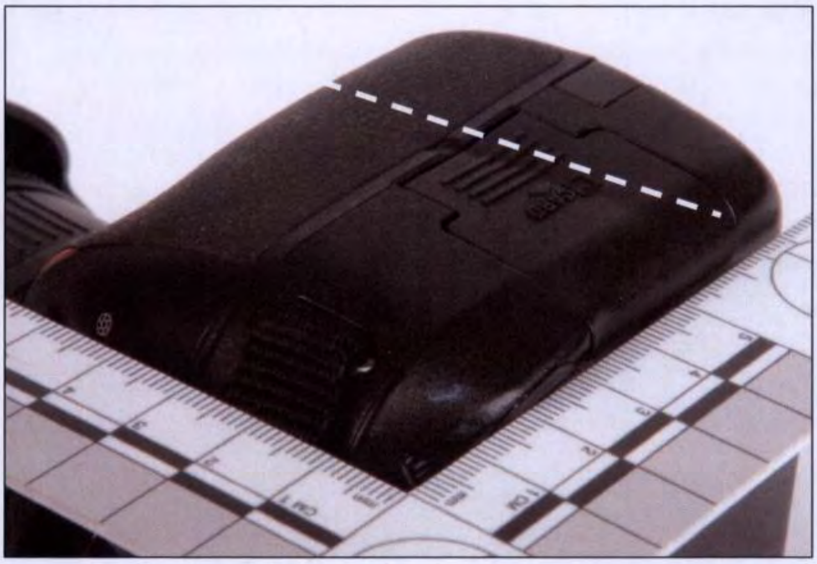

Figure 6: Location and orientation of large dent in camera (dotted line).

1.4.27 The camera was found to have a large linear dent on its right hand side (Figure 6). The dent extended from the softer hand grip region towards the front of the camera, across a thin part of the main body frame, and across the memory card flap. Annex A

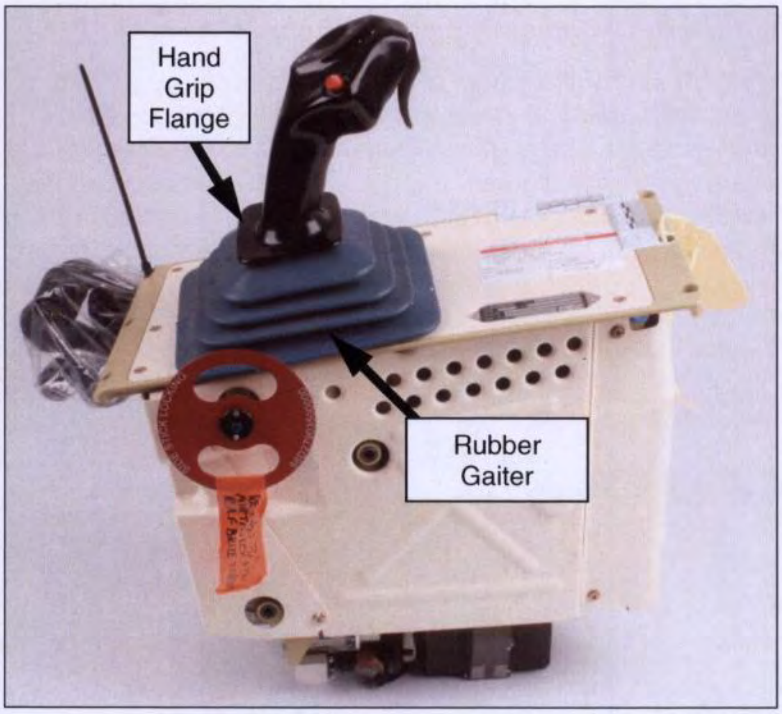

Figure 7: Side-stick unit as received by Panel.

1.4.28 The profile of the large dent was mapped forensically using surface profilometry and compared with the hand grip flange (Figure 7) at the base of the side-stick. The dent in the camera was found to be consistent with having been caused by the flange of the side-stick. Furthermore, chemical analysis indicated that trace amounts of materials present in a swab from the camera indentation were consistent with the material type of the side-stick. The rubber gaiter at the base of the side-stick was examined using binocular microscopy, revealing two distinct perforations. The perforations were assessed to be the result of the gaiter material being pushed against the edges of the lower side-stick flange from the outside. When considered alongside other smaller witness marks on the camera, it was assessed as highly likely that the camera had experienced a significant compression against the base of the side-stick at some point during the flight. Specifically, it was assessed that the damage was consistent with the side-stick being pulled back forcefully against the body of the camera. Annex A, para 2.5

Figure 8: Re-construction of Captain's camera behind side-stick.

