**Investigating the Voyager pitch down incident – a case study in civil / military co-operation.**

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## Introduction

On 9 Feb 14, a Royal Air Force (RAF) Airbus A330 Voyager aircraft (Figure 1), with 189 passengers and 9 crew on board, was flying on its first ever non-stop routing to Afghanistan. At 1549 UTC (night time) the aircraft was in the cruise at FL330 over Turkey with Auto-Pilot 1 engaged. The Captain was alone on the flight deck as the Co-pilot had left his seat for a break and was in the forward galley. Suddenly and without warning, the aircraft pitched down violently, throwing unrestrained passengers and crew to the ceiling. The Captain attempted to take control by pulling back on his side-stick controller and pressing the Auto-Pilot (AP) Disconnect button, but these actions were ineffective. The aircraft lost 4400ft in 27 seconds registering a maximum rate of descent of 15,800 ft/min and reaching Mach 0.9 as the crew wrestled with what they thought to be an auto-pilot malfunction. Fortunately the aircraft was brought back under control and diverted successfully to Incirlik Airbase in Southern Turkey. 25 passengers and 7 crew members reported minor injuries, however the consequences, had the incident occurred closer to the ground, could have been catastrophic. This paper will outline the investigation undertaken by the UK's Military Air Accident Investigation Branch (MilAAIB) in support of a Service Inquiry to establish the cause of the incident and make recommendations to prevent a recurrence. It is as a case study of civil /military co-operation demonstrating that independence most certainly does not mean isolation.


Figure 1: Airbus A330 Voyager aircraft

The MilAAIB was established in 2011 following Charles Haddon-Cave QC's independent review of the broader issues surrounding the loss of the RAF Nimrod aircraft XV230 in Afghanistan in 2006.[i] Amongst his many criticism of the MOD's airworthiness regime, he made a number of specific recommendations with respect to accident investigation. Consequently, the MilAAIB was established as a professional, joint, military air accident investigation branch, completely independent of the Army, RN and RAF. The branch was established at Farnborough alongside the civilian Air Accident Investigation Branch (AAIB) to ensure maximum benefit from their corporate knowledge and experience, gained from 100 years of investigations since Captain George Cockburn of the Royal Flying Corps was appointed as the very first inspector of air accidents. Operating under a Charter from the Secretary of State for Defence and reporting directly to the Director General of the Defence Safety Authority (DG DSA), the MilAAIB is as independent as it

could be, whilst also employing military experts who can deploy at a moment's notice to accidents worldwide, including to operational theatres.

**Initial investigation**

When notification came in of the Voyager incident, the MilAAIB was ideally placed to coordinate any response with the AAIB. The Voyager is an Airbus A330 aircraft modified to provide a Multi-Role Tanker Transport capability to the RAF. The aircraft are owned and operated by Air Tanker Ltd, a joint venture made up of Cobham, Airbus, Rolls-Royce, Thales and Babcock, but the majority of deployable personnel (aircrew and engineers) are military. Each aircraft must be able to switch between the Civil Aircraft Register and the Military Aircraft Register depending on how it is being used. On 9 Feb, ZZ333 was operating as a military aircraft and so the lead for any investigation fell to the MilAAIB. However, we were delighted to be able to include an AAIB investigator with extensive experience of the A330 in the team of three that deployed.

Their immediate task was to secure the vulnerable and perishable evidence, and provide an initial assessment of the situation. The Quick Access Data PCMIA Card, the Digital Flight Data Recorder (DFDR) and Cockpit Voice Recorder (CVR) were returned to the UK for download and analysis, concurrent with initial technical investigation and interviews in Turkey. Incredibly, there was very little damage to the aircraft, and it soon became apparent that the crew's diagnosis of an auto-pilot fault was not supported by the physical and data evidence, which indicated that the event was triggered by a full scale deflection of the Captain's side-stick controller (Figure 2), at which point the auto-pilot had disengaged. Following MilAAIB's Initial Report on 12 Feb, DG DSA elected to convene a full Service Inquiry[ii].

