SA-413

File No. 1-0004

AIRCRAFT ACCIDENT REPORT

UNITED AIR LINES, INC.
BOEING 727-22C, N7434U
NEAR LOS ANGELES, CALIFORNIA
JANUARY 18, 1969

Adopted; March 18, 1970

NTSB AAR-70-6
from p 2169 World Airline Accident Summary.

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NATIONAL TRANSPORTATION SAFETY BOARD
DEPARTMENT OF TRANSPORTATION
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SYNOPSIS

United Air Lines, Inc., Flight 266, a Boeing 727-22C, N7434U, crashed into Santa Monica Bay, approximately 11.3 miles west of the Los Angeles International Airport, at 1821 P.s.t. on January 18, 1969. The airman was destroyed and the six crewmembers and 32 passengers on board were all fatally injured.

. Flight 266 departed from Los Angeles Airport at 1817 P.s.t., and 2 minutes later reported to Departure Control that they had experienced a fire warning on the No. 1 engine and wished to return. This was the last communication with the flight. The secondary or transponder target disappeared from the radarscope immediately following the above transmission. Thereafter, movement of the primary target indicated the aircraft continued to track a straight course on the last assigned heading of 270° for approximately a minute and a half, after which the aircraft commenced a left turn. The target then disappeared from the radarscope.

. The Los Angeles weather report in effect at the time of the accident indicated 700 feet scattered, measured ceiling 1,000 feet broken, 2,000 feet overcast, visibility 3 miles in light rain and fog.

The Board determines that the probable cause of this accident was loss of attitude orientation during a night, instrument departure in which all attitude instruments were disabled by loss of electrical power. The Board has been unable to determine (a) why all generator power was lost or (b) why the standby electrical power system either was not activated or failed to function.

Safety Board recommendations designed to prevent the occurrence of similar accidents are set forth in detail in section 3 of this report. These recommendations primarily involve measures directed toward assuring (a) that the standby electrical power system will be effectively activated, either automatically or by the crew, in the event of the loss of all generators, and (b) that the crew will have available attitude indicator instruments following disruption of electrical power.

1. INVESTIGATION

1.1 History of the Flight

United Air Lines, Inc. (UAL), Flight 266 was a regularly scheduled passenger and cargo flight from Los Angeles, California, to Milwaukee, Wisconsin, with an en route stop at Denver, Colorado. N7434U, a Boeing 727-22C, which was utilized for this flight on January 18, 1969, arrived in Los Angeles from Denver at about 1530 1/ on that date.

While N7434U was on the ground at Los Angeles, a routine en route inspection was performed by a UAL mechanic who found the aircraft to be serviceable and noticed nothing unusual. This check consists basically of an interior and exterior visual inspection of the aircraft for any condition that might require corrective action. During the period the aircraft was on the ground, rain was falling intermittently. However, the aircraft was equipped with a protective canvas shroud designed to prevent water from dripping into the electrical bay area.

As indicated in the logbook, N7434U had been operating since January 15, 1969, with the No. 3 generator inoperative. The second officer on board the aircraft during the flight immediately preceding Flight 266 on January 18, 1969, stated that "inoperative" tape had been placed over the No. 3 generator CSD (constant speed drive) low-pressure light, the No. 3 generator breaker circuit open light, and the No. 3 generator field relay open light. He also believed that tape was placed adjacent to the No. 3 generator position of the AC (alternating current) meters selector switch.

The UAL dispatcher, who was responsible for dispatching Flight 266, was informed approximately 30 or 40 minutes before departure that the No. 3 generator was inoperative. After referral to the Minimum Equipment List, which, in effect, states that the aircraft is airworthy with only two generators operable provided certain procedures are followed and electrical loads are monitored during flight, he approved the dispatch.

Conversation recorded on the cockpit voice recorder prior to departure indicates that the crew was aware that the No. 3 generator was inoperative. UAL procedures prescribe that when only two generators are operable, the galley power switch and one of the two air conditioning packs should be turned off before takeoff. These switches can be turned to the "on" position during climbout when the flaps have been raised.

Flight 266 was scheduled to depart the gate at 1755, but was delayed until 1807 because of the inclement weather and loading problems. The flight commenced its takeoff roll on Runway 24 at approximately 1817. The local controller in the tower who observed the aircraft during its takeoff run, and until it was 400 or 500 feet in the air and about 8,000 feet down the runway, noticed nothing abnormal.

1/ All times herein are Pacific standard, based on the 24-hour clock.

At 1818:13, Flight 266 contacted Departure Control and was instructed to ". . . turn right heading two seven zero report leaving three thousand feet." 2/ The cockpit voice recorder indicates that, at 1818:30, the sound of an engine fire warning bell was heard in the cockpit. 3/ At 1819:05, Flight 266 reported to Departure Control that ". . . we've had a fire warning on number one engine we shut down we'd like to come back." This was the last communication with Flight 266. Departure Control attempted repeatedly to contact the flight during the time period following this transmission but was unsuccessful.

The departure controller who was handling Flight 266 stated that the flight responded to his heading instruction of 270°. Approximately 5 seconds after the transmission from the flight reporting the fire warning, the secondary or transponder target of the aircraft disappeared from the radarscope. The movement of the primary target indicated the aircraft continued to track a relatively straight course on 270°. At 1820:30, when the aircraft was about 10 miles west of the shoreline, the departure controller instructed the flight to turn right to a heading of 060°, but again received no reply. At this point, the primary target movement indicated the aircraft started a left turn, after which the target disappeared from the scope within two sweeps. 4/ The controller also stated that the speed of target movement during these last few sweeps increased greatly.

Appropriate emergency procedures were initiated following the disappearance of the target from the radarscope. It was later determined that the aircraft crashed at approximately 1821 at a point 11.3 miles west of the airport.

Two ground witnesses observed an aircraft taking off from Runway 24 at a time corresponding to the departure of Flight 266. One of these witnesses, wh identified the aircraft as a B-727 based on the engine arrangement, noticed nothing unusual about the aircraft as it flew directly over his car. The othe witness' attention was attracted by many sparks, reddish in color, coming from the right side and rear engine of the aircraft. She observed the aircraft when it was about 1,000 feet high and climbing gradually at what appeare to be normal speed.

Another ground witness, who was located on a hill above Paradise Cove (northwest of the impact point), observed an aircraft over the water, turn

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2/ The communications between Los Angeles Departure Control and Flight 266 ar set forth in full in the Communications section.

3/ For a transcription of the recorded crew conversation during this period, see Appendix C.

4/ The radar antenna rotates at a speed of 15 revolutions per minute.

5/ The approximate flightpath of Flight 266, based on the departure controlle memory chart, is attached to this report.

to its left, and head east back toward the airport. As the plane hescended into a thick fog bank, he heard an explosion and saw a flash of light. A fourth ground witness was driving along Malibu Beach in an easterly direction when his son exclaimed "Look, Dad, fire." The man stopped the car, got out and saw an aircraft "on fire", which seemed to be coming from the front of the plane. The aircraft was descending, heading toward the airport and then it plunged straight down into the ocean. This witness also heard several "firecracker" or "backfire" sounds while the plane was still in the air.

1.2 Injuries to Persons

Injuries	Crew	Passengers	Others
Fatal	6	32	0
Nonfatal	0	0	0
None	0	0	

1.3 Damage to Aircraft

The aircraft was destroyed by impact with the water.

1.4 Other Damage

None.

1.5 Crew Information

The crew was properly certificated and qualified to conduct the flight. The captain had recently completed DC-8 training and Flight 266 was his first flight in a B-727 since December 2, 1968. The second officer completed B-727 transition training on December 19, 1968, and completed his line check on January 2, 1969. He had a total of 40 hours as second officer in the B-727, of which at least 18 hours were in the QC model.

The official medical files of the flight crewmembers and interviews with relatives revealed no conditions which might have adversely affected the crewmembers' fitness for duty.

For detailed crew information, see Appendix B.

1.6 Aircraft Information

N7434U was a being Model 727-22C (QC), 6/ S/N 19891, with a date of manufacture of September 1, 1968. A standard airworthiness certificate was issued on September 19, 1968, and the aircraft was delivered to United Air Lines on September 20, 1968. The aircraft had accumulated 1036:47 hours operating time since new, including 217:09 hours since the last maintenance check and 90:01 hours since the last service check.

6/ Quick change, cargo/passenger.

The aircraft was equipped with three Pratt & Whitney JT8D-7 engines. Engines No. 2 (S/N 655074) and No. 3 (S/N 655085) had been on the aircraft since new and had accumulated 1037:00 hours. Engine No. 1 (S/N 654366) was a replacement engine with a total of 4,505 hours, including 1,021 hours since heavy maintenance.

The actual gross weight of N7434U at the time of takeoff was computed to be 148,800 pounds, as compared with the maximum allowable *gross* takeoff weight of 156,100 pounds. The center of gravity of the aircraft was calculated to have been within the prescribed limits both at the time of takeoff and the time of the crash.

All of the records examined during the course of the investigation disclosed that the aircraft had been maintained in accordance with applicable company and Federal Aviation Administration (FAA) directives and procedures. These records were examined with particular reference to the fire warning and electrical systems.

The records pertaining to N7434U contained no reports of prior fire warnings on the No. 1 engine or of any condition to which the fire warning experienced on Flight 266 might have been related. With respect to the United Air Lines B-727 fleet in general, a total of 73 in-flight shutdowns due to firewarnings was experienced during the period from January 1966 through March 1969. Of these, *only* 10 were "false" warnings -- i.e., warnings for which there was no identifiable cause such as overheat or fire. Most of the engine shutdowns in which no actual fire occurred were due to overheat resulting from hot, high-pressure engine bleed air leaking into the fire warning sensor area through failed or cracked ducting.

Research into the records concerning the fire warning system also disclosed that being Service Bulletin No. 26-15 was issued on May 7, 1968, ". . . to reduce false fire or overheat indications on airplanes using the Lindberg engine fire detector system" 7/ The bulletin provided for optional replacement of a sensor element designed to actuate warnings at 325° ± 25° F., with a sensor designed to actuate warnings at 375° ± 25° F.. The system installed on the No. 1 engine on N7434U incorporated the 325° ± 25° F. sensor.