1.4.29 Using the Voyager simulator, the Panel reconstructed an arrangement of the armrest, the camera and the side-stick to assess the possibility of causing flight-control interference (Figure 8). The armrest was adjusted to the specific parameters used by the Captain on the flight in order to re-create the angle that was present during the event. Although the setting was within limits, it created an unusual angle, resulting in a particularly steep downward incline from back to front. The camera was placed in the gap between the armrest and the side-stick, with the damaged side presented towards the grip flange at the base of the side-stick. The seat motor was moved forward until the camera was gently flush against the base of the side-stick. Witness 1, Panel Interview 1

Figure 9: Side-stick locked in fully forward position (substitute camera).

1.4.30 The seat motor was operated in a forwards direction as heard at the onset of the pitch-down event. The effect was to push and hold the side-stick fully forward in a manner consistent with the pitch-down command seen on the DFDR (Figure 9). The motion resulted in the grip flange becoming aligned with a location exactly consistent with the dent in the camera. The re-construction took no more than a few seconds to set up. Exhibit 2 Exhibit 20

1.4.31 Using the calculated movement of the seat, the position of the armrest and the location of the camera, the analysis found that it was feasible for the seat movement recorded on the CVR to have caused the movement of the side-stick to the fully-forward position. Annex A

1.4.32 In the meantime, the Panel continued to pursue a standard of evidence that would allow a thorough range of other causes to be ruled out. A full examination of possible technical causes is in the MilAAIB Report at Annex A. In summary, the following were assessed by the Panel to have not caused the incident: Annex A

a. **Mechanical or electrical failure of a side-stick transducer.** Tests conducted with the side-stick manufacturer, UTC Aerospace Systems, established that the side-stick transducer unit was fully serviceable.

b. **Mechanical or electrical failure of a side-stick solenoid.** Tests conducted with the side-stick manufacturer, UTC Aerospace Systems, established that the side-stick solenoid was fully serviceable.

c. **Failure of the side-stick damper rods & linkages.** Tests conducted with the side-stick manufacturer, UTC Aerospace Systems, established that the side-stick damper rods and linkages were fully serviceable.

d. **Mechanical failure of artificial feel spring and dampening system.** Tests conducted with the side-stick manufacturer, UTC Aerospace Systems, established that the side-stick transducer unit was fully serviceable.

e. **FOD blockage in the side-stick pitch rods.** An X-ray computed tomography (CT) scan showed that there was no FOD blockage within the side-stick unit. This was confirmed by a subsequent visual inspection by the side-stick manufacturer.

f. **Cross-talk or electromagnetic interference inducing a false pitch-down signal**. Tests conducted with Airbus examining the effects of electromagnetic interference from the Captain's portable electronic devices established that their level of emissions were below the demonstrated immunity level of the equipment installed on aircraft.

g. **Single event effect (atmospheric particles from solar flare event).** Solar flare activity at the time of the incident was measured in the lowest range of emissions (class C), below that which could have caused interference with the aircraft systems. Exhibit 127

h. **Auto-pilot fault**. The autopilot behaved correctly in response to a positive control input from the Captain's side-stick.

i. **Hardware or software design fault or bug.** Analysis found no evidence to doubt the integrity of the flight control system. No faults or spurious flight control inputs were recorded on the Flight Data Maintenance system and Built-in Test logs. It was confirmed that the auto-flight system and the five flight computers responded to an autopilot disconnection in accordance with the commands provided to them. The pitch-down command was correctly authorized in response to a positive control input from the Captain's side-stick.

j. **Weight and balance related malfunction**. Analysis of the aircraft's post-flight report showed no errors in the weight and balance calculation for the aircraft. The aircraft Load and Trim Sheet (Form AS.OGD.007) indicated that the aircraft trim was within normal limits for the duration of the flight. There was no shifting of the load on board the aircraft at any time during the flight.

Exhibit 124

k. **Control surface malfunction**. DFDR analysis showed that the flying controls responded correctly to positive control inputs from the Captain's side-stick. All control surfaces, including those mounted on the trim-able horizontal stabilizer, responded as expected to command input parameters and within design intent.

l. **Turbulence**. Although turbulence had been experienced earlier in the flight, no turbulence was reported at the time of the incident. Neither was any significant turbulence forecast for the area in which the incident took place.

