
Explosion in-flight, Trans World Airlines, Inc., Boeing 707-331B, N8734, in The Ionian Sea, September 8, 1974

Micro-summary: This Boeing 707-331B exploded when in cruise over the Ionian Sea.

Event Date: 1974-09-08 at 0940 GMT

Investigative Body: National Transportation Safety Board (NTSB), USA

Investigative Body's Web Site: <http://www.nts.gov/>

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AIRCRAFT ACCIDENT REPORT

TRANS WORLD AIRLINES, INC.

BOEING 707-331B, N8734

IN THE IONIAN SEA

SEPTEMBER 8, 1974



NATIONAL TRANSPORTATION SAFETY BOARD

Washington, D.C. 20594

REPORT NUMBER: NTSB-AAR-75-7

FILE NO. 1-0024

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SEPTEMBER 8, 1974

SYNOPSIS

At 0940 Greenwich mean time, September 8, 1974, Trans World Airlines, Inc., Flight 841, crashed into the Ionian Sea about 50 nmi west of Cephalonia, Greece. There were 79 passengers and 9 crewmembers on board; no one survived. The aircraft was destroyed.

The National Transportation Safety Board determines that the probable cause of this accident was the detonation of an explosive device within the aft cargo compartment of the aircraft which rendered the aircraft uncontrollable.

1. INVESTIGATION

1.1 History of the Flight

Trans World Airlines (TWA) Flight 841, a Boeing 707-331B, N8734, was a regularly scheduled international passenger and cargo flight from Ben Gurion International Airport, Tel Aviv, Israel, to John F. Kennedy International Airport, New York, New York. En route stops were scheduled at Athenai Airport in Athens, Greece, and Leonardo DaVinci Airport in Rome, Italy.

The flight departed Tel Aviv at 0613, ^{1/} 43 minutes late because it was delayed by passenger security procedures. There were 105 passengers, 9 crewmembers, and 5,186 lbs. of cargo aboard. The

^{1/} All times herein are Greenwich mean time, based on the 24 hour clock.

cargo consisted of mail, checked baggage, airfreight, and company material; 3,875 lbs. was placed in the front cargo compartment and 1,311 lbs. was placed in the rear cargo compartment. No restricted articles were loaded.

At 0804, Flight 841 landed at Athens. The crew had not reported any mechanical difficulties while en route, nor was any maintenance required or accomplished at Athens. Fifty-six passengers deplaned and their baggage and some cargo was offloaded.

Thirty passengers boarded the flight at Athens, bringing the number of passengers to 79. Most of the checked baggage for the boarding passengers was placed in the aircraft's forward cargo compartment. Some baggage and cargo were loaded in the rear cargo compartment where containers are not used. The rear compartment is normally used for cargo, mail, and the checked baggage of late arriving passengers.

According to TWA ground service personnel in Athens, one transit cargo container with bags destined for Rome was left unopened in the front cargo compartment. Four containers were offloaded and emptied, and three were then refilled with originating bags. The four containers, including the empty one, were then placed aboard. The originating Athens mail was also loaded into the forward compartment. Baggage handlers stated that there were 30 to 35 passenger bags in the rear cargo compartment en route from Tel Aviv and destined for Rome or New York; however, they could not recall exactly how many pieces of checked baggage were loaded in that compartment at Athens.

Three thousand lbs. of jet A-1 fuel was added at Athens; additional oil was not required. According to the TWA servicing crew, no unidentified or unknown personnel were seen in the loading area while TWA 841 was on the ground at Athens.

The flight filed an instrument flight plan with an estimated 1 hour 48 minutes flight time to Rome and requested a flight level of 35,000 feet (FL 350). Athens control cleared the flight to Rome, via Airway Green 8, at FL 140. After takeoff, the flight was to proceed via Standard Instrument Departure No. 6, then to Korinthos (Corinth), to maintain FL 120 until given further clearance. (See Appendix D.)

At 0912, the flight departed Athens. At 0930, TWA 841 reported level at FL 280 and acknowledged ATC instructions to maintain that altitude and to report upon reaching the next Flight Information Region (FIR). ^{2/} This was the last known radio transmission of the flight. All contacts had been routine flight reports.

At 0939, Pan American Flight 110 (Pan Am 110), eastbound from Rome, Italy, to Beirut, Lebanon, at FL 330 on Airway Green 8, entered the Athens FIR, reported to Athens ATC, and give an estimated arrival time at Araxos of 0951. At 0940, the captain of Flight 110 alerted Athens ATC that he had seen "a four-engine aircraft going down in flames" at their position, which was about 100 nmi west of Araxos. (See Appendix D.)

Communication between Pan Am 110 and Athens ATC was weak, so Olympic Airlines Flight 201, which was flying in the area, relayed messages between Pan Am 110 and ATC. For the next several minutes, both Athens ATC and Olympic Flight 201 attempted to make radio contact with TWA 841 but were unsuccessful. At 0943, after Olympic Flight 201 asked Pan Am 110 what type aircraft was on fire, Pan Am 110 replied that there had been a mistake, since the aircraft was not burning. The Pan American pilot said that he thought the airplane was a B-707 and that it was a TWA aircraft. He also stated that it appeared that an engine had separated from the aircraft. When asked by Olympic Flight 201 if he saw the engine falling or the aircraft falling, the pilot said, "No, the aircraft is falling too. I saw an aircraft pitch up into a steep climb then roll over on its back and start in a dive, then a slow spiral...."

Immediately after Pan Am 110 described the falling aircraft, Athens ATC telephoned Brindisi and other control centers, followed by inquiries to airports in the area of the TWA flight. The Greek Search and Rescue (SAR) Control Center was notified and a Greek SAR C-47 aircraft was dispatched. About 2 1/2 hours after the accident, the crew of this aircraft reported debris and bodies at coordinates 38° 25' north latitude and 19° 22' east longitude.

^{2/} FIR-Airspaces of defined dimensions within which flight information service and alerting service are provided by the control center designated on en route flight charts. Green 8 ALPHA divided Athens FIR and Rome FIR.

Safety Board investigators interviewed the captain, the first officer, the flight engineer, and two passengers of Pan Am 110, all of who observed the TWA aircraft.

According to the Pan American crew, their flight was cruising at 33,000 feet on an easterly heading at Mach .806. ^{3/} The weather was good, and the visibility was unlimited, with scattered clouds at lower levels; the sea surface was visible, and the sun was at 3 o'clock; there was no turbulence. The crew did not recall seeing any condensation trails from other aircraft. The first officer was flying the aircraft on autopilot.

The captain stated that he first saw Flight 841 at the 11 o'clock position, on a reciprocal heading, about 4 to 7 miles away, and about 4,000 feet below him. The aircraft appeared to be in level flight and in normal configuration. The captain had no reason to be concerned about that aircraft and looked away for a few moments. When he saw the aircraft again it was in a steep climb attitude, which kept increasing. He also thought he saw an object behind the left wing of the aircraft, about a wingspan away. When the aircraft passed abeam, it had reached about the same altitude as Pan Am 110. It then rolled to the left into a steep descent, and was rolling to the left as it disappeared from his view. At that time, he noticed that an engine was missing and speculated that the object he had seen when he first saw the aircraft in a steep climb might have been the No. 2 engine. He also was aware of a considerable amount of debris below his own flight level. He did not see any smoke; however, he did see a whitish vapor coming from the left wing and believed it to be fuel. He said that the debris he noted below Flight 841 looked like pieces of paper fluttering down. He indicated that there was one large rectangular piece and that the debris appeared to shine. He estimated that there were about 25 to 30 pieces of debris through which Flight 841 descended and thought that the debris was at Flight 841's original flight level. The captain commented that he thought that no attempt was made to recover. He saw at least one full 360° roll as the aircraft went down. The captain estimated that his observations lasted about 20 seconds.

The first officer said that the captain drew his attention to the TWA aircraft. His observations of the aircraft's pitchup were similar to those of the captain. When the aircraft disappeared from

^{3/} Mach Number - The ratio of true airspeed to the speed of sound.

his view, it was in a vertical roll to the left. He saw no debris, fire, smoke, or structural damage. He saw a brownish vapor coming from the middle of the left wing which extended about as far back as the horizontal stabilizer before dissipating. As the TWA aircraft passed abeam, it was 1 to 1 1/2 miles away from Pan Am 110. At no time was he concerned about the proximity of the TWA aircraft with regard to their own safety. He did not leave his seat, disconnect the autopilot, or make any flightpath corrections.

When the flight engineer, who was standing with his face close to the left cockpit window, looked down on the aircraft he noticed debris, consisting of fluttering shiny objects that reflected the sunlight. He saw no colors in it. The debris was evenly dispersed, not clustered, and the individual pieces appeared to be of about the same size. He had the impression that the debris had come from the aircraft before, or at the point where, it stopped gaining altitude.

The two passengers aboard Pan Am 110 who observed Flight 841 were seated side by side on the left side of the first-class section. They saw the TWA aircraft several thousand feet below them and spinning at a high rate of speed.

None of the witnesses saw the aircraft strike the water. There were no reports of missile firings or military aircraft activities in the area.

1.2 Injuries to Persons

<u>Injuries</u>	<u>Crew</u>	<u>Passengers</u>	<u>Other</u>
Fatal	9	79	0
Nonfatal	0	0	0
None	0	0	

The bodies of 24 passengers were recovered from the sea.

1.3 Damage to Aircraft

The aircraft was destroyed.

1.4 Other Damage

None.

1.5 Crew Information

The captain, first officer, and flight engineer were qualified and certificated according to FAA regulations. (See Appendix B.)