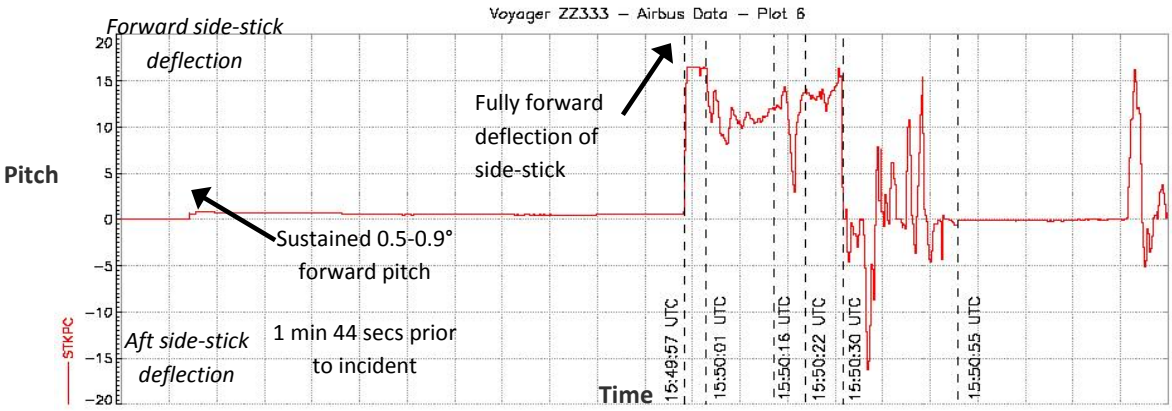


Figure 2: DDFDR trace showing pitch commands from Captain's side-stick

**What caused the pitch down?**

The initial focus for the inquiry was to determine what caused the pitch down event as this was still unknown and there were a wide range of possibilities. There was some urgency to this as Air Officer Commanding 2 Group, the Operational Duty Holder, had elected to 'pause' Voyager flying, and there was considerable public interest given the huge number of A330 aircraft flying worldwide. From the outset, we had full engagement and support from the operator (Air Tanker) and the OEMs (Airbus and Rolls-Royce) with these companies providing valuable assistance to the investigation in Turkey and back in the UK. AAIB kindly downloaded the DFDR and CVR data for us and the DFDR data was sent to Toulouse for detailed examination by Airbus flight control specialists. In parallel, the side-stick unit (SSU), which had passed all functional checks, was returned to the UK for a more detailed forensic technical examination.

The breakthrough came a few days later when one of the MilAAIB investigators was listening (for the 100th time) to the CVR and detected a distinct noise on the cockpit area microphone channel, 1 min and 44 seconds before the pitch down event. This corresponded with a very small forward displacement of the Captain's side-stick that was too small to cause the auto-pilot to disengage and so did not result in any disturbance to the aircraft. The noise re-occurred just before the pitch down event and spectral analysis confirmed that the sound exactly matched the electric motor used to move the Captain's seat forward. This temporal and directional correlation between seat and side-stick movement was compelling and the investigation sought to establish how they could be connected. The small initial displacement of the side-stick and the subsequent linear ramp to full scale deflection in the fore-aft axis without any lateral input could not be recreated by human pilot input and so the Panel's focus turned to the possibility of an object connecting the seat to the side-stick. All official items and personal effects which had been on the flight deck at the time were examined, with particular interest in the Captain's camera, which had been seen in the vicinity of the Captain's side-stick shortly before the event.

Twenty eight photographs had been taken of the cockpit in the eight minutes prior to the incident with the last photo taken 1 min 35 seconds before the initial side-stick displacement. Analysis of the CVR revealed that four seconds after the last photo was taken, the Purser had come onto the flight deck and had a short conversation with the Captain before returning to the cabin. On close examination, the camera was found to have a large dent on its right hand side. This was mapped forensically using surface profilometry and found to be a perfect match with the hand grip flange at the base of the side-stick. Furthermore, chemical analysis indicated that trace amounts of material in the indentation matched the material type of the side-stick.

