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PHYSICS, COMPUTER SCIENCE and MATHEMATICS DIVISION

ANNUAL REPORT

1 January - 31 December 1976

Lawrence Berkeley Laboratory
University of California
Berkeley, California

LBL-6750 c.1

Building complex housing Physics, Computer Science and Mathematics Division.

PHYSICS, COMPUTER SCIENCE and MATHEMATICS DIVISION

Robert W. Birge
Division Head

ANNUAL REPORT

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Joseph V. Lepore
Editor

Lawrence Berkeley Laboratory
University of California
Berkeley, California

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INTRODUCTION

This annual report of the Physics, Computer Science and Mathematics Division describes the scientific research and other work carried out within the Division during the calendar year 1976. The Division is concerned with work in experimental and theoretical physics, with computer science and applied mathematics, and with the operation of a computer center.

The major physics research activity is in high energy physics; a vigorous program is maintained in this pioneering field. Experimental work is carried out at the Stanford Linear Accelerator Center (SLAC), at the Fermi National Accelerator Laboratory (FNAL), and at the Brookhaven National Laboratory (BNL).

The unexpected and revolutionary discoveries made over the last few years by SLAC and LBL scientists using the Stanford Positron Electron Accelerator Ring (SPEAR) have renewed a sense of excitement within the Division. These experiments resulted in the discovery of the ψ-particle and, almost immediately thereafter, in discovery of the ψ'; in the anomalous μe pair-production indicating a heavy lepton; and finally in the production of charmed mesons disintegrating into $k\pi\pi$. All of these discoveries undoubtedly imply that we are now at the start of a new period in the development of high energy physics. The results expected in the energy region up to 30 GeV with the positron-electron colliding beam project (PEP) will probably produce more surprises.

The high energy physics research program in the Division now focuses on experiments with e^+e^- colliding beams using advanced techniques and developments initiated and perfected at the Laboratory. A balance is maintained by continuing experimentation at FNAL and BNAL. The research activities and experimental facilities research and development, as well as future experimental facilities operations, are all closely related.

Planning for PEP, a joint effort by LBL and SLAC, has been intensively pursued during 1976. The guiding committees—the PEP Policy Committee and the PEP Experimental Program Committee—have been formed and have met during this year. A conference on PEP experiments was held at SLAC in late June 1976 and the proceedings have been issued.

The Division continues its work in medium energy physics, with experimental work carried out at the Bevatron and at the Los Alamos Pi-Meson Facility (LAMPF).

Work in computer science and applied mathematics includes construction of data bases, computer graphics, computational physics and data analysis, mathematical modeling, and mathematical analysis of differential and integral equations resulting from physical problems.

The computer center serves the Laboratory by constantly upgrading its facility and by providing day-to-day service.

The scientific staff of the Division is composed of staff and faculty (UCB) senior scientists, divisional fellows, term appointees, postdoctoral students, and graduate students. The graduate students contribute substantially to the Laboratory's research program while fulfilling the requirements for their advanced degrees.

EXPERIMENTAL AND THEORETICAL PHYSICS

ASTROPHYSICS

A. Buffington
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D. M. Chew
R. P. Ely
G. Gidal
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L. Smith
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M. Suzuki
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J. A. Kadyk
K. H. Nguyen
F. Pierre
G. H. Trilling
J. S. Whitaker
F. Winkelmann

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Karlyn Wright
D. H. Zurlinden

1. EXPERIMENTAL PHYSICS

1. EXPERIMENTAL PHYSICS

HIGH ENERGY PHYSICS

ANNIHILATION OF E^+E^- AT SPEAR

MARK I MAGNETIC DETECTOR. The LBL-SLAC collaboration has continued its successful study of e^+e^- annihilation at SPEAR. The most important results obtained during the year are the discovery of charmed mesons, the further determination of the radiative decay rates of $\psi(3684)$, and determination of properties of the intermediate states reached in radiative transitions. The latter show a close correspondence to the $c\bar{c}$ bound state model (charmonium). The charged and neutral mesons D^0 and D^+ were found and shown to have decay modes consistent with selection rules for charmed meson decays. In addition, it was shown that the decays are parity violating, indicating a weak interaction.

Determination of the properties of the χ states, the intermediate states between the $\psi'(3.7)$ and the $J/\psi(3.1)$, was attacked from two points of view. First, by a direct measurement of the photon spectrum in ψ' decay, obtained by studying the electron pair spectrum from photons converted in the vacuum pipe and cylindrical counter of the SLAC-LBL detector. This method allowed a measurement of the direct transition rate to $\chi(3500)$. And secondly, by identifying several hadronic decay modes of the χ states by applying fitting techniques, originally developed for bubble-chamber work, to the SLAC-LBL detector at SPEAR.

A careful study of SPEAR data in the 3.9-4.6 GeV energy region led to the discovery, in May 1976, of a new narrow particle at a mass of 1.865 GeV decaying to $K\pi$ and $K3\pi$ final states. Subsequent work has revealed, beyond any reasonable doubt, that this is the long sought-after charmed meson predicted by S. L. Glashow and co-workers. The experimental results that lead to this conclusion are as follows:

1. There is a definite threshold for the production of this new particle at $E_{cm} > 3.1$-3.7 GeV.

2. The particle is produced in associated production with another of equal or higher mass.

3. A charged counterpart, observed at a slightly higher mass, decays only in an exotic mode into $K\pi\pi$.

4. A comparison of the three-body and two-body decay shows parity violation and hence a weak decay.

5. In the recoil spectrum the first excited state has been observed at a mass of 2006 MeV, and evidence for higher excited states at about 2430 MeV has also been found.

6. The study of the recoil spectrum puts an upper limit of 5 MeV on the width of the ground state as well as on the first excited state.

7. While a definitive spin measurement has not as yet been made, all indications point to spin zero for the ground state and spin one for the excited state.

As noted above, a pattern of behavior has been found which fits the charm model precisely, one that would be very hard to achieve by other means.

Staff, in collaboration with SLAC:

(G. S. Abrams, W. Chinowsky, R. G. DeVoe, C. Friedberg, G. Goldhaber, J. A. Kadyk, R. J. Madaras, K. H. Nguyen, C. Pang, F. Pierre, B. Sadoulet, S. R. Shannon, G. H. Trilling)

Graduate Students:

(M. Coles and S. Cooper)

LEAD-GLASS WALL EXPERIMENT AT SPEAR. The lead-glass wall is a particle detector sensitive to photons and electrons. The primary aim of this experiment is to search for events that may arise from
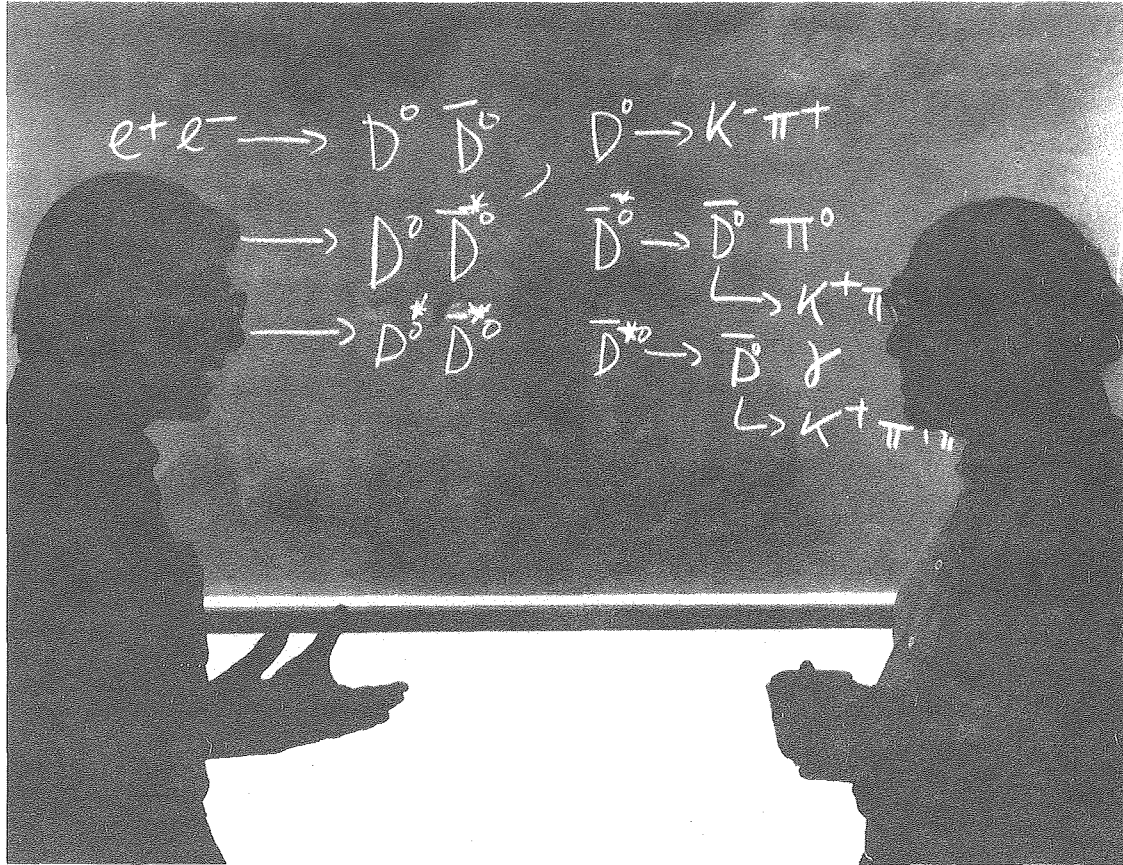
UCB–LBL scientists George Trilling and Gerson Goldhaber discuss production and decay processes of D^0 and D^+ charmed particles.

CBB 765-4012
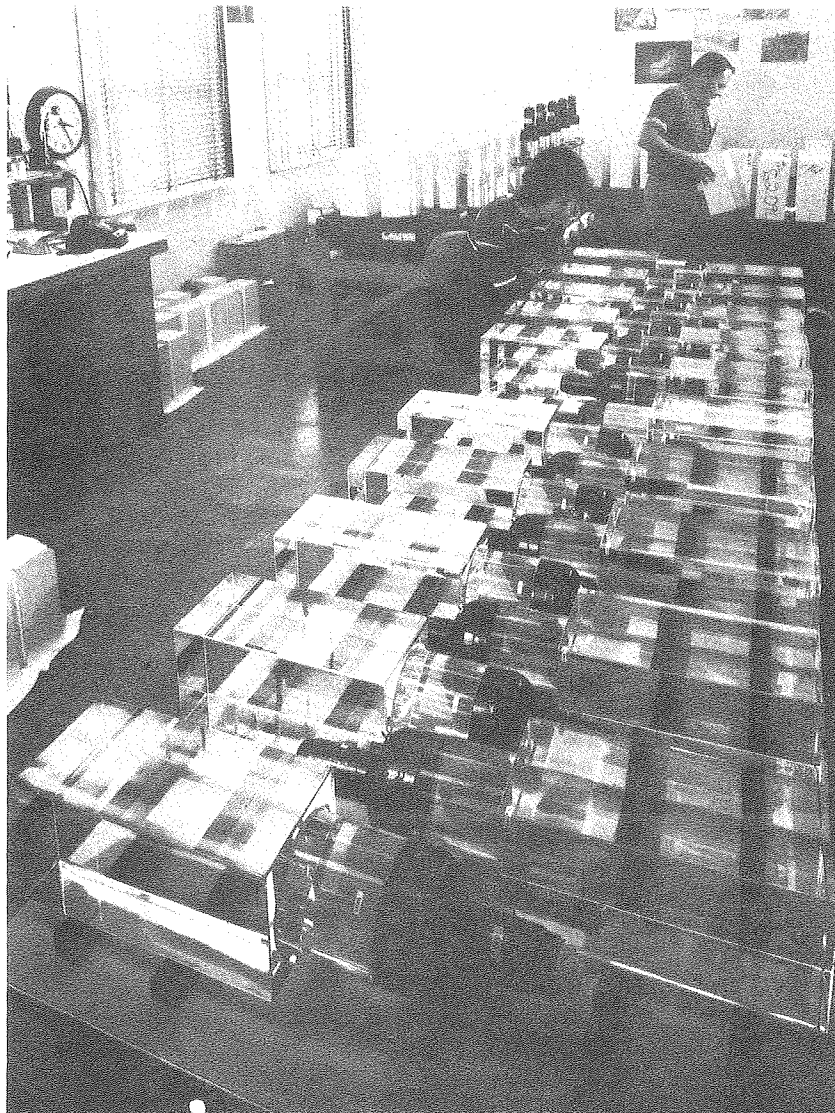
LBL senior scientist Angela Galtieri inspects elements of
the lead glass wall.

the production and decay of new particles (charmed particles, heavy leptons, or possibly new objects). During this year all apparatus was assembled, a monitoring system was developed to check its functions, and programs were constructed for data handling. Data-taking will continue at SPEAR until about 300,000 hadronic events have been recorded.

Staff, in collaboration with Northwestern University, SLAC, and University of Hawaii:

(A. Barbaro-Galtieri, R. Ely, B. Gobbi, P. LeComte, R. Madara, B. Pardoe, M. Ronan, R. Ross, T. Trippe, V. Vuillemin)

Graduate Students:

(J. Feller and A. Fong)

Mark II Magnetic Detector.

LBL has undertaken a major share of the construction of the Mark II detector at SPEAR. This effort includes work on the liquid argon lead shower counters for the Mark II detector, and the development of a software package for both the drift chamber system and the shower counters at Mark II. In this respect Mark II differs sufficiently from Mark I so that a completely new start in software systems must be made.

The LBL Mark II Liquid Argon Project is engaged in tests, design, and checkout of shower counters and components. Tests of a prototype design with small scale (area 1 ft^2) model were performed in January 1976. The results of these tests confirmed the high resolution, long-term stability, and rugged performance of such devices. It was shown that energy resolution approaching that of lead glass could be obtained and that electron/pion separation was also quite good. Testing and checkout of components will proceed through the summer of 1977. Detailed tests are planned to study possible degradation of performances in the large-scale liquid argon array relative to prototype results.

Staff, in collaboration with SLAC:

(G. S. Abrams, C. Broll, W. C. Carithers, W. Chinowsky, R. G. DeVoe, G. Goldhaber, J. A. Kadyk, C. Pang, S. R. Shannon, and G. H. Trilling)

Graduate Students:

(C. Blocker, M. Coles, S. Cooper, and R. Millikan)

Time Projection Chamber and Associated Superconducting Solenoid

The time projection chamber (TPC), based on powerful new detector concepts, is conceived as the central element of the PEP facility. The TPC will provide three dimensional spatial data about the configuration of particles produced in electron-positron collisions. In addition, mass measurements of charged particles and good momentum measurements are also readily obtained. Generally, particle detectors based on TPC concepts will be of importance wherever storage ring accelerators are used.

The TPC will require the use of superconducting solenoids with a conducting bore tube. The momenta of charged particles from a collision will be measured inside the coil, using the resulting magnetic fields; additional information about charged or neutral particles that have traversed the coil will be collected by other detectors (Cerenkov, shower counters, etc.) outside the coil. Diameters of 2 to 3 m are typical for these superconducting solenoids.

Activity this year involved the construction and operation at the Bevatron of two TPC prototypes using conventional magnets. These detectors were designed to provide new data on energy loss in ultrathin gas samples by comparing electrons and pions and, most importantly, to demonstrate the feasibility of the TPC concept. In addition, tests of the idea of using conducting bore tubes for the superconducting solenoids were made. By inducing quenches artificially in solenoids built using this technique, it was found that the magnets behaved as expected and that simple rules could be developed for their operation so that the possibility of burnout during a quench is avoided.

Staff, in collaboration with groups at UCLA, Yale, Johns Hopkins, and UC Riverside:

(W. C. Carithers, A. R. Clark., O. Dahl, P. Eberhard, D. Fancher, A. Barbaro-Galtieri, M. Garnjost, M. A. Green, R. W. Kenney, L. T. Kerth, P. LeComte, S. Loken, G. Lynch, R. Madras, J. Marx, D. Nygren, P. Oddone, P. Robrish, M. Ronan, G. Schnurmacher, G. Shapiro, M. L. Stevenson, M. Strovink, J. D. Taylor, V. Vuillemin, W. Wenzel)

PEP Experimental Area Coordination

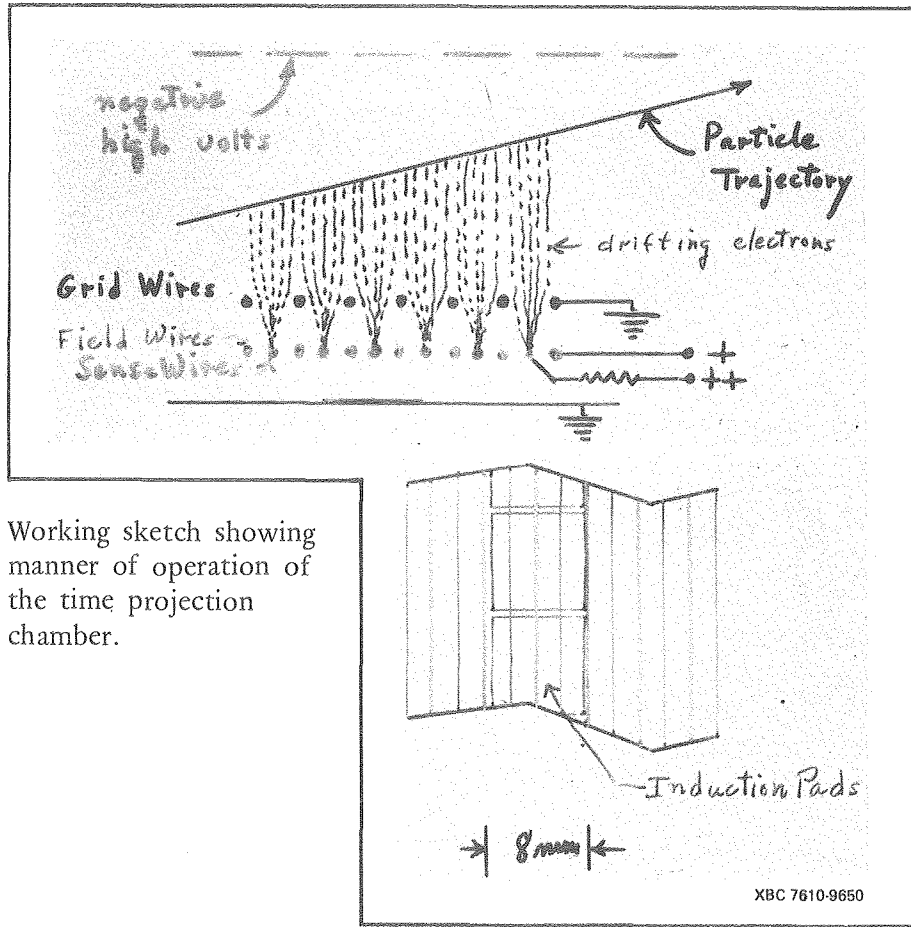The PEP experimental area coordination group is concerned with the following activities:

CBB 767-6700

LBL team working on development of supercon-
ducting solenoids to be used in conjunction with
PEP detectors.

Working sketch showing manner of operation of the time projection chamber.

XBC 7610-9650

CBB 760-10480

LBL physicists William Wenzel and David Fancher at work on prototype time projection chamber.

1. The design of the PEP experimental area

2. The solution of technical problems associated with the interaction of the machine and the proposed experiments

3. The interfacing of users and the PEP machine

4. The development of support systems for PEP experiments such as on-line computers, real-time links to the main computer center, cryogenic support for superconducting magnets, and the design of systems for access and movement of detectors

5. The evaluation of the effect of proposals on PEP resources and equipment funding

In the future, as experiments and facilities are approved and developed, the group will provide the coordinating function necessary for utilizing LBL resources in the PEP experimental program.

The conceptual design of the experimental areas has been completed. A series of experiments on radiation shielding was carried out at SLAC to determine the most economical and effective shielding configurations for the experimental halls. The present design represents both a significant departure from and a major improvement over the original design.

Computer programs have been developed to study the effects of magnets on the ring operation. These programs have been used to check all the proposed magnets. Calculations on synchrotron radiation backgrounds and on masking arrangements have been carried out to help users design the vacuum chambers for their experiments. Backgrounds due to beam-gas collisions have also been calculated in order to aid experimental design.

Planning work leading to the choice of the on-line computer systems for PEP will soon be completed. A preliminary plan for the construction of a link from the on-line PEP computer to the CDC 7600 has been finished. Planning activities leading to the design of the cryogenic plant for superconducting magnets is also under way.

LBL Staff:

(A. Clark, P. Nemethy, and P. Oddone)

SLAC Staff:

(B. Anderson, B. Ash, J. Brown, H. DeStaebler, and J. Murray)

STUDIES OF NEUTRINO INTERACTIONS

The External Muon Identifier consists of a set of multiwire proportional chamber particle detectors placed behind the FNAL 15-ft bubble chamber. The identifier is of prime importance in the study of neutrino interactions using the muon neutrinos produced there. Evidence for the semi-leptonic decay of charmed mesons and branching ratios for such decays relative to the total decay rate was obtained this year. An LBL data analysis system was developed for these studies.

A search similar to the one described above but using anti-neutrinos was in progress during 1976. Evidence has already been obtained showing that anti-neutrinos are less effective in producing charmed mesons. Work is also under way on an intensive search for di-muon events; such events would suggest the existence of new mesons containing quarks heavier than those having charm and exhibiting another property similar to strangeness and charm.