1.6 Aircraft Information

The aircraft was certificated and maintained according to FAA regulations. The aircraft's gross weight at takeoff was about 205,070 lbs., which was below the maximum allowable takeoff weight. The center of gravity was within allowable limits.

The aircraft's fuel load at the time of takeoff was 39,900 lbs.

The aircraft had a recent history of yaw damper malfunctions; however, no further discrepancies were noted after the yaw damper was changed on September 5, 1974. There were no uncorrected safety-of-flight items noted in the aircraft log when the aircraft departed Tel Aviv, and no aircraft malfunctions or failures were reported before or after the aircraft departed Athens. (See Appendix C.)

1.7 Meteorological Information

The National Meteorological Service at Greek Air Force Headquarters, furnished information pertaining to weather from Athens to the vicinity of the crash. The following data pertained to the accident area from 0800 to 1200 on September 8, 1974:

Weather, Araxos to accident site: Fine to fair.
Clouds: Scattered cumulus and strato cumulus between 3,000 and 6,000 feet. Visibility: 15 to 20 kn. Surface winds: NW 10 to 15 kn. Pressure at site: 1010.5 MB. Light turbulence between 25,000 and 30,000 feet.

Upper Winds and Temperatures

<u>Altitude in Feet</u>	<u>Athens</u>	<u>Carafa (Italy)</u>
5,000	320° /10 kn., temp. +8° C	320° /20 kn., temp. +13° C
10,000	320° /10 kn., temp. +3° C	320° /25 kn., temp. +4° C
18,000	280° /35 kn., temp. -13° C	340° /40 kn., temp. -10° C
30,000	290° /50 kn., temp. -41° C	330° /55 kn., temp. -39° C

1.8 Aids to Navigation

All navigational facilities between Athens and the accident area were serviceable and operating.

1.9 Communications

There were no difficulties reported with the communications between Flight 841 and ATC. All transmissions from Flight 841 were normal.

1.10 Aerodrome and Ground Facilities

Not applicable.

1.11 Flight Recorders

N8734 was equipped with a Lockheed Aircraft Service Co., model 109-C flight data recorder (FDR) which was installed in the rear of the aircraft behind the cabin pressure bulkhead, near station 1440. In accordance with 14 CFR 121.343, an underwater locator beacon (Dukane Model N15F210B) was mounted on the recorder. According to its manufacturer, this locator (Pinger) had an operating depth of 20,000 feet, a detection range of 2,000 to 4,000 yards, and was capable of transmitting acoustic signals for 30 days after activation by water.

From September 8, 1974, to September 20, 1974, air, surface, and subsurface units from the U.S. Sixth Fleet attempted to locate the recorder by conducting visual, radar, and acoustic searches; however, their efforts were unsuccessful. The Safety Board then contracted the Supervisor of Salvage, Department of the Navy, to search the area in which the Sixth Fleet believed the wreckage to be located. On October 4, 1974, salvage experts, using a dipping hydrophone system, detected the pinger signal in an area with a depth of 10,380 feet. Another marking device was released to mark the area. The precise location of the pinger was recorded as 38° 18.1' north latitude and 19° 15' east longitude. The average accuracy of the marked location was within 1 nmi.

Flight 841 also was equipped with a Fairchild Industrial Products model A-100 cockpit voice recorder (CVR) which was installed in the rear of the aircraft on the forward side of the cabin's pressure bulkhead.

Neither the FDR nor the CVR was recovered.

1.12 Aircraft Wreckage

1.12.1 Location

The crew of the Greek Air Force SAR C-47 aircraft who initially located the flotsam stated that the area of scattered debris resembled a runway in the sea. The area was even; it had straight boundaries about 150 feet wide, 1 mile long and oriented north and south. The crew reported 15-to 20-foot swells.

Aircraft parts, debris, and human bodies were retrieved from the sea by a surface fleet of 10 ships, including the aircraft carrier USS Independence. Helicopters and fixed wing aircraft directed surface craft to retrieval sites. The search was terminated at 1100 on September 10, 1974. However, all ships that transited the area were requested to maintain a lookout for bodies and debris.

According to U.S. Navy personnel who surveyed the impact area on September 9, 1974, about 16 hours after the crash, there were two separate areas; one where the bodies and various portions of the aircraft structures, furnishings, baggage, and cargo were recovered and another, 15 to 20 miles southeast, consisting of what appeared to be papers in a light oil slick. With regard to the latter debris area, Navy personnel stated: "Based upon the 0.4-kn. south-southeast surface current in the area, this debris was probably not associated with the airliner's water impact."

1.12.2 General Examination

About 2,500 lbs. of floating debris was recovered. Except for a few items from the wing area and one small fillet section in the stabilizer area, all of the recovered wreckage consisted of material from the fuselage. Most of the fuselage materials consisted of non-structural interior items. The only structural fuselage pieces recovered were three overwing emergency exits, the front cargo door, and two crumpled pieces of the aft cargo door. In addition, ten pieces of fuselage frames were recovered. One of these was identified as an upper fuselage frame at station 1260.

Other major units recovered were five oxygen bottles (one from the forward and four from the aft cargo compartment), six of the seven liferafts, and one badly damaged triple coach seat. The interior fuselage pieces consisted of floor panel sections, hatrack

sections, seat cushions, many sections of plastic floorcover material, aft lavatory partitions and doors, and several pieces of cabin sidewall and ceiling lining. The original location of the recovered items ranged from the cockpit door to the tailcone. Nineteen pieces of passenger luggage and about a cubic yard of passenger clothing, pillows, and blankets were recovered.

About 30 percent of the cabin flooring aft of the cockpit was recovered and identified. In addition, there were eight unidentified pieces of floor panels with an area of about 36 square feet. Only one center panel from the area above the forward baggage compartment between body stations 360 and 600G was recovered. About 60 percent of the floor panels over the center wing section and main landing gear wheel wells were identified. In the area between stations 960 and 1300, over the aft baggage compartment, approximately 40 percent of the floor panels were identified. In the lavatory area aft of station 1300, about 60 percent of the flooring was identified.

The wreckage and debris were initially examined in Athens by the investigation team members, which included a principal investigator of the United Kingdom's Accidents Investigation Branch. The latter participated at the Safety Board's request to insure that the more recent experiences of the British Government in the investigation of sabotage-related aircraft accidents would be used in this case. 4/

All the parts that could be identified were placed in a mockup. Passenger baggage and clothing were segregated from other recovered items and examined separately. All recovered aircraft structure was closely examined to identify possible explosive damage and shrapnel damage from free engine parts. No evidence of penetration by free engine parts was found. During the examination, items with markings that could not be readily attributed to impact were selected for

4/ The National Transportation Safety Board expresses its appreciation to the United Kingdom's Accident Investigation Branch, Department of Trade and to the Royal Armament Research and Development Establishment, Department of Defense, for their assistance in the investigation of this accident. Such assistance is an exemplary demonstration of the international cooperation required in the field of aircraft accident investigation and prevention.

independent laboratory examination by the Federal Bureau of Investigation (FBI) in Washington, D. C., and the Royal Armament Research and Development Establishment (RARDE) in England. The selection of these items was based on their possible similarity to some of the items found in the floating debris recovered from a de Havilland Comet Series 4B, which disappeared over the Mediterranean on October 12, 1967, en route from Athens to Nicosia, Cyprus. ^{5/} That accident was caused by the detonation of an explosive device in the cabin. Tests showed that the trajectories and physical characteristics of minute particles found in some of the soft materials in the debris could only be associated with the extreme velocities and heat produced by an explosive device.

1. 12. 3 Items Selected For Laboratory Examination

Passenger Baggage ... The lid of a suitcase was punctured and torn in numerous locations, and there were areas of black deposits on the plastic material. The covering was carefully cut away from the frame to expose an intermediate layer of foam and a plastic inner lining. The inner lining had not been penetrated, and the material which had perforated the plastic outer material remained trapped in the foam. A number of particles, both metal and nonmetal, were extracted from the foam and examined in the laboratory. The lid recovered from a similar suitcase, possibly from a matched pair, contained some blackened areas and tears in the fabric. (See Figures 1 and 2, Appendix F.)

Seat Cushions ... The fabric on one of the coach section cushions contained several tears. The cushion was X-rayed and debris showed on the X-ray. The cover was removed to expose the plastic foam, and a number of particles were probed from the foam and examined in the laboratory.

Floor Panel Section ... A portion of one of the floor panel sections contained penetration markings. The panel section was recovered in four parts and was pieced together. The panel had been penetrated from below and through the lower skin. A piece of metal was embedded in the plastic core of the metal sandwich construction and examined in the laboratory.

^{5/} Board of Trade, Civil Aircraft Accident Report, C. A. P. 305, London, Her Majesty's Stationary Office (1968).

Aft Baggage Door Parts . . . Two crushed pieces of the aft baggage compartment door were sent to the laboratory for examination to determine if any foreign particles were embedded in the foam lining of the door.

1.12.4 Recovery

By the time the FDR pinger was located, two British explosives experts had completed their examination of selected debris in the Safety Board's laboratory and had concluded that the physical evidence indicated the detonation of an explosive device.

This development, as well as the following factors, was considered in determining the practicability of recovering the B-707 wreckage:

1. The depth of the sea, the apparent degree of breakup of the aircraft at impact, and the sea currents at different depths.
2. The possibility that the pinger separated from the FDR at impact, or that the FDR and the pinger were separated from the aircraft.
3. The debris, or parts, that separated from the aircraft in flight, would not be in the same location as the main wreckage.
4. Since the engines probably separated at the initial impact with the water, they might not be close to the main wreckage. If the observation of the captain of Pan Am 110 was correct, the No. 2 engine would not be found in the main wreckage area.

