N90AG Prior to the accident

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Figure 1

N90AG Accident site

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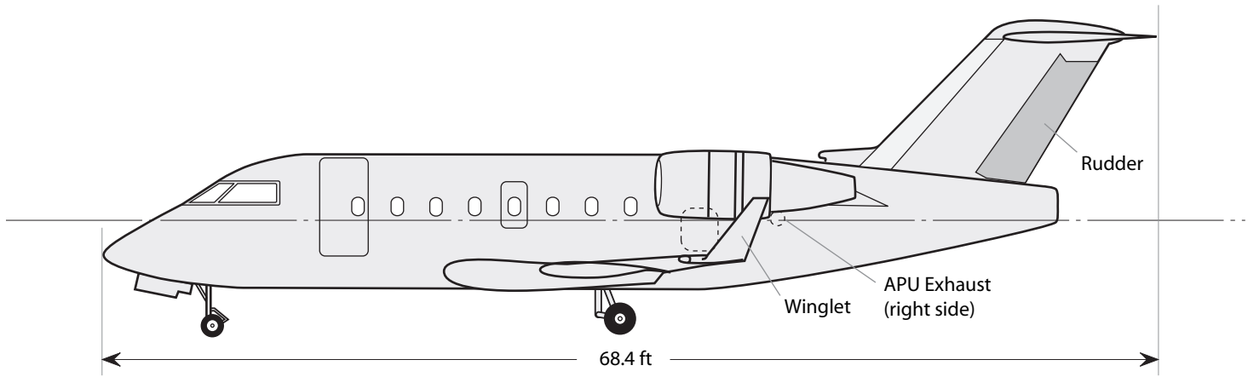
Figure 2

Figure 3

CHALLENGER 604 GENERAL ARRANGEMENT



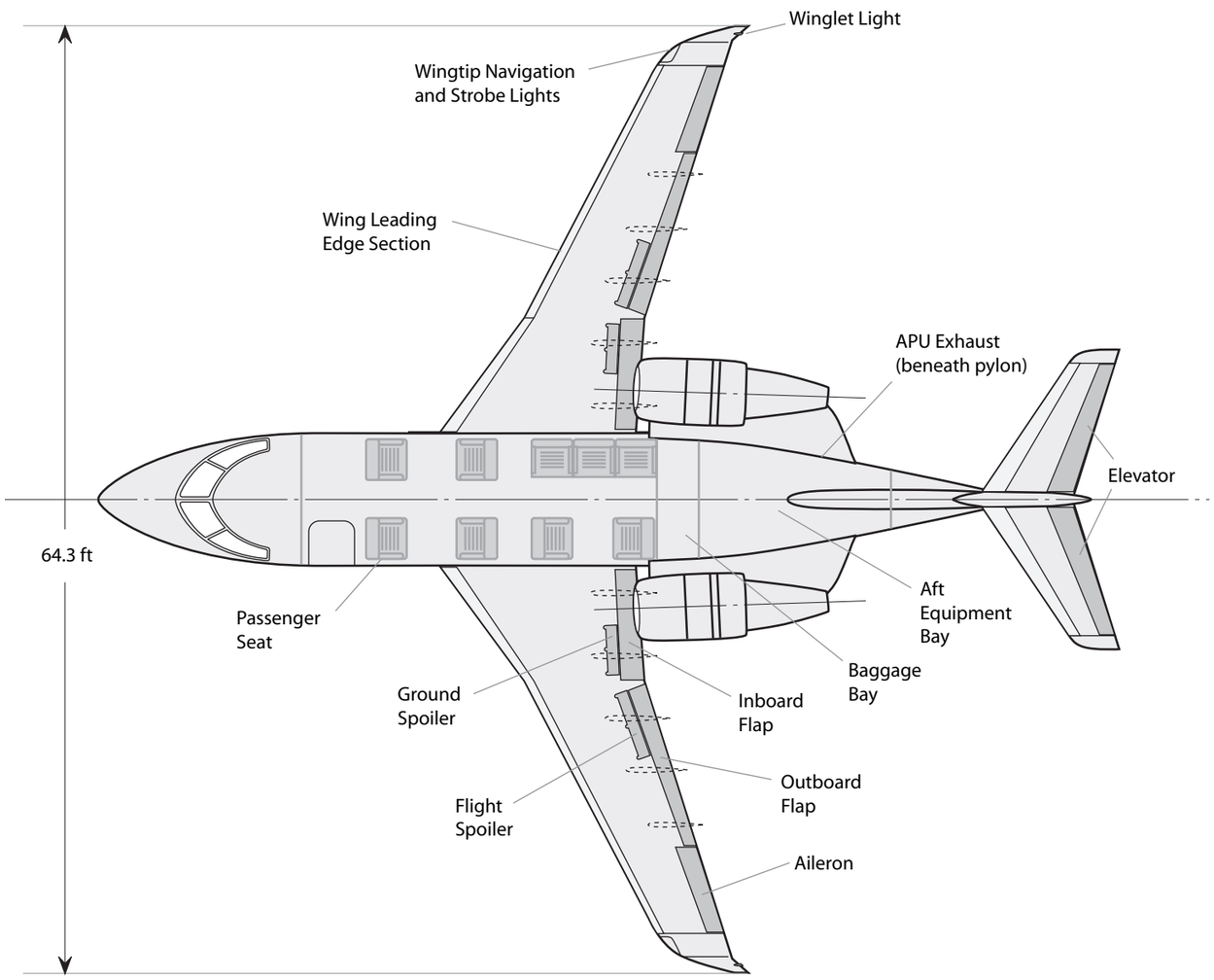
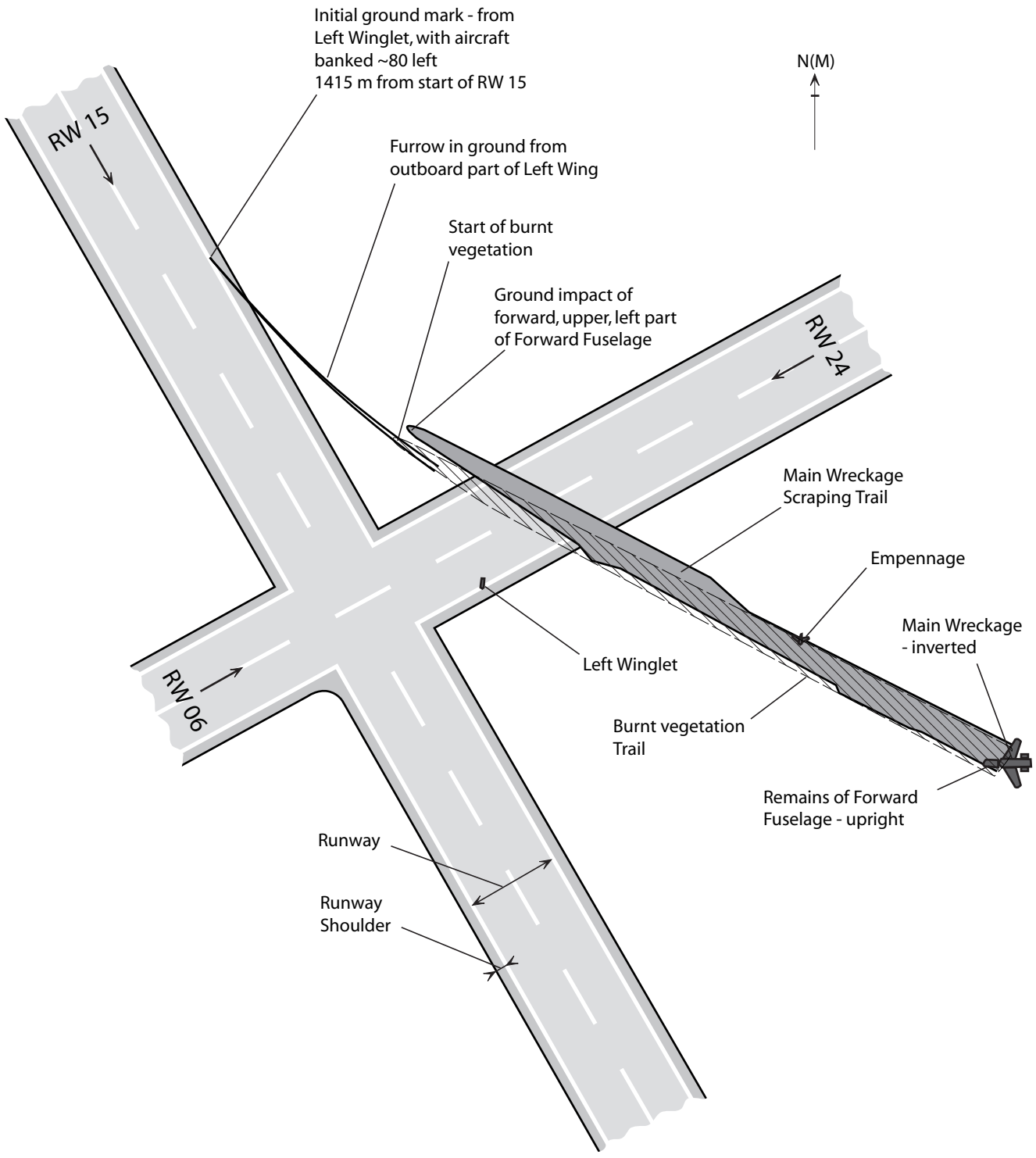


