ANALYSIS OF THE XB-70 ACCIDENT

All of the pilots in the formation had considerable flying time and had qualified in the particular aircraft involved.

Mr. White, pilot of the XB-70, had logged in excess of 5,900 flying hours as of 8 June 1966 in a variety of aircraft. He has had extensive flight test experience and was fully qualified in the XB-70, having flown the first and some seventy-plus other flights in the two XB-70 aircraft. His total time since 1 July 1965 was approximately 93 hours, a good share of which was in the XB-70.

Major Cross, co-pilot of the XB-70, had flown a total of 8,530 hours. He had gained considerable experience in flight test operations and was experienced in a variety of aircraft, including heavy multi-engine jet aircraft, and was a graduate of the Air Force Test Pilot School. He had undergone ground training on the XB-70 and was, on this flight, having his first familiarization ride in the aircraft preparatory to becoming one of the test pilots in the XB-70 program.

Mr. Walker, pilot of the NASA F-104, had a total of 4,998 hours of flying time. He had an extensive background and experience in experimental flight testing, including the X-15 program. His experience included a variety of aircraft, including the F-104 in which he was current and had logged 27 hours and 45 minutes in the 90-day period preceding the accident. Mr. Walker had completed the XB-70 formal ground course having been chosen as the NASA pilot for the continuing XB-70 test program. He had additionally flown as chase pilot on XB-70 test missions on ten occasions, eight of which were flown in an F-104.

Mr. Fritz, pilot of the General Electric F-5, is a former Air Force pilot who had logged considerable flying time as of the date of the accident. He has been a civilian test pilot since 1956.

Commander Skyrud, pilot of the Navy F-4, had logged 4,249 hours flying time. He is also a qualified test pilot having graduated from the Empire Test Pilot School (British).

Colonel Cotton, riding in the T-38, had logged 11,263 flying hours at the time of the accident. Additionally, he is an experimental test pilot of many years' standing, and has flown the XB-70 in the test program numerous times as pilot and co-pilot.

Captain Hoag, pilot of the T-38, had logged 2,452 flying hours, is a graduate of the Aerospace Research Pilots School, and is currently assigned as an experimental test pilot at the Air Force Flight Test Center.

With regard to aircraft condition, the pre-flight mechanical condition of the XB-70 was without discrepancies of significance. Some minor discrepancies were carried on the maintenance records, as is usual with aircraft, but have no relation to the accident which occurred. This is borne out by the XB-70 telemetry record analysis of the flight from time of take-off to ground impact.

The pre-flight condition of the F-104 did not exhibit any maintenance deficiencies that would be contributory to the accident occurrence. The NASA system of maintenance follows Air Force practice and uses Air Force type documentation.

The mechanical condition of the XB-70 prior to the collision was determined from the on-board instrumentation with telemetered relay to the ground control. Telemetry was received throughout the flight, including the times immediately prior to and during the collision and until the XB-70 ground impact. For a period of 44 seconds prior to the collision the XB-70 was in essentially straight and level flight. There was no indication of any abnormal condition or operation on any recorded data during this period.

The condition of the F-104 immediately prior to the collision cannot be as positively stated as that of the XB-70. Because the airplane was used only for chase and proficiency flying and was not a research vehicle, no recording or telemetering type instruments were aboard, so that all conclusions must be based on observer reports and the post-accident mechanical analysis of the wreckages. It should be noted that because of the severe damage to the airplane, the post-accident analysis could cover only portions of the mechanical system, and for these portions no malfunctions were indicated. The analysis could not cover any part of the electronic portions of the control system. However, no indications of impending trouble were noted either visually or aurally by any surviving members of the flight. Films of the flight showed a slight pitch oscillation of the F-104 when it was close to the XB-70 and also a momentary orange streak in the F-104 jet exhaust. These happenings have been interpreted as normal occurrences and are not believed to be indicative of any F-104 malfunction.

In examining the data with respect to the accident, the following possible causes and contributing factors were explored:

1. Air turbulence causing motion of one of the aircraft.
2. Mechanical malfunction in one of the aircraft.
3. Physiological problems of one or the other crew.
4. Distraction of the F-104 pilot.
5. Aerodynamic effects on the F-104 due to airflow near the XB-70.
6. Inadvertent movement of the F-104 towards the XB-70 not perceptible to the pilot as a result of the available visual references.

