LA-UR -80-3382

CONF-810406--1

TITLE: CORRTEX: A COMPACT AND VERSATILE SYSTEM FOR TIME DOMAIN REFLECTOMETRY

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SUBMITTED TO: Presentation to be given at the 27th International Instrumentation Symposium, Instrumentation for a Blast Environment Session, April 27-30, 1981 at Indianapolis, Indiana.

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CORRTEX: A COMPACT AND VERSATILE SYSTEM FOR TIME DOMAIN REFLECTOMETRY

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ABSTRACT

The CORRTEX (COntinuous Reflectometry for Radius versus Time EXperiments) system was designed to be an adaptable and versatile unit for performing time domain reflectometry (TDR). The system consists of a coaxial cable, a digital TDR, which uses a Motorola 6800 microprocessor, a power source or battery pack, and an output terminal or recording driver. Desirable criteria for the system are discussed as well as the operation of the CORRTEX system. The types of present applications of the CORRTEX system are summarized and data presented.

INTRODUCTION

The CORRTEX system, developed at the Los Alamos Scientific Laboratory, is a digital system used to measure the position of a shock front as a function of time. The system was developed under the auspices of the Peaceful Nuclear Explosives and Weapons Test programs. During the early stages of the development, several criteria were formulated which the system needed to satisfy. These include 1) the collection of a relatively large number of highly accurate measurements closely spaced in time, 2) units which are self-contained and field-deployable in a relatively small package, 3) versatility in deployment, 4) allowance for future modifications, 5) self-calibration, 6) only passive components in the usually inaccessible region where the shock wave is to be measured, and 7) the ability to rapidly reduce the data to produce shock times of arrival (TOA - the shock location as a function of time) in the field.

Over the past six years, more than 200 measurements have been made in a variety of applications, and we are convinced that all criteria are well satisfied. In the next section, we outline the components of the CORRTEX System and their properties. Section III indicates the range of applications in which the system has been employed. Finally, we comment on the current state of the system and the prospects for future directions of development.

THE CORRTEX SYSTEM

The CORRTEX system has been described in detail elsewhere, so that we shall focus here on a brief summary of its components and specifications and a discussion of its attractive features. The concept is quite straightforward and is displayed in Figure 1. A coaxial cable is run from a recorder containing the units to some known distance from the source of the shock wave. A pulse emitted by the system travels down the cable and is reflected at the point where the shock front is currently crushing the cable. The return pulse is received at the trailer and the time interval between pulse emission and reception measured and stored in memory. With the previously determined velocity of propagation of the pulse through the cable, one finds the cable length from the recorder to the current shock location. Therefore, monitoring this time interval as a function of time allows determination of shock location as a function of time.

This configuration allows many advantages in terms of the cable alone. Among these is that virtually any 50 ohm cable can be used and that the cable calibrated for any experiment is the exact cable used on that experiment. The current experience includes cables that crush reliably under pressures of a few tens of bars to those that crush only under pressures of kilobars. Thus, the choice of cable is determined by the type and goal of the experiment rather than any limitations of the system. The cable calibration is both quick and accurate. The cable to be used in the experiment is pulsed 2000 times and the time between pulse emission and reception measured. A piece of cable of accurately measured length is cut off and the remaining cable pulsed another 2000 times. The pulse propagation velocity can then be determined from the difference in cable length and the difference in pulse transit time. A typical standard deviation over the 2000 pulses is about 480 ps, which corresponds to about 1 cm in cable length.

The 2000 pulses correspond to the number of data points that can be stored in the memory of the digital recorder. In keeping with the desired criteria, the digital recorder is both light (27 lbs) and small (15.6 x 17" x 5.25). The size may be visualized in Figure 2. The units are powered by external 24-V batteries, but they include an internal battery for maintaining data storage for up to eight hours should the external battery fail. This internal battery allows unit transport while retaining data.

