National Aeronautics and
Space Administration

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Wallops Island, Virginia 23337

NASA

SEP 9 1992

Reply to Attn of 841.2

TO: 841.2/Flight Vehicles and Systems Section/Mendel Silbert

FROM: 841.2/Flight Vehicles and Systems Section

SUBJECT: Payload Impact Analysis for Nike-Orion Flights 31.084 UU and 31.085 UU (Zipf/University of Pittsburgh)

This memorandum presents the findings of an investigation into the forces acting on a recoverable sounding rocket payload upon impact with the Earth's surface. Two sounding rocket flights were analyzed; Nike-Orion 31.084 UU and Nike-Orion 31.085 UU, both launched from White Sands Missile Range. Each of the flights consisted of a 465-pound payload that descended on a nylon cross chute (see Table 1) until impact.

TABLE 1
Recovery System Characteristics for
Nike-Orion 31.084 UU and 31.085 UU

	31.084 UU	31.085 UU
Suspended Payload (Pounds)	465.0	465.0
Parachute - Cross (Feet)	46.0	50.25
Terminal Velocity (Ft./Sec.)	22.33	21.36

An environmental shock and vibration sensor/recorder, model EDR-3, (see Appendix 1) was flown on flight 31.084 UU. The sensor was mounted to the inside of the parabay and arbitrarily set to record any accelerations registering above 15 g's during the flight. This allowed the sensor to record the liftoff accelerations (see Figure 1). The value of 16.18 g's compared favorably with the TM longitudinal accelerometer data of 17 g's (see Figure 2). Shown in Figure 3 are the component accelerations acting on the payload as it touched down onto the landing site. Figure 4 shows the resultant acceleration for the same impact. Each of these figures show that the forces on the payload during impact were in excess of 38 g's.

Although flight 31.085 UU did not have a sensor/recorder on board to measure the impact loads, it can be seen that the impact forces experienced by the payload on flight 31.085 UU were much less in magnitude then those experienced by the payload of flight 31.084 UU. This becomes evident by comparing the on site photographs of each of the payloads' crush rings (see Figures 5a, 5b, and 5c) each of which were attached to the touchdown surface of the payload. Figure 6 shows the destroyed crush ring from flight 31.084 UU, while Figure 7 shows that the crush ring on flight 31.085 UU suffered almost no damaged.

The differences in the amount of damage can be explained by comparing the landing site photographs for each of the flights. Figure 8 shows that flight 31.085 UU touched down on a soft surface (possibly soft sand) which absorbed much of the impact force, reducing damage to the crush ring. Figure 9 shows that flight 31.084 UU impacted onto a hard surface (possibly gypsum) which transmitted most of the impact force into the payload, and thereby bouncing and damaging the crush ring more severely.

It is evident from the data gathered on flights 31.084 UU and 31.085 UU that the impact forces experienced by a payload are substantially reduced when a payload impacts on a soft, resilient surface versus when a payload impacts on a hard and unyielding surface. Additional flights, where possible, would enable additional verification of this data while providing insight to the impact conditions of sounding rocket payloads.

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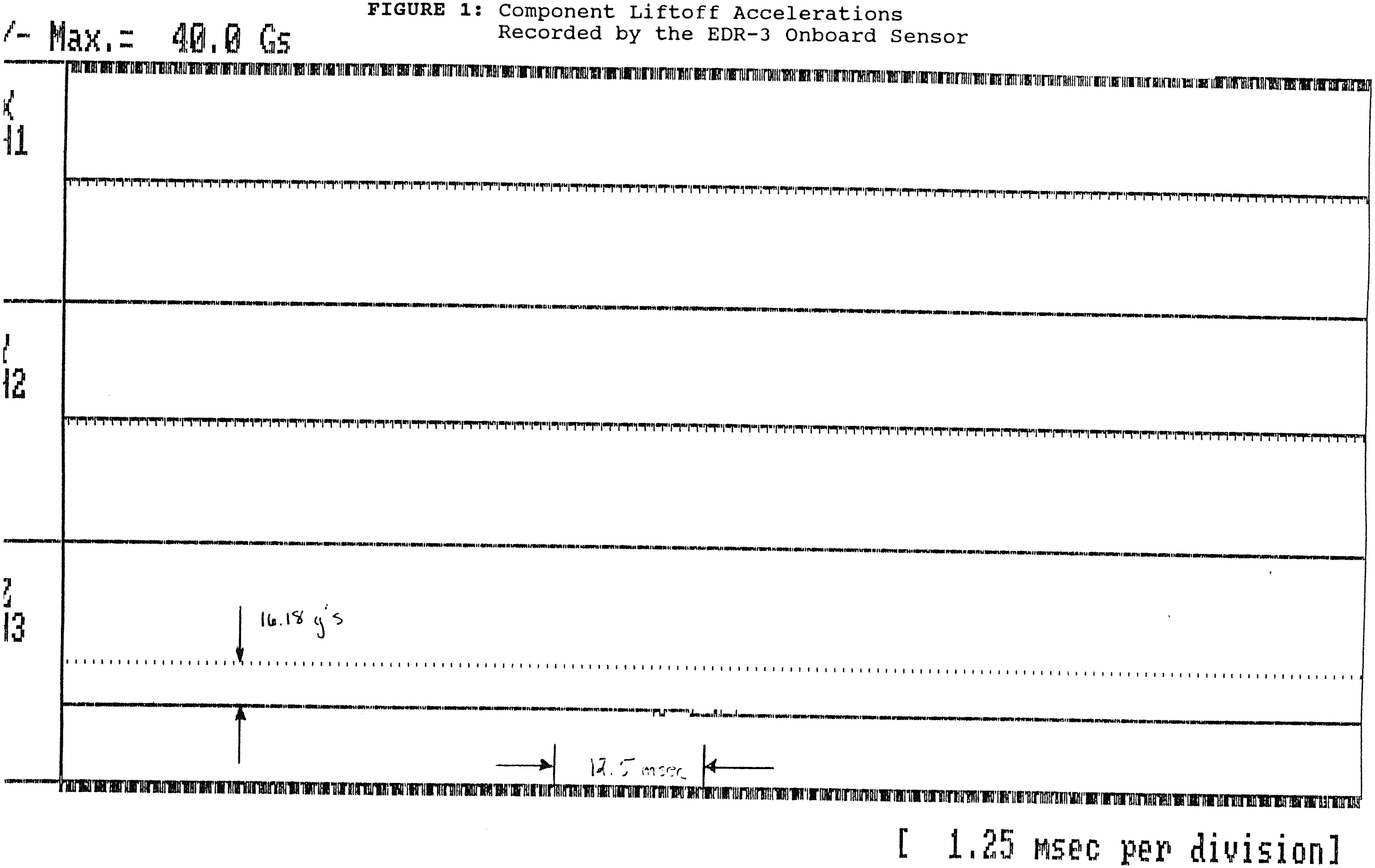
FIGURE 1: Component Liftoff Accelerations
Recorded by the EDR-3 Onboard Sensor