Figure 4

N90AG ACCIDENT SITE PLAN VIEW



Plan View

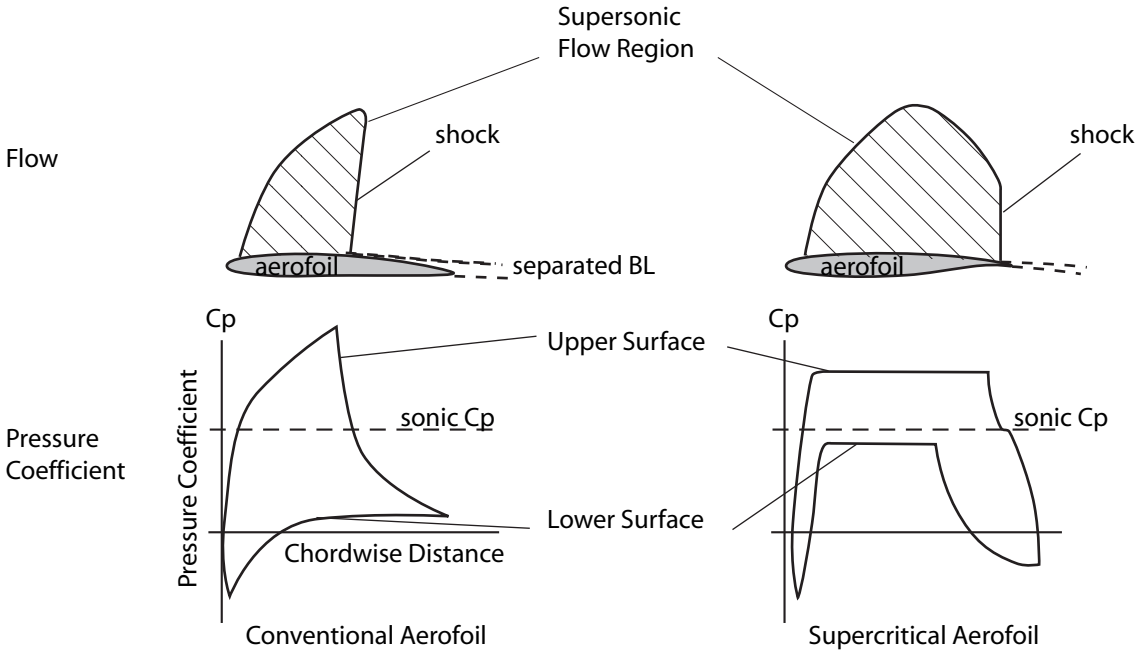
0 100 200 300 400

Approximate Scale - metre

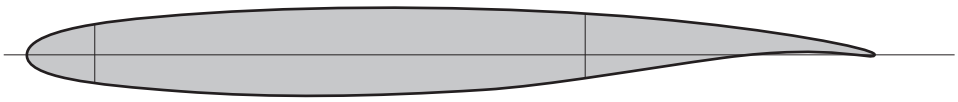
Figure 5

WING AEROFOIL SECTIONS

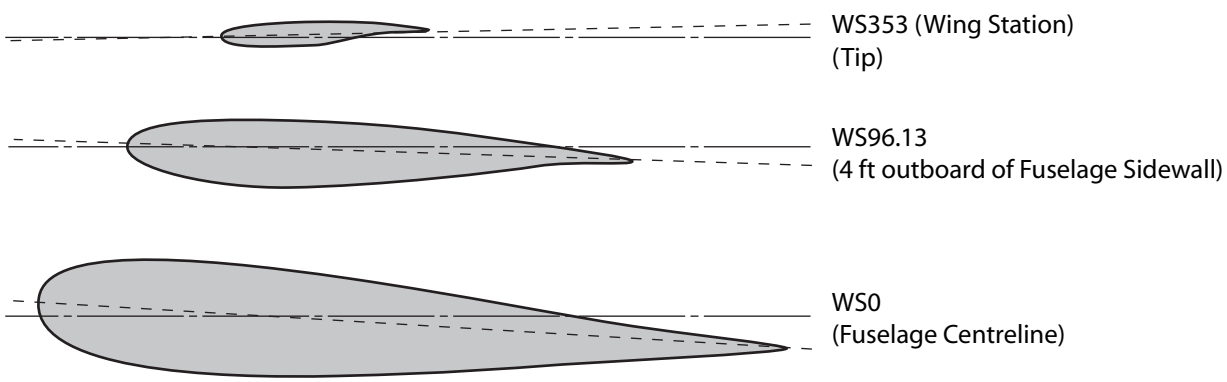
Typical Aerofoil Flow Patterns and Pressure Distribution at Cruise Conditions