Pulses may be emitted in time intervals from 20 to 90 μs. A portion of each pulse is routed to time interval measuring circuitry to start the time count. Counting cannot be stopped until the pulse is well down the cable. A discriminator detects the reflected pulse and terminates the time count. The data are then interpreted, formatted, and stored in memory. After the memory is filled, the system is shut down.

Data retrieval may be carried out in a variety of ways. One of these is displayed on the front panel of the digital recorder. The data can also be recorded or displayed on any device that can communicate through an RS232 port. The same applies to directly attaching a computer interface to the recorder.

Another highly desirable feature is the speed of data reduction in the field. Once the data has been transferred into computer memory (which usually depends on factors completely external to the CORRTEX system), reduction to the shock radius versus time curve can be accomplished in about ten minutes.

Speed and efficiency are characteristics of the entire system. The entire operation can be set up, calibrated, run through the experiment, and data reduction by a small number (characteristically three, but possibly two would suffice) of personnel. The portability is adequately demonstrated by the fact that five complete units were transported to a hot, dry rock experiment in the United Kingdom at a cost under $1000. One unit has even been checked as ordinary airline baggage, functioning perfectly after the ordeal. With the variety of cables and output devices allowed, one might guess that use of the system is intended for a number of applications. To show this, and the quality of information, we now look at some individual results.

APPLICATIONS

We summarize in Table I the types of CORRTEX experience to date.

TABLE I

CORRTEX Experience

Working Medium	Number of Measurements	Data Quality (cm)	Cables
Underground	>100	1-2	RG-218, RG-8, FSJ1-50, RF-18
Air	18	10-15	RG-178
Mine holes (ANFO)	>20	3-7	RG-178 FSJ2-50
Pipe Flow Diagnostics (air and vacuum)	6	5-10	RG-178, FSJ1-50
Geothermal Fracturing (TATB + water)	9	3-"	RG-178 FSJ1-50

Included in the Table are the medium of the experiment, the number of independent data sets, a measure of the quality (noise in the TOA curve in cm), and the types of cables used. Clearly, a large range of experimental conditions have been sampled.

The ability to use a variety of cables provides benefits in addition to the matching of cable type to experimental goal. Once the pressure at which a cable ceases to crush regularly has been determined, both an estimate of the pressure at one distance from the explosion and some information about the shock front can be obtained. An example of the difference between cable response is shown in Fig. 3. Clearly, the high crush threshold RG-214 cable has ceased to crush smoothly by roughly 16.5 ms. Furthermore, the data for the two different cables between 25 and 30 ms suggest that the shock front may have become sufficiently diffuse to allow the separation of initial arrival and peak pressure. We also note that a very good approximation to the late time TOA curve can be found by connecting the peaks of the RG-214 curve.

