CONTROLLED IMPACT DEMONSTRATION ON-BOARD (INTERIOR) PHOTOGRAPHIC SYSTEM

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INTRODUCTION

Langley Research Center (LaRC) was responsible for the design, manufacture, and integration of all hardware required for the photographic system used to film the interior of the CID B-720 aircraft during actual crash conditions. The photographic system devised to accomplish this task was comprised of four main elements (Fig. 1). Four independent power supplies were constructed to operate the ten high-speed 16 mm cameras and twenty-four floodlights. An up-link command system, furnished by Ames Dryden Flight Research Facility (ADFRF), was necessary to activate the power supplies and start the cameras. These events were accomplished by initiation of relays located on each of the photo power pallets.

	Responsibility
• Power pallets (4)	LaRC
• Cameras (10)	LaRC
• Lights (24)	LaRC
• Up-link command system	ADFRF

Figure 1

CID AIRCRAFT PLAN VIEW

A plan view of the B-720 aircraft (Fig. 2) shows the distribution of the interior photographic equipment throughout the cabin area. Power pallet no. 1 was located on the right side of the forward cabin aft of the galley. Power pallets nos. 2 & 3 were located just aft of the left wing, and pallet no. 4 was on the right side forward of rear service door. The forwardmost camera and two lights were located in the cockpit.

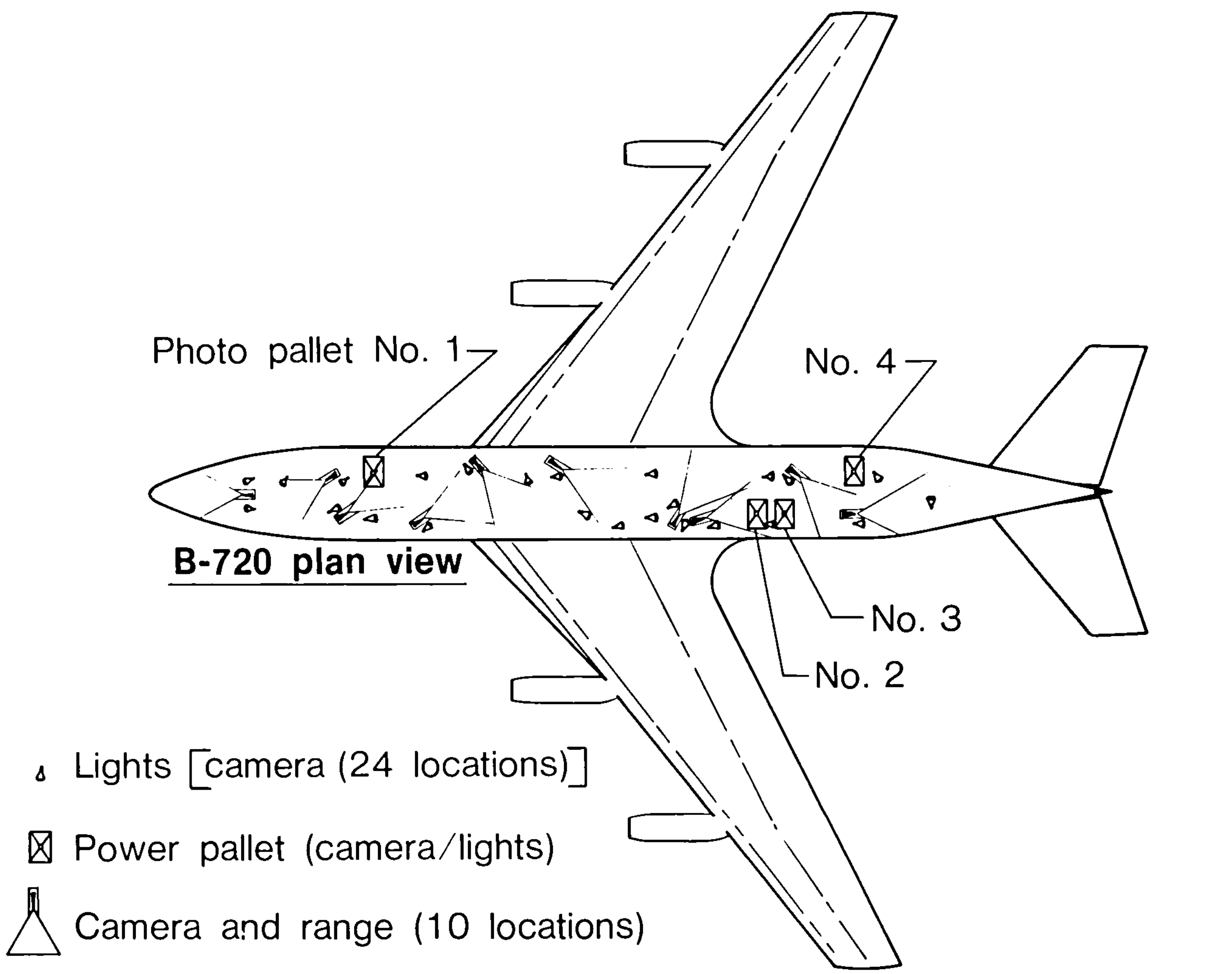


Figure 2

CID AIRCRAFT INTERIOR VIEW

This interior photograph (Fig. 3) was taken looking aft from the galley and shows how the cameras and lights were attached to the upper fuselage.

Figure 3

PHOTOGRAPHIC POWER SYSTEM

It was desirable to design and construct a power system to drive the cameras and lights completely independent of the aircraft power systems. As stated previously, four power supplies were installed. A list of the components used in this power system is given in Fig. 4. All of these components were qualified for use on aircraft or missiles except the alkaline lantern batteries. These alkaline batteries did not have to survive any stringent environment as they were used only to activate the primary silver-zinc batteries prior to impact.

1. Battery (28VDC) silver-zink	Delco-Remy	PP-3250/DJW-15
2. Battery (12VDC alkaline	Duracell	1D9260
3. Relay, camera power		6042H202
50-amp, 28VDC, 3 pst, 50 G's	Cutler-Hammer	MS27222-2
4. Relay, control (200 G's)		
4PDT, magnetic latching	P and B	TL17DG
5. Relay, external power		6041H202
200A, 28VDC, 25 G's	Cutler-Hammer	AN3370-1
6. Diode, 157 AMP. DC	Motorola	MR1215SL
7. Fuses	Bussman	ANL type
8. Connectors, power	Amphenol (MS)	MIL-C-5015
9. Connectors, control	Bendix	MIL-C-23216
10. Terminal strip	Fed. stock	MS27212-3-8

Figure 4

CID PHOTO POWER PALLETS

The physical layout and construction of the power pallets are depicted in the photograph of power pallets nos. 2 and 3 (Fig. 5). Each pallet was covered by a fire resistant heatshield and bolted to the aircraft seat rails. The pallets were constructed to withstand the most severe expected impact (15 g) but in one vertical impact test a pallet survived 60 g's. The heatshield was designed to survive a major cabin conflagration, and performed as expected.