In view of the above, the Safety Board decided that the uncertain contribution of any part of the recovered wreckage would not justify the high cost to recover it.

1.13 Medical and Pathological Information

Twenty-four passenger bodies were taken to the Athenai Air Base in Athens. No bodies of crewmembers were recovered.

A medical examination to establish the cause of death was conducted by the Chief Medical Jurist of the Ministry of Justice in Athens. Additional post-mortem examinations were performed by

pathologists of the U.S. Armed Forces Institute of Pathology (AFIP) on 18 of the 24 bodies; 14 bodies were X-rayed. Toxicological and histological tests were also made.

The various examinations revealed that all 24 passengers died from impact with surrounding aircraft structure or furnishings at impact; all 24 passengers received similar injuries--fractures of the extremities, ribs, and head, and severe internal injuries; seatbelt marks were observed on all but one of the bodies; there were no signs of drowning; there were no burns; and none of the bodies showed the effects of the detonation of an explosive device.

Based on the probable seating locations, the bodies of 41 percent of the passengers in the forward half of the cabin were recovered and 16 percent of those in the rear half were recovered. The assigned locations of passengers whose bodies were identified ranged from the 3rd row in the first-class section to the next to the last row in the coach section.

1.14 Fire

No evidence of fire was found.

1.15 Survival Aspects

This was not a survivable accident. The recovered lifevests had not been used; the liferafts were not inflated. Two evacuation slides were loose, but not inflated. No seatbelt failures were observed.

Search and rescue activities were promptly initiated. Despite conflicting information, the crash location was spotted within 2 1/2 hours after the accident. The recovery of bodies and debris in the main impact area was coordinated and handled efficiently by units of the Greek, Italian, and United States Navies, and by Greek and Italian Merchant vessels.

1.16 Test and Research

1.16.1 Performance

A comparative study was made of Flight 841's pitchup as described by the witnesses aboard Pan Am 110 and the performance capability and flight control characteristics of the Boeing 707. The

study was based on an aircraft gross weight of 200,000 lbs., a c. g. at 27.5 percent MAC, and an initial cruise at Mach .82 at 28,000 feet pressure altitude. The routing of the control cable systems through the fuselage was also examined.

The position of the elevators is controlled by the control columns which are connected by a cable and linkage system to a trailing edge control tab on each elevator. The control cable systems from the captain's and first officer's control columns are independent to provide redundancy. Both systems are routed below the cabin floor throughout the length of the fuselage to a common attachment point on the elevator control quadrant.

To reconstruct the described maneuver, two conditions with constant incremental noseup pitching moments were examined. One corresponded to 5.5° and the other to 10.5° of elevator trailing edge-up deflection. The study showed that the 5.5° elevator deflection would theoretically have caused the aircraft to climb 5,000 feet in approximately 19 seconds. At the peak altitude, the pitch attitude would have been about 55° and the airspeed about Mach .55. With a 10.5° elevator deflection, the aircraft would have entered a regime of probable stall buffet after about 2 seconds and would have reached aerodynamic stall after about 8 seconds. The altitude gain would have been about 3,000 feet, and the aircraft's pitch attitude would have been about 52° .

Elevator deflections of between 5.5° and 10.5° can be commanded through the control column and would require the pilot to exert between 100 and 130 lbs. of full force.

It was determined that these elevator movements could also be produced if a control cable were stretched or distorted by a force applied to one or more of the cables at any point between the control column attachment at the forward end of the fuselage and the elevator control quadrant attachment at the rear. In this abnormal condition, 12 inches of control cable stretch could cause full tab travel, or about 13° of up-elevator motion without breaking the cable. If either of the redundant cable systems remains intact, the crew might be able to reduce the elevator deflection by exerting forward pressure on the control column.

The elevator can also be moved by electrical signals generated by a malfunctioning autopilot. The torque which can be exerted by the autopilot servo motor is limited by design to 80 in -lbs which is equivalent to 20 lbs. of pressure at the control column. If an unwanted pitch excursion occurs while in automatic flight, the pilot can disengage the autopilot by a switch on the control column. Regardless of disengagement, the control column pressures required to overpower the elevator servo motor are well below a pilot's physical limitations.

Means of producing aircraft noseup pitching moments by a runaway stabilizer trim and symmetric extension of only the outboard speed brakes were also considered.

A continuously running main electric trim motor will cause the stabilizer to move at $0.4^{\circ}/\text{sec}$. This rate of stabilizer movement would have caused the aircraft to pitch up into a stall after gaining less than 2,000 feet. A stabilizer trim runaway can be stopped by any of several crew actions: (1) By selecting opposite direction stabilizer trim with the trim switch on the control column; (2) by removing electrical power from the trim motor by a stabilizer trim cutout switch; (3) by grasping and holding one of the mechanical stabilizer trim wheels which are mounted on each side of the center control stand. The study indicated that the maneuver which would correspond to continuous stabilizer movement would not produce aircraft loads which would cause structural failure.

Symmetric extension of only the outboard speed brakes will also produce an aircraft noseup pitching moment, the increment of which would be equivalent to about 5.3° of elevator deflection. Such a condition could occur if full-up speed brakes were commanded by the crew and the inboard spoiler hydraulic system was inoperative. In that case, 67 lbs. of push force at the control column would be required to counteract the noseup pitching moment produced by outboard speed brake extension.

The study included an analysis of the loads required to fail an inboard engine mounting. The analysis indicated that a combined pitch and side slip maneuver could cause vertical and side inertia loads and added air loads that approach the design load capability of an inboard nacelle structural attachment. Such a maneuver could be produced if full trailing edge-up elevator and full rudder travel were applied almost simultaneously.

The B-707 rudder is positioned by a combination of hydraulic and mechanical systems. The rudder pedal movement is transmitted from a forward quadrant to an aft control quadrant located in the vertical fin by a cable system which is routed beneath the cabin floor near the elevator control cables. Mechanical linkage transmits the motion of the aft control quadrant to a hydraulic valve on the rudder power control unit which hydraulically moves the rudder in response to linkage motion. As with the elevator system, any motion of the rudder control cable system, whether it results from deliberate pedal movement or from an abnormal mechanical force applied to stretch or distort the control cable, will displace the rudder.

The rudder control system will also respond to electrical yaw damper signals. These signals are applied directly to an electro-hydraulic transfer valve which is incorporated in the rudder power control unit. The yaw damper authority is limited to $+4^{\circ}$ of rudder travel. It was concluded that a yaw damper failure alone could not cause the aircraft to enter a maneuver such as that described by the witnesses.

The study showed that the witnesses' observations of vapor could not be related with fuel release from the wing tip vent outlets of the aircraft at climb attitudes of 60° or more.

1.16.2 Results of Laboratory Examinations

British Reports

The two RARDE explosives experts (a chemist and a metallurgist) and the FBI reported to the Safety Board the findings of the laboratory examinations of selected debris. (See Appendix G for a partial listing of the laboratory exhibits; the figure references which follow correspond with the photographs in Appendix F.)

A summary of pertinent portions of the RARDE reports follows:

Exhibits A, E, G, and H are aluminum alloy fragments that were examined optically and in the electron scanning microscope. They showed rolled back edges, engraving, and spalling (Figure 3). These are all features typical of explosively formed fragments. The deformation of fragments E and H was extensive and "wrap around" features comparable

with those found on the fragments extracted from the Comet seat cushions were found (Figure 4). There were few signs of conventional microvoid rupture in these fragments, and an explosion is the only phenomenon known which can produce the observed surface features.

Exhibit ARC/1 is a zinc alloy fragment. It is severely distorted but salt water corrosion has obliterated any surface rupture features (Figure 5). Exhibit I, an iron fragment, is also corroded but the fragment deformation and polyurethane bonded to it are again similar to that found in the Comet inquiry (Figure 6), indicating that the particle had been hot and was derived from an explosive source. Both these fragments are foreign to the aircraft structure.

Exhibit I was polished and etched. The micro-structure is that of a low carbon iron with a grain size between 15 and 20 microns (Figure 7). This is considerably finer than that found in commercially available material and is the product of a heavily cold worked structure, recrystallizing rapidly at a high temperature but with grain growth inhibited. This structure is expected in an iron fragment which has undergone extensive deformation and heating at the source of an explosion, followed by drastic cooling on impact with suitcase. Similar structures have been produced in tests at RARDE when high explosives were detonated against iron plates. The similarities between the structure of fragment I with the structures obtained in controlled explosive trials can be seen in Figure 8. Evidence of explosive deformation is apparent in the micro-structure of the strained steel case hinge (Figure 9). The strain in the hinge was small, but deformation twins were found in a portion of the grains. These twins are effective signature of an explosive shock passing through the hinge. Twinned structures were found in the Comet fragments, though the density in these was considerably higher because the fragments suffered greater strain.

Exhibit DGH/12 is a fibrous plastics perforation area, cut from the ribbed liner in the lid of the red suitcase. It shows penetration of blackened fibrous matter from the outside of the case which took with it some of the pink cotton substrate of the outer red plastic cover. From this fibrous matter the following items were isolated:

1. A fragment of heavily distorted copper, as indicated by the blue color imparted by an ammonium hydroxide/peroxide dissolution and confirmed by the brown precipitate given with rubearic acid.
2. A grey, metallic, distorted, rodlike particle with brassy smears on some areas. Tests showed that this was iron-based metal.
3. A minute fragment of copper embedded in plastic material. Examination of the plastic material and its perforated edges led to the conclusion that this material was penetrated by a heated object, or that the force of impact generated localized heat. To support this contention, a control sample of plastic was removed and penetrated by a steel probe at ambient temperature. The area immediately around the penetration was seen to be quite opaque, as indeed are the stitch holes around the edges of the case lid where the red fabric is attached. This phenomenon is known as cold worked crystallinity, changing the transparent amorphous polymer to localized opaque crystalline polymer. In contrast, the penetrations observed in the case lid all have clear transparent edges showing no evidence of opacity. This difference in behavior to distortion could only result from the application of sufficient heat to cause reversion of induced crystallinity, or indeed, to prevent its original formation.

