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BOARD OF TRADE

CIVIL AIRCRAFT ACCIDENT

Report on the Accident to Hawker Siddeley Argosy AW 650 Series 22 - G-ASXP at Stansted Airport, Essex on 4th December 1967

LONDON: HER MAJESTY'S STATIONERY OFFICE

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1970

Board of Trade
Accidents Investigation Branch
Shell Mex House
Strand
London WC2

May 1970

The Rt Hon Roy Mason MP
President of the Board of Trade

Sir

I have the honour to submit the report by Mr G M Kelly, an Inspector of Accidents, on the circumstances of the accident to Hawker Siddeley Argosy AW 650 Series 22, G-ASXP, which occurred at Stansted Airport, Essex on 4 December 1967.

I have the honour to be,

Sir,

Your obedient Servant,

V A M HUNT
Chief Inspector of Accidents

ACCIDENTS INVESTIGATION BRANCH

Civil Accident Report No EW/C/0194

Aircraft:	Hawker Siddeley Argosy AW 650 Series 22 - G-ASXP
Engines:	Four Rolls Royce Dart 523/1
Owner and Operator:	British European Airways Corporation
Crew:	Commander: Captain H H Jones - Uninjured Pilot under training: Captain R Dark - Slightly injured Supernummery: First Officer I Bashall - Slightly injured
Passengers:	None
Place of Accident:	Stansted Airport, Essex
Date and Time:	4 December 1967 at 1327 hrs
	All times in this report are GMT

Summary

The accident occurred shortly after take-off on a training exercise when the aircraft swung to the right after the simulated failure of the starboard outer engine, and went out of control. The aircraft cartwheeled on its starboard wing and caught fire. The crew escaped through a hole in the damaged fuselage. The report concludes that the loss of control probably resulted from the starboard outer propeller (No 4 engine) going temporarily into ground fine pitch.

1. Investigation

1.1 History of the flight

The aircraft was engaged on crew refresher training and had landed at Stansted to carry out take-offs and landings. For the flight on which the accident occurred Captain Dark occupied the first pilot's position and Captain Jones in his capacity as training captain occupied the second pilot's seat. First Officer Bashall occupied the third pilot's seat but had no designated duty, having completed his training exercise.

The windscreen in front of the first pilot's position was fitted with the standard BEA blind flying screen, which obstructs the view of the pilot under training except for a small aperture that allows limited visual reference outside the flight deck. The training captain normally closes the aperture at 100 feet or so from the ground. In this instance the aperture was open throughout the flight.

The exercise to be carried out was the simulation of an engine failure during a take-off on instruments, and the training captain told the pilot to expect the 'failure' between rotation speed (V_R) and take-off safety speed (V_2).

The pre-take-off checks were completed satisfactorily. Flaps were set to 'take-off' (12^o) and the flight fine pitch locks were set to 'engage'. The take-off was made on runway 23 and during the first part of the roll all the systems appeared to be operating normally, although the crew could not be sure about the indications of the flight fine pitch indicator lights which in certain conditions of light are not easy to see. The rotation speed of 102 knots and take-off safety speed of 111 knots used on the previous take-off were used again for this one. The take-off run was normal, on a constant heading, and about 960 metres long. At 102 knots the aircraft was rotated at about $1\frac{1}{2}^o$ per second. At 107 knots Captain Jones throttled back the starboard outer engine (No 4) to 190 kgs per hour fuel flow (the standard setting for the purpose) to simulate the failure of the engine. In accordance with standard practice he kept his feet on the rudder pedals to monitor the reaction of the pilot under training.

Immediately following the simulated engine failure there was a change of heading of about $2\frac{1}{2}^o$ to starboard, which the pilot under training corrected, regaining the original heading about three seconds after becoming airborne. About one second later, having climbed about 50 feet, the aircraft yawed sharply to starboard at 11^{o} per second. Almost immediately the starboard wing went down and the training captain took the controls to help the pilot under training but found that full port aileron and rudder had already been applied. The training captain momentarily released one hand from the control column to reopen No 4 throttle and managed to push it forward three or four inches (about one-third of the way), but before the crew could detect any response from the engine the starboard wing tip struck the ground. From the second yaw to starboard (11^{o} per second) to collision with the ground took six seconds.