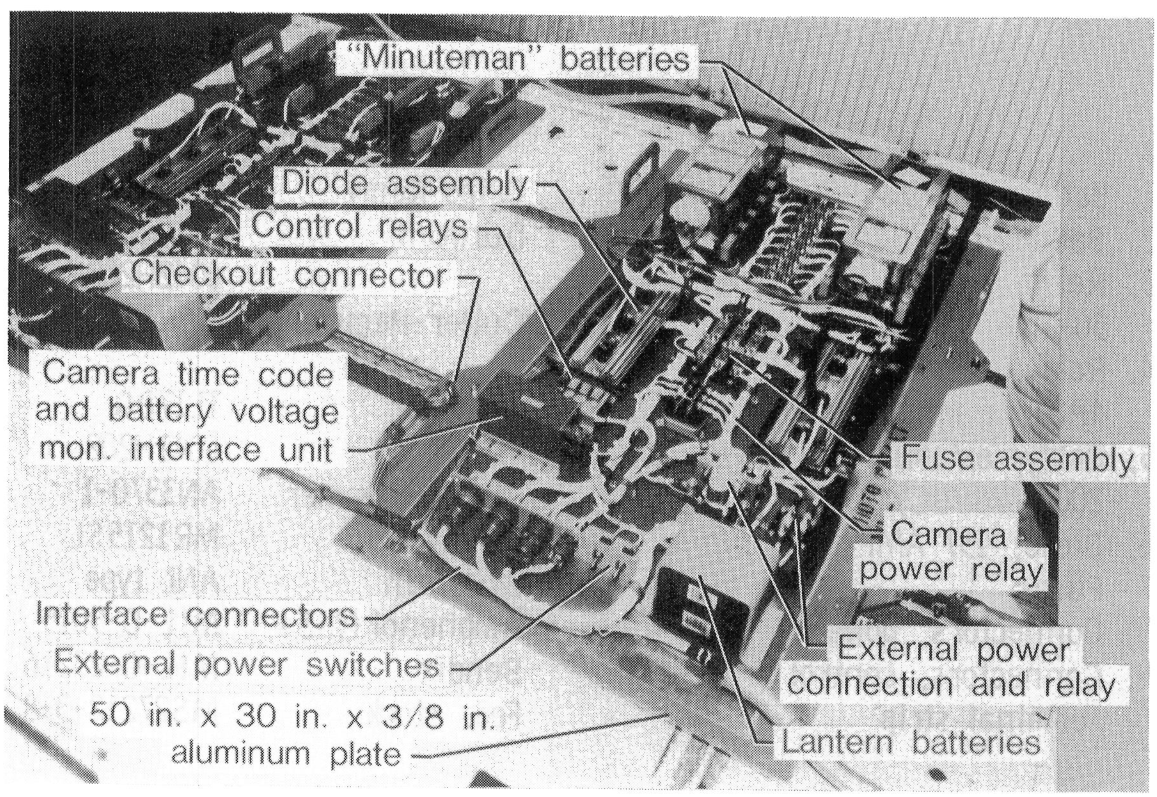


Figure 5

PHOTOGRAPHIC POWER SYSTEM BATTERY

The most unique feature of the power system design was the power source (Fig. 6); a remotely activated, hermetically sealed unit with dual 28-volt sections was selected. We obtained these batteries, which were manufactured in 1964, from outdated surplus of the minuteman program at Hill Air Force Base, Utah. The LaRC Impact Facility had been using these batteries to operate cameras and photolights on several crash tests without experiencing a single failure. These SE12G batteries were selected for this application because they had no maintenance requirements, low cost and presented an acceptable risk.

- Battery, 28 volt, remotely activated, hermetically sealed, dual section (PP-3250/DUW-15)
- Built by Delco-Remy for Autonetics, A Division of North American Aviation (1964)
- Obtained by NASA Langley from outdated surplus of Minuteman Project, Hill AFB, Utah
- Silver-zink dry charged cells
- Electrolyte: Potassium Hydroxide solution
- Weight: $<$ 17.5 lbs.

Figure 6

SE 12G BATTERY POWER SPECIFICATIONS

The SE 12G batteries were rated to deliver greater than 44 watt-hours from the "A" section and 84 watt-hours from the "B" section. The CID required 46 watt-hours and 92 watt-hours, respectively. During testing here at Langley, 90 and 103 watt-hours were obtained. They were more than adequate to meet our requirements. To provide some redundancy in the unlikely event one battery should fail, two batteries were connected in parallel on each pallet. Forty-six (46) SE 12G batteries were expended on the CID program without a failure. (See Fig. 7.)

	Battery "A"	Battery "B"	
	28 ± 0.7 volts	28 (+2, -4) volts	
Spec.	> 44 watt-hours	>84 watt-hours	218 seconds
Req'd	46 watt-hours	92 watt-hours	210 seconds
Test	90 watt-hours	103+ watt-hours	

Figure 7

SE12G BATTERY ASSEMBLY

An exploded view of this remotely activated battery is shown in Figure 8. The potassium hydroxide electrolyte, stored in the reservoir, is forced into the cells when the pyrotechnic gas generators are initiated. Within one second after activation, the batteries reach full voltage. The batteries are externally vented to prevent pressure buildup within the case after activation. To prevent contamination of the power pallets by the caustic gas and/or liquid expelled, the vents were piped overboard the aircraft.

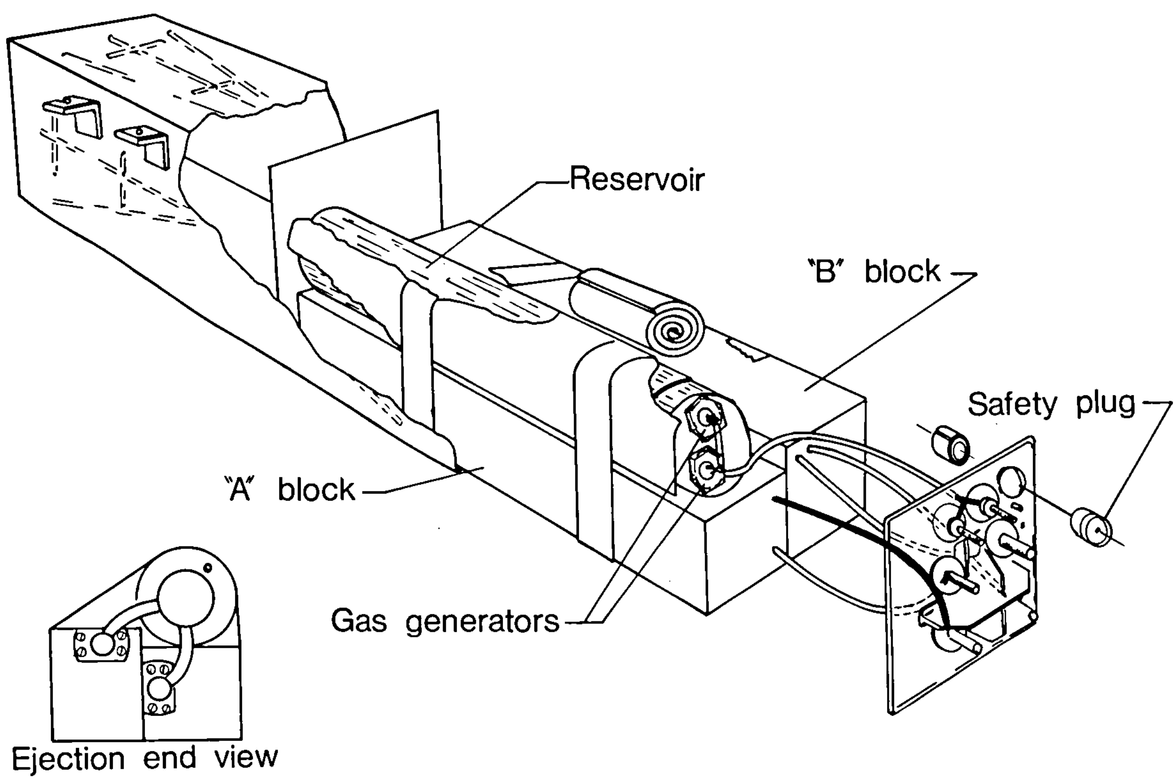


Figure 8

SE 12G BATTERY

Cell blocks and reservoir from a disassembled SE 12G battery are shown in Figure 9.

