CANADIAN FORCES
FLIGHT SAFETY INVESTIGATION REPORT (FSIR)

FINAL REPORT

FILE NUMBER: 1010-114006
DATE OF REPORT: 12 March 2003

AIRCRAFT TYPE: CT-114 Tutor
DATE/TIME: 1451 local 21 June 2001
LOCATION: London, Ontario YXU 155R at 30 DME
CATEGORY: 114006,"A" Category damage, major injury/minor injury
114081, "C" Category damage, no injury

This report was produced under authority of the Minister of National Defence (MND) pursuant to Section 4.2 of the Aeronautics Act (AA), and in accordance with A-GA-135-001/AA-001, Flight Safety for the Canadian Forces.

With the exception of Part 1 – Factual Information, the contents of this report shall be used for no other purpose than accident prevention. This report was released to the public under the authority of the Director of Flight Safety, National Defence Headquarters, pursuant to powers delegated to him by the MND as the Airworthiness Investigative Authority (AIA) of the Canadian Forces.

SYNOPSIS

(For ease of understanding throughout this report, pilots, passengers and aircraft will be referred to with reference to their positions within the formation. (ie. "pilot #1", "passenger #1 and "aircraft #1". Aircraft #1 is tail number CT114006 and aircraft #5 is tail number CT114081).

431 Air Demonstration (AD) Squadron was conducting a nine-plane media flight at London, Ontario on 21 June, 2001. At the time of the accident, aircraft #1 was leading aircraft #5 to rejoin on the remaining seven aircraft in formation. The two aircraft collided when approximately 300 feet behind the main formation while conducting the rejoin. Control of aircraft #1 was lost and the two occupants ejected successfully. The pilot sustained minor injuries and the passenger sustained more serious (defined as major) injuries. Control of aircraft #5 was maintained and it was flown back to London airport without further incident.

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1. FACTUAL INFORMATION

1.1 History of the Flight

The Team was conducting a media flight two days prior to performing an air display at the London Airshow. Each of the nine pilots on the team was accompanied by a passenger; seven of these were civilian media representatives and two were military members. Aircraft #1 and aircraft #5 had broken away from the remaining seven aircraft in a "Concorde" formation to obtain some photographic opportunities of the Lead aircraft and had begun their rejoin to the main formation. As the rejoin proceeded, pilot #1 broke his aircraft away from aircraft #5 to position himself to re-take the lead of the main formation. Pilot #5 simultaneously manoeuvred to rejoin to his normal position in the main formation. The two aircraft collided at approximately 300 feet behind the main formation. Control of aircraft #1 was lost and pilot #1 commanded an ejection. Both the pilot and the passenger ejected and landed in the water in Lake Erie approximately 2.5 km from the shoreline (approximately 155 degree radial at 33NM on the London (YXU) vortac). Control of aircraft #5 was maintained and pilot #5 was able to land the aircraft at London International Airport without further incident.

The positions in the formation during the rejoin and the positions after the intended rejoin as depicted as follows:

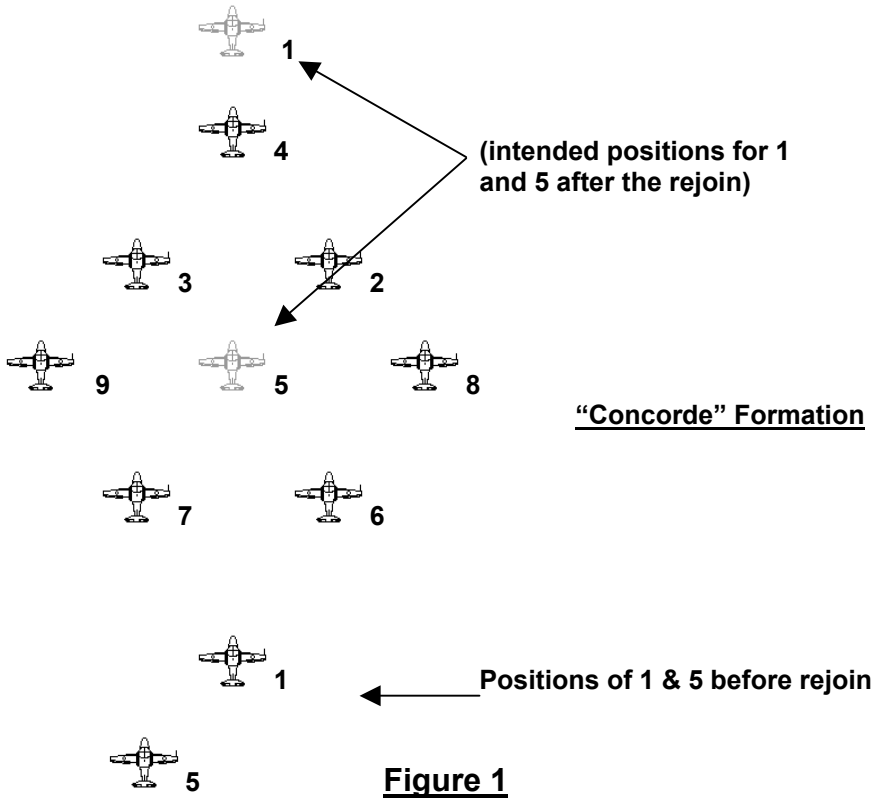


Figure 1

(note: all spacings not to scale

1.2 Injuries to Personnel

	Pilot #1	Pax #1	Pilot #5	Pax #5
Fatalities	Nil	Nil	Nil	Nil
Injuries	Minor	Major	Nil	Nil

1.3 Damage to Aircraft

Aircraft #1 sustained “A” category damage. The right wing trailing edge was damaged to the extent that aircraft aileron control was lost when it impacted the right wing leading edge of aircraft #5 during the mid-air collision. A post ejection fire caused some fire damage primarily to the skin aft of the cockpit area. The aircraft was subsequently destroyed on water impact (Annex A, Photo 1).

Aircraft #5 sustained “C ” category damage. The right wing leading edge was damaged when it impacted the right wing trailing edge of aircraft #1. A portion of this leading edge was missing and numerous scratches and dents were found on the upper surface of the wing (Annex A, Photo 2, 3 and 4). The right hand aileron was bent and scratched at the outboard attaching point. Wiring was broken and pitot and static lines were damaged in the right wing leading edge. Although affected by this damage, control of aircraft #5 was maintained and the aircraft was flown to a safe landing.

1.4 Collateral Damage

There was no collateral damage. Although the majority of the wreckage of aircraft #1 was recovered from Lake Erie, some parts were unrecoverable and, therefore, remain at the bottom of the Lake. A claim against the crown is not anticipated.

1.5 Personnel Information

	Pilot #1	Pilot #5
Rank	Maj	Capt
Medical Category validity	valid	valid
Total flying time	5300 hrs	2200 hrs
Flying hours on type	2150	2180
Flying hours last 30 days	24.9	23
Flying hours last 48 hours	3.9	3.9
Flying hours on day of Occurrence (not including accident flight)	0.9	0.9

1.6 Aircraft Information

Aircraft #1 had accumulated 10335.5 flying hours. It was serviceable prior to the accident. Aircraft #5 had accumulated 5687 flying hours. It was also serviceable prior to the accident.

1.7 Meteorological Information

The forecast weather for London airport at the time of the occurrence was:

CYXU 211731Z 211818 11010KT P6SM FEW050 SCT120 OVC220

The actual weather at the time of take-off and time of the accident was:

CYXU 1700Z 10010KT 15SM FEW100 SCT170 BKN270 23/14 A3007 RMK AC1AC3CI2

CYXU1800Z 13008KT 15SM SCT034 BKN100 OVC 270 24/15 A3007 RMK SC3AC2CI2

Weather was not a factor in the accident.

1.8 Aid to Navigation

The London VORTAC (YXU) is located on the field. The VOR frequency is 117.2 and the London TACAN channel is 119. There are two beacons located off the field. London (382) is 6.2 km from the departure end of Runway 33 and Uniform (201) is 5.3 km from the departure end of Runway 15. All navigation aids were functioning properly and were not a factor in the accident.

1.9 Communications

All aircraft in the formation were on the Snowbird common frequency at the time of the accident. Pilot #5 switched to London tower frequency while recovering individually. Pilot #6 switched to London tower while maintaining station over the crash site.

1.10 Aerodrome Information

Runway 33 was in use at London airport. All runways were bare and dry at the time of the accident.

1.11 Flight Recorders

Both aircraft were equipped with an Operating Loads Monitor (OLM). Data from these devices was successfully recovered from both aircraft.

1.12 Wreckage and Impact Information

Aircraft #1 impacted the water approximately 2.5 km from the shoreline of Lake Erie (YXU vortac 155/33). The primary wreckage was located using local witness testimony; side scan sonar provided by the Bedford Institute of Oceanography; and the Ontario Provincial Police (OPP) Diving Unit. All of the primary components of the aircraft, other than the ejection seats and canopy, were recovered from the bottom of the lake utilizing the Canadian Forces (CF) Fleet Diving Unit Atlantic and a local barge/crane/tugboat contract.

1.13 Medical

Pilot #1 suffered multiple minor injuries. These injuries were sustained as a result of the ejection event. He was released from hospital within 24 hours. Passenger #1 suffered multiple major injuries. These injuries were sustained as a result of the ejection event. He was initially released from hospital after 5 days. He was subsequently readmitted on numerous occasions for both treatment and re-evaluation.

Toxicology tests were performed on both pilots and the results were negative.

1.14 Fire, Explosives Devices, and Munitions

Witness testimony and crash analysis indicated that aircraft #1 was engulfed in flames as it descended towards and into the water. Previous similar cases of fires that occurred during CT114 ejections were already and remain under investigation by Quality Engineering Test Establishment (QETE). One non-detonated canopy remover internal/external handle charge M3A2 was found in the main wreckage that was recovered from the lake. This, along with an oxygen canister, was disposed of by the OPP Explosive Ordinance Disposal unit.

