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Progress Report

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E-Division Semiannual Report

July 1—December 31, 1978

University of California

LOS ALAMOS SCIENTIFIC LABORATORY

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Progress Report

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July 1—December 31, 1978

P. W. Keaton
Division Leader

Compiled by
Patricia A. Kelley

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E-DIVISION SEMIANNUAL REPORT

July 1-December 31, 1978

Compiled by

Patricia A. Kelley

P. W. Keaton, Division Leader

ABSTRACT

We report the status of the programs and projects of the Electronics Division for the period July through December 1978. The presentation is divided into three sections: Research, Engineering Support, and Technical Services. Each of these sections presents the activities and accomplishments of the corresponding branch within the Division. The primary goal of the Research and Development branch is to advance technology for future applications. The primary goal of the Engineering Support branch is to apply advanced technology to Laboratory and material problems. The primary goal of the Technical Services branch is to provide a technical base and support for Laboratory programs. These goals are reflected in this report.

1. RESEARCH, P. W. KEATON, DIVISION LEADER

A. Solid-State Electronics [Ahrenkiel, E-10]

1. Introduction. Group E-10 performs basic and developmental research on a variety of solid-state devices. The work is primarily directed toward the development of high-speed electronics and radiation detection. It is applicable to a variety of programs including weapons, nuclear physics, laser fusion, geothermal, solar power, high-energy physics, nuclear medicine, and nuclear safeguards.

2. Onsets of the Electron-Hole Droplet Luminescence in Silicon [Hammond, E-10; Silver, T-11].

The nucleation kinetics of electron-hole droplets (EHD) from a free-exciton (FE) gas in semiconductors has been of considerable interest both theoretically and experimentally. The EHD provide a unique test of nucleation kinetics because of new phenomena predicted due to the finite lifetimes of the condensing particles. As in ordinary liquid-gas transitions, there are two threshold gas densities at each temperature. A coexistence line separates the

lower densities where the liquid is unstable from the higher densities where the liquid is stable. At higher densities than the coexistence line, a supersaturation line, or "onset line," separates densities where nucleation is too slow to be observed from the densities where nucleation can be measured. The effects of finite lifetime on these thresholds are to raise the thresholds above the infinite lifetime limit, to make them weakly temperature-dependent at low temperatures, and to cause the coexistence line and supersaturation line to merge at low temperatures. These predictions and others, such as stable droplet sizes, have been successfully tested for EHD in unstrained germanium. However, other materials where EHD have been observed (silicon, gallium phosphide, cadmium sulfide, cadmium selenide, silicon carbide, silver bromide) will provide more stringent tests of the theory because the EHD in these materials have more than 2 orders of magnitude shorter lifetimes than in germanium. We have done detailed measurements of the

onsets for EHD formation in silicon, and we have shown that they are in agreement with finite lifetime nucleation kinetics.

Our experimental conditions were chosen to minimize the effects of both the temperature variation of the FE lifetime and of FE diffusion. The FE lifetimes increase from $\sim 1 \mu\text{s}$ at 4 K up to $\sim 50 \mu\text{s}$ at 12-18 K. The EHD lifetime was $165 \pm 10 \text{ ns}$ and temperature independent for $T < 19 \text{ K}$. The EHD onsets were observed with pulse-excitation parameters, which insured that the FE density was proportional to laser power to within $< 10\%$. The laser-excitation pulse length was 300 ns, the repetition period was 100 μs , and the photon counter was gated to count only during the laser pulse. Thus, the FE did not decay significantly during a single pulse but decayed almost completely between pulses. The effect of FE diffusion during a single pulse was minimized by the long absorption length of $\sim 50 \mu\text{m}$ in silicon of the 8505-A excitation radiation from the gallium-arsenide laser.

In order to determine onsets, the intensities of silicon luminescence at 1.0960 eV and 1.0806 eV were measured as a function of laser intensity. These energies are the peak positions of the strong FE and EHD recombination luminescence. Onsets were determined by two methods. Below 8.3 K the luminescence at 1.0806 eV was observed to rise linearly with laser power above onset. Thus, linear extrapolation to zero intensity as shown in Fig. 1 determined the onset laser intensity. Above 7.3 K a weak FE background appeared at 1.0806 eV. At these temperatures the ratio of intensities at 1.0806 eV and 1.0969 eV is constant below onset and is observed to rise linearly above the onset as shown in Fig. 2. The onsets were measured at 17 temperatures from 2.5 K to 19.3 K.

Figure 3 shows the measured onsets as a function of $1/T$. Above 11 K the data can be fit to the form $I_{th} \sim T^{3/2} \exp(-\phi_{\infty}/T)$ expected for an infinite lifetime phase diagram as shown by the solid line. However, the yielded value of $\phi_{\infty} = 44 \text{ K} \pm 10 \text{ K}$ is well below the spectroscopic value of $\phi_{\infty} = 95 \text{ K}$.¹ This is somewhat analogous to germanium where determinations of work functions from onset measurements (typically 16-17 K) are consistently below spectroscopic values ($\sim 22 \text{ K}$).

Fig. 1. The luminescence intensity at 1.0806 eV is plotted vs laser pump intensity for 2.5 K. The linear extrapolation to zero intensity yields the laser intensity of the onset of the EHD luminescence.

Figure 4 shows our results (circles) plotted vs T . The normalization of our measured onset laser intensities to FE densities is determined by comparison to finite lifetime nucleation kinetics. Shown as the dotted line is the infinite lifetime coexistence line using the spectroscopic work functions. Even apart from normalization it is apparent that with decreasing temperature the measured onsets

Fig. 2. The ratio of luminescence intensities at 1.0806 eV and 1.0969 eV is plotted vs laser pump intensity for 13.2 K and 16.3 K. The horizontal line is the value of the ratio when only FE are present. The linear extrapolation to the FE ratio yields the laser intensity of the onset of the EHD luminescence.

THERMODYNAMIC WORK FUNCTION FOR EHD IN SILICON

Fig. 3. The EHD luminescence onsets are plotted vs T^{-1} . The solid line is a best fit of the high T data to $I_{th} \sim T^{3/2} \exp(-\phi_{\infty}/T)$. The fit yields $\phi_{\infty} = 44$ K.

in silicon depart increasingly from the dotted line and become temperature independent at low temperature as theoretically expected. The variable parameters are the surface tension S and the sticking fraction γ . We find that fits can be obtained only for $S \leq 1.1 \times 10^{-2} \text{ erg/cm}^2$ and for $\gamma \leq 0.05$. The fits shown in Fig. 4 take the theoretical value $S = 8.75 \times 10^{-3} \text{ erg/cm}^2$ and $\gamma = 0.037$, which is barely within the range of ordinary liquid-gas transitions. Fits could be obtained for arbitrarily small S provided S/γ is fixed at 8.3×10^{-2} for $S \leq 5 \times 10^{-3}$. At $S \leq 5 \times 10^{-3}$ the onset line is merged with the coexistence line, which depends only on the ratio S/γ . These low values of S and γ could be ruled out by the observation of measurable hysteresis.

Previous successful fits to EHD nucleation in germanium assumed a sticking fraction of 1. For silicon the small sticking fraction may be a phenomenological description of other physical phenomena not included in the model. The very much faster Auger-dominated EHD recombination in silicon

produces a relatively high flux of nonequilibrium phonons emanating from a droplet. Interaction of excitons with these phonons could decrease their probability of capture at the droplet surface.

In summary, we have measured the onsets for the nucleation of EHD in silicon and have shown them to be in agreement with finite lifetime nucleation kinetics.² All of the qualitative phenomena predicted have been observed. Our fits determine a surface tension $\leq 1.1 \times 10^{-2} \text{ erg/cm}^2$ consistent with theoretical estimates and a sticking fraction ≤ 0.05 within the range of other liquid gas transitions. Our results suggest that finite lifetime nucleation kinetics will be an applicable theory to EHD formation in other semiconductors.

Fig. 4. Our data (circles) are plotted vs T . The solid line is a best fit of our onset data to the finite lifetime nucleation theory. The dashed line is the predicted coexistence line. We assume a surface tension of $8.75 \times 10^{-3} \text{ erg/cm}^2$ and sticking fraction 0.037. The dotted line is the infinite lifetime prediction for the coexistence line.

3. Superconducting Josephson Digital Electronics [Wang, E-10].

a. Background. Ultrahigh-speed (13 ps) switching gates with extremely low-power dissipation (~ 2 mW/gate) based on Josephson junctions have recently been demonstrated at IQM.³ Consequently, a program for high-speed instrumentation designed to meet specific needs at Los Alamos Scientific Laboratory (LASL) was initiated.

b. Current Activities. Recently, a high-vacuum pumping system and a four-hearth electron beam gun were obtained. The vacuum system was installed and tested with the base pressure of less than 1.3×10^{-7} Pa (1×10^{-9} torr). The electron beam system with the proper mechanical drive was installed. An elaborate fixture for substrates, masks, and the shutter was designed. This fixture will allow arbitrary combination of any one of six different masks to be used with any one of six sets of substrates without breaking the vacuum. Three thermal evaporation boats are being incorporated into the system for either sequential evaporation of seven different materials or coevaporation of twelve different combinations of materials. Servo-controlled heaters were assembled for outgassing the vacuum system and maintaining substrate temperature up to at least 500°C.

The feasibility of using materials other than the conventional Nb_2O_5 as the tunneling barrier for niobium-based Josephson junctions was investigated. Si_3N_4 , Al_2O_3 and hydrogenated silicon are promising candidates in terms of their mechanical and electrical properties for high-speed switching. Preparations of these barrier materials will be made when the system is completely assembled.

c. Future Efforts. The existing power supply to the electron beam system will be modified to power the turret electron source. Direct current glow discharges will be used for cleaning the substrate and electrodes before depositions are made. A precision automatic gas flow control system together with rf discharge will be designed and installed to facilitate control of the barrier formation. The rf amplifier, the gas flow control system, and the thermal evaporation power supply should be delivered in the next 2 months.

4. Spin-Glass-Like Phase in Reentrant Magnetic Superconductors [Wang, E-10; Kohn, Huang, Q-10; Smith, CMB-5].

a. Introduction. The study of competing mechanisms between magnetic ordering and superconductivity has been of considerable interest. We have investigated the interaction between these two competing mechanisms for ordering in the reentrant magnetic superconductor $Gd_xEr_{1-x}Rh_4B_4$. Measurements of the low-field ac susceptibility on these pseudoternary compounds for x between 0 and 1 have revealed three different concentration regimes:

- A high-temperature superconducting phase followed by a low-temperature ferromagnetic transition and loss of superconductivity for $x \leq 0.26$.

- A direct paramagnetic to ferromagnetic transition for $x > 0.28$.

- A phase similar in certain respects to that observed in spin glass for $x \approx 0.28$.

A discussion on the nature of the reentrant magnetic superconductivity in these compounds was recently presented.⁴ Here we report our results on ac susceptibility measurements for samples with $x \approx x_c$, where x_c is the critical concentration at which the superconducting transition temperature T_c and the ferromagnetic ordering temperature T_m coincide. Many observed features are similar to the characteristics of a spin-glass system.

b. Experimental Results and Discussions. The samples were prepared following the method employed by Fertig, et al.⁵ The susceptibility was measured at a typical frequency of 400 Hz and a driving field of the order of 10^{-2} Oe.

For $x \approx 0.28$ the ferromagnetic exchange interaction competes with superconductivity. An analogous phase with peculiar ac susceptibility and resistance behavior occurs near the critical concentration.

In Fig. 5 the salient features are:

- The sample is not superconducting down to 0.6 K.

- In the absence of externally applied static magnetic field H , a pronounced maximum in the ac $\chi(T)$ and a minimum in $R(T)$ are observed near 2.4 K and 2.6 K, respectively.

- With a small magnetic field ($H \approx 10^2$ Oe), the extrema in both $\chi(T)$ and $R(T)$ are depressed and rounded with corresponding shifts in the

Fig. 5. Magnetic field and temperature dependencies of ac susceptibility χ and resistance R for $Gd_{0.28}Er_{0.72}Rh_4B_4$.

temperatures at which these extrema occur. With increasing fields, there is a displacement of the susceptibility peak (T_0) temperature towards lower temperatures, and a second smaller susceptibility bump begins to appear at increasingly high temperatures.

The temperature and field dependencies of the magnetic susceptibility in $Gd_{0.28}Er_{0.72}Rh_4B_4$ exhibit striking similarities to that observed in a spin glass. In the absence of an external field $H = 0$, we have a sharp peak in $\chi(T)$ at T_0 . Small external fields ($\sim 10 - 10^2$ Oe) round the maximum in χ and shift T_0 to lower temperatures. In a spin glass the field hinders the occurrence of the spin glass transition and hence depresses the "freezing temperature," T_f .⁶ By spin glass, we mean that as the temperature is lowered in the absence of an external

magnetic field, impurity spins become locked in random directions with no net macroscopic movements and there is no long-range magnetic order. The freezing occurs at a well-defined temperature T_f .

For values of $x < x_c$, a paramagnetic + superconducting $\rightarrow$ ferromagnetic transition occurs. For $x > x_c$ these pseudoternary compounds change from paramagnetic to ferromagnetic ordering directly without any intervening superconducting or spin glass-like regime. For x near x_c the ordering energies of the two opposing mechanisms present in the system nearly balance each other and result in the mixed regime lying between the two limits. There might be two different transitions very close to each other, resulting in a sharp peak of $\chi(T)$ in the absence of field. With finite fields the appearance of the second susceptibility bump at a temperature higher than T_0 may imply a ferromagnetic transition. An external field is favorable for ferromagnetism and would enhance the ferromagnetic transition temperature, but it depresses the spin-glass freezing temperature.

For a spin glass, the order parameter $q(T)$ is defined as the spatial average of the square of the thermally averaged local moment. From the temperature dependence of the inverse susceptibility, the order parameter can be extracted. The experimental results are given in Fig. 6 by the solid dots, whereas the solid curve is a fit of $q(T) \propto (T_f - T)^\beta$ with $\beta = 0.97 \pm 0.03$. Excellent agreement of our data with the mean field prediction ($\beta = 1$) was obtained.⁷

At present most spin-glass systems are composed of 3d-magnetic solutes with locally random competition between antiferromagnetism and ferromagnetic ordering. The rare earth 4f wave functions are highly localized, and the indirect exchange interaction mediated by conduction electrons is much weaker. In the reentrant magnetic superconductor one may ask whether spin-glass phase may be caused by competition between superconductivity and ferromagnetism. More work needs to be performed in order to characterize the spin-glass-like phase observed in $Gd_{0.28}Er_{0.72}Rh_4B_4$.

5. Pyroelectric Detectors [Stotlar, E-10; Gibbs, E-2]. An effort to develop fast pyroelectric detectors with high-damage thresholds for the LASL high-energy laser program has been under way since

Fig. 6. Temperature dependence of the spin glass order parameter $q(T)$. The solid curve is a fit of $q \propto (T_f - T)^\beta$ with $\beta = 0.97 \pm 0.03$. The spin glass freezing temperature T_f was taken to be the temperature of susceptibility cusp T_0 . Mean field theory predicts $\beta = 1$.

June 1978. A pyroelectric detector is a thermal sensor where the electrical signal is proportional to a change in temperature. Some of the materials that will be investigated under this program are strontium barium niobate (SBN), lithium tantalate (LiTaO_3), lithium niobate (LiNbO_3), lanthanum-doped lead zirconate (PLZT), and polyvinyl fluoride films (PVF, PVF_2).

Strontium barium niobate with a strontium-to-barium ratio of 1 (50/50 SBN) was obtained from Crystal Technology, Inc., and Harshaw Chemical Company. Preliminary bulk measurements of the Curie temperature and pyroelectric coefficient were performed. The Curie temperature is measured by plotting the capacitance or dielectric constant as a function of temperature. The temperature at which a phase transition occurs (as shown by a maximum value of ϵ) is called the Curie temperature. The pyroelectric coefficient is measured by monitoring the current across the detector as a function of temperature for a linear heating rate. The electric field must be held constant during the measurement, but need not be zero. For constant stress and electric field the current generated will be

$$I = \frac{dQ}{dt} = A \frac{dD}{dt} = pA \frac{dT}{dt}, \quad (1)$$

where I is the pyroelectric current, A the electrode area, Q the charge, and d/dt the change in temperature with respect to time (constant). Then the pyroelectric coefficient p is

$$p = \frac{I}{A} \frac{dt}{dC}. \quad (2)$$

For these measurements, the Crystal Technology material had a dielectric constant ($\epsilon = c\ell/t_0A$ where C is the capacitance, ℓ the electrode separation, and ϵ_0 the permittivity of free space) one-third higher than the Harshaw material, half the pyroelectric coefficient, and a Curie temperature curve with several maxima. The material appeared to be a mixture of different stoichiometric ratios.

The first investigation under this program was the proper mount and mounting techniques for a fast pyroelectric detector. A rugged, easily available, easy to use package is the goal. Detectors were built in connector packages to reduce the number of interfaces between the chip and the 5-GHz oscilloscope, which was designed by Group J-14 and built by Group E-2. The connectors used included SMA to BNC, type SMA to N, BNC to BNC, and type N to type N. Using the time domain reflectometer (TDR) to evaluate the fall time of the detectors, the SMA to BNC connector provides the best package for very fast pyroelectric detectors to follow 100-ps pulses.

A fast detector was designed as shown in Fig. 7. This device was compared with a Molecron P5-00 SBN pyroelectric detector in following nominally 100-ps CO_2 laser pulses (see Fig. 8). The Molecron detector was measured before and after remounting in the LASL package. The full width at half maximum (FWHM) improved from 184 ps to 169 ps, and the ringing on the tail was eliminated. The LASL detector in combination with the oscilloscope and the pulse had a FWHM of 150 ps.

The fall time of the detector, as determined from TDR results; was 31 ps ($2.2 RC$), indicating a stray capacitance of 0.14 pF. The risetime of the detector, inductance limited, was less than 15 ps. These are the fastest measurements of any pyroelectric detector reported to date.

The next phase of this program will be to measure the damage threshold of various pyroelectric materials for single and multiple pulses.

Fig. 7. Schematic drawing detailing a fast detector.

6. Alternating Current Josephson Effect in NSN Junctions [Wang, E-10].

a. Introduction. In 1962 Josephson predicted that a supercurrent would flow through an insulating barrier between two superconductors (SIS). As a result of the interference between two macroscopic quantum states associated with the two superconductors, the current would be dc at zero voltage difference

Fig. 8. Comparison of detector responses.

across the two superconductors, but ac otherwise. Nearly all of Josephson's predictions have been experimentally verified. The Josephson phenomena are not unique to tunnel junctions, but are known experimentally to occur in other weakly coupled superconductors including superconductor-normal metal-superconductor (SNS) structures.

It is important and interesting to understand how generalized the concept of quantum interference is. Experiments by D. W. Palmer on superconductor-normal metal (SN) interface suggested the existence of a modified form of quantum interference from the rf-induced step structures in the current-voltage (I-V) characteristics.⁸ In the present work, well-defined planar normal-superconducting normal-metal junctions (NSN) were examined for evidence of quantum interference. Critical current and rf-induced step structures were found in the I-V characteristics. The similarity of these characteristics to those of SNS bridges suggests that ac Josephson or quantum interference effect can exist in NSN geometry.

b. Results. Planar NSN bridges were fabricated at California Institute of Technology. Through proximity effect, as shown in Fig. 9, the bridge (length, l , and width, W) region has a higher superconducting transition temperature, T_C' , than that of the "normal" banks (T_C) made from composites of normal (N) and superconducting (N) films. As an example, in the upper insert of Fig. 9, 400 Å of Ta film was evaporated on top of 200 Å of W film with $l = 0.7 \mu\text{m}$, $W = 18 \mu\text{m}$ and thickness difference between the bridge and the adjacent depressed banks about 300 Å. This NSN bridge showed a transition temperature in the bridge $T_C' = 3.3 \text{ K}$ and in the "normal" region $T_C \approx 2.22 \text{ K}$ (Fig. 9).

Application of low-power rf radiation (0.1-10 GHz) resulted in step structures above the critical current. The modulation of the differential resistance at the step voltage involved only the resistance at the bridge region 0.015Ω in the example shown in Fig. 10 and not the series resistance (0.50Ω in Fig. 10) associated with the adjacent normal banks. A critical current of 2.3 mA was determined by four terminal measurements at 3.08 K in the absence of rf radiation (Fig. 10a). When the bridge was irradiated with microwaves at a frequency of $f = 10 \text{ GHz}$, harmonics and subharmonics of the

Fig. 9. Temperature dependence of the differential resistance of a particular NSN bridge with the configuration shown in the upper insert. The bridge is made of 400 Å of tantalum film on top of 200 Å tungsten normal film. The length of the bridge, l , in the current flowing direction is 0.7 μm , the width 18 μm , the depressed "normal" bank (N) regions 300 Å. Superconducting transition temperature T_c of the bridge, S, is 3.3 K and that of the bank, N, 2.22 K. The normal resistance of the bridge (about 0.015 Ω) is in series with that of N regions (0.5 Ω).

fundamental voltage $V = hf/2e$ (Josephson frequency-voltage relation) were observed where h is Planck's constant and e is the electron charge ($2e/h \approx 484$ GHz/mV). The modulation of the critical current and step widths with rf power closely resembled the Bessel function dependence seen in the usual SNS or SIS junctions.

The effect of rf irradiation at 900 MHz is shown in Fig. 10c with the higher harmonics up to $n = 4$ identified ($V = nhf/2e$). Experimental verifications on other geometries of NSN bridges are under way. A theoretical analysis of this unusual phenomenon is being developed.

7. III-V Compound Semiconductors [Ahrenkiel, Dunlavy, Hammond, Maggiore, Stotlar, E-10]. The

development of metal-insulator-semiconductor (MIS) technology for III-V compound semiconductors promises to produce a new generation of solid-state electronics comparable to silicon-based MOS devices. However, such devices have the potential advantages of higher speed, lower dark current, radiation hardness, and operation at higher ambient temperature. The MOSFET device structure requires the deposition or growth of a thin insulating layer on the semiconductor surface. A major obstacle to the development of MOSFET devices, based on III-V compound semiconductors, has been the inability to form a stable insulator with a low density of insulator charge and interface states. We are currently producing MOS structures based on anodically grown oxides on gallium arsenide. Consequently, we have set up the equipment to make capacitance-voltage

Fig. 10. The ac quantum interference effect of an NSN bridge with bridge dimensions given in the preceding figure caption. Differential resistance vs bias current in the absence (a) and presence (b) of external rf radiation at $f = 10$ GHz. The fundamental ($n = 1$) and the first subharmonic ($n = 1/2$) steps in the Josephson frequency-voltage relation $V = nhf/2e$ are identified as shown. Fig. 10c illustrates the ac Josephson effect at $f = 900$ MHz with the higher harmonics (up to $n = 4$) identified. The ac quantum interference was observed from 100 MHz up to at least 10 GHz in the temperature range of 3.25 K down to at least 2.6 K.

measurements as a function of frequency to characterize the interface and insulator.

Anodic oxides are grown by making the semiconductor the anode of an electrolytic cell.^{9,10} The cathode here is a platinum electrode. A constant-current supply capable of peak voltages of 150- to 350-V sets up an electrostatic field at the semiconductor interface. Under the influence of the electric field, oxygen ions are pulled to the surface where they combine with the gallium arsenide surface atoms. The electrolytic solution used here consists of a 3 to 1 solution of ethylene glycol to a 4% aqueous solution of tartaric acid that has been pH adjusted to 6 with ammonium hydroxide. The current may be adjusted from 100 μA to 2 mA/cm^2 . The voltage will rise linearly at about 10 V/min for a current level of 0.5 mA. The process is terminated when the voltage reaches a level indicating the desired thickness of the oxide. This thickness is approximately 21 $\text{\AA}/\text{V}$. If the current becomes too small, back etching can occur.

A variation of this method has been used by Hartnagel.¹¹ Here a current-limiting resistor in series with a high-voltage supply produces constant current at small oxide thickness. As the oxide resistance increases to values comparable to the series resistor, the current begins to drop. This apparatus is shown in Fig. 11. We have used Hartnagel's method and the current behaves as expected; the growth rate decreases as the resistance of the film increases. If the process is terminated before the current reaches I_0/e , the films do not exhibit back etching when viewed under 70 times magnification. The relationship of the final thickness to the initial potential is not known. Furthermore, the visual appearance of the oxides grown by the constant-current method is far superior to those grown by the Hartnagel method.

Films with nominal thicknesses of 3000 $\text{\AA}$ have been grown by the constant-current and Hartnagel methods. The wafers have been fabricated into capacitors for CV evaluation.

8. Nuclear Microprobe [Maggiore, E-10]. The nuclear microprobe development has been delayed for two reasons. The first delay is the delivery of the superconducting solenoid final lens that is undergoing final tests before installation in the cryostat. The factory where the cryostat is being built

Fig. 11. Oxide formation at a constant potential in a solution of ethylene glycol to a 4% aqueous solution tartaric acid, pH adjusted to 6 with ammonium hydroxide.

was destroyed by a tornado last summer; it is now back in operation and the cryostat is ready for magnet installation. Initial magnet tests indicate some training effects are present and the critical field is approximately 78 kG. The field is cylindrically symmetric to 3 parts in 10^3 , but this is probably measurement limited and further tests are under way. If the asymmetry is real, a trim coil will be added. By moderate pumping on the liquid helium, the magnet's critical field can be increased to 32.5 kG. The training effects are expected to decrease with repeated cycling of the magnet to the critical field. Pumping on the liquid helium bath is possible for those times when a full 80-kG field is necessary. Installation in the cryostat, final testing, and delivery is expected to take an additional 2 months.

The second delay is the rebuilding of the vertical Van de Graaff accelerator by P-9. Shutdown of the machine was delayed 2 months for completion of a high-priority experiment. Tube replacement in the column is under way and delivery of the new ion

source is expected by January 1, 1979. The P-9 staff estimate that low-energy operation of the accelerator may begin about the first of March.

On the microprobe beam line the vacuum system, scattering chamber, and liquid nitrogen transfer control system have been installed. The pump performance is in the low 10^{-9} range. When all internal fixtures are installed, a scattering chamber pressure in the low 10^{-8} range is expected. This pressure is compatible with minimizing residual gas scattering for good spatial resolution.

The microcollimator control circuits have been checked and calibrated. The control system monitors the temperature of the jaws and the copper control rods with thermistors, and adjusts the cooling water flow to keep the jaws at a preset temperature and consequently at a preset separation. The 6-way cross holding the control rods and jaws is independently controlled at a preset temperature to provide stable reference points for the jaws. The 6-way cross can be controlled to $\pm 0.005^\circ\text{C}$, which means the reference surfaces are fixed relative to each other to $\pm 8.5 \times 10^{-3} \mu\text{m}$. The jaws and control rods can be controlled to $\pm 0.033^\circ\text{C}$ from 15°C to 65°C . This means the absolute separation of the jaws can be controlled from $10\text{-}145 \mu\text{m} \pm 0.64 \mu\text{m}$. The absolute alignment of the jaws was set by measuring the single-slit diffraction pattern from the jaws using a helium neon laser.

If there are no further delays in the delivery of the final superconducting solenoid lens, final testing will begin as soon as the accelerator is operational. It is hoped this will be March 1, 1979.

B. Electronic Temperature Monitoring and Identification for Livestock (USDA/H-6) [Bobbett, E-4; Koelle, E-5; Landt, E-DOR; Salazar, E-2]

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

1. Background. In 1971 LASL began work for the Animal and Plant Health Inspection Services (APHIS) branch of the USDA to remotely identify cows electrically. 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.

In the fall of 1973, 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 batteries. It was soon found that animal tissue presented significant problems in 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 acceptable biological nonionizing radiation standards. A demonstration of the subdermally implanted, temperature-only indicating transponder was accomplished in September 1975. A second unit implanted in November 1975 was still functioning as of May 1977, but had ceased returning temperature data by July 1977. The unit is still implanted in order to determine long-term biological effects.

In December 1975 a system for passively monitoring the temperature of six cows was installed at the National Animal Disease Laboratory at Ames, Iowa, under the supervision of Dr. Gary Seawright (currently with H-6). This experiment suggested that an animal's subdermal temperature changes with even minor stresses. These animals are periodically subjected to interrogation and observed. There is no evidence of degradation or biological incompatibility.

An informal report, LA-6725-MS, on the Model 75 temperature-only system was published in February 1977 and a progress report, LA-6812-PR, on the Model

76 temperature and identification system was published in July 1977.

2. Current Activities. The field tests, which were to occur this fiscal year, have been delayed due to the extremely slow progress of negotiations with the prospective suppliers of the field test hardware and software. This, in part, is because of risks associated with commercial development of a new technology and, in part, due to assurances LASL personnel have given to the National Livestock Identification Board (NLEIB) that only a system that will meet national identification needs will ultimately be adopted. In order to avoid a complete stop of field-test progress, we are preparing to enter into the field tests on a very limited basis (perhaps 50 animals rather than the eventual 1000) with the electronic identification system we have developed. This approach will also allow us to recognize and understand problems potential manufacturers may have in configuring a system in an unfamiliar environment.