Staff, in collaboration with University of Hawaii, University of Wisconsin, and CERN:

(W. Koellner, G. Lynch, and M. L. Stevenson)

Graduate Students:

(J. Marriner and J. Orthel)

STUDIES OF RATE MUON REACTIONS AT FNAL USING THE MULTI-MUON SPECTROMETER

An exploration of rare muon-induced reactions at FNAL has been planned for some time. Construction and testing of the proportional chambers, trigger counters, and associated electronics is well under way. Tests on a group of calorimeter counters were carried out both at SLAC and at Fermilab to verify predicted operating characteristics of the counters. The steel plates and coil assemblies for the magnet were fabricated and delivered to Fermilab. Access to the muon laboratory for the installation of this experiment was gained in February 1977, and installation of the magnet has begun. The Fermilab schedule calls for

XBB 764-3632
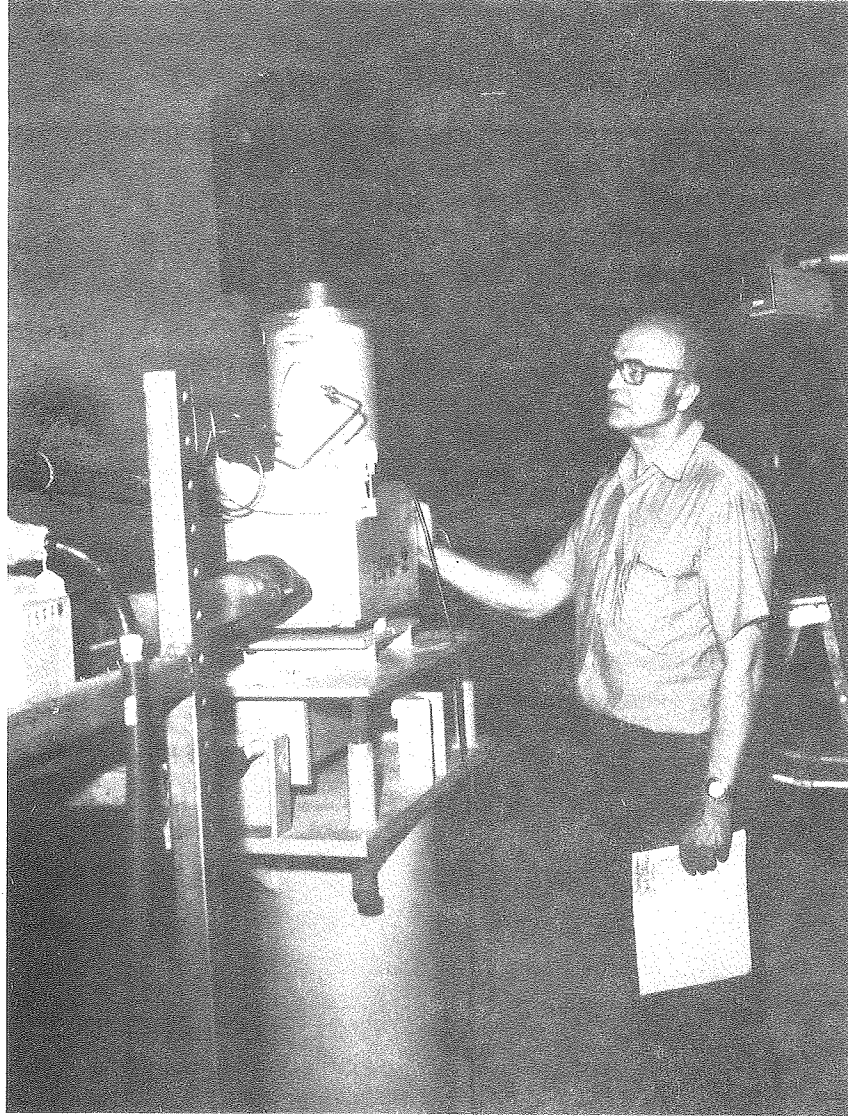
LBL senior scientist Jack Peterson inspecting component
of prototype PEP accelerator.

the magnet to be completed in April with magnet test-ing, magnetic field mapping, and installation of the proportional chambers and counters to follow. Final checkout of the apparatus and test runs to deter-mine trigger rates will be completed during the summer of 1977.

Staff, in collaboration with Fermilab and Princeton University:

(A. R. Clark, L. T. Kerth, S. C. Loken, M. Strovink, and W. A. Wenzel)

Graduate Students:

(T. Markiewicz, P. Meyers, and W. Smith)

Pion Scattering from Polarized Targets

A study of polarization effects in elastic scattering on protons at FNAL energies produced data at 100 GeV (secondary beam energy). About equal numbers of π^+, π^-, and p were incident on the polarized proton target. Preliminary results show polarization is small, as expected, and there seem to be no disagreements with Regge theory. That is, the polarization is smaller than that at lower en-ergies by about the amount expected according to Regge theory. It is hoped that the 100 GeV π-ρ results will be completed. The results on p-p polarization are currently under suspicion because the incident beam may have been polarized to an ex-tent as yet unknown.

Staff, in collaboration with Harvard:

(W. Brucker, O. Chamberlain, G. Shapiro, and H. Steiner)

Inclusive Production of Neutral Mesons in π^-p Collisions at FNAL

This project concerns π^-p reactions in the momentum range of 20 to 200 GeV/c. The reactions under investigation are (1) $\pi^-p \to \pi^0n$; (2) $\pi^-p \to \eta n$; (3) $\pi^-p \to \pi^0$ + anything; and (4) $\pi^-p \to \pi^0$ + neutrals. Three different investigations are possible by al-tering the configuration of particle detectors. These are (1) an investigation of Regge trajectories, (2) studies of models for production mechanisms, and (3) a test of the triple-Regge formalism inclusive cross sections.

The first two reactions are classic from the point of view of Regge theory since each is dominat-ed by the exchange of a single Regge trajectory, the ρ and the A_2, respectively. Studies of these same reactions at large transverse momenta provide the first detailed comparison between these reactions at high energies and should yield significant informa-tion about the possible quark or parton of the par-ticles involved in the reactions.

The triple-Regge formalism has been successful in fitting the p-p inclusive cross sections but since there are so many parameters this is not a very con-clusive test. The corresponding prediction for the $\pi^-p \to \pi^0$ + anything reaction is simple by comparison, and measurement of this inclusive cross section should provide a definitive test of the theory.

Staff, in collaboration with CIT:

(O. Dahl, R. Kenney, R. Johnson, M. Pripstein, and S. Shannon)

Graduate Students:

(R. Hamilton and A. Ogawa)

High Energy πp Interactions at SLAC

Work is about finished on the diffractive pro-duction and decay of nucleon isobars produced by 14 GeV/c pions. Counters and wire spark chambers were used to trigger the SLAC 40-in H_2 bubble chamber on pictures with a fast outgoing track of more than 8 GeV/c. The external measurements of the fast for-ward track allow both an efficient trigger and in-creased resolution.

In addition, an ambitious program to study interference between the pion exchange amplitudes and the diffraction amplitude is under way.

Staff, in collaboration with CIT and SLAC at SLAC:

(R. Ely)

Search for Baryon Resonances at BNL

Low energy k^-p and $\bar{p}p$ scattering has been studied at BNL to search for baryon resonances in the $\bar{K}$-nucleon system. A run is planned in 1977 to measure the momentum dependence of the 180° differ-ential cross section for the reactions $k^-p \to k^-p$

and to $\Sigma^+\pi^-$ and $\Sigma^-\pi^+$ from 500 to 1100 MeV/c to clarify the spectrum of hyperon resonances in this region.

Staff, in collaboration with Mt. Holyoke and CERN:

(M. Alston-Garnjost, R. Kenney, B. Pardoe, S. Shannon, and R. Tripp)

Graduate Students:

(R. Hamilton, R. Johnson, and D. Pollard)

High Energy p-p Interactions at FNAL

An exploratory program to study p-p interactions at high energies is under way. The 15-ft bubble chamber is being used. The first phase of this program is to develop scanning and measuring techniques and to develop reconstruction programs. These are being tested on a 25,000 picture exposure of 400 GeV/c protons in hydrogen.

In order to facilitate the measurement of the complicated events in this film, one of the dual magnification scan tables which were developed last year has been interfaced to the IBM 7044 COBWEB system. Digitized points on each track are recorded and used to drive the measuring machines. This provided an ambiguous track identification on the measuring machine and uses the stereo pair track matching from the scan table. This combined hardware and software development has been christened CICERO.

The objective of the present program is to measure all events with one or more neutral strange particle decays or gamma-ray conversions to e^+e^- pairs and four-pronged and six pronged events. To date about 2500 events have been processed.

Staff:

(R. P. Ely, G. Gidal, and W. Michael)

Graduate Student:

(P. R. Hanson)

Baryon Exchange Reactions at the Bevatron

This experiment was designed to study baryon exchange mechanisms in backward π^-p inelastic scattering around 4 GeV/c. A large aperture Cerenkov counter and hodoscope were used to trigger the LBL streamer chamber on interactions producing a fast forward proton or K^+.

The final results of this experiment:

1. Production and decay distribution of backward π^- and ρ^- mesons

2. Fixing of 5 μb upper limits on backward A_1^-, A_2^-, and B^- production

3. Demonstration of strong interference between ϕ^- and $\omega^{*0}(1670)$ states in the $p\pi^-\pi^0$ final state and comparison with a Regge phase prediction

4. A test of time reversal in the reaction $\pi^-p \rightarrow K^+\Sigma^-$

5. A study of backward production of neutral mesons, π^0, η^0, ω^0, ρ^0, f^0; their production and decay distributions were also investigated

6. A study of the reactions $\pi^-p \rightarrow \Lambda^0\pi\pi$ and $\pi^-p \rightarrow \Lambda^0 K\pi\pi$ where a fast forward Λ^0 is also made

Staff:

(J. Chapman, R. Ely, G. Gidal, W. Michael, and P. Oddone)

Graduate Student:

(D. Scharre)

Analysis of πp Elastic and Charge Exchange Scattering

Using all available data up to 2.4 GeV center-of-mass energy, a Barrelet moment analysis, which expresses the results in terms of the location of Barrelet zeros, was performed. Systematic experimental errors are revealed by the moment analysis, thus making possible a selection of the most reliable data. A surprising and still not understood result is that best charge-exchange data imply important contributions from substantially higher J than the best πp elastic scattering data at the same energy.

By a combination of unitarity and causality consideration, encouraging progress has been made toward resolving the Barrelet-zero discrete ambiguity and toward translating information about zeros into information about resonances.

Staff:

(D. M. Chew)

1976 Publications: High Energy Physics

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Bell's Theorem Without Hidden Variables.
 P. H. Eberhard, LBL-4888, May 1976, to be published in Nuovo Cimento.

Calibration and Monitoring of a Large Lead-Glass Counter System.
 R. Madaras, A. Barbaro-Galtieri, J. Dorfan, R. Ely, G. Feldman, J. Feller, A. Fong, B. Gobbi, G. Hanson, F. Heile, J. Jaros, B. Kwan, P. LeComte, A. Litke, D. Lüke, J. Martin, T. Mast, D. Miller, B. Pardoe, S. Parker, M. Perl, I. Peruzzi, M. Piccolo, T. Pun, P. Rapidis, M. Ronan, R. Ross, B. Sadoulet, T. Trippe, V. Vuillemin, D. Yount. Abstract submitted to American Physical Society Meeting, Washington, D.C., April 25-28, 1977.

CICERO or The On-Line Scanner and the Guided Franckenstein.
 W. Michael, et al., December 1976, UCID-3880.

Communication at the Applied Superconductivity Conference.
 P. H. Eberhard, M. Green, W. Michael, J. Taylor, and W. Wenzel. Conference, Stanford, CA, August 1976, LBL-5364.

Communication at the International Cryogenic Engineering Conference.
 M. Green, P. H. Eberhard, and J. Taylor, Conference, Grenoble, France, 1976, LBL-4824.

Communication at the Thinkshop on Physics: Experimental Quantum Mechanics.
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THE PARTICLE DATA GROUP

The Particle Data Center is involved in the six major activities described below:

● Compilation of particle properties, and the issuance of "Review of Particle Properties," with its associated data booklet.

● Compilation of descriptive and bibliographic information on current high energy physics experiments and on preprints and published articles; and issuance of indexed guides to current experiments and the current literature.

● Maintenance of a data base of compiled high energy physics data. Periodic issuance of reports and tapes covering these data.

● Development of a computerized data base management system to store, maintain, update, retrieve, and display the compiled information referred to above.

● Development of statistical techniques of data analysis with applications to πp scattering data.

● Support of individual participation in outside research projects, to the extent necessary to maintain the expertise of group members in their respective fields.

Accomplishments in each of six activity areas are outlined in the following paragraphs.

PARTICLE PROPERTIES.
The "Review of Particle Properties" was published.

HIGH ENERGY PHYSICS.
An indexed compilation of detailed descriptions of all current high energy physics experiments at major laboratories throughout the world was published. Progress was made in assembling the data base for a similar document for published articles; publication is scheduled for FY78. Annual publication of an updated version of the compilation of experiments will continue and similar reissues of the catalog of published articles are planned.

HIGH ENERGY PHYSICS DATA.
Compilations assembled by outside collaborators (at the California Institute of Technology, Durham University, Glasgow University, McGill University, and Rutherford Laboratory) are being incorporated into our data base for experimental reaction data. A flexible language for encoding all such data has been completed and is being used by our collaborators. Work on special processors to standardize the data and make it easily accessible is proceeding.

DATA-BASE MANAGEMENT SYSTEM.
The first generation of the Berkeley Data Base Management System became operative in 1976 and was used to produce LBL-91.

STATISTICAL TECHNIQUES APPLICABLE TO πP SCATTERING.
Techniques for amalgamation of πp scattering data have been developed and applied to existing data for the energy range of 800 to 2000 MeV/c.

INDIVIDUAL PARTICIPATION IN OUTSIDE RESEARCH.
Several members of the group are active in research projects, both with LBL and with outside collaborators. These projects include (1) the lead-glass wall experiment at SPEAR to study neutral particle production and anomalous electron production in e^+e^- annihilation; (2) the CMU-LBL partial wave analysis collaboration which published results on Δ resonance parameters, a Z^* search, and preliminary results of a πN partial wave analysis in the 1-2 GeV/c region in 1976; (3) deuterium bubble chamber experiment to study absorption effects and structure in πN systems produced in $\pi^+ n \rightarrow \pi^+ \pi^- p$ at 15 GeV/c; and (4) pion and anti-neutrino beam bubble chamber experiments at SLAC and FNAL.
Staff:

  (R. Crawford, C. Horne, R. Kelly, A. Rittenberg, A. Rosenfeld, T. Trippe, C. Wohl, and G. Yost)

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MEDIUM ENERGY PHYSICS

The reaction of negative kaons and pions with
molecules, atoms, and nuclei is being investigated
over a wide range of chemical compounds and ele-
ments. Measurements of the energies and intensi-
ties of the emitted x-rays are used to determine
properties of the kaon-nucleus interaction. A sort
of "mesic chemistry" is evolving that may have
applications to solid state and atomic physics.

PIONIC X-RAYS

Pionic x-rays from a target of liquid argon
were found to be emitted isotropically. If the
pions had been captured into atomic states when
their kinetic energies were high enough to impart
definite angular momentum to the pionic atoms, x-
rays could have been emitted in a preferred direc-
tion with respect to the incoming beam. If an iso-
tropy had been observed, it would have led to im-
portant conclusions concerning the little-understood
formation of mesonic atoms.

Pionic x-ray intensities of two hydrides were
compared to their corresponding deutrides. It had
previously been observed that kaonic x-ray emissions

from some elements were unexpectedly inhibited when
their hydrides were used as targets. Attachment of
a neutron to the proton caused a slight diminution
of the x-ray intensities, possible because the deu-
trons, being heavier, lingered inside the atoms long-
er than the protons.

Staff:

(C. Wiegand)

Graduate Student:

(G. Lum)

MESON AND LIGHT NUCLEI STUDIES

Mesons and light nuclei have been used to
study the properties of the fundamental interactions
and to investigate the details of nuclear structure.
The program has shifted from the 184-in cyclotron to
the Bevatron, with future experiments scheduled at
LAMPF and TRIUMF.

Recent studies have included: a test of time-
reversal invariance in the reaction $pd \to {}^3He \, \gamma$; a mea-
surement of the axial vector form factor in radiative
pion decay; use of the muon to probe the fission bar-
rier in ${}^{238}U$; and extensive studies of elastic scat-
tering in the p-${}^4He$, p-d, and ${}^4He$-${}^4He$ systems. The
elastic scattering experiments are being extended to
the p-${}^3He$ and d-d systems, and a further expansion
of the nuclear wave function studies will include
measurements of elastic polarization in d-p, ${}^3He$-p,
and ${}^4He$-p scattering.

PION RADIATIVE DECAY.
The branching ratio of
the decay $\pi^+ \to e \nu \gamma$ has been measured to be (5.6 ± 0.7)
$\times 10^{-8}$, and the ratio of axial vector to vector form
factors was determined to be (0.44 ± -0.12) or
(-2.36 ± 0.12). The results are in disagreement with
the results of the naive quark model, which require
the ratio to be zero.

TIME REVERSAL INVARIANCE.
A test was made of
time reversal invariance in the reaction
$pd \to {}^3He \gamma$. Results obtained from comparisons of
the angular distributions and the absolute cross
section (not available in earlier tests) were con-
sistent with validity of T invariance. The sensi-
tivity of the parameter-free comparison was about
5 percent in cross section.

ISOBAR SUPPRESSION IN $pd \rightarrow {}^3He \, \pi^0$. The differential cross section for $pd \rightarrow {}^3He \, \pi^0$ has been studied at energies spanning the $\Delta(1238)$ resonance. In contrast to the similar reaction $pp \rightarrow d\pi^+$, no pronounced effects of the resonance are visible in the cross section.

FISSION STUDIED WITH μ MESONS. An experimental program to study interactions of muons with fissile actinide nuclides was begun. Of particular interest is the double-humped fission barrier, its role in the muon capture process, and the possibility of measuring the parameters of the shape-isomer potential. The capture of μ^- in ${}^{238}U$ was used to search for back decay gamma rays from the shape isomer. Results were consistent with significant excitation of the isomer during the muon cascade.

NUCLEAR STRUCTURE STUDIES. Forward elastic cross sections in the p-${}^4He$ system have been measured at (equivalent) proton kinetic energies of 0.4, 1.05, 2.68, and 4.89 GeV. The measurements cover the region of the first interference minimum and, at the highest energy, also extend well beyond the second minimum. Analysis of most of the data has been completed. Our results show:

1. A rapid change with energy below 1.0 GeV
2. A shallow minimum at 1.05 GeV, in agreement with the recent results from Saclay, but also provide a good absolute normalization and an accurate measurement of the locations of the minimum
3. Very little change in the cross section between 1.05 and 2.68 GeV
4. A rapid decrease in the cross section from 2.68 GeV to 4.89 GeV

The data should yield considerable information about the helium wave function and about the behavior of the nucleon-nucleon amplitudes in this energy range. The 1.05 GeV results have been submitted to Physical Review Letters, and the 2.68 GeV results to Physics Letters. A description of the experiments and a compilation of all the results will be prepared for publication in Physical Review.

Staff, in collaboration with UCLA:

(J. Carroll, S. Kaplan, D. Ortendahl, V. Perez-Mendez, A. Sagle, and R. Talaga)

Graduate Students:

(B. Director, K. C. Tam, E. Whipple, and F. Zarbaksh)

LOW ENERGY PIONS AND MUONS

Other studies using low energy pions and muons are also concerned with their intrinsic properties and with their use as probes for nuclei and condensed materials.

RADIATIVE PION CAPTURE. The study of radiative pion capture, that is, the measurement of the high energy gamma ray spectrum produced when pions are captured in nuclei, has been approached from several different points of view.

First, the understanding of basic quantitative structure of the photo-pion transition operator has been accurately fixed by a comparison of theory with measurements on a series of light nuclei. Second, the results have been compared with those from electron scattering and photo-pion production near threshold and muon capture processes on the same nuclei. Only recently have these comparisons led to a consistent set of constants. Third, a new set of reactions has been chosen to use this as a probe to study the excited states of nuclei. The new phenomena which have been seen are giant dipole states, possible quadrupole excitations, and other more complex states. Fourth, since radiative pion capture has been shown to induce the same Gamow-Teller transitions as the axial-vector part of ordinary muon capture, it is expected that the matrix elements for the transitions to bound states (e.g., $\pi^- {}^6Li \rightarrow {}^6He\gamma$, $\pi^- {}^3He \rightarrow T\gamma$, $\pi^- {}^{12}C \rightarrow {}^{12}B\gamma$) can be combined with information from other weak and electromagnetic processes dealing with the same state to test predictions from CVC, PCAC, etc.; for example, the Goldberger-Treiman relation for the nuclear case.

GAMMA RAY SPECTRA. The systematic study of gamma ray spectra from the capture of negative pions in nuclei has been an ongoing program. The current studies are of the light nuclei ${}^3H$ and ${}^{20}Ne$.

Staff:

(K. M. Crowe, J. Miller, S. Rosenblum, and P. Rowe)

1976 Publications: Medium Energy Physics

The Application of High Energy Physics Techniques in Medical Research.
V. Perez-Mendez. LBL-3851 - IEEE Trans. Nuc. Sci. NS-23 (August 1976) 1334-1343.

Axial Tomography and Three-Dimensional Image Reconstruction.
L.T. Chang, B. Macdonald, and V. Perez-Mendez. LBL-3872. IEEE Trans. Nuc. Sci. NS-23 (Feb. 1976) 568-572.

Comparisons of Coded Aperture Imaging Using Various Apertures and Decoding Methods.
L.T. Chang, B. Macdonald, and V. Perez-Mendez. Lawrence Berkeley Laboratory, Berkeley, California. LBL-5342 (1976) - Proceedings of Applications of Optics in Medicine and Biology, San Diego, California, August 1976 - SPIE Vol. 89.

Determination of the Axial-Vector Form Factor in the Radiative Decay of the Pion.
A. Stetz, J. Carroll, D. Ortendahl, V. Perez-Mendez, G. Igo, and M. Nasser. LBL-5393 (Ph.D. Thesis; D. Ortendahl). To be published in Phys. Rev.

