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TITLE ADVANCING INSTRUMENTATION AND CONTROL AT THE NEVADA TEST SITE: AN INCREMENTAL APPROACH TOWARDS A GLOBAL SOLUTION

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ADVANCING INSTRUMENTATION AND CONTROL AT THE NEVADA TEST SITE:

AN INCREMENTAL APPROACH TOWARD A GLOBAL SOLUTION

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ABSTRACT

The increased overall complexity and cost of modern experiments involving underground nuclear weapons testing at the Nevada Test Site (NTS) demands that we use modern computer control systems rather than "well-established" traditional technology. Historically, instrumentation and control have employed large numbers of expensive, heavy hardwire cables extending from surface ground zero, to a diagnostics area underground in a vertical shaft. The cables are then terminated and in most cases perform singular functions. By adapting industrial instrumentation and control techniques (namely programmable computer control and distributed input/output) we can be connected to a large number of data and power distribution channels with a single pair of fiber optic or coaxial cables. However, to gain system confidence and to modify transferred technology to our unique needs, we integrate such technology incrementally. This paper will discuss examples of our incremental approach by describing some weapon event tests. This paper will also discuss goals for future automation at the NTS.

INTRODUCTION

Since 1963, when the Limited Test Ban Treaty was signed by the United Kingdom, the Soviet Union, and the United States, nearly all U.S. nuclear tests have been conducted deep underground at the NTS. Such nuclear tests are performed using one of two distinct formats. The first format, used to determine nuclear weapon or "device" yield and/or to test the reliability of stockpiled weapons, is performed by inserting the nuclear device and a diagnostics rack down a vertical shaft (Fig. 1). These shafts range from 48 to 120 inches in diameter and are typically 600 to 2200 feet deep. The diagnostics rack and device are backfilled in a way that prevents radioactive debris and gases from escaping the shaft--called stemming. The second format, used to evaluate the effects of device detonation on various critical components of missiles and warheads, is performed within a horizontal tunnel mined into the side of a mesa. The device and diagnostics equipment are positioned in drifts deep within the tunnel (Fig. 2). The drift is sealed with a cement-like grout to contain the blast's shock wave and the radioactive debris and gases.

For both testing formats, we establish a forward area control station to house equipment for viewing and controlling various experimental system: before detonation. For vertical tests, the control station consists of specially designed instrumentation trailers situated up to 2500 feet from ground zero. Both hardwire and fiber optic cables are laid across the desert floor and conduct information and commands between the trailers and the diagnostics rack. The cables are lowered along with the diagnostics rack, before final stemming. For horizontal tests the forward area control station is situated within small alcoves carved into the side of the main shaft deep within the mesa. Communication is relayed between the diagnostics equipment and the control station through hard wire and fiber optic cables.

Because remaining in these forward control stations during the detonation is impossible, the monitor and control signals from ground zero must be transmitted via microwave to a manned location, called the control point. The control point becomes the operational center for the tests shortly after device insertion and stemming. The physical distance between the control point and ground zero varies from a few miles to approximately thirty-five miles.

Because the number of tests performed at the NTS varies for a given year and each test requires a different process configuration, our tests are not designed, built, and used repetitively for long periods of time.

TRADITIONAL INSTRUMENTATION AND CONTROL

In the past, individual experiments have been controlled as they would be at any other process control plant. Hardwire conductors are directly connected to a control panel and are terminated directly to the piece of equipment being controlled. Simple switches and actuators from the control panel often directly supply the proper operating voltages and currents to this equipment. Analog and discrete monitors are terminated at sensors on the diagnostics rack and again at the control panel; typically, each monitor has its own signal pair. In addition, select analog channels are multiplexed through pulse coded modulation units and sent to control point computers for data archiving. This is a simplified description of a complicated process; however this description provides a general overview of the instrumentation and control system we use.

It is difficult to argue with both the simplicity and reliability of this system when good equipment is used. And, to attempt an alternate method of operation when "it's been done that way for years" meets with a good deal of resistance. Because the very nature of nuclear weapon testing requires an extreme degree of reliability, we scrutinize new testing and diagnostics techniques thoroughly. However, improving traditional techniques is essential. Without an aggressive program to develop faster, more accurate, and safer techniques we are in danger of becoming stagnant.