When the wing tip touched the ground the aircraft was banked to some 45^{o} and still rolling rapidly to starboard. It immediately caught fire, cartwheeled and began to disintegrate. The wreckage came to rest some 500 feet to the right of the runway and almost immediately a second fire broke out as fuel was spilled from the ruptured port wing tanks.

The crew escaped through a hole in the broken fuselage. The airport fire service was promptly on the scene and both fires were brought under control.

1.2 Injuries to persons

Injuries	*Crew*	*Passengers*	*Others*
Fatal	-	-	-
Non-Fatal	2	-	-
None	1	-	

1.3 Damage to aircraft

Destroyed

1.4 Other damage

None

1.5 Crew information

Captain Harold Hugh Jones, aged 47, held a valid airline transport pilot's licence. He had joined British European Airways in 1947 from Royal Air Force Transport Command, having accumulated 858 hours service flying. At the time of the accident, he had accumulated a total of 11,957 hours flying of which 3,148 were in Argosy aircraft.

Captain Jones had been flying in command of Argosy aircraft since 1961, and had been a line training captain since 1964. He had completed the statutory competency checks at the appropriate times. He had not flown for three days before the accident but during the preceding 25 days had flown some 50 hours.

Captain Raymond Arthur Lancelot Dark, aged 44, held a valid airline transport pilot's licence. He had joined British European Airways in 1952 five years after leaving the Royal Air Force, in which service he flew 700 hours. At the time of the accident he had acquired a total of 8,248 hours of which 2,318 were on Argosy aircraft.

Captain Dark flew as a first officer in Argosy aircraft from 1961 to 1966, and thereafter in command. He had completed the statutory competency checks at the appropriate times. In the twenty-eight days before the accident he had flown 40 hours 20 minutes and in the last three days 10 hours 30 minutes, of which 7 hours were during the last twenty-four hours.

First Officer Iain Bashall, aged 33, held a valid airline transport pilot's licence. He had flown a total of 4,384 hours of which 1,343 were in Argosy aircraft.

1.6 Aircraft information

G-ASXP was built by Hawker Siddeley Aviation Ltd in 1965 and was registered in the name of British European Airways. The mandatory inspections and modifications had been carried out on the airframe and engines and valid certificates of airworthiness and maintenance were in force at the time of the accident. The aircraft had flown a total of 7,297 hours, of which 245 hours were since 8 November 1967, when the last Check 1 inspection was completed.

The weight of the aircraft at the time of the accident was 1,400 kgs less than the authorised maximum landing weight and the centre of gravity was within the prescribed limits.

1.7 Meteoroligical information

The weather was fine with good visibility and no cloud. The temperature was +8°C, the aerodrome barometric pressure (QFE) 1019 mbs and the wind velocity 260°/10 knots.

1.8 Aids to navigation

Not applicable to this accident.

1.9 Communications

Two-way VHF R/T with the control tower was normal, using standard procedures. There was no significant message from the aircraft.

1.10 Aerodrome and ground facilities

Runway 23 at Stansted is asphalt, level at an elevation of 346 feet, and 61 metres wide. The take-off run and emergency distance available is 3,048 metres and the take-off distance 3,071 metres.

1.11 Flight recorder

1.11.1 The equipment

The aircraft was fitted with a Plessey-Davall Type PV 710 digital system using pulse code modulation on a stainless steel wire. The parameters recorded against a common time scale were limited to those mandatory to this aircraft under the Air Navigation Order:

1. *Indicated airspeed*

2. *Pressure altitude*

   Signal inputs for these two parameters were obtained from the airspeed and altitude transducers fitted to the mounting tray of the processing unit in the equipment rack on the flight deck. Pitot pressure was supplied from a tapping off the starboard pressure system and static pressure from No 2 static vent.

3. *Heading*

   Signal input for this parameter was taken from No 2 synchro repeater in the port compass amplifier.