The Elastic Scattering of α Particles from Helium at 0.85 and 0.65 GeV.
J.C. Fong, M. Gazzaly, G. Igo, A. Lieberman, R. Ridge, S. Verbeck, Ch. Whitten, V. Perez-Mendez, and W.R. Cocker. Nuclear Physics A262 (May 1976) 365-371.

Experiments on Hadronic Atom X-ray Intensities of Hydrides and Deuterides.
C.E. Wiegand, G.K. Lum, and G.L. Godfrey, LBL-5389 (scheduled for Phys. Rev. A, April 1977).

High Efficiency Gamma Converters and Their Application in a MWPC Positron Camera.
D. Chu, K. Tam, V. Perez-Mendez, S. Kaplan, C. Lim, R. Hattner, L. Kaufman, D. Price, and S. Swann. LBL-5516. To be published in Proc. IAEA Symposium on Medical Radio Nuclide Imaging (Los Angeles - Oct. 1976).

Negative Muon Capture in Ionic Compounds and Some Related Elements.
L.F. Mausner, R.A. Nauman, J.A. Monard, and S.N. Kaplan. LBL-5544 - To be published in Phys. Rev. A (March 1977).

New Developments in Nuclear Medicine Imaging.
V. Perez-Mendez. LBL-6114 - Published in Proceedings, First Asia and Oceania Congress of Nuclear Medicine, Sydney, Australia, September 1976.

Observation of Dynamic E2 Mixing via Kaonic X-ray Intensities.
G.L. Godfrey, G.K. Lum, and C.E. Wiegand. Phys. Letters 61B, 45 (1976).

Observed Isotropy in Pionic Argon X-ray Angular Distribution.
G.K. Lum, C.E. Wiegand, and G.L. Godfrey, Phys. Letts. 65B, 43 (1976).

P + ^{4}He Elastic Scattering at 2.68 GeV.
M. Nasser, M. Gazzaly, J. Geaga, B. Hoistad, G. Igo, J. McClelland, A. Sagle, H. Spinka, J. Carroll, V. Perez-Mendez, E. Whipple. LBL-6125. To be published Phys. Letters.

P-^{4}He Elastic Scattering at 1.05 GeV.
J. Geaga, M. Gazzaly, G. Igo, J. McClelland, M. Nasser, A. Sagle, H. Spinka, J. Carroll, V. Perez-Mendez, and E. Whipple. LBL 6127. To be published in Phys. Rev. Letters.

P + He Scattering at T_p (Lab) = 0.4, 1.05, 2.68, and 4.89 GeV.
M. Gazzaly, J. Geaga, B. Hoistad, G. Igo, J. McClelland, M. Nasser, P. Qillataguerre, A. Sagle, H. Spinka, M. Strang, J. Carroll, V. Perez-Mendez, and E. Whipple. LBL-6126. To be published in Phys. Rev.

Radiative Formation of ^{3}He and a New Test of Time Reversal Invariance in the Electromagnetic Interaction.
C.A. Heusch, R.V. Kline, K.T. Macdonald, J. Carroll, D. Fredrickson, M. Goitein, B. Macdonald, V. Perez-Mendez, and J. Stetz. LBL-4688 (November 1975). Phys. Rev. Letters 37 (August 1976) 409-412).

A Scintillator Counter Hodoscope for Low Energy Light Ions.
J. Geaga, G. Igo, J. McClelland, M. Nasser, S. Sander, H. Spinka, J. Carroll, D. Fredrickson, V. Perez-Mendez, and E. Whipple. LBL-6124. To be published in Phys. Letters.

Shape Isomer Excitation by μ^- Atomic Capture.
S.N. Kaplan, J.A. Monard, and S. Nagamiya. LBL-5334, Physics Letters 64B (1976) 217-220.

A Study of the Reaction pd $\rightarrow$ ^{3}He π^0 in the Resonance Region.
D. Fredrickson, A.W. Stetz, J. Carroll, V. Perez-Mendez, R. Kline, and C.A. Heusch. LBL-4877. To be published in Nuc. Phys.

Techniques for Particle Identification and Energy Measurement of Helium Ions in the Intermediate Energy Range.
N. Chirapatpimol, J.C. Fong, M. Gazzaly, G. Igo, A. Lieberman, R. Ridge, S. Verbeck, C. Whitten, J. Arvieux, and V. Perez-Mendez. LBL-4691. Nucl. Inst. and Methods 133 (March 1976) 475-483.

Three-Dimensional Imaging with Large-area Positron Cameras.
V. Perez-Mendez, L.T. Chang, and B. Macdonald. Lawrence Berkeley Laboratory, Berkeley, California. LBL-5501 (1976). Proceedings-First Asia and Oceania Congress of Nuclear Medicine, Sydney, Australia, September 1976.

ASTROPHYSICS AND ASTRONOMY

The properties of compact astronomical objects (white dwarfs, neutron stars, black holes)

are being investigated. This work has been pursued by studying the short time scale behavior of these kinds of objects, both photometrically and spectrophotometrically. Fast photometry is well suited to the study of pulsations or flickering from these kinds of objects and is being used to explore their characteristics. More recently we have been using high speed spectrophotometry to further elucidate the nature of the objects under study. These experimental techniques require extensive computer analysis. Various programs to search for and study weak periodic signals are undergoing development and refinement to suit the objects under study. One interesting aspect of the objects results from their usually being found in close binary systems. The study of these accretion disks is becoming a significant part of our effort; such study is beginning now in earnest and should continue for the next several years. HZ Her-Her X-1 is an extremely important binary system to which we have devoted a substantial effort in the past. The pulsed optical spectrum from "reflected" light from HZ Her has been obtained, and the pulsed spectrum from the accretion disk is now being analyzed.

Another part of the astrophysics program at LBL is aimed at detecting and mapping the large-angular-scale anisotropies in the 3°K primordial black-body radiation to a sensitivity 10-20 times better than has been done previously. It will be possible to detect the motion of the earth (aether drift) with respect to the distant and ancient matter of the universe that emitted the primordial radiation. This motion is due to the rotation of the Milky Way Galaxy, as well as the orbit of the earth around the sun. It will be possible to detect rotation of the universe with respect to local inertial frames. In addition, it will be possible to detect anisotropies from irregularities in the primordial plasma which must have been present if current theories of galaxy formation are correct. Radiometers flown on a U-2 aircraft at 65,000 ft altitude are used to measure the radiation. Several flights made over a period of a year are necessary to understand the source of the anisotropy in detail. Fabrication of the experiment has been completed and Lockheed has finished modifying the U-2 upper hatch

to accommodate the experiment. The radiometers were installed in a U-2 mock-up and tested. After this initial checkout the instrument was then installed in the modified U-2 upper hatch and the equipment was tested in three flights. This year the first data were gathered. A series of data collection-flights spread out over a year has now begun. A satellite-borne version of this experiment is under study.

Work on astronomy is concerned with a project aimed at reducing greatly the atmospheric distortion in ground-based, optical astronomical telescopes. An optical element, called a "rubber mirror", capable of correcting the perturbed phase-front of the incoming light, and a feedback loop driven by an image plane sharpness definition are employed. Existing equipment may be used to measure properties of the perturbing atmosphere, resolve close binary pairs, and perhaps improve some planetary measurements. Future larger apparatus could greatly extend these measurements. A 12-inch telescope has been used to record diffraction-limited images of bright stars at Leuschner and Lick Observatories. Instrumentation improvements have increased the stability and convenience of the apparatus and have made possible an equatorial mount that should facilitate future measurements. The National Science Foundation has begun some support for the project.

Staff:

  (L. Alvarez, A. Buffington, T. Mast, J. Middleditch, R. Muller, J.E. Nelson, C. Orth, and G. Smoot)

Graduate Students:

  (G. Chanan, P. Lubin, and S. Pollaine)

1976 Publications: Astrophysics and Astronomy

The Geometry of the Eclipse of a Point-like Star by a Roche Lobe Filling Companion.
  Gary A. Chanan, John Middleditch, and Jerry E. Nelson, LBL-4290. Astrophysical Journal, Sept. 1976.

Measurement of the Spectrum of Optical Pulsations from HZ Hercules/Hercules X-1.
  Jerry Nelson, Gary Chanan, and John Middleditch, LBL-4815. To be published in the Astrophysical Journal, Feb. 1977.

XBB 779-9257
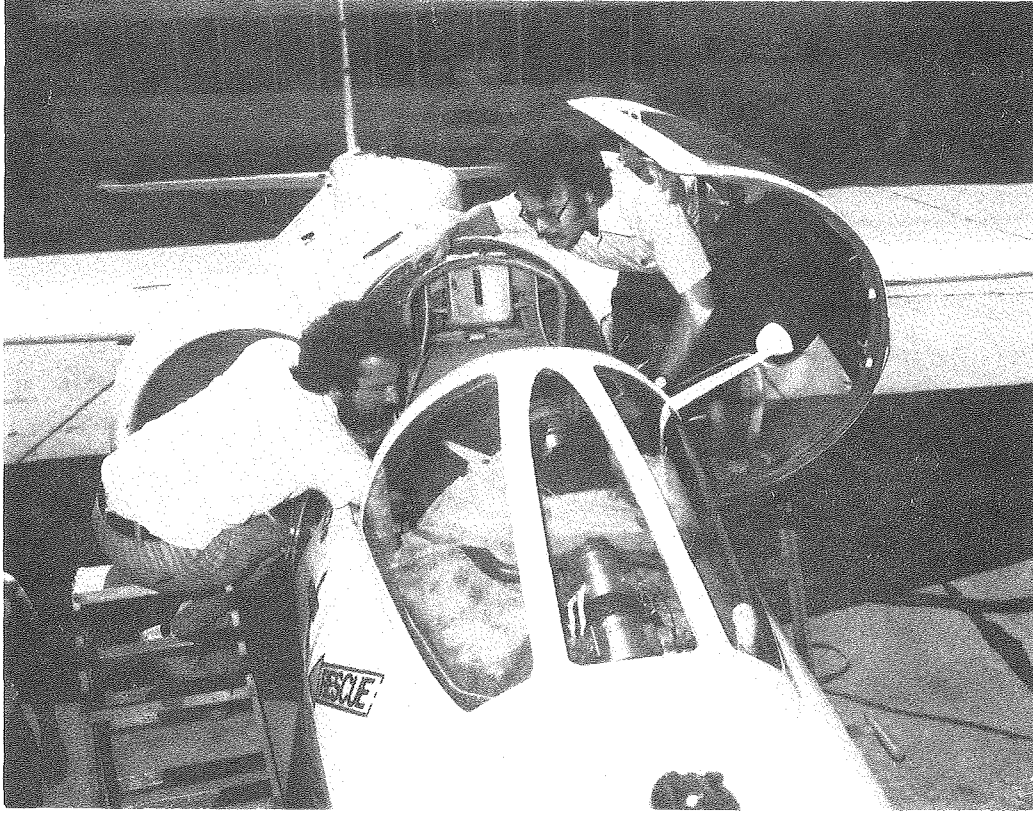
LBL scientists Richard Muller and Marc Gorenstein placing radiometer
aboard U-2 aircraft at Moffett Field, California.

A Spectrophotometric Survey of the A0535+26 Field.
Bruce Margon, Jerry Nelson, Gary Chanan, John
Thorstensen, and Stuart Bowyer. To be published
in Astrophysical Journal 1977.

Studies of Optical Pulsations from HZ Her-Her X-1:
A Determination of the Mass of the Neutron Star.
J. Middleditch and J. Nelson, LBL-4282. Astro-
physical Journal, Sept.. 1976.

Time Resolve Spectrophotometry of D Q Hercules.
Jerry Nelson, Gary Chanan, and Bruce Margon,
LBL-5556, to be published in the Astrophysical
Journal, 1977.

INSTRUMENTATION DEVELOPMENT

LARGE-SCALE DIGITIZER SYSTEM

The Large-Scale Digitizer (LDS) System, an
economical modular system for the simultaneous
digitization of analog data from hundreds of events
channels, has been a continuing activity since
FY76 when the first 320-channel charge-digitizing
system was successfully used in the lead-glass
wall experiment at SLAC. During FY 77, we will
install an additional 576 channels of charge digi-
tizer. Also, the time converter development was
completed, and 384 channels were fabricated and
installed for use in experiments and in drift
chamber studies at LBL. The circuitry for com-
bining groups of 16 wires into four TDC converters
has been designed and a prototype printed-circuit
board has been fabricated for final checkout.

CHARGE COUPLED DEVICES

Charge coupled device (CCD) analog shift
registers show great promise for use as buffer
storage devices for signals from drift chambers.
Purportedly, they can retain both analog
information and time correlation of signals ac-
quired at high clocking speeds, while later read-
ing out at slower clock speeds, or while pausing
for other decision logic to determine the valid-
ity of a potentially interesting event.

Since these devices are new and thus unproved
in applications such as these, it is necessary
to evaluate them. We have studied two seemingly
useful devices from Fairchild, the CCD 211 and the
CCD 321. The characterization measurements on
these devices are nearing completion and will

be published in mid FY 77. Indeed, the first
units procured did not perform to specifications
(probably because other users were not pushing to
this limit). Later units, however, show good promise.

EXTERNAL MUON IDENTIFIER DIGITIZER

In collaboration with Fermilab, we designed
a time digitizer module for use with delay line
read-out of multiwire proportional chambers used
as External Muon Identifiers. This digitizer
used the latest of high speed emitter-coupled-
logic memories in order to digitize directly at
the 28 MHz rate called for by the resolution re-
quirements of the experiment. Nine inputs allow
for time measurements from each end of x, y,
u, and v coordinate delay lines, and of the
reference timing pulse. Digitization over the
complete beam spill interval of the Fermilab
accelerator is accommodated via a tenth identifi-
able channel, which records each "wrap around"
of the 12-bit time-scaling binary counter. A pro-
totype instrument has been assembled, and is being
extensively tested.

PHOTOMULTIPLIER TUBE EVALUATIONS

Phototube evaluations, including microchan-
nel photo versions for ultra-precision timing, are
a continuing activity carried on within this pro-
gram. Similarly, research and development of a
solid state detector are supported by the program.

PHYSICS TECHNICAL SUPPORT OPERATION

About one-half of the total physics instru-
mentation effort is involved in day-to-day support
of pool-type instruments and systems presently
valued in excess of $2.5 million. These activi-
ties include operation of the counter equipment
pool, test and alignment of pool instruments, on-
line support of pool items, commercial equipment
evaluation, phototube and base handling, cable
shop activities, and training.

CID CONTROLLER

A clocking and readout controller module has
been developed for use with the charge injection

device (CID) video camera which is to be evaluated for use in direct viewing of streamer chamber tracks. The module receives analog video data from the camera, converts the video data to digital form, selects only "valid" data (i.e., data over a computer-adjustable digital threshold), buffer-stores the selected data in an FIFO (first-in first-out) memory, and provides interrupt and handshake protocol for data transfer within the CAMAC standard digital data busing system. By means of the preselection capability of this device, the number of data words per event is reduced from every pixel location in the 128 × 128 camera matrix to nominally 2k words for a five track event.

Drift Chamber Development

A set of two high-accuracy cylindrical drift chambers, one 88 cm in diameter and the other 82 cm in diameter, both 150 cm in length, were designed and built. The chambers operate at voltages such that the drift velocity of electrons is saturated, as was shown by tests using small chambers. The chambers are currently being used to gather cosmic ray data in order to determine the spatial resolution of these chambers. We expect final results early in FY77.

Staff:

(M. Alston-Garnjost, R. Althaus, R. Kenney, F. Kirsten, P. LeComte, K. Lee, B. Leskovar, C. Lo, J. Millaud, M. Nakamura, S. Olson, D. Ortendahl, V. Perez-Mendez, R. Ross, and L. Wagner)

1976 Publications: Instrumentation Development

Characterization of Charge-Coupled Analog Memories for Nuclear Data Acquisition.
F. A. Kirsten and E. Yazgan. To be published in 1977.

Evaluation of Factor Contributing to Position Accuracy in Delay Line Readout of MWPC.
V. Perez-Mendez, M. Greenstein, and D. Ortendahl. LBL-4800, IEEE Trans. Nuc. Sci. NS-24 (Feb. 1977).

Large-Scale Digitizer System, Analog Converters.
R. F. Althaus, et al., LBL-5357 and Proceedings of IEEE Nuclear Science Symposium, February 1977, Vol. NS-24, No. 1, pp. 218-220.

A Large-Scale Digitizer System (LSD) for Charge and Time Digitization in High-Energy Physics Experiments.
R. F. Althaus, et al., LBL-5358 and Proceedings of IEEE Nuclear Science Symposium, February 1977, Vol. NS-24, No. 1, pp. 408-412.

Performance Studies of Prototype Micro-Channel Plate Photomultiplier.
C. C. Lo, et al., LBL-5520 and Proceedings of IEEE Nuclear Science Symposium, February 1977, Vol. NS-24, No. 1, pp. 302-311.

Preliminary Evaluation of the HR400 Prototype Micro-channel Plate Photomultiplier.
C. C. Lo, et al., EE-WE1454, July 1976.

Selection of the Proper CCD Device and Conditions of Operation.
J. Millaud, EET-1461, to be published March 1977.

Summary of CAMAC: Status and Outlook, U.S. NIM Committee CAMAC Tutorial Articles.
L.J. Wagner, October 1976, TID-26618, pp. 91-98.

2. THEORETICAL PHYSICS

2. THEORETICAL PHYSICS

Particle theory and accelerator theory and design are the principal research areas of the Theoretical Physics Group. Other areas of importance are nuclear science and atomic physics.

An important adjunct of this research is the training of graduate students working for the doctorate in theoretical physics. These students make important contributions in the course of fulfilling the requirements for the degree.

For the past 26 years the Theoretical Group has maintained a stimulating summer program. The Berkeley research program and the unusual features of the Bay Area have made it relatively easy for us to attract outstanding scientists. Both the theoretical and experimental programs at the laboratory benefit from these visitors who often interact as much with the experimenters as with the theorists.

The influence of the LBL Theoretical Physics Group in particle theory is made evident by the outstanding scientists who participated in the summer and academic year programs. The participants are provided with office space and use of computer facilities. Those who participated in 1976 were:

Capra, Fritjof

Chen, Chih Kwan, Argone National Laboratory

Clark, Thomas, University of California, Berkeley

Coleman, Sidney, Harvard University

Dash, Jan. W., University of Oregon/CNRS, Marseille, France

Farrar, Glennys, California Institute of Technology

Finkelstein, Jerome, Columbia University

Frishman, Yitzhak, California Institute of Technology-Weizmann Institute

Harper, Charlie, California State University, Hayward

Jakob, Hans Peter, Max Kade Foundation Fellow

Klink, Wm. H., University of Iowa

Kawai, Takahiro, Miller Fellow/Mathematics Dept., University of California, Berkeley

Koplik, Joel, Columbia University

Meuller, Alfred, Columbia University

Nicolescu, Basarab, University of Paris/NATO

Quinn, Helen, Harvard University

Rarita, William R., Retired, Brooklyn College, N. Y.

Rosenweig, Carl, University of Pittsburgh

Schmid, Christoph, ETH-Zurich

Senjanovic, Pavao I., University of California, Berkeley

Tornqvist, Nils, University of Helsinki, Finland

Tuan, San Fu, University of Hawaii

Vasavada, Kashyap V., University of Indiana, Purdue University

Wada, Walter W., Ohio State University

Webber, Bryan, Cavendish Laboratory, University of Cambridge

Wichmann, Eyvind, University of California

PARTICLE THEORY

Research in particle theory encompasses the strong, electromagnetic, and weak interactions. Although many different approaches are used, ranging from field theory to the phenomenological analysis of data, the LBL Theoretical Physics Group is especially noted for and concerned with the scattering matrix (S-matrix) approach to the theory of strong interactions. This method, which is based on very general physical requirements such as causal behavior, unitarity and relativistic invariance, deals more directly with measurable quantities than the older field-theoretic approach. Over the years the LBL Theoretical Physics Group has made decisive contributions to the development of the S-matrix approach.

