CONTROLLED IMPACT DEMONSTRATION
FLIGHT DATA RECORDERS/COCKPIT VOICE RECORDERS

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We know what the probable cause of the accident was in the CID program, obviously, and that was not why we had flight data recorders on the airplane. We decided, about 3 years ago, to see how well we could get suitable instrumentation and flight data recorders on a Boeing 720 aircraft to correlate the performance data on the aircraft itself with data from the various experiments we had on the aircraft in the crashworthiness area. Also, in trying to come up with the scenario alluded to earlier (ref. 1), where we had a certain sink speed, glidepath angle, and so forth, we went through 20 years of air carrier accident data to try to arrive at an impact scenario. The required data are not, in all cases, in NTSB accident reports. So, we're hoping that we can provide enough information from this experiment to be able to develop a survivable crash scenario should the need arise. (See fig. 1.)

Basically, on the airplane we had three DFDRs (digital flight data recorders), one each from Sundstrand, Fairchild, and Lockheed. We borrowed them with the promise that we would not hurt them, and they were subsequently practically destroyed by fire, but they all operated properly. We also had a Teledyne Flight Data Acquisition Unit (FDAU), which is nothing more than a signal conditioner. We had 11 sensors, which I will describe in more detail shortly. In addition, we had a new Fairchild Cockpit Voice Recorder (CVR) installed. We wanted to make sure that we would get data during the slideout of the aircraft, or if there had been a second impact we wanted to be able to get additional data assuming the original power supply of the aircraft failed. So we had a 28-V battery and a 115-V/400-Hz inverter also installed on the airplane. We left the existing foil flight data recorder on the airplane, and we had a Navy Deployable Flight Incident Recorder (DFIR). We also had a special Lear Siegler Solid-State Memory Unit on the airplane. Neither of these two devices was attached to sensors or recording; they both had prerecorded data sets in them. Figure 2 shows the various groups that participated.

Figure 3 shows the parameters to be recorded. We wanted aircraft performance data during impact and slideout, so we put in a new transducer for pressure altitude. We could not tie into any of the aircraft systems that dealt with the RPV system because there is a potential for signal contamination there, so we wanted a completely independent sensor system with the exception of two signals. We had new transducers for altitude and airspeed. For magnetic heading, we were allowed to tie into the existing sensor system on the airplane. We procured a special triaxial accelerometer for this experiment with a vertical acceleration range of 50 g's, a longitudinal range of 50 g's, and a lateral range of 10 g's. This assumed that we could have a fairly high kinetic energy impact condition. We found out later that the range was too high. We lost some resolution as a result. We had a vertical gyro installed in the aft end of the aircraft to give us our pitch and roll information. Because of the ground effect on the airplane, the airspeed and pressure altitude signals started to get a little unreliable as the plane got closer to the ground. Accordingly, we also wanted to record radar altitude. We procured a special vertical speed indicator, which was a pressure transducer with vertical accelerometer complimentation, from Teledyne to see if it could record vertical velocity independently.

Figure 4 is a schematic of the overall installation of the three recorders. Everthing was to be mounted on a common pallet the flight data acquisition unit; pressure altitude, indicated airspeed, pitch, roll, and vertical speed sensors; and the static inverter/battery power supply. For the final flight we did not use aircraft electrical power; we used the battery pack and static inverter unit. Figure 5 shows the installation, which was in the aft end of the passenger area of the aircraft. Here we had the three data recorders, flight data acquisition unit, static inverter, and battery pack. Of course, we also had the existing flight data recorder and the CVR units in the aft closet area. The FAA had put them there some time ago, probably for easier maintenance.

Figure 6 shows the installation of the existing cockpit voice recorder and foil flight data recorder in the most aft bulkhead in the aircraft. The vertical speed sensor (fig. 7) was located on top of that pallet for ease of maintenance.

On December 2, one day after the crash, we were the first group, as in any accident, to go in and retrieve the flight data recorders (fig. 8). We took the flight data recorder pallet out and placed the units, the three flight data recorders, the flight data acquisition unit, and the battery pack on the lakebed (fig. 9). We then had the units shipped down to Lockheed for preliminary checkover (fig. 10). They were pretty well scorched on the outside, but later on we found that overall they were in pretty good shape inside. Figure 11 shows the Lockheed digital flight data recorder. It has a protection environment for impact and fire. What we were concerned about was saving the data tape.

Figure 12 shows the tape deck removed from the unit as well as the drive mechanism. Figure 13, which is a back view, shows some scorching inside in the tape drive section, but again, this was of no concern to us. Figure 14 shows a closeup of the tape drive system recording heads and the interconnect module.

Lockheed took this data tape and put it on a regular recorder at their plant (fig. 15), plugged it into their data reduction or data retrieval and plotting system, and came up with good data.

What we learned from this was survivability in the impact and fire environments; all the flight data recorders survived (fig. 16). In fact, the flight data recorders with the battery pack ran for 8 minutes after the initial impact. The impact environment was, as far as g loads go, not a problem from a high-g viewpoint in survivability of the data tape. However, as far as operations went, regular operation of the recording mechanism was a problem. Data from the foil recorder were processed by Douglas (fig. 17). The cockpit voice recorder data were handled by the National Transportation Safety Board, and the tapes from the DFDRs were handled by their respective vendors.

