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USER'S MANUAL FOR THE ARES (ADVANCED RESEARCH ELECTROMAGNETIC SIMULATOR) FACILITY

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Stanford Research Institute

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USERS' MANUAL FOR THE ARES FACILITY

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ABSTRACT

An introduction to the ARES (Advanced Research Electromagnetic Simulator) Facility is provided for assistance in evaluating the suitability of the facility for specific weapons system EMP testing. A brief description of the physical and electromagnetic characteristics is provided, along with information regarding test instrumentation and administrative procedures and responsibilities of the various agencies involved.

PREFACE

This manual has been prepared in order to provide a reference source that would be useful to potential users of the ARES Facility. The intention has been to provide a general description of the facility, convey a feel for the test-planning requirements, and make it possible for the experimenter to reach a preliminary conclusion regarding the suitability of the facility for his specific EMP testing requirements.

It is obviously impossible to anticipate every aspect of future users' requirements; thus the intent has been rather to address the general aspects of users' needs and, in so doing, give enough background to provide guidance in the consideration of specific, unique topics not covered. This approach also served the goal of providing a digestable package of information.

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GLOSSARY

AEC	Atomic Energy Commission
AFWL	Air Force Weapons Laboratory
A/M	Amperes per meter--a measure of magnetic-field intensity
ARES	Advanced Research Electromagnetic Simulator
DACC	Data Acquisition and Calibration Complex
DASA	Defense Atomic Support Agency (now DNA--Defense Nuclear Agency)
DNA	Defense Nuclear Agency
DoD	Department of Defense
DTP	Detailed Test Plan
ECS	Event Controller System
EM	Electromagnetic
EMP	Electromagnetic Pulse (also referred to as NEMP--Nuclear Electromagnetic Pulse)
FC/DNA	Field Command/Defense Nuclear Agency
GPP	General Program Plan
GTP	General Test Plan
HP	Hewlett-Packard
HVGC	High-Voltage Generator Center
Hz	Hertz--measure of sinusoidal frequency equal to one cycle per second
JOA	Joint Operating Agreement
MTS	Master Timer System
RF	Radio Frequency
RPG	Repetitive-Pulse Generator

GLOSSARY (Concluded)

SPO	System Project Office
SPOIC	System Project Officer in charge
T&F	Timing and Firing
TD	Test Director
Termination	The load impedance at the end of the simulator, which ultimately absorbs the energy that has transited the simulator
Tesla	Equals one Weber per square meter and is a measure of magnetic flux density
TWG	Test Working Group
TWT	Traveling-Wave Tube
V/M	Volts per meter, a measure of electric-field intensity
Working volume	The portion of the Simulator within which specimen equipment may be placed for testing
X-Band	Commonly used designator for microwave frequency band between 8 and 12 GHz

I INTRODUCTION

A. Purpose

The ARES Facility was developed and designed by the Defense Nuclear Agency with technical support from the Air Force Weapons Laboratory. The facility is intended to provide an electromagnetic test environment to make possible experiments that will produce realistic data to support analysis and evaluation of the EMP vulnerability and survivability of complete missile systems. The operational goal for ARES is to provide the best possible service to users, thereby meeting the requirements of Department of Defense contractors designing systems that might be exposed to high-altitude EMP.

Before proceeding, there is a point to stress: The data obtained through experimentation at ARES are necessarily only a portion of the information eventually required for an assessment of the EMP vulnerability and survivability of any system. The ARES facility is not intended for (nor is it feasible to do) proof tests that can stand alone, unsupported by analysis and other test efforts. As a general rule, a comprehensive assessment program should be well under way before an attempt is made to design the experiment to be conducted at ARES.

Such an assessment program will include identification, and ranking by relative importance, of all paths of entry of electromagnetic energy into the weapon system; identification of the critical circuits within the system; determination of the threshold amplitudes for these critical circuits (both for upset levels and component damage levels); and analysis of the coupling paths within the system. Clearly, some test effort will have to be completed prior to designing a test program to be executed at ARES. The preliminary testing, such as experimental verification of circuit thresholds, should be completed and understood before the ARES testing is begun.

With a good understanding of how the system reacts in the laboratory, the experimenter is well equipped to make use of the facility, and will probably encounter a minimum of unexpected results during the ARES tests; however, there will almost certainly be some.

Further in-house testing following the ARES tests should also be anticipated. The surprises alone will deserve some investigation, and the testing of the complete system in a high-level environment will reveal characteristics that can be developed only by a facility such as ARES.

While the facility was designed to handle complete in-flight missile systems, it can certainly be useful for testing other systems as well. Regardless of the type of system being tested, the yield of the experimental effort will depend on the care with which the experiment is designed and executed, especially with regard to the characteristics of the facility and the ways in which these characteristics satisfy the users' EMP test requirements. Accordingly, it is the purpose of this manual to provide initial guidance to prospective users so as to assist their preliminary test planning and selection of conditions.

Since the facility was completed in 1970, it has operated with essentially no idle time. Scheduling is established by DNA, with due regard for weapon system priorities, and the fact that it usually requires about a year to prepare for an ARES test gives an idea of the time scale involved in the use of the facility.

B. Physical Characteristics

The ARES Facility is a 37-acre installation located at Kirtland Air Force Base, East, New Mexico, at an altitude of about 5350 feet. Weather statistics are given in Table 1.* The Facility consists of a parallel-plate transmission line simulator, associated pulse generators and various buildings for monitoring and other instrumentation activities. Also available at the site are laboratory and office space, and support facilities including data acquisition, recording, and processing functions. Photographs of the site are shown in Figures 1 and 2. The site layout is shown in Figure 3, and the simulator layout is shown in Figure 4.

The ARES working volume is the rectangular region bounded by the four tall towers (see Figure 1) that support the upper set of wires that are the top section of the transmission-line simulator. The equipment being tested is placed within this volume. If fixtures are required to hold the equipment, such fixtures must also fit into the working volume, and must be designed so as to avoid perturbation of the electromagnetic environment--i.e., be nonmetallic and nonconducting.

The horizontal dimensions of the working volume are 33 by 40 meters; the height is 40 meters. The guys required for the support towers are positioned to allow an unobstructed opening 20 m wide and 40 m high into the working volume. The floor of the working volume is concrete, designed for a ten-thousand-pound wheel load. The ground-plane wires, or lower portion of the simulator, are imbedded in this concrete floor.

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* The weather will require consideration in planning test activities because the simulator working volume is unprotected.

Table 1

ALBUQUERQUE WEATHER STATISTICS

Summer Temperatures (23-year average)

	Apr.	May	June	July	Aug.	Sept.
Avg. Daily Max.	69.1	78.3	88.6	91.2	88.0	82.3
Avg. Nightly Min.	41.2	51.9	61.1	65.8	64.3	57.6

Winter Temperatures (23-year average)

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
Avg. Daily Max.	70.7	53.1	48.3	46.4	52.2	58.8
Avg. Nightly Min.	45.3	31.1	25.6	23.5	27.5	32.7

Precipitation

	Apr.	May	June	July	Aug.	Sept.
Summer (inches)	0.61	0.35	T	1.87	0.98	1.57

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
Winter (inches)	0.04	0.21	0.49	0.07	1.12	0.13

Snowfall

Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
0.0	T	0.30	0.50	8.2	1.3

Surface Winds

Month	Mean Speed (knots)	Mean Max. (knots)	Most Frequent Direction (from)	Most Frequent Direction of Mean Max. (from)
Jan.	7.0	Over 41	North	East
Feb.	7.7	28-40	North	East
Mar.	9.0	Over 41	North	West
Apr.	9.8	Over 41	South	East
May	9.2	28-40	South	East
June	8.5	Over 41	South	East
July	7.9	28-40	Southeast	East
Aug.	6.9	28-40	Southeast	East
Sept.	7.5	28-40	Southeast	East-Southeast
Oct.	7.4	28-40	South	East-Southeast
Nov.	7.0	28-40	North	East
Dec.	6.4	Over 41	North	East

NOTE: The maximum wind speed ever recorded at Albuquerque was 79 knots from the southeast in December 1948.

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FIGURE 1 THE ARES FACILITY — HIGH VOLTAGE GENERATOR CENTER TO THE LEFT