Although no significant technical developments have occurred in the past 6 months, several improvements have been considered and some have been implemented. A progress report for the USDA has been written to update the changes that have occurred since the last formal report, as well as to express our thoughts on further potential improvements. The progress report is now in the typing and editing stage.

The FCC has allocated a frequency of 462.6625 MHz for the electronic identification system. Because this frequency is in a mobile radio communications band, and our application must meet FCC licensing requirements, we are conducting interference tests with a company in Albuquerque that has communications equipment in this frequency.

These quotes have been received from a request for quote (RFQ) for field-test hardware submitted to the responders of the Commerce Business Daily advertisement of January 13, 1978.

This program has received an Industrial Research 100 Award for the development of a hand-held interrogator-receiver that remotely interrogates a passively-powered transponder for its identification and ambient temperature. A plaque presented to LASL is on display in the National Security Resources and

Study Center (NSRSC). The hardware was on display in Chicago for 2 weeks last August.

C. High-Temperature Electronics [McCormick, Wilde, E-4; Helm, Roybal, E-2]

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

Therefore, the LASL approach is that of the integrated thermionic circuit (ITC). A typical cross section of an ITC gain device is shown in Fig. 12. In essence, the ITC is a microminiaturized vacuum tube that relies on processing techniques similar to those employed in the fabrication of standard integrated circuits (IC).

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, Fig. 13, 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

Fig. 12. Basic gain device for ITC.

Fig. 13. Experimental verification of the triode model for ITC.

utmost care and reliable delineation and wire-bonding techniques have been developed.

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

2. Processing. Since basic ITC fabrication techniques have been developed to the stage where initial high yield can be expected, processing considerations during this period have dealt primarily with those effects that occur over the device life span. Therefore, thin-film deposition by electron beam evaporation was investigated. Film adherence was evaluated as well as bondability. Based on the positive results of these tests, a dual beam evaporation system was installed and the ITC thin film process was converted to electron beam.

During this period a new wire bonder was installed and brought on-line. Since the bonder that

was previously used is no longer in production, we felt that for technology transfer reasons, a bonder currently available should be used. Therefore, a new Unitek parallel-gap bonder was purchased and modified to meet our needs and a new bonding schedule was developed. For the purpose of testing 5- and 10-mil-platinum wire bonds to the substrate, we have defined as acceptable bonds where the wire broke before the bond failed during pull tests. Our current bond yield is about 98%, using this very stringent standard.

The second phase of our recent effort has been preparation for the high-temperature package. We have addressed the cleaning, outgassing, and gettering techniques to be used with the new package and these evaluations are continuing. Initial results indicate that appropriate use of titanium, zirconium, and tantalum will provide high-temperature gettering capability.

During the next period, the computer code will be used to guide device designs for specific circuit applications.

3. Packaging. With the development of device fabrication and modeling techniques, the need for a high-temperature package has increased. Because of this increased need, SLA is evaluating the applicability of glass ceramics for high-temperature packaging. Glass ceramics may hold great promise in that the expansion coefficient can be tailored to match various metals. However, sufficient high-temperature electrical properties will have to be incorporated into the technology before a successful high-temperature geothermal ITC package can be fabricated.

Development possibilities for a metal or conventional ceramic package are also being investigated. One potentially promising approach that we are studying is the use of a stainless steel package with alumina pin seals around nickel feedthroughs.

D. Adaptive Optimal Control Applied to Heating, Ventilating, and Air-Conditioning (HVAC) Systems [Farris, Murray, McDonald, E-4; Melsa, University of Notre Dame]

1. Background and Introduction. The objective of this project is to investigate the use of adaptive control techniques in HVAC systems to minimize the consumption of auxiliary energy while maintaining a comfortable environment in solar heated and

cooled buildings. Optimal control theory is used in conjunction with the adaptive control techniques to accomplish this objective. The resulting technique is known as adaptive optimal control (AOC).

Earlier work led to simulations of heating system operation in which an adaptive optimal controller demonstrated a substantial savings, 28.8%, in auxiliary energy consumption when compared with operation by a conventional controller. Recent refinements have yielded even greater auxiliary energy savings; these results will be given later in this report.

2. Nature of the Problem and Solution. Generally, optimal building control means controlling the interior temperature within some region of comfort while using minimum auxiliary energy to support the solar system. The parameters of the HVAC system must be accurately known, regardless of the technique used to produce the optimal control. Because of uncertainties, changing system values during operation, and external uncontrollable disturbances, we believe that an adaptive approach can yield more effective control strategies than the fixed conventional type of control currently available.

Because the thrust of this study is to investigate minimization of auxiliary energy consumption with adaptive control techniques, an approach that minimizes an externally stated cost functional was selected. In this way, one can ensure minimization of auxiliary energy consumption for the cost functional selected. In order to make the problem tractable, we chose the integral quadratic form for the externally stated cost functional and a linearized model of the plant is used to track plant parameters. Together, this cost functional and model provide the linear regulator solution for the control. A consequence of this problem formulation is that the resulting control law is closed loop. This is essential for practical implementation in a building in order to reach desired set points.

3. System Description. The block diagram for the AOC solution is shown in Fig. 14. The building, or plant, represents the nonlinear dynamics of the building and the entire HVAC system. The model identification block represents a system identification process, which identifies a linear model that accurately reproduces the nonlinear plant behavior at the given operating point.

Fig. 14. System block diagram.

Once the linearized parameters have been identified, they are used in conjunction with the cost functional to compute the optimal controller feedback gains. The controller then generates the appropriate control u to minimize the cost functional. The model identification is an on-line process; after a fixed amount of time it will have an updated linear model available. That updated linear model is then used to recompute the optimal control law. The control system is adapted to remain optimal as the system undergoes various changes.

4. Building and HVAC System. Simplified models of the building solar heating and cooling system are used. Schematics for the solar heating system and cooling system are shown in Figs. 15 and 16, respectively.

Auxiliary energy is provided for both systems by a steam-to-water heat exchanger. The steam is supplied by a central steam plant. The cooling system uses these sources of hot water to drive a lithium-bromide absorption chiller. The cold water

Fig. 15. Solar heating system model.

Fig. 1b. Solar cooling system model.

from the absorption chiller flows through coils in the air duct to cool the air flowing over them. The heating system uses the same coils, but hot water from the storage tank or the auxiliary heat exchanger flows through the coils and heats the air flowing over them. The heated and cooled space in the building is represented by a single enclosure. In both systems, the air-handling system provides air movement and a capability for recirculation of some of the partially conditioned air. It also introduces fresh air as appropriate. In the cooling system, an additional capability is provided to bypass air around the coils if cooling is not required, but air movement is. This is necessary because the evaporator side of the absorption chiller requires a continuous flow of water. The heating system is described by four state variables and the cooling system is described by seven state variables. The equations are available on request.

5. Performance Bound. Since the AOC approach uses a linear model of a nonlinear system, the resulting control is actually suboptimal. In order to determine how well the AOC approach performs, the heating system operation was simulated using the maximum principle directly. The resulting two-point boundary-value problem (TPBVP) was solved using a technique to account for the saturation limits on the control variables.

In this study, perfect knowledge of the weather parameters was assumed in order to investigate whether such advance knowledge can help control the

building in a more energy-conserving manner. The AOC approach was simulated using the original partial-derivative system identification process and the more recently developed sequential least squares (SLS) system identification process.

The results, shown in Table I, represent a 24-h simulation. The primary result is that the powerful, completely general application of Pontryagin's maximum principle yielded results that were only marginally better than the AOC approach. We have a great deal of confidence in this result and, if it holds up under further testing, the conclusion can be made that the adaptive linear regulator approach used in the AOC technique is an excellent one.

6. System Identification Process. The building and HVAC system are mathematically described by a nonlinear system of differential equations. In order to utilize the optimal control approach and obtain a closed-loop control law, a linearized system representation is needed. In work reported earlier, the linearized model was obtained by carrying out direct numerical evaluation of the partial derivatives. This linearization was done at the beginning of each adaptation interval. Although this form of system identification is artificial and could not be used in practice, it was used initially because of its simplicity. Since the simulation results using this identification approach were quite encouraging, more practical methods of system identification were investigated. In particular, an SLS approach is used to provide a system identification process that identifies the needed parameters.

TABLE I
SIMULATION RESULTS (24 H) FOR OPTIMAL CONTROLLER COMPARISON

System/ Solution Technique	Average Room Temperature (°C)	Room Temperature Extremes (°C)	Auxiliary Energy Used (10 ⁹ J)	% Savings Compared to Conventional Controller
Conventional controller	21.17	21.00 21.28	3.95	----
AOC (partial derivative identification)	20.72	20.00 21.17	2.82	28.5
AOC (least squares identification)	20.89	20.33 21.22	2.82	28.5
TPBVP	20.89	20.28 21.22	2.74	30.5

This technique was tested on the solar collector of the NSRSC. Difficulties were encountered that we believe are attributable to the long time constants and consequent lack of spectral richness in the variables. Further system identification technique investigations will be made to overcome these difficulties.

7. Set-Point Computation. A technique has been developed to compute the system set points in an optimal fashion. Some of the system set points are specified and are not subject to computation; room temperature is such a variable, although its set point can be changed to achieve nighttime setback. The other set points are recomputed each time the adaptation takes place. The computation is made to provide a group of set points that provide an equilibrium condition for the system. This procedure yields an improvement in the auxiliary energy savings. It may also solve the erratic behavior observed in the initial phases of the project when attempts were made to optimize the collector system along with the storage and the air-handling systems. Simulation results are presented in a subsequent paragraph.

8. Practical Considerations. The use of hot water from storage and the auxiliary heat exchanger to supply energy to the HVAC system requires hardware to combine the two sources. A common practice is to use a valve arrangement that allows full flow from one supply while the other is turned off. We refer to this as a mutually exclusive arrangement. This technique is used in the conventional controller simulation. The optimal control approach used here does not readily lend itself to a mutually exclusive arrangement because it considers both supplies available and establishes the optimum use from each. Thus, earlier reported simulations considered a mixing-valve arrangement where a continuum of flow rate values could be obtained from both sources simultaneously. Besides being difficult to implement in terms of hardware, this mixing arrangement makes it possible to use auxiliary energy to heat the storage tank. There may be situations where this is desirable, for example, during off-peak hours, but it is generally considered undesirable.

To provide a mutually exclusive arrangement for the adaptive optimal controller in the heating sim-

ulation, the derivative of the room temperature is examined at each adaptation time. This derivative accounts for all the variables affecting the system. The room temperature is projected during the interval until the next adaptation time using a straight-line approximation. If the projected room temperature stops above some comfortable value, the elements that couple auxiliary energy into the system are set to zero. This forces the algorithm to consider only the storage tank as an energy supply and compute controls accordingly. If the projected room temperature falls below the comfortable value, the elements that couple the storage tank to the system are set to zero, the algorithm considers the auxiliary heat exchanger as the only energy supply, and computes the controls accordingly. This strategy is used because the storage tank is less capable of heating the building under extreme conditions. The simulation results employing this development are presented in the next paragraph.

9. Further Heating Results. Heating simulation results obtained using the AOC developments described earlier are presented in Table II. The simulation runs are for a 48-h period. The conventional controller simulation uses the control strategies in the NSRSC with a mutually exclusive arrangement for the two energy sources. The AOC simulation uses the AOC technique with the SLS identification procedure. The two energy sources are connected by a mixing arrangement. The AOC with

TABLE II
HEATING SYSTEM PERFORMANCE

System/ Solution Technique	Average Room Temperature (°C)	Room Temperature Extremes (°C)	Auxiliary Energy Used (10 ⁹ J)	% Savings Compared to Conventional Controller
Conventional controller	21.11	21.00 21.33	7.12	----
Adaptive optimal controller (AOC)	20.94	20.22 21.22	4.36	38.8
AOC with set point computa- tions	20.89	19.83 21.39	4.13	42.0
AOC with mutual- ly exclusive arrangement	20.94	19.67 21.39	3.46	51.3

set-point computations simulation uses the AOC technique with the SLS identification procedure and the procedure for computing the set points. The two energy sources are again connected by a mixing arrangement. The AOC with mutually exclusive arrangement simulation uses the AOC technique with the strategy for forcing the algorithm to select one energy source or the other, but not both. The set-point computation process is not used here. All the control systems simulated maintain the room temperature within a comfortable range. However, all the AOC technique simulations do so with a significantly smaller amount of auxiliary energy. The primary energy-saving mechanism is operation of the storage tank at a lower temperature. This collects and uses more solar energy.

10. Cooling Results. The AOC technique has also been applied to the cooling model of Fig. 16. The conventional control simulation uses the control strategies of the NSRSC with slight modifications. The AOC controller uses the partial derivative system identification technique and does not yet employ the set-point computation strategy or the mutually exclusive arrangement for connecting the energy supplies. Consequently, these results are still preliminary, but encouraging. The results for a 48-h simulation are shown in Table III.

The AOC controller offers better temperature extremes, although the conventional controller's extreme of 29.06°C occurred during the evening when the building had low occupancy. There is a significant difference in the amount of energy required to operate the absorption chiller. The load on the chiller is only moderately less for the AOC controller, but the energy required to drive the chiller is significantly less for the AOC controller.

If we consider the average thermal COP for the 48-h simulation period as

$$\text{COP} = \frac{\text{Chilled water energy output}}{\text{Hot water energy input}},$$

we obtain a COP of 60.0% for the AOC controlled chiller and 53.0% for the conventionally controlled chiller.

As in the heating system simulation, the storage tank is operated at a lower temperature by the AOC controller than the conventional controller; and, again, this accounts for an increase in the collection of solar energy.

11. Model Upgrading. We have begun to upgrade the heating model. A second zone has been added so that the model represents a building with both an interior zone and a perimeter zone. The mass of the building has been added for both zones and the temperature of the mass in each zone has been defined as a state variable. Improvement and simplification of the collector model has begun and an evaluation will be done soon. This upgrading has been done only in the AOC simulations, so comparisons with a conventional controller are not yet available. Similar upgrading will be done on the cooling model.

12. Technology Transfer. We made an informal presentation of the AOC technique to members of the Control Theory and Application Committee of the American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. (ASHRAE) at the Albuquerque, New Mexico, meeting in June 1978. Comments from the committee were extremely favorable.

TABLE III
COOLING SIMULATION RESULTS

System	Average Room Temperature (°C)	Room Temperature Extremes (°C)	Cooling Load (10 ⁹ J)			Energy Used by Chiller (10 ⁹ J)			% Savings of Aux. Energy
			Internal	Building Shell	Vent.	Total	Solar	Aux.	
Conventional	25.61	21.78 29.06	11.57	-0.49	0.32	11.40	3.64	18.12	21.75
Adaptive	25.50	23.28 26.00	11.57	-0.44	-0.38	10.75	9.03	13.96	17.99 22.9

Another development in our technology transfer effort is that Johnson Controls, Inc. (JCI) has expressed an interest in a joint research project to implement, test, and develop the AOC technique in a building such as the NSRSC. In such a project, provision would be made for testing other modern control strategies that may be developed. Representatives from JCI have visited LASL and the NSRSC and an outline of a proposal has been pre-

pared. Work is now under way with JCI on the details of the effort.

13. Plans. Our plans in the technical area for the immediate future are to complete the simulation models upgrading and continue the simulation studies. Parameter variations and longer-term simulations are planned. We should then be in a position to thoroughly study implementation of the AOC technique.

II. ENGINEERING SUPPORT, R. A. GORE, ALTERNATE DIVISION LEADER

A. Development Projects

1. Introduction. The activities reported in this section include both LASL-funded projects and projects funded by outside agencies. These projects are usually aimed at obtaining an understanding of a problem, the development of a solution to a given problem, or the development of a new capability or resource required in support of basic research.

2. NSRSC System Performance Studies [Murray, E-4]. The objectives of the studies of the NSRSC are to provide data acquisition and reduction for performance analysis on the solar heating and cooling system, to analyze the performance of the system, and to perform system optimization experiments. Data have been provided continuously for two cooling seasons and one heating season with analysis of the second heating season now in progress.

During the cooling season, May through September 1978, an improved solar cooling control strategy was tested. The hardware changes required to implement the new strategy were made during the previous heating season. The system makes use of both hot and cold water storage for building cooling. In the original system, solar-heated water was stored as an energy source for the water chiller and cold water was stored using night evaporative cooling. The chiller was run only when the building was sufficiently warm to require additional cooling, and auxiliary energy was used whenever the solar-heated water storage tank fell below a preset temperature.

In the modified strategy, the chiller is run whenever the solar collectors have raised the temperature of hot storage sufficiently, even if the building does not call for cooling. The excess cold water is put into storage for later use. Also, the use of auxiliary energy is prohibited if the cold storage temperature is below a given set point. The scheme has the following desirable features:

- The chiller is running while the collectors are running, reducing collector temperature and therefore increasing efficiency.
- Chiller cycling is minimized.
- The chiller is run at full capacity.
- Cold storage must be exhausted before auxiliary energy can be used.

Using this strategy the system provided 97% of the building's cooling needs from solar energy, as opposed to 75% the previous summer.

Additional software on the data-acquisition computer provided smoothed hourly data for computer simulation validation of basic system variables for LASL and the International Energy Agency.

3. Nambé Pueblo Solar Heating System [Murray, E-4]. The Nambé Pueblo solar heating system is an air system with rock bin storage and a reflected collector. Data collection, started in the spring of 1978, assesses the performance of the solar heating systems, studies rock bin behavior, and gathers data on the performance of the vertical reflected collector. The problems encountered with data acquisition at a remote site were solved and data for the first full heating season are now being obtained.

Studies on using the rock bin for night evaporative cold storage are complete. The cooling study indicates that a large portion of the building cooling load can be shifted to the night hours by using cold storage. However, the rock bin could not be cooled sufficiently to meet the entire daytime cooling load.

Heating data gathered so far this winter show, in Table IV, the following system solar performance data.

Some problems were encountered with a flow sensor zero drift, and with collector control system failure. These problems were solved by replacing defective components.

Data handling was vastly improved by storing the data on an HP-9845 calculator disk and processing it locally rather than at the Central Computing Facility (CCF). This provides faster turnaround and

TABLE IV

NAMBÉ 1977-78 SOLAR SYSTEM PERFORMANCE

Month	Solar Heating (%)	Collector Efficiency (%)
Oct.	90	77.4
Nov.	56	33.1
Dec.	39	36.0

the ability to quickly provide high-quality data plots as shown in Figs. 17-19.

4. Passive Solar Heating Data Processing [Murray, E-4]. The Solar Energy Research Group, Q-11, is evaluating the performance of various passive solar heating systems in New Mexico. Data are obtained from several remote sites in the form of ASCII coded data cassettes at a nominal rate of 10 per week. These tapes have been transmitted over a 300 baud line to the CCF to create data files for system performance evaluation and simulation code validation. In practice this has proved to be an extremely cumbersome process, requiring the full-time support of one data analyst.

We suggested to Q-11 that the NSRSC computer, a PDP-11/34, be used to process the passive system data tapes. The proposed system includes a 2400-baud tape cassette reader and a Digital Equipment Corporation (DEC) 200 UT emulator software package to transmit the recorded data to machine "0" at the CCF at 4800 baud.

The hardware and software required to implement this plan were installed and are now being successfully used to process the passive solar heating program data. Only minor problems were encountered during implementation, and the entire system runs without interfering with normal NSRSC data processing operations.

One tape can now be processed and transmitted in about 1/2 h. This represents at least a factor

Fig. 18. Nambé Community Center, December 1978, storage temperatures.

of 4 in overall improvement and a factor of 10 or more in time reduction.

5. Eastern Gas Shales Project [Springer, E-4]. The Cottageville gas-shale reservoir in West Virginia is an area where natural fracturing has made gas production economical since 1948. The production and geological data that have been obtained from this reservoir provide a highly concentrated source of information that we are using to calibrate and check a simulation we have made. We have obtained much of these data from E. B. Nuckols, West Virginia University. Production data include well locations, completion dates, initial open-flow rates, stimulated open-flow rates, rock pressures,

Fig. 17. Nambé Community Center, 1978-1979 heating season, daily total load, solar, and auxiliary.

Fig. 19. Nambé Community Center, 1978-1979 heating season, collector input and output.

yearly production data, shut-in pressures, and line pressures. Geological data consist of subsea depths of various stratigraphic layers obtained from 118 well logs, as well as core analyses from one or two wells. Production history is documented for 58 of the wells, but is missing for 19 of them.

An interactive computer program, ACOT, was developed to assist in analyzing the Cottageville data. The program presents the data in various ways. Some of the tasks ACOT performs include computing average production over a period, selecting a set of wells for which certain attribute conditions are satisfied; for example, all the wells with natural open flow > 500 MCF/day and production in the first 5 yr between 50 000 and 150 000 MCF, ranking the selected set, and mapping the selected wells. Other tasks include least squares fitting, two-dimensional graphs, contouring, and rotating the well coordinates.

After studying the data and confirming a correlation between the structure of the producing shale layer and the wells with high or low initial open-flow rates, we decided to model the reservoir flow and pressures on SIMGAS, a modification of a digital gas diffusion code obtained from the Morgantown Energy Technology Center (METC). A 1075-node, two-dimensional representation of the Cottageville field has been set up, with observed flows introduced at well locations. The object is to develop a method to generate local flow parameters from geological parameters. Regions of high fracture may be correlated with the structure that existed in Devonian time when organic material settled on the sea bottom and with the change in the structure since that time. Since the permeabilities may be highly anisotropic, the simulation mesh is aligned along the major fracture trend.

In order to show both pressure surfaces and structural surfaces that are necessary to the modeling, we have obtained the National Center for Atmospheric Research (NCAR) graphics software. This software provides contouring, isometric surface display, and other features.

The producing regions appear to be continuous and distinct from the nonproducing regions, so we have decided to use the CDC 7600 rather than the hybrid computer for data reduction. At one time it appeared that a Monte Carlo approach might be war-

ranted in which different fracture distributions would be used and many solutions of the reservoir would be required. This would have required the hybrid computer. The data from Cottageville indicate a more deterministic model with greater detail and fewer necessary solutions, which the digital computer can provide.

6. Short-Pulse Light Flasher and Fast, Low-Cost Photomultiplier Detector [Hiebert, E-5; D. Martin, E-2]. A subnanosecond pulsed-light source has been developed for testing photodetectors. A fast photodiode detector assembly was used to measure the flasher properties, and a fast photomultiplier base assembly was developed and tested with the new pulsed light source.

There is a need for a triggered, short-duration light source in an easy to use package for testing photodetectors. Conventional light-emitting diodes (LED) or pulsed-arc lamp sources have durations of several nanoseconds or more, but this is not adequate for the higher speed photodetectors. Several years ago, J. R. Andrews¹² described a gallium arsenide injection laser pulser for testing fiber optics, and we concluded that a flasher of this type would be useful for photodetector tests.

Figure 20 is a schematic diagram of the pulser. A 5- Ω microstrip transmission line is charged to about 150 V. An avalanche transistor is triggered to discharge the line into the GaAs injection-laser diode. If the wavefront of the current pulse is fast and if the peak current is 6 A or greater, the diode will be stimulated into a Q-switching mode and a short optical pulse will be emitted. The drive-current amplitude must not be too large, or after-pulsing will result.

As measured with a fast photodiode assembly, the pulser has a risetime < 200 ps, an FWHM < 400 ps, and a fall time < 400 ps. The measurement values were limited by the photodiode speed. The yield is about 0.2 nJ/pulse, and holders are provided to attenuate the light with neutral density filters. Wavelength is 0.9 μ m and maximum pulse rate is about 10 kHz.

A fast 1P28-type side-on photomultiplier detector base was designed and tested with the flasher. The base was made using a Hamamatsu R928 that responds to the laser wavelength. To achieve speed, we truncated the base so that it used only four

Fig. 20. Schematic diagram of injection laser short-light pulse generator.

dynodes and provided voltage beyond the structure specifications. The resulting gain was about 10 000 and the measured response times were 1-ns rise and 0.5-ns fall. This photodetector therefore covers the domain between photodiodes (good speed but no gain) and conventional photomultipliers (gain but a response time of several nanoseconds). The detector has been applied to the fast fluorescence decay studies of Group H-10.

7. The Universal Peripheral Calculator System [Hanna, E-5]. The original goal of this project was to download from a host processor to a calculator system 32 program steps and 5 variables. Since this required twice the memory available, a dynamic memory allocation operating system was designed that allows five variables to be loaded and the remaining RAM to be used as program steps. Using 1 variable, 42 program steps remain; using 5 variables, 18 steps remain. Most applications do not require all five variables, and for applications where more steps are needed, intermediate results can be found and the steps can be chained together. In addition, for interactive calculations, one or more variables can be changed without re-entering the program. A scientific relation notation for the data was adopted.

A general outline and flow chart for the operating system is shown in Fig. 21. Figure 22 details the job manager input-buffer flow chart.

8. Distributed Computing [Slocumb, E-5]. It has become apparent that there is an interest in and a need for general-purpose distributed computing systems throughout LASL. In an effort to meet this need, we have begun a program of familiarization and training in the software-hardware aspects of distributed computing systems and data communications. We plan to actively support systems that require a communications port to the CCF as well as those that need to communicate with other non-CCF computer systems. This will require that we develop sufficient knowledge in vendor operating systems and data communications software and hardware to provide support to LASL groups who have data communications requirements.

We have invested several man-months in the first stages of familiarization. We have completed a survey of the distributed computing literature, studied data communications software including a detailed study of communication protocols, and have

Fig. 21. Flow chart of the UPI-41, power on, initialization, and idle state.

Fig. 22. Input buffer full interrupt flow chart.

made an initial study of the VAX-11/780 computer system.

Our future plans are to study the VAX-11/780 software and hardware in detail; work with Group C-9 in testing their remote computer concentrator (RCC); develop, test, and implement an independent computer connection to the RCC; and maintain an active involvement in development of software for the LASL-wide network.

9. Computerized Tomography [Lundy, E-5; Rose, Waechter, E-2]. We have continued with the fabrication and check-out of an x-ray tomograph system in conjunction with R. Morris, M-1, and M. Cannon and R. Kruger, M-8. We have not yet produced a tomographic image because of unexpected hardware difficulties, but do expect to accomplish this in January. The project, originally funded by a LASL new research initiatives proposal (NRIP), continues through outside funding.

10. Modem Evaluation [Shoemaker, E-5]. The purpose of this project is to evaluate modems that

will operate on voice-grade telephone lines at speeds up to 9600 bps. The reason for this evaluation is that modems now in use, the Gandalf 120, are affected by line conditions; consequently, they do not operate adequately at times.

Modems from five manufacturers were tested on some of the telephone lines where problems had occurred. We felt this was a good test because problems should be apparent and easily identified. The actual evaluation was done by using the modems with graphics terminals. By doing this, the modems were tested on actual lines under normal operating conditions, which is much more effective than a bench evaluation.

None of the modems worked well enough to give the users suitable bit-error rates. As a result, it appears that a different line than voice grade is needed. Mountain Bell Telephone Company is in the process of tariffing a new service specifically designed for limited-distance modems at speeds up to 9600 bps. This new service will be called series 82. We feel that this new service should be tested as soon as possible to determine if it will provide lines that give adequate bit-error rates.

11. Port-Contention Compatibility [Shoemaker, E-5]. This project, a determination of the requirements for a commercially available port-contention device to interface adequately with the keyboard concentrator controllers (KCC) in the CCF, was coordinated with C-9 while they wrote the functional specifications for a new dial-up KCC.

The KCCs now in use do not control or monitor control signals on the ports; this is a problem when using them with port-contention devices. For example, a terminal user could turn off his terminal or otherwise be logged off the port-contention device and not be logged off the KCC. Another user could then be connected through the port contender onto the KCC port that had not been cleared. The second person would then be in the middle of the previous user's programs.

In order to prevent this, the port contender and the KCC must pass control signals between them. This capability exists on port-contention devices and therefore should be a requirement on the new KCC.

Another problem area is the interface between the KCC and the worker computers. If a user is

disconnected from the KCC for any reason, he also should be logged off the worker computer. Otherwise another user could be connected through the port contender to the KCC port of a previous user and into his programs. To prevent this, the KCC software must send a message to the worker computer to notify it that the user has been disconnected.

These problems appear to have been solved in the initial specifications, but C Division has not released the final revised specifications for the new KCC.

12. Fuel Cells in Transportation [McCormick, Lynn, Bobbett, E-4; Nachamkin, E-DOR; Derouin, E-00].

a. Introduction. The fuel cell is a device that directly converts chemical energy to electrical energy. Most fuel cells are hydrogen-air units that generate electricity directly from the chemical reaction of hydrogen and oxygen.

The most important property of a fuel cell is that the energy conversion efficiency is not limited by the Carnot cycle as are heat engines. Theoretical efficiencies for a pure hydrogen fuel cell could be as high as 83% and fuel cell systems with efficiencies greater than 50% have been fabricated.