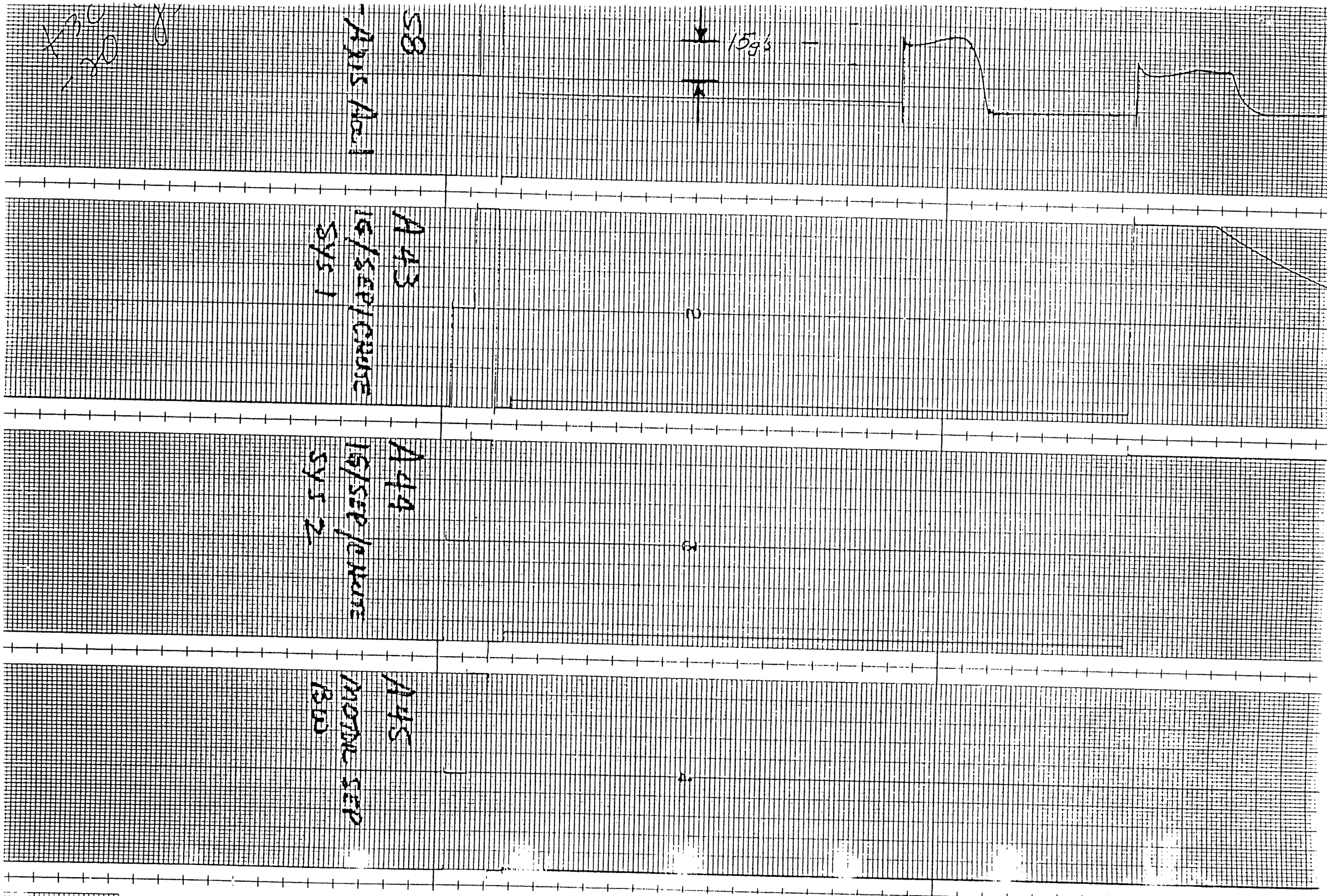


FIGURE 2: Liftoff Accelerations Recorded by the Longitudinal Telemetry Accelerometer