With respect to items of interest in the history of the electrical system on N7434U, the No. 3 generator control panel was removed on January 13, 1969, and replaced with panel S/N 163. The latter panel had been removed from eight different aircraft for varying reasons during the period from May 2, 1967, until December 31, 1968. 8/ Three hours later, on this same date, the crew

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7/ This bulletin was issued in connection with the B-727-200 series aircraft, which had an engine nacelle temperature that ran slightly higher than earlier versions.

8/ Search of the records also disclosed that Westinghouse Service Bulletin 66-103 (September 1966), which recommended replacement of a silicone controlled rectifier in order to prevent nuisance tripping of the differential protection circuitry, had not been accomplished on panel S/N 163.

which brought the aircraft into O'Hare Field reported: "No. 3 generator underexcitation light on before generator connected to bus, Reset fault but generator field after 2 tries still would not stay closed with no load on generator. Disconnected CSD." The corrective action was to replace the No. 3 generator. 9/ The generating system apparently passed all the ground testing necessary to put the No. 3 system back in service. However, 3-1/2 flight-hours later, a crew disconnected the newly installed generator because the field relay would not stay closed. The No. 3 generator was then rendered inoperative by ground maintenance personnel and carried as a deferred item in accordance with the Minimum Equipnent List.

The No. 3 generator was still being carried as a deferred item 3 days and 42 flight-hours later at the time of the accident. During this period, the aircraft operated through a total of 28 stations, 23 of which possessed line maintenance capability. The item was not repaired during this period because of the exigencies of available aircraft and flight scheduling.

1.7 Meteorological Information

An extensive area of rain, fog, and low cloudiness prevailed along much of the California coastline and into central sections of the state in advance of a frontal system approaching from the Pacific Ocean. The 1900 surface weather chart showed, in part, a cold front extending southwestward from near San Francisco into the Pacific and a warm front extending from near San Francisco southwestward along the Pacific Coast near Monterey, Santa Maria, and San Nicolas Island.

The official surface weather observations taken at Los Angeles at times most immediate to the accident were as follows:

1755 Record special, 700 feet scattered, measured 1,000 broken, 2,000 overcast, visibility 3 miles, light rain, fog, temperature 55" F., dew point 50° F., wind 160°, 5 knots, altimeter setting 29.96 inches. 10/

1827 Special, 800 scattered, measured 2,500 overcast, 4 miles, light rain, fog, temperature 54° F., dew point 49" F., wind 140°, 6 knots, altimeter setting 29.96 inches.

The departure controller who was handling Flight 266 reported that there were two large intense weather returns on the radarscope, one of which was due

9/ The generator which was removed from the aircraft was later examined in the shop and no discrepancies were found.

10/ At the time of departure of Flight 266, the 1755 weather observation was being continuously broadcast in the Los Angeles area on frequency 118.6 MHz as part of the Automatic Terminal Information Service (ATIS).

west of the airport and moving eastbound. When the primary target of the flight disappeared, it was just approaching the northern edge of this weather return. The controller also related that pilots were generally reporting rain showers west of the airport in all quadrants. Such reports were consistent with ground witness observations.

The pilots of Air West Flight 312, which departed from Runway 24 1 minute prior to Flight 266, stated that their aircraft entered the overcast at 800 feet. After crossing the shoreline while climbing through 1,000 to 1,200 feet, the flight encountered complete darkness and thereafter was without any reference to an outside horizon. The first officer on UAL Flight 111, which departed from the same runway 4 minutes after Flight 266, reported entering an overcast 1/2 mile off the coast at an altitude of 1,000 to 1,500 feet.

No weather briefing was furnished to the crew of Flight 266 by personnel of the Weather Bureau or Flight Service Station, Los Angeles, nor was there a known formal weather briefing of the crew by company personnel. However, the company maintains a self-help weather briefing display at their Los Angeles facility, which under most circumstances is the method used by crews to familiarize themselves with current and forecast conditions.

1.8 Aids to Navigation

Ground certification checks, which began about 10 minutes after Flight 26 disappeared from the radarscope, indicated that the Los Angeles radar, secondary radar gear, and radar display equipment were operating within established tolerances. Ground checks also disclosed that the back course localizer (for Runway 25L) of the Instrument Landing System (for Runway 7R) was operating satisfactorily.

A flight check conducted on January 18, 1969, by the FAA indicated that the primary and secondary radar were operating satisfactorily. A second flight check was conducted on January 21, 1969, to determine minimum altitude coverage between 7 and 15 miles west of Los Angeles Airport. The secondary radar was good at 500 feet in the area, while the primary radar was good at 700 feet and intermittent below 700 feet.

1.9 Communications

The communications between Flight 266 (UA 266) and Los Angeles Departure Control (DC), as recorded in the Los Angeles Air Traffic Control Tower, were as follows:

TIME	SOURCE	CONTENT
1818:13	UA 266	United two six six on departure
	DC	United two sixty-six Los Angeles departure control radar contact turn right heading two seven zero report leaving three thousand

1818:21	UA 266	Two seven zero Wilco
1818:58	UA 266	Ah departure United two six six
	DC	United two sixty six go ahead
	DC	United two sixty six go ahead
1819:05	UA 266	We've had a fire warning on number one engine we shut down we'd like to come back
	DC	United two sixty six Roger what is your present altitude
1819:20	DC	United two sixty six maintain three thousand and say your altitude
1819:45	DC	United two sixty six say your altitude maintain three thousand three thousand five hundred what's your altitude now
1820:10	DC	United two sixty six if you hear do not climb above five thousand traffic twelve o'clock three miles west-bound level at five thousand a Fairchild en route to Ventura.
1820:30	DC	United two sixty six ah turn right heading zero six zero
1820:40	DC	United two sixty six if you hear turn right heading two six uh zero six zero
1821:55	DC	United two sixty six if you hear us squawk two zero zero zero or zero four zero zero

At 1822:05, United Air Lines Flight 111, also departing from Runway 24, called Departure Control and was vectored clear of ". . . traffic we lost out west." At 1822:25, departures were stopped and, at 1823:50, Departure Control was informed by United Flight 111 that Flight 266 had not been talking with the company.

The flight check of the Los Angeles radar conducted on January 18, 1969, also demonstrated that radio communications on 125.2 MHz, the frequency on which Flight 266 was communicating with Departure Control, were satisfactory in the area west of the airport.

1.10 Aerodrome and Ground Facilities

Not involved in this accident.

1.11 Flight Recorders

(a) Flight Data Recorder

The aircraft was equipped with a Fairchild Industrial Products flight data recorder, Model 5424, S/N 1423, which was installed in the right ventral stairway area aft of the rear pressure bulkhead. The flight recorder was recovered, still encased in its housing which had collapsed around the recorder. The flight record medium was readable and showed that all parameters were functioning.

A data graph was plotted to reflect two separate time periods. The first covers the period commencing with lift-off and ending 1 minute 34 seconds later when the traces ceased their normal appearance and became widely divergent, indicating an electrical power interruption. This power interruption occurred 5 seconds after the completion of a 4-second VHF transmission from Flight 266 to Los Angeles Departure Control. 11/ The second time period commenced at an indeterminate later time and lasted 15 seconds, during which divergent traces were recorded for all parameters.

Examination of the data graph reveals that following lift-off, the aircraft climbed approximately 2,300 feet in 1 minute 30 seconds at a steady rate of climb of about 1,500 feet per minute. In the 4 seconds prior to the power interruption, the aircraft descended 50 feet. The indicated airspeed trace shows that the speed increased steadily from 142 knots at lift-off to 212 knots 1 minute later. At this point, the airspeed started to decrease, reaching 203 knots 13 seconds later, at which point it started to increase again, reaching 217 knots when power interruption occurred 21 seconds later. The magnetic heading trace remained on 250° until 30 seconds after lift-off. It then shifted gradually during the next 30 seconds to 270°, where it remained until power was interrupted 34 seconds later. The vertical acceleration trace recorded erratic excursions in the period following lift-off which tended to flatten out in the final 15 seconds prior to power interruption.

During the second period plotted on the data graph, when power was restored, the initial trace indications on all parameters were particularly erratic. When the power was again lost 15 seconds after being restored, the following readings were being reflected: altitude 630 feet, indicated airspeed 326 knots, heading 264°, and vertical acceleration ± 1.75 G's.

(b) Cockpit Voice Recorder

The aircraft was equipped with a United Control cockpit voice recorder (CVR), Model V-557, S/N 1670, located just forward of the aft pressure

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11/ The foil record contains two auxiliary binary traces which reflect excursions when transmissions are made on the No. 1 and No. 2 VHF communications system.

bulkhead, on the right-hand side of the aircraft. The CVR was recovered almost 6 weeks after the accident. Despite having been immersed in 1,000 feet of sea water during this period, the CVR yielded a good tape.

A transcription from a recording of the tape was prepared covering the period following receipt by the flight of takeoff clearance at 1816:58. This transcript is set forth in Appendix C. With respect to the recording prior to this time, all four channels of the original tape were monitored to determine whether there was any conversation relative to the status of the aircraft's electrical generating system, as well as other information which might be pertinent to the accident. The only crew conversation noted in this regard was a reference to the inoperative status of the No. 3 generator, of which the captain was made aware.

The CVR indicates that the fire warning bell sounded at 1818:30. At 1819:13.5, 5 seconds after completion of the transmission from Flight 266 regarding the fire warning, CVR operation ceased. At a later indeterminate time, the CVR resumed operation for a period of 9 seconds. When the recording terminated a second time, sounds normally associated with impact were not detectable.

1.12 Wreckage

The aircraft crashed into the Pacific Ocean at latitude 33° 56' 56" N., and longitude 118" 39' 30" W., or approximately 11.3 miles from the Los Angeles VOR on the 260" radial. The ocean depth at this point is approximately 950 feet. The general orientation of the wreckage path was east-west, covering an approximate area 600 feet long and 400 feet wide. The largest sections recovered, including the engines, were distributed along a relatively straight line bearing 262" true.

Approximately 50 to 60 percent of the bulk of the aircraft was recovered. Components from all major sections were identified in the wreckage. The aircraft was destroyed by the impact, with only small fragments remaining from all sections. The fragmentation and distortion were most complete toward the nose of the aircraft and the right-hand side, and less material from those areas was identified. Conversely, pieces from the left-hand side and aft end were greater in number, larger in size, and less mangled.