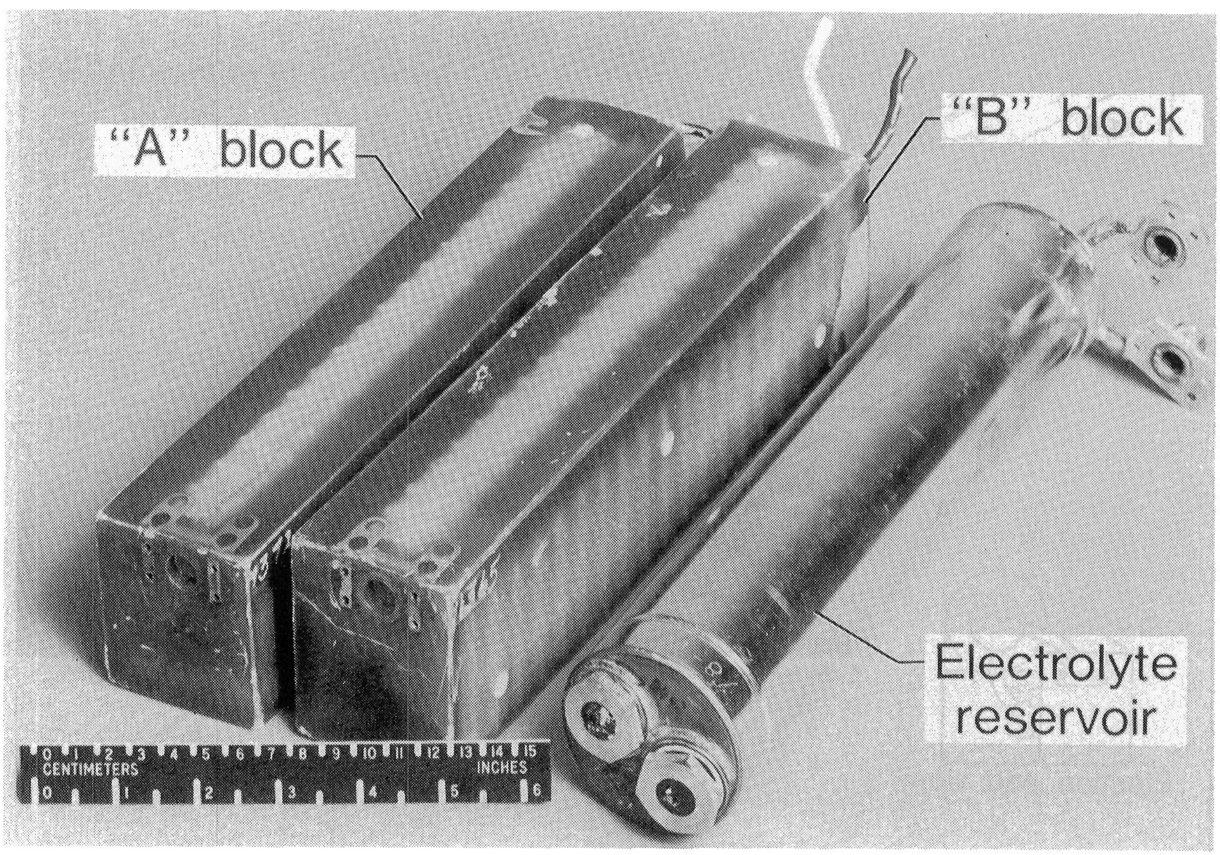


Figure 9

PHOTO POWER DISTRIBUTION

The 13KW of power required by the photographic system was distributed as shown in Figure 10. Pallets 1 and 2 supplied power to six (6) lights and three (3) cameras each. The multiple power source design concept was chosen to guarantee some film data would be obtained if one or more pallets were lost upon aircraft impact.

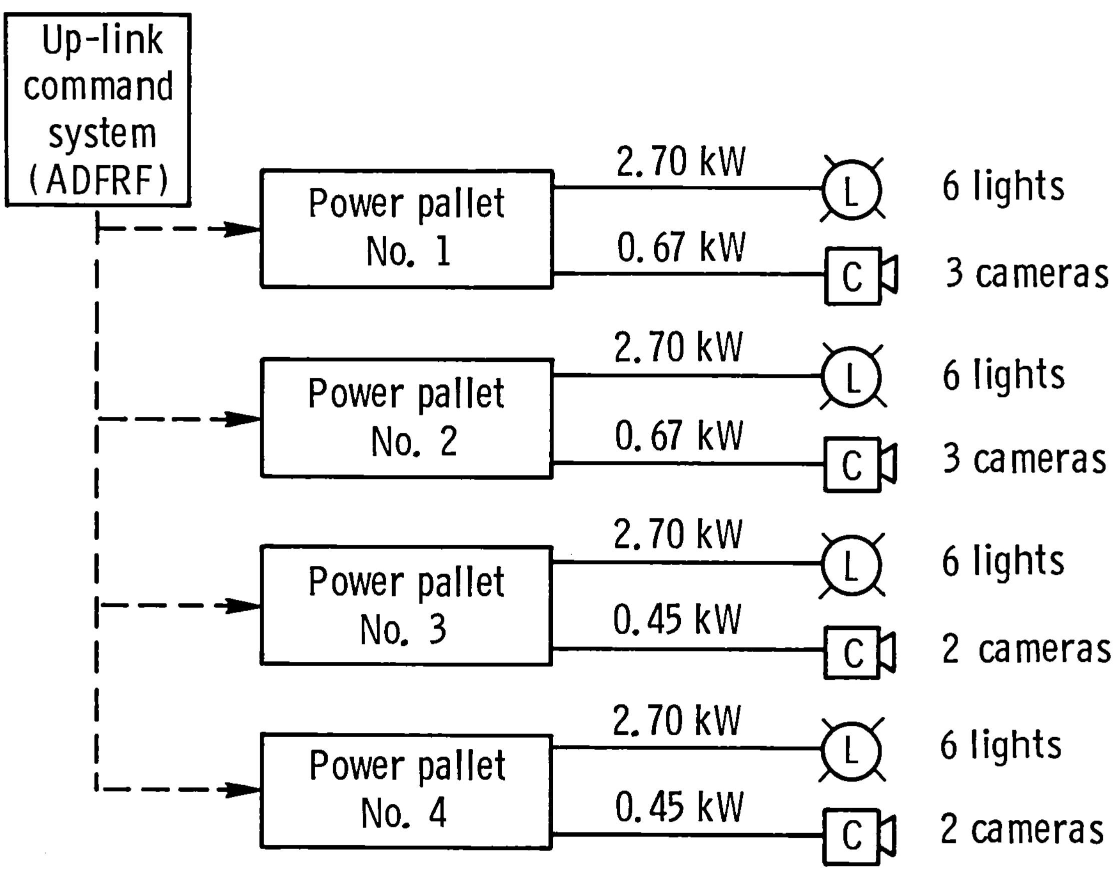


Figure 10

PHOTOGRAPHIC POWER SYSTEM ONE-LINE DIAGRAM

Each power supply was a relatively simple yet functional design as shown in this one-line diagram (Fig. 11). The up-link command energized relay K2 which completed the main battery activate circuits. The squibs were initiated by the two 12-volt alkaline lantern batteries and electrolyte was forced into the cells by the resultant gas generated. In less than one second the batteries were at full voltage and the photo lights illuminated. These batteries perform better when activated under load. For this reason, the lights were tied directly to the batteries. The second command was given to energize relay K1 to start the cameras. Diodes were employed to isolate each battery and the external power, which was supplied by a power cart for ground operational tests on the aircraft. Each circuit was fused to prevent a short circuit on the battery if the external conductors were severed during the crash. Each of the two remotely activated batteries supplied two 28-volt sources, designated "A" and "B." For clarity, only the "A" battery is shown in the diagram. The loads were divided between the two batteries with "B" carrying twice the load as "A."

