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RESEARCH, S. W. Depp, Assistant Division Leader
Detector Research and Development

Introduction. Group E-10 does basic and developmental research on a variety of detectors and materials for radiation detection. The work is applicable to a variety of programs including weapons, nuclear physics, high-energy physics, nuclear medicine, laser fusion, geothermal energy, nuclear safeguards, solar power, and environmental radiation detection.

The E-10 fabrication and measurement facilities have achieved minimal operational capability in that first sensor projects are underway. The work emphasis relative to these two facilities is twofold. The first is to achieve first results. The second is to expand the analysis and technological capabilities of the facilities. The first two sections below discuss these facilities and the analysis techniques being developed.

The first of the two special sensor projects is being used on a "first results" basis to increase facility capabilities. The second special sensor project is concerned with beam alignment problems at the Eight-Beam CO₂ Laser Facility. A new detector concept will be introduced here as a possible solution for the alignment problem.

We have three physics experiments in progress. The results of the first, a measurement of the most probable energy loss in thin silicon by ultrarelativistic charge particles, are in the final stages of preparation for publication in Physical Review. One theoretical paper on the second, a study of the charge transport and energy exchange mechanisms, has been prepared and submitted to the Nuclear Science Symposium of the IEEE. Apparatus for this experiment is nearly complete and in operational form. The third experiment, a study of the phase diagram in the condensation of electron-hole droplets in semiconductors, is being prepared. A new research initiative proposal (NRIP) for this experiment was proposed and approved for funding. We are acquiring all of the experimental apparatus for this experiment.

Group E-10 conducted its first industrial workshop, which was well received by both the Los Alamos Scientific Laboratory (LASL) participants and the industrial representatives. Minutes of the meeting will be issued in report form.

Facilities.

Counting Facility [Edmiston, Maggiore, E-10]. The E-10 counting facility, located in the sub-basement of the P-9 Van de Graaff is now operational. We have acquired the equipment to enable us to perform studies on detector characteristics and performances. The central core is a PDP-11/20 computer with 28-k memory. Software and data are stored on a disk system consisting of a Wanco drive and an IMS controller. The drive has a fixed and removable plotter with 260-k storage capacity each. Communication is via a 4010 Tektronix terminal with a hard-copy attachment. Data can be taken either through a CAMAC interface or digital processing oscilloscope (DPO). The CAMAC crate uses an RT-11 operating system and the DPO a Tektronix SPS-BASIC operating system. Although both systems cannot reside in the computer simultaneously, a switch can be made between the two in a matter of seconds.

Data-taking software is progressing well. The Michigan State University Cyclotron Laboratory gave us a data-taking software library for CAMAC, which operates under RT-11. Professor Clare Morgan, who wrote the software, was hired as a consultant for 1 wk to adapt the software to our system. Additional software has been prepared and continues to be written by E-10 and E-5 personnel. Software development is now compatible with or ahead of our needs and data acquisition is not dependent on software development.

Clean Room Facility [Gibbs, Glick, E-2; Hammond, E-10]. The clean room facility, shared equally between E-3 and E-10, has come into full operation since the last status report. It consists of five rooms: entry room, dressing room, class-100 room, random-flow room (class 10 000), and utility and storage room. A downward laminar air flow of 50 cm/s is maintained in the random flow at 21°C and 35% humidity. Personnel using these rooms are required to wear jumpsuits and booties, which are available in the dressing room. These rooms are cleaned by E-10 and E-3 personnel and a schedule for this cleanup has been established. The deionized water system, acid and solvent hoods, photoresist spinners and baking tubes, and the mask aligner are all operational. The room lights have been tested and do not affect the photoresist. One section of

the four-section Thermo furnace is fully operational. Systematic temperature profiling has been performed and the furnace is found to be well within specifications. Thus far it has been used for phosphorus diffusions from doped oxide into Si wafers at 1000°C. The Varian ion-pumped high-vacuum system is being assembled for initial checks. The storage room contains LN₂ dewars for the blow-off system, which is installed and leak checked, and gas bottles for use with the furnace. The gas lines and gas-flow systems to the furnace are installed.

A standard operating procedure for the clean room has been drafted and is receiving final revisions. Inspections by H-Division personnel have shown that this laboratory now satisfies LASL safety requirements. A Halon fire protection system has been installed in the class-100 room.

Analysis Techniques.

Materials Analysis [E-10 Collaboration]. Group E-10 continues to assemble a wide variety of apparatus, instrumentation, and expertise for the characterization of detectors and detector materials.

The Tektronix digital-processing oscilloscope and associated software enables us to take Fourier power spectra of current and voltage signals in a matter of seconds. This is a particularly powerful tool for diagnosing noise sources in semiconductor detectors. The tandem Van de Graaff accelerator at P-9 gives us a monochromatic source of any ion in the few million electron volts energy range. This is also a useful tool for detector characterization.

A collaboration has been initiated with CMB-1 to use their electron microprobe as a tool for scanning resistivity of silicon wafers. The technique, which has been developed at Bell Telephone Laboratories, enables one to probe epitaxial layers from 1- to 15-μm deep by using electron beam energies up to 50 keV. The method depends on collection of beam-deposited charge in a Schottky barrier junction. It allows resistivity profiling with ~10-μ spatial resolution and ~1% accuracy. This procedure will be extremely important in screening Si wafers for resistivity uniformity for detector use.

The availability of the P-9 tandem Van de Graaff will allow E-10 to implement backscattering of megavolt light ions, a very powerful surface analysis technique.

Also, apparatus to perform thermally stimulated current measurements is being designed and constructed. This will enable the characterization of trapping centers in Si with concentrations as low as 10¹⁰ cm⁻³. Finally, an optical laboratory is being set up which will enable absorption, transmission, and luminescence spectroscopy of materials between 1.5 K and room temperature. A wide variety of electrical measurements will also be possible in this temperature range.

C-V Measurements [Stotlar, E-10] Evaluation of capacitance-voltage data is a standard method for obtaining the dopant density profile of a diode. The application of a reverse bias to a p⁺ or n⁺-p diode causes the depletion width to increase to a depth x from the junction. This gives rise to a (depletion) junction capacitance. The majority carrier concentration $n(x)$ in the lightly doped side of the junction at a depth x is given by:¹

$$n(x) = - \frac{C^3}{qc \epsilon_0 A^2} \frac{dV}{dC} \quad (1)$$

The junction depth is related to the capacitance by:

$$x = \frac{\epsilon \epsilon_0 A}{C} \quad (2)$$

where ϵ_0 is the permittivity of free space, ϵ is the dielectric constant, and A is the diode area.

The doping profile is usually equivalent to that of the majority carriers. In the case of steep profiles in lightly doped materials, the dopant density profile differs from the carrier density profile. The two can be related by:²

$$N(x) = n(x) - \frac{kT\epsilon\epsilon_0}{q^2} \frac{d}{dx} \left[\frac{1}{n(x)} \frac{dn(x)}{dx} \right] \quad (3)$$

where $N(x)$ is the dopant density.

This technique is limited to regions of the semiconductor where doping is sufficiently low to permit depletion without breakdown at the diode

junction. Debye length L_D is a limit to the depth resolution of the method. The Debye length is given by:

$$L_D = \sqrt{\frac{kT\epsilon\epsilon_0}{nq^2}} \quad (4)$$

Further limitations involve the resolution capability of the measuring equipment.

An automated method of obtaining capacitance vs reverse bias voltage data is being developed. A preliminary program (CAPV1) has been written in SPS-BASIC for use with the PDP-11 computer to calculate and graph diffusion profiles from the C-V data.

A Boonton Electronics 72BD digital capacitance meter and a Keithley 616 digital electrometer have been received. By externally biasing the 72BD, a device under test can be reverse biased. As the reverse bias is increased, the capacitance decreases. The data are stored on a DPO system. Figure 1 is one possible circuit to provide C-V data. The display is a plot of capacitance vs reverse bias. The digitized data stored in the DPO are transferred to the PDP-11 computer for further analysis.

The same PDP-11 is also CAMAC interfaced. It is planned to have the CAMAC control the measurements by controlling a programmable power supply. The local memory of the DPO is used for data storage. The data are transferred to the computer using SPS-BASIC for further processing.

Fig. 1. Capacitance vs reverse bias data input circuit.

Fig. 2. The light and signal paths of the dual-laser scanner.

The preliminary program, CAPV1, is based on a program developed by B. J. Smith of Harwell.³ A program written by Mattis and Buehler of the National Bureau of Standards (NBS)⁴ was evaluated, but found to be incompatible with the PDP-11 BASIC. The CAPV1 program calculates the carrier and dopant density as well as the depletion width from the C-V data. It makes corrections for stray and peripheral capacitance. Capacitance vs bias, $1/C^2$ vs bias, and carrier and dopant density profiles are graphed.

Laser Scanner [Stotlar, Maggioro, E-10]. A dual wavelength scaling laser system, based on an NBS design,⁵ is being developed for use in evaluating silicon detectors. The system is designed to provide nondestructive mapping of optical interactions in semiconductor devices. Two low-power lasers can provide information on the uniformity of surface and bulk properties, thickness uniformity, weak or stressed points on a functioning device, and failure locations on nonfunctioning devices. In general, both devices and material can be characterized in terms of the optical interactions.

Figure 2 shows the basic system layout. The laser scanning system consists of two helium-neon lasers, one set at 6328-Å and the other at 1.15 μm, with output levels at 5 mW and 2 mW, respectively. The 6328-Å and 1.15-μm wavelengths will probe two different regions of a device. The 6328-Å laser, with an attenuation length of 3 μm in silicon, can be used for regions near the surface. The 1.5-μm laser, with an attenuation length of about 3 cm, can be used to probe the bulk of a device and regions of high-charge density. The laser beams are directed

by mirrors and lenses to a vertical scanning mirror and then to a horizontal scanning mirror. The latter is located at the exit pupil point of a Wild-Heerbrugg M5 microscope. The focused beam moves in a raster pattern across the test area. The beam reflected from the test device is collected and focused onto a germanium photodiode. For devices or materials transparent to $1.15\text{ }\mu\text{m}$, the transmitted light is collected and focused onto a second germanium photodiode. The photoresponse of the device under test can also be obtained. These three signals are mixed and displayed in any combination on a modified color TV receiver. The scanning rates of the mirrors are $\sim 10\text{ Hz}$ vertically and 3.2 kHz horizontally. The scanner is designed to be compatible with computer control. The scan drivers can be controlled by the PDP-11 computer via CAMAC digital-to-analog converters (DAC) and the output of the mixer recorded on the disk via CAMAC analog-to-digital converters (ADC).

The system can be used with the microscope between $7.5\times$ and $250\times$ to scan an area 2 cm by 2 cm to $600\text{ }\mu\text{m}$ by $600\text{ }\mu\text{m}$. Without using an aperture the smallest spot size on the device is $4\text{ }\mu\text{m}$. The system can be used for probing large diameters on the order of 5 cm without the microscope.

Drawings for the optical portion of the system including the lasers, scanners, optics, microscope, detectors, mounting frame, and dust cover have been completed. The mechanical section is being fabricated by Group E-2. The lasers, mirrors, scanners, lenses, and microscope optics have been received. The electronics are also being fabricated by E-2. The display, a commercial color TV, is being modified by Group E-1. The laser scanner will be portable. The optical section is 91.4-cm wide, 76.2-cm high, and 45.7-cm deep. Assembly of the laser scanner is expected to begin in June with completion projected for August.

Special Sensor Projects.

Low-Energy X-Ray Spectrometer [E-10 collaboration]. A low-energy x-ray detector of the epitaxial silicon avalanche diode (ESAD) design is being developed by E-10. The detector, intended to operate at LN_2 temperature with a cooled FET preamplifier, is expected to be of use in the energy range from $\sim 0.3\text{ keV}$ to 10 keV . There are now four types of x-ray spectrometers available -- gas-ionization proportional counters, gas-scintillation pro-

portional counters, lithium-drifted silicon detectors, and focusing crystal spectrometers. The ESAD x-ray spectrometer is expected to provide the simplicity, efficiency, solid-angle, and nonfocusing characteristics of the $\text{Si}(\text{Li})$ detector with improved energy resolution below a few kiloelectron volts.

The design and characteristics of the ESAD have been reported previously. Using photolithography to define the mesa and guard structure, devices of the $n^+ - p^+ - p - p^+$ form have been made with a 1.8-mm-diam mesa, an 0.3-mm-wide low-field guard, and a 1.5-mm-wide guard ring separated from the low-field guard by 0.3 mm . Four devices were separated by chemical etching. Table I lists the characteristics of the starting material used. The phosphorus diffusions were performed at 1000°C . For initial tests no attempt to provide a thin entrance window for the x rays has been made, x rays will enter the detector through the n^+ and high-field region. In the finished design a thin entrance window will be made by removing the p^+ substrate to the p region under the mesa. Contact to the mesa was made with 1-mil Au wire and silver epoxy.

Since the detector is designed primarily for low-energy x rays, a dipstick cryostat of windowless design is being used. The cryostat has a double valve that enables the source and target to be changed without having to warm the detector. A ^{241}Am alpha source is used to fluoresce a solid target to provide low-energy x rays. For example, copper can be used to provide x rays at 0.948 , 8.047 , and 8.904 keV . Aluminum can be used to provide an x ray at 1.49 keV .

The internal hardware of the cryostat is designed for use with a pulsed optical feedback preamplifier. Pulsed optical feedback with a separated guard ring will require the use of a dual FET design. It is anticipated that this mode of guard operation may create crosstalk problems during the

TABLE I
MATERIAL CHARACTERISTICS

Batch No.	p+ Region		p Region		Diffusion Time
	$\delta(\Omega\text{-cm})$	$t(\mu\text{m})$	$\delta(\Omega\text{-cm})$	$t(\mu\text{m})$	
9, 10, 11	3.1	6.0	91.4	31.4	1/2 hour
12, 13	3.0	6.3	182.0	31.8	1 hour

reset cycle. This has not been tested; instead, for simplicity, the device was looked at without the guard ring attached.

At a bias of less than 30 V the leakage current is stable. The reset rate of the preamplifier is proportional to the leakage current, and the time between resets, ~ 40 ms, is compatible with a leakage current of 10^{-12} A. At biases above 30 V, the reset rate becomes unstable and the leakage current is too high to be used with the pulsed optical feedback preamplifier. To deplete the detector, calculations indicate that a bias of ~ 70 V is required.

The detector has been repackaged in the cryostat without the pulsed optical input. We are currently testing the I-V, C-V, and noise characteristics of the detector with an external noncooled preamplifier.

Large-Area Beam Alignment Sensors for the Eight-Beam CO₂ Laser Facility [Gruhn, Hammond, E-10; Silver, T-11].

We have assumed the task of designing, fabricating, and testing the large-area beam alignment sensors for the Eight-Beam CO₂ Laser Facility. The requirement is to locate the beam positions to within 5% of the diameter of the beam. In Table II we list the expected beam characteristics at the large-area sensors.

We decided to look at the properties of silicon as a potential sensor for the CO₂ beam. This decision was based on our experience with silicon and the high technology in back of silicon. A new beam alignment concept, thermopower division, has been discovered and is discussed here.

In Table III we list those properties of silicon relevant to the thermopower division beam alignment sensor concept.

The damage threshold for silicon is about 50 times higher than that observed for typical pyro-

TABLE III

SILICON PROPERTIES

(1) High Damage Threshold	
Breakdown Field (DC)	$\sim 3 \times 10^5$ V/cm
Laser-Induced Breakdown (10 μ m)	$\geq 10^5$ W/cm ²
(2) Transparent	
Residual Absorption (10 m)	1 cm ⁻¹
Reflectance	30%
(3) High Thermopower	
Thermoelectric Power	1.7 mV/ K (100- Ω -cm) 1.0 mV/ K (0.1- Ω -cm)
(4) Technology	
Electrical Contacts	
Variable Resistivity	10^{-4} - 10^5 - Ω -cm
Epitaxy	
Cheap Crystals	$\sim \$0.65/\text{cm}^2$ of wafer
Precise Geometries	(Monolithic processing)
Thin	$> 10^{-4}$ cm
Large Areas	≤ 125 cm ²
(5) Other Properties	
Density	2.33 g/cm ³
Specific Heat	0.7 J/g K
Thermal Conductivity	1.5 W/cm K

electric sensors. The damage threshold can be raised in cases where an MIS sensor can be presented to the beam. In cases where the metal is copper, damage thresholds approaching those achieved with the copper mirrors can be expected.

One potential advantage of silicon is that it is nearly transparent to the beam with a residual absorption coefficient of 1 cm⁻¹. As long as the free carrier density is low, this absorption coefficient will dominate. As purchased, a typical silicon wafer thickness is 0.02 cm, which will absorb 2% of the beam. For small areas, our group has thinned silicon wafers to 1 μ m in thickness implying an absorption of 10^{-4} . Because of the high reflectance $\sim 30\%$, in order to have a high transmission, an anti-reflection coating would have to be applied.

The thermopower of most semiconductors is 10 to 100 times higher than typical metals. The highest for any metal is 75 μ V/ K, which is for Bi, a semimetal. Copper is 2 μ V/ K at room temperature, whereas 100- Ω -cm Si is 1.7 mV/ K.

The thermopower division position-sensor concept is shown in Fig. 3. The material is 100- Ω - cm p-type silicon 0.02-cm thick. The material has a sheet resistance of 5000 $\Omega/\square$. The resistance between the contacts is about 5000 Ω . The beam passing through the sensor loses about 2% of its energy

TABLE II

BEAM CHARACTERISTICS AT LARGE-AREA SENSORS

Beam Diameter	2.4 cm
Energy	8 to 290 mJ
Pulse Length	0.2 ns
Power (Peak)	4×10^7 to 1.5×10^9 W
Power Density (Peak)	7.9×10^6 to 2.9×10^9 W/cm ²
Position Resolution	~ 1 mm

to photons causing a temperature rise with a maximum centered on the centroid of the absorbed energy. The density of ionized impurities (acceptors) depends upon the temperature and is a maximum at the centroid of the beam. Because of the concentration gradient, a radial diffusion current centered on the beam centroid flows following the radial diffusion of the heat. The concept at this point is similar to that of the charge or current division on a resistivity strip with a nuclear-particle position sensor.^{6,7} The position dependence of the charge signals is given in Fig. 3. This description is expected to be qualitatively correct with differences being associated with the long thermal relaxation time (~ 1 s) and the sensor equivalent circuits.

Figure 4 shows the layout of the electrodes for a two-coordinate thermopower division beam-position sensor. In this case the signal is divided four ways yielding the x and y positions.

For first tests a dual electrode single-coordinate thermopower sensor having a 5.0-cm diameter has been constructed and tested in collaboration with R. Ahrenkiel, C. Phipps, and S. Thomas, L-9. The test was made with one electrode grounded and the other viewed by a microvolt meter. The L-9 CO₂ Laser Facility was used for the measurements. The beam power remained the same throughout all the measurements, the energy was 2 J, the pulse length was 2 ns, and the area was 2 cm².

Sensor response to beam energy was measured using filters placed directly in front of the sensor, thus changing the energy of the beam impinging on the detector. These results are seen in Fig. 5. The sensor had a linear response to the beam energy

Fig. 4. Configuration of electrodes for thermopower division position sensor.

to within 1% up to 1.3 J. Above this energy the sensitivity was enhanced due to the increased absorption coefficient caused by beam-induced avalanche and a high free-carrier absorption. This nonlinearity at the highest peak powers reflects that we are near the damage threshold although no damage was observed with this device (the measurements were reproducible). It is expected that the energy sensitivity will depend upon the beam profile since it will create different temperature gradients and therefore different diffusion currents. To first order, one can be independent of this problem by seeking a null signal when the beam is centered.

Fig. 3. Schematic design of thermopower division position sensor.

Fig. 5. The thermopower sensor response to energy.

First results on the position sensitivity were obtained by moving the sensor between three points spaced by 1.2 cm. The signal was normalized to the beam energy, which was kept approximately the same for all three positions. The results are shown in Fig. 6. It is seen that the signal is linear in position to within the errors and has a sensitivity of $5.9 \mu\text{V}/\text{mmJ}$.

On the basis of these results electronics have been designed and are being constructed so that the position resolution for the lowest beam powers can be achieved.

A major advantage of the thermopower division concept is that the sensor gives directly the coordinates of the centroid of the power distribution. No beam profile assumption is needed. No computer algorithm is needed to know the position. The position is given with the required precision on each laser shot. The digital readout of the electronics can be in millimeters.

Physics.

Energy Loss of High-Energy Electrons in Thin Silicon Foils [Ogle, WPC-2; Goldstone, P-9; Gruhn, Maggiore, E-10]. Analysis of the experiments done at the National Accelerator Laboratory (NAL) has been completed and local experiments with $\gamma_L = 3$ have been done to provide an absolute measurement. The local experiments give independent verification of the energy loss measured in the detector by measuring the energy shift of a ^{207}Bi K and L conversion electron beam (with and without the NAL detector in the beam) by a second stopping detector.

Fig. 6. Position sensitivity of the thermopower division position sensor.

The experimental result is that the energy loss equations of Sternheimer have been verified to hold within $\pm 2\%$ for $100\text{-}\mu\text{m}$ -thick silicon up to electron Lorentz factors of $\gamma_L = 10^5$.

There is no evidence for the relativistic rise predicted by Garibyan for thin foils (in this case $100\text{-}\mu\text{m}$ silicon), nor for the decrease in energy loss due to radiative corrections predicted by Tsytoich. We explain the former as being due to multiple scattering effects, which reduces the critical foil thickness for which the relativistic rise occurs. The latter can be explained qualitatively as being due to low-energy photon absorption by the material, which was assumed to be transparent by Tsytoich.

A paper combining theory and experiment is being written for submission to the Physical Review.

Liquid Ionization Chamber Developments [Edmiston, Gruhn, -10]. Over the past decade many people have realized that ionization chambers utilizing liquid noble gases could fill a significant need for high-resolution, large-volume detectors.⁸⁻¹¹ An ionization chamber filled with liquid argon (LAr) or liquid xenon (LXe) should yield energy resolution only two or three times worse than semiconductors; yet they could be made with large volumes (one to hundreds of liters) unimaginable with semiconductors. Such detectors could be widely utilized in high-energy and medium-energy physics, for example at LAMPF, and in certain low-energy experiments where high efficiency and high resolution are required. Since ionization chambers can be made as position-sensitive wire counters, these chambers could become highly efficient cameras.

Because of the promise of LAr and LXe as detector materials, many of their electronic properties have been measured.¹¹⁻¹⁴ These properties lead one to conclude that LAr should yield about 4-keV FWHM energy resolution for a 1-MeV particle and LXe should yield about 2.1 keV. However, to date Shibamura et al.¹¹ have set the resolution record at 35-keV FWHM for LAr using a gridded ionization chamber and the 1-MeV conversion electron from ^{207}Bi .

Group E-10 decided to reassess the evidence in favor of liquid-ionization chambers and to develop a theory as to why the ultimate resolution has not been reached. Having established the theory, we would build a detector designed to achieve the theoretical resolution.

We summarize below the properties of LAr and LXe, the theory we have developed, our experimental progress, and our goals.

Liquid Noble-Gas Properties. Table IV lists the properties of LAr and LXe that are relevant to ionization chambers; ¹¹⁻¹⁴ germanium is listed for comparison. All numbers are experimental except for the Fano factors, which are calculated. (The ultimate resolution is in turn calculated from F and W.) It is quickly obvious that for large volumes LAr and LXe are much cheaper than Ge, and current technology limits the production of Ge crystals to less than 1 L. Liquid densities are lower than Ge, but for LXe the Z is higher. This should allow a LXe detector to have similar efficiency to an NaI detector. While both liquids and Ge will suffer radiation damage, the continuous purification necessary with the liquids will remove troublesome transmutations. The liquids will require a sacrifice in time resolution because of the low-drift velocity in comparison to Ge.

Theory. To develop our theory we simply try to account for and understand all factors that contribute to energy resolution. We find these to be electronic noise, statistics in the production of electron-ion pairs, charge losses, and geometry considerations. We will first write down the equation for the variance in the number of electrons that form the signal, then we will define the terms and how to deal with them.

$$\sigma^2 = \sigma_{\text{elect.}}^2 + \sigma_{N_0}^2 + \sigma_{\text{losses}}^2 \quad (5)$$

$\sigma_{\text{elect.}}^2$: This term accounts for the electronic noise inherent in the detector preamplifier circuit. In order to minimize this term, one chooses his preamplifier carefully and tries to keep the capacitance of the detector low. With modern FET preamplifiers one can obtain the following values for $\sigma_{\text{elect.}}$:

Commercial room-temperature FET with resistive feedback	$\sigma = 425 \text{ e}$
Optimized room-temperature FET with resistive feedback	$\sigma = 235 \text{ e}$
Cooled FET with resistive feedback	$\sigma = 50 \text{ e}$
Cooled FET with pulsed-optical feedback	$\sigma = 17 \text{ e.}$

Shibamura et al. used warm electronics. This accounts for about 24 keV of their 35 keV.

$\sigma_{N_0}^2$: This is the fluctuation in the number of electrons produced by the ionizing particle. With Poisson statistics we would expect $\sigma_{N_0}^2 = N_0$, but the charge loss mechanism does not follow Poisson statistics. We have, according to Fano, ¹⁵ $\sigma_{N_0}^2 = FN_0$ where $0 \leq F \leq 1$. It is the remarkably low values of F that make LAr and LXe so attractive. If the pure liquid F is fixed; this presents an ultimate energy resolution limit that cannot be changed. There is, however, evidence that F can be lowered by mixing in the proper impurity. It is calculated that 1% LXe in LAr will change F from 0.12 to 0.07, ¹⁴ yielding nearly LXe resolution at LAr prices.

σ_{losses}^2 : This represents the fluctuation in the losses of charge caused by various factors. We expect this to follow Poisson statistics, so $\sigma_{\text{losses}}^2 = LN_0$ where L is the fraction of charge

TABLE IV

ARGON, XENON, AND GERMANIUM PROPERTIES

	<u>Argon</u>	<u>Xenon</u>	<u>Germanium</u>
Density (p)	1.4 g/cm ³	3.7 g/cm ³	5.33 g/cm ³
Cost per ion pair (W)	23.6 eV	15.8 eV	2.84 eV
Drift velocity of electrons at 10-kV/cm field (V ₀)	4 x 10 ⁵ cm/s	2 x 10 ⁵ cm/s	4 x 10 ⁷ cm/s
Fano factor (F)	0.12	0.05	≈ 0.05
Ultimate FWHM energy resolution for a 1-MeV particle	4.0 keV	2.1 keV	1.0 keV
Cost/liter	\$6	\$4k	> \$20k

lost. This has two effects. First, the LN_0 increases σ^2 . Second, the signal is reduced. Thus losses are very important to minimize as they simultaneously increase the noise and decrease the signal.

We see two major causes of charge loss; recombination of the electrons and positive ions, and trapping of the electrons by impurities. If the electric field is high (≈ 10 keV/cm) and the ionization track is not too dense (for particles lighter than alpha particles) we expect recombination not to be significant. The 1-MeV electron from ^{20}Bi should be acceptable at moderate to high electric fields.

Trapping, however, is a serious problem. Any electronegative impurity that can trap the electrons for a long time compared to the drift time will contribute to charge loss. We feel that we can speak primarily of oxygen as this impurity. This is because oxygen is the only electronegative impurity likely to be found in commercial Ar and Xe, and any purification scheme to remove oxygen will most likely remove any other electronegative impurities that might be present.

Only a couple of numbers for the mean life towards trapping have been reported in the literature and these are not in complete agreement. We have tried to estimate this mean life from these numbers and from the success of others using different purities of commercial Ar in detector applications. Using this estimate we calculate the oxygen effects shown in Fig. 7. The overwhelming conclusion is that the liquids must be extremely free of oxygen contamination. Because the mean life towards trapping is only estimated, the curves may be somewhat incorrect relative to the oxygen axis. However, the relationship between the curves is probably correct; LXe shows the strongest oxygen dependence because it tends to increase the drift velocity.

Now we can write the equation for energy resolution:

$$\Delta E(\text{FWHM}) = \left[2.36\sigma + N_0(1-G)f(x,D) \frac{E}{N} \right]. \quad (6)$$

In this equation we have E for the energy of the particle, and N for the final number of electrons comprising the signal (that is, $N = N_0(1-L)$).

$N_0(1-G)f(x,D)$: This term results from positive ion immobility compared to electron mobility. This

Fig. 7. Resolution dependence on oxygen level.

means (with integration times comparable to the electron transit time) that only one charge carrier is present, and by Ramo's theorem the preamplifier develops only half the signal for an electron that starts in the center of the chamber compared to one that travels the whole distance. Thus, if electrons are scattered along the particle track, even if N_0 is fairly constant from one particle to the next, the signal depends greatly on the length and orientation of the particle track. This contributes $N_0 f(x,D)$ to the resolution where x is the particle range, or, more accurately, the spread in the location of the ionization track, and D is the chamber size. If the radiation uniformly distributes electron-ion pairs across x , then $f(x,D) = \frac{x}{D}$. Usually the source-detector geometry will yield a true $f(x,D)$, which is less than $\frac{x}{D}$, so $\frac{x}{D}$ represents an upper limit.

By using a Frisch grid we can separate the chamber into two parts with the ionization taking place in one part, and electron detection taking place when they drift into the other part. Thus the preamplifier is shielded from the various ionization geometries. The grid is not a perfect shield so the $N f(x,D)$ term still appears, but is reduced by $(1-G)$ where G measures how effectively the grid acts as a shield. We can increase G by increasing the distance between the collector and the grid; however, as this distance is increased, the oxygen becomes

more important. If we are committed to some particular oxygen level because of our purification system, then there will be an optimum cell geometry. The results of our calculations for this effect are shown in Fig. 8.

Explaining Shibamura's Results. We know all of the parameters for Shibamura's experiment except the oxygen level. If we assume it to be zero, we calculate $\Delta E(\text{FWHM}) = 32.3 \text{ keV}$. This result can be increased to 35 keV if L is 7%. An L of 7% would be caused by an oxygen level of only 15 ppb. This level is consistent with their purification method.

Predicting Shibamura's result has given us confidence in our theory and a basis for improving upon their result.

Experimental Progress. The first and major experimental problem we have solved is oxygen removal. We have assembled a 5-L dewar which contains a parallel-plate, gridded ionization cell. The liquid thermodynamically circulates through a gettering furnace for oxygen removal. The oxygen level currently reached is 10 ppb. For monitoring these low levels of oxygen we have purchased a fuel-cell oxygen meter. This gives a quick, continuous monitor of our oxygen level, enabling us to study the oxygen effect in detail.

Our grid calculations show the optimum cell size to be 1.5 cm from grid to collector. We have built the cell shown in Fig. 9. The ^{207}Bi source with its 1-MeV conversion electron is an excellent

Fig. 9. The E-10 test cell; electrodes are stainless steel, the grid is nickel, and the separations are provided by Teflon washers.

source for our tests. The range of this particle is 0.45 cm in LAr so the 0.6-cm spacing assures that the preamplifier is shielded from the ionization track.

We have purchased a stable 0- to 25-kV power supply for the high fields necessary to minimize the effects of recombination and trapping. A simple calculation lets us choose HV_1 and HV_2 to avoid grid losses. We are building the high-voltage feed-throughs that will enable us to use the full 25 kV in our dewar.

We have contracted Group E-3 to fabricate a preamplifier that they have designed. It will be cryogenically cooled and should give σ_{elect} to 50 e.

We expect our resolution to be 5.3-keV FWHM. This number will improve if more oxygen can be removed, but even if 10 ppb O_2 is a practical limit for LAr, this resolution is quite good and certainly worth achieving.

Goals. Our first goal is to achieve the 5.3-keV prediction. This would prove our theory and yield an experimental determination of the Fano factor. We can then systematically measure the oxygen dependence and the effects of other impurities. Work with the more expensive Xe will follow. Some organic liquids such as methane show promise and will probably be investigated.

In short, we would like to understand the resolution limitations in liquid-ionization chambers. In the process we will learn the technology necessary to make these detectors, that is, purification,

Fig. 8. Resolution dependence on grid shielding. The distance is grid to collector distance.

packaging, and high-voltage control. We anticipate carrying our involvement through to first applications.

Electron-Hole Condensation [Hammond, E-10; Silver, T-11]. It has been established that electrons and holes in materials such as silicon and germanium undergo a first-order phase transition. The liquid phase is a Fermi degenerate electron-hole plasma. The gas phase is insulating because the electrons and holes bind into hydrogenic states termed "excitons." Properties of this new kind of matter are very unusual.¹⁶ First, since electrons and holes emit radiation when they recombine, it is the only phase transition in which one can observe directly the energy distribution of the condensing particles. Second, the properties of the electron-hole phase transition strongly depend on the semiconductor band structures. In addition to Si and Ge, condensation is expected in diamond, GaP, SiC, CdS, CdSe, and other materials so that a wide variety of parameters are available to test theories. Third, because of the finite lifetimes, electron-hole condensation is a nonequilibrium phenomenon and novel tests of phase transition theories are possible.

Both the nucleation kinetic¹⁷ and hydrodynamic theories¹⁸ predict that, in contrast to an ordinary liquid-gas transition, there should be:

1. stable droplet sizes that increase with temperature,
2. a minimum supersaturation required for the existence of stable droplets, which increases with decreasing temperature, and
3. hysteresis (differences in the threshold excitation levels for the appearance and disappearance of the condensed phase) characteristic of a first-order phase transition at high temperatures, but which disappears at low temperatures ($T \ll 1$ K in Ge). In germanium these predictions appear to be verified experimentally.¹⁹ The existence of stable droplets has been established by light scattering²⁰ (Rayleigh-Gans) and charge-measurement techniques in which droplets produce current pulses when they break up in the high electric field of a p-n junction.²¹⁻²² The minimum supersaturation and hysteresis behaviors have

been observed in luminescence and charge-measurement experiments.²¹⁻²³

Silicon is a more interesting material because of its dominant role in semiconductor technology. The much shorter electron-hole lifetime in the liquid phase, $\frac{1}{300}$ compared to Ge, makes experiments more significant and more difficult. This is because hysteresis is predicted to disappear below 8 K so that a large temperature range is available where strong deviations from ordinary liquid-gas behavior are expected. The stable droplet sizes at temperatures above 8 K are predicted to be much smaller than in Ge so that measurements based on detecting droplets require considerably improved accuracy. Light-scattering techniques are no longer applicable because the required shorter wavelengths are strongly absorbed. The improvement required is possible with the unique charge measurement capabilities of E-10. Moreover, these capabilities may be tested to their limit in other materials with extremely short-pair lifetimes where electron-hole condensation is expected. Charge measurements may also be used to determine the critical point because stable droplets are predicted to exist for $T < T_c$ but not for $T > T_c$. The critical point may also be determined by luminescence studies because the spectral lines of liquid and gas phases merge as the critical temperature is approached from below T_c .²⁴

Research Approach. Figure 10 illustrates one kind of charge collection measurement that can be used to detect the presence and size of electron-hole droplets (EHD) in a semiconductor. Electron-hole pairs are created by a laser, which then bind into excitons and EHD. These are broken up when they drift into the high-field region of a reverse biased PIN diode. The resulting current is observed by an oscilloscope. Excitons, free electrons, and holes are seen as a steady current while EHD are seen as current pulses. The magnitude of the current pulse observed should give a measure of the total charge in a droplet, and thus its size since the droplet density is well known from spectroscopic studies.