Witness 2, Panel Interview 1
Exhibit 37

1.4.33 [redacted], the Captain agreed that a physical interference with the side-stick, in the manner suggested above, represented the most probable trigger for the pitch-down command. Given the weight of evidence therefore, the Panel concluded that **the cause of the pitch-down event was an inadvertent physical input to the Captain's side-stick, by means of a physical obstruction (a camera) that jammed between the left armrest and the side-stick unit when the Captain's seat was motored forward.**

Witness 1, Panel Interview 3

Factors leading to the pitch-down command

1.4.34 A series of individual acts took place in the moments before the pitch-down command which were assessed as having contributed to the incident itself. The individual acts however, were influenced by a combination of error promoting conditions, organizational influences and breached defences. The following paragraphs are drawn principally from Human Factors analysis conducted by RAFCAM. Figure 10 illustrates the key factors which were considered in determining how the pitch-down command happened, and forms the structure for the analysis in these paragraphs.

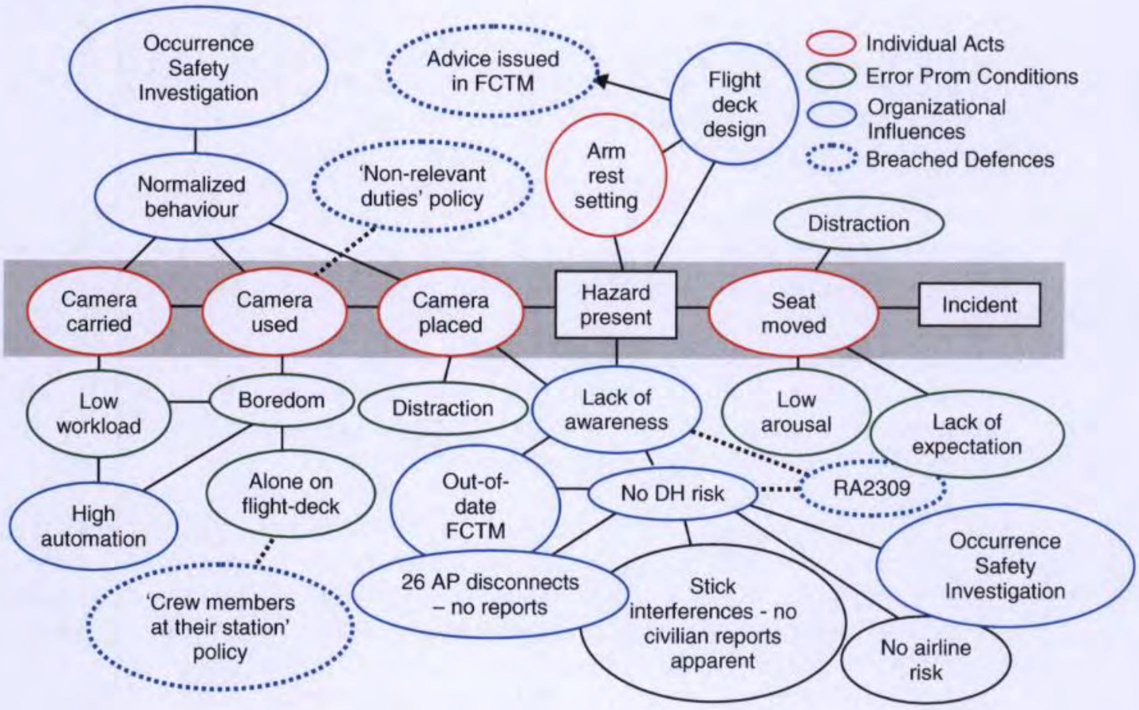

Figure 10: Diagram of key factors leading to pitch-down command.

1.4.35 **Carriage of the camera**. The carriage of the camera had a direct bearing on the incident, in as much as it was the object responsible for the side-stick interference. As such, the Panel concluded that **the carriage of the camera on the flight deck was a contributory factor**. This however, was influenced by a number of associated factors.

a. **Normalized behaviour**. The carriage of the camera was consistent with normalized behaviour regarding loose articles on RAF air transport aircraft. The Panel found evidence that the issue of loose articles on flight decks had been the source of considerable debate amongst junior Air Safety staff at RAF Brize Norton for several months leading up to the incident, but that it had not been resolved: Witnesses 10 & 11