1.15 Survival Aspects

After the accident occurred, pilot #6 broke his aircraft away from the main formation and circled overhead the crash site in an attempt to maintain visual contact with the survivors in the water until fuel forced him to leave. Both pilot #1 and passenger #1 were recovered from the water at approximately 1550 local (approximately 1 hour after the ejection occurred). They were recovered by a Labrador helicopter from 424 Sqn Trenton, Ontario operating in the vicinity of Cobourg at the time of the accident. The two individuals were then transported to the St. Thomas Municipal Airport where they were met by an air ambulance (helicopter) and a land vehicle ambulance. The air ambulance transported passenger #1to the London Health Sciences Centre. Pilot #1 was transported by land ambulance to the St. Thomas-Elgin General Hospital.

Some anomalies with respect to the personal aircrew life support equipment (ALSE) carried by the occupants of both aircraft were noted. These are discussed in paragraph 2.12.

If pilot #1 and passenger #1 had remained with aircraft #1 to water impact they would not have survived the impact. The survivability of the ejection is discussed in paragraph 2.9.

1.16 Test and Research Activities

The main wreckage of aircraft #1 and the right-hand wing and canopy of aircraft #5 were sent to the Quality Engineering Test Establishment (QETE) for further analysis. The OLM container was taken by the National Research Council to the manufacturer to ensure proper data retrieval procedures. All recovered aircrew life support articles were analysed by the Aerospace Engineering Test Establishment (AETE), Defence Research and Development Canada - Toronto (DRDC-T, formerly DCIEM) and QETE.

1.17 Organizational and Management Information

All nine aircraft in the formation belonged to 431 (AD) Squadron stationed at 15 Wing, Moose Jaw, Sask.

2. ANALYSIS

2.1 General

The mission was properly authorized and briefed. The issue of whether media flights are required to fulfill the public relations role of the team is beyond the purview of this investigation. All aircrew involved in the mishap were fit for flying duty.

2.2 The Aircraft

Both aircraft, CT 114006 and CT 114081, were serviceable prior to the accident. There were no maintenance or aircraft handling anomalies identified that contributed to the accident.

2.3 The Mission

2.3.1 The Briefed Mission

This sortie was designed to take members of the media, and military personnel associated with public relations, for a one-hour familiarization flight with the Team. The passengers had been briefed and fitted with ALSE prior to the flight. Minimal manoeuvring was planned due to the passengers' inexperience. Pilot #1 was flying with a military member as passenger #1 who had a combat arms and parachute training background but had never flown in an ejection seat equipped aircraft before. Pilot #5 was flying with an experienced civilian aviation photographer (passenger #5) who had flown with the Team previously.

Due to a request by passenger #5, pilot #1 had briefed the Team prior to the flight that both pilot #1 and pilot #5 would break away from the main "Concorde" formation (as depicted in Figure 1), to take photographs of aircraft #1. Pilot #1 briefed that he would lead aircraft #5 to the rear of the main formation, where passenger #5 could take some photographs of aircraft #1 while aircraft #1 was in straight and level flight as well as in inverted flight. This was the only aerobatic manoeuvre that was briefed. Aircraft #5 would then also move to inverted flight to take more photographs. Pilot #1 would then lead the two aircraft back to the main formation where pilot #1 would drop off aircraft #5 at the rear of the main formation and then proceed to the front of the main formation. Pilot #1 would then instruct pilot #4 (who would be leading the main formation at the time) to rejoin the main "Concorde" formation in his normal position.

2.3.2 The Actual Mission

While most of the flight was flown as briefed, there were several deviations before the accident. The first was that, after departure, pilot #1 directed the formation of all 9 aircraft to move to a "wider than route" position in order to perform a "shake-out" manoeuvre to check for loose articles. This is normally flown positive to negative 'G'

for Snowbirds 1-7 and inverted flight for Snowbirds 8 and 9. On this “shake-out” some of the Snowbirds 1-7 flew inverted. Other deviations involved pilot #1 moving around and beneath the main formation after the first rejoin and a second break away and rejoin of aircraft #1 and #5. These had not been previously briefed and will be further discussed in paragraph 2.6.

After the formation had flown for approximately thirty minutes over and around Lake Erie, pilot #1 called for himself and aircraft #5 to break away from the main formation and aircraft #4 to take the lead of the main formation. Pilot #1 and pilot #5 then proceeded to manoeuvre behind the main formation as briefed. Pilot #1 instructed pilot #5 to take the lead of the two-plane formation while they continued with the photographic work also previously briefed. After several photos were taken by passenger #5 of aircraft #1 while aircraft #5 was leading, pilot #1 directed pilot #5 to lead them back to the main formation. Pilot #5 lead the two aircraft back towards the main formation and moved his aircraft into its normal position (Figure 2). Pilot #1 then came up on the right side of the main formation, moved forward and in front of the main formation. Pilot #1 then directed pilot #4 to form the main formation onto aircraft #1 whereby pilot #1 assumed lead of the main formation.

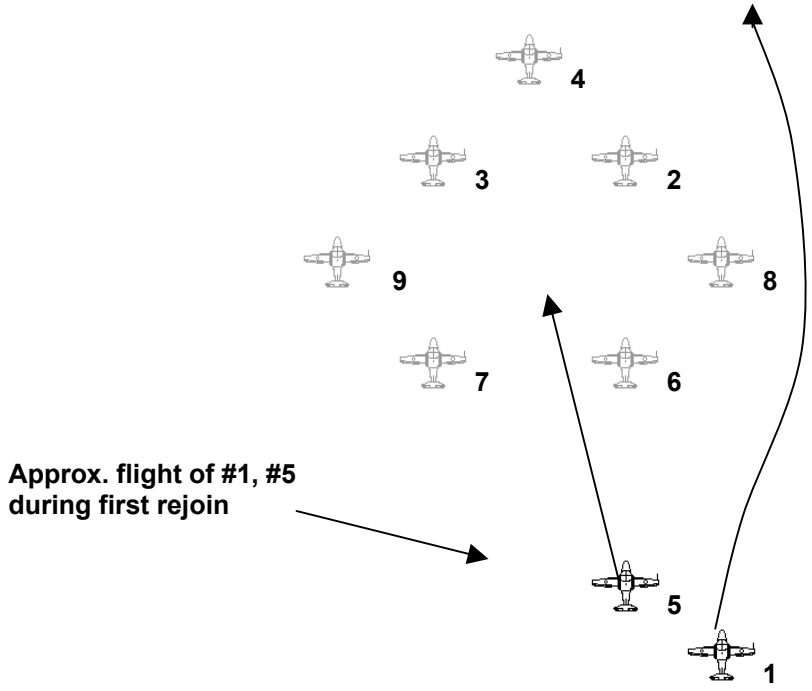


Figure 2

Once in this position, pilot #1 realized that passenger #5 had not gotten any pictures of aircraft #1 while aircraft #1 was leading the two-plane formation. He subsequently indicated to pilot #5 that they would break away again from the main formation in order to accomplish this task. Pilot #5 transmitted to pilot #1 that this was not necessary, however, pilot #1 stated that it was too late as he had already begun to move away from the main formation. Pilot #1 again gave the lead of the main “Concorde” formation to pilot #4 and aircraft #1 and #5 joined up again at the

rear of the main formation. At this point, aircraft #5 was in an echelon left position on aircraft #1 and passenger #5 continued with his photographic work, which included some inverted flight. After they completed the photo work, pilot #1 transmitted to pilot #5 that he would lead aircraft #5 back to the main formation and drop him off at the rear of the formation. Pilot #5 acknowledged this. Subsequent to this, pilot #1 felt that it would take too long to effect this type of rejoin so he directed to pilot #5 a transmission to the effect of "take your own rejoin line" (the exact terminology used could not be precisely verified from witness testimony; pilot #1 believed that he had added "I will cross under and to the left of the formation", but others could not recall having heard that transmission). At this point, pilot #5 moved his aircraft to the left and set up on an extended rejoin line towards his normal position at the back of the main formation (Figure 3). Simultaneously, pilot #1 moved his aircraft off to the right assertively. Pilot #5 continued to follow his extended rejoin line towards the main formation. Pilot #1 then transmitted to pilot #4 to bank the main formation to the right to expedite the rejoin.