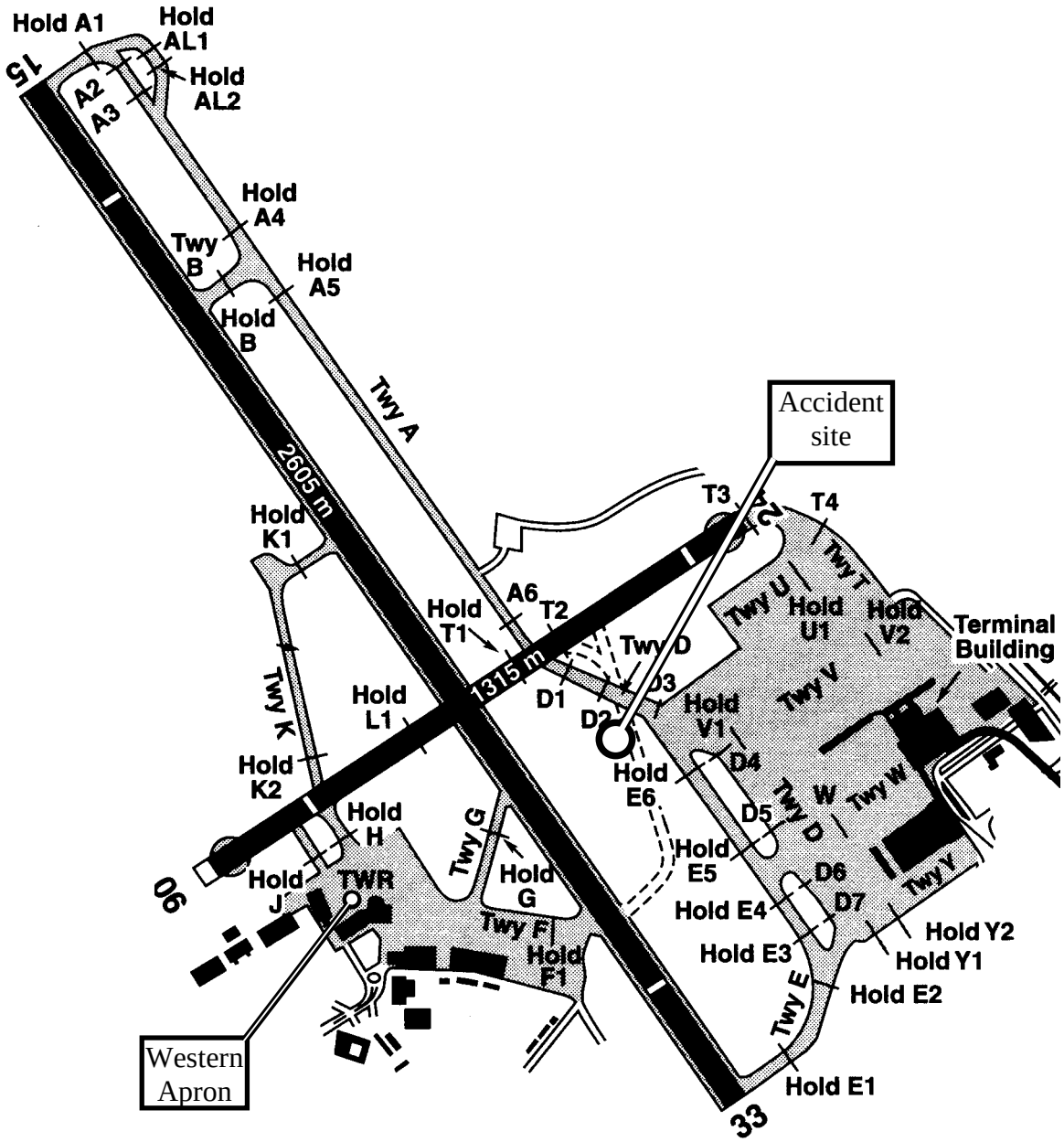


Challenger 604 Wing Tip Aerofoil Section

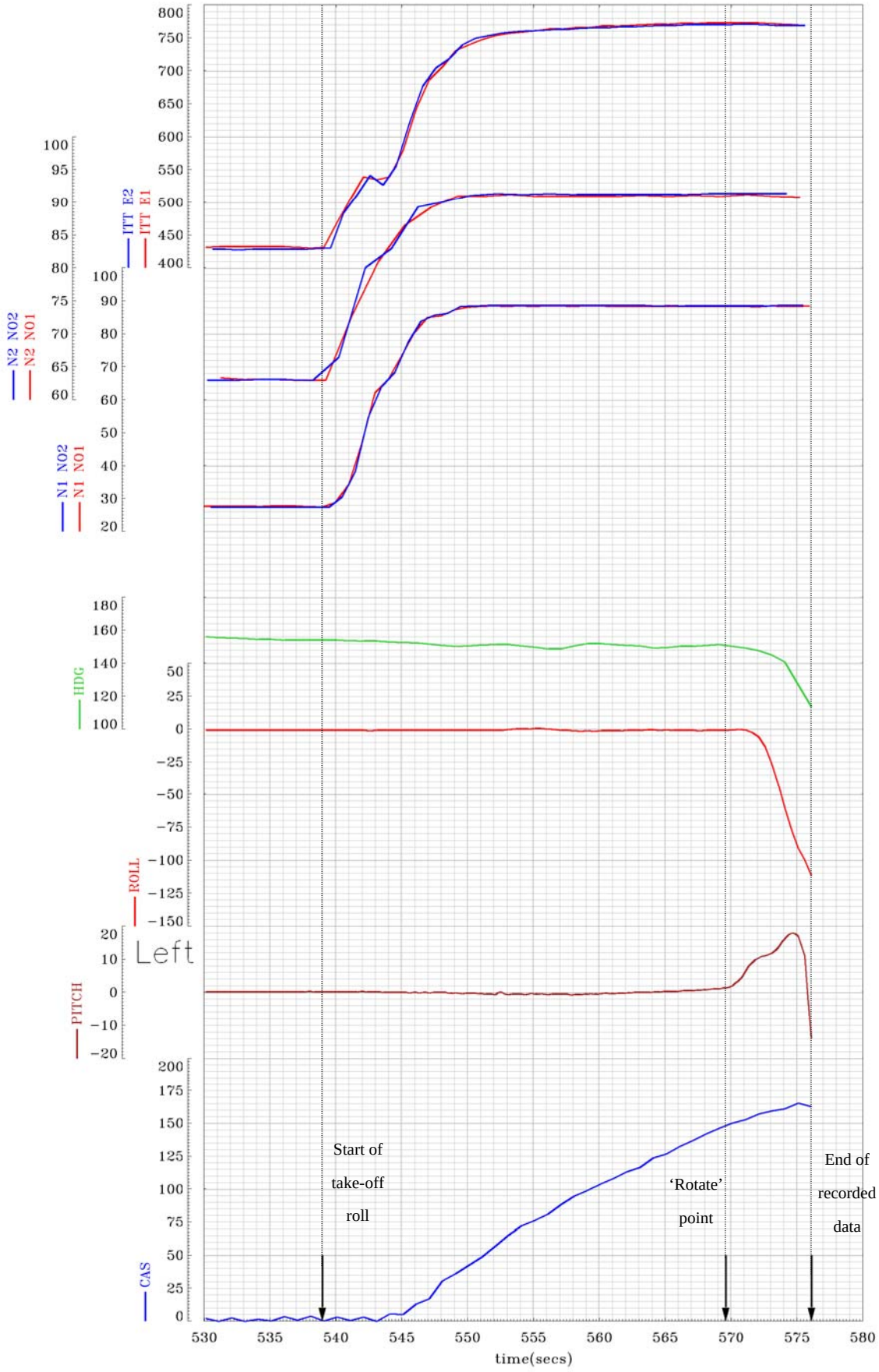


Challenger 604 Wing Aerofoil Sections and Incidences

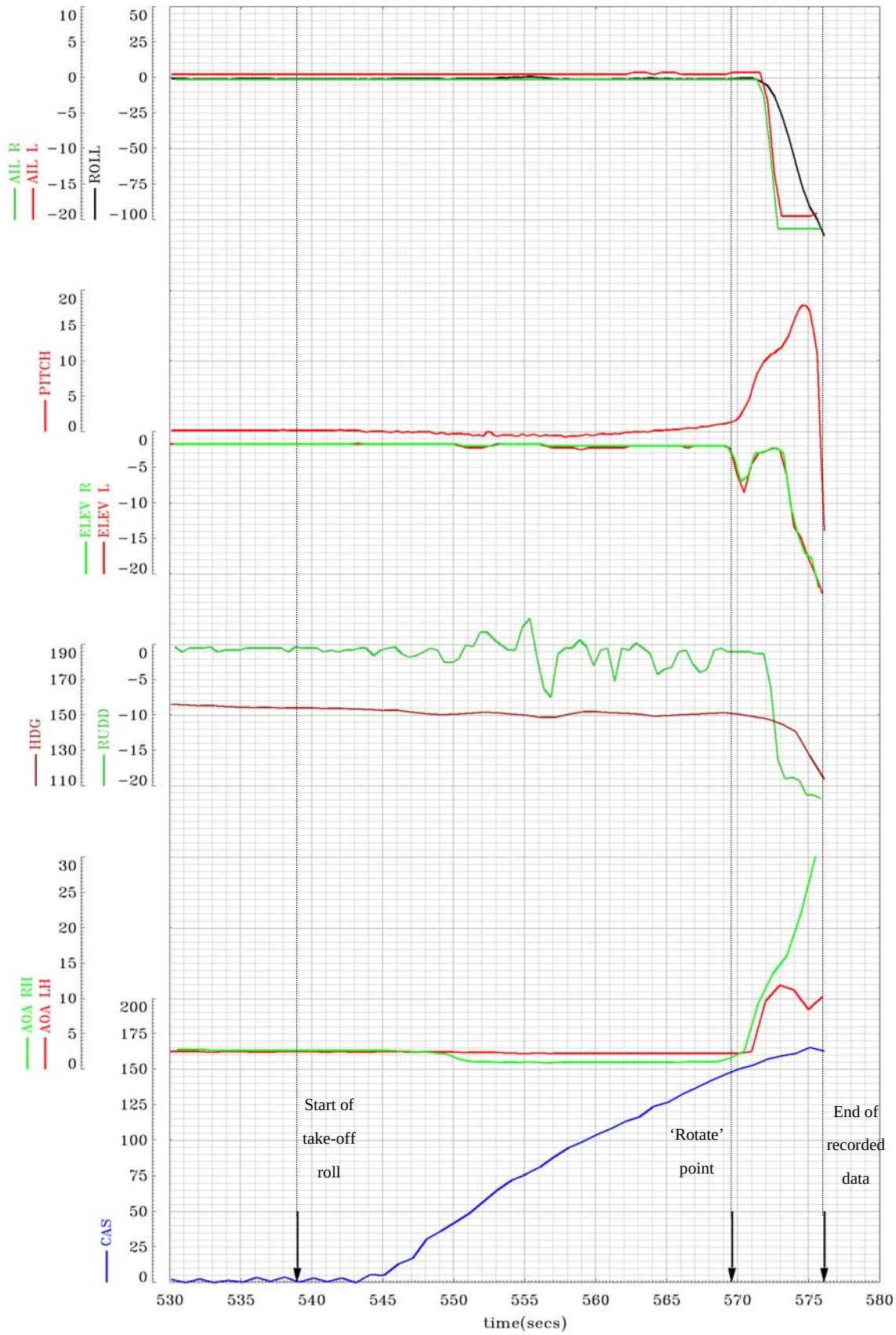




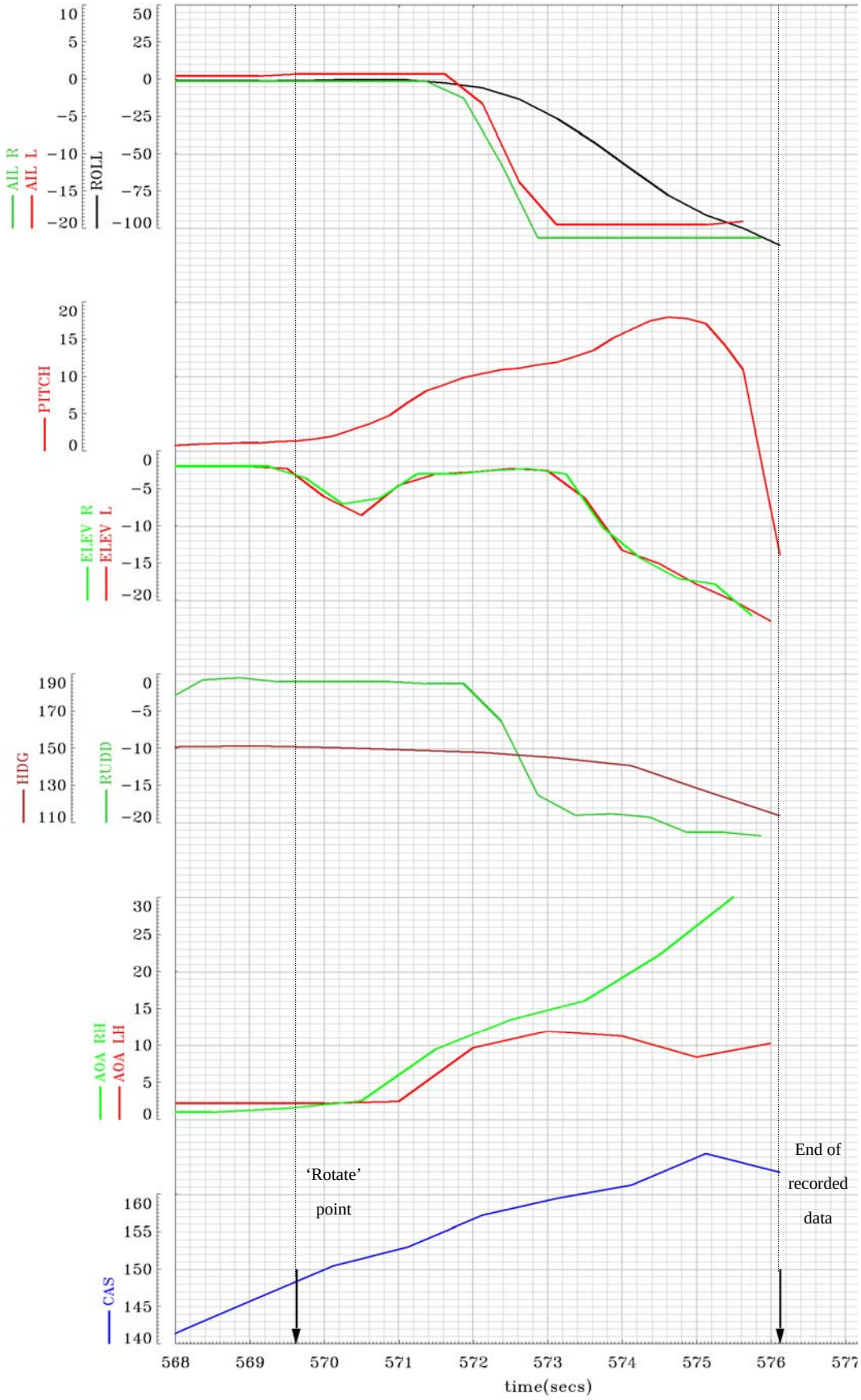
Birmingham International Airport - Movement areas



Engine parameters related to aircraft attitude, airspeed and heading from just before take-off.



Control inputs related to aircraft attitude, AOA and airspeed from just before take-off.



Control inputs related to aircraft attitude, AOA and airspeed. (last 8 seconds of record)

DIPHENHYDRAMINE

The following is a summary of the findings of the aviation pathologist from the RAF Centre of Aviation Medicine who carried out the autopsies on N90AG's crew members on his research to determine the possible significance of the toxicology findings concerning Diphenhydramine:

1. It is now clear that both pilots reported for duty in Atlanta, Georgia at 0400 hrs EST on 3 January 2002. They therefore had little sleep on the night of the 2-3 January. They flew to Birmingham where they were accommodated in an hotel. In