Using this technique we will measure up-going and down-going laser power thresholds for the production and decay of EHD in Si (hysteresis). We will carry out systematic measurements of droplet

Fig. 10. Schematic diagram for an electron-hole condensation experiment. Laser radiation is absorbed in a semiconductor crystal creating electron-hole pairs. Single electron-hole pairs bind to form a hydrogenic state termed an "exciton." Much larger aggregates (10^3 - 10^8) of electrons and holes bind to form Fermi degenerate EHDs. Each of these kinds of matter has a characteristic recombination luminescence as observed by a spectrometer. When EHDs are broken up in the high-field region of a reverse biased p-n diode, a current pulse is observed, which is a measure of the droplet size.

size as a function of temperature and excitation. We will also measure junction noise characteristics in the region near the critical temperature for the phase transition. This should enable us to make an independent determination of T_c , which has recently been measured by luminescence spectroscopy in Si.²⁵

Our experiments will be a vast improvement over the previous charge measurement studies of electron-hole condensation.^{21-23,26,27} These may be characterized as using crude contacts, relatively impure material ($|N_A - N_D| \geq 2 \times 10^{14} \text{ cm}^{-3}$), and unsophisticated electronics insensitive to current pulses less than 10^5 charges. Results were obtained for excitation thresholds in Ge, which agree well with luminescence experiments for $T > 2 \text{ K}$, but the experiments could not be extended to the low-temperature region where hysteresis disappears because of an insensitivity to small EHD ($\sim 10^3$). The size measurements in Ge have been in rough agreement with light-scattering studies, but no systematic results have been obtained.* Further, these experiments have

used short wavelength laser excitation that was absorbed within a micron of the semiconductor surface. Because of this, poorly characterized transport and surface effects were present, which makes comparison with theory hazardous.

Most of the facilities required for our experiments are already available in E-10. The needed device fabrication capabilities are very similar to those for nuclear-particle detector fabrication. In E-10 we are set up to produce the highest quality p- and n-type contacts on high-purity Si while introducing the least amount of unwanted impurities. We will use $|N_A - N_D| \sim 10^{11} \text{ cm}^{-3}$ starting material. This is important because luminescence studies show that even in the highest purity material some dopant effects are observed, and that for $|N_A - N_D| \sim 10^{11} \text{ cm}^{-3}$ dopant effects dominate the exciton luminescence.²⁸ Cooled electronics facilities available in the E-10 counting room give us a charge measurement sensitivity to as few as 30 charges, which is about three orders of magnitude better than previous studies. This capability is unsurpassed and will be essential in the study of Si and other materials at low temperatures. A tunable dye laser is available that can be down converted to produce radiation with a long absorption length in Si. In this way transport and surface effects may be avoided. A Janis Research liquid helium cryostat with temperature control between 1.5 K and room temperature is also on order.

The principal new acquisition for this experiment is a spectrometer for luminescence studies. This is on order. Luminescence spectroscopy has been the basis of most of the fundamental data gathered to date on electron-hole condensation. We will use it to monitor fundamental properties of EHD such as chemical potential, density, Fermi level, and work function simultaneously while performing the charge collection measurements.²⁸ This will be especially important near T_c . It will also enable us to ensure that the properties of EHD have not been altered by an unwanted effect in the bulk Si introduced during contact formation or by stray electric fields from the diode.

The essential apparatus for the electron-hole condensate experiments will be assembled during July and August 1977.

*A single attempt at droplet size measurement in Si by this technique has been made (M. Capizzi, M. Voos, C. Benoit a la Guillaume, J. C. McGroddy, Solid State Communications 16, 709 (1975)). The temperature was not known in this experiment so it is of little use for comparison with theory.

Industrial Workshop [Endebrook, E-10]. Group E-10 held its first Industrial Workshop on LASL semiconductor radiation detector research and development, May 19 and 20, 1977. A total of 26 people participated in the 2-day workshop that was divided between talks and discussions at Rancho Encantado and tours of the various LASL facilities.

Speakers included Richard Taschek, Associate Director for Research at LASL, who gave the welcoming address on behalf of the Director and LASL. Raymond Gore, Alternate E-Division Leader, and Steven Depp, Assistant E-Division Leader for Research, welcomed the participants on behalf of E Division. Charles Gruhn, E-10 Group Leader, gave an overview of E-10 activities and goals, and presented the workshop goals. These were:

1. To become acquainted.
2. To discuss sensor and electronic problems.
3. To learn and understand what problems industry feels it can address.
4. To learn what industry perceives the LASL role should be in addressing the new class of problems.
5. To identify effective means for making technology transfer to industry.

Peter Lyons, Alternate J-14 Group Leader, spoke on detectors and weapons testing and a film on the Nevada weapons testing was shown.

Richard Mischke, MP-4 Associate Group Leader, spoke to the group on detectors and the LAMPF experimental program.

Paul Higbie, P-4 Staff Member, spoke on the use of detectors and astrophysics.

Speakers from E-10 included Robert B. Hammond, detectors, materials, and material analysis; Carl J. Maggiore, x-ray spectrometer development; and Michael D. Edmiston, liquid-ionization chamber developments.

Tours of LASL included the E-2 Fabrication Facility conducted by Ronald Wagner, E-2 Alternate Group Leader; the Clean Room Facility with Byron McCormick, E-3, presenting the portion on high-temperature electronics, and Robert Hammond, E-10, presenting detectors and solid-state electronics. Carl Maggiore, E-10, conducted a tour of the E-10 Measurements Facility.

Tours on the second day included LAMPF, conducted by Richard Mischke, MP-4; the WNR facility,

conducted by Gary Russell, P-11, and the Eight-Beam Laser Facility, conducted by Irving Liberman, L-1.

The workshop concluded with a group discussion and summary chaired by Arthur Lucas of Harshaw Chemical Company. At this time there was input from industry people on modes of cooperation that could be achieved between LASL and industry.

Electronic Temperature Monitoring and Identification for Livestock (USDA/H-6) [Bobbett, Koelle, Lynn, E-3; Landt, E-DOR; Depp, E-D0; Salazar, Shapolia, E-2]

The US Department of Agriculture (USDA) and the Energy Research and Development Administration (ERDA) have been supporting an electronic identification and temperature-monitoring project at LASL since early 1973. The development indicates that a subdermally implanted, electronic transponder having no batteries can be remotely activated and transmit temperature and identification information back to a receiver in a few tenths of a second. If this electronic identification and temperature-monitoring system is developed into a commercially available product line and widely accepted by the cattle industry, it will enable them to carry out more extensive management control practices.

Background. In 1971 scientists at LASL became engaged in work for the Animal and Plant Health Inspection Services (APHIS) branch of the USDA. In the course of discussions with APHIS personnel, additional problems were discussed. The inadequacy of present animal identification systems was frequently mentioned as a very important problem in disease control, and LASL scientists were asked to consider ways of improving identification. Many concepts were considered such as magnetic-tape ear tags, battery-powered transmitters, color-coded ear tags, implanted capsules with stable or radioactive isotopes, laser branding, cryogenic branding, solar-powered electronic ear tags, inductively powered electronic transmitters, and resonant antenna backscatter from a radar beam.

In the winter of 1972, LASL scientists were also asked to consider the possibility of passively monitoring the temperatures of animals during ante mortem inspection at slaughterhouses. In considering this problem, a remote temperature-monitoring system was envisioned using encoded microwave backscatter from a fixed frequency interrogator. It soon became apparent that identification numbers

could also be encoded on the temperature signal. Thus, a combination of animal identification and temperature monitoring seemed possible, and work was started to determine the technical feasibility of the concept. The first step was to demonstrate the feasibility of a passive remote transponder having both identification and temperature. No effort was made to optimize the circuitry or to include the full number of digits that might be required. This stage was accomplished in the fall of 1973, and the equipment was demonstrated at the US Animal Health Association (USAHA) meeting in St. Louis. The next step was to develop a temperature-only monitoring transponder, which would function under the skin without the use of batteries. It was soon found that animal tissue presented significant problems for powering an implanted transponder and obtaining a valid return signal. Solving these problems required the development of new antennas and new circuits for extracting energy from the interrogating beam. A very important consideration was the necessity of powering the transponder with an interrogating beam whose intensity was within accepted biological radiation standards. A demonstration of the subdermally implanted, temperature-only indicating transponder was accomplished in September 1975. A second unit was implanted in November of 1975 and was still functioning as of May 1977.

In December 1975, a system for passively monitoring the temperature of six cows was installed at the National Animal Disease Laboratory at Ames, IA, under the supervision of Dr. Gary Seawright. Preliminary data from this experiment suggest that the animal's subdermal temperature changes with minor external stresses. These animals are periodically interrogated and observed. There is no evidence of degradation or biological incompatibility.

Current Status. Most of the effort this past reporting period was nontechnical in nature. An informal report on the Model 75 temperature-only system was written and published. A progress report on the Model 76 temperature with identification system was also written and is expected to be published by July.

The only technical activity being conducted is concerned with optimizing the transponder antenna performance. Transponder load impedance has been analyzed and other possible antenna configurations

and matching circuits have been investigated. We have been working with an integrated-injection-logic (I²L) kit to determine if this low-voltage logic family can satisfactorily replace the complementary metal on silicon (CMOS) currently used.

After 5 months implantation, one of our transponder implants was ejected by our bull. Dr. L. M. Holland of H-4 examined the wound. Apparently, the ejection was a mechanical one, as there was no evidence of immunological rejection. This phenomenon will require more investigation to minimize its occurrence in the future.

Publicity and Technology Transfer. In our continuing efforts to transfer this technology to industry, we have consulted with Identronix, a company that was begun last year to market a product based on our work. A presentation was given by Ronald Bobbett to the Oregon State Veterinary Association in February. On May 6, Alfred Koelle and Bobbett demonstrated the system to representatives of NRC, TD-7, and others for their evaluation of the potential of monitoring personnel flow in sensitive and/or hazardous areas. Our project was mentioned on Paul Harvey's radio program on May 10, and the project was covered in a UPI article of the May 11 New Mexican.

Preparations are now being made for a live demonstration of the Model 76 system at the International Livestock Brand Conference to be held in Albuquerque in August. We plan to automatically interrogate each animal for its temperature and identification as it passes over a weighing platform. The temperature, weight, and identification of the animal will be recorded on an ASR terminal. Support will be obtained from Group E-5 for designing the control system.

Electromagnetic Probing (G Division) [Landt, E-DOR; Koelle, E-3; Trump, E-4; Shapolia, Salazar, E-2]

Background. The extraction of energy from hot dry rock depends on circulation of a working fluid through the rock. The feasibility and economics of establishing a circulation system by massive hydraulic fracturing in hard granite is being investigated by LASL. Accurate fracture mapping is vital to the success of this project. To date, several techniques for mapping these fractures have been used with varying degrees of success.

The technique discussed here is an alternate to those used earlier. A set of wire coils will be lowered into a deep borehole in which a fracture has formed. One coil will be driven by a low-frequency (100-kHz) electric current. A second coil, parallel to the first, will be used to detect eddy currents in the fracture, filled with conductive fluid. The response will be greatest when the coils are coplanar with the fracture. Thus, the fracture orientation can be determined by observing the received signal as the coil set is rotated.

The task of this project is the analysis, design, and construction of a ruggedized instrument using this induction technique to map downhole fractures. In an effort to stimulate technology transfer, ERDA has requested that as much work as possible be subcontracted.

Preliminary studies indicate that coplanar coils will respond unambiguously for only a single fracture. Fortunately, a single fracture is expected in the proposed application. It has also been determined that the annulus between the instrument and the borehole wall must be filled with a nonconducting material. A laboratory experiment was constructed to validate these calculations and help in instrument development.

The desired signal is in phase with the current in the driven coil. A large unwanted signal is also received, but this signal is 90° out of phase and can be eliminated by phase detection and careful attention to system phase shifts. A coil driver was designed to provide accurate control of the current in the drive coil.

Mechanical design efforts were conceptualized and several industrial contacts were made to solicit support and interest for the proposed instrument. It was also decided that electronic rotation of the coils would be easier to accomplish than mechanical rotation. This will be done by using two sets of coils held stationary and perpendicular to each other. Fracture orientation will be referenced to the local geomagnetic field. Tool design goals are 15-cm o.d. maximum, 10 000 psi operating pressure, and 275°C operating temperature. Maximum borehole size will be slightly less than 25 cm.

Recent Efforts. Electronic effort has been concentrated on construction and check-out of prototype systems. A complete dual-channel system is now

operational including the coil system, coil drivers, receiver, phase-sensitive detectors, and a downhole multiplexer, ADC, and serial data link. While careful attention was a necessity in the design and construction of these items, the required performance was obtained in a straightforward manner without any major surprises. The receiver and phase-sensitive detector are very responsive as signals on the order of tens of nanovolts can be detected. It was also demonstrated that fracture orientation could be measured as predicted by analytic efforts.

Work on mechanical design was concentrated on a materials and vendors search. This work was performed by EG&G and reported in a publication, EG&G, 1183-5078, in April. Suppliers for all of the critical, nonstandard items have been found.

The efforts to find industrial support were finally successful. An oil service company indicated interest, and several preliminary design meetings were held to outline the mechanical design and construction effort required. These outlines formed the basis for a request for quote (RFQ); unfortunately, the response to this RFQ was at a much higher cost than originally estimated. This, combined with financial difficulties in G Division, has forced a temporary halt in mechanical construction efforts.

Future Plans. For the near future, analytic and electronic efforts will end with the completion of a presentable demonstration unit and documentation of the work. E Division will provide technical support in G Division's efforts to find a source of funds to complete the mechanical design and construction. When these funds materialize, some additional E-Division effort will be required to ruggedize the electronics and place them in service.

Fiber Optics for Downhole Instrumentation (J-14)
[Golob, E-3]

Introduction. An initial experiment using fiber optic transmission at the Nevada Test Site (NTS) has been successful. This was the first attempt where optical fibers were used as complete communication links on an underground weapons test, from the rack downhole to the uphole recording system. Two Corning coreguide cables provided twelve 100-MHz analog data channels, which transmitted information about gamma and neutron effects induced in the fibers. Both luminescence and absorption effects were observed.

Rack Layout. The main fiber optic cables were terminated on the downhole end in a junction box on the rack about 14 m above the working point. In this box individual fibers were spliced to the main cables and were then routed through copper conduit to locations closer to the nuclear device where radiation detectors monitored the exact dose delivered to the fibers. Experimental stations were set up at two different dose levels to allow for uncertainty in the expected effects and the device yield. Included in the junction box was a flashlamp that served as a light source for the absorption measurements.

Downhole Operation and Backfill. The lowering of the rack to the bottom of the hole and the subsequent backfill were anticipated to be the most critical part of the experiment for the fiber-optic cables. The downhole operation went smoothly and the coreguide cables were taped to the outside of the main cable bundle as they were lowered at the wellhead. This ensured that the optical cables would not get pinched between the more massive coaxial cables during the descent, but required them to be subjected to greater abrasion during backfill. The speed of the downhole procedure was in no way impaired by the addition of the fiber-optic cables.

An optical time-domain reflectometer was used to monitor fiber continuity at periodic intervals during the downhole operation and backfill. This instrument confirmed that no fibers were broken nor any observable degradations in performance induced during any part of the experiment.

Recording System. The recording system consisted of about 35 photomultiplier tubes (PMT) and 90 oscilloscopes to cover the complete dynamic range of the possible optical and radiation-monitor signals. The PMTs were located in a separate recording skid to isolate the delicate fiber-handling operation from the more routine oscilloscope trailer setup. Coaxial cable was used to transmit the signals from the PMTs to the oscilloscopes, and this link limited the system bandwidth to 100 MHz, although the actual optical signal of the fibers was greater than 200 MHz.

Two separate problems in the detection and recording system have added significant complexity to the data reduction of the absorption measurements. Field electronics (amplifiers and pulse transform-

ers) have generally been optimized for signals with positive slope such as the output of alpha detectors. In the optical absorption measurements the data are on a negatively sloping portion of the signal, and pulse transformers used in the oscilloscopes have introduced nonlinearities into the data. A second complication has been the ion feedback effect in the PMTs, which becomes significant after they see a large light level over an extended time interval. Unfolding these two effects has added delay to the data reduction.

Gas Blocking. The need for radiation confinement on underground tests requires that all cable receive the approval of the Containment Evaluation Panel (CEP). Initially the CEP required that two cable gas blocks be installed in each of the containment seals in the downhole shaft. Since adjacent gas blocks have been shown to adversely affect cable integrity in laboratory tests, and it was not desirable to set an unwieldy precedent for the conservative CEP, work was undertaken to relax this requirement. Before the first fiber transmission experiment, Barbara Killian of J-9 conducted a gas blocking experiment on the underground event in which coreguide cables were terminated beneath the surface where radiation and pressure was presented to the CEP, which then approved a relaxation of gas blocking requirements on subsequent shots.

Optical Time-Domain Reflectometry. Design and construction of an optical time-domain reflectometer (TDR) was completed by EG&G, Santa Barbara, and this instrument proved to be invaluable for monitoring fiber transmission during all aspects of the field operation. However, in the initial version, performance was limited by light coupling between the diode laser light source and the PMT in the TDR package. Reflections and scattering from the focusing optics would saturate the PMT when the start pulse was focused into the fiber. This stress on the PMT made it ineffective in detecting reflections from short fiber lengths because it was still recovering from saturation.

In the second version of the TDR, polarization was used to isolate the initial light pulse from that reflected from the fiber. In this scheme, the PMT is configured so that light directly from the laser is of the wrong polarization to reach the detector. Light that enters the fiber, however, is

polarization mixed immediately so that the PMT can see light reflected from within the fiber. This technique has markedly improved the capabilities of the instrument and a patent disclosure is now under way.

Radiation Effects. Luminescence effects observed in the underground test closely followed predicted patterns of Cerenkov light. Gamma-induced light per unit dose was somewhat larger than laboratory measurements, but this would be expected since the higher average energy of the downhole spectrum would produce more intense radiance into the fiber at the proper Cerenkov angle. Neutron-induced luminescence was lower than that for gammas since the Cerenkov light was isotropic after being generated through the neutron-gamma-electron process. For both neutrons and gammas the relative amplitudes at the two wavelengths measured obeyed the relationship characteristic of Cerenkov radiation. In general, the excellent consistency of these results at different wavelengths and in different fibers was acknowledgment of the success of a determined effort to accurately calibrate fiber loss, splice loss, and PMT response in these measurements.

Radiation-induced transient absorption effects observed downhole were somewhat larger than predicted from preliminary laboratory tests. A number of explanations have been proposed to account for this discrepancy. One hypothesis was that all samples used in laboratory tests had been preirradiated during setup shots, which had decreased their sensitivity to further irradiation. Thus, the downhole sample could have shown increased radiation sensitivity since it had not been prehardened. A second explanation for the discrepancy was that the higher average energy of the downhole spectrum had introduced additional damage mechanisms. Both of these hypotheses have since been discounted, however, and the increased absorption observed downhole is a result of the extreme nonlinear character of the damage mechanism. Thus, the laboratory measurements taken over a 2.54-cm section at high dose levels did not accurately extrapolate to the 7.62-cm length of fiber exposed downhole. Further laboratory investigations of this effect are now under way.

Looking Ahead to the Golden Egg. Planning is being directed toward a high-speed multipoint imaging experiment on a weapons test in approximately 10

months. In this scheme each individual image point will be transmitted uphole on a separate optical fiber with a total image bandwidth of 100 MHz. This first-try experiment will contain 50 to 100 image points, and with improved resolution in the future, could evolve to become the ultimate weapons diagnostic experiment.

The project has been titled, "The Golden Egg," referring to a streak tube produced by A. Lieber of J-14 that will record from 50 to 100 fibers on a single tube. Redundancy on the recording end will be achieved with PMTs as a check against the streak tube.

The transducer on the downhole end will be a plastic scintillator. Since conventional plastics emit blue light where fiber losses are large, research at EG&G, Santa Barbara, is directed toward development of a fast red plastic. Progress to date has produced a scintillator at 590 nm with 5-ns response. This wavelength is acceptable, but the speed needs to be doubled before being suitable for the golden egg.

Adaptive Control Applied to HVAC Systems [Farris, E-4]

Since the last status report, substantial progress has been made in the adaptive control project. In transferring the computer programs developed by our consultant, J. Melsa of Notre Dame, to operate under NOS, we discovered some errors in the system integration process and some numerical convergence problems in the solution of the matrix Riccati equation in the adaptive controller. Correction of the integration errors yielded comparable performance for both the adaptive and the conventional controllers. Melsa visited LASL from January 31 to February 2 to reassess this adaptive control approach and investigate these problems. The convergence problems of the solution to the matrix Riccati equation were eliminated by some variable scaling and adjustments in the solution interval as well as the convergence test. The system structure was also made more realistic and the improved performance of the adaptive controller over the conventional controller was demonstrated. The status report written for ERDA last November was then modified to reflect these recent findings and released.²⁹

Following the reassessment above, the models were extended and refined to become a quite accurate

representation of a single-zone heating system. The strategy used by the adaptive controller was modified to permit the use of set points for the control variables as well as the states. Operation of these models showed a substantial energy savings. For a case in which parameters were set to cause the building to use large amounts of energy, the adaptive controller yielded an auxiliary energy savings of about 18%. For a case in which the parameters were the best estimate of those in the energy conservative National Security and Resource Study Center (NSRSC), the adaptive controller yields an auxiliary energy savings of about 38%.

Further model extensions and refinements, as well as studies of alternate system structures, are planned by Melsa and one of his graduate students. They also plan to study the system identification problem. Details of these studies will be discussed during a visit to Notre Dame in late May. While these studies are being done at Notre Dame, work on the air-conditioning model will be done at LASL.

Some of the results to date are being made known in the industrial and academic communities through papers and personal interaction. One paper has been accepted for the 1977 International Conference on Cybernetics and Society and another has been submitted for the International Federation of Automatic Control 7th Triennial World Congress. A recent visit to LASL to discuss adaptive control was made by John Wagner, Director of Programs in the Corporate Technical Office, and Tom Taylor, Manager of Electronic Control Systems in the Corporate R&D Laboratory, both of Singer Corp. It is hoped that more visits such as this can be held.

In the project management area, we presented a summary of the adaptive control project to Mike Maybaum, Program Manager of the Solar Heating and Cooling Branch in the Division of Solar Energy, ERDA, when he visited LASL. A proposal was also written for extension of the current project to the implementation study phase.

Energy Environmental Simulator [Narud, Lynn, E-3]

During the past 6 months much of the design of the microprocessor version of the energy environmental simulator (EES) has been completed. The simulator is designed around an Intel single-board computer, SBC 80/10, which utilizes an 8080 microprocessor.

Some of the differences between the new digital version and the existing analog version are:

1. The new version uses 16-position switches for the major inputs rather than potentiometers.
2. Both population growth and energy demand growth are exponential, rather than linear, functions of time.
3. A digital population display has been added.
4. The simulator clock runs at 124, 25, 50, and 100 yr/min rather than 25 and 100 yr/min.

Software. Software for the EES is written in 8080 assembly language. The CROS assembler on the Central Computing Facility (CCF) machine 0 was used to assemble the source code. Much of the program check-out was done on the 8080 emulator on machine 0. Further program check-outs were done with the 80P monitor.

There are two major portions of software, the I-O loop, which is executed continuously, and the new year update routine, which is executed once per simulator year.

The functions of the I-O loop are:

Read inputs

Average front panel and lap unit inputs

Calculate:

Energy contribution of all six resources

Pollution (air, heat, nuclear)

Energy demands per person:

Before growth

After growth

Population after growth

Total energy demand

Food production

Chemical energy pool balance

Electrical energy pool balance

Food pool balance

Check for energy of food shortage

Output to displays

The new year update routine keeps track of the remaining energy reserves and increases the growth factors according to the growth rates. Specifically, the routine functions are to:

Increment year counter

Update coal, oil, natural gas, and nuclear reserves

Update new technology

Update growth factors
 Energy demand (FE)
 Population (FP)
 Overall (FE * FP)
 Food supply

The software requires a little over 2-k bytes of memory.

Hardware. The major hardware components are:

Input controls (rotary switches and 2-position switches)
 Input multiplexer
 SBC 80/10 single-board computer
 Output latches and demultiplexer
 Output displays (LEDs, incandescent lamps, and digital displays).

The rotary switches have 16 positions and provide a 4-bit binary output. Currently three 8-bit I-O ports are used to read the thirty-one 4-bit inputs and five 1-bit inputs and supply the fifteen outputs. One port is used for the inputs, a second for the outputs, and the third port is used to supply addresses for both inputs and outputs.

The SBC 80/10 contains a CPU set (central processor, clock generator, and system controller), 1-k 8-bit bytes of read/write memory, and provides for up to 4-k bytes of read-only memory. The board also contains both serial and parallel programmable I-O interfaces as well as the necessary system bus interface logic. From four to six 8-bit parallel I-O ports are available, depending on the mode of operation.

High-Temperature Electronics [McCormick, Lynn, Wilde, E-3; Depp, E-D0; Nachamkin, E-DOR; Hancock, E-4]

Background. The high-temperature electronics program at LASL was initiated in response to the need for high-temperature instrumentation in geothermal environments. Conventional silicon transistor technology can only be applied over a restricted temperature range, and wideband gap semiconductors, although possessing great potential, have many unsolved fundamental problems.

Therefore, the approach taken at LASL is that of the integrated thermionic circuit or ITC. A typical cross section of an ITC gain device is shown in Fig. 11. In essence, the ITC is a microminiaturized vacuum tube that relies on processing techniques not unlike those employed in the fabrication of standard integrated circuits.

Fig. 11. Basic gain device for integrated thermionic circuit.

These ITC gain devices have been modeled previously using computer programs especially developed to provide high-resolution electron ballistics. Promising geometries have then been selected and fabricated. Analytical models have been confirmed by experiment within a vacuum system, Fig. 12, and a library of device models has been developed for SCEPTRE, a widely used circuit analysis program.

Primary emphasis has been on developing manufacturing techniques amenable to high-yield mass production. Materials have been selected with utmost care and reliable delineation and wire bonding techniques have been developed.

A high-temperature package development program has been started in conjunction with Sandia and a high-temperature passive program, now funded by ERDA, was begun at the University of Arizona.

Developments During This Period. Primary emphasis has been on technology consolidation. Device fabrication techniques have been evaluated and upgraded with the utmost consideration given to manufacturability. The computer program VALVE has been used to better understand interactions between devices caused by electric fields, and new "quadrupole" geometries have been developed to minimize interactions between differential pairs.

Development of simplified analytical device models has been emphasized so that results can be

Fig. 12. Experimental verification of the triode model for ITC.

obtained with a calculator, rather than requiring large computer models. Progress has been made to this end; however, work continues.

Finally, simple ITC circuits have been designed and breadboarded. Design emphasis is now on circuits whose performance sensitivity to device parameters is minimized.

Processing. The high point of our work this period was the successful fabrication of devices with 1-mil lines on 1-mil spaces. Since the cathode coating thickness is on the order of 0.5 mil, the delineation of a line half as thick as it is wide creates problems both in the line narrowing as the developer works from the top and in reduced adhesion to the substrate. The latter problem proved to be the most difficult. However, by employing a series of well-defined bakes and soaks and a mild ultrasonic bath during developing, a reliable processing schedule for devices with 1-mil lines with 1-mil spaces was developed. Figure 13 shows the plate characteristics for a 1-mil device.

Fig. 13. Plate characteristic for an ITC device (1-mil lines, 1-mil spaces).

The importance of the 1-mil device is that g_m , the transconductance per unit device area is greatly enhanced. Thus, g_m divided by the capacitance, the gain bandwidth product, is improved, as well as the line driving capability per unit area. For example, by employing 1-mil lines and spaces and a substrate area 100 mils by 100 mils with a cathode-to-anode space of 100 mils, a device with characteristics nearly identical to a 6SN7 can be fabricated.

The process for 1-mil lines is currently being used in the fabrication of a simple three-device array, which is used as a vehicle for testing interactions between devices, device matching tolerances, and as a general set of devices for simple circuit design.

In general, the ITC processes are progressing well and the refinements implemented during the previous period have increased yield and improved device performance. The remaining programs seem to be related to gas evolution from the sputtered films and organic contaminants on the substrate. These problems are being intensively studied as they presently limit device characterization. During the next period, emphasis will shift toward the lifetime and reliability aspects of processing.

Device Characteristics. Device characteristics efforts during this period have been in two areas:

Simplifying the analysis so that the device parameters g_m , the transconductance, and K , the perveance, can be approximated from a knowledge of device dimensions. Recall that previous work has shown that μ , the amplification factor, is linearly

related to the ratio of grid-to-cathode spacing and cathode-to-anode spacing (for equal lines and spaces).

These efforts have yielded some excellent preliminary results. The work is still ongoing and it is expected that within the next period algorithms for g_m and K will be derived in a form amendable to a hand calculator.

The analytical understanding of the interactions between devices has been the second important consideration during this period. Initially the computer program VALVE was used to quantize the degree of interaction generated by the voltages on adjacent devices. Shields between devices were found to be an aid in reducing the interaction. Furthermore, these interactions were found to obey a modified form of the convention vacuum triode law, such that

$$I_1 = K \left(V_{gK1} = \frac{V_{pK1}}{\mu_1} + \sum_N \frac{V_{pN-K1}}{\mu_{1N}} + \sum_M \frac{V_{gM-K1}}{\mu_{1M}} + \sum_Q \frac{V_{KQ-K1}}{\mu_{1Q}} \right)^2 \quad (7)$$

where V_{pN-K1} is the voltage of each of the plates relative to the voltage of cathode 1, V_{gM-K1} is the voltage of each of the grids relative to cathode 1, V_{KQ-K1} is the voltage of each cathode relative to the voltage of cathode 1, and μ is defined by electrostatics. Notice that this equation allows for the total quantification of the effects on any device, caused by any other device. Simple models amendable to hand calculators have also been developed.

For many device geometries in many applications, interactions between devices have been found to be negligible. However, in cases where high-voltage gain may be present between adjacent devices, the interaction terms may become significant. In these cases the differential quadrupole structure shown in Fig. 14 can be used to greatly reduce cross-coupling. This structure requires a differential circuit design and may be understood by considering a differential voltage output between anodes A_1 and A_2 . Anode A_1 is geometrically designed so that its contribution in the far field almost exactly cancels

Fig. 14. Quadrupole device.

the contribution of A_2 , which is in the opposite direction from A_1 .

Improvements in our understanding of the device-to-device interaction during this past period is seen as fundamental to realization of flexible ITC circuit design capabilities.

Circuit Design. Since we want to exploit the ITC in a manner analogous to integrated circuits, that is, relying on device matching and the low cost of active devices, our initial effort has been consideration of circuit building blocks; for example, active loads and level shifters. Figures 15 and 16 are two such circuits. The gain stage with active load shown in Fig. 15 has a gain of $\mu/2$. Notice that we are taking advantage of the fact that we can run the grid and cathode at the same potential. The stage gain can be designed for different values simply by varying the area of the load device. Notice also that the gain is independent of the size of the two devices as long as they are matched, allowing us

Fig. 15. Gain stage with active load.

The level shifter circuit shown in Fig. 16 again takes advantage of that device matching. The voltage used for level shifting is across device A and is $V_{CC}/2$ because of the match between it and other devices. (They all have the same area.)

These are but two examples of using ITC technology to design circuits that were not practical with discrete devices. Using only conventional designs, we have implemented a simple, three-device amplifier for demonstration purposes and over the next few months our efforts in designing such circuits will become an ever-increasing portion of our program.

Fig. 16. Gain stage with level shift.

ENGINEERING SUPPORT, R. A. Gore, Alternate Division Leader

Development Projects

Microprocessor Development (E-5) [Criscuolo].

The E-5 Mini- and Microcomputer Section continues to center its activities on the 8080 NMOS and 1802 CMOS microprocessors. A new entry to this group, the 8748 single-chip computer, has generated considerable interest. The significant activities of this period are the acquisition of the Intel MDS 800, completion of the SBC 80/10 prototype, and acquisition of the Intel prompt 48.

MDS 800. The microprocessor development system (MDS) is a hardware software tool for micro users. Intel claims that it can support all their processor families. Group E-5 now has the software and hardware to support the 8080, 8748, 8085, and 8035 CPUs. The hardware includes the main frame with 65 k of RAM, ICE 80, ICE 48 (on order), a dual diskette drive, a TI-733 ASR, and a Data I-O prom blower. The software consists of the 8080, 8085 assembler, 8035, 8748 assembler, and resident PL/M compiler for the 8080 and 8085. The software has been modified to support the TI-733.

SBC 80/10 Prototype Package. The SBC 80/10 prototype package is operational and the monitor has been modified to support the TI-733 ASR. The package contains a card cage with printed-circuit (pc) bus for all power and signals. The card cage will accommodate the 80/10 CPU and three other cards. The package also contains all necessary power supplies, two cooling fans, and a hinged front panel that permits easy access to the pc cards and I-O cables. This package is intended to be the starting point for most microprocessor system applications.

Intel Prompt 48. The prompt 48 is a design aid for the 8748 single-chip computer. Its features include a programmer for the internal PROM, keyboard for data entry, display for memory and I-O, and a prewired I-O connector for interconnection to application hardware. Hardware has been ordered to allow connection of the prompt 48 to the MDS for down-line loading.

Miscellaneous. A PROM card that utilizes the 8708 (1 k by 8) erasable PROM has been designed for our 8080 microcomputer. The card contains decoding and drivers for 14 k bytes of memory.

Applications

Coulometer (CMB-1). The coulometer control system (CCS) has been completed; the hardware has been installed in the user's area and the user has been orientated. A LAMS report describing this is being issued. The CCS consists of three basic units, the Princeton Applied Research Model 179/173 potentiostat/coulometer, the HP-5150A thermal printer, and the E-5 microcontroller (MC). The units and their pertinent subunits are illustrated in Fig. 17. The MC is the central control unit of the system. Commands are entered through the thumb-wheel switch to direct the controller. Experiment parameters are also entered through the thumbwheels. The MC controls message displays on the HP printer. When the "control coulometer" command is given, the MC takes control of the PAR coulometer until completion of the titration.

Film Reader (M-3). In January 1977 work was started to upgrade a single-axis film reader belonging to M-3. Most of the hardware has been ordered and received; however, the system interconnect cables are yet to be fabricated and the software must be written. When these tasks are completed, system integration will begin.

The present M-3 film reader was designed and built about 15 yr ago and is rapidly approaching retirement age. We plan to upgrade the single-axis reader by replacing the Datex encoder

Fig. 17. System block diagram.

electronics, the paper-tape punch, and the encoder and serializer readouts; enhancing the data-editing process; providing a data medium that is compatible with CCF NOS input; and preserving the "quick look" data-reduction capability.

Figure 18 is a block diagram of the proposed system. The dashed boxes indicate functions that may be added in the future. A microcontroller is the major unit of this system. When activated by the foot switch, it will record data from the X encoder on the diskette and display the data on the TEK 4013. In addition, the microcontroller will maintain the encoder and serializer displays and handle the data editing on the TEK 4013.