FIGURE 2 THE ARES FACILITY — LOOKING TOWARD TERMINATOR

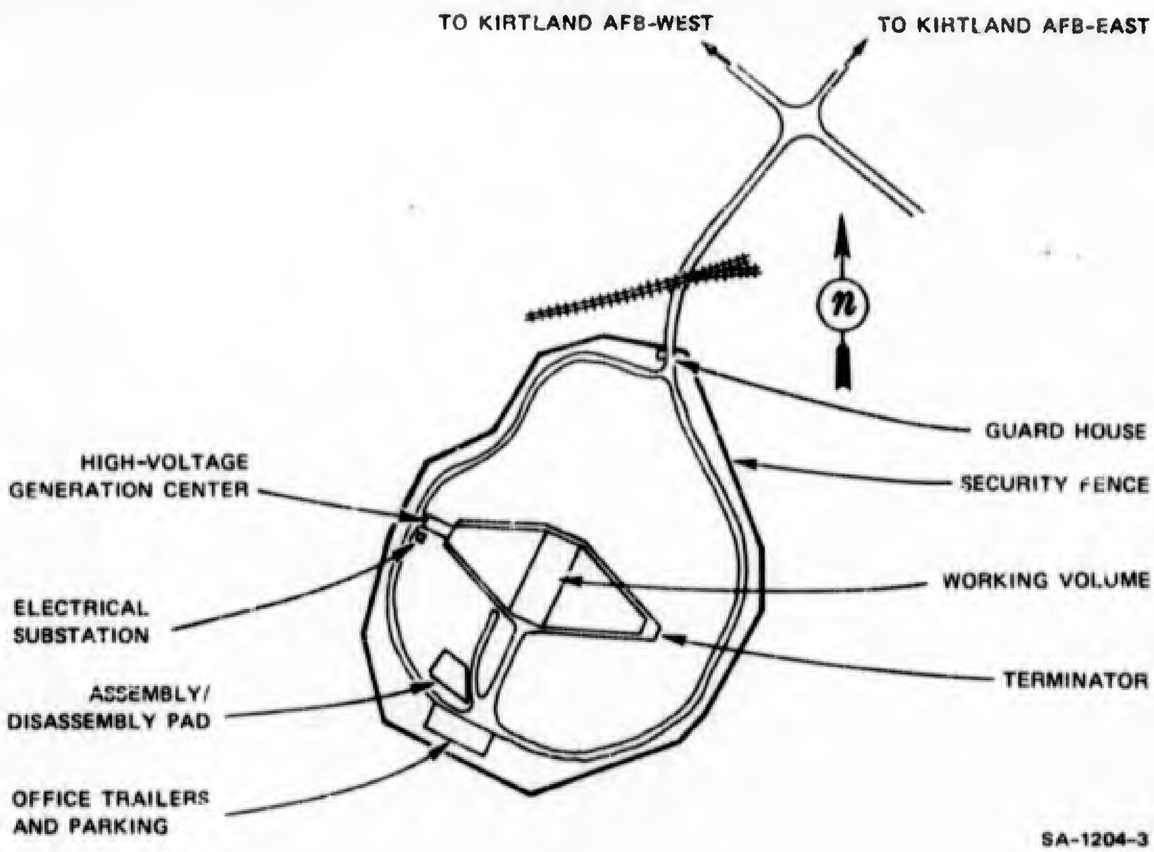

FIGURE 3 FACILITY LAYOUT

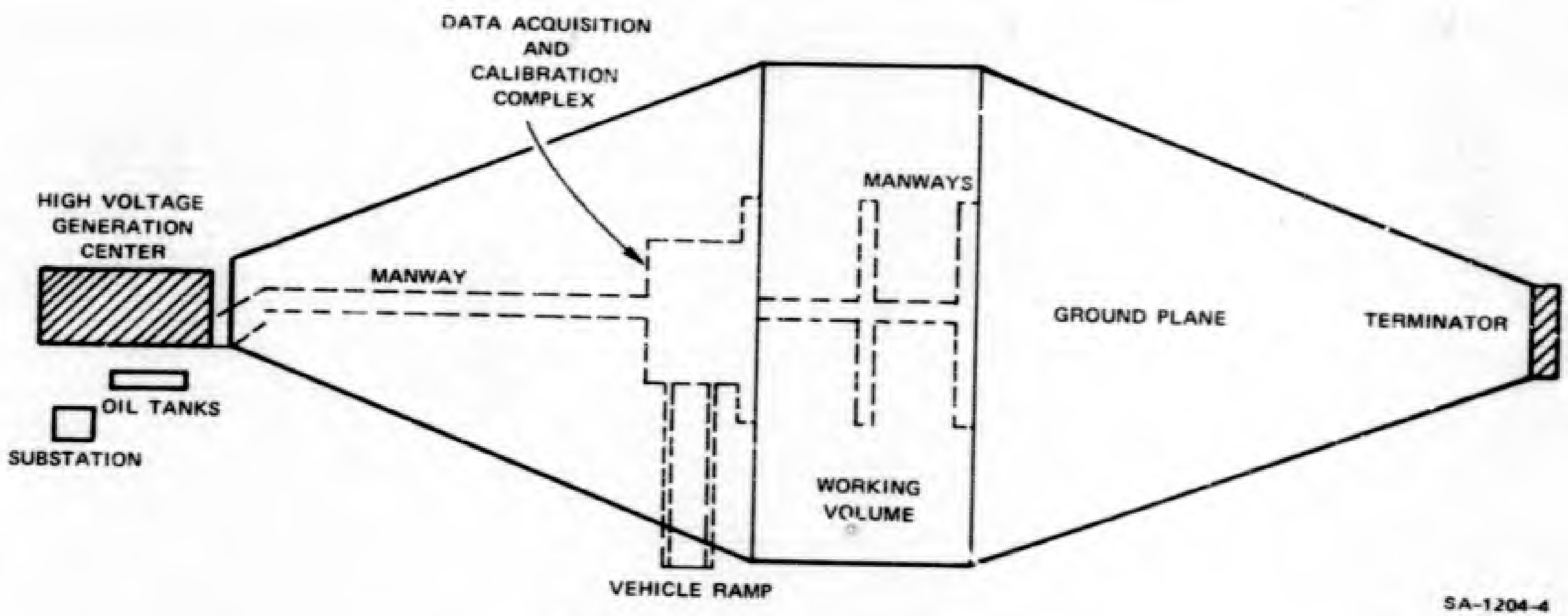

FIGURE 4 SIMULATOR LAYOUT

The man-ways, shown in Figure 4, are provided for cable runs and personnel access between various access points in the floor of the working volume, and the below-ground data-acquisition and calibration complex (DACC).

The DACC includes work areas that are available to users for installation of their experimental and other required equipment. It includes a shielded room for data instrumentation requiring a high degree of isolation from ambient sources of interference. Permanent installations within the shield room include diagnostic instrumentation and recording equipment used to record the environmental data describing details of each test shot; the receiver portion of the microwave telemetry system used to measure test vehicle response currents; and the timing and firing system.

Over 250 square feet of floor space is available to users in the shield room. In addition to the shield room, there is work and storage space of over 1,000 square feet available in the DACC. Access to the DACC is via a 15-by-15-ft tunnel, shown on the left of Figure 5, a man-way to the high-voltage generator center, and a roof hatch leading to the working volume.

C. Electromagnetic Characteristics

The ARES Facility was designed to simulate the EMP resulting from a high-altitude nuclear detonation. The working volume is a section within a parallel-plate transmission line. The parallel-plate section is connected to the pulse source on one side, and the load impedance (terminator) on the other side, through tapered-transmission-line sections.

To a first approximation, the EM fields within the working volume are those predicted by transmission-line theory--a TEM mode with vertical electric field and horizontal magnetic field, propagating as a plane wave

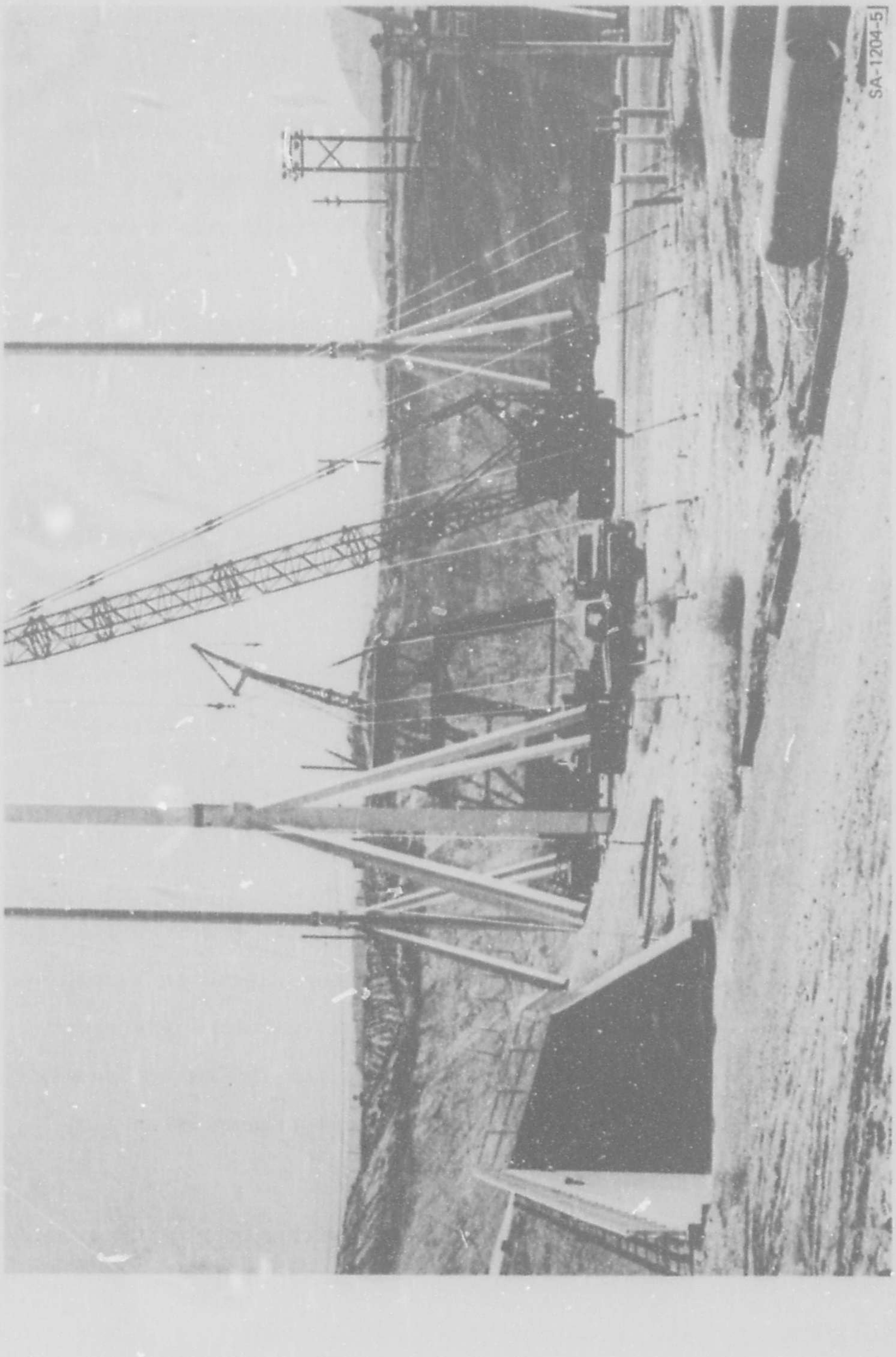

FIGURE 5 CLOSE-UP OF WORKING VOLUME AND ACCESS TUNNEL

from the source to the load. The pulse may be produced with either positive or negative polarity.

In some detailed respects there are deviations from the EM description offered above.* The relative importance of these deviations will be determined by the requirements of specific tests. These deviations from the idealized description result from the finite dimensions of the simulator; this is evidenced by fringing of the fields near the outside edges of the working volume, from reflections back from the termination and discontinuities, from diffraction at discontinuities, and from the unavoidable spherical nature of a wavefront launched from the single drive point. Plots of the measured signals within the simulator indicate that the magnitude of these deviations are of the order of ±1 dB, and therefore of little concern for most tests.

There are presently two pulse generators available at the facility--a high-level, single-shot pulser, a view of which appears in Figure 6, and a lower-amplitude repetitive-pulse generator (RPG). The high-level pulser consists of a gas-filled coaxial capacitor and a triggered-gap breakdown switch. The capacitor is charged by a Van de Graaff generator. When the capacitor is charged to the required voltage the gap is triggered, initiating breakdown, which applies the capacitor voltage to the transmission line. The resulting transient then propagates along the transmission line, through the working volume, and is finally absorbed by the matched load, or terminator. The peak amplitude may be adjusted between 300 kV and 3.9 MV, for peak electric-field strengths within the working volume between 7.5 kV/m and 97.5 kV/m. The 10-to-90% rise time, measured at the input to the tapered section, is less than 10 ns, and

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* For measurement and analysis detail reports will be provided to facilities users.