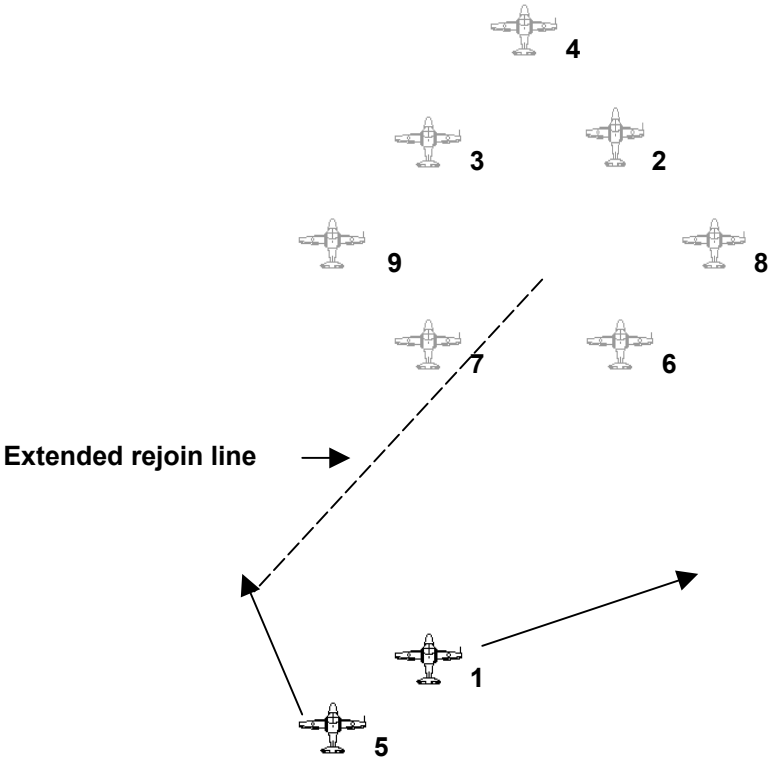


Figure 3

Pilot #1 then continued to the right of the main formation until approximately 500 feet behind. He then began to slow his aircraft down by reducing power and selecting the speed brakes out and moved from right to left across the back of the formation in order to move up along the left hand side of the main formation. His plan was then to move ahead of the main formation and have pilot #4 move the

main formation up and into aircraft #1 where pilot #1would again resume lead of the main formation. There were no radio transmissions made during this portion of the rejoin. Aircraft #5 was simultaneously continuing in towards the main formation on his extended rejoin line at approximately 300 knots indicated airspeed (KIAS). As aircraft #1 passed approximately 250-300 feet to the rear and crossing the approximate seven o'clock line of the main formation at approximately 260 KIAS, aircraft #1 and #5 collided (Figure 4).

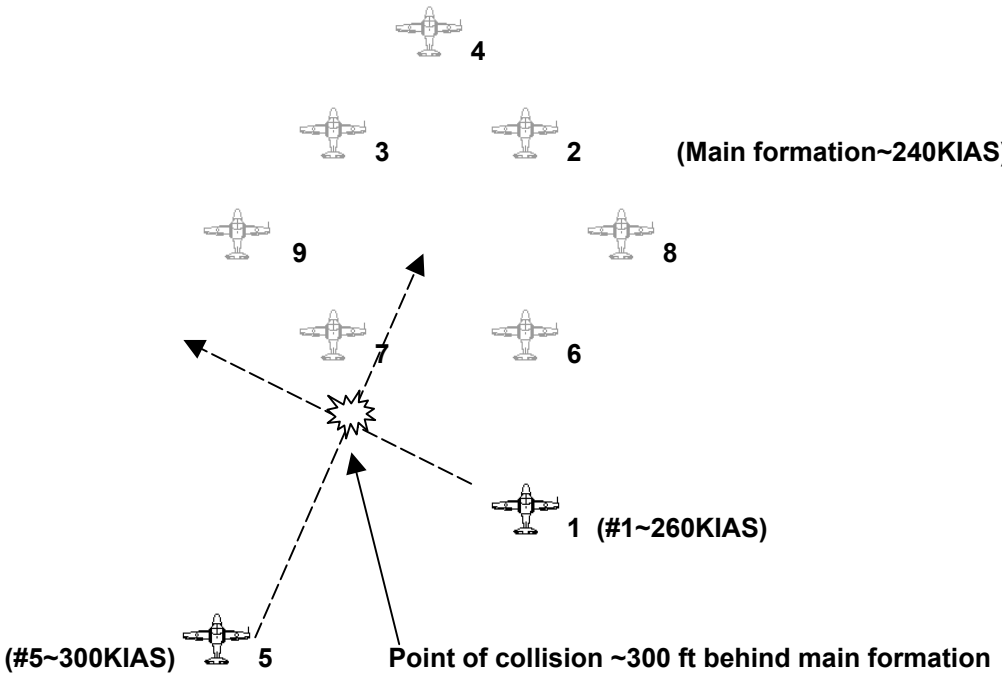


Figure 4

2.3.3 Pilot #1's understanding

While this was the third year Pilot #1 had been the Team Lead and he had flown with the Team on a previous flying tour, most of his flying had been on fighter aircraft. During his 2500 hours flying time on the CF5 Freedom Fighter and CF18 Hornet as an Operational pilot/instructor, rejoins had been carried out routinely using the term "rejoin line". During discussions with Snowbird pilots during the investigation, it became clear that to pilot #1 and other Snowbird pilots with a fighter background, this meant that each aircraft within a formation would rejoin to the main formation in numerical order and be responsible for missing the aircraft ahead of him at all times. Pilot #1 expected pilot #5 to maintain the "miss contract" i.e. to keep him in sight and avoid a collision.

When pilot #1 directed pilot #5 to "take your own rejoin line", pilot #1 intended that pilot #5 would take an extended rejoin line (fly directly to his position - see Figure 3) to his normal position at the rear of the main formation and follow it in. Pilot #1 also expected that pilot #5 would, at all times, maintain visual contact with aircraft #1 as

aircraft #1 was, in pilot #1's mind, still leading aircraft #5. Pilot #1 expected Pilot #5 to keep him in sight and maintain separation from him throughout the rejoin as pilot #1 slowed and crossed from right to left across the rear of the main formation.

It is the opinion of many, especially in the fighter community, that the primary cause (perhaps the only cause) of this accident was the failure of pilot #5 to honour the requirement for a wingman to maintain visual contact with his lead. At some point in this rejoin, however, pilot #5 would have had to stop following pilot #1's lead and direct his attention to the main formation to safely complete the rejoin. At this point, pilot #5 would need to sacrifice his awareness of lead's position in order to concentrate his attention on the main formation. Where this was to occur in the rejoin plan intended by pilot #1 is unclear to DFS and was manifestly unclear to pilot #5. It would thus be inappropriate not to consider the reasons for this lack of clarity. If it is always and in every case the wingman's responsibility to miss lead, why did he not understand that?

2.3.4 Pilot #5's understanding

All of pilot #5's post training flying was as a CT114 Tutor instructor or Snowbird. He had approximately 2200 flying hours on this aircraft, and had flown in position numbers 2 and 5 with the Team for two years. While a "school" rejoin is similar to that explained above with each aircraft rejoining in numerical order and respecting the "miss contract" with the aircraft ahead, rejoins for positions 2 and 5 during "show" manoeuvres generally involved rejoining within your own specific "lane". These "lanes" are designed to ensure that visual contact with other aircraft can be retained but acknowledge implicitly that pilots cannot focus on all other aircraft at the same time and can concentrate on their primary reference aircraft while maintaining a general awareness of the position of the others. Also, "school" formations never involved more than four aircraft and usually only involved two.

When pilot #5 was directed by pilot #1 to "take your own rejoin line", pilot #5 believed that he was to take an extended rejoin line to his normal position at the rear of the main formation and follow it in. He understood that he would effect his own rejoin individually as would aircraft #1 and that pilot #1 was transferring pilot #5's lead to the formation ahead. He expected aircraft #1 to move off to the right (which he did) and then move forward to the right of the main formation as he had done on the previous rejoin. In this manner, pilot #5 was free to rejoin along his rejoin line without conflict with aircraft #1. Pilot #5 was then solely focussed on his rejoin to the main formation and did not attempt to maintain visual contact with aircraft #1.

2.3.5 Other Team Members Understanding

Rejoins for fighter pilots are generally flown unbriefed (guidelines are covered in SOPs), because the pilot does not know exactly when the rejoin may be required. For basic flying training instructor pilots, the rejoin is anticipated and briefed before the flight and generally flown the same way every time. This may mean that when

fighter pilots join the Snowbird squadron, they have more experience in performing "ad hoc" rejoins than other pilots. Consequently, what may be obvious to a fighter pilot may not be to the pilot with another background. In interviews of the other Team members, this was borne out as each member was asked his or her interpretation of the terminology “take your own rejoin line” and its application in this scenario. Those pilots with a fighter background understood that this directive required you to maintain visual contact with and miss the aircraft ahead (aircraft #1 in this case), as per pilot #1’s intent. Those pilots without a fighter background had interpretations that fell into two categories. Some found this directive to be confusing and ambiguous while others interpreted it as pilot #5 had. All the non-fighter types would have interpreted the directive to mean that you would rejoin the main formation directly without reference to aircraft #1, as he would maintain his own rejoin with clear separation to the right. The difference is that some would have queried the call by pilot #1 while the others would have flown the rejoin as pilot #5 had done. This interpretation seemed to be validated by the first rejoin accomplished by aircraft #1 and #5; aircraft #1’s actions to separate from aircraft #5 to the right; and aircraft #5’s echelon left position on aircraft #1 prior to the split.

Also, when asked if the Team used the term “take your own rejoin line”, the majority of Team members did not recollect having heard the term while on the Team. Pilot #1, however, believed that the Team used this term on a regular basis.

2.4 Cockpit Seating

Another factor is the cockpit position occupied by pilots #1 and #5 in their respective aircraft. Pilot #1 occupied the right seat of aircraft #1 while pilot #5 occupied the left seat of aircraft #5. This was their normal seating. As aircraft #5 was on the left side of aircraft #1 for this rejoin, both pilots were “cross cockpit”. As aircraft #1 was ahead of aircraft #5, the only way pilot #1 could have seen aircraft #5 would have been through the use of his mirrors. Pilot #1 stated that he did not have visual contact with aircraft #5 at any time after the initial split. The cross cockpit seating would have made it more difficult for pilot #5 to see pilot #1 especially as he also had a passenger occupying the right seat. Although pilot #5 stated that he did not make a conscious effort to maintain visual contact with aircraft #1, his cross cockpit seating and right seat passenger may have blocked any peripheral visual cue which pilot #5 may otherwise have had of aircraft #1.