1. With regard to air turbulence, the XB-70 telemetered traces induced little or no acceleration about any airplane axis, conclusively ruling out any abrupt motion of the XB-70 in pitch, roll, or yaw. The F-5 pilot who was flying in a position close to the F-104 and with the F-104 between his airplane and the XB-70 stated there was no turbulence during this period, nor was it reported by other members of the formation. Since turbulence is not normally confined to an area small enough to affect single aircraft within a flight of five without being felt by any other member of the flight, turbulence can be discounted as a contributory factor in the collision.

2. As previously discussed, a malfunction in the XB-70 is ruled out. Although the probability of a malfunction of the F-104 being a cause factor is remote, it cannot be eliminated from consideration.

3. The XB-70 pilot indicated no physiological problem to himself either in testimony or statement. As he was flying the aircraft at impact, physiological problems in the XB-70 crew can be eliminated in cause considerations.

The post-mortem examination of Mr. Walker indicates little or no likelihood of pre-collision coronary problems. Due to the condition of the body, the determination of whether pre-collision dysbarism or hypoxia existed cannot be made with certainty.

No other pilot in the formation noticed any abrupt or unusual movement of the F-104 or Mr. Walker prior to the initial collision. Although this supports to a large extent the possibility that Mr. Walker was not suffering physiological problems, it also is not totally conclusive. Even slight hypoxia, for example, could result in loss of judgment on the part of the pilot and a gradual movement of the F-104 into the XB-70 that might not be sensed by him.

Based on the above analyses, the possibility of physiological problems as the primary cause of the accident is considered remote.

4. Numerous reasons for the F-104 pilot being distracted can be postulated. One possible reason was a B-58 which was on a sonic boom run and approaching from the opposite direction and above the formation just prior to the collision. This was reported to the flight by radar approach control (RAPCON) approximately 16 seconds prior to collision. Mr. White reported he had the B-58 in sight.

Mr. Walker could have diverted his attention from the XB-70 to the B-58. Such diversion is unlikely in the case of an experienced pilot such as Walker. However, had it occurred, head movement would probably have been too slight to have been noticed by the F-5 pilot because of the relative position of the B-58 to the formation. Another possibility was that the Lear Jet, which was hovering at the left of the formation and hence was observable by the pilots on the

right side of the formation, was an object of the pilot's attention. In view of the foregoing, it must be concluded that pilot distraction was a possible, but improbable, causative.

5. The aerodynamic phenomena of a swirling air vortex which emanates from the wing tip and trails behind an aircraft is common to all lifting wing surfaces. The vortex is created by the natural flow at the tip of the wing from the high pressure area below the wing to the low pressure area above the wing. The strength of the vortex varies both with lift and with planform. The combination of high weight and low aspect ratio probably results in the XB-70 generating a vortex of greater strength than any other airplane now flying. Because of a lack of both wind tunnel and flight data, flow gradients about the XB-70 wing tips were computed after the accident using a vortex lattice theory. These theoretical results showed that if the tail of the F-104 approached within about five feet of the XB-70 wing tip the force gradients would be so severe that the pilot would find it difficult to maintain straight and level flight even though the control limits of the F-104 would not have been actually exceeded. Thus, a close pass of the F-104 with respect to the XB-70 wing tip could result in forced contact because of this upsetting action of the XB-70 flow field. There is no evidence of other chase pilots ever having flown this close to the XB-70 wing tip on any previous flight. It can be concluded that airflow effects of the XB-70 on the F-104 did contribute to the collision after the F-104 tail was within a few feet of the XB-70 wing tip.

6. Rather than a more common type V formation where there is nose-to-tail clearance between airplanes, the photographic mission required that the four small airplanes move forward so that the tails of the outboard airplanes were even with the trailing edge of the XB-70. This assigned formation placed the inboard two airplanes where it was difficult to maintain any given position because of the lack of a good visual reference on the long highly swept leading edge of the XB-70 wing. The pilot of the F-4 airplane recognized this difficulty and devised a clever scheme for sighting on the XB-70 inlet to maintain his longitudinal and vertical position. However, the distance from his cockpit to this reference point on the XB-70 was so great (about 100 feet) that it was difficult for him to judge and maintain his lateral wing tip clearance (about 25 feet). He, therefore, used the services of a second crewman aboard the F-4 airplane to maintain this lateral clearance. It is believed that Mr. Walker also recognized this difficulty, but not having a crewman to assist, was forced to use a closer portion of the XB-70 for all references, namely the tip of the wing hinge line. This would account for his remark during the formation rendezvous as follows:

> "As long as he's (XB-70) flying straight ahead we don't have any particular problem on any location longitudinally, but when he gets in a turn, it's rough on that inside guy if he's much ahead of the tip hinge line."