4. *Normal acceleration*

   Signal input for this parameter was taken from an acceleration transducer unit fitted under the freight floor within the longitudinal limits of the aircraft's centre of gravity.

5. *Pitch attitude*

   Signal input for this parameter was derived from No 2 pitch potentiometer in the port vertical gyro unit.

The time scale of the recording was controlled by a crystal oscillator in the processing unit.

1.11.2 Damage sustained in the accident

The equipment suffered only minor damage in the accident and none of the components was displaced significantly from its normal mounted position. The break-up of the aircraft structure, however, resulted in complete electrical disruption of the system.

1.11.3 Recovery of information

Recovery of information was delayed by a number of defects. A high degree of distortion due to wow and flutter in the recording precluded the production of a satisfactory analogue trace and rendered impracticable any automatic punch-out and print of all the digital data relating to the accident. A waveform presentation of the digital data was produced on an ultra-violet photographic recorder and analysed as far as possible by hand. Certain areas of the final part of the record were so distorted, however, that some of the information relating to the final seconds of flight could not be resolved. To determine some of the errors in the record, digital data from previous flights were obtained which showed a digitising discontinuity in the 512 digit area, the centre of the digitising scale. This error was due to the effect on the AC to DC converter of harmonic distortion of the supply voltage. The error was of most significance to the acceleration trace of the record of the accident flight because in this instance the accelerometer had a 'zero' increment datum at the 512 digit point.

1.11.4 Calibrations and corrections

The airspeed, altitude, and accelerometer transducers were apparently undamaged but because of the significance of their related parameters to performance calculations required in the investigation a post accident calibration of each was made to check the validity of the pre-accident calibrations, and to establish the validity of an integrated height plot derived from the available acceleration data.

Airspeed

The post-accident calibration curve of the airspeed transducer differed considerably from the pre-accident calibration curve. In the absence of any evidence of damage to the mechanism the difference was attributed to a long term change due to temperature variations. The post-accident calibration was considered to be the more valid.

Pressure altitude

Calibration of the pressure altitude transducer revealed no significant scale errors. The datum was adjusted so that the altitude could be plotted as equivalent height above air-field level.

Normal acceleration

No dynamic calibration of the accelerometer transducer was undertaken because the static calibration showed hysteresis errors on the instrument in the plus or minus 1 'g' increment range. This error, combined with the error due to harmonic distortion referred to above, was found to produce errors greater than some of the incremental measurements. An attempt to produce an integrated height plot from the acceleration data was therefore abandoned.

Pitch attitude

Calibration of the vertical reference unit potentiometer supplying the pitch information to the flight data recorder showed that its output varied significantly in both climb and descent. The variation was attributed to a sluggish mercury erection switch. Error curves were plotted and used to provide probable maximum and minimum values of pitch attitude during the flight. The pitch attitude data had been recorded in the reverse sense. The vertical reference unit in the Argosy is installed back to front, and the wiring connection had not been reversed to conform with the installation. Corrections were made to the data to take account of both this error and a small platform datum error.

Heading

The heading data had also been recorded in the reverse sense as the result of incorrect wiring connections and the datum was displaced. The recorded data was accordingly corrected.

1.11.5 Results

The deductions that could be made were limited to:

1. The heading was constant during the take-off run and the aircraft left the ground about 3,150 feet from the take-off threshold. This distance was compatible with the calculated performance for the prevailing conditions. After a gentle rotation the heading changed by about $2\frac{1}{2}^{\circ}$ to starboard, but the original heading was regained 3 seconds after the aircraft became airborne. One second later there was a sudden change of heading to starboard that became continuous at some 11°/second. Six seconds later the starboard wing hit the ground.

2. The heading of the aircraft at the impact was 64° to starboard of its original take-off heading. Comparison with the approximate track derived from the wreckage trail suggests that the aircraft had been sideslipping to port at an angle between 10° and 20°.

3. The displacement to the right of the runway centreline (380 feet in 6 seconds) would correspond to an average lateral acceleration of 0.6 g - an average force of about 50,000 lb. With a sideslip angle of between 10 and 20 degrees this force would be generated by an angle of bank of 25° to 30° to starboard.