FIGURE 3: Component Impact Accelerations
Recorded by the EDR-3 Onboard Sensor

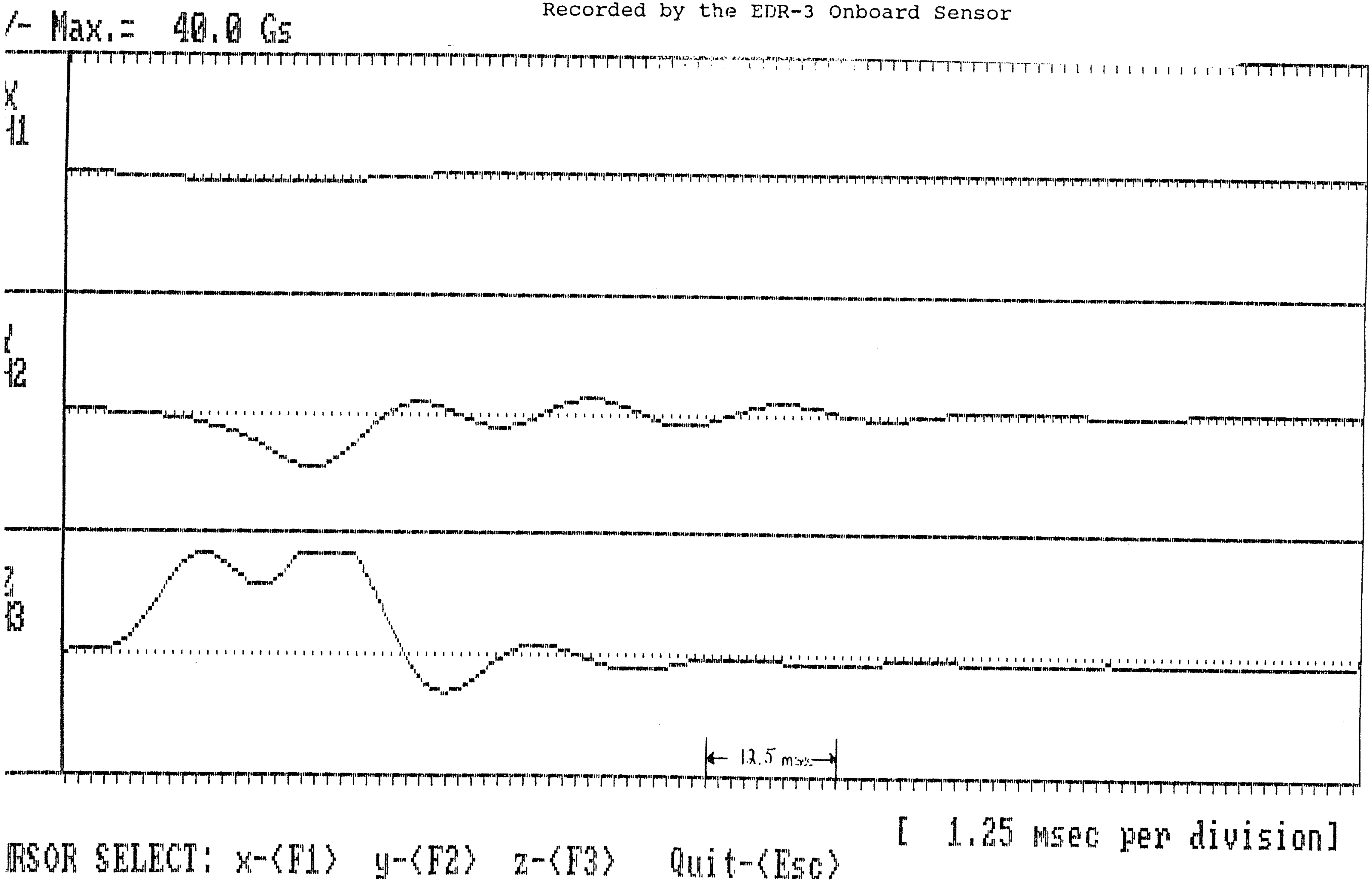


FIGURE 4: Impact Acceleration Recorded