When data recording is completed, the microcontroller will, on command, transfer the data on diskette to the Wang 720 for quick-look processing.

Intelligent CAMAC Controller (E-5)[Coy, Vanuxem, E-5]. Based on the Data General NOVA microcomputer, this controller, the "microNOVAC," is intended to span the gap between expensive minicomputers and much simpler, microprocessor-driven CAMAC data-acquisition and control systems. Applications include not only relatively small stand-alone CAMAC systems, one or two crates, for example, but also

larger CAMAC systems required when local processing or preprocessing of data is desired.

The first microNOVA ordered for evaluation was received late in February 1977. It has been evaluated and appears to be adequate for the anticipated applications. The microNOVA and its associated CAMAC controller have been tested using all of the facilities provided by a larger machine, a NOVA-3, to create the test programs, which were then down loaded via a 9.6-kbaud asynchronous link, and finally run into the microNOVA. Programs have been written in FORTRAN and assembly languages to allow easy communication between the two machines during the test phase. Test programs have been written using the RDOS operating system of the NOVA-3; the software compatibility between the NOVA-3 and the microNOVA has proven to be a real advantage.

The basic CAMAC crate controller (the program-controlled part) is now available in its final pc version, while the pc version of the optional DMA unit is expected to be ready in July 1977. This crate controller fully conforms to the latest, but as yet unpublished, developments of the NIM-CAMAC Working Group on distributed intelligence in a CAMAC crate.

Three Data General standard microNOVA boards have also been made available as CAMAC modules so that the microNOVAC can now be entirely contained within a CAMAC crate including the microNOVA computer. In addition to a better homogeneity, this allows a smaller size and hopefully a lower cost.

Two identical microNOVAC systems are now being assembled and tested for use in AP-3 experiments. Each of them consists of 28 k of RAM, an asynchronous interface, and a crate controller in its basic version. Another system with 13 k of RAM is being prepared for a CNC-4 mass spectrometer experiment. All three systems are expected to be completed in July 1977.

Future plans include writing FORTRAN callable subroutines for CAMAC programming on the microNOVA. This should make the internal features of the crate controller more transparent to the user.

CMOS Microprocessor [Stephenson, Phillips, Jennings, Backsen, E-5]. The development of a CMOS intelligent data-acquisition system was started in December 1975 using the RCA two-chip CPU, the CDP-1801. In March 1976 the development was switched

Fig. 18. Film reader block diagram.

from this two-chip machine to the single-chip CDP-1802. Funding was derived from R-2 (now Q-2), J-13 (now G-2), J-D0, H-1, H-8, and E-5. Six hardware systems were fabricated, one each to be delivered to Q-2, G-2, H-1, H-8, J-D0, and E-5.

Software is being funded separately by each of the groups.

H-8. The H-8 system software and hardware were configured to measure up to 16 different weather variables. The software computes a mean and standard deviation for each channel. The pre-processed data are recorded in Texas Instruments (TI) Silent 733 compatible format on a Memodyne cassette tape drive. The H-8 system has been delivered and is undergoing field tests by H-8 at G Site.

Q-2. The Q-2 system is a two-channel gamma-ray spectrometer that provides program-controlled accumulated time intervals to two 24-bit counters receiving pulse streams from two different energy level window gamma-ray detectors. The computer then solves the following equation:

$$(\text{ALARM} = \bar{C}_p > \bar{B}_A + \Delta) . \quad (8)$$

Here $\bar{C}$ is the pulse count over the programmed time interval; $\bar{C}_p$ is the short-term mean count computed over P count intervals; $\bar{B}_A$ is the long-term (background) mean count computed over A count intervals; and Δ is a pure numerical threshold programmable from 1 to 9999. P is programmable from 1 to 16, and A is programmable from 16 to 256. The Q-2 system is in the final stages of hardware/software check-out and is expected to be delivered by mid-June.

G-2. The G-2 system hardware is essentially complete and software is well under way. The software is designed to measure up to four channels of seismic data and to analyze the data for the probable occurrence of a seismic event, that is, earthquake, quarry blast, or underground test. The program computes a long-term background noise level for one of the channels and then performs several tests on the data as collected to characterize an event. First, a programmable threshold above background must be exceeded, that is, the signal must exceed the threshold by a program-selected magnitude in order to be treated as a possible event. Second, if threshold is exceeded, pretrigger data are saved and the slope of the signal is tested. Again, this

slope is program controlled. Third, if the first two tests are met, a rough frequency analysis is performed; the number of threshold penetrations are counted over a programmed test interval and, if the number of penetrations per time interval exceeds the required programmed number, an event is declared. At this point, the time of the event onset, peak values, and number of zero crossings are saved in a data buffer for subsequent recording on the TI compatible tape deck.

H-1. Check-out of the H-1 system hardware has not yet started and the software effort has just begun. This is a low-priority project for H-1, and is being done on a time-available basis. The system will monitor a radiological detector array configuration around ground zero and a weather station for events at the NTS. Data will be transmitted via model over both UHF and microwave data links in real time to the CP PDP-11 computer. Means and standard deviation for all channels will be computed as collected. A threshold detection scheme for excursions over background will cause these data to be recorded on the on-board TI-733 compatible tape deck.

J-D0. The J-D0 hardware requires some rework and final check-out. The software will be identical to the G-2 software. This system should be delivered by midsummer.

E-5. The E-5 hardware check-out has not started but should be complete by late summer on a fill in, low-priority basis. No special software will be developed for this system, since copies of all of the other applications software will be available.

Outstanding Proposals. Several proposals for follow-on units have been prepared and submitted.

CNC-11-WS. This is a particulate pollutant monitoring system consisting of sixteen 24-bit counters driven by 16 crystal oscillators. Each oscillator will be impacted by a stream of air containing a specific mass of particulate pollutant and the oscillator frequency will change as a function of the total mass of the pollutant impinging on the crystal. The computer will analyze these data, control sampling intervals, and possibly control the air jet mechanism. Data will be recorded on the TI-733 compatible tape deck. It appears that this proposal will be accepted by CNC-11.

H-8 Spectrum Analyzer. A proposal to use the CMOS MADAS system as a simple format translator between a Lawrence Livermore Laboratory (LLL) designed instrument and the CCF has been submitted to H-8.

NOAA-EDL. We are in the final stages of working out an acceptable agreement between E-5 and the Engineering Development Lab (EDL) of the National Oceanographic and Atmospheric Administration (NOAA) for nine MADAS systems. This contract will be for hardware only with EDL responsible for software. This proposal is almost certain to be accepted.

NOAA-NWS. We have submitted a proposal to the National Weather Service (NWS) for three MADAS systems with a modified H-8 weather station program. The NWS has an upcoming requirement to expand their weather station network from the current 700 to about 2000. It appears that our MADAS system can provide a considerable improvement both in data quality and equipment reliability. In addition, the MADAS reprogrammability should postpone system obsolescence for many years. We believe that there is a good possibility that this proposal will be accepted.

Sandia da Vinci Project. We have consulted with Bernard Zak, Sandia, regarding his requirements for helicopter and balloon borne data acquisition of pollutant monitoring instrument data. He has included \$30 000 for LASL in his proposal to the National Science Foundation (NSF) for doing this experiment. It appears that MADAS is essential to the accomplishment of the da Vinci project objectives and therefore LASL will be funded if any part of the project is approved. We expect to hear from Mr. Zak by mid-July regarding the project funding status.

H-DO, H-5. H Division and Group H-5 have expressed some interest in the miniaturization of MADAS to fulfill their potential requirements for intelligent programmable analytical instruments. Group H-5 has requirements for several OSHA conformance analysis instruments for hood compliance certification and H-DO is interested in biomedical applications involving ambulatory patient monitoring and free-roaming-animal monitoring. We plan to meet with these people in the near future to further identify and define these potential applications.

Fiber-Optic Link (E-5) [Coy, Longmire, E-5]. Production engineering is being done on a standard, moderate-speed (9600 to 40-k baud) digital fiber-optic link. Using available components, this link will provide a communications capability up to a distance of 70 m in high-noise environments for systems with high-potential differences. The link will interface to systems with TTL or RS-232C levels. It is anticipated that this equipment will have wide applicability throughout LASL.

PDP-11 PROM (E-5) [Coy, E-5] A number of PROM boards for PDP-11 computers have been produced. This board is useful as a bootstrap loader, formatter, and enabler for fast subroutines. At the request of several users this board is being modified to provide a capability for front-panel pushbutton bootstrapping.

Computer-Aided Design and Manufacturing [Johnson, Booth, Whitworth, E-4]. E Division has been considering a computer-based automatic drafting system for several years. After considerable evaluation it has been decided to purchase a minicomputer-based automatic drafting system that will produce a working logic diagram or schematic from a rough engineering sketch. The system will also provide a net list and bill of materials. System capabilities will allow the data base generated by the drafting system to be used as input to an in-house written placement code. This information can then be used as input to the wire-wrap code that we use now. Thus, one can start with a rough drawn logic diagram and generate a wire-wrap control tape with one code serving as input for the next code.

During this reporting period the minicomputer-based automatic drafting system specification has been written and an RFQ has been sent to 15 companies. The quotations are due on June 3, 1977.

The automatic placement software has been written and will handle a simple test problem. Considerable work will be required before this software is useful for production jobs.

The placement software consists of three pre-processing codes followed by the main placer code. A data base containing all the wire-wrapping board geometrics used by E-2 has been generated. This data base defines the wiring pin geometries for each wire-wrap card. With this data base and the selected

cards for a given job, a working file is generated by the first preprocessor which contains each socket.

The second preprocessing code uses a standard wire-wrap input deck and generates a list of integrated circuit (ic) types required for a given job. This preprocessor also packs the wiring data for input to the placer code.

The last preprocessing code uses a data base of all the ic information required for all ic's and the list of ic's for the given job and produces a file of the required ic information for the given job.

When the format of the drafting code net list is known, another preprocessor will be written to convert this format to the format required by the placement code.

The main placement code uses the output of the three preprocessing codes described above and does the placement. The user interactively starts the placement by assigning any ic's to any sockets he may choose. Normally the user would locate any I-O chips in the appropriate sockets. Upon command the code will automatically place the remaining ic's in the remaining sockets. The algorithm used is based on an initial placement algorithm for pc applications described by Breuer.³⁰ The algorithm places an unassigned chip, having the maximum number of connections, as close to an assigned chip as possible. The present output is a listing of the placement results. A code has been written that uses computer graphics to draw the wire-wrap boards used for a given job. This code, when connected to the placement code, will generate pictorial output of the placement results. These data along with the net list data will be merged to generate the input for the wire-wrap code.

The placement information and the drafting data base will be merged to make a drawing of the logic diagram that will include the physical placement of each chip.

The purpose of the system described above is to begin a drawing with a rough engineering sketch and, using a data base driven system, produce a wire-wrap control tape, thus greatly reducing human error and turn-around time from design stage to fabrication.

Wire-wrap activity during this reporting period has been about 0.7 of the level for the previous full fiscal year. In an attempt to determine the reason for the lower level of activity, a question-

naire was sent to users. Preliminary response shows that a large number of designers are between major jobs at this time. During this reporting period control tapes for 29 new jobs were completed and updates were completed on 16 other jobs; 12 new wiring boards were added to the system.

The production wire-wrap codes are run under the CROS operating system. Since one of the two 7600s is switched from CROS to LTSS for the last half of each week, production wire-wrap runs are difficult, if not impossible, for the last half of each week. Since the CROS operating system is being phased out at LASL, conversion of the wire-wrap codes to LTSS has begun. At the same time E-2 has asked that we improve the wire-wrap code. They have requested a control tape to check the mounting alignment and the location of the power and ground tab connections before wiring is begun and a second control tape to locate the ends of each net to aid continuity checking when wiring is completed. These modifications have required the use of overlays since the code is too large to fit on a 7600. Approximately two-thirds of the code is running under LTSS now and we have just begun to break this portion of the code into overlays.

A relatively new method of ic interconnection, called solder wrap, has become available. This interconnection scheme uses a fully automatic machine to wire ic's using 38-gauge wire. The machine uses one continuous wire to make all required nets then thermally strips and solders the connections checking for continuity to the pin; next it cuts the wire connecting the individual nets. The greatest appeal of this system is that the finished product will fit into connectors on 1.52-cm centers while maintaining a high density of ic's on the surface of the card. It appears that this process will produce cards of high density that will plug into adjacent slots on CAMAC and NIM bins rather than require two slots/card as the wire-wrap board does.

A presentation on solder wrap by R. Whitehead was well received here. We will compare the cost, turn-around, and field changeability of solder wrap and wire-wrap in the near future.

Hybrid Computer Laboratory [Sanders, E-4; Joyce, EAI]. The hybrid computer facility modifications have been completed. The new trunking

system, incorporating three EAI TR48 analog computers as trunking stations, provides much more versatility. These trunking stations provide variable gain trunks between two EAI 7800 analog computers, two EAI 680 analog computers, a 14-channel analog tape drive, and some DACs that are interfaced to the Honeywell DDP-116 digital computer. The TR48 analog computers also provide additional components, which increase the computing capability of the facility. The function input-output processor (FIOP) used for multivariate function generation in the facility, was also modified to interface with 10- as well as 100-V analog computers. This modification allows the FIOP to be connected to all four main analog computers in the facility.

An effort was made to calibrate all analog components in the facility. A new DAC check-out system was constructed to calibrate DDP-116 DACs and FIOP DACs. This system uses the stable power supplies in the FIOP analog interface cabinet in conjunction with a test box. The new system was used to check and calibrate all operating DACs in the facility. In addition to the DACs, all analog multipliers and all integrating capacitors were calibrated and, if necessary, repaired. The 48-channel multiplexed ADC was calibrated using a special program that measures ADC errors and plots them on the Versatec printer-plotter in the facility. This procedure was used to avoid measuring internal ADC voltages. These measurements have been a problem in the past since the ADC test points are hard to reach and a probe could easily short circuit components. In addition to calibrating the ADC, the test program provided dynamic testing by using control signals from the DDP-116. These control signals were also used to check the ADC interface operation.

A support program was written that takes data from an electronic data terminal and punches tape header information on paper tape. This program was written to support the CASH wire-wrap program in operation at the hybrid computer facility. In addition, the main CASH wire-wrap program was modified; previously, the main program would read IBM-formatted magnetic tape that was processed at the CCF, make conversions on the data, and punch the result on paper tape. This program was modified to read magnetic tape cartridges in addition to the IBM-formatted magnetic tape.

Two facility interfaces have been completed since the last report. The first interface, between the DDP-116 digital computer and a TI 733 electronic data terminal, was initiated some time ago, but because of its low priority, has only now been completed. This interface allows communication with a printer-keyboard unit at 300 baud as well as communication with two cassette tape drives at 1200 baud. These two data rates are programmable from the DDP-116.

The second interface, between the DDP-116 and the FIOP, expands the number of computer-controlled DACs in the hybrid computer facility from 52 to 116, the number of ADC channels accessible from the DDP-116 is similarly expanded from 48 to 112. In addition, core data storage for the DDP-116 is essentially doubled. The interface allows expansion of DDP-116 capability and also allows the FIOP to be loaded and controlled from the DDP-116. In the past, the FIOP was manually controlled and could only be loaded by paper tape. The combination of the interface and one FIOP feature allows partitioning of DACs in the FIOP interface cabinet under program control from the DDP-116. Partitioning allows the DDP-116 to control previously programmed DACs independently of the FIOP. Therefore, with the aid of this interface, the FIOP and the DDP-116 may operate simultaneously with different DACs in the cabinet.

Support for the hybrid facility is being reduced to a level that better matches the amount of simulation work being done at the present time. The contract with EAI was cancelled the last of May releasing a field engineer the company had supplied for the facility. Laboratory facility support is also being reduced from one full-time staff member to a part-time level-III technician until the facility needs can be determined.

NET-2 Support [Hancock, E-4]. The purpose of the NET-2 support project is to maintain an up-to-date, operational NET-2 package and provide additional assistance required to make this package an effective problem-solving tool for Laboratory personnel.

During the past period this support has included helping new users get started with NET-2 and NOS, setting up and running circuits on NET-2 for users, varying circuit parameters to achieve customer

design objectives, and troubleshooting to distinguish user errors, computer system errors, and NET-2 errors. Customers have also been provided a central source of information regarding NET-2 and some of its limitations, together with ways of working around these limitations.

In addition, the three NET-2 errors have been documented; they are

1. transmission line parameter errors,
2. plot package errors, and
3. nonlinear algebraic equation loop problems.

Effort continues in resolving the NET-2 classification question so that we can obtain a "clean" source code free of LASL-introduced errors.

Because NET-2 is not documented, correcting errors and adding capabilities is extremely difficult, if not impossible. We have obtained the latest Kirtland AFWL version of SCEPTRE and hope to be able to offer support in the near future. Additional computer-aided design programs may be implemented as time and user interest dictate.

Improved Programmable Delay Line [Brown, Narud, E-3; Neumann, E-2]. A 64.5-ns programmable delay line prototype has been built and tested. The unit was described in the LAMPF Users Newsletter and this generated inquiries from KMS Fusion Labs and from Rice University. The summary of a paper, submitted to the IEEE Nuclear Science Symposium, is given below.

Standard cable delay units are often used to delay fast NIM pulses. These units use a series of DPDT switches to insert or remove binary weighted lengths of coaxial cable. This practice of sending fast NIM pulses through six or seven mechanical switches sometimes results in unreliable operation. The switches do not always close with negligible impedance. This results in reflections (at these switches), which can cause a degradation in the timing and the width of subsequent pulses. Sometimes wiggling the arm of the switch results in variations in switch resistance large enough to cause intermittent operation. Also, the risetime of the output pulse is a function of the delay setting due to the attenuation in the coaxial cable. This could degrade the performance in certain situations.

We have developed a programmable delay that addresses these problems. The approach is to use

microstrip transmission line with electronic switching.

The delay element is a meander line on a Teflon pc board and the switching is performed by temperature compensated subnanosecond ECL gates. The delay is controlled by dc levels on the appropriate gates. This arrangement has several advantages over coaxial cable delay boxes.

1. One can choose switches (to control the gates) that have high reliability, rather than use low-inductance slide switches to pass the fast-NIM pulses with minimum reflections.
2. The system can be adapted for remote operation either by manual switches or under CAMAC control.
3. By placing the delay line (microstrip) and the switch (gate) on the same pc board, the reflections at each point are well controlled. In the coaxial cable delay unit there are the uncertainties in the coaxial cable dressing and how it is soldered to the switches.
4. Changes in switch contact resistance from milliohms to more than 100 Ω have negligible effect on the delay. This insures reliable switch operation. The specifications for the unit are given below.

Delay settings	0-64.5 ns in 0.5-ns steps
Delay stability	8.1 ps/ $^{\circ}$ C at max delay 6.1 ps/ $^{\circ}$ C at min delay
Min delay	< 6 ns
Input	Standard NIM pulse into 50 Ω , min width < 3 ns, reflection < 10% for 1-ns risetime
Output	NIM pulse from bridged 50- Ω outputs. Risetime $\approx$ 1 ns independent of delay setting.
Pulse fidelity	(P_w output - P_w input) $\pm$ 150 ps

The delay stability of the unit at max delay (8.1 ps/ $^{\circ}$ C) is equal to 126 ppm/ $^{\circ}$ C. The measured stability for RG-055B/U coaxial cable was 194 ppm/ $^{\circ}$ C.

Figure 19 is a bottom view of the prototype unit and shows the various lengths of meander lines

Fig. 19. Prototype of the 64.5-ns programmable delay.

used. The unit was packaged with its own power supplies to fit in a standard relay rack. We used a panel height of 89 mm for the prototype because low-profile supplies were not readily available. In the final version we expect to have two independent delays in a unit with a panel height of 44.5 mm.

In the course of the unit development, various meander delay lines were evaluated. The paper discusses the results of these tests and the design trade-offs possible. Also described is a compensating method for different gate thresholds. A review of different methods of building a programmable delay is included.

Medical Electronics and Imaging [Lundy, E-3]. Randy Brill, M.D., Prof. of Nuclear Medicine at Vanderbilt University, visited E Division in January to discuss possible LASL involvement in nuclear medicine.

As mentioned in the previous report, an NRIP proposal for development of a computerized tomography system for nondestructive testing was prepared in conjunction with Groups M-1 (nondestructive testing) and M-8 (image and signal processing) and submitted. This proposal was approved and work will start October 1, 1977.

A paper titled, "Electrical Calibration of Dose Integrators," was presented at the annual meeting of the Rocky Mountain Chapter of the American Association of Physicists in Medicine held in Phoenix, February 18. A 1-day workshop on quality control of

medical ultrasonic diagnostic techniques was attended the following day at Maricopa County Hospital.

In March, Walter Weyzen and Robert Wood, Division of Biomedical and Environmental Research (DBER), ERDA, were visited. Possible new LASL funding opportunities from within DBER were discussed and, in particular, whether or not LASL should respond to the "Potchen Report," which calls for continued ERDA support of nuclear medicine and increased efforts for technology transfer in the nuclear medicine area. Before making this trip, discussions were held with other LASL people in CNC, H, E, J, and M Divisions who may be active in future nuclear medicine work. Dr. Robert Moseley, Prof. of Radiology at the UNM Medical School, was also contacted. As a result of Mr. Weyzen's encouragement, a 189 proposal will be submitted requesting funds to survey the nuclear medicine areas where LASL might be able to make significant contribution.

Solar Energy Support [Murray, E-4]. A considerable amount of time was spent serving on the Technical Evaluation Committee to assist in reviewing the Division of Solar Energy PRDA-2 for ERDA.

Preliminary requirements for the Nambe community center data handling were assessed.

Study Center System Optimization Studies [Murray, E-4]. The objectives of this program are to optimize the Study Center energy system to minimize auxiliary energy consumption and to develop and validate a system mathematical model to predict system performance. The project status is that an initial 1-zone model of the energy system and building load has been implemented to predict overall problems in the operation of the energy system and a number of observations and adjustments have been made to improve system performance. Understanding energy system behavior is limited considerably now because sensor field calibration is still taking place and only limited data-acquisition capability exists because the arrival of the PDP-11/34 computer data-acquisition front end has been delayed. Specific investigations that have been performed are described below.

Simulation results have consistently shown that cycling would be a problem in the absorption chiller. This has been found to be an accurate prediction. The typical cooling sequence is as follows:

- Stored cold water from the 37 850-L tank is used to cool the building until mid-morning.
- The load increases and the chiller starts, using stored solar hot water for energy.
- During this phase, the solar energy system continues to collect energy.
- In late afternoon, the system returns to cooling from the tank.

If a typical afternoon thundershower occurs, the stored solar energy is depleted in less than 0.5 h and the chiller is switched to auxiliary energy. Problems now arise because some solar energy may become available and the system will switch back and forth between solar and auxiliary energy. This is undesirable because the chiller is generally operating somewhat below design load, and with the varying generator inlet temperatures, tends to go into the dilution cycle because of low chilled water temperature. This mode makes the chiller unavailable for about 20 min. The average performance coefficient for the chiller has been about 0.5, far below what was hoped for.

One solution to this problem, which was studied by means of computer simulation, is to use the chiller to cool down the 37 850-L tank instead of night evaporative cooling. This technique, used in the Study Center, has been found to be an effective alternate way to store solar energy. The possibility of using this approach is enhanced by the fact that temperatures achieved in the cold water tank have been 3.9°C to 4.5°C higher than predicted. Temperatures of 11.1°C to 12.8°C were predicted, but actual temperatures are 15.6°C to 16.7°C. Also, the time required to cool the tank is longer than anticipated, which results in a large expenditure of energy in the form of cooling tower pump and fan power. The cooling tower is currently being run from 12:00 midnight until 6:00 a.m. to cool the tank.

The vortex damper control on the supply and return fans was found to be unstable, causing large oscillations in the air flow rates. This problem was solved by slowing down the response of the damper actuators.

It was found that the terminal boxes in the interior zone of the building were not equipped with stops to prevent the air supply from going below 50% of design. This has invalidated some of the simulation results and has also caused some difficulty in

obtaining adequate air temperature control in zones with high cooling loads.

The building was also overheating during the 6:00 p.m. to 6:00 a.m. period of energy system shut-down, causing the system to go into cooling modes immediately in the morning. This was traced to the fact that the building lights were being left on all night. The lighting level is now reduced to one-half at night. In addition, a control system modification is being considered whereby cooling modes are locked out until the building has been partly cooled by fresh air in the morning.

A problem with the collectors undergoing seasonal false starts when they begin to heat up has appeared in the Study Center system. This phenomena is caused by cold fluid from the pipes being pumped into the collectors, cooling them somewhat, and reducing the temperature differential between the collector and storage. An effort is now being made to simulate the phenomena and determine a solution.

The set points on the supply air discharge controllers were roughly adjusted to give the desired sequence of cooling modes, namely full fresh air, air washers, stored cold water, and absorption chiller. The air washer control parameters were set to give about 60% relative humidity for the supply air.

These efforts have led to a rough setup of the system. The next project phase will consist of extensively varying the control system set points to obtain the most effective use of the solar energy system.

Some results of the initial simulation studies are given in Fig. 20, (a) through (g).

These results were obtained using a 1-zone system model, but using a fairly detailed model of the control system. The first two plots show the weather and solar data for one 24-h period. The chiller load plot shows the significant fluctuations in the performance of the machine. The room temperature and main air flow plots show the effect of turning off the fans at night. However, the model used here assumed that the lights are turned out also and that the terminal boxes never go below 50% of maximum air volumes.

NSRSC Instrumentation [Murray, Trump, E-4]. The NSRSC, a 6131-m² library and conference center, was completed this year and is in full operation.

Fig. 20(a). Chilled water temperature °F.

Fig. 20(c). Room temperature °F.

Fig. 20(b). Air washer bypass ratio.

Fig. 20(d). Insolation, July 1, 1973, BTU/h ft².

Fig. 20(e). Air supply flow, ft³/h.

Fig. 20(f). Ambient dry bulb temperature °F July 1, 1973.

Fig. 20(g). Chiller load, tons.

An integral part of the building is a solar energy system designed to supply up to 95% of the heating and 75% of the cooling requirements. The three systems, solar energy, heating, and cooling, have been heavily instrumented to permit monitoring of energy production and consumption. Additionally, sufficient instrumentation has been added to one area of the building shell to permit eventual verification of the models used to predict building performance.

The solar energy and heating, ventilating, and air-conditioning (HVAC) instrumentation has been selected, installed, and is being checked out. Liquid system temperature measurements are made primarily by means of platinum RTDs. Air temperature measurements are made with copper-constantan thermocouples, and nickel Balco resistance thermometers. Liquid flows are measured by turbine flowmeters and annubar, pitot-static, probes. Air flow measurements are made by propeller anemometers calibrated by pitot-static arrays. Electrical power inputs to major subsystems are measured by means of watt transducers. Control system inputs and states are measured by means of shaft-position potentiometers and binary contact closures.

A computer-based data-acquisition system was specified and ordered to handle the 160 analog and 16 digital (binary) data inputs resulting from the instrumentation plant. The system has sufficient computational power to permit on-line data gathering and performance calculations to proceed simultaneously. Data will be stored in summary form, primarily energy balances, in order to reduce volume. The computer portion of the data-acquisition system has been delivered and installed and program development is proceeding. The data-acquisition "front-end" is currently scheduled for delivery in August of this year. At that time the system will be integrated; it should be fully operational by the end of the current fiscal year.

MER Studies for the USGS [Springer, E-4; McFarland, University of Houston]. A simulation study to provide regulatory insight of a rate-sensitive gas-water reservoir has been completed for the US Geological Service (USGS). As gas is removed from the reservoir, encroaching water can trap some of the remaining gas. The physical and economic history of the gas reservoir was determined from the time production began, with a fixed number of wells,

until production ceased because either the reservoir volume or pressure dropped to some predetermined minimum value. Figure 21 shows some typical results of the study. The internal production rate, which is proportional to the number of wells drilled, is plotted on the abscissa. The three curves, from top to bottom, respectively, show the ultimate recovery fraction, the present value of the reservoir at a 15% discount rate, and the internal rate of return. Six potential regulatory rate definitions, called MERs, are indicated by the cluster of numbers from one to six just above the rate axis. Number 1 indicates the rate at which ultimate recovery is maximized subject to the internal rate of return being equal to an acceptable rate of return (15%). Number 2 indicates the rate at which ultimate recovery is maximized subject to the internal rate of return being greater than or equal to the acceptable return. Number 4, preferred by economists, is the rate at which present value is maximized. Number 5 is the rate at which internal rate of return is maximized. Four different reservoirs were studied with variations in the economic parameters providing a sensitivity analysis. Results of this study were sent to the USGS and will be published in a LAMS report. A paper on this subject will be presented at

Fig. 21. Ultimate recovery, present value, and internal rate of return vs initial production rate curves, reservoir case 2, royalty rate variation.

the second Pacific Chemical Engineering Congress to be held in Denver in August 1977.

Gas Diffusion Simulation for EGSP [Springer, E-4]. The immediate objective of the gas diffusion simulation portion of the Eastern Gas Shales Project (EGSP) is to demonstrate the ability to simulate gas diffusion in a nonhomogeneous, nonisotropic medium in two-dimensional, Cartesian, or cylindrical geometry using the LASL hybrid computer. Additional tasks planned include obtaining a purely digital capability of solving gas diffusion problems for crosscheck and solving a few selected test problems of interest to the explosive simulation program.

A purely digital gas simulation capability has been attained. SIMPAC, a Morgantown Energy Research Center (MERC) three-dimensional general-purpose diffusion code, was obtained from MERC and converted to LTSS. Only the gas diffusion capability was retained; slightly compressible fluid and heat diffusion were eliminated. SIMPAC was designed for Cartesian geometry, but a method where the permeabilities and porosities can be modified to mock up a cylindrical geometry has been developed. This has been incorporated into the code.

Using SIMPAC, a study has been made of the effect on gas production by forming two parallel vertical, hydraulically fractured disks, as opposed to one, when the distance between the disks is one-tenth the diameter of the fracture disks. Production rates were obtained for short and long times for a range of permeabilities and crack widths for one disk and for two.

A one-dimensional 12-node model (6 hardware nodes time-shared) has been programmed on the hybrid computer to establish the techniques to be used in the two-dimensional (180- to 218-node) model. Several diagnostic tools have been built into the program. The one-dimensional model is used to determine the dynamic range of permeabilities possible, the number of times a hardware section can be time-shared and the accuracy and speed with which a problem can be solved. It is first used in plane geometry, then it is switched to cylindrical geometry. The one-dimensional hybrid computer gas diffusion model has been satisfactorily compared with an identical one on the digital SIMPAC model. This confirms the viability of the analog computer method

for solving the diffusion problem. Two of the four analog consoles required for the two-dimensional model have been wired.

Data-Communications Study [Lindberg, E-5; Lewis, C-DOR]. The broad goals of the LASL data-communications study are to evaluate the feasibility of a unified Laboratory-wide data-communications system that would facilitate the timely and accurate transfer of information among LASL activities; to identify LASL activities which do, will, or might utilize such a data-communications system; and to investigate current data-communications technologies that are applicable to LASL's needs.

Data communications can be broadly defined as data movement between two or more points by some physical means. A person carrying a page containing numbers that describe the output of an experiment is performing data communications. A telephone conversation is another form of data communications, although not usually thought of in that sense. More specifically, data generally refers to a collection of numbers or other identifying information and data communication usually refers to some rapid means (for example, a pair of wires carrying electrical currents) of transmitting that data between two or more points.

To achieve our stated goals, the study has been broken into five phases with overlaps. These phases are:

Phase 1: Organization and preliminary ground work. Search for and identify suitable data-communications consultants. Review existing applicable literature, identify possible data-communications technologies, identify existing data-communications systems whose methods may be applicable, review current LASL data-communications users and their activities, and identify a few friendly users to help us get started.

Phase 2: Survey LASL data communications and set up contracts with consultants. Prepare a question guide, interview LASL groups, prepare a LASL data-flow matrix, and review the study with LASL management.

Phase 3: Survey existing (non-LASL) data-communications system architectures and visit prototypical installations.

Phase 4: Analyze data and report preparation, re-interview selected LASL groups in light of current

Intelligent Data-Acquisition and Control System

(CMB-3)[Damran, E-4; Seifert, E-5]. The intelligent data-acquisition and control system (IDACS) will be a transportable system available to many users. The system will accept a wide range of signal levels that will be passed through signal conditioners and filters before being converted to a 12-bit binary value recorded on a TI 733 ASR tape cassette. Various operating modes will be available by operator interaction through the keyboard. A program-selectable number of TTL input and TTL output signals will also be available.

The system is approximately 95% complete. All major hardware items have been purchased and delivered. The hardware and software portions of the project are approximately 75% and 50% complete, respectively. Effort on the project has been temporarily suspended due to a lack of funds. The project will be completed subsequent to the receipt of CMB-3 authorization.

Master Data-Acquisition and Control System (MDAC) for TSTA (CMB-3) [Damran, E-4; Stutz, ENG-8].

TSTA Function. The tritium system test assembly (TSTA) is dedicated to the development, demonstration, and interfacing of technologies related to the deuterium-tritium fuel cycle for fusion reactor systems. The first such system to be built will be a Tokamak, the next step (TNS) deuterium-tritium burning machine. This TNS will be followed by a TNS-upgrade or an experimental power reactor (EPR). Either of these later devices will build on and expand the tritium handling system used in TNS. The principal objectives for TSTA can be rather concisely stated:

1. Demonstrate the fuel cycle for fusion power reactors.
2. Develop, test, and qualify equipment for tritium service in the fusion program.
3. Develop and test environmental and personnel protective systems.
4. Provide a final facility that can be used for demonstration and be directly copied by industry.
5. Demonstrate long-term reliability of components.
6. Demonstrate long-term safe handling of tritium with no major releases or incidents.

7. Investigate and evaluate fuel cycle and environmental package response to normal, off-normal, and emergency situations.

The TSTA will consist of a large gas loop that can simulate the proposed fuel cycle for a fusion facility. The loop will not include any specific fuel injection system, but will be sufficiently versatile so that such systems can be added as the design requirements are better defined. The gas loop will be designed to handle up to 500 moles/day DT. This flow will provide cycle operating experience on a scale that is equal to or greater than the full-scale fuel cycles currently being addressed for TNS and EPR systems. To accomplish this at TSTA will require an on-site tritium inventory of approximately 200 g.

The required assembly will consist of a number of integrated subsystems as follows:

- Vacuum pumping
- Transfer pumping
- Fuel cleanup (ash and impurity removal)
- Hydrogen isotope separation
- Fuel mixing and injection (including impurity simulation)
- Interfaces with external systems (neutral beam, coolant, and breeding blanket systems)
- Fuel storage

Essential functions associated with the overall assembly must include:

- Tritium waste treatment
- Emergency room cleanup and effluent controls
- Waste disposal
- Radiation monitoring
- Personnel safety
- System maintenance
- Instrumentation
- Computer control and simulation
- Analytical systems (that is, gas analysis)
- Quality assurance procedures.

Project Timing. The present TSTA development will permit design and evaluation of the required fuel cycle before the final design of a TNS tritium system. This timely accumulation of data will insure that the design and development of the tritium system will not be a pacing item in the design of TNS.