2.5 Communication

Communication factors involved in past aircraft incidents show that information transfer problems usually do not occur because information is unavailable. Communication as a Crew Resource Management (CRM) problem occurs because either A) the person who should have transferred the information did not think it was necessary to transfer it or; B) the information was transferred inaccurately. In the first case, information is so obvious to one of the people involved that it was assumed the other person knew. Because humans can only interpret information

presented to them in the context of their own biases and mental models, what may be obvious to one person is not necessarily obvious to another.

Of these two miscommunication modes, type A was a factor in this accident. During the time of the second rejoin pilot #1 assumed that pilot #5 understood completely what he was being directed to do and understood the arrangements of the “miss contract”. Indeed, pilot #1 in his witness testimony made it clear that he did not understand why pilot #5 had not "honoured the miss contract" and hadn't understood his directive to "take your own rejoin line".

A related issue is the requirement, in a large team or formation of aircraft, for short and succinct radio transmissions - to keep the radio available for when it is really needed, to ensure all members hear critical information, and to allow all members to concentrate on their flying rather than communications. There may, therefore, be a tendency for team members to use short phrases and directives, whether or not included in a lexicon of standard brevity codes, in an attempt to maintain this “radio discipline”, to avoid longer but more informative radio transmissions. This, naturally, increases the risk of a misunderstanding, as was the case with the phrase “take your own rejoin line”. To avoid this, formation pilots must either use only standard phraseology or give an explanation of the intended action with enough detail to make it unambiguous. It is equally important for recipients to query any term or phrase whose meaning they are not 100% sure of.

2.6 Culture and Communications

The investigation team examined the possibility that cultural issues may have led to unbriefed manoeuvres being introduced during this media flight. The Snowbirds brief, fly and debrief their performances with great discipline and professionalism. This accident, however, is evidence that the rigid procedures of the show and strict adherence to pre-planned manoeuvres did not apply outside of the show. Specifically, there was less detailed planning, and not all the manoeuvres which were planned and briefed were flown exactly as planned for this non-show flight. In the pre-flight briefing for this sortie, the only aerobatic manoeuvre briefed was inverted flight during the actual photo-shoot. During the flight, however, the Snowbirds also performed a "shake-out" manoeuvre involving inverted flight (which is defined as an aerobatic manoeuvre) as well as more inverted flight during the photo-shoot (of note, 431 (AD) Squadron orders state that, during media flights, there will be no aerobatic manoeuvres). Further, the initial photo-shoot rejoin was well briefed on the ground, but was not flown as briefed and pilot #1's manoeuvring around the formation before completing his rejoin was not briefed. Also, the second rejoin was not pre-briefed.

Another possible indication of a change in normal Snowbird planning and procedures is pilot #1’s decision to relinquish lead of the 9-plane formation to accomplish the photo-shoot. It could be argued that pilot #1 should not have been behind the main formation conducting media photo opportunities in the first place, but rather in front of the formation leading the other eight aircraft where his role is

clear and important. Pilot #1 in fact stated that as he was conducting the accident rejoin he was a little more cautious than usual because he did not do rejoins as often as he used to, or as often as the other team pilots do.

The Snowbirds are noted for their excellent flying ability, and have the requisite piloting skills to deal with last minute changes during the flight and they often do so with minimal communication based on well briefed, understood and practiced "contracts" or SOP's. Minor changes and additions to a manoeuvre plan such as this should have been easily and safely accomplished. However, great flying skill will not help when missions have multiple aims (photo-shoot and media familiarization), different mental models of the mission sequence or the intentions of pilots in separate aircraft differ. The risk associated with multi-plane formations and in-flight changes is further compounded when the manner in which the mission being conducted is at odds with the normal operating paradigm or culture of the unit – note that the previous Snowbird accident in Toronto also involved an unexpected departure from the sequence as planned. Normally missions are highly choreographed affairs and air-to-air communications are often quick and brief, or non-existent between pilots. In this case, the use of brief communications and non-standard phraseology resulted in a misinterpretation of pilot #1's intentions. One must also consider the fact that Snowbird pilots come from different flying backgrounds and therefore may interpret air-to-air communications differently if non-standard phraseology is used during the flight. This case shows the importance of the use of standard transmissions and if a standard call is not heard or understood, it should be queried.

It is very important to note that this in no way points to a Snowbird culture lacking in professionalism or discipline – the Snowbirds are noted for both. Rather, it suggests that the part of the discipline that applies to show performances, the detailed sequencing of all manoeuvres, was not followed as fully as normal in this event and that the formation members did not have a clear mental picture of the mission sequence. Thus, the ability to operate quickly and safely with minimal air-to-air communications was compromised. This may have happened partly because they are so capable and confident and non-show flying seemed so straightforward, and certainly the team lead was confident that the team members could easily handle such simple manoeuvres. Possibly contributing to the accident was the acceptance of multiple aims for one mission to gain maximum benefit from the flight, the typical 'can do' attitude. Much had been said about the Snowbird's real value to the Canadian Forces being public relations, so a belief that their role went beyond air display, and perhaps even that their survival as a team depended upon meeting the public's and the media's expectations, may very well have also contributed to decisions to conduct non-briefed manoeuvres.

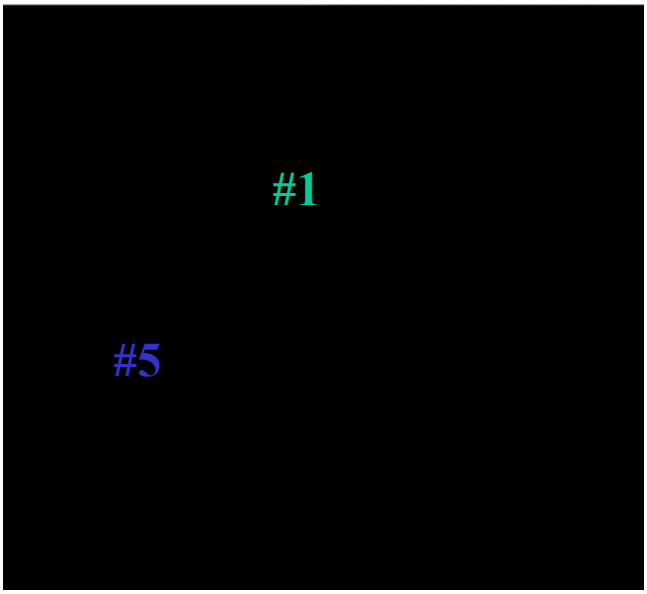
Certainly, for this unit, accepting a deviation from strict show discipline for expediency when conducting non-show duties is an element of the culture that is very difficult to detect. This is the reason that the Air Force has experts from outside units monitor unit performance and behaviour through standards inspections. However, standards inspections typically observe during fixed training

or ‘show piece’ activity on site. Mid-show season evaluations might prove of greater value. The difficulty arises from the fact that there are few experts knowledgeable in Snowbird operations except past team members. Stricter oversight and a tighter, more detailed standing regulatory structure governing non-show and particularly media flight operations would be appropriate for this unit.

2.7 The Collision

The two aircraft collided at approximately the seven o’clock position and 250-300 feet behind the main formation (see Figure 4). Impact marks were taken from aircraft #5, which landed safely, and aircraft #1, which was recovered from the bottom of Lake Erie, and matched to determine angles of impact between the two aircraft. Based on witness testimony and impact marks, it was determined that, at the time of collision, the angle between the longitudinal axes of the two aircraft was approximately seven degrees (Figure 5). Aircraft #1 was also banked at approximately thirty degrees to the right relative to aircraft #5. The right trailing edge of aircraft #1 impacted the right leading edge of aircraft #5. A portion of the right aileron of aircraft #1 was found stuck in the right leading edge of aircraft #5 (Annex A, Photo 5). Considerable damage was caused to the right wing aileron of aircraft #1, causing the loss of control that pilot #1 experienced. The underside of the rear fuselage of aircraft #1 scraped along the top of the right wing of aircraft #5 causing gouge marks to both aircraft.

Figure 5



As aircraft #1 scraped and gouged its way along the right wing of aircraft #5, aircraft #5 was in a nose down pitch moment as pilot #5 had “bunted” the aircraft over when he saw a flash of aircraft #1 just prior to the collision. This nose down pitch moment allowed aircraft #1 to pass narrowly over the canopy and then the tail of aircraft #5 avoiding further damage to both aircraft.

Pilot #1, still unaware of having collided with aircraft #5 and thinking he had just passed through some type of heavy turbulence, then experienced an uncontrollable slow roll to the right due to damage to his right hand trailing edge and aileron. He attempted to control aircraft #1 but was unsuccessful. As the aircraft passed through approximately forty five degrees of right bank with pitch level, pilot #1 directed his passenger to prepare for an ejection and subsequently called for the ejection. The passenger did not respond and pilot #1 then attempted to eject the passenger by manually pulling the passengers left-hand ejection handle. After an unsuccessful attempt at locating the handle, and through approximately ninety degrees of right bank and a slight descent, pilot #1 ejected himself by assuming the proper posture and pulling both of his ejection handles.

Based on data retrieved from the on-board Operational Loads Monitoring (OLM) system and witness testimony, the passenger then ejected approximately three to four and a half seconds later.

2.8 Ejection Envelope

2.8.1 Pilot's Ejection Envelope

To determine the point at which the pilot ejected from the aircraft, OLM data from the two incident aircraft were compared to determine the time of collision. Strain and acceleration data were then analysed to determine the point at which the pilot initiated ejection from the aircraft and the time when the pilot departed the aircraft. It is estimated that the pilot departed the aircraft while it was at approximately 960 feet AGL, an airspeed of 241 KIAS, a sink rate of 3450 ft/min and in a right bank of 107 degrees. Based on witness testimony and a detailed mathematical analysis, it was determined that the pilot was under a full parachute for approximately twenty seconds prior to water impact. It is, therefore, determined that the pilot's ejection was within the survivable envelope.