Fuel cells have been used extensively in space applications. More recently, fuel cell development has been geared toward utilities applications. As a result of these efforts, fuel cell performance has been greatly improved. In particular, the weight and size of the fuel cell has been reduced to levels reasonable for vehicular application. Furthermore, the price of fuel cells is predicted to drop dramatically in the next few years. Price reduction due to basic design improvements combined with mass production techniques could make the fuel cell economically competitive with the internal combustion engine (ICE) in the foreseeable future.

Because the fuel cell has an inherently high-energy efficiency, substantial energy savings could result from the conversion to fuel-cell-powered automobiles. This fact alone mandates that the fuel-cell-powered vehicle be given careful consideration as a possible replacement for the ICE automobile.

Based on these considerations, the task of this DOE-sponsored program is to evaluate the applicability of current fuel cell technology to vehicular applications, identify unresolved technical prob-

lems, and recommend a program of research and development to obtain the knowledge and information necessary to thoroughly evaluate the fuel cell as a transportation alternative.

This program is a joint LASL, Brookhaven National Laboratory (BNL), US Army (Ft. Belvoir) program, with BNL evaluating fuel cells, the US Army providing program management, and LASL evaluating vehicle systems and economics.

During this report period, we have performed the following tasks.

- An applications study in which a number of candidate fuel cell vehicles were evaluated technically and economically, and recommendations were developed for future directions in the possible development of fuel-cell-powered vehicles.

- The formulation of a general computer simulation for the detailed evaluation of fuel cell vehicles.

- The determination of technical data necessary for the utilization of the computer code. This includes a fifth-wheel instrumentation system, developed by Lamar Instruments, that was programmed at LASL for application to roll-down vehicle aerodynamic tests. Parameters derived from these tests were used in the technical evaluation portion of the application scenario.

b. Application Scenario. In this study, four specific vehicle applications are considered, the city bus, highway bus, consumer vehicle, and delivery van.

Current fuel cell technology data, supplied by Energy Research Corporation (ERC) and BNL, is used in developing both a technical and economic assessment of each of the candidate vehicles. Future fuel prices, vehicle maintenance costs, and institutional factors are also included in the evaluations.

The performance of current ICE vehicles for each of the applications is used as a base line for comparing both component sizing and performance evaluation.

(1) City Bus. In considering possible fuel-cell-powered vehicle applications, the city bus has a number of features that makes it an attractive candidate for fuel cell propulsion.

- The procurement cost of a city bus is 80% subsidized by the federal government.

● In total dollar outlay, the cost of fuel and maintenance tends to be more dominant than procurement costs.

● Particulate and noise pollution are serious problems.

The city bus application represents a market of 5000 vehicles per year, in excess of \$100 000 each, which would increase the manufacture of fuel cells in a reasonable increment without demanding ultimate mass production costs. The bus would be propelled by propane or methanol fuel in parallel with a nickel-zinc battery for acceleration.

(2) Highway Bus. A fuel-cell-powered bus or large highway truck could be an economically and technically viable option in the 1990 time frame. The available volume is more than adequate for a fuel cell propulsion system and the relative weight increase is small.

The potential for future fuel cost savings, when combined with reduced maintenance costs, could save between \$29 000 and \$49 000 over the vehicle life span.

These two applications account for 21.9% of the 1972 transportation energy consumption in the United States. Penetration of fuel cells into these applications would have a beneficial effect on the nation's energy requirements.

(3) Consumer Vehicle. A Volkswagen Rabbit was chosen for a comparison of the gasoline and diesel engines and the fuel cell for consumer vehicles.

The entire propulsion system (15-kW fuel cell, methanol reformer, motor, and 4-kWh battery) will fit under the hood of a Rabbit and will give performance comparable to that of the diesel with a net weight increase of approximately 520 lb.

Using cost and vehicle mark-up data derived from Ford Motor Company, the Department of Transportation, and Volkswagen, and assuming \$200/kW for the fuel cell reformer system, a fuel-cell-powered Rabbit was projected to have a sticker price of \$7239.33.

Fuel consumption was calculated for both cruise and J227 metropolitan drive cycle. Substantial improvements in vehicle system efficiency were found; however, considering the projected fuel costs for 1990, no clearcut economic advantage based on fuel savings was found. It was projected that reduced

maintenance costs and reliability could be extremely favorable factors in the marketplace.

(4) Delivery Van. Data on delivery van drive cycles are difficult to obtain, therefore no detailed analysis or preliminary system design was performed. It was concluded, however, that a conventional battery electric vehicle with fuel-cell augmentation for on-board recharging would be significantly more efficient than a comparable ICE vehicle and would significantly increase the range and number of applications for electric delivery vans. In addition to the reduced maintenance costs, 30-40% or battery-powered electric vans demonstrated by the Bell System and United Parcel Service, further reductions in maintenance are expected with the fuel cell addition. The fuel cell not only reduces the number of batteries, but maintains a voltage across the cells, thus prohibiting deep discharge and cell reversal.

Currently available fuel cell modules could be interconnected to provide a fuel cell power source, thereby allowing considerable evaluation of the fuel cell in a vehicular environment without requiring the development of either a special vehicle or fuel cell.

c. Computer Simulation. In order to manage the complex interactions between the various vehicle subsystems, we have developed an all-electric vehicle software program model that may be used as a tool for evaluating the performance of individual vehicle subsystems as well as evaluating the total performance of a simulated vehicle. We are working jointly with BNL to provide the fuel cell, fuel processor, battery performance, and physical data that will meet the propulsion system requirements we define. Only real or conservatively extrapolated fuel cell system and battery data were used to demonstrate what can be achieved with the current state of the art.

In the computer program each major vehicle subsystem is separately modeled as a subroutine. Furthermore, each subsystem is modeled in terms of its fundamental I/O variables such as voltage, current, torque, and rpm. With this approach there is no need to interleave the subsystem models. Thus, the user can easily substitute or modify a model of a particular subsystem in order to test its impact on overall vehicle performance.

Figure 23 shows the major components involved in propelling a fuel-cell-powered vehicle. The following paragraphs briefly summarize the basic relationships on which each model is based.

(1) Vehicle Road Load. An equation relating tractive effort, F_T , with the retarding forces of change in momentum per unit time, F_A ; rolling resistance, F_R ; aerodynamic drag, F_D ; and road grade, F_G :

$$F_T = F_A + F_R + F_D + F_G \text{ pounds} \quad (3)$$

where

$$\begin{aligned} F_A &= K_1 W_e \frac{dv}{dt} \\ F_R &= K_r W \cos(\tan^{-1} G) \\ F_D &= K_2 \rho C_d A v_r^2 \\ F_G &= W \sin(\tan^{-1} G) \end{aligned}$$

where

$$\begin{aligned} K_1 &= 0.0455 \\ K_2 &= 0.0334 \\ K_r &= \text{coefficient of rolling resistance} \\ W &= \text{weight, lb} \\ W_e &= \text{effective weight, lb} \\ G &= \text{per cent grade/100} \\ dv/dt &= \text{acceleration, mph/s} \\ \rho &= \text{air density, lb/ft}^3 \\ C_d &= \text{drag coefficient} \\ A &= \text{projected frontal area, ft}^2 \end{aligned}$$

Fig. 23. Fuel cell vehicle configuration.

v_r = relative vehicle speed (wind plus ground speed, mph)

The coefficients, K_r and $C_d A$, are determined from coast-down tests.

(2) Drivetrain. The differential is described by an equation relating torque as a function of load as derived from gear efficiency curves,

$$\text{Eff} = 1/(1 + K/\sqrt{T}) \quad (4)$$

where K is the loss coefficient and T is the load torque.

The transmission is modeled identically to the differential, except the loss coefficient K may have a different value.

Specific traction motor curves that (Fig. 24) relate both flux as a function of motor current and motor efficiency as a function of motor current and speed are used as the basis for calculating motor output torque and losses. Relating the motor performance to flux allows the use of measured data that includes degree of saturation.

The motor controller is modeled as a solid-state SCR chopper circuit with variable frequency and variable pulse width controls.

Battery voltage and state of charge is determined from battery curves that relate battery voltage capacity, and state of charge (discharge) as shown in Fig. 25. Curves such as those shown in Fig. 26 are used to derate the battery as a function of discharge rate.

Fig. 24. ElectraVan's baldar motor 100-V characteristics.

Fig. 25. Lead-acid battery charge-discharge characteristics.

Fig. 26. Rate of discharge vs A-h capacity (yield) at different temperatures.

Fig. 27. Characteristics of 60-kW ERC methanol fuel cell system.

The fuel cell output voltage is derived from curves relating fuel cell voltage and load current for a specific fuel cell type and rating (Fig. 27).

The fuel cell processor is the hardware associated with reforming a liquid fuel in order to supply the fuel cell with hydrogen. The processor hydrogen output is determined from data relating efficiency as a function of fuel cell output power.

The fuel cell-battery controller subsystem determines how much vehicle power is supplied by the battery, fuel cell, or both. It also controls when and how much current is available from the fuel cell for battery charging.

The structure and capability of the vehicle simulator described will allow the user to predict vehicle performance. The simulator outputs are in terms of fundamental variables in order to directly compare results with measured vehicle data.

d. Microprocessor-Based System for Roll-Down and Acceleration Tests. A microprocessor-based, road-test system for measuring and recording roll-down and acceleration data for various vehicles has been designed and built.¹³ The system provides for rapid vehicle testing, can be operated by one person, and allows detailed data acquisition when required. Digital data storage and output capability allow direct exchange of data with other computers or calculators for data analysis and reduction. System input is distance, which is obtained from a fifth wheel, and elapsed time. The microcomputer system records time to the nearest 0.01 s, distance to the nearest foot, and calculates velocity to the nearest 0.1 mph. Data can be stored at specified time, distance, and velocity intervals. Current time, distance, and velocity are displayed on a liquid-crystal display panel. A calculator prints a summary of the run. Detailed data are stored in RAM and are output to magnetic tape at the end of the run. The tapes are input to plotting programs and to data reduction programs that calculate rolling friction and aerodynamic drag. The road-test system has been used to test a number of vehicles. In most of the tests one person drove the vehicle and operated the system.

(1) Hardware Configuration. A simplified block diagram of the road-test system is shown in Fig. 28. The primary system input is 100 pulses/ft from the fifth wheel. These pulses are divided by 100 for

Fig. 28. Simplified diagram of Lamar Instrument's road-test system.

the distance counter and fed directly to a BCD counter for the velocity calculation. The remaining inputs are provided by two timers and the status switches. The time counter is updated every 10 ms. Velocity is determined by reading the BCD counter every 68 ms. Then

$$v = \frac{N/100}{0.068} \times \frac{60}{88} = \frac{N}{10} \text{ mph} \quad (5)$$

where N is the number of counts.

The status switches define whether an acceleration or coast-down run is required and whether the system is in the run or standby condition. A coast-down run begins when the run-standby status is changed from standby to run. An acceleration run begins automatically when the foot counter reaches 1 ft.

The two timers and the foot counter interrupt the microprocessor so that it can update time, distance, or velocity. The timers interrupt at 10- and 68-ms intervals; the foot counter interrupts at

$$T_v = \frac{1}{v} \frac{60}{88} = \frac{0.68}{v} \text{ s} \quad (6)$$

For $v = 100 \text{ mph}$, the foot counter interrupts the processor every 6.8 ms. The three interrupts occur on the average of every 3.82 ms. The external status switches are read during initialization, in the background program, and immediately after each interrupt.

The highest priority is assigned to the 68-ms timer, which is the most critical interrupt. The

BCD counter must be disabled, read, reset, then enabled at precise intervals in order to give accurate velocity readings. The disable, read, reset, enable sequence takes 22 μs , or about 0.03% of the 68-ms count time. As long as the 10-ms timer and foot counter are updated before the next time interval or foot occurs, there is no error accumulation in time or distance.

The system diagram shown in Fig. 29 includes a more detailed description of the processing unit. The processing unit contains a MOS Technology 6502 microprocessor, 4 kbytes of read-write memory, sockets for up to 8 kbytes of program read-only memory, twelve 8-bit I/O ports, 10 timers, 4 shift registers, and a 2-kbyte monitor stored in ROM. The road-test system requires 512 bytes of RAM (2 to 4 kbytes for detailed data storage), 2 kbytes of program ROM, eight 8-bit I/O ports, 3 timers, and the 2-kbyte ROM monitor. The remaining capacity can be used for an expanded vehicle instrumentation system.

System output is provided by a 16-digit liquid crystal (LC) display and on an HP-97 printing calculator. The LC display is normally placed on the vehicle dashboard and shows elapsed time and distance and current velocity. The HP-97 prints time elapsed and distance and velocity at specified times, velocities, and distances. For acceleration runs the printer prints at 10 and 20 s (at each 10-mph interval) and at 100, 300, 500, 900, 1320, and 1400 ft. The print points for coast down are 10, 20, 50, 70, and 90 s (each 10-mph interval) and 100, 500, 1000, 2000, and 5000 ft.

Additional data can be saved in RAM if desired. The data can then be output to tape or printed on a data terminal at the end of the run. Time, velocity, and distance are now saved each second and each mile per hour for both acceleration and coast down. In addition, data are saved every 200 ft for acceleration runs and every 500 ft for coast down. For most applications, saving data each second is adequate. Both the print points and the save points are software defined and can be easily changed.

The data stored on tape can be processed by a number of systems. At LASL most of the data were processed by a HP-9820A desk calculator with a 9862A plotter. Some data processing was done with a 6502 microprocessor system and some with a CDC 7600 computer.

Fig. 29. Lamar Instrument's computerized road-test system.

The keyboard and display can be used to address memory, enter data, begin execution of a program, reset the system, or interrupt the processor. The display consists of six 7-segment digits to display the address (4 digits) and data (2 digits).

A data terminal can be connected through the TTY interface to enhance the I/O capabilities of the system. Specifically, a TI 733 ASR with a TTY to RS-232C adapter is used, although other TTY 20-mA current loop or RS-232C compatible terminals can be used.

The audio tape is used to enter data and programs into RAM or store them on tape. In addition, the TI 733 ASR can be used for the same purpose, except that the tapes are in a digital format compatible with the LASL CCF, as well as most other data centers.

(2) Software Description. The major portions of the software are the initialization routine, the background programs that provide output to the LCD and the printer, the interrupt ID routine, and the three interrupt service routines that update velocity, distance, and time.

The turn-on sequence and background programs are shown in Fig. 30. After the processor is initialized, the default print and save values for time, velocity, and distance are loaded from ROM to RAM. Once in RAM, these values can be changed with the keyboard, if desired. The default values are stored in an erasable PROM and are easily changed with an EPROM programmer. The LCD-output routine updates the display with the current values of elapsed time, velocity, and elapsed distance. The display is updated every 0.5 s. If the display is updated too rapidly, readability is reduced. The

Fig. 30. Initialization and background program.

HP-97 output routine sends data to the HP-97 as long as there are data in the print buffer. Since there is no handshaking with the HP-97, delays are used between output commands. A delay of 120 ms between each data character and a 1.28-s delay between print commands provides reliable operation.

The interrupt identification routine first saves the accumulator and the two index registers, reads the external status switches, and reads the priority interrupt encoder. The routine then determines if the interrupt was from the 68-ms timer, the foot counter, or the 10-ms timer, and jumps to the velocity distance or time service routine accordingly.

The interrupt service routines update velocity, distance, and time when required. A flow chart of the velocity update routine is shown in Fig. 31. This routine reads the BCD counter, stores the current value of velocity, determines if a run is in progress (system in run and distance greater than 1

Fig. 31. Velocity update routine.

ft), saves data if appropriate, resets the mph interrupt flag, and returns. The foot and time routines increment and store distance or time when appropriate, reset the interrupt flag, and return to the background program.

The 2-kbyte ROM monitor, supplied by MOS Technology, permits input and output through the keyboard and display, a TTY-compatible data terminal, and an audio tape unit. Use of a TI 733 ASR and RS-232C adapter permits I/O from digital tape cassettes. The monitor also allows program execution to be started or stopped from the keyboard or the data terminal. Data are saved on tape at 1-s and 1-mph intervals and are then available for plotting or further data reduction.

Some additions to the MOS Technology monitor have been written that

- provide more convenient display of a memory block on the data terminal,
- move memory block 1 to memory block 2,
- set memory block to a hex number,
- compare memory block to a hex number,
- compare memory block 1 to memory block 2. and provide faster dump of memory block to audio tape.

e. Determination of Vehicle Rolling Resistance and Aerodynamic Drag.

(1) Data Analysis Techniques. The rolling resistance and aerodynamic drag were determined for a number of vehicles by conducting roll-down tests at the Albuquerque, New Mexico, drag strip. This section describes the data analysis techniques, the testing procedures, and the results of those tests. Straight-line vehicle motion on a level surface is described approximately by

$$F = \frac{W}{21.95} \frac{dv}{dt} + W(k_r + \sin \alpha) + \frac{\rho C_d A}{29.94} (v + w)^2, \quad (7)$$

where

- F = road force, pounds
- W = vehicle weight, pounds
- v = vehicle velocity, miles per hour
- w = velocity of wind component parallel to vehicle and in opposite direction, miles per hour
- α = slope, degrees
- t = time, seconds
- k_r = rolling resistance
- ρ = air density, lb/ft³ ($\rho = 0.0766$ at 15°C, 1 atm)
- C_d = drag coefficient
- A = frontal area, ft².

When the vehicle is coasting, $F = 0$ and

$$0 = -21.95(k_r + \sin \alpha) - \frac{\rho C_d A}{1.364W} (v + w)^2. \quad (8)$$

For a level surface and no wind, this equation has the solution

$$v = \tan(t_f - t), \quad (9)$$

$$= \frac{v_0 - \tan \beta t}{1 + \frac{v_0}{Y} \tan \beta t},$$

where

$$Y^2 = 29.94 \frac{k_r W}{\rho C_d A},$$

$$\beta^2 = 16.10 \frac{\rho k_r C_d A}{W},$$

$$t_f = \frac{1}{\beta} \tan^{-1} \frac{v_0}{Y}.$$

and

v_0 = initial coast-down velocity.

Equation (8) indicates that for coast down with constant grade and $w = 0$, acceleration is a linear function of v^2 . Then, if acceleration is calculated from the coast-down data and plotted as a function of v^2 , the linear regression line can be used to calculate k_r and $\rho C_d A$. The correlation coefficient provides an indication of the quality of the data, provided a reasonably large number of points are used.

If the wind is not negligible, $\dot{v}$ vs v^2 from Eq. (8) departs from a straight line. Ideally, the coast-down tests should be done with no wind; however, program schedules and deadlines rarely permit this luxury when a number of vehicles are to be tested. Therefore, the effects of the wind were approximated so that corrected values of k_r and $C_d A$ can be obtained. In addition, the wind can be calculated from the coast-down data and compared with the value measured at the time of the run.

When a vehicle is being characterized with coast-down runs, half of the runs should be done in one direction, the other half should be done in the opposite direction. This partially cancels the effects of wind and grade. To illustrate, Fig. 32 shows $\dot{v}$ vs v^2 for a number of east and west runs done with a Rabbit. The linear regression lines for each direction are also shown. The different slopes of the east and west regression lines are caused by an east to west wind of approximately 5 mph.

Fig. 32. Acceleration as a function of v^2 for a VW Rabbit.

The approximate effects of the wind can be obtained from the east and west coast-down equations, which are

$$-\hat{v}_E = 21.95 (k_r + \sin \alpha) + \frac{\rho C_d A}{1.364W} (v_E + w)^2 \quad (10)$$

and

$$-\hat{v}_W = 21.95 (k_r - \sin \alpha) + \frac{\rho C_d A}{1.364W} (v_W - w)^2 \quad (11)$$

where an east to west wind is positive. If the wind effects are small, Eqs. (10) and (11) can be approximated by

$$-\hat{v}_E = B_E + M_E v_E^2 \quad (12)$$

and

$$-\hat{v}_W = B_W + M_W v_W^2 \quad (13)$$

where the effects of the wind modify the B and M coefficients. If the least square error criterion is used to match Eqs. (12) and (13) with Eqs. (10) and (11), then

$$B_E = 21.95(k_r + \sin \alpha) + \frac{\rho C_d A}{1.364W} \left(w + \frac{3}{8} v_o \right) w \quad (14)$$

$$B_W = 21.95(k_r - \sin \alpha) + \frac{\rho C_d A}{1.364W} \left(w - \frac{3}{8} v_o \right) w \quad (15)$$

$$M_E = \frac{\rho C_d A}{1.364W} \left(1 + \frac{15}{8} \frac{w}{v_o} \right) \quad (16)$$

and

$$M_W = \frac{\rho C_d A}{1.364W} \left(1 - \frac{15}{8} \frac{w}{v_o} \right) \quad (17)$$

The B's and M's are the intercepts and slopes of the east and west linear regression lines, which can be obtained graphically. The values obtained for the Rabbit are given in Fig. 32. Having determined the B's and M's, Eqs. (14)-(17) can then be used to determine w , $C_d A$, and k_r , provided the vehicle weight and air density are known

$$w = \frac{8}{15} v_o \frac{M_E - M_W}{M_E + M_W} \quad (18)$$

$$C_d A = \frac{1.364W}{2 v_o} (M_E + M_W) \quad (19)$$

and

$$k_r = \frac{B_E + B_W - (M_E + M_W) w^2}{2 \times 21.95} \quad (20)$$

The coast-down data are therefore analyzed in the following manner. First, a linear regression analysis is performed on all the east runs and all the west runs (an equal number in each direction should be used). Next, Eqs. (18)-(20) are used to verify the wind velocity, then calculate $C_d A$ and k_r . If $\hat{v}$ vs $(v + w)^2$ or v^2 is plotted using the correct value of wind, Eqs. (10) and (11) indicate that the east and west regression lines should be parallel. This provides an additional check on the data and the calculations. An example of the process is given in the results section.

(2) Test Procedures. Roll-down tests were conducted on 12 vehicles over a 3-day period at the Albuquerque, New Mexico, drag strip. At least four runs were made for each vehicle; one run in each

direction from approximately 60 to 35 mph and from approximately 40 to 0 mph. Time was measured to the nearest 0.01 s, velocity to the nearest 0.1 mph, and distance to the nearest foot. Velocity and distance were saved in read-write memory at 1-s intervals, then stored on magnetic tape at the end of each run. The tapes were then used as input to plot routines and for data reduction programs that calculate C_dA and k_r .

Extreme care was taken in conducting the coast-down tests so that valid data would be obtained. Vehicles were thoroughly warmed up, weighed, tire pressures checked, windows rolled up, and wind velocity, air temperature, and air pressure were measured. The drag strip was surveyed and the quarter mile section was found to be level (average grade 0.006%, maximum grade 0.07%). The maximum grade was 0.29% at the end of the deceleration track. This would change the acceleration by 0.064 mph/s and, for a 3000-lb car, would change the force by 8.7 lb. This portion of the track was not used for coast-down tests. Equation (10) or (11) shows that a constant wind velocity changes C_dA by a factor

$$1 + \frac{15}{8} \frac{w}{v_0},$$

for a one-way run. For a 5-mph wind and an initial velocity of 60 mph, the factor is 1.156. When the two-way average is taken, this error is substantially eliminated.

It was found that vibration and bounce of the fifth wheel seriously affected the coast-down tests. A substantial effort was made to minimize wheel vibration and bounce. A smooth test track is also an important factor in minimizing vibration and bounce.

Most of the data analysis and reduction was done on an HP-9820A desk calculator with a 9862A ink plotter. Both calculator and plotter were taken to the test track so that plots could be obtained and data analyzed immediately. This provided valuable immediate feedback for evaluating the quality of data obtained and the effects of factors such as wheel bounce, wind, and variations in track grade.

(3) Results. As an example, C_dA and k_r will be calculated for a Rabbit from data obtained from the roll-down tests. Five runs were done in each direction and data were saved at 1-s intervals.

Figure 33 shows a v vs t plot, corresponding to Eq. (3), for one of the runs. The $\dot{v}$ vs v^2 plot for all 10 runs and the linear regression line for each direction are shown in Fig. 32. In addition, the values of M_E , M_W , B_E , and B_W are given in the equation for $\hat{v}_E$ and $\hat{v}_W$.

The altitude of the drag strip is 5000 ft, the pressure was 24.9 in. of mercury, and the ambient temperature was 25°C. The density of dry air is

$$\rho = \rho_0(T_0/T)(P/P_0) \quad (21)$$

where ρ_0 is a known density at absolute temperature T_0 and pressure P_0 . Since $\rho_0 = 0.0766 \text{ lb/ft}^3$ at 15°C, 1 atm (29.92 in. of mercury), the corrected air density is

$$\rho = 0.0766 \times \frac{238}{298} \times \frac{24.9}{29.92} = 0.0616 \text{ lb/ft}^3 \quad (22)$$

The test weight of the Rabbit was 2500 lb and the initial coast-down velocity was 62.3 mph. Using the values for the B's and M's in Fig. 32, the calculated wind is

$$w = \frac{8}{15} \times 62.3 \times \frac{2.213 - 1.597}{2.213 + 1.597} \quad (23)$$

$$= 5.37 \text{ mph (east to west).}$$

The aerodynamic drag and rolling friction are

$$C_dA = 10.5$$

Fig. 33. Coast-down plot for a VW Rabbit.

and

$$k_r = \frac{0.6528 - 0.0110}{2 \times 21.95}$$

$$= 0.0146.$$

It was pointed out above that when $\dot{v}$ vs v^2 is plotted using the correct value of wind, the east and west regression lines should be parallel. Figure 34 is a plot of $\dot{v}$ vs v^2 of the two regression lines for a 5.4 mph east to west wind, showing that the two lines are, in fact, essentially parallel.

Acceleration was calculated every second and velocity was measured to the nearest 0.1 mph. This allows a same direction run-to-run variation of 0.2 mph/s, which accounts for much of the scatter in data shown in Figs. 32 and 34.

The same technique was used to calculate rolling friction and aerodynamic drag for the other vehicles tested. The results are tabulated in Table

Fig. 34. Acceleration vs v^2 corrected for wind.

V. These results have been used in a technical and economic evaluation of fuel-cell-powered vehicles. They have also been used as input to a computer program capable of detailed simulation of a battery-powered or fuel cell battery-powered electric vehicle.

(4) Conclusions. During this period, the preliminary technical and economic evaluation of fuel-cell-powered vehicles has been performed and a number of basic tools necessary for a more detailed analysis have been developed. A general electric vehicle simulation code has been written and a fifth wheel microprocessor-based vehicle instrumentation system has been developed.

The mode of this program at the present time, based on the results obtained during this period, is cautious optimism. It appears that the fuel cell vehicle may indeed be a viable option in the future; however, there remains far more preliminary work to be performed before final conclusions can be drawn.

TABLE V

ROLLING FRICTION AND AERODYNAMIC DRAG RESULTS

Vehicle	k_r	$C_d A$
Honda Accord	0.0166	10.4
VW Rabbit	0.0146	10.5
Ford Granada	0.0164	12.8
Ford Pinto	0.0166	13.6
ElectraVan	0.0183	14.4
Ford pickup truck	0.0197	26.7
Air Force truck (1-1/2-ton Dodge)	0.0142	38.7
Air Force bus	0.0117	39.2
Toyota	0.0129	11.6
GMC plus camper	0.0170	56.7
Ford van	0.0155	24.5

B. Program Support

1. Introduction. This section of the report describes E Division's role in those LASL programs where there is a long-term dedicated effort. The discussions include the general nature of the overall program, as well as the technical nature of our support.

2. Security and Alarm Systems (Associate Director, Administration) [Des Jardin, Brenner, Cornell, Criscuolo, Hall, Hart, Hartway, Horn, N. Johnson, P. Johnson, Kissane, Parker, Reitzel, Rivera, Rose, Sanders, Shoemaker, Whitfill, Wilkins, Williams, E-5; Lucero, Gentry, Myers, E-2; Schwalm, E-1].

a. Central Alarm Station. The central alarm station (CAS) is under construction and should be completed by early summer 1979. The building will initially be occupied by the Group E-5 Security and Alarm Section personnel, who will prepare it to accommodate the separately contracted LORAX CAS computer system. Depending upon the successful contractor for LORAX, early equipment staging in the CAS may be necessary; therefore, allocation of all CAS space has not been done.

b. LORAX FY-78 Purchase. The functional specifications for LORAX have been completed and released with an RFQ by the Supply and Property Department. The final specification included 4 volumes with a total of 370 pages. Approximately 150 copies were sent to LASL and DOE personnel, invited bidders, and interested subcontractors. From a list of 120 interested parties, 40 companies were selected and invited to bid as prime contractors on the LORAX. The RFQ was written as a total system, firm fixed-price purchase, from a single prime contractor over a two-phase procurement. Phase I includes all CAS equipment necessary to accomplish the full upgrading of the intrusion detection system (IDS); it must be compatible with phase II additions of fire, plant, and Badge Office security systems (BOSS). Phase I field implementations require multiplexing a few buildings for IDS, an IDS operator console in Station 100 and the CAS, and miscellaneous support function consoles for maintenance and data communications expansion. Phase II field implementations will include all field upgrading for the remaining IDS, all fire and plant alarm operator console upgrading in all DOE fire stations, com-

puter-aided dispatching capabilities, further support capabilities in the CAS, and implementation of the BOSS.