Evidence in the wreckage indicated that the landing gear was in the retracted position and the wing flaps were in the 2° extended position. The No. 2 leading edge slat, the only slat section positively identified, was extended at the time of impact.

The condition of the small portion of the overall electrical system which was recovered was not considered to be pertinent to the accident. None of the instruments from the flight panel or the engineer's panel was recovered.

All three engines were recovered within a 100-foot circle in the main wreckage area. The No. 1 engine exhibited only minimal rotational damage, thus indicating that it was not rotating at impact, which is consistent with the reported crew action of shutting down the No. 1 engine. There were no engine case penetrations, nor was there any evidence of overheat conditions present on engine interior or exterior areas. There likewise was no evidence of gross bleed air duct leakage or rupture.

Both No. 2 and No. 3 engines had sustained massive rotational damage and twisting of low turbine shafts, indicating high-speed rotation at impact. All three thrust reverser assemblies were found in the forward thrust position.

Also recovered were two damaged sensor responders which had been mounted on engines No. 1 and No. 2 and which constituted major portions of the engine fire detector systems. These components were subjected to extensive functional testing and were found to be operating within design specification limits.

1.13 Fire

One ground witness reported seeing an aircraft on fire plunge into the ocean, another saw a flash of light as an aircraft descended into a fog bank, while a third saw sparks coming from a departing aircraft. However, there was no evidence of fire on any part of the recovered wreckage, including the No. 1 engine and adjacent structure.

1.14 Survival Aspects

The complete destruction and extreme degree of fragmentation of the aircraft, particularly the occupiable area, are indicative of impact forces far exceeding human tolerance. Apart from one severely mutilated body, *only* body fragments were recovered and only two identifications (both of which were passengers) could be .made.

1.15 Tests and Research

An extensive series of ground and flight tests was conducted subsequent to the accident in an attempt to shed some light on the electrical and associated problems experienced by Flight 266. These tests generally showed that during one and two, generator operations, the aircraft electrical system could more than adequately carry the design load, provided. prescribed procedures were followed. Tests also showed that electrical outages have no significant adverse effect on the flight control system.

Among the more relevant information developed by the tests was the fact that during certain extreme overload conditions, sufficient induced electrical interference *may* be present on some B-727 aircraft to inhibit proper operation of the No. 2 time delay circuit of the protection panel. The expected action

of this panel during such an overload would be to trip the bus tie breaker, thereby isolating the generator and load bus from the remainder of the electrical system and clearing the overload. However, if the No. 2 time delay circuit is disabled by the induced interference, the No. 1 time delay circuit will continue to sense the overload and, after 5 to 9 seconds, will trip the generator control relay and the generator circuit breaker, thus removing the generator from the system. Flight tests indicated that, particularly with the battery switch off, the generator field relay would trip prior to the bus tie breaker in approximately half the time under overload conditions.

It was also attempted, during the tests, to simulate the voltage condition reflected on the CVR at the point when power was restored for 9 seconds. These tests indicated a low voltage condition of 50 volts at that time. This power level was simulated by starting one generator with loading for two generators applied.

1.16 Other Pertinent Information

(a) UAL Emergency or Abnormal Procedures

Pertinent UAL procedures in effect at the time of the accident were as follows: 12/

Engine Fire

If fire warning light illuminates steadily and bell rings:

Phase I

Thrust Lever	Idle
Start Lever	Cut-Off
Essential Power Selector	On Operating Generator
Engine Fire Switch	Pull

Additional UAL Items:

Engine Fuel Shutoff Valve Switch	Close
Fuel Boost Pump Switches	As Required

Phase II

Fire Warning light ON:

Bottle Discharge Switch	Push

If fire warning light remains ON after 30 seconds:

Bottle Transfer Switch	Transfer
Bottle Discharge Switch	Push

12/ Engine fire and loss of all generators are emergency procedures, while one generator and two generator operations are abnormal procedures. With respect to emergency procedures, Phases I and II are minimum immediate action items, with Phase I being completed before Phase II. Phase III is accomplished as soon as time permits.

Phase 111

Land if fire persists

Two Generator Operation

1. Generator Breaker Switches

Operative Generators	Close
Inoperative Generator	Trip

2. Bus Tie Ereaker Switches (3) . . . . . Close, observing manual paralleling procedure

3. If generators cannot be paralleled, operate generators isolated.

4. If generators cannot be paralleled and inoperative generator is #1 or #2:

#3 Generator Bus Tie Breaker Switch	Close
Inoperative Generator Bus Tie Breaker Switch .	Close
Remaining Bus Tie Breaker Switch	Trip

5. During takeoff, approach, and landing:

Galley Power Switch	***Off***
A/C Pack Switches	Maximum of one On

6. Electrical Loads . . . . . Monitor

Notes: a. Other loads not required for the particular operating condition should be turned off to limit the total load to 57 KVA (54 KW)

b. Both A/C packs may be operated during Cruise Flight if necessary, however, one must be turned OFF prior to extending Wing Flaps for APPROACH and LANDING. Cargo heat valves should be closed when only one A/C pack is operating.

One Generator Operation

1. Generator Breaker Switches:

Operative Generator	Close
Inoperative Generators	Trip

2. Bus Tie Breaker Switches (3) . . . . . Close

3. Galley Power Switch . . . . . Off

4. A/C Pack Switches . . . . . Both OFF, prior to extending flaps

5. Electrical Loads . . . . . Monitor

Loss of All Generators

Phase I and II

Any Generator Field Relay . . . . . Close

Note: To permit closing generator field relay when a differential fault is indicated, PULL and RESET the associated generator control circuit breaker or place battery switch OFF then ON.

Essential Power Selector . . . . . To Operating Generator

Repeat if necessary until essential power failure warning light remains off.

Phase III

Restore system to normal if possible.

Apart from the three generators, the UAL version of the B-727 aircraft also has a standby electrical power system which can be activated by positioning the Essential Power Selector Switch to Standby and turning the Battery Switch ON. 13/ This will provide power for the captain's gyro horizon, captain's compass, No. 1 VHF receiver, No. 1 VHF transmitter, No. 1 VOR, No. 1 glide slope, radio altimeter, and the first officer's RMI (remote magnetic indicator) card. Although the action of switching to the standby system is not included in the "Loss of all Generators" emergency procedure set forth above, the UAL second officer on Flight 266 was instructed during training to attempt to close the generator field relay(s) only once before going to standby.

(b) Other Incidents Involving Loss of all Generators

During the months of June and July 1969, there were three occasions on which UAL B-727 aircraft experienced loss of all three generators. The first of these incidents occurred on June 10, 1969, near San Francisco and involved aircraft N7411U. When the flight was approaching the San Francisco LOM in Visual Flight Rules (VFR) conditions, the second officer noted that his background flight lights were fluctuating. He tripped all three bus tie breakers to isolate the generators. He then selected No. 3 on the essential power switch and checked the phase lights. The left light was steady, the right light was flashing, and voltage was fluctuating. He switched essential power to the No. 2 generator and lost all generator power momentarily, although the No. 3 generator field relay remained closed. The second officer switched to standby power and then reset No. 1 generator field relay and set essential power on No. 1 and power was restored. The No. 1 generator breaker was opened, and the No. 2 field relay and the No. 2 and No. 1

13/ The B-727 also has an Auxiliary Power Unit (APU), but it is operable only when the aircraft is on the ground.

bus tie breakers were closed. The No. 3 bus still remained unpowered because No. 3 field relay had opened. The No. 3 breaker was closed, and No. 3 bus tie left open. All power was then normal. After the landing, the fault panel showed the No. 2 generator was underexcited.

UAL was unable to duplicate the above sequence of events either on the ground or in flight tests. A number of parts were removed and examined, but the reason for the loss of all generator power is still unknown.

The second incident occurred on a touch-and-go landing at Cheyenne, Wyoming, on a training flight on June 26, 1969. The No. 3 engine had been pulled back simulating a two-engine approach. As the throttles were advanced to the takeoff position, the instructor noted that the No. 2 or No. 3 EPR 14/ gauge did not advance as rapidly as the No. 1 EPR gauge. Accordingly, the takeoff was aborted. The crew then noted the loss of all three generators. The No. 2 generator was showing a differential fault, while No. 1 and No. 3 generators indicated an overvoltage condition.

It was later found that the No. 2 generator control panel had a faulty SCR 15/ in the differential control circuit; after being heated for about 45 minutes, it would cause a standing differential fault to exist which could not be reset. The No. 1 voltage regulator was found to modulate at about 25 volts peak-to-peak, at about 20 cycles per second, due to an intermittent open circuit in the conductor L-1 in the voltage regulator itself.

The third incident occurred at San Francisco on July 18, 1969. After the aircraft turned off the runway, essential power was switched from No. 3 generator to No. 1, the No. 1 bus tie breaker then tripped on overexcitation and the No. 1 generator breaker was tripped manually. All generator power was lost. Essential power was switched to standby and normal power restored.

UAL was unable to duplicate the above circumstances, either on the ground or in flight tests. The generator control panels were removed from the aircraft and functionally tested. The incident is still under investigation.

14/ Engine pressure ratio.

15/ silicone controlled rectifier.

2. ANALYSIS AND CONCLUSIONS

2.1 Analysis

On the basis of the evidence adduced from the wreckage, and the recorded crew conversation in the final moments of flight, it is apparent that the aircraft was in an abnormal attitude when it struck the water, The limited scatter of the wreckage is indicative of a steep impact angle, while the fragmentation pattern indicates that the aircraft impacted at a relatively high rate of speed in a right wing low, nose low attitude. The exclamations of the first officer during the final seconds ("Keep it going up - you're a thousand feet - pull it up") further demonstrate that loss of attitude orientation was experienced prior to striking the water.

Based upon the fact that parts of all major elements of the aircraft were either recovered or were identified by means of television, coupled with the fact that these parts were all located within a relatively small area on the ocean bottom, it can be concluded that the aircraft was essentially intact at impact. The extensive fragmentation of the wreckage precluded any determination concerning the condition of the control system at impact. However, there was enough evidence to conclude that the No. 2 and No. 3 engines were capable of producing a sufficient level of power to sustain the aircraft in flight, despite the fact that the No. 1 engine was shut down.