A significant goal at TSTA will be the demonstration that large quantities of tritium can be

handled safely on a routine basis. Establishment of environmental and safety packages for tritium systems within TSTA will serve as a baseline facility that will provide a large data base that can be used to establish future guidelines and requirements for fusion facilities.

The E-4 responsibility includes the design, procurement, fabrication, installation, check-out, and operation of the data-acquisition and control subsystems that will interface with the computer subsystem being designed by R. Stutz, ENG-3. Group E-4 is also responsible for the design and implementation of a man-machine interface subsystem, an uninterruptible power supply (UPS) for the MDAC, and an emergency generator set (EGS) for the TSTA. The preliminary designs of the MDAC, UPS, and EGS are presented in the following paragraphs.

System Functions. The primary, compound purpose of the MDAC is to accurately measure performance parameters and provide control of components, subassemblies, and the TSTA as a whole; to assure adequate safeguarding and accountability of records of the large tritium inventory; to provide alarms for out-of-limit processes and conditions; and to record the resulting information as a permanent data base.

Secondary purposes of the MDAC are to perform real-time data reduction and display; provide status of equipment via CRT graphics display; provide graphic display of data via CRT with hard-copy capability; provide system simulation for control studies; develop TSTA software control; perform off-line data reduction; provide a printout of data in engineering units; provide training for LASL personnel and personnel from other laboratories who will be involved in tritium technology at other fusion facilities; study tritium damage effects and determine long-term reliability of a wide variety of instrumentation and controls; assist in check-out of various TSTA systems and components; and provide and maintain preventive maintenance and history records for TSTA.

System Description. The MDAC hardware configuration consists of a data-acquisition subsystem (DASS), a process control subsystem (PCSS), a man-machine interface subsystem (MMSS), a computer subsystem (CSS), and software subsystem (SSS). Figure

Fig. 23. TSTA MDAC subsystems interface.

23 is a block diagram of the hardware subsystems and their interfaces.

Data-Acquisition Subsystem. The DASS contains a collection of transducers and other signal sources, interconnecting cabling between these sources and major DASS equipment components, and a collection of major equipment components used for conditioning, formatting, and interfacing TSTA parameters to the CSS.

The calibration of the DASS instrumentation channels may be accomplished either under manual or computer control. A single channel may be addressed and calibrated separately or all channels calibrated as required by the operational circumstances. Under normal operational conditions, periodic calibration of all DASS instrumentation channels shall be accomplished under computer control.

Figure 24 is a block diagram of the DASS and its interface to the CSS. Table V is a summary of the preliminary measurement list required by each TSTA subsystem.

Process Control Subsystem. The process control subsystem (PCSS) and the DASS are integrated subsystems. All process-oriented functions of the TSTA shall be under computer control. The amount and type of computer control will vary for each application. The exact control required for each process is yet to be established. The amount of redundancy with the PCSS will be addressed at a later date. A summary of the number of presently identified control points per subsystem is included in Table V. The block diagram of the PCSS is also shown in Fig. 24.

Fig. 24. Block diagram, integrated data-acquisition and process control subsystem.

Man-Machine Interface Subsystem. The man-machine interface subsystem (MMSS) serves as an interface between system operators and the MDAC. Two CRT monitors are provided for viewing displays of the TSTA operation and performance. The two key-

TABLE V
DATA ACQUISITION CONTROL CHANNEL SUMMARY

TSTA Subsystem	Data Acquisition			Control	
	Analog Chs	Status Chs		Analog	Digital
		1 Bit	2 Bit		
Vacuum Facility (VAC)	9	40			40
Fuel Cleanup (FCU)	57	4	4	6	4
Isotope Separation (ISS)	66	2	19	2	19
Transfer Pumping (TPU)	150	10	105		120
Impurity Simulation (IMS)	19	8	1	8	
Fuel Injection (FIJ)					
Neut. Beam Intf. (NBI)	4			2	
Cool. Loop Intf. (CLI)					
Breed Blkt. Intf. (BBI)					
Building Vent'l. (VEN)	2		7	1	7
Emer. Trit. Cleanup (ETC)	57	4	4	8	4
Trit. Waste Trmt. (TMT)	35	20	196	13	128
Exper. Contamination Stud. (XCS)					
Waste Disposal (WD)					
Tritium Monitor (TM)	12				5
Secondary Containmt. (SEC)					
Data Acq. & Cont. (MDAC)	36		12		
Gas Analysis (GAN)	6				1
Uninterrupt Power (UPS)	6	4			
Emergency Generator Set (EGS)	7	3			
Inventory Control (INV)	24		13		24
TOTALS:	490	95	361	40	352

boards permit operators to input data, supervisory control commands, and requests for displays to the computer. The logging printer provides sequential logs of alarms, supervisory control actions, and TSTA system performance.

A display generator serves as the interface device between the computer and the keyboard/CRT monitor.

Computer Subsystem. The TSTA computer subsystem (CSS) is designed as a modular redundant system wherein the control and data-acquisition functions of the four CPUs and disks can be shared for continued safe operation in case of malfunction of any one or more units. This redundant network of CPUs and disks is required for system reliability and fault tolerance.

The major components of the TSTA computer control system along with the logic data paths are shown in Fig. 25. The function of each component during normal operation is:

CPU-1: The main control computer that oversees the complete operation of the TSTA and computer subsystem.

CPU-2: Serves for system studies (simulation), data reduction, training, software development, and backup to the other CPUs.

CPU-3: The data capture computer from the data-acquisition and process-control interface.

Fig. 25. Basic data flowpaths for control systems.

CPU-4: Used in conjunction with CPU-2 to perform system studies, data reduction, training, software development, and back-up functions.

Disk 1: Software storage for CPU-1, data for the control software and collected data from the controlled and monitored functions.

Disk 2: Used to store software for CPU-2, data for reduction and display, software for training, and software for systems simulation.

Disk 3: Used for short-term storage of all collected data from monitored functions and software for CPU-3.

Disk 4: Used for CPU-4 software storage and in conjunction with CPU-2 for TSTA simulation and training.

Table VI shows the 16 various operating modes for the network of four CPUs, ranging from complete normal operation to total loss of computer control. The redundant fault tolerant nature of the TSTA computer system is clearly shown. Ten operating modes represent normal operation of the control and data-acquisition functions of the TSTA computer system, five modes require controlled shutdown, and one results in total loss of computer control, with

manual shutdown required. The various optional modes are:

1. With the loss of CPU-1, CPU-2 functions as the main control of the TSTA; however, the system operates without the off-line data reduction capability.
2. Loss of CPU-2 is identical to the operation described above.
3. Loss of either of the small CPUs, CPU-3 or CPU-4, results in the remaining small CPU to be used for data capture while the system simulation capability is lost.
4. Loss of two CPUs results in further loss of flexibility of the computer system; however, only in the event of the loss of both CPUs, CPU-1 and CPU-2, with the control functions being handled by CPU-3 and CPU-4, does the system have to be shut down with controlled subcycle with only a small cost incurred. With loss of CPU-1 and CPU-2, data-recording capabilities are lost.
5. Loss of both small CPUs, or a combination of a small CPU and a large CPU, results in full control function capabilities and data-acquisition functions; however, no off-line data reduction or system studies can be performed. The TSTA can operate normally in this mode.
6. With the loss of any three CPUs, the system must be shut down under controlled procedures (system should not be in operation without a back-up computer).
7. With the loss of all four CPUs, the TSTA facility would require manual shutdown.

TSTA Control Data-Collection Software. The

data-acquisition and control software gathers information telemetered from the TSTA and stores this information in an orderly fashion. This software also transmits control actions to various TSTA devices to allow the operator and various software routines to maintain desired TSTA control.

The key functions performed by the control software are:

1. To provide a generalized interface with the communication channel.
2. To provide periodic data acquisition based on a predefined scan list (status scanning by exception).

TABLE VI

OPERATION OF TSTA COMPUTER SYSTEM UNDER LOSS OF DISKS AND CPUs

DISK DOWN DISK																
	NONE	1	2	3	4	1,2	1,3	1,4	2,3	2,4	3,4	1,2,3	1,2,4	1,3,4	2,3,4	1,2,3,4
1	C	-	C	C	C	-	-	-	C	C	C	-	-	-	C	-
2	DR	C	-	DR	DR	-	C	C	-	-	D	-	-	C	-	-
3	DC	DC	DC	-	DC	C	-	DC	-	DC	-	-	CC	-	-	-
4	SS	DR	DR	DC	-	C	DC	-	DC	-	-	CC	-	-	-	-
OPERATION STATE OF SYSTEM	FN	CN	CN	CN	CN	CND	CN	CN	CN	CN	CN	CND	CND	CND	CND	CSD

CPU DOWN CPU																
	NONE	1	2	3	4	1,2	1,4	1,2	2,3	2,4	3,4	1,2,3	1,2,4	1,3,4	2,3,4	1,2,3,4
1	C	-	C	C	C	-	-	-	C	C	C	-	-	-	SD	-
2	DR	C	-	DR	DR	C	C	-	-	-	DC	-	-	SD	-	-
3	DC	DC	DC	-	DC	-	DC	SD	-	DC	-	-	SD	-	-	-
4	SS	DR	DR	DC	-	DC	-	SD	DC	-	-	SD	-	-	-	-
OPERATION STATE OF SYSTEM	FN	CN	CN	CN	CN	CN	CSD	CN	CN	CN	CSD	CSD	CSD	CSD	CSD	MSD

C - CONTROL
DR - DATA REDUCTION
DC - DATA COLLECTION
SS - SYSTEM STUDIES
SD - SHUTDOWN MODE OF OPERATION FOR TSTA
CC - CONTROL CYCLE LOSS OF DATA COLLECTION

FN - FULL NORMAL
CN - CONTROL NORMAL
CSD - CONTROLLED SHUTDOWN
MSD - MANUAL SHUTDOWN
CND - CONTROL NORMAL LOSS OF DATA FOR LATER REDUCTION

3. To provide random data scans for special case applications with scan priority control.
4. To provide both periodic and random control command checking (check before operating safeguards).
5. To provide data for the data management software.

Control Software Organization. The control software will be organized into major functions as follows:

- Interrupt processor (IP). The IP is called upon by an interrupt resulting from the completion of an input-output transfer (data input-control output) or an operator command to the TSTA.
- Scan controller (SC). The SC initiates and manages all command communications.
- Data input controller (DIC). The DIC calls the appropriate data processor.
- Status data controller (SDC). The SDC processor extracts the status data and determines if changes in status are normal.
- Audit controller (AC). The AC keeps a record of all commands and error conditions found.
- I-O buffers. The I-O buffer table provides a list of available buffers for incoming and outgoing data and commands. The buffer is returned to the dynamic buffer pool when it is again available.
- Scan list (SL). The SL, a roster of routine commands used to gather data from TSTA subsystems, is read by the scan controller.
- Controlled shutdown list (CSDL). The CSDL is a list of commands to execute for shutdown of the TSTA.
- Emergency shutdown list (ESDL). The ESDL is a list of commands to execute for emergency shutdown of the TSTA.

Training software. This software will be used to train TSTA operators, experimenters, and health physics monitors.

Data-reduction software. The data-reduction software will be used to reduce experimental data and to generate reports.

Maintenance software. The maintenance software will be used in scheduling TSTA preventative maintenance (PM) and to maintain PM history for TSTA.

Simulation software. The simulation software will be used to simulate each subsystem, the total system, and some experiments.

System configuration. With the exception of the instrumentation transducers, which will be mounted on the TSTA subsystems hardware, all MDAC equipment will be located in the control room. Particular attention shall be given to instrumentation and control cable routing to and from the control room so that the system may be operated or shut down safely in the event of an emergency.

The MDAC will be in a temperature- and humidity-controlled room isolated from all tritium operations by air-lock doors and zone ventilation. A tentative control room layout is shown in Fig. 26.

The MDAC will provide control and data-acquisition functions through standardized bipolar ± 5 Vdc interfaces for all analog and digital parameters. Control functions will be standardized through use of CAMAC hardware. The interface provided by CAMAC will allow development of control software independent of eventual hardware selection.

Uninterruptable power supply (UPS). A UPS will be provided that will be capable of supplying the total power requirements of the MDAC at the specified frequency, voltage, and phase. The support UPS battery system will provide specified power to the MDAC for a period of 2 h in the event of a power line failure. A static transfer switch, to be supplied with the UPS, will transfer the MDAC to line power in the event of UPS failure with less than 70- μ s power interruption. The UPS will be designed to provide for further expansion of the MDAC and the UPS distribution panel will be located in

Fig. 26. Control room plan.

the control room. The UPS instrumentation and controls will be designed to provide both local and remote monitors and local and remote control of all UPS functions.

Emergency generator set (EGS). An EGS will be provided to supply power to the TSTA in the event of a power line failure, when it will start automatically; when the EGS is operating at the proper speed, the TSTA load will be transferred automatically from the power line to the EGS. The maximum time for the EGS to start and assume the TSTA load will be no more than 20 s. The EGS will provide TSTA power at the proper voltage, frequency, and phase. The EGS fuel supply will be sufficient to maintain 24 h of continuous operation at full rated load. Instrumentation on the engine and alternator will be designed to provide both local and remote monitoring of operating conditions. Control of the EGS will be fully automatic in the event of power line failure with provisions for manual control for system maintenance and check-out. The EGS will be installed in a suitable enclosure outside of the TSTA facility.

Software subsystem (SSS). The software for the TSTA computer subsystem can be divided into the computer operating system, TSTA control data collection, training, data reduction, simulation, and the software controller, see Fig. 27.

Fig. 27. TSTA control software interaction chart.

Fig. 28. System software interaction.

Software controller. The software controller will oversee the interaction of the four CPUs and four disks to insure that the system is in the best operating mode. The primary objective of the software controller, to maintain TSTA operation by keeping the system in the full normal mode or control normal mode, is shown in Fig. 28.

New Plutonium Facility (CMB-11) [Des Jardin, Reitzel, Hart, Owens, Dorin, Seamans, Coy, Garcia, E-5; Thomas, Spears, E-2].

Background. Since late 1974, E Division has been responsible to CMB-11 for the design, procurement, fabrication, installation, and check-out of the Plutonium Facility data systems and process-line instrumentation.

Summary. During the past reporting period the following significant activities have taken place:

1. Fifty 107 limited-volume chilled water systems (CWS) have been modified to incorporate a flow by-pass valve.
2. All gas control panel designs were completed and fabrication is 50% complete.
3. The design for moisture alarm and oxygen alarm panels was completed and fabrication is approximately 50% complete.
4. The 300-area welder system design has been completed and fabrication is approximately 50% complete.
5. The 200-area welder design is complete, drafting is about 50% complete, and long lead items have been ordered.

6. Control panel racks for the 200- and 400-areas have been completed. The 100- and 300-areas are 98% complete.
7. Three density tank heaters have been designed and fabricated.
8. Preliminary design of the gas autoclave control has been completed and long lead items have been ordered.
9. Four additional 400-variable power panels (VPP) have been fabricated.
10. A special control panel for a Heraeus pump has been designed and is 50% complete.
11. The initial design for the hydraulic control panel for two presses in the 300-area has been completed.
12. The remote multiplexers have been installed in the plant and the central control units installed in the control room.
13. Software for implementing the switchgear control algorithms and displays has been completed and checked out.
14. Software for implementing the heating and ventilating system has been completed and is presently being checked out.
15. Software for the fire control system has been completed and has been partially checked out.
16. Software to perform computer failover has been started.
17. Tenny chamber modification has been completed.

Data-Logging System. All of the old CRT units have been replaced by new high-resolution models. These CRT units are being unpacked and checked out. One of the new CRTs received is not functional; the factory will be asked to send a representative to repair the failed unit and align remaining units.

SCADA Software. The SCADA system is on a more solid base now and is running reasonably well. Two 32-k MOS memory boards are expected soon, one for each machine. This will allow an expanded data base to reside in core and alleviate system degradation problems caused by keeping parts of the data base on disks. Current software development status is:

1. The switchgear has been checked out with the software simulation and additional

changes are being made as requests are received.

2. The heating and ventilation system is being checked out with the software simulation, but progress is slow.
3. The fire system has been implemented and some gross checks made with software simulation. No problems are apparent at this time.
4. Some fairly major changes have been made in the radiation (CAMS) system, mostly in the area of calibration. It appears that we have a workable design and we will proceed with implementation during June 1977.
5. The multiplexer interface is running although errors are occurring. This is discussed more fully in the multiplexer write up.
6. The alarm limit table was moved from disk to extended core storage to improve performance.
7. Display format language is complete and the final display formats are being generated for those displays available.
8. The teletype console command input program has been implemented and is now working.
9. Computer failover software should be operational by the end of May.

Welders. The 300-area welder control racks (ME334CR and ME365CR) are being fabricated. All commercial hardware items are on hand, they have been installed in the control racks, and fabrication of the LASL custom design units is approximately 50% complete.

A 2½-day welder instrumentation interface discussion was conducted with Cyclomatic Industries of San Diego. Projected welder delivery is now anticipated in July.

Approval has been received from CMB-11 to proceed with the design and fabrication of the 200-area welder control rack (ME207CR). All commercial equipment required has been ordered. Drafting of the LASL custom units is approximately 50% complete. Design of the Hobart welder power supply modifications required for system interfacing has been completed.

Tenny Chamber. A new Tenny chamber system was modified to split the environmental chamber from

its controls. The modification has been completed and checked out.

Multiplexer. During the last 6 months the multiplex system, located in the TA-55 cafeteria, was interfaced to the Data General computer. Acceptance tests of the multiplex system and its interface to the computer system were finished. After the acceptance tests were completed, the system remained integrated while switchgear software algorithms were tested. This was accomplished using software, as previously mentioned, and hardware simulation of switch closures. At the same time, the multiplexer signal termination panels, auxiliary power supplies, thermocouple reference board, and multiplexer cabinets were installed in the facility. Multiplexer signal input cables were connected at the termination panel. Main bus and drop cables were pulled into place and left unterminated. In April, after the system check-out was completed, the multiplex system was dismantled and installed in the permanent location. All main bus drop cables were terminated at the bus isolators. All bus cabling has been checked for continuity and wiring integrity.

Two multiplexer receive-transmit units were returned to I/C Engineering for modification to correct a continuing operational problem encountered during acceptance tests. This problem caused numerous errors to be generated. Both units have been repaired and returned, but they have not been checked out because power is not yet available in the control room.

There has been some difficulty in keeping the multiplexers dry during the basement clean-up operations. Several multiplexer cabinets have been inundated with water; whether or not damage has resulted cannot be ascertained until the UPS power system is completed and the multiplex system turned on. This is anticipated during the last week of May.

Process Line Instrumentation. The 50 CWS required modification to incorporate a flow bypass valve. In addition to this modification, on three units an additional heat exchanger was installed. All modifications have been completed and the units made available for installation in the facility.

The prototype voltage-time programmer purchased from Research, Inc., was received and evaluated. Production authorization for the final units

has been given to Research; we expect to receive them in June.

The work on the gas control panel designs, which includes mechanical fabrication, painting, silk screening, and component installation, has been completed.

Four additional variable power panels were requested and fabricated during the reporting period.

Assembly of the 200- and 400-line control panel racks has been completed, and they have been checked out. The units for the 100 and 300 lines are approximately 98% complete.

A control panel has been designed for the gas autoclave being received from Rocky Flats. All of the long lead items have been purchased and received. Final control panel design will not begin until the facility design has been completed.

Moisture- and oxygen-alarm panels were designed and are approximately 50% fabricated. These alarm panels will indicate which one of six gloveboxes being monitored for moisture or oxygen is in an alarm condition.

The density tank heater control panel was designed and three units fabricated.

A special panel was designed to control the ion etcher pumping system. Fabrication of this panel is approximately 50% complete.

Preliminary design has been completed on splitting the metering and control panels from two new hydraulic systems being used in the 300 area.

Continuous air monitors built by Eberline Instruments have all been received and checked out and are being installed in the TA-55 facility.

Hand-and-foot monitors built by Eberline Instruments have all been received and checked out.

The criticality system is being built by Victoreen Instruments. The control panel design has been received, reviewed, and approved. Production of the criticality system is continuing and is expected to be completed in June 1977.

The zinc-sulfide counting system fabrication and check-out was completed during this reporting period.

SCYLLAC Support (CTR Div.) [Handy, E-4]. The helical-shaped discharge tube experiments were discontinued on February 27, 1977. A new L = 1.2 system was installed and is being checked out. The new

system has two more main bank racks, more feedback, and twice as many Jones circuits.

All Jones, crowbar, and submaster circuits are working now and the feedback control circuits are still under test. Experiments, excluding the Jones and feedback circuits, have been conducted and the tube is still in the cleanup cycle. It is expected that data will be received in the very near future.

Integrated Minicomputer Pulse (IMPULSE) (H-1) [Coy, Seamons, E-5; Parker, E-3]. This project, initiated in the third quarter of 1975, has been essentially completed during the past report period. Two operational IMPULSE systems have been installed at the TA-55 Plutonium Facility for use and operation by H-1. Group H-1 has completed acceptance tests and has formally accepted these systems. A third system scheduled for installation and use by H-1 at NTS is in final check-out by Groups E-5 and E-1.

Background. Group H-1 has the responsibility for monitoring concentrations or radionuclides in occupational areas and in building stack-effluent air. The concentrations are determined by periodically measuring absolute alpha activities collected on filter media. Approximately 1000 filters must be analyzed daily. In the past, commercial analysis systems were used to count large numbers of air samples; these systems employ a single proportional counter, and a mechanical sample changes to sequentially count many samples. The principal shortcomings of these systems have been excessive turn-around times and low-production analysis rates.

The IMPULSE system was conceived by H-1 and a prototype system was designed and built as a co-operative project by Groups H-1, E-2, E-3, and E-5. This system employs a number of logically independent counting stations, which are coordinated by a single system controller that interfaces to a minicomputer. The computer memory and I-O structure substitute for external counters, scalars, and timers. A key design objective was to overcome the shortcomings of commercial systems as described above.

The prototype system consisted of four counting stations and a system controller that was interfaced to E-5's systems development PDP 11/40 computer. Results from the prototype lead to commitment to the system design and to the fabrication

of two 52-channel systems for use at TA-55 and one 16-channel system for use at NTS.

System Configuration. A block diagram for the two systems, as installed at TA-55, is shown in Fig. 29. A computer was acquired for each system to provide redundancy. Each computer is equipped with two general-purpose digital I-O interfaces (DR11C) such that a single computer can control both systems concurrently. The system software allocates memory, resources, and logic so that a two-system computer configuration appears as a contiguous 128-channel system to the operator.

Counting Stations. The counting stations are organized into "quads" of four stations each. A counting station consists of a zinc sulfide detector photomultiplier (PM) tube and a light-baffled sliding drawer. Filter media disks to be analyzed are inserted in a drawer recess and the drawer is closed to expose the detector to alpha radiation from particulates collected on the filter.

Each quad contains a power supply to support the individual electronics of the four PM tubes. High voltage for operation of all PMs is derived from a source common to all quads.

Each count station has a single digit LED display associated with it. One of 16 characters can be sent to an LED by the system software via the system controller. The LED characters are used to display to the operator the physical or logical status of each count station; that is, station idle and available for use, idle for cause, assigned to one of four types of count.

System Controller. The system controller consists of four data modules -- each servicing four quads, a master controller section, a 64-word

Fig. 29. Block diagram of IMPULSE systems I and II.

(16 bits each) FIFO (first-in first-out) buffer, and logic required to interface to a DEC general-purpose digital (programmed) I-O port (DR11C). Logic in the controller includes a data latch, a read enable/disable status bit excess PM current status bit, and drawer open/closed status for each of 64 possible stations in a system.

The system controller provides decoding for five system operation commands output from computer via the DR11C.

1. READ-DATA: A general system clear command that clears the FIFO buffer, FIFO-full flag, and data latches.
2. READ-DISABLE: Logically disables a specified channel.
3. READ-ENABLE: Logically enables a specified channel.
4. READ-STATUS: Encodes, for a specified channel, a 16-bit word containing channel number, states of the data lines (1) read enable/disable, (2) excess current, (3) drawer open/close, and stores this status word in the FIFO, which subsequently is read by the program via the DR11C.
5. WRITE-LED: Extracts a 4-bit character from the command and writes it into an LED for a specified channel. This character is latched by the display so no refresh cycles are required.

A data "hit" (sufficient current flow in a PM) is sensed by the analog electronics of a PM and sets the data line (latch) associated with the hit channel. If that channel is read-enabled the associated data module encodes the channel number and transmits this to the master controller section.

The master encodes three hardware-status bits, six address bits, and one flag bit indicating data into a 16-bit hit data word, which it stores in the FIFO. All information flow from the system controller to the computer is directed through the FIFO buffer. The basic cycle rate of the controller is about 1 MHz, that is, the controller can process $\sim 10^6$ data hits or read-status requests per second. The computer/software bit/request handling rate is approximately 10^4 events per second. The 64-word FIFO buffer provides buffering external to the computer to handle instantaneous bursts of data input. The controller tests for a FIFO-full

condition after each word entry to the FIFO and flags all data words queued in the FIFO as having contributed to any full condition. The response to this situation is to lock out further inputs from controller to computer until all 64 data words have been processed from the FIFO. The program further maintains a tally of this situation and reports it to the system operator.

Computer Hardware. The current computer hardware configuration consists of the following DEC equipment:

1. PDP 11/04 with 28-k memory.
2. KW11-P programmable clock.
3. LA-36 keyboard/printer.
4. Two DR11C general-purpose digital I-O interfaces.
5. An RX11 diskette (floppy) controller with two drives.
6. RT-11 single job operating software system.

An RK05 disk controller with two drives is on order from DEC and is expected to be installed during August 1977.

System Software. Two software packages have been written to support the IMPULSE system.

Diagnostic Program. This package is written in assembly language and was developed to facilitate check-out of the IMPULSE systems. The program consists of a monitor and set of operator input commands, which can be used to exercise single system functions on a single-shot or repetitive basis or to exercise all functions simultaneously. The diagnostic is designed to support whatever maintenance work that is required on the system.

Operational Program. The current program/system was written to H-1 specifications that cover the intended use of the one system at NTS. These specifications also define about 80% of the system capability required for operation of the two systems installed at TA-55. Some extensions to the specification, peculiar to the TA-55 operation, have been implemented and are in use. This augmented program was used by H-1 to evaluate system performance leading to system acceptance. Additional extensions are in the design implementation stage. General characteristics of the operational program are as follows:

1. The program is written about 95% in FORTRAN and the remainder is assembly language --

the later segment being restricted to interrupt handling of clock functions and I-O between the computer and system controller.

2. The program is configured to handle two system controllers from one computer. Sufficient self-timing logic is built into the program to ensure that the computer can handle input from both systems at the expected aggregate count rates.
3. The program is structured into three main logical segments.

Main Program: This module consists of a large FORTRAN "DO LOOP," which continuously scans the status of all channels checking for logical consistency between the hardware and software status. This loop monitors elapsed time count or maximum number of channels assigned to counting. The results of a time-out or count-out are further processed depending on the type of count assigned to a channel (see Calibration). This main loop also monitors for the completion of command input by the operator from the LA-36 keyboard and initiates execution of commands. A secondary program loop, operating once per second, issues a read-status request for all channels, updates the LED display associated with each channel, and does other low-rate support functions.

Command Processors: A total of 28 commands is currently available to the operator for control or interrogation of the system. Character-wise input of a command is handled on an interrupt basis such that a command is not executed until a "return" key is struck, that is, all count handling and main-loop procedures are active until a command plus any segments is complete. Commands are checked for validity and command arguments are inspected for "reasonableness." Some critical commands, which affect operation of the system in a gross sense, are password-protected to minimize possibility of unintentional usage.

The main commands are concerned with assigning channels, individually or in a group, to one of four count types and for retrieval of counted results from mass storage.

Support for H-1T [Backsen, Seamons, E-5; Carrier, E-2].

RADAS. Some additional remote area data-acquisition system (RADAS) hardware was fabricated

during this reporting period. We now have enough RADAS hardware installed at the NTS to support three simultaneous events. This should be sufficient and it is not anticipated that any more RADAS hardware will be fabricated. The older RAMMS systems have been phased out and replaced with the RADAS units.

VORP. Fifty additional voltage output radiation probes (VORP) were fabricated and installed at the NTS.

CMOS Microprocessor. About 2 man-months of effort were spent developing both hardware and software for the 8080 microsystem. The CMOS microprocessor project is discussed in more detail elsewhere in this report.

UHF Telemetry Link. The design for a portable UHF telemetry link has been completed and fabrication has begun. The system consists of two "suitcases," each with self-contained battery pack and charger. The remote suitcase includes a transmitter, receiver, duplexer, and tone-decoder network. The central suitcase includes mating transmitter and receiver modules, duplexer, and tone encoder. This telemetry link will be used to transmit RADAS signals from the forward area to the CP on NTS events. In addition, remote control is provided from the CP to the forward area in the form of the tone encoder and decoder circuitry. The system is designed for full duplex, continuous-duty data transmission. In addition, voice communication is also provided.

TARAS Operating Software. A major revision of the TARAS software was started this report period. The revision has been completed to the extent that it can be checked on the E-5 11-40; however, software simulation of I-O devices is available only at NTS. A field trip to NTS will be required to complete verification and installation of the new system. The major areas of change and addition to the system are:

Remote Data Channel Terminal. This software addition enables access of a LASL-based keyboard-pointer terminal to the NTS system. Through this terminal it will be possible to request execution of a selected subset of the 60 commands operable under the TARAS system. Master system control is maintained at one of the NTS terminals with a master-only command that enables or disables access of the remote terminal to individual commands.

Raw Data File Management. This section of the system was rewritten to provide more flexibility in manipulating raw data storage and recall. Raw data files can now be opened, closed, reopened, deleted, and renamed using direct TARAS commands. The file structure has been changed from formatted ASCII to random-access binary to speed up file access and economize, by a factor of 5, on the use of mass storage. The raw data files are further assigned to the system operating device "SY": that can be either RK05 disk or dec tape, the latter being the primary back-up device with paper tape a last resort as a systems device. Raw data logging to punched paper tape in ASCII format is still available with provisions for transcribing this data to mass storage when mass storage is operable.

A stage for core queuing the raw data before writing onto mass storage has been added. The data-logging task has been rewritten to inhibit actual writing to mechanical devices (disk, dec tape, or punch) when test operations are within ± 1 min of any of three possible LASL H-zero times. During these periods data is queued in core. The objective of this change is to avoid corrupting mass storage files when shock waves hit the CP at NTS.

Message and Display Formatting. The message and display formatter package has been rewritten to provide a write and encode statement capability similar to FORTRAN. This feature should simplify making minor on-site system changes.

RADAS-Input Unit Diagnostics. Some difficulties maintaining RADAS address sync have been encountered with the system in the recent past. The RADAS data-handling package has been modified to provide on-line diagnostics and control of the handling logic.

Operational Changes. All commands have been modified to allow assignment of data channels to equipment and tasks in terms of input unit (1 to 4) and channel number (1 to 32). All commands that refer to output devices now do so in symbolic form rather than device number. These changes should

simplify system operation. Other changes include a general clean up of the system for improved readability and documentation.

Biomedical Flow System Instrumentation (H-10) [Hiebert, Greenwood, E-3; Sandler, Van Lyssel, Hansen, Hume, E-2]. Support demands for high-speed biological cell instrumentation have increased in the past year. This results from several factors. There are three visiting doctoral candidates and one postdoctoral appointee in Group H-10, and their special instrumentation requirements add to the on-going staff programs. In addition, our exposure to the outside world has increased to the point where more time is required to fulfill technology transfer commitments. The following summary is not divided into subheadings because of the interwoven nature of the projects.

The Model 417 multiparameter signal processor design is nearly complete and fabrication has begun on five of the circuit cards. Sixteen or more cards will be required in the complete system. The processor will be used on a system that can have two Coulter volume sensors and four light-signal (either fluorescent or light-scatter) detectors. Light signals will be derived from two lasers (argon and krypton) exciting the cells in the flow stream at different wavelengths. Since a given cell can intersect with a measurement station at three different times, the triggering and logic requirements become quite complicated. Analog processing includes pulse-amplitude ratio taking and dual-gated, single-parameter analysis. System outputs will feed to a multiparameter display system and to cell separation logic circuitry.

Design work has started on the Model 317 computer interface, which will have a general-purpose modular concept. Construction will use NIM hardware and bussed interconnections, which will allow considerable flexibility in system configurations. As many as eight incoming cell measurement parameters may be processed. Four parameters may be used to establish "sort right" criteria, and four parameters

for "sort left." The system will use DEC DR11-L/DR11-M general-purpose I-O interfaces to transfer 16-bit words between the experiment and the PDP-11 processor. One of the main objectives of the new system is high-speed processing; for the sake of speed some of the functions formerly done in the computer will now be accomplished with hardware. Experiment control setup, done by the computer, will have ample panel displays and monitors to assure users.

The demand for higher processing speed has resulted in the design of another circuit that will be used peripherally with the interface mentioned above. Since cell measurements are frequently made at sequentially located observation stations in the cell stream, the measured level from an "early" detector must be stored to await a correlation decision from a downstream transducer. We have been doing this with analog peak sense-and-hold circuits on early signals, but they have the disadvantage of a dead time corresponding to the entire cell transit time through the detector chain. To cope with this problem, the Model 8155 waveform-preserved analog delay has been designed. The heart of this circuit is a Reticon serial analog delay device (SAD-1024) in a bucket-brigade configuration. This charge-transfer device, consisting of a chain of MOS transistors and storage capacitors, can be used to store as many as 10 analog pulse signals as they are "persistently" propagated through the delay. Delay time is simply controlled by changing the clock frequency. There are complications in preserving analog fidelity in the presence of clock noise and other disturbing effects, but breadboard performance has been encouraging.

Measurements of fluorescent decay times in cells, using a pulsed nitrogen laser source, has required several circuit developments. The Model 257 high-voltage pulser has been built to trigger a spark gap, which dumps the charge from a distributed capacitor to excite the laser flash. The circuit is an adaptation of a streak camera design of J. Lunsford. The problem of measuring the rather weak excited cell fluorescence with nanosecond fidelity has been approached by using a 931B photomultiplier tube in a high-speed base circuit, derived from some work done earlier by G. Beck. Tube operation is truncated to five stages and gives a gain of about 10

with a risetime less than 1 ns. As a spin-off from this work, Group M-6 is testing this detector arrangement in some of their high-speed optical studies.

The application of optical line scanners to do scattered-light cell measurements is proceeding smoothly. The 360° light-scatter flow system uses a Reticon self-scanned circular photodiode array and incorporates an upstream Coulter volume sensor to allow correlating measurements to a nonoptical parameter. A peak sense-and-hold circuit and analog multiplexer have been designed to properly condition and route the signals to a fast ADC, under computer control. A spasm of activity occurred when, during a visit here, G. Seter, Battelle Institute, discussed his thoughts on using a linear self-scanned array in lieu of image dissectors for light-scatter pattern measurements. A 128-element array was hastily assembled in a flow system along with electronics to properly synchronize and read out the array in a random-triggered fashion. The experiment was successful and proof of principle was established.