The RFQ was let in mid-October and a bidders' conference hosted by Group E-5 was held at LASL on October 30, 1978. Approximately 20 companies registered and LASL, DOE, and other interested personnel attended. The conference was well received by the attendees and approximately 10 companies indicated their intention to bid as prime contractors.

Following the general bidder conference, 3 wk of individual sessions were held with interested bidders. These sessions helped bidders significantly in their understanding of the LORAX program and provided an opportunity for our personnel to assess the bidder capability for LORAX. Clarifications resulting from the bidders' conference and the individual sessions were provided to all invited bidders as a 45-page errata list covering programmatic, contractual, and technical aspects of the LORAX purchase.

The initial due date for the proposals was January 4, 1979, but this was extended to January 29, 1979, because of the holidays. The LASL proposal evaluation of the proposals is expected to take about 60 days. Because of DOE approval time and other unknown factors, the contract will probably not be awarded until July 1979. Delivery times and implementation schedules will be determined entirely by the successful bidder, but typical times would be an 18-month installation, shakedown, and acceptance test period, with final IDS alarm operation by LASL and DOE personnel within 24 months.

Phase II contracting should begin with the award of the contract with the available fire protection improvements funding from FY-79 and any remaining FY-76 funds. Phase II IDS funds are still being negotiated. The total phase II upgrading for all integrated fire, security, and plant alarm systems is expected to take place over a 5-yr period.

c. Intrusion Detection Sensors. Because much higher technology is required in the interim system and LORAX, the efforts of Group E-1 are being augmented by the E-5 Security and Alarm Section in supplying engineering effort for data communication, sensor development, multiplexers, and computer systems.

The E-5 responsibilities include developing a statement of work (SOW) for each alarmed security area. The SOW will indicate the purpose of the work and provide data on sensor selection, coverage, operation, validation, and maintenance. In addition to the SOW, we will be responsible for establishing schedule, budget, and manpower requirements. After necessary approvals have been obtained, we will be responsible for the sensor and control set implementation.

Current activities involving the existing ADT system include expanding it with additional alarms installed in TA-18, TA-21, and TA-3. Upgrading activities involving TA-3, SM-29, and TA-41, W-4, have been completed and are now the only areas on the interim system. We expect to begin upgrading TA-3, SM-66, and SM-35 in January. Areas to be upgraded in the near future include TA-18; TA-16; and TA-3, SM-164. We have not yet determined sensor requirements for these areas.

Representatives from Sandia Laboratories, Albuquerque (SLA) visited LASL to examine TA-21, DP-3 and DP-4, in response to a request from the Albuquerque Operations Office (ALO). The SLA representatives requested that we supply them with preliminary plans for alarming these buildings. A first-pass plan was explained in a memorandum that specified only the types and numbers of devices expected to be used in the buildings. More accurate information was not available because tests could not be completed due to time constraints.

The PM-203 portal monitor, manufactured by Tom Scurry Associates, was evaluated from the standpoint of its susceptibility to defeat. This examination revealed that the monitor could be protected with little difficulty, that it possessed better line supervision, and that it was easier to operate than portal monitors now in use at LASL.

Two new microwave space alarms are being purchased for evaluation from Omni Spectra, Inc. The first is a Model 120-33062, which is a ceiling-mount detector. This detector will be evaluated for use in areas that would otherwise require numerous standard wall-mount detectors. The second space alarm is a Model 160-33059 that incorporates a 120-Hz filter. The filter allows this detector to be used in areas that must be illuminated by fluorescent lights in the secure mode.

Investigations into perimeter alarms for special nuclear material (SNM) areas have begun. These investigations include obtaining various meteorological and seismic data for SNM areas. We have contacted Del Norte Technology, Inc., a supplier of perimeter alarm equipment, about using either their AIDA or CIRCE system at LASL. The Del Norte Technology representative made a number of suggestions including making on-site seismic studies. It is evident that these studies must be made; however, until funds become available the study must be postponed. The Del Norte system, as well as other systems such as the Sylvania FPS-II system, will be investigated in more detail in the future.

d. Communications. Data communication links must be provided from the Los Alamos Area Office (LAAO) to interim system sites. These sites include the CMR building, TA-41, Sigma, TSL-87, and TA-21. Communication line speeds up to 4800 bps are required. Type 82 lines will be ordered for the interim system. These lines will be evaluated for availability and line speed requirements. The two most pressing needs in terms of interim system communications are documentation requirements and compatibility with LORAX.

The access control booths at TSL-87 must be supplied with TV and data communications lines. A bid of \$42 000 for installation of coaxial cable from TSL-87 to Pajarito road was received. After reviewing this bid, a tentative plan to use slow-scan TV was formulated, although this approach may not be as effective.

A determination of the data communications needs for LORAX must be made and recommendations of how to meet these needs developed. Liaison and guidance will be required in these areas. A determination of LORAX needs for a LASL-wide data communication system must be made. One problem has already become apparent. Since the LASL-wide communication system may not be ready, the LORAX system will have to operate over telephone lines initially. When the wideband communication lines are available, the telephone line modems will not be readily switchable to the coaxial cable. Conversations with Network Analysis Corporation have indicated that they are willing to advise us and work with us. If this is not done soon, modems may be purchased for LORAX that will later be unusable. Properly

conditioned telephone lines are difficult to maintain to their specifications. This will become a major problem for the LORAX and, coupled with the above mentioned modem problem, should provide adequate reasons to rapidly press for a LASL wideband communication system to provide the reliability and redundancy needed.

e. Fire Liaison. Liaison with the Los Alamos Fire Protection Advisory Committee (LAFPAC), ENG-2, and the DOE Fire Department has been initiated. Fire Department personnel have been given a set of E-5 floor plan drawings for the CMR building to mark for appropriate fire alarm system (FAS) signations. An outline of work to be initiated in the areas of microfiche, fire preplans, multiplexer installation, and the interim system was made and a preliminary book on the CMR building was started. An on-site review of work related to the SESCOA dialing systems at TA-54 and TA-36, with its associated bunker sites, was conducted.

f. LORAX Plant Monitor System. Initial contacts have been made with ENG-4 personnel in preliminary efforts to initiate problem definition and system requirements. We are awaiting documentation that describes the existing ENG-4 SCAM plant monitor system.

g. Interim Security System. The interim security system central station equipment consists of a PDP-11/34 computer and support peripherals including a programming terminal, a data base manager terminal, a high-speed alarm logger, and an alarm operator console. The field equipment includes the communications network, 20 data concentrators (multiplexers), the wiring plant, and various alarm devices. The interim system is intended to satisfy the need for immediate security coverage until a more comprehensive and flexible system can be designed and acquired.

The computer and peripherals were installed at TA-0 and checked out in June 1978. The typical problems attendant with new equipment were solved by the second week of July. This part of the system has run continuously since that time with only periodic maintenance interruptions.

The multiplexers were delivered in three groups: five in June, ten in August, and five in December. The TA-3 (CMR) installation, which required eight multiplexers, was essentially complete

by mid-August. It has been running in a test mode since that time in order that we may observe reliability and develop appropriate displays and procedures for the security operators. The installation at TA-41, which required two multiplexers, is finished except for the data base entries and system check-out. These items will be completed soon. Plans have been made for installation at SM-164, SM-66, SM-35, TA-35, and TA-21. Surveys are being conducted for future expansion into TA-16 and TA-18.

The diesel generator and uninterruptable power supply have been installed at LAAQ, building 100, and acceptance tests run. The power system is complete except for some items associated with the diesel generator and final closure of the distribution boxes. The entire system should be completed by the third week of December.

The computer system was moved to building 100 during the first week in November. Problems generated by the move have now been solved and the system is functional. Protective force training will start on Monday, December 18, and the system should be fully operational for TA-3 and TA-41 during January 1979.

The software has been modified to provide the displays, logs, and communication monitoring required for this kind of system. Innocent appearing program changes can often produce catastrophic malfunctions, but virtually all the repairs have been made by E-5 programmers working from PDP-11 code listings. The applications programming is now complete and the present package appears to be stabilizing; however, the possibility exists that as more areas are brought into the system some problems may appear.

h. CMR Access Control System. A contract was awarded to Harco Industries, Inc., for a stand-alone automated Security Access Control System (SECA) to be installed in the CMR building. This SECA will be used to control physical access to the CMR area, building, and vaults. Control will be accomplished through the use of the standard LASL magnetic-stripe badges, which are encoded with personnel and badge identification numbers. In some instances, a memorized 4-digit identification number will also be required to be input for more highly controlled access into sensitive areas. The SECA is comprised of a NOVA-3 minicomputer, associated control and

interface electronics, four badge reading units, one redundant indicator panel, a system activity logger, and a printer-keyboard terminal. Only three of the badge reading units will be operable when the SECA first becomes operational. Two of the badge reading units will aid the inspectors in controlling access through the front door and loading dock entrances; one unit will be used to control access to a storage vault and the other unit will be used to control access to the CMR area through the Mardix booth located at the back gate entrance. The redundant indicator panel informs the inspectors at the front door station of vault and booth activity by redundantly displaying the access status of the various stations through indicator lights.

The system logger is also located at the front door station. Its chief functions are to inform the inspectors of any unusual activity, record all vault activity, record all after-hour activity, and provide on-demand status reporting such as listings of all personnel in the building. The printer-keyboard terminal is primarily used to enroll authorized personnel into the data base, which is used to determine if access is to be permitted or denied. All updating and querying of the data base can be accomplished only through this terminal.

Harco delivered and installed the SECA during the latter part of November 1978. Acceptance testing was conducted December 2, 1978. All deliverable hardware, firmware, and software were acceptable with the exception of the redundant indicator panel. Changes required to make the redundant indicator panel acceptable are currently being implemented, and the unit is expected to be operational by the end of December 1978. The SECA documentation is in various stages of completion. Most of the documentation has been completed and needs only to be put into a more formally organized package.

The application software for the SECA is being implemented. This effort is scheduled for completion during the latter part of January 1979. The software effort includes all access control algorithms, data base management, and information retrieval reporting. The operational target date for the SECA is February 1, 1979.

i. TSL-87 Access Control Booth. A proposal was submitted September 1978 in response to a request from L-DO for an unattended automated access

control booth for building TSL-87. The proposed booth is to be used for controlling access to the security areas of TSL-87 during all periods outside established working hours.

The proposal was approved by ALO, LASL Security, and L-DO with some minor modifications in November 1978. A work order was issued the week of December 4, 1978, and the implementation effort was started at that time. The booth should be operational by the latter part of June 1979.

The TSL-87 access control booth will eliminate the need for the physical presence of a guard in order to enter or exit from the security area within the building during off-hour periods. Individuals desiring entrance to TSL-87 will be required to possess a valid LASL magnetic-stripe badge, be properly enrolled into the TSL-87 data base, and possess a key to the outside set of vestibule doors. Entrance will be permitted only when the access control booth properly validates an individual's LASL badge and the individual enters a designated number. Access will not require any guard intervention. If any unusual conditions are detected by the booth, the individual will be required to use the telephone located at the booth to contact Station 100 so the situation can be satisfactorily resolved. All booth activity will be permanently recorded on the system logger located at Station 100.

3. AP-Division Support [Deal, Robinson, Winston, E-5; Shapolia, E-2]. We provide electronic support to the various AP laser photochemistry experiments before and while they are conducted. Individual experiments may vary in length from a few days to several years. Almost all of them are conducted in a high EMI environment and the more sophisticated ones employ computer-based real-time control and data-acquisition systems. The electronics for these experiments must, therefore, be designed or specified by those knowledgeable in the special requirements of this composite environment.

Our contribution to this effort requires that we design new circuits, modify existing circuits for new applications, modify new and old instruments for compatibility with existing hardware, supervise technicians in the fabrication, testing, and installation of new equipment, write specifications and order new instrumentation, trouble shoot the experimental equipment and software and fabricate

and install urgently needed electronic components. This includes such tasks as the control circuitry for the PRL-III experiment, a computer interface for an optical multichannel analyzer, and a three-dimensional servopositioner.

One experiment, laser-induced fluorescence (LIF) studies, used all available computer memory, yet program requirements continued to grow. The solution was to use a fiber optic link to a host computer, a Data General Eclipse, for data analysis and reduction. Data can now be acquired on the NOVA satellite, quickly sent to the Eclipse user disk, and later recalled for analysis and plotting. This eliminates the need to use floppy disks to transport data to the host. The LIF experimenter can quickly switch to the Eclipse and run data analysis using the NOVA as an intelligent terminal, and switch back to collect more data. By removing all data plotting and analysis from the satellites, about 25% more satellite memory is available to the experimenter.

Support for the JUMPER project during this period has involved developing components for fiber optics links. A relay control link for a noisy environment was developed and operates satisfactorily. Additional units have been built. A light pulser was developed for AP-2. The light source is an injection laser with an output of up to 20 W. The pulser, which will dump up to 100 A into the laser, may be externally triggered or run at its own rate from 10 Hz to 3 kHz. Transmitter and receiver circuitry for a fiber optics link was developed for AP-2. This system now being fabricated will evaluate a special laser diode, a light-sensitive diode, and fiber optics. A fiber optics link with a high-voltage output for firing spark gaps was also designed. An output pulse of 50 to 100 kV is required. The link has been completed, but difficulties are being encountered with the pulser.

4. CMB-Division Support.

a. TSTA (CMB-3) [Grundmann, McDonald, Springer, E-4; Damran E-5].

Analysis. The Tritium System Test Assembly (TSTA) is a LASL facility being constructed for the purpose of developing, demonstrating, and interfacing technologies required in the deuterium-tritium fuel cycle of future fusion reactor systems. An artistic version of this facility is shown in Fig. 35. The facility is basically a physical simulation of a

Fig. 35. Tritium systems test assembly.

fusion reactor tritium system including the vacuum system, fuel injection, fuel cleanup, isotope separation, control, and emergency systems. Flexibility is being designed into the system to allow testing of new components under actual deuterium-tritium conditions. The overall objective of the project is to demonstrate the long-term reliability and safety of deuterium-tritium handling facilities. The estimated cost of the project is \$12 million and is presently scheduled for completion in the 1980-81 time frame.

E-Division support involves assisting in the design and installation of the instrumentation and computer control system in the facility. To aid in the TSTA effort, computer simulations of the vacuum, fuel cell cleanup, and isotope separation systems are in progress. These simulations will aid in the design process by providing simulated performance evaluation of any component as it interacts with the rest of the system in which it operates. The first computer simulation of a major component was completed in November 1978. It is a dynamic model of one isotope separation system distillation column including automatic controls. This simulation is described below.

When the distillation column design was completed, analysis revealed that controls would be necessary to maintain constant tritium concentration overhead (Y_{T2}) even when the tritium concentration of the feed (Z_{T2}) varied (see Fig. 36). This overhead control can be accomplished by controlling the flow out of the column at the bottom (B). Hand calculations can verify the validity of bottom control when they are manually operated. However, if

Fig. 36. The distillation column modeled by 66 finite difference nodes with overhead tritium stabilized by 2 bottom flow control loops.

automatic bottom controls such as those in Fig. 36 are desired, then a dynamic simulation of the entire column with controls is required to verify the automatic control loop stability.

The required dynamic simulation was implemented by first writing equations that model the two control loops in Fig. 36. One loop is a fast acting proportional feed forward control loop. The other loop is slow acting (due to transport delay between the column feed and overhead), but it eliminates overhead error in the tritium concentration (Y_{T2}) by using proportional plus integral control action. The second part of the simulation is a 66-node finite difference model of the distillation column. At each node equations that describe mass and energy balances were written. There are 330 equations describing the column.

When completed, the simulation was run first without controls and then with controls. The results of these runs are shown in Fig. 37. Without

controls the concentration of tritium overhead (Y_{T2}) increased from 4.9% to 6.9% in response to a 5% increase in tritium at the feed (Z_{T2}). With the automatic control loops, the overhead tritium shows a slight oscillation immediately following the increase in tritium at the feed but the overhead then settles down to its original value. Since the controls are stable and prevent permanent offset of tritium in the overhead, the simulated control schemes were judged to be adequate. Subsequently, construction of the controls for the actual distillation columns was initiated.

b. Master Data-Acquisition and Control System (MDAC) for TSTA. The E-5 responsibility for this project includes the design, procurement, fabrication, installation, check-out, and operation of the data-acquisition and control subsystems that will interface with the computer subsystem (CSS). The original design of the CSS was performed by R. Stutz, ENG-8. A temporary reduction in program funding required redesign of the CSS. Group E-5 assisted in this redesign, which resulted in replacing two minicomputers with two microcomputers and reducing the overall scope of the CSS. The MDAC system design description (SDD) has been revised to incorporate these and other changes to the MDAC precipitated by this redesign. Group E-5 is also responsible for the design and implementation of a man-machine interface subsystem, an uninterruptable power supply (UPS) for the MDAC, and an emergency generator set (EGS) for the TSTA.

Fig. 37. Response of the distillation column overhead (Y_{T2}) to a 5% increase in feed quality (Z_{T2}).

(1) 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 records accountability 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.

(2) System Description. The MDAC hardware configuration consists of a data-acquisition subsystem (DAS), a process control subsystem (PCS), a man-machine interface subsystem (MMI), a CSS, and software subsystem (SSS). A block diagram of the hardware subsystems and the interfaces between them is shown in Fig. 38.

(3) Data-Acquisition Subsystem. The data-acquisition subsystem (DAS) contains a collection of transducers and other signal sources, interconnecting cabling between these sources and major DAS equipment components, and a collection of major equipment components used for conditioning, formatting, and interfacing TSTA parameters to the CSS. Figure 39 shows a block diagram of the DAS and its interface to the CSS subsequent to the redesign of these two subsystems. The analog signals from the facility will be brought into the control room and routed to the appropriate signal conditioning-calibration circuit by way of a patch board system. This circuit will condition all signals to ± 5 Vdc full scale and filter them to a bandwidth of 1, 3, or 10 Hz as applicable before they are patched to

Fig. 39. MDAC-DAS and PCS block diagram.

an analog multiplexer and sent to the 12-bit analog-to-digital converter (ADC). These data will be stored in the microcomputer (CPU-3) memory that controls this section of the DAS. The data will then be transferred to CPU-1 or -2 as applicable at a predetermined rate.

The digital signals from the facility will be brought into the control room and routed to optical or relay signal isolation circuits by way of a patch board dedicated for digital signals. The signals will be patched into registers that will be read by micro CPU-3 and the information passed onto CPU-1 or -2 when a status change is recognized.

The signal conditioning and calibration units will be printed circuit boards (PCB) placed in drawers located in two 48.3-cm racks. The multiplexer, ADC, digital isolation circuits, registers, and micro CPU will be CAMAC equipment located in other racks in the control room. These input signals will make up branch 1 of the parallel CAMAC system specified in IEEE Standard 596-1976.

The data-acquisition and control functions of the ISS subsystem will be controlled by micro CPU-4 and be dedicated to branch 2 of the CAMAC system. The analog and digital measurements will be transferred to CPU-1 or -2 at a predetermined rate.

The CAMAC branch couplers will be located in a CAMAC master (system) crate. This master crate will be interfaced to all four computers in the computer subsystem. A priority arbitration circuit in the master crate allows only one CPU at a time to have control of a CAMAC cycle.

Figure 40 depicts the master crate redundancy that contains the interface to the four CPUs of the

Fig. 38. TSTA MDAC subsystems interface.

Fig. 40. MDAC-CAMAC subsystem block diagram.

CSS and the CAMAC branches. The CAMAC branches will be multiplexed to either of two identical master crates. The four CPUs will be interfaced to both master crates. This configuration permits communications with the facility should a malfunction in either master crate occur. Redundancy is not carried beyond this point in the DAS and PCS subsystems with the exception of some duplication of transducers.

Separate power supplies for signal conditioning, transducers, logic circuits, calibration voltages, and control voltages are part of the DAS and PCS subsystems. With the exception of the calibration voltage power supply, each unit will be duplicated for redundant operation. The power supplies will be operated in parallel with diode isolation so that should one power supply fail, the back-up unit will automatically assume the load. Connecting the units in this manner eliminates switching transients and power interruptions. Each power supply will be able to carry the full load indefinitely with no degeneration in performance.

The calibration of the DAS 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 operational circumstances. Under normal operational conditions, periodic calibration of all DAS instrumentation channels shall be accomplished under computer control.

The 2-bay and 6-bay racks have been received and installed in the control room. The patch board system, not wired, and the CAMAC crates have been installed in these racks.

The DAS signal conditioning and calibration sections are now being designed. Purchase orders have been placed for candidate hardware to evaluate before a final design. The instrumentation and controls are being designed and purchased for the emergency tritium cleanup, isotope separation, heating and ventilating, and facilities subsystems.

The facility J box panels were prepared for installation of the terminal boards, and the terminal boards were installed during this reporting period. The wire list for the installation of the analog and digital MDAC cables from these J boxes to the control room is complete and has been approved and released. The installation of these MDAC cables has started and is scheduled for completion by mid-February 1979.

(4) Process Control Subsystem. The PCS and the DAS are integrated subsystems. All process-oriented functions of the TSTA will be computer controlled. The amount or type of computer control will vary for each application. The exact control required for each process has not yet been established. A block diagram of the PCS is shown in Fig. 39.

The analog control signals will be received from CPU-1 and -2, conditioned by digital-to-analog converters (DAC) before they are patched to an analog control signal patch board then sent to a controller located on a facility subsystem. The DAC will be packaged in CAMAC configuration.

The digital control signals will be received from the CPUs, sent to optical or relay isolation circuits, and then through drivers to the controller display alarm located in the facility. These digital control signals will be routed through a patch-board dedicated for digital control functions. Again, CAMAC equipment will be used to identify, isolate, and condition the control signals sent by the CPUs.

Micro CPU-4 will be dedicated for the data-acquisition and control functions of the ISS. To include the ISS in the closed-loop control of the entire TSTA process loop, CPU-1 or -2 will send the necessary closed-loop control instructions to the ISS micro CPU.

Branches 3 and 4 of the CAMAC system are dedicated to facility control (other than ISS control). These branches will contain the DACs, registers, digital isolation circuits, and drivers required for facility control.

(5) Man-Machine Interface Subsystem. The MMI serves as an interface between system operators and the MDAC. Two CRT monitors are provided for viewing TSTA operation and performance displays. Two keyboards permit operators to input data, supervisory control commands, and requests for displays to the computer. The logging printer provides for 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. This display generator has dual ports, which allows the connection of both CPU-1 and -2 to the unit for redundant operation. The detailed design and subsequent purchase of this subsystem is scheduled for FY-79.

(6) Computer Subsystem. The TSTA CSS is a modular redundant system wherein computer and disk facility control and data-handling functions can be shared in case any one or more units malfunction. The TSTA system can therefore continue safe operation. This redundant network of CPUs and disks is required for a highly reliable and fault tolerant system.

The major components of the TSTA computer subsystem, along with the logic data paths, are shown in Fig. 41. The function of each component during normal operation is:

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

- CPU-2 is intended to serve for system studies (simulation), data reduction, software development, and back-up to the other CPUs.

- Micro CPU-1 is a back-up for CPU-1 and -2, in that it will automatically shut down the facility in a safe and orderly manner should both CPU-1 and -2 fail.

- Micro CPU-2 is used in conjunction with CPU-2 to perform system studies, data reduction, software development, and back-up functions for micro CPU-1.

- Disk 1 will be used to store the software for CPU-1, data for the control software, and collected

Fig. 41. Basic data flow paths for CSS.

data from the controlled and monitored functions. These data will be transferred to disk 2 for data reduction.

- Disk 2 is used to store software for CPU-2, data for reduction and display, and software for systems simulation.

- Floppy disk 1 is used for short-term storage of selected data from monitored functions and facility shutdown software for micro CPU-1.

- Floppy disk 2 is used for storage of software for micro CPU-2 and will be used in conjunction with CPU-2 for TSTA simulation and software development. This disk, along with micro CPU-1, also provides a back-up for floppy disk 1.

- A magnetic tape unit will be used to record data, back-up copies of all disk files, software programs, and TSTA operational documentation.

- A high-speed printer will output operating reports, results of data-reduction programs, copies of software documentation, listing of control programs, wire lists, catalogs of disk files, and other reports related to the TSTA.

- The I/O bus switch will be used to link the printer and magnetic tape units to either CPU-1 or -2, thus removing the present need for two magnetic tape units.

As a result of the reduction in scope of the CSS, the various optional modes are:

- With the loss of CPU-1, CPU-2 functions as the main control unit of the TSTA; however, the system operates without the off-line data reduction capability.

- With CPU-1 operating, loss of CPU-2 is identical to the operation described above.

Only in the event of the loss of both large CPUs (CPU-1 and -2) does the system have to be shut down using micro CPU-1 or -2. With loss of CPU-1 and -2, the majority of all data-recording capabilities are lost.

- Loss of either of the micro CPUs (micro CPU-1 or -2) results in the remaining micro CPU being used for controlled shutdown of TSTA.

- Loss of both micro CPUs or a combined loss of a micro CPU and large CPU will still result 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.

- With the loss of any three CPUs the system must be shut down under controlled procedures.

- With the loss of all four CPUs the TSTA facility would require manual shutdown.

The CSS was received from Data General Corporation during the last reporting period. The six computer racks, along with all peripherals, have been moved into the control room and secured to the floor as required. Data General personnel have completed the acceptance tests on this subsystem as required by the purchase specification. Interfacing of the CSS to the CAMAC equipment in the DAS has been initiated.

(7) Uninterruptible Power Supply. A UPS will be provided that will supply the total power requirements of the MDAC at the specified frequency, voltage, and phase. A specification for this equipment has been drafted; however, procurement has been delayed until FY-79. The SDD for this subsystem was revised during this reporting period.

(a) Emergency Generator Set. An EGS to supply power to the TSTA in the event of a power

line failure will be provided. Purchase of this item is scheduled for FY-80; therefore, design effort will be scheduled in FY-79.

(b) Software Subsystem. The software for the TSTA computer subsystem consists of the computer operating system, TSTA control-data collection, data reduction, simulation, and the software controller. The software task is being outlined and the specification controlling its structure is being prepared.

5. G-Division Support.

Seismic Monitoring System (G-2) [Jennings, Seamons, E-5]. A prototype microprocessor adaptive data acquisition system (MADAS) seismic monitoring system was completed for group G-2 during this period. Group G-2 installs and operates sensing instrumentation for a network of seismic stations in New Mexico and at NTS for seismic measurements associated with tests. The seismic stations telemeter raw data to a central reading station at LASL. The number of stations involved, and sampling frequencies required, generates vast quantities of field data to be stored and subsequently analyzed. Group G-2 is automating the collection and analyses of the data at the central location. The group is investigating various approaches in the use of intelligent data collection at remote sensing locations to improve the quality of data collected, drastically reduce the volume of data transmitted to the central station, and reduce the elapsed time for entry of significant data into the seismic data base. One approach to the intelligent remote station uses the MADAS developed by Group E-5. Two MADAS units, configured to G-2 hardware and software applications, have been fabricated and programmed. Group G-2 is setting up a facility to evaluate the units before they are installed in the field. A block diagram of the G-2 MADAS system is shown in Fig. 42. Standard MADAS peripherals are used to interface to G-2 equipment. The G-2 input to the system consists of one seismometer channel operating into an 8-bit ADC unit with 125 μ s conversion time and a time-sync pulse, implemented as an interrupt to the MADAS 1802-CPU, used for synchronizing the MADAS clock to an external time base.

The MADAS outputs are candidate seismic events recorded on the cassette logging unit and universal

Fig. 42. MADAS block diagram.

asynchronous receive and transmitter (UART) output to formatted graphic output for display of candidate events in plot form on a 4010. This output is temporary and is intended only to facilitate laboratory evaluation of the system.

Another output is UART to modem for transmission of data to seismic station network. The modem is not yet installed on the G-2 units, but an equivalent modem has been used on another MADAS application.

The system objective is to continuously sample a seismometer analog input channel, sense and report out, or record, only valid seismic events. The reported events must be tagged with precision time to enable subsequent time correlation of events from a network of monitoring stations. Signal frequencies of interest range from 5 to 50 Hz.

The event-sensing algorithm implemented for the current system consists of data acquisition at a 100-Hz rate with a continuous recalculation of a short-term ratio to long-term average. A candidate event is declared when this ratio exceeds a designated (variable) threshold. The candidate event is

time tagged to the nearest hundredth of a second and logged as a 256-sample segment of raw data that preceded event declaration. The system monitors the maximum ratio attained and the duration of the event; these attributes are logged out with the associated event.