In attempting to determine the factors underlying the loss of attitude reference, the thrust of the investigation was primarily focused on two areas: (1) The circumstances surrounding the fire warning on the No. 1 engine, and (2) The nature of the electrical power problems experienced during the flight, including their effect on the capability of the crew to fly the aircraft.

With respect to the first of these two areas, there was no evidence of fire on any part of the recovered wreckage, including the No. 1 engine and adjacent structure. It is difficult to reconcile this lack of physical evidence of fire with ground witness observations of fire or sparks in flight. It is possible, however, that a phenomenon did in fact occur which provided ground witnesses with a view of flames or the appearance of sparks. One such possibility would be a transient compressor stall on one of the two operating engines after the aircraft assumed an unusual flight attitude prior to impact. One other possibility, although remote, is a transient compressor or turbine rub or the ingestion of a small particle by one of the two operating engines, which could result in

the emission of sparks. Such an occurrence would not necessarily impair the operation of the engine, nor would evidence of it necessarily be detectable after impact and the resultant massive deformation of engine rotating components.

To the extent that these two sources of evidence are deemed inconsistent, the Board is of the view that physical evidence, or lack thereof, is more persuasive than the observations of several witnesses on a dark, rainy night. It is therefore concluded that an in-flight engine fire did not occur.

The remaining possible causes of the fire warning, once an actual fire is discounted, are an overheat or a false warning. The physical evidence derived from the wreckage, although negative in regard to both of these possibilities, cannot be considered definitive. Accordingly, no conclusive reason for the fire warning could be established.

Based solely on the past history of fire warnings on the subject type of engine, the most probable cause of the fire warning was an overheat condition within the engine compartment, which in turn probably resulted from a duct leak. Even if such an assumption were to be made, however, we do not believe the fact that a 325° ± 25° F. sensor was incorporated on the No. 1 engine, rather than a 375° ± 25° F. sensor, can be considered a causal factor in regard to the fire warning. The incorporation of the higher temperature sensor was not mandatory. Furthermore, the higher temperature sensor merely delays the activation of the fire warning, it does not reduce the number of warnings. It therefore appears that while a 375" sensor would not have been triggered at the same precise point in time as the 325° unit, it would have been actuated eventually, again assuming that some duct leakage did, in fact, exist.

In any event, the No. 1 engine fire warning and shutdown, and the resultant reduction of available generators to one, should not alone have causedthe subsequent loss of attitude orientation and crash of the aircraft, inasmuch as the aircraft should have been operable with *only* one generator or, indeed, with none at all. In other words, the crew should have been able to land the aircraft safely if there had been no problems other than'the loss of the No. 1 engine.

As the investigation progressed, it became increasingly apparent that the electrical power problems encountered by Flight 266 were most directly responsible for the eventual loss of orientation. In order to facilitate an analysis of the cause, nature, and effect of these problems, a chronological discussion of the pertinent events which occurred on Flight 266 is set forth below.

The CVR shows that the crew on Flight 266 was aware that the No. 3 generator was inoperative prior to departure. It can therefore reasonably be assumed that the second officer turned off the galley power switch and one of the two air conditioning packs prior to takeoff, as prescribed by UAL procedures. Based on the cockpit voice recorder and the flight data recorder, the takeoff and early portion of the climbout were normal. The only indication of anything unusual during this period was the observation of one ground witness that sparks were emanating from the rear engine and right side of the aircraft. As noted previously, one possible explanation for the reported sparks would be a transient compressor or turbine rub or the ingestion of a small particle into the engine. It is also possible that the sparks were an early manifestation of the electrical problem which later was to cause the loss of all generator power. The above explanations are no more than possibilities, however, inasmuch as the available evidence does not permit a conclusive determination concerning the sparks.

At 1818:30, the sound of a warning bell was heard in the cockpit. Four seconds later, the first officer identified the bell as the "number one fire warning," and shortly thereafter the recorded conversation indicates that he pulled back the thrust lever on the No. 1 engine, as prescribed by the engine fire emergency procedures. At 1818:44, a second warning horn was heard, which undoubtedly was the result of the landing gear warning switch being activated as the thrust lever was retarded with the landing gear in the up and locked position.

Commencing at 1818:45, the first officer stated twice that the aircraft was now on one generator. The captain responded by stating "Yeah, watch that electrical loading." It is therefore apparent that the crew was clearly aware of the limitations imposed by the reduction in available electrical power. At 1818:52, the first officer posed the question "Everything off?" which could have been directed to the second officer as a followup to the preceding remark by the captain to assure that all unnecessary electrically powered components were turned off. The first officer's inquiry was apparently satisfied, since there was no further conversation on the subject.

At 1819:05, the first officer reported to Departure Control the predicament of the flight along with the crew's intention to return. At 1819:13.5, 5 seconds after the end of the transmission to Departure Control, CVR operation ceased. Flight recorder operation terminated simultaneously. In addition, the departure controller stated that the transponder target of the aircraft disappeared off the radarscope at approximately this same point in time. It can therefore be concluded that the aircraft lost its only operating generator (No. 2) at 1819:13.5.

The preceding analysis of the events leading up to and including loss of electrical parer is based primarily on the cockpit voice recorder. Although the CVR provides no indications as to the second officer's actions during this period, several deductions in this regard can be made. At the time of the fire warning, the essential power selector switch was probably on the No. 1 engine. 16/ The second officer's first step, as prescribed by the emergency procedures, would have been to move this switch from the No. 1 engine to the No. 2 engine. That he in fact accomplished this step prior to the shutdown of the No. 1 engine is shown by the fact that the CVR, which is connected to the essential bus, remained operating after the No. 1 engine was shut down.

The No. 1 engine would have been shut down by the pulling of the fire switch, which probably occurred not later than-the time (1818:52) when the first officer posed the question "Everything off?" The pulling of this switch energizes a time delay circuit that in turn trips the generator field relay and the generator breaker within 5 to 9 seconds. Accordingly, by 1819:01 at the latest, the No. 2 generator would have been carrying not *only* the essential bus load, but also the loads of all three buses, since it can be assumed that all three bus tie breakers were still closed. At 1819:13.5, the No. 2 generator tripped off the line, leaving the aircraft with no generator power.

The dearth of physical evidence makes it difficult to explain the loss of the No. 2 generator at this point in time. It is not possible to determine from the CVR whether normal electrical power (115 volts) was being developed at the time power was lost. Although the level of power indicated on the CVR was apparently normal, voltage drops of 30 to 40 volts are not detectable on the CVR. If it is assumed that the power level was normal, any of the various fault detection circuits could have operated to trip the No. 2 generator.

In *any* event, it is apparent that the placement of the electrical load of all three generator buses plus the essential bus on the No. 2 generator was instrumental in tripping that generator off the line. If the line voltage dropped abruptly from normal to zero, one possible cause could have been a differential fault. If the problem were a

16/ This switch is normally selected to the operating generator which has the least amount of electrical load on its bus. Of the three generators, No. 3 has the smallest bus load, No. 1 the next largest load, and No. 2 the largest. Since No. 3 generator had been rendered inoperative, No. 1 would have been selected.

differential fault, 17/ it might not have created the 30 to 40 amperes differential required to activate the differential protection circuitry until the loss of the No. 1 generator placed the full electrical load on the No. 2 generator.

Another possible cause of the No. 2 generator's tripping off the line could have been an overload or under voltage condition. Such a condition could have resulted from appropriate reductions in the electrical load not being accomplished subsequent to the loss of the No. 1 generator. Single generator procedures prescribe that the galley power switch and both air conditioning pack switches should be turned OFF. One of the pack fans and the galley power switch should already have been in the OFF position at the time the No. 1 generator was lost since the flaps had not yet been retracted, 18/ leaving *only* the remaining pack fan switch to be turned off to reach the prescribed load level. Accordingly, it is difficult to believe that crew mismanagement of the electrical system produced an overload condition. However, if any one of the various components turned off were not in fact disengaged from the electrical power source, an overload could result. Even if the electrical load had been reduced to the proper level, it is possible that an overload condition resulted from the remaining generator supplying a lower than normal amount of voltage.

If an overload condition did in fact occur, the severity of the condition as well as the manner in which it was imposed may have been significant. Extensive ground and flight testing conducted after the accident indicated that during certain extreme overload conditions, sufficient induced interference may be present on some B-727 aircraft to inhibit proper operation of the No. 2 time delay circuit of the protection panel. The expected action of this panel during such an overload would be to trip the bus tie breaker (BTB), thereby isolating the generator and its load bus from the rest of the system, which usually clears the overload. However, if the No. 2 time delay circuit is disabled by the induced interference, the No. 1 time delay circuit will continue to sense the overload and, after 5 to 9 seconds, will trip the generator control relay and the generator circuit breaker, thus removing the generator from

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17/ A differential fault exists when there is a difference of a certain preset amount line current between the current transformers connected on the neutral side of the generator and those connected on the line side.

18/ Immediately prior to the sound of the fire warning bell, the crew conversation indicates that the first officer moved the flap handle from the 5° to the 2° position.

the system. Applying this theory to Flight 266, it is possible that the sudden shift of the entire electrical load to the No. 2 generator produced a shock load of sufficient dimensions to trigger the sequence described above. 19/

It is remotely possible that the apparently uncorrected problem which existed in the No. 3 generator system may have been a factor in the loss of the No. 2 generator. The No. 3 system was relatively free of problems until the installation on January 13, 1969, of control panel S/N 163, which had an extensive history of malfunctions for a variety of reasons. 20/ Shortly thereafter, the No. 3 generator was replaced because the field relay would not stay closed. Three and a half hours later a similar discrepancy occurred, after which the No. 3 generator was rendered inoperative. The occurrence of two similar problems within such a short time after installation of a control panel, coupled with the fact that the generator which was removed functioned properly in shop tests, indicates that the problem was not corrected and probably was associated with the control panel. At the same time, however, it is unlikely that this problem could have affected the No. 2 generator system since the No. 3 system should have been effectively isolated when it was rendered inoperative 3 days prior to the accident, assuming that the relays involved in isolating the No. 3 system circuitry functioned properly.