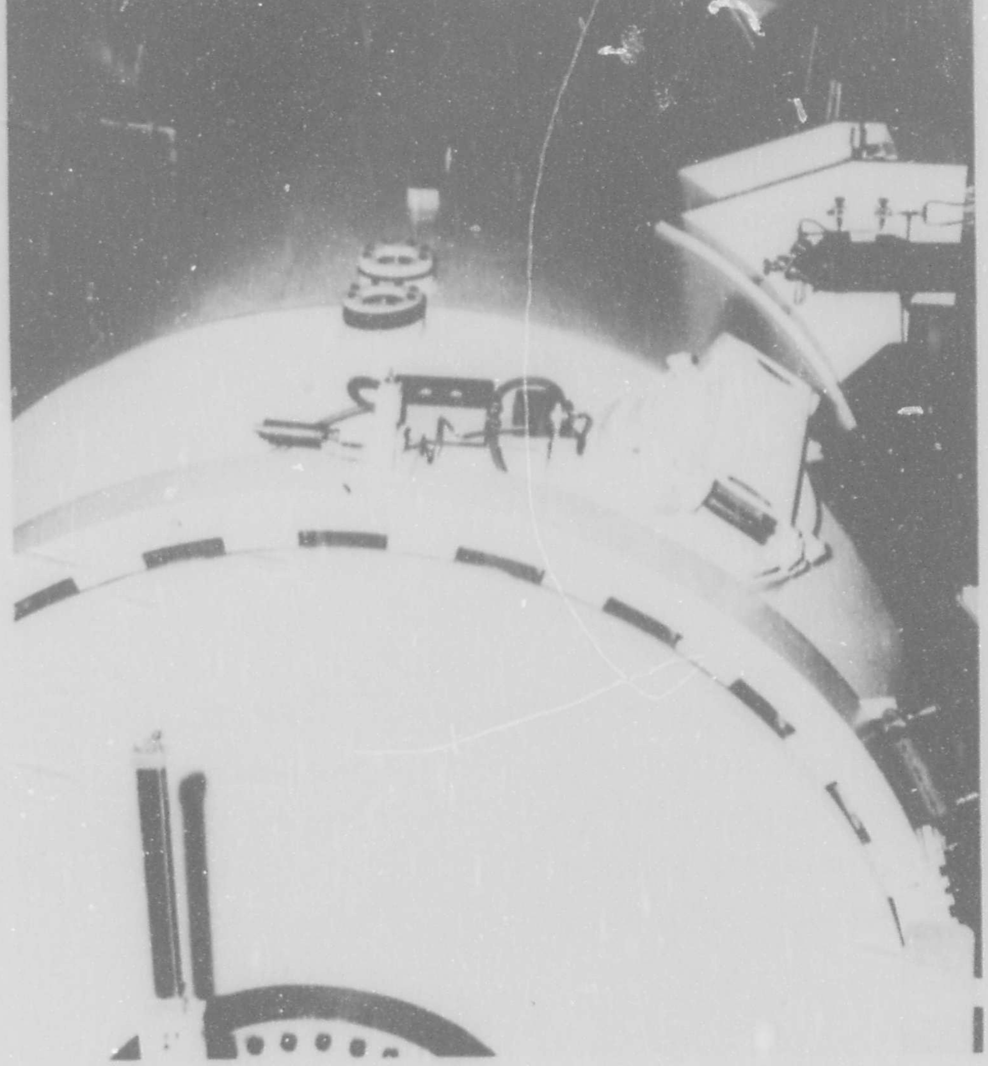

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FIGURE 6 HIGH-LEVEL PULSER

the time to decay, roughly exponentially, from peak to 10% of peak, is approximately 500 ns. Typical waveforms are shown in Figure 7.

The repetitive-pulse generator may also be used to drive the simulator. Its peak amplitude can be varied between 5 and 50 kV (125 V/m and 1.25 kV/m in the working volume), and it can operate with a pulse repetition rate up to 10 pulses per second, or it may be triggered from the DACC in a single-shot mode. Additional pulsers will, in all probability, be added to meet special test requirements in the future.

As can be seen from the photograph of the high-level pulser, it is a large piece of equipment, so it requires a fair amount of time to change drivers, and changeovers between drivers should be efficiently laid out in time to avoid undue delays.

D. Instrumentation

The facility has most frequently used available on-site instrumentation, available for users in their experimental program. As an example, there are 24 oscilloscopes (HP Model 183B) equipped with Polaroid cameras located in the shielded room of the DACC. There are also a variety of environmental detectors available to monitor the fields produced by the simulator. These detectors, as well as the outputs from the users' sensors, may be connected to the oscilloscopes either by hard-wire cables run through shield ducts in the manways, or by using the microwave telemetry system (described below). In addition, a timing and firing system provides up to 36 separate, adjustable event signals of which 24 are usually available for users. These signals may operate scope camera shutters, trigger scope sweeps, fire the pulser, and initiate calibration sequences. These signals can be provided as relay closures, voltage pulses, and pressure changes on eight pneumatic actuator lines.

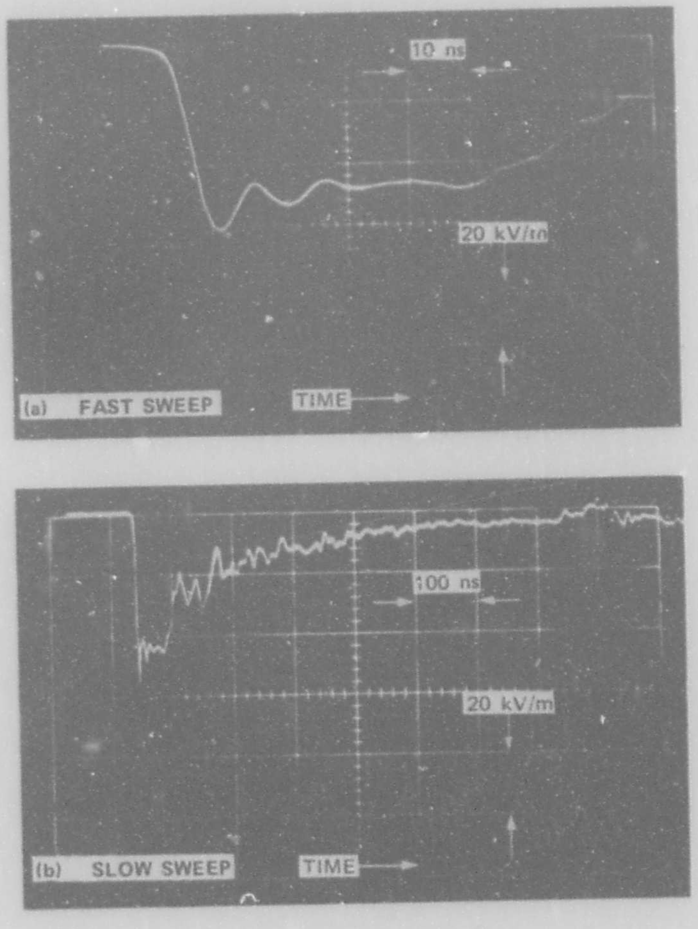

FIGURE 7 TYPICAL ARES WAVEFORMS — ELECTRIC FIELD

Also provided at the facility are data-handling equipment, analog-to-digital converters, keypunches, microfilming facilities, and computer access.

One of the most difficult problems in making EM measurements is how to avoid disturbing the normal environment while sensing it. The sensors themselves are little problem--with the field strengths at ARES these sensors can be small, but the extracting of useful information from them can be a problem. A sensor will not itself perturb the fields appreciably, but the wires connected to it frequently do so. The problems most frequently encountered are contamination of data by coupling to the wires directly, and by distortions of the EM fields resulting from the presence of the conducting wires. These problems are solved at ARES by making use of two creditable techniques: the microwave telemetry system, and the shielded system.

The microwave telemetry system provides a means of acquiring data from within the working volume without danger of perturbing the fields, by avoiding the use of conductors leading to the measurement point. The system is capable of handling ten simultaneous data channels, with a frequency response of 10 to 100 MHz, and a dynamic range of 40 dB. There is also the capability to operate this system with four channels originating in one location and six in another, and there is one single-channel link available. The output end of these systems is in the DACC, where connections may be made to the oscilloscopes or user-provided instrumentation. The link is via dielectric waveguide, and the system operates at X-band. The user, of course, is responsible for the instrumentation of the test specimen, and for assuring compatability with the telemetry system.

The shielded system operates by virtue of avoiding exposure to the high field levels within the working volume. There is little or no wiring within the working volume; the system cables are routed via the manways, which are underneath the bottom ground plane of the simulator. Connections are made only to sensors located on the ground plane. These environmental sensors, such as shown in Figures 8 and 9, can then provide calibrated measures of the environmental fields for each shot. (The long, exposed cables connected to the sensors in the photographs are present only during sensor calibrations.)

The reader is referred to Section IV for more details regarding these systems.

E. Organizational Responsibilities

DNA has the overall responsibility for the ARES Facility. From the viewpoint of the potential user, the primary role DNA exercises is that of scheduling tests at ARES. This naturally involves determining the relative priorities among potential users, and adjusting the schedules accordingly. DNA also funds the facility, and the user must make available to DNA appropriate funds to support his tests.

AFWL represents DNA regarding technical aspects of tests carried out at the facility, and is directly responsible for technical direction of the ARES Facility Contractor, who operates and maintains the facility. It is also AFWL's job to coordinate the activities of all agencies involved at ARES, and to advise DNA regarding pertinent aspects of test planning and conduct.