Both RARDE experts arrived independently at the conclusion that an explosive device was detonated aboard the aircraft.

FBI Report

The FBI conducted two laboratory examinations of recovered debris. Their initial microscopic examination, which was directed toward the identification of items associated with bomb components or the initiating mechanism for an explosive device, was negative. Subsequently, they conducted a detailed metallurgical examination of various debris items. Their final report to the Safety Board stated, in part: "Based on deformation and fracture features exhibited by metal fragments in specimens Q1, Q5A, Q6A, and Q24, and on the

microstructure of the piece of metal hinge designated as specimen Q19A, it was concluded that the objects from which these metal parts originated were damaged as a result of exposure to the detonation of a high order explosive. "

Specimens Q5A and Q5E are mentioned as specimens A and E in the British reports. Specimen Q6A, a metal fragment, was found by the FBI in the foam liner of the aft cargo compartment door.

The FBI findings were consistent with, and corroborated, the findings of the RARDE experts.

1.17 Other Information

1.17.1 Security

Investigation disclosed that Flight 841's passengers and luggage had been processed in Tel Aviv and Athens according to ICAO Assembly Resolution A 17/10^{6/} and Annex 9 specifications and 14 CFR 121.538.^{7/} In Tel Aviv, these procedures included the examination of all carry-on and checked baggage, while in Athens, only the carry-on baggage was examined. TWA procedures in Athens insured that no unaccompanied checked baggage would be loaded on the aircraft. After the accident, the security examinations at Athens were increased to include examination of checked baggage.

1.17.2 TWA Rome, Italy, Incident

On August 26, 1974, there was an incident involving TWA Flight 841 from Athens to Rome.

^{6/} ICAO Resolution A 17/10: "Precautions should be taken to ensure that normally only baggage of passengers actually travelling on the flight (and previously cleared unaccompanied baggage) is loaded on the aircraft. "

^{7/} 14 CFR 121.538 requires certificate holders to prepare in writing and submit for approval to the Administrator a security program that is designed to (a) prevent or deter unauthorized access to aircraft, (b) assure that baggage is checked by a responsible agent or representative of the certificate holder, and (c) prevent cargo and checked baggage from being loaded aboard its aircraft unless handled in accordance with the certificate holder's security procedures. TWA had complied with this requirement.

When the ramp agent in Rome opened the rear cargo compartment door, he noticed smoke. Maintenance personnel and airport authorities responded immediately with firefighting equipment, and the smoke source was suppressed. All bags were removed and it was determined that the bag that caused the fire was the property of a passenger who readily came forward and identified it. Italian authorities examined the bag and concluded that the fire probably began when the batteries of a tape recorder caused leaked lighter fluid to ignite. Both items were in the suitcase. The aircraft was not damaged, and the passenger was allowed to continue to his destination.

On September 18, 1974, the suitcase and its contents were delivered to the FBI laboratory in Washington, D. C. The FBI found small particles of unconsumed C-4, a military-type high explosive, and other evidence of an "improvised explosive device or bomb which malfunctioned, resulting in a fire, rather than the intended detonation."

When it became evident that this suitcase had contained an explosive device, attempts were made to determine the whereabouts of the passenger who had identified the suitcase. These attempts have been unsuccessful to date.

2. ANALYSIS AND CONCLUSIONS

2.1 Analysis

Although most of the aircraft wreckage, including the flight data and cockpit voice recorders, was not recovered, sufficient evidence was obtained to analyze the probable sequence of events that led to the accident.

The witnesses' observations indicate that control of the aircraft was lost completely. The debris which witnesses saw during the pitchup and subsequent descent of the aircraft is proof that some of the aircraft's structure, skin, interior furnishings, or cargo compartment contents separated during flight. Another indication of the violence of the occurrence is the fact that the Pan American captain reported an engine separation and that he and other witnesses saw vapor from the left side of the aircraft. The absence of radio communication from the flightcrew further indicates that a sudden catastrophe occurred aboard the aircraft. This evidence prompted the examination of a number of factors that could cause a sudden and complete loss of aircraft control.

First, the Safety Board considered the possibility that the flightcrew initiated an evasive maneuver after sighting Pan Am 110 on an opposite flightpath. According to the performance study, the steep pitch attitude and climb described by witnesses could have been produced by pilot action. However, such action would require about 100 lbs. of pilot effort. The pitch maneuver alone would not produce loads that would exceed structural limits. Therefore, after considering the altitude separation and relative positions of the two aircraft, the excellent visibility reported by the crew of Pan Am 110, the amount of pilot effort required, and the lack of evidence to suggest that a recovery was attempted, the Safety Board dismissed the possibility that the flightcrew initiated an evasive maneuver.

Secondly, the Safety Board considered the possibility of a turbulence encounter. The weather in the vicinity of the accident area was reported to be fine to fair with light turbulence between 25,000 to 30,000 feet. The crew of Pan Am 110 encountered no turbulence at 33,000 feet. Therefore, the Safety Board concluded that in-flight turbulence was not a factor in this accident.

Thirdly, the Safety Board considered the possibility that either the aircraft's structure or one of its systems failed. Although insufficient physical evidence was recovered to determine precisely the integrity of the aircraft's structure or the functional status of its flight control systems, the five witnesses agreed that no major aerodynamic surfaces of the aircraft separated in flight. Since the captain of Pan Am 110 saw that an engine was missing from the TWA aircraft, the Safety Board examined the possibility that the engine malfunctioned, separated in flight, and caused a subsequent loss of control of the aircraft. There have been eight incidents in which an engine has separated from a B-707 aircraft. Six of these separations resulted from excessive loads on the engine attachment structure; the loads were imposed by uncoordinated training maneuvers or by turbulence. The remaining two separations resulted from engine failure and subsequent fire. In no case did the separations produce uncontrollable pitchups. Therefore, the Safety Board does not believe that the engine separation caused a pitchup maneuver.

With regard to the possibility that a system malfunction could have caused the pitchup and uncontrollable descent, the performance study included a failure mode analysis of specific malfunctions of the flight control system which would have caused the observed maneuver.

Autopilot "hardover," stabilizer trim "runaway," speed brake extension, and yaw damper failures were analyzed. It was concluded that no known single failure could produce a pitchup of sufficient violence to cause structural damage that would account for the debris and vapor described by witnesses. The study did show, however, that the observed events were compatible with nearly simultaneously applied elevator and rudder displacements.

The control cable systems which interconnect the pilot pitch and yaw controls with the respective control surface mechanisms are routed through the fuselage of the aircraft beneath the cabin flooring. Any mechanical interference with these control cables which would result in distortion, stretching, or unequal deflection would, in turn, cause displacement of the respective control surfaces. The resultant combined pitch and sideslip maneuvers could produce inertia and air loads which could fail the engine mounting structure.

Based on the abrupt initial change in Flight 841's flightpath, the vapor from the left wing, and the probability that the No. 2 engine mounting structure was overloaded, the Safety Board believes that there were sudden and violent inputs into the rudder and elevator controls in excess of the crew's and the control system's capabilities. Simultaneous mechanical pitch and yaw inputs of that magnitude can be accounted for by the detonation of an explosive device. Therefore, based on the available evidence the Safety Board concludes that the detonation of such a device affected the elevator and rudder control cables which caused the pitchup and uncontrollable descent.

The recovery of an explosively formed metal fragment from the foam liner of the aft cargo compartment door indicates that the detonation took place in that compartment. Since there is no pathological evidence to indicate that persons aboard the aircraft had been exposed to a detonating device, the Safety Board believes that the explosion took place below the cabin floor, which shielded the cabin occupants. The presence of an explosively formed fragment in one of the seat cushions proves that the floor had been penetrated or damaged. Finally, the incident on August 26, 1974, appears to have been an attempt at the same form of sabotage.

In conclusion, the Safety Board believes that the detonation of an explosive device in the aft cargo compartment buckled and damaged the cabin floor in such a manner that one or more of the

elevator and rudder system control cables was stretched and, perhaps, broken. The resultant displacement of the control surfaces caused a violent pitchup and yaw and made the aircraft uncontrollable. The No. 2 engine most likely separated at the nacelle structural attachment. The fuel released as a result of the engine separation was observed by the witnesses as a trail of vapor. Some of the floating debris may have been associated with the engine separation; however, the reference to "pieces of paper fluttering down" suggests strongly that some of the contents of the aft cargo compartment were expelled during the explosive decompression that undoubtedly occurred when the pressure hull of the aircraft was ruptured locally by the explosion. A damaged pressure hull and the limited penetration of the cabin floor suggest that the center of the detonation was closer to the cargo compartment floor than the cabin floor.

2.2 Conclusions

(a) Findings

1. All crewmembers were certificated and qualified for the flight.
2. The aircraft was certificated and maintained according to approved procedures.
3. The boarding passengers and luggage in Athens were processed in accordance with approved security procedures.
4. An explosive device was detonated within the aft cargo compartment while the aircraft was cruising at 28,000 feet.
5. The explosion disabled the control system of the aircraft.

(b) Probable Cause

The National Transportation Safety Board determines that the probable cause of this accident was the detonation of an explosive device within the aft cargo compartment of the aircraft which rendered the aircraft uncontrollable.