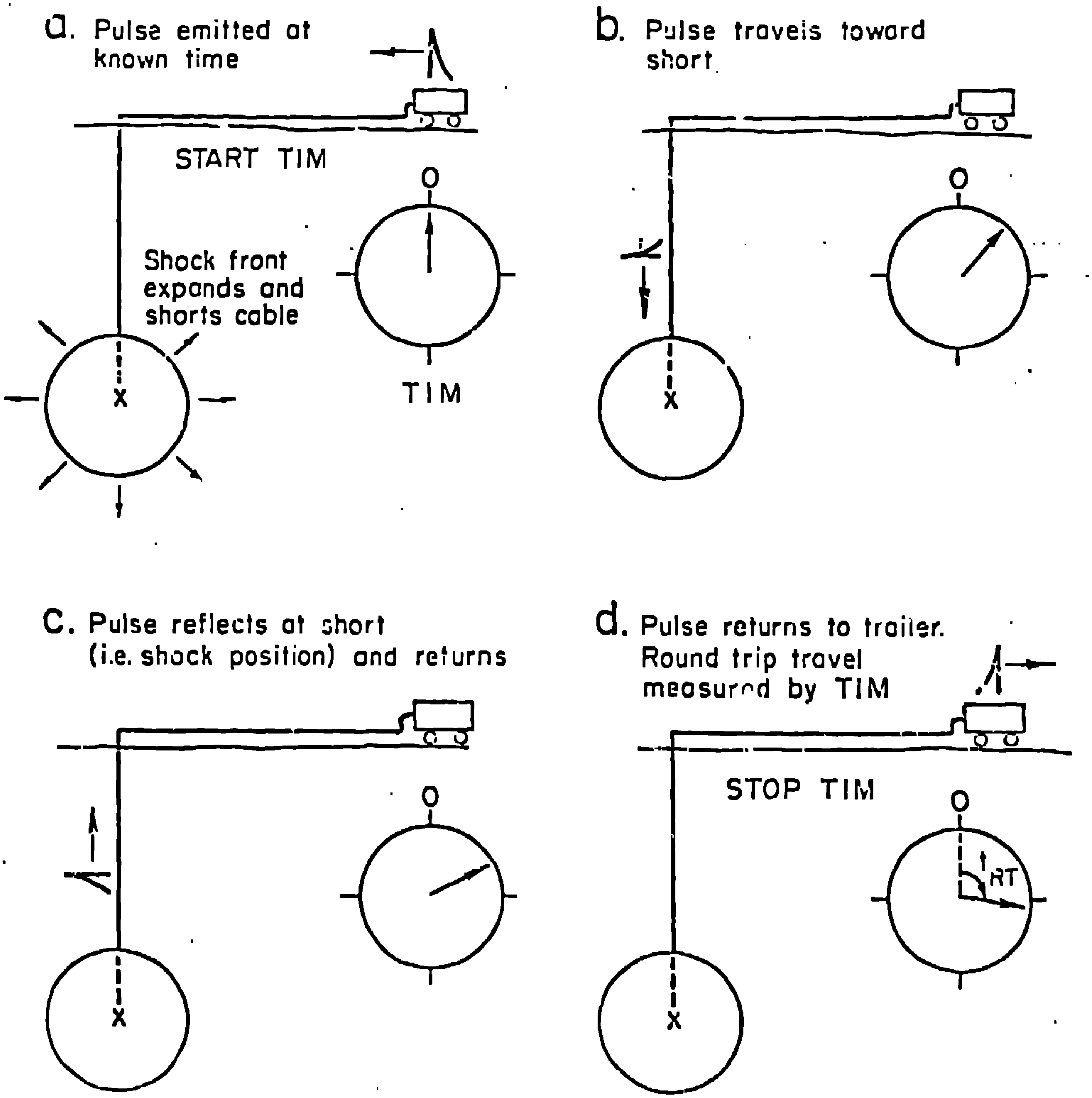
A final example of the utility of the system is demonstrated by examination of a high explosive oil shale rubblization event conducted by G Division of LASL. The event consisted of four 15' deep holes with 5' of ANFO explosive in the bottom. The holes formed a square 7' on a side. The configuration is diagrammed in Fig. 4. The CORRTEX data for the four holes are shown in Fig. 5. The data show that all the HE in Holes 3 and 4 ignited, that only partial burn was obtained in Hole 1, and that there was no ignition in Hole 2. These results were obtained shortly after the event and are clearly vital for safety reasons in case of reentry. One can also obtain accurate estimates of burn velocities of the HE from this data.