The user systems Project Office, SPC, is the link between the user and DNA. The responsibilities of the SPO are of utmost importance because it is here that the actual tests, and therefore the information

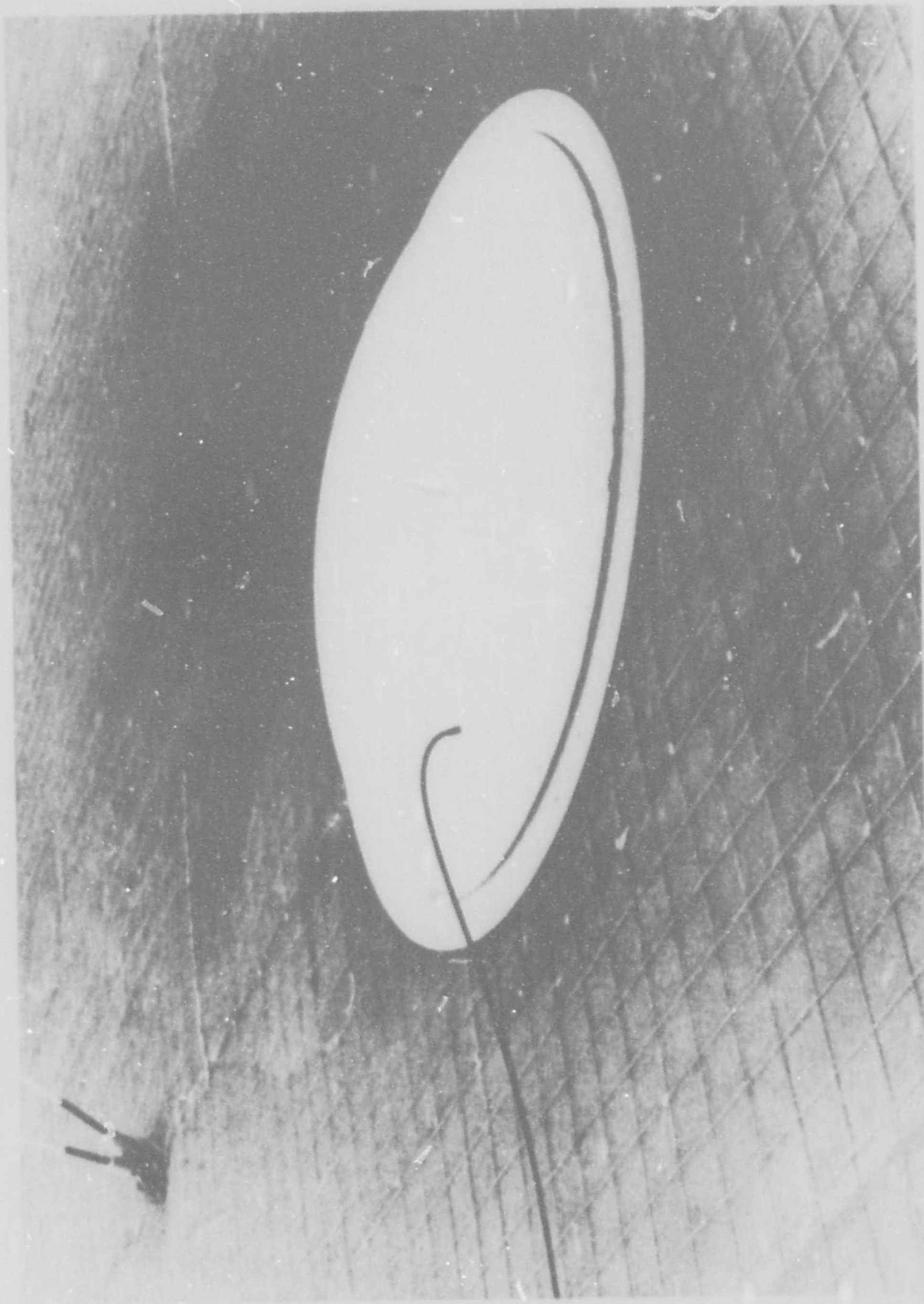

FIGURE 8 E-FIELD SENSOR

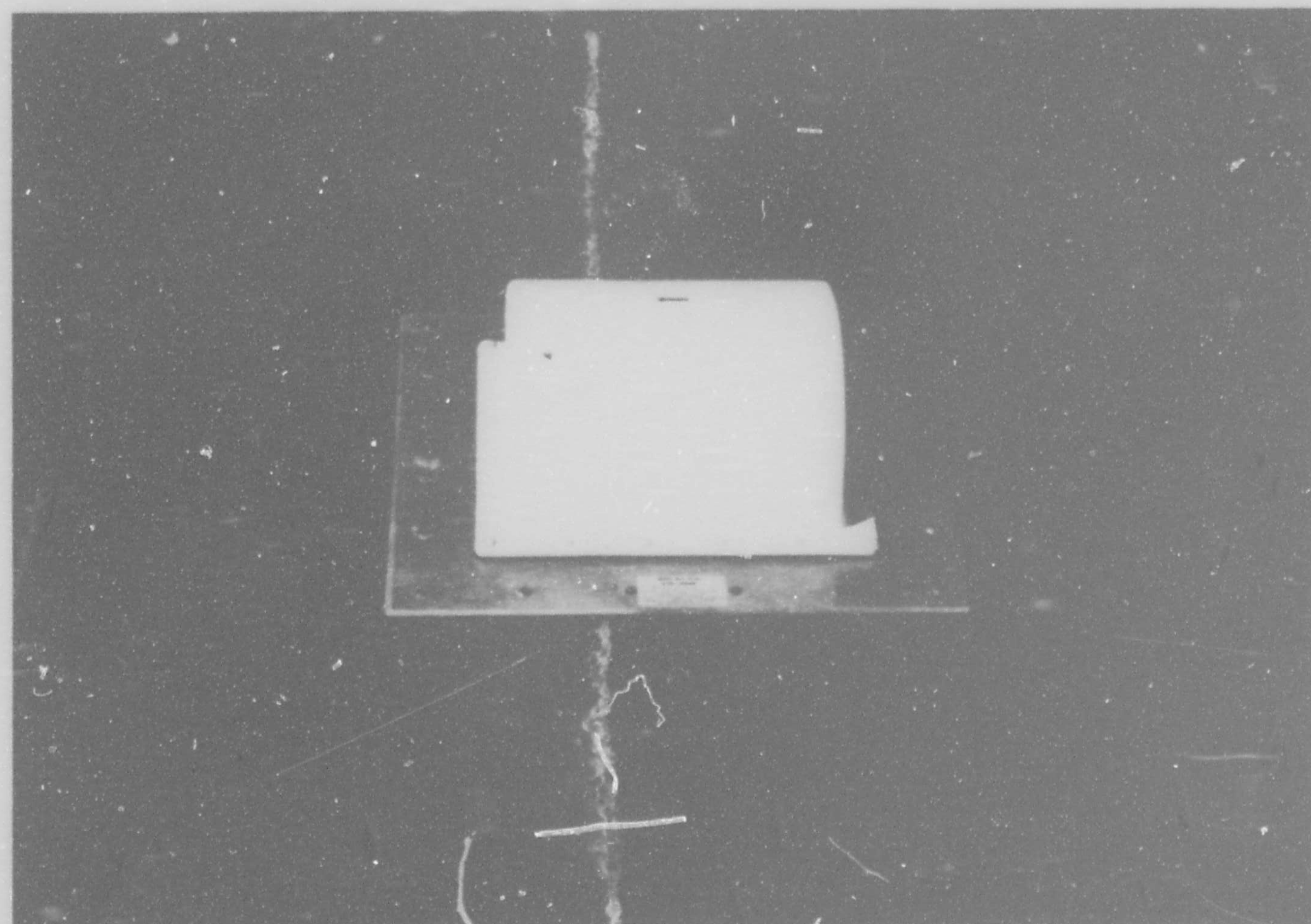

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FIGURE 9 MAGNETIC-FIELD SENSOR

yield, are determined. The SPO provides the chairman for the Test Working Group (TWG--see Section II), and has the job of formulating the various plans for facility use.

There are two, overlapping organizational structures involving the ARES Facility. The first can be called the permanent organization, and represents long-term administrative relationships between various agencies. The second structure is that set up for each test program; it can be called the test organization. Diagrams of both appear in Figures 10(a) and (b). More details regarding the responsibilities of each group are provided in Section III.