A system to view and record the optically transformed images of cells under a microscope using a Reticon photosensor area array is being developed. The first step circuits will allow displaying the scanned images continuously on a CRT. If the results are promising, the video will be digitized and sent to a computer for image processing routines.

A Becton-Dickinson (BD) cytophotometer front end has been purchased by H-10, and considerable electronics must be designed and built for it. The Model 76 ST sorting system, designed some time ago in anticipation of the BD machine purchase, had to be modified to be compatible with the actual BD arrangement. Special preamplifiers have been built for the three signal parameters available. Considerable assembly and wiring changes between our circuits and the commercial hardware remains.

We upgrade our instruments at the National Cancer Institute (NCI) as needed. A circuit for sensing doublet cells (pairs which are kissing close in flow systems) has proven useful in a certain class of experiments here at LASL; the Model 8152 doublet sensor and gate was designed, fabricated, and delivered to the NCI.

There is continuing interest in measuring dielectric differences between a cell and its

surroundings in flow systems. This requires making accurate measurements and determining the reactive component of cell impedance as well as the usual resistive component from the Coulter effect. To accomplish this, an operational prototype of a high-frequency (1 to 10 MHz), high-resolution amplitude and phase-measuring circuit has been constructed. The orifice in the flow system constitutes one leg of a balanced bridge driven by an oscillator at the frequency of interest. The amplifier and phase-sensing circuits yield a change-of-capacitance (ΔC) resolution capability of 0.005 pF, and an in-phase sensitivity (ΔR) of about 25 Ω in 150 k Ω . These circuit capabilities compare favorably with anticipated ΔC and ΔR of cells in passage through a typical flow system orifice.

The Fifth Conference on Automated Cytology, held at Pensacola, FL, had strong LASL representation at the meetings. Richard Hiebert chaired a workshop on instrumentation, light sources, detectors, and standards. Attendance and enthusiasm at the workshop was good. As evidence of the desire to publicize developments in this fast moving technical field, a book, Flow Cytometry and Cell Sorting is being prepared with P. Mullaney, M. Melamed, and M. Mendelsohn as editors. An invited chapter on light sources, detectors, and flow chambers has been written by R. Hiebert.

Laser Fusion Support (L-1) [Sutton, Day, Hansen, Johnson, Remington, Sanders, Trump, Tucker, Wells, E-4; Parker, E-3; Gallegos, Nava, Winter, E-2]. E Division is supporting the L-Division development of three carbon-dioxide pulse lasers to be used in LASL's fusion research. The three lasers discussed here are the single-beam laser at building 67, the eight-beam system at building 86, and the High-Energy Gas Laser Facility.

Single-Beam Laser Support.

Calorimeter Calibration System. A system used for the routine calibration of the 2.54-cm- and 10.16-cm-diam calorimeters at TSL-67 was designed, developed, and delivered during this period. The calibration setup consists of a 0- to 500-V dc power supply, 50- to 200- μ F energy-storage capacitors, and a mercury contactor that connects the charged capacitor to the calibration winding of the calorimeter under test. The calibration is self-contained, portable, and capable of delivering elec-

trical pulses of 0.1 to 25 J to the 80- Ω calibration input on the calorimeters.

SBL #4 PA Filament Control Chassis.

This filament control chassis has failed twice during the past 6 months primarily because of inadequate components and improper fusing. A replacement chassis to remedy the problem has been designed and is being constructed.

Eight-Beam Laser System. The eight-beam laser system (EBS), being constructed by L-1, has been supported in several areas by E Division for the past few years. These areas include control system design, fabrication, and installation, computer-control programming, electrical and mechanical optical alignment support, target insertion and alignment, mechanical design and fabrication, and electrical and mechanical assembly technical support of the eight-beam laser. Virtually all E-Division groups have been involved in this support. The present support level includes eight full-time staff members from E-3 and E-4, seven full-time graded series personnel from E-4 and E-2, and many part-time or occasional peripheral personnel from E-2. Due to a recent L-1 schedule acceleration, the support level has increased. The present goal is to have all eight beams on target by the end of March 1978.

On March 24-26 a planning retreat was held at Chama, NM, for all staff members assigned to the eight-beam laser project. At this meeting plans and schedules were prepared to establish the work tasks and personnel required to accomplish them in achieving the March 1978 goal for completion of the eight-beam system. An intermediate goal, called the integrated system test, planned for the month of June 1977, was also established. This test will be the operation of all eight laser power amplifiers, associated controls, and data acquisition using the computer. One-half of the power amplifier system has now been tested and the integrated system test requires only the completion of the fourth dual-beam power amplifier module.

In January, a paper³¹ giving a brief description of the eight-beam laser control system was written and submitted to the 1977 IEEE/OSA Conference on Laser Engineering and Applications. Although this paper was not accepted for presentation

at the conference, the effort was useful. Parts of it have been presented in LASL meetings on the subject.

The following is a summary of specific E-Division activities and their present status.

Control Programming. In early December 1976 the E-Division support for controls programming increased by one staff member. This brings the level of effort to three staff members including the L-1 staff member assigned to this phase of the project. The major effort in controls programming has been to write a program to support the integrated system test to be performed in June 1977. This program, the dual beam module (DBM), was completed and tested in its initial form early in May. It is evolving somewhat and becomes more useful as system needs are more clearly defined.

The DBM program has two basic parts, machine controls and data acquisition. The operation of the electron beam Marx generators, pulse-forming network pulsers, supporting spark gap gas systems, electron-beam chamber vacuum system, and other micro supporting subsystems are all included in the machine controls phase. Data acquisition includes testing the high-speed digitizers, reading the high-speed digitizers, displaying acquired data, storing digitized and other shot parameters on disk and magnetic tape, retrieving lost data from magnetic tape, and updating parameters.

Another controls programming effort has been to convert to a new FORTRAN IV compiler, which uses the hardware arithmetic unit. A version of FORTRAN V has also been added to the Data General machine.

Electron-Beam Vacuum System Controller

Wiring and Check-out. On January 14, 1977, all control and power wiring for the four sets of electron-beam vacuum hardware and the vacuum roughing pumps were completed and checked out. The four vacuum chambers are now routinely evacuated into the 10^{-7} torr range while operating personnel use the manual control panel as required for day-to-day operation of the valves and pumps. Computer control and vacuum hardware monitoring are also done by the program, which fires the power amplifier modules.

Recently a new sensing circuit to detect rotation of the 1397 pumps, which are connected to the forelines of the diffusion pumps, was built. This circuit uses a magnetic sensor that is pulsed

by the rotating spokes of the drive pulley. These pulses trigger a one-shot multivibrator having a long time-out period, which is continually extended as long as the pump continues to run. The multivibrator interlocks the power circuit to the diffusion pump, removing the power if the pump fails.

Magnetic sensor circuits have been installed on forepumps 1 and 3; additional sensors are on order for installation on pumps 2 and 4. These circuits replace photoelectric sensors, which have exhibited appreciable failure rates due to exciter lamp burnout and filter capacitor failure.

Modification of the Model 841 Ionization

Gauges. An RC filter, to suppress noise transients in the Varian Model 841 digital ionization gauge, has been designed and tested. This filter has been installed in the six L-1 units. Also the rear panel connectors for the two thermocouple gauges on each 841 have been changed from the Amphenol 126 series to the Amphenol 91T series. Using this better connector has essentially eliminated random drift of the meter zero point, which previously had been observed. The schematic diagrams in the factory manual have been reproduced with the addition of cabling information between pc boards.

Target Chamber Vacuum Controls. During March a project team for target chamber installation was appointed. This team will also be responsible for system design and control. The project engineer for the vacuum system design is G. Wilson, L-10. Initially, F. D. Wells was appointed project engineer for the controls design. On June 1, 1977, L. D. Sanders, E-4, will assume responsibility for this work.

The target chamber vacuum system will consist of two cryogenic helium refrigeration vacuum pumps, one turbomolecular pump, four rotary vane pumps, and an assortment of valves. Four ionization gauges will be used to monitor the vacuum at different points in the system.

In response to an L-1 request, a catalog search was made for a vacuum gauge that could measure pressure in the range from atmospheric to the milliton region more accurately than thermocouple gauges can. Strain gauges, variable reluctance gauges, and capacitance manometers were evaluated. The catalog data indicate that strain gauges are not at all useful in this pressure range. The variable

reluctance gauge will work well, but the electronics package, mounted adjacent to the transducer head, could be susceptible to emi damage. The capacitance manometer provides the best accuracy, but requires two transducers to cover the total range.

After evaluating the various devices it was decided that thermocouple gauges would be adequate for the system. This is principally true because the pressure range of interest is the 10^{-6} to 10^{-7} -torr range. The Varian Model 841 ionization gauges provide measurements for this range; each 841 also contains two thermocouple gauges. Four Model 841 gauges were ordered from Varian during the reporting period, along with four additional Model 810 thermocouple gauges. This purchase request included an extensive sole-source justification. The order has been placed and delivery is expected about July 1, 1977.

Recently a proposed layout of the vacuum system control panel was prepared. After an initial review, the layout is being completed.

Oscillator - Preamplifier High-Voltage

Controls. The high-voltage power supply controller design has been selected. It consists of an autotransformer in the ac input circuit and a 150- μ F capacitor in series with the power transformer primary. The series capacitor allows the output capacitor bank to charge to 40 kV in about 10 s, while limiting the primary current to an acceptable level. Seven controllers have been fabricated and installed on the high-voltage power supplies.

Concurrent with the controller work, the rack-32 cable harnesses of room 101 were removed, trimmed up, and reinstalled. This work made the terminal strips more accessible and greatly improved rack appearance.

In January, Group L-1 decided to purchase four CO₂ laser amplifiers from Lumonics Corp. These units will be used as output amplifiers for the four beams leaving room 101. This installation will require substantial redesign of the high-voltage, gap gas, and laser gas controls. The responsibility for this work was assigned to M. Trump, who took over the project in March.

The laser gas and spark gap gas control chassis have been reworked to provide consistent indication and control functions with respect to fa-

cility requirements. Modifications are being made to the preamplifier control chassis to accommodate the four Lumonics preamplifiers, which will be used to deliver the signal from the front-end room to the main amplifiers. Additional small monitoring and recording tasks have been identified by front-end room personnel and we are incorporating these tasks into the data system.

Delta Mirror Mount Controllers. The TSL-86 target chamber will contain sixteen mirror mounts including eight flat turning mirrors and eight parabolic focusing mirrors. These mirrors will be positioned to direct and focus the eight laser beams onto the target. Each mirror mount will contain a three-point drive mechanism having three stepping motors located at the corners of an equilateral triangle. A delta mirror mount controller has been designed to provide manual positioning of these motors in an ordered sequence. The controller will allow selection of any one mirror mount and operation of its motors under any of the following control modes:

Focus - In this mode the three motors are driven in the same direction, forward or reverse, with all motors moving the same number of steps. This moves the mirror mount either toward or away from the target.

Rotate - This mode drives motor A in one direction, motor B in the opposite direction, while motor C remains stationary. The mirror thereby rotates around the axis through motor C and the center of the mount. Either direction of rotation can be selected.

Tilt - This mode drives motors A and B in one direction while motor C is driven two steps in the opposite direction for each A and B step. As a result the mirrors tilt about the axis parallel to the AB edge of the triangle and through the center of the mount. The same focus distance is thereby maintained from the mount center to the target. Either direction of tilt can be selected.

Three counters that register the number of pulses applied to the motor drive circuits are associated with the three control modes. These counters, preset to any desired starting number, register the mirror position relative to the starting point as the motors are stepped. There are also three other registers, which can be preset to store

numbers called set points. The set point function will be discussed below.

Three choices of motor activation are provided.

Single Step - Pressing the RUN button activates the motors for one step position, per the mode selection criteria and the forward/reverse selection.

Slew - Power is applied to the motors for as long as the RUN button is pressed. The motors operate according to the mode selection criteria and the forward/reverse selection.

Set Point - Pressing the RUN button drives the motors from the present position, indicated by the control mode counter, to a new position defined by the set point register. Any desired position can be loaded into the set point register before pressing the RUN button.

The logic design for this controller has been completed. The wire-wrap software was recently generated and the logic boards are being wired. The front panel and control box have been fabricated and a few components have been installed. Final wiring should be completed by June 30, 1977.

Shaft Angle Encoders. The lack of mirror position information relative to lead screw limits is a major problem with target chamber mirror alignment hardware. Counters, which count the pulses applied to the motors, are used in the delta mirror mount controller. However, the controller contains no permanent memory and the count is lost when power is turned off. If a lead screw binds and the motor fails to turn, no indication of this is given.

This problem can be alleviated by attaching a shaft angle encoder to each mirror-positioning motor. A catalog survey was made and several companies were contacted to obtain information on these devices. Subsequently, an order was placed for an encoder and digital readout package to be evaluated for this purpose. This equipment should be delivered by early June. A second manufacturer is also sending an encoder and readout package for evaluation. Testing factors to be considered include resolution, accuracy, mechanical compatibility with existing equipment, and the cost of full system implementation.

Triple-Pass Mirror Mount Controller.

Control cables and electronic hardware for the triple-pass mirror mount beam-positioning equipment were installed on power amplifiers 1, 2, and 3. The mirror mounts for amplifiers 1A and 1B were also installed and checked out. These mirrors are being used to test the triple-pass laser system.

Ralph Partridge, J-8, recently assumed the design responsibility for the automatic beam alignment system for the front-end and triple-pass mirrors. He has determined that the rotational steps of the 7.62-cm mirror mounts is too coarse for beam alignment requirements. Originally, these mounts were supplied with a differential screw for setting the mirror position; however, direct drive screws were substituted because of the design requirements of the TSL-29 two-beam laser alignment scheme. It will now be necessary to reinstall the original differential screws.

A coupler to connect the differential screws to the stepping motor drive shafts has been designed. A pair of couplers was fabricated and R. Partridge is testing the mounts. If the modification is satisfactory, the differential screws will be reinstalled on all of the mounts.

Optical Systems Group. In March an Optical Systems Group, including all individuals concerned with the beam alignment problem, was formed. Weekly meetings are held for presentations and discussion on alignment system topics. The first meeting, held on May 4, featured a discussion of methods for detecting the beam-positional error. Subsequent meetings have considered the beam alignment algorithm, silicon detectors for 10.6- m radiation, and the results of EG&G detector work.

Facilities Monitoring. It is essential that the operational status of certain features of the EBS facility be monitored continuously to avoid time loss or facility damage. For example, the oil temperature in the pulse-forming network (PFN) tanks must not be allowed to drop below 18.3°C. The heaters in these tanks have failed on weekends during cold weather occasionally and this was not discovered until Monday. Because of the large volume of oil in the PFN tank and the finite size heater, two days were required to bring the temperature back to 18.3°C. Therefore, a facilities monitoring system was designed that provides local audible and

visual alarms. In addition, a dedicated telephone pair will provide 24-h, 7-day-wk monitoring at SM-223 when such critical facility failures occur. The chassis work is complete, wire scheduling is under way and will be completed in early June. The dedicated telephone line will not be available until late June or early July.

Fan Control and C66 Temperature Monitoring. The homogeneity and temperature of the gas mixture used in the triple-pass amplifiers (TPA) are potentially critical parameters. Therefore a heat exchanger and fan combination and a thermocouple has been installed for cooling and mixing the gas and monitoring the gas temperature.

A fan control system was developed to provide programmable fan operation following each test firing for any desired length of time. Chassis at each power amplifier control rack in the experimental area were developed, which display the fan and gas temperature status for all power amplifiers. These chassis also provide a choice of manual or computer control.

Precision requirements for temperature measurement were not known. To attain greater precision and eliminate junction complications involved with thermocouples, the sensors were replaced with thermistors. Earlier work at LAMPF by J. Richardson, MP-11, and Parker has shown thermistors to be unaffected by an exposure to 10^{18} . Circuitry developed by Richardson for linearizing the thermistor response at LAMPF was modified to cover the range of 10- to 38°C with a system error of less than $\pm 17.5^{\circ}\text{C}$. The linearization is much better than that available from industry.

The temperature will be displayed at the fan control and gas temperature chassis in the control room. A measure of the temperature at each power amplifier will be provided to the computer via CAMAC. The five chassis involved are being fabricated by E-4 and should be completed by early June. Wire scheduling is in process and should also be completed by early June.

TPA Spatial Filter. The TPA spatial filter pressure, in the 1- to 20-torr range, is critical to TPA operation in that it must be adjusted so that the return laser pulse, reflected from the target and amplified while passing backwards through

the TPA, breaks down the gas at a focus point and is absorbed in the process so that it will not destroy delicate optics following (or preceding) the TPA. This breakdown must occur for the return laser pulse, but not for the outgoing laser pulse. The minimum ratio of return pulse intensity to outgoing pulse was found to be about 20. The corresponding minimum field intensity ratio of about 4.5 was used with an extension (albeit illegal) of Paschen's law to show that the precision of the best thermocouple vacuum gauges was not adequate. Therefore, a pressure measuring system based on the electronic manometer was designed. This linear system has 2% accuracy.

System components have been ordered and will be shipped in June. Chassis and panels have been designed to display the pressure and "in" or "out-of-limits" condition at each power amplifier control rack in the experimental area and at one panel in the control room. The in or out-of-limits status and analog pressure signals are available to the computer for appropriate control action. Contacts are provided, should they be desired, to hard-wire the in or out-of-limit condition to the interlock system. Chassis and panels are being fabricated and should be complete in June. Wire scheduling is in process and will be completed by early June.

Laser Gas System. The laser gas system is designed to acquire helium, carbon dioxide, and nitrogen gas from a supply station and mix the gases to the desired proportions for use in the oscillator, preamplifiers, and main amplifiers. Mixing is accomplished at two mixing stations; one station for the oscillator and preamplifiers, and one station for the main amplifiers. The mixing is accomplished with sonic orifices. For a given orifice upstream pressure, and if the orifice downstream pressure does not exceed a certain critical pressure, which is a function of the orifice upstream pressure, the flow rate remains constant. Therefore, by adjusting the orifice upstream pressure for each gas, the flow rate will be defined, and thus the gas mix is determined.

All hardware for the system has been installed. The cryogenic CO_2 supply and the helium supply tank have been plumbed into the system. Check valves for eliminating flow from one power

amplifier chamber to another have been incorporated into all power amplifiers.

The oscillator, two preamplifiers, power amplifier 2, and power amplifier 3 have been tested while using a laser gas mixture, which was obtained by using gas supplied by the sonic orifice mixing system. All modules have been performing satisfactorily using the gas mixture.

Cryogenic Target Insertion Mechanism.

A target-positioning system is desired for the EBS that will:

- Move a target through an airlock into the proper location.
- Cool the targets to 4 K.
- Maintain an absolute target positional accuracy to $\pm 5 \mu$ in the x, y, and z directions when the target is cold.
- Contain an optically finished alignment sphere, which will act as both a radiation shield and the alignment reference for the laser beams.
- Maintain the relative positional accuracy of the alignment sphere and target centers to within 5μ in the x, y, and z directions when the target is cold. Move the reference sphere out of the beam paths before each shot in 0.001 s. Figure 30 shows the

disassembled and assembled views of a conceptual design in the region of the target.

The present effort is in the areas of determining the target stalk movements when cooling the targets, and in devising a means of accurately locating each target.

A fixture has been built to determine target stalk movement when cooled to 4 K. Positional repeatability after the stalks have encountered numerous successive thermal cycles will also be determined.

A fixture for testing a variety of target-locating schemes has been made. The first tests were performed on a kinematic-locating system. Figure 31 details the type of kinematic mount used. The test results show that this locating system should be able to repeatably locate the target to within the $\pm 5 \mu$ requirement.

A preliminary thermal analysis has been performed on the target-cooling region of the cryogenic target insertion mechanism. The purpose of the analysis is to determine the acceptable amount of thermal loading in the region of the target before inhomogeneities are likely to occur in a frozen target.

Fig. 30. Conceptual design in the region of the target.

Fig. 31. Details of kinematic mount for locating target.

The Ayer finite element heat transfer code was used for performing the analysis. Figure 32 shows some temperatures after 459.5 s of cooling time; also the boundary conditions are given for this analysis. At 459.5 s, the temperature in the alignment sphere ranges from 26.52 K to 26.48 K. The temperature in the cooling block ranges from 2.82 K to 3.02 K. The analysis was stopped at this point in order to change boundary condition 1 so that the effect of the helium exchange gas can be modeled; also a Pyrex target stalk will be placed at the end of the stainless-steel shaft in order to determine the temperature at the target.

Fig. 32. Thermal analysis of cryogenic target positioner (CPT) time = 0.4595E+03.

A thermal stress analysis was performed on the cooling and the alignment sphere. The analysis was conducted in order to determine deflections and stresses when cooling these parts. Results from the Ayer heat transfer program were useful in that it could be assumed that a constant temperature would exist throughout each part. For the analysis, both parts were assumed to be at 4 K. This is a good assumption since the alignment sphere must be close to 4 K in order to freeze the targets properly and also because of the fact that below 60 K the thermal expansion coefficient is very small.

Figure 33 shows the finite element mesh with the boundary conditions. Figure 34 gives the vertical displacements and Fig. 35 gives the horizontal displacements. Figure 36 shows the maximum stress. It should be noted that the analysis shows that the alignment sphere will, indeed, remain a sphere; also, since the yield strength of copper is 1 265 580 kgs/sq m, some localized yielding occurs in the cooling block.

Room-Temperature Target Insertion Mechanism. Due to the requirement of designing a target insertion mechanism that can be

Fig. 33. Thermal stress analysis of a copper alignment ball in TSL-86.

IDENTIFICATION	CONTOUR VALUE
A - - - - - A	.171236E-02
B - - - - - B	.146772E-02
C - - - - - C	.122310E-02
D - - - - - D	.978483E-03
E - - - - - E	.733862E-03
F - - - - - F	.489241E-03
G - - - - - G	.244621E-03
H - - - - - H	0.
I - - - - - I	.244621E-03
J - - - - - J	.489241E-03
K - - - - - K	.733862E-03
L - - - - - L	.978483E-03
M - - - - - M	.122310E-02
N - - - - - N	.146772E-02
O - - - - - O	.171236E-02
P - - - - - P	.195697E-02
Q - - - - - Q	.220169E-02
R - - - - - R	.244621E-02
S - - - - - S	.269083E-02

Fig. 34. Thermal stress analysis of a copper alignment ball in TSL-86.
Time 0.000000 /R DISP

IDENTIFICATION	CONTOUR VALUE
A - - - - - A	.893485E-02
B - - - - - B	.829666E-02
C - - - - - C	.766844E-02
D - - - - - D	.702024E-02
E - - - - - E	.638204E-02
F - - - - - F	.574383E-02
G - - - - - G	.510563E-02
H - - - - - H	.446742E-02
I - - - - - I	.382922E-02
J - - - - - J	.319102E-02
K - - - - - K	.256281E-02
L - - - - - L	.191461E-02
M - - - - - M	.127641E-02
N - - - - - N	.638204E-03
O - - - - - O	.142247E-16
P - - - - - P	.638204E-03
Q - - - - - Q	.127641E-02
R - - - - - R	.191461E-02
S - - - - - S	.256281E-02

Fig. 35. Thermal stress analysis of a copper alignment ball in TSL-86.
Time 0.000000 /Z DISP

Fig. 36. Thermal stress analysis of a copper alignment ball in TSL-86.
Time 0.000000 /MX stress

installed in the target chamber by September, it was decided to delay the cryogenic target insertion mechanism design so that one that will operate exclusively at room temperature could be developed.

A track-and-cart arrangement for carrying the target through the airlock to the final target position has been designed. A model of this idea has been fabricated and is being tested. Thus far it has been performing rather nicely.

Two methods for locating the targets in the chamber are being examined. One is called the hard-stop method; the other is called the kinematic mount method. The hard-stop method consists of accurately locating the target relative to a target holder, and then accurately locating the target holder on the cart. The cart will then be located in the target chamber by means of a tight precision track and by seating against a hard stop. For the kinematic mount method, the target is located relative to a target holder and then placed loosely on the cart. The cart will deliver the target holder to a receiver block where it will be accurately located by a kinematic mount as described in Fig. 30. The hard-stop method has been tested and has positioned the targets well within the $\pm 2.5\text{-}\mu$ toler-

ance. The hardware for the kinematic mount method is being assembled.

An aluminum mounting bench, which has a rectangular cross section, has been designed. This mounting bench will support the portion of the insertion mechanism that is inside the vacuum chamber. Consideration is being given to making the beam out of stainless steel.

Analysis for EBS Target Chamber Turning Mirrors. A stress analysis was performed on the EBS target chamber turning mirrors. The analysis was performed to determine the deflections that will occur in the mirrors when they are mounted and loaded by their own weight. The SAP IV finite element stress analysis code was used for this purpose. Figure 37 shows the mirror orientation with respect to the horizontal and vertical planes, and defines the x, y, and z directions.

Three mounting configurations were modeled. Two of the three configurations used kinematic mounts, the third used a six-point mount approach. The first kinematic scheme had the cone and the v-groove located at a higher elevation than the flat. The maximum deflection of 0.11μ occurred at the upper edge close to the minor axis; the maximum

Fig. 37. EBS turning mirror orientation.

deflection near the center of the mirror was 0.09μ . Figure 38 shows the actual location on the mirror where these deflections occur. The second kinematic approach located the cone and v-groove at a lower elevation than the flat. The maximum deflection was 0.46μ , which occurred at the lower edge close to the major axis.

Fig. 38. Location on mirror when deflections occur.

The maximum deflection near the mirror center was 0.06μ . Figure 39 summarizes these results. For the six-point mount, three points had the x, y, and z directions. The remaining three points had only the x direction fixed. The maximum deflection of 0.05μ occurred at the lower edge near the major axis. The maximum deflection near the mirror center was 0.02μ . Figure 40 summarizes these results.

In summary, these results indicate that the six-point mount will give the minimum deflections of the schemes analyzed. However, if one chooses to mount the mirror kinematically, the cone and v-groove should be placed at a higher elevation than the flat.

High-Energy Gas Laser Facility (HEGLF) [Gutscher, Thuot, E-4].

Introduction. The HEGLF being developed by L-10 will use a distributed task computer system for laser control. The system will consist of an HP-3000 central minicomputer and several hundred microprocessors distributed throughout the system. The laser gas and vacuum systems, high-voltage charge systems, and mirror-positioning stepping motors are typical subsystems the microprocessors will control. The microprocessors will also serve as data-acquisition controls. The central minicomputer will provide overall control and data reduction for the microprocessor network and it will be required for

Fig. 39. Deflections for kinematically mounted EBS target chamber turning mirror.

Fig. 40. Deflections for six-point mounted EBS target chamber turning mirrors.

full system testing and operation. The microprocessors will have local control capabilities so that subsystems can be operated without the central computer. The entire system will be tied together with electromagnetic impulse (EMI)-immune fiber optic data links.

Fiber Optics. One of the basic components of the HEGLF distributed task microcomputer network is the communication and data fiber optic links. The control system will be subjected to high-level EMP interference generated by the 500-kV, 6×10^6 J pulse power supplies. The network microcomputers are locally shielded and grounded to a distributed hf ground mesh. This mesh provides local common grounds but cannot insure a common ground for the facility. Communication to various areas of the facility must be done through a nonconductive, EMI-immune medium, fiber optics. In this system fiber optics will be used for digital asynchronous ASCII communication between computers, analog data acquisition, and control of elements in various subsystems, for example, valves and contractors.

Over the past year these three required functions have been developed. Recently we have

improved the digital data-communication links through the use of a new pure silica cable. This cable has lower attenuation, about 100 dB/km, it is rugged, and will withstand 14 800 dr tensile. The average operating length limit with this cable and our fiber-optic transceiver is 86 m. A three-sigma design with these components would limit the length to about 60 m. We have tested this type of fiber optic link for 10 bits with no errors at the design length limit and 38.4-k band.

The second function, analog data transmission, uses the same type of pin diode-amplifier as the digital system shown in Fig. 41.

A linear coupler, current transformer, or shunt is used to generate a current proportional to the current in the high-voltage conductor. This generated current is used to drive a light-emitting diode (LED) as a fiber-optic transmitter. Thus the transmitter is self-powered from the circuit measured and entirely isolated from ground. At the other end of the fiber-optic cable a diode-amplifier integrated circuit (ic) is used as a receiver. It generates an output voltage proportional to the current in the high-voltage conductor. This system

Fig. 41. Analog fiber optic link for current measurement at high potential.

rejects the common mode voltage of the source and produces EMI-free output. This system has been tested over a 17-dB current range, 20 to 100, with a Pearson 411 transducer and found to be linear within a few per cent. Several of these units have been installed in the HEGLF prototype where they are working well in the severe EMP environment. The length limit for this type of transmission is about 30 m where the full dynamic range is important. With 25 m of fiber-optic cable, the output is about 2 V with 100-V input to the transmitter. The signal bandwidth, 3 dB, is about 10 MHz.

The third function, remote control, has been accomplished with a special solid-state relay, which has a fiber-optic input. This relay is powered by the circuit being controlled so that no external power supply is required. The relay operating on the 117 Vac line can switch up to 8 A of load current with an input of about 1.5 ms W from the fiber-optic cable. The circuit is immune to line transients since it is a fully floating two-terminal device. This device will be applied where it is necessary to control a solenoid valve, motor, or contractor from the output of a microcomputer.

Used in these ways, fiber optics will reduce or entirely eliminate the need to route wiring into the microcomputer shielded areas. This will improve system reliability and increase resistance to the EMP environment.

Stepping Motor Controller. Many of the HEGLF mirrors must have the capability of being remotely positioned. These mirrors will be on mounts driven by stepping motors. The stepping motor controller will provide the interface between the central computer and the motors. It will contain a microprocessor and associated circuitry that will enable it to convert commands received over a serial fiber-optic communication link into parallel outputs capable of driving stepping motors.

The stepping motor controller design is nearly complete. It will use the Motorola MM01A micromodule card containing the 6800- μ processor for the local controller. A logic card and a motor drive card are required to supplement the MM01A. A software programmable reset has been designed into the system so that during power down, power interruptions, or shot times the system can be disabled so that noise will not alter the program or stored

data. A battery in the controller will preserve the data stored in memory when power is removed from the box. A DAC and multiplexer have been included to monitor power supply voltages and box temperature for state-of-health diagnostics.

The main power will be provided by a 24-Vdc power supply, which will feed a dc-to-dc converter in the controller. The converter has been designed with special shielding and low coupling between input and output to combat EMI intrusion into the box. Opto-isolators will decouple the 24-V powered motor drive transistors from the rest of the logic. The motor drive card will be in a separate shielded compartment in the box and the 24-Vdc power lines will pass through line filters before connecting with the converter or the motor drive card.

It will be possible to address each motor controller individually from the central computer or from a hand-held controller. As many as 32 motor windings will be operated by each controller; this means that each unit can control eight motors with four windings each, or four motors with eight windings each. Only software changes are required to switch from one motor configuration to another.

Circuit design is almost complete and the box layout has been drawn. The cards are being drawn and should be finished in 30 days.

Hand-Held Controller. The hand-held controller will be used for local operation of the stepping motor controllers. It will contain a 6800 microprocessor that will convert commands entered from a keyboard into a serial command format that will emulate the commands sent from the central computer. These commands will be transmitted over fiber-optic communication lines to the motor controller. Liquid crystal displays on the hand-held controller will inform the operator of individual motor status under its control.

The design of the hand-held controller is complete and a prototype is being fabricated. The microprocessor board has been received, assembled, and tested. Some components are still on order; assembly and testing of the complete unit will take place as soon as the components arrive.

Beam Alignment. One of the crucial HEGLF problems is to align and focus all 72 beams onto a 500- μ meter target and keep them there until after each shot. The stepping-motor-driven mirror mounts

will be part of the Leam alignment system. Detectors strategically placed along the beam lines will provide position and focus data to an observer or to the central computer. In the manual mode an observer will be able to align one beam at a time. The computer will be able to align all 72 beams simultaneously in the automatic mode.

A study of various alignment schemes and detectors has been initiated. It is hoped that by January 1978, an optimum approach will have been determined and work can begin on prototype construction.

PHERMEX Enhancement Program (M-2)[Johnson, E-5]. Software for R-7912 digitizer calibration via the in-house designed auto-cal subsystem has been written and is about three-quarters tested. The auto-cal hardware, believed operational, will not be tested until calibration software has been written for the other digitizing devices in the system. Approximately three-quarters of the auto-cal features have been verified.

Group M-2 has contracted with Physics International to build a multiple pulser to provide driving voltage for the hot-cathode space-charge-limited diode electron gun on PHERMEX. The specification allowed interpretation on acceptance testing and test-data reduction procedures. Some time was spent here and at the Physics International facility examining methods and equipment available for performing testing and arriving at a statistical philosophy for the specified confidence and reliability figures. The possibility of transporting the microNOVA backup data-collection system to their facility for total sample data analysis was discussed.

The Data General microNOVA equipment arrived in February without operating software, which required in-house effort to write a driver for the diskette, an executive for installing-loading-executing diskette resident programs, and two utility-debugger programs. These are all operational. The NOVA-3 instruction definition symbol table was modified and installed in the macroassembler of M-2's Data General eclipse system; the microNOVA program development object code is thus transferred to the eclipse diskette, the common storage medium for the two systems.

The Data General interface circuit boards have been wire wrapped for the 16-bit CAMAC branch driver and are being checked out. Programs have been writ-

ten for retrieving data from M-2's PTD and Biomation 8100 digitizers via microNOVA/CAMAC and will be debugged after branch driver check-out. Another program must be written for the R-79123 digitizer.

Detonation and Shock Wave Physics Support (M-3, M-6, WX-7) [Love, Lundy, Parker, E-3; Martin, Rose, E-2]. Work has continued on the new firing site control system being developed for M-3 and M-6. This system will use an Intel 8080 based microcontroller to replace existing relay control systems and will provide accurate preshot timing signals and more comprehensive interlocking of equipment than the existing systems provide. About 85% of the system circuit design and pc board layout have been completed and installation of the first system should be finished near the end of the next quarter. Panel control layouts have been made and program flow charts are nearly complete.

A high-voltage, 0- to 100-V, oscilloscope calibrator for M-6 was completed and delivered. The design for a similar low-voltage, 0- to 10-V, unit was completed and will probably be built at the beginning of the next fiscal year.

Extensive work on support electronics to provide short, ~ 15 -ns pulsing of 40-mm microchannel plate image intensifier tubes was done. The capacitive load presented by these tubes is as high as 240 pF, which is considerably more than the 30 pF of the 18-mm tubes used previously. The manufacturer (ITT) will not permit supplying overvoltage to the photocathode microchannel plate gap as was done previously to attain short turn on. The new technique is to generate a pulse of 1000 to 1200 V with avalanche transistors connected in series (up to 12 transistors), and a 30- Ω coaxial charge line. This pulse is then attenuated at the image intensifier tube to the required 270 V. The attenuation gives an effective source impedance significantly lower than 30 Ω to allow rapid charging of the tube capacitance, which minimizes reflections on the drive cable due to the capacitive tube load. In the middle of this development the avalanche transistors that had been used, the Motorola MPSU-04, ceased to avalanche. The problem was finally traced to a change in Motorola's manufacturing process. Considerable time was spent locating another transistor suitable for avalanche service at high voltage, 250 V or higher per transistor. Finally a National 2N3700 was found to

work satisfactorily and a hybrid assembly is being laid out to connect six of these transistor chips in series. Two of these six will be used in the final version of the pulser. An abstract of a paper describing this development was submitted to the IEEE Nuclear Science Symposium to be held in October. Authors of the paper were Lundy, Parker, Lunsford, E-3, and Martin, E-2. The paper also describes the design of the dc voltage divider network for the image intensifier tubes. Job orders for five 10-channel avalanche pulsers of this type have been received from M-3 and WX-7.