DISCUSSION

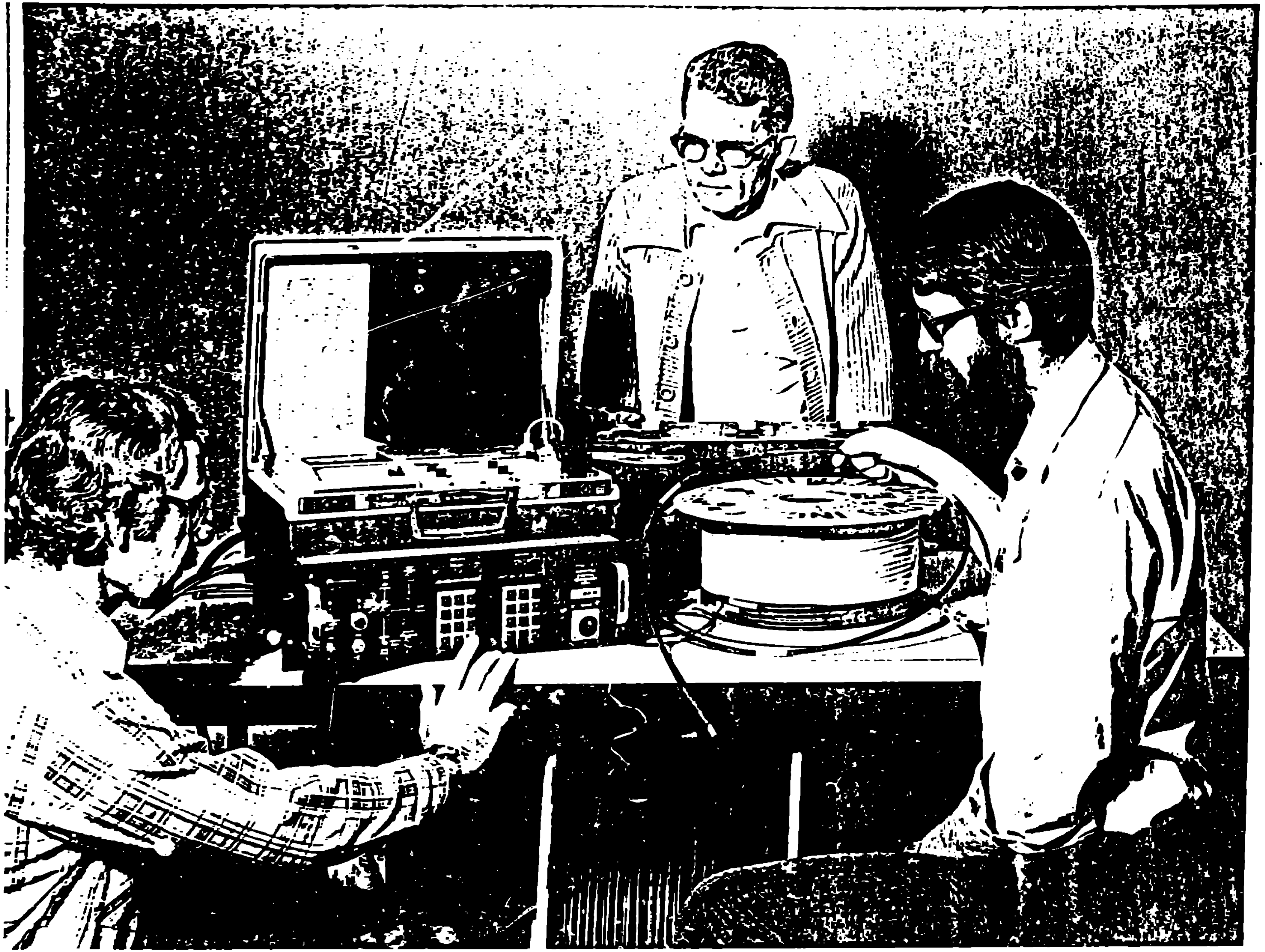
We have shown the CORRTEX system to be a rapidly deployable, highly versatile, fast, and efficient system for obtaining accurate shock time of arrival curves. The units are currently routinely applied and the data reduced in the field. The system has shown itself to be highly reliable and accurate, even after extensive travels and frequent use.

A second generation of these units is currently being developed. The primary added criterion is environmental hardening. We anticipate a wide variety of applications and extensive use of these new units.