In reality, policy makers and managers are not always willing to commit themselves to this type of forward thinking. Also, most systems such as ours cannot simply shut down while a totally new system is being implemented or a new operating philosophy developed. To overcome this limitation we have established a section within our group for investigating enhancements to our operating procedures and then phasing in these enhancements. This continuous, ongoing research and development activity is designed to prevent us from stagnating while keeping our instrumentation and control systems extremely reliable.

A NEW GENERATION

Although the NTS instrumentation and control system appears extremely efficient and reliable, we must update it to meet increased requirements. As the test systems become more complex, more data channels must be designed into the system. Remember, with each additional data channel a minimum of one pair of hardwire conductors must be added (often more conductors must be added for a particular data channel for gauge excitation etc..). Eventually the size of the cable bundle becomes too large and too heavy to be lowered into the vertical shaft. Also, these cable bundles are very expensive and are destroyed with each test.

Modern experiments involve unprecedented sophistication and require close self-interrogation with provisions for emergency shutdown and evasive action algorithms, reliable unattended supervisory control, and alarm annunciation. These features are somewhat standard for programmable logic control (PLC) systems within the process control industry and, therefore are directly applicable at the NTS.

In February of 1984, in "T" tunnel, the nuclear test, code-named MIDAS MYTH/MILAGRO, involved the first major use of PLC at the NTS. The controller was responsible for monitoring, displaying, and scaling analog gauges; monitoring and displaying digital inputs and outputs; distributing power to a large vacuum system (supplying vacuum to 46,000 liters of volume); and linking the vacuum system as the human interface to experimentalists (Fig. 3). The vacuum system consisted of a Root's blower and mechanical vacuum pump, two cryogenic vacuum pumps each with separate compressors, and two mechanical roughing pumps. The pressure-operated valves used nitrogen and required control for two nitrogen manifold control valves. Two Leybold-Heraeus solenoid valves, one six-inch pressure actuated gate valve and one twenty inch pressure actuated gate valve were used. A water cooling system, used for the cryogenic compressors and the Root's system, was also controlled and monitored through pumps and flow meters. All controlled items carried 100% redundancy to prevent single-point failures.

In keeping with the spirit of incremental integration of new equipment and concepts, we disturbed as little of the operating process as possible. The PLC was configured between a conventional hard wire control panel (in the forward control alcove) and the diagnostics conductors just before the stemming wall. The operator interface consisted of conventional switches and lights with which operators were familiar and also provided the security of watch-dog procedures derived from fault-tree analysis.

We also enhanced communications between the control point and the forward area control alcove (Fig. 4). Fiber optics carried RS-232 data signals between the PLC system and the tunnel portal. The signals were then modulated for microwave transmission to the control point where they were demodulated for remote control and monitoring the entire operation. Because of channel limitations of the microwave system during previous tests, only data channels labeled "critical" could be sent to the control point; with the new system, all data channels were supplied to the control point. To emphasize the potential of this new system, we used a conventional telephone modem at the forward area control alcove so that we could use commercial lines to control the vacuum system from Los Alamos.

THE SECOND GENERATION

The system handling information and the man/machine interface for the MIDAS MYTH/MILAGRO test were undoubtedly the weakest points. System status was displayed in tabular form (from the programming unit) and lacked appropriate I/O point identifiers, thus taxing the user's memory and requiring the user to coordinate control with look-up tables. And essentially no computer-generated event logging or data archiving existed. With these shortcomings in mind and with an immediate programmatic requirement to instrument a very large experiment, we began evaluating a commercial control software package that promised to meet our requirements.

Although the PLC performed flawlessly, we felt uncertain about placing the programmed "intelligence" of the system down a vertical test hole where it would be inaccessible. And we were uncertain about transmitting the programmed "intelligence" over microwave links because of possible signal breaks in the links. Therefore, all programmable subsystems would be located at the forward area control stations.

In October of 1984, we chose one of the few available control software packages with the features that met our needs. The control software operates under concurrent DOS on an IBM/XT or equivalent computer. The package supplied us with interactive color graphics and with static and dynamic point status. For the first time, this system provided experimentalists with a multidimensional approach to process visibility by using color, shapes, and dynamic symbols. All support programs--I/O driver, historian, alarm, and data reduction for historical viewing--run concurrently with what ever program is required by a particular application. Communication to the remote I/O is established through an RS-422 port within the host computer and is immediately converted to a fiber optic signal for communication down the shaft. A second port on the host computer, RS-232, is also converted to a fiber optic signal and is sent to the microwave sending station so that a remote data terminal can be used for process control at the control point.