TOPOLOGICAL EXPANSION OF THE S-MATRIX

The physical content of the S-matrix topological expansion was studied further. It was shown that observed hadronic total cross sections at moderate energy are compatible with pomeron-f identity. Extension of the topological approach to unnatural-parity exchange led to the prediction of a high-lying H trajectory with properties

similar to those of the pomeron. Certain conver-
gence factors in the topological expansion were
identified as manifesting the low statistical
weight of those configurations that can flow along
handles; these convergence factors were shown to
depend on the dynamical region being studied. It
was demonstrated that higher terms in the topo-
logical expansion systematically tend to restore
G parity as a good quantum number for the discon-
tinuities of the S-matrix, this symmetry not being
obeyed at the planar level; a practical method
thereby emerged for calculating exchange-degeneracy
breaking of nonsinglet trajectories. In a more
speculative vein, an attempt was made to predict
properties of baryonium states through an interpre-
tation or planarity for baryons based on the di-
quark notion. (G. F. Chew)

The topological structure of duality dia-
grams was investigated in the framework of the
S-matrix topological expansion with the aim of
defining the amplitudes appearing in the expansion
in pure S-matrix language without reference to
underlying field-theoretical models. A first step
in this direction was to determine how the duality
diagrams representing the amplitudes have to be
cut according to the Cutkosky rules to generate
the discontinuities through which the amplitudes
can be defined (see LBL-5338). In order to write
down the precise unitarity equations, the boundary
structures of the diagrams will have to be incor-
porated into this approach. Work along these lines
is in progress. (F. J. Capra)

An explanation has been given of why the
cylinder correction to the leading unnatural
parity planar Regge trajectories π - B, η - H
has opposite sign relative to the cylinder correc-
tion to the natural-parity planar reggeons ρ - f,
ω - A_2. The argument is based on a model proposed
by Chew and Rosenzweig according to which the main
contribution to the unnatural-parity cylinder in
the vicinity about t = 0 is given by an unsym-
metrical π - ρ twisted loop. The sign of this
unsymmetrical twisted loop turns out to be opposite
to that of the symmetrical ρ - ρ twisted loop
for the natural parity sector because the leading
unnatural-parity pole in the π-link has J = 0
while the leading natural-parity pole in the
ρ-link has J = 1. (Jaime Millan)

A major problem in dual theory has been the
inclusion of baryons into the topological expansion
scheme of Veneziano. Veneziano's formulation
applies only to systems of mesons. It has been
shown that the scheme may be naturally generalized
to include baryons. (H. P. Stapp)

A slightly different approach to the above
problem of constructing a dual Regge theory of
baryons and mesons has also been developed. (F.
J. Capra)

FOUNDATIONS OF S-MATRIX THEORY

A new approach to the analysis of the singu-
larity structure of the S-matrix has developed out
of the work of the Japanese mathematicians work-
ing with Professor Sato of Kyoto. They have intro-
duced the concept of the singularity spectrum of
a function that is represented as a sum of boundary
values of analytic functions. It has been proved
(by the mathematician Boner) that the equivalence
between the macrocausality postulate and the normal
analytic structure proved in 1969 by Iagolnitzer
and Stapp implies that the singularity spectrum of
the S-matrix is confined to a surface determined
by the Landau equations. This surface lies in a
space of higher dimension than the Landau sur-
face, and fixes both the positions of the singu-
larities in p space* and also the directions from
which the boundary value is to be approached (i.e.,
the iε prescription). Mathematical considera-
tions have led Sato to conjecture that the S-
matrix should be the solution of a holonomic system
of microdifferential equations whose characteris-
tic variety is the above-described surface. This
conjecture, if true, would impose very severe
local and global constraints on the singularities
of the S-matrix. It has been shown that the gen-
eral S-matrix discontinuity formula derived earlier
by Stapp and Coster ensures that Sato's conjecture
is satisfied locally at points corresponding to a
large number of special cases. This work involves
exhibiting the nature of the singularity of the S-
matrix at points where several Landau surfaces inter-
sect. The proofs require an analyticity assumption
that goes slightly beyond what can be derived from

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*momentum space

macrocausality. This assumption, called local maximal analyticity, is that the singularities in a complex neighborhood of a physical point are confined to the local complexifications of the positive-α Landau surfaces that pass through that point. (H. P. Stapp with T. Kawai of Kyoto University)

Proofs of the S-matrix discontinuity formulas rely on a basic theorem, called the structure theorem, that specifies the singularity spectrum of products of connected parts of the S-matrix. However, this theorem fails to give information at certain exceptional points called $u = 0$ points. A conjecture about the singularity spectrum of these products at $u = 0$ points has been formulated. This conjecture is based on detailed studies of (1) the characteristic variety of the holonomic system of micro-differential equations that Feynman integrals satisfy; (2) the singularity spectrum of the phase space integrals that arise in S-matrix theory; and (3) the semiclassical model that is the basis of the macrocasuality postulate. All these considerations lead to the same generalization of the Landau equations at $u = 0$ points. (H. P. Stapp with T. Kawai and M. Kashiwara of Kyoto University)

The failure of the usual structure theorem to give information about $u = 0$ points has been circumvented in proofs of the S-matrix discontinuity formulas by introducing the assumption that positive-α and negative-α singularities in the various terms of equations derived from unitarity cancel among themselves, rather than with the so-called mixed α singularities. It has been shown that the simplest of the S-matrix discontinuity formulas, namely, the pole-factorization theorem below the four-particle threshold in the equal-mass case, can be derived without using the mixed-α cancellation assumption if one admits instead the conjecture of Kashiwara-Kawai-Stapp about $u = 0$ points, and the local maximal analyticity postulate of Kawai-Stapp. (H. P. Stapp with D. Iagolnitzer of Saclay)

Bell's theorem, as formulated by Stapp, apparently requires the existence of superluminal connections. On the other hand this formulation requires the simultaneous theoretical consideration of the results of alternative possible experiments, only one of which can actually be performed. This simultaneous consideration of alternative possible experiments might appear contrary to the precepts of quantum theory. However, Stapp has argued that the theoretical framework used in his formulation of Bell's theorem is in accordance with the philosophical precepts of quantum theory as promulgated by Bohr. The logical alternatives to the existence of superluminal connections are described. (H.P. Stapp)

PHYSICS OF THE NEW PARTICLES

In the phenomenology of the new particles an analysis was made of how to decide, by the study of possible angular correlations in the sequential decays of D^* and D mesons, whether the lighter state could be the vector particle. The experimenters have performed the analysis and conclude that the conventional assignment of spins (lighter state $J = 0$, heavier state $J = 1$) is favored by the data. (J. D. Jackson)

An application of two sum rules from atomic physics was made to be the radiative transitions among the Psi(3684), to intermediate Xi states, and to the Psi(3095) in order to set upper and lower estimates on some of the rates and so determine approximate values for the total widths of the Xi states. (J. D. Jackson)

Production of charmed meson pairs of $J^P = 0^-$ and 1^- is examined near the threshold. Production cross sections are parametrized by a quark model of a broken SU(8) symmetry. The charmed hadron production cross section is dominated by $(0^-, 1^-)$ pairs, and $D^*\bar{D}^*$ production comes out to be much too small to reproduce the higher peak in the recoil mass spectrum obtained from $D^0\bar{D}^0$ production by reflection. We point out a few experimental measurements that will clarify the origin of the higher peak of the recoil mass spectrum. (R. Simard and M. Suzuki)

An argument has been presented to support the conclusion that the charmed meson of $J^P = 1^+$ is produced copiously at the center-of-mass energy 4.028 GeV in electron-positron annihilation. The energy dependence of the recoil mass peak has been determined and methods to test the 1^+ production experimentally have been found. (M. Suzuki)

On the basis of current algebras and duality a general rule was proposed to relate large higher symmetry breaking to meson decay rates. The rule was applied to charmed meson decays. An upper bound on the $D^{o^*} \to D^o + \pi^o$ decay rate was also found which is used to set a lower bound on its Q value. This limit is particularly useful in view of the fact that the Q value determined experimentally is very close to the upper bound. (M. Suzuki)

The spectrum of the even charge conjugation states between ψ and ψ' was investigated. A probable quantum number assignment for these states was deduced. This assignment is consistent with quark model expectations and seems to be supported by subsequent experimental results. This assignment was then used to assess the validity of nonrelativistic potential models and of short distance arguments about quark-gluon dynamics. (Michael Chanowitz with F. Gliman of SLAC)

With a broader perspective than the above, the success of theoretical models of the radiative transitions of ψ and ψ' was evaluated. The uncertainties inherent in applying vector meson dominance to the new particles was also analyzed. The principal conclusion was that the angular momentum, $L = 1$, even, charge conjugation triplet seems to behave very much as expected in quark model approaches, but that the candidates for η_c and η'_c display unexpected features. This could be due to unexpectedly large spin-spin forces or to more basic misconceptions in the conventional approach. This work was presented as an invited talk at the 18th International Conference on High Energy Physics, Tbilisi, USSR. (M. Chanowitz)

SPEAR-PEP e^+e^- PHYSICS

Assuming the existence of a weak neutral electron current a possible right-left asymmetry of inclusive hadron production with highly transversely polarized beams of electrons and positrons has been calculated. Measurement of this asymmetry would provide unambiguous evidence for parity violation in e^+-e^- annihilation and would confirm the existence of a weak neutral current for electrons. (R. Simard and M. Suzuki)

A forward-backward asymmetry in the angular distribution of inclusive hadron production resulting from the weak decay of the heavy lepton at

SPEAR has been calculated. Using longitudinally polarized e^+e^- incident beams, it should be possible to distinguish between a V-A and a V+A current for the heavy lepton. (R. Simard and M. Suzuki)

The inclusive pion spectra in e^+e^- annihilation have been analyzed in a parton fragmentation model with nonvanishing transverse momenta and with heavy partons. The nonscaling phenomena in the small x region are explained quite satisfactorily in this model. (M. Suzuki and W. W. Wada)

Parity mixing in the weak current of charged heavy leptons causes a conspicuous forward-backward asymmetry in the $\cos\theta$ distribution of inclusive hadron spectra near the high energy end when one of the initial electron-positron beams is longitudinally polarized. The asymmetry is estimated for vector and axial vector currents at PEP/PETRA energies. It is quite easy to distinguish experimentally between V-A and V+A provided that the decay branching ratio of $L^\pm$ into $L \to \nu_L + \pi$ is not too far from the value predicted by the universality (~10 percent). (M. Suzuki)

DUAL RESONANCE MODELS

The presence of a new type of high energy behavior is demonstrated in the six-point function of the Veneziano model. This behavior reveals the existence of a previously unknown family β of Regge trajectories. The parent β trajectory is related to the leading ordinary trajectory α by $\beta = \frac{1}{2} \alpha - \frac{1}{2}$. Thus β gives the leading contribution when $\alpha < -1$. It factorizes and has positive charge conjugation parity. Since it decouples from two particles, it therefore contributes only to amplitudes with at least six external legs. (Paul Hoyer, N. Törnqvist, and B. R. Webber)

The previous calculation has been generalized to the eight-point Veneziano model. It is shown that in addition to the ordinary α and β trajectories there is in high energy limits a contribution from a third trajectory $\gamma = \frac{1}{3} \alpha - 1$. Based on this it is conjectured that there exists in the Veneziano model an infinite set of "sister" trajectories α_k ($k = 1, 2, 3, \cdots$), the first three members of which are α, β, and γ. The kth trajectory is given by $\alpha_k = \frac{1}{k} \alpha - \frac{1}{2} (k-1)$, and is expected to couple only to $k + 1$ or more particles. (Paul Hoyer)

The analytic structure of reggeon-reggeon amplitudes are investigated using the Veneziano model. The existence of the β trajectory is shown to follow from general factorization constraints. This indicates the existence of β-like contributions also in more realistic amplitudes. The phenomenological consequences of this are explored. It is shown that ordinary finite energy sum rules do not hold for reggeon-reggeon amplitudes. However, such sum rules do exist for certain discontinuities of the full amplitude. This has a natural interpretation in terms of resonance production and cascade decay. The theoretical discussion is supplemented by numerical examples of the Veneziano amplitude. (Paul Hoyer, N. A. Törnqvist, and B. R. Webber)

Finite energy sum rule constraints have been used to show that the ηNN coupling is weak and the (reggeized) fNN, ωNN couplings conserve helicity. This work completes a previous investigation of the RNN, $RN\Delta$ and $R\Delta\Delta$ couplings, where R is an isovector reggeon. It is also shown that the striking production properties of the enhancement at low missing mass in the diffractive reaction $pp \to pX$ can be quantitatively understood using finite mass sum rules. (Paul Hoyer with H. B. Thacker at Stony Brook)

Distinguishing Between Quark Models

This work is part of a program to identify experimental tests that distinguish between fractional and integral charge quark models below the color threshold, where in most instances the models give identical predictions. The basic observation is that certain two-photon amplitudes can distinguish the two models below the color threshold. This was the basis of an analysis of η and η' decays which seemed to favor functional charges. In this work an effort is being made to show that inelastic Compton scattering, $\gamma N \to \gamma X$, may be another such process. It is argued that the ratio of the fourth power to the square of the parton charges must equal 1 in the integral charge model below or above the color threshold while it is between 1/9 and 4/9 for fractional charges. The ratio will be extracted experimentally from a comparison of $\gamma N \to \gamma X$ and $eN \to eX$. (Michael Chanowitz)

Equivalent Theories, Gauge Models and Strings, Quark Confinement

The equivalence of field theories has been investigated. Bosonic equivalent theories for the Schwinger model and for two-dimensional quantum chromodynamics (QCD) have been constructed. It was shown that the latter theory does not seize; that is, there is a Goldstone boson in the spectrum. (Martin B. Halpern)

New functional integral methods have been developed which allow the restatement of certain gauge theories in two dimensions in terms of the Bars-Bardeen-Hanson-Peccei string. (Martin B. Halpern and Paul Senjanovic)

The difficulties of a canonical Hamiltonian formulation when surface terms cannot be neglected have been studied. As an example of these problems the Schwinger model with nonzero Coleman angle has been explicitly discussed. All difficulties may be removed by the introduction of dynamical surface variables for the theory. Extensions to four dimensions have also been proposed. (Martin B. Halpern)

't Hooft's two-dimensional SU(N) gauge theory model for mesons has been studied in two different axial gauges. Using numerical techniques employed in aerodynamical wing theory, the bound state spectra are compared in the $A^+ = 0$ and $A_1 = 0$ gauges. Agreement is found in the weak coupling limit. Furthermore, Lorentz covariance of the weak-coupling $A_1 = 0$ theory is numerically confirmed. Also investigated is the massive-end string model, which is equivalent to 't Hooft's $A^+ = 0$ model when the $x^+ = \tau$ gauge is chosen. It is found that the numerical spectrum of the string model in the $x^0 = \tau$ gauge differs from the $x^+ = \tau$ gauge string spectrum as well as from the $A_1 = 0$ gauge theory spectrum. A Bethe-Salpeter equation approach to the spectrum of the gauge theory in the $A_1 = 0$ gauge is developed for any coupling. While the strong coupling theory in this gauge presents severe difficulties, the weak-coupling limit is shown to be completely consistent. (Andrew J. Hanson with R. D. Peccei and M. K. Prasad of SLAC)

There are three useful gauges in which 't Hooft's two-dimensional model for mesons may be studied. (1) The Minkowski-space $A^+ = 0$ gauge, which

has consistent, solvable self-energy equations the vanishing bare fermion mass, $m = 0$. (2) The Minlowski space $A_1 = 0$ gauge, which has inconsistent Dyson self-energy equations for $m = 0$. The Dyson equations become consistent, however, upon changing the coupling $g \rightarrow ig$. (3) The Euclidean space $A_\theta = 0$ gauge, which had not been previously examined, and is the subject of this research. The constant-radius Euclidean quantization methods of Fubini, Hanson and Jackiw have been employed to show that 't Hooft's SU(N) quark-gluon gauge theory is consistent in two Euclidean spacetime dimensions for $m = 0$. Using the axial gauge, $A_\theta = 0$, the 1/N expansion and the analog of a principal value infrared cutoff, the Dyson self-dimension equation has been solved exactly for a quark with zero bare mass. Thus the inconsistency present in the time-like gauge Minkowski-space approach to the theory is avoided. Continuing to Euclidean space, in effect, replaces g by ig and makes the Dyson equations consistent. (Andrew J. Hanson with M. K. Prasad of SLAC)

It has been shown how the boundary condition of the relativistic string model of strong interactions may be changed in such a way as to lower the intercept of the leading Regge trajectory. By using the relativistic string formalism, factorization and absence of ghosts are manifest. In the modified orbital model, the intercept $\alpha(0)$ was lowered to $1 - \frac{1}{16}(26 - D_0)$, where D_0 is the dimensionality of the Poincare-invariant subspace of spacetime ($4 \leqslant D_0 \leqslant D = 26$). In the modified spinning-string model, the boson intercept became $\frac{1}{2} - \frac{1}{8}(10 - D_0)$, while the fermion intercept was unchanged. The formerly-massless vector particle in these models was seen to be given a mass by a Higgs-like mechanism. Interacting strings were treated in the modified orbital model, and, unfortunately, it was found that some of the scattering amplitudes were not dual. (Warren Siegel)

Gauge-invariant methods of perturbation expansion for the nonrelativistic monopole—particularly, semiclassical expansions of the Feynman path-integral—have been investigated. In addition, the relativistic monopole has been investigated using a covariant set of two-particle wave equations to describe a system of monopoles interacting with a charge. (Warren Siegel)

Work on spontaneous symmetry breakdown in dual models has continued. It has been shown that the whole problem can be reduced to phase transition in one-dimensional field theory. In deriving this result, use is made of the string formalism and Mandelstam's vertex coupling. (K. Bardakci)

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ACCELERATOR THEORY AND DESIGN

PEP BEAM LOADING AND THE ROBINSON INSTABLILITY

The PEP rf system is subject to heavy beam
loading when operating at design conditions and the
parameters of the system, some of which cannot be
adjusted rapidly, must be set to take the loading
into account. As a result, the system can be badly
mismatched, before and during the time required to
fill the ring with electrons and positrons, to the
detriment of the klystrons supplying the power. An
analysis was made of the possibility of separating
the accelerating cavities into two classes which
could be tuned independently and phased with respect
to each other to meet the various requirements while
filling the ring. An extension of the theory of the
Robinson instability was required for this investi-
gation. This scheme still had undesirable aspects
and it was necessary to extend the analysis of the
circuitry to include other elements and to general-
ize the concept of the Robinson instability further.
The formalism has been incorporated into a computer
program by M. Lee of SLAC. (Lloyd Smith)

ESCAR BEAM DYNAMICS

Further studies have been made of basic beam
dynamics in ESCAR to explore the range of flexibil-
ity in operating parameters both with the full sys-
tem and with constraints which might simplify ini-
tial operation. The ring does indeed prove to be
capable of running in a wide range of configurations.
(L. J. Laslett and Lloyd Smith)

ELECTRON AND STOCHASTIC COOLING

These techniques have recently attracted in-
creased interest in this country and in the future
they may be the subject of experimental study with
the ESCAR facility.

With respect to electron cooling, formulas
developed by Mauer, of the Karlsruhe Laboratory,
were used in the creation of a computational pro-
gram designed to indicate the manner in which the
electron-cooling process may be expected to proceed.
Numerical computations and independent analysis
indicated that in two important limiting cases the
Mauer formulation leads to results given by corre-
sponding simple formulas cited in early reports
from Novosibirsk. (L. J. Laslett and Lloyd Smith)

With respect to stochastic cooling, computa-
tional programs were designed and employed to illus-
trate how this process ideally might be expected to
perform. An analytic theory, based on the same ini-
tial model, also was developed. It led to a par-
tial differential equation for the evolution in time
of the distribution function characterizing the
damped particles. An explicit solution to this
differential equation then was obtained in terms of
Laguerre polynomials whose coefficients are readily
obtained from parameters characterizing the initial
distribution function. The computational and an-
alytic results appeared to be in agreement and could
be employed to illustrate, for example, the manner
in which an initial multi-group distribution would
evolve. Thus one finds that an initially complex
distribution tends in the course of time (if no ad-
ditional particles are added) to a single character-
istic form with a mean-square width that decreases
in the manner suggested by van der Meer's original
work. The results of this work have not been pub-
lished but they were circulated to several interested
individuals prior to the 1976 Brookhaven Summer Study.
(L. J. Laslett and Lloyd Smith)

LOS ALAMOS PROTON STORAGE RINGS

It is proposed to increase the capabilities of
the pulsed neutron time-of-flight facility now com-
ing into operation at LAMPF by adding a storage ring
to accumulate 800 MeV protons accelerated in LAMPF.
At the request of Los Alamos, assistance in develop-
ing the parameters of the ring has been given to the
group designing the storage ring. (Lloyd Smith)

SYNCHROTRON LIGHT FROM SPEAR

A detailed study was made of the possibilities
of improving future performance of the SPEAR Storage
Ring as a source of synchrotron light. Present light

quality is not optimum because the focusing is chosen for colliding-beam physics. Focusing patterns were devised that suggest a potential fourfold increase in brightness, provided that magnet misalignments can be sufficiently suppressed or compensated. The study revealed the importance of proper wiggler magnet placement. These magnets, intended to intensify and harden the photons, will either degrade or improve the light quality according to whether they are placed at lattice locations where the dispersion function is large or small. (A. A. Garren)

Storage Ring Operation When the Normal Periodicity is Disturbed

Previous work on running the ISABELLE storage ring, when the insertions are tuned differently, was extended by comparing cases where one or two insertions had high or low β-values compared to the normal ones. With only two sextupole families to control the chromaticity, the variation of betatron tunes over the momentum window was modest, as was that of the β-functions, with the exception that the β-values in the normal insertions varied up to 50 percent of their unperturbed values. Hence more complex correction schemes, in which the sextupole periodicity is also broken, may be indicated. (A. A. Garren)

Heavy Ion Fusion

In light of the growing interest in the use of heavy ions as the igniter for an inertially confined fusion reactor, work was begun to develop general parameters and to investigate the relative merits of various accelerator schemes which might be used to produce beams of heavy ions in the range of several hundred terawatts for a few nanoseconds. Efforts to date have been mostly in the areas of acceleration at very low velocities, the use of an induction linac as principal accelerator, high intensity beam transport, and final bunching. (LLoyd Smith)

Problems relating to heavy-ion fusion, especially those associated with the transport of intense beams of heavy ions have been investigated. A large portion of this investigation had been based on the envelope equations of Kapchinskij and Vladimirskij (and on the associated linear single-particle equations of motion for particles moving under the combined influence of an applied alternating gradient focusing field and the defocusing space-charge forces). Such work has to some extent paralleled that of the ERDA 1976 Summer Study on Heavy Ion Fusion, but has served to clarify the problem and has raised some questions that warrant further consideration. As an outgrowth of this work, various stationary distributions (other than just that of the Kapchinskij-Vladimirskij formalism) have been developed for beams in a nonalternating-gradient focusing channel (e.g., in a solenoid) and their characteristics examined. Stability questions concerning such distributions, and for beams subjected to alternating-gradient focusing, are now being examined and will be the subject of simulation computations now being initiated. (L. J. Laslett and Lloyd Smith with Glen R. Lambertson)

The focusing of an intense beam of high-energy heavy ions onto the target in a pellet-fusion reactor was studied analytically. The problem is difficult because, among other things, of the large distance between the last focusing lenses and the target, high rigidity, and space charge defocusing. Subject to simplifying assumptions, a way was found to express all the dimensions of a quadrupole doublet lens system as functions of a single parameter that depends on quadrupole pole-tip field, distance to target, target spot size, and beam properties (energy, emittance, current, charge state, and atomic weight). As a result of this parametrization it is possible to find useful results such as the charge state and number of beams that will best reduce the size of the lens system. (A. A. Garren)

An ERDA Summer Study of Heavy Ions for Inertial Fusion was held in Oakland during July 19 to August 1, 1976. The study was organized and conducted jointly by LLL and LBL and included some 60 participants from 15 institutions. David L. Judd acted as co-chairman of the study and afterwards served as the principal editor of its report.