(1) In Mar 13, 11 months before the incident, an Air Safety Occurrence Report (ASOR) was raised amongst Air Safety staff at RAF Brize Norton, who were concerned at the number of loose articles being found on board C-130 flight decks. A growing body of Exhibit 38

reports were being received from C-130 engineers describing how numerous aircrew items were being left on flight decks at the end of flights. In one three month period they included: five personal oxygen masks; one aircrew knife; three sets of spectacles plus cases; two NVG eyepiece covers; seven NVG helmet counter-weights, and six folders or notebooks. None of the items had been reported as missing by crews. By 12 Apr 13, RAF Brize Norton Air Safety staff began an Occurrence Safety Investigation (OSI) to examine whether the issue was limited to the C-130 fleet, and what measures should be taken to address it. The Occurrence Safety Investigators searched for reports on all of the fleets at RAF Brize Norton with the exception of Voyager, which was excluded because of perceived differences between their safety reporting system and that of the rest of the station. The investigators found no reports outside the C-130 fleet of loose articles on flight decks, leading to an assumption that the issue was limited to that fleet only. Witnesses 10 & 11 The issue was highlighted within the C-130 fleet over the next few months; however, loose articles continued to be reported. For the month of Oct 13 this included: two NVG batteries; one set of spectacles; one mobile phone; one finger-torch pouch; one NVG helmet counter-weight; one set of flight reference cards; two maps, and one jacket. Exhibit 38 None of the items found had been reported as missing by crews.

(2) By the time of the Voyager incident on 9 Feb 14, the OSI had still not published a formal report and an Occurrence Review Group had yet to convene to consider any findings (as required by AP 3207, Section 200.120 – Occurrence Safety Investigation). Witnesses 10 & 11

(3) The Panel saw and heard evidence that the issue of loose articles was not, in fact, limited to the C-130 fleet. Witness 1, Panel Interview 3 The C-130 was the only aircraft type at RAF Brize Norton whose engineers were Annex B, para 25 constituted separately (and geographically remotely) from its flying squadrons. Witness 10 & 11 As such, some Air Safety staff believed that the issue of loose articles was simply being dealt with more directly on other squadrons where the engineers were embedded, rather than reported officially. Witness 10 & 11 Similarly to C-130 crews, Voyager aircrew were required to take a large number of items of equipment on board the aircraft for operational flights. These items included two sets of body armour for each crew member, combat survival waistcoats, crew weapons, aircraft documentation, two route bags, a set of worldwide navigation kit and charts and a bag of classified material. Annex B, para 23 Only some of these items had designated storage, with the rest usually found space around the flight deck; for example, on the floor behind the pilots' seats (Figure 11 and Figure 12). Exhibit 39 This volume of items was a result of the nature of the tasking and the associated volume of paperwork necessary to support the mission. It is likely that the number of required items on the flight deck promoted an attitude that it was generally acceptable to have a large volume of items on the flight deck, such that the carriage of a small number of personal effects would not have seemed unreasonable. Accordingly, all pilots Annex B, para 24 interviewed on 10 Squadron by RAFCAM reported having a personally acquired tablet computer that they would take with them on the flight to enable access to the large amount of aircraft documentation. It was also considered normal to carry a personal

navigation bag in which items such as clipboards, their tablet computer and additional paperwork would be carried. Annex B, para 24

Figure 11: Carriage of in-flight publications.

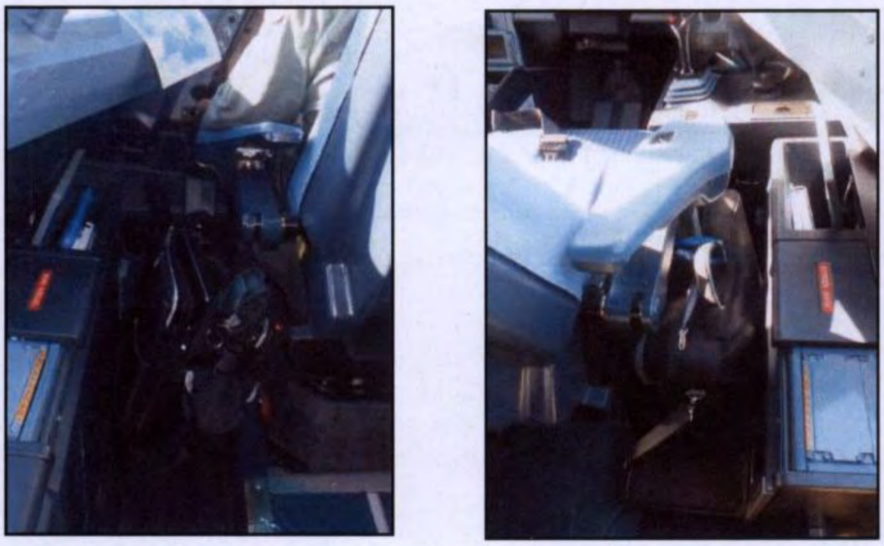

Figure 12: Floor area around Captain's and Co-pilot's seat.