3. RECOMMENDATIONS

As the result of this accident, the Safety Board on January 10, 1975, submitted Safety Recommendations A-75-2 through 5 to the Administrator, Federal Aviation Administration. (See Appendix H.)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ JOHN H. REED
Chairman

/s/ FRANCIS H. McADAMS
Member

/s/ LOUIS M. THAYER
Member

/s/ ISABEL A. BURGESS
Member

/s/ WILLIAM R. HALEY
Member

March 26, 1975

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in Original Document**

APPENDIX A

INVESTIGATION AND HEARING

1. Investigation

The National Transportation Safety Board was notified of the accident at 0930 e. d. t., on September 8, 1974, by the FAA Communications Center in Washington, D. C. An investigation team was dispatched immediately. Since the accident involved a United States aircraft in international waters, the United States was responsible for the investigation. A working group was established for operations, weather, air traffic control, witnesses, and security. Other working groups established were structures, systems, and powerplants; human factors; maintenance records, and flightcrew records.

Parties to the investigation were the Government of Greece, Federal Aviation Administration, the Boeing Company, Trans World Airlines, Inc., Pratt & Whitney Division of the United Aircraft Corporation, and the Air Lines Pilots Association.

2. Hearing

A public hearing was not held.

APPENDIX B

CREW INFORMATION

Captain Donald H. Holliday

Captain Donald H. Holliday, 55, was employed by Trans World Airlines on October 20, 1945. He held Airline Transport Pilot Certificate No. 140157 and was type rated in Boeing 707 aircraft. His initial equipment check was on April 9, 1963. He had completed his last semiannual proficiency check on February 27, 1974, and his last annual line check on June 3, 1974. He completed recurrent emergency training on February 26, 1974. Captain Holliday had accrued about 21,960 flight-hours of which 8,280 hours were in jet aircraft and 7,280 hours were in the Boeing 707.

Captain Holliday held a first-class medical certificate dated April 26, 1974. The certificate contained the following limitation: "Holder shall possess correcting glasses for near vision while exercising the privileges of his airman certificate."

First Officer Jon L. Cheshire

First Officer Jon L. Cheshire, 36, was employed by Trans World Airlines on January 4, 1965. He held Airline Transport Pilot Certificate No. 1485878 and was type rated in Boeing 707 aircraft. His initial equipment check was on September 17, 1965. He had completed his last semiannual proficiency check on January 17, 1974. He completed recurrent emergency training on January 16, 1974. First Officer Cheshire had about 9,139 flight-hours, all of which were in jets and 5,311 of which were in the Boeing 707.

First Officer Cheshire held a first-class medical certificate dated March 6, 1974, with no limitations or waivers.

Flight Engineer Ralph H. Bosh

Flight Engineer Ralph H. Bosh, 37, was employed by Trans World Airlines on May 27, 1966. He held Airline Transport Pilot Certificate No. 1660915 and Flight Engineer Certificate No. 1703903. He was qualified in Boeing 707 aircraft. His initial equipment check was on

February 29, 1966. He had completed his last semiannual proficiency check on June 28, 1974; he completed recurrent emergency training on June 26, 1974.

Flight Engineer Bosh had about 6,634 flight-hours, all of which were in jets and 3,548 of which were in the Boeing 707.

Flight Engineer Bosh held a first-class medical certificate dated July 25, 1974, with no limitations or waivers.

Flight Attendants

Flight Attendants Gianpaolo Molteni, Silvia T. Buhler, Alja Bunk, Isabella Lucci-Masera, Angela Magnoni, and Lajwanti Kripalani were all currently qualified in Boeing 707 aircraft.

APPENDIX C

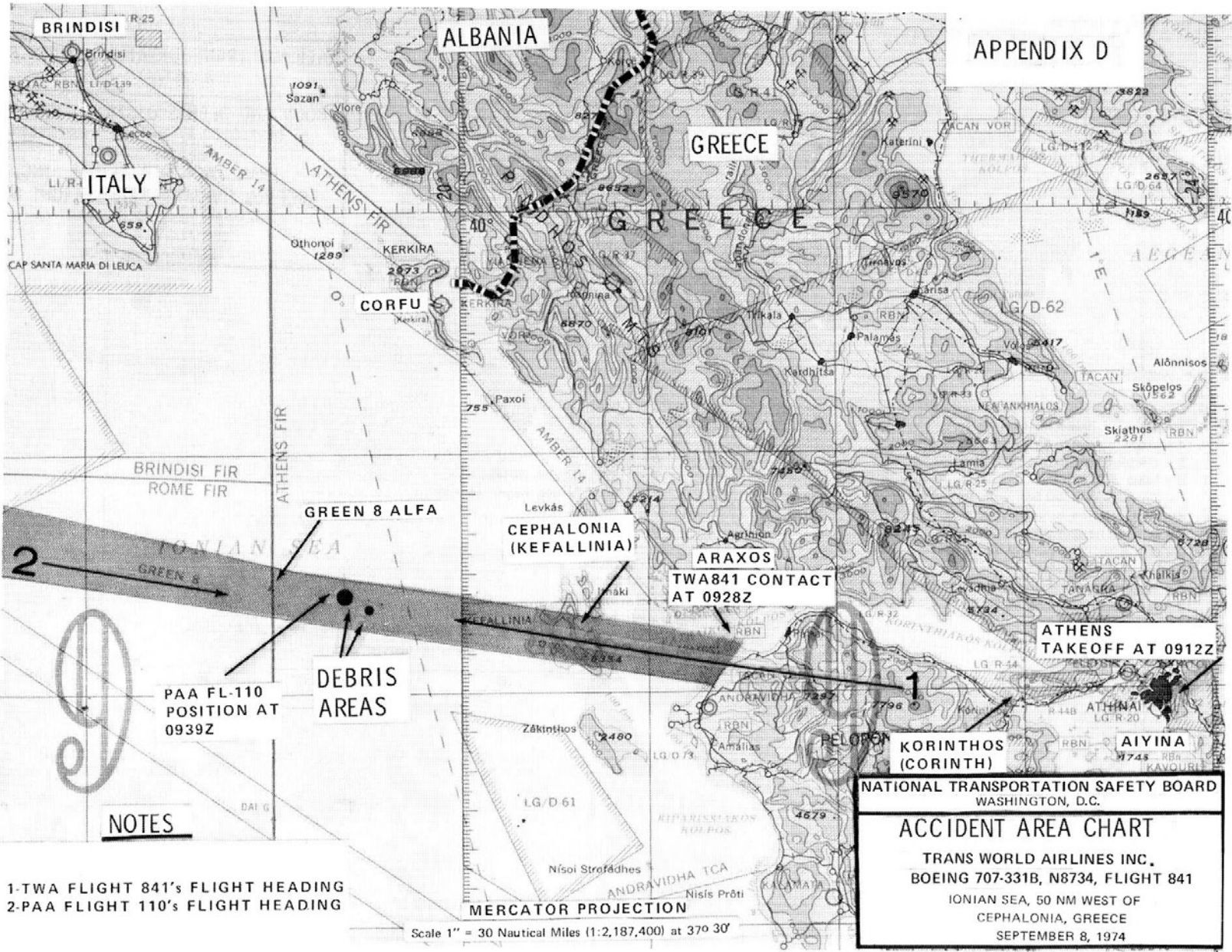
AIRCRAFT INFORMATION

Boeing 707-331B, Serial No. 20063, N8734, had a date of manufacture of March 1969 and an airworthiness certificate dated March 27, 1969. The aircraft was owned by Irving Trust Corporation, New York, New York, and was leased to Trans World Airlines.

The aircraft had accumulated 21,733:24 hours total time; it had been operated 2,324:49 hours since its last base overhaul and 579:40 hours since its last "C" check. Periodic service No. 21 had been accomplished at Tel Aviv, Israel, on September 7, 1974.

The aircraft was equipped with four Pratt & Whitney JT3D-3B engines. Engine serial numbers, times and cycles were as follows:

<u>Position</u>	<u>Serial Number</u>	<u>Total Time</u>	<u>Cycles</u>
1	P645168BAB	28,153:28	10,528
2	P668506BAB	18,679:38	5,772
3	P643451BAB	35,773:31	6,049
4	P643540BAB	34,123:20	10,366



NOTES

- 1-TWA FLIGHT 841's FLIGHT HEADING
- 2-PAA FLIGHT 110's FLIGHT HEADING

Scale 1" = 30 Nautical Miles (1:2,187,400) at 37° 30'