by the EDR-3 Onboard Sensor

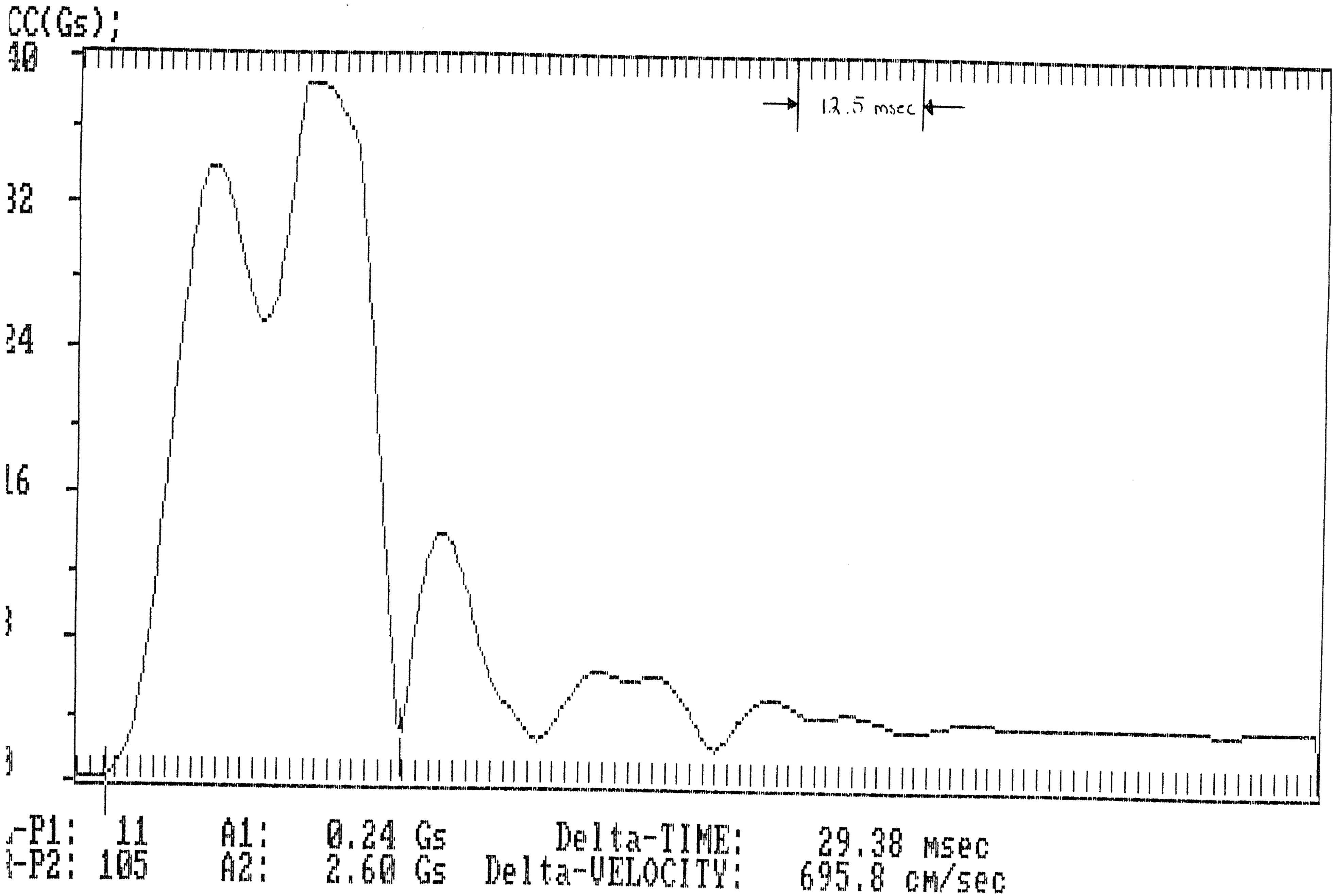
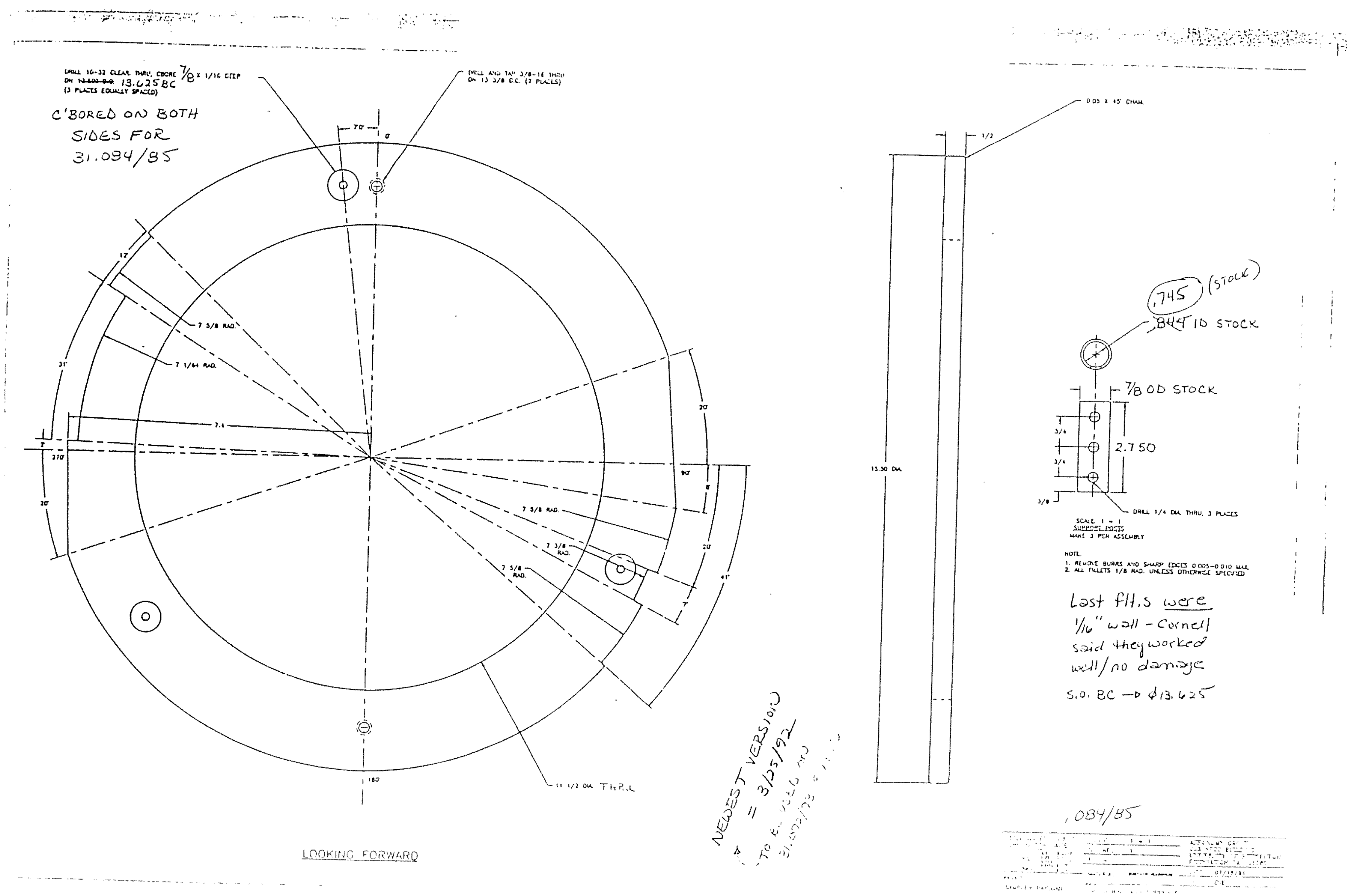
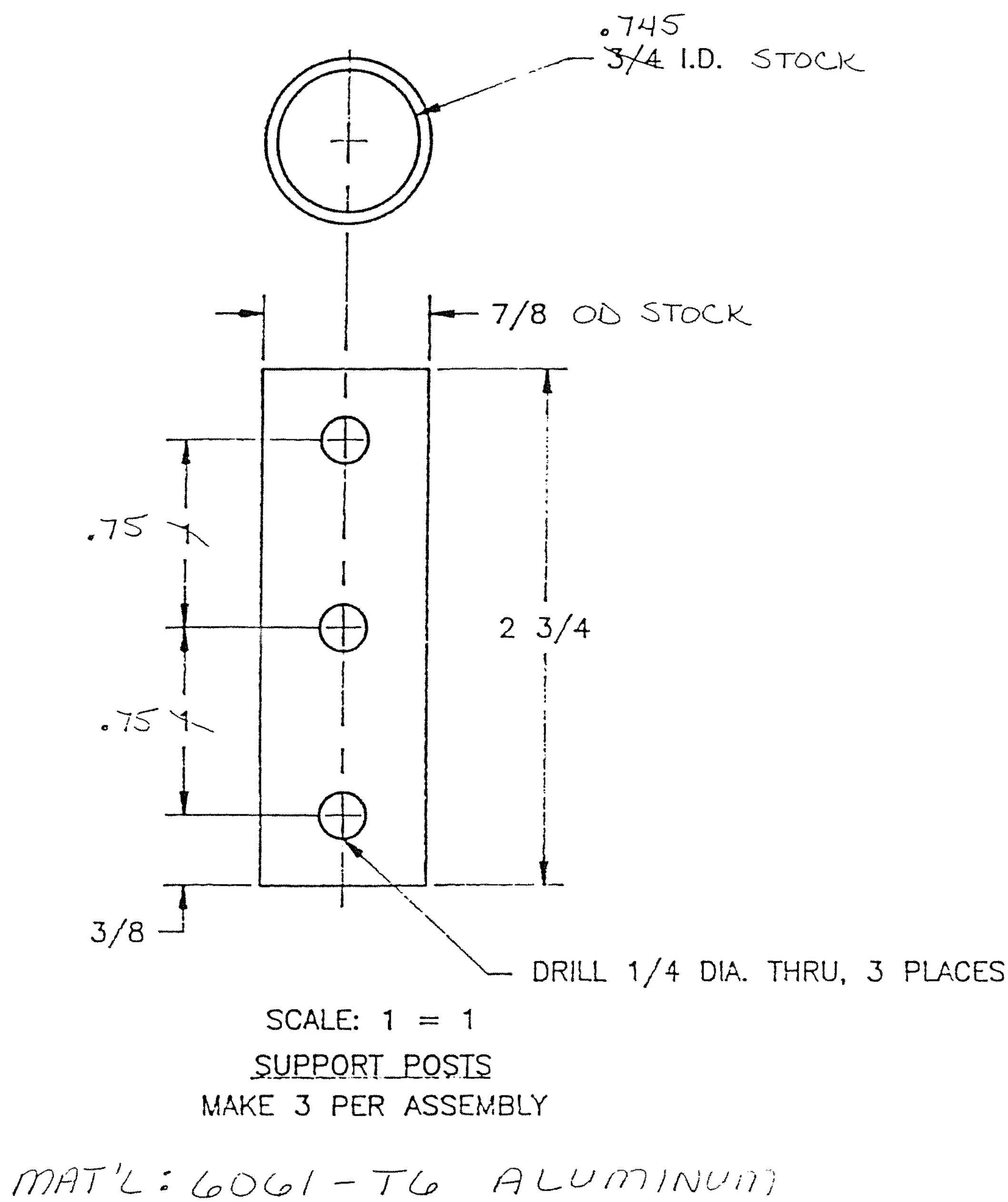