Instrumentation to detect certain anomalous events during the static test firing of a US Air Force MX missile stage was prepared, installed, and operated during a static test at the US Air Force Rocket Propulsion Laboratory, Edwards Air Force Base, in January. This work was a cooperative effort with Group M-3. In connection with the instrumentation support provided in this test and with previous M-3 support to Navy programs, we have begun to investigate other equipment to support similar programs. This includes the modification of videotape recorders to record high-frequency analog signals and high-speed computerized data-acquisition systems with 1-MHz or 10-MHz digitizing rates; the development of a 20-channel CMOS time-interval meter, battery powered, with 100-ns time resolution over a 10-min interval; and investigation of acoustic emission signal techniques for certain diagnostic purposes.

A proposal to build a fast, low-resolution (100 pixels) solid-state camera capable of 50 000 frames/s, a period of 5 ms minimum, and capable of distinguishing eight shades of gray was prepared in conjunction with E-5 and submitted to the US Air Force Space and Missile Systems Organization (SAMSO) at Norton Air Force Base. A unique feature of this camera is that the continuously recorded picture data are prestored in a first-in first-out (FIFO) memory. A trigger signal applied at any time allows the recovery of the previous 5 ms of pictures. This proposal resulted from previous M-3 discussions with SAMSO.

In February, Love and Lundy participated in discussions with representatives of the US Navy Strategic Systems Project Office, the Lockheed Missiles and Space Corp., and the Hercules Power Company concerning instrumentation developments required for

rocket motor test and development programs. It is planned, in conjunction with M Division, to continue work in these areas.

Image Processing System (M-8) [Selfert, E-5]. The M-8 image evaluation system is being upgraded with E-5 support. Effort is now being directed at enhancing the magnetic tape subsystem of the imaging PDP 11/40 minicomputer so that tapes written on either the 11/40 or an LTSS 7600 may be easily read by either system. Additionally, the tape handling mechanism of the 11/40, used for image processing, is being upgraded so that the magnetic tape to disk transfer of image data is more efficient and easier to use. By employing many of the file handling features of the UNIX operating system the image processing system user will be afforded much more powerful means of manipulating and displaying the large data arrays encountered in imaging (up to 512 by 512 8-bit picture elements).

Future effort will include assisting M-8 in installing the software interface for a high-speed serial data link to the Central Computer Facility (CCF) integrated computer network (ICN), for a multiprocessing image evaluation system, which will consist of the present PDP 11/40 and a recently purchased PDP 11T/55. Software required to interface the SDS video digitizing scanner to the UNIX operating system will also be prepared. The current level of support will be continued through December 1977.

Intense Neutron Source (INS) Support (P-14)[Barnett, W. Ford, Robinson, E-5; Myers, E-2]. The INS facility will be used by LASL to conduct a program of high-level neutron irradiation of metals and insulators that are to be used in the national magnetic fusion energy (MFE) program. The major objective of this program is to contribute to the nation's energy production. The 14-MeV neutrons produced in the INS facility will be used primarily to study radiation-damage phenomena similar to that anticipated in fusion reactor structural materials.

The early development of fission reactors was significantly delayed when radiation damage effects caused a flurry of re-engineering and redesign. In fusion devices much higher energy neutrons are produced with greater radiation damage effects. The US Government, through ERDA, has initiated a program to study radiation damage effects; a major portion of this effort is invested in the construction of

intense neutron sources. The LASL INS facility is under construction and expected to be operational by late 1981.

The unique feature of this facility is the use of a supersonic flow of gas to dissipate an enormous quantity of heat generated in the neutron-producing target by multiple Coulomb collisions. By producing 14-MeV fusion neutrons for radiation damage studies of potential fusion reactor materials, one must contend with the problems of heat dissipation in the target material. In all cases, the target material must move rapidly to continually remove heat and allow sufficient neutron production.

The monitor and control system required for INS can be separated into three general areas: the operational controls for the tritium ion beam accelerator and the deuterium jet target; the operation support systems, such as communications and radiation safety; and the experimental support system. The monitor and control system will provide flexible and reliable operation of the entire facility.

An independent hard-wired, fast-protect system will be provided to rapidly shut down the intense ion beam in case of a major malfunction before excessive equipment damage occurs. All personnel interlock and safety systems will also be tied into the fast-protect system.

Within the various INS disciplines, each module retains complete local control for purposes of independent tuneups, maintenance problems, or diagnostic evaluations. Those modular control channels, needed for data acquisition and/or control, are channeled to a computer at a centralized location. The INS facility contains six basic modules: high-voltage power supply, ion source, beam transport, jet-target pressure-recovery system, distillation processing unit, and the experimental data acquisition and control.

This system will control the two tritium ion beams, the gas flow loops, and the experiments in the two source cells. The system receives, processes, and records all data required for the operation and safety of the facility and to conduct experiments.

Every significant parameter of the facility such as voltages, currents, temperatures, and pressures will be received by this system. All parameters are obtained by electrical signals conditioned

to suitable form and transmitted through transducers or other means. Signal processing will occur at electronic stations throughout the INS and output will be converted for transmission to the computer. The computer analyzes the data and takes appropriate action depending on the parameters involved and its value. Possible actions are alerting the operator, making an adjustment, shutting down the system, storing the data for future analysis, or computing statistical parameters for large volumes of data. The data may be output in a number of different forms.

The control signals may be initiated individually by the computer or at operator discretion even though control signal transmission is computer controlled. At every electronics station there is provision for overriding computer control for check-out and troubleshooting. The system will be designed so that a computer failure would only result in continued facility operation at the last setting. A separate system will rapidly shut down the intense ion beam in case of a major malfunction before excessive equipment damage occurs. A computer-aided control system will be used for the current of T^+ ions produced in the ion source. It will control the beam-transport magnets, guiding the beam through the beam line to the jet target and ensuring that the intersection is 1 cm in diameter. The necessary steering and focusing parameters will be operator-provided with the computer ensuring that the commands are effected instead of measuring beam parameters and making corrections in a closed-loop fashion.

The computer will control deuterium gas pressure and temperature and actuate the necessary control valves and heaters to maintain these operating parameters. It will also detect error or danger conditions and take appropriate action to isolate or correct the gas flow loops.

The isotope separation process will be computer controlled with working conditions supplied by an operator or by stored program with supplied operating conditions.

Neutron source cell data will be recorded and processed and beam parameters may sometimes be tailored to accommodate experimental conditions. Safety interlocks and fast-protect systems will be computer monitored. Thus system status data will immediately and automatically be available to the

operator. Radiation monitoring devices will also be checked.

The computer will be connected to a control console that will have visual readouts of critical operating parameters for both the facility and experiments. Many different options will be available to the operator for displaying and analyzing the data. Necessary peripherals will be required to allow data reduction and theoretical calculations by experiments on and off the control computer.

Experience with similar accelerators and facilities in many parts of the world over the last decade have shown that for data acquisition and control a digital computer is indispensable. Many of the processes occur so fast that an operator cannot respond with sufficient speed. By computer use, the information displayed at any one time can be limited to relevant system conditions or specific information needed. Color displays also allow specified information to be highlighted with respect to other information. Although the working display (color CRT) is volatile, hard-copy printouts are available either automatically or on demand. A supervisory computer control will be used rather than a closed-loop feedback for the entire process. Data will be collected via two CAMAC serial highways.

The INS computer system will handle several hundreds of monitor and control signals. The computer will also be required to handle up to 10 terminals in a multiprogramming environment. Large data bases will be generated with the collected data and their subsequent analysis. This, plus past experience with similar systems, generates the requirement of the following system hardware.

1. A CPU with approximately 90 k (16-bit words) with a cycle time of 1 s or less. This amount will accommodate user tables and programs, utility programs, and an operating system for multiple users plus the monitoring and control software.
2. A disk with approximately 90-Mbytes to store users programs, the operating system modules, the controls electronics and experiment data base, and the reformatted analyses data.
3. Dual 9-track magnetic tape drives required to efficiently store archival data, programs, and other files. Two units are re-

quired for master file updating, merging, and sorting. On occasion data will be dumped to magnetic tape for analysis in the CCF. Also, the disk will be periodically dumped to magnetic tape for backup. The units will be used for maintenance programs since they will represent the only feasible input media.

4. The initial terminals will be CRT and hard-copy output, each with keyboards. This is the minimum feasible in the foreground-background operation planned.
5. A communications multiplexer is required for expansion plus a means of communication to existing microprocessors.
6. A CAMAC interface is initially required to communicate from the computer to the CAMAC modules.

With the exception of the issuance of the INS minicomputer specification, activity has been relatively small during this period. Major effort has been a prototype for the beam-on-target (BOT) project that uses three microcomputers in a CAMAC data-monitoring and control system. This system has been totally implemented including a data-reduction program for the CCF.

The BOT system has four major parts including the jet target and hydrogen blowdown, beam transport, vacuum system, and ion source which is a subset of the INS system. The CAMAC system and microcomputers collect data, process data, issue commands where required to actuate relays or motors, and record the data onto magnetic tape and a CRT terminal.

The ion source portion of the BOT system is being checked out. Full system check-out is expected to start about June 1, 1977.

JUMPer Project (Q-PR)[Kozubal, Milich, E-5; Winston, E-3]. E Division has continued to provide hardware and software support for JUMPer Project experiments.

Groups E-5 and AP-3 have participated with Data General Corp. in the evaluation of AOS software. Several software problems were identified and documented and this information was sent to Data General. A multiterminal AOS system with one dial-up port has been used extensively. Conversion of PLOT-10 TCS and advanced graphing routines to AOS have

been accomplished. Software to allow generation of DOS and RTOS programs under AOS is under development.

New data-acquisition and reduction programs have been produced, and existing programs upgraded to support blowdown II, PRL-II, and off-line diode experiments. A second Biomation 805 transient digitizer was added to the PRL-II data-acquisition system to record the ir diode reference beam.

The information retrieval programs for the AP-3 budget data base have been improved and converted to AOS. These programs provide on-line access to all job orders and purchase orders via a dial-up terminal in the AP-3 Group Office.

Prototype models of fast transient digitizers manufactured by LeCroy and SEC were evaluated. Each of these provides sampling rates up to 50 MHz, has 8 bits of resolution, and are CAMAC compatible.

Routines have been written to allow down-line loading of diagnostic programs into a microNOVA from a NOVA-3. These are being used by E-5 to develop a microNOVA CAMAC crate controller. One of these crate controllers will monitor and control the new continuous flow recirculating loop (CFRL).

Four additional data-acquisition systems have been ordered. These will each use a NOVA-3 and a dual diskette drive.

Group E-3 JUMPer support mainly consists of working with C. Tallman, AP-1, designing and fabricating electronics instrumentation. The four-channel digital delay mentioned in the previous report was completed and seems to be working satisfactorily. The four delays are variable in 100-ns increments to 100 ms. Three acoustic gas analyzers, also described in the last report, have been completed and work on three more has started. The electronics seem to be satisfactory. A problem has been encountered in that some of the gases analyzed are quite corrosive and cause problems in the cell where they are contained. Tallman is working on this problem and fabrication of more units will begin when it is corrected. These analyzers utilize the difference in the velocity of sound in various gas mixtures to indicate gas composition. Two two-channel trigger delays were built recently. Each has a maximum delay of 0.5 ms and one of 10 ms. Both units were sent to Oak Ridge for use there. Two "minipulsers" are being fabricated by A. White-

more, E-2. Pulser output is a variable repetition rate and variable width pulses to drive solenoids.

Real-Time Inventory System (Q-2) [Ethridge, Kuckertz, E-5]. Group Q-2 is engaged in a research and development program to investigate ways to continuously inventory and safeguard special nuclear material (SNM) while in storage vaults.

The E-5 support of this project has been expanded from 0.3 staff member to 1.3 staff members through this fiscal year.

Previously we were participating in only the shelf monitor design effort, but our role has now been expanded to include the systems software design effort.

The real-time inventory system physical layout is shown in Fig. 42. The basic concepts of this system are to continuously monitor all SNM in the storage vault; to measure the physical and nuclear parameters of all SNM entering and leaving the vault; and to monitor all personnel entering and leaving the vault. A minicomputer (Data General NOVA-3 in the prototype system) will be used on-line to do the monitoring and transaction processing. A typical transaction would take place as follows. A person wishing to place SNM into the storage vault would enter a request for this transaction at the transaction terminal. The computer would ask certain questions to authenticate the requestor's identity and authority. The material destined for the storage vault would be placed in the vault via door

Fig. 42. Physical system layout.

1 of the material verification station (MVS). Next, the material would be weighed and a gamma spectra and neutron count taken. This information would be retained by the computer until the material is removed from the vault. The requestor then enters an ante-room of the vault via the gamma portal monitor. The requestor is not permitted to carry SNM or any metal objects through the gamma portal monitor. The SNM is removed from MVS via door 2 and placed on a previously designated shelf monitor in the vault. The requestor then leaves the vault and anteroom without any SNM or other metal objects. The SNM is monitored continuously for evidence of unauthorized tampering or removal.

Other types of transactions are completed in a similar manner with the basic proviso that all SNM enter and leave the vault via the MVS while all people enter and leave the vault via the gamma portal.

With the exception of the shelf monitor and some special-purpose interfaces, all of the system hardware is being purchased from commercial sources. The main thrust of the system development is divided into two main areas; the design and development of the shelf monitors and the design and development of computer software to operate the system.

Shelf Monitors. The shelf monitor has been redesigned primarily to reduce cost. Electronics material costs have been reduced from approximately \$70.00 to \$30.00 in the 10 000 quantity range. This cost reduction was realized by replacing the hardware logic components with an Intel 8048 microcomputer. The integrated circuit package count of 40 has been reduced to 7. Approximately 20% of the microcomputer on-board program memory is required to achieve present shelf monitor requirements. The addition of intelligence to the shelf monitors will undoubtedly lead to an increase in the design requirements as the system development continues. The 8040 contains 1 k of ROM program memory. For the first 16 shelf monitors, the 8748, which contains 1 k of UV EPROM program memory, will be used. The use of the 8748 with erasable-programmable memory allows for systems changes with no hardware cost involved.

As a result of this program, Group E-5 has developed complete 8048-8748-8035 microcomputer system design capability. The microcomputer software, the hardware breadboard, and the programming of the

first 8748 is complete. System check-out of the new shelf monitor design is beginning.

Operating Software. The system schematic diagram is shown in Fig. 43. Most of the system is standard and software supplied with the computer by the CPU manufacturer will be used to control this portion of the system. Custom device drivers will be needed for shelf monitors, the CAMAC crate controller, and the material verification station.

Applications programs will be required to process data to and from the special-purpose peripheral devices. These programs will be required to detect tampering with the shelf monitors; to allow for radioactive decay of SNM without initiating an alarm; to initiate an alarm condition when an abnormal event occurs within the system; and to process transactions. A great deal of effort will be spent defining an abnormal system event.

Device drivers have been written for the shelf monitors and the CAMAC crate controller. The shelf monitor driver is approximately 90% debugged; the CAMAC driver has not been debugged due to crate controller hardware bugs.

DYMAC Program (Q-3) [Ford, Slocumb, Sandoski, Glascock, Dorin, Wooten, E-5; Hagen, Q-3]. This major safeguards research and development effort merges state-of-the-art nondestructive assay instrumentation and computer technology with the objective of demonstrating a workable, cost-effective system of stringent, "real-time" control of nuclear materials in a modern plutonium-processing facility. Emphasis is placed on developing practical solutions to generic problems of materials measurement and control so that resulting safeguards techniques and instrumentation will have widespread applicability throughout the nuclear community.

The traditional methods for the safeguards assessment of materials accounting and control within a plant, namely periodic plant shutdown and cleanout followed by physical inventory and material-unaccounted-for (MUF) and limit of error of MUF (LEMUF) calculations, have certain obvious shortcomings that have long been recognized. Principal among these shortcomings is the lack of timeliness of the material assessment, the relative insensitivity of the accumulated figures representing MUF, the practical difficulties in achieving a MUF of less than 0.5% throughput (or some small "trigger" quantity of

Fig. 43. System schematic diagram.

fissile material), and the severe economic penalty levied by frequent shutdowns and cleanouts. Clearly there is a need for a system of in-plant materials control that can provide accurate, real-time inventory assessment based on direct measurements of special nuclear materials. Such real-time accounting systems are only now feasible because of recent advances in nondestructive assay (NDA) technology and supportive computing and data-handling capabilities.

Under DYMAC, material balances are drawn around each unit process, which is defined on the basis of process logic, residence time of material in process, and/or accessibility for measurement. For example, a unit process could be a dissolver tank, a single ion-exchange column, or a storage area. All material composing an input batch to a unit process is measured. The batch product, residues, and wastes leaving the process are also measured, thereby enabling a direct determination of the batch MUF (MUF - input minus product, residues, and wastes, all being measured quantities). The error associated with MUF, customarily called LEMUF, can be determined from knowledge of the various measurement un-

certainties. Cumulative material balances and control charts can be maintained for all unit processes in a plant by a computer-based system programmed to alarm if any cumulative MUF value should signal the possibility of either unauthorized removal of nuclear material or excessive holdup. The individual batch or unit process MUF values can then be combined to obtain the overall plant MUF without losing the detailed information contained in the individual MUFs. This accounting system provides not only material accountability data, but also basic information on plant operations, process and quality control, criticality safety, and other factors.

DYMAC, Phase I, involved a pilot program of research and development and in-plant testing of nondestructive assay instruments coupled to an interactive computer system. Several NDA instruments were used routinely to draw timely material balances around individual processes. DYMAC, Phase II, is a follow-on program in which the technology, equipment, and experience developed in Phase I will be expanded, tested, and subsequently integrated into

the new Plutonium Facility for full-scale demonstration of the DYMAC system.

Group E-5 is responsible for the specification, procurement, design, and installation of the DYMAC computer hardware and software as well as the communications lines and terminals.

Phase I - DP-Site Progress. A different unit process, metal dissolution, has been incorporated into the DYMAC system at DP-Site. This unit process switch was used to check out the ability of the DYMAC software to respond to changes by virtue of the packet and image structure discussed in the previous report. This change showed that the responsiveness was excellent but that some better implementation tools were required so that this kind of change could be accomplished by operational personnel instead of system programmers. As a result, a packet editor and debugger are being designed. This conversion to a new unit process now completes the effort at DP-Site. The NOVA-840 computer that has been used will be moved to TA-55 where it will be used as a backup and training system.

Phase II - TA-55 Progress. The new computer system has been installed and accepted. Additional air conditioning has been requested for the computer room. The accountability program that has been running at DP-Site has been rewritten to run on the new machine using the INFOS data-base management system. This program has been debugged and is now running.

The structure of the TA-55 data base has been agreed upon and the impacted software is being rewritten. The procedures for interacting with the Laboratory-wide accounting system have been decided upon and a DYMAC transaction magnetic tape was written and has been successfully read by the ADASF system.

For material leaving TA-55, an ADASF-like transaction will have to be printed on four-part paper. The format for this printout has been designed, tested, and approved and a search for the proper printer is under way. A general ledger scheme has been agreed upon to aid in daily reporting to ADASF.

The information needed to characterize the transactions in the ^{239}Pu research and development wing is being gathered by CMB-11. When complete

these transactions will be implemented and demonstrated to the wing supervisors for approval.

The various back-up procedures have been designed and approved. Design and development is continuing in traffic simulation and monitors, program size reductions, uniform methods of error returns and logging, and the measurement control program.

The communications network has been designed and the materials purchased. Group ENG-4 is supervising the contractor installation and when it is completed, E-5 will check out and accept the network. The 1801 study for the terminals has been approved and procurement has been started. Circuits for use by the various instrument designers have been designed and are in the process of being tested and approved.

Instrumentation Support

Introduction. In our support of LASL programs and basic research activities there are many opportunities to develop unique electronic instruments or instrumentation systems, which may have a wider area of application than the specific purpose for which they were initially intended. This section of the report documents these developments and hence makes their results available to a wider audience.

Model 617 Serial Display and Driver (AP-3)[Nickell, E-5]. In computer-based data-acquisition systems it is often necessary that the computer equipment be located some distance from the experimental apparatus where it may be necessary to display computer acquired or recorded data. In order to fulfill this need for one of the data systems used in the laser isotope separation program, a special dual 20 alpha-numeric character display and associated driver system were developed. The design is based on a commercially available gas discharge tube with associated addressing and memory capability. This rack-mounted unit receives serial binary data (conforming to EIA RS-232-C standards) in ASCII format and displays the data on one of two 20-character displays. A unique device code can be assigned to each display encoder in the unit so that the chosen display may be addressed. Characters in a display may be addressed individually without disturbing the contents of other display characters.

Individual characters are 0.89 by 0.51 cm, fluorescent blue-green, and can be easily read at a distance of 6.10 m. The unit can be interfaced to any EIA serial output port or fiber-optic link. A jumper-selectable feature permits data transfer rates of 300, 1200, 2400, 4800, or 9600 baud. Data received by either EIA hard-wired cable or fiber-optic link is retransmitted as EIA hard-wired cable and fiber-optic link. Approximate cost of a dual display unit is \$2 000.

Tektronix 4000 Series Terminal CRT Controller - Model 627 (AP-3) [Nickell, E-5]. The cathode ray tubes (CRT) of the Tektronix 4000 series terminals can be damaged in a matter of hours by leaving them in the initial "flood" condition or the lifetime reduced severely by prolonged graphics displays.

In order to prevent this damage and prolong the life of the tube a special circuit has been designed to control the display function during long periods of terminal inactivity. The controller, contained on a pc card that plugs into a minibus connector, performs the following operations automatically:

- Initial paging following power-up.
- The display intensity is reduced to 10% of normal if the terminal receives no data from the keyboard or a computer within a selectable period of 5, 9, or 13 min.
- If no data is received within a selectable time of 16 or 32 min, a page command is issued.

Installation of this circuitry, which requires nothing more than insertion into a spare minibus card connector, could extend the life expectancy of the CRT by a factor of 3.

Tektronix R7912 Interface (AP-3) [Coy, Longmire, E-5]. Many of the LASL programs acquire their experimental data with Tektronix R7912 transient digitizers, which subsequently transfer these data to a computer-based data-acquisition system. A controller has been designed that accomplishes this transfer between the R7912 and a Data General Corp. (DGC) NOVA computer. Provisions are made with the controlled transfer commands from the computer to the R7912, to read the status of the R7912, and to transfer data from the R7912 directly to the memory of the computer (DMA transfer). The controller consists of a DGC general-purpose interface board (4040/4041/4042) with appropriate custom logic, a

DGC internal cable (4192), and a short adapter cable for connection to the R7912.

There are no inherent limitations on the number of controller (R7912) devices that may be attached to a computer. Each controller occupies one slot, draws 1.18 A from the ± 5 -V supply, and requires two device addresses. Standard DGC I-O protocols are used for this device. The controller may be jumpered for any desired device address. Two device codes are provided, which respond to INTA with separate device codes in an even-odd pair arrangement. On-board monitoring circuits are provided to verify correct operation and aid service operations. Eight units have now been constructed and placed in service.

Converter for ac-dc (AP-4) [Buchen, E-4]. A converter for a laser pulse intensity measurement system was designed and a mockup made. The laser light pulse passes through an acoustic chamber wherein a fraction of the photon energy is absorbed to produce an audible sound that is monitored by a capacity microphone. The electrical signal from the microphone is then amplified and fed to the ac-dc converter for data acquisition as a parameter in laser-activated chemical process studies.

Hollow Cathode Lamp Source (CMB-1) [Buchen, E-4; Harvey, E-2]. A 0- to 600-V, 0- to 500-mA power supply was obtained from LASL excess and modified to provide about 200 mA $\pm 1\%$ to a hollow cathode lamp for a joint CMB-1/CNC-2 experiment. Constant current voltage in the hollow cathode lamp, which contains neon gas and uranium metal, will be monitored while the lamp is illuminated by a tunable laser. As the laser is tuned through wavelengths unique to the uranium isotopes, the lamp voltage will vary as a function of isotope content and laser intensity.

Constant-Voltage Power Supply (CMB-3) [Buchen, E-4; Umphres, E-2]. A system has been designed and is being fabricated to provide 0- to 2000-V, 0- to 1-A dc with voltage regulation of $\pm 0.1\%$ NL-FL for surface ionization studies. To conserve space and reduce expense, the raw dc power for the voltage regulator will be obtained from the primary dc power and sent to the constant power system, which was recently installed on the CMB-3 mass spectrometer. The regulator contains an Eimac 290 Pentode as the pass element. The grid voltage is obtained from an

operational amplifier-drive transistor voltage regulator circuit.

Plutonium Reduction Furnace (CMB-11) [Buchen, E-4]. In cooperation with D. Court, CMB-7, a graphite-element resistance furnace was designed and was recently operated successfully at its design temperature and time-temperature program.

The active volume of the furnace is 25 cm diam and 50 cm high. The graphite element is an open top, solid bottom cylinder that is split for nearly its full height to produce a U-shaped resistor. It produces a uniform heat zone 45 cm high within $\pm 20^{\circ}\text{C}$ at 1000°C . A ceramic crucible, ~ 23 cm diam by 45 cm high, placed in the center of the element will contain the plutonium salt and reduction salts.

Several attempts were made to run the furnace at the required heat-up rate of $50^{\circ}\text{C}/\text{h}$ with Honeywell ceramic crucibles loaded with dummy salt loads; however, each of the runs resulted in catastrophically cracked crucibles. We contacted the CMB-6 ceramics section and they provided us with crucibles they had manufactured and carefully fired. Test runs with the CMB-6 crucibles have been successful. One more test run is planned soon before the system is installed at DP-West.

Weld Fixture Speed Control and Monitor (CMB-11) [Buchen, E-4; Reitzel, E-5]. A speed-control system for inert gas atmosphere arc welding of cylindrical components at DP-West and TA-55 was designed and is being fabricated. The controllers, containing Electro-Craft Model 550 controls and motors, have been modified to permit remote, digitally set speed selection, and two-station CW/CCW direction control as well as automatic start-stop with weld program. Provision is also made for monitoring and recording the motor speed and fixture position. Three two-station units are being fabricated by E-4.

Model 14 Profilometer Computer System (CMB-14) [Greenwood, E-3; Ford, Coy, E-5; Whittemore, E-2; Booth E-4]. Problems were encountered with the fuel rod optical profilometer data-acquisition system. These problems were associated with the obsolete magnetic tape transport being used and the excessive record lengths being generated, which involved special CCF software when the tapes were processed. The obsolete magnetic tape transport and associated data logger have been replaced with a minicomputer system that includes a magnetic tape

unit and a control chassis. System check-out has been completed and the unit has been installed at TA-21. The high-noise environment has created problems that are being corrected; the system is now operational and being used for fuel rod profile data acquisition.

The fuel rod optical profilometer is also being updated; the obsolete stepping motor indexer driver chassis and brush longitudinal encoder and readout system are being replaced with an improved driver chassis and magnetic encoder readout system.

A second system, based on this configuration, has been requested. This second system will be installed in the Wing 9 area of the CMR building. Some control chassis are complete. A radiation hardened encoder system that can tolerate the 1 to 10 R/h beta-gamma radiation environment expected in the Wing 9 hot cell has been found. Design, fabrication, and bench check-out of the control chassis and stepping motor driver chassis has been completed.

Profilometer Computer System (CMB-14) [Seifert, E-5]. A nuclear fuel pin profilometer system used by Group CMB-14 at TA-21 is being upgraded by E-5. The present system consists of an optical imaging system; Raytheon Model ADC 24, 14-bit ADC; Model 14 profilometer computer system; E-5-designed TTL-level multiplexer/interface system; brush-shaft encoders; Data General NOVA 2/10 minicomputer with 8 k of core memory; ASR-33 teletype; and a 7-track magnetic tape transport. The operational program image presently resides only in core memory. System enhancements include the addition of 8 k of MOS solid-state memory and a single-drive floppy disk, and inclusion of the operational program into the floppy disk based operating system.

Group CMB-14 is also upgrading their SM-29 system with the installation of a new profilometer system. The system will include a Data General NOVA-3 computer with 16 k of MOS solid-state memory, a TI KSR-743 terminal, a dual-drive floppy disk system, and a 7-track magnetic tape transport. The present NOVA-2 software will be upgraded for this system, since the NOVA instruction set is upwardly compatible.

V/F Converters (CNC-2) [Buchen, E-4; Decker, E-2]. Two 2-channel and one 1-channel V/F converters for use with multichannel scalars in laser system studies have been designed and fabricated.

They include Teledyne 4705 V/F converters and buffer/inverters that produce both positive negative polarity output pulses to multichannel scalars.

Piezoelectric Detector (G-6) [Buchen, E-4]. Assistance was provided to G-6 personnel in the detection and measurement of rf signals produced by the fracture of quartz-bearing rock. It is possible that these signals could be detected before and during earthquakes. A broadly tuned rf pickup coil and wideband rf amplifiers were provided for these experiments. The single-shot rf bursts were diode detected and fed to a Biomation Model 8100 transient digitizer, which was borrowed from AP-4.

Data-Analysis System (L-2) [Kuckertz, Coy, E-5]. One of the methods proposed for producing controlled thermonuclear (fusion) reactions is to bombard a deuterium pellet with intense laser light. If the deuterium pellet is illuminated under proper conditions, pressures and temperatures high enough for the fusion reaction to proceed will occur. An optical system capable of transmitting a single laser beam intense enough to start the fusion reaction does not exist. The transmission problem is being solved by taking many laser beams and focusing each on a single target. The goal is to minimize the number of laser beams while at the same time maximizing the energy density on the target pellet. To do this it is necessary to select components for the laser optical systems that can transmit laser light of very high energy densities without being damaged.

LASL Group L-2 operates an experimental arrangement that tests various optical system components and determines the threshold energy density at which the component is damaged. Initially all of the data required to calculate the damage parameters were gathered manually from photographs of oscilloscope traces and strip-chart recordings. The raw data were then processed using hand-held calculators. In March 1976, a request was received to design a data-acquisition and analysis system that would automate most of the data collection and analysis operations of this experiment.

A data-acquisition system, based on a DEC microcomputer (PDP-11/03), was designed to measure damage parameters every time a pulsed laser was fired at a selected optical target. A fundamental design philosophy was to let the microprocessor control, via a stored program, as much of the instru-

mentation as possible, excluding the laser itself. The experimental signals measured by the microcomputer are those associated with a calorimeter, an energy meter, a diode array, a spark (not laser light) intensity measurement circuit. The first two items measure the energy in a laser shot, the diode array measures the spatial distribution of the laser pulse, and the spark intensity measures damage above a particular threshold. Suitable mathematic manipulation of the measured quantities will yield the energy density of the laser pulse, which is of primary importance.

The computer system is comprised of a PDP-11/03 central processing unit; two general-purpose parallel interfaces (DRV-11); a serial interface (DLV-11); 4 k of PROM (MRV-11); a memory refresh circuit (REV-11); an ASR-733 terminal, and 8 k of RAM. The memory refresh circuit is required because the Reticon diode array produces erroneous data whenever the CPU pauses to refresh responsibilities, the amount of erroneous data from the diode array is greatly reduced. Custom hardware interfaces the computer to the instruments that measure the damage parameters. This custom hardware includes an ADC card, interrupt-request circuitry, and analog signal conditioning circuitry.

The design and fielding of this microcomputer system was performed without the purchase of a separate development system; rather an existing minicomputer system performed the development function. Additionally, the microcomputer system is almost devoid of standard peripherals since the terminal device performs the function of the system residence device.

In the development of the operating software a high-level language, FORTRAN IV, was used to code as much of the system as possible while assembly language was used to code those sections of the system where execution speed was of paramount importance. The operating system consists of three tasks outside of RT-11. The first is a default task, which monitors the keyboard and performs most of the routine accounting functions. The second, an interrupt-driven task starting 33 ms before the laser is fired, initializes the instrumentation. The third, another interrupt-driven task starting when the laser is fired, gathers the raw data and calculates report quantities.

The development of this system has greatly enhanced the data collection and analysis capabilities of Group L-2. The time required to collect and analyze damage parameters has been decreased by an order of magnitude. This permits testing more components than was possible previously. More accurate data analysis is now possible because more data can be collected on each sample and assumptions necessary to simplify manual processing of the raw data have been eliminated.

Model 9144S Time-Interval Meter (M-2, M-3) [Greenwood, E-3; Whittemore, E-2]. The measurement of time intervals between associated events in a given experiment is a common part of the data-taking activity. To accomplish this measurement several instruments have been developed in the past and recently. A second generation 100-MHz time-interval meter has been developed. This 6-channel meter will make time-interval measurements between 100 ns and 10 s with an accuracy of ± 10 ns. It will accept start pulses from +5 V to +100 V (+400 V in the M-2 version) and readout on a 9-digit calculator display as well as through a data bus to a remote controller. The chassis can be reset manually, with a +5-V pulse, or a contact closure to ground. A buffer for an external master clock reference can be substituted for the local oscillator to allow simultaneous operation of multiple chassis. The meter is packaged in an 8.8-cm-high standard chassis.

Network for Microchannel Plate Image Intensifier (MCPII) (M-3) [Lundy, Parker, E-3; Hancock, E-4].

The network shown in Fig. 44 has been employed at M-3 to establish the required polarizing voltages on their MCPII tube, to provide a low-impedance path for the gating signal, and to provide the required current during the image time. When M-2 decided to adapt the circuit to a more expensive and larger MCPII tube, they requested that we ascertain that the tube voltages were always within the specified maximum values and, if possible, modify the circuit to provide programmable gain in "f" stop steps.

The original version of this network had been fabricated of 5% carbon resistors. Though the resistors were operated within their ratings, measurements on the network with 6000 V applied showed the voltage coefficients to be large enough to cause unacceptable shifts in gain from the design values.

Fig. 44. Network schematic for microchannel plate image intensifier.

Therefore, the new network was fabricated of 1% metal film resistors. The network voltages and the gains were then found to be well within the design values.

The turn-on and turn-off transients, which occur when S1 is closed and opened, were studied with the NET-2 code. This study revealed that the transient voltages across the MCP section of the tube and across the photocathode-to-MCP gap could be five times greater than the tube ratings. Also, the accelerating voltage from the MCP to the output phosphor would drop appreciably during an intense exposure, introducing appreciable nonlinearity.

The output linearity was easily improved by adding capacitor C_x across the output capacitance C_o of the tube to provide the required charge storage. It was impossible to reduce turn-on and turn-off transients while retaining an adequately low-impedance path (C_3 to C_i to C_4) for the gate signal. The value of C_i was determined by the tube and ranged from 10 pF to 30 pF. To obtain most of the gate signal across the photocathode-MCP gap it was essential that C_3 and $C_4 \gg C_i$. A large capacitance C_y would have solved the problem, but physical space was not available for it. Therefore, a string of zener diodes Z_{d1} to Z_{d4} was placed across the photocathode-MCP gap to limit this voltage from 3000

to ± 180 V. The remaining turn-on transients across the MCP were found to be limited adequately by the power supply output impedance.