Recording operations were our major problem. Right at impact, certain things can happen. The tape can stretch and the electrical-mechanical drive system can malfunction momentarily. (I'm speaking now of the three flight data recorders.) We had a momentary recording malfunction to the three flight data recorders, on the order of 5 to 7 seconds. The three contractors or vendors from whom we procured the flight data recorders feel that they can still come up with useful data right at the point of impact and for about 3 or 4 seconds after impact. However, this is a deficiency in the recording system. Because we wanted to compare the data that we acquired on the tapes with those from the experiments on the airplane, this may pose a problem for the time interval right at and immediately after impact.

We found that the sampling rates were too low although they were higher than those required now by regulations. For example, the sampling rate for roll angle is one per second, but you saw what the aircraft was doing as it was coming in for impact. One moment we got a sample of zero degrees; the next thing you have is the aircraft in a 6-degree bank angle, then a 12-degree bank angle. The sampling rate for normal acceleration is also fairly low. Existing regulaitons require only 4 samples per second; we had 16 samples per second, and we're starting to lose some data just during the initial impact. We're not getting the frequency response we would like to have.

As far as correlation with the crashworthiness experiments onboard - structural loads, seat loads, and anthropormorphic dummy loads - that remains to be seen.

REFERENCE

1. Barber, Russ: CID Flight/Impact. Full-Scale Transport Controlled Impact Demonstration, NASA CP-2395, 1986, pp. 17-28.

REQUIREMENTS

- PROCURE/INSTALL STATE-OF-THE-ART DFDRS/CVRS AND APPROPRIATE SENSORS TO ACQUIRE AIRCRAFT PERFORMANCE DATA DURING IMPACT AND "ROLLOUT"

OBJECTIVES

- DEMONSTRATE ADEQUACY/USEFULNESS OF ADDITIONAL DATA IN POST-IMPACT ACCIDENT INVESTIGATION/ANALYSIS IN HUMAN FACTORS AND CRASHWORTHINESS AREAS AND CRASH SCENARIO DEVELOPMENT

COMPONENTS AND LOCATION

- FAA
  - BASIC INSTALLATION
    - THREE DFDRS
    - ONE FLIGHT DATA ACQUISITION UNIT (FDAU)
    - 11 SENSORS
    - ONE COCKPIT VOICE RECORDER (CVR)
    - BATTERY/INVERTER POWER SUPPLY
  - CURRENT B-720 INSTALLATION
    - ONE FDR
    - ONE CVR
- NAVY
  - DEPLOYABLE FLIGHT INCIDENT RECORDER (FIR)
  - ELECTRONIC LOCATOR TRANSMITTER (ELT)
  - (NON-OPERATIONAL RECORDING SYSTEM)
  - (PRE-RECORDED DATA SET)
- OTHER:
  - LSI AVIONICS SOLID-STATE MEMORY UNIT
  - (NON-OPERATIONAL RECORDING SYSTEM)

Figure 1

ORGANIZATION	KEY PERSONNEL	POSITION
FAA (TECHNICAL CENTER) (ATLANTIC CITY, NJ)	LEO GARODZ	DFDR/CVR PROG MGR
LOCKHEED AIRCRAFT SERVICES (ONTARIO, CALIF)	DICK NANCE GRAHAM LEROY DAVID GONZALEZ	PROGRAM MANAGER, SR SR. SYSTEMS ENGINEER SYSTEMS ENGINEER
TELEDYNE CONTROLS (W. L.A., CALIF)	LARRY FOX GEORGE ORENDY	PRINCIPAL DESIGN ENGR TECHNICAL ADMINISTRATOR
FAIRCHILD AVIATION RECORDERS FAIRCHILD WESTON SYSTEMS, INC.	HANS F. NAPEL BARRY HAWKINS	DIRECTOR OF ENGINEERING (MARKETING MANAGER)
SUNDSTRAND DATA CONTROL (REDMOND, WASHINGTON)	RAY E. JOHNSON MICHAEL RHODE	DFDR DATA REDUCTION SPEC. (MARKETING MANAGER)
NAVY (NATC) (PATUXENT RIVER, MD)	DAN WATTERS	PROGRAM MANAGER
LEIGH INSTRUMENTS LTD. (CANADA)	JAMES W. WELLS	PROGRAM MANAGER
LEAR SIEGLER, INC.	ISADORE LURMAN	PROGRAM MANAGER

Figure 2

PARAMETER	RANGE	SOURCE
1. TIME (ELAPSED)		INTERNAL TO FDAU
2. ALTITUDE	-1000 to 40,000 ft	NEW TRANSDUCER
3. AIRSPEED	75 to 350 knots	NEW TRANSDUCER
4. MAG HEADING	0 to 360°	EXISTING AIRCRAFT SIGNAL
5. VERTICAL ACC: N	+50 g	
6. LATERAL ACC: N	+10 g	NEW TRANSDUCER
7. LONGITUDINAL ACC: N	+50 g	
8. PITCH ALTITUDE	$+82^{\circ}$	NEW VERTICAL GYRO
9. ROLL ANGLE	$+180^{\circ}$	
10. RADAR ALTITUDE	0 to 2500 ft	EXISTING AIRCRAFT SIGNAL
11. VERTICAL SPEED	0 to 600 ft/min	NEW TRANSDUCER