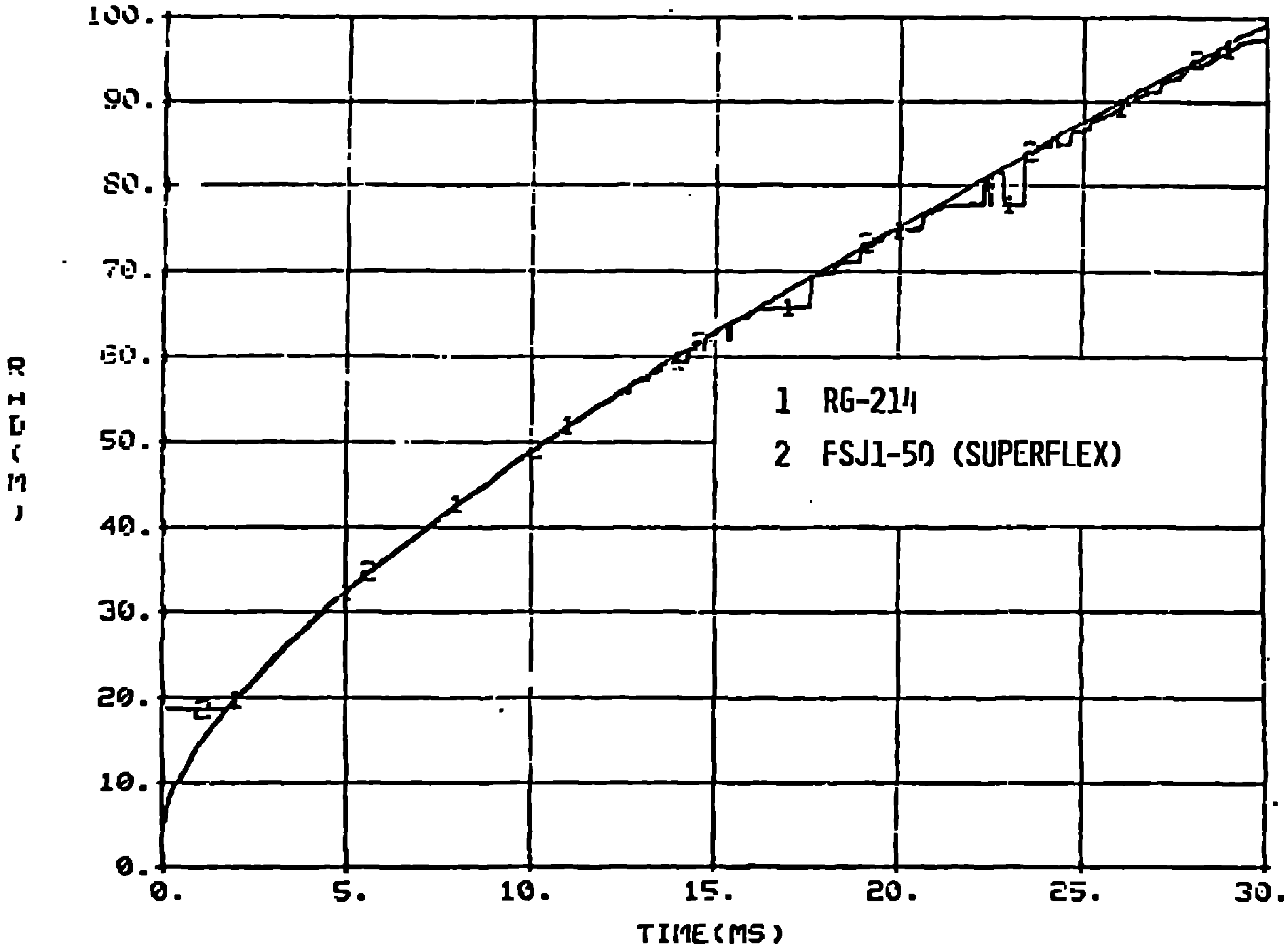
PRINCIPLES OF TDR OPERATION
"Radar on a Wire"



Total Cable Length = Pulse Propagation Velocity x (Round Trip Time / 2)