Regardless of the cause of the No. 2 generator's tripping off the line, the loss of all generator power should not in itself have resulted in loss of all electrical parer. The aircraft is equipped with a standby system, completely separate from the normal system powered by the generators, which supplies power from the battery to those instruments and radios necessary to allow the captain to make a safe approach and landing under instrument conditions. The standby system is activated, if the battery switch is on, by placing the essential power selector switch in the standby position.

There is evidence, however, that the standby system was not in operation during the period subsequent to loss of the No. 2 generator and prior to the brief restoration of electrical power at an indeterminate later time. If the standby system had been activated, the crew would

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19/ As discussed hereinafter, the battery switch may have been inadvertently turned off prior to loss of the No. 2 generator. Flight tests showed that this too could affect the normal sequence of the tripping of the various breakers.

20/ These problems may have been caused by the fact that Westinghouse Service Bulletin 66-103 (September 1966), which recommended the replacement of a silicone controlled rectifier in order to prevent nuisance tripping of the differential protection circuitry, had not been accomplished on panel S/N 163. This replacement had been accomplished on the panels installed in the Nos. 1 and 2 generating systems on N7434U.

have had available the No 1 VHF transmitter and receiver and, therefore, would have been able to communicate with Departure Control. The flight, however, not only failed to respond to Departure Control's repeated calls, but also reacted to the heading instruction of 060° by turning in the opposite direction. It thus appears that the VHF communications system and, by the same token, the standby system were not functioning. Furthermore, if the standby system had in fact been activated and had operated properly, there would have been no reason to switch the essential power back to the No. 2 generator, which was the setting when power was restored and the aircraft apparently went out of control. In view of the foregoing, the Board concludes that the standby system was not activated or failed to function.

In regard to the fact that the aircraft was flown on a straight course after losing the No. 2 generator, without having reference to attitude instruments, it should be noted that the captain would have had adequate time between the fire warning and the loss of the No. 2 generator to level the aircraft and trim it up for two-engine flight. Unless he had consciously attempted to change heading, the trimmed condition would have kept the aircraft on a relatively straight course, at least for the brief period of time involved. Moreover, when the aircraft lost power and the cockpit became darkened, the captain may have had some outside reference, even if only to a cloud layer.

Although the available evidence does not permit a conclusive determination as to why the standby system was not activated or why it failed to function, one logical explanation therefor involves the relative positions of the battery and galley power switches. N7434U was a QC model aircraft, and due to the requirements for installation of a cargo smoke detector, the battery panel had been moved and the battery switch relocated just above and slightly to the left of the galley power switch. Both are ON-OFF toggle switches. When the No. 1 generator was shut down, one of the first actions of the second officer would have been to reduce the electrical load. One of the components which should be off when operating on one generator is the galley power. Accordingly, even though galley power should have been off since prior to takeoff, the second officer may have instinctively brushed the galley power switch with his hand to make certain it was off and hit the battery switch instead. If the battery switch had been inadvertently turned off in the above manner, there would have been no indication of its being off in the cockpit at that time. Thereafter, when the No. 2 generator was lost, an attempt to activate the standby system would have been unavailing with the battery turned off.

If the battery switch had not been turned off, there are several other possible explanations why the standby system was not activated. The first involves the UAL emergency procedures for loss of all generators. As

constituted at the time of the accident, these procedures included no mention of switching to standby, but rather prescribed that any generator field relay should be closed and the essential power selector placed on the operating generator. It is therefore possible that, following loss of the No. 2 generator, the first officer, either directly referring to the checklist or with it in mind, repeatedly attempted to bring the No. 2 generator back on the line. On the other hand, a UAL instructor trained the second officer to restore generator power only once before switching to standby. Furthermore, if the second officer had not attempted to switch to standby reasonably soon after the No. 2 generator was lost, either the captain or the first officer probably would have reminded him to do so. 21/

A second possible reason that the standby system was not activated, if the battery switch was on, involves the essential power selector switch itself. This switch must pass through a gate in order to be moved into the detented standby position. 22/ Although the second officer should have been familiar with this characteristic of the switch, it is possible that when the cockpit became suddenly and unexpectedly darkened upon loss of the No. 2 generator, he moved this switch counterclockwise until he encountered the obstruction and assumed it was in the standby position. In fact, it would have then been in the APU position, which is a dead circuit in flight.

It is also possible that the standby system failed to function because of a malfunction in the battery or battery charger. This could also explain why the crew eventually switched the essential power switch from standby back to the No. 2 generator, even though that generator was supplying low voltage. A battery malfunction could also constitute a differential fault which might have been the cause of the No. 2 generator initially tripping off the line.

When all generator power was lost, and assuming the standby system was not activated or failed to function, the only lighting available, apart from that which might have been provided by flashlights, would have been the emergency exit lights over the door leading to the passenger compartment. 23/ If that happened, it can be assumed that the second officer was attempting either to activate the standby system or to bring the No. 2 generator back on the line, while the pilots were doing their best to control the aircraft in a semi-darkened cockpit with no attitude

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21/ In this connection, it should be noted that a red light on the second officer's instrument panel becomes illuminated when essential parer is lost. This light will remain on after the essential power selector switch is moved to standby, assuming that the battery switch is on, and thus does not constitute an indication that the standby system is not operating.

22/ The purpose of the detent is apparently to assure that the operator is aware that he is switching to an emergency operation.

23/ These lights are powered by a separate battery and are activated automatically when electrical parer is lost.

instruments. If the battery switch were off, thus making it impossible to activate the standby system, it is difficult to comprehend why one of the crewmembers did not think of this possibility and check the switch. The *only* explanation is that the cockpit was in a state of confusion and each of the crew was busily engaged with his own immediate problems, with the consequence that a switch such as the battery, which is presumed to be on at all time, was overlooked. 24/

As reflected by the reactivation of the flight data recorder and the cockpit voice recorder for 15 and 9 seconds, respectively, the No. 2 generator came back on the line at some later indeterminate time. Although the precise point in time when the two recorders became reactivated, or whether they were reactivated simultaneously cannot be determined, some rough approximations in this regard can be made. The radar controller who was handling Flight 266 estimated that the primary target of the aircraft disappeared from the radarscope within two sweeps, or 5 to 11 seconds, after he directed the flight to turn right to 060°. The controller made two successive transmissions containing this heading direction, the first of which ended at 1820:33, while the second terminated at 1820:44. *primary* target disappearance, based on flight tests, should have occurred as the aircraft was descending through 700 feet and thus can be closely related to the final remarks at the end of the CVR. Three seconds prior to CVR termination, the first officer said to the captain "Keep it going up Arnie, you're a thousand feet" and 2 seconds.later said, "Pull it up." It therefore appears that the CVR ceased operating at about the same time the primary target disappeared. 25/ In view of the absence on the CVR of the Departure Control transmissions at 1820:30 to 1820:33 and 1820:40 to 1820:44, it can be further approximated that the CVR terminated 10 or 11 seconds after completion of the second of these transmissions and had resumed operation at 1820:45 or 1820:46.

The approximate time when the flight data recorder ceased operation following the reactivation period of 15 seconds can be deduced *only* if the final trace indications can be considered reasonably valid. Thus, if the final altitude trace of 630 feet is accepted as a reasonably accurate reflection of the aircraft altitude at that point, it could be concluded that both recorders ceased operation at the same time. It would then follow that the flight recorder resumed operation 6 seconds prior to the CVR.

24/ The *only* indication that the battery switch was not on, apart from the inability to activate the standby system, would have been the absence of certain lights in the cockpit. Under the circumstances, however, their absence might not be recognized.

25/ The conclusion that. the CVR terminated prior to impact, while the aircraft was still airborne, is substantiated by the absence of impact sounds on the recording.

The reasons underlying restoration of the No. 2 generator are difficult to assess, again due to the lack of physical evidence. The fact that components powered by the essential bus (CVR), the No. 2 bus (flight recorder), and the No. 1 bus (air data computer) 26/ indicates that the No. 2 field relay, circuit breaker, and bus tie breaker were all closed and that the essential power selector switch was positioned to the No. 2 generator. 27/ In this connection, the remark by one of the crew, following restoration of power, that the "field's out" undoubtedly was a reference to the field relay light being off, as it should have been since the generator was operating.

Tests based on the power level reflected by the CVR showed that a low voltage condition of approximately 50 volts (as opposed to normal voltage of 115 volts) existed when power was restored on Flight 266. This power level was simulated by starting one generator with normal aircraft loading for two generators applied. If the problem which caused the No. 2 generator to trip off the line still existed, it is possible that the second officer on Flight 266, in a last desperate attempt to restore power, manually closed the No. 2 field relay and held it closed to keep the protection circuitry fromtripping it. Seconds later, as the aircraft entered an abnormal attitude, the second officer's hand may have been thrown away from the panel, thus causing the complete loss of the remaining generator power available.

It is also possible that power was restored as a result of the clearing of the differential fault, if one caused the initial loss of No. 2 generator. If this happened, the low voltage condition should have activated the protective circuitry which, in turn, would have tripped the bus tie breaker and the generator breaker. However, if the battery switch were still off, the sequence and timing of the tripping of these breakers would again have been disrupted. 28/

The fact that the two recorders operated for different lengths of time is difficult to rationalize. The most plausible explanation is that these units require different levels of voltage for their operation and, therefore, as the voltage output of the No. 2 generator built up and then receded, the CVR either became activated later, or deactivated sooner, than the flight recorder.

26/ The flight recorder traces would have been straight horizontal lines if power to the air data computer had not also been restored.

27/ The transponder did not come back on because it has an 80-second protective time delay circuit.

28/ The time delay circuitry, if functioning properly, should have tripped the generator off the line 5 to 9 seconds after power was restored at an undervoltage level. Based on the flight recorder, however, some generator power was available for 15 seconds.

Regardless of the reasons underlying restoration of power, it appears that the second officer was aware that the predicament of the flight was not yet remedied. This conclusion is based on his remark, several seconds after power was restored, that "We're gonna get screwed up," followed by "I don't know (what's going on)."