(4) On the flight deck of any large aircraft a certain number of loose articles are inevitable if the aircraft is to operate effectively (pens, notebooks, spectacles etc). There was no evidence however, of official guidance or training within 2 Gp which related to the carriage and use of these items and how they should be stored and positioned on the flight deck, increasing the likelihood that personnel would develop their own norms and practices as a result of experience and advice of others. Photographs taken on the flight deck of ZZ333 shortly before the incident indicated that there were a number of loose articles placed in areas around the flight deck, some not officially designated for stowage (Figure 13). The selection of typical locations used to store items illustrates the challenge imposed by the imbalance between the available storage on the flight deck, the required volume of official equipment and documentation and the carriage of personal items. While the Voyager flight deck had adequate space for these items to be carried, there were not enough dedicated storage locations for the sheer volume of official items, resulting in items being stored on the floor and in ad hoc areas. In particular, the area around the side-stick appeared to be treated no differently to any other surface on the flight deck. Annex B, para 21 Witness 1, Interview 3 Annex B, para 25

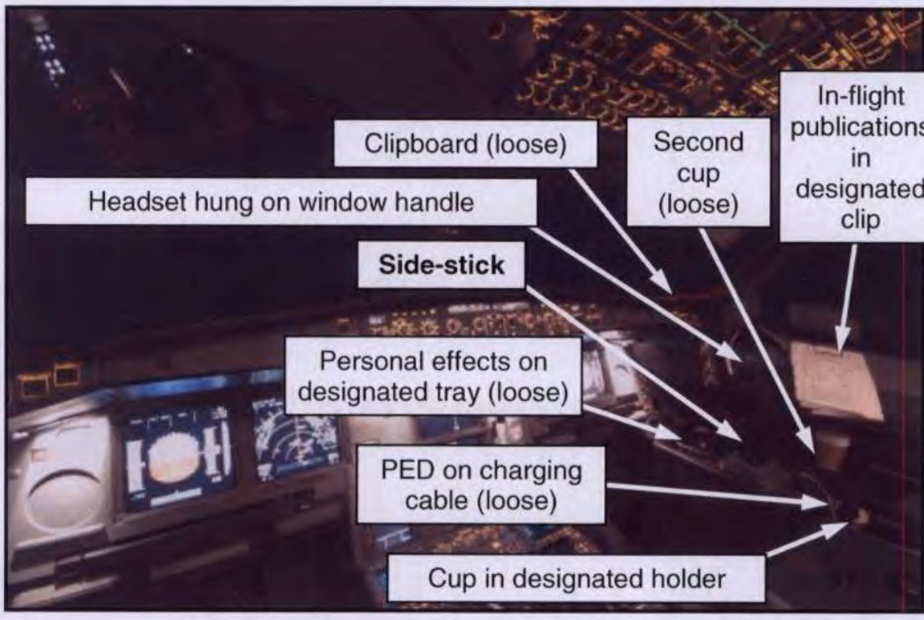

Figure 13: Photograph of Co-pilot's position 6 mins 15 seconds prior to incident.

(5) The carriage of personal items may also have been perceived as advantageous as it would provide access to items in flight which could be used to help maintain general mental alertness (see paragraph 1.4.36 (b) regarding **low workload** and **boredom**). Annex B, para 24

(6) Reports of side-stick interference continued in the aftermath of the incident, even after safety advice had been issued by the MAA highlighting the risk of control interference. In Jun 14, four months after the incident, two reports emerged of inadvertent inputs to Voyager side-sticks resulting in one case from a loose article and in

another, from a pilot's leg knocking against the stick. In the case of the loose article, a documents folder had slipped from the pilots' tray table and made contact with the side-stick, disconnecting the autopilot and causing a master warning. In the other case, the pilot had been resting his foot on the raised foot-rest in the centre of the foot well, when his leg inadvertently knocked against the side-stick. He had been unable to feel the pressure of the side-stick against his leg because of the flight publication which was in his flying suit leg pocket. On both occasions, the autopilot was immediately re-engaged without the aircraft deviating from its flight path. Exhibit 40 Exhibit 41