Because this IBM/XT-based system was not well established, or over time proved, we operated a back-up system using a DEC LSI-11/23 computer and custom in-house software concurrently with the IBM/XT system. The back-up system did not have a graphics capability and displayed the data in tabular form, but it proved to be a much faster, real-time controller. We used four IBM/XT computers on this event to accommodate the large number of users and to decrease system load. Each IBM/XT system carried approximately 25% of the system load, while all data channels were fed concurrently into the single 11/23 computer. We handled all communications to the remote I/O and to the control point identically on both the 11/23 and the IBM/XT, thus providing 100% redundancy.

We selected this system's remote I/O for its flexibility, simplicity, and overall economy. The remote I/O is not tied to a PLC. Configured on printed circuit board, the I/O modules can be randomly inserted in any of 16 slot positions. Each board carries its own address and RS-422 communication integrity logic. Additional boards are added serially or in a multidrop configuration along the data network. All I/O points were backed up with identically configured (but isolated) counterparts to provide full redundancy. Including redundancy, I/O points. this system carried 1100 I/O points

NEW HORIZONS

The system we have described is essentially the same as our standard system today. We have dropped the LSI-11/23 system and enhanced our hardware to relieve some of the slow operations and awkward configurations we encountered on the IBM/XT system. Vendor software enhancements have also helped increase overall efficiency. Since we first used this overall control concept, engineers and experimentalists working at the NTS have increased their demands for greater across-the-board speed, graphics that are more easily configured, that are expandable, and provide effective interfacing with large main-frame computers. To satisfy these demands, we have purchased for evaluation a possible third-generation system.

This system functions around a local area network in a masterless, token-passing protocol. Each node on the network has a dedicated function and includes its own high-speed co-processor and memory. This type of "functional partitioning" is well suited to enhance system speed and easy expansion of the system. The man/machine interface can be adapted to any user's preferred command peripheral or phobia. For example, the interface will allow the user to interact with the I/O driver by keyboard, trackball, mouse, or touchscreen. Generating graphics with this system is similar to modern computer aided design equipment. This system captures, archives, and displays a large number of data channels without a significant CPU or system burden. As a separate node of the system, a PLC gateway will be used as the remote I/O interface.

We plan for the system front end to be a PLC with distributed I/O. The programmed intelligence will remain accessible through the entire nuclear test and only the actual I/O modules will be destroyed. We will use the PLC to execute system procedures that must occur at high speeds and to report to the operator during normal gateway communications. Procedures that would normally tie up a PLC (linearization algorithms, for example) could be accomplished within the control host, thus relieving the PLC burden. As before, all remote communications would be transmitted through redundant fiber optic cables.

FUTURE ENHANCEMENTS

By using local area network protocol through a microwave or fiber optic transmission media, we hope that any nuclear test could be controlled from numerous and distant locations (Fig. 5). We are at the dawn of I/O systems that are so "fault tolerant" that we would not need parallel redundant I/O systems. Manufacturers are beginning to meet compatibility requirements instead of developing proprietary communications protocol. This will allow allow us to choose the PLC best suited for any particular application without restructuring the total system. And, finally, we will communicate with faster, more efficient number crunching computers to reduce data more efficiently.

SUMMARY

We have adapted a tool that industry is as excited about as we are. And while this tool does not meet all of our requirements for speed and overall adaptability, our operating efficiency and system capabilities have increased dramatically. We will continue in our testing to implement this rapidly growing technology.

We would encourage control system design engineers to expand their research oriented horizons and to harness new capabilities that will better support research environments. A few of today's research instrumentation requirements are: greater point sampling rates for historical archiving, faster changes on computer screens that display dynamic point data, and greater flexibility for on-line additions to the instrumentation and control process.

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1. Wolf, Walter 1984, A Typical Los Alamos National Laboratory Underground Nuclear Test. Los Alamos "MINI-REVIEW", LALP-84-47, Los Alamos, N.M.