The remaining question concerns the causal relationship between the electrical system problems discussed above and the eventual crash. Flight tests indicated that electrical power outages would not have a substantial impact on the flight control system. It therefore appears that the most significant adverse effect of the electrical power loss on the capability of the pilots to fly the aircraft would have involved the attitude reference instruments, which are so critical to the operation of an aircraft under instrument conditions.

The basic instrument in the cockpit from which a pilot in a B-727 derives attitude information is the attitude indicator, which in turn receives data from an electrically powered vertical gyro. When N7434U was initially started up, this vertical gyro would have established a vertical plane with reference to the ground. When electrical power was lost in flight, a flag labelled *"gyro"* would have appeared in the lower face of the attitude indicator instrument and the indicator would have rolled to a 90° pitchup attitude. 29/ The gyro itself would then have started to coast down, although a certain amount of stability would have been retained in the gyro assembly. However, if the aircraft attitude were altered from the level position by climbing or descending, or banking left or right, precession of the gyro gimbals would have occurred.

Upon restoration of power, the attitude indicator presentation of 90° pitchup would have rolled back toward the attitude of the vertical gyro. In addition, the vertical gyro would have gone into the-fast erection cycle. However, if the gyro had precessed during the period electrical power was lost, or if the aircraft were in a position other than level when power was restored, the gyro would not be referenced to the ground, but rather would be sensing and erecting toward a false vertical plane. Accordingly, if the captain had attempted to change the attitude of the aircraft toward an instrument indication of level flight under the above conditions, he would have been maneuvering the aircraft with reference to a false "horizon," which would have served to aggravate further an already serious orientation problem.

29/ The *only* other instrument in the cockpit which provides attitude information, the turn needle, is controlled by an electrical signal and therefore would also have been rendered inoperative. When the electrical signal to this instrument was removed, the needle would have remained centered, thus indicating level flight.

The gyro warning flag should have remained in view during the brief period power was restored. 30/ Nevertheless, when the cockpit lights suddenly came on upon restoration of power, causing the loss of whatever outside reference may have been available, the captain might have turned to the gyro horizon as a last resort in attempting to establish the attitude of the aircraft. On the other hand, the intensity of the cockpit lights, in view of the low voltage conditions, may not have been bright enough to allow the pilots to view the instruments. In either event, the pilots would have been without a reliable attitude reference, either inside or outside the aircraft. 31/

The reasons underlying the left turn commenced by Flight 266 prior to disappearing from the radarscope cannot be conclusively determined. The captain may have been attempting to turn back toward the airport, and elected to do so to the left in view of hilly coastline which lay to the north, or right, of the aircraft at that time. It is also possible that the turn represented the early stages of disorientation with regard to the attitude of the aircraft. In *any* event, once the turn was initiated the difficulty of the captain in determining the attitude of the aircraft would have accelerated. This conclusion is substantiated by the remarks of the first officer during the final moments ("Keep it going up . . ." "pull it up"), which apparently were prompted by his concern about the rapid loss of altitude. Even if the captain had pulled back on the yoke in response to those remarks, the descent would not have been arrested unless the wings were levelled. Without any attitude reference, the captain *may* have held the yoke as nearly centered as possible, thus causing the left turn to tighten as the aircraft descended to impact.

One final matter which warrants comment concerns the fact that the captain on Flight 266 had been flying only DC-8's since December 2, 1968. Apparently, there is no difference between the B-727 and the DC-8 in terms of cockpit configuration and instrument location that could have significantly affected the captain's reactions under emergency conditions, other than the fact that the DC-8 has no standby electrical system. Nevertheless, the relative lack of familiarity in itself, resulting from 7 weeks' absence from the aircraft, may have posed problems, albeit minor. For example, the flight controls on the DC-8 require greater pressure to move than those on the B-727. That such a difference is noticeable to pilots is demonstrated by the captain's comment to the first officer, shortly after take-off, "You handle these things light on the controls," to which the first officer responded "Yeah."

30/ Under the low voltage conditions prevailing after power restoration, there would have been no power supplied to the flag retraction circuitry.

31/ The turn needle may also have been affected by the deficiency in the restored power level.

On balance, there is insufficient evidence to support a conclusion that the captain's having flown *only* DC-8's in the 7 weeks preceding the accident was a contributing factor. Nevertheless, the Board believes that this type of scheduling could potentially lead to a compromise in safety. Accordingly, we note with approval that United Air Lines has adopted a procedure whereby pilots who have completed transitional training in a particular aircraft are afforded the opportunity to re-familiarize themselves in another aircraft, in which they had previously been checked out, prior to being assigned flights in the latter aircraft.

2.2 Conclusions

(a) Findings

1. The flightcrew was properly certificated and qualified to conduct the flight.

2. The captain had been transitioning to the DC-8 during the period prior to the accident and had not flown in a B-727 since December 2, 1968.

3. The aircraft was properly certificated and airworthy.

4. The aircraft had been operating for 42 flight hours prior to the accident with the No. 3 generator inoperative, as allowed by the Minimum Equipment List.

5. The discrepancy which caused the No. 3 generator to be rendered inoperative had not been corrected and probably was associated with its electrical control panel.

6. The flight experienced a fire warning on the No. 1 engine during climbout and the engine was shut down.

7. There was no physical evidence in the recovered wreckage indicating that an in-flight fire had occurred.

8. shortly after shutdown of the No. 1 engine, electrical power from the remaining generator (No. 2) was lost.

9. The available evidence does not permit a determination as to the exact cause of the loss of all generator power, other than associating this loss with the sudden placement of all three generator bus loads, as well as the essential bus, on the No. 2 generator.

10. Following loss of all generator power, the standby electrical system either was not activated or failed to function.

11. Electrical power at a voltage level of approximately 50 volts was restored approximately a minute and a half after loss of the No. 2 generator.

12. The duration of power restoration was 9 to 15 seconds, following which power was again lost at some indeterminate point prior to impact.

13. The aircraft was in an abnormal attitude at impact.

14. The No. 2 and No. 3 engines were developing power at impact.

15. There was no evidence of a malfunction in the flight control system.

16. The flight was conducted under night, instrument conditions.

17. The pilots would have been without a reliable attitude reference, either inside or outside the aircraft, from the point in time the No. 2 generator was lost until impact.

(b) ~~Probable Cause~~

The Board determines that the probable cause of this accident was loss of attitude orientation during a night, instrument departure in which the attitude instruments were disabled by loss of electrical power. The Board has been unable to determine (a) why all generator power was lost or (b) why the standby electrical power system either was not activated or failed to function.

3. RECOMMENDATIONS AND CORRECTIVE MEASURES

By letter dated July 11, 1969, the Chairman of the Safety Board recommended to the Administrator of the FAA that the automatic switching of essential power to standby power upon loss of all generators be made a mandatory requirement for all turbine-powered aircraft. It was further recommended that until such time as the above requirement could be implemented throughout the industry, the emergency checklists for all airlines pertaining to "Loss of all Generators" require that the second officer, or captain if appropriate, check to assure that the battery switch is ON, then immediately switch essential power to the standby or emergency position. It was the Safety Board's view that this would give the captain the instruments and lights necessary to fly the aircraft while the second officer could "troubleshoot" the electrical system.

In his response of July 28, 1969, the Administrator stated that the FAA had been investigating electrical emergency operating procedures for some time and action was being taken to prescribe procedures for the B-727 consistent with Safety Board recommendations. 32/ With regard to automatic switching for essential flight instruments, the Administrator's letter referred to Sections 25.1309 and 25.1333 of Notice of Proposed Rule Making (NPRM) 68-18, which provide for the immediate availability of essential instruments after electrical failures and which apply to aircraft with a date of application for type certification after adoption of the proposed rule. For inservice aircraft, the FAA had issued NPRM 69-26 which provides for the installation in large turbojet-powered airplanes used in the air carrier service of a third independently powered attitude indicator. 33/ The Administrator expressed the belief that this action, combined with specified airplane flight manual emergency procedures, will provide for a satisfactory level of safety for inservice aircraft.

In order to remove *any* doubt as to the status of the standby system during a "Loss of all Generators" emergency, it is further recommended that the second officer on a B-727 be provided with a positive indication on

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32/ The FAA issued an Airworthiness Directive, effective August 1, 1969, requiring revision of the Boeing 727 Airplane Flight Manual, Emergency Procedures Section, Loss of all Generators paragraph, to include procedures which would direct the flightcrew to switch to the standby power system, insure the battery switch is "ON", and reduce loads.

33/ The proposal embodied in NPRM 69-26 was adopted on January 8, 1970, and became effective on February 5, 1970, as Section 121.305(j) of the FAR, which requires that the additional attitude indicator be installed on all large turbojet aircraft after August 5, 1971.

his panel when the standby system is being powered from the battery. Such an indication could take the form of a light, such as that installed on the B-747 aircraft for the same purpose. The light would become illuminated when the standby system is activated. Another alteration which might be considered in connection with the foregoing recommendation would be the transfer of the standby feature from the essential power selector switch to a separate ON-OFF toggle switch, which again is the arrangement on the B-747. The addition of such a switch would not only serve to simplify activation of the standby system, but would also facilitate troubleshooting the generators when the standby system is on.

The FAA also took several other actions relating to the subject accident. As a result of information developed during the early stages of the investigation, the FAA issued an Airworthiness Directive by telegram on January 31, 1969, requiring B-727 operators to provide a means to prevent inadvertent operation of the battery switch in those aircraft in which the battery switch is located within 10 inches of the galley power switch.

On August 1, 1969, the FAA proposed an Airworthiness Directive requiring the installation of a capacitor, in accordance with Boeing Service Bulletin No. 24-47 (March 3, 1969), for the purpose of filtering out electrical interference which may be present to a sufficient extent on some B-727 aircraft that, under an overloaded condition, the generator control panel may disable the generator before opening the bus tie circuit breaker.

On September 10, 1969, the FAA proposed an Airworthiness Directive which would require replacement of both silicon controlled switches CR 10 and CR 28 with a transistorized amplifier and a miniature two-pole relay on B-727 airplanes, in accordance with Westinghouse Service Bulletin 103, dated September 15, 1966. As a reason for this replacement, the FAA cited failures of the generator overload protection circuit silicon controlled rectifiers, causing a single generator system lockout on B-727 aircraft.