their hotel, both pilots had a meal that included some alcohol. It is estimated that each man consumed some five units of alcohol before retiring to bed at approximately 2330 hrs. The handling pilot telephoned his wife in the United States at 0200 hrs.

2. Toxicological examination revealed 0.12mcgs per millilitre of diphenhydramine in the commander. Diphenhydramine was also detected in samples from the handling pilot, at a level of 0.04mcgs per millilitre.

3. The level of diphenhydramine in the commander was a therapeutic level and suggests that the drug had been taken within a few hours of his demise. The half-life of the drug is between 5-8 hours and comparable levels to those found in the commander were seen experimentally two hours after a therapeutic dose of diphenhydramine.

Technical difficulties made interpretation of the level in the handling pilot more difficult but the evidence indicated that it was highly probable that it corresponded to a therapeutic concentration of diphenhydramine. I believe that this indicates both pilots took the drug sometime between 12 to 24 hours before their deaths. However it must be stressed that the problem of post mortem redistribution of drugs makes the interpretation of the levels very difficult (Pounder and Jones 1990).

4. Diphenhydramine is a sedative anti-histamine used in a number of cough and decongestant preparations on sale to the public. It is also used in a number of products used to aid sleep. In Britain these are marketed with such trade names as 'Nytol'. In Britain all preparations containing diphenhydramine carry the warning label 'Warning may cause drowsiness. If affected do not drive or operate machinery. Avoid alcoholic drink'. In addition to drowsiness this drug may also cause blurred vision, dizziness or nausea. In the United States many products containing diphenhydramine carry similar warnings with regard to alcohol to those in the UK. The Federal Aviation Administration does not issue a list of approved or forbidden drugs for use by pilots but relies on them reading the material in the American Flying Literature about over-the-counter medications. It was noted that at least one product containing diphenhydramine was found in the possession of the handling pilot.