Radiation Damage Facility

There is urgent need in the CTR program for an intense source of 14-MeV neutrons for use in studying radiation damage to possible reactor materials. It is possible to achieve substantially greater fluxes, than are either presently available or under development, by use of a deuteron linear

accelerator operating in a continuous mode at about 30 MeV. The basic parameters for such an accelerator and the associated facility were developed jointly by LLL and LBL and included in a proposal to ERDA. (Lloyd Smith)

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NUCLEAR SCIENCE

Pion Condensation and Abnormal Nuclear Matter

The sigma model in nuclear matter has been used to study the relationship between two unusual phenomena which may occur at high density: the abnormal nuclei of Lee and Wick and the phenomenon of pion condensation discussed in the sigma model context by Dashen, Campbell, and Manasch. In each of those two areas the model has been solved with mutually exclusive assumptions; that is, in the study of pion condensation it was assumed that abnormal

nuclei will not form and, vice versa, pion condensation was excluded by assumption in the study of abnormal nuclei. The model has now been solved without making either assumption. For the case of neutron matter with nonrelativistic kinematics it is found that there is a substantial reduction in the effective nucleon mass as expected for abnormal matter but that whether pion condensation also occurs depends on the value of the renormalized axial charge in the neutron matter. For $g_A > 1.11$ there is a pion condensate but for $g_A < 1.11$ there is not.
(M. Chanowitz with P. Siemens of the Niels Bohr Institute)

Nuclear Cluster Model

A model of the ^{12}C nucleus based on the cluster model of Wildermuth and co-workers has been developed. This model is based on three clusters and so represents an extension of the three-alpha model for ^{12}C. The wave functions of particles in a cluster are of the simple-harmonic-oscillator type with two free parameters. Both antisymmetrization for all particles and momentum conservation are treated exactly. The combination of these features introduces great complexity into calculations using the model, but when realistic parameters are used, it is found that simplifying assumptions that ignore either effect do not produce a satisfactory approximation to the complete model. The parameters in the model have been deduced by comparison with electron scattering data, and it is found that reasonable agreement with the data can be achieved. One of the parameters obtained in this way is approximately the same as that which would be obtained for a three-alpha particle model. (J. V. Lepore and R. J. Riddell, Jr.)

MISCELLANEOUS THEORETICAL PHYSICS

CTR Containment Problems

A considerable effort was directed to the formulation, programming, and testing of ideas intended to further the understanding of containment methods under experimental study by the CTR Group of this Laboratory. (Paul Channell and L. J. Laslett)

The Monopole Candidate

The famous event of Price, Shirk, Osborne and Pinsky is reinvestigated and preliminary, unofficial

results are given. (1) The particle is the most highly penetrating particle observed to date: consistent with only fast, heavy, normal nuclei which fragment at least once within the Lexan stack.   (2) The particle was deficient in high knock-on energy delta rays when examined in the thick nuclear emulsion: consistent with only slow, heavy normal nuclei.

The technique of calibrating the Lexan data has been discussed elsewhere. The calibration of the thick nuclear emulsion is reported on the basis of the measurement of the normal core radius and the measurements of two-separate thin nuclear emulsions through which the particle passed. On the basis of (1) and (2) one may conclude that the particle in question was not a normal nucleus. Several unique possibilities are under further investigation including an abnormally heavy nucleus, an anti-nucleus, a heavy, extended-charge lepton, a monopole, and a super-heavy nucleus $Z \approx 114$. (Ray Hagstrom with P. B. Price and E. K. Shirk of UC-Berkeley and W. Z. Osborne of the University of Houston)

The above event has been tentatively analyzed as the first observed heavy anti-nucleus. This explanation fits the data because anti-nuclei are more penetrating than their charge conjugate, they may have greater charge changing interaction cross sections than their charge conjugates, and they have greatly diminished cross sections for production of high energy knock-on electrons. No specific recommendation is made to help settle dispute over the identity of this particle; namely, to examine photo micrographs of the thick emulsion track. If the particle was an anti-nucleus, the differences in the track from normal nuclei which might fit the rest of the experiment would be great. The interpretation of this event as an anti-nucleus demands that the emulsion track match the tracks of normal nuclei with $75 \lesssim Z/\beta \lesssim 85$. Comparing this interpretation as an anti-nucleus to the previous (negative) results of anti-nucleus searches shows that there is no serious discrepancy. The region of charge and rigidity sampled is untouched by any previous experiments. (Ray Hagstrom)

Heavy Ion Stopping Powers

Stopping powers were computed for various nuclei with $|Z/\beta| = 114$. The calculations were done using the distant encounter approximation as calculated by Ashley, Brandt, and Ritchie. The exact form of the close encounter cross section as tabulated by Doggett and Spencer was used. The results are that, compared with $Z = +92$, $|Z/\beta| = 114$, all anti-nuclei with $-96 \leqslant Z \leqslant -75$ and $|Z/\beta| = 114$ have considerably decreased stopping powers. The differences range from 10 percent to 25 percent, depending on Z. This work bears on the interpretation of the famous event of Price and collaborators as a heavy anti-nucleus and it allows understanding of the extraordinarily penetrating behavior of the particle in the Lexan stack. (Ray Hagstrom)

Solution of the Helmholtz Equation

A dipole-distribution integral equation technique was previously developed for solution of the Helmholtz equation subject to boundary conditions. A major advance in understanding various features of the technique has now been made. The integral equation approach is not strictly equivalent to the Helmholtz boundary-value problem, and one finds, for example, eigenvalues for the equation at values other than the known solutions of the Dirichlet problem for simple figures. The associated "spurious" eigensolutions of the integral equation for an interior, Dirichlet problem have now been identified as being generated by solutions of a related exterior Neumann problem. Such solutions prevent direct use of the integral representation for solution of the inhomogeneous Dirichlet problem at their eigenvalues. Techniques were developed which remove such difficulties and allow a significant extension of the range of applicability of the method. The Mellin representation for the integral equation has been developed in greater detail, and a proof obtained that the dipole distribution for a homogeneous problem near a corner can be expanded in a series of Bessel functions in which the order of the functions is obtained from the zeroes of a function which had been found in earlier work. (R. J. Riddell, Jr.)

Diagonalization of Certain Integral Equations

Formulas relating to the generalized Legendre functions of the first and second kind were summarized and proved. A group-theoretic interpretation of some of these formulas (addition theorems) has

been given by explicitly calculating certain SU(1,1) group matrix elements. It has been shown how these formulas provide the immediate partial diagonalization of integral equations containing the invariant group or coset measure of SU(1,1) in any basis. (Philip Lucht)

1976 PUBLICATIONS: MISCELLANEOUS THEORETICAL PHYSICS

Boundary-Distribution Solution of the Helmholtz Equation for a Region with Corners.
J. V. Lepore and R. J. Riddell, Jr., LBL-4673, February 1976.

Electromagnetic Experiments with the Iron Beam.
R. Hagstrom, Internal Physics Report Theo-RH-2, October 1976. (Internal Report)

An Elementary Scheme to Measure Anti-Nucleus Interaction Partial Cross Sections.
R. Hagstrom, Internal Physics Report Theo-RH-8, December 1976.

Further Studies of the Monopole Candidate.
P. B. Price, E. K. Shirk, Internal Physics Report Theo-RH-4, July 15, 1976. (Internal Report)

The Generalized-Legendre Addition Theorems, SU(1,1), and the Diagonalization of Convolution Equations.
P. Lucht, LBL-5527, October 1976.

"Have We Seen a Heavy Anti-Nucleus?"
R. Hagstrom, submitted to Phys. Rev. Lett.; LBL-5593, December 1976.

Identifying Particles by de/dx, a Few Practical Comments.
R. Hagstrom, Internal Physics Report Theo-RH-1, October 1976. (Internal Report)

Inclusion of the Exact Form of Close Encounters in Heavy Ion Stopping Powers.
R. Hagstrom, Internal Physics Report Theo-RH-5, December 1976.

A Little Brown Jug to Measure Nuclear Interaction Cross Sections.
R. Hagstrom, Internal Physics Theo-RH-3, November 1976. (Internal Report)

Numerical Solution of the Helmholtz Equation for Two Dimensional Polygonal Regions.
J. V. Lepore and R. J. Riddell, Jr., LBL-4814, March 1976.

Revision of Steignan's Flux Limit Table.
R. Hagstrom, Internal Physics Report Theo-RH-6, December 1976. (Internal Report)

What is Needed to Identify Anti-Nuclei by This Knock-On Spectra Alone?
R. Hagstrom, Internal Physics Report Theo-RH-7, December 1976. (Internal Report)

3. COMPUTER SCIENCE and APPLIED MATHEMATICS

FEMALE FAMILY HEADS
AS PERCENT OF TOTAL
FAMILY HEADS

PERCENT FEMALE OF
TOTAL FAMILY HEADS

	ABOVE 9.0
	7.8 - 9.0
	7.3 - 7.7
	6.7 - 7.2
	5.9 - 6.6
	5.0 - 5.8
	4.0 - 4.9
	BELOW 4.0

MAP 10
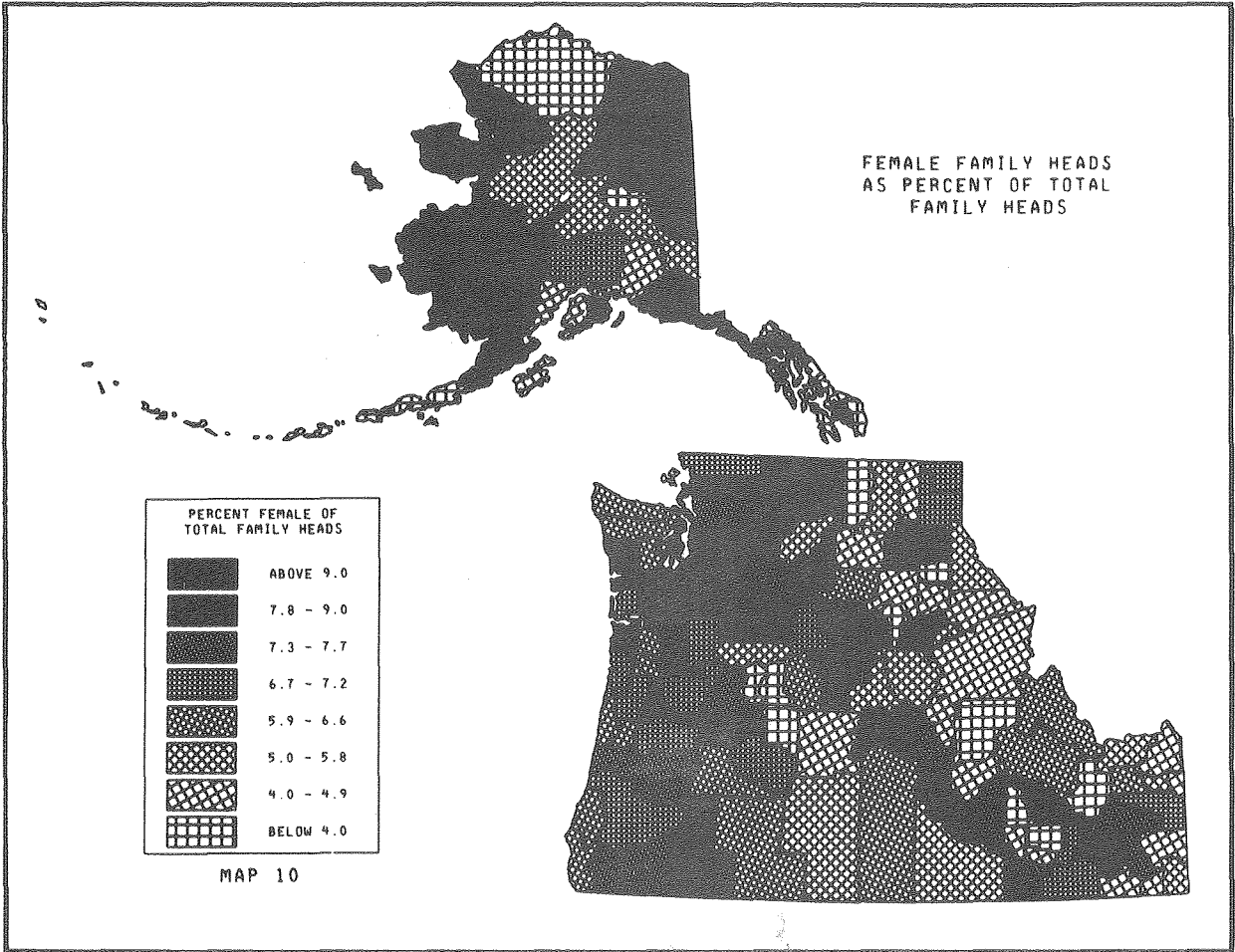
Computer-prepared (colored) map presenting demographic data.

3. COMPUTER SCIENCE AND APPLIED MATHEMATICS

The Computer Science and Applied Mathematics Department (CSAM) engages in research in a variety of computer science and mathematics disciplines. A balanced mix of 70 percent project-oriented work and 30 percent discipline-oriented research is maintained by funding from the U. S. Energy Research and Development Administration (ERDA) and from other federal and state agencies.

Currently, the Department permanent staff includes 67 computer scientists, mathematicians, engineers, physicists, computer technicians, and administrative personnel. This year there are six postdoctoral and predoctoral temporary positions in computer science and mathematics and two joint UCB/LBL faculty appointments. The Department works close with the computer center staff which runs and maintains the Laboratory's CDC07600/6600/6400 triplex. LBL's center is one of the largest unclassified scientific computer centers, serving federally-funded users nationwide over a sophisticated remote job entry time sharing system and the worldwide ARPA network.

This year several major new long-term programs were begun which are expected to lead CSAM into state-of-the-art research and development over the next 5 to 10 years.

CSAM was selected to build a nationwide network of large minicomputers for distributed data management and general time-sharing facilities. The network will eventually grow to 12 nodes and provide access to large-scale centers at LBL and elsewhere. This project is funded through a Memorandum of Understanding between ERDA and the Department of Labor.

LBL received approval for three major programs in which CSAM staff will participate: the Time Projection Chamber for the PEP facility; the National Resource for Computational Chemistry; and the Magnetic Fusion Energy program.

Research and development activities undertaken span the following disciplines:

- Data Management Systems. The special problems involved in managing large scientific, socio-economic, and environmental data bases require advanced techniques in data management. Investigations of specialized hardware and software techniques of hierarchical and distributed data bases are under way. A general, transportable system, the Berkeley Data Management System, is under development for several projects and as a research system for investigating distributed data management techniques.

- Socio-Economic Environmental Demographic Information System (SEEDIS). The SEEDIS project includes a very large integrated data base (over 10 billion characters) used for energy policy analysis and environmental impact studies by agencies all over the United States. The system provides interactive retrieval, analysis, and display of a wide variety of characteristics and statistics gathered from many government agencies. Current research activities include techniques for integrating information collected by several sources, synthesizing data for specific modeling studies, and updating base data from auxillary sources. The CSAM Department is acting as scientific liaison between ERDA and the Bureau of the Census, in activities relating to the 1980 Decennial Census, and energy-related data gathered by the Census Bureau. In addition, LBL is participating in the ERDA-wide Inter-laboratory Working Group for Data Exchange (IWGDE), a group which is developing a computer-independent DATA Exchange Standard.

- Computer Graphics. The static and dynamic display of the results of information retrieval and analysis provide the user with a comprehensible representation of results not possible with printed formats. Computer-generated maps, charts, graphs, and movies, usually created interactively, have proven the most

effective way to communicate complex results. Current projects include a national geographic information system, a graphical analysis system for decision making, a device-independent graphics system, and a graphics modeling system.

- Computer Networks. Resource sharing over computer networks has been proven to be a valuable and challenging research area. Unique resources, including hardware, software, and data-bases, can be accessed over a distributed network, providing full capability at all sites. Interlaboratory communication is greatly facilitated through the use of computer network mail and computer teleconferencing. The development of high-level protocols, common language interfaces, and distributed data management techniques will enhance the computational power available for every site on the network and provide a common resources pool for the solution of regional and national problems. Currently, LBL's staff is chairing the ERDA Network Experimentation Project Investigator's Panel, whose mission is to provide a resource sharing environment for ERDA-sponsored laboratories and universities over the ARPA Network. A project to build a distributed data management network based on minicomputers was begun this year. The pilot network will consist of four nodes (LBL, San Francisco, Denver, and Washington, D.C.) and will grow to 12 nodes in the next few years.

- Management Information Systems. The retrieval, analysis, and display of information from a variety of data sources requires an integration of sophisticated techniques in data management, human-machine interface, and automated report generation. Current projects include a local MIS for LBL managers in scientific research divisions, technical support groups, and in personnel.

- Computational Physics and Data Analysis. Program development and research support is given to the design and analysis of controlled thermonuclear reactors (e.g., TOKAMAK, TORMAC) and mirror machines, design and analysis of particle accelerators (e.g., PEP and ESCAR) through beam tracing, space charge, and magnet design programs, and to the analysis of experimental high energy physics data.

- Mathematical Modeling. This effort includes the development of a linear programming system used in econometric models, a critical path analysis program for project scheduling, a biomedical modeling system for compartmental models, and extension of a large program to solve magneto-hydrodynamic problems.

- Programming Languages. This research centers on the development of structured FORTRAN-derived languages and proposed extensions to FORTRAN standards. Related work in systems implementation languages is also under way.

- Applied Mathematics. The group conducts research in numerical analysis and applied mathematics, provides consulting services to LBL staff members, and supervises the Computer Center mathematical software library. In its research, the group places increased emphasis on the development of mathematical, numerical, and statistical methods related to the study of energy processes, typically in cases requiring the solution of partial differential equations. One of the topics under active investigation is the numerical solution of elliptic partial differential equations. Combinations of fast-direct conjugate-gradient, and other methods are being developed for the iterative solution of nonlinear equations and of problems on irregular domains in two and three dimensions. Another is the development of numerical and statistical techniques, such as the random choice, vortex, fine-grained, and coarse-grained methods for application to the study of turbulent combustion phenomena. We are extending our earlier studies of capillary free surfaces to include questions of stability and applications to the flow of petroleum in underground reservoirs. In connection with its consulting and software activities, the group maintains broad interests that cover

most areas of contemporary numerical analysis and selected areas of applied mathematics.

● Educational Programs. The Department supports a post-doctoral visitor's program in several of the above disciplines and, in conjunction with the University of California, Berkeley Campus, a program for training graduate students in their doctoral research. It also sponsors regular Computer Science colloquia, Applied Mathematics colloquia, and the annual Berkeley Workshop on Distributed Data Management and Computer Networks.

DATA MANAGEMENT SYSTEMS

BERKELEY DATA-BASE MANAGEMENT SYSTEM

The Berkeley Data-Base Management System (BDMS) is a hierarchical data-base management system specifically designed to efficiently handle numerical as well as character and bit string data. It has a data-base definition language that is easy to learn, a powerful free-format data input language, and a sophisticated data-base editor. Its query language includes Boolean and relational operators, range searching, and the ability to use intermediate search results in later queries. All system capabilities are available as user-callable subroutines, so that specialized data retrieval systems may be built upon BDMS. At LBL it operates in both interactive and batch modes on the CDC-6400 and 6600, and in batch mode on the 7600. It is easily transportable to other operating systems and to non-CDC computers.

A second version of the system has been implemented. Its new features include:

1. A Boolean query language for record retrieval that can be used interactively or by an application program
2. Simplification of the data-base definition language (DDL)
3. Addition of double precision and bit string type data elements
4. Replacement of EXTERNAL data elements and user-constructed (KGEN ed) keys by the single concept at VIRTUAL data elements

5. Addition of "hooks" for user-supplied storing and fetching processors, and DDL specification of the form of data to be passed to and from the user-supplied processors
6. Elimination of relational qualifiers for data element values
7. Re-indexing only of modified data element values during update operations
8. Addition of an audit trail facility
9. Addition of data-base load and dump facilities
10. Improvements to the efficiency of the I/O routines

BDMS was installed on the IBM-360/195 at the Rutherford High Energy Laboratory (RHEL) in England to support the operation of the UK contingent of the International Particle Data Group. Little difficulty was encountered, demonstrating successful adherence to the design goal of transportability. The system also was installed on Brookhaven's CDC-7600, which is run under the SCOPE operating system. (S. Cassinelli, P. Chan, T. Clements, T. Coffeen, D. Richards, and S. Sorell)

INTERACTIVE ACCESS TO FILES

Work continued on Interactive Access to Files (INTERAC), a system designed to allow LBL INTERACTIVE programmers a standard and high level method of reliable access to their files on the CDC-6600B (where "access" implies storage as well as retrieval). INTERAC is independent of the type and content of files. It is designed to provide access to files that are not routinely updated. When used in its most general sense, INTERAC stores copies of a file on all LBL storage devices (disk, PSS, MSS, and tape) and will retrieve the file from the fastest device that is currently operational. This relieves users of any need of specific knowledge of LBL storage devices (is MSS up?). They may be assured that the "LBL access system" will "fetch the stored data" through a taxation of all available resources. INTERAC allows interactive programmers complete freedom in the use of LBL storage devices. It also provides automatic elimination of infrequently used files from fast storage devices (while maintaining archival copies on slower devices).

INTERAC updates the index to the files each time they are accessed (stored or retrieved). This allows interactive programmers to know file retrieval patterns as well as where the files are located. INTERAC can provide a standard index report, in detailed and/or summary form. The index itself may be randomly read to satisfy a programmer's specific needs (an example would be the need to provide interactive users an on-line list of files available which satisfy some user-specific criteria).