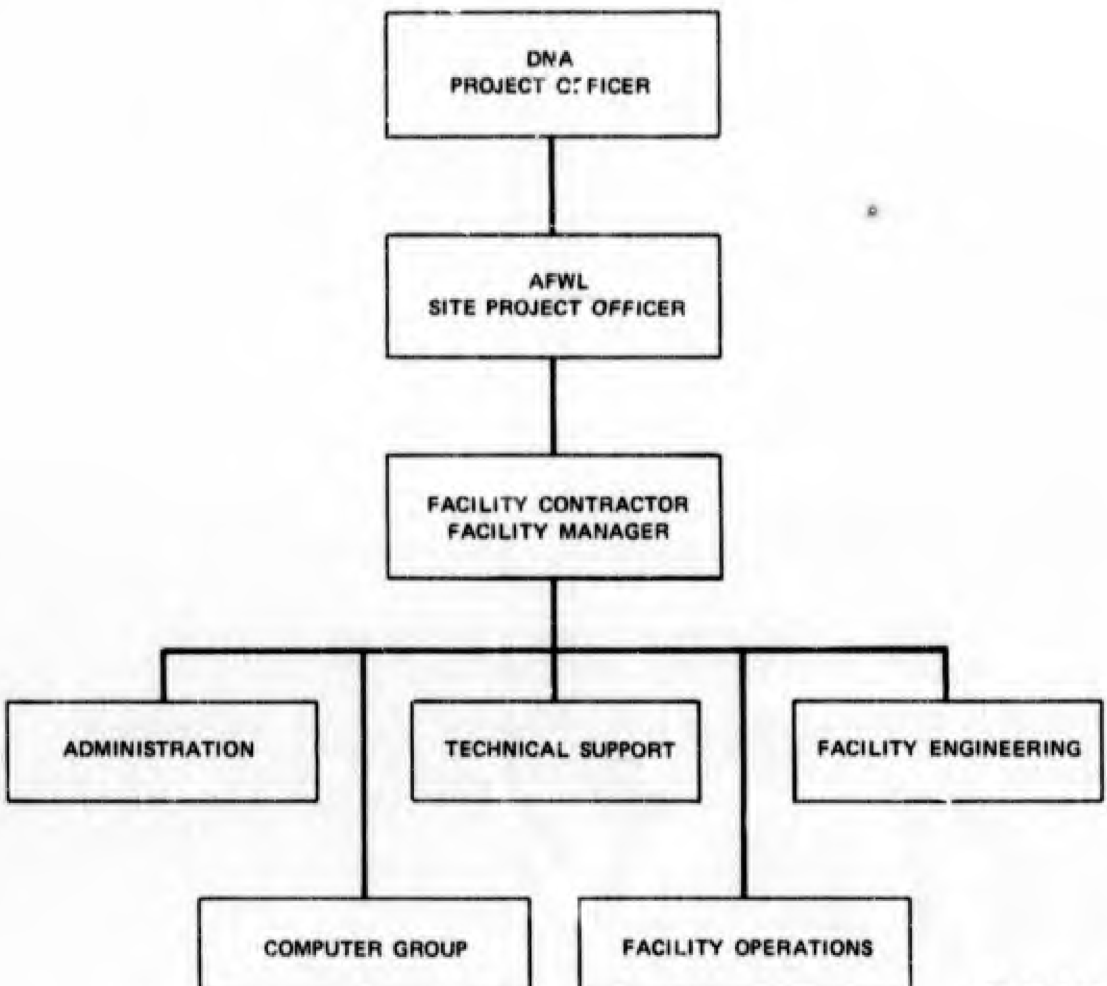

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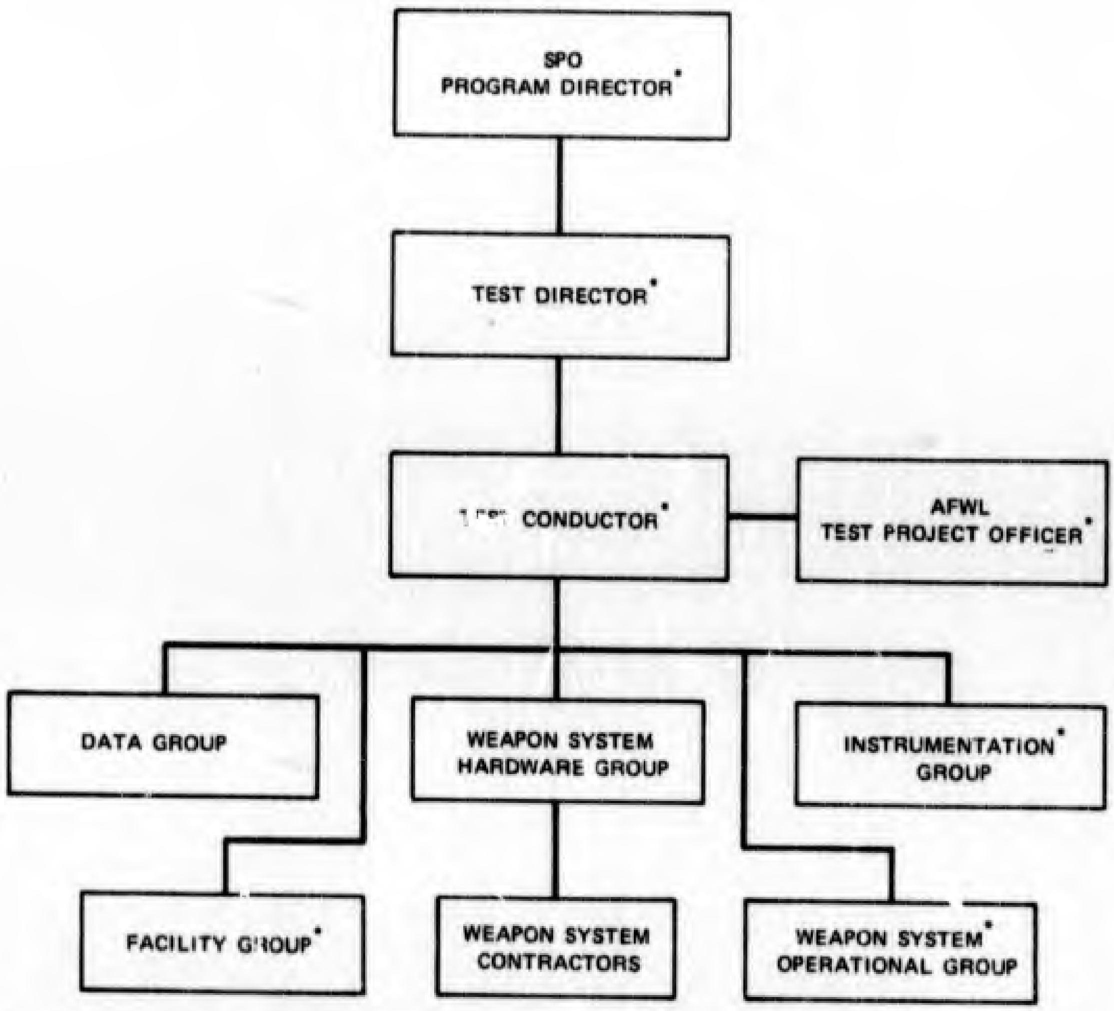
FIGURE 10(a) PERMANENT ORGANIZATION



* INDICATES MANDATORY TWG MEMBERSHIP.

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FIGURE 10(b) TYPICAL TEST ORGANIZATION

II PRE-TEST PROCEDURES

A. General Planning

The decision to use the ARES Facility for a specific test program can be made only by the prospective user. The following broad guidelines will give some feel for the time, money, planning, re-planning, and amount of data that is involved in the majority of tests. The actual testing will probably be the easiest portion of the program, especially if the planning has been complete.

A typical ARES weapons system test takes about a year to plan and organize, and little of that time is consumed by waiting for others to take action--it is a busy year of planning and assembling equipment. And it is important to realize that the planning, to a large extent, will require the results of in-house tests and analyses of your system. It would be impossible to overemphasize the need for an in-house test program to be essentially completed before the system is tested at ARES. Only so many contingency plans can be built into the test program at the facility, and the time allotted will seldom leave much room for additional measurements. It is fairly safe to say that some additional measurements will be indicated by the data obtained during the test, no matter how complete the test plan, so it is very unwise to leave any loose ends in the test plan; there will be enough unexpected problems that come up anyway!

It is imperative, then, to allow ample time for preparations before the start of testing at ARES. These preparations will include the test planning and necessary administrative work, as well as completion of in-house testing and analysis. This in-house research work must be complete and understood before the ARES test can be properly specified.

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The amount of detail required of this pre-test effort should be sufficient to allow predictions to be made, with confidence, of expected waveforms at critical circuits and other test points within the specimen weapon system. Without that much detail it would be impossible to identify the required test points to be used in the ARES test, nor would it be possible to specify what instrumentation should be used during the tests. Use of the facility before these details are available is simply premature and should be avoided.

The objectives of the tests at ARES should be clearly understood. ARES is not a proof-testing facility; the data obtained there will be an indispensable aid in making a vulnerability and susceptibility assessment, but the ARES test cannot be expected to yield all the answers.

What one should be looking for in the ARES-obtained data is confirmation of previous analytical and experimental results, extrapolated to apply to the complete system exposed to high-level fields. This includes not only reasonable agreement between the ARES and previous test results, but also satisfactory evidence to validate assumptions made in the course of the previous work. What will be unique, from a testing viewpoint, will be the test of the completely assembled system exposed to high-level pulses with a variety of orientations. This situation will probably provide enough surprises that the experimenter will be kept in a frantic state even if the previous work has been complete and thorough. The experimentor should give primary emphasis to obtaining threat-level data, but certainly should not overlook the need for measurements that can be used to evaluate previous analytic assumptions.

Now, it is worth considering what the ARES Facility will do and what can be expected of the test program. As mentioned, the tests in the facility can be made on a completely assembled system at high levels of EM fields. By adjusting the orientation of the system it is possible to test for sensitivity to different polarizations of EM waves, as well as to vary the direction of arrival of the waves on the system.

The facility was designed to simulate a high-altitude EMP threat, and to allow vulnerability and survivability testing of all existing and anticipated defense missile systems. It can also be used to test any other system that can be placed in the test volume.* It is possible to place several systems in the working volume and carry out tests on both, which may be the best way to test smaller equipments, or conduct brief tests. This procedure is sometimes possible even during a lengthy test of a large system, but of course in such a case the smaller system tests would be made at the convenience of the principal experimenter.

B. Obtaining Use of ARES

To obtain use of ARES, the user develops four documents for submission to DNA/AFWL. First, the prospective user and the SPO develop a general program plan (GPP). The GPP, outlined in Table 2, describes the who, what, when, and why of the proposed program. At least ten (10) months prior to the desired test starting period, the SPO submits the GPP to DNA and AFWL for review. DNA and AFWL then review the GPP,

* It should, however, be recognized that a ground-based system, in real life, will be reacting to the EM fields in which it is immersed. These fields will be the sum of the incident fields and the fields reflected from the earth's surface. The reflected fields over a real earth will not, in general, be simulated in ARES because the bottom, or floor, of the working volume is intentionally highly conductive.

Table 2

GENERAL PROGRAM PLAN*

1.	Objectives of the test.
2.	Proposed test schedule.
3.	General description of the proposed test.
4.	Special test requirements that could require modification of the ARES Facility.
5.	List of all contractors and agencies that will be involved.
6.	The DoD priority associated with the proposed test.

* Minimum contents.

schedule the system for test, and advise the SPO of any changes required in the GPP.

On acceptance of the GPP by DNA, the SPO appoints a System Project Officer in Charge (SPOIC) who convenes and chairs a Test Working Group (TWG--see Section II-C). The TWG provides to the SPOIC the technical assistance necessary to work out the details of the test, and to write the general and detailed test plans (GTP and DTP). Concurrent with establishment of the TWG, the SPO, with DNA and AFWL concurrence, designates a Test Conductor for the test program.

The GTP, outlined in Table 3, reflects the philosophy to be followed in the test and explicitly defines the scope. Six (6) months prior to start date the SPO forwards the GTP to the AFWL for comments and to DNA

Table 3

GENERAL TEST PLAN*

1.	Precise statement of the overall objectives to be attained in the test.
2.	General statement of how the overall objectives will be attained.
3.	Brief description of the facility environment levels and orientations to be used.
4.	General statement of the obligations of the participants.
5.	General description of the test model.
6.	General test schedule with annotation of what is to be achieved during each phase of the test.
7.	List of all reports that are to result from the test. This is not to include interim reports to be issued.

* Minimum contents.

for approval. When the GTP is received, AFWL appoints a Test Project Officer who advises the SPOIC and is directly responsible to DNA for ensuring adequacy of all test plans.

The DTP, outlined in Table 4, explicitly s ates the procedures used in the test. It is intended to be the working document by which the test will be run. It fully describes and justifies each step-by-step, day-by-day operation. Four (4) months prior to start date the SPO forwards the DTP to the AFWL for comments and to DNA for approval. The Test Conductor is bound by this document, and departure from the plan is allowed only by agreement with the TWG and the AFWL Test Project

Table 4

DETAILED TEST PLAN*

1.	Detailed description of the test model noting all differences from the standard model.
2.	Detailed description of all instrumentation including purpose and characteristics of each probe.
3.	Detailed description of all probe installation, with supporting justification.
4.	Specific objectives of the test and each phase of the test.
5.	Complete description of all data that must be obtained, on a shot-by-shot basis.
6.	Description of the complete data flow and reduction procedures to be used both during and after the test. This should include provision for error bounds, as known.
7.	Complete description and purpose of any special teams that are formed for the test (e.g., Data Team).
8.	Detailed schedule that includes specifically what will be done on a day-by-day basis.
9.	Glossary of all terms and abbreviations used in the plan.
10.	Complete description of the ARES facility and missile orientation to be used in the facility.
11.	Detailed description of any facility modifications performed or to be performed to support the test.
12.	Supporting drawings and diagrams of missile, instrumentation, component wiring diagrams, functional diagrams, etc.
13.	Complete listing of all reports that will result from the test, to include interim reports.