2.8.2 Passengers Ejection Envelope

The investigation was unable to precisely determine the point at which the passenger ejected from the aircraft due to erratic OLM data and inconsistent ATC data at this lower altitude. Therefore, witness testimony, last known aircraft attitude, the location of the passengers Rigid Seat Survival Kit (RSSK) from the bottom of the lake and the aircraft wreckage location from the bottom of the lake, were used to determine approximate trajectories. These trajectories were then used to calculate aircraft altitude and attitude at the time of ejection. It is estimated that the passenger departed the aircraft at approximately 750 feet AGL, an airspeed of approximately 235 KIAS, a sink rate of approximately 2400 ft/min and in a right bank of approximately 175 degrees. Based on these estimations, it is likely that the passenger was within the survivable ejection envelope of a properly functioning seat, however, it cannot be determined with certainty.

2.9 Escape System Performance

The only escape systems equipment recovered from the accident scene was the pilots' and passengers' RSSK and the passengers' parachute. As with the aircraft canopy, neither ejection seat nor the pilots' parachute were recovered. The determination of the escape system's performance during the ejections is based upon inspection of the passenger's parachute, both occupants ALSE and witness testimony.

2.9.1 Pilot's Ejection

As discussed at paragraph 2.7, the pilot attempted to eject his passenger prior to ejecting himself. Evidence suggests that this action delayed the pilot's ejection for approximately one second. After the pilot departed the aircraft, the passenger did not initiate his own ejection until approximately three to four and one half seconds later. An ejection sequencer would have eliminated both of these timing delays in the ejection. The installation of a command sequenced ejection system in the CT114 should be further investigated, especially if passengers will be flown in the future.

The pilot indicated that he did not have time to fully tighten his harness or declare an emergency before initiating his ejection. He did however assume the correct ejection position prior to pulling his seat handle, except that he did not pull his feet in towards his seat and, subsequently, suffered minor injury (bruising) to his calves. The aircraft canopy ejected automatically; the pilot's lap belt released automatically; the automatic seat-man separator achieved seat-man separation; and the parachute automatically deployed.

The pilot described the parachute opening shock as moderate and that it felt like a "good opening". He was unsure of his body position at parachute deployment. As previously indicated, the pilot was under his inflated parachute for approximately 20 seconds. While descending, the pilot released his mask, inflated the life preserver mounted on his Universal Carrier (UCLP) and deployed his RSSK (at approximately 100 ft AGL) in preparation for a water landing. When attempting to inflate his life preserver during the descent, the pilot stated that the inflation handle was hard to find (it had come away from the Velcro patch which is designed to hold the handle in place) and that it took him three tugs to discharge the inflation device. This anomaly has been observed before during testing of the Tutor Ejection seat. The Velcro is insufficient to restrain the UCLP activation handle when subjected to wind blast. A new method of holding the UCLP inflation handle in place during an ejection should be investigated.

The pilot described his descent under his parachute as "very fast" and that he wasn't prepared for his landing though his hands were on the risers when he hit the water. The pilot was wearing a parachute (24 ft) in accordance with regulations and his weight together with that of his equipment would have resulted in a decent rate of approximately 24 ft/sec. This is the maximum descent rate listed in the CFTO C-

22-010-022/MF-000 for a 24-foot canopy. As the pilot was on the limit of meeting the requirement for a 28ft parachute, had he been wearing a 28 ft parachute, his estimated descent rate would have been greatly reduced to approximately 19 ft/sec. It is recommended that the elimination of the 24 ft parachute and the issue of 28 ft parachutes to all aircrew regardless of aircrew weight be further investigated.

Notwithstanding the above issues, the pilot's ejection is classified as successful.

2.9.2 Passenger's Ejection

According to the passenger's testimony, when the two aircraft collided he felt "a good jolt." After the impact, the passenger waited to see what the pilot would do. The pilot then directed the passenger to prepare for an ejection and subsequently called for the ejection with the directive, "Eject, eject." The passenger then ejected, stating that it was "two seconds at most" from the time he saw the flash from the pilot's ejection seat until he pulled his own seat handle. From the OLM analysis, it was estimated that the passenger ejected between 3.2 seconds and 4.45 seconds after the pilot's seat rocket fired. The perception discrepancy is likely due to the extreme nature of the ejection environment, the noise, flame and smoke from the jettisoning of the canopy and the pilot's ejection, and the passenger's resulting momentary "disorientation".

The passenger stated that when he pulled his ejection seat handle with his right hand, he was leaning forward and not in the correct ejection position. He also stated that he kept his eyes open during the ejection and that he tumbled forward after departing the aircraft. As a former paratrooper with 108 parachute jumps, he stated that this one never developed into a controlled parachute descent. In fact, it is estimated that the time between ejection initiation and water impact was less than 10 seconds.

The passenger parachute (28 ft flat circular) was recovered from the bottom of Lake Erie with the RSSK still attached. The parachute canopy was in poor condition and showed signs of significant seat-parachute interference. There were numerous tears, holes and burns indicative of contact with the seat during the parachute deployment sequence (Annex A, Photo 6). Additionally, deposits of cadmium found on the parachute indicate that the parachute was in close proximity to the Rocket Catapult (ROCAT) while it deployed, shortly after ROCAT burnout. Finally, grey paint chips and seat handle tape were found embedded in a number of the parachute seams. This phenomenon is not uncommon with older generation ejection seats equipped on aircraft such as the CT114 Tutor. These seats have a history of poor seat-man separation. The descent rate for the passenger cannot be precisely determined due to the unknown inflation extent of the parachute at the time. However, the injury potential would be high after a descent even in a fully inflated 28ft parachute with two gores missing coupled with a suspended weight of approx 270 lbs. Additionally, during inspection of the passenger's parachute, blue scuffmarks were found on a significant number of the shroud lines. QETE analysis determined that these marks were from the passenger's flight suit. This material transfer from the passenger's

flight suit to his parachute's shroud lines clearly indicates parachute deployment anomalies.

It is believed that the damage to the parachute occurred during canopy deployment and not after the parachute was inflated (or partially inflated).

During his parachute descent, the passenger did not deploy his RSSK. When interviewed, the passenger did not seem to be aware that he had a survival kit in his RSSK and did not know that he could and should deploy it during his descent (this issue is addressed at paragraph 2.13.1). Regardless, considering the short time period between ejection initiation and water impact and the disoriented, semi-aware state of the passenger, it is doubtful as to whether any passenger, trained or untrained, would have had time to deploy his RSSK.

The majority of the passenger's injuries resulted from impact with the water at a high descent rate. The attitude of the passenger on water entry could not be determined. As the passenger did not release his RSSK prior to water impact, the impact of the RSSK with the water most likely contributed to bruising to the passenger's buttocks, rear of his upper legs and back, and may have contributed to the injuries to the passenger's shoulder. Green paint transfer on the parachute pack and scuff marks on the RSSK indicate that, during water impact, the RSSK was forced up between the passenger's body and the parachute pack.

Given the evidence of seat-parachute interference and the severe damage to the parachute combined with the passenger's injuries, the passenger's ejection is classified as an unsuccessful but survivable ejection. If the passenger had impacted on land vice water, his injuries would most likely have been fatal.

Due to the evidence of seat-parachute interference for the passenger's ejection, and the past history of CT114 ejection seats, it was recommended early in the investigation that the solution utilized for the CT133 escape system (the ARAD system) be immediately installed on all CT114 aircraft. This was accomplished.

2.10 Water Survival

2.10.1 The Pilot

After the pilot entered the water, he surfaced and attempted to release his parachute from his body by releasing the Quick Release Box (QRB). He found it very difficult to access the QRB underneath the inflated bladder of the life preserver in the rough water but eventually succeeded. The waves caused the parachute shroud lines to wrap around his arms and legs and he had to fight against being pulled downward and under water by them. He pulled himself to his inflated raft (which had inflated automatically when he manually deployed his RSSK prior to water entry) and attempted to swim free of the parachute. Initially unsuccessful, he removed his personal knife and, with some difficulty, cut enough shroud lines away to pull himself into the life raft where he continued to cut away the remaining shroud lines. He then attempted to bail out the water that had accumulated in the raft using

his helmet but the waves were causing water to enter the raft more quickly than he could remove it. The pilot then closed up the canopy to the raft and waited for the rescue, approximately one hour later.

The pilot's difficulty in releasing the QRB with the life preserver inflated in rough water suggests that an alternate means of parachute release (such as a riser release system) should be investigated to supplement the current system in use with the UCLP / LPSV and flex back parachute.

2.10.2 The passenger

The passenger came to full consciousness in the water in considerable pain. He could not move his right shoulder or arm and felt pulled down by the weight of what he thought was the ejection seat underneath him. In reality, this was the RSSK, which was still attached to him via the parachute harness. He then went through the egress sequence he had remembered from his pre-flight brief, but performed the ground egress sequence vice the water egress sequence. Nevertheless, he managed to remove the parachute harness and allow it, along with the RSSK and contents, to sink to the bottom of the lake. The passenger now had the LPSV supporting him, however, the right lobe of the vest had been damaged during either the "ejection sequence" or "water impact" so only the left lobe supported him. The passenger then, concerned with the state of the pilot, began to search for the pilot by swimming a calculated search pattern with one arm. After approximately forty-five minutes of searching and calling out for the pilot, he was forced to stop due to exhaustion and pain. He then waited for the rescue operation, not sure that the pilot had survived.

2.11 Search and Rescue

A Search and Rescue Labrador helicopter discovered the survivors at approximately 1550 hours local time, about 1 hour after the ejection. The helicopter flew past the passenger and dropped a SAR technician into the water at the location of the pilot. The helicopter then returned to the passenger, retrieved him from the water, and then went back to retrieve the pilot and the SAR technician accompanying him in the water. The helicopter then delivered the survivors to hospital (see para 1.15).