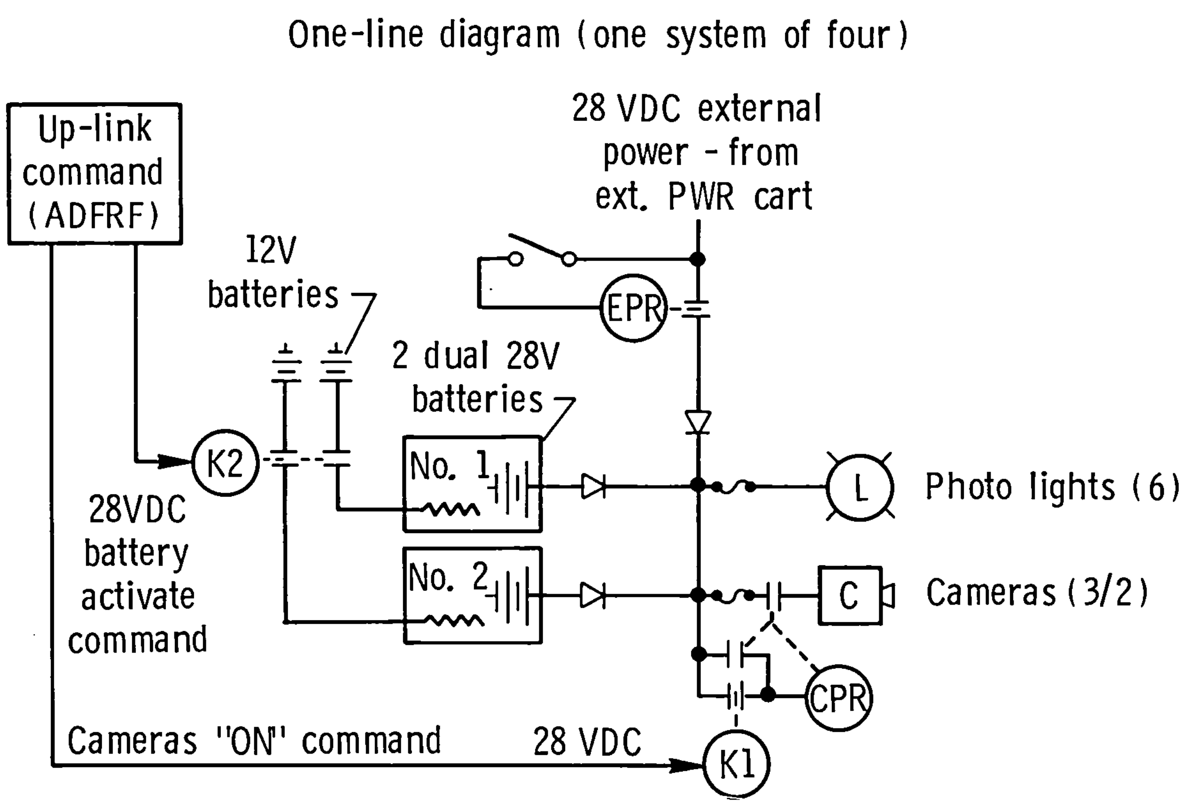
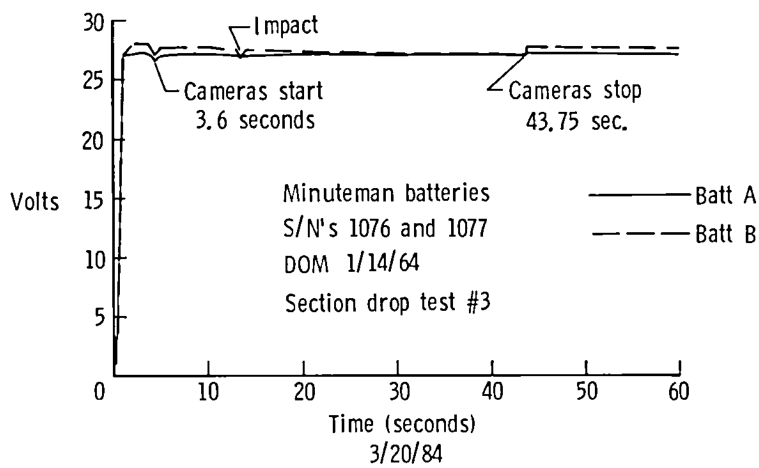


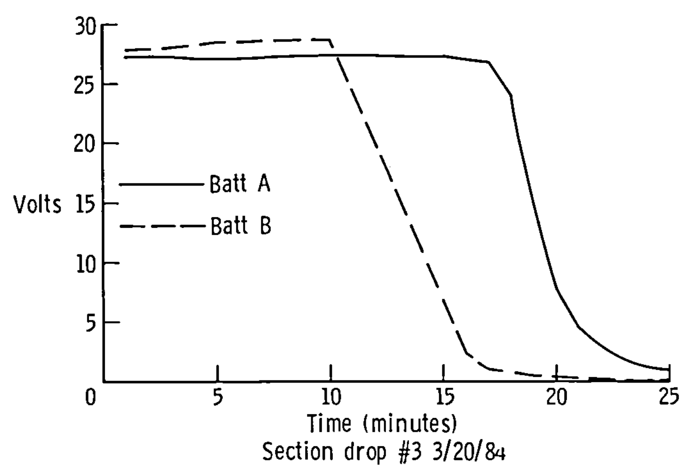
Figure 11

TIME-VOLTAGE DISCHARGE CURVES

Three fuselage section drop tests were performed at Langley (ref. 1). Fuselage section drop test #3 was used as a qualification test for the photographic system with one power pallet with two (2) paralleled batteries, and a full complement of six (6) lights and three (3) cameras. The battery voltages were recorded during this test and the results are shown in Figure 12. The data is typical of other recorded tests. Figure 12a displays the events which occurred in the first 60 seconds. The batteries reached full voltage within one second after activation, cameras were started at 3.6 seconds, fueslage impact on a concrete surface occurred at 15 seconds and the cameras were fully stopped by their end-of-film cutoff switches in about 44 seconds. The lights continued burning until battery depletion (Fig. 12b). Battery A began decaying in about 10 minutes and Battery B in about 17 minutes.



(a)



(b)

Figure 12

PHOTO SYSTEM TELEMETRY REQUIREMENTS

The telemetry requirement of the photo system was for eight (8) "real time" downlink channels to monitor battery voltages. These voltages were recorded by the on-board tape recorders, ground tape recorders, and on strip chart recorders in the control rooms. Two uplink commands were required to activate the batteries and start the cameras. (See Fig. 13.)

- Photo power system "Real time" data
  - Battery voltages

    8 channels required
- "Up-link" command signals required
  - Battery activate

    28 VDC to relay on four pallets
  - Cameras "start"

    28 VDC to a relay on four pallets

Figure 13

CAMERAS

The D.B. Milliken cameras (Fig. 14), now manufactured by Teledyne Camera Systems, Arcadia, CA, were chosen for use on the CID because of their ruggedness, reliability and experience.

- Selected for ruggedness and reliability
- First used by LaRC on Mercury Program (1958)
- Used last 10 years on numerous crash tests at LaRC Crash Facility
- Survived up to 100 g's during those tests
- Now manufactured by Teledyne Camera Systems

Figure 14

TYPICAL CID CAMERA AND LIGHT INSTALLATION

A typical camera and light installation is shown in Figure 15. This particular installation was in the galley. A sheet of heat retardant material was mounted under each camera and a heat shield (not shown in photograph) was placed over the camera which left only the lens and electrical connector exposed.

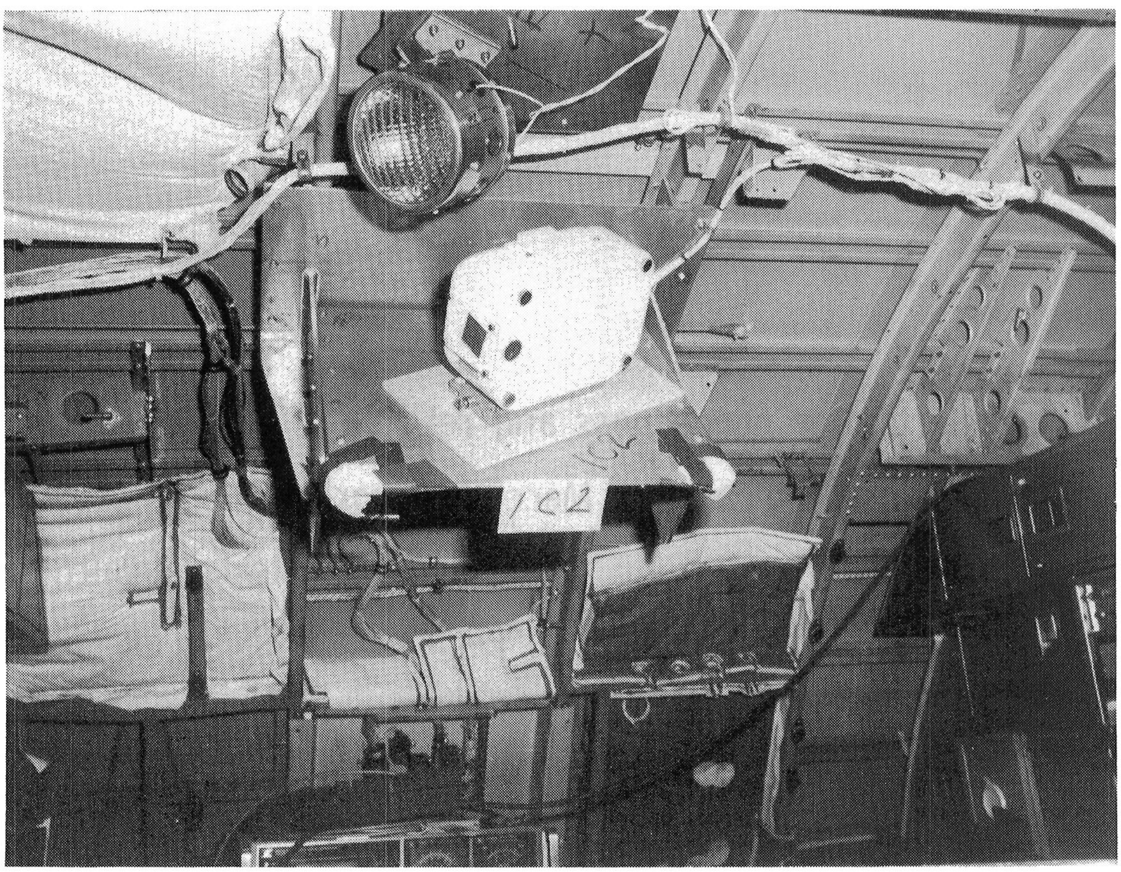


Figure 15

CAMERA SPECIFICATIONS

A brief summary of the camera specifications are listed in Figure 16. The time code was impressed on both the left and right sides of the film by light emitting diodes (LED). The end-of-film cutoff switch removes power from the camera when film has been expended.