Note: It is more convenient if this document can be kept unclassified.

* Minimum contents.

Officer, although minor departures from the DTP are allowed by agreement with the AFWL Test Project Officer.

Finally, two (2) months prior to start date the TWG forwards through the SPO the Joint Operating Agreement (JOA) to DNA/AFWL for approval. This JOA, outlined in Table 5, is the administrative document of the test and defines the organizational structure, responsibilities, interfaces, and procedures to be followed in the conduct of the test and operation and use of the ARES Facility.

Table 5

JOINT OPERATING AGREEMENT*

1.	Each participating organization's responsibility for providing equipment.
2.	Each participating organization's responsibility for providing test support.
3.	Each participating organization's relationship and authority within the test structure.
4.	Each participating organization's responsibility for administrative support.
5.	All security and safety requirements.
6.	Statement of all funding procedures.

* Minimum contents.

C. Test-Working-Group Functions

The TWG is established for planning and coordination of the pending ARES test and is the technical backbone of the test program. The TWG is chaired by the SPOIC and is convened during test organization at least eight (8) months prior to the desired starting date. All associate weapon system contractors are eligible for membership on the TWG.

The TWG meets approximately once each month prior to the start of field testing. Problems relating to meeting test schedules are discussed and resolved. The status of each member's items of responsibility is also presented. The GTP, DTP, and JOA are written as a result of these meetings.

During the field test, the TWG meets only to discuss major changes to the test program. Upon test completion, the Test Conductor submits the test results and preliminary and final test reports to the TWG for review.

The wise user will learn early to look to the TWG for essential aid as well as useful criticism. As a working body it will include two essential groups--associate weapon system contractors, on whom the user would necessarily rely heavily even if the TWG did not exist, and experienced experimenters concerned with efficient use of the facility.

Probably the most important single personnel assignment that can be made during the test program is the representative to the TWG. He must be able to work easily with the other TWG members, and must have the authority to make policy decisions during the progress of the program. To ignore these requirements is to invite chaos and disaster.

III TEST CONDUCT

A. Personnel

1. Test Conductor

The Test Conductor, with assistance from the AFWL Site and AFWL Test Project Officers prepares documentation for the SPOIC regarding technical aspects of the test. He therefore must have a complete understanding of the electrical and physical details of the entire missile/weapon system. With this background of weapon system detail, the Test Conductor may outline, for the SPOIC and AFWL Test Project Officer, the potential antennas, points of entry, subsystem failure levels, and suggested areas for instrumentation in the ARES EMP test. He also provides estimates of frequency content and levels expected on all selected measurement points during testing.

When the weapon system is tested in ARES, the Test Conductor specifies the test sequence and requirements for physical configurations and environment. Any major problem that will affect test objectives or cause deviation from approved plans or procedures is referred to the TWG for resolution. After the test is completed, the Test Conductor, with assistance from the TWG, will analyze the test results, recommend system hardening or additional test requirements to the TWG, and prepare a preliminary report and a final test report.

2. AFWL Test Project Officer

The AFWL Test Project Officer acts as an independent advisor to the SPOIC and is directly responsible to DNA for assuring that the program established by the SPO is adequate to meet the test objectives.

He further assures DNA that the direction of the test by the Test Conductor is done in a manner that will achieve the test objectives. As a member of the TWG, the Test Project Officer makes all suggestions and observations directly to the SPOIC.

3. ARES Site Project Officer

The AFWL ARES Site Project Officer is responsible for overall management, supervision, and technical direction of the ARES Facility. He provides technical direction to the DNA Facility Contractor as required in the day-to-day operations. He coordinates ARES activities with HQ DNA and other organizations as required to achieve effective use and expenditure of all resources and to assure efficient, economical, and timely completion of all operations. He must evaluate all modifications to the facility and facility equipment that are thought necessary to achieve the test objectives of any given program. He is responsible for research, analysis, and solution of problems associated with the ARES Facility in keeping with DNA directives and test objectives. He coordinates matters concerning funds, schedules, test support, and relationships of other agencies with DNA.

4. Test Director

A field Test Director is appointed by the TWG from among the group members. Prior to the start of the test, the Test Director (TD) provides technical consultation to the SPO Program Director, specifies instrumentation and measurement requirements, and reviews contractor efforts. The Test Director also organizes the data group and supervises the planning of the data-group operating procedures, data logging, and format requirements. During the testing all questions are directed to the Test Director for resolution and he is responsible to the Program Director for conduct of the test program.

An Assistant Test Director usually assists the Test Director during the planning phase and while the test program is being conducted. The Assistant Test Director co-chairs the data group and is the Program Director's on-site technical representative.

5. Test Crews

a. Facility Group

This group is supervised by the facility contractor and is responsible for all the activities associated with the operation and maintenance of the ARES test facility. The facility group is responsible for the operations and maintenance of all data-recording equipment that is a permanent part of the ARES Facility.

b. Weapon System Hardware Group

This group is supervised by a group leader from the System Management Office and is responsible for handling and control of all user-furnished hardware and equipment including assembly/disassembly of test vehicle. This group also has the responsibility for scheduling and co-ordinating the implementation of all tasks associated with performance of the test in accordance with the approved test procedure, and operates all missile functional instrumentation, functional data recording equipment, and missile control hardware. The test-instrumentation and data-recording equipment that is a part of the ARES Facility is operated by the Facility Group, but during the test period is coordinated with and supervised by the Test Director.

c. Data Group

The Data Group has the responsibility for processing and controlling all tests data. All data is processed in accordance with approved data-processing and analysis procedures. The Data Group observes the installation of the instrumentation for assurance of calibration and proper installation and shielding protection. The Data Group is also responsible for the on-site reduction and analysis of the environmental test data. The Data Group is co-chaired by the Test Director and his assistant. All test participants generally provide members to the Data Group.

d. Weapon System Operational Group

The Weapon System Operational Group is responsible for reduction of system performance data. The data reduction is performed on-site, with complete reduction of selected test runs to be accomplished at the contractor's facility. The services of the computer group (see Section IV-A) are available to the Weapon System Operational Group through the Data Group Leader.

e. Instrumentation Group

The Instrumentation Group provided by the Facility Contractor has the responsibility for controlling, installing, operating, calibrating, and maintaining all instrumentation hardware and equipment to be used in the test series. The Weapon System Hardware Group provides manpower for the installation of missile instrumentation, but the effort is supervised by the Instrumentation Group. The Instrumentation Group is thoroughly familiar with the test procedures and cognizant of the status of the test so that the necessary instrumentation hardware will be calibrated and installed to support the test schedule. The Instrumentation Group is responsible for setting up and assuring the correct operation of the X-band microwave system, the response-data-recording equipment, and the functional-data system. The Instrumentation Group maintains a checkout and calibration log book, and supplies to the data group copies of all calibration data.

B. Equipment

1. Facility Maintenance

Scheduled preventive maintenance is required to maintain the ARES Facility in satisfactory operational condition. In general, maintenance is performed on a schedule that does not interfere with test operations. Inspection and maintenance of the high-voltage pulse generator requires approximately two and one-half calendar days and is performed every 90 days or during microwave system maintenance periods, whichever occurs first. During this maintenance on the pulser or microwave system, the ARES Facility will not be operational.

The TD is kept informed by the AFWL Site Project Officer of all scheduled maintenance that will influence test operations. In the event that operations must be changed, the TD is notified immediately by AFWL.

If they are required, AFWL provides minor revisions to the test area. All requests are submitted through the TD, to the AFWL Project Officer, who will take action to effect the change.

2. Shipping and Receiving Procedure for Visiting Companies and Agencies

Each participating organization is responsible for shipping its own equipment to Kirtland AFB to support the ARES test, providing personnel to pack and unpack the equipment, and presenting to AFWL a list of equipment descriptions, part numbers, and identification numbers. After the test is completed at ARES, each organization is required to package its equipment for shipping and provide AFWL with written shipping instructions. A DD1149 form is required for the shipping operation.

A list of all classified equipment will be coordinated with AFWL/ARES prior to shipment to or from AFWL/ARES to ensure proper security measures. Each operation must have a representative at ARES until the equipment is shipped.

3. On-Site Preparation

Each participating organization is responsible for the preparation and functional testing of their respective systems. For the benefit of potential experimenters without field-test experience, it should be pointed out that calibrations, repairs, and even routine maintenance procedures are several times more difficult in field situations than at the home laboratory. Needless to say, the test instrumentation should be completely assembled and checked out before it is shipped to the facility. The natural tendency to "leave it until we get there" should be effectively resisted. Spare parts for the instrumentation should be provided, and a generous length of time should be included in the schedule for check-out at the facility, and for correction of the inevitable malfunctions that plague operations away from home.

4. Response Instrumentation

EMP response data is obtained by use of voltage and/or current probes and an X-band data-transmission system. All instrumentation hardware up to the input interface of the X-band transmitter is supplied by the user; all other response instrumentation and data-recording equipment is furnished by the ARES Facility. Facility contractor personnel will operate, maintain, calibrate, and reconfigure facility instrumentation, but it is the responsibility of the user to calibrate his portion of the instrumentation.

Consultation with the TWG members and experienced personnel at the facility is advised with regard to selection of instrumentation in general, and especially for the instrumentation that may be exposed to the EM environment within the simulator. Many pieces of laboratory instrumentation will not give normal performance in the environment, and a little help from those with experience may save a lot of trouble later.

Specifications for typical probes are given in Table 6.

5. Facility Mapping

Facility mapping is done by the AFWL Facility Contractor in accordance with a test plan coordinated with, and approved by, the Test Conductor. Mapping is done without the missile system in the working volume.