2.12 Aircrew Life Support Equipment (ALSE)

2.12.1 Universal Carrier Life Preserver (UCLP)

The UCLP was worn by both occupants. The only survival items stowed in the UCLP were a whistle and sea dye marker. CFTO C-22-521-000/MS-001 requires that the survival vest or universal carrier pockets include, as a minimum: sea dye marker, whistle and distress light marker. 431 (AD) Squadron should ensure that their UCLPs are equipped with these items prior to flight. The passenger's UCLP suffered significant damage during either the "ejection sequence" or "water impact". The right lobe of the bladder tore free from the universal carrier, which prevented

the vest from working as designed in the water. The passenger commented that the one lobe of the bladder was trailing behind him while the other was still attached to his front, making it a struggle to keep his face out of the water. This would have been so even without his injuries, but was made more difficult by them. The passenger had no recollection if the vest was deployed prior to water entry or not, however, he made no attempt to deploy the vest prior to or after water landing. He was not aware of any contents in the vest and commented that he was surprised that he had no signalling devices, when in fact he did have a Sea Dye Marker in his vest that may have aided in his rescue. 431 (AD) Squadron passenger briefings are discussed at paragraph 2.13.1.

2.12.2 Shroud Knife

The pilot did not have a shroud knife tied into the leg pocket of his flight suit. The fitted, red Snowbird flight suit did not have a pocket long enough to fit this survival item at the time. In its place, the pilot had an untied Swiss Army knife. If the pilot had dropped his knife while attempting to free himself from the shroud lines, he might have drowned. Although the passenger was wearing a standard CF flight suit with a pocket fitted for the shroud knife, he was not issued with a shroud knife, and had no knife of any kind with him. The passenger was fortunate in that he had previous experience with water landings from his days as a paratrooper. If the passenger had not known how to extract himself from the shroud lines without a shroud knife, he could easily have survived his ejection and then drowned.

There is no CF directive that requires ejection seat aircrew to tie a knife into the pocket of either their flight suit or g-suit. CFP B-22-050-278/FP-000 (Manual of Life Support Equipment and Techniques), Chapter 12, Paragraph 3 states that an aircrew emergency knife is available for CF aircrew and describes how the knife is to be tied into the flight suit pocket, but this is not a requirement. This requirement should be included in CF Flying Orders.

2.12.3 Flying Gloves and Undergarments

The pilot was wearing issue leather outer flying gloves at the time of ejection without the glove liner. The passenger was not issued flying gloves, and was flying with bare hands.

The pilot was not wearing long underwear. The passenger was not wearing long underwear but was wearing combat pants under his flight suit. Though not ideal, the combat pants do meet the dual layered clothing requirement.

1 CAD Orders, Vol 2, 2-007, Section 2, paragraph 19, states, “Personnel engaged in flying operations shall adhere to the dual layered clothing principle for fire protection” and “WComds/Unit Commanding Officers shall promulgate an order on the wearing of dual clothing layers, with due consideration to heat stress depending on local, environmental and climatic conditions.” Such an order could not be found in either 15 Wing Flying Orders or 431 (AD) Squadron Flying Orders. 431 (AD)

Squadron should promulgate an order on this issue, stating clearly whether and when the requirement to wear dual layer clothing while conducting flying operations is waived due to heat stress.

2.12.4 Rigid Seat Survival Kit (RSSK)

The passenger did not release his RSSK prior to water impact. After his water landing, the passenger removed his parachute while carrying out ground egress procedures. In doing so, he inadvertently released his RSSK and it sunk to the bottom of the lake. During the investigation, the passenger's RSSK was recovered with all of its contents intact.

The pilot's and passenger's RSSK log sets indicated that they were packed in a "Global Configuration" (most complete for this time of year). They were, however, not packed in this configuration as they were missing a few items (tear away bag, survival knife, axe, sunscreen, plastic bags, insect net and snow scoop). The RSSKs were not packed in an approved survival kit configuration as per CFTO C-22-115-000/MF-000. 431 (AD) Squadron maintenance personnel should be briefed to pack RSSKs in accordance with the approved contents list.

2.12.5 ALSE Recap

There are several points contained in this report that are ALSE related. We have referenced B-22-050- *278/FP-OOO* (Manual of Life Support Equipment and Techniques), which was last updated in 1979 and does not support much of our existing ALSE. There is no supporting documentation on care or training considerations with our current ALSE. This document, however is supposed to be the bible for aircrew on the techniques for everything from hypoxia and post ejection procedures to care of ALSE. Current training methods utilize the Safety Systems Technicians' corporate memory to train the new aircrew. Unless a checklist is developed at the unit level, information will be missed as personnel turn over or depart the air force. There is no common standard to the training or information provided to the member by different Safety Systems personnel. Items like the shroud knife and its use would not be missed if contained in this manual.

2.13 Passenger preparation

2.13.1 Briefing

According to the 431 (AD) Squadron Life Support Specialist, passengers are usually given a 20-45 minute group brief depending on the time available. The briefing is mostly verbal with a few visual aids; however, the first time the passengers see the ejection seat is when they are strapped into the aircraft. Passengers are briefed on location of ejection handles, body positioning during ejection, ground egress and RSSK / UCLP operation. The emphasis of the briefing is placed on ground egress and very little emphasis is placed on ejection or landing procedures. The briefing is also modified depending upon the time available to brief the passenger. The procedures as outlined in 1 CAD Orders, Vol 5, 5-305 were not

being followed and no formal documentation could be found which exempts 431 (AD) Squadron from this order.

The passenger's actions during and after ejection initiation suggest that the passenger briefing used by 431 Squadron is inadequate:

1) When the passenger initiated his ejection, he pulled only one handle, as he was not aware that the CT114's ejection seat had two initiation handles;

2) Whether he would have had time to do it or not, the passenger did not know that he could deploy his RSSK while under his parachute. Additionally, he did not deploy his RSSK while he was in the water as he was not aware that he had any survival kit attached to him;

3) After impacting the water, the passenger completed the ground egress procedure (vice water parachute removal) on which he had been drilled during the passenger briefing, "Oxygen 1-2-3, Lap belt, Lanyard, QRB", and consequently sent his RSSK and all of its contents (life raft included) to the bottom of the lake. This was confirmed by the recovery of his parachute with the RSSK still attached; and

4) Once the passenger saw the SAR helicopter, he did not deploy any supplementary signalling devices to aid in his rescue, as he was not aware of the sea dye marker located in his UCLP.

2.13.2 Pre-flight Requirements

To fly in a CF ejection seat equipped aircraft, a CF pilot requires extensive training and experience. An ejection is a violent and injury-susceptible event requiring fitness and training. A CF pilot of ejection seat aircraft must have undergone land and sea survival training, extensive medical examination, fitness testing, aeromedical training, parachute training to include land and water procedures, ejection seat training, precise parachute fitting, precise ALSE fitting and outfitted with the required personal survival items. This level of training attempts to reduce the risk of injuries in the event of an ejection, and considers the extended exposure to the risk of people who fly regularly.

The requirements for a passenger to fly in a CF ejection seat equipped aircraft are considerably less stringent. As indicated at paragraph 2.13.1, passengers with 431 (AD) Squadron will simply be given a short briefing on, primarily, the ground egress actions if required. They then sign a waiver purportedly removing liability from the CF in the event of injury or death to the passenger. A legal opinion on this issue might be worth pursuing/investigating.

The probability of a passenger having to eject from a CF aircraft is much lower than that of a CF pilot due to much less time spent in the ejection seat. However, in the event of an ejection, the risk of injury to a passenger is much higher based on the greatly reduced level of training and non-tailored ALSE equipment.

The question is worth asking: does the CF have a moral obligation to provide each passenger of an ejection seat equipped aircraft with a level of training which would further reduce the risk of injury or death? Is a simple short brief enough? Is the risk too high to keep flying civilians at all? These questions would have been painfully asked had the passenger been a civilian, been killed or both. Those outcomes were luckily and narrowly averted.

Mindful that risk can only be reduced and not eliminated, consideration should be given to the development of a standardized pre-flight briefing/demonstration/ practice, in accordance with 1 CAD Orders, covering ground egress and ejection procedures, location and operation of all survival equipment. Passengers' seeing and touching the equipment (i.e. parachute, ejection seat including both ejection handles, RSSK deployment handle and its contents, UCLP activation handle and contents, etc.) would improve the probability of their reacting appropriately.

2.13.3 Passenger Equipment Fitting.

Interviews with the ground crew and 431 (AD) Squadron Life Support Specialist indicate that for media flights or flights with any non-aircrew passengers, parachutes are not fitted or adjusted to the individual as required by B-GA-100-001/AA-000 2001-05-25, Change 1, para 54. The ground crew simply attempts to match the passenger to a Team ground crew member of similar size. This procedure probably does not ensure that a properly fitted parachute has been issued to the passenger. Additionally, passengers use the ground crew's ALSE (i.e. parachute, helmet, UCLP), with no adjustments made. According to the 431 (AD) Squadron's Life Support Specialist, he does not have the time to properly fit ALSE to each passenger as he is the only individual qualified to fit parachutes. The parachutes are left in the aircraft, and when the passengers enter the aircraft, they strap into the seat and parachute.

An improperly fitting parachute harness could cause unnecessary injury to the occupant. Improperly fitted ALSE may not function as it is designed and may also cause unnecessary injury to the individual. Consideration should be given to reviewing 431 (AD) Squadron passenger ALSE-fitting procedures to ensure the passengers are being properly fitted with parachutes and other life support equipment before flight.