INTERAC addresses the problem of elimination of data from a continually growing data base which must eventually be limited. It does this by first allowing the programmer to associate subsets of the files in the data base with particular tapes and MSS "special sets" (particular MSS boxes). Secondly, the index may be purged of all files associated with these tapes and MSS special sets when they are physically removed. Thirdly, a particular file may be purged from the index and PSS cache even though the entire set of tapes and MSS boxes associated with it are not eliminated.
(R. Allan, W. S. Gee, P. Healey, B. Heckman, and J. Miller)

TRAINING FACILITY MANAGEMENT PROJECTS

Maintenance continued on the Training Facility Management System, which maintains inventory, equipment characteristics and configuration, and documentation data bases for the civil service arm of the U. S. Naval Combat Systems Maintenance Training Facility.

The fully operational system is based on the STOFI Data Management System and allows users to update, monitor, and generate reports via a remote terminal.
(S. Cassinelli and D. Scherrer)

FLEXIBLE DATA MANAGEMENT SYSTEM FACILITY

Work began this year on the investigation of distributed data management systems. A study group was initiated for a flexible data management system facility (FDMF) to specify and design structured modules to perform four levels of data management functions: logical data models, performance specification, access methods, and operating system interface. Most of the work to date has concentrated

on the logical model level. As a result, a project is being initiated whose goal is to build a human-engineered interface to data management. This type of interface will be designed to serve users having no computer experience. Other projects now in the planning stage will involve study and design of access methods and languages for performance specification.

Several experimental systems were investigated for future research, including a comparative experiment on the INGRES Relational Data Management System, which runs on the UCB PDP-11/70. A data base (PARAP) containing air-quality and mortality data, which runs on the Berkeley Data-Base Management System (BDMS) on the CDC-6600, was also loaded on INGRES. A fairly complex query, which requires a FORTRAN program interface in BDMS, was described by the INGRES query language and executed interactively. This comparative experiment provided useful insights into the power necessary in query languages and into the performance variables involved in data management query processing. The installation of BDMS on the RHEL IBM-360/195 and the BNL CDC-7600 provided another research tool for distributed data management investigations.
(W. Greiman, P. Kreps, D. Richards, and Shoshani)

NILAND GEOTHERMAL LOOP EXPERIMENTAL FACILITY

The Niland Geothermal Loop Experimental Facility (GLEF) in the Imperial Valley of California is jointly funded by the San Diego Gas and Electric Company (SDG&E) and the Energy Research and Development Administration (ERDA). In addition to providing technical support and funds for construction and operation, ERDA is sponsoring a program (at LLL) to assess the potential environmental effect of future geothermal power plants. A detailed test program for the 10-MW Niland test facility has been recommended by the Bechtel Corporation, and is being implemented with funding obtained from ERDA's Division of Geothermal Energy.

The processing and analysis of the operating data are the responsibility of the Lawrence Berkeley Laboratory. LBL's Computer Science and Applied Mathematics Department has developed a specialized data management and retrieval system, under which the data describing the operating characteristics of the

Niland facility can be readily retrieved for inspection or futher analysis. Technicians at Bechtel, at SDG&E, and at LLL are routinely accessing the on-line data for diagnostic purposes.

Through the IWGDE (Interlaboratory Working Group for Data Exchange), CSAM has contacted the persons at LLL who are processing the environmental data related to the Niland project. It is envisaged that the ARPANET will provide the means of integrating the operating data (at LBL) with the environmental data (at LLL), thus permitting a coherent integrated assessment of the Niland facility. (B. Levine and D. Merrill)

System 2000 Projects

A commercial data-base management system, SYSTEM 2000 (S2K), has been purchased by the LBL Computer Center from MRI Systems Inc., and will be installed in the LBL CDC-6600 in October 1977. Optional features purchased include a flexible report generator and a fully documented program language interface, features heretofore not available with LBL's in-house system BDMS.

To increase user awareness of SYSTEM 2000, a computer teleconference has, for almost a year, been used as a forum for questions related to SYSTEM 2000. Manuals are now available for potential LBL users.

Software for conversion to and from other data-base formats (including BDMS and the IWGDE standard) is being written and/or obtained from other ERDA installations, especially from BNL and LASL. S2K data bases at BNL, ANL, LASL, and EPA have already been explored, and experience gained with S2K's powerful immediate access language.

An early benchmark test will be performed by converting the PARAP (Populations at Risk to Air Pollution) from BDMS to S2K format. This will be the first opportunity for a direct comparison of costs and efficiences between the two systems, operating on the same data base in the same computer. The PARAP data base will be extended to cover the entire United States, and installed in S2K in the EPA Univac in Research Triangle Park, N. C. Because S2K is now being used by five ERDA installations (ANL, BNL, LASL, LLL, PNL) and by ERDA headquarters,

it will become an important vehicle for the interlaboratory exchange of data. (D. Merrill)

SOCIO-ECONOMIC ENVIRONMENTAL DEMOGRAPHIC INFORMATION SYSTEM

Data-Base Acquisition and Development

The objective of the SEEDIS project is to establish a coherent, comprehensive, computer-based information system for energy policy analysis, environmental impact studies, and other socio-economic analysis applications. Many LBL projects contribute significantly to the SEEDIS system by supporting research and development of retrieval, analysis, and display programs; others utilize existing software but contribute new data resources. The system contains a variety of large data bases, such as the 1970 Census, air quality data, geographic base files, and land use data, that are accessible through on-line retrieval systems over the ARPA network, dial-up terminals, and remote batch stations. A comprehensive set of user-oriented retrieval, analysis, and graphical display modules provides tables, charts, and maps, both on interactive terminals and on high-quality hardcopy output.

SEEDIS activities include acquisition and installation of data bases required for specific projects, the documenting and cataloging of those data, and the implementation and investigation of data retrieval, analysis, and display techniques. The new data bases acquired, upgraded, or developed this year by CSAM included:

* General
  PARAP (Populations-at-Risk to Air Pollution) data bases, containing geographic, demographic, air quality, and mortality data for California

  Selected portions of APPAR, a populations-at-risk data base developed by Systems Sciences, Inc., in the EPA Univac 1100

* Socio-Economic Data Bases
  Quarterly data on employment and wages by establishment, for eight western states for 1974, 1975, and first quarter 1976 (similar in content to County Business Patterns, but more current, comprehensive, and finely disaggregated)

Total population estimates as of 1 April 1970, 1 July 1973, and 1 July 1975, and per capita income for 1969, 1972, and 1974, for all U. S. counties and minor civil divisions (1975 Revenue Sharing file from U. S. Bureau of the Census

Population, labor force, and unemployment projections, by county, to 1978

ES202 employment and earnings data, 1967-74, U.S., by county and two-digit Standard Industrial Classification (SIC) code.

● Demographic Data Bases
Population by county for 1 July 1973, 1 July 1974, and 1 July 1975, and net migration and number of births and deaths by county for the period 1 April 1970 to 1 July 1975

Net Migration by county, 1960-70

1970 U.S. Census, Fifth Count by Block Group and Enumeration District (BG/ED) and Minor Civil Division and Census County Division (MCD/CCD).

● Environmental Data Bases

Air quality data for many pollutants, western U.S. through 1974, from the National Aerometric Surveillance Network (NASN)

Sulfur dioxide and sulfate air quality data from the Sulfate Regional Experiment (SURE)

1975 EPA SAROAD (Storage and Retrieval of Aerometric Data) yearly summary data for seven pollutants

Endangered species by county

1960 air quality data from Buffalo, New York.

● Energy -related Data Bases

Energy technology coefficients (requirements and residuals) from the BNL Energy Model Data Bases

Operating characteristics and emissions data for California power plants

Technology coefficients for advanced energy technologies

Operating data from the Niland Geothermal Loop Experimental Facility in Imperial County, California.

● Mortality and Health Statistics

Age-adjusted annual mortality rates by sex, race,

and county, for 35 types of cancer, for 1950-69 combined (used recently by the National Cancer Institute to produce Atlas of Cancer Mortality, 1950-69

Age-adjusted annual mortality rates by sex, race, and county for 53 causes of death, for 1968-72 combined

Third National Cancer Survey, containing complete cancer incidence data, 1969-71, for seven SMSA's by census tract and two states by county

Extract from Third National Cancer Survey, containing additional detailed information obtained by interview of 20 percent of all cancer patients

Complete 1972 mortality statistics (extracts from individual death certificates), from National Center for Health Statistics (NCHS)

1960 mortality data from Buffalo, New York.

● Cartographic Data Bases
MED-X (Master Enumeration District List, extended), containing latitude-longitude coordinates and associated FIPS geocodes (tract, county, SMSA etc.) of all 230,000 BG/ED's in the U.S.

World Data Bank II, containing latitude-longitude coordinates of all coasts, islands, lakes, rivers, and international boundaries of the world; U.S., state, and Canadian province boundaries for North America.

Geographic boundaries of EPA Federal Regions, and BEA (Bureau of Economic Analysis) areas

Boundaries of EPA AQDR's for California

ERA SAROAD SITE Directory, containing latitude-longitude coordinates and other information for all U. S. Air Quality Monitoring Stations

County geographic centroids (calculated from polygon boundaries) and population centroids (calculated from MED-X) for California.

● Geocode Conversion Files

Geocode conversion dictionary, EPA (SAROAD) county Codes to FIPS county codes

Geocode conversion dictionary, NCHS county codes to FIPS county codes

Geocode conversion dictionary, Tekrekron county codes to FIPS county code.

INTERLABORATORY WORKING GROUP FOR DATA EXCHANGE (IWGDE)

The Interlaboratory Working Group for Data Exchange (IWGDE), consisting of members from Argonne National Laboratory (ANL), Brookhaven National Laboratory (BNL), Lawrence Berkeley Laboratory (LBL), Lawrence Livermore Laboratory (LLL), Oak Ridge National Laboratory (ORNL), Pacific Northwest Laboratory (PNL), and Savannah River Laboratory (SRL), met in Washington in August 1976 and in Oak Ridge in November 1976. The group plans to meet in Berkeley in May 1977, at Argonne in June 1977, and in Washington in September 1977.

The implementation of software packages to read and write tapes in the IWGDE exchange standard was completed at most of the installations, and tapes were exchanged for testing purposes. Users' Guides for the CDC and IBM software implementations were circulated to the various laboratories. A revised version of the standard specifications was submitted to the ANSI X3L5 Standards Committee, as a proposed extension of the existing ANSI standards.

World Data Bank II, a worldwide cartographic data base produced by the Central Intelligence Agency, was received at LBL, and the North America portion was implemented for retrieval and plotting in MAPEDIT. Copies of the full data base are being distributed by LBL to other ERDA installations.

During the past year, the IWGDE facilitated the following data exchanges between LBL and other ERDA installations:

From ANL: MED-X file (centroids of Census BG/ED's)

To BNL: 1972 employment data for Input-Output industry sectors 1960; air quality and mortality data from Buffalo, New York; census tract boundaries for SMSA's in eastern states; EPA-to-FIPS County Geocode Conversion file; dictionary of FIPS counties by EPA Air Quality Control Region

From BNL: EPA SAROAD Monitoring Station Site Directory

To LASL: World Data Bank II

To ORNL: EPA-to-FIPS County Geocode Conversion file; World Data Bank II

From ORNL: Routines for conversion of UTM coordinates to latitude-longitude

To PNL: County and state boundaries in NICKEL format.

(D. Austin, H. Holmes, and D. Merrill)

PROJECTS USING SEEDIS DATA BASES

LABOR MARKET PROJECTIONS MODEL. The affiliated State Employment Security Agencies (SESAs) of the Department of Labor Employment and Training Administration (DOL-ETA) supply local planners in CETA projects with estimates of persons in need of manpower services. To be of maximum use, these estimates should reflect "current" local needs. In collaboration with DOL-ETA, Lawrence Berkeley Laboratory (LBL) has developed an estimation procedure through its Labor Market Projections Model (LMPM). The goal of the LMPM project is to provide a comprehensive modeling system to be used by local SESA analysts.

Since LMPM started at LBL in the summer of 1975, two methods of estimating "current" local needs have been developed. The first method updates certain tabulations of the 1970 Fourth Count Census by using the 1970 Current Population Survey (CPS) tapes and the latest CPS tapes. Updated census tabulations were computed by multiplying the 1970 census data by the ratio of the latest CPS data to 1970 CPS data and normalizing the results.

The second method of estimating current local needs uses a refined cohort-component method to determine population projections. This involves the separate projection of mortality, fertility, and net migration for 5-year-age cohorts to give population by age, by sex, and by race for a particular area. Labor force and unemployment projections are based on the population projections and on national changes in the structure of the labor force and unemployment. In order to implement this model, data from several diverse sources had to be collected and integrated into a comprehensive data base, GISFILE:

1. 1970 Fourth Count Census, tabulations 17, 54, and 55
2. 1970 Sixth Count Census, tabulation 1150
3. 1960-1970 County Migration by race, by sex, by age, from G. K. Bowles, U. S. Department of Agriculture, Economic

Research Service; University of Georgia, Institute for Behavioral Research; and National Science Foundation

4. Total population control estimates for January 1978 by county, from the Bureau of the Census

5. Labor force participation rates for January 1978, from the states

6. Unemployment rates for January 1978, from the states

7. National Fertility Rates by age and by race from Vital Statistics of the United States 1971, Vol. 1

8. National Survival Rates by age and by sex, from Current Population Reports, Population Estimates and Projections Series, p. 25, Vol. 493, December 1972

After 2 years of effort, LBL in cooperation with DOL-ETA has developed two computerized models to help supply analysts in CETA projects with estimates of persons in need of manpower services. At the end of each calendar year, both models are run for all states, SMSAs, and prime sponsors. The results are mailed to the State Employment Security Agencies in each of the 50 states.
(W. Benson, S. Cassinelli, F. Gey, H. Holmes, E. Schroeder, E. Williams, P. Wood)

URBAN MIGRATION STUDY. The purpose of the Urban Migration Study is to develop and test a model for analyzing and forecasting in-migration and out-migration, employment change, and wage change for metropolitan areas at the two-digit level of industrial details. With the change in labor market decisions from the national to the local level, there has been an increased demand for labor market information for metropolitan areas. The model was developed for those SMSA's with 250,000 people or more, as this is about the smallest geographic unit with the desired amount of socio-economic data.

Several different data sources were combined in building this model:

1. 18% sample from the Continuous Work History Sample (CWHS) that is maintained by the Office of Research Statistics of the Social Security Administration

2. 1969, 1970, and 1971 County Business Patterns

3. Quality of life data from Quality of Life in U. S. Metropolitan Areas: A Statistical Analysis by Liu, Ben C.

4. Change in the consumer price index from the CPI Detailed Report for 1970, 1971, 1972,

5. 1970 and 1972 unemployment rates from 1974 Manpower Report of the President, Tables D-8, D-4

The coefficients for the four simultaneous equations that define in-migration, out-migration, changes in wages, and changes in employment were estimated using two-stage least squares. Using these estimates, forecasts for in-migration and out-migration were made using data from the Office of Research Statistics of the Social Security Administration. (E. Schroeder)

ENERGETICS OF THE UNITED STATES MAPPING PROJECT. During 1976, BNL's Biomedical and Environmental Assessment Division developed the COENDA data base. COENDA contains 1970 county-level data on U. S., energy production and use. With the use of LBL's interactive graphics system CARTE, BNL and LBL personnel made a series of 40 color maps of the U. S., by county, which have been included in the recently published United States Energetics Atlas. Recently, LBL personnel incorporated the same data-base into REAP, a flexible interactive query system in SEEDIS. (B. Burkhart and P. Wood)

SIRAP/REAP. Implementation of the SIRAP (System of Information Retrieval and Analysis for Planners) Data Display and Mapping Facility was the main emphasis of the ongoing SIRAP project. An interface was constructed between the Qwick Qwery retrieval and report generation system, the MAPEDIT map extraction system, and the CARTE and SYMAP data mapping packages. Thus, SIRAP data can now be retrieved and mapped in a single computer job.

The REAP system for rapid retrieval of socio-economic and demographic data became a production system this year, serving the needs of the U. S. Army Corps of Engineers and other governmental agencies. Data files of value to planners are installed

in the SEEDIS data base at LBL. On-line access to
these data provides timely information to planners
in evaluating the social, economic, and environmental
effects of their civil works projects. Numerous
enhancements to REAP were implemented this year in-
cluding multi-user access to a single data base, a
facility to permit specification of ranges of geo-
graphic areas for data retrieval, indexing of files
stored on computer tapes, uniform indexing of all
files by FIPS codes, and a help command to assist
new users accessing the system interactively. In
addition, preliminary specifications were developed
for providing accesss via REAP to 5th count 1970
census data.
(S. Cassinelli, F. Gey, H. Hogan, J. Miller, and
E. Williams)

REGIONAL MANAGEMENT INFORMATION SYSTEM.

Research and development continued on the Regional
Management Information System (RMIS) project. Ini-
tially funded in 1974, the project seeks to investi-
gate and test the feasibility of installing DO-ETA
Employment Security Automated Reporting System
(ESARS) data bases and available SEEDIS data into a
coherent, readily accessible information structure
useful for meeting current and projected demands for
data. Activity has included developing computer
tools (interactive retrieval, computer graphics, re-
port generation, and computer mapping systems) which
will enable managers to access data quickly and
easily.

During the past year, the interactive retrieval
tool has been further developed and linked to

- Newly developed file access software designed
  especially for interactive tools
- The graphical analysis and output formatting
  tool
- The SEEDIS executive program and report gen-
  eration module.

In addition, significant field development took
place, including seminars, demonstrations, and the
development of users' guides, work books, films,
video tapes, and monthly status reports. Field de-
velopment activities also included making nonprogram-
mer LBL personnel available to answer questions con-
cerning any SEEDIS tool. Friendly and reliable con-
tact with the user community has been the key to

obtaining the high quality feedback so necessary for
further research and development progress.

Finally, the design of a new ESARS summary
level data structure was completed. Because the de-
sign is not tied to a particular output format, it
has become known as the Employment Security Table
Independent Cell Structure (ESTICS). A prototype
based on BDMS and INTERAC and incorporating a high
level interactive interface language was designed
and implementation begun.
(R. Allen, W. Benson, T. Coffeen, W. S. Gee, R.
Healey, B. Heckman, P. Kreps, J. Miller, and V.
Sventek)

ERDA PARTICIPATION ON THE FEDERAL AGENCY COUN-
CIL ON THE 1980 CENSUS.

Initial contacts were made
with the chairman of the Federal Agency Council on
the 1980 Census with regard to ERDA participation in
defining the scope and use of this important data
source. LBL, because of its extensive experience
with the 1970 census, is serving as staff support in
coordinating ERDA input to the Federal Agency Council
on the 1980 census, its working committees, and other
pertinent census organizations. Composed of approx-
imately 90 Federal agencies, the Council provides an
organizational channel through which federal agen-
cies making extensive use of decennial census mate-
rials can transmit advice to the Office of Management
and Budget and the Census Bureau. The Council's ef-
forts focus on broad aspects of the 1980 census, in-
cluding proposals for new questions, major changes
in procedures or samples, and tabulation and publi-
cation plans.

Contacts have also been established with other
appropriate organizations. Interactions with the
Bureau of the Census have focused on determining
relative priorities in the proposed summary tabula-
tions and the methods and timetables by which data
will be released. LBL was officially registered as
a Census Summary Tape Processing Center. As such,
LBL is kept informed of Census Bureau activities
through the monthly Data-Use-News. As in the past,
LBL continues to respond to a considerable number of
requests for information about census and census-
related data.

At the local level, LBL has made contact with
the persons (in the Association of Bay Area Govern-
ments and the Metropolitan Transportation Commission)

who are responsible for the GBF-DIME files which will be used in defining the enumeration districts of the 1980 census. These boundaries, for the whole nation, will be "frozen" during FY 1977, at which time construction of geographic files for the 1980 census can begin.

(B. Burkhart, S. Kranz, D. Merrill, and C. Quong)

GEOGRAPHIC DATA-BASE. The Geocoding Subcommittee of the IWGDE began investigating the standards for geocoding geographical and political areas, coordinate systems in use, and exchange of geographic base files among ERDA sites. The Harvard University packgage POLYVRT was installed at LBL and an interface module between LBL's MAPEDIT and POLYVRT was designed and implemented. A test file was sent to ORNL for processing since POLYVRT is running on IBM equipment there. Based on our experiences with POLYVRT, we are proposing a chain file structure which will be transmitted using the IWGDE exchange standard.

World Data Bank II, produced by the Central Intelligence Agency, was obtained by LBL and is being distributed to other ERDA laboratories. This cartographic data base contains digitized coastlines, islands, lakes, rivers, and political boundaries for the entire world, to an accuracy of about 100. The data base is an untagged "spaghetti" file, which will have to be appropriately geocoded for mapping and land use applications. The North America portion of WD83 has been implemented in an interactive retrieval system using MAPEDIT, allowing for selective plotting and editing at a graphics terminal.

MED-X, the extended Census Master Enumeration District list produced by DUALAOS Inc., was acquired from Argonne National Laboratory through the IWGDE. This file, which contains populations and latitude-longitude centroids for the 230,000 Census Block Groups and Enumeration Districts (BG/ED), is being used to calculate population centroids for counties and census tracts; these in turn are being used in the PARAP project, in Department of Labor projects, and elsewhere.

With the use of the map editing program ZING, digitized boundaries have been produced for the air quality control regions and hydrologic study areas of California (which do not follow county boundaries).

These data are required for mapping applications in the Energy Analysis Group of the LBL Energy and Environment Division.

Point locations of the 6000 Air Quality Monitoring Stations in the EPA SAROAD Site Directory were received from Brookhaven National Laboratory in the IWGDE standard exchange format. These data are being used in the PARAP project.

Discussions are under way to obtain digitized files of transportation networks, including railroads, major roads, oil pipelines, and electric transmission lines.