Figure 3

720B — FLIGHT DATA RECORDING SYSTEM

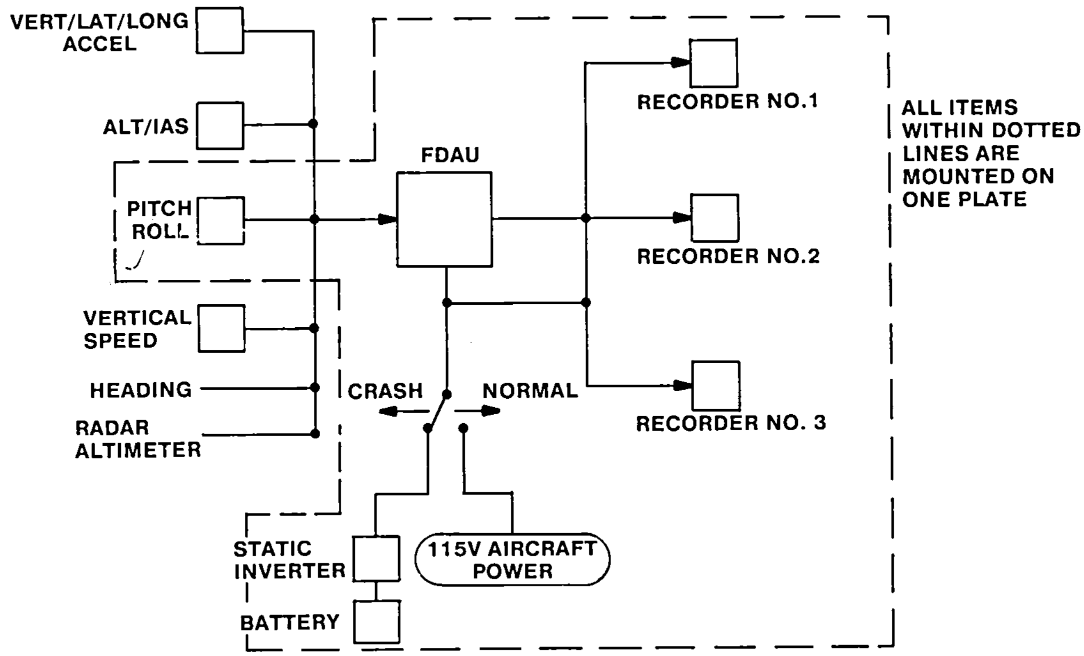


Figure 4

INSTALLATION DETAILS

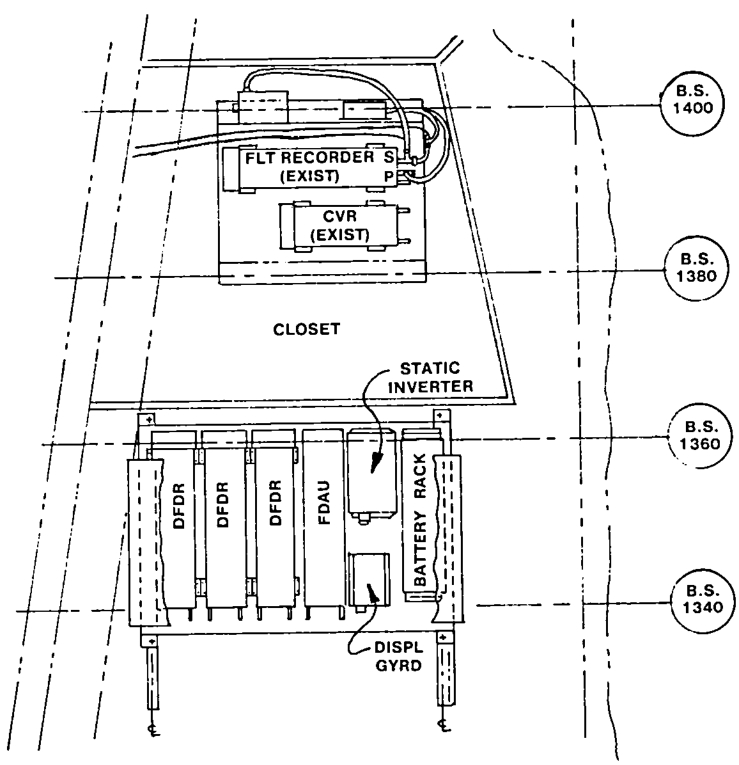


Figure 5