FIGURE 5a: Crush Ring and Supports





NOTE:

1. REMOVE BURRS AND SHARP EDGES 0.005–0.010 MAX.

FIGURE 5b: Crush Tubes as Flown on Flights 31.084 UU and 31.085 UU

FIGURE 5c: Crush Ring Cross-sectional View

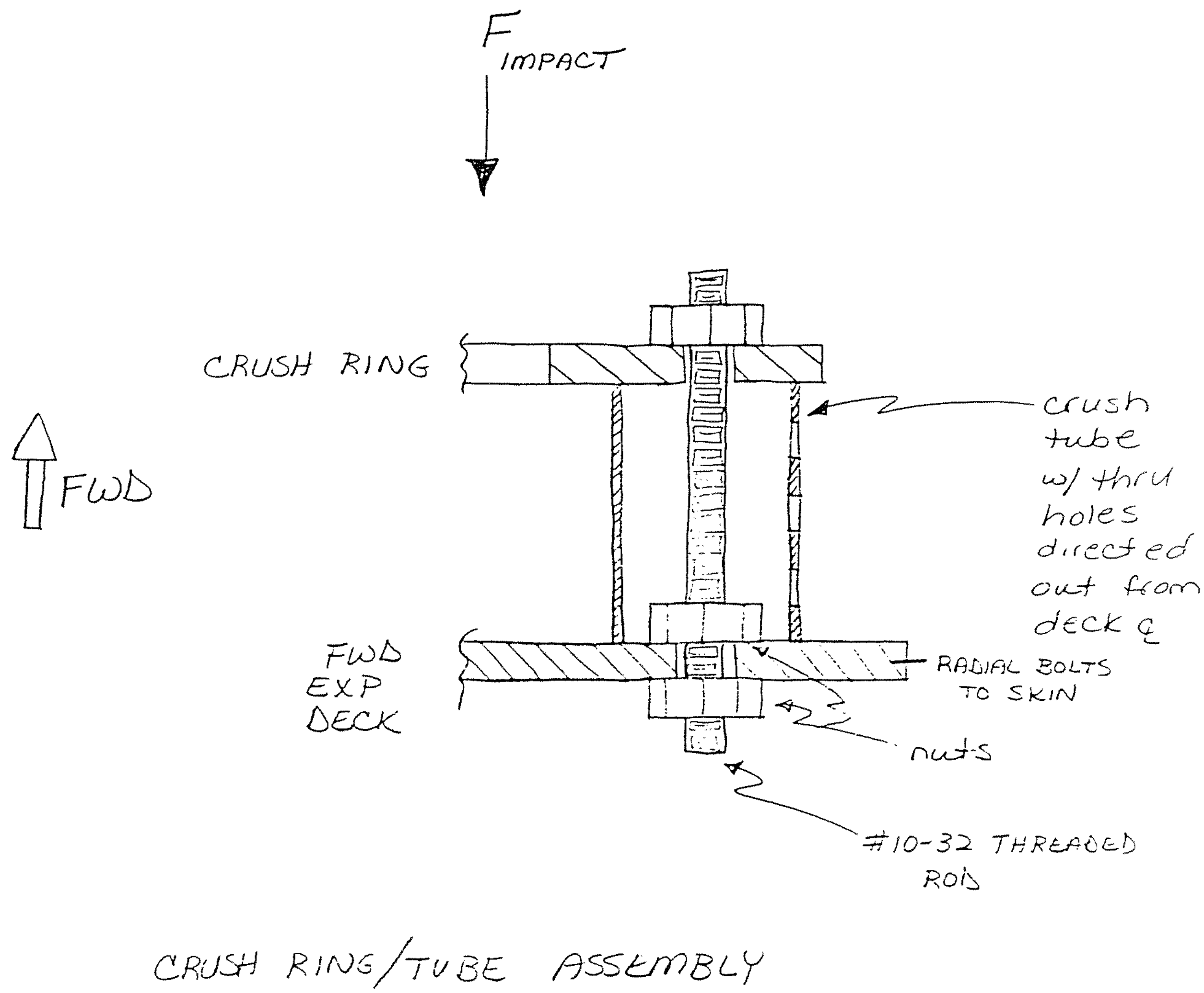


FIGURE 6: Crush Ring for 31.084 UU After Impact (WI-92-403-27)