Using the Voyager simulator, the team placed a copy of the camera between the armrest, which had been adjusted to the Captain's preferred setting, and the side-stick. When the seat was motored forward, the camera pushed the side-stick fully forward and became geometrically locked in place (Figure 3). The hand control base-plate was perfectly aligned with the position of the dent in the Captain's camera. The reconstruction took only a few seconds to set up and could be repeated time and again.

Figure 3: Re-construction of camera behind Captain's side-stick

The investigation continued to examine all other possible explanations for the pitch down event but with the likelihood of a technical cause diminishing and Airbus coming under increasing pressure from worldwide customers to clarify the situation, Urgent Safety Advice was issued to the RAF and to Airbus on 28 Feb, confirming that Human Factors was the probable cause of the Voyager pitch down event and highlighting the magnitude of the risk presented by foreign objects in the

immediate vicinity of the side-stick. This was followed by an Interim Report which was published on the Gov.uk website a couple of weeks later.

Once all other possibilities had been eliminated, 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 moved forward.

**How was the aircraft recovered?**

Having established the potential for the camera to geometrically lock in place, the investigation sought to establish how the aircraft was recovered. When the aircraft pitched down, the Captain's instinctive reaction was to pull back on the side-stick and this can be seen clearly from the DFDR traces, albeit the side-stick remained substantially blocked in the forward position. Convinced it was an auto-pilot malfunction, the pilot repeatedly pressed the AP Disconnect button on the side-stick (although the auto-pilot had in fact already disconnected). The Co-pilot, who had hauled himself back into the cockpit, also pulled back on his side-stick and reacting to the Captain's shouts that he couldn't get the auto-pilot out, pressed his AP Disconnect button repeatedly. The button has a dual function, and when the auto-pilot is disconnected, as it was in this case, the button switches the priority stick input to the Flight Control System (FCS) between the LHS Captain's side-stick and the RHS Co-pilot side-stick. Had control been formally handed to the Co-pilot, the Captain's inputs would have been locked out and the problem neutralised. But, in the confusion of the event, on a darkened flight deck, in a negative 'g' bunt, the crew became fixated on trying to get the auto-pilot out and control priority kept switching back to the fully deflected left stick.

Fortunately, the A330 fly-by-wire FCS incorporates overpeed and pitch down self-protection features to prevent exceedance of flight envelope limitations. 3 seconds after the initiation of the pitch down, the FCS acted to limit the pitch attitude to 15 degrees nose down, and 10 seconds later the high speed protection feature activated to reduce the engine thrust to idle and pitch the aircraft up at approximately 1.75 'g' (Figure 4). The aircraft flew itself out of the dive.

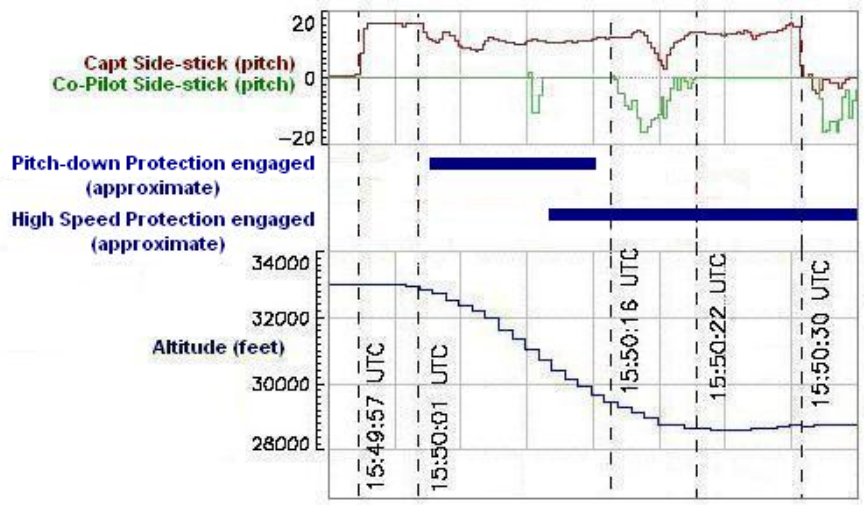


Figure 4: Activation of pitch and high speed protection features

33 seconds after the pitch down, the obstruction was cleared, the Captain's side-stick sprung back to the neutral position and the crew regained full control of the aircraft. The investigation considered whether the obstruction was cleared by a movement of the side-stick, the seat, the

armrest, the camera, or a combination of these. Extensive simulator tests were conducted and the evidence strongly suggested that the camera was physically manipulated from behind the side-stick but the crew were unable to clarify this.