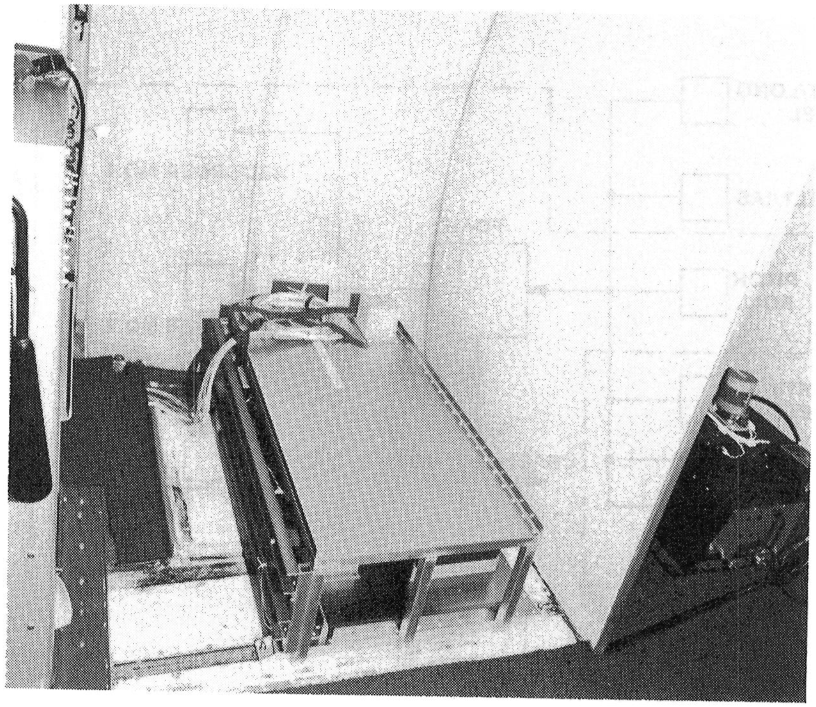
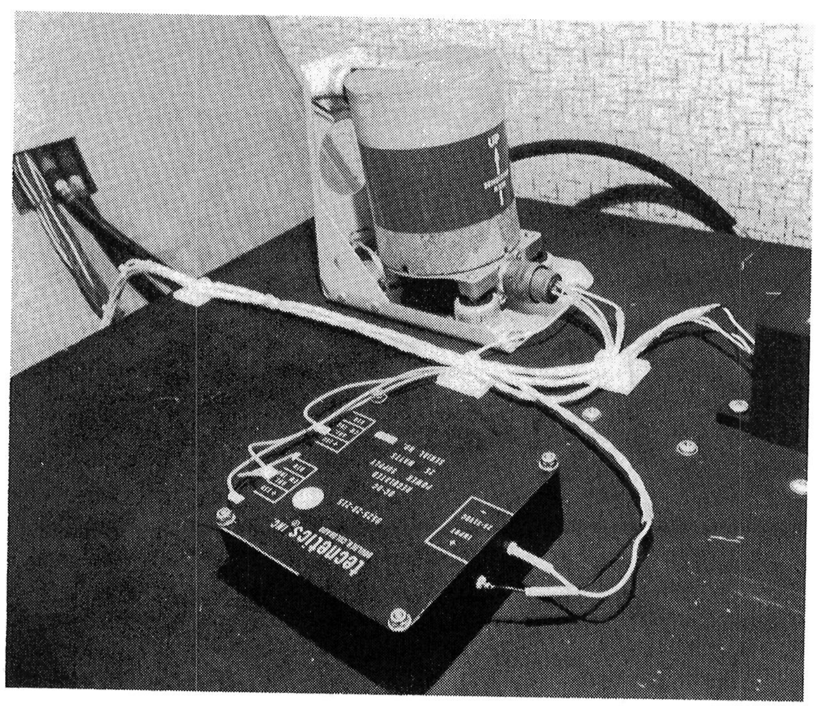


Figure 6



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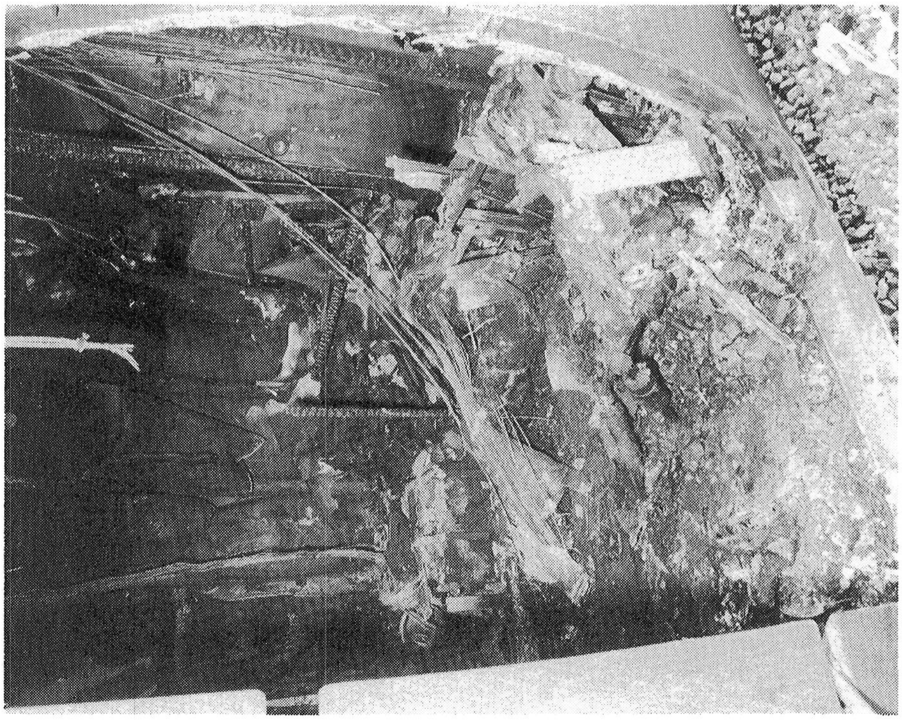