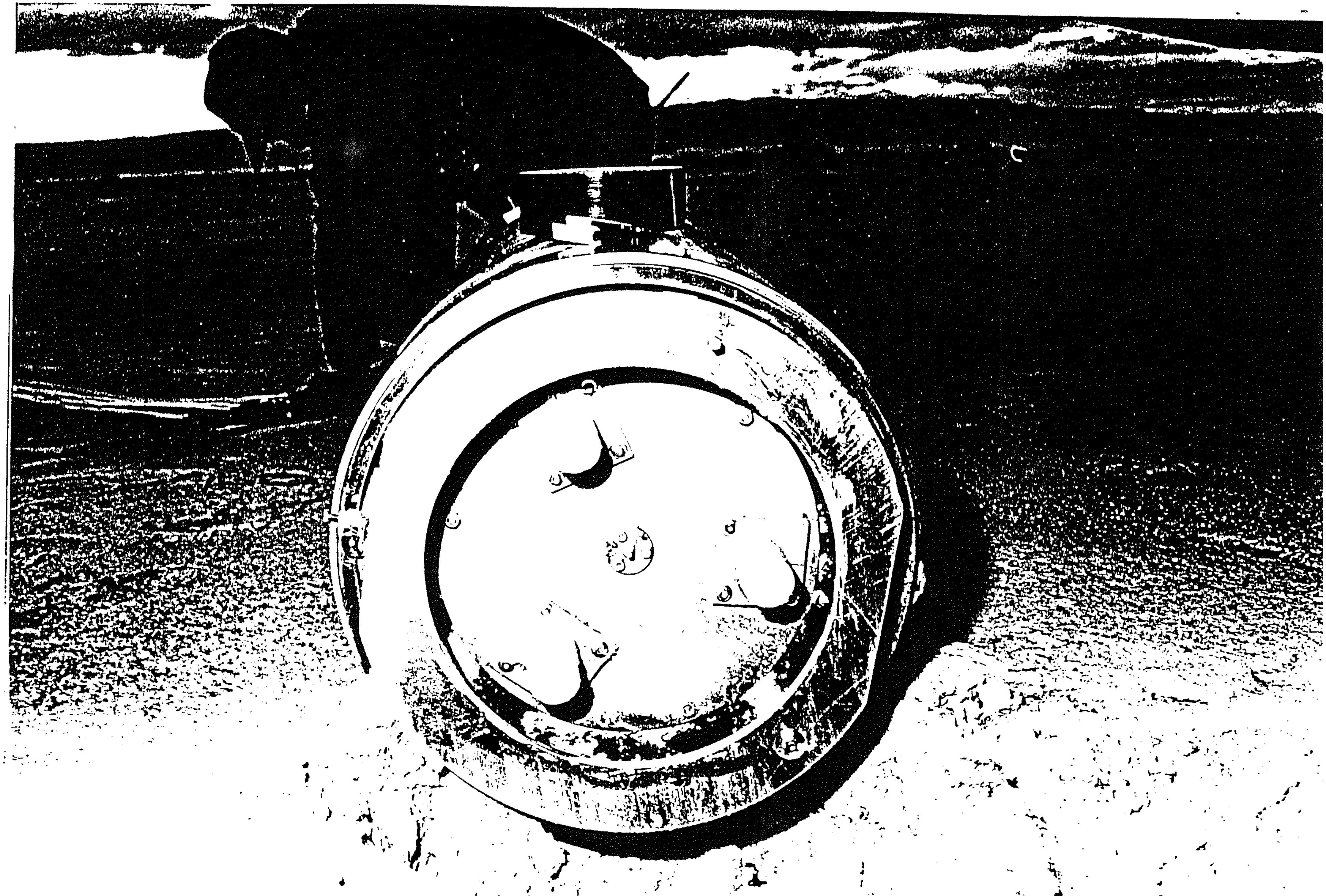


FIGURE 7: Crush Ring for 31.085 UU Afte[r] Impact

FIGURE 8: Impact Area for 31.085 UU

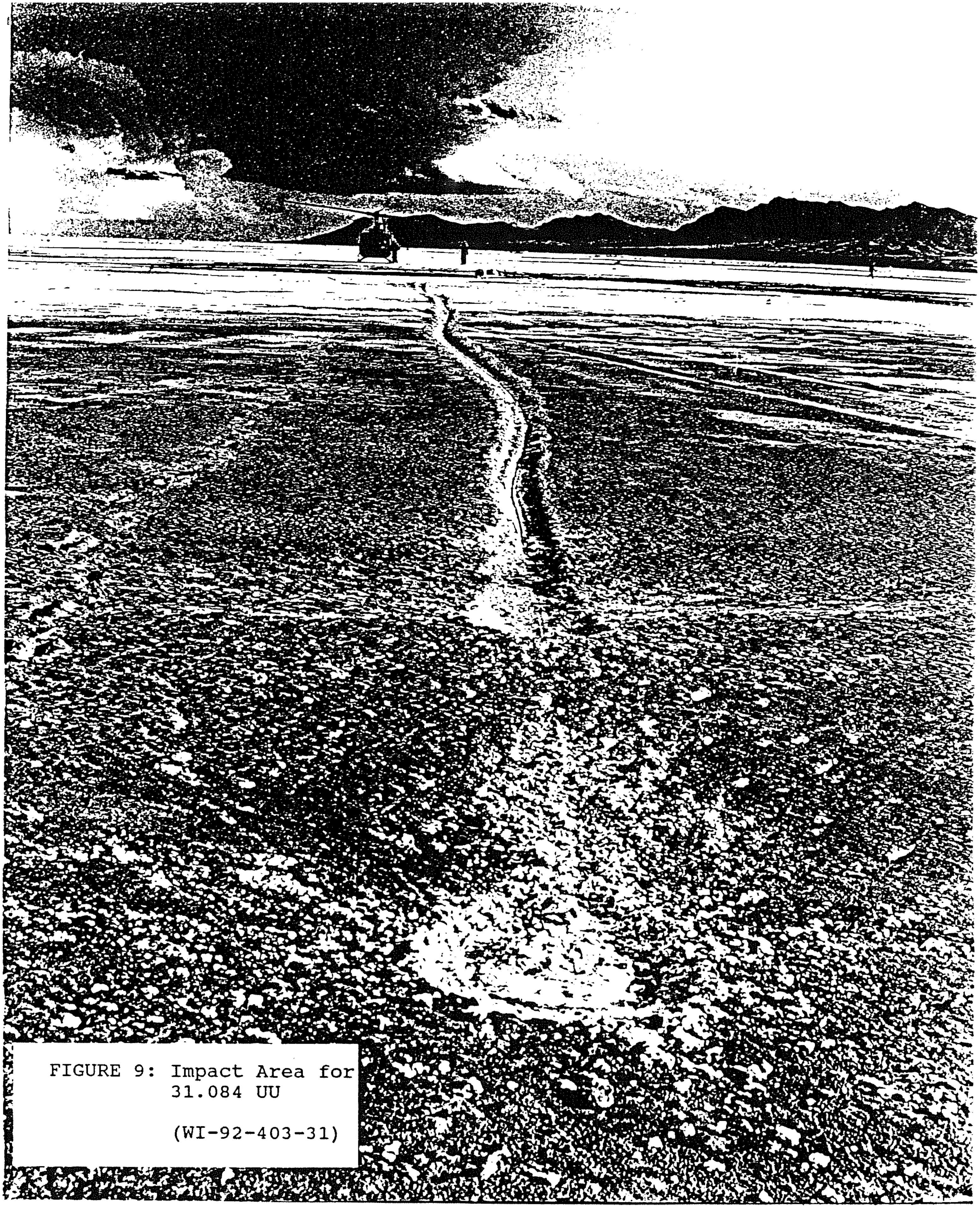


FIGURE 9: Impact Area for 31.084 UU

(WI-92-403-31)

APPENDIX 1

Environmental Shock & Vibration Sensor/Recorder

Model EDR-3

PROGRAMMABILITY

The EDR-3 is completely user programmable to support accurate recording of either high-level transient shock or low-level pseudo-stationary vibration. The instrument may be preprogrammed to operate under either **event (amplitude-based)** or **time (delay-based) triggered recording**. Once triggered, digital recording takes place simultaneously on all three of the selected set of accelerometer input channels (internal or external). Each recorded time-frame (or event) of three-channel data is then time-indexed, with current date and time, and stored in digital memory.