(7) It was concluded that the carriage of a camera on the flight deck and its subsequent treatment in terms of stowage was consistent with wide-spread normalized behaviour at RAF Brize Norton regarding loose articles. The Panel assessed that **normalized behaviour regarding the carriage and treatment of loose articles was a contributory factor**. Furthermore, by excluding the Voyager fleet from its scope and not issuing a report by the time of the incident, the OSI was not sufficient in its thoroughness or timeliness to identify the extent of normalized behaviour with respect to loose articles. As such, Panel assessed that **the incomplete RAF Brize Norton OSI was a contributory factor**.

b. **Rules and regulations.** The carriage of the camera on the flight deck was not prohibited by any rules or regulations. Guidance in the Voyager Operations Manual, the aircraft Release to Service and Military Regulatory Publications, stated that portable electronic devices could be carried. Restrictions on the use of such items were only in regard to their transmitting properties during different phases of flight. Exhibit 42 Exhibit 43 Exhibit 44

1.4.36 **Use of the camera in flight.** The use of the camera on the flight deck during the flight had a direct bearing on the incident, in as much as it had just been used at the time it became lodged behind the side-stick. As such, **the use of the camera in flight was a contributory factor;** however, this was influenced by a number of associated factors:

a. **Rules and regulations.** The use of a camera on the flight deck during flight was not explicitly prohibited by any rules or regulations. As described in paragraph 1.4.35 (b), specific restrictions in the Voyager Operations Manual on the use of personal electronic devices related only to their transmitting properties during different phases of flight. However, in more general terms, the Voyager Operations Manual Part B, Section 2.1.2.6 stated that: Exhibit 45

- *Flight crew must refrain from non-relevant duties (e.g. paperwork, casual conversation), in circumstances such as (but not limited to): while the other pilot is away from the active Air Traffic Control (ATC) frequency.*

While on his own, the Captain took 28 photographs of the flight deck between approximately eight minutes and three minutes prior to the Exhibit 36 incident, which were not related to the duties he was carrying out at the time. In the judgement of the Panel, this was probably not a deliberate and conscious contravention of the rules. However, the use of the camera on the flight deck represented a lack of compliance with **the policy regarding non-relevant duties**, thus rendering the policy **a breached defence.**

b. **Low workload and boredom.** Voyager has a high level of automation. Of particular relevance to the ZZ333 incident is the impact of automation on workload. During a phase of flight (the cruise) when the workload on a pilot is low, a high level of automation can make it even lower, resulting in boredom and complacency. Individuals who are more susceptible to boredom are those with a high level of knowledge, education and ability, people who are keen for a demanding job, or people who are fatigued or not-adapted to night work. The cruise phase was described as a very quiet phase of the flight. The Captain and Co-pilot described the level of arousal, demands, and task difficulty during the cruise as between 'low' and 'very low'. The CVR provided some evidence of a low level of arousal, with yawns being audible in the 30 minutes prior to the incident, audible sighs and whistling while the Captain was alone on the flight deck and comments which indicated that it was perceived as a long and boring phase of flight. In the period immediately preceding the incident, the Captain reported that there were no aircraft indicated on the Traffic Collision Avoidance System (TCAS) and few ATC communications. The required tasks related to the flying of the aircraft at this stage were described by the crew in RAFCAM interviews as system monitoring, including checking fuel times and waypoints, checking the navigation display, running through the electronic system pages, monitoring the ATC frequency and obtaining the latest weather information. These tasks contained characteristics that give rise to boredom, in that the tasks demanded prolonged supervisory work, requiring vigilance, but with few cues to capture the crew's attention. Given the operating conditions, it was highly likely that the crew would take actions to raise their level of alertness and alleviate boredom. The crew described performing many of the actions considered by Human Factors experts as typical for Voyager air transport operations to maintain alertness during the flight. Specifically, they described having regular visitors to the flight deck, taking comfort breaks, reviewing in-flight paperwork and using personal items. In the Captain's case, this also included taking a considerable number of photographs. Notwithstanding the Voyager Operations Manual policy on non-relevant duties, undertaking actions such as these would have the perceived benefit of maintaining alertness and alleviating boredom. The Panel assessed that **low workload and boredom were contributory factors.**

Annex B, paras 17-19
Witness 1, Panel Interview 1
Exhibit 19
Witness 1, Panel Interview 1, A2
Annex B, paras 17-19
Exhibit 36
Exhibit 45
Annex B, para 18

c. **Single person on flight deck.** The Co-pilot left the flight deck approximately 18 minutes before the incident. As a result, and for most of this period, the Captain was alone on the flight deck and strapped into his seat. Approximately two and a half minutes after the Co-pilot left the flight deck, he returned briefly to bring the Captain a cup of tea. Approximately twelve minutes later the Purser came on to the flight deck and had a brief conversation with the Captain, departing approximately two minutes before the incident. While alone on the flight deck, there were a number of ATC communications between other aircraft, and one ATC communication