Figure 8

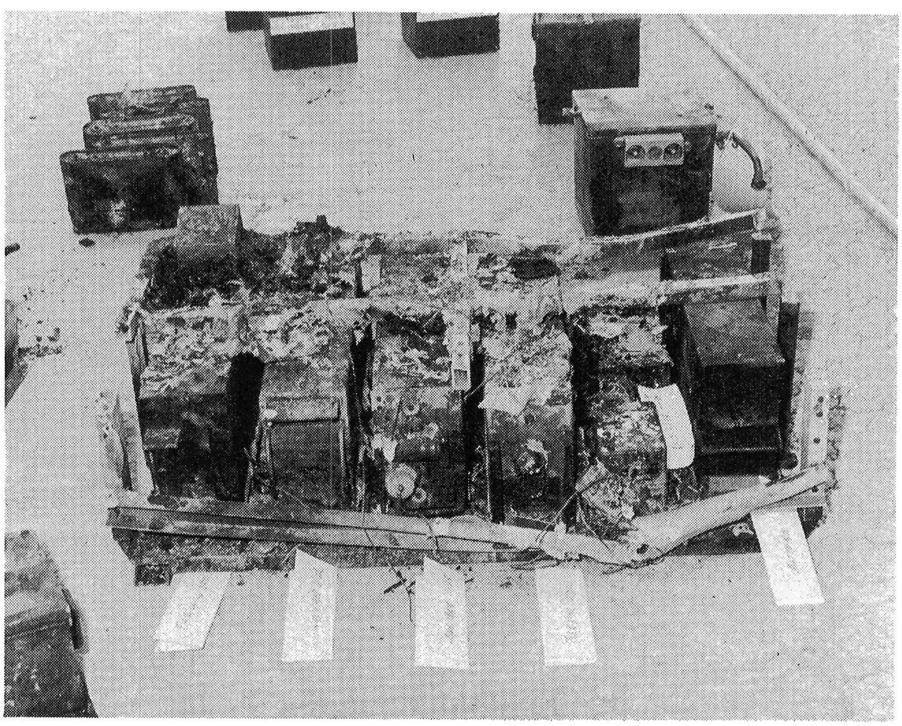

Figure 9

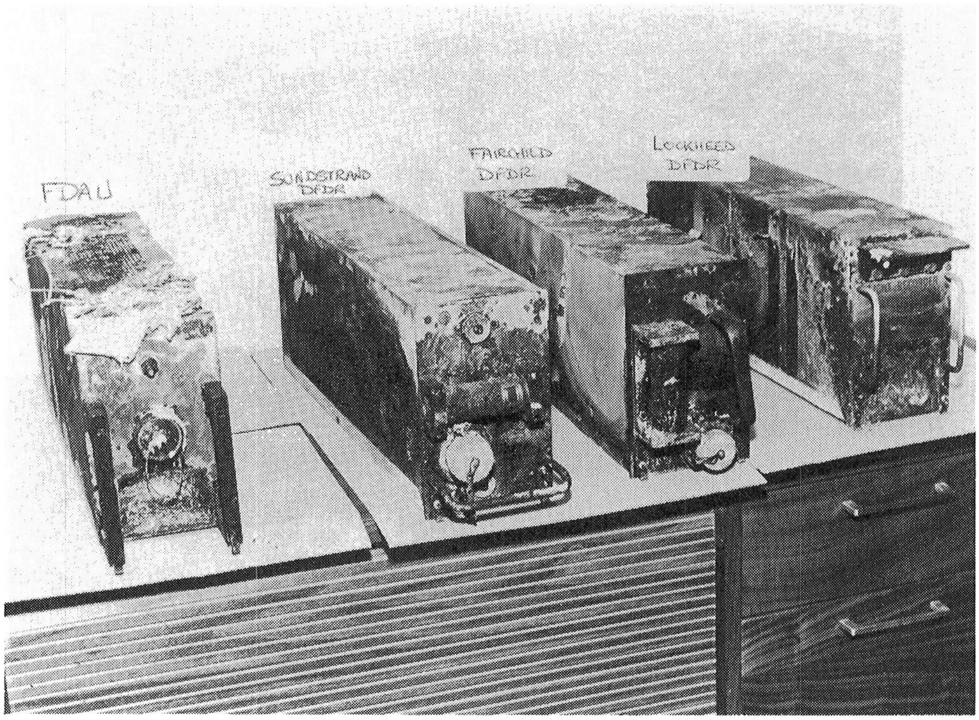

Figure 10

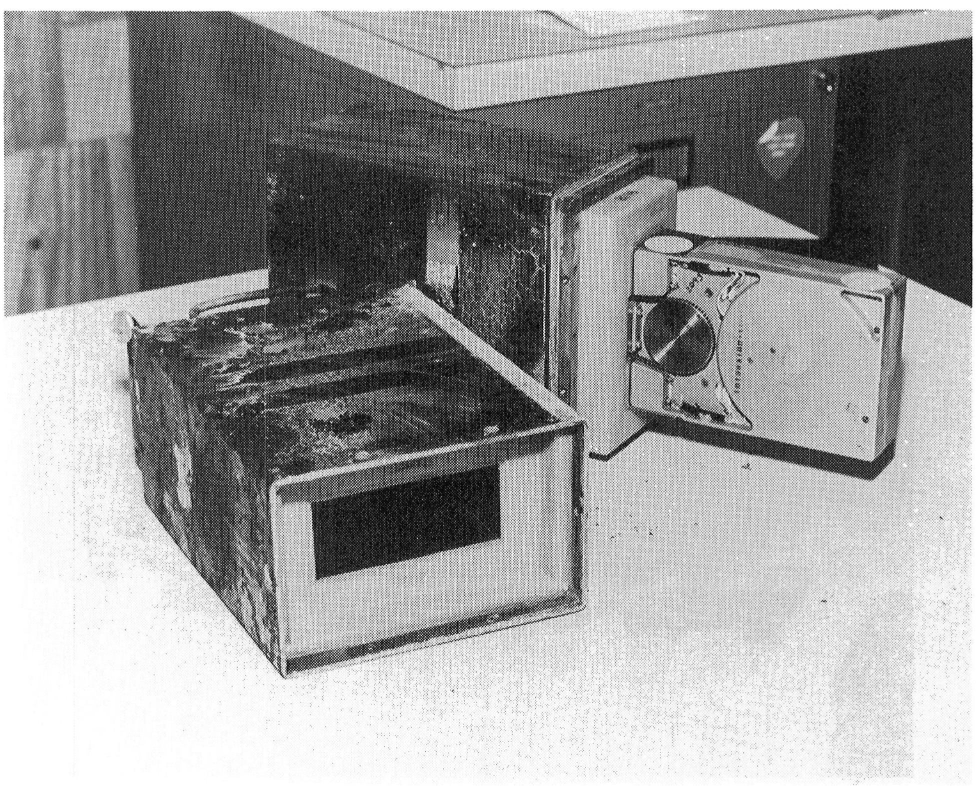

Figure 11

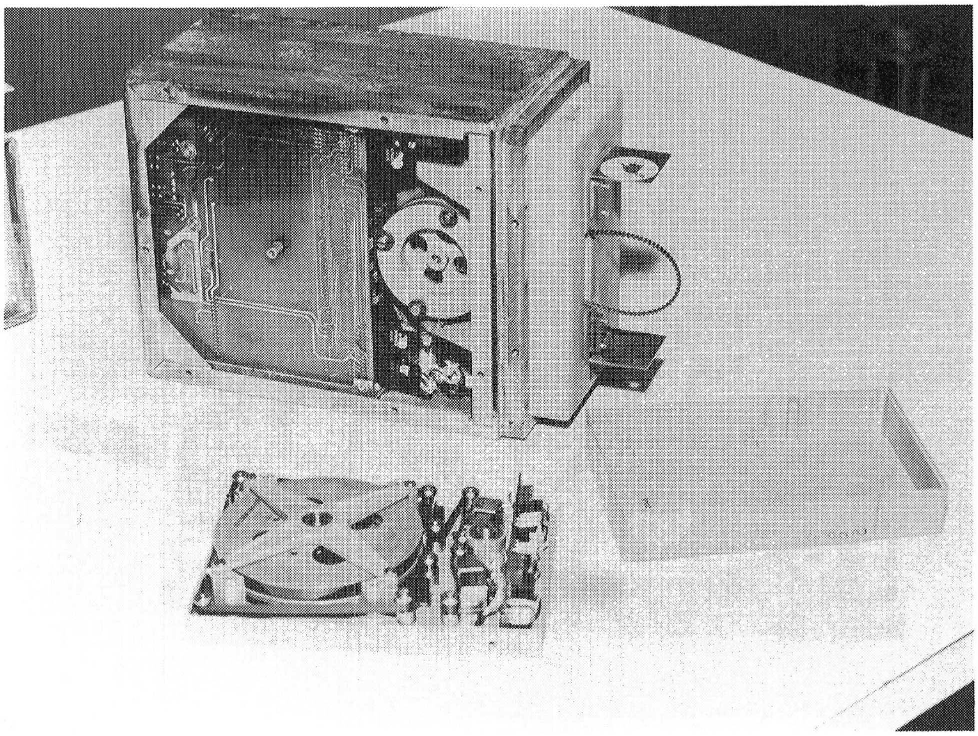

Figure 12