A special, low-capacitance 1000-M Ω probe pair was built and employed with a differential input oscilloscope experimentally to verify the NET-2 calculations.

The tube gain, an exponential function of the voltage across the MCP section of the tube, is represented by R_r . The value of R_d was found to range from 20 M Ω to 500 M Ω among the tubes in stock at M-2 and M-3. It was possible to operate all of the 40-mm tubes satisfactorily with one network except from R_g . Therefore, to provide programmable gain in "f" stop steps, R_g was tailored for each tube and mounted with an appropriate switch in an external box for each tube.

Nonlinear Microdensitometer Output Signal Modifier (M-6)[Koelle, E-3]. Group M-6 has an old Jarrell-Ash microdensitometer, Model 2305, acquired from surplus, which is being used to interpret films exposed in transient high-temperature experiments. The apparatus, like all microdensitometers, presents the output as a signal linearly proportional to the light transmitted through the film. The linear output suffers in usefulness since most of the information of interest, which occurs in the more highly exposed and therefore darker portions of the film, is crowded against one end of the strip-chart recorder range, making interpretation tedious and inexact.

It appears that there are two nonlinear transformations that can be made on the microdensitometer output signal that would make the strip-chart record considerably more useful. A logarithmic transformation would present the signal directly proportional to optical density and expand the resolution in the dark region of the film. An exponential transformation, using the appropriate fractional exponent, about 0.3, would present the output directly proportional to radiation density by factoring in the film's "gamma," which describes the relationship between exposure and optical density of the developed film.

Burr-Brown now offers analog function modules that make it possible to conveniently implement both of these transformations. Model 4127 is a multi-function logarithmic amplifier that can be used for

the logarithmic conversion. The Model 4302 multi-function converter has the capability for exponentiation by taking the logarithm of the input, multiplying it by a settable factor, and then taking the antilog.

Group M-6 has asked us to build a module to be attached to their microdensitometer that will house the Burr-Brown modules, coefficient adjusting potentiometers with 10-turn locking dials, power supply buffer amplifiers, and calibrating signal source. A digital panel meter will also be included to aid in setting up and characterizing the nonlinear function, and to interface between the existing microdensitometer output and Brown recorder.

Expendable Signal Follower Circuit (M-6)[Koelle, E-3; Salazar, E-2]. This has been developed for M-6 to replace an old vacuum tube cathode follower now used with capacitive transducers to measure motion to explosives-driven experiments. Since the transducer and line driver are destroyed in most experiments, it is desirable that they be low in cost. It was suggested that a solid-state circuit might replace the vacuum tube cathode follower, allowing a more compact assembly and eliminating bulky filament and high-voltage plate supply batteries.

The application requires that signals with risetimes to about 3 ns be passed with minimal degradation. Input capacitance should be low so that they do not load down the transducer.

After studying available semiconductor devices, it appeared that a Signetics DMOS N-channel enhancement mode FET connected as a source follower might do the job. The DMOS devices have transconductance, capacitance, and frequency response similar to those of the 417A tube used in the cathode follower circuit.

A source follower circuit was constructed and tested, using an SD203 DMOS transistor that had previously been purchased for evaluation. The schematic is shown in Fig. 45. The circuit was built with short, low-inductance connections to minimize lead length effects.

Rise and fall times were found to be on the order of 1 ns, which is near the limit of the oscilloscope used. There were no aberrations seen that were not present on the input pulse from the HP-8082A pulser. With a 5-V positive pulse, the output was about 2.5 V into the 50- Ω termination, showing

Fig. 45. Source follower test circuit.

that the output impedance was about 50 Ω , as could be expected from the 20 000- μS transconductance. Compared with the tube cathode follower, the source follower using an enhancement-mode FET has a distinct advantage in that the dynamic range is not limited by grid current or space-charge effects.

A mechanical layout for the transducer mounted units was designed after discussion with the M-6 users. Six units were built and delivered for evaluation.

Guard Ring Beam Detector (MP-13) [Brown, E-3; Spencer, E-2; Hoffman, MP-13]. As the LAMPF proton beam began to increase in intensity, there was concern that the beam might accidentally strike one of the tungsten collimators. Calculations indicated that if the beam, with a peak intensity of 17 mA at 800 MeV, was to strike the collimator, the thermal stress would exceed the yield strength in 200 μs . To detect the position of the beam, nine secondary emission guard rings were installed in the main beam line of Area A and A-East during the 1974-1975 shutdown. The goal of these rings plus associated electronics is to provide hard-wired disaster-level protection for the collimators and some diagnostic information about beam position, intensity, and halo.

The guard rings consist of an aluminum disk that surrounds the beam. The ring is split into four quadrants to provide position information. When the beam of the beam halo passes through the quadrants, secondary emission produces a signal current at each quadrant equal to $\approx 10\%$ of the beam. Emitted electrons are collected by an electrode. Signal amplification is accomplished by a set of

four amplifiers located in a box just outside the shielding. The amplified signals are then sent to the guard ring beam detector module. There the signals are filtered and compared to an adjustable threshold to detect whether the beam halo has exceeded the threshold. If threshold is exceeded, the guard ring beam detector outputs a signal to the fast-protect system, which turns off the beam at the injector. Logic levels are also output to the RICE system so that the control computer can identify which quadrant caused the interrupt.

When this project began, the guard rings, the cables to the amplifier box, the amplifier box, and the amplifier box output cables were in place. We were asked to improve signal reliability from the amplifiers and design and construct the guard ring beam detector modules. It was observed that the amplifier outputs had up to 0.6 V peak-to-peak SCR noise and that under certain cable loading conditions the amplifiers would break into oscillation.

To reduce the possibility of oscillation, a 1-k resistor was added at the amplifier outputs in series with the cables they have to drive. Also a 1-k resistor was added in series with the input to the LH0002 driver.

The amplifier box also contained a CAL TEST pulse amplifier, which produced a fixed amplitude pulse. This circuit was modified to provide a pulse whose amplitude could be adjusted. The purpose of this circuit is to apply a calibrated pulse to the high-voltage collecting electrode in the guard ring and check the gain of each of the amplifiers. Unfortunately the wire connecting the guard ring and collecting electrode is unshielded and lies in the same cable as the signal wires from each of the four quadrants. There is much more capacitance between the wires in the cable than between the collecting electrode and the signal electrodes in the guard rings. Also the capacitance to each of the signal wires in the cable is unequal. Until the cabling to the guard ring is modified, the CAL TEST pulse will be used as a simple test to check if the collecting voltage is present and if all the amplifiers are working.

The collecting voltage polarity was originally negative. It was noted that when this voltage was reduced to less than 10 V the signals from certain quadrants would reverse polarity and become more

differentiated while other signals from the same guard ring would not. Changing to a positive polarity resulted in a more predictable mode of operation.

The guard ring beam detector was built as a triple width NIM module, which could monitor the eight signals from two guard rings. To eliminate ground loops, each signal goes through a buffer amplifier with differential input. The amplifier has a low-pass filter time constant of 30 μ s to reduce the SCR noise spike amplitude. The signals then go to a comparator to determine if they exceed threshold. The comparator output is latched and if threshold is exceeded, the latch output triggers the fast-protect system and identifies the offending guard ring quadrant.

The four identify signals are ORed to form a guard ring identify signal. All five signals are available from the guard ring beam detector. The RICE system will soon input only the guard ring identify signal from each of the nine guard rings. Additional inputs will have to be added to the RICE system to identify which quadrant or quadrants of a guard ring are causing the fast-protect interrupt.

The guard ring beam detector also sends a CAL TEST pulse to the CAL TEST amplifier after every beam pulse. The amplitude of the CAL TEST pulse is adjusted to be large enough so that the signal coupled into each of the amplifier inputs results in a signal that exceeds the threshold of all the comparators (even with maximum threshold setting). The logic provides that if these signals are not detected between beam pulses, a fast-protect interrupt is generated in the same manner as if the beam had struck one of the guard ring quadrants. By initiating the CAL TEST disable pushbutton on the module front panel, one can determine what caused the interrupt. Experience at LAMPF has shown that safety system disable switches should not be the toggle type since they are easily left engaged; MP Division has insisted that front panel controls (except threshold level) be a pushbutton type.

The first guard ring beam detector module has been checked out at LAMPF. Operation seems to be satisfactory and they have requested five additional units to be built by E-2.

"Super Cube" Digital Control System (P-9)[Greenwood, E-3]. This system (titled Model 13) was designed for control and position readout of the

"super cube" experimental apparatus designed by G. Colsen, P-DOR. The super cube is a detector platform, which is designed to utilize the P-9 accelerator beam down its longitudinal axis. It may be rotated around the beam axis by a stepping motor. A detector arm is mounted on each of the four longitudinal sides of the cube with stepping motors for positioning. Optical encoders are coupled to each of the four detector motors to provide position readout data.

The Model 13 digital control system consists of two main chassis, control unit 1 and control unit 2, plus an analog multiplexer subchassis. Control unit 1, located near the super cube contains conversion and transmission logic for multiplexed encoder position information and manual control for the stepping motors. A subchassis located on the cube multiplexes the low-level encoder analog position data. Control unit 2, located in the tandem control room, contains manual control, logic for position reading, set-point storage, ramping, comparison, and stepping motor drive sequencing. In addition, I-O logic for communication with the XDS-930 computer is located in this chassis. The POT and PIN transfer sequences are used by the computer for control and readout of the encoder and cube position information. A stepping motor driver chassis is located near control unit 2, and in conjunction with the stepping motor power supply chassis located near the cube, provides the stepping motor drive.

Optical switches are used on the cube to determine positions of 0°, 90°, 180°, and 270° and overlimits both for the cube and the encoder arms. To request a desired position, the operator can enter the position information manually with pushbutton switches on the controller front panel, or with a computer POT transfer. The current position is then compared with the desired position information, and the stepping motor is stepped until the position is reached. In addition to the 0°, 90°, 180°, and 270° switches, a 13-bit up-down counter has been provided to allow a more accurate determination of the cube position. This information is available to the computer by a "Pin 2" PIN transfer. If any of the overlimit switches are activated, the stepping motor driver sequencers are disabled and will remain so until the overlimit condition is corrected and the operator pushes the

overlimit monitor reset button on one of the control unit front panels. To allow greater flexibility, the manual control may be activated with an overlimit present, by holding down the reset button. Care should be exercised to determine the correct direction in this situation.

Full manual control of all five stepping motors has been provided at both control units. A toggle switch with a single step-rate selector determines direction and rate. Detector selection is achieved by pushing the "read" button on the front panel, which sequences the encoder select. A separate set of switches is provided for the cube position. Both control units display the selected encoder position in "binary units" represented by the 14-bit output code (16 383 units for one revolution of the encoder). Drive gear ratios determine the number of stepping motor pulses required to move the encoder one unit. This ratio is currently four driver pulses to one encoder unit.

The readout sequence starts with the appropriate EOM, 34100, 01, 02, or 03 used to select the individual encoder. When this command is given, it sets up the logic for data transfer of the 14-bit position word through the analog multiplexer into a parallel-to-serial converter, through a gray to binary converter, to a storage register. This information is transferred when any bit changes value in the encoder selected. The sequence will be repeated with ~ 25 μ s required for transfer of the word until another read EOM is given or the mode is changed to manual. At the end of each encoder position data update, a latch is strobed to allow the computer to read the information with a pin input sequence. An SKS 34105 has been provided to test the pin for transfer ready.

Set-point information is loaded into the registers for each detector by an EOM-PDT sequence. The set-point data are then compared with the encoder data, proper direction is determined, and when they are equal, the stepping motor clock is inhibited. The appropriate SKS, 34100, 01, 02, or 03 is used to test the state of this drive inhibit gate to determine if the motor is active. If all stepping motors are activated at the same time, appropriate software will be required to sequentially read the encoders to provide updated information to the comparators.

Set point EOMs are 3411(0), 14(1), 15(2), 16(3), and 17(4).

A force-step mode has been provided, which allows the computer to simulate the manual control and force the stepping motor sequencer direction logic to the direction indicated by SKS 34107 (step up if given, down if not); SKS 34106 requests the mode. The two SKS functions are used as commands in this logic. Step EOMs are used to step the sequencers one step at a time. The switched reset [pin 26 (aux input) connector] is used to reset this mode.

The general-purpose EOM associated with the pin connector is used to step the cube portion, motor 4, sequencer one step at a time.

When the pin register is read into the computer, pin-1 information (encoder number, position word, cube position switches, and alarm bit) is normally presented. Pin 2, selected by EOM, 34112 presents the 13-bit cube position counter data. The alarm bit (Co) is set if there is an overlimit condition.

An interrupt (interrupt X on pin 27 P in connector) is generated when the set-point position has been reached or an overlimit condition is present.

A static read EOM 34104 has been provided to initiate an encoder reading when the encoder is stationary. It simulates the bit change signal from the encoder data lines.

Electronics for Electron LINAC Experiment
(P-DOR)[Winston, E-3; Whittemore, E-2]. This work involves providing electronic support for the construction of a small electron accelerator. Recently it has included feasibility studies of using radiography in connection with the reactor safety program.

Several days were spent with W. Stein and O. Hoover, P-DOR, using the Godiva pulsed reactor to study the effects of neutrons on various types of scintillators, which might be used in reactor radiography. This is a study of the instantaneous background noise generated by the neutrons and not of the long-term degradation effects. The radiographic technique appears quite feasible, although a lot of work remains.

The following electronics gear was also worked on in the past period.

A constant-current power supply for a bending magnet that can supply ~ 300 mA to + 4 A was

completed. This power supply can be controlled to defield as determined gauss meter. Accuracy is field as determined by a gauss meter. Accuracy is about 0.05% in the current mode and as accurate as the gauss meter in the field control mode. This unit requires two chassis.

A multiple constant current supply setup consisting of seven supplies, each capable of regulating from 1 A to 3 A is now being constructed. The unit consists of two chassis and will be used for beam steering and focusing magnets.

A system for stabilizing the beam energy of the LINAC has been designed. As the electron beam is bent by the bending magnet, any energy change or drift will alter the bending radius and cause the beam to be unusable for many applications. The system to be tried will hopefully center the beam between two targets. Output signals from the targets will be compared and the difference signal will change the rf energy going into the cavities. Construction has been started and will proceed as time is available.

Albatross IV (Pulsed Neutron Radiation Monitor)

(H-1 and P-11)[Koelle, Brown, E-3]. Albatross IV is a neutron monitor instrument intended for use in the pulsed neutron environment at the WNR facility. It will be functionally similar to the Albatross III design produced in 1973 at NAL, but with some modifications desired by the LASL users. Group H-1 has one of the Albatross III instruments on loan from NAL and is using it occasionally in the P-11 area at LAMPF. They would like to have about a dozen similar instruments built to their specification by E Division, hence the designation Albatross IV.

Albatross III measures neutron bursts by integrating neutron dosage in a silver foil surrounding a Geiger-Mueller detector. The neutrons, thermalized in a polyethylene "pseudosphere" are captured in the silver, producing an unstable isotope that beta decays with a half-life of about 22 s. The beta particles released from the silver are detected in the GM tube. The beta activity is proportional to the previously acquired neutron dose that has not yet decayed. The response time for a steady reading after a step change in the neutron dose rate is of the order of 1.5 min due to the half-life of the induced activity. The NAL design uses an electronic averaging time constant of 10 s to smooth out the

randomness in the radioactive decay process. This averaging time adds negligibly to the overall reading time.

There is some gamma background associated with the neutron reading process and there may be some unrelated gamma background where the neutron activity is to be monitored. Since the GM tubes do respond to gammas and since the gamma rate may be a significant fraction of the beta counts from the neutron activation in the silver, the NAL designers chose to include a second GM tube to respond to the gamma background so that the gamma count interspersed with the neutron-induced beta decay counts could be corrected for. This second GM tube is placed near the other one, but does not have a silver cladding; it has a tin cladding to give it gamma response similar to that of the silver-clad tube.

The NAL instrument is operated with ac power and uses a combination analog and digital design, with the digital logic implemented in standard TTL. The GM tube pulses first pass through a threshold detector to reject low-level noise and then converted to standard length ($\sim 70 \mu\text{s}$) pulses in a one-shot. This is done separately for the silver and tin lined GM tube channels. The pulses are then integrated in a 10-s time-constant averaging circuit in such a way that the neutron-gamma channel drives the output up and the gamma compensating channel pulses drive the output down. The output voltage is used to control a voltage-controlled oscillator, which in turn feeds pulses back to the input in a direction to drive the output down. The net effect is that the voltage-controlled oscillator produces a pulse train in which the number of pulses in a given time period is proportional to the difference between the number of pulses inputted from the two detector channels.

In the NAL instrument this pulse train is then used as the input to a nonlinear diode pump circuit, which produces a voltage that is approximately proportional to the logarithm of the pulse rate. This voltage is used to drive a meter, which has a scale reading logarithmically in mR/h. Analog comparators are also used to sense the meter drive voltage and are set to indicate when the reading exceeds 2.5 mR/h and 20 mR/h. The NAL instrument displays on the meter a range from 1 to 100 mR/h and has incandescent lights to show when the reading is below 2.5

mR/h (green), between 2.5 and 20 (yellow), and above 20 (red).

The H-1 and P-11 users wished to retain most of the features of the NAL design and add several others. These include the ability to operate from internal rechargeable batteries for several hours, an extension of the range to 300 mR/h, a provision for external gating so that the detectors can be disabled during the LAMPF beam pulse, and an adjustable audible alarm threshold.

Upon examination, the Albatross III circuitry appeared to be fairly complex, with many adjustments in the analog circuitry. While some simplification could be achieved with more modern components, a straight copy of the NAL hybrid analog-digital design approach would result in a rather complex and expensive instrument.

Some thought was given to implementing a straight digital design, using an up-down counter for the differencing operation. This had the disadvantage of rather slow and jerky response if one made the averaging time long enough to smooth out the statistical variations in count rate. There was also difficulty in presenting the output in standard units if one used a digital display. A running average operation would solve the response time problem, but would be very complex and expensive if done in hard-wired logic.

A running average operation could, however, be implemented easily in software with a simple microprocessor and this is the approach that will be used in Albatross IV. An Intel 8748 microprocessor will be used. This has 1 k of on-board EPROM program memory and 64 words of RAM scratch pad memory. It has an on-board clock and two 8-bit latchable output ports in addition to the 8-bit multiplexed address and data bus port. In this application no additional microprocessor associated devices will be needed, such as external PROM or RAM or output latches, making it a very simple and economical system to implement.

The GM tube pulses, after passing through threshold detectors and some simple CMOS logic, will be counted inside the microprocessor. An external oscillator will define a counting period of about 1.75 s, at the end of which the latest neutron-gamma and gamma-compensating counts will be differenced and used to replace the oldest of eight previous

counts in a rotating stack. The stack contents are then summed internally and the sum bits reformatted so that a direct digital to log-analog conversion can be performed. The reformatted bits in an 8-bit word are latched into one of the output ports. Digital comparisons are also made to test for the "green, yellow, or red" alarm stated and the information latched into the other output port.

The digital to log-analog conversion uses a pair of quad CMOS analog switch packages, nine weighting resistors, and an op-amp to form a very close approximation to the true log function. The readout is on a meter. A meter with a built-in threshold setting pot coupled to a manually settable dial pointer, will be used along with an analog comparator to allow easy setting of the audible alarm threshold.

The microprocessor implementation of this system will end up with less than half the number of components used in the NAL Albatross III design and should be less expensive to produce and maintain. A proposed block diagram for Albatross IV is shown in Fig. 46.

VISAR Sequencer (WX-7)[Greenwood, E-3]. A sequencer to provide control for the VISAR velocity measurement apparatus has been requested by W. Hensing. This sequencer will provide appropriate triggers and control signals for pulser, power supplies, and oscilloscopes. Interlock circuitry will be required to assure that proper equipment conditions exist before a start signal is allowed. Auto, manual, and setup modes of operation have been specified. Because of the experimental nature of the device, each time delay in the sequence must be variable over a wide range.

An approach utilizing TTL logic was investigated first because of the delivery requirement (before October 1, 1976) but after a careful analysis of the flexibility required, it was proposed that an alternate approach be considered using a microprocessor controller. Hensing was very favorably impressed with this proposal and directed that the balance of the job order be used for such an approach.

Hensing was able to set up a very primitive delay sequencer using oscilloscope time bases to satisfy his immediate requirements for testing the VISAR apparatus. An 8080 microprocessor-based card

Fig. 46. Proposed Albatross IV block diagram, with microprocessor count, store, and average, and log-analog meter.

rack system has been purchased for this project. Design has been completed, and fabrication is approximately 90% completed. The programming effort for the microprocessor controller is in progress.

Microdosimeter Electronics (MP-3) [Hiebert, E-3] Special preamplifier and pulsed high-voltage circuits have been developed for use with microdosimeters in high-intensity beams at LAMPF. Dosimetry must be done during the 1-in-10 low-intensity beam pulses at the pion biomedical channel.³² To pro-

tect the proportional counters from radiation damage during the high-intensity beam pulses, the counters must be operated at low voltage and the applied voltage should be pulsed to normal level only during the 1-in-10 pulse. This places a recovery time burden on the preamplifier, and a design has evolved that allows low-noise operation within 4 ms after the high-voltage pulse on the counter. A circuit configuration for a second microradiation detector using hybrid circuit techniques has been developed.

TECHNICAL SERVICES, H. S. Olafson, Assistant Division Leader

General Group Activities (E-1)

Group E-1, Maintenance and Standards, is made up of several diverse sections. The activities of these sections are detailed below.

Management Information. During the past 6 months several data bases have been created for Group E-1. These data bases support intrusion detection (IDS), radio communications, and preventive maintenance. Two FORTRAN working programs were created, one for Schwalm pending conversion from the NOS to LTSS system, and one for Henry. In addition, an EZPERT that includes network, bar chart, and X and Y graphs was prepared and updated for the IDS section. A property management EZPERT with network and bar chart was generated and updated for AADP, AQ, and SP. A data communication EZPERT with network and bar chart was generated and updated for several users including C Division, E-DO, E-5, and E-1. Consulting was provided to E-DO and E-2.

Standards Laboratory. Several pieces of new electrical equipment ordered early in the fiscal year have been received. Areas of measurement now include: resistance from 0.001 to $10^{16}\Omega$, dc voltage and 1 nV to 100 kV, dc current to 300 A, ac voltage to 1100 V, ac current to 10 A, frequency to 8 GHz, and capacitance from 0.1 μ F to 1 μ F. Most of the equipment is state of the art, which will permit measurements with very small uncertainties assigned. A differential pressure system is nearing completion. Other areas of continuing effort are temperature, humidity, and flow measurements, as well as maintenance of balances for the Laboratory.

Physics and Radiation Instruments. Many maintenance and support functions have been undertaken during this report period as detailed below. We have designed and built a supplemental sweep generator for an ion probe. The probe originally had one sweep generator that could be used for either of two functions; the purpose of the second sweep generator is to allow both functions to be monitored at once. This design uses stock components. We are modifying an RIDL analyzer-Newport printer interface. This modification will allow the user to read out the memory of two analyzers into one Newport printer. A feature that will be installed will allow the ribbon color to be selectable; thus it will be possible to

identify the analyzer associated with the printed tape. We have modified an index counter for CMB-1 to permit vertical and rotating stepping motors to start simultaneously. This will allow a helical scan of fuel rods. A minor modification to the indexer was required to control stepping motor speed. Some old Model 15 neutron counters that were being sent to salvage were modified into alpha counters. This modification saved H-1 about \$8000 in the purchase of new alpha counters and provided them with some spare units that they desperately needed. In association with H-1 we repaired an RIDL analyzer and printer interface for Highlands University. The repair involved several trips to Las Vegas. We assisted E-2 in the check-out and quality assurance of 18 Model 8141S digital delay units. Since this turned out to be an all-out effort by E-1, E-2, and E-3, several people from each group were involved. Group H-1 requested technician support in setting up their LAMPF counting systems. This effort, which took 4 months to complete, included installing several counting systems in different LAMPF areas and installation of the gate monitor. We continue to supply technician support to Chaim Richman in running his experiments. The runs, generally on weekends, range from 16 to 24 h in length. We assist in setup, data acquisition, and tear down. We were privileged to assist in the first live patient experiment on May 18. The radiation spill at DP Site created havoc with our probe and radiation instrument scheduling. During this incident 640 probes were made and 850 new probe faces were laid. The radiation instruments received for repair reached an all-time high of 1634 units. It may require 2 months to recover from the backlog of probes alone. The Model 76 alpha counting system (IMPULSE) was turned over to H-1 on May 5. We have had several sessions with D. Coy and M. Seamons, E-5, and J. Umbarger and D. Vasilik, H-1, regarding various system operations. We covered user and designer requirements, spare parts, work area, and software programs. A diagnostic troubleshooting program has been written by M. Seamons. Most of the TA-55 radiation instruments have been checked out; some have been installed but are not wired into the computer. We are experiencing problems with the Ludlum 214 glovebox monitors; the problems are being addressed by Ludlum but have not yet been solved. We received

a request from Geo-Data, Dallas, TX, to repair their Canberra 7000 processor. Apparently Canberra no longer has trained people for that model and therefore could not service it. We repaired the unit and sent it back to Geo-Data in good working condition.

Instrument Repair Section. We have begun to level off in the total number of instruments handled. We have spent considerable effort to reduce our instrument turn-around time; this is now about 1 to 2 wk. During this period we have processed 1267 jobs and recharged 5011.2 h to customers (this does not include repair and maintenance of our own equipment, which is an average of 3.96 h/instrument). We have emphasized training in order to maintain a professional status in servicing equipment. As a section we have tried to make training available for lower graded technicians so they can advance, and to higher graded technicians so that they may enhance their advancement opportunities. Specific maintenance areas we are now engaged in include:

Shops Dept. We continue to provide regular maintenance duties. In addition, a power supply was built and interfaced to the rotary table so that the table could be manually operated. The NC control for the rotary table was beyond repair and Shops did not wish to purchase a replacement; therefore the table was converted to manual control. The Shops people would like to convert the #2 Bendix 1800 controller to metric measurement. Since Lawrence Livermore Laboratory (LLL) has already done this, we are attempting to contact one of their people involved on the project in order to eliminate duplication of effort. We are also working with Shops personnel on converting their #3 mirror lathe to NC control.

General Instruments. We continue to provide considerable on-site maintenance to customers. This activity will require that we cross train technicians for these jobs. Maintenance requirements on old equipment continue; the major problem in this area is the long delay often involved in finding parts, assuming that the parts are still available. Ironically new instruments sometimes present even more of a problem. These problems center on deciding what parts to stock and what equipment to use in check-out procedures. Microprocessors are becoming more and more popular in the Laboratory with the result that we are receiving more maintenance requests for them. This means that we will need to

train all of our personnel in this area of new technology.

Quality Assurance. We have begun a quality assurance program so that instruments are checked before being returned to customers. Although new, this function has been very successful. To date 166 instruments have been checked for quality assurance and 19 were found to be defective.

Engineering Support. During this quarter a report³³ on the field phoswich has been written and is now being prepared for publication. The phoswich is in use and has successfully passed a series of environmental checks. Groups H-1 and H-8 have requested several new phoswiches and construction of these units has begun. A prototype for a new alpha radiation detection instrument was designed, constructed, and delivered. One design criterion was that power consumption of the unit be below ≈ 50 mW. A bidirectional scaler was designed, constructed, and delivered to the customer who has requested several extensive modifications and ordered five additional units, which we will produce in the next few months. We have instituted procedures for Group E-2 to construct pulse boosters that we have designed. The pulse booster has been a successful instrument; 20 units have been constructed to date and there are identified demands for at least 25 additional units in the next few months. Minor projects that have been completed during this period are audible rate meters for H-1, a temperature monitor and controller for P-DOR and P-4, and a bare bulb slave xenon flash for M-5.

Mechanical and Vacuum. During this period we have installed 12 new leak detectors and provided user training as required. The average cost of these units is \$9000 each. Seven turbomolecular pumps were modified from oil to grease seals and 10 drums of waste oil were packaged for disposal by Group H-7. On the average we send 60 to 70 office machines to salvage every 2 months. In addition, we continue to repair mechanical typewriters and adding machines. We have designed a new solid-state alarm for leak detectors that is nearly ready for testing and we are also working on a solid-state preamp and amplifier for older mass spectrometers, which we have to test in a few months. We continue to emphasize training both from outside commercial sources

and E-Division-sponsored courses so that our people can increase their technical capabilities.

Process Control Instrumentation. Our major effort at this time is support of the new plutonium facility at TA-55. The major thrust of this support effort is relocation of existing recorders and controllers and installation of about 70 additional recorders. This work is about 95% complete and now consists mainly of catching overlooked details and additional small new tasks. We are on schedule with this work and all recorders and controllers should be on-line when they are needed. We are also supplying recorders to one other program, the solar home project. Twenty-two 16-point recorders have been supplied to this project and it is expected that more will be requested.

Terminals. During this report period the Terminal Section has handled more than 1800 trouble calls of a significant nature; that is, problems involving more than operator error, installation errors, or lock-box malfunction. These calls have covered the complete spectrum of Laboratory-owned remote data terminals and their associated systems. We have also been heavily engaged in limited-access box installations and secure check-outs for C Division and Laboratory-wide terminal interface problems and associated wiring. We have implemented a "ready pool" of modems and acoustical couplers for sale or short- or long-term loan to interested groups. This pool has been quite successful as evidenced by the fact that more than 30 modems and couplers have been provided to users. We are awaiting delivery of TI Model 743-745 spares for our maintenance program. We are preparing to install and maintain the new TA-55 terminal nets. These terminal nets will be TEL/RAY units; we have completed training on these units and compiled spare parts lists but have not yet received spare parts.

Communication Services (Radio, CCTV, ESS, IDS, Audio). During the last 6 months a large number of mobile radios were removed and reinstalled for the ERDA Protective Force. Frequency changes were made for 110 pocket pagers and an antenna rotor system was built for H-8 and sent to Alaska. Testing was performed on a Vicon telephone line TV transmitter for black and white and color. A remote security booth was installed at the new Study Center using the Vicon system to transmit video information to

the control point. The Study Center has been one of our largest projects in terms of intrusion detector systems since a number of new alarms have been installed there. This activity has been in addition to our regular maintenance of IDS systems. The new pc boards for the in-house audio system have been completed. A lot of effort has gone into the audio system for TA-55 and this will continue until August. New alarm systems are being developed for the CMB building at TA-55; this effort should be complete late this summer. We are now evaluating several new alarm systems for future applications. New ESS alarm equipment was installed for ENG-4; it is planned to use a Honeywell multiplexing system to increase the amount of ESS alarm equipment to meet their needs. During the last few months we have run tests with different dial seizure equipment for possible fire alarm use. In the future a full digital dial seizure unit will be tested.

Data Communications. The charter of this section of E-1 is to provide support to Group D-9. During this report period this support has been multifaceted. A large effort has involved prevention of security violations via telephone lines or power lines. This has involved rerouting cables, relocating telephones and telephone lines; installing bridges over existing cable routes for new cabling; checking grounding and bonding of cables, cabinets, and other equipment; and relocating cabinets and equipment as required. We are also preparing for the expansion of the CCF, which will include installation of two more KCCs in SM-43 and consolidation of lines to outlying sites via jackfield and multiplexers. During this period the medium-speed port rates were increased from 300-1200 BPS to 300-9600 BPS. This speed increase required installation of new modems for all medium-speed port users in locations remote from the CCF. We have continued to emphasize training for our people to upgrade their capabilities.

Data Transmission. Current major programs that are being addressed are semi-annual inspections of protected wirelines for the Security Office; providing additional outlet boxes for WPC-2; completing line filter installation at TSL-87; completing protected wireline installation at SM-28; writing a proposal and providing materials for protected wireline expansion and modification at WX-3; providing

field support and coordination for TD Jackfield modification; providing field support and ensuring proper installation of additional telephone cables within SM-43; and providing additional protected wireline outlets within SM-43 at approximately 20 locations. We also continue to provide telephone services support through interaction with various groups and individuals concerning broad aspects of data transmission; creation of a protected wireline handbook that includes actual drawings; and gathering information relative to ERDA management information systems requirements regarding computer C/MIS forms.

Radio. Our principal efforts are in two areas. The first is providing radios for the ERDA Protective Force. In this area we have delivered 12 wide-channel IEC Electronics radios to the Protective Force and they are now in use. We have ordered MX-350 portable radios but they have not yet been received. The delay is apparently caused by problems of inadequate shielding in the receiver when used with the specified 6-W transmitter. This problem is being addressed and we have been informed that the first batch of radios will be shipped this month. We have approximately \$75k in equipment on order for the Protective Force, which will make that part of the radio replacement program about 85% complete. The initial stage of mobile relocations is complete; the next step will involve installation of the Conventa-Com consoles in place of existing radios. Our second area of effort is coordination of all H-Division radio equipment acquisition and change. This coordination has been arranged through a meeting with H. Jordan, H-DO, and should result in standardizing procedures concerning radios. This arrangement should also pave the way for more cost-effective use of radio equipment in H Division. Radio operating procedures will also be addressed through this arrangement.

Telephone. Telephone facilities for the NSRSC have been installed and services are complete. Considerable effort in coordination of services for new buildings has been necessary. These new buildings include the Weapons Neutron Physics Office Building and High-Energy Gas Laser Facility. Additional cables requested for TA-15 have been delayed due to the heavy workload. A new reinforcement cable for TA-35 has been issued but completion of this

project has also been delayed by the required design and planning of the new High-Energy Gas Laser Facility, which affects the contours of the proposed routing. Programmatic changes and division and group relocation and shuffles have resulted in an increased workload and depletion of facilities in most areas. We have issued 750 work orders to Mountain Bell and these orders have resulted in approximately 1500 service orders issued by Mountain Bell for the work required.

Recharge Programs (E-2)

Production Control. During this period we began work on over 850 different jobs supporting more than 70 groups throughout LASL. Some of the larger jobs undertaken during this period were: Model 9144 time-interval meter for M-2; Model 200 decoder-drivers for L-1; laser pulser units for AP-2; Model 403B power supplies for various groups; and work for prototype units of the Model 1776 MCP oscilloscope for J-14.

Photographic. Front lighting has been added to our camera to enhance our photographic capabilities.

Silkscreen and Paint. Preparations are under way for equipment installation for a new and improved painting facility and a complete in-house silkscreen facility.

Electronic Fabrication. The cable fabrication facility has recently been moved to TA-6. This facility is now operational. We expect to have a new strander/braider for special shielded cables operational on June 15. The new paint and silkscreen facility will also occupy this area.

Printed Circuit Facility. Progress has been made in reducing turn-around time and meeting schedules. The vacuum system is now complete and operational. During this period a new pc drill has been installed and a new light table has been ordered.