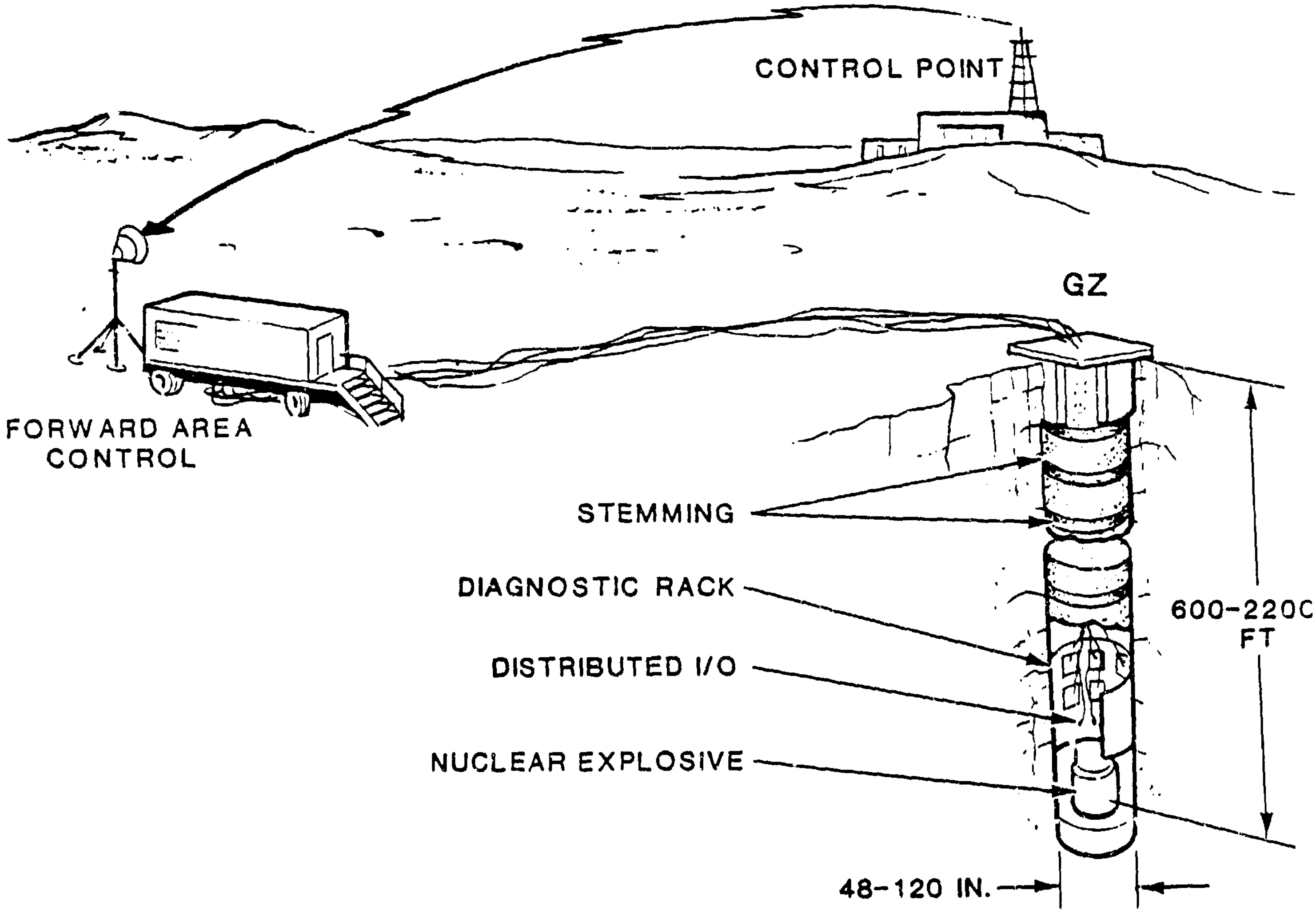


Figure 1