TWO CORRTEX DATA SETS FROM A NUCLEAR EVENT



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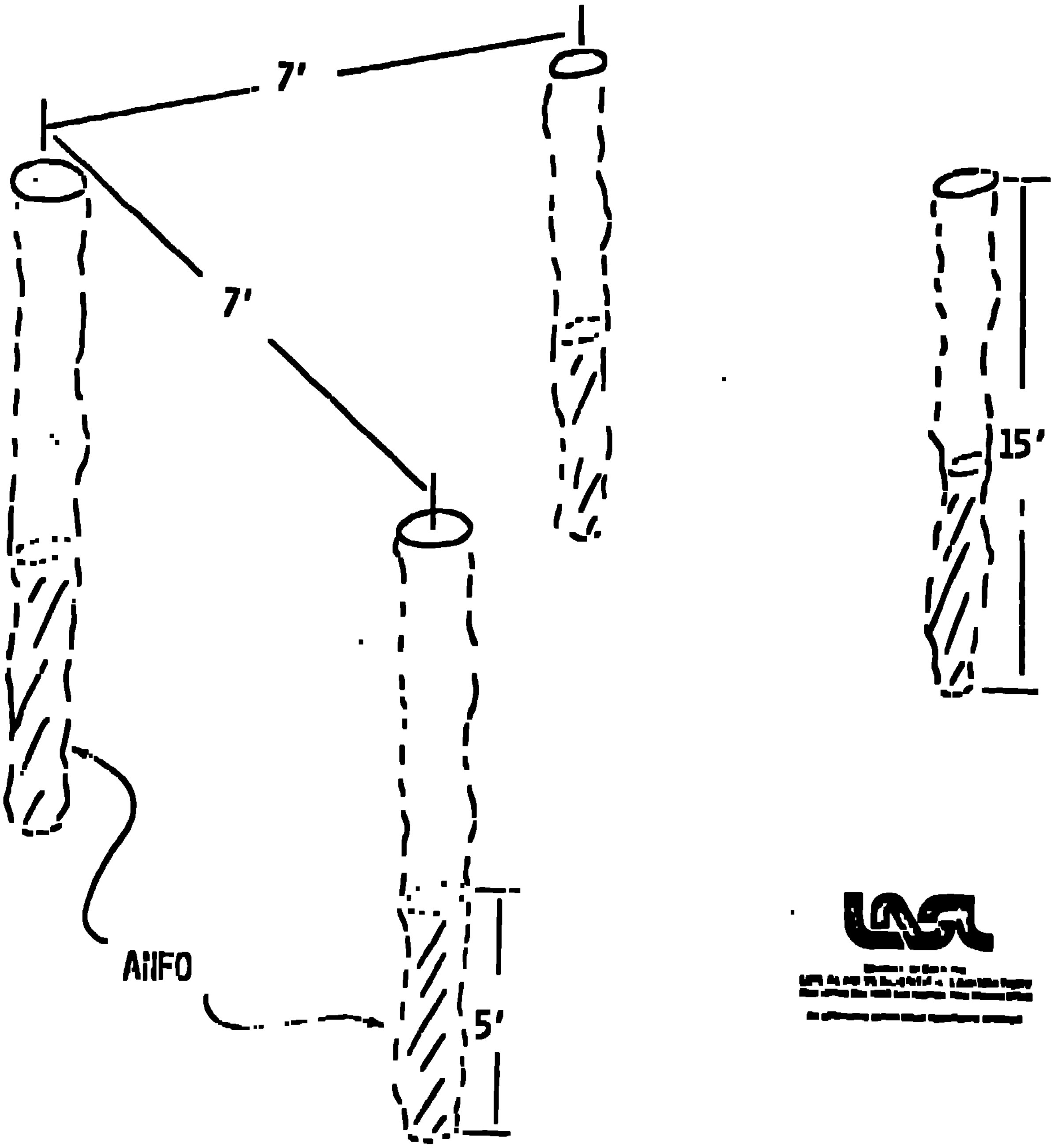

G-7 SHOT 79-16 HOLES 1, 2, 3 AND 4