1.12 Wreckage

1.12.1 Distribution

Inspection at the scene of the accident showed that the starboard wing tip touched the ground 380 feet to the right of the centreline of runway 23, 4,782 feet from the threshold. The wing structure broke up progressively inwards as it took the weight of the aircraft. The nature of the break-up and marks on the ground indicate an angle of bank of about 45°.

The starboard outer wing became detached outboard of No 4 engine and caught fire. The remainder of the aircraft continued to roll to the right as it cartwheeled a further 150 feet, the starboard boom and centre plane breaking off at the centre plane fuselage attachments and forward of the attachment point of the fin. The port boom buckled round the fuselage rear end. The wreckage came to a rest with the port wing, complete with Nos 1 and 2 engines, still attached to the fuselage. The tanks in the port wing were ruptured and the wing was destroyed when the spilled fuel caught fire.

1.12.2 Examination

Examination of the airframe and systems revealed no evidence of pre-crash damage or mechanical defect. All damage was consistent with the impact with the ground. No inferences could be drawn from the settings of control levers and trim wheels on the flight deck, all having been moved during the break-up of the airframe. The port centre flap was the only one sufficiently intact to provide guidance on flap position. It was found at a position a little above the "approach" setting. The flap control unit (which is an 'irreversible' gear) and the selector mechanism of the flap control unit were in agreement with this setting. However, the damage sustained by the flaps was such that it could only have occurred when the flaps were at the take-off setting. It is considered that the flap operating mechanism had been temporarily set in motion during the break-up of the structure.

All control locks were found disengaged and there was no evidence that they had been engaged at impact.

The settings of the engine and propeller controls could not be reliably assessed from the positions of the levers on the flight deck. It was possible to establish that the LP fuel cocks were open and the fuel transfer cocks closed, as required by the fuel management procedure.

Strip examination of the propellers showed that the blade angles at impact were:

No 1	-	$26\frac{1}{2}^{\circ}$	No 2	-	$23\frac{1}{2}^{\circ}$
No 3	-	24°	No 4	-	$18\text{-}18\frac{1}{2}^{\circ}$

The blade angles of 1, 2 and 3 propellers are consistent with the development of full power. The flight fine pitch stop blade angle on these propellers is 18°. No 4 propeller was at a slightly coarser pitch than the flight fine setting.

Examination of the throttle pedestal showed that the throttle levers could be moved forward (open) without moving the fine pitch stop lever far enough to operate the propeller control switches. If the fine pitch stop lever does not move fully forward - the flight fine pitch lock will not engage and the operation of the hub switch will be inhibited. The electrical safeguards are then invalidated and a propeller could go into ground fine pitch if its engine were throttled back. However, the pedestal had been slightly distorted in the accident and it was not possible to establish that the malfunction could have occurred before the accident. It could not be reproduced on the throttle pedestals of the other Argosy aircraft in the BEA fleet, all of which were examined.

1.13 Fire

Fire broke out in the starboard wing when the tanks were ruptured by the collapse of the structure after the impact with the ground. Fuel spilled from the ruptured port tanks caught fire after the wreckage came to rest. The fuel in use was aviation kerosene. Both fires were quickly brought under control by the aerodrome fire service.

1.14 Survival aspects

The accident was survivable. The crew were secured by full (shoulder) harnesses and the flight deck structure remained intact. The third pilot received cuts and bruises when his seat became detached from the floor.

1.15 Tests and research

1.15.1 Argosy simulator tests

The parameters recorded by the flight data recorder were basically inadequate to determine the flight path of the aircraft, since bank angle and lateral acceleration were lacking. Attempts were made on the Royal Air Force Argosy simulator to reproduce the behaviour of G-ASXP so as to provide the missing parameters and to examine the consequences of applying incorrect control responses to the failure of No 4 engine. In no case were all the required parameters achieved, and in every case the pilot was able to correct the deviation resulting from the failed engine and the wrongly applied controls.