Hybrid Facility. The hybrid microelectronics section of E-2 has worked on 65 jobs for 29 Laboratory groups during the report period. Major efforts have been: a thermoelectric laser beam position detector for L-1; a pulse-shaping circuit for M-2; a photomultiplier tube base assembly for E-5; a varistor pulse clipper for J-14; a fast-current sensitive preamplifier for P-3; an avalanche transistor pulse generator for E-3; an SCR pulse generator for M-3; a cell counting orifice for H-10; a voltage output radiation probe for E-5; a CCD clock driver for J-8; a

100-kHz precision rectifier for MP-4; a delta rate monitor for Q-2; and a resistor network for J-14. We have continued to prepare high-stability, high-precision resistors for many groups. Our expertise in screen printing, assembling extremely small electronic devices, and providing assistance in materials technology has been used by many groups. We are considering plans to expand our services by providing a Parylene coating service, applying resistors to pc boards by screen printing, and developing fabrication technology for special fiber-optic devices.

Design and Packaging. We are continuing to expand the drafting section with additional people in pc layout, hybrid circuit layout, and electromechanical packaging. We are providing drafting services to the following Groups: L-10, MP-3, CTR-4, CMB-7, and J-14. We have also provided support to the following major projects during the past quarter: the 3.5-GHz oscilloscope for J-14, a cable winder for E-2, hybrid circuit artwork for R-2 and pc layout for Q-1.

Technician Services. Recognizing that we are a service-oriented section, we have emphasized on training.

In order to keep abreast of the state of the art and enhance the technical growth of our technicians, they have participated in the following courses, seminars, and workshops: vacuum technology, microprocessor design and utilization, integrated circuit technology, laser, instrumentation and measurement engineering, data acquisition, digital circuit design, modern electronic circuit analysis, soldering, and others. The technician services supervisors have participated in courses in time management, team training, and communications to enhance their management and human relations skills.

We are presently providing technician support to AP-1, CMB-7, CMB-14, CTR-DO, CTR-4, CTR-9, E-1, E-3, G-4, H-7, L-1, L-4, L-9, L-10, MP-3, P-3, P-9, P-11, Q-1, Q-10, WX-5, H-10, J-14, and Q-24.

We have initiated a Tech-III technical meeting once a month. This meeting is intended to keep our Tech IIIs abreast of current technology as well as allow them to share areas of expertise. We anticipate similar Tech-II and Tech-I meetings in the future. We hope these meetings will enhance the overall technical competence of our technicians to better serve those whom we support.

Quality Control. We have submitted purchase requisitions for new test equipment with emphasis on high-speed oscilloscopes and a greater variety of pulse generators. All equipment should be received before the end of FY-77.

We have initiated a corrective action plan in conjunction with fabrication section leaders. Action items are based upon historically recurring problems.

Research and Development Programs (E-2)

Technician Services. We continue to support E-Division research programs in the magnetic induction fracture mapper, the computer security system, and the USDA livestock identification and temperature monitoring program.

Hybrid Facility. We continue to support the E-Division animal identification program by fabricating implant devices.

Design and Packaging. We continue to support the E-10 detector research and development effort. Our principal effort was cutting Rubylith mask masters for a planar, ceramic-mounted integrated thermionic circuit.

Detector Services. Detector services received its first job order during this time period for an L-Division silicon thinning project. We are also working on an FSD detector project for P-4. We have received actuator valves, which will allow the repair of Ge(Li) spectrometers.

Minicomputer Maintenance (E-5) [Spector, Buchser, Bujnosek, Carlson, Cummings, Garcia, Grall, Horn, Liebee, Santana, Schmidt, Torrez, Wagner, Ward].

The E-5 Minicomputer Maintenance Section has continued to increase in size and capability. Plans for steady moderate growth have been successfully implemented. Current monthly contract revenues including Data General contract administration are approximately \$37 000 per month plus recharge income and Form B. Significant achievements in the past period have been continued improvement of the LAMPF commitment; an increase in revenues; receipt of the DEC microfiche documentation package; on-site coverage of the TA-55 computer, multiplexer, display, and trolley systems; training on the DEC-X diagnostic system, the MBD, the Diva disk system, and other devices. Additional personnel have been acquired to accommodate the increased commitments throughout the Laboratory for minicomputer maintenance. These

commitments include data-acquisition system maintenance for MP, TA-55 control systems maintenance, system maintenance for the E-4 hybrid computer, and CBI and general LASL minicomputer maintenance.

Logistics has continued to grow with acquisition of Datum/Kennedy, Diva, and Calcomp spare parts to cover new areas of service support.

During the next period, we will acquire two additional technicians, one for TA-55 and one to augment general LASL minicomputer maintenance. We will continue the on-going training program to support the group's commitment to professional excellence with emphasis on training the junior level technicians.

Information and Training Services

Summary [Lindberg]. The Information Services Catalog has been updated and is available for distribution. A visit by Mabry to Sandia has provided ideas for improved technical information service. Usage of the visual search microfilm (VSMF) continues to be good with an average of one-third of the activity coming from outside the Division.

Training Services has sponsored minicourses thus far in FY-77 with an enrollment of 126 students, 50 of whom were from outside of the Division. The courses are:

- Fabrication Techniques
- Electromagnetic Interference and Electro-magnetic Compatibility
- Certified Soldering (presented four times)
- Practical Digital Electronics
- Basic Electricity and dc Circuits
- Management Overview of Microprocessors

Three new videotape series comprised of 33 tapes have been added to the self-study library. An audiotape "Speed Learning" self-study course has been added to our collection and additional micro-processor "modules" have been purchased.

In the employee development area three 1-day courses on the theme of effective communications have been presented to Division personnel. A Career Assessment Workshop for Laboratory-wide participation is being planned for the fall. This is a co-operative effort between E Division and ERO and PER Departments. Procedures and forms for individual career development planning are being developed; they will attempt to integrate present job skills and goals, future goals, educational and job activi-

ties needed to implement future goals, and commitments from the individual and supervisor.

An upsurge of interest has occurred in video-assisted self-study since January of this year; the number of participating Divisions/Departments has increased, as have the number of "person-tapes" viewed each month.

Increased emphasis is being placed on identifying the problems associated with technician training. Our recent experience with the Basic Electricity Course for Technician I/II personnel suggests that a structured on-the-job training (OJT) program may be more effective for fabrication personnel. Barbera Stephenson, Training Consultant, is working with B. Mabry to develop effective training formats for technician personnel.

The video-equipped LASL Learning Center has been completed and has been effectively used to videotape the Management Overview of Microprocessors Course. A Mini-Review, an ATOM article, and an open house are being prepared to promote the facility.

Information Services [Babb, Mabry, O'Mara]. The E-Division Services Catalog has been updated and is ready for distribution. E-Division secretaries have been given copies for use in the various group offices. Others may request copies by calling 5431.

Sandia recently hosted a visit to their Design Information Center by B. Mabry. An interesting and informative day was spent touring the facilities and evaluating their information program. With the aid of several data bases and microfilm systems, Sandia offers a highly organized and easily accessible library of materials. Arrangements were made with the Design Center to receive their eight-volume Parts Catalog and the annual updates. These catalogs are now available in Information Services.

Visual Search Microfilm (VSMF). In the 9-month period from October to May a total of 317 searches was made. E-Division personnel made 236 searches and the remaining 81 searches were made by personnel from AP, C, CMB, CNC, CTR, H, J, L, MP, P, and WX. Table VII summarizes this activity. A total of nine courses has been conducted since the beginning of the fiscal year. The courses total 244 contact hours with an average enrollment of 14 students. The total of student contact hours was 3632. The courses are summarized below and in Table VIII.

TABLE VII
E-DIVISION VSMF USAGE

<u>Month (FY-77)</u>	<u>Monthly Total</u>	<u>Running Total</u>	<u>Projected For Year</u>	<u>Monthly Total</u>	<u>Running Total</u>	<u>Projected For Year</u>	<u>% Non-E Usage</u>
Oct.	25	25	300	5	5	60	20%
Nov.	16	41	246	6	11	66	38%
Dec.	30	71	284	14	25	100	47%
Jan.	48	119	357	15	40	120	31%
Feb.	30	149	357	20	60	144	67%
Mar.	33	182	364	14	74	148	42%
Apr.	32	214	366	5	79	135	16%
May	22	236	354	2	81	121	9%

TABLE VIII
CONTINUING EDUCATION COURSE SUMMARY

<u>Course</u>	<u>Contact Hours</u>	<u>E-Div. Registration</u>	<u>Non-E-Div. Registration</u>
Fabrication Techniques	40	20	0
EMI/EMC*	40	9	15
Soldering I	40	6	2
Resistance Soldering II	12	3	1
Resistance Soldering III	12	3	1
Soldering IV	40	3	6
Practical Digital Electronics	20	12	0
Basic Electricity	24	17	0
Mgt. Overview of Microprocessors**	16	3	25
Totals	244	76	50

*Individuals from seven other Divisions participated in this course:
AP, CNC, L, M, MP, R, and WX.

**Individuals from 11 other Divisions participated in this course:
AP, C, CADP, CMB, G, H, J, M, MP, Q, and TD.

1. A Fabrication Techniques course held in the Industrial Arts wing of Los Alamos High School started March 1, 1977, and ended May 26, 1977. Twenty students, all E-2 technicians, registered for the course and seventeen attended regularly. Louis Baca, fabrication coordinator in E-2, and several guest lecturers have instructed the 12-wk course. The students are in the final stages of assembling their multimeters, a project that has given them an opportunity to practice their newly acquired fabrication knowledge and skills. The students and instructor have responded quite favorably to the "hands-on" experience in class. A program of on-the-job fabrication training is being developed as a result of the successful laboratory experiences in this course.

2. A 5-day commercial course entitled Electromagnetic Interference and Electromagnetic Compatibility was presented January 17-21, 1977. Of the 24 students enrolled in the course, 15 were non-E-Division employees (63%). They represented nine different groups. The course was instructed by Don White, a specialist in grounding and shielding. The course evaluation results indicated that the students were very pleased with the presentation from the standpoint of theory and application. The student notebooks and documentation provided for each class member were outstanding and useful for future reference. E-Division employees who participated in the course met to review and discuss ideas for applying information acquired in the course. This group has continued to meet and has been working with the LASL Stock Committee compiling a list of grounding and shielding materials available in stock.

3. A commercial soldering course taught by Robert Waters was offered four times this spring: January 24-28, March 29-30, March 31-April 1, and April 4-8. Of the 25 students who participated in the 4 courses, 10 were non-E-Division employees (40%). The course evaluations of each class indicated the students were very pleased with the method of instruction and impressed with the instructor's expertise in soldering techniques. In May, Waters will begin a program of recertification for those who have not taken a formal soldering course in the past year. Approximately 30 students from E-2 will participate in the recertification program.

4. A Practical Digital Electronics course was begun April 11 and will end June 20, 1977. Twelve technicians, eight from E-2 and four from E-1 enrolled in the 10-wk course. The proctor, Mike Wolf, originally taught the course in 1975. This semester the students are participating in the course through videotapes made of the live course. One day each week, Wolf attends the class to answer questions and discuss laboratory exercises. The text used is Hewlett-Packard's (H-P) Practical Digital Electronics, with accompanying lab workbook. Sharing four H-P logic labs, the students perform logic circuit experiments.

5. A Basic Electricity and dc Circuits course began March 21 and will end May 27, 1977. Seventeen technicians from E-1 and E-2 registered for the 8-wk course. Approximately nine students have regularly attended and will complete the course. The class is being taught by Barbera Stephenson, Training Services, consultant. A recently purchased TI videotape series on basic electricity has been used as a training aid in the course. Students spend a half hour viewing a videotape and another half hour discussing newly learned concepts and practicing mathematical problems. Students have been given an opportunity to participate in special small group or individual tutoring sessions. Several students have used this time to review and improve their math skills.

6. A 16-contact-hour course entitled Management Overview of Microprocessors was conducted by Edward Klingman April 6-8, 1977, in the new video classroom. There were 28 persons enrolled, 26 of whom attended at least one day and 18 of whom attended each of the three sessions. Non-E-Division personnel accounted for 89% of the enrollment. The course was videotaped for make-up and as a maiden voyage for the new video classroom. The facilities proved to be excellent; the instructor and students all seemed to enjoy the use of the overhead camera and student monitors for written material during the lecture. We were very satisfied with the quality of the videotapes. The written course evaluations supported the informal feedback; the class was very well received. Klingman is an excellent instructor who presents the course material in an interesting manner. The students indicated that the information presented was exactly what they wanted.

A survey was made of LASL employee interest in four commercial courses offered by InfoScope, Inc. Forty-five persons responded to the survey expressing greatest interest in logic design and digital systems engineering. Training Services is planning to offer one of these courses next fall.

We have discussed some of our continuing education needs with Evelyn Valdez of the University of New Mexico (UNM) Continuing Education Program. She will attempt to set up some of the needed courses for use through that program. Continuing education units (CEU) would be awarded by UNM for successful completion of offered courses.

Preliminary discussions have been held with Sandia on the possibilities of transmitting their professional-level CE classes to LASL via microwave. Although no commitments have been made, the discussions have been quite promising.

New Training Materials and Equipment.

Videotapes. New videotapes in the self-study collection are:

1. "The Data Domain, Its Analysis and Measurement," H-P, 4 tapes, 20 min each. A 13-part series that uses two microprocessor systems to illustrate the analysis and measurement problems in the data domain.
2. "Basic Electricity and dc Circuits," TI, 14 tapes, 30 min each. An introductory course covering fundamental concepts, terminology and mathematical tools required to understand basic electricity.
3. "Basic Electricity and dc Circuits Laboratory Sessions," TI, 15 tapes, 15 min each. A set of supplementary laboratory exercises covering the analysis of dc electricity, and the prediction of its behavior with simple circuit laws.
4. The "Metric Tutorial Series," H-P, 5 tapes, 15 min each, was evaluated. The five-part series, introducing the most commonly used metric units and prefixes was previewed and returned as interest in the tapes was limited.

Self-Instruction Learning Modules.

1. "Project Learn," Learn, Inc., 4 audio cassettes and study materials. A program designed to teach the average reader to systematically organize his or her thinking so

that learning is more efficient and quicker in all reading-learning situations. We have obtained a number of microprocessor systems, which are available to persons wishing to work with such devices. The TI videotape series, "Designing With Microprocessors," serves as a general introduction to microprocessors. We now have available four 4-bit TI microprocessor learning modules, one 8-bit Intersil intercept junior, and one 8-bit EVK-100 system.

Employee Development [Brown].

Communication Workshops. Three 1-day Effective Communication workshops were held April 4, 5, and 6, 1977. A total of 79 E-Division employees attended one or more days. Robert Simmons, University of Utah, taught the course in a practical, dynamic way that involved the class in practice sessions and discussions. The general workshop objectives were that participants would acquire some basic skills and concepts to improve their communication in common on-the-job situations. An outline of the course follows:

1. A model for interpersonal communication.
2. Filters and judgments; their effects on listening.
3. How to listen when the other person has a problem.
4. How to confront when I have a problem.
5. How to solve a problem that two (or more) people share.
6. How to deal with values conflicts.

The first workshop provided a background and some practice to a general audience, concentrating on listening skills. The second workshop focused on supervisory situations and emphasized confrontation and problem-solving skills. The third workshop, for customer contact situations, included listening, confrontation, problem-solving, and values conflicts. The course was extremely well received. Many participants asked that more courses of this kind be presented. Follow-up mini-workshops will be held in June on an experimental basis, with Molly Brown acting as coordinator/facilitator.

Career Assessment Workshop. Based on the E-Division Career Workshop presented last September, an experimental Career Assessment Workshop for LASL employees has been developed in cooperation with the PER Department and ERO Office. The workshop will be

a prototype to gather data regarding the potential value of such a program on a Laboratory-wide basis. The workshop will meet outside of normal work hours 1 day/wk for 10 wk, beginning in September. A short orientation for the supervisors of participants will also be presented.

Participants, selected from a pool of candidates submitted by the various Divisions and Departments, will provide a cross section of Laboratory employees. They will complete evaluation instruments before and after the course to assess course effectiveness in terms of its objectives. Participant objectives will be increased job satisfaction; greater use of interests; development of skills and abilities; increased self-awareness and self-responsibility; setting realistic goals and planning steps to reach them; increased productivity and creativity on the job; and more open communication with management and employees. Participants will be given tools and an environment to accomplish these objectives. Emphasis will be on self-assessment of career options rather than on Laboratory opportunities.

Career Development Plan. A format for a formal Individual Career Development Plan has been developed. The form includes spaces to indicate immediate job goals, required courses, necessary job assignments for experience, and approvals from the employee, supervisor, and Group Leader. It is clearly stated that job advancement is dependent on performance and job availability. This form has not

yet been distributed because an increased demand for career counseling is anticipated when it is implemented. Training Services intends to provide career counseling when adequate facilities and structure make it possible.

Video-Assisted Self-Study [Galvez, O'Mara]. Use of the video self-study resources has increased during the first 5 months of FY-1977. New videotapes have been added to the library from commercial sources and from in-house courses sponsored by PER-5 and videotaped by ISD. Table IX shows monthly activity and yearly projections for both total usage and for non-E-Division usage. The data are also shown graphically in Fig. 47. Table X shows the average number of Divisions/Departments using the viewing facilities (averaged weekly for each month).

Technician Development [Brown, Lindberg, Mabry]. Barbera Stephenson, consultant to Training Services, has begun working on the three-level technician curriculum written last summer by J. Fox. Stephenson is developing course outlines and writing objectives for designated courses.

Stephenson and Mabry have been working with the fabrication coordinators on developing a separate curriculum for fabrication technicians. Experience has shown that a general curriculum developed for electronic technicians is not necessarily appropriate for individuals with long-term interest or potential in fabrication technology. A program of OJT is now seen to be a key form of continuing education for

TABLE IX
E-DIVISION VIDEO FACILITIES USAGE (PERSON TAPES)

Month (FY-77)	Total Usage			Non-E-Division Usage			
	Total For Month	Running Total	Projected For Year	Total For Month	Running Total	Projected For Year	% Non-E Usage
Oct.	274	274	3288	99	99	1200	36
Nov.	380	654	3924	145	244	1464	38
Dec.	218	872	3488	66	310	1240	30
Jan.	404	1276	3828	205	515	1545	51
Feb.	363	1639	3933	197	712	1708	54
Mar.	357	1996	3992	196	908	1816	55
Apr.	380	2376	4073	165	1073	1839	43
May (3 wk)	387	2763	4530	134	1207	1944	35

Fig. 47. Total usage for 8-month period.

the fabrication technicians. Fabrication coordinators, with the aid of the Training Services staff, will develop and write objectives and goals and act as instructors for the DJT program. The program will be reviewed monthly and changes will be made as needed.

LASL Learning Center [Brown, Lindberg, Mabry]. The video-equipped Learning Center, designed and built by E Division for LASL-wide use in CE activities, has been completed. The classroom, outfitted for 28 students, is equipped for videotaping and recording all classroom activities. An overhead camera picks up the instructor's notes, diagrams, or text, which are displayed directly on student TV monitors. Equipment demonstrations are also easily accommodated. A camera at the back of the room films the students, instructor, and blackboard.

A compact video control center contains a slide/film chain, videotape recorder/player, system monitors, electronic character generator, video switching system, special effects generator, remote camera control, and closed-circuit TV modulators. The entire system can be operated by one person, an important feature in reducing costs.

Courses are videotaped for review, and, if they are of general interest, for long-term retention for

TABLE X

self-study. The facility will be featured in an Atom article and an open house will be held in late June or early July. The facility will be available for general use after final alignment and calibration are completed in August.

Audio-Visual Equipment Pool Procedures [Babb, Lindberg]. The Information and Training Services Office has adopted a policy of loaning equipment to persons having legitimate need for it. Our earlier procedures have been highly informal but we now find it necessary to tighten them. We have established definite loan periods for certain equipment to discourage persons from holding it longer than necessary.

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31. E. L. Jolly, J. G. Sutton, M. D. Thomason, and F. D. Wells, "Minicomputer/CAMAC Control System for an Eight-Beam CO Laser Facility," submitted for publication.

32. M. Zaider, J. F. Dicello, and R. D. Hiebert, "A Pulsed System for Obtaining Microdosimetric Data with High Intensity Beams," submitted to 1977 Nuclear Science Symposium, San Francisco, CA, October 19-21, 1977.

33. M. A. Wolf, "Portable Survey Instrument for Low Levels of Transuranic Contaminants," to be published as a Los Alamos Scientific Laboratory informal report LA-6860-MS.

APPENDIX A

DIVISION PAPERS, REPORTS, TALKS, AND MEETINGS

Papers Submitted for Meetings

R. R. Bartsch, E. L. Cantrell, R. F. Gribble, K. B. Freese, L. E. Handy, R. Kristal, G. Miller, and W. E. Quinn, "Feedback Stabilization Experiments Using $\lambda = 2$ Equilibrium Windings in Scyllac," European Conference on Controlled Fusion and Plasma Physics, Prague, Czechoslovakia, September 19-23, 1977.

David Brown and Ulrich Neumann, "An Improved Programmable Delay Line," 1977 Nuclear Science Symposium, San Francisco, CA, October 19-21, 1977.

Steven W. Depp and J. Byron McCormick, "Electronic Gain Devices for High-Temperature Instrumentation," Dresser Industries, Inc., Meeting, Houston, TX, December 9, 1976.

J. F. Dicello, R. D. Hiebert, and M. Zaider, "A Pulsed System for Obtaining Microdosimetric Data with High-Intensity Beams," 1977 Nuclear Science Symposium, San Francisco, CA, October 19-21, 1977.

M. Edmiston, C. Gruhn, R. Hammond, and C. Maggiore, "Energy Resolution Considerations in Liquid Ionization Chambers," American Physical Society Meeting, Washington, DC, April 25-28, 1977.

Michael D. Edmiston and Charles R. Gruhn, "Energy Resolution Considerations in Liquid Ionization Chambers," 1977 Nuclear Science Symposium, San Francisco, CA, October 19-21, 1977.

C. Dwayne Ethridge and Gary M. Worth, "Scientific Calculating System with a Number-Oriented Microprocessor Sequenced by a Single Component Microcomputer," 1977 Nuclear Science Symposium, The Institute of Electrical and Electronic Engineers, Nuclear Plasma Society, San Francisco, CA, October 19-21, 1977.

Donald R. Farris and James L. Melsa, "Energy Savings for a Solar Heated and Cooled Building Through Adaptive Optimal Control," IFAC VII World Congress, Helsinki, Finland, 1978.

Donald R. Farris, James L. Melsa, Hugh S. Murray, Thomas E. McDonald, and Thomas E. Springer, "Energy Conservation by Adaptive Control for a Solar Heated and Cooled Building," 1977 International Conference on Cybernetics and Society, Washington, DC, September 19-21, 1977.

L. A. Franks, M. A. Nelson, T. J. Davies, P. Lyons, and J. Golob, "Use of Time Dispersion in a Delta

Function Light Pulse to Determine Optical Fiber Transmission," Conference on Laser Engineering and Applications, Washington, DC, June 1-3, 1977.

J. E. Golob, P. B. Lyons, and L. D. Looney, "Transient Radiation Effects in Low Loss Optical Waveguides," 1977 IEEE Conference on Nuclear and Space Radiation Effects, Williamsburg, VA, July 12-15, 1977.

J. S. Ladish, R. L. Carlson, E. L. Jolly, M. D. Montgomery, J. G. Sutton, M. D. Thomason, and E. L. Zimmerman, "Multiline Energy Extraction Measurement in the LASL Eight-Beam Laser Fusion Facility," 1977 IEEE/OSA Conference on Laser Engineering and Applications, Washington, DC, June 1-3, 1977.

J. A. Landt, "A Unified Time Domain Electromagnetic and Circuit Analysis Code," USNC/URSI Meeting, Stanford, CA, June 20-24, 1977.

J. A. Landt, "Massive Hydraulic Fracture Mapping Using Magnetic Induction," USNC/URSI Meeting, Stanford, CA, June 20-24, 1977.

Arvid Lundy, Joseph R. Parker, James S. Lunsford, and A. Don Martin, "Avalanche Transistor Pulser for Fast Gated Operation of Microchannel Plate Image Intensifiers," 1977 Nuclear Science Symposium, San Francisco, CA, October 19-21, 1977.

P. B. Lyons, L. D. Looney, R. E. Robichaud, M. A. Nelson, T. J. Davies, and J. E. Golob, "Fiber Optics Utilization at the Nevada Test Site," 1977 Electro-Optic/Laser Conference and Exposition, Anaheim, CA, October 25-27, 1977.

James W. McFarland, Thomas E. Springer, Ellis A. Monash, and Ronald G. Cummings, "Long-Term Alternatives Between Production Rate and Supply of Oil and Natural Gas: Some Implications from a Simulation Study," Second Pacific Chemical Engineering Congress (PACHEC '77), Denver, CO, August 28-31, 1977).

E. J. McLellan and J. S. Lunsford, "A Single-Sweep 5-GHz Oscilloscope Detector Combination for CO₂ Laser Pulse Measurements," 1977 IEEE/OSA Conference on Laser Engineering and Applications, Washington, DC, June 1-3, 1977.

Hugh S. Murray, Michael A. Trump, and James C. Hedstrom, "Solar Heating and Cooling System Performance Experiments in the Los Alamos National Security and Resources Study Center," 1977 Annual Meeting of the American Section/International Solar Energy Society, Orlando, FL, June 6-10, 1977.

Dwight L. Stephenson, "A Portable Intelligent Adaptive Data-Acquisition System," American Geophysical Union Meeting, San Francisco, CA, December 7, 1976.

Dwight L. Stephenson, "MADAS - The Suitcase Portable Computer," '77 NCC "The Great Computer Roundup," Dallas, TX, June 13-16-1977.

Bobby G. Strait and Michael E. Thuot, "A Microprocessor Controller for Stepping Motors," IEEE Microcomputer '77 Conference, Oklahoma City, OK, April 6-8, 1977.

B. G. Strait and M. E. Thuot, "Distributed Microcomputer Control System for a High-Energy Gas-Laser Facility," IEEE Microcomputer '77 Conference, Oklahoma City, OK, April 6-8, 1977.

Michael E. Thuot and Neville A. Black, "A Microcomputer-Based Area Control System," IEEE Microcomputer '77 Conference, Oklahoma City, OK, April 6-8, 1977.

Papers Submitted for Publication

R. E. Bobbett, A. R. Koelle, J. A. Landt, and S. W. Depp, "An Electronic Identification and Temperature Monitoring System," submitted for publication as a Los Alamos Scientific Laboratory informal report.

A. Criscuolo, "E-5 Microcontroller User's Manual," submitted for publication as a Los Alamos Scientific Laboratory informal report.

L. A. Franks, M. A. Nelson, T. J. Davies, P. B. Lyons, and J. Golob, "A Technique for Measuring Optical Fiber Transmission Using the Time Dispersion of Cerenkov Radiation," submitted for publication in the Journal of Applied Physics.

B. L. Hartway and E. N. Shaskey, "The LASL Upgraded Alarm System Functional Requirements," submitted for publication as a Los Alamos Scientific Laboratory informal report.

Jack Nachamkin and John H. Hancock, "Rules Equivalent to an Application of Green's Reciprocity Theorem to Space-Charge Electronics," submitted for publication in the IEEE Transactions on Electronics Devices.

Dennis G. Perry and J. Donald Nickell, Jr., "A 11-croprocessor Controlled Dual Parameter ADC System with a CAMAC Interface," submitted for publication in Nuclear Instruments and Methods.

Gary C. Salzman, Richard D. Hiebert, and John M. Crowell, "Data Acquisition and Display for a High-Speed Cell Sorter," submitted for publication in Computers and Biomedical Research, an International Journal.

Luciano Stanchi, "A Self-Patching Firmware Program," submitted for publication as a Los Alamos Scientific Laboratory informal report.

B. G. Strait and M. E. Thuot, "A Microprocessor Stepping-Motor Controller," submitted for publication in a book entitled, "Microcomputer Design and Applications," Academic Press, Norman, OK.

B. G. Strait, M. E. Thuot, and J. P. Hong, "Distributed Microcomputer Control for a High-Energy Gas-Laser Facility," submitted for publication to Computer Magazine.

T. C. Wallace, G. E. Cort, J. J. Damran, and M. C. Cline, "Development of Pyrolytic Graphite/Silicon Carbide Composite Materials for Rocket-Nozzle Applications," (Vol. I: Description of the Injector Deposition Furnace), submitted for publication as a Los Alamos Scientific Laboratory formal report.

T. C. Wallace, G. E. Cort, J. J. Damran, and D. R. Court, "Development of Pyrolytic Graphite/Silicon Carbide Composite Materials for Rocket-Nozzle Applications," (Vol. II: Description of the Channel Flow Deposition), submitted for publication as a Los Alamos Scientific Laboratory formal report.

Papers Accepted for Publication

R. Hiebert, H. Ide, and H. Boyd, "Low-Background Assaying Using a Modified Commercial Liquid Scintillation Detector and Sample Changer," accepted for publication in Health Physics Journal.

R. D. Hiebert, H. A. Thiessen, and A. W. Obst, "Photomultiplier Tube Base for High-Pulsed Anode Currents," accepted for publication in Nucl. Instr. and Meth.

APPENDIX B

ABSTRACTS OF PUBLISHED PAPERS

DECEMBER 1, 1976 THROUGH MAY 30, 1977

R. E. Bobbett, A. R. Koelle, J. A. Landt, and S. W. Depp, "Description of a Passive Temperature Telemetry System," Los Alamos Scientific Laboratory informal report LA-6725-MS, February 1977.

An electronic temperature-monitoring system is described. This system, designated Model 75, was designed and fabricated in 1975 to demonstrate the feasibility of monitoring the temperature of a bovine animal via a passively powered transponder implanted under the animal's skin. The purpose of

this report is to document the functional elements comprising this successful preprototype system.

D. Brown, A. Greenwood, J. C. Pratt, and J. E. Spencer, "Multichannel Remotely Programmable Logic Delay System," Nucl. Inst. and Meth. 138, 695-713, 1976.

A remotely programmable logic delay system is described consisting of up to 16 independent electronic delays for fast NIM pulses -- each having a delay capability of 0-101 ns. Each delay can be set locally at the delay unit or remotely from a two-wide CAMAC unit which permits front-panel manual or computer selection of any delay channel and its delay. Individual delay settings over the full range show less than a ± 1 ns maximum accumulated error from their nominal settings for typical NIM pulse widths down to 6 ns fwhm at instantaneous rates up to 50 MHz. Pulse-width variations between input and output are less than ± 1 ns for the same pulse widths and rates.

Donald R. Farris, Hugh S. Murray, Thomas E. Springer, Thomas E. McDonald, James L. Melsa, and Richard V. Monopoli, "Adaptive Control for Energy Conservation, Report No. 1," Los Alamos Scientific Laboratory status report LA-6753-SR, March 1977.

This report describes the work to date on the project, Adaptive Control for Energy Conservation. The objective of this project is to study the applicability of using adaptive control techniques to reduce the auxiliary energy needed in a solar heated and cooled building. A brief survey of available adaptive control techniques is given and arguments are presented to explain why the particular approach used was selected. A cost functional to define optimal performance and an identification scheme to produce a linearized plant model are proposed to yield an adaptive linear regulator solution. Simulations have shown a substantial reduction in auxiliary energy required. These results and plans for the remainder of the project are described.

C. R. Gruhn, "Epitaxial Silicon Semiconductor Detectors Past Developments, Future Prospects," IEEE

Transactions on Nuclear Science, Vol. NS 24, No. 1, February 1977.

A review of the main physical characteristics of epitaxial silicon as it relates to detector development is presented. As examples of applications, results are presented on (1) epitaxial silicon avalanche diodes (ESAD); signal-to-noise, non-linear aspects of the avalanche gain mechanism, gain-bandwidth product, (2) ultrathin epitaxial silicon surface barrier (ESSB) detectors, response to heavy ions, (3) an all-epitaxial silicon diode (ESD), response to heavy ions, charge transport and charge defect. Future prospects of epitaxial silicon as it relates to new detector designs are summarized.

C. R. Gruhn, P. D. Goldstone, and Nelson Jarmie, "An All Epitaxial Silicon Diode Heavy Ion Detector," IEEE Trans. on Nucl. Sci., Vol. NS-24, No. 1, February 1977.

An all epitaxial silicon diode (ESD) heavy ion detector has been designed, fabricated, and tested. The active area of the detector is 5 cm^2 and has a total thickness of 50μ . The response of the detector has been studied with fission fragments, alpha particles, oxygen ions, and sulfur ions. A number of advantages in terms of both fabrication and performance are discussed.

R. D. Hiebert and H. A. Thiessen, "Photomultiplier Tube Base for High Pulsed Anode Currents," Nucl. Inst. and Meth. 142, pp. 467-469, 1977.

The stability of photomultiplier tube (PMT) gain for signal conditions of high pulsed anode currents required a PMT base circuit capable of maintaining constant voltage to the last few dynodes for the pulse duration. For the experimental conditions at the Los Alamos Meson Physics Facility (LAMPF) with a macropulse duration of $500 \mu\text{s}$ at 120 Hz, conventional base circuits do not meet stability requirements. The new base circuit uses high voltage transistors to furnish pulse currents to the last four dynodes of the PMT from a single capacitor source which is recharged during the period between macropulses.

Alfred R. Koelle and Steven W. Depp, "Doppler Radar with Cooperative Target Measures to Zero Velocity and Senses the Direction of Motion," Proc. of the IEEE, pp 492-493, March 1977.

A Doppler radar system is described which uses a modulated scatterer as a cooperative target. The amplitude modulation sidebands in the return signal allow effective discrimination against background reflections and enable measurement to zero velocity and sensing of the direction of motion.

Alfred R. Koelle, Steven W. Depp, Jeremy A. Landt, and Ronald E. Bobbett, "Short-Range Passive Telemetry by Modulated Backscatter of Incident cw rf Carrier Beam" Biotelemetry, III, pp 737-340, (Academic Press, New York, NY), 1976.

Modulated backscatter telemetry was developed as a means for reporting the temperature of cattle, along with an identification code for each animal. Objectives included low cost and passive (no battery) operation of the implanted transponders. This novel telemetry method should be useful in other applications. The paper describes the principle of operation and solutions to some of the problems encountered during the development.

C. J. Maggiore, P. D. Goldstone, C. R. Gruhn, Nelson Jarmie, S. C. Stutlar, and H. V. DeHaven, "Thin Epitaxial Silicon for dE/dx Detectors," IEEE Trans. on Nucl. Sci., Vol. NS-24, No. 1, February 1977.

The techniques for fabricating thin self-supporting epitaxial films for dE/dx detectors have been studied. Detectors having thicknesses between 1 and 4 μm with areas of 12.5 mm² have been fabricated and tested. The response of the detectors has been studied with alpha particles, oxygen ions, and fission fragments.

L. Stanchi and M. R. Vasey, "Effluent and Sanitary Sewer Monitors," Los Alamos Scientific Laboratory Manual LA-6638-M, March 1977.

Two similar instruments that monitor the liquid wastes from the plutonium facility are described. The operation of the two instruments is completely automatic and performs a continuous surveillance in the frame of Nuclear Safeguards. One instrument controls the liquids from the facility and the other checks the sanitary sewer wastes. Both have self-diagnosing capabilities and take automatic actions in case of abnormal occurrences.