Exhibit 19
Exhibit 19

to which the Captain responded. Although the Captain had some interaction with other people while the Co-pilot was outside the flight deck, there was a much reduced level of personal interaction during this time and, due to being strapped into the seat, there were few opportunities for physical movement. Addressing the requirements for, 'crewmembers at their station,' the Voyager Operations Manual Part A, Section 8.3.10 stated that during the cruise: Exhibit 19 Exhibit 46

- *...each pilot required to be on flight deck duty shall remain at his station unless his absence is necessary for the performance of his duties, or for physiological needs...*

There was no time limit associated with this guidance, although the Panel was told by a senior training officer that a pilot would not normally be expected to be absent from the flight deck for more than around five minutes. On the RAF C130J fleet, another two-pilot flight deck, standard operating procedures stated that no pilot was to be left alone on the flight deck for any amount of time. In the event that one pilot left a C-130J flight deck, a third crew member was to be present on the flight deck to monitor the remaining pilot. The presence on ZZ333 of only a single person in the flight deck for an extended period of time increased the risk of boredom and under-arousal, thus increasing the likelihood that the Captain would take actions to maintain his general alertness. The Panel assessed that **the presence of only a single person on the flight deck for an extended period of time was a contributory factor.** This represented a potential lack of compliance with the policy regarding crew members at their station, although it was possible to apply a wide interpretation to the rule. Nevertheless, as it did not prevent the extended absence of a pilot from the flight deck, **the policy regarding crew members at their station was assessed by the Panel to be a failed defence.** Witness 14 Exhibit 47

1.4.37 **Placing of the camera.** The placing of the camera between the armrest and the side-stick created a hazard. This went unrecognized initially, leading directly to the interference with the side-stick and the subsequent pitch-down. As such, the Panel assessed that **the placing of the camera was a contributory factor.** The reason why this act created a hazard, and the fact that it went unrecognized, was influenced by a number of associated factors.

a. **Distraction.** Immediately after the camera was last used, the CVR indicated that the Purser entered the flight deck and began a conversation with the Captain. This conversation could have drawn the Captain's attention and so reduced his focus on the task of stowing the camera. It cannot be positively determined that the camera was put down at this time, but if the point at which the camera was put down coincided with the Purser entering the flight deck, then it is possible that a distraction occurred. Without this distraction, it is possible that the camera may not have been placed behind the side-stick. The Panel assessed that **distraction of the Captain while using the camera was a possible contributory factor.** Exhibit 18 Exhibit 19

b. **Design of the side-stick area.** The side-stick is located on the outside of the Captain and Co-pilot seats.

(1) **Layout.** The seat can be positioned so that the side-stick is within the reach of the pilot. An armrest provides support to the pilot's elbow while using the side-stick, which is in line with good ergonomic practice to enable continuous adjustments and extended periods of use[2]. The armrest is adjustable to enable the pilot to achieve a comfortable working posture. A combination of the setting of the armrest and the seat position brings the armrest into the vicinity of the side-stick. The minimum distance the armrest can achieve relative to the side-stick when the seat is moved is 50mm. Annex B, para 27
There is a minimum of 140mm clearance between the side-stick and the nearest fixed obstruction (Figure 14).

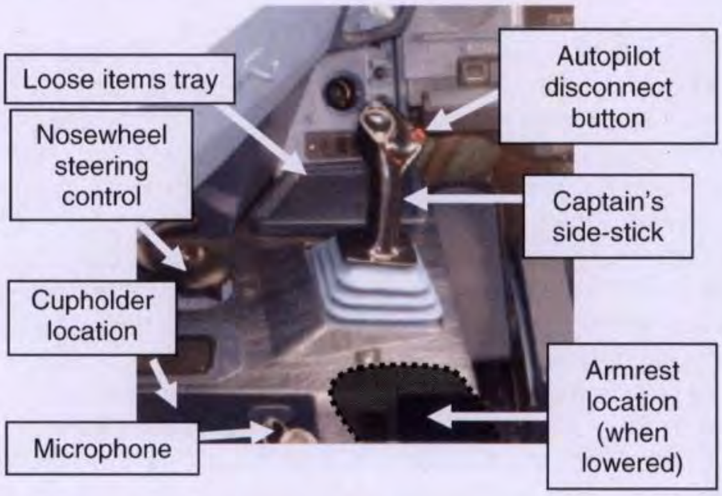

Figure 14: Layout of Captain's side-stick area.