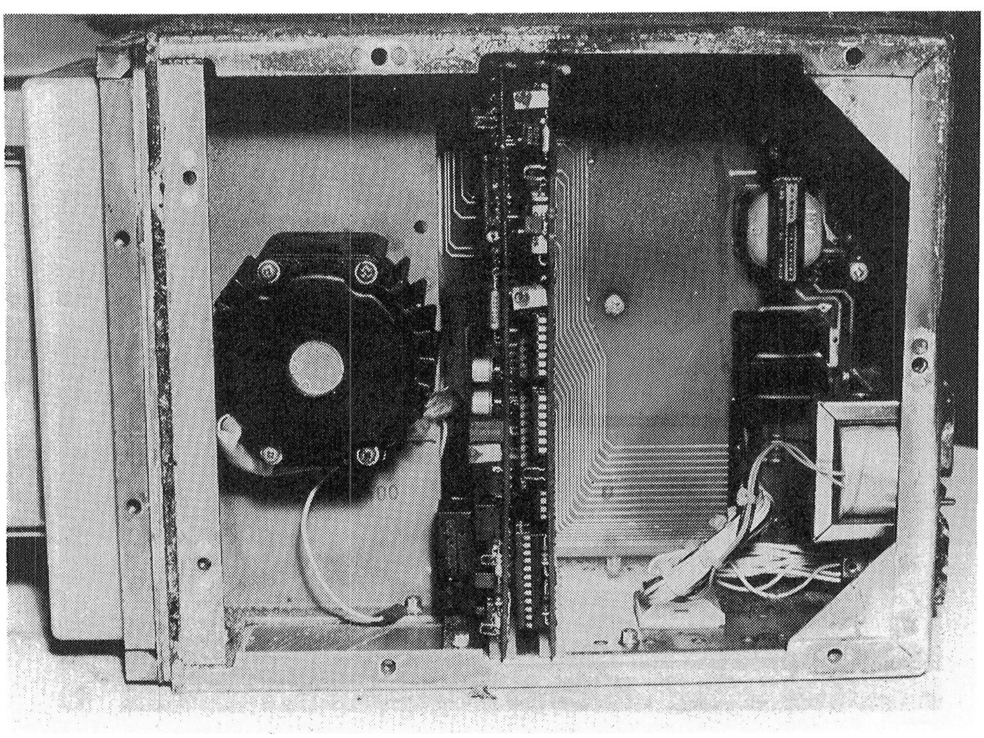

Figure 13

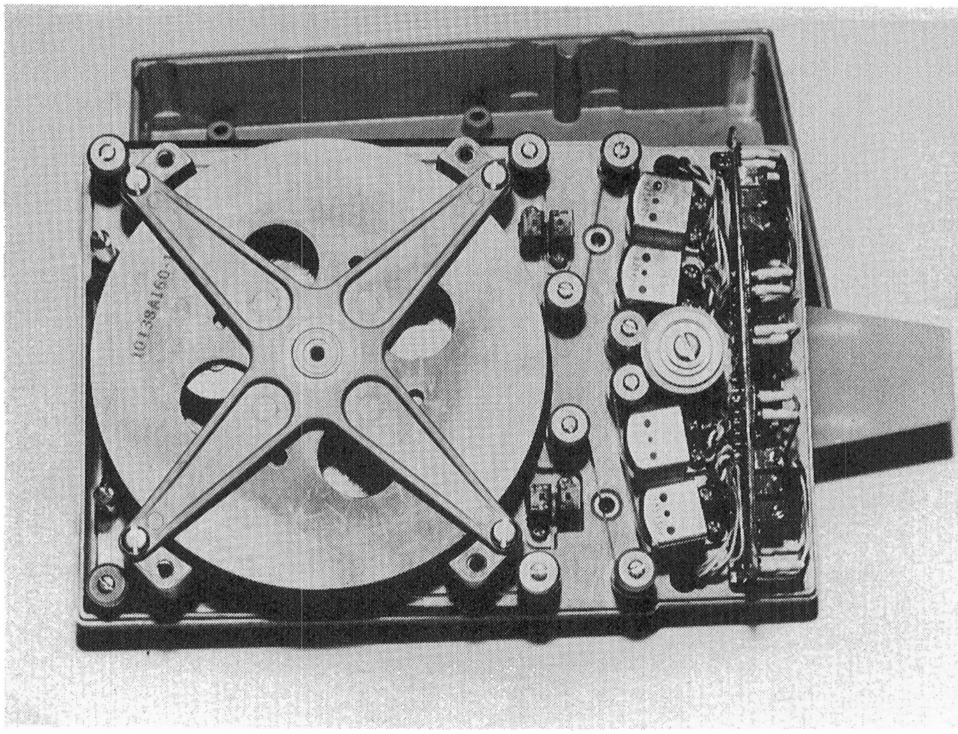

Figure 14

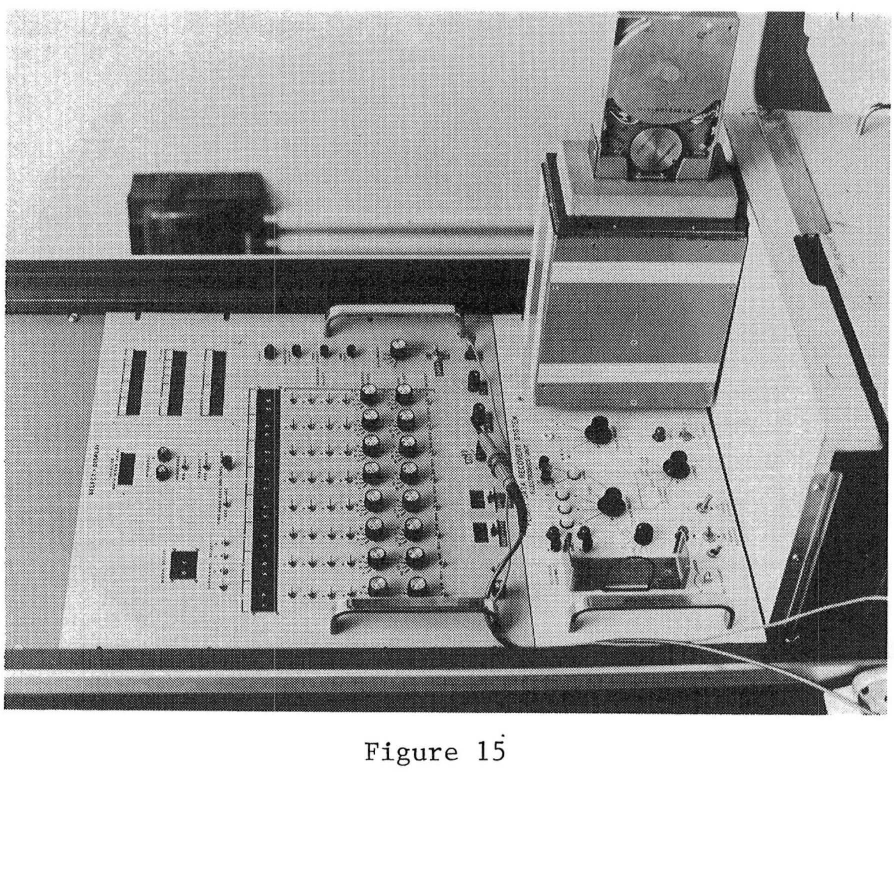

Figure 15

- <u>FDR/CVR</u>
  1. SURVIVABILITY
     - A. FIRE ENVIRONMENT
     - B. IMPACT ENVIRONMENT