5. Why both these men should be taking diphenhydramine is open to speculation. It is possible that the handling pilot had a cold or similar upper respiratory tract infection

and was taking diphenhydramine. Had the commander developed a similar cold, the handling pilot may have shared his medication with him. It is equally possible that both men had taken this drug to aid sleep and prevent jet-lag. There is no way of knowing why they took this medication. In my opinion the most likely explanation is that they took the drug to aid sleep. However, it is certain that both men had taken the drug.

6. Diphenhydramine is one of the commonest drugs found in pilots who are killed in aviation accidents. Between 1994 and 1998, 1,683 pilots were killed in the United States. Over-the-counter drugs were found in 18% of these. Of these drugs, diphenhydramine was amongst the most common, being found on 54 occasions. It was found in Class I pilots on five occasions (Canfield et al 2001).

7. Recent work undertaken at the University of Iowa compared diphenhydramine with alcohol (Weller et al 2000). Both were compared with a placebo. The alcohol was given such that a level of 100mgs per 100 millilitres was obtained in the blood. The participants then drove in a driving simulator for one hour. The driving performance of the participants was poorest after they took diphenhydramine, indicating that diphenhydramine had a greater impact on driving than alcohol at the administered levels. Drowsiness ratings were not a good predictor of impairment and this suggested that drivers cannot use drowsiness to indicate when they should not drive. Extrapolating this information to aviation means that diphenhydramine should not be used when flying. However in this study, the impairment observed was principally with co-ordination and it did not affect judgement.

8. However, a recent study (Hindmarch and Shamsi 1999) reviewed the literature on the sedative and other effects of antihistamines such as diphenhydramine. They identified a number of tests that appear to be sensitive to the central effects of antihistamines. These included tests of psychomotor performance, sensory-motor co-ordination speed, information processing and sensory skills. Diphenhydramine was included in 18 studies, and impairing effects were noted in all studies with one exception. However, in this study assessments were only made two hours following ingestion.

9. Of particular relevance to this accident, various observations have been made demonstrating that diphenhydramine impairs short-term memory and attention. In particular it has a significant effect on divided attention tasks when one of the tasks may be ignored (Kay et al 1998). It is well known that all the effects of diphenhydramine are potentiated by alcohol; this is the reason for the warnings printed on products containing diphenhydramine.

10. I understand that the underlying cause of this accident may have been an error of judgement on the part of the operating crew. The medical interest is in the adverse physiological states that may have impaired the function of the pilots. There can be no doubt that both men had disturbed and probably inadequate sleep for the two nights preceding the crash. It is possible that they were suffering from circadian dysrhythmia (jet-lag). A psychologist is better placed than I to comment on these factors. Both men had consumed a moderate amount of alcohol on the evening before the accident and both had diphenhydramine in their tissues. The effects of diphenhydramine include impairment of short term memory and attention.

11. It is my opinion that it is possible that the tiredness, possible 'jet-lag' and diphenhydramine all combined to impair the ability of the pilots to deal with the situation with which they were faced.

References:

Canfield D V, Hordinsky J, Millett D P et al 2001: Prevalence of drugs and alcohol in fatal civil aviation accidents between 1994 and 1998. Aviat space Environ Med 72; 120-124.

Hindmarch I and Shamsi Z 1999: Antihistamines; models to assess sedative properties, assessment of sedation, safety and other side effects. Clin Exp Allergy 29 (Suppl 3); 13-142.

Kay G G, Berman B, Mockoviak S H et al 1998: Initial and steady state effects of diphenhydramine and loratidine on sedation, cognition, mood and psychomotor performance. Arch Intern Med 158; 1949-1950.

Pounder D J and Jones G R 1990: Post-mortem drug redistribution - a toxicological nightmare. Forensic Sci Int 45; 253-263.

Weiler J M, Bloomfield, J R, Woodworth G G et al 2000: Effects of fexofenadine, diphenhydramine and alcohol on driving performance. Ann Intern Med 132; 354-363.

Appendix 4

The following is the professional opinion of the Principal Psychologist from the Centre for Human Sciences at QinetiQ, Farnborough, who reviewed the performance of N90AG's flight crew members based on the available evidence.

1 **Resume of events:** The crew flew the aircraft from Atlanta (USA) to Birmingham (UK) on 3rd January via Fort Meyer and Palm Beach. On 4th January, they prepared the aircraft for a take off shortly after noon. On take off the aircraft rolled left. Large rudder and full aileron inputs did not arrest the roll. All on board were killed.

2 **Discussion:** Investigation has revealed no technical malfunctions to explain the accident. Ice was observed on the aircraft's wings during the pre-start checks. It is possible that warm air from the auxiliary power unit directed over the right wing by the wind during start up cleared that wing of ice while leaving the left wing contaminated.

3 Why did the crew not take steps to de-ice the wings?

4 The requirement for de-icing seems to have been evident. All other crews departing that morning in aircraft that had been parked in the same area chose to de-ice. Both crewmembers inspected the aircraft. The cockpit voice recording (CVR) shows that there was some discussion about the issue, but the necessary decision was not made. Several factors could, in principle, have had an influence.

5 *Experience:* The captain had roughly 8000 hours experience and was operating as P2. The first officer had about 20000 hours and was operating as P1. They were of similar age (51 and 58, respectively) and both had qualified on type about two years previously. It seems unlikely that lack of experience was a factor.

6 *Fatigue:* The crew came on duty at 04:00 (EST) in Atlanta, which suggests some truncation of sleep on the night of 2nd/3rd January. As a result, they may have experienced high levels of fatigue during the later part of the transatlantic flight. It is not known whether they were able to take naps during the flight. Eastwards time zone transitions are harder to adjust to than westwards transitions. The five-hour time shift between Atlanta and Birmingham would have had some impact on the quality of rest obtained by the crew on the night of 3rd/4th January. The evidence suggests that they retired to bed some time after 23:36 (GMT), but they could well have had difficulty initiating sleep before 02:00 (GMT). They each imbibed roughly five units of alcohol during the evening. Although the alcohol may have assisted with initiating sleep, it may also have disrupted later sleep. The overall effect on the morning of 4th January is likely to have been a significant degree of fatigue that conceivably could have impaired judgement or reasoning. The CVR reveals that the P1 was less efficient than might be expected in programming the flight management computer and needed assistance to complete the task. This could be evidence of impairment of cognitive function resulting from fatigue (or other factors) but, without evidence on his performance in other circumstances for comparison, it is only suggestive.