It is noteworthy that during the pitch down, the Captain, in his desperation to regain control, considered switching off the Air Data and Inertial Reference Units (ADIRU) in order to place the aircraft into 'direct law' control mode. Had he done this, the aircraft's pitch and over-speed self-protection features would have been disabled and the aircraft would almost certainly have exceeded its certified flight envelop limits by a considerable margin, potentially leading to significant damage to the aircraft.

**Human Factors analysis**

Having established 'what' happened during the incident, deeper analysis was undertaken with the assistance of the Human Factors experts from the RAF Centre of Aviation Medicine, to probe 'why' it had happened to enable formulation of recommendations to prevent recurrence. The pertinent sequence of events was: the camera was taken onto the flight deck, the camera was used, the camera was placed behind the side stick and the seat was then moved without any appreciation of the potential outcome.

Carriage of the camera was not prohibited by any rules or regulations, and the investigation found its presence was consistent with normalised behaviour regarding loose articles on RAF air transport aircraft. This behaviour had itself been the subject of a Safety Investigation at RAF Brize Norton, following concern at the number of loose articles found by maintenance personnel on the flight deck of C130 aircraft. The Voyager crew were required to take a large number of items with them including two sets of body armour, combat survival waistcoats, crew weapons, aircraft documentation, two route bags and worldwide navigation charts, and there was little dedicated storage for these items. With the acceptance of a large number of official items on the flight deck, the carriage of a small number of personal effects was not considered unreasonable.

Equally, there was no specific rule that prohibited use of the camera during flight. The Captain was a photography enthusiast and had often taken pictures on the flight deck. However, the Voyager Operations Manual did state that 'flight crew must refrain from non-relevant duties while the other pilot is away from the active ATC frequency', and this procedural defence was breached by the pilot taking 28 photos when alone on the flight deck. It was a very quiet period of the flight and it was assessed that low pilot workload and boredom, compounded by the presence of only a single person on the flight deck for an extended period of time, all made the use of the camera more likely, and therefore was a contributory factor.

The placing of the camera behind the side-stick created a hazard that was unrecognised and subsequently led directly to the pitch down. The distraction of the Captain by the Purser entering the flight deck may have contributed to this. The minimum distance between the armrest and the side-stick was 50mm but as this incident proved, the two could be coupled by a foreign object placed in the space between. Although there had been no recorded incidents of this happening in 190 million flying hours of Airbus aircraft, inadvertent disconnection of the auto-pilot by knocking the side-stick had occurred 26 times on the Voyager in the previous 2 years, none of which had been reported. The Airbus Flight Crew Training Manual advocated a clean cockpit – 'objects not stored in their dedicated area in the cockpit may fall and cause hazards such as damage the equipment or accidentally operate controls or pushbuttons.' And MAA Regulatory Article 2309 directs 'that the aircraft commander should ensure that all loose articles and stores are properly stowed such that there is no possibility of fouling the flying controls.' However, the risk regarding

flight deck control interference on Voyager had not been specifically identified and was therefore not being actively managed by the Duty Holder.

The final link in the chain was the movement of the seat which is a routine occurrence in flight on the A330. The investigation considered that the time delay between the Captain putting the camera down when the Purser entered the flight deck, and his separate action to adjust his seat position 104 seconds later using a switch in a different area of the flight deck, meant that the resultant change in aircraft attitude would have been extremely unexpected and it is not surprising that the Captain did not see the connection between these events at the time.