     - C. BATTERY/INVERTER POWER SUPPLY
  2. RECORDED DATA PROCESSING/ANALYSIS
     - A. FDR (ANALOG-FOIL)
     - B. CVR
     - C. DFDR (MAGNETIC TAPE)
  3. PRELIMINARY RESULTS
     - A. RECORDER OPERATIONS
     - B. IMPACT EFFECT ON RECORDERS
     - C. SAMPLING RATES
     - D. CORRELATION
- <u>LSI SOLID-STATE MEMORY UNIT</u>
- <u>NAVY FIR</u>
  1. DEPLOYABILITY
  2. SURVIVABILITY
  3. ELT/STROBE OPERATION

Figure 16

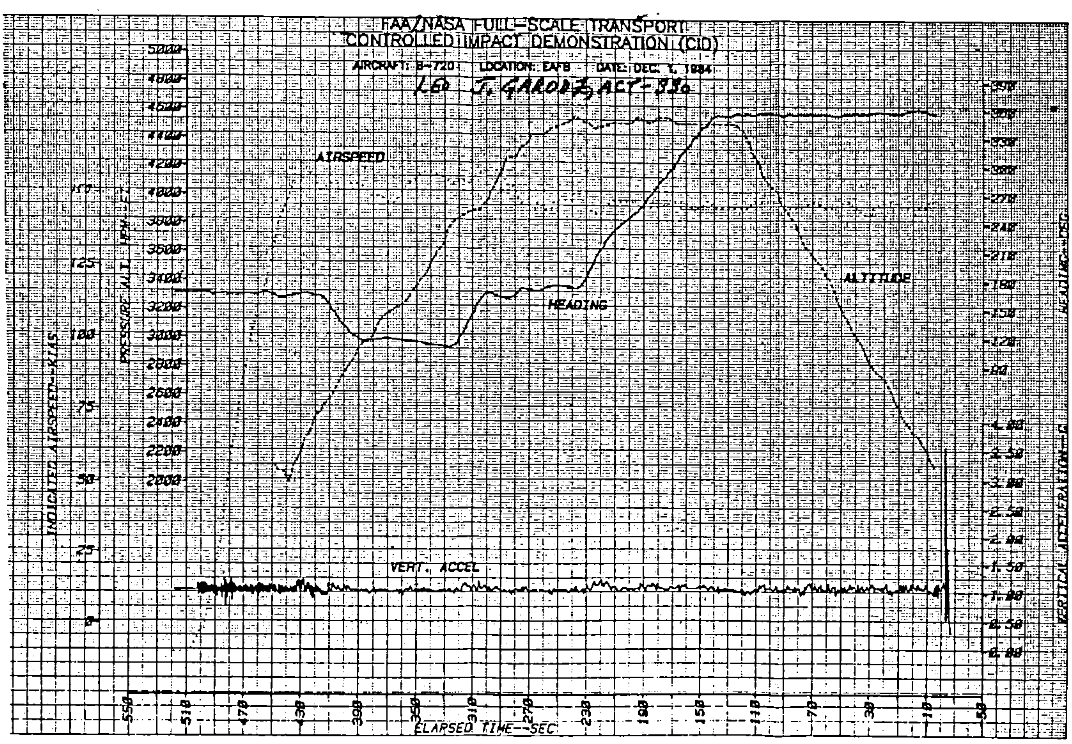

Figure 17