This method of exception logging will provide a significant reduction in the amount of data recorded at the remote stations. The data segments logged are to be further analyzed by G-2 to determine more detailed event specifics such as precise time onset and frequency characteristics of the event. An end objective is to develop one or more adaptive event pick algorithms to be implemented at the remote station, which would further reduce station event reporting to onset time, duration, and magnitude.

The initial software written for the system is based on the use of a general system software package developed for MADAS systems in support of the AQES/SANDIA project. Under this system, most programs are applications-specific and are written in the form of tasks, which are called and executed from a generalized system EXEC program. The G-2 MADAS system is organized into four tasks. Minor modifications to the general system interrupt handler were required to accommodate the specific G-2 input configuration. The main applications task, EPIC, which does the candidate event sensing, is structured so that add-on of more sophisticated event pick algorithms will require a minimum of change to other components of the software system.

6. H-Division Support.

a. Group H-1 [Backsen, Seamons, E-5; Carrier, Lucero, E-2].

(1) WADI. Design and development of the Wahl display interface (WADI) was completed, and four of these interfaces were packaged in a single chassis and installed at NTS during this reporting period. An instruction manual is being prepared. The WADI, shown in the block diagram of Fig. 43, uses an Intel 8748 microprocessor to interface the NTS telemetry and release analysis system (TARAS) PDP-11/20 to a digital display system, built by Wahl Electronics, Albuquerque, New Mexico. The digital display system consists of 24 separately addressable display modules and associated electronics. The display modules are used to indicate dose-rate

Fig. 43. WADI block diagram.

radiation reading from remote detectors over a range for 0.01 mR/h to 9.9 kR/h. The primary function of the WADI is to translate the data encoded in the 16-bit parallel word from the PDP-11 DR11-C to a 19-bit format compatible with the Wahl display as shown in Table VI. These data are then transmitted in a serial-synchronous mode to the Wahl display. The display modules are identical, are updated on an individual basis (one 16-bit DR11-C word updates one module), and have a display format as shown.

where normally,

X = 0 - 9, MSD BCD encoded data,

Y = 0 - 9, LSD BCD encoded data,

M when lit indicates mR/h,

K when lit indicates kR/h,

Decimal points are lit for the desired valve,
and R is always lit.

The address bits, X-BCD bits and Y-BCD bits map directly as shown in Table VI. The 3-bit exponent (DR11 bits, 8 through 10) determines which, if any, of the 2 decimal points are to be lit and whether or not the M or K will be lit. These data are translated as shown in Note 2 of Table VI and encoded as shown in the Wahl serial-bit description.

The Wahl display system is capable of addressing 64-display modules; the WADI is capable of ad-

ressing 32 modules, and in actual practice only 24 modules are attached to 1 display system. For this reason, bit 2 of the Wahl serial data code is always 0. The start bit is always 1.

There are some exceptions to the normal data translation, as shown in Note 3 of Table VI. The WADI now recognizes the request for three special display formats. The DR11 Y character is used to obtain these special display formats as follows.

TABLE VI
WADI DATA TRANSLATION TABLE

DR11 Bit	DR11 Bit Description	DR11 Data Encoding	8748 Serial Bit	Serial Data Bit Description
Out 15	ADDR MSB		1	Start bit
Out 14	ADDR	5-bit binary	2	Zero (display address MSB)
Out 13	ADDR	Encoded display	3	Display address MSB
Out 12	ADDR	Address	4	Display address (Note 1)
Out 11	ADDR LSB		5	Display address
Out 10	E MSB	3-bit exponent	6	Display address
Out 09	E	(Note 2)	7	Display address LSB
Out 08	E LSB	Translates to	8	MSD DP
Out 07	X MSB		9	MSD MSB (8)
Out 06	X	MSP	10	MSD MSB (4)
Out 05	X	Encoded BCD	11	MSD MSB (2)
Out 04	X LSB		12	MSD LSB (1)
Out 03	Y MSB		13	LSD DP
Out 02	Y	LSD	14	LSD MSB (8)
Out 01	Y	Encoded BCD	15	LSD (4)
Out 00	Y LSB		16	LSD (2)
			17	LSD LSB (1)
			18	
			19	

Notes: (1) Display electronics is capable of addressing 64 displays; however, this interface will address only up to 32.

(2) E translates as follows:

(3) Special Y flag words:

Function	Y	X.Y	Serial Bits 8-19	E	X.Y	Exp
Blank Display	1111	Blank	01111011101	0	X.Y	M
Off-time	1110		11111111101	1	X.Y	M
Below BKGO	1101	[]	01010010101	0	X.Y	M
				1	X.Y	M
				2	X.Y	M
				3	X.Y	M
				4	X.Y	M
				5	X.Y	M
				6	X.Y	M
				7	X.Y	M

●If Y = 1111, the display module will be blanked.

●If Y = 1110, both decimal points will be lit.

●If Y = 1101, brackets will be lit.

The WADI recognizes these special Y characters and sets up the Wahl code format appropriately. When a special Y character is detected, all other data in the DR11 word, other than the display module address, are ignored.

The circuitry for one system is mounted on a single Wyle-size pc card and consists of an Intel 8748 microcomputer chip and associated circuitry, as shown in Fig. 43. Ports 1 and 2 of the 8748 are used to read the 16-bit parallel data word from the DR11-C. The data are translated and output in a serial-synchronous mode to the Wahl display. The control circuitry consists of a REQ and RDY (T1) flip-flop used to handshake with the DR11-C. A 3- μ s machine cycle time is derived from the 5-MHz crystal. Each interface card has a separate 5-V power supply.

The timing is a function of the firmware (software in PROM). A normal timing sequence is:

●The 8748 generates a request pulse (REQ).

●A request for new data is issued to the DR11-C (REQ A flip-flop).

●The DR11-C acknowledges the request and outputs a new 16-bit data word to the WADI (NEW DATA RDY).

●The 11 flag indicates to the 8748 that new data are available.

●The 8748 acknowledges the 11 flag (ACK pulse) and reads the data.

●The 8748 translates and outputs the data in a serial-synchronous mode, at a 5-kHz rate, to the Wahl display.

●The 8748 delays for 10 ms, allowing the Wahl display system to reset, then repeats the above cycle.

There are two exceptions to the above timing sequence.

●On reset (power-on or front panel), the 8748 goes through an initialization process, including generation of an ACK pulse, preceding the normal timing sequence.

●If a request for new data (REQ A) is not serviced by the PDP-11 (NEW DATA RDY) within 20 ms, a time out results and the timing sequence is re-

started (new REQ pulse generated). This prevents the possibility of a system hang-up, where the REQ A flip-flop is reset prematurely due to noise, before the PDP-11 has a chance to acknowledge it.

The firmware, software in PROM, is used to generate the timing and translate the data. The software was developed on an Intel Intellec ISIS II software development system. An Intel Prompt 48 was used for the firmware development.

The software is written in modular form and contains a main program and four major subroutines. The main program controls the timing associated with the DR11 and issues calls to the subroutines. On reset, the program initializes the system by clearing the bus port and generating an ACK pulse to clear the external circuitry. The normal timing loop is then entered and proceeds as follows.

●A REQ pulse is generated, resulting in a request for new data from the PDP-11 (DR11-C).

●The interval timer is loaded to a 20-ms time out and the time out starts.

●The program then enters a loop that continually examines the 11 flag and the time-out flag. If an 11 flag is detected, indicating a new data word is available from the DR11, the program exits the loop and continues. If new data from the DR11 (11 flag) are not available within 20 ms after a request has been issued, a time out occurs. This is an indication that the system might be hung up (REQ flip-flop reset prematurely by noise) and a new request pulse is generated.

●On detection of an 11 flag, new data ready, an ACK pulse is generated, resetting the 11 flip-flop.

●The new data word is read (ports 1 and 2).

●The special character subroutine is called, which tests to see if the new data contain a special Y character.

●If a special character is detected, the output subroutine is called and the appropriate data are output to the display system.

●If a special Y character is not detected, the exponential subroutine is called, which translates the E character bits according to Table VI and loads the appropriate bits in the output word.

●The data subroutine is called, which maps the address bits and X- and Y-character bits appropriately in the output word.

•The output subroutine is called, which serially outputs the data, along with a 5-kHz clock, to the display system, thus updating the appropriate display module.

•The WADI at this point delays for 10 ms, allowing the display system to reinitialize, before issuing another request for new data and repeating the cycle.

(2) TARAS. All software modules associated with real-time display of radiation levels on the Wahl LED display were replaced. The former Wahl device driver operated in time mode slaved to the computer system clock. The revised Wahl system, using the WADI interface described above, uses the output ports of the three DR11-Cs available in the system, so that display outputs are now handled on an interrupt basis with less system overhead. The TARAS dead-start procedures were modified to assign system clock functions to a KW11-L clock in the absence of the programmable KW11-P clock. This change was made to facilitate check-out of revised TARAS software on the PDP-11/34 before NTS verification. The TARAS operation has been expanded to monitor status from a set of permanent station probes at NTS. At the request of H-1, the arithmetic sections of the software were modified to extrapolate and convert raw data from these probes in the range 0.01 to 0.99 mR/h. The arithmetic change also enables definition of two additional log decades of dose rate. These changes required rework of output-formatting subroutines associated with dose-rate display, print, and plot. Several changes were made in the operator input command logic verification to improve operability of the system. At the request of H-1, NTS test operations were observed to assess the state of repair of the 11/20 TARAS compute subsystem. Group E-5 recommended to Reynolds Electrical & Engineering Company, Inc., and H-1 that the 11/20 be ECO upgraded and placed on a regular DEC maintenance schedule.

b. H-7 Radioactive Liquid Waste Management [Reitze], Wilkins, E-5]. Group H-7 is engaged in a construction program to modernize existing radioactive liquid waste handling equipment. Group E-5 is providing an automated data-acquisition and control system that will allow H-7 to monitor and control liquid waste handling from TA-50.

System requirements have been defined and specifications written with the intent of buying a commercially available turnkey system. The RFQs have been sent to prospective bidders and the bid due date has been set for mid-March 1979. Contract award is expected by mid-1979.

c. Instrumentation for Automated Cancer-Cell Sorting and Analysis (H-10) [Hiebert, Greenwood, E-5; Van Lyssel, Rose, E-2]. Cell biology research support for the National Cancer Institute (NCI) through Group H-10 continues. Primary emphasis is on special instruments for high-speed measurement and control of individual biological cells in flow systems. Physical and optical properties of cells are measured at high rates, the data are processed through computer control, and cell-sorting decisions are made. The technique of rapidly identifying and isolating closely related types of cells can be a powerful tool for cell biologists. Significant progress has been made on a new general-purpose data-acquisition system, on several new light-scatter systems, and on several special-purpose instruments.

The prototype LACEI data system has been completed and delivered for implementation with the detectors and computer. As many as eight input parameters can be processed. Input timing decisions are made with 8-fold logic, and two sorting directions are established on the basis of time and amplitude decisions made on four parameters for each direction. The system is arranged to allow simultaneous experiments to be operated through the interface to a single computer. The system is modular, and the final element to be completed is the sort module. Earlier modules in the system development were the dual-analog data-in module that receives two parameters and digitizing their values for transmission to the computer, and the data coincidence module that makes input timing decisions under computer control.

Light-scatter instruments are evolving to higher levels of sophistication and usefulness. The amplifier sections of the Model 74 scattered-light processing system have been modified to cope with signals from either the wedges or the rings of the recognition systems photosensor array, or the custom Model 1527 photodiode arrays we have designed. Three of these unique arrays with amplifiers have

been fabricated in our hybrid facility. Preliminary tests indicate excellent array performance with actual cell scatter signals. The new electronics for the Model 8174 scattered-light processing system to be used with the arrays has been designed, and fabrication is nearly complete. The system will assimilate data from as many as 32 photodetector channels carrying the individual cell scatter pattern signature in less than 200 μ s.

In order to enhance the precision with which decisions on measured cell characteristics can be made for sorting, new data analysis techniques are being developed. An early design for an analog discriminant function processor has been completed. This processor will allow optimum discrimination against redundant information in multiparameter data and yield higher quality cell sorter performance.

Measurements of short fluorescent decay times of stained cells excited by a pulsed nitrogen laser have been improved with a special photomultiplier base designed for truncated operation of a Hamamatsu R928 tube. Knowledge gained from this detector has led us to a design to be used with 1P28 tubes, yielding higher gain and greater linear output currents, while preserving 1-ns fall time.

Several special-purpose instruments have been developed or completed. A Model 74 piezoceramic LED drive and metering module has been built for use at NCI. This module furnishes power to the piezoelectric transducer used to mechanically vibrate the droplet-formation assembly of a flow system. It also provides pulses to the light flashers mounted to illuminate the flow stream for microscope viewing at the point of droplet formation. The Model 1108 high-current pulser is being built to provide excitation to a copper-ion uv laser. The instrument is designed to provide current pulses of 50-A typical amplitude from a 300-V voltage source.

7. L-Division Support.

a. Laser Fusion Support (L-1) [Sutton, Hanna, Sanders, Wells, E-5; Remington, Tucker, E-4; Karpin, Silva, Spencer, E-2]. E Division has supported several areas of the Helios laser system being constructed by L-1 for the past few years. These areas include control system design, fabrication and installation, computer control programming, optical alignment support (electrical and mechanical), target insertion and alignment, mechanical design and

fabrication, and technical support for electrical and mechanical assembly of the eight-beam laser. The Helios laser is now well into its experimental schedule and the E-Division team is contributing substantially to this effort. A summary of specific activities and their present status follows.

(1) Control Programming. The control program (called Helios) for the eight-beam laser has been evolving for the past 3 yr. Several versions of the program have been written to develop one that will support the target experiments. The Helios program has two basic parts: machine controls and data acquisition. Machine controls include operation of the E-beam Marx generators, pulse-forming network (PFN) pulsers, supporting spark-gap gas systems, E-beam chamber vacuum system, laser gas control system, and other minor supporting subsystems. Data acquisition includes testing and reading the high-speed digitizers, displaying acquired data, storing digitized data and other shot parameters on disk and magnetic tape, retrieving lost data from magnetic tape, updating parameters, and logging operations.

The Helios control program has evolved into a three-task multiple overlay (three overlay areas) using almost 28 k of core storage on the Data General Eclipse S/200 control computer. Recent additions and changes to the control program have been absorber gas pressure change routines and replacement of the monitor task with a more core-efficient version. The absorber gas pressure change uses the major portion of the stand-alone absorber gas program as another overlay. This routine controls the gas pressure in the saturable absorber cell, which is used to stabilize the power amplifiers. In conjunction with the control routine there is a color display task to show the operator the absorber system status. To reduce the overall size of the Helios operating program, the color display monitor task was divided into smaller overlays. Due to many small additions to the program, it required about 31 k of core memory. After the change, Helios again runs in 28 k.

In addition to the main operating program, other supporting stand-alone programs have been written or modified. Continuing effort has gone into studying the new asynchronous line multiplexer (ALM) and its interface with a remote microprocessor

to be used for the beam diagnostics. Some subroutines to support the ALM have been written and tested. The front-end checking program was modified to accommodate changes in the front-end hardware. Two other support programs for EBS are being updated. These are called CRASHSV and TAPESV. The CRASHSV program was written to allow data to be retrieved from the digitizers in the event of a system crash at shot time. The TAPESV program allows data to be retrieved from the on-line tape in case they are lost from the disk. TAPESV and CRASHSV will also update the operations log file.

(2) Computer System. A second Data General Eclipse computer was added to the Helios laser control system. This will enable L-1 to do several things. The second computer will act as a back-up in case the first computer was down and it will allow further program development while laser operations continued on the first machine. It will allow use of the computers to run diagnostics codes within the facility with access to the laser data. An Eclipse S/230 was ordered and delivered. Much effort has been required to prepare for the second computer, such as purchase and modification of additional terminals, additional cabling for the new machine, and installation of ac power for the new equipment. A quad hard-copy interface for the Tektronix terminals was purchased and installed. The S/230 is now being installed and necessary hardware modifications have been made.

(3) Delta Mirror Mount Controllers. Contained within the Helios target chamber are 16 mirror mounts, 8 flat turning mirrors, and 8 parabolic focusing-mirrors. These mirrors are positioned to direct and focus the eight laser beams onto the target. Each mirror mount contains a three-point drive mechanism having three stepping motors located at the corners of an equilateral triangle. To provide manual positioning of these motors in an ordered fashion, a delta mirror mount controller has been designed.

(a) Mirror-Position Display System. During the reporting period the hardware design has been completed, the control room chassis and the target chamber circuits have been wired and checked out, and the majority of the software development has been completed. The equipment is now installed in building TSL-85 where it is being tested with a 38-cm mirror mount.

While the mirror-position display chassis is performing satisfactorily, the counting algorithm needs additional testing and debugging before the system will operate properly. The major problem is a mechanical transient generated by the mirror mount each time a motor is stepped. This causes generation of multiple outputs by the incremental optical encoders for each step. A counting algorithm has been developed that generally produces only one count per step. However, during long stepping sequences, a few counts may be gained or lost. Because of this problem, additional time will be required to debug the algorithm to obtain the desired accuracy. It is anticipated that equipment installation will occur during the winter quarter of 1979.

(b) Mirror Position Display Software. All programs for the delta mirror mount position display have been written in Intel 8085 assembly language. Programming for a system of two 8085 microprocessors has been done. One microprocessor in the vicinity of the target chamber counts motor steps and relays this information across a fiber optic link to a mirror position display (MPD) microprocessor in the control room that arithmetically massages and displays motor step information (three modes of display are possible) on the front panel of the MPD microprocessor chassis. Large programs (500 instructions at the target chamber; 2000 instructions at the MPD chassis) have been written and burned in PROMS that are part of the main memories of the two system microprocessors. A system of code words for addresses, motor-step data, and errors has been developed that allows us to retransmit words for which transmission errors have occurred. Both microprocessors are interrupt driven so in addition to all of the monitoring functions, all interrupt routines were also developed and written. All necessary arithmetic routines had been previously developed.

The counting program operates well for a smoothly rotating motor shaft; however, when stepper motors are installed on the shaft, the counting program fails to count correctly. Both software and hardware modifications are being made to overcome this problem; several test programs have been written in order to help disguise counting problems. Progress has been made, but occasionally some counts get lost, so final modifications need to be made.

In order to carry out the programming, the capability to assemble programs and burn PROMS automatically has been developed. A cross assembler that allows us to assemble Intel 8085 assembly language programs, was obtained from Boston Systems, Inc., and installed on the Zebra disk system of the Eclipse S/200. A program to burn PROMS automatically from the cross assembler output has been developed. Object files from the Zebra disk are sent across the asynchronous line multiplexer (ALM) to a portable PROM programmer. Another PROM programmer is being ordered for exclusive use for Helios.

(4) E-Beam Vacuum Control System. Early in July the roughing line interlock controls for the four E-beam modules were rewired to eliminate a potential problem. The interlock now prevents opening any E-beam roughing line valve if any power amplifier roughing line valve is open. This will reduce the risk of a pressure surge from any power amplifier reaching an E-beam chamber through the roughing line.

(5) Target Chamber Controls. The system for controlling the Helios target chamber vacuum system has been completed. This system is now in operation. A first-version computer program for automatic operation of the target chamber vacuum system has been written and will be improved during the coming year.

(6) Three-Axis Manipulator and Burn-Paper Controls. The 3-axis manipulator and burn-paper controls prototype was tested and the final version of the system was fabricated and installed. This system is now in use.

(7) Building Safety and Warning Light System. The automatic safety and warning light system is now fully operational. Hazardous conditions throughout the building are monitored and displayed at the doorways of all rooms. An additional circuit has been designed and installed to advise people entering hazardous rooms of the type of protective eyewear to use.

(8) CO₂ Alignment Laser Remote Control. To facilitate automatic alignment, a remote computer controller for the CO₂ alignment laser was designed and is now in operation. This allows both manual and computer selection of pulse width and repetition rates from the control room.

(9) Optical Isolation for Shielded Rooms.

To eliminate ground loops between the control and computer rooms, the CAMAC parallel branch highway, along with several other signals, will be optically coupled between the two rooms. Circuit boards have been designed and tested, and fabrication and packaging is under way.

(10) Saturable Absorber Gas Control System.

Due to instability problems in the laser power amplifiers, a saturable absorber was designed for the Helios laser. This system was designed and built in the first half of 1978. It consists of a mixing station, four cell-control chassis and a control room chassis with the mixing station where desired amounts of various gases can be mixed in a large tank. The pressure in the gas manifold, or mixing tank, is monitored on digital panel meters (100 and 1000-Torr). The mix tank, or manifold, may also be evacuated by a vacuum pump. The cell-control chassis monitors the absorber cell pressure and controls two valves to allow the cell to be evacuated or filled with absorber gas from the mix tank or with buffer gas. The four cell-control chassis may be operated from the floor or from the control room chassis when placed in the remote mode. The control room chassis operates in manual or computer mode through CAMAC. This system has been modified in the last half of this year to meet changing needs. Computer programs have been written to control this system and are now incorporated in the main operating program.

(11) TPA Spatial Filter Pressure Control System. The triple-pass amplifier (TPA) contains a spatial filter housed in a chamber that is kept at a pressure of a few Torr. The control system consists of five control chassis, four of them are located in room 100. They are used to control valves to vent the TPA tanks and allow a pump to evacuate the tanks to desired pressure levels. The controller holds the pressure between two set points by sensing the pressure and opening or closing a valve on the vacuum side to maintain pressure in the selected range. These four chassis have been designed, fabricated, and installed. The fifth chassis, for the control room, allows for manual control from the control room and computer control by CAMAC. This chassis has been designed, fabricated, and is now ready to be checked out. Installation and final system check-out will be completed in early January.

b. Antares Project Support (L-10) [Gutscher, Kozubal, Longmire, Seifert, Whitfill, E-5]. The controls support effort for the Antares project has expanded in the past 6 months. Group E-5 is providing software development, front-end control subsystem management, and specification and development of fiber optic interfaces required in the Antares high-fields environment.

The project software development efforts encompass many areas. Some of these are:

- Training controls personnel in the RSX operating system.
- Development of software aids for hardware check-out.
- Network software specifications.
- Procurement of the Antares computer network (ACN).
- Superset software specification for all ACN processors.

Other scheduled training activities include classes for the RT-11 operating system, the PASCAL programming language, and LSI-11 hardware. Instructors from outside LASL will be employed where in-house expertise is not available. Hardware check-out functions and machine-dependent control algorithm development will be done on PDP-11V03s running the RT-11 operating system and an RT-11 compatible version of PASCAL. A variety of test routines have been written for the system and are being used for testing and evaluating CAMAC modules. Close interaction with the Antares system managers by the control section continues to be a high priority. Control specification documents have been developed and are constantly being updated. The design of the control system hardware and software will be frozen on December 22. Software design documents will then be produced, based on requirements known at that time. Top-down specification and design of all Antares controls software is an absolute requirement.

The decision to employ a top-down design approach was based on a detailed PERT network chart analysis of two likely methods of implementing the control software: by major subsystem with overall integration done late in the project stages and strictly by top-down methods with overall integration being accomplished from the first day that software is designed. The first approach resulted in every major deadline being missed by many weeks.

The second approach, employing a superset software scheme and estimates made by the same personnel as the first approach, resulted in some deadlines being missed by only a few weeks, while 12-beam operations for the first power amplifier showed up 11 wk early on the PERT network estimate. The notion of superset software designed to run on all processors in the ACN came about when some estimates were made concerning the time required to design, implement, and maintain the control software for a computer network now estimated to incorporate approximately 100 processors, including LSI-11s. In this manner, specific application dependencies are implemented as very low-level modules in the control hierarchy of the software design.

The subsystem manager for front-end controls has been acting as liaison between the front-end system manager and the controls section. A thorough review of the front-end control requirements has been completed and a specification document produced. A detailed function list is being produced to define locations and functions associated with all machine interface processors, including channel identification for all I/O (binary, analog, v/f, and f/v) and data specifications (magnitudes, ranges, and resolutions). A specification of a color graphics CRT terminal has been generated and procurement is in progress.

Fiber optic communications link development continues with increased emphasis on evaluation of commercially-available fibers and transmitter-receiver modules. The evaluation is required to insure that all such interfaces will survive within the Antares EMI environment. Life testing, error rates, and transmissivity tests are among those in progress. A specification document for all fiber optic requirements has been generated and discussions with vendors in relation to those requirements are being held.

The controls section of the Antares project is awaiting vendor responses to the specification document for the ACN. An absolute requirement of that specification is network support of the LSI-11, which was adopted as the standard Antares microprocessor. A purchase order for the computers required for operation of the first power amplifier is likely to be placed by January 15, 1979.

8. M-Division Support.

a. Detonation and Shock Wave Physics Support

(M-3, M-6, M-00) [Lundy, Conley, Love, Parker, E-5; Martin, Staley, E-2]. The M-Division support involves three areas, firing-site control updating, microchannel plate-image intensifier-tube electronics, and MX missile hazard test support for the US Air Force.

(1) Firing-Site Controls. Two years ago updating of the site-control systems at M-3 (Kappa Site) and M-6 (Ancho Canyon) was begun. The new systems provide more comprehensive personnel safety interlocks, equipment-ready interlocks and automatic preshot triggering of equipment, provision for synchronizing multiple rotating-mirror cameras on a single shot, and provision for easy addition of an automatic data logging system. The first version of the new system was tested at Ancho Canyon in July and found to have severe crosstalk problems on the device interface bus. In correcting this problem, the circuit was completely redesigned, and much of the circuitry was changed to CMOS logic. The main fire control chassis is still built around a PRO-LOG 8080 microprocessor, and each device interface module (DIM) is still built around an Intel 8035 one-chip microprocessor. The revised hardware will be installed at Ancho Canyon during the first part of January. The initial system includes only the main fire control chassis and a rotating mirror camera DIM. This DIM is highly complex as it provides fast camera-speed synchronization. The other DIMs will be essentially a subset of the rotating mirror camera DIM design. It is expected that a system will be installed at M-3 (Kappa Site) within 4 months.

(2) Image-Intensifier Camera Electronics.

A number of microchannel plate image-intensifier cameras with luminous gains up to 15 000 and effective shutter speeds as short as 10 ns have been assembled for M-3 over the last 14 months. These units have all utilized ITT 40-mm tubes, which have ≈ 15 line pair/mm resolution in pulsed mode, thus giving excellent quality pictures. These tubes do, however, have high gating capacitance and require care in the pulser circuitry to allow fast gating.

During this period we have tested several new tubes with the test system built last spring and built pulsers for several other organizations including Lawrence Livermore Laboratory (LLL), PANTEX,

and Group M-4. We will build systems for group J-14 and Mound Laboratory during the next 6 month period.

A new pulser based on Unitrode 6A-301 ultrafast SCRs was designed and built for longer duration pulsing of image-intensifier tubes. It provides pulses with durations 50 to 400 ns.

In testing new tubes it was discovered that the conductance of many microchannel plates is not ohmic as described by the manufacturer, but varies as a function of applied voltage. Because of this, we are now plotting the voltage-current characteristics of all tubes we receive to allow accurate preset gain calibration when the tubes are used with resistive divider high-voltage networks.

(3) MX Missile Hazard Test Support. We have contracted with the US Air Force Rocket Propulsion Laboratory to provide instrumentation support on a hazards evaluation of an MX missile stage. This will be an intentional detonation of the solid propellant in an MX stage engine to determine the explosive yield and resulting air-blast pressures. A 20-channel digital time-interval meter based on CMOS logic was assembled. This will be used with pin switches to determine detonation wave arrival times and thus confirm that complete detonation occurred. The time resolution of the instrument is 0.1 μ s, and the time range is 1000 s. The instrument is equipped with battery back-up power so data will not be lost in the event of ac power line failure.

The fast solid-state camera (FSSC) discussed in the last report was completed and will also be used on this test. A hard-copy output device and a telescope are being added to the FSSC system. The FSSC will continuously record low-resolution pictures (100 pixels each) with 9 shades of gray over a 2000:1 range of light intensity. It records up to 100 000 frame/s with all pixels being recorded simultaneously so there are no scan artifacts. The last 256 frames are always held in solid-state memory so that a stop trigger signal will always allow analysis of the 256 frames just before the stop signaling event.

9. NM-Department Support.

LASS System (NM-00) [Wooten, Dorin, E-5; Cordova, Holleman, AADP-2]. The Los Alamos safeguard system (LASS) is being developed for the LASL Nuclear Material Department (NM-00), which has overall responsibility for LASL nuclear materials accountability at LASL. The official inventory of

SNM, approximately 16 000 items, is in a constant state of flux as nuclear material items enter and leave LASL and are moved between sites.

The accounting system, which NM-DO uses to keep track of the nuclear material inventory, has evolved over the years to the present CCF-based manual entry system. The present system is adequate for periodic inventory reporting, but cannot handle the increasing demands for timely accountability information. The DOE Division of Safeguards and Security has instructed NM-DO to upgrade their inventory accountability system to provide real-time accountability.