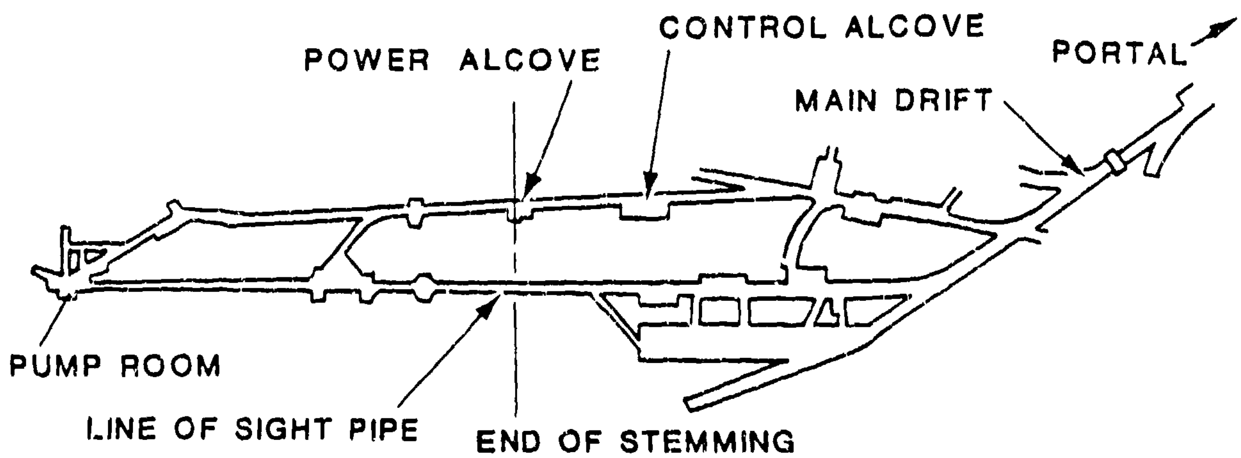
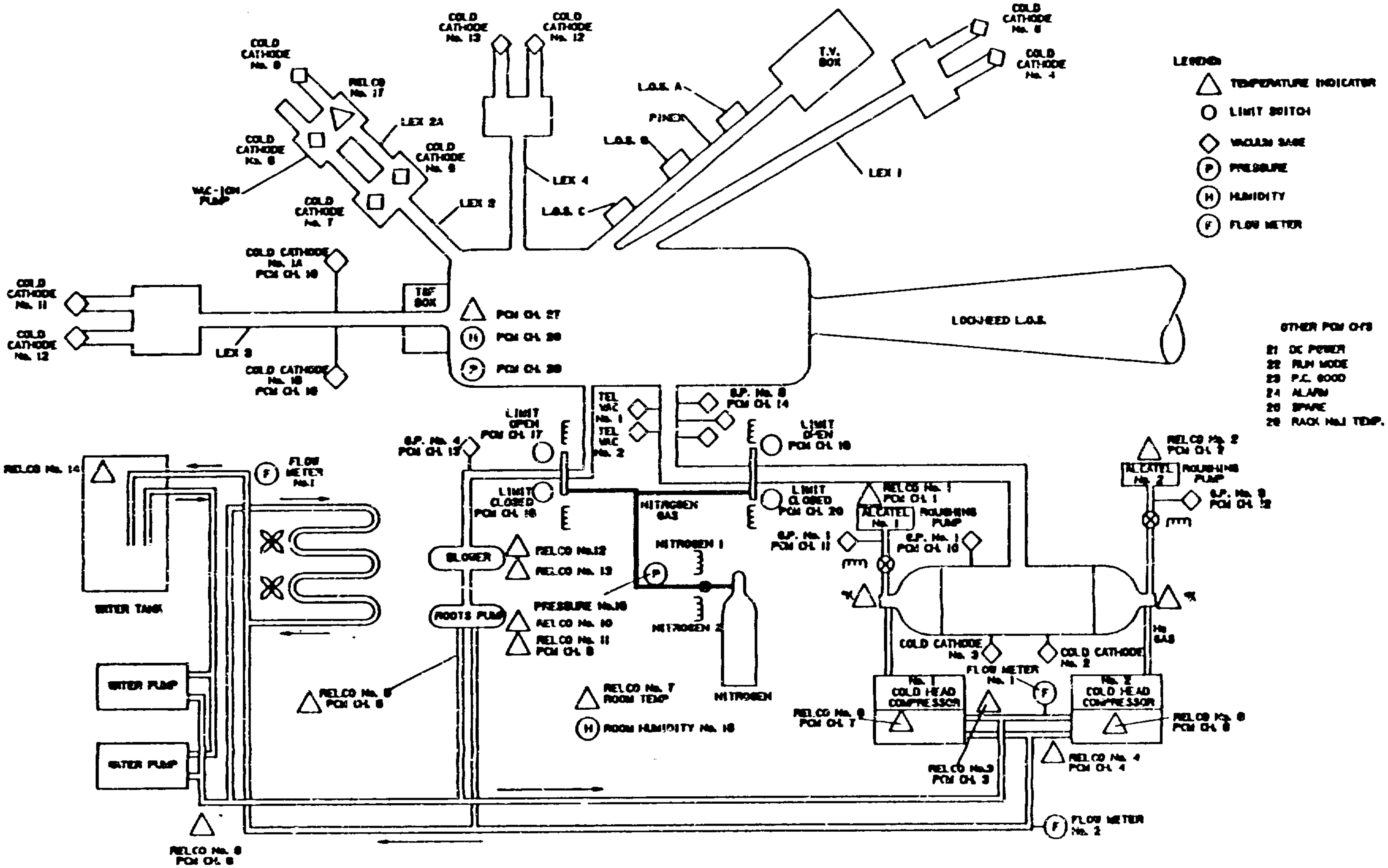