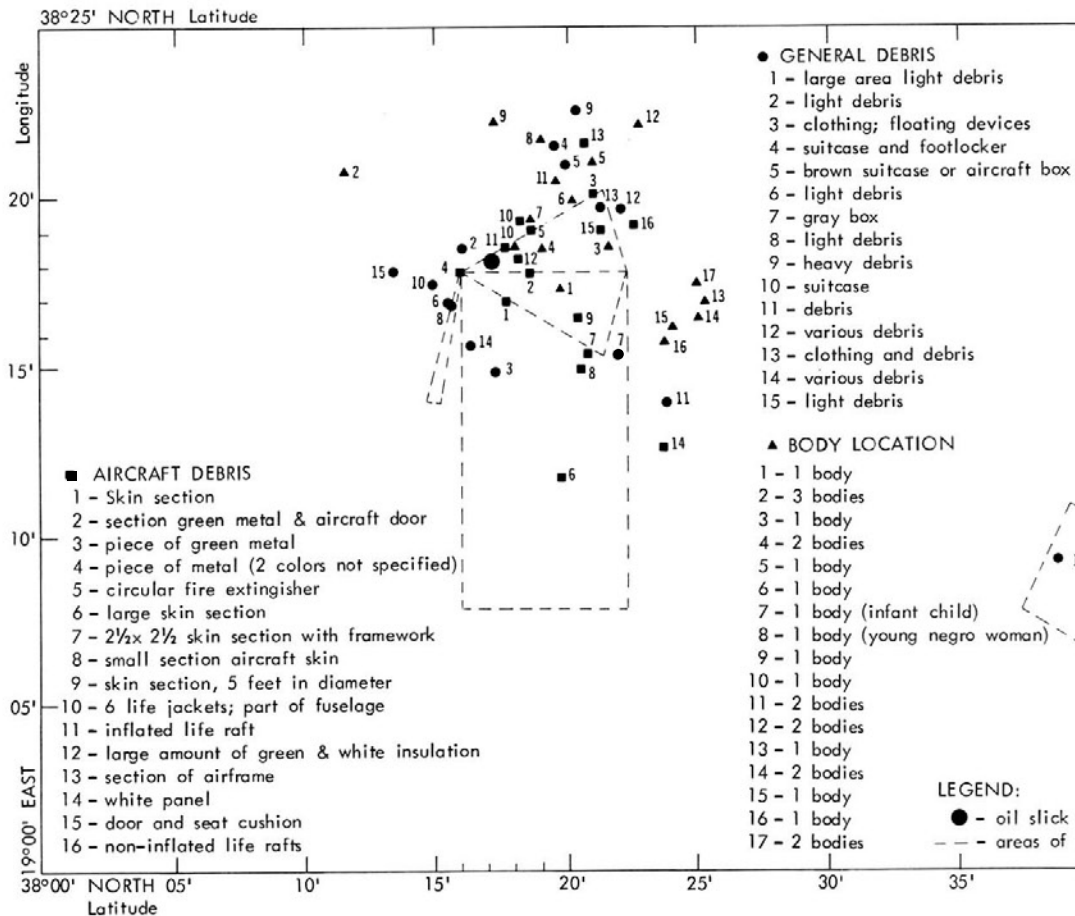
NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C.

ACCIDENT AREA CHART

TRANS WORLD AIRLINES INC.
 BOEING 707-331B, N8734, FLIGHT 841
 IONIAN SEA, 50 NM WEST OF
 CEPHALONIA, GREECE
 SEPTEMBER 8, 1974

NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C.

BODY AND DEBRIS DISTRIBUTION CHART
AS DEVELOPED BY THE USS INDEPENDENCE
U.S. SIXTH FLEET
TRANS WORLD AIRLINES, INC.
BOEING 707-331B, N8734, FLIGHT 841
IONIAN SEA, 50 NM WEST OF
CEPHALONIA, GREECE
SEPTEMBER 8, 1974



APPENDIX F

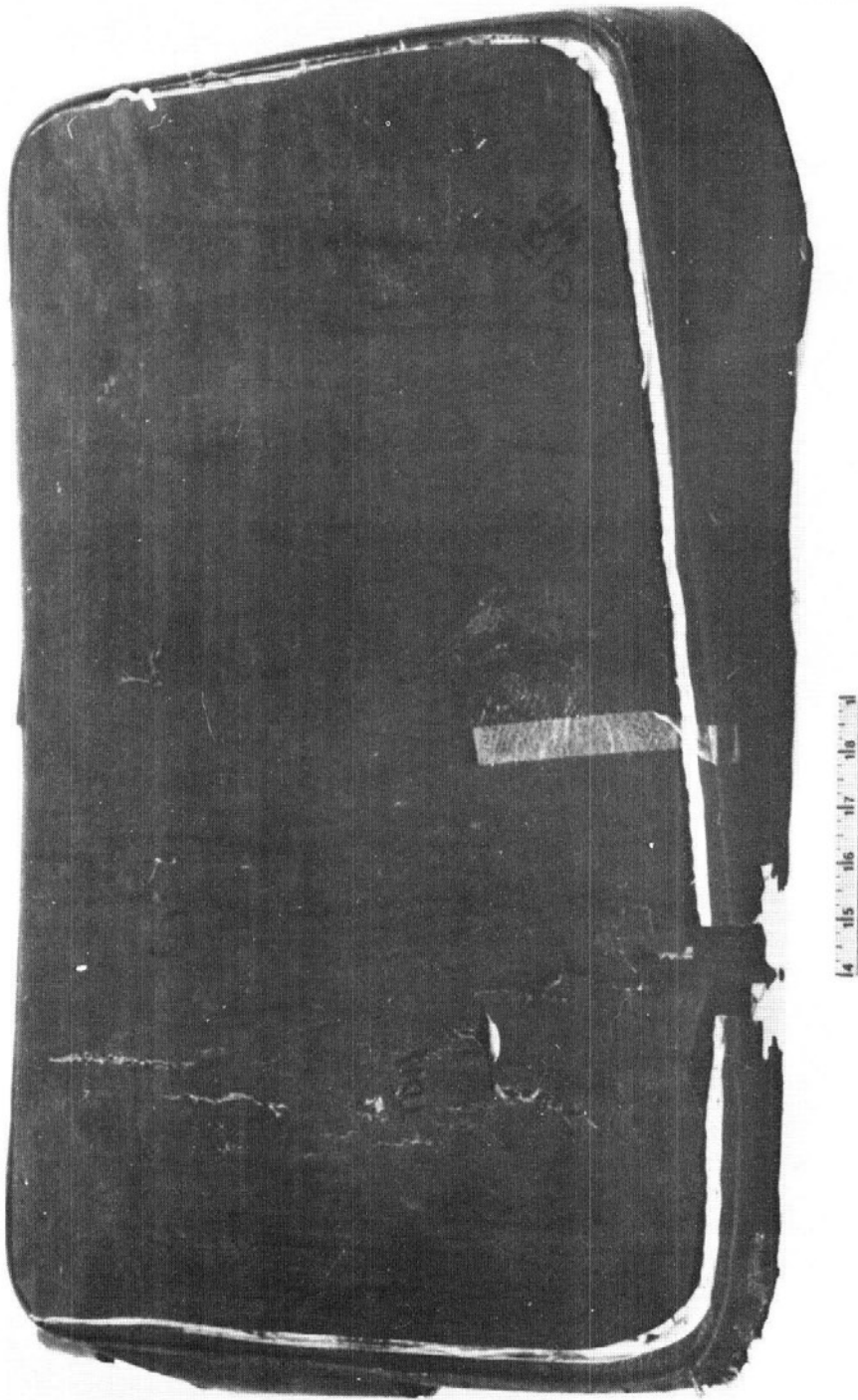
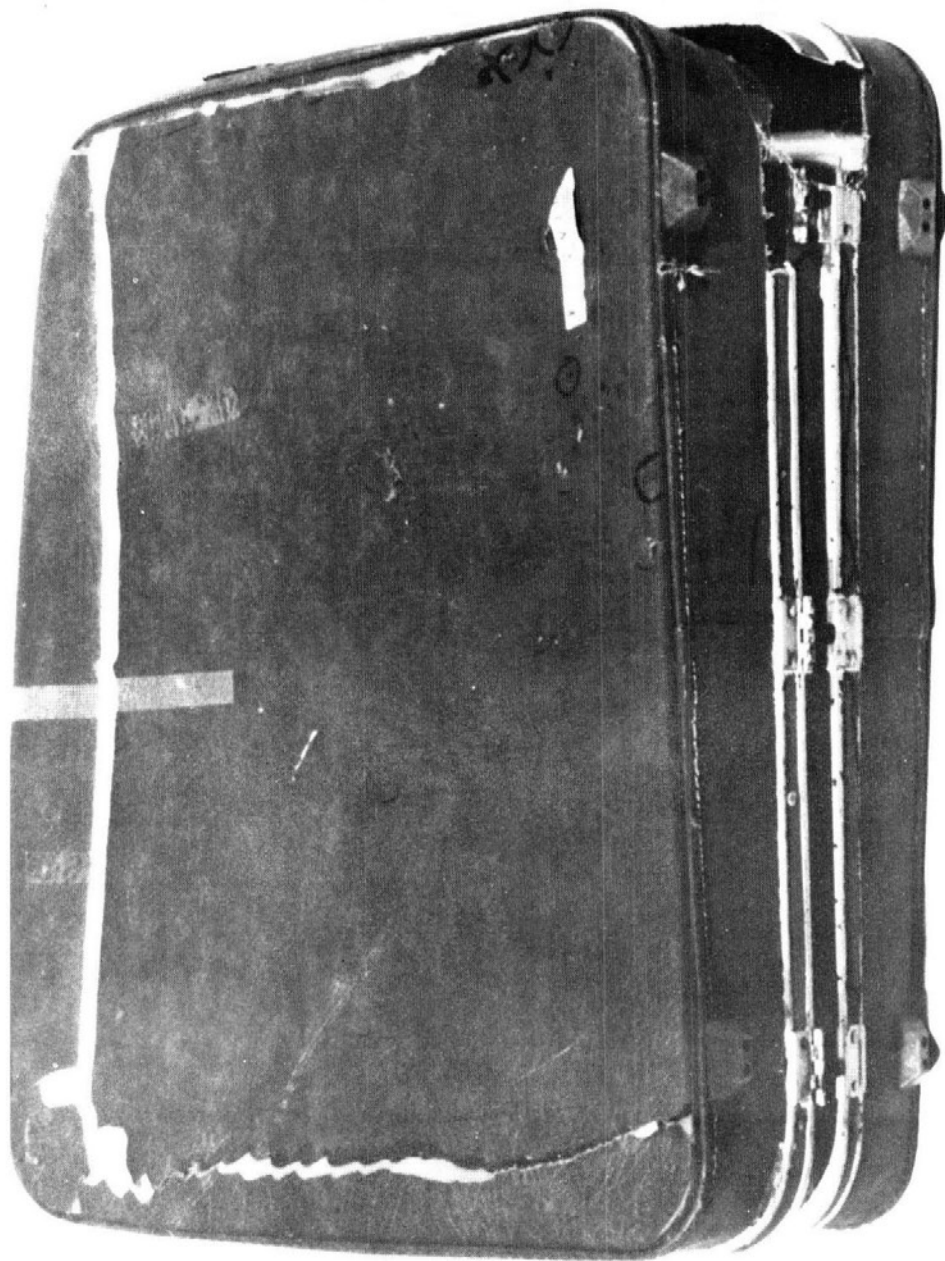