2.14 Groundcrew Awareness

During interviews with the ground crew from 431 (AD) Squadron, with the exception of the Sqn Life Support Specialist, none of the members interviewed were aware of the location or type of survival equipment available in their UCLP (i.e. sea dye marker) and RSSK. Given that the 431 (AD) Squadron Maintenance personnel are members of and fly regularly with the team, they should be aware of the location and type of survival equipment available to them in the event of an ejection. 431 (AD) Squadron aircrew should also be made aware of the UCLP and RSSK survival kit contents and their locations during aircrew seat checks.

2.15 Parachute training

During the pilot #1's testimony, he opined that current in-water training (i.e. pool dingy drills) for ejection seat aircrew does not adequately address the procedure for releasing oneself from parachute shroud lines following a water landing. Improved, follow-on parachute training was directed by CAS (31 May 1999) after accidents with CT133266 (27 Jul 94), CF188713 (15 Jun 95) and CT114048 (25 Sept 97) and has still not been fully implemented. 1 CAD Order Vol 5, 5-315 was created directing that annual parachute landing training shall be conducted on CT114, CT155 and CT156 aircrew by the Canadian Parachute Centre. This was completed once in 1999, however, waivers have been given since that time exempting aircrew from this requirement. Annual parachute hanging training is completed, but the full intent of the CAS directive has not been implemented. Some greater level of annual training is recommended; this annual training should also include procedures for releasing oneself from parachute shroud lines following a water landing. Orders governing annual parachute training should either be followed as written, amended, or rescinded.

2.16 Pre-Impact Fire

This is not the first Tutor ejection with evidence of a significant aircraft fire prior to ground impact. Both videotape and examination of burn and scorch marks on the recovered airframe surfaces of this and several past accidents have identified post-ejection, pre-impact fire. The cause of this fire has been investigated but remains undetermined. The investigation therefore concludes that, for unknown reasons, aircraft 114006 experienced an airborne fire after the ejection sequences took place.

Though the phenomenon is restricted to the post ejection phase when the aircraft is most likely committed to destruction anyways, there is a possibility that it could contribute to damage on the ground. QETE should thus continue to investigate this post-ejection fire phenomenon.

2.17 Naval Assistance

In order to recover aircraft 114006 and other specific items from the bottom of Lake Erie, the services of the Fleet Diving Unit Atlantic were utilized. Together with a rented local boat, tugboat, barge and crane, the six-day salvage operation successfully removed the aircraft and related located parts for analysis by the investigating Team. Although the operation went smoothly, it would be beneficial to have a DFS/Navy Memorandum of Understanding (MOU) in place for future aircraft accident assistance by the Navy. It is recommended that DFS initiate and implement such an MOU to include an initial site assessment by a Navy representative for required resource determination.

3. CONCLUSIONS

3.1 Findings

3.1.1 All aircraft involved in the mishap were serviceable prior to the accident.

3.1.2 All nine aircraft had both a pilot and a passenger on board.

3.1.3 The mission was not flown precisely as briefed.

3.1.4 The mission involved unbriefed and unapproved aerobatic manoeuvring with media.

3.1.5 There is some evidence of a culture allowing changes in normal show discipline for non-show flights resulting in occasional non-briefed manoeuvres being conducted. Possibly contributing to this was a belief that their role included meeting the public's and the media's expectations.

3.1.6 Pilot #1 used non-standard rejoin terminology that was interpreted differently than intended by pilot #5.

3.1.7 Aircraft #1 and aircraft #5 collided approximately 300 feet behind the main formation during a second rejoin attempt to the "Concorde" formation.

3.1.8 The collision occurred when pilot #5 purposely switched his primary focus to the main formation rather than pilot #1 due to a misinterpretation of the rejoin directive given by pilot #1.

3.1.9 Other Team members also had different interpretations of the rejoin directive depending on their flying background.

3.1.10 Based on pilot #1's interpretation of the directive given, pilot #1 assumed that pilot #5 would fly an extended rejoin line to his normal position but always maintain visual contact and respect the "miss contract" on aircraft #1. It is unclear when pilot #5 was expected to divert his attention from aircraft #1 to his references in the main formation.

3.1.11 Based on pilot #5's interpretation of the directive given, pilot #1's actions during the first rejoin and pilot #1's initial movement to the right on the accident rejoin, pilot #5 assumed the two aircraft were rejoining individually and he no longer had a requirement to maintain visual contact with aircraft #1. Pilot #5's understanding was that pilot #1 had transferred lead to the main formation with the call "take your own rejoin line" and that it was now pilot #5's responsibility to rejoin taking his references from the main formation.

3.1.12 Pilot #5 did not expect aircraft #1 to reduce speed and cut across and through his rejoin line.

3.1.13 Visibility from pilot #1 to aircraft #5 was reduced due to his cross-cockpit seating and presence of his passenger.

3.1.14 Visibility from pilot #5 to aircraft #1 was reduced due to his cross-cockpit seating and presence of his passenger.

3.1.15 The two aircraft collided while angled towards each other at approximately seven degrees longitudinally and aircraft #1 banked to the right at approximately thirty degrees.

3.1.16 The collision resulted in significant damage to the trailing edge of the right wing of aircraft #1. Control of the aircraft was lost due to damage to the control surfaces.

3.1.17 The collision resulted in damage to the leading edge of the right wing of aircraft #5. Control of the aircraft was maintained and the aircraft was flown back to London International Airport and landed safely.

3.1.18 After no response from the passenger to a commanded ejection, pilot #1 unsuccessfully attempted to pull the passengers right ejection handle.

3.1.19 Pilot #1 ejected himself at approximately 960 feet AGL, an airspeed of 241 KIAS, a sink rate of 3450 ft/min and in a right bank of 107 degrees.

3.1.20 Pilot #1 suffered minor injuries due to the ejection.

3.1.21 Passenger #1 is estimated to have ejected himself 3 to 4.5 seconds after pilot #1 at approximately 750 feet AGL, an airspeed of 235 KIAS, a sink rate of 2400 ft/min and a right bank of 175 degrees.

3.1.22 Pilot #1 had difficulty locating the manual inflation handle on his life preserver during parachute descent.

3.1.23 Pilot #1 was wearing a 24 ft parachute; a 28 ft parachute would have reduced his descent rate significantly.

3.1.24 Pilot #1's ejection was successful.

3.1.25 Passenger #1 experienced seat/man/parachute interference during the ejection sequence.

3.1.26 Passenger #1 suffered major injuries as a result of water impact after an extremely high descent rate due to a damaged and possibly un-inflated parachute and with the RSSK still attached.

3.1.27 Passenger #1's injuries would most likely have been fatal had he impacted land vice water.

3.1.28 Passenger #1's ejection is classified as survivable but unsuccessful.

3.1.29 Pilot #1 had difficulty accessing the QRB underneath his inflated life preserver bladder.

3.1.30 Pilot #1 used his personal knife to cut away shroud lines which had wrapped around his body and were dragging him under water.

3.1.31 Pilot #1 entered his inflated life raft and waited for rescue for approximately one hour.

3.1.32 Passenger #1 came to full consciousness in the water and, being pulled under water by his still attached RSSK and parachute and performed the ground egress procedure (vice water egress). This released his RSSK (including his life raft) and parachute, both of which sunk to the bottom of the lake.

3.1.33 Passenger #1 then began a calculated swim search pattern in search of pilot #1 until exhaustion and pain forced him to stop and he waited for rescue.

3.1.34 A SAR Labrador helicopter flying in the vicinity retrieved the two survivors from the water at approximately 1550 hrs local (approximately one hour post ejection) and delivered them to the awaiting helicopter and ambulance.

3.1.35 Both survivors wore the UCLP which did not have all of the mandatory survival contents.

3.1.36 Neither survivor had the issue shroud knife designed specifically to cut away shroud lines. The Snowbird flying suit did not have a pocket long enough to hold this item and pilot #1 carried a personal knife instead. The passenger was wearing the standard CF flight suit with a pocket designed to fit the shroud knife but he had no knife.

3.1.37 There is no CF directive that requires ejection seat aircrew to tie a knife into the pocket of either the flight suit or G-suit.

3.1.38 Pilot #1 was wearing issue flying gloves without the liner.

3.1.39 Passenger #1 was flying with bare hands.

3.1.40 Pilot #1 was not wearing full dual layered clothing.

3.1.41 No 431 (AD) Squadron order exists which exempts its aircrew from adhering to the dual layered clothing principle.

3.1.42 The RSSK's were not packed in an approved survival kit configuration.

3.1.43 The passenger pre-flight briefing was insufficient to ensure appropriate ejection behaviour, and did not follow a 1 CAD Order.

3.1.44 The level of training and preparedness given to Snowbird passengers was inadequate to assure their safety.

3.1.45 The life support equipment fitting of passengers flying with 431 (AD) Squadron was inadequate to assure their safety.

3.1.46 431 (AD) Squadron ground crew were unaware of UCLP and RSSK survival kit contents.

3.1.47 Improved follow-on parachute training was directed by CAS on 31 May 1999 after past accidents but remains unimplemented.

3.1.48 Current parachute water landing training (pool dingy drill) may not adequately address the procedures for releasing oneself from parachute shroud lines following a water landing.

3.1.49 A post-ejection fire, which has been observed on previous CT114 ejections, was evident in this accident.

3.1.50 A DFS/Naval MOU would be beneficial to facilitate further successful water recovery operations.

3.2 Cause

3.2.1 The collision between aircraft #1 and aircraft #5 occurred when pilot #5 purposely switched his primary focus to the main formation earlier than pilot #1 anticipated due to the interpretation of the non-standard rejoin directive given by pilot #1.