Sideslip angles reproduced by the simulator were of the same magnitude as those deduced from the flight recorder data, but bank angles were very much less in all instances except when wrong rudder and wrong aileron were applied simultaneously in response to the failure of No 4 engine. In each case the yaw, after the failure of the engine, developed at about half the rate recorded on the flight data recorder; the heights achieved by the simulator in the time taken by G-ASXP to accelerate and stop was 50-100 feet above the ground and the lateral displacement was between 0 feet and 200 feet. Thus the divergence of the simulator from the normal take-off path was considerably less violent and much slower than the recorded divergence of G-ASXP, even when wrong aileron and wrong rudder were applied simultaneously.

Accurate interpretation of these results depends on how representative the RAF simulator was of the BEA Argosy. Simple handling and performance checks showed that the principal aerodynamic derivations and the basic thrust/drag relationship were reasonably representative. There were two areas of doubt:

1. The simulator did not allow for the effect of sideslip on drag.

2. The yawing moment due to rudder deflection was calculated by the simulator according to a simple linear relationship, whereas on the real aircraft this function is a more complex non-linear one.

1.15.2 Calculated time history of No 4 propeller

The time history of No 4 propeller moving from take-off to the ground fine position was calculated by the manufacturer, assuming the conditions prevailing at the time of the accident and accepting that the flight fine pitch stop and its back-up system (the hub switch) were inoperative. The calculations showed that after closing the throttle to simulate engine failure at about 115 knots at sea level (taken from the less favourable airspeed curve derived from the flight recorder) the propeller blades would go right through to ground fine pitch about 4 seconds after the engine had been throttled back and stay there. These calculations are valid where the hub switch and flight fine pitch stop are inoperative for 1½ seconds or more. Subsequently advancing the throttle 3" or 4" at 90 knots equivalent airspeed would cause the propeller pitch to increase to the flight fine pitch position in 4.2 and 4.16 seconds respectively.

Calculations also showed that in the same ambient conditions and at 90 knots equivalent airspeed the propeller pitch would increase to the flight fine position if the hub switch became operative again.

A theoretical time history of blade angle for the same ambient conditions but with the propeller proceeding only to the flight fine pitch stop when the throttle was closed showed that with neither throttle opening (3" or 4") would the propeller lift off the stop again.

2. Analysis and Conclusions

2.1 Analysis

The data provided by the flight data recorder was basically inadequate to determine the flight path of the aircraft, and faults in the equipment resulted in shortcomings as regards the amount of data it was possible to recover. However, some valid inferences could be drawn. The rate of change of heading after the second yaw was about 11^{o} per second, but the lateral movement of the aircraft from the runway centreline (350 feet in 6 seconds) indicates a rate of change of track of only 6^{o} per second. This would imply an impossible angle of sideslip long before the impact with the ground. From this it can be inferred that the angle of bank was about 45^{o} and the normal acceleration about 1.0 g. Such a bank angle was consistent with the indications of the wreckage trail.

A bank angle of this order takes several seconds to develop. The change of heading must first of all have been a sideslip, and the curves derived from the flight data recorder were consistent with large acceleration in yaw - up to about 12^{o}-15^{o}. Most of the lateral excursion of 350 feet would then have taken place in about 3 seconds, which is consistent with the evidence.

To build up these changes of sideslip and bank a large moment would have to have been applied. Analysis suggests that the yawing moment due to one outer engine idling, with the others at take-off power, is only about half that required to produce the swing recorded. Both engines throttled back on the same side would not provide a large enough yawing moment, and the evidence was that No 3 engine was delivering take-off power at impact.

It had therefore to be assumed that either there was an application of wrong rudder and aileron (or a reversal into the wrong application after initial over-correction) or a propeller malfunction of some kind to explain the large changes in sideslip and bank. Since the natural stability of the aircraft in roll would offer a strong counteraction to the development of the bank angles achieved despite the asymmetrical lift due to the outer engine being throttled back it was necessary to consider some disruption of the airflow over the wing by a malfunction of the propeller.