FIG 1

APPENDIX F



Ex. 115 - 116 - 117 - 118 - 119 - 120

FIG. 1

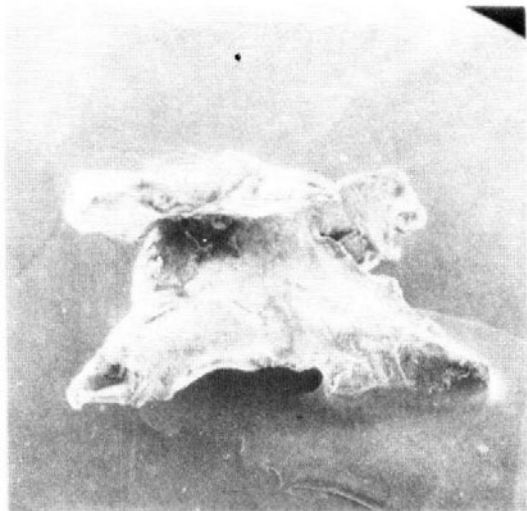


FIG 3a FRAGMENT A x 20

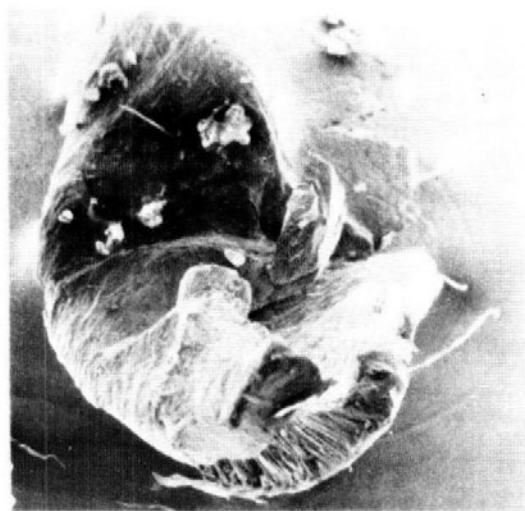


FIG 3b FRAGMENT E x 40

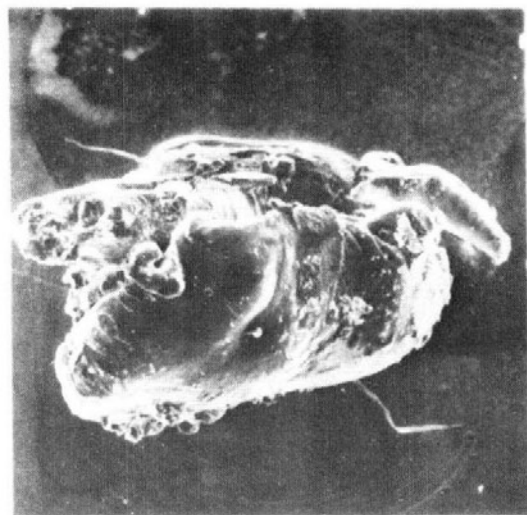


FIG 3c FRAGMENT G x 60

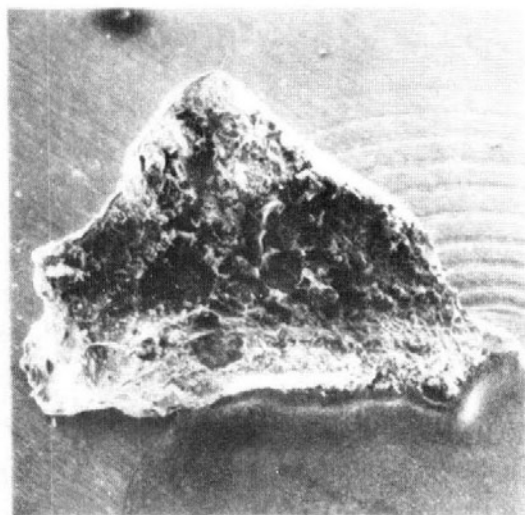


FIG 3d FRAGMENT H x 40

FIG 3 ALUMINIUM ALLOY FRAGMENTS

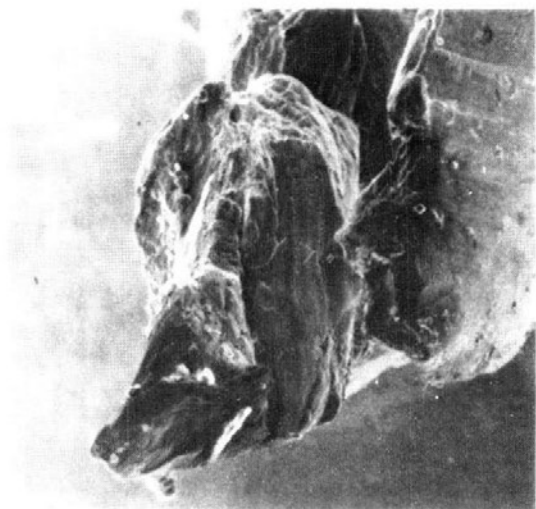


FIG 4a FRAGMENT E x 80

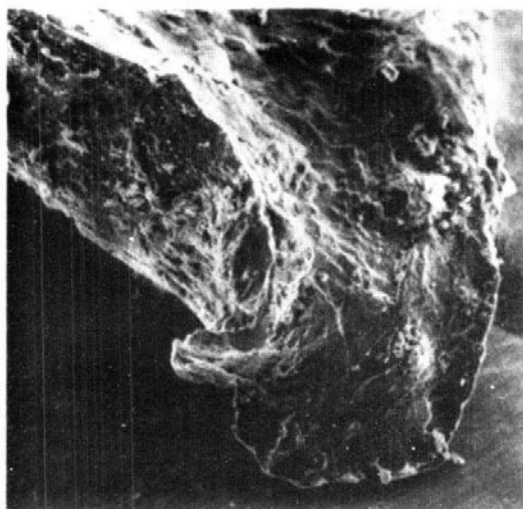


FIG 4b FRAGMENT H x 90



FIG 4c FRAGMENT FROM COMET G-ARCO x 225

FIG 5 FRAGMENTS FROM TWA 707 & COMET G-ARCO AIRCRAFT

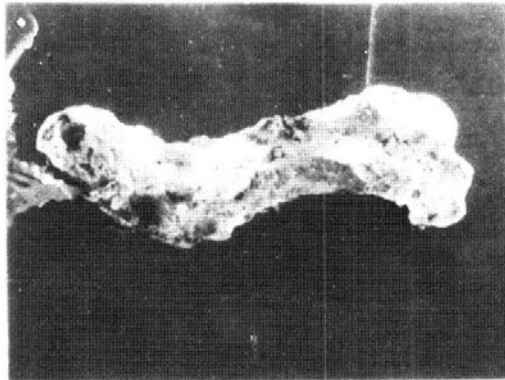


FIG 1 ZINC ALLOY FRAGMENT ARC/I x15

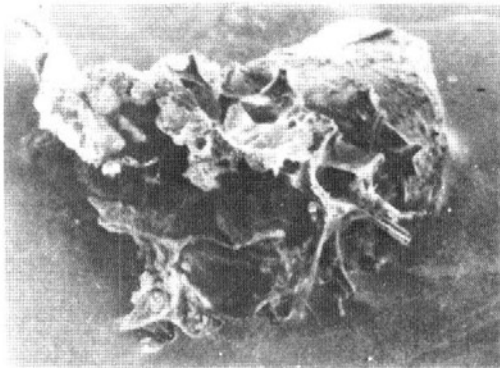


FIG 2 FRAGMENT I x40

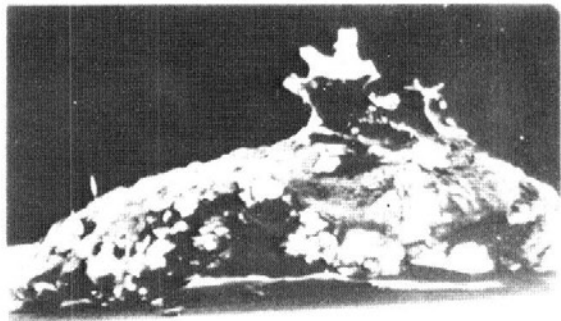


FIG 3 FRAGMENT FROM COMET
G-ARCO x54

FIG 4 FRAGMENTS WITH ATTACHED PLASTICS

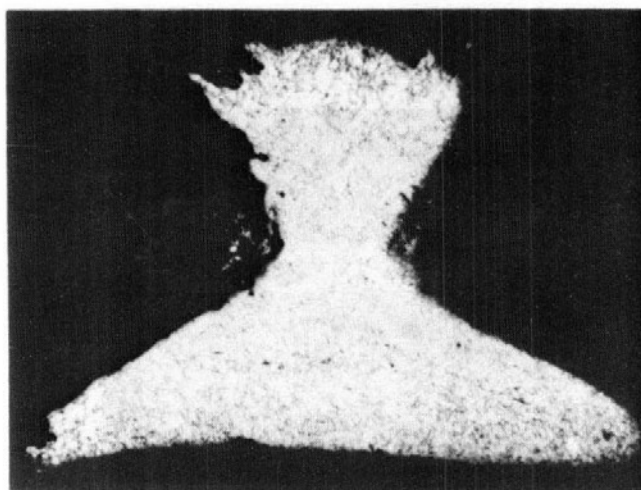


FIG 7 METALLURGICAL SECTION OF FRAGMENT I x 75

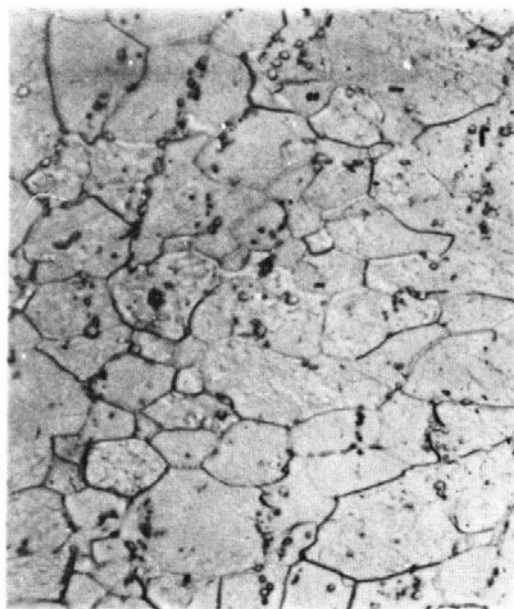


FIG 8a SECTION OF FRAGMENT I
x 1000

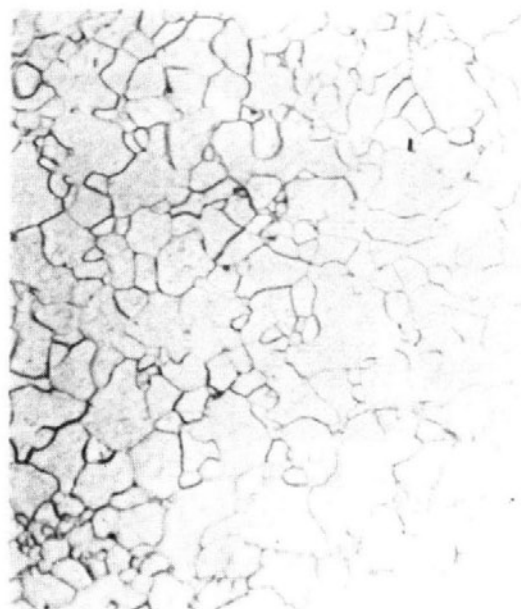


FIG 8b SECTION OF EXPLOSIVELY
DEFORMED IRON

x 1000

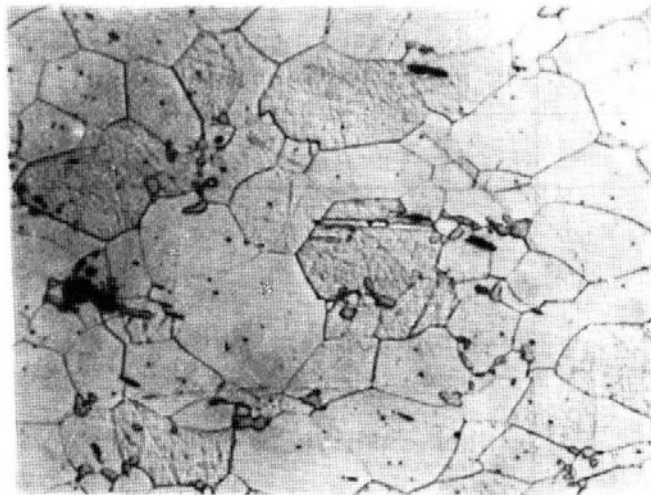


FIG 9a

x 500

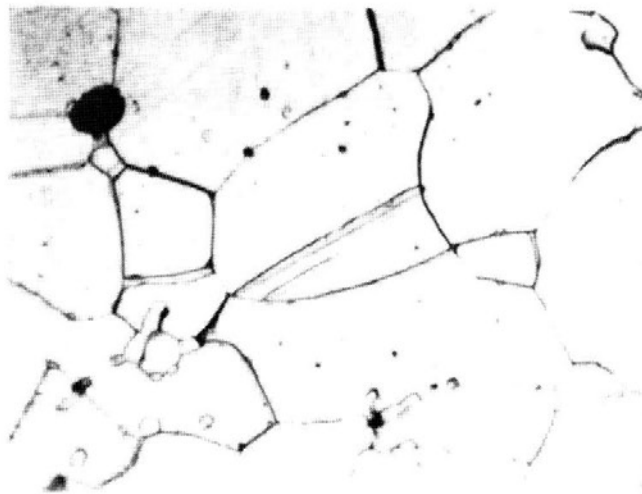


FIG 9b

x 1000

FIG 9 METALLURGICAL SECTION OF DAMAGED HINGE

APPENDIX G

PARTIAL LIST OF EXHIBITS EXAMINED

Identification				Brief Description of Exhibits/Specimens	Location Found
FBI	NEWTON	HIGGS	COX		
Q1				Lid of Samsonite suitcase	
Q2				Complete Samsonite suitcase	
Q3				Seat cushion	
Q4				Floor panel	
Q5A	A			Aluminium alloy fragment	Q2 lid
Q5E	E			Aluminium alloy fragment	Seat cushion (X-ray)
Q5G	G			Aluminium alloy fragment	Q2 lid
Q5H	H			Aluminium alloy fragment	In floor panel foam
	I			Iron fragment	Q2 lid
			ARC/1	Zinc fragment	Q2 lid
Q6A				Metal fragment	In foam of aft cargo door
Q19A				Metallographic specimen	Hinge of Q2
Q24				Metallographic specimen	Metal fragment from Q2 lid
		DGH/12		Fibrous plastic perforation area	Q2 lid

APPENDIX G

The identification numbers of the exhibits were originally established by the organizations or persons listed in the corresponding columns. "Newton" refers to Mr. E. Newton of the Accidents Investigation Branch, Board of Trade, England. "Higgs" and "Cox" refers to Messrs. D. G. Higgs and A. R. Cox, of the Royal Armament and Research Development Establishment, England.

NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C.

APPENDIX H

ISSUED: January 10, 1975

Forwarded to:

Honorable Alexander P. Butterfield
Administrator
Federal Aviation Administration
Washington, D. C. 20591

SAFETY RECOMMENDATION(S)

A-75-2 thru 5

On September 8, 1974, Trans World Airlines Flight 841, a B-707-331B, crashed in the Ionian Sea, about 50 miles west of Cephalonia, Greece. The aircraft was on a flight from Tel Aviv, Israel, to New York, New York, with scheduled stops in Athens, Greece, and Rome, Italy.

The results of the laboratory examination of certain items in the recovered flotsam establish conclusively that the detonation of a high order explosive took place in the aircraft's aft cargo compartment.