It would also account for the fact that Walker generally flew with his tail about in line with or behind the XB-70 trailing edge, which was somewhat aft of his assigned position. Only by flying this far aft could Walker effectively keep the XB-70 hinge line tip in view.

In this aft position Walker would still have difficulty in judging lateral clearance. The position also placed his airplane under the subtle influence of the sidewash effect from the wing tip flow field previously discussed. This effect, though slight, would be to push the vertical tail outboard and thus cause the F-104 to drift in closer to the XB-70. It is believed that at best this position was a strain on the F-104 pilot and would account for the fact that the F-104 lagged in each turn and recovered in the straight portions of the tract. Such lagging would ease the strain of looking sharply across the left shoulder.

Throughout most of the formation flight, both the F-104 and the F-5 airplanes on the right of the XB-70 flew a "tighter" formation than those on the left. This condition did not cause comment or a request for correction from those photographing the formation or from the F-5 pilot who had planned the mission. The length of the formation flight (originally 30 minutes and then extended in flight to 45) was such that it was essential that the pilots seek positions that minimized the piloting task. This position will vary with the pilot and the type of aircraft. Walker had a great deal of experience both in flying close to other airplanes and in flying the particular F-104 he was in, and also had flown adjacent to the XB-70 on ten previous occasions. It can be reasoned that his inboard deviations from the position given at the briefing was to lessen piloting fatigue. The position generally maintained by the F-104, with a lateral clearance of 10 to 17 feet from the XB-70 wing tip, is not regarded as hazardous by other XB-70 chase pilots. This position could become hazardous if maintained for an unusually long period of time, because of the poor visual references and resulting undetected position changes. Walker may have neglected to give full consideration to this possibility.

It is concluded that the most probable cause of the accident was the gradual and inadvertent reduction in lateral separation between the F-104 and the XB-70 airplanes as a result of the F-104 pilot's flying for a long period of time under conditions of poor visual references and in the vicinity of an undefined flow field.

Both the post-mortem examination and the analysis of the collision point to a conclusion that Mr. Walker was most probably killed either when the left vertical stabilizer of the XB-70 severed the F-104 behind the cockpit or subsequently when the forward area of the F-104 struck the left wing of the XB-70. In either case there would have been no opportunity for ejection as the total time from initial impact to the point of contact with the left vertical tail was approximately 2.8 seconds. During the latter part of this period, extreme forces on the pilot were inevitable.

The XB-70 is equipped with an individual escape capsule for each of the two crew members, which can be closed in two manners for completely encapsulated ejection. First, these can be closed manually after the seat is manually moved aft. (Moving the seat aft would be difficult, if not impossible, while under forces directed forward.) The second manner and the one used by the XB-70 pilot is "ballistic" encapsulation. To encapsulate ballistically, the pilot raises either or both armrests and gas pressure from charges moves the seat back and closes the door. When either armrest is raised, a trigger is exposed. Squeezing this trigger completes the ejection sequence. (Should forward forces be greater than the gas pressure could overcome or beyond the limit of the safety burst mechanism, the gas would be lost without seat retraction and escape would be impossible.) After ejection, certain sequences occur automatically, including parachute deployment and pressurization of a gas-filled "attenuation bag" for reducing the landing shock. Emergency handles within the capsule allow operation of some of these post-ejection sequences during descent in case of an automatic sequence failure.

Mr. White reported that he seemed for a period to be unable to move in the capsule due to loads throwing him forward and to the left, even after he heard the call, "Bail out! Bail out! Bail out!" Finally, he pulled the right handle of his escape capsule and encapsulated ballistically. In the excitement and stress of the moment, he failed to keep his right elbow inside the capsule and it became wedged in the door. Mr. White was finally able to free his arm and complete his ejection. (Mr. White had such difficulty on his own part that he could not contact Major Cross or help him physically in any way.) The parachute opened smoothly and since the doors had not fully closed, Mr. White closed them manually. Mr. White had lost the emergency checklist during ejection and, although he was aware that the gas-filled bag for landing shock attenuation was not inflated, he could not recall where the emergency inflation control was. Mr. White sustained minor injury.