- Description: 16 mm high speed (400 fps) motion picture camera, Teledyne Camera Systems Model DBM-55
- Speed stability: ± 1% or 1 fps
- Power requirements: 28 ± 4 volts DC; 7.5 amps at 400 fps
- End of film cut-off switch
- Timing lights: Light emitting diodes (LED)
- Operational environment:
    - Acceleration: 25 G's
    - Temperature: - 65°F to 150°F
    - Vibration: 5 to 5000 Hz with 10 G peak loading
- Film used: Eastman Ektachrome Video News Film - 7239 - Daylight

Figure 16

TIME CODE AND VOLTAGE MONITOR

The Inter-Range Instrument Group (I.R.I.G.) "B" time code impressed on the film was supplied from two independent time code generators, one on each Data Acquisition System (DAS) pallet. These timing signals were transmitted to an LED drive unit located on each photo power pallet and then distributed to each camera. The photo power system battery voltages were conditioned within the same unit containing the LED drive circuitry and sent to the DAS for recording and telemetering to the ground stations. Figure 17 shows a block diagram of the time code distribution.

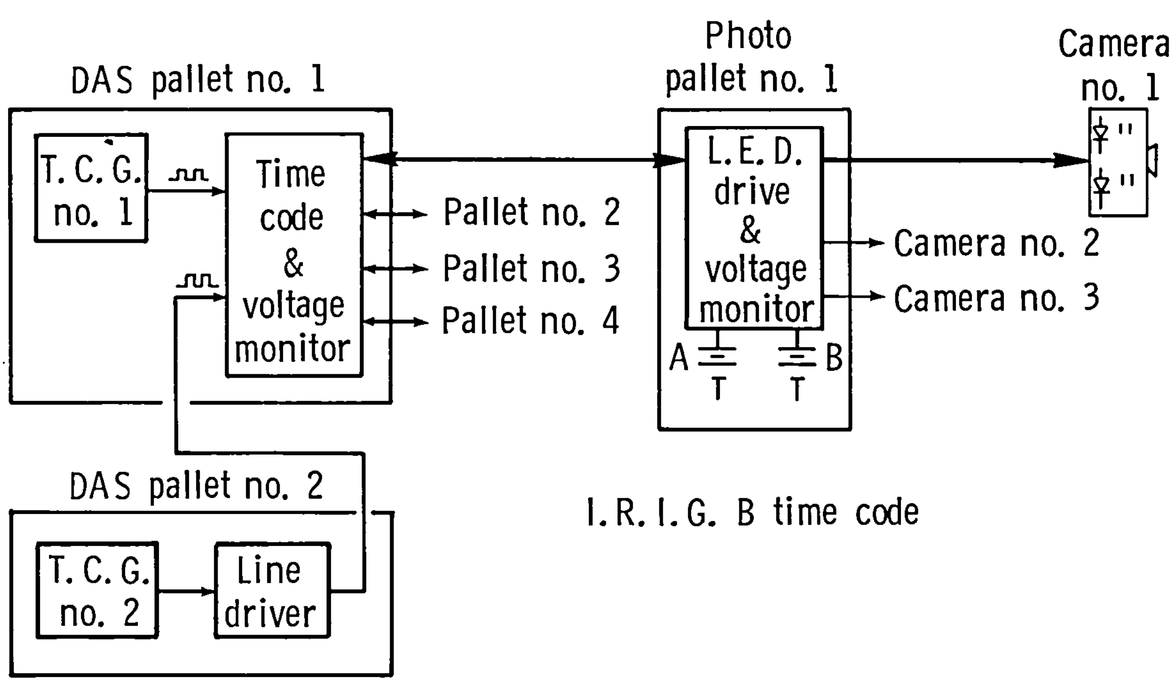


Figure 17

CAMERA ANOMALY

Only one camera anomaly occurred on the CID (Fig. 18). The take-up reel jammed on one camera, for some unexplained reason, shortly after it started, causing the film to "bunch-up" within the camera housing. The film was removed in a darkroom, as was all the other film, and successfully processed.

- Take-up reel jammed on one camera on CID
  - Film recovered and processed

Figure 18

POST CRASH PHOTO OF CAMERA, HEATSHIELD AND MOUNTING PLATE (FRONT VIEW)

The post crash condition (front view) of a typical camera, heatshield and mounting bracket is shown in Figure 19. The heat resistant material under the camera and the heatshield provided excellent protection for the camera despite the fact that the aluminum mounting bracket practically melted away. The smoke deposits on the camera housing was cleaned off revealing the original paint hardly scorched.

Figure 19

POST CRASH PHOTO OF CAMERA, HEATSHIELD AND MOUNTING PLATE (REAR VIEW)

Figure 20 is the rear view of the same camera and other hardware shown in Figure 19.

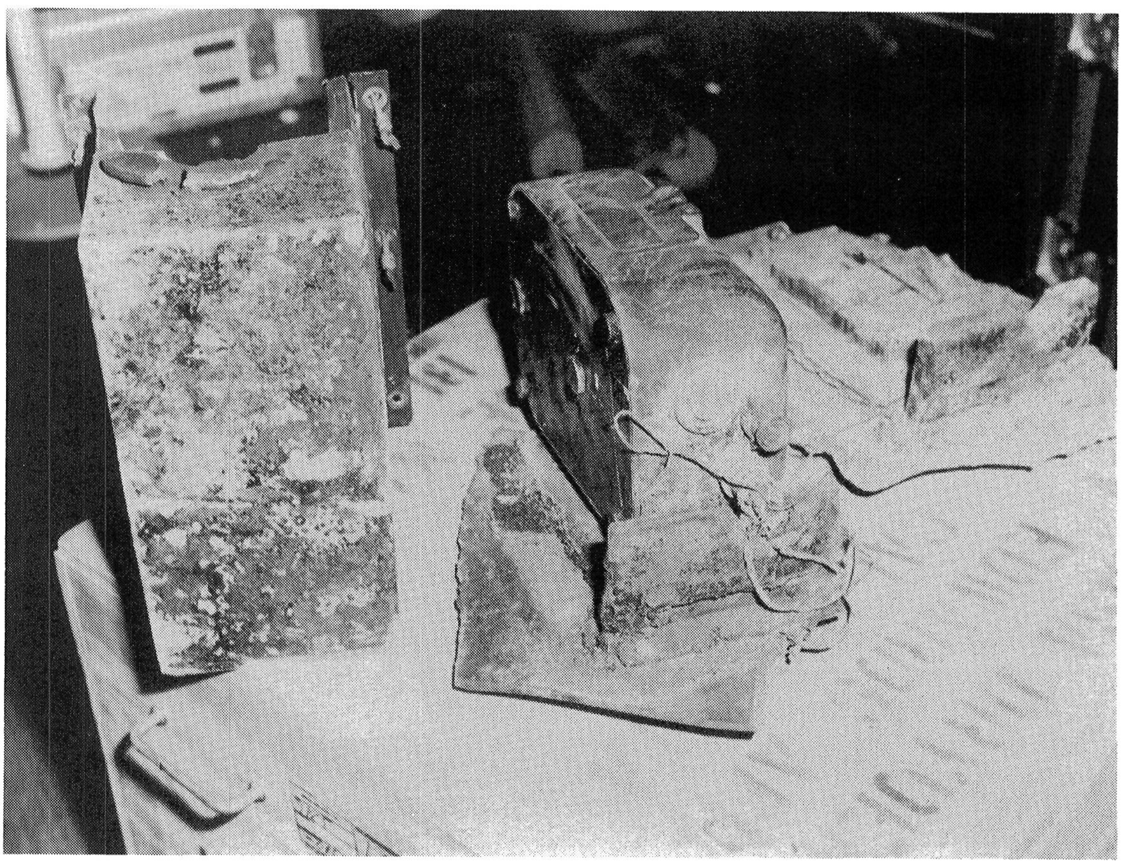


Figure 20

POST CRASH PHOTO OF CAMERA (INTERIOR VIEW)

The interior of the cameras were surprisingly clean when opened after the crash (Fig. 21). The lenses were destroyed, however, and the portion of the electrical connectors protruding from the heatshield was melted.