Subsequent to the accident it was determined that an aft cargo compartment fire on a similar flight on August 26, 1974, was caused by a malfunctioning explosive device contained in a suitcase. In both instances, the passengers' checked baggage at the last boarding point was not examined, nor was this required. Trans World Airlines' procedures now include the examination of checked baggage at that boarding point.

The National Transportation Safety Board is aware of the problems in maintaining an adequate level of aircraft security without undue costs, delays, or passenger irritation, especially when an air carrier operates in other countries. Since aircraft security, in most cases, is a joint responsibility of the air carrier, the airport authority, and the regulatory agency involved, it is apparent that close coordination among all parties involved is a prerequisite for the effectiveness of the security program. The Federal Aviation Administration's Aviation Security Technical Assistance Program plays a vital role in adapting security programs to the needs of time and locale. Although many nations have already availed themselves of this program, it has not yet reached all countries where American flag carriers make scheduled stops.

Honorable Alexander P. Butterfield (2)

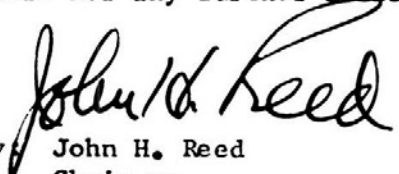
The Safety Board notes that, with the exception of the FAA's Regional headquarters in Brussels, Belgium, for Europe, Africa and Middle East, all regional headquarters have security offices. The establishment of such an office in your Brussels headquarters would provide a much-needed focal point for the coordination of aircraft security measures in the area served by that headquarters.

Although aircraft sabotage can take many forms, it appears that, in most cases, some type of high explosive is involved. The Safety Board is aware of the ongoing research in the development of explosives detection equipment and believes that the use of suitable detection equipment would not only simplify examination procedures but serve as a deterrent.

Accordingly, the National Transportation Safety Board recommends that the Federal Aviation Administration:

1. Reemphasize to the nations served by American flag carriers the importance of participating in the Aviation Security Technical Assistance Program.
2. Establish an Aviation Security Office in the Federal Aviation Administration's Europe, Africa and Middle East Regional Headquarters in Brussels, Belgium.
3. Expedite the development and use of suitable explosives detection equipment to preclude the introduction of explosive devices on board an aircraft.
4. Ensure that the aircraft security programs of U.S. air carriers, as prescribed by 14 CFR 121.538, contain provisions that are more responsive to high risk situations in international as well as domestic operations.

Our technical staff is available for any further assistance they may be able to provide.


By John H. Reed
Chairman

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