6. Operational Section Responsibilities

Confirmed users will be provided with a complete set of ARES Operating Directives, including the following, concerning equipment responsibilities:

3.1 Daily Turn-On and Checkout Procedures

3.2 Daily End-of-Shift Procedures

3.3 Pulser Operation

3.4 ARES Facility Weapon Convoy Procedures

3.5 Radio Frequency Interference

3.6 Adverse Weather Conditions.

Table 6

CHARACTERISTICS OF TYPICAL PROBES

Model	Type	Z_t* (ohms)	Z_o (ohms)	f_L (-3 dB)	f_H (-3 dB)	t_r	Aperture (inches)	Shunt or Insertion Impedance	Remarks
Genestron GCP-5130	Clamp-on current probe	5	50	≈200 kHz	50 MHz	--	1	--	
Stoddart 91550-2	Clamp-on current probe	1	50	80 kHz	100 MHz	--	1.25	--	
Tektronix P6040/CT-1	Small aperture, high frequency current probe	5	50	35 kHz	1 GHz	<350 ps	0.065	1 Ω shunted by 5-μH 1.5-pF shunt	
P6041/CT-2	current probe	1	50	1.2 kHz	200 MHz	0.5 ns	0.050	0.04 Ω shunted by 5-μH 2-pF shunt	
P6042	Small broadband clamp-on current probe	1	50	dc	50 MHz	<7 ns	0.150		Includes amplifier; 4-1/2" × 7-1/2" × 9-3/4" Requires 20-W ac power.
HP456A	Clamp-on current probe	1	22	<25 Hz	>20 MHz	<20 ns	0.156	<50 mΩ +0.05 μH, series and 4-pF capacity to ground	
Tektronix P6046	Differential voltage probe	--	50	dc	100 MHz	3.5 ns	--	Across terminals: 1 mΩ in paralled ≤10 pF	Includes amplifier requiring low ac power. Requires shielding if exposed to EM fields; performance sensitive to adjustment, excellent probe if properly used and adjusted.
Tektronix P6051	Broadband voltage probe		50	dc	1 GHz	<0.35 ns	--	1 mΩ shunted by 2.8 pF	Requires power.

* $Z_t = \frac{V_o}{I_{in}}$

IV SUPPORT

A. Data

1. Acquisition

Diagnostic instrumentation is installed at the ARES Facility for monitoring the operation of the pulse generator. The nucleus of this activity is the shield room of the Data Acquisition and Calibration Complex. Here, instrumentation racks house the 27-oscilloscope/camera capability for displaying and recording the microwave and hard-wire output waveforms. Data received may be from working-volume field sensors, or the microwave receivers. A typical data channel for single-pulse measurement of an appropriate sensor in the environment, a length of high-quality, double- or solid-shielded coaxial cable between the sensor and the microwave transmitter, the microwave link, the recording instrumentation, a high-frequency oscilloscope, and a trace-recording camera with an electrically actuated shutter mechanism.

The microwave telemetry system illustrated in Figure 11 comprises two transmitter/receivers, four channels and six channels respectively, thus providing a three-way packaging capability (namely, four, six, and ten channels). Both the four- and the six-channel configuration contain their own antennas (one at the transmitter, one at the receiver), polarized horizontally and vertically, respectively. The ten-channel configuration is but a simultaneous use of the four- and six-channel capability housed in a single shielded transmitter box. The system has a 40-dB dynamic range to tangential sensitivity from 10% nonlinearity. A signal at tangential sensitivity is nominally

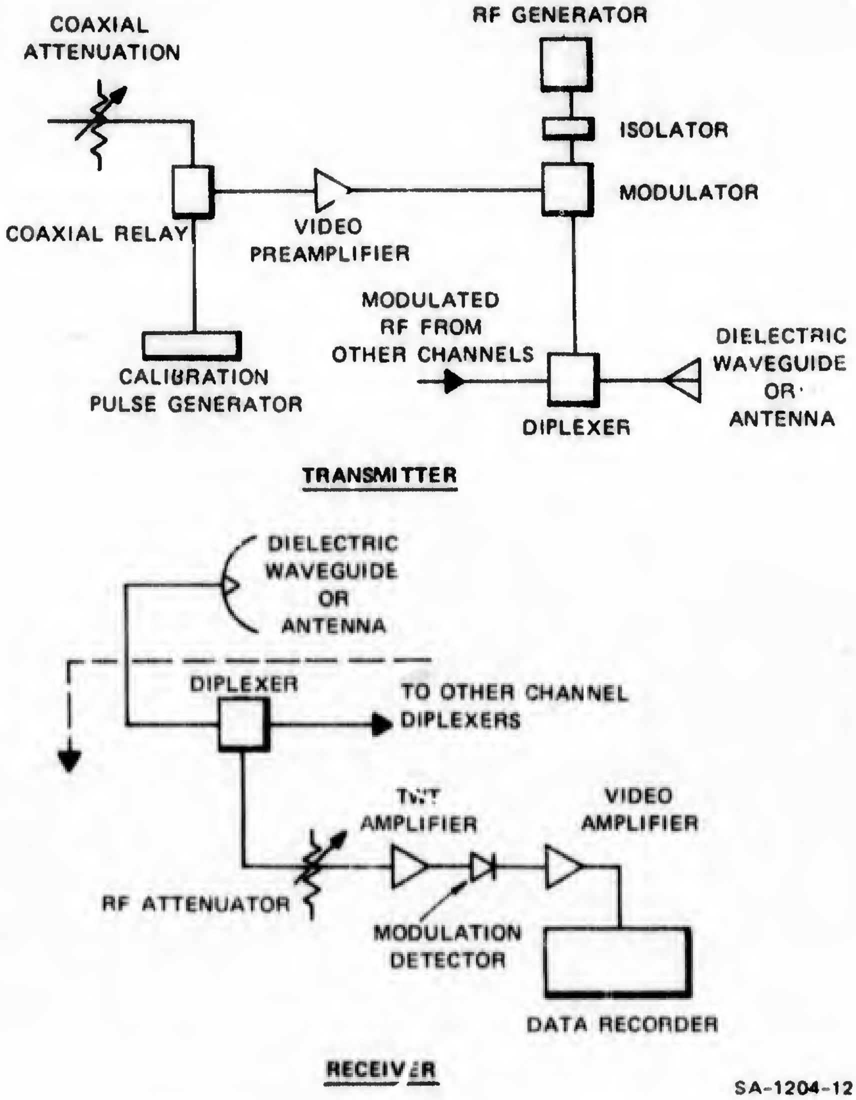

FIGURE 11 ARES TELEMETRY SYSTEM

200 μV into 50 ohms at the input. Input attenuation up to 110 dB is selectable in 1-dB steps. The 3-dB bandpass is from 10 kHz to 110 MHz. The system can transmit bipolar pulses and/or continuous sine-wave signals as required by an EMP test. The transmitter on/off and operate/calibrate functions are controlled pneumatically to preserve the RF-tight integrity of the transmitter box. Connection to the test item is generally made by a 30-inch-long Hipernom bellows that shields the signal cables from environment pickup. One single-channel system is also available.

The battery-operated transmitters contain microwave oscillator/modulators that are modulated by the video signal. The modulated X-band energy is piped through dielectric waveguide to the microwave receivers. The receivers contain traveling-wave-tube (TWT) amplifiers, one for each transmitted frequency. Filters select the appropriate channel frequency, which is amplified by the TWT, and the video is extracted by a detector. The demodulated information signal is then amplified by a video amplifier and sent via coaxial cable to one or more recording oscilloscopes. An end to end calibration of the system is effected by applying the output of a calibration pulse generator to the transmitter video amplifier.

A hard-wire data-acquisition system is provided for the gathering of both event and environmental data by direct connection (coaxial cable). Capabilities exist for monitoring four environmental sensors, two in the gas-transition section and two on the slope above DACC. Four Tektronix RM454 oscilloscopes are provided as the recording instruments.

The instrumentation network produces sufficient data to determine the waveform present in the transition and working volume with an accuracy of better than ±10%.

Additional coaxial cabling is provided to acquire data from up to 20 additional sensors. This cabling is available within the 12-inch shielded ductwork that runs throughout the manways beneath the working-volume floor. Access ports to these manway ducts provided easy connection of data-collection devices to the cabling. Time interval counters with 10 nanosecond resolution provided an additional diagnostic tool.

2. Processing

The Computer Group is responsible for reducing the environmental data. ARES provides digitizing equipment. ARES digitizes and performs Fourier analysis of photographs as required by the Data Group. Data is reduced and analyzed with respect to the test objectives and the results are reported to the Data Group within 24 hours of the time that it was recorded. ARES files the data in computer card decks and subsequently generates and files a film copy of the oscilloscope photographs.

Using computer programs, ARES sorts the data and provides listing as required by the Data Group. Upon completion of testing, data card decks and microfilm copies are provided, as required, to contractors for further analysis.

Data-processing support from the Facility Data Group is made available to the user. This support function, the interface with the Data Group Leader, and detailed data-processing procedures are defined in the ARES Operating Directives.

The AFWL also maintains and operates a CDC User 200 terminal operation on-site. This includes a 136-character line printer, a card reader, a CRT terminal, and associated hardware.

A flow diagram of a typical data-acquisition and processing sequence is presented in Figure 12.

B. Timing

The Timing and Firing (T&F) system, primarily located in the T&F rack, consists of an HP105B (1-MHz) oscillator, a master timer (MTS), and four event controllers (ECS). A slaved clock is located in the pulser building.