A dedicated minicomputer system is being developed for LASS. This provides a "live" inventory data base that is continuously updated as nuclear material movements and processing are performed. The software will be developed jointly by AADP and E-5 personnel. The major application language will be COBOL with FORTRAN V as needed. The data base will be developed with INFOS file management software. The LASS software will be phase developed. Phase 1, which will require about 1 yr, will culminate in a stand-alone system that will replace use of the CCF. Phase 2 will bring the system up to full performance, and phase 3 will involve future enhancements.

The minicomputer, a Data General Eclipse M600, was purchased on a sole-source basis on the strength of hardware-software experience gained on the DYMAC project at the new TA-55 plutonium facility. The computer, now located at DP-West, will eventually be moved to the new facility at TA-55.

The eventual LASS system configuration is difficult to project now due to a number of uncertainties. Initially, NM-DO envisioned a network of approximately 25 terminals to be remotely situated at user sites and tied into the computer by communication lines. Questions concerning data base classification and eventual location of the computer must be addressed. It appears that a phased development beginning with a basic in-house system will allow NM-DO to change from the CCF to a new semibatch system. Enough system flexibility must be provided to cope with future developments.

(1) Objectives. This system will improve LASL's ability to track the SNM inventory on a timely basis and capture more relevant data about

inventory items and transaction activity than the current system does. Data errors will be minimized by extensive preediting of data entered through terminals. Reporting capabilities will be improved and extended, both on-line and off-line. NM-DO will be relieved of much of the tedious data hand checking and AADP will be relieved of keypunching responsibility for transactions. This system will develop better archival methods and more useful information from the mass of historical data.

(2) LASS Performance Requirements. Transaction data entered through terminals must immediately enter the data base and result in a globally available updated inventory. At least 1 yr of historical transaction data must be on-line. Any activity that affects the inventory of the system's data tables must be permanently logged. Comprehensive back-up and recovery procedures must insure that transaction data are never lost. The DOE and LASL reporting requirements and procedures must be satisfied, and NM-DO must be provided with special software utilities to allow tracking of in-transit items and special report generation. The LASS must be able to input transaction data from DYMAC by magnetic tape and, eventually, from other local computing sites.

(3) Implementation. The LASS implementation will be a series of steps: phase 1 will be a basic minimal in-house system, phase 2, a full system with remote terminals, and phase 3, enhancements and back-up system.

In order for LASS to replace the current system, phase 1 must result in the implementation of the following programs and data sets.

- All necessary information tables and maintenance utilities.
- Basic transaction set and maintenance utilities.
- Basic on-line reports.
- Basic off-line reports.
- DYMAC interface with daily transaction activity tape and biweekly inventory tape for data base verification.
- On-line and archival back-up procedures.
- Transaction recovery procedures.
- Authorization-access-password procedures.
- Data base internal verification checks.
- DOE reporting procedures.

Phase 1 will bring LASS to a parallel status with the current CCF system. A period of parallel testing will then be necessary before a permanent changeover is made.

(4) System Design. The key element in the LASS design is a data base structure that is flexible and accessible. The LASS data base will be created, modified, and accessed by INFOS file-management software. The INFOS system provides methods for access to data base records through multiple index structures. Access may be relative positioning or by key; that is, by name within a field. On the DYMAC project INFOS has proven to be fast, efficient, and relatively flexible. Preliminary index structures that have been identified as necessary for LASS are:

- Beginning inventory
- Current inventory
- Receipt area
- Project
- Location
- SNM balance by account or material number
- In-transit items
- Internal transaction by "from" item name
- Internal transaction by "to" item name
- Internal transaction by transaction number
- External transaction by "from" item name
- External transaction by "to" item name
- External transaction by transaction number
- Text (remarks) by item.

Transaction data entry will be performed on terminals and will be limited to the basic transaction and reports appropriate to the level of responsibility and location. During phase 1, users will fill out the same 80-column forms that they now use, and NM-DO personnel will enter the transactions. After a testing period, NM-DO will switch over to the new system using a new form that will require all of the information for the full system. Later, during phases 2 or -3, processing personnel may be provided with remote terminals for their own use.

A terminal will be provided for NM-DO from which they can do special restricted actions such as monitoring in-transit items and generating special reports. System terminals will be available on a restricted basis to NM-DO and to software development personnel. Off-line utilities such as

table updates and printed reports will be executed from system terminals.

Magnetic tape input will come from DYMAC and, eventually, from other remote sites that have their own local computer systems. The magnetic tape will also be used as a back-up medium to log on-line transaction activity.

Based on the DYMAC project and time and budgetary constraints, most of the necessary phase 1 hardware has been purchased. This includes a Data General Eclipse M600, 512-kbyte main memory, two 190-Mbyte disk drives, two 9-track magnetic tape drives, 32 asynchronous communications line interfaces, a 600-LPM printer, and 4 Teleray system terminals. Two Data Graphix 132-column CRT terminals have been purchased for user terminal evaluation. This system will run the AOS operating system with COBOL, INFOS, and FORTRAN V.

A projected breakdown of major phase 1 activities is shown in Fig. 44. Once the data base design is completed and a test data base has been created, a number of design tasks may proceed in parallel. This time schedule is only as a rough estimate.

During phase 1, a number of important decisions must be made concerning future implementation; for example, when and how to switch from the current system to the new one. A proposal must be written detailing the objectives and manpower requirements of phase 2.

Phase 2 will involve moving to the new NM-DO building, and customized transactions and reports for approximately 25 individual sites must be made. Remote terminals, communications lines, and on-line instrumentation will have to be specified. reports that are desired but not crucial for phase 1 must be identified. Phase 2 will include the system additions and improvements necessary to make LASS a full accountability system with remote terminal support. One of the primary tasks to be performed during phase 1 is a detailed analysis of what remains to be done and the generation of a phase 2 proposal detailing objectives and required manpower.

Phase 3 will include permanent maintenance and enhancements based on NM-DO's experience with the system. These may include improved on-line diagnostics and statistics tools, color graphics, and audit reporting tools.

Fig. 44. LASS phase 1 schedule.

10. Q-Division Support.

a. Electronic Identification for Vehicles (Q-2) [Landt, E-DOR; Bobbett, E-4; Koelle, E-5; Salazar, Payne, E-2].

(1) Introduction. Remote passive electronic identification systems have been under development at LASL since 1972. Until recently, systems were designed for livestock applications and the progress of these efforts is included separately in this report. The latest generation of this system is in the early stages of commercialization, with the equipment operating reliably with adequate performance for livestock applications. Support for this early work was shared between DOE and USDA.

The DOE and DoD applications of this system have long been recognized (Mini-Review 77-1). During the fall of 1977, an effort was begun to identify areas and programs where remote passive electronic identification would be useful. It was soon apparent that, while the concept was well received, most programs could not afford the time and effort required to reengineer the system for their particular application. For example, a personnel badge

system would require a custom-integrated circuit chip, which requires considerable time and money.

During the late spring of 1978, a need to identify vehicles, as a part of a larger system, was identified in Q-2. The identity of a vehicle was required as it was parked at a monitoring station. This task was well within the capabilities of the existing LASL electronic identification equipment. Consequently, an effort was begun to construct a system tailored for vehicle identification. Since some reengineering was required and this was to be a showcase demonstration system, costs are being shared by E Division and Q-2.

(2) Current Efforts. Many constraints placed on transponders designed for livestock can be relaxed for vehicles. As a result, the system was designed around the new battery-powered FET modulator transponders. These transponders provide free-space interrogation ranges in excess of 40 m using an rf interrogation beam power of <1 W. Printed circuit board transponders were designed and tested. A prototype unit was installed on the E-4 vehicle on August 29, 1978. The transponder was

placed in a protected area under the truck hood. This unit is still functioning properly and purchase of transponders is proceeding. These transponders are powered by a single C-size lithium cell. Expected lifetime without battery replacement is in excess of 10 yr.

The receiver electronics were made board-for-board interchangeable with the existing "suitcase" unit of the USDA equipment. This eases construction and troubleshooting as well as minimizing the spares inventory. An AS232 interface was designed and constructed to pass the vehicle number to the Q-2 mini-computer. Receiver equipment is being installed in a semiportable equipment case.

(3) Future Efforts. In the immediate future, equipment construction will be completed, transponders will be mounted on vehicles, and the system will be delivered to Q-2. We also plan to continue to support this system and assist with the inevitable start-up problems. A movie is being prepared that will describe this system and demonstrate spin-off reimbursable projects for DOE and DoD needs. Outside interest is high for this system. The upcoming USDA field tests and the LASL vehicle system will demonstrate the true capability and potential of the LASL electronic identification system.

b. Real-Time Inventory System (Q-2) [Ethridge, Kuckertz, Rose, E-5]. Group Q-2 is engaged in a research and development program to investigate ways to continuously inventory and safeguard SNM while it is in storage vaults.¹⁴

The real-time inventory system physical layout is shown in Fig. 45. 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 requester's identity and authority. The material destined for the storage vault would be placed in the vault by way

Fig. 45. Real-time inventory system physical layout.

of the material verification station (MVS) door 1. Next, the material would be weighed and a gamma and neutron spectra taken. This information would be retained by the computer until the material is removed from the vault. The requester then enters an anteroom of the vault by the gamma portal monitor. The requester is not permitted to carry SNM or any metal objects through the gamma portal monitor. The SNM is removed from MVS by door 2 and placed on a previously designated shelf monitor in the vault. The requester 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 enters and leaves the vault by the MVS while all people enter and leave the vault by 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.

(1) Shelf Monitors. The shelf monitor has been redesigned primarily to reduce cost. Electronics material costs have been reduced from approximately \$70 to \$30 in the 10 000 quantity range.

This cost reduction was realized by replacing the hardware logic components with an Intel 8048 microcomputer. The IC package count of 40 has been reduced to 7. Approximately 20% of the microcomputer on-board program memory is needed 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 Intel 8048 contains 1 k of ROM program memory. For the first 16 shelf monitors, the Intel 8748, which contains 1 k of uv EPROM program memory, will be used. The first 16 units are assembled and final tests are being performed for vault installation at TA-18. The use of 8748 with erasable programmable memory allows for systems changes with no associated hardware costs 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 are complete.

The microcomputer shelf monitor design has been completed. The 20- by 20-cm printed wiring board

has been reduced to a 10- by 10-cm design, a size reduction of 75%. Sixteen units are being fabricated for the Q-2 system. Two hundred fifty units are being constructed by E-2 for installation at TA-55 in February 1979.

(2) Time Monitor. An additional microcomputer unit to be placed on the shelf monitor bus to report the data-acquisition internal time to the minicomputer has been designed. The hardware-software design is primarily a subset of that of the shelf monitor.

(3) Diagnostic Unit. A final test diagnostic microcomputer unit is being designed to test the 250 units for TA-55 as well as provide maintenance support. The unit will also monitor the minicomputer shelf monitor array for proper operation in real time.

(4) NOVA-3 Computer System. The computer system that will monitor SNM in a vault is shown in its entirety in Fig. 46. The system consists of a NOVA-3 central processing unit with 64 k words of memory attached to devices: four line RS232C serial interface units, a 600-baud terminal, a 10-Mbyte disk, a 9-track tape drive, a printer-plotter, and

Fig. 46. Real-time inventory system schematic diagram.

a type U CAMAC crate controller. All peripherals were supplied by Data General Corporation with the exception of the Versatec printer-plotter and the BiRa Systems crate controller. All instrumentation controlled by this computer system is interfaced to the NOVA-3 I/O bus by one of two standard interfacing schemes: the EIA RS232 or the CAMAC Dataway. The RS232 interface is a standard device supplied by Data General Corporation, while the crate controller, which allows communication with the CAMAC crate, is a commercial product obtained from BiRa Systems Corporation. All instrumentation, with the exception of the shelf monitors, is connected to the NOVA 3 by way of a CAMAC crate. This CAMAC subsystem is shown in Fig. 47.

Software has been written to simulate a 16-shelf monitor system plus a time monitor. At present this software exercises each of the shelf monitors and keeps appropriate statistical data pertain-

ing to their operation in a disk storage file. This system has been run for long periods of time, 7 days, with results that show that the scale in the shelf monitor appears to be stable to within 2 counts/s out of a total of 1400 counts/s.

The NOVA-3 system will be used to control the 250 shelf monitors destined for installation in the TA-55 vault. Because the NOVA-3 system is used to support a number of projects not associated with the shelf monitor effort, a decision has been made to retain the NOVA-3 system at TA-18 and communicate with the shelf monitors and the DYMAC computer system over dedicated telephone lines. Two unloaded telephone pairs were installed between TA-18 and TA-55, cable distance 10 km, to investigate the communications problem. The design specifications of the shelf monitor called for communications with the NOVA 3 to be at the rate of 9600 baud. Extensive testing of the two telephone pairs revealed that

Fig. 47. Real-time inventory system CAMAC subsystem.

reliable data transmission between the sites was not feasible using available telephone pairs. The testing also revealed that communications at 4800 baud and below is feasible. A minor software change in a shelf monitor will enable communication at 2400 baud. Thus, data communication with DYMAC and the 250-shelf-monitor system will be at the rate of 2400 baud.

c. DYMAC Program (Q-3) [Ford, Elkins, Dorin, Wooten, E-5; Hagen, Gorlitz, Q-3]. Group Q-3 is responsible for developing, implementing, demonstrating, and evaluating the DYMAC program. DYMAC is an in-plant materials control system that uses a plant-wide network of in-line nondestructive assay (NDA) instruments coupled with automatic data processing equipment to continuously pinpoint the quantity, form, and location of SNM throughout an operating nuclear plant.

DYMAC subsystems include NDA instrumentation, data acquisition, data base management, and real-time accountability. The NDA instrumentation subsystem provides rapid, quantitative on-line measurement for SNM as it moves from one unit process accounting area to another. The data acquisition subsystem provides accurate and reliable material control information to the central computer. The data base management subsystem accepts and organizes incoming data into files for efficient retrieval of specific information. The real-time accountability subsystem draws on the data base for continuous status monitoring of the nuclear material within the facility. On detecting an abnormality, it signals the condition and provides inventory data to aid plant personnel in determining the appropriate response.

A DYMAC system is being integrated into the new LASL plutonium processing facility at TA-55 to serve as a working demonstration. The DYMAC TA-55 goals are to demonstrate the reliability and operational feasibility of in-line NDA instrumentation in a production environment, accurate and efficient data generation, sensitivity to missing material, and compatibility with production control and quality assurance in a cost-effective manner.

The DYMAC TA-55 program is divided into three phases. Phase I was a pilot program of research and development and in-plant testing of NDA instruments coupled with an interactive computer system at the

LASL DP-Site facility. This phase has been completed.

In phase II, currently under way, the technology and equipment developed in phase I will be integrated into the new plutonium facility. The DYMAC TA-55 will be a full-scale, plant-wide system with NDA measurement stations in each unit process accounting area, interactive computer terminals, and real-time SNM accountability and control. In phase III the data collected during operation of all subsystems will be evaluated in depth, focusing on effectiveness of material control, reliability, operational ease, costs, and applicability to other facilities.

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. The principal shortcoming 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% throughout (or some small "trigger" quantity of 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 SNM. Such real-time accounting systems are only now feasible because of recent advances in 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 uncertainties. 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.

The DYMAC system became operational on January 19, 1978, and it processes 200 to 300 transactions and 300 to 400 on-line inquiries per day. During this reporting period, the back-up computer system has been received and is being used for program development and training. The new disk subsystem has been received and is being installed. A timing problem associated with a user who is timed out and

is striking a key at the same time has appeared, and a fix has been implemented. A statistical package has been added for the purpose of obtaining information about the users such as how many of what kinds of transactions are taking place at any time during the day; how long these transactions last; how many time-outs take place; and how many transactions does the user escape from. The on-line inventory by location report has been amended to include the total fissile content at that location as a first step towards aiding in criticality determinations. Additional transactions for the recovery wings have been added. A new off-line report of the material-in-process (MIP) activity has been produced.

d. Data-Acquisition and Control System for the Gas-Cooled Fission Reactor (GCFR) Disruptive Core Test Program (Q-13) [Damran, E-5; Miller, E-2]. This task involves E Division acting as design consultants for the duration of the GCFR disruptive core program with responsibility for the design and implementation of the instrumentation and control system to gather diagnostic data and to control the independent variables. Testing of the first 37-rod GCFR fixture has been completed. The seventh test, intended to be destructive, was successful in this respect. The fixture was disassembled, and the failures of the fixture, as recorded by the instrumentation, were verified.

Programming support was provided for several experiments that were conducted to obtain a data base from which a more reliable spacer grid could be designed for use in future GCFR test fixtures.

Installation and check-out of a test fixture to be used in measuring the resistance profile of the graphite heater rods to be used in subsequent GCFR have been completed.

Programming and technical support have also been provided for several tests that were conducted on the HP-3052A data-acquisition system to determine the maximum sampling speed of which it is capable.

11. Sandia Support.

a. Air-Quality Effects Study (SLA) [Jennings, Seamons, Backsen, E-5]. The initial phase of the E-5 participation in this project has been completed. The air-quality effects study (AQES), a follow-on to the Da Vinci experiment is an SLA project. The primary objective of AQES is to provide

necessary information to control the large-scale regional, 50-1000 km, and subcontinental scale air-quality problems, which a national shift to less desirable fossil fuels will entail. The AQES approach uses a combination of ground-based, aircraft, and balloon-borne measurement systems to acquire necessary data to understand long-range air pollution phenomena.

Two airborne remote-sensing systems to be used on the project are the Lagrangian measurement platform (LAMP), a balloon payload, and Skyhook, a slightly modified LAMP payload that will be borne at the end of a cable on a helicopter for stack-plume sampling. Both of these payloads will evolve into fully automated remote-controlled systems.

The microprocessor adaptive data-acquisition system (MADAS) suitcase computer developed by Group E-5 was selected as the central data-acquisition, processing, and logging subsystem for LAMP and Skyhook. One MADAS unit, configured to AQES specification, has been delivered for LAMP and was field tested in late September 1978. A second MADAS unit for the project is being fabricated by E-2.

Most of the sensing instrumentation on the payloads is being developed by the University of Denver. They have assembled the one payload tested thus far, which was subsequently shipped to Alabama for field tests. The MADAS was hand carried to the University of Denver and we assisted in the MADAS integration into the payload and system check-out.

A block diagram of the AQES-MADAS system is shown in Fig. 48. With exception of the LORAN navigation gear, all payload instrumentation incorporated standard MADAS interfaces for digital and analog I/O to and from the MADAS computer. The LORAN equipment outputs data at a much higher rate than was consistent with other acquisition modes (56 bits at 400 kHz every 1.2 s). To handle these data, a special shift register buffer external to digital input was built. This buffer, with appropriate digital I/O handshaking, enabled the computer to acquire the most recent LORAN data on request, once every 4 min. The UART-to-modem interface was modified for the AQES radio application.

Another subunit constructed for the project, but not computer related, was a time-pulsed output that provided a sequence of pulsed control signals for some of the instrumentation.

Fig. 48. AQES-MADAS block diagram.

Instrument inputs by type, rate, and special software processing required are summarized below. All inputs were software converted to University-of-Denver-designated engineering units except as noted.

Analog, 12-bit word inputs read every 10 s.

- Radar altimeter, reported and logged every 2 min.
- Pressure altitude, reported and logged every 2 min.
- Balloon superpressure.
- Balloon temperatures, top and bottom.
- Instrument bus voltages, A and B.
- Helium valve open time.
- Reinflation pump time.
- VHF voice transmission.
- Ambient temperature.
- Reference voltage.
- Relative humidity.
- SO₂ mode.
- SO₂ concentration, 10-s readings were averaged over a 4-min report and logging interval.
- Ozone concentration, averaging same as SO₂.

- SO₂/SO₄ filter pack number, no processing (NP).

- Impactor number, NP.

- Grab sample number, NP.

Digital.

- LORAN navigation, 56 bits (fourteen 4-bit BCDs). requested every 4 min. input by interrupt, no processing.

- Three-axis anemometer, three 13-bit binary words every 2 s. Input by interrupt; averages and standard deviations for each axis calculated from 2-s data over 4-min report period.

Raw or processed input was converted to ASCII characters and logged on the MADAS cassette unit. Basic subframe logging rate was every 2 min. Alternate subframes, A and B, contained different data except for radar altimeter and pressure altitude repeated on both subframes. The output subframes were also telemetered to ground by way of the UART modem interface. Subframe A was date- and time-tagged with data from a 1-Hz interrupt-driven software clock. Data acquisition and processing were organized so that all data for a subframe were acquired as simultaneously as possible to facilitate data channel-to-channel time correlation.

Systems and project-specific software for the AQES-MADAS project were developed using the RCA CSDP package installed on the E-5 PDP-11/34. This package consists of a one-pass cross-assembler and simulator for the 1802 COSMAC microprocessor. The CSDP, although agonizingly slow in execution, proved to be very effective in software development. The simulator, in particular, was of sufficient scope to enable more than 95% debugging of the software before verification of the same on the 1802. This was also applicable for debugging of I/O and interrupt-handling software, often a serious deficiency of host machine simulators.

All software was written in COSMAC level 1 assembly language. The total package required 5 kbytes of memory organized into 2900 bytes of system software, 1200 bytes of project specific software and 900 bytes of I/O buffer, and other variable space shared by systems and project software. Due to overlapped data acquisition and results logging, the system software had to be designed in-house. Very little predecessor 1802 software was applicable or usable.

The software was structured, as noted above, into a set of systems modules and application-specific tasks. The systems modules are application independent and required a large part of the project software development effort. Structuring into systems vs applications required additional initial effort, but has paid off in that the system segments have already been utilized on another MADAS application.

The systems modules perform the following functions.

- A task scheduler EXEC, a table-driven, round-robin task manager that executes applications tasks or systems tasks on either a demand or timed basis.

- A man-machine interface, ENTR, that enables at least some orderly operator-to-software communication using the MADAS operating panel. This panel includes a 4-digit LCD display output unit, a 2-digit thumbwheel input switch, and an enter button.

- A timed task, POLL, to handle character output of ASCII records to UART-modem and bit output to the cassette tape logger.

- A set of general-purpose arithmetic subroutines:

- Multiple precision (40-bit) add, subtract.

- Double precision multiply (16 by 16) divide (32 by 16).

- Square root.

- Average and standard deviation calculation.

- Subroutines for managing I/O to and from ring buffers.

- A generalized interrupt handling procedure.

The applications software was organized into four tasks run by the EXEC, which acquired data at required rate and time, processed or converted results, and requested output by way of system software facilities.

The initial LAMP payload involving the MADAS unit was a prototype verification test. The balloon carrying the payload also carried a pilot, whose duties included launch and landing of the balloon and managing the not-yet-automated functions of payload instrumentation. A second phase of the project is expected wherein E-5 will upgrade the MADAS hardware and software to fully automate the payload and possibly enable remote flight control of the balloon. This upgrading will enable transmission of

commands from the ground-based terminal to MADAS, which will verify and decode commands for remote execution of instrument and balloon control functions.

C. Instrumentation Support

1. Introduction. This section contains reports on a wide variety of small instrumentation projects that support LASL research on a continuing basis. Additional information on the items described here can be obtained from the people identified in the headings.

2. Electron LINAC Experiment (AT-1) [Winston, E-5; Stein, AT-1]. This project, electronic support for the construction of a small electron accelerator, was formerly in P-DOR and P-1, but has been transferred to AT-1. The accelerator will be used for a number of physics experiments, including some on low-energy x rays and some with AP-2 on the feasibility of using the electron beam to excite lasers.

In order to make it more useful to the laser program, several modifications need to be made to the LINAC. These modifications include:

- A higher beam current on target. For physics experiments a few hundred milliamperes were adequate; for the laser work, at least 2 A are desirable.

- A higher repetition rate and more rf power. The machine can now be operated to about 50 pps; the laser work will require about 300 pps. This will require several small changes and redesign of the modulator power supply. A 30-kV supply is now used to charge the line through a resistor, but for the higher repetition rates and more power, regulated resonance charging will be needed.

- A new interlock system. The present system is rather elaborate and occasionally is tripped by electrical noise.

The dump magnet power supply is now in use. Several small pieces of gear were completed, including a chassis for gating an analyzer and laser and three laser detectors and amplifiers for various applications.

3. Mass Spectrometer Modification (CMB-1) [Buchen, E-5]. A Varian mass spectrometer, with electronic components fabricated in Germany several years ago, is being modified to improve reliability and ease of repair. The ion acceleration power supply module was removed and has been replaced by a Bertran 0- to 3-kV power supply modified to permit remote resistance programming of output voltage. The emission regulator will be replaced by an operational power supply and electron energy dc power

source, each operating at up to 3 kV above ground potential as soon as spectrometer downtime is available.

4. Tritium Line Instrumentation (CMB-3) [Buchen, E-5]. A 4-channel detection and control system was designed and fabricated for a tritium process line at DP-East. This system replaced a vibrating reed electrometer system that had been in service for several years. Each channel consists of an ionization chamber, solid-state parametric amplifier, output level recorder, control circuit, and level alarm. Although the system has performed satisfactorily to original specifications, CMB-3 has requested that the control function be modified to provide two settable control levels for each channel and variable hysteresis at the control setting. A preliminary design for the modification has been prepared and the modification will be effected as soon as engineering and system downtime are available.

5. Pu₂₄₂ Neutron Diffraction Experiment (CMB-5) [Buchen, E-5; McCurdy, Southard, E-1]. Temperature and pressure indication and control instrumentation were provided for a WNR neutron diffraction experiment with Pu₂₄₂ as the target material. Diffraction studies were conducted with the sample material subjected to ambient pressure up to 50-k psi and 350°C. Automatic temperature control was provided by a remotely programmable Dialatrol temperature controller whose output drives a phase-fired SCR to provide proportional control of power to four cartridge heaters imbedded in the sample container. Provision was made for temperature indication at the experiment site and computer logging at the WNR control room. The sample container was designed and fabricated at Argonne National Laboratory and was reputed to operate continuously at temperatures as high as 350°C. However, we experienced repeated failure of the heater and it was assumed to be due to the originally installed burst-fired SCR control. Phase fire provides limited peak voltage application to the heater element and thus reduces the possibility of heater failure due to short duration thermal shock.

6. Pu Heat Source Impact Study Instrumentation (CMB-5) [Buchen, E-5; Gallegos, E-2]. Fabrication of a 0- to 20 kW, 0- to 2-kV dc electron bombardment power supply is in process to raise the temperature

of an encapsulated Pu heat source for space applications before it is fired in an air gun to simulate thermal shock on atmosphere reentry. The sample source is heated by electron bombardment and its temperature is controlled within 2°C up to 2100°C . Following elevation of the capsule to simulated reentry temperature, the capsule is fired in an air gun and is impacted to simulate collision with the earth. Capsule velocity before impact is measured by detection of light-beam interruption caused by fins at known distances on the capsule projectile. Velocities in the order of 61 m are consistently measured with an accuracy of $\pm 1\%$.

7. Three-Zone Horizontal Tube Furnace (CMB-6) [Buchen, E-5; Gamble, Southard, E-1; Gallegos, E-2]. A control system has been designed and fabricated for a 0 to 1500°C , 7.6-cm diam, 1.2-m-long hot zone tube furnace. The temperature of the two end zones is a function of the center zone temperature and the temperature difference between end and center is manually set for each end. Each end zone is power controlled by a separate burst-fired SCR control.

8. Dynapak Press Velocity Measurement (CMB-6) [Buchen, E-5]. Instrumentation is being provided for the measurement of ram-to-anvil distance, ram-to-anvil relative velocity, and ram acceleration on a high-velocity (several meters per second) press in order to determine impact energy. The ram velocity will be measured directly by a linear velocity transducer and interruption of a light beam by a perforated tape attached to the ram and anvil. An accelerometer signal will be integrated and a displacement transducer signal will be recorded as a function of time.

9. High-Temperature Calorimeter Instrumentation and Control (CNC-2) [Buchen, E-5; Southard, E-1]. A control system was assembled to provide 208-Vac power to an isothermal twin calorimeter operation at $\sim 800^{\circ}\text{C}$. A Dialatrol proportional control is employed to drive a phase-fired SCR control. The SCR control modulates the power to the calorimeter resistance heaters to control the steady-state temperature within $\pm 0.1^{\circ}\text{C}$ for a 1-h period. The differential temperature between standard and sample is detected by a pair of thermocouples connected to achieve a differential temperature measurement with a sensitivity of $\pm 0.05^{\circ}\text{C}$. The output of a Keithley null detecting micrometer, employed for differential

temperature detection, is recorded on a strip-chart recorder.

Due to the close proximity of the heater and thermocouple leads in the calorimeter, noise transients induced by the heater control were greater than the signal derived by the calorimeter measurement. The inclusion of phase-fired SCR control and detector shielding has reduced the noise to an acceptable level.

10. Multichannel Scaler (CNC-2) [Nickell, Brown, E-5].

a. Purpose. The multichannel scaler (MCS) is a double-wide CAMAC module designed to count events for selected time intervals, starting at an externally supplied timing mark (TM), and to store that information in memory. The MCS can receive data up to a 10-MHz rate and count for selected time intervals from 1 μs to 20 μs per channel. Data stored in memory may be nondestructively read by conventional CAMAC commands.