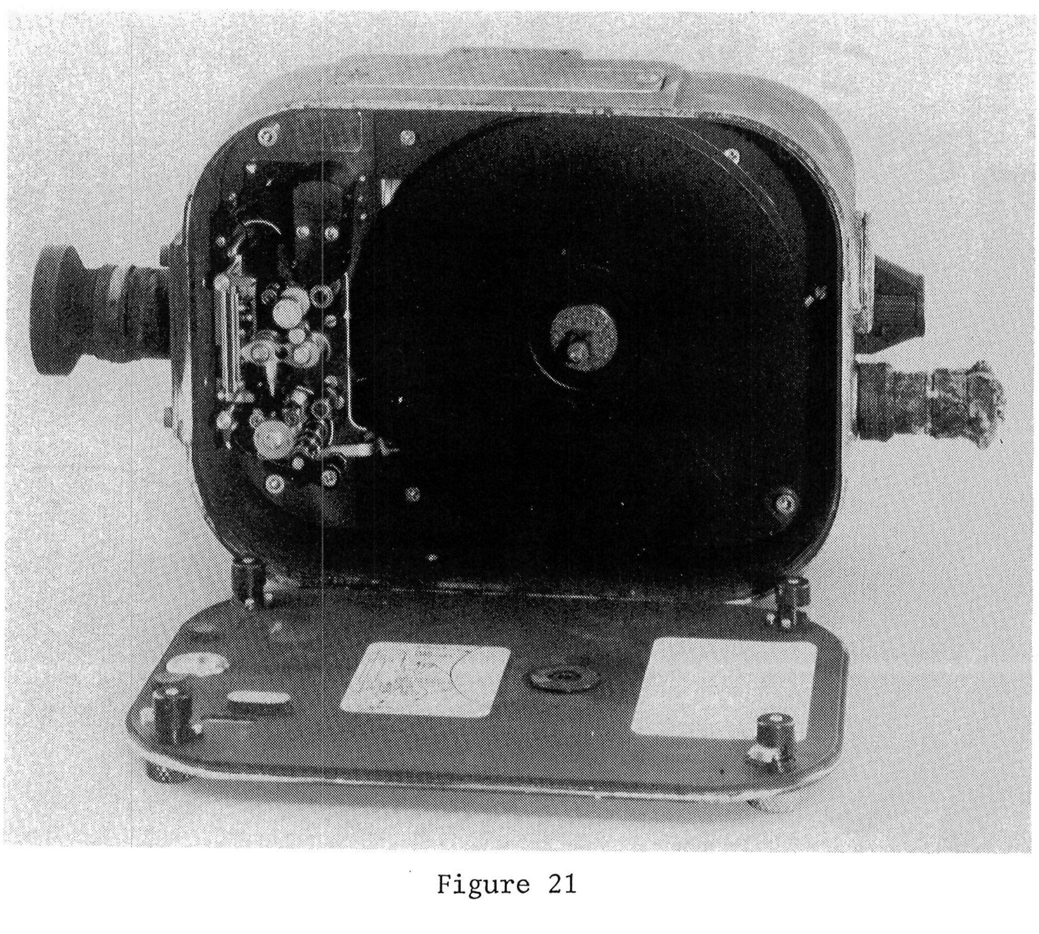


Figure 21

POST CRASH CAMERA CONDITION

Actual physical damage to the cameras was very slight, except for the lenses which could not be reused (Fig. 22). Total repair costs for all cameras was less than the original cost of one camera. Three of the CID cameras are currently being used on the LaRC Landing Loads Facility carriage testing program.

- All 10 lens were surveyed
- Seven (7) cameras are serviceable with only a clean-up
- Three (3) cameras require replacement of parts
  - Two requires relatively minor rework
  - One requires major replacement of gears, etc. mounting bracket melted, camera fell through floor, sustained water damage, gears rusted
- Total repair cost: Approximately $3,000
- Original cost: $7,200 each

Figure 22

CID PHOTO LIGHT FIXTURES

The photo lamp holders and mounting brackets, as well as the camera mounting hardware and heatshields, were designed, manufactured and tested at the LaRC. A shock-absorbing polyurethane, trade name "Sorbothane", was used to isolate the lamp holder from the mounting bracket and the mounting bracket from the aircraft structure to prevent breakage of the lamp filament (Fig. 23). After other shock-absorbing designs failed, this method proved highly successful in shock tests, as well as on the CID. Sorbothane is manufactured by Hamilton Kent, a division of BTR, Inc.

- Lamp holders and mounting brackets were designed, manufactured and tested at LaRC

- "Sorbothane", shock-absorbing material, was installed between lamp holder, mounting bracket and aircraft structure

Figure 23

TYPICAL LIGHT AND CAMERA INSTALLATION

The lamp holders and cameras were attached to the aircraft structure as shown in Figure 24. A swival section of micarta was used between the lamp holder and its mounting bracket so the lamp could be rotated for optimum illumination of the camera field-of-view, then drilled and locked into position with aircraft bolts.