**Recommendations to enhance safety**

This incident was an extraordinary and possibly unprecedented event. However unlikely an exact recurrence may seem, the consequences of flight control interference can be catastrophic. The Service Inquiry illuminated a number of underlying issues that warranted attention and made 24 recommendations to enhance flight safety. Some of these issues are not unique to Voyager (or indeed to military aviation in the UK) and the following recommendations may be of interest:

- Implement a comprehensive strategy to effect a positive change in the safety culture with respect to loose articles on the flight deck.
- Take steps to minimise what is carried on the flight deck and maximise the use of designated stowage areas.
- Review the rules governing minimum crew numbers at their station.
- Take measures to further strengthen the reporting culture.
- Ensure that the critical importance of a clear handover of control in side-stick equipped aircraft is emphasised throughout training.
- Examine ways of managing low in-flight pilot workload.
- If possible, implement measures that could help prevent the placing of loose articles in close proximity to the side-stick.

**Concluding remarks**

**The incident.** This incident was a very serious near miss and serves as a timely reminder that one simple and unthinking act such as placing a loose article close to the aircraft controls could develop quickly into a catastrophic event. On this occasion, the A330 automatic self-protection features likely prevented a disaster of significant scale. Fortunately, there was no accident but the occurrence was nonetheless investigated to the same degree by the MilAAIB and others in support of a full Service Inquiry.

**No blame safety investigation focused on identifying carefully targeted recommendations to enhance safety.** The investigation was a no-blame safety investigation, so whilst others outside our community may focus on the rights or wrongs of the crew's actions on the day, we were able to probe the underlying human factors and organisational issues, and illuminate wider cultural concerns that need to be addressed to prevent other loose article related events. The recommendations made have been carefully targeted at those senior post holders in Defence who have the means to effect the changes required. Their implementation will be tracked to completion and may only be closed by DG DSA.

**Thorough and expert team effort.** The inquiry was undertaken impartially by a panel and a professional investigation branch that were completely independent of the operator, the regulator, the manufacturer et al. However, a thorough and evidence-based investigation could not have

been completed effectively without: the full co-operation of Air Tanker Ltd and the MOD Project Team, the full support of the civil AAIB and the Airbus Investigation Team, the technical assistance of Rolls-Royce, the forensic laboratory capabilities of the Materials Integrity Group, 1710 Naval Air Squadron, the data fusion capabilities of QinetiQ, the evaluation skills of test pilots from the Air Warfare Centre and Airbus, and the Human Factors expertise residing in the RAFCAM. Working together as a team, we were able to resolve the apparent conflict between the crew's perception of what happened and the evidence from the DFDR, and understand what was initially a perplexing mystery.

**Independence** It is my contention that independence is very important, especially in the leadership of an major investigation. The investigation must be protected from improper interference and investigators must have the freedom of manoeuvre to conduct the investigation without fear or favour. But it is our experience that this does not mean and cannot mean isolation. We in the MilAAIB recognise that we are dependent on other agencies; some are independent, and some are not; but we highly value their necessary expert contribution regardless. Hence we go to some lengths to develop our support network and ISASI seminar are a marvellous opportunity to further cultivate that!

**Transparency** We also recognise, that despite being a military unit engaged on very sensitive work, there is a balance to be struck between protecting sensitive information and sharing information that can enhance safety. In this we draw a distinction between protecting the inputs to an investigation (confidential witness testimony for example), and providing maximum transparency of the process and the outputs. Following the Voyager pitch down incident, there was legitimate concern from Airbus operators worldwide until the probable cause was established and communicated. It was therefore beholden on us to promulgate that Safety Advice to stakeholders as soon as we had something tangible to release. At the end of an investigation we always publish the Final Report on the internet.[iii] But with Voyager, in a first for us, we also published an Interim Report on the world-wide-web, as soon as the probable cause was established, and whilst the investigation was still on-going. This public release was hugely effective in defusing public concern, and is a practice that we have now adopted as an SOP. We think this transparency of process and output helps to demonstrate our independence without in any way compromising it. We steadfastly defend that independence but we also strongly support the view that independence does not mean isolation.

[i] The Nimrod Review: an independent review into the broader issues surrounding the loss of the RAF Nimrod MR2 aircraft XV230 in Afghanistan in 2006.
[ii] With full statutory powers under the Armed Forces Act, 2006
[iii] https://www.gov.uk/government/publications/service-inquiry-incident-involving-voyager-zz333-on-9-february-2014