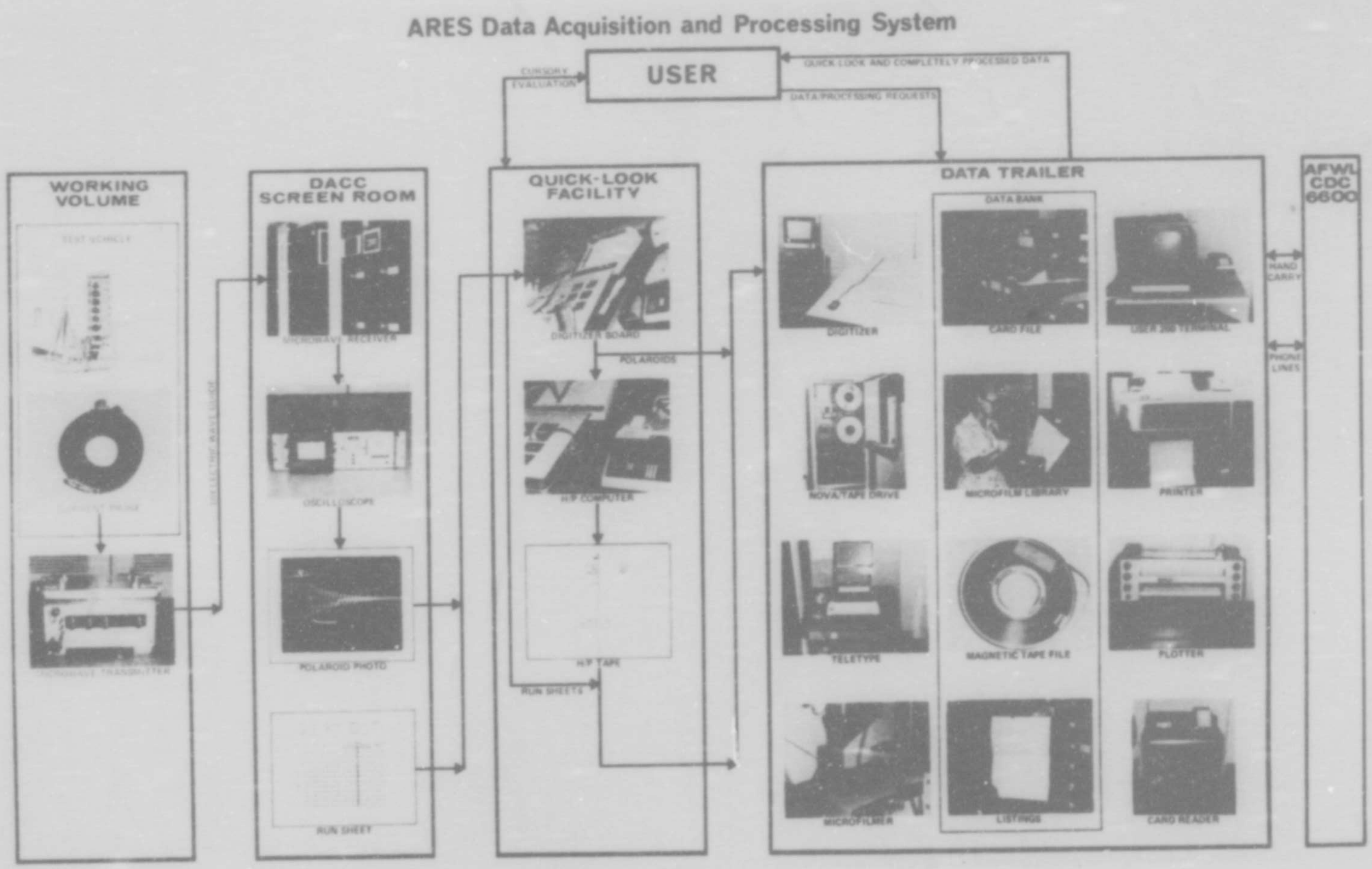

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FIGURE 12 DATA-ACQUISITION AND PROCESSING FLOW DIAGRAM

Specifications of the T&F system are:

- Long-term stability--better than one part in 10^9
- Events--36
- Event pulse jitter referenced to zero time--less than 10 μs
- Relay function jitter--less than 10 ms.

The Event Control System is capable of controlling up to 36 separate "events." An "event" consists of up to three relay closures (or opens) and a +5 V pulse output. The relay functions are available at the rear of each event controller chassis and may be connected with a 28-V power supply and the output connectors of the chassis. Each event may be programmed to occur at a time that is preset at the front of the chassis. Typical T&F events may include opening and closing of camera shutters, resetting of scope sweeps, firing of the pulser, microwave transmitter "on" and "calibrate" functions, and up to eight pneumatically controlled functions. Typically, 24 events are available for the Facility user.

C. Safety

The usual requirements for safety, such as hard-hats, safety belts, and similar personnel equipments, naturally apply at the facility. It is not expected that these requirements would present any unusual problems for prospective experimenters.

Not so obvious, perhaps, are the safety requirements regarding missile propellants and operational ordinance, including initiators and explosive bolts. It would be easiest if one could simply use an inert missile and disconnect and remove any squibs and other such devices. Indeed, this is the best procedure, but it is not enough; the experimenter must also satisfy himself (and probably the TWG) that this procedure will not invalidate the tests being conducted in the facility, and that the possibility of an actual EMP triggering some of these devices is not overlooked. This means that the electrical characteristics of the disconnected and removed components must be determined so that electrically identical circuits can replace them during the tests, and their leads should be measured during the tests and the induced voltages and currents be compared to other data to evaluate the probability of inadvertent triggering by EMP. It should be recognized that these measures are necessary, and that a satisfactory solution will not necessarily be easy or fast.

DNA/AFWL is responsible for implementation of a sound safety program on-site and will assign a Safety Officer, usually the Test Conductor or some other designated representative. An initial safety briefing concerning safety requirements, hazards, and subcontractor's responsibilities is usually given to permanently assigned personnel and visitors. AFWL monitors for compliance with the Safety and Fire Protection requirements included in the ARES Operating Directive No. 8.1 concerning ARES personnel safety standards and also other appropriate military directives.

ARES Operating Directive No. 8.1 summarizes the ARES safety program for test events and provides safety assistance and direction for participating subcontractor agency personnel. It covers the safety program responsibilities, standards, and accident-prevention procedures. Participating personnel use these standards to plan, organize, and employ safety procedures for their on-site activities. Project Officers should familiarize themselves with the safety standards pertinent to their project and inform their personnel accordingly.

The responsibility to ensure that all subcontractor agency personnel participating in ARES tests comply with the safety criteria rests with the project engineer. The project engineer is defined as the individual who is charged with the responsibility of installation, alignment, instrumentation, and recovery by the user agency. Each user agency submits the name of its project engineer to the SPO prior to the agency's arrival at ARES. The project engineer is responsible to the SPO for the conduct of personnel working under his direction.

When a conflict exists between the AFWL safety criteria and the safety standards of a project agency, the standard providing the highest degree of protection should be followed However, deviations from ARES Personnel Safety directives are allowed onlv with the specific approval of the Test Conductor and AFWL Site Project Officer.

Certain other special safety factors should be recognized. The normal operation of the facility involves high-level EM fields, which should be considered as potentially hazardous to users of electrical or electronic health aids--e.g., hearing aids, heart-beat pacers, etc. The possibility of lightning during local thunderstorms will require a stop of testing and the grounding of the simulator. If testing is carried out during periods of potential lightning weather the user should allow time in his schedule for delays so created. The user should also consider the need for precautionary grounding or isolating of elements of the test equipment or system being tested during local thunderstorm activity.

D. Security

The ARES Operating Directive on security procedures is provided by DNA to all potential users. The directive prescribes the responsibilities for security procedures to be implemented within the ARES Facility. It also prescribes visit procedures to gain access to the ARES Facility, on a long-term and short-term basis, and the badging methods for both long- and short-term visitors.

The AFWL is responsible for the overall program managership of the ARES Facility. All internal security is the responsibility of the Air Force, represented by AFWL.

The Air Force Special Weapons Center is responsible for providing the physical safeguards for the ARES Facility. Security Police personnel man the entrance to the facility 24 hours per day, 7 days per week. A roving patrol makes periodic checks of the facility during non-duty hours.

All personnel working on the test must be on an SPO-approved access list, a copy of which will be furnished to the AFWL Project Officer. This list will be used to control access during the conduct of the test program.

All DoD and DoD Contractor personnel requiring access to the ARES Facility will submit their visit requests through their normal security channels and the responsible Contracting Government Agency to:

COMMANDER
4900th Air Base Group
SPA
Kirtland AFB, New Mexico 87117

All requests for visit must clearly identify that the visit is for access to the ARES Facility, cite a specific program, and list the AFWL Site Project Officer as the point of contact.

AEC and AEC Contractor personnel will submit an AEC Form 277 through their security channels to the address specified in the paragraph above.

DoD Contractor personnel not performing on an AFSWC contract will route their visit requests through their contracting activity for verification of "need to know." Action on approval will not be initiated until such certification is accomplished.

See also ARES Operating Directives:

5.2 Special Orders for Security Post No. 7, ARES Site

5.3 ARES Facility Security Container Procedure

5.4 Procedures for the Receipt, Storage and Transfer of Classified Test Items.

E. Photographic

The Facility Contractor is responsible for furnishing at least one photographer for the facility. The user is responsible for providing its own photographer and for taking all photographs for test documentation.

All DoD and DoD Contractor photographer personnel requiring access to the ARES Facility will submit visit requests through their normal security channels; Contractor personnel requests will further be processed through the responsible government contracting activity to

4900th Air Base Group
Attn: SPA
Kirtland AFB, New Mexico 87117.

No photograph taken at the ARES Facility may be released for dissemination, publication, etc. without the written permission of the AFWL Project Officer.

(See ARES Operating Directive on photographer clearance and photographer control.)

F. Communications

The ARES Facility provides no channels for dispatch or receipt of contractor mail. Contractors must therefore establish their own mail channels.

Telephones are available in all manways, the shield room, and the working volume. Each station has the capability of communicating with any other station or selecting the paging system by dialing the assigned PA input number.

G. Housing

The ARES Facility has no provision for personnel housing. The commercial housing available in Albuquerque is, however, extensive and should provide accommodations for a wide range of needs.

H. Transportation

The ARES Facility has one 1/2-ton short-wheel-base pick-up truck, a 1-1/2-ton stake-bed truck, and an 18,000-lb forklift available for contractor or customer use. These vehicles are assigned to ARES by AF, and must be used in accordance with AF regulations. In order to operate any AF vehicle, the driver will need a license for that type of vehicle. Drivers' licenses are issued through the Kirtland AFB Motor Pool, Driver Testing Division. (See ARES Operating Directive 4.11 on ARES Facility vehicle procedures.)

Privately owned vehicles operated at Kirtland AFB must be registered by the operator with the base Security Police within three days after coming on base. Registration is made at the Base Vehicle Registration Office. (See ARES Operating Directive 10.1 on Base vehicle registration.)

Registration requires a letter from ARES Project Officer verifying employment at ARES in addition to vehicle registration or proof of ownership, current inspection sticker, and driver's license. An affidavit is also required stating that your automobile insurance will be in effect during the period of operation at the Base. If the vehicl is leased, a copy of the lease agreement is required upon registration.

Commercial air transportation is available to Albuquerque on several air lines, including Continental, TWA, Frontier, and Texas International Air Lines. This service is to the Albuquerque Sunport terminal, which shares runways with Kirtland Air Force Base. Auto rentals are available at the terminal, as well as pick-up service for many of the local hotels and motels.

I. Medical

The Base hospital provides medical care and treatment for emergency occupational injuries and illness. In cases of serious illness or injury, necessary ambulance service is provided. The equipment provided by the Base is also available for any personnel on-site when emergency situations and circumstances warrant. (See ARES Operating Directive 10.2 on availability of medical services.)

Emergency treatment is also provided for nonoccupational illness when medical or dental disposition prevents the proper performance of assigned duties.