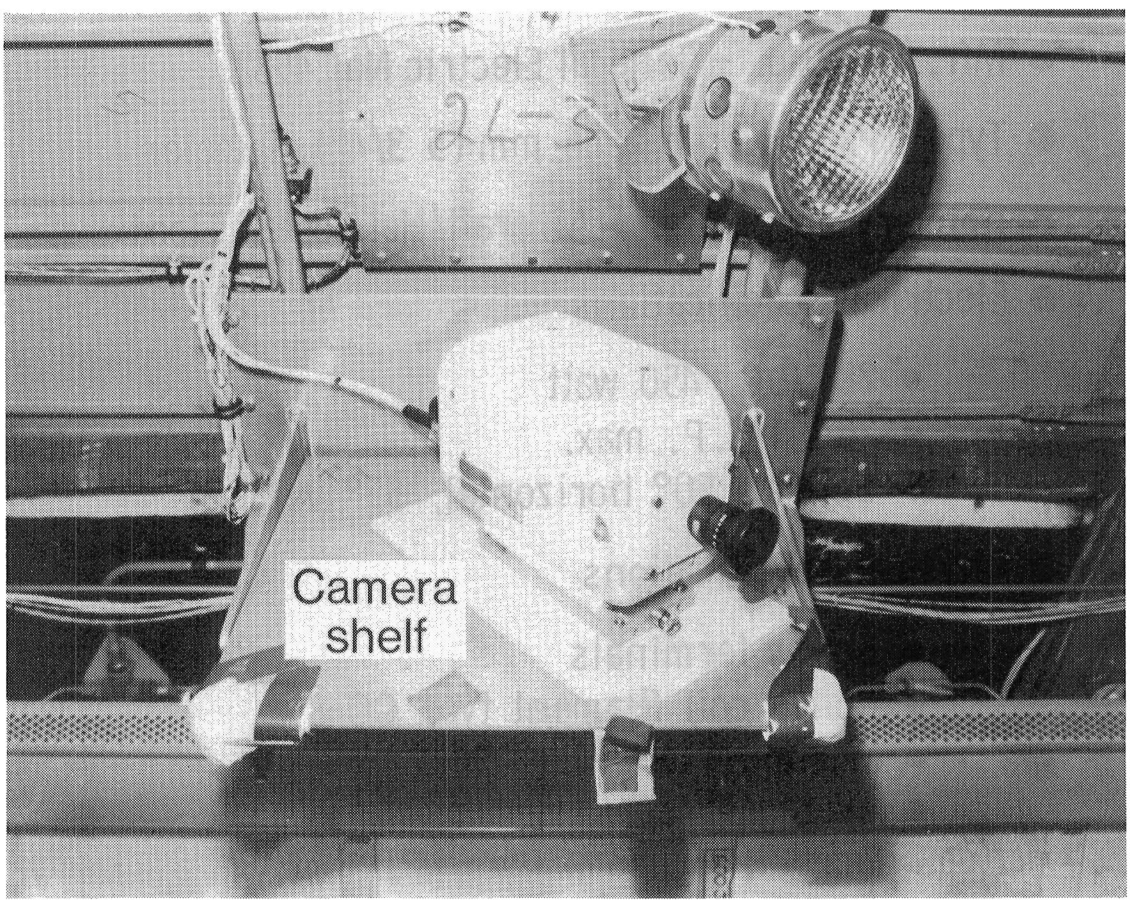


Figure 24

PHOTO LAMP SPECIFICATIONS

The specifications for the photo lamps used on the CID are given in Figure 25.

- Mfr./part no. - General Electric No. 4582
- Type - PAR46 bulb, 146 mm (5 3/4") diameter
- Primary application - Aircraft/Helicopter Flood
- Electrical specifications
    - 28 VDC, 450 watt
    - 20000 C.P. max.
    - Spread, 50° horizontal, 55° vertical
- Physical specifications
    - Screw terminals
    - Coiled coil filament type CC-8
    - Maximum length, 3 3/4"
    - Average life, 10 hours

Figure 25

POST CRASH PHOTO OF LIGHT FIXTURE

This photograph of one light fixture (Fig. 26) was taken shortly after the crash. It is obvious that the assembly, as did all 24, survived the crash with no physical damage. However, the extreme heat did melt the wires and polyurethane material.

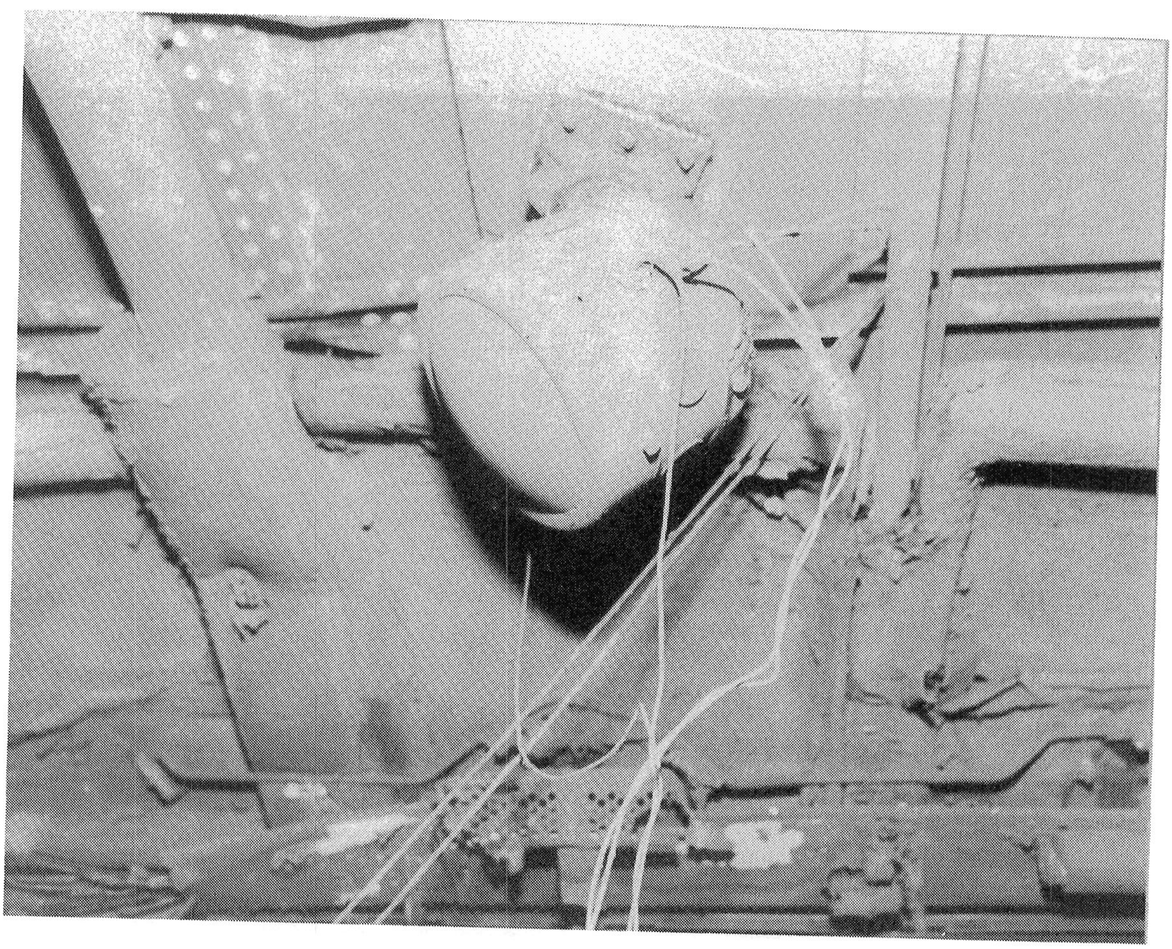


Figure 26

POST CRASH POSITION OF PHOTO PALLETS 2 & 3

Photo power pallets 2 and 3, which were located just aft of the left wing, are hardly discernible among the debris (Fig. 27). They fell through the floor, as did the other pallets, when the floor melted away. Red tags were placed on each unit by the safing crew, to indicate a possible personnel hazard because they still contained batteries.

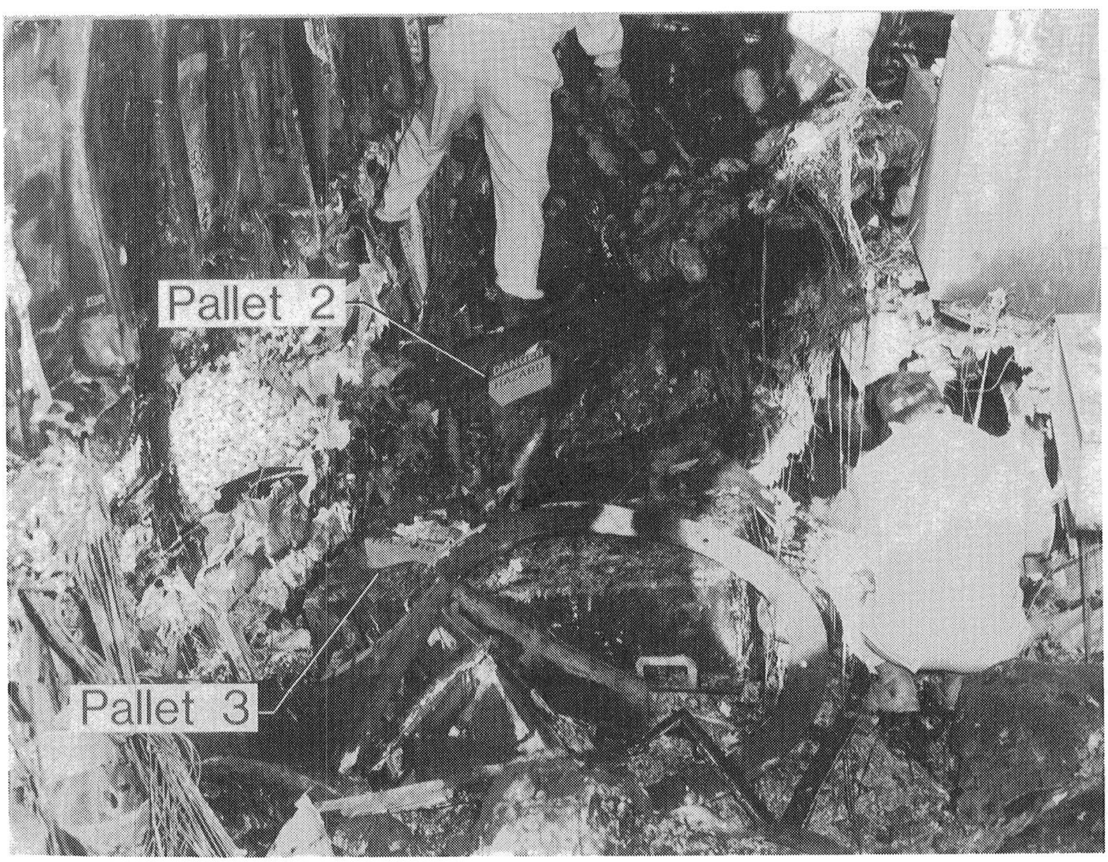


Figure 27

PHOTO PALLET NO. 3 - POST CRASH CONDITION (WITH HEATSHIELD)

Photo pallet No. 3 after removal from the aircraft (Fig. 28). The heatshield damage looks worse than it really was. Only the outer coating was partially burned away.