(W. Benson, B. Burkhart, H. Holmes, D. Merrill, and P. Wood)

WATER RESOURCES PROJECT. A series of tables, generated for the California State Department of Water Resources, shows water use by manufacturing industries in California in 1970. The tables are patterned on a previous study for the years 1957-1959. The tables present, for each major Standard Industrial Classification and/or county, the water intake, use, source, recirculation, discharge, and potential acceptance of reclaimed water of approximately 6000 reporting manufacturers, and an estimate of the total fresh water use by all 27,000 manufacturing industries in California.

(C. Lederer)

NATIONAL TECHNICAL INFORMATION SERVICE (NTIS). An interagency agreement between ERDA and the National Technical Information Service (NTIS) provides government agencies, affiliates and grantees of those agencies, and the public with access through NTIS to SEEDIS data bases, data, and retrieval and display programs. Currently, a series of manpower reports developed under the sponsorship of the Department of Labor are available through NTIS for user-specified geographic areas. Users may also request special analyses which might require unique structuring of data within SEEDIS or data not available in a standard format.

(R. Allen, B. Burkhart, R. Healey, S. Kranz, and E. Schroeder)

CALIFORNIA SOLAR RADIATION. Programming has been completed for the collection, analysis, and formatting of the California daily solar radiation in preparation for a California Solar Data Manual

sponsored by ERDA and the California Energy Re-
sources Conservation and Development Commission.
(C. Lederer)

LAND USE AND REMOTE SENSING. A new aspect of
SEEDIS is the increasing use of remote sensing data
and associated data analysis techniques. The Land
Use Project utilizes LANDSAT data, the best-known
source of remotely sensed information. LANDSAT data
tapes corresponding to more than 10 scenes have been
acquired, and several software systems have been in-
stalled to process these data. Available systems
include:

1. Training set selection routines for
   establishing land use classes
2. Unsupervised classification routines
   (automatic clustering)
3. Supervised classification routine (inter-
   active clustering
4. Coordinate transformation and re-gridding
   software
5. Polygonal masking routines, for compar-
   ison of grid and polygon data
6. Grid overlay routines for combining data
   according to a user specified constraint
   function
7. Statistical analysis routines for eval-
   uating classifications
8. Versatile color display routines for
   interpreting gray scale, false color,
   etc.
9. Contour, isopleth, hidden surface, and
   point-to-point visibility routines.

In the past, gridded data have been processed
only for particular geographic areas under study.
A goal of the Land Use Project is to incorporate
these data into the SEEDIS data base and make them
available for all geographic areas. In this way,
processed LANDSAT data will be conveniently avail-
able for input to other projects.

An image processing system and large disk stor-
age units have been added to an existing mini-
computer for land use display and analysis. Routines
are also available which are useful for more general
applications. These include polygon-to-grid and
grid-to-polygon transformations, contour plotting,

and hidden surface routines, and point-to-point vis-
ibility calculations.
(H. Holmes, W. Johnston, F. Montalvo, P. Wood)

PARAP (POPULATIONS-AT-RISK TO AIR POLLUTION).
The Populations-at-Risk project, funded by
EPA, spans a 27-month period from 1 July 1976 to
30 September 1978. The project has as its goal the
creation and analysis of an integrated county level
data base containing data on socio-economic and
demographic characteristics, air quality, and mor-
tality.

During the first year, a prototype California
data base was created with the use of BDMS, the
Berkeley Data-Base Management System. The data
elements include:

- For each air quality monitoring station:
  EPA station code, UTM and latitude-
  longitude coordinates, place name, pollu-
  tants measured, analysis and collection
  methods, number of observations, number of
  National Ambient Air Quality Standard(s),
  arithmetic and geometric means of measured
  values, arithmetic and geometric standard
  deviations

- For each county:
  FIPS and EPA county codes, county name,
  population in 1970, 1973, and 1975; area,
  latitude-longitude coordinates of boundary
  points, latitude-longitude coordinates of
  geographic and population centroids, medi-
  an family income, per capita income in
  1969, 1972, and 1974

- For each county, by sex:
  Median years of education, labor force
  status, distribution of employment by oc-
  cupational and industrial categories:

- For each county, by sex and race:
  Age distribution (21 groups); age distri-
  bution of married and unmarried persons
  separately (7 groups); age-adjusted death
  rates (a) 1950-69, for 35 types of cancer
  (b) 1968-72, for 53 causes of death

- For each county and each pollutant:
  County estimates of the arithmetic and
  geometric means, and arithmetic and geo-
  metric standard deviations of pollutant

concentrations, for seven pollutants in 1975. The estimates are weighted averages of measurements from all stations within 50 km of the county centroid.

During the second year, the data base will be expanded to cover the entire United States. It will be implemented in BDMS in the LBL computers, and in SYSTEM 2000 in the EPA Univac 1100.

An important by-product of this project was the experience gained with the EPA Univac 1100 computer in Research Triangle Park, N. C. The EPA SAROAD (air quality) and NEDS (emissions) data bases, which are maintained in this computer, will be valuable resources in future projects.
(S. Knif, C. Lederer, B. Levine, D. Merrill, and E. Schroeder)

SEEDIS MONITOR

The SEEDIS Monitor was developed as an executive system to ease the problems of job control for interactive users of SEEDIS subsystems and to provide a user-friendly interface to system resources. Through the SEEDIS Monitor, users may access several data management, analysis, and display modules, as well as file management, mail, on-line help, and user-feedback facilities. Users issue simple one-line commands with a few options. Prompting is used to facilitate interactive control and reduce the burden of remembering long sequences of parameters. Using the Monitor, users may now access more than one SEEDIS module within a single job or computer session.

The present implementation, which is to be considered an experimental vehicle, was developed using a general command language interpreter called DOIT, which has been developed by another group at LBL. We consider our experience to be a strong validation of the utility of such an interpreter system. Equally important, the Monitor has demonstrated the value of a user-oriented executive in providing easy access to a complex computer system and an environment which facilitates resource sharing and encourages standardization.

The nature of the Monitor, with its avoidance of a complex job control language, allows the non-computer user to devote time and effort to learning and experimentation with the SEEDIS systems. The learning process has been simplified dramatically with the added benefit that the user's projects can now be completed within more realistic time frames. (P. Kreps, and V. Sventek)

TRAINING IN THE USE OF SEEDIS INTERACTIVE SYSTEMS

With the development of the SEEDIS interactive data retrieval and analysis systems, the need for an educational program arose. This program has progressed along five fronts. The first is a set of users' guides for each SEEDIS system created by the individual system designer. These users' guides describe in detail the capabilities and, to a varying degree, the usage to which each system can be put. Second, a set of workbooks is being prepared to take up where the users' guides leave off and provide step-by-step examples of the system. These workbooks are directed toward the non-computer user who wishes to apply the system to his particular application but feels the need for cookbook-like instructions at the onset. Three systems now have workbooks: SEEDIS Monitor, CHART, and CARTE.

Third, a full-time consultant is available at LBL, either by telephone or through computer terminal-to-terminal communication, to help the user from the beginning, starting with equipment familiarization and log-in procedure, to data storage and access.

Fourth, copies of each users' interaction with the SEEDIS system via the SEEDIS Monitor are made and routed to the system designers and to the consultant on a daily basis. In this way a user having difficulties is spotted and help is offered, often before the user realizes what his problem is. The SEEDIS Monitor also provides a method for the user to enter comments into the session record to be seen by the system designers.

Fifth, week-long training sessions are held at the Laboratory. At this time, the user is given comprehensive training in those systems for which he has applications and interests as well as a cursory look at those for which he may not have a present need. As the systems continue to evolve, follow-up training sessions may be available.
(R. Allen, N. Burkhart, and V. Sventek)

LBL INTERACTIVE RESOURCE INDEX (LBLIRI).

Work progressed on LBLIRI, the LBL Interactive

Resources Index. LBLIRI, as a BDMS data base, was incorporated as a retrieval package in the SEEDIS Monitor. At present, the difficulties with LBLIRI are: (1) it is about 1 year out of data; (2) it contains miscellaneous entries not directly related to LBL data bases; (3) it is still in Version I BDMS, which does not have a Boolean search capability; (4) there is no HELP package to aid the inexperienced user; (5) it is tape-stored, so that a 5-10 minute delay may be experienced if the data base has not been recently accessed and stored as a common file; and (6) it is in upper case only, which is aesthetically unpleasant for a bibliographic data base like LBLIRI.
(D. Merrill)

LIST OF LBL COUNTY-LEVEL DATA BASES.

In view of the LBLIRI shortcomings mentioned above and the amount of work required to overcome them, it was decided to concentrate on a smaller data base in a simpler format; the simpler format would contain information on LBL data bases only. Using the ASCII version of BDMS (Version II) recently developed by CSAM, a trial data base was constructed; it contains information of only the 30-odd county-level data bases at LBL. As closely as possible, the format matches that of similar lists which have been constructed at ORNL, in printed and machine-readable form. The LBL county data base list, in print format, has been transmitted to the BBN POP-10 and widely publicized in ERDA computer teleconferences. Thus, all potential users of LBL data bases will have ready access to a constantly updated list.

In the future, the list will be expanded to cover all SEEDIS data bases. The list will be kept current and distributed in printed form. Conversion of the list to more aesthetic formats awaits further development of BDMS-linked report generators.

A machine-readable version of the ORNL list, in similar format, has been received at LBL. A small effort will be required to merge the two lists in a common format. It is expected that the merged list will form the nucleus of, and be an incentive for, similar lists from all of the ERDA laboratories.

The LBL data-base list will be provided to Lawrence Livermore Laboratory, in printed and machine-readable form, to permit updating of the National Index of Energy and Environmentally-Related Data Bases and Models (which is now available through ERDA/RECON).
(D. Merrill)

CENSUS ENERGY INDEX.

The Office of Environmental Information Systems (EIS) within ERDA's Administration for Environment and Safety (AES), has recognized the need for a detailed and comprehensive guide to all of the energy-related data collected by the U. S. Bureau of the Census. The data of interest to ERDA come from a great number of primary sources, including the decennial Censuses of Population and Housing, the Current Population Survey and Annual Housing Survey, the quinquennial Censuses of Manufactures, Mineral Industries, Agriculture, Transportation, Construction, and Wholesale and Retail Trade; the Annual Survey of Manufactures, Retail Trade Surveys, Current Industrial Reports, Construction Surveys, and Foreign Trade Reports.

Under an ERDA-Census Interagency Agreement, ERDA's EIS will fund, during FY77 and FY78, a census Energy Index. The Index will be produced by Census Bureau Staff, with LBL acting as technical liaison for the project.

LBL has specified that the data guide to be produced by the Bureau of the Census should be supplied in machine readable form, with individual data items tagged for selective retrieval. In such a form, the Census Energy Index will be easily integrated with existing machine-readable data directories, and can serve as a tool in future automatic data retrieval systems to be incorporated in SEEDIS. (A similar index, produced by the Census Bureau for data from the 1970 Census of Population and Housing, has already been incorporated in SEEDIS to provide user-specified selective retrieval of Fourth Count Population data.)
(S. Kranz, D. Merrill, and C. Quong)

COMPUTER GRAPHICS

COMPUTER GRAPHICS AND INTERACTIVE PROGRAMMING TECHNIQUES

Research in computer graphics is directed toward the goal of enhancing human-machine communication in the areas of data analysis, manipulation,

and display. Graphical displays provide immediate comprehension of trends, clusters, and relationships in complex data. By expressing data transformations in graphical terms, the non-mathematical user can gain insight into the underlying structures of data.

Research in natural language interfaces to information systems is aimed at employing artificial intelligence techniques to build "intelligent" user inferfaces to existing or planned facilities, such as data management systems, network operating systems, and geographical and management information systems. Work has begun on the design of a top-level controller and query process on interface to SEEDIS (which currently contains a variety of independent data retrieval, analysis, and display modules), and to the ERDA Network Virtual Operating System concept. (W. Benson, H. Holmes, W. Johnston, P. Kreps, I. Kuo, F. Montalvo, V. Sventek, and P. Wood)

MAPPING SYSTEM

The LBL thematic mapping system, CARTE, provides several types of displays based on geographic base files and geographically-coded data. CARTE incorporates a variety of data integration and manipulation facilities to allow the interactive analysis of geographic data by real-time displays of thematic maps. Enhancements completed this year provide the user with several new or improved interactive design capabilities including revising map orientation and titling, specifying the design of crosshatch patterns, identifying binning intervals, performing arithmetic computations on variables, and utilizing point and line display techniques.

In addition, polygon mapping capabilities were extended to include data in gridded form. Undertaken in collaboration with the Space Sciences Laboratory at UCB, the Association of Bay Area Governments, and Oak Ridge National Laboratory, this effort focused on general data handling, particularly in LANDSAT (formerly ERTS) data analysis. The Video Frame Buffer will be utilized for image display of LANDSAT data, and its use in the actual analysis of LANDSAT data is also being explored.

GRAPHIC REPRESENTATION OF TABULAR DATA

CHART, an interactive analysis and display program for tabular data, was converted to run on a

minicomputer, and several new features were implemented. People generally have trouble assimilating even small amounts of data in tabular format. Hence, familiar graphic representations such as those found in newspapers, magazines, and technical journals are frequently helpful. CHART uses a vocabulary of basic forms—lines, bars, pies, shading—which may be successively modified until a satisfactory picture is obtained. Manipulations that may be performed include table reorganization—for example, ranking on the basis of a particular row or column, data calibration and selection, scaling and binning, selecting graphic variables, and display annotation and embellishment.

Limited data analysis capability is also provided. Raw data may be systematically transformed into profiles by comparing rows or columns with a standard reference. Change, or percent change, from the reference allows objects to be compared across attributes when raw data values cannot be compared directly.

MATBOARD, developed in parallel with CHART, is a prototype program which has been designed in order to study the feasibility of integrating data analysis techniques with graphic formats to aid decision makers. One particular class of graphic displays (matrix display) and one type of data analysis (dimensional scaling) are integrated within MATBOARD to offer an aid for two different cognitive tasks—ordering and clustering rows and/or columns of a data matrix.

In addition, a bridge between ESARS and CHART has been built as a first step toward supplying a data retrieval facility for CHART. Given a user-designed report template where tabular data values are designated by data descriptors, the two programs are used in tandem to retrieve and display the desired data. This prototype report generator can now use multiple files and multiple data sources.

DIAGRAMMATIC LANGUAGE PROCESSORS

The PICASSO graphics modeling system analyzes user-drawn diagrams in terms of user-specified primitives and serves as a translator between two-dimensional diagrammatic problem specifications and the linear languages of most analysis programs. This system was used as a basis for the development of

the CUPID graphics language processor for the relational data management system INGRES. The graphics editor module of PICASSO was implemented on the INGRES PDP-11 at UCB, leaving the complicated topological analysis and macro processor modules resident on the CDC-6600. This provides a distributed computing environment with fast response to the interactive diagramming phase on an intelligent terminal and transfers the complex operations to the large machine. A hardwired link was established between the INGRES machine and the LBL complex, affording network access to all these systems.

GENERALIZED DISPLAY ROUTINES

The Integrated Data Display System (IDDS) is a general purpose scientific system with emphasis on complex transformation and display (e.g., contour plots, gray-level plots, streamline plots, generalized hidden surface display, and 3D vector field display). It will display one-, two-, and three-dimensional scalar fields in a large variety of ways—X-Y plots, histograms, polar coordinate plots, scatter diagrams, contour fields, gray-level plots, perspective-viewed surfaces, 2D vector fields, 2D streamline plots, 3D vector fields, 3D streamline plots (under development), 3D scalar fields (as isosurface plots), and generalized 3D hidden surface plots. IDDS also includes a suite or routines to do least squares, cubic spline fitting in one to four spatial dimensions. These routines are frequently used to reconstruct sparsely represented scalar fields (for example, geopotential fields). The system is capable of producing thematic maps using gridded data and may be used in conjunction with LBL's polygonal mapping system, CARTE.

A general system that can be used whenever graphical display of data is desired, IDDS has been used for display of scalar and vector fields in one, two, and three dimensions and thematic and gridded map data (LIRAQ, MASOON, METDATA, SOURCES). The system is undergoing continual development, and its documentation is continually upgraded. One of its several "spin offs" is the ASTOG text composition system, a general purpose photo composition system used to produce camera-ready output of scientific reports with illustrations suitable for publication. Features include several alphabetic fonts and several special fonts.

HARDWARE DEVELOPMENT

A Video Frame Buffer (VFB) will be installed and interfaced to a PDP-11, which in turn is interfaced to the CDC-6600. In addition, a cross assembler (for the PDP-11), a loader, and a debugger for the microprogrammable processor attached to the VFB were provided. Software is available to display conventional vector and alphanumeric displays as well as gridded (raster) data. This software allows color pictures to be interactively created and displayed. A real-time video digitizer has been added to the system. Current applications include: (1) cell colony counting for evaluation of radiation therapy for cancers; (2) contrast enhancement, density level identification, and multiple-image correlation for radiography; (3) analysis of land-use data from LANDSAT satellites for siting studies; and (4) three-dimensional image reconstruction for tomographic studies at the Bevalac.

OFF-LINE PHOTOCOMPOSITION OF TEXT FROM THE IRATE KEY-BOARD (OPTIK)

The equation processor in OPTIK (Off-line Photocomposition of Text from the IRATE keyboard) was reprogrammed. OPTIK is the program used by the Particle Data Group (PDG) to prepare publishable output on film using the IRATE terminal for editing. The equation processor removes from the user the responsibility for correct placement of numerators and denominators on the page. It now correctly takes into account different character sizes, subscripts, superscripts, and other special spacing when determining where portions of the equation should be placed.

Several report-generator programs were written to prepare LBL-91, a published report consisting of indices for and detailed listings of information in PDG's particle-physics-experiment proposals data base. Other report generators have been begun for LBL-90, a report to be published containing indices and listings from the PDG data-base containing all documents in experimental particle physics (preprints, published articles, theses, etc.).
(M. Hutchinson)

COMPUTER NETWORKS

ARPANET IMPLEMENTATION AND EXPERIMENTATION

LBL and six other ERDA research centers (ANL, BNL, LLL, MIT-LNS, NYU, and UCLA) now have direct, on-site access to the full range of ARPANET facilities, including access to remote time-sharing systems, file transfer, and remote batch capabilities. Moreover, network access to these major ERDA centers, as well as nearly 100 non-ERDA sites, is available at most other ERDA sites via dial-up facilities (local or FTS).

During the past 2 years, more than 60 network-based applications involving ongoing research projects have been initiated and analyzed. In these cases, the network was used to achieve:

- Scientific collaboration on a national and international scale, involving scientists and managers from nearly every major ERDA site
- Access to unique hardware, software, and data bases in ERDA and other agencies
- Reduction of duplicate development of specialized software and data bases
- Off-loading large computational tasks from smaller centers to large centers
- Research and development of computer networking techniques
- Interaction with researchers from the University and private sectors.

Some technical barriers were discovered which make attempts to use the network difficult. These include the lack of adequate documentation and consulting services, differences in command and programming languages, and saturation of host machines. None of these barriers is fundamental in restricting network use except, perhaps, the lack of sufficient computing capacity to support resource sharing. Non-technical barriers to network-based resource sharing were also encountered. These include the difficulty of dealing with network communication and maintenance costs on an equitable basis and potential loss of funding arising from excessive use of remote facilities.

The following conclusions can be drawn from network implementation and experimentation to date:

- It has been demonstrated that general purpose computer networks can be used in the ERDA community to achieve better utilization of resources and improved quality of research.
- The ARPANET is a smoothly functioning, general purpose computer communications network which supports the most versatile capability for heterogeneous, independent computer centers in existence. In particular, the large scale computational facilities available at ERDA centers can be adapted to support practical resource sharing on an operational basis.
- Unique or special computational resources will be effectively utilized in energy research and development programs if the resources are easily available to researchers.
- Electronic mail and computer teleconferencing significantly increase scientific collaboration and management coordination.

- Duplication of effort in software development can be reduced by providing network facilities for accessing special programs at remote sites and for transporting software between cooperating sites.
- Large scale computations can be off-loaded to large centers, providing extra resources to a wider range of researchers in the ERDA community.
- Interaction with non-ERDA research activities in the university and active private sectors is greatly enhanced by computer network facilities.
- The initial costs for network connection are minimal compared to the long-term benefits obtained.

(D. Austin, S. Furst, D. Hall, R. Healey, B. Heckman)

DISTRIBUTED COMPUTER NETWORK

Through a Memorandum of Understanding between ERDA/AES and the Department of Labor, LBL is beginning work on the design and implementation of a Distributed Computer Network (DCN) for distributed data management and other general purpose tasks. A study

was made of available minicomputer hardware and software, and specifications for an experimental distributed computer system were prepared. An RFP (request for proposal), based on this study, was sent to minicomputer vendors. Responses to the RFP were evaluated and benchmarks were run on several systems. The Digital Equipment Corporation (DEC) PDP-11/70 CPU was selected as the most suitable machine for this network. Several operating systems run on the 11/70, RSX, IAS, and UNIX were evaluated and IAS was selected as the best system for this application. Network communications will be based on DECNET. The initial configuration will be a four-node minicomputer network, with nodes in Berkeley, San Francisco, Denver, and Washington, D.C. The current schedule calls for the addition of eight nodes by 1979, to include each of the 10 Federal Regional Headquarters and the National Office in Washington, D. C. The Berkeley node will provide a gateway to the LBL SEEDIS facilities on the main computer center, which in turn will serve as access to the ARPANET. It is expected that research on a homogeneous minicomputer network will point the way for future evolution of the ERDA Network.
(R. Allen, H. Gin, A. Greiman, H. Holmes, and D. Richards)

NETWORKING APPLICATIONS

COMPUTER TELECONFERENCING. Computer teleconferencing was heavily used as a mode of communication between ERDA laboratories and other installations during the past year. At least 30 separate conferences were active in the PDP-10 of Bolt, Beranek, and Newman (BBN) in Cambridge, Mass., using the PLANET teleconference system developed by the Institute for the Future of Menlo Park, California. By far the most active conference was that of the ERDA Investigators panel, which was used by workers at seven different installations to prepare a comprehensive paper on ERDA networking activities. In this conference more than 1000 messages were exchanged in the period of a few weeks.