Figure 2



LEGEND:
TEMPERATURE INDICATOR
LIMIT SWITCH
VACUUM GAGE
PRESSURE
HUMIDITY
FLOW METER
T.V. BOX
L.O.S. A
PINEX
L.O.S. B
L.O.S. C
LEX 1
LEX 2
LEX 2A
LEX 3
LEX 4
VAC-ION PUMP
TBF BOX
LOCKHEED L.O.S.
OTHER PCM CH'S
21 DC POWER
22 RUN MODE
23 P.C. GOOD
24 ALARM
25 SPARE
26 RACK No.1 TEMP.
WATER TANK
WATER PUMP
WATER PUMP
BLOWER
ROOTS PUMP
NITROGEN GAS
NITROGEN
PRESSURE No.16
RELCO No. 7 ROOM TEMP
ROOM HUMIDITY No. 16
No. 1 COLD HEAD COMPRESSOR
No. 2 COLD HEAD COMPRESSOR
ROUGHING PUMP
FLOW METER No. 2

FIGURE NO. 3

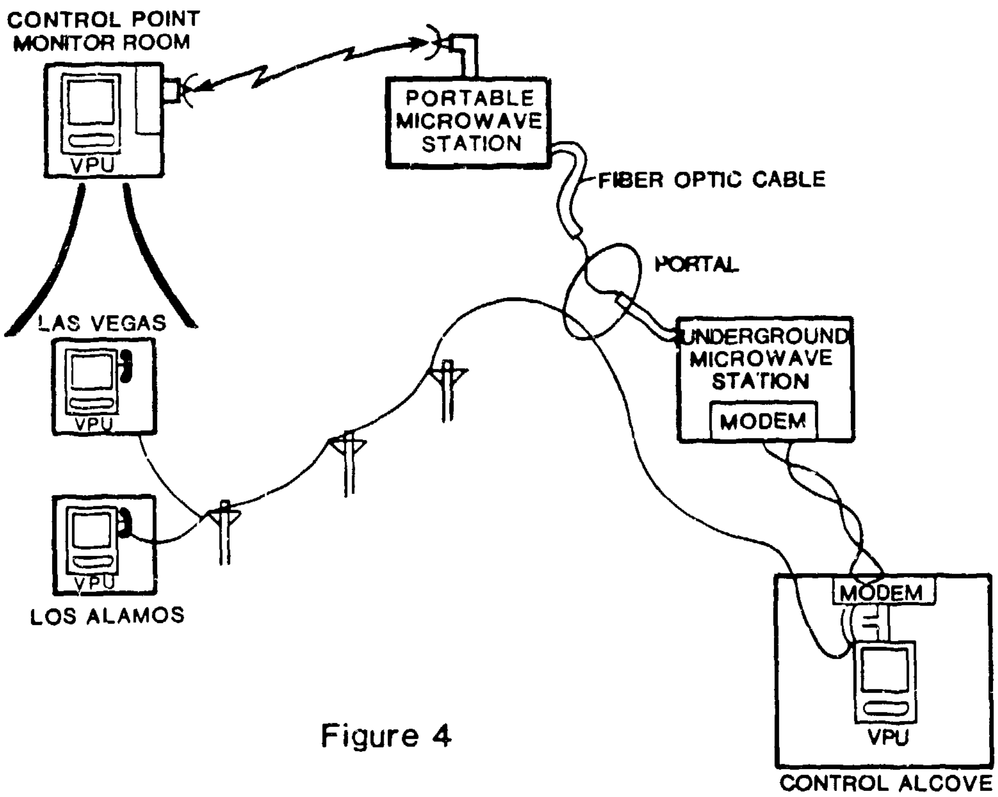
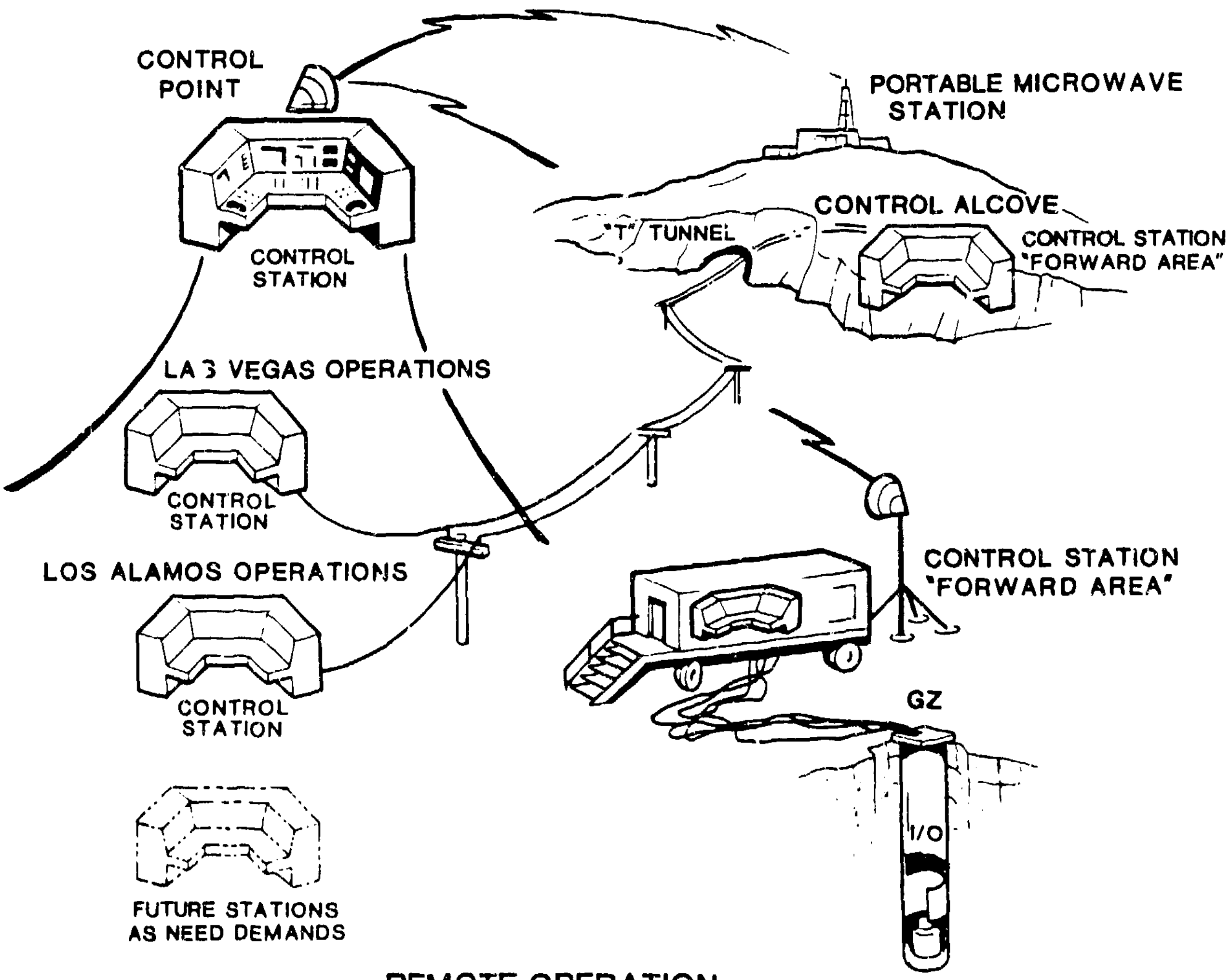


Figure 4

NEVADA TEST SITE



REMOTE OPERATION