A companion unit, the MCS display driver, provides oscilloscope x, y, and z signals that enable the memory contents to be displayed either during data-acquisition time or during CAMAC read operations.

b. Application. The multichannel scaler, designed at the request of CNC-2, will be used in their molecular beam experiment. In that experiment, molecules of different characteristics will be collided in an intermittent laser atmosphere. The resulting chemical reaction, in the laser atmosphere and with no laser beam present, will be detected and signal processed by a Princeton Applied Research Model 1120 amplifier-discriminator. The amplifier-discriminator outputs nominally 10 ns, -30 mA pulses into a $50\text{-}\Omega$ load. These output pulses will be counted and stored in the MCS memory for subsequent readout and analysis by a computer.

The nature of this experiment requires that the multichannel scaler exhibit a counting dead time of < 100 ns after externally supplied TM, at count-rates up to 10 MHz.

c. Electrical Description. The MCS memory is 512 words, 21 bits per word including 1 sign bit. Memory is arranged in two banks, and is accessed alternately so that dead time between adjacent channels, that is, memory locations, is zero. Each memory bank has its own accumulator so that while

counts are being accumulated in channel A(n), data for channel B(n-1) are being written into memory, and then the memory data from channel B(n) are loaded into the accumulator in preparation for counting during the coming dwell time.

Data being counted by either accumulator are first passed through a pulse synchronizer to avoid splitting a pulse at dwell-time transitions. This technique assures that pulses cannot be counted twice by adjacent channels.

When counting in the continuous sweep mode, a run is automatically concluded at the end of a memory scan if the count in any channel reached 917 504 counts during that scan. Subsequent start commands will result in a single data-acquisition scan through memory.

Provisions are made for clearing data memory by a single action. The clear action will stop any active operation and automatically write zeros in all memory locations. A separate command will permit the user to stop data acquisition at the end of a memory scan and restart at the next timing mark without altering memory contents.

d. Data Count Error. When a particular memory scan begins, some propagation delay is experienced in the countdown of the 32-MHz crystal oscillator to the selected dwell time. During initial unit calibration, the normal count deviation between channels was ± 300 counts out of 900 000 or $\pm 0.03\%$ maximum.

e. Conclusion. The MCS is a complex unit because of its many modes of operation. We will not attempt to detail the instrument specifications here, but all specifications will be provided to anyone requesting this information.

11. Automated Rock Testing (G-6) [Green, E-5]. This project involves automating a rock-testing facility. A stepper motor, operating through a set of reduction gears, and a ram are used to apply constant stress to a rock sample. As creep or fracturing takes place, data on various points and time are collected and stored on a floppy disk. An LSI-11 computer operating through a controller, sends pulses to the stepper motor to keep constant stress on the sample. A Biomation data analyzer is used to collect data during fast sample transformations. Later these data are fed into the computer for storage.

A program was written to prompt the operator for input parameters and then collect data to be stored on a floppy disk. An ADC is used to sample the force transducer. The value, converted to floating point, is used in a formula together with position to compute stress. The stress is compared to a set point, and if it is different, a stepping motor change is made.

12. Tritium Monitoring Instruments (H-1) [Hiebert, Greenwood, E-5]. We are continuing our expansion of the tritium monitoring instrument family and our most recent efforts have been addressed to monitoring of radioactive gases in stack effluents, and real-time selective tritium measurement in the presence of radioactive noble gases or activated air.

Our stack monitor developments have been directed by the needs of R. Dvorak, H-1, since he desires to use stack monitor instruments for environmental measurements. This places stringent requirements on instrument performance; using a 50-L Kanne ionization chamber, a stability of $\pm 6 \times 10^{-16}$ A over month-long measuring periods in ambient temperatures ranging from -5°C to 27°C is desired. To achieve this specification, we have designed an electrometer preamplifier, which has been evaluated and found satisfactory. It uses a varactor bridge electrometer in a controlled oven. With this proof of feasibility, a document entitled, "Specifications for the Procurement of Instruments for Monitoring Radioactive Gas Effluents" was written for H-1 to include in RFQs from industry. In parallel, we were asked to prepare a proposal for a complete gas monitor prototype instrument, including integration and readout circuitry to allow real-time indication of total charge from the Kanne chamber. Instrument range would be 10^{-2} C full scale, with the least significant digit in readout representing 10^{-12} C.

Measuring tritium in the presence of other radio gases is a problem associated with the Princeton Tokamak fusion test reactor. An instrument for this monitoring problem has been proposed and we are designing and testing a prototype. The ionization chamber assembly consists of two concentric chambers. The inner flow-through sampling chamber is surrounded by a closed compensating chamber. The thickness of the common wall between the chambers is chosen to be slightly greater than the range of

the most energetic tritium beta. As a result, tritium ionization effects are limited to the inner chamber, but the other radiations penetrate to the outer chamber to produce compensating currents for those generated in the measuring chamber. Differencing electronics makes the subtraction to yield readings proportional to tritium only.

Mechanical and electronic design problems for this tritium monitor have been encountered. Materials selection was critical to avoid generation of disturbing emf's within the chamber and to assure minimal adsorption of gas in the walls and chamber sealant materials. The performance is basically limited by the gas dynamics resulting from a rapid gas transient to be measured. Two Model 75 electrometer amplifiers have been built with controlled and matched response times for the chamber signals.

13. Calculating Display System for H-5 Prototype Exhaust Stack Sampler (H-5) [Ethridge, E-5; Littlefield, Elder, H-5]. The exhaust stack sampler, incorporating a calculating display system of an ASM-48 microcomputer and 57109 number cruncher microprocessor, will be recommended to the EPA in conclusion of a contract, "Evaluate and Improve the Present Method-5 Emission Control Standards." Group E-5 estimates and a proposal to H-5 detailed, a cost of \$16 k to develop and design the system, software, and hardware prototype for the calculating display. At present, H-5 has funded only \$6 k for system and software design. Additional funds may become available to allow us to participate in the hardware fabrication and system debugging phase of the project. Approximately 1000 units exist at present without a calculating display system. A potential replacement of 200 units with the design under development is possible.

The hardware design is complete with prototype assembly finished. Software design has begun and some of the peripheral driver routines are being written.

The major LSI devices incorporated in the design include:

- ASM-48 8035 microcomputer
- National MM 57109 number cruncher
- Intel 8279 keyboard-display controller
- Intel 8155 expansion 256-word RAM and I/O

unit

●Intel 8755 expansion 2-k word EPROM and I/O unit

●National ADC-0816 single-component 16-channel, 8-bit ADC

●Litronix DF-111 quad LCD driver and latch.

All of the LSI devices are incorporated in a 40-pin, dual-in-line package except the number cruncher, which is packaged in a 28-pin DIP package.

14. PDP-11/70 Interface (L-4) [Green, E-5]. Group L-4 requested E-5 to connect a microdensitometer and film reader to their PDP-11/70. These two items were previously connected to a Data General NOVA computer; however, the NOVA was not in the same room with the film reader and microdensitometer and this created operator problems. A terminal is located near the equipment and a CAMAC crate; therefore, the obvious answer was to use CAMAC to connect the equipment.

This arrangement posed several problems however. The data-acquisition programs run under computer time sharing are subject to being time-sliced out of execution. This created "holes" in the data coming from the microdensitometer, which sends data whether the last data sent were read or not. The film reader stops scanning until the data are read, so there was no loss there. However, operation was much slower than on the NOVA, and the problem could not be solved by raising program priority.

We attempted to use interrupts using the SC handler, written by MP Division. This also was not a good solution because of complications in interactions over the serial-crate highway. It was decided to connect the equipment to an LSI-11 running RT-11 and using floppy disks. Parallel interfaces are used to gather the data that are then stored on floppy disks. The floppies are taken to the PDP-11/70, which can read them using FLEX.

The next step will be to connect the LSI-11 and the PDP-11/70 using a serial line. The data can then be passed back directly and programs can be down-line loaded.

15. High-Speed Cine-Radiography (M, WX Divisions) [Lundy, E-5]. A joint M and WX Division contract has been let to the University of Dayton to develop a high-speed cine-radiography system. Group E-5 is assisting in monitoring this contract, which involves high-voltage peaked-power systems and the development of a new image-intensification system.

A meeting was held with University of Dayton personnel in December and subsequent follow-up will be required. The resultant system is expected to have an x-ray energy in excess of 300 kV and be capable of at least 200 000 frames/s. Nine frames of 30- by 30-mm size can be recorded with a resolution of 20 to 50 line pairs/mm. Exposure time per frame will be approximately 30 ns.

16. MWPC Fast Encoding Electronics for Proton Tomography (MP-3) [Brown, McCabe, E-5]. An experiment in computed tomography using protons is being planned by K. Hanson and other MP personnel. The results of a preliminary experiment¹⁵ indicate that for the same radiation dose as commercial x-ray CAT scanners, a proton scanner could produce a significant improvement in density resolution. In the experiment, biological specimens with abnormalities will be used (a plastic phantom was used in the preliminary experiment) and the data-acquisition time will be reduced from 45 h required in the first experiment to 20 min.

The proton beam detection will be done with a multiwire proportional chamber (MWPC). The MWPC will be a single plane of about 200 wires at 2-mm spacing. The emerging proton energy will be measured by a 32-element range telescope. The goal is to collect 60 million events in about 20 min using the LAMPF beam. Because of the 6% duty factor at LAMPF, this implies an average event rate of 1 MHz during the beam pulse. To minimize the dead time and thus excess radiation, the MWPC should be able to accept a peak event rate of 5 MHz. For each event, we must encode the wire "hit" by the proton, 8-bits, and the energy of the proton, 5 bits. This data will be buffered in a first-in first-out (FIFO) memory before it goes to a multimicroprocessor auxiliary crate controller.¹⁶

a. MWPC Encoding. The wire data handling and encoding are done by a priority encoding method similar to the MWPC data handling system developed for P-7.¹⁷ In the priority encoding method, the dead time, while encoding, is variable depending on the number of wire addresses to be generated. This contrasts to the serial readout method that has a readout time fixed by the time required to generate all possible wire addresses.

The original MWPC data handling system was modified to permit an event rate of about 6 MHz. To

achieve this high rate, events that would require more than one wire address are rejected and only one wire address per event is encoded.

The flip-flops on each 8-channel comparator logic module that detect and store the wire hits, output their data onto an 8-wire data bus as soon as the flip-flop is set. The 8-channel module also outputs a current onto a fixed current summing bus if any of the wires are active; that is, flip-flops are set. This signal is used to reject events if more than one module is active. An analog current sum is also performed on the 8-wire data bus to determine the number of wires active. Events that have more than two wires active are rejected. Events that have two wires active but are not adjacent are also rejected. For the events that are accepted, an 8-input priority encoder generates the address of the active wire. The three bits from the priority encoder plus one bit that indicates if there were adjacent active wires, form part of the wire address. The rest of the address is formed by using two levels of priority encoding to determine the address of the active module.

b. Range Encoder. The range telescope encoding is a natural for a priority encoding system. All 32 scintillator outputs are gated into coincidence registers. The last scintillator will be connected so it has the highest priority and the first has the lowest priority. With scintillators connected in this order, the address encoded will correspond to the last active scintillator and therefore to range, or energy, of the proton entering the range telescope. The range encoding system is independent of the MWPC fast encoding system. It can handle up to 64 inputs, and outputs a 6-bit binary word giving the address of the highest-order active input about 85 ns after the gate signal, which latches the inputs, goes true.

17. Data Link for Nevada Downhole Physics Experiment (P-3) [Koelle, E-5]. Group P-3 has conducted neutron time-of-flight experiments using neutrons from underground weapons tests for many years. The apparatus is located downhole and the raw detector signals are sent uphole by coaxial cable. While this has worked well in the past, recent structural changes in these tests have increased the background noise accompanying the signal to the point where the

desired data cannot be extracted. The signal frequency components of interest are in the 10-kHz to 5-MHz range; the noise has components in the 100-kHz range, several times as large as the signal. It appears that this noise is induced in the coaxial cable.

Several alternatives to sending the baseband signal up on coaxial cable are being studied, including the use of an analog fiber optic link; however, the immediate need is a method that would allow use of existing coaxial cable assemblies. One way to accomplish this would be to put the signal on an rf carrier with high enough frequency to allow the several hundred kilohertz noise to be removed by a bandpass filter centered about the carrier frequency. Frequency modulation would ordinarily be the preferred method, but the wide bandwidth of the baseband signal seems to make this impractical. The remaining alternative is amplitude modulation. Ordinary amplitude modulation would require a 10-MHz bandwidth, which seems quite practicable with car-

rier frequencies in the 30- to 60-MHz range, as used in radar intermediate frequency (IF) amplifier systems. By choosing one of the standard radar IF frequencies, one can purchase commercial bandpass filters.

The proposed system block diagram is shown in Fig. 49. A low-power cw carrier is amplitude modulated with the information signal and amplified in a wideband linear amplifier to about 1-W peak level. This signal, sent to the surface by coaxial cable, is split to feed two channels. In one channel the signal will be recorded directly to allow examination of the composite signal and noise components. In the second channel the signal is sent through a bandpass amplifier to strip off the noise, then amplified if necessary, envelope detected, and recorded.

Of the required system components, the bandpass filter and the wideband linear power amplifier will be purchased as standard items. The uphole amplifier, if needed, will also be a purchased device.

Fig. 49. Amplitude modulation rf data link for P-3 downhole experiment translating the 0- to 5-MHz baseband signal to 55- to 65-MHz double sideband am.

The 60-MHz carrier generator will probably be a purchased crystal oscillator module. The most crucial components are the modulator and the envelope detector, since this application requires stability and linearity in the modulation and demodulation processes beyond that ordinarily required in communication systems.

It is expected that demodulation will present no big problems. A diode detector using a hot carrier diode and a diode-generated dc offset to compensate for the diode forward drop should work well, as shown in Fig. 50. If this arrangement is not sufficiently linear, a more complex synchronous detector can be built.

The most difficult component to build is the linear amplitude modulator. Work done so far has shown that a simple diode-ring modulator with coupling transformers, which are widely available for doubly balanced mixer applications, suffers from poor linearity and has a poor output waveshape. An active modulator, with a transconductance multiplier, works better but still suffers from poor linearity. The best result so far has been with an integrated circuit analog mixer device, the Motorola MC12002. This has adequate linearity and a sufficiently good output waveshape as long as the signal levels are kept low enough, at about 0.1-mW output level.

18. Reactor Power Monitor (Q-2) [Lewis, Ethridge, E-5]. The function of the reactor power monitor is to independently record reactor power levels for comparison to operating power levels now identified by normal operating procedures and personnel. The monitor will be packaged in a small briefcase or suitcase enclosure so that it may be handcarried to a reactor site and left unattended to record the power level for 30 days. A unit is being designed for International Atomic Energy Agency (IAEA) evaluation with a potential for more units.

Preliminary testing has been accomplished using the CMOS 1802 microprocessor suitcase unit supplied to Q-2. This testing has generated additional requirements and features, which are the factors requiring a new system design.

The performance requirements, operator controls, and operation procedures have been documented in an operation manual before hardware-software design. The hardware schematic is complete and proto-

Fig. 50. Proposed linear diode detector.

type construction is beginning. The software programs are flow charted with much of the program coding ready for editing and assembly on the microcomputer development system.

The monitor will incorporate two Intel ASM-48 single-component microcomputers. The Intersil CMOS equivalent microcomputer will be substituted when and if it is available. The present power requirement for the system is operation from 115 Vac, 60-Hz power and to contain battery back-up for 8 h.

A master microcomputer will perform the data acquisition, computation, and all I/O interfaces. A slave microcomputer will control the cassette tape recording.

Group E-5 is responsible for the hardware-software design. Group Q-2 is responsible for the unit fabrication.

19. Reduced Variance Calculator (Q-2) [Ethridge, E-5]. The primary task of this unit is to perform data acquisition, analysis, and calculations in the determination of basic fission physics parameters, specifically identification of fissionable material. The original unit software-hardware design has been upgraded to allow input of additional variables, definition of parameters for calibration, and equation selection as applicable to a specific environment.

Development of the Feynman variance calculator was detailed in our previous semiannual report. The reduced variance calculator is an improved design incorporating the high-speed data accumulation and scientific calculating system (8748 microcomputer and 57109 number cruncher) into one physical package for field deployment.

The E-5 task has been design integration of new requirements and hardware-software into the new unit. Groups E-2 and E-4 have packaged the new hardware. Group Q-2 will debug the power supply lines and data-acquisition electronics. Group E-5 will then debug the total system, including the scientific calculation system, using the newly acquired ICE-48 in-circuit emulator for the ASM-48 microcomputer. Upon final check-out, the unit will be installed in one of the vans belong to the nuclear emergency search team (NEST) for field deployment.¹⁸ Two additional units will be manufactured for Group Q-3.

20. Hardware Speech Synthesis (Q-2) [Ethridge, E-5]. The goal of this research and development is to add speech generation capability to NEST search briefcases and safeguard equipment. This feature, provided with an earphone, allows identification or alarm to the briefcase search personnel without indication to the environment being searched.

One speech synthesizer module manufactured by Telesensory Systems, Inc., has been purchased and evaluated. The evaluation system consists of a microcomputer sequencing the speech module, whose output drives an audio amplifier and speaker. The speech module in operation is the Model S2C, which contains a fixed, 64-word ASCII vocabulary.

This module is exercised by a supplied 6-bit word code, a start pulse, and examination of a ready signal. New vocabularies may be achieved by generating custom read-only memory semiconductor components for the module. Other units for possible evaluation and consideration use sequenced word codes based upon phonemes instead of read-only memory fixed vocabularies.

21. TA-55 Weight Measurement System (Q-3) [Backsen, Nickel, E-5; Carrier, E-2]. Design and development of a solution weight measurement system to be used in the TA-55 gloveboxes is under way. The weight measurement system will be used to weigh solution samples within the glovebox and transfer this information to the DYMAC system by way of the solution assay instrument (SAI).

The gloveboxes now have tanks and pressure transducers with associated voltage-to-frequency (VF) converters. The remote electronics is being developed in two stages. The first stage is an interim system that consists of a separate signal conditioning box for each tank. These remote boxes are then daisy chained on a serial bus to a central power supply and readout box. There is a separate power supply and readout box for each glovebox line, about six tanks. The interim stand-alone system will not be interfaced to the SAI. The readout is simply a frequency count of the VF converter and must be translated to weight information by a table or graph. Six remote electronic boxes and one central power supply and readout box have been fabricated, checked out, and delivered.

The second stage will include intelligent remote boxes, interfaced to the SAI by a serial daisy chain data communication bus. The remote boxes will translate the data, display the data locally in engineering units, and transfer the data upon request, either local or from the SAI, to the SAI. The remote box will contain an Intel 8748 microprocessor and associated electronics. Design and development is under way.

Specification of the remote box to SAI interface at this time is rather vague and must be clarified in the near future.

22. Model 498 Active Filter Differentiator (WX-2) [Hiebert, E-5; Van Lyssel, E-2]. This instrument was designed for electrochemistry applications requiring precise sensing of the point of maximum slope in a changing chemical reaction. This problem has been approached by Callicott and Carr,¹⁹ who suggested using active filter differentiators. The present design uses a Burr-Brown UAF-11 active filter to yield controlled cut-off frequencies ranging from 0.05 Hz to 0.9 Hz. Control of Q is furnished to allow adjustment for critical damping and this control is independent of cut-off frequency to simplify adjustments. The active filter circuitry also allows pick-off of a second derivative signal from the high-pass output; in some chemical studies this gives a more accurate measure of the time of the peak of reaction rate.

III. TECHNICAL SERVICES, H. S. OLAFSON, ASSISTANT DIVISION LEADER

This section of the report describes E-Division capabilities to support other technical divisions and groups in terms of maintenance, technician services, fabrication, and telecommunications support. This discussion is a general description of these capabilities in terms of personnel and facilities.

A. General Group Activities (E-1)

We have made a number of organizational changes in this report period. The Telecommunications Section transferred from Group E-1 to form a new Group E-9. The E-5 Minicomputer Maintenance Section was transferred into Group E-1, and a new E-1 section, Radiation Survey Instruments, was formed. We now have 11 sections in the group all doing maintenance. The bulk of our work is electronic, but we do some mechanical maintenance including vacuum pumps, leak detection, and balances.

With the formation of Group E-9 our responsibility for the telecommunications function has changed. Radio maintenance is performed by E-1 with E-9 as our customer: this same customer-vendor relationship exists between E-1 and E-9 in protected wireline (PWL) installation.

Our relationship with Group SD-4 has also changed during this report period. We formerly received indirect funds for support of the Electrical Standards Section, located in the main shop building and operated in conjunction with Group SD-4 and their metrology work. Beginning in FY-79, all of the indirect funding for this effort went to SD-4. We are now attempting to support our calibration efforts by recharge. We intend to continue the calibration effort in the same location with the same people who have been under indirect funding.

The Computer Maintenance Section transferred in its entirety to us October 1, 1978. The major effort in this section is concentrated on Digital Equipment Corporation (DEC) equipment. We are training personnel for maintenance of Data General computers and now have our first system under contract. There are many Data General systems in the Laboratory and we anticipate a large potential business in this area.

The new section formed to maintain radiation survey instruments is funded primarily by Group H-1. In addition to that effort, the section performs

maintenance on doorway monitors and criticality alarms. Our support to groups other than H-1 to is expected to expand.

Our nine other sections continue to expand gradually. We expect about 10% increase in business during FY-79. The key to maintaining our ability to respond to customer needs lies in our recruitment of competent technicians and subsequent training to update skills.

B. Recharge Programs (E-2)

1. Detector Services Section. During this report period, the capabilities of the Detector Services Section have been expanded significantly. This capability expansion includes general personnel upgrading and applying semiconductor fabrication techniques to areas other than semiconductor detectors. These techniques have been helpful in several L-Division target-and-beam diagnostic projects. Two of these projects, ultrasonic grinding of approximately 50 glass ovals 0.012-in. wide by 0.020-in. long by 0.005-in. thick and producing several 30-m-thick silicon filters by electroetching epitaxial silicon wafers, were performed for L-7 and L-4, respectively.

We have made more than 20 pyroelectric detectors for E-10 with pulse risetimes of < 20 ps. This technological advance has resulted in several E-10 publications and papers. The development and fabrication of thermopower laser beam alignment detectors continues; additional devices were made for L-1, L-4, and L-10, and a new device with annular ring-and-hole geometry was designed and built for L-10.

New on-line equipment includes a vacuum coater for depositing aluminum and gold and two 15% Ge(Li) spectrometers. The spectrometers are available for use on a loan basis.

2. Quality Control. In response to printed wiring board plated-through hole fabrication problems, an inspection procedure to insure hole integrity has been initiated. Board samples are sent to the CMB-6 Materials Technology Group for cross-sectioning; the results are used to determine the acceptability of boards produced during the sample interval. A nondestructive test instrument based on a microresistance measurement method has been ordered and should be available for verifying plated-through hole metal thickness during the third quarter of FY-79. This instrument will permit

inspection of each run of boards and, in conjunction with cross-sectioning techniques, will improve the quality of plated-through boards produced in E-2.

A staff member who is assigned to E-2 while awaiting clearance has begun an engineering study to determine if the economics of printed wiring assembly testing is feasible. The results and recommendations from this study will be available early in 1979.

In support of E-2 fabrication services, 8600 items were inspected during the past 6 months. A new 61-cm height gauge and surface plate are now being used for some mechanical inspections.

3. Printed-Wire Board Section. A numerically controlled (NC) drill was recently purchased and personnel are being trained to operate it. The NC drill will provide us with greater precision and speed in drilling and routing printed-wire boards.

The state of the art in printed-wire board production is being actively evaluated to determine how we can improve our overall process operations. In the next few months, we will concentrate on improved turnaround and product quality.

4. Production Control Section. During this period we initiated 1238 work orders representing more than 750 jobs and supporting approximately 75 LASL groups. In addition, approximately 3100 fabrication hours were awarded to Missouri Research Laboratories (MRL) for various electronic manufacturing jobs. Five Model 96 PDP-11 debugging tools, a popular item manufactured by E-2, were built for customers during this period. Other significant jobs completed were: 2 CAMAC crate controllers for Union Carbide, Oak Ridge, 18 thyatron trigger chassis for AP-Division, and 340 pc boards for the CTR-8 ZT-40 control system.

Scheduling and cost control have continued to improve as evidenced by monthly surveys. Schedule control has suffered setbacks due to model and paint shops remodeling and problems in the pc shop. Progress in establishing a materials control system has slowed due to delays caused by remodeling and delays in assignment of a purchasing analyst. However, parts control and flow to the fabrication floor have been greatly improved.

5. Fabrication. The wire wrap facility has undergone some recent changes in that software and hardware functions have been consolidated. This

consolidation should increase overall efficiency, performance, and customer satisfaction.

The new NC drill should enhance our capabilities enough to allow a 15% increase in pc assembly. We hope to improve cost, schedule, and product quality through the purchase of a wave solder machine; we are comparing prices and models. We have purchased a pneumatic swager that will allow installation of a variety of terminals in half the time now required. The swager should be operational January 1, 1979. The working environment and conditions have been greatly improved by the fabrication shop remodeling.

6. Mechanical Fabrication Shop. Fifty new punches and dies have been purchased for the Strip-pit; the Strippit becomes job-cost efficient when three or more panels are punched. We have produced five jobs on this machine to date.

A new lathe and several bench tools have been added to the staff shop.

7. Spray Painting Section. Professional painting jobs are now possible due in part to new and more efficient filters in the compressed air and booth air.

8. Photographic Section. An automatic photo processor is being considered for the camera room. If this equipment is obtained, processing time will be cut by a factor of 4. The amount of work per operator could increase by 20%.

9. Screen Printing Section. A new screen cleaning tank filled with a biodegradable cleaner is now being used. Cleaning time has been cut from 40 min per screen to 10 min.

10. Technician Services Section. During this report period we have had a 21.5% personnel growth rate. While our manpower requirements have increased, our customer base has remained relatively constant. Thirty-four LASL groups are currently using E-2 technicians. This customer base represents our support of most of the major experiments being conducted at LASL including: laser spectroscopy, AP-3, proton storage ring, AT-3, geothermal technology, G-4, biophysics instrumentation, H-10, solar, Q-11, international safeguards, Q-1, and high-energy gas laser, L-10. Kirk-Mayer, Inc., was the successful bidder on our outside technician contract, replacing the incumbent MRL. As in the past,

we are emphasizing training; digital and high-voltage pulse work are the two areas of highest demand from our technicians and customers.

11. Hybrid Microelectronics Section. During this report period, we have supported numerous Laboratory projects by providing microelectronic fabrication services. These included preparation of precision thin-film and special-purpose thick-film resistors; manufacture of standard hybrid circuits including logarithmic amplifiers, avalanche and SCR pulsers, and component carriers; and microelectronic assembly operations that require special equipment and skilled technical personnel. We have also provided consultation services for several groups who require unusual electronic fabrication services and advice on electronic materials technology problems.

12. Design and Packaging Section. This section has undergone a number of changes and as a result we have several new capabilities. A new drafting contract for 20 000 h is now out for bid, an increase of 14 000 man-hours over last year. We now have 12 contract draftspersons who support several major LASL projects. We now offer preparation of flip charts and viewgraphs for high-quality professional presentations. A new Duostat camera was purchased and is in operation. This equipment enhances our illustration capability and speeds up our artwork turnaround. The new off-line computer-aided drafting digitizer for generating schematics and diagrams has been set up at SM-39. As soon as the design aids system and plotter are operational, the off-line digitizer can be put into operation. The 3-day turnaround for pc board artwork mentioned in the last report is now possible. This means that we can produce, on the average, a drill drawing, assembly drawing, and camera-ready artwork from an engineer's sketch within 3 days.

An LSI-11 chassis has been designed for user groups through LASL. When the prototype design is finalized, the chassis will be a stock item.

13. Special Projects. This section is completing eighteen 2.5-GHz Model 1776 MCP oscilloscopes and two 5-GHz Model 76 French tube oscilloscopes for L Division. These projects will be completed in March 1979. Additional orders from J Division, L Division, and other organizations are expected, which will maintain the oscilloscope production effort through calendar year 1979. J Division

expects funding for large quantities, 100 or more, of the Model 1776 to begin in FY-80.

C. Research and Development Programs (E-2)

Hybrid Microelectronics. During this report period we have placed major emphasis on the development of high-reliability hybrid microcircuits for use in the P-4 space electronics systems. Hybrid layout, design, construction techniques, and packaging methods have been carefully considered in these designs. A number of circuits have been constructed and will be tested by a commercial laboratory for temperature cycling and thermal shock, acceleration, particle impact noise, fine and gross seal, and electrical operation.

A digitizer counter hybrid circuit was developed for Group M-4. It contains six digital integrated circuits packaged in a 24-pin DIP. We have begun work on a similar unit containing nine integrated circuits. This will be used in a major data-acquisition system. Approximately 800 of these circuits will be required and we expect that they will be purchased from a commercial supplier after we have completed the development work.