(2) **Design to prevent accidental operation of the side-stick.** Joystick controls, such as the Voyager side-stick have a high likelihood of inadvertent operation[3]. Spurious or accidental operation of controls has been identified as an issue in safety critical systems[4], so it is good practice to include design features to reduce the likelihood of such accidental operation. For instance, British Standard (BS) 894 Part 3, though not specific to aviation, offers Annex B, para 28
guidance on how equipment design can mitigate the likelihood of accidental operation such as recessing the control, shrouding the control, placing a collar around the control, using a lock out system, or requiring two-handed controls. European aviation regulations (specifically European Air Safety Agency (EASA) regulation Exhibit 48
CS25.777) state that controls must be designed 'to prevent inadvertent movement'. The nature of the protection against spurious operation that is appropriate will depend entirely on the context in which the control is operated. The certification of Voyager when it was brought into military service was conducted in

[2] Kroemer, K.H.E. and Grandjean, E. "Fitting the Task to the Human", Fifth Edition (1997) London: Taylor and Francis, and DEF-STAN 00-250, Part 3, Section 15.
[3] DEF-STAN 00-250, Part 3, Section 15.
[4] UK Health and Safety Executive, David Fox, "Inadvertent operation of controls in excavator plant - insight, analysis and recommendations for prevention by design." (Jan 14), http://www.hse.gov.uk/research/rrpdf/rr1000.pdf (accessed 2 Jun 14); and Australian Transport Safety, "Safety Bulletin 3 – Lifeboat Accidents," (1 Dec 03), http://www.atsb.gov.au/media/43401/lifeboat_accidents.pdf (accessed 2 Jun 14).

accordance with Joint Aviation Requirements 25 (civil two-crew cockpit certification) and Military Certification Review Items F11 and F16. Human factors assessments were conducted by the Design Organization, independently verified by INTA (the Spanish National Institute of Aerospace Technology) and witnessed by the UK Aircraft Test and Evaluation Centre. The Voyager side-stick is protected against accidental movement principally by its position being remote from other controls. In addition, when the autopilot is engaged, additional force is required to move the control from the neutral (central) position (see paragraph 1.4.19), reducing the likelihood that a low force impact against the side-stick by a person or an item would cause the aircraft to change trajectory. Furthermore, when inadvertent operation occurs, a specific audio and visual warning is triggered to alert the pilot. In respect to the seat controls, switches are designed to ensure that movement can only occur while the switch is held in position by the pilot.

Exhibit 49

Exhibit 126

Exhibit 48

Annex B, para 28

(3) **Potential for accidental operation of the side-stick**. Interviews with the ZZ333 crew indicated that there was a known issue that inadvertent contact with the side-stick (most commonly by a knee) could result in the autopilot being disconnected. Such incidents had been resolved immediately by re-engaging the autopilot and had not been reported formally. Data from AirTanker Services indicated that there may have been up to 26 incidents since the start of Voyager flying when the autopilot had been disconnected in the cruise by moving the side-stick against the increased force, although it is not clear how many of these were accidental. The layout of the side-stick means that there are few other controls in the vicinity that could interfere directly with it. The closest items to the side-stick are the nose-wheel steering control, microphone, and armrest. Of particular interest to the ZZ333 incident was the proximity of the armrest to the side-stick. The armrest moves with the seat and is never less than 50mm from the base of the side-stick. As a result it is not possible for the armrest itself to interfere directly with the side-stick, but the operation of the seat when an item of appropriate size is located between the armrest and the side-stick could create a situation in which movement of the seat causes the side-stick to be moved out of the central position while the autopilot is engaged. As such, **the design of the side-stick area was a contributory factor**.

Annex B, para 29

c. **Armrest setting.** Both the Co-pilot and Captain had tall upper bodies, with a sitting height that placed them between the 80th to 85th percentiles of the population. As a result, their required seat setting for operating the flying controls was lower than that of the majority of pilots. This seating position would cause the armrest to have no vertical separation from the side-stick. Vertical separation from the side-stick would reduce the scope for an item to become jammed between the armrest and the side-stick, because a wheel located on the underside of the armrest would enable it to simply roll over the top of any obstruction. The Captain's settings for the armrest are shown in Figure 15. Reconstruction of the incident in the Voyager simulator indicated that the configuration of the armrest, when combined with the nature of the camera obstruction and the lack of vertical separation of the armrest from the side-