At the time of the flight, Major Cross had completed ground training for checkout (except for some simulator flying time), including complete coverage of the crew escape system. Although Major Cross did not "grow up" with the system as Mr. White had during its development, there is no reason to believe that he failed to escape due to a lack of understanding its operation. This is most apparent in light of the fact that ballistic encapsulation and ejection requires the two steps of lifting armrest(s) and squeezing trigger(s) which is common to a majority of Air Force airplanes and therefore completely familiar to a pilot with Major Cross' experience.

Major Cross was not ejected from the crippled XB-70 and apparently died in the crash. The following possibilities were considered in searching for the reason ejection was not accomplished:

-- Failure to follow proper ejection procedures.
-- Escape system malfunction.
-- Forces beyond system capability due to XB-70 motions.
-- Major Cross burned or injured during Mr. White's ejection.
-- Incapacitation or injury due to the violence of XB-70 motion.
-- Failure to remove safety pin prior to flight.

Considering the ground training received by Major Cross, his experience in aircraft with ejection seats, and the simplicity of procedures for ballistic encapsulation and ejection (identical to numerous other Air Force ejection systems), the probability of not following procedures as the reason for Major Cross failing to escape is remote.

The materiel analysis of Major Cross' capsule does not indicate any failure in the system. However, the condition of the equipment after impact with the ground makes a positive conclusion impossible. A system failure must therefore be retained as a possible, though reasonably unlikely, cause for failure to eject.

In statement and testimony, Mr. White indicates extreme forces were holding him forward and to the left during the period after loss of control of the XB-70 and until his own ejection was completed. The following three quotes from his statement indicate the severity of these forces:

-- "For the next few seconds I seemed unable to move in the capsule; the loads being somewhat oscillatory, throwing us forward and to the left."

-- "During this period of time I tried to talk, thinking that I had a hot mike; but I could only hear myself grunting under the excitement and extreme force that seemed to be exerted on us and throwing us forward and to the left. While I was trying to free my arm, I did observe Major Cross' head bobbing in the right-hand capsule."

-- "I was aware that the main force was throwing me forward at this time ..."

Since it is mandatory for successful completion of ballistic encapsulation and ejection from the XB-70 that the seat be moved to the full aft position, the gas pressure must overcome any forward forces. (Manual encapsulation under these conditions would be extremely difficult, if not impossible.) Capsule analysis indicated that the relief diaphragm which releases the gas overpressure when the seat reaches a full aft position had been ruptured. This could have occurred as the result of gas pressure building to the limit when the system attempted to move the seat back against extreme

forward forces. Had the latter occurred, no further opportunity for ballistic encapsulation would have existed. Even though moments of lowered force levels may have allowed successful ejection by one crew member, an unfortunate timing for actuation of the ballistic cycle during his forward forces by the other may have resulted in the seat failing to retract precluding further possibility of escape. It should be noted here that the XB-70 remained in a flat spin, which would impose forward forces on the crew, from shortly after loss of control until ground impact.

It is concluded that this was a likely cause for Major Cross' failure to escape.

The possibility that Major Cross was incapacitated due to burns or injury suffered when Mr. White ejected exists since the pilot's capsule was ejected upward by the reaction to downward firing rockets. Since when Mr. White last saw Major Cross, he does not think Major Cross was encapsulated, he would have been burned by the rocket blast or struck by an object propelled by this gas. One static ground test tends to indicate that this effect is not too severe.

Autopsy can neither confirm nor refute this so it must be retained as a possible but improbable reason for failure to escape.

As with the foregoing case, autopsy can neither support nor deny the possibility of incapacitation or injury due to violence of XB-70 motion. Major Cross was restrained with both a seat belt and shoulder harness. He was wearing protective headgear so that he should have been able to withstand extreme motions and forces without injury. Under the extreme stress of an aircraft in violent maneuvers, pilots have been successful in reaching the ejection handle. Even so, this cannot be entirely discounted as a cause.

Failure to remove the safety pin is not considered a cause as Mr. White observed that Major Cross had removed the safety pin prior to taking the runway for take-off.