When operating under event triggered recording a user selectable acceleration **amplitude threshold** (g-level) in conjunction with an acceleration **time duration threshold** (milliseconds) provides the trigger criterion. Using this threshold combination selective capture of transient shock based upon measured duration as well as amplitude is possible. Recorded time-frame sample lengths may be pre-selected by using specific **pre-** *and* **post-trigger sample lengths** for each frame, or allowed to be data-dependent.

Two different memory mode storage features are available for handling large numbers of captured frames. A first **fill and stop memory mode** results in recording all frames satisfying the trigger criterion sequentially in time until the digital memory in the instrument is full. A second **overwrite memory mode** option causes selective recording (and re-recording) in digital memory of a pre-selectable **number of frames** having *the largest RMS levels* of all frames measured by the unit. This powerful memory mode option is used to selectively record the highest level accelerations sensed by the instrument over an entire test period.

Additional programmable parameters are **digital sample frequency** (30-3200 Hz/channel), overall **start and stop times** for active sensing/recording, and **time interval for temperature/humidity** measurement.

INSTRUMENT MOUNTING

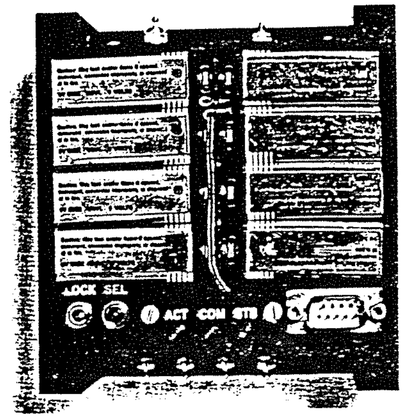
The instrumentation and sensors of the EDR-3 are built into a specially designed machined aluminum enclosure. The enclosure is designed for accurate mechanical transmission of acceleration levels directly to the internal accelerometers. Four holes in the base flange of the housing are provided for fastening and rigid mounting of the instrument enclosure by the user.

SETUP/DATA-RECOVERY/ANALYSIS

Supplied with the EDR-3 instrument is the EDR1S software program and utilities diskettes. The software is supplied on 3½" diskettes for use on PC-DOS or compatible personal computers. The software package is used for pre-programming the EDR-3 prior to field testing, retrieving recorded data subsequent to test, and processing and analyzing recorded acceleration data.

APPLICATIONS

The EDR-3 instrument is designed for applications requiring remote, unattended monitoring and recording of shock or vibration over extended periods of time. Its ultra-small size and weight make it particularly attractive for recording applications where space and added weight come at a premium. Since human monitoring during recording is not required, personnel costs associated with field testing using the EDR-3 can be reduced significantly. The instrument also affords a high degree of operational reliability under harsh environmental testing conditions by incorporating all of the sensors, electronics, and power supply within a single, secured package. Specific applications for the EDR-3 vary from industrial packaging and handling environmental monitoring to in-transit, vehicular measurements, to avionics environmental reliability data collection and qualification.



Watertight battery and control panel compartment.

If there is an application for the EDR-3 you would like to consider, feel free to give us a call and we would be pleased to discuss it.

SPECIFICATIONS

Size: 4.2" x 4.4" x 2.2" Black anodized Aluminum Housing
Mounting: Four holes in flange for #10 cap screws
Weights: 2.2 lbs. including 8 batteries
Battery Pack: Eight 9-volt type, alkaline or lithium
Battery Life: 60 days at 200 SPS, 30 days at 3200 SPS
Temperature: Operating/storage -40 to +70 C
Fragility: 500 gs or 20xfs (fs = full scale sensitivity)

Digitization: 10 Bits
Memory: 256 kbytes battery backed RAM

Acceleration Recording:
- **Channel Selector:** Internal or External
  - **Internal Accelerometers:** 3 piezoresistive
  - **External Accelerometers:** 3 piezoelectric inputs
- **Sample Frequency:** 30-3200 SPS/channel
- **Trigger Selector:** Individual channels or trigger input
  - **Trigger Output Selector:** Individual channels or none
  - **Amplitude Trigger Threshold:** 0 to fs in 512 steps
  - **Trigger Duration Threshold:** 1 to 65,535 samples
- **Maximum Number of Frames:** 5291
- **Time Trigger Delay:** 0 to 3,495 seconds
  - **Resolution:** 53 msec
- **Frame Style Select:** Fixed or variable length
  - **Pre-Trigger Length:** 2 to 16,536 samples
  - **Variable Length:** All samples above trigger
  - **Post-Trigger Length:** 1 to 16,536 samples
  - **Maximum Length Cut-Off:** 3 to 16,536 samples
- **Auto-Zero Correction Rate:** 1 %fs/second (near DC response)
- **Factory Options:**
  - **Sensitivity:** 2,10,20,50,100,200 gs full scale
  - **Anti-Alias Filter:** 30,60,200,400,800 Hz

Temperature Recording:
- **Channel Select:** Internal/External
- **Range:** -40 to +140 F
  - **Resolution:** 1 degree F
- **Sample Period:** 14 to 917,504 seconds
  - **Period Resolution:** 14 seconds

Humidity Recording:
- **Range:** 0 to 100 %RH
  - **Resolution:** .2 %RH
- **Useful Temperature Range:** 34 to 140 F
- **Sample Period:** Same as Temperature

Digital Clock: Month/Day/Year Hour:Minute:Second
- **Maximum period:** 3 years
- **Resolution:** 53 msec
- **Accuracy:** +/- 1 minute/month
- Time Tagged to Each Acceleration Frame
- Programmable Automatic Recording On-time
- Programmable Automatic Recording Off-time
- On-time and Off-time logger