3.3 Contributing Factors

3.3.1 Contributing to the accident was a culture of accepting as necessary, for Public Affairs missions, the need to conduct non-briefed manoeuvres during non-show operations with less detailed preparation and attention to specific communication requirements than is typical for performances. Possibly contributing to this was the perceived criticality of meeting the media's expectations.

4. SAFETY MEASURES

4.1 Safety Measures Taken

4.1.1 431 (AD) Squadron “show” Team members underwent post incident stress debriefings after the accident.

4.1.2 1 CAD FSO provided a three-day, focused CRM course in Jul 01 and again in Dec 01.

4.1.3 Pilot #1 and pilot #5 each received a formation training/confidence flight with a CFS Standards pilot prior to resuming normal Team formation flights.

4.1.4 431 (AD) Squadron flew numerous training flights prior to resuming air display flights on July 20, 2001. The requirement to maintain situational awareness of the other members of the formation was stressed.

4.1.5 431 (AD) Squadron ceased flying any non-essential personnel immediately following the accident. CAS is the approving authority for carrying media. Media personnel will only be flown by the co-ordinators outside of the main formation.

4.1.6 15 WComd initiated a formal risk assessment on conducting media flights on 431 (AD) Squadron.

4.1.7 The Aero Rigid Arm Drogue (ARAD) project was accelerated and all Snowbird show aircraft were equipped with this device.

4.1.8 431 (AD) Squadron immediately began a review and standardization of the personal ALSE carried in flight suits during flights.

4.1.9 The red Snowbird flight suit has been reconfigured to enable a shroud knife to be fit into the inner thigh pocket.

4.1.10 431 (AD) Squadron initiated a system to ensure that all RSSK’s are packed in accordance with the approved contents list.

4.2 Further Safety Measures Recommended

It is recommended that:

4.2.1 431 (AD) Squadron review all procedures to ensure that only standard radio terminology is used.

4.2.2 Independent review of 431 (AD) Squadron non-show sequence operations to ensure adequate communication protocols are used by the team in order

to effectively deal with both planned and unplanned deviations from its highly developed and extensively practiced show routines.

4.2.3 The formal risk assessment initiated by 15 WComd on conducting media flights on 431 (AD) Squadron be finalized.

4.2.4 431 (AD) Squadron finalize its review and standardization of the personal ALSE carried in flight suits to include the UCLP during flights.

4.2.5 The installation of a command sequenced ejection system in the CT114 be further investigated.

4.2.6 A new method of holding the UCLP inflation handle in place during an ejection be investigated.

4.2.7 The 28 foot parachute be considered for use by all CT114 aircrew;

4.2.8 An alternate means of parachute release (such as a riser release system) be investigated to supplement the current system in use with the UCLP / LPSV and flex back parachute.

4.2.9 A directive be created/amended to require that ejection seat aircrew tie a shroud knife into the pocket of either the flight suit or G-suit;

4.2.10 431 (AD) Squadron promulgate an order in accordance with 1 CAD Orders, Vol 2, 2-007, Section 2, paragraph 19, with respect to the wearing of dual layer clothing;

4.2.11 431 (AD) Squadron ensure that their UCLPs are equipped with the items specified in the CFTOs.

4.2.12 If 431 (AD) Squadron continues to fly untrained passengers, the passenger pre-flight briefing be standardized in accordance with 1 CAD Orders (Vol 5, 5-305). Equal emphasis should be placed on ground egress and ejection procedures to ensure that all necessary topics are covered including water entry;

4.2.13 If 431 (AD) Squadron is given authorization to fly untrained passengers, the passenger life support equipment fitting procedures be improved to ensure appropriate protection in accordance with current directives;

4.2.14 The level of training and preparedness given to passengers of all CF ejection seat equipped aircraft be reviewed to ensure an appropriate level of preparedness for ejection and landing, on land or in water;

4.2.15 431 (AD) Squadron ensure that all flying personnel are aware of the UCLP and RSSK survival kit contents;

4.2.16 B-22-050- *278/FP-OOO* (Manual of Life Support Equipment and Techniques) be reviewed and brought up to date; and

4.2.17 QETE continue to investigate the post-ejection fire phenomena observed during various CT114 ejections.

4.3 Other Concerns

4.3.1 DFS initiate and finalize an MOU with the Navy to ensure the continued success of aircraft water recovery operations;

4.3.2 A legal opinion on the validity of signed waivers removing liability from the CF in the event of injury or death to the passenger should be sought;

4.3.3 An appropriate level of resource be allocated in order to accomplish the CAS directed (31 May 1999) follow-on parachute training for all ejection aircraft. This annual training should also ensure that the procedures for releasing oneself from parachute shroud lines following a water landing are addressed.

4.4 DFS Remarks

The cause of this unfortunate and avoidable accident was differing expectations. This investigation report has explored some reasons and potential reasons for these differing expectations. Whatever the paradigm (or culture) from which we come, we cannot afford to oversimplify the cause – all of the reasons for the differing expectations must be considered in arriving at corrective measures.

In such a dynamic and error-intolerant environment as a 9-plane air display formation, standard terminology is essential and must be utilized at all times and not just during the “show”. If standard terminology is not used, then the receiver must query the directive to ensure that all players are interpreting it in exactly the same way.

Cultural issues are key to safe flying operations. It is absolutely normal human behaviour when a culture of acceptance of deviations from the norm enters an organization; it happens so insidiously that people within the organization don’t notice the change until after it has become dangerous. It is important that any organization, no matter how good and professional, be monitored from outside for performance and behaviour. The CF does this through standards inspections; people conducting these inspections at any unit in the air force must be particularly alert to the possibility that attitudes have developed or are developing that might, however obliquely, compromise safety. I note that the previous Snowbird accident in Toronto also involved an unexpected departure from a sequence as planned.

Had the passenger involved in this accident not been a trained, fit and experienced parachutist (in other words, had it been one of the other eight passengers flying that day), the result would most likely have been tragic, and many difficult questions

would have been asked from very high levels. The benefits of flying passengers in ejection seat aircraft must be compared with the potential downside, and if it is determined that the benefits are worth the potential cost, we must improve the preparation of these passengers for flight. An ejection is a hazardous and violent experience which subjects the human body to unusual forces for which untrained people are unprepared. I believe the CF has a moral obligation to ensure that each occupant of one of these seats, be it a civilian or military member, is suitably prepared for this type of event. In my opinion, a quick brief and a waiver does not fulfill this obligation.

Reflecting on the newly expanded 431 (AD) Squadron I can't help but wonder about the demands placed on the Commanding Officer. His responsibilities not only include the functions of a squadron CO but also the duties of Snowbird lead and a public affairs spokesperson and media interface. His role as team lead is probably a small part of how he is judged overall, yet is the most important in terms of the safety of the team; this may be asking too much of one person.

R.E.K. Harder
Colonel
Director of Flight Safety

Annex A: Photos

Photo 1 – Wreckage of 114006 as pulled out of Lake Erie

Photo 2 – 114081 showing damaged right leading edge

Photo 3 – 114081 closer view of damaged right leading edge

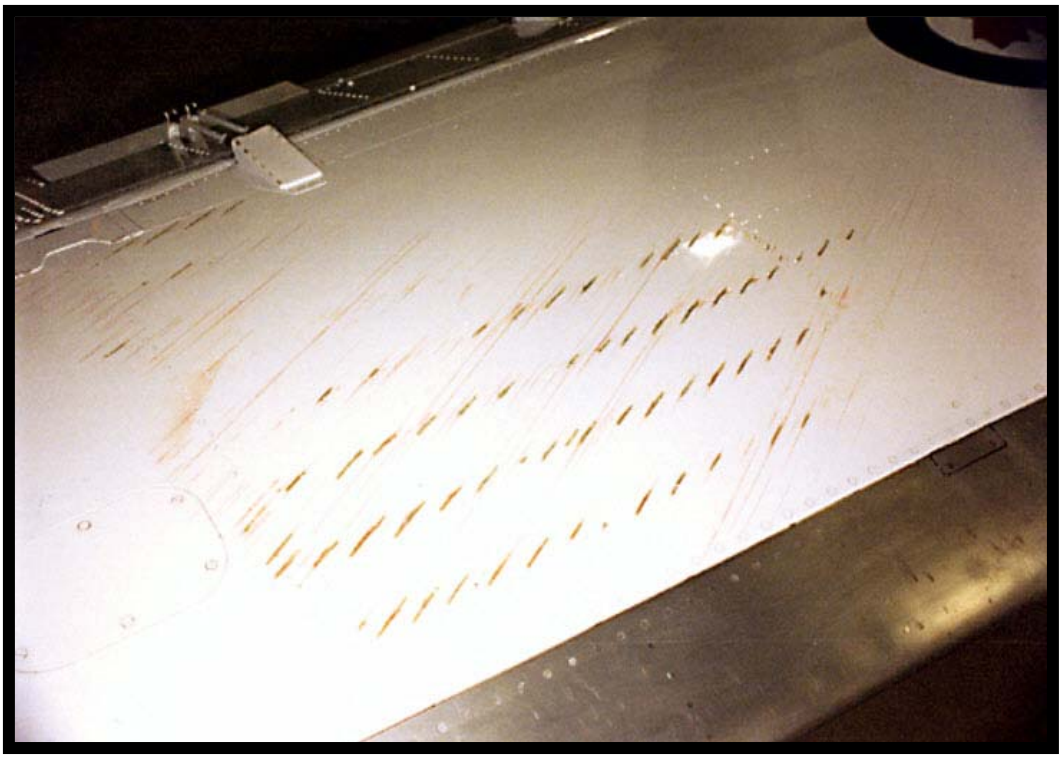


Photo 4 – 114081 Top of right wing

Photo 5 – Portion of 114006 right trailing edge embedded in right leading edge of 114081

Photo 6 – Passenger #1 Parachute