A hybrid microelectronic circuit has been developed in conjunction with Groups E-1 and H-1 for use in a new personnel radiation monitor. This film-badge-size unit contains a cadmium telluride radiation detector, electronic circuitry, batteries, and a miniature loudspeaker. It is designed to warn the wearer of low levels of radiation by providing a chirping sound. We have completed approximately 50 of these hybrid circuits and expect to build another 400 before the design is transferred to a commercial vendor for quantity production.

D. Telecommunications (E-9)

Group E-9 was formed on October 1, 1978, by the transfer of the Telecommunications Section of E-1. The primary responsibilities of E-9 include administration of the telephone system, management of the radio program, and wireline services.

A new emphasis in telephone service has been the effort to have all requests for moves, changes, and new systems handled by Mountain Bell's government service representatives. Beginning January 2, 1979, the phone number for service requests, 667-3400, will be answered by Mountain Bell personnel who will make all initial customer contacts. Group E-9 personnel will continue to monitor and approve

all telephone work orders and will handle liaison with the ENG Department and Zia Company crafts when necessary. A telecommunications system study is being conducted to detail the growth of the telephone system, data circuits, radio systems, and costs since 1969. This study will be the foundation for our planning activity for future telecommunications services growth. Various devices designed for connection to the telephone network are being obtained by E-9 for evaluation and loan to users. We have on hand three portable conference telephone sets, Model 50A1, and have ordered three "Rapidialers.". We hope to expand this capability as more unique and cost-effective customer-provided equipment (CPE) becomes available.

In the radio program, an experimental age-based flat-rate maintenance cost schedule has been developed and is being added to AAUP's radio cost-charging software. We have participated in the new Emergency Operations Center design; the center is scheduled to be completed in January 1979. We are beginning an analysis of our radio program management in an attempt to identify LASL administrative needs and the needs of radio users. This will enable us to perform a meaningful and satisfying role.

Wireline (data communications) needs are increasing within LASL. Major PWL projects are under way in TA-3. The Directors Office has requested that we submit a project management proposal for the portion of the project within SM-43. The project includes installation of conduit runs to A and D wings on the first, second, and third floors; pulling in 7000 pairs of shielded telephone cable; terminations at cross-connect boxes and extensions to collector boxes and protected outlet boxes for approximately 250 users. The proposal has been prepared and submitted to the Directors Office for review. We believe that increasing emphasis on computer security and moves toward distributed remote computing will increase the demand for wireline services.

An important emphasis in E-9 will be close cooperation with other LASL organizations that have telecommunications interests. Preliminary contacts have been made and mutual interests are under continuing discussion. We intend to deemphasize daily user contacts and emphasize advance planning of the LASL telecommunications system.

Projects for the first half of 1979 include review and upgrading of our facilities drawings, possibly implemented on computer graphics, and development of a facilities data base to aid in planning expansion of our cable plant. We plan to explore practical problems involved in administration of wideband communications resources including charging algorithms, methods of cost recovery, and financing system expansion.

E. Information and Training (I&T)

1. Summary [Fox]. Personnel changes in I&T Services have impacted our goals. Due to an overall reduction in staff, we have focused our efforts inward toward satisfying E-Division needs. Much less effort was expended on LASL-wide training problems. It is anticipated that this new posture will continue.

New projects initiated during this report period include the development of a SECA training program and a technician training program for Group E-1. We have continued to refine the plans for a technician training program for E-2; with their cooperation training activities have been scheduled for all of FY-79. Progress has been made in the computerassisted instruction area; our experimentation with programmed logic for automatic teaching operations (PLATO) will be the first system of this kind used by I&T Services. A 6-month experiment is planned for January through June 1979.

The Video Learning Center (VLC) was moved to the Trinity Square Complex. Group PER-5 has assumed responsibility for the facility and the production of quality educational videotaped instruction. Major equipment and benches have been purchased for a technical training laboratory. Six stations are equipped to serve 12 students as soon as space becomes available.

Seven courses were conducted during this report period with 82 E-Division participants. Seminars in psychology are being conducted weekly. Individualized instruction modules have been heavily used with the microprocessor training modules most in demand. New videotaped instructional series have been added to the I&T library with the purchase of three DEC series and two Texas Instruments series. Video viewing continues to be a viable resource to E Division and other LASL employees. Video search microfilm (VSMF) usage increased with a total of 180 searches conducted.

Continuing education for I&T personnel included courses in American sign language, computer-assisted design, and PLATO author language.

2. Employee Development [Brown]. Upon return from a leave of absence to work on her masters degree in psychology, Molly Brown has assumed the responsibilities of E-Division Affirmative Action Representative. In addition to her AAR duties, she is available to all E-Division employees to discuss problems in work situation, career plans, and personal life that affect their work. When appropriate, she can informally investigate a situation, act as "interpreter" between people experiencing interpersonal or communication problems, and refer people to other LASL resources for specific help. Molly will study human relations areas that are general problems within E Division and conduct short courses to help supervisors and employees resolve these problems.

3. Programs for Handicapped Employees [Simon]. In conjunction with the LASL Employee Relations Office, I&T Services is examining several areas of importance to deaf employees. A procedure is being established to standardize hiring interpreters throughout LASL. Several sources of interpreters are being examined for availability, costs, certifications, and affiliation with national groups. It is hoped that a standard procedure will provide the most effective interpreters for deaf employees. The feasibility of installing telecommunication devices in homes of deaf employees and LASL work sites to allow communication between the employee and employer is being considered. Seven E-Division employees participated in a basic sign language course twice a week from October 3 through December 15. The class learned the alphabet, how to count, and over 1000 signs in American sign language. Benefits of this training are already evident in the day-to-day communication with two deaf E-Division employees.

4. New Programs.

a. SECA Training Program [Simon, Fox]. In conjunction with E-5 and the DOE Protective Force, I&T Services is helping develop and produce a training program to instruct guards in the use of the SECA. The initial orientation will be in slide-lecture format using an instruction booklet.

After revisions are made, the program will be converted to a self-instructional videotape with workbook.

b. Group E-1 Training Program [Fox, Brown]. I&T Services is working with E-1 to develop an intensive training program for Tech I level personnel. The purpose is to provide upward mobility opportunity for women and minorities to allow them to advance to TEC II and TEC III levels and help meet affirmative action goals. The training will be vigorous, requiring dedication and commitment from the employee. Each trainee will be given an individually tailored program to meet their needs and goals. During the first year of the program four employees will be selected. They will alternate 8-wk periods of half-time training, half-time work, and full-time work.

c. People at Work: Seminars in Psychology [Brown]. Molly Brown will present luncheon seminars to be held weekly, 11:45 a.m. to 1:15 p.m. on Thursdays, in the South Mesa Cafeteria, beginning November 30, 1978. Each seminar will present a basic psychological concept, with opportunities for discussion about application to the work environment and suggestions for further reading and study. E-Division personnel are invited to attend any or all sessions as their interest and schedule permits. Topics will include:

- What Do People Need?
- Passing the Buck: Blaming, Projection, and Defensiveness
- Feelings: Expression or Repression
- Subpersonalities: The Many Faces of Everyone
- Taking Charge: Will and Choice
- Lend Me an Ear: Listening in Communication
- Making Myself Available: Self-Disclosure in Communication
- The Person-Centered Politics of Carl Rogers
- Life Transitions at Work

5. New Materials.

Instructional Videotapes [O'Mara]. Three DEC programs were obtained during this period. They are "Introduction to VAX-11 Concepts," a self-paced series that includes an 11/780 overview, HEX number system, data representative operating system overview, process structure exceptions and interrupts, memory management, and compatibility mode. One new program, "Introduction to VAX-11: Instruction Set,"

is designed to teach the viewer how to code VAX-11 instructions. "Introduction to Data Communication Concepts," includes discussions of trends, basic concepts, system types, channel concepts, common carriers, error handling, terminal equipment, linear control, and software. "MOS Integrated Circuits," a 20-tape series, was obtained from Texas Instruments. Discussions about electronic calculators, the development and operation of FETs, and reasons for the rapid growth of MOS technology are included. "TI Calculator Series," includes the evolution of programmable calculators, basic calculator functions, variable value entry, labels, and unconditional and conditional branchings. One program was acquired from LLL, entitled, "Basic Strengths and Mechanics of Materials for Draftsmen and Designers." These videotapes cover introduction and forces, kinds of stress, relation between unit stress and deflection testing, moments and types of beams, shear diagrams for concentrated loads and disturbed loads, cantilever beams, theory of bending, properties of sections, and previously developed formulas, moment of inertia, and section modulus calculation.

6. Continuing Programs.

a. Visual Search Microfilm [O'Mara]. In the past 6 months a total of 180 searches were conducted. Of these, 68 searches were made by E-Division personnel and 72 were made by personnel from other divisions. These divisions include AP, AT, CNC, CTR, G, H, J, P, Q, SD, and WX.

b. Laboratory-Classroom [Fox]. A training laboratory-classroom is being established by I&T Services. Six portable workbenches equipped with meters, power supplies, signal generators, and oscilloscopes are stored and will be installed when space becomes available. This classroom will greatly enhance the practical technical training efforts of I&T Services.

c. Affirmative Action [Brown]. At the end of FY-78, E Division had met virtually all affirmative action goals for the year. The only goals not met were for anticipated openings that did not occur. After the first quarter of FY-79, E Division has made good progress towards filling our goals for this year. We have met about 26% of our goals for female hiring and 23% of our goals for minority hiring.

d. Group E-2 Technician Training [Fox, Simon].

A training program designed for E-2 fabrication technicians was developed through the cooperative efforts of E-2 and I&T Services. The program consists of a series of minicourses to be presented on a continuing basis. After an extensive job and task analysis, many skills and techniques were selected for presentation. Outline rough drafts for each minicourse were developed. Criterion-referenced objectives will be written and evaluation will be based on how well these objectives are met. Further evaluation will answer the question, "How well did each course meet the needs of E-2 and the fabrication technicians?" Minicourses instructors will be selected from E-2 and will be assisted by I&T Services staff. Some instruction will be provided by John Fox. Outside specialists will also be selected for various training program aspects, for example, the Certified Soldering School.

The I&T staff will provide criterion-referenced instruction training for each of the in-house instructors selected. During this training period, approximately 1 wk for each course, the final course planning will be done. Specific training aids, laboratory experiments, and other assignments will also be developed for each class.

7. Courses Conducted [Simon]. I&T Services conducted seven courses with some courses having six individual sections. Continuing education courses accounted for over 3000 student contact hours of class time. Course statistics are shown in Table VII and course descriptions follow.

TABLE VII
CONTINUING EDUCATION COURSE SUMMARY

<u>Course</u>	<u>Contact Hours</u>	<u>E-Division Registration</u>	<u>Non-E-Div. Registration</u>	<u>Non-E Per Cent</u>
Certified soldering (1)	40	7	1	12.5
Certified soldering (2)	40	10	0	0
Mechanical soldering 1	20	0	8	100
2	20	0	8	100
3	20	3	7	70
4	20	2	5	71
5	20	5	3	37.5
6	20	3	7	70
Soldering recertification	12	10	0	0
Hybrid microcircuit soldering	16	6	1	14
Theory 2	24	23	1	4
Operational amplifiers	16	8	25	76
TI-59 programmable calculator	4	5	0	0
Totals	272	82	66	45%

a. Certified Soldering. This course develops advanced soldering skills and self-evaluation techniques for improving manufacturing quality and reliability.

b. Soldering Recertification. This course follows Certified Soldering by approximately 1 yr and is intended to reestablish and reevaluate techniques and skills that may have deteriorated.

c. Mechanical Soldering. This course is designed to provide trainees with the knowledge and skills necessary to accomplish mechanical soldering and brazing. Instruction in solder theory, material preparation, and heat requirements is presented. Upon completion, students should have mastered the techniques and are proficient in the soldering or brazing of copper, aluminum, stainless steel, cast iron, and mild steel.

d. Hybrid Microcircuit Soldering. This course provides soldering training unique to hybrid microcircuits. Topics presented include fluxes and removers, soldering to gold-plated pins, soldering covers on packages, design of conductor pads, application of solder paste, inspection of joints, and solder compositions for particular conductor systems.

e. Theory Z. This course is a workshop lecture dealing with the use of goals, motivation, feedback systems, error correction, and goal revision in management systems.

f. Operational Amplifier Theory, Circuit Design, and Applications. This course is designed to introduce the operational amplifier as a basic circuit element in analog systems to design engineers and scientists not well versed in analog circuit techniques. The theory of operational amplifiers is discussed using both the ideal model and the complete model. Circuit design, with applications in active filters and signal manipulation, nonlinear signal processing, analog switching, and ADC and DAC conversion is considered. The methods of estimating the effects of manufacturer's specifications on circuit performance will also be covered.

g. TI-59 Programmable Calculator. Texas Instruments developed this course using videotapes and slides with a student workbook. The pilot groups will be proctored by two instructors. The course explains TI-59 capabilities and presents practice problems to help familiarize students with

the calculator, its functional grouping of keys, basic problem solution, and various features of the TI-59.

h. Computer-Assisted and Managed Instruction [Fox, Simon]. PLATO was developed at the University of Illinois; Control Data Corporation of Minneapolis markets the system. I&T Services will have a PLATO terminal for 6 months, beginning in January 1979. Experiments will be conducted to evaluate PLATO's contribution to E-Division continuing education needs. John Fox has completed some of the course work necessary to design and program learning modules for the PLATO system. He will complete future courses on the terminal when it is operational at LASL.

Another system to be investigated is the time-shared interactive computer-controlled information television (TICCIT). TICCIT was developed under a National Science Foundation contract by the Mitre Corporation of Boston and Washington. Courses were developed by the Institute for Computer Uses in Education at Brigham Young University. TICCIT is a more specialized system than PLATO. While PLATO uses a large powerful computer, TICCIT uses a small local computer; PLATO is far more flexible than TICCIT and therefore is more difficult to program. I&T Services plans to study the TICCIT system during the latter part of 1979.

i. Coordination with PER-5 [Fox, Simon]. E-Division I&T personnel will concentrate future efforts on E-Division training requirements. Any courses offered by I&T Services on a LASL-wide basis generally will be electronic in nature. Group PER-5 has assumed full responsibility for the VLC. All equipment has been moved to and installed in the Trinity-Square complex. I&T Services will continue to have representatives on the educational committees established by PER-5. Vickie Simon will represent us on the Engineering and Science Committee, and John Fox will represent us on the Technical Support Committee. Through work with these committees, we will remain abreast of LASL electronic training needs and new continuing education developments of interest to E-Division personnel.

Group PER-5 will acquire additional space in January 1979. The space is to be dedicated to a laboratory-classroom for training purposes. In anticipation of the availability of this training

space, I&T Services has purchased laboratory benches, electronic equipment, and electronic training aids to equip this facility. When the benches and equipment are installed, we will offer technical training with six laboratory stations. Each laboratory station is equipped for two students working as a team. Maximum class size will therefore be limited to 12 students. The first class is planned for March 6-10, 1979.

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APPENDIX A

DIVISION PAPERS REPORTS, TALKS, AND MEETINGS

Papers Submitted for Meetings

R. E. Bobbett, J. B. McCormick, D. K. Lynn, and J. Nachamkin, "Electric Vehicle Simulator," 29th Vehicular Technology Conf., Arlington Heights, Illinois, March 28-30, 1979.

A. L. Criscuolo, "Controlling a Fast Solid-State Camera with a Microcomputer," 1978 CUBE Symp., Los Alamos, New Mexico, October 4-6, 1978.

- Anne Demuth, Joel Robinson, J. David Schnieder, and William Barnett, "DAISY, A Data Acquisition and IO Control System," 1978 CUBE Symp., Los Alamos, New Mexico, October 4-6, 1978.
- Edward J. Dowdy, C. Dwayne Ethridge, Carl N. Henry, and David R. Millegan, "A Microprocessor-Based Neutron Count Moments Logic Module for Special Nuclear Material Assay by the Neutron Fluctuation Method," 1st Symp. on Safeguards and Nucl. Material Management, Brussels, Belgium, April 25-26, 1979.
- Donald R. Farris, "Adaptive Optimal Control for Energy Conservation and Management in Solar Heated and Cooled Buildings," 1978 ASHRAE Semiannual Mtg., Albuquerque, New Mexico, June 25-28, 1978.
- Robert F. Ford, "On-line Accountability of Special Nuclear Material (DYMACE)," 1978 CUBE Symp., Los Alamos, New Mexico, October 4-6, 1978.
- Jack G. Grundmann, "Dynamic Computer Simulation of a Tritium System Test Assembly in Support of Fusion Reactors," 1978 CUBE Symp., Los Alamos, New Mexico, October 4-6, 1978.
- Jane Hager and R. F. Ford, "DYMACE Computer System," 1st Symp. on Safeguards and Nucl. Material Management, Brussels, Belgium, April 25-26, 1979.
- Robert B. Hammond and Richard N. Silver, "Nucleation of Electron-Hole Droplets in Si," Am. Phys. Soc., Chicago, Illinois, May 19-23, 1978.
- Dale M. Holm, Ronald E. Bobbett, Alfred R. Koelle, Jerry Landt, and Richard E. Nelson, "Electronic Identification and Temperature Monitoring-1978," Livestock Conservation Inst. Mtg., Des Moines, Iowa, May 18, 1978.
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- J. B. McCormick, W. Kerwin, D. Hamilton, S. Srinivasan, J. McBreen, J. Huff, R. Bobbett, D. Lynn, and J. Nachamkin, "Fuel-Cell-Powered Vehicles," 29th Vehicular Technology Conf., Arlington Heights, Illinois, March 28-30, 1979.
- J. Byron McCormick, Ronald Bobbett, David Lynn, S. Srinivasan, J. McBreen, and James R. Huff, "Applications of Fuel Cells in Transportation," 1979 Intersociety Energy Conversion Engineering Conf., Boston, Massachusetts, August 8-10, 1979.
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- Frank D. Wells and David Remington, "Mirror Position Display Equipment for the Target Chamber Mirror Mounts of the 8-Beam Laser Fusion Research Facility," 1978 CUBE Symp., Los Alamos, New Mexico, October 4-6, 1978, and 1979 IEEE Region Six Conf., Sacramento, California, April 25-27, 1979.

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Charles R. Gruhn and William B. Maier II, "An Impurity Monitor for Liquid Ionization Chamber Media," Nucl. Instrum. Methods.

R. B. Hammond and R. N. Silver, "Onsets of the Electron-Hole Droplet Luminescence in Si," Phys. Rev. Lett.

R. B. Hammond and R. N. Silver, "Analysis of LO and TO Phonon-Assisted Free-Exciton Luminescence in Silicon," Solid State Commun.

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R. K. Ahrenkiel, D. Dunlavy, J. F. Figueira, C. R. Phipps, S. Thomas, and A. J. Sievers, "A New 10.6- μ m Saturable Absorber: KCl Doped with $KReO_4$," Proc. Intl. Conf. on Lasers - '78, Orlando Florida, December 11-15, 1978.

R. H. Augustson, N. Baron, W. Ford, J. Hagen, T. K. Li, R. S. Marshall, V. S. Reams, W. R. Severe, D. G. Shirk, and R. F. Ford, "A Development and Demonstration Program for Dynamic Nuclear Materials Control," Proc. IAEA Symp. on Nucl. Material Safeguards, Vienna, Austria, October 2-6, 1978.

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Donald R. Farris and James L. Melsa, "Energy Savings for a Solar Heated and Cooled Building Through Adaptive Optimal Control," Proc. 17th IEEE Conf. on Decision and Control, San Diego, California, January 10-12, 1979.

Donald R. Farris, Thomas E. McDonald, and James L. Melsa, "A Brief Comparison of the Inherent Capabilities of Conventional Controllers and Linear-Regulator Controllers," Proc. Control of Solar Energy Systems for Heating and Cooling Conf., Hyannis, Massachusetts, May 23-25, 1978.

Charles R. Gruhn and Robert Loveman, "A Review of the Physical Properties of Liquid Ionization Chamber Media," Proc. 1978 IEEE Nucl. Sci. Symp., Washington, DC, October 18-20, 1978.

James C. Hedstrom, Hugh S. Murray, and J. Douglas Balcomb, "Control of a Rankine Chiller and an Absorption Chiller in the National Security and Resources Study Center," Proc. Control of Solar Energy Systems for Heating and Cooling Conf., Hyannis, Massachusetts, May 23-25, 1978.

J. C. Hedstrom, H. S. Murray, and J. D. Balcomb, "Solar Heating and Cooling Results for the Los Alamos Study Center," Proc. Conf. on Solar Heating and Cooling Systems Operational Results, Colorado Springs, Colorado, November 28-December 1, 1978.

Andrew J. Kozubal and Charles P. Milich, "A Network for Data Acquisition in an Experimental Laboratory," Proc. 12th Hawaii Intl. Conf. on System Sci., Honolulu, Hawaii, January 1979.

R. P. Kruger, T. M. Cannon, A. S. Lundy, and R. A. Morris, "Simulation and Preliminary Performance Characteristics of a Computed Tomography Device for Industrial Applications," Proc. SPIE Conf., San Diego, California, August 28-31, 1978.

D. K. Lynn, J. B. McCormick, R. E. Bobbett, C. R. Derouin, J. Nachamkin, and W. Kerwin, "Determination of Vehicle Rolling Resistance and Aerodynamic Drag," Proc. 29th Vehicular Technology Conf., Arlington, Illinois, March 28-30, 1979.

D. K. Lynn, C. Derouin, and P. Lamar, "Microprocessor-Based System for Roll-Down and Acceleration Tests," Proc. IEEE 29th Vehicular Technology Conf., Arlington, Illinois, March 28-30, 1979.

J. C. Martin, S. R. McLaughlin, and R. D. Hiebert, "A Real-Time Delay Monitor for Flow-System Cell Sorters," Proc. (J. of Histochemistry and Cytochemistry) 6th Engineering Foundation Conf. on Automated Cytology, Elmau, West Germany, April 23-29, 1978.

Thomas E. McDonald, Donald R. Farris, and James L. Melsa, "Energy Conservation Through Adaptive Optimal Control for a Solar Heated and Cooled Building," Proc. Control of Solar Energy Systems for Heating and Cooling Conf., Hyannis, Massachusetts, May 23-25, 1978.

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H. S. Murray, "Active Systems Studies at LASL," Proc. 3rd Annual Solar Heating & Cooling R&D Contractors' Mtg., Washington, DC, September 1978.

H. S. Murray, J. C. Hedstrom, and J. D. Balcomb, "Solar Heating Results for the Nambe Community Center," Proc. Conf. on Solar Heating and Cooling Systems Operational Results, Colorado Springs, Colorado, November 28-December 1, 1978.

Hugh S. Murray and Michael A. Trump, "Instrumentation System for the Los Alamos National Security and Resources Study Center," Proc. 3rd Annual Solar Heating and Cooling R&D Contractors' Mtg., Washington, DC, September 24-27, 1978.

M. Somasundaram, James L. Melsa, and Donald R. Farris, "Optimal Control Studies of a Solar Heating System," Proc. MIDCON 1978 Conf., Dallas, Texas, December 12, 1978.

APPENDIX B

ABSTRACTS OF PUBLISHED PAPERS

JULY THROUGH DECEMBER 1978

J. M. Crowell, R. D. Hiebert, G. C. Salzman, B. J. Price, L. S. Cram, and P. F. Mullaney, "A Light-Scattering System for High-Speed Cell Analysis," IEEE Trans. Biomed. Eng. BME-25, No. 6 (1978).

A flow-system instrument is described in which the light scattered by a biological cell is detected simultaneously at 32 angles in the forward direction as the cell passes through a focused laser beam at 10 m/sec. Cluster analysis is applied to the scatter pattern data to enable discrimination among cell types.

J. Byron McCormick, Editor, "High-Temperature Electronics Workshop, Progress in the Development of Microelectronics for the 500°C Environment," Los Alamos Scientific Laboratory Conf. Proc. LA-7409-C (July 1978).

This workshop proceedings describes the status of the Los Alamos Scientific Laboratory (LASL) and University of Arizona programs in the development of high-temperature microelectronic devices for geothermal well-logging applications.

Marjorie Endebrook, Compiler, "Industrial Workshop on LASL Semiconductor Radiation-Detector Research and Development," Los Alamos Scientific Laboratory Conf. Proc. LA-7408-C (November 1978).

An Industrial Workshop on LASL Semiconductor Radiation Detector Research and Development was held at the Los Alamos Scientific Laboratory (LASL) in the spring of 1977. The purpose was to initiate communication between our detector research and development program and industry. LASL research programs were discussed with special emphasis on detector problems. Industrial needs and capabilities in detector research and development were also presented. Questions of technology transfer were addressed. The notes presented here are meant to be informal, as were the presentations.

C. Dwayne Ethridge and Gary M. Worth, "Scientific Calculating System with a Number-Oriented Microprocessor Sequenced by a Single Component Microcomputer," IEEE Trans. Nucl. Sci. NS-25, No. 1, 506-509 (February 1978).

A scientific calculating system for large distributed-task processing systems and for small isolated intelligent data acquisition and instrumentation systems is established with a number-oriented microprocessor sequenced by a single component microcomputer. A MOS/LSI number-oriented microprocessor provides the scientific calculating capability with Reverse Polish Notation data entry. Input data sequencing, computation processing, intermediate

result comparison, answer display and/or answer feedback to master processors is controlled by a single component microcomputer.

Allen Q. Howard, "Effect of Borehole Fluid on Induction Fields of an Encapsulated Magnetic Loop," Los Alamos Scientific Laboratory report LA-7516-MS (December 1978).

The modification of the induction fields of a magnetic dipole created by truncated cylinders of borehole fluid is treated. An expression is derived for the coefficients of the Fourier-Bessel series, which describes the scattered fields in a cylindrical capsule. This capsule contains the source and observation dipole loops. The results are important in interpretation of induction logs where the non-isotropic effects of the borehole must be understood. A fundamental difference between this work and others on the general subject is that here the excitation loop is oriented vertically to excite eddy currents in vertical structures.

J. A. Landt, "A Magnetic Induction Technique for Mapping Vertical Conductive Fractures: Theory of Operation," Los Alamos Scientific Laboratory report LA-7333-MS (July 1978).

Utilization of a hot dry rock geothermal resource requires circulation of a fluid (water) through fractures in the rock. The Los Alamos Scientific Laboratory is presently investigating the feasibility and economics of tapping this energy resource. Presently, the fractures in the rock are created by conventional hydraulic fracturing techniques. Accurate determination of the geometry of the fracture system is required so that boreholes may be drilled to complete the circulation system. This report presents the theory of a technique designed to map vertical conductive fractures located in resistive rock. The technique is based on magnetic induction. Fracture thickness and strike can be determined from measurements made in a single borehole.

W. Ogle, P. Goldstone, C. Gruhn, and C. Maggiore, "Ionization Energy Loss of Relativistic Electrons in Thin Silicon Detectors, Phys. Rev. Lett. 40, 19, pp 1242-1244, May 8, 1978.

We have measured the ionization loss of electrons with Lorentz factors $\gamma = 2.91$ and $1.6 \times 10^4 < \gamma < 10^5$ passing through a $(100.71 \pm 0.15)\text{-}\mu\text{m}$ silicon detector. Our results are in agreement with accepted theory for $\gamma = 2.91$ and $\gamma = 1.6 \times 10^4$; however, for $\gamma \geq 3 \times 10^4$ our results are systematically $(7 \pm 2)\%$ below the theoretical value. We suggest an explanation in terms of the finite detector thickness and a relativistic effect.

G. C. Salzman, R. D. Hiebert, and J. M. Crowell, "Data Acquisition and Display for a High-Speed Cell Sorter," Comput. Biomed. Res. 11, 77 (1978).

Data acquisition and control hardware and display and processing software are presented for a biological cell sorter in which the four parameters of information about each cell are stored event by event on a computer disk.

R. H. Wang, R. J. Laskowski, C. Y. Huang, J. L. Smith, and C. W. Chu, "Magnetic and Superconducting Transitions in $\text{Gd}_x\text{Er}_{1-x}\text{Rh}_4\text{B}_4$ and $\text{Gd}_x\text{Y}_{1-x}\text{Rh}_4\text{B}_4$," J. Appl. Phys. 49, No. 3, 1392-1394 (March 1978).

The magnetic and superconducting transition temperatures and upper critical fields have been measured for $\text{Gd}_x\text{Er}_{1-x}\text{Rh}_4\text{B}_4$ and $\text{Gd}_x\text{Y}_{1-x}\text{Rh}_4\text{B}_4$. The pressure dependence of T_c for the Er system for $x \leq 0.05$ is 0.5×10^{-2} K/kbar. Both systems exhibit reentrant behavior, that is a superconducting transition followed by a magnetic transition at a lower temperature that destroys the superconductivity. For the Er system, the initial additions of Gd actually raise the superconducting critical field followed by the expected decrease for greater additions.