Connectors: One DB-9 for RS232
- One ¼-24 for external power input
- Five 10-32 for accelerometers, temperature, trigger

Controls: Three LEDs, one push button and one toggle switch
- **Manual Control Functions:** Start, stop, reset and trigger

Standard Equipment:
- Three internal accelerometers and temperature sensor
- Calibration data and operating manuals
- EDR1S programming and Analysis software

Warranty: 1 year

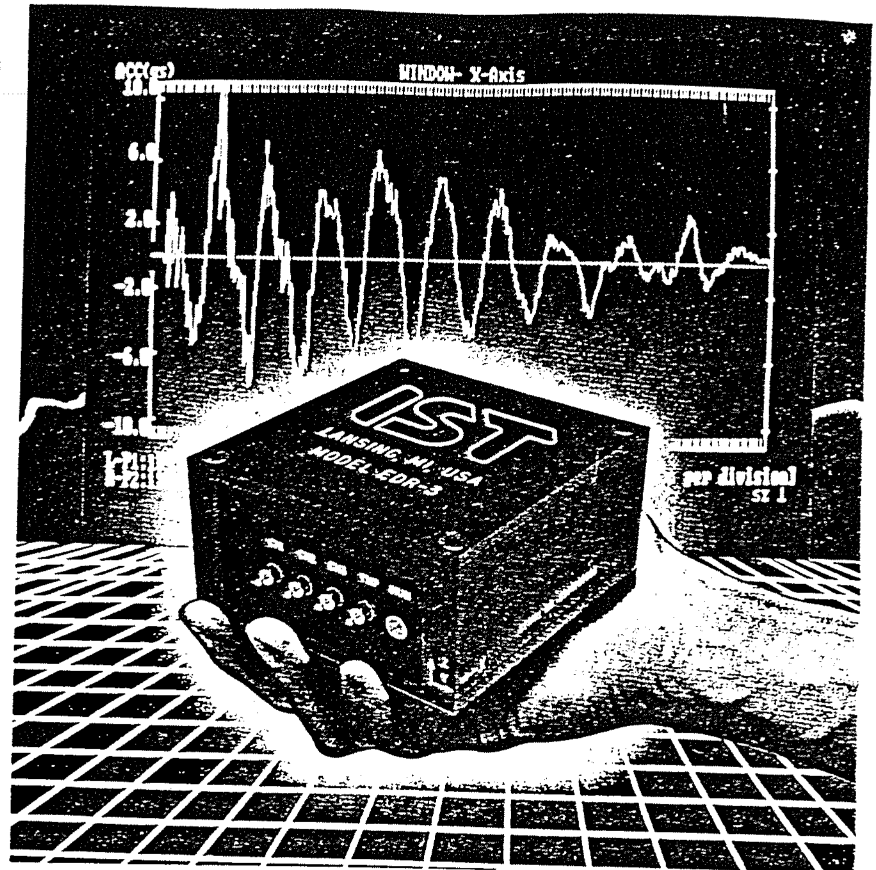
Required Equipment:
IBM compatible PC, RS232 port, EGA/CGA and 640K

OPTIONAL EQUIPMENT:
- Humidity Sensor
- EDR2S Vibration Analysis Software
- External Accelerometers
- Lithium Battery Pack(s)
- External Temperature Sensor

ENVIRONMENTAL SHOCK & VIBRATION SENSOR/RECORDER

MODEL EDR-3

- Measures Shock and Vibration
- Built-in Triaxial Accelerometer
- 10 Bit A/D, 54dB Dynamic Range
- Three External Accel Channels
- DC-1600 Hz Frequency Response
- 256K Battery-backed SRAM
- Programmable Time or Event Triggering
- Battery Powered
- Easy to Setup, Easy to Use
- Ultra-small and Rugged, 40 Cubic inches, 2.2 lbs.
- Completely User Programmable



TYPICAL APPLICATIONS

- Transportation Monitoring
- Cargo Shipping & Handling (Packaging)
- Avionics Environmental Reliability
- Naval Ship/Submarine Shock Monitoring
- Machinery Monitoring
- Armament Environmental Monitoring
- Environmental Test Level Qualification
- Industrial Production/Material Handling
- Concealed Environmental Monitoring
- Railcar Coupling Impacts
- Vehicle Test Track Performance Monitoring
- Launch Vehicle Vibration

DESCRIPTION-Instrumentation

The Model EDR-3 data recorder is a self-contained, programmable, electronic, acceleration sensor/recorder. The compact, 2.2 lb. unit is designed for remote, stand-alone shock and vibration measurement and recording over extended time periods ranging from several hours to several weeks. Recorders are programmed for test via a standard RS-232 interface to a host PC-compatible computer using the supplied EDR1S or optional EDR2S software package. After field recording, data is transferred back to the host computer for processing and analysis. Each unit is powered from a built-in battery pack. The instrument s recording function is controlled by a microprocessor-based digital data acquisition and storage system. During active recording, acceleration signals are digitized to 10 bit resolution and stored in digital memory within the instrument. The instrument offers 256Kbyte of digital memory capacity, which can be used to capture up to several hundred three-channel shock signatures and/or real-time vibration frames. Acceleration recording can be configured for measurement from either the three internal (triaxial) accelerometer channels, or from up to three optional external accelerometer channel inputs.

The EDR-3 also measures and records environment temperature using sensors built into the instrument. Optional external temperature sensors are also available. A relative-humidity sensor option is also available.

SENSORS

Each instrument is supplied with a specially designed, built-in triaxial accelerometer. The internal accelerometers are piezoresistive (solid-state silicon) devices, which offer excellent low frequency response characteristics and low power consumption for long duration battery-powered operation. Internal accelerometers are mounted approximately at the center-of-gravity of the instrument enclosure itself, enabling accurate sensing of the gross accelerations to which the unit is *itself subjected*. The rigid, machined aluminum instrument housing permits accurate transmission of mechanical shock and vibrations directly to the internal accelerometers, with a mechanical frequency response up to several kilo-Hertz. Internal accelerometers are available in several different sensitivities to meet a variety of acceleration measurement range/resolution requirements.

External accelerometer input channels are designed for use with piezoelectric accelerometers. External accelerometers are available as a factory option, in either single-axis or tri-axial configuration. Several sensitivity ranges are also available to satisfy various measurement range/resolution requirements.

Instrumented Sensor Technology

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