During the investigation, a considerable amount of attention was focused on the Minimum Equipment List (MEL) and, more specifically, on the question of whether the MEL, with regard to the required number of operative generators, was adequate in light of the subject accident. The MEL for the E727 was established through extensive ground and flight testing, after which it was agreed through meetings with the involved parties, including the FAA, Boeing, and United, that the aircraft would be airworthy with two generators. An additional margin of safety was provided by the standby system, through which electrical power could be supplied from the battery to those instruments and components necessary to enable the pilot to make an approach and landing under instrument conditions. The third generator was included on the B-727, not as a

matter of safety, but rather to enhance schedule dependability. For example, if one of the three generators should become disabled, the aircraft would still be able to operate without delay through small fields which lack the maintenance capability to repair an inoperative generator.

Subsequent to certification, the B-727 electrical system has been altered in minor respects *only*, which primarily involved changes in procedures rather than increases in loading. Furthermore, the flight tests conducted after the accident substantiated the ability of the aircraft to carry design loads during one and two generator operation. Finally, and perhaps most importantly, the fact that Flight 266 departed with one generator inoperative cannot be classified as a causal factor in the accident. The shutdown of the No. 1 engine, the loss of the No. 2 generator, and the nonactivation of the standby system are all unrelated to the No. 3 generator in terms of cause.

In view of the foregoing, the Board believes there is no basis upon which to recommend that the MEL for the B-727 be revised to require that all three generators be operative. At the same time, we believe that repairing components beyond those required by the MEL, as soon as practicable, is consistent with sound maintenance and engineering practices. Furthermore, it can even be said that maintaining such components in operating condition has the added effect of enhancing safety, inasmuch as it increases the available degree of redundancy.

Finally, a brief comment is warranted concerning the overall electrical system on the B-727. Recommendations have been made and corrective measures adopted, as described hereinabove, to correct those discrepancies and procedures uncovered during the investigation which might have contributed to the accident. The Board believes that these steps should go a long way toward preventing the occurrence of a similar accident. At the same time, we recognize that effective prevention is limited by the fact that the lack of physical evidence has not allowed a conclusive determination of why the No. 2 generator was lost and why the standby system was not activated or failed to function. Our concern in this instance is increased by the several incidents subsequent to the accident involving loss of all three. generators on B-727 aircraft. Despite the generally excellent performance history of the B-727 electrical system, the possibility remains, unless and until the reasons underlying these

power losses are determined, that a common problem within the system is responsible. Accordingly, the Board urges all B-727 operators to be particularly thorough in investigating *any* incidents of a similar nature in order that every possible effort be made to uncover this problem, should one exist.

BY THE **NATIONAL TRANSPORTATION SAFETY BOARD:**

/s/ JOHN H. REED
Chairman

/s/ OSCAR M. LAUREL
Member

/s/ FRANCIS H. McADAMS
Member

/s/ LOUIS M. THAYER
Member

/s/ ISABEL A. BURGESS
Member

March 18, 1970

INVESTIGATION AND HEARING

1. Investigation

The Board received official notification of the accident at approximately 2200 e.s.t., on January 18, 1969. An investigating team was dispatched from Washington, D. C., several hours thereafter and arrived in Los Angeles in the early morning hours of January 19. Upon arrival, working groups were established for Operations, Witnesses, Air Traffic Control, Human Factors, Weather, Structures, Powerplants, Systems, Maintenance Records, Cockpit Voice Recorder, and Flight Recorder. Parties of Interest participating in the investigation included the Federal Aviation Administration, United Air Lines, the Boeing Company, Air Line Pilots Association, Pratt & Whitney Division of United Aircraft Corporation, and Professional Air Traffic Controllers Organization. Due to the difficulties involved in locating and recovering the wreckage, the on-scene investigation was not completed until March 19, 1969.

The on-site investigation consisted basically of four phases: (a) search for the wreckage, (b) identification and plotting of wreckage, (c) recovery of priority items, and (d) recovery of remaining parts of the wreckage. The wreckage was located on January 31, 1969, in approximately 1,000 feet of water by a vessel equipped with side-looking sonar equipment. 34/ The plotting and identification of the wreckage was accomplished by this same vessel utilizing "J-Star" equipment, which has both television and sonar capability. The three engines were recovered on February 11, 1969, with the assistance of this equipment outfitted with a special clamp. The voice recorder, flight recorder, small engine components and some electrical parts were recovered during the period February 21, 1969, through March 4, 1969, by a submersible vehicle. The final gross recovery phase was carried out during the period March 6, 1969, through March 19, 1969, by means of a trawler, which involves dragging a net over the ocean floor.

2. Hearing

A public hearing was held at the Miramar Hotel in Santa Monica, California, on August 13 to 15, 1969.

3. Preliminary Reports

A preliminary aircraft accident report summarizing the facts disclosed by the investigation was published by the Board on June 9, 1969. A summary of the testimony which was taken at the public hearing was released on September 5, 1969.

34/ Sonar (sound navigation ranging) is an apparatus which transmits high-frequency sound waves in water and registers the vibrations reflected back from an object.

APPENDIX B

CREW INFORMATION

	Captain	First Officer	Second Officer
Address:	Leonard A. Leverson 2036 Victoria Drive Santa Ana, Calif.	Walter R. Schlemmer 3131 Old Coach Drive Camarrillo, Calif.	Keith R. Ostrander 506 Dena Drive Newbury Fark, Calif.
Age:	49	33	29
Hire Date:	9/26/46	5/4/64	10/9/67
Certificates Held:	ATR 470722 Class I Medical Dated 11/26/68	Commercial 1582882 F/E - 1601250 Class II - 1/29/68	Commercial 1711270 F/E(S/O) - 1812272 Class II - 9/13/68
Limitations:	None	None	None
Pilot Ratings:	ASEL & MES & Instrument DC-3, CV-340, DC-6/7 DC-8, B-727	AMEL & Instrument DC-6/7, B-727	ASEL nc-6, B-727
Total Time (T.T.):	13,665 hours	6642 Pilot, 889 S/O	174 Pilot, 460 S/O
T. T. in Type:	1,908 hours	1842 Pilot, 543 S/O	40 S/O
T. T. Last 90 Days:	78 hours	200 hours	40 hours
T. T. last 90 Days in Type:	61 hours	200 hours	40 hours
Rest Period 24 Hours Prior to Accident:	22.6 hours	22.6 hours	22.6 hours
Duty Time Last 24 Hours:	1.4 hours	1.4 hours	1.4 hours
Time This Flight:	.3 hours	.3 hours	.3 hours

APPENDIX C

TRANSCRIPTION OF VOICE COMMUNICATIONS RECORDED ON THE LAST 2 MINUTES AND 25 SECONDS OF THE CAM AND COPILOT'S RADIO CIRCUITS OF THE COCKPIT VOICE RECORDER TAPE FROM UNITED AIR LINES FLIGHT 266, N7434U, B-727, WHICH CRASHED INTO THE SEA SHORTLY AFTER TAKEOFF FROM LOS ANGELES INTERNATIONAL AIRPORT, LOS ANGELES, CALIFORNIA, ON JANUARY 18, 1969.

Legend

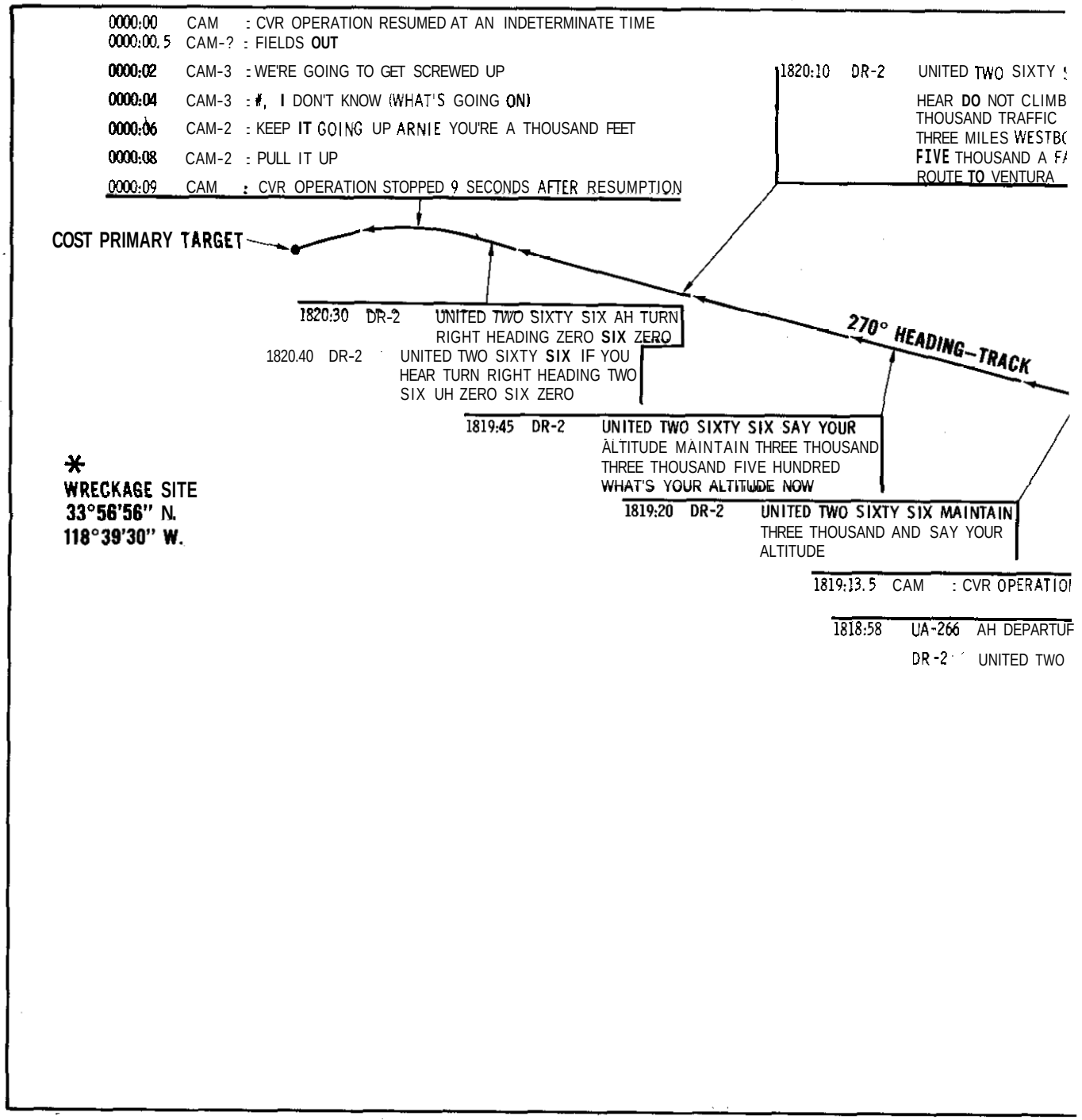
CAM	-	Cockpit area microphone circuit
1	-	Voice identified as the Captain's
2	-	Voice identified as the Copilot's
3	-	Voice identified as the Engineer's
RDO	-	Radio transmission from UAL 266
TWR	-	Radio transmission from Los Angeles Tower's Local Control Position
LAX DR	-	Radio transmission from Los Angeles Departure Radar
%	-	Unrelated Radio Transmissions
#	-	Non-pertinent word or phrase
( )	-	Words enclosed within parentheses are not clearly understood and are subject to interpretation. Those shown represent the interpretations of what the speaker said.
---	-	Series of dashes indicates a pause in a transmission.