There was no evidence that the flying controls were applied wrongly. The crew were examined carefully on this point, and all the arguments in favour of wrong application of the controls were put to them. The evidence of the flight recorder shows that the initial swing due to the simulated engine failure was corrected. There was insufficient time to have applied the controls correctly, then incorrectly, then correctly again before the aircraft hit the ground. The training captain (who had his feet on the rudder pedals all the time) had had previous experience of pilots applying control the wrong way and the behaviour of the aircraft on those occasions had not been the same as on the occasion of the accident. The pilot in the simulator tests had had no difficulty when the reproduction of the accident by wrong application of controls had been attempted. That the accident was due to this sort of mishandling was therefore ruled out.

There remained the possibility that No 4 engine moved into ground fine pitch. A number of arguments can be marshalled in favour of this theory. The calculated time history of propeller blade angle gave a time to change from take-off thrust to the ground fine position that was strikingly similar to the time recorded on the flight recorder between throttling No 4 engine back and the onset of the violent yaw to starboard. No 4 propeller was at a slightly coarser pitch than flight fine at impact, and the calculated time histories of blade angle show that the propeller could have moved to such a position only if the coarsening movement had started from the ground fine position. Moving the throttle lever forward 3" to 4" would have initiated this movement and the resulting increase in thrust was not incompatible with the damage sustained by the propeller blades.

No way could be found to account for the behaviour of the aircraft without introducing a malfunction of No 4 propeller. An assessment of the effect in the rolling plane of No 4 propeller going into ground fine pitch led to the conclusion that the resulting loss of lift over the starboard wing would require about 15^{o} of aileron to control. The aileron available was 18^{o} and the 3^{o} remaining would only be enough to control additional adverse sideslip up to an angle of sideslip of 6^{o}. The minimum rudder control speed with No 4 propeller in ground fine pitch was estimated as about 115 knots. The speed recorded on the flight data recorder may have been as low as 107 knots at the critical time, and since at this speed adverse sideslip would have substantially exceeded 6^{o} it would have been impossible to maintain control in the rolling plane. There was still doubt that the high rate of change of heading was compatible with this course of events, but since the flight recorder did not record bank angle it was not possible to assess what, if any, elements of pitch change were contained in the recorded change of heading.

There are arguments tending to detract from the theory that No 4 propeller moved into ground fine pitch. For it to have done so in flight two safeguards would have to have broken down - the flight fine pitch lock, and the hub switch. Both were electrically controlled, and no evidence of electrical malfunction was found; the greater part of the electrical circuitry for these systems was destroyed by fire. If the flight fine pitch lock had withdrawn, the appropriate indicator lamp on the flight deck would have illuminated. If it did, no member of the crew noticed it, although, since the indicator was behind the throttles the illuminated lamp could have been missed. The flight fine pitch lock could have been withdrawn and the operations of the hub switch inhibited if the fine pitch stop lever on the throttle pedestal had not moved fully forward when the throttles were opened. While this malfunction was possible on the pedestal recovered from the wreckage some manipulation was required to make it happen, and there was no proof that it happened before the accident. The distortion that made the malfunction possible after the accident was quite consistent with damage that could have been caused in the break-up of the aircraft.

However, the argument that the behaviour of the aircraft could not be accounted for except by No 4 propeller moving into ground fine pitch is considered to be an overriding one, and it is concluded that this was the most probable cause of the accident.

2.2 Conclusions

(a) *Findings*

(i) The documentation of the aircraft was in order.

(ii) The aircraft was properly loaded and trimmed.

(iii) The pilots were properly licensed.

(iv) The aircraft went out of control after the throttle had been pulled back to simulate a failure of the engine.

(v) The loss of control was most probably due to No 4 propeller moving into ground fine pitch when the engine was throttled back.

(vi) No evidence was found to explain the failure of the flight fine pitch protection systems of the propeller.

(b) *Cause*

The accident was due to a loss of control during a take-off with a simulated failure of the engine. The loss of control was most probably the result of No 4 propeller going into ground fine pitch when the engine was throttled back.

G M KELLY
Inspector of Accidents

Accidents Investigation Branch
Board of Trade
May 1970

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