7 *Drugs:* Post mortem examination of both crewmembers revealed traces of diphenhydramine, a sedating antihistamine drug. Cursory inspection of the airborne data recorder evidence suggests that the P1 reacted promptly and appropriately in trying to counter the uncommanded roll, so impairment of psychomotor function seems unlikely. I recommend that you seek medical opinion as to the possible effects on reasoning or judgement taking into account the concentrations found and the possible interaction with the alcohol they consumed on the night of 3rd/4th January.

8 *Social factors:* On the evidence of the CVR, the crew appeared relaxed and focussed on the task of preparing the aircraft for flight. The captain showed notable patience in assisting P1 to program the flight management computer. During the take-off roll, he gave a clear, direct instruction to manoeuvre away from the centre line. On this limited evidence, there seems to have been no impediment in their relationship to proper and constructive communication. Nevertheless, their discussion of the icing issue was ineffective. The recording is not all clear, but the key exchange (at about 11:52) was:

P2: *Got a* (unintelligible*) frost on the leading edge, on there.*

P1: *Huh?*

P2: *D'you* (unintelligible*) that frost on the leading edge – wings?*

P1: *Did I feel it?*

P2: *Yeah, did you all check that out?*

P1: *Yuh.*

9 The unintelligible utterances allow some leeway for interpretation. Two possibilities seem more or less plausible. First, the captain wanted to confirm that P1 had arranged for de-icing. Second, that the captain wanted P1's assessment of the icing in order to decide whether or not to de-ice.

10 The first fits less well with the words that are audible. It also has the disadvantage that there was, of course, no confirmation later that the de-icing had been done. It would be reasonable to expect the captain and P1 to look for such confirmation and their acceptance of its absence could only be explained by oversights due to preoccupation or fatigue.

11 The second interpretation is arguably more consistent with the audible discussion. It could suggest that the captain was deferring to the P1's greater flying experience in assessing the seriousness of the icing. The plausibility of this suggestion would depend on further evidence on the relationship between the crewmembers and their personalities that is not currently available.

12 Both these interpretations raise questions about the effectiveness of the crew's co-operation and any crew resource management training they may have received that cannot be answered with the evidence currently available. They also raise doubts about P1's awareness and assessment of the icing.

13 *Pre-flight inspection:* If the P1's pre-flight inspection was conducted before the auxiliary power unit was started, then both wings would have been contaminated with ice. Even if he walked round less than 360°, he should have seen some ice on the wings. The character of his discussion with the captain about icing suggests that P1 was focussing on some other activity at that time and may not have given the question a great deal of thought. Later, de-icing came up as an item in the pre-take off checks. The P1's response was "…*we may need it right after take off*." This response seems to embody a token acknowledgement of the de-icing problem – as something that could be left until later – but indicates no immediate concern and, perhaps, little thought about it. If P1 had considered the icing warranted action, he could have selected the anti-icing system on immediately. The icing does not appear to have been an important issue to P1, which suggests that he had not given it appropriate attention during his pre-flight inspection. This could be a reflection of his habitual approach to pre-flight inspections, of fatigue, or of other factors for which we do not have evidence.

14 **Conclusions**: It seems inescapable that two errors occurred. First, the P1 failed to arrive at a proper appreciation of the icing problem during his pre-flight inspection. Second, the discussion on icing initiated by the captain did not adequately address the issue or arrive at an appropriate conclusion.

15 The evidence for causal factors underlying these errors is slight. The available evidence suggests that both crewmembers were probably suffering significant fatigue on the morning of 4th January and this could have predisposed them to errors of judgement or reasoning. This factor probably contributed to the second error and may have contributed to the first. The second error could also be ascribable to an attitude or relationship problem and, as such, raises questions about the effectiveness of any crew resource management training the crew had received. There is, however, no collateral evidence for this factor.

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MEDICATION, ALCOHOL AND FLYING

1 Research has shown that 'human factors' may be involved in up to 75% of aircraft incidents. Indeed accidents and incidents have occurred as a result of pilots flying while medically unfit and some have been associated with what have been considered relatively trivial ailments. Although the symptoms of colds, sore throats, diarrhoea and other abdominal upsets may cause little or no problem whilst on the ground they may become a problem in the flying environment by distracting the sufferer and degrading his/her performance in the various flying tasks. The inflight environment may also increase the severity of symptoms which may be minor while on the ground.

2 The following are some of the more widely used medicines which are normally considered incompatible with flying.

(a) Antibiotics may have short term or delayed side effects which can affect pilot performance. More significantly, however, their use usually indicates that a significant infection is present and thus the effects of this infection will almost always mean that a pilot is not fit to fly.

(b) Tranquillisers, antidepressants and sedatives affect reaction time and psychomotor performance, as well as altering mood. As with antibiotics, the underlying condition for which these medications have been prescribed will almost certainly mean that a pilot's mental state is not compatible with the flying task.

(c) Stimulants such as caffeine, amphetamines etc (often called 'pep' pills) used to maintain wakefulness or suppress appetite are often habit forming. Susceptibility to the various drugs varies from one individual to another, but all of them may cause dangerous over confidence. Overdosage causes headaches, dizziness and mental disturbance. The use of 'pep' pills while flying cannot be permitted. If coffee is insufficient, you are not fit to fly and remember that excessive coffee-drinking may have unwanted effects including disturbance of the heart's rhythm.

(d) Anti-histamines can cause drowsiness. They are widely used in 'cold cures' and in the treatment of hayfever, asthma and allergic rashes. They may be in tablet form or be a constituent of nose drops or sprays. In many cases the condition itself may preclude flying, so that if treatment is necessary advice from an Aviation Medicine Specialist should be sought so that modern drugs, which do not degrade human performance, can be prescribed.

(e) Certain drugs used to treat high blood pressure can cause a change in the normal cardiovascular reflexes and may impair intellectual performance, both of which could be a problem when flying. If the level of blood pressure is such that drug therapy is required the pilot must be temporarily grounded and monitored for any side effects. Any treatment instituted should be discussed with an expert in aviation medicine and a simulator assessment or line check may be appropriate before return to flying.

3 Following local and general dental and other anaesthetics, a period of time should elapse before return to flying. The period will vary considerably from individual to individual, but a pilot should not fly for at least 12 hours after a local anaesthetic and for 48 hours after a general anaesthetic.

The more potent analgesics (pain killers) may produce a significant decrement in human performance. If such analgesics are required, the pain for which they are being taken generally indicates a condition which precludes flying.