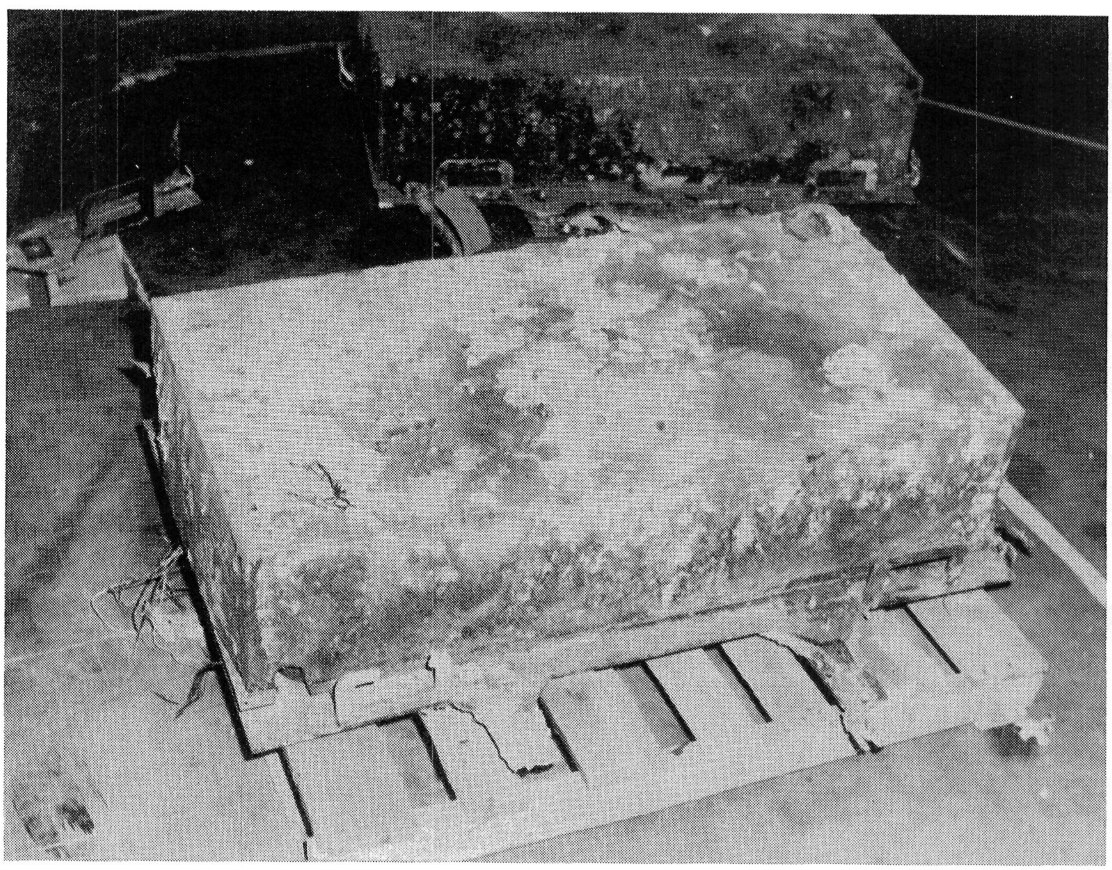


Figure 28

PHOTO PALLET NO. 3 - POST CRASH CONDITION (HEATSHIELD REMOVED)

Except for smoke deposits, there was surprisingly little damage to the pallet components when the heatshields were removed. Pallet number 3 (Fig. 29) was one of the worst and except for the batteries (not shown), fuses and wiring, most of the other hardware could have been salvaged.

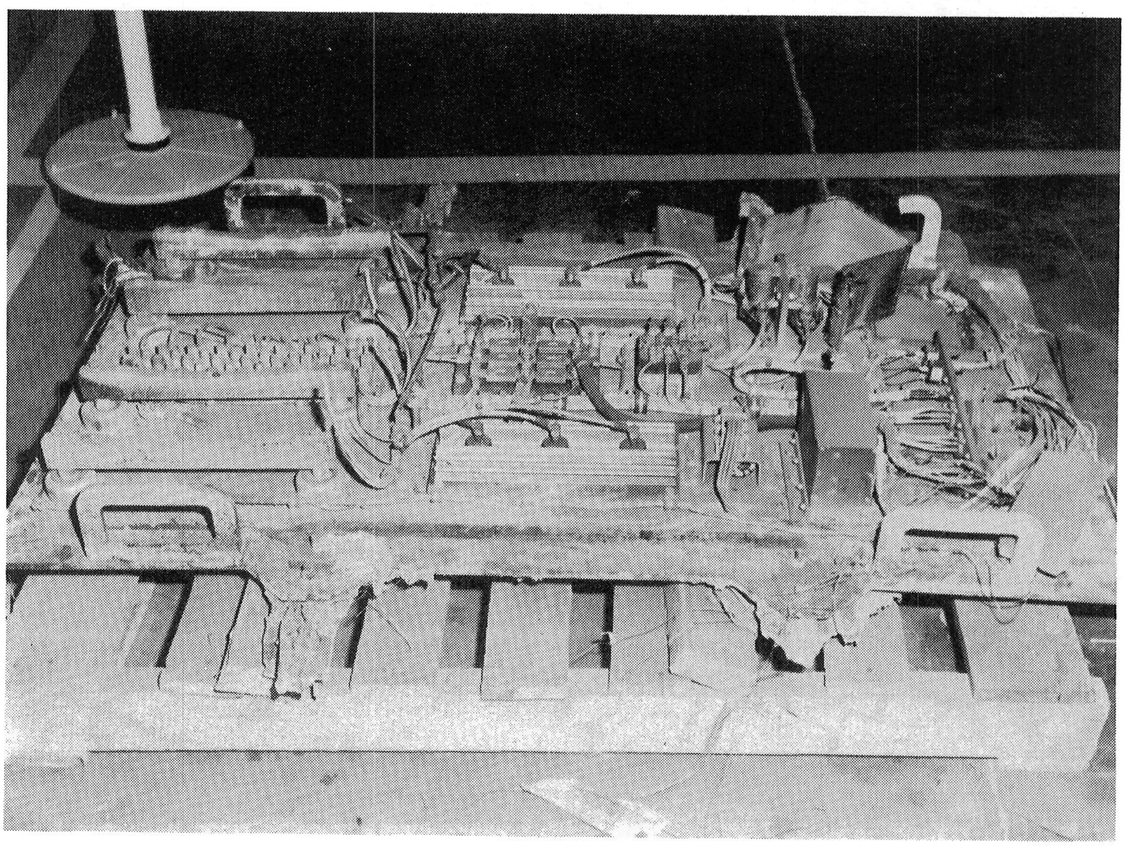


Figure 29

SUMMARY

- Photo system performed beyond expectations
  - All four (4) power distribution pallets with their 20 year old Minuteman batteries performed flawlessly
  - All 24 lamps worked
  - Recovered all ten (10) on-board high speed (400 fps) 16 mm cameras with good resolution film data

REFERENCE

1. Pride, J. D.: CID-720 Aircraft LaRC Preflight Hardware Tests: Development, Flight Acceptance and Qualification. Full-Scale Transport Controlled Impact Demonstration, NASA CP-2395, 1986, pp. 303-328.