Transcript begins with flight's clearance for takeoff. When clearance is received, the aircraft is holding position for takeoff on Runway 24.

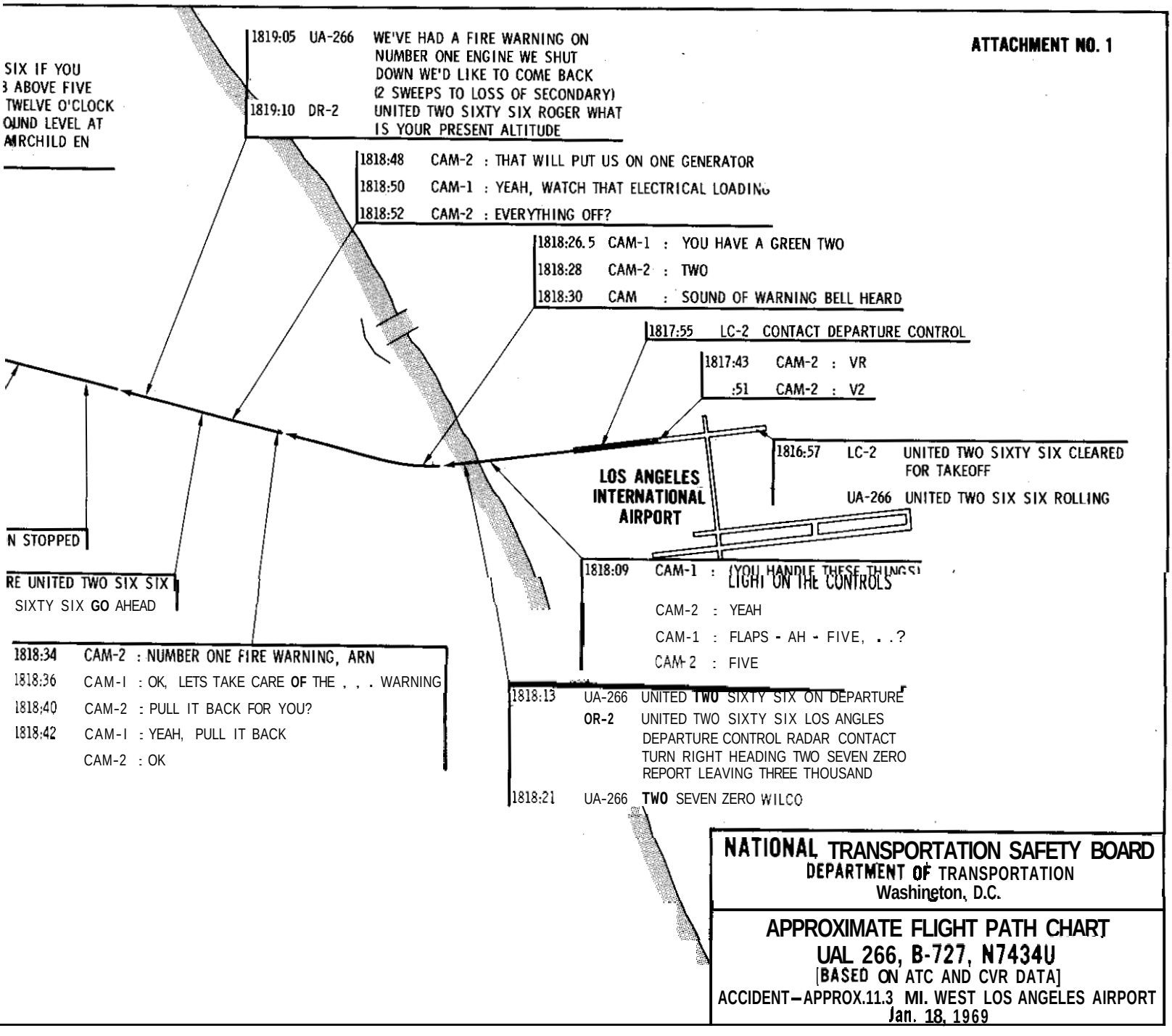
TIME	SOURCE	CONTENT
1816:58	TWR	United two sixty six cleared for takeoff
1817:00	RDO 2	United two six six rolling
:02	CAM	Last three items
:05	CAM 3	Engine start switches
:06	CAM2	(Three on)
:07	CAM 3	Anti skid
:10	CAM2	On (release)
1817:11	CAM?	(Yeah that's good)
	CAM?	Oil cooler (comin) ground off
	CAM ?	(You kicked off Dick?)
1817:14	CAM 2	They're stabilized
1817:20.5	CAM	Take off thrust
:22	CAM2	Set
:23	CAM2	Looks good
		% % %
1817:37	CAM2	One hundred
:39.5	CAM2	One ten
:42	CAM 2	One twenty
1817:43	CAM2	VR
:51	CAM2	V2
:52.5	CAM 1	Gear up
:53	CAM2	Gear up
1817:55	TWR	United two sixty six contact departure control
:59	RDO 2	Changing
		% % %

1818:09	CAM1	(You handle these things) light on the controls
	CAM2	Yeah
	CAM1	Flaps-ah-five . . . ?
	CAM2	Five
1818:13	RDO 2	United two six six on departure
:15	LAX DR	United two sixty six Los Angeles departure control radar contact, turn right heading two seven zero report leaving three thousand
1818:21	RDO 2	Two seven zero wilco
1818:26.5	CAM1	You have a green two
:28	CAM 2	Two
1818:30	CAM	Sound of warning bell heard
1818:31.5	CAM2	# #
:32.5	CAM1	What the hell was that?
:34	CAM2	Number one fire warning, Am
:36	CAM1	OK, lets take care of the - - - - - warning
:40	CAM2	Full it back for you?
:42	CAM1	Yeah, pull it back
	CAM2	OK
1818:44	CAM	Sound of warning horn heard
1818:45	CAM2	That puts us on one # # generator too
	CAM1	Huh?
	CAM2	That'll put us on one generator
:50	CAM1	Yeah, watch that electrical loading
:52	CAM2	Everything off?

1818:58	RDO 2	Ah-departure United two six six
1819:04	LAX DR	United two sixty six go ahead
:05	RDO 2	Ah we've had a fire warning on number one engine, we shut down we'd like to come back
1819:10	LAX DR	United two sixty six roger what is your present altitude?
1819:13.5	CAM	CVR operation stopped
0000:00	CAM	CVR resumed operation at an indeterminate later time
:00.5	CAM ?	Fields out
:02	CAM 3	We're gonna get screwed up
:04	CAM 3	#, I don't know (what's going on)
:06	CAM 2	Keep it going up Arnie you're a thousand feet
:08	CAM 2	pull it up
:09	CAM	End of recording. CVR ceased to operate


0000:00 CAM : CVR OPERATION RESUMED AT AN INDETERMINATE TIME
0000:00.5 CAM-? : FIELDS OUT
0000:02 CAM-3 : WE'RE GOING TO GET SCREWED UP
0000:04 CAM-3 : #, I DON'T KNOW (WHAT'S GOING ON)
0000:06 CAM-2 : KEEP IT GOING UP ARNIE YOU'RE A THOUSAND FEET
0000:08 CAM-2 : PULL IT UP
0000:09 CAM : CVR OPERATION STOPPED 9 SECONDS AFTER RESUMPTION
1820:10 DR-2 UNITED TWO SIXTY
HEAR DO NOT CLIMB
THOUSAND TRAFFIC
THREE MILES WESTBO
FIVE THOUSAND A FA
ROUTE TO VENTURA
COST PRIMARY TARGET
1820:30 DR-2 UNITED TWO SIXTY SIX AH TURN
RIGHT HEADING ZERO SIX ZERO
1820.40 DR-2 UNITED TWO SIXTY SIX IF YOU
HEAR TURN RIGHT HEADING TWO
SIX UH ZERO SIX ZERO
270° HEADING-TRACK
1819:45 DR-2 UNITED TWO SIXTY SIX SAY YOUR
ALTITUDE MAINTAIN THREE THOUSAND
THREE THOUSAND FIVE HUNDRED
WHAT'S YOUR ALTITUDE NOW
1819:20 DR-2 UNITED TWO SIXTY SIX MAINTAIN
THREE THOUSAND AND SAY YOUR
ALTITUDE
1819:13.5 CAM : CVR OPERATIO
1818:58 UA-266 AH DEPARTUF
DR-2 UNITED TWO
*
WRECKAGE SITE
33°56'56" N.
118°39'30" W.

ATTACHMENT NO. 1



NATIONAL TRANSPORTATION SAFETY BOARD
DEPARTMENT OF TRANSPORTATION
Washington, D.C.

APPROXIMATE FLIGHT PATH CHART
UAL 266, B-727, N7434U
[BASED ON ATC AND CVR DATA]
ACCIDENT—APPROX.11.3 MI. WEST LOS ANGELES AIRPORT
Jan. 18, 1969