4 Many preparations are now marketed containing a combination of medicines. It is essential therefore that if there is any change in medication or dosage, however slight, the effect should be observed by the pilot on the ground prior to flying. Although the above are the commonest medicines with adverse effects on pilot performance, it must be noted that many other forms of medication, although not normally affecting pilot performance, may do so in individuals who are 'oversensitive' to the particular preparation. You are therefore advised not to take any medicines before or during flight unless you are completely familiar with their effects on your own body. If you are in doubt at all ask a Doctor experienced in Aviation Medicine.

5 If you are taking any medicine you should ask yourself the following three questions:

(a) Do I feel fit to fly?

(b) do I really need to take medication at all?

(c) have I given this particular medication a personal trial on the ground of at least 24 hours before flight to ensure that it will not have any adverse effects on my ability to fly?

Confirming the absence of adverse effects may well need expert advice and the assistance of Medical Examiners authorised by the Civil Aviation Authority, both in the United Kingdom and Overseas, Airline Medical Officers or Royal Air Force Medical Officers. The Medical Division of the Civil Aviation Authority should be contacted if you are in any doubt.

6 If you are ill and need treatment it is vitally important that the Doctor whom you consult knows that you are a member of air crew and whether or not you have recently been abroad.

7 Drugs of Addiction

Drugs in this group cover a wide field ranging from heroin and morphine to hypnotics, tranquillisers and so-called recreational drugs such as marijuana, 'crack' and 'ecstasy'. All have effects on the central nervous system and as such they are not compatible with the control of an aircraft. A person using them is not fit to be a member of flight crew.

8 Alcohol

Alcohol has been a contributory factor to a number of aircraft accidents. It is well established that even small amounts of alcohol in the blood produce a significant and measurable deterioration in the performance of skilled tasks. Research has shown that blood alcohol concentrations of 40 milligrams per 100 millilitres are associated with a highly significant increase in errors committed by both experienced and inexperienced pilots even in simple aircraft. This level is half the legal driving limit and may be produced after consuming two units of alcohol, eg one double whisky or one pint of beer. JAR-OPS specifies a maximum blood alcohol limit of 20 milligrams per 100 millilitres of blood.

Alcohol is removed from the body at a relatively constant rate (approximately 15 milligrams per 100 millilitres, or one unit, each hour) regardless of the concentration present. Pilots should not fly for at least eight hours after taking small amounts of alcohol and proportionally longer if larger amounts are consumed. It should also be remembered that alcohol can have delayed effects on blood sugar levels and the balance mechanism of the inner ear. The effects on the inner ear can be prolonged and increase susceptibility to disorientation and even motion sickness. It would be prudent for a pilot to abstain from alcohol for at least 24 hours before flying.

9 Attention is drawn to the following Articles in the Air Navigation (No 2) Order 1995:

Article 57(1) and (2): Drunkenness in aircraft

(1) A person shall not enter any aircraft when drunk, or be drunk in any aircraft.

(2) A person shall not, when acting as a member of the crew of any aircraft or being carried in any aircraft for the purpose of so acting, be under the influence of drink or a drug to such an extent as to impair his/her capacity so to act.

Article 22(D) and in particular 22(D) 3(a) and (b), states that:

(a) A person shall not be entitled to act as a member of the flight crew of an aircraft registered in the United Kingdom if he knows or suspects that his physical or mental condition renders him temporarily or permanently unfit to perform such functions or to act in such capacity;

(b) Every holder of a medical certificate issued under this article who:

(i) Suffers any personal injury involving incapacity to undertake his functions as a member of the flight crew;

(ii) suffers any illness involving incapacity to undertake those functions throughout a period of 21 days or more; or

(iii) in the case of a woman, has reason to believe that she is pregnant:

shall inform the Authority in writing of such injury, illness or pregnancy, as soon as possible in the case of injury or pregnancy, and as soon as the period of 21 days has elapsed in the case of illness. The medical certificate shall be deemed to be suspended upon the occurrence of such injury or the elapse of such period of illness or the confirmation of the pregnancy; and

(aa) In the case of injury or illness the suspension shall cease upon the holder being medically examined under arrangements made by the Authority and pronounced fit to resume his functions as a member of the flight crew or upon the Authority exempting, subject to such conditions as it thinks fit, the holder from the requirement of a medical examination; and

(bb) in the case of pregnancy; the suspension may be lifted by the Authority for such period and subject to such conditions as it thinks fit and shall cease upon the holder being medically examined under arrangements made by the Authority after the pregnancy has ended and pronounced fit to resume her functions as a member of the flight crew.

This Circular is issued for information, guidance and necessary action.

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Recommendations made by the U.S. National Transportation Safety Board

The US National Transportation Safety Board, which has divisions which investigate accidents involving all modes of transport, has investigated many accidents in all passenger transportation modes in which the use of a licit medication by a vehicle operator has been causal or contributory. As a result, the Safety Board has recommended that various agencies take certain actions to address issues pertaining to the use of medications.

The following Safety Recommendations were amongst a number made by the US National Transportation Safety Board to the US Department of Transportation, the transportation modal administrations and the US Food and Drug Administration in January 2000.

To the U.S. Department of Transportation

> Develop, with assistance from experts on the effects of pharmacological agents on human performance and alertness, a list of approved medications and/or classes of medications that may be used safely when operating a vehicle. (I-00-2)
>
> Expressly prohibit the use of any medication not on the U.S. Department of Transportation's list of approved medications (described in Safety Recommendation I–00-2) for twice the recommended dosing interval before or during vehicle operation, except as specifically allowed, when appropriate, by procedures or criteria established by the applicable modal administration (the Federal Aviation Administration, the Federal Motor Carrier Safety Administration, the Federal Railroad Administration, the Federal Transit Administration, or the U.S. Coast Guard). (I-00-3)

To the Federal Aviation Administration

> Establish, with assistance from experts on the effects of pharmacological agents on human performance and alertness, procedures or criteria by which pilots who medically require substances not on the U.S. Department of Transportation's list of approved medications may be allowed, to use those medications when flying. (A-00-4)
>
> Develop, then periodically publish, an easy-to-understand source of information for pilots on the hazards of using specific medications when flying. (A-00-5)
>
> Establish and implement an educational program targeting pilots that, at a minimum, ensures that all pilots are aware of the source of information described in Safety Recommendation A-00-5 regarding the hazards of using specific medications when flying. (A-00-6)

To the Food and Drug Administration

> Establish a clear, consistent, easily recognizable warning label for all prescription and over-the-counter medications that may interfere with an individual's ability to operate a vehicle. Require that the label be prominently displayed on all packaging of such medications. (I-00-5)