Another very active conference on county-level data bases, was initiated by Sam Morris of Brookhaven National Laboratory, and is scheduled to be published as a BNL report. This conference, which was publicized in advance by mail, attracted more than 100 participants from more than 30 research installations, including all ERDA laboratories, government agencies (Dept. of Labor, Bureau of the Census, Department of Agriculture, etc.) and many universities. Contacts were developed which have been fruitfully maintained since the teleconference ended.

Other active teleconferences have been maintained by the IWGDE (Interlaboratory Working Group for Data Exchange), in connection with data-base exchanges, implementation of data exchange standards, and development of geocoding standards for cartographic data bases. Conferences on BDMS and SYSTEM 2000 are being used to keep participants informed of new developments in data-base management systems. (D. Austin, D. Hall, S. Furst, and D. Merrill)

DOCUMENT PREPARATION. A serious deficiency at LBL is the lack of flexible and powerful document preparation program. The system in common use at LBL, BARB, is extremely difficult to use for mixed upper and lower case applications. Rather than cope with these difficulties, most LBL users (including the Computer Center, for all systems documentation) have preferred the standard upper case version of BARB. The LBL Real Time Systems Group has undertaken the writing of an improved document preparation program for LBL applications.

CSAM is utilizing the program MRUNOFF, which was written at Bell Laboratories in 1969 and has been extensively improved over the years. Unfortunately MRUNOFF is written in BCPL, which cannot be compiled on the LBL 6000 computers. As an alternative, ARPANET interface packages have been written which allow the user to run MRUNOFF at BBN as easily as he might run BARB at LBL. The issuance of a few terminal commands causes an MRUNOFF input file, stored at LBL, to be automatically shipped to the BBN computer, processed through MRUNOFF, converted to LBL print format, shipped back to LBL, and printed on LBL's ASCII line printers.

Extensive use of computer networks has been limited until now to relatively experienced users who must understand the detailed differences between dissimilar computers. The advent of automatic file transfer capabilities will permit widespread use of network capabilities by a larger number of users, who need not be aware of the complicated data manipulations taking place.

(R. Allen, D. Austin, D. Hall, S. Furst, D. Merrill, and V. Sventek)

MANAGEMENT INFORMATION SYSTEMS

REGIONAL AUTOMATION SYSTEM

The Regional Automation System (RAS) study is a comprehensive evaluation of the management information system utilized by regional and national offices of the Department of Labor for tracking employment and training programs, primarily under CETA (the Comprehensive Employment and Training Act). The LBL study focused on operational and managerial deficiencies within the existing RAS procedures. The study, which was completed in September 1976, provided a set of detailed alternative plans for the improvement of RAS, ranging from minor modification of existing operations to replacement of the existing centralized system with a distributed data base minicomputer network operated from regional offices. (P. Chan, F. Gey, D. Kane, and D. Richards)

BIBLIOGRAPHIC INFORMATION SYSTEM

Bibliographic Information System (BIS) projects are carried out in support of LBL's Information Research Group (IRG), Library, and Technical Information Division. The IRG's selective dissemination of information system was maintained, improved, and generalized to conform with changing input, programmatic requirements, and operating systems. Support of the IRG effort also involved research in the area of data-base evaluation, comparison, and mapping.

The needs of the library and Technical Information Division are being served by the Reports Issued Systems (RIS) projects. When ready, RIS will replace the current system for handling LBL reports. RIS will use the IRATE system as well as standard terminals for input, a 12-bit version of BDMS for data management, and interactive terminals, standard COM, and OPTIK for output. (S. Sorell)

FISCAL MANAGEMENT SYSTEMS

Work continued on three separate systems serving the three management orientations--project management by research divisions, resource management by the support departments and overall coordination by the Budget Office. Both project and resource managers may enter and store plan data about allocation and scheduling of resources to projects. The accounting data, obtained from Data Processing Services at Livermore, are entered into the system for monitoring against the managers' plan data, as well as for providing interactive access, and thereby minimizing the need for printed reports.

The Budget Management System is used by project and division managers to plan and monitor projects. During this year the number of users expanded from about 8 to about 22. Various enhancements were made to accommodate new needs and the file management procedures were completely revised to handle the larger numbers. A new interactive facility was developed to allow managers to control their own file structure, including specification of the budgeted groups, account assignments, and report orderings. In addition, managers are now able to define their own resource line items in terms of generalized types of expense, and liens are indicated in the expense reports. The Users' Manual (UCID-3670) was extensively revised and a Learners' Guide added.

The Support Management System was brought into full production use for resource management by the support departments of the Engineering and Technical Services Division. The data aggregation and report generation programs were developed, and a backup tape was added to the file management procedures. The managers can restructure the file's groups, account assignments, and report selection and ordering.

The Budget Office uses the SKED92 system for overall coordination of the Laboratory's fiscal requirements. This was modified to accommodate budgetary changes, methods of reporting, and reorganization of accounts by code, division, or program. An interactive system was developed to greatly facilitate the editing of the coordination data.

In addition to these three continuing systems, a major effort was undertaken to interface the accounting data to CPMG, a critical path method scheduling system. This involved not only monthly data at the sub-account level, but also weekly data at the job-order level. Procedures, programs, and access modules were developed to select, store, and supply these data as well as aggregation specifications.

Routines were developed to prepare data for the Qwick Qwery general purpose report generator and for the CHART general purpose plotting program.

There was a variety of developments in the area of general operations. BROWSE, a general purpose interactive information retrieval system was completed and documented (LBL-6104). A wide variety of accounting data bases was implemented for BROWSE-- the detail ledger, time cards and other-effort accounting, computer usage, purchase order commitments, stores issues, and job orders. Programs were developed to accumulate individual employee effort recharges from month to month. All report generation was transferred to the CDC-7600 machine to tree the CDC-6000's for interactive use. And a small data-base facility was set up for the Protective Services department to keep track of card keys.

Design was begun for an integrated fiscal management system.
(N. Brown, D. Kare, A. Kenney, and D. Scherrer)

Space Utilization System

The programs that aid in the analysis of space utilization were enhanced to accommodate the increase in the Laboratory's workforce and to provide interactive information retrieval using the BROWSE program. Data gathering and data entry techniques are being reviewed to provide the dynamic, up-to-date, information necessary to manage the space assignments for the growing Laboratory.
(S. Buckman and D. Kane)

Personnel System

The first phase of an LBL Personnel System was developed utilizing the Personnel Payroll Master Tape which is prepared at Livermore. This tape is received twice a month at Berkeley, encrypted, and stored on the data cell. Information retrieval is made available, through access codes, to the Personnel Department, the Affirmative Action Department, and to the Division. Two retrieval methods are supported: batch process report generation through QWICK QWERY and interactive information selection through BROWSE. The second phase of the system, which is presently under way, will provide both a data-base structure, to accommodate historical data

for analysis, and an in-house updating capability.
(S. Buckman, P. Chan, D. Kane, D. Richards, and C. Ward)

Systems for the Director's Office

An interactive system was developed for managing data pertaining to foreign travel. Features of this system include template-type prompting for update and input, formatted data display, control lists for input validation, and a facility to permit truncated searches. A system was also developed for use in interactively maintaining a data base from which several different lists of mailing labels can be produced. Its main features parallel those of the foreign travel system, but it will eventually also generate upper and lower case output.
(D. Kane and S. Sorell)

ERDA/SAN MIS Study

A study was conducted of management information requirements for the San Francisco Operations Office of ERDA. The study derived quantitative estimates of data-base size and transaction processing load for future management information development at SAN. In addition, the study surveyed strengths and weaknesses of significant data-base management systems and minicomputer hardware capable of satisfying SAN management information requirements.
(S. Cassinelli, F. Gey, and B. Levine)

COMPUTATIONAL PHYSICS AND DATA ANALYSIS

Controlled Thermonuclear Reactor (CTR)

Atomic Beam Simulations. Computer calculations were performed with the EGUN code to simulate the operation of an atomic and molecular beam device for experimental determination of the factors influential in the production of negative ions in atomic collisions. The electrode structure and potentials were determined for the propagation and focusing of the H(-) ions. The acceptance of the mass-spectrometer and its dependence on the geometry and potentials of the system were determined.

Application of the WOLF program was made to determine the low energy ion beam acceptance in a

device of known geometry which serves as a spectrometer of the electrostatic type. The potentials of several electrodes were found such that ions of a given energy were collected on a detector. The collection efficiency was also calculated.
(A. Paul and L. Soroka)

NEUTRAL BEAMS SIMULATIONS.

The injection of high power neutral beams into fusion devices requires knowledge of locations of beam loss. A complete program was undertaken to evaluate the power density contours for an array of elliptical or rectangular sources of neutral particles located on a bicylindrical surface. The power loss on elliptical or rectangular slits, placed symmetrically or asymmetrically along the beam line, is determined as are the transmitted power and power density profiles.
(A. Paul)

PLASMA SOURCE COMPUTATIONS.

A computer model of the plasma ion source in neutral beam systems has been developed. The objectives of this effort are (1) to provide certain calculated plasma parameters, very difficult to measure experimentally, as input for the WOLF program (used for optimization of the ion accelerating structure); and (2) to provide a solid theoretical basis for optimization of the performance of the plasma ion source. The model is an extension of work by Self, and includes recycling of ions and neutrals at the walls. The problem is assumed to be one-dimensional. After simultaneous solution of the equations of motion for ions, Poisson's equation, and the local ionization rate equation with particle conservation, the model provides a calculated potential distribution through the plasma, the self-consistent electron temperature, and the available ion current density at the wall of the discharge chamber. Useful predictions from the model are already available--for instance, the gas efficiency should be improved by making the plasma source deeper. Power balance will be included in the model at a future stage in its development to reduce the number of input parameters that has to be specified from experimental observations and to try to use the model to predict the ion temperature (which presently limits our beam divergence) and the ionic composition.
(C-F. Chan)

ELECTRON SUPERCONDUCTIVITY ACCELERATOR RING (ESCAR).

Work continues on designing the magnetic components of ESCAR (Electron Superconductivity Accelerator Ring) using computer programs such as TRIM. Modifications made to TRIM included a new algorithm for handling problems of boundaries at infinity for the special case of dipole symmetry. Similar algorithms to incorporate boundaries with general symmetries are in the process of being formulated.
(V. Brady)

3D MAGNETIC FIELDS

A three-dimensional computer program for the calculation of magnetic fields has been implemented at LBL. This program, called GFUN3D, was written at the Rutherford High Energy Physics Laboratory.
(J. Colonias)

HEAVY ION FUSION AND ELECTRON TEST ACCELERATOR

Numerical simulation of high current beams continues in support of the LBL Heavy Ion Fusion (HIF) program and the LLL Electron Test Acclerator (STA). Application of EGUN and TRANSPORT has been made to the study of high current beam propagation down a round pipe surrounded by a solenoidal magnetic field whose profile is chosen to prevent beam breakup. The electron beam is very relativistic and space charge must be included. Acceleration cavities are placed along the device to increase the beam energy. This problem possesses axial symmetry and has been modeled with both TRANSPORT and the EGUN code. The simulation has also been done with the TRANSPORT program for both solenoidal and quadrupole focusing structures for a uranium beam without axial symmetry. Development continues on a general 3D orbit code for use in static magnetic fields. This work is an extension of the TRAJ and GOC 3D programs which find application in simulation of particle spectrometers and accelerator magnets of large bore where median plan field expansions are inadequate to represent the field.
(A. Paul)

MMRD

Two computer codes were developed to simulate a model of the methane formation which occurs in

hydrogen-graphite reaction in the presence of platinum as the catalyst. The model is taking into account surface diffusion of hydrogen atoms from platinum to the graphite surface. One-dimensional and two-dimensional cases were considered. In one-dimensional cases, an iterative algorithm was designed and implemented using the Newton-Raphson method for solution of one-dimensional ordinary differential equations of the second order. The Runge-Kutta method was used for integration. To describe the physical situation in two-dimensional cases, one had to solve a system of the two coupled ordinary differential equations of the second order.
(L. Soroka)

Isotope Separation

Design of an accel-decel extraction for use in an atomic-vapor, laser isotope-separation system was completed on the basis of the computer simulations using the WOLF code.

A suitable electrode geometry, set of potentials, as well as proper plasma location within the electrode system were determined for necessary discrimination between thermally-generated ions from the uranium oven and the laser-produced plasma.
(A. Paul and L. Soroka)

PEP/SPEAR

The LBL/SLAC design for the PEP storage ring is reaching its final design stage. The use of magneto-static computer programs such as POISSON have contributed to the design of the optimum shape of the pole face for the quadrupole magnets of this machine. Program SUPERFISH, applied to find the resonant frequencies of cavities, contributed to the design of the cavities.

Several modifications to the matrix type, ion optic program TRANSPORT were made to directly calculate surveyor coordinates for all magnets on the PDP injection line. Additionally, CALCOMP plotting was made available, perturbation analysis is now performed automatically, and long linacs can be simulated directly. The number of data elements has been increased to 900.

Studies to simulate beam-beam interactions were carried out, particularly to investigate the dynamic beam envelope of two colliding beams in the SPEAR

storage ring. Having determined the effect of this simulation, the beam-beam program PEP was modified to include this dynamic effect.

A program, ALIGN, is being developed to simulate misalignment errors and to correct displaced equilibrium orbits in the PEP storage ring. This is a modular program that presently contains modules to:

- Simulate a misaligned equilibrium orbit arising from magnet survey error
- Simulate a measurement of the closed orbit
- Perform a harmonic analysis of the orbit
- Correct the displaced orbit by calculating correction magnetic strengths necessary to eliminate the unwanted harmonics or excessive closed orbit displacements.

The program SYNCH is a large multi-purpose system for design of synchrotrons and analysis of orbit properties, which was written originally in the 1960s and has been expanded from time to time for different applications. Because of the PEP project, additions relevant to electron storage rings have been made in collaboration with A. Garren. Facilities added recently include:

- Computation of closed orbits, emittances, and damping rates in a ring with misaligned magnets
- Computation of effects of wiggler magnets and certain nonlinear elements on the beam
- Improvements in the description of the magnet lattice in the input language
- Introduction of a general fitting facility

Since the program is used at other laboratories, considerable effort has been made to provide them with up-to-date versions. For example, large changes were required for SLAC's IBM computer because the input language of SYNCH is character-oriented; the previous IBM version is about 9 years old. For CERN, and for future use at LBL, the program was adapted from the RUN76 to the FIN4 compiler.
(V. Brady, E. Close, A. Kenney, and A. Paul)

Tokamak Fusion Test Reactor (TFTR)

TFTR studies were carried out for the design of the extracting accelerating-focusing grid structure of the plasma ion source. The code WOLF was

used for the minimization of the outgoing beam angular divergence by arranging (automatically) the optimal shape of the grids, the potential loads, and the ion current density. In particular, a major effort was made in the design study of the 120-kV source for the Princeton TOKAMAK Fusion Test Reactor. (C-F. Chan)

Torodial Magnetic Cusp (TORMAC)

Computational support for TORMAC (LBL's Torodial Magnetic Cusp Plasma Containment device) continues with the implementation of a series of codes for computer reconstruction of the light intensity and spectral line width as spatial functions using atomic spectral radiation data from TORMAC 0 IV plasma.

3D-plots of time series of the reconstructed spatial functions of the light intensity of the He II 4686 A line were used to produce the computer movie "Plasma Containment in TORMAC." This movie was shown at the Annual APS Plasma Division Meeting during the presentation of the invited paper by the principal investigator of the TORMAC project, M. Levine.
(L. Soroka)

COBWEB and Other Ely Group Support

A new scanning and measuring system was added to the COBWEB system. This system, CICERO(1), is designed to facilitate the scanning and measuring of film from the large volume bubble chambers now in operation. To accomplish this, an SP58 digitizing scan table was put on-line to the IBM-70-4. This scan table has dual magnification and provides precision digitizations to serve as guidance points to the measurer at the Franckenstein. At the Franckenstein, the cross hair is driven to within 5 μm of the tracks to be measured, thereby relieving the measurer of scanning responsibilities. This system is now in production and further refinements are being implemented.

Effort was spent on the maintenance and development of ERGON, a data summary and display system for high-energy physics data analysis. ERGON performs many statistical and summary operations, and provides a variety of display options.

Work was done for the Bevatron Backward Inelastic Scattering experiment, and the TST (Track Sensitive Target) experiment in the Rutherford Laboratory Hydrogen Bubble Chamber. Maintenance and development were also continued on TVGP (Three View Geometry Program for reconstructing bubble chamber tracks), SQUAW (Kinematic Fitting program for testing bubble chamber reaction hypothesis), and APACHE (Streamer Chamber Vertex Finding program). Small programs and subroutines were written (1) to modify the format of data; (2) for physicists in the group or at other laboratories; (3) to deal with new blocks of data through the system of programs; and (4) to be used by physicists in conjunction with their ERGON analysis programs.
(H. Albrecht, W. Michael, and V. Morgan)

Spear Mark II Drift Chamber

Programs under development take drift-chamber ionization signals corresponding to e(-)e(+) annihilation events and reconstruct these events in three-dimensional space. The detector consists of concentric cylindrical layers of drift chamber cells. Each charged particle from an event triggers a sequence of these cells, and the distance from the particle orbit to a sense wire in each excited cell is measured by recording the ion drift time. Data for one event are a set of numbers, each containing a chamber layer, wire number, and drift time.

The programs ORBIT, ARCS, and VTX first organize these data into tracks by exploiting correlations in curvature and position, then resolve the inherent left-right ambiguities which result from the drift-time measurements, fit these tracks individually to orbits in three-dimensional space, allowing for variations in magnetic field and other perturbations, and finally fit these tracks collectively to a vertex constrained to lie in the beam-beam interaction region. Development has been done primarily on the LBL computers, but the programs also operate on the SLAC triplex and on a variety of on-line computers. Target data for completion is November 1977.

In addition to this effort, the usual support has been maintained for the Goldhaber-Trilling physics groups, and improvements have been made to

the display program KIOWA which make this program faster and more versatile.
(P. Cook and A. Johnson)

COMPUTATIONAL ASSISTANCE TO NUCLEAR CHEMISTRY

A program to plot statistical quantities, for example, moment of inertia, magnetic moment, energy versus angular momentum from theory for three paired nuclei, was finished. All quantities were displayed as functions of neutrons alone, protons alone, and neutrons and protons together. In addition, a program to allow a user to make lin-lin, log-lin, lin-log, and log-log Cartesian plots was finished. Consulting and general programming assistance was provided to the Nuclear Theory Group.
(T. Clements)

HEMP PROJECT

The HEMP program, capable of solving the Navier-Stokes equation for the simulation of problems relating to plastic-elastic flow, has become operational on the CDC-7600 computer system. The program was revised with a new slide-line algorithm which models the interaction between materials and slide line much more accurately and broadens the class of problems for which the program is suited. The first draft of a program manual has also been prepared and is being readied for publication. Future plans include implementation of:

1. A set of options for boundary conditions for UPRIGHT and INVERTED slide line problems
2. "Void opening" and "void-closing" algorithms that will enhance further the capabilities of the program
3. "REZONING" and DEZONING" algorithms that will allow the use of different mesh size at different parts of a slide line
4. Graphic capabilities to prepare 16-mm movies or CALCOMP plots.

(J. Colonias, P. Iqbal, and D. Soroka)

MATHEMATICAL MODELING

OPTIMIZATION

LINEAR PROGRAMMING. During the year, testing and modification continued on the GUMPS linear programming package, which is used both by local users and those at remote sites (PNL, BNL, ANL) to solve a variety of problems. The files were reorganized for better access in report writing and interfacing to other programs. Improvements have been made in post-optimal processing, and some problems of scaling and tolerances have been investigated. Causes of reduction in speed have been determined and appropriate fixes are under way.

The GUMPS code has been used in numerous projects. For example, output from GUMPS was used to provide input to the CARTE program for graphical representation of solutions from the Stewart model for people-grizzly bear interaction in northern Glacier Park.
(R. Hinkins and P. Iqbal)

COMPUTER ASSISTED PROJECT PLANNING AND MANAGEMENT WITH GRAPHICS. The CPMG program is intended to be used as an aid to management and project coordinators. From the detailed information about the many activities that comprise a project, the CPMG code can provide the project planner with summarized tables and graphs that make the project as a whole comprehensible. Thus, areas of potential difficulty, such as schedules that cannot be met or over-allocation of resources (staff or capital), can be identified early in the planning stage. The programs provide easy update capabilities to facilitate the incorporation of better data as the project progresses and give the manager many options to interactively explore facets of the "what if ..." questions that occur during planning.

Efforts to date have emphasized developing a system capable of efficiently handling large projects and of providing interactive facilities. Data

organization and critical path identification fea-
tures have been developed, and information can be
requested, sorted, and displayed in many forms and
with various levels of detail. The user selection
of output has been greatly enhanced by the addition
of three sort keys for plots and lists. Specifica-
tion of hourly, weekly, or monthly salary rates for
each craft code has been used to provide manpower
costs which may now be combined in various ways with
the two types of capital expenditures. Input for
both the interactive and batch versions has been
simplified. Some restructuring of the code has been
done in experiments on the Mod Comp. The unfinished
programs have already been used in planning several
multimillion dollar projects—PEP, HILAC Improvements,
and TFTR Prototype Beam Line—as well as somewhat
smaller projects such as the 150 kV Neutral Beam Test
Facility and Biomed Cave 1.
(R. Hinkins, P. Iqbal, and S. Knif)

INTERACTIVE THREE-DIMENSIONAL GRAPHICS FOR SAP IV.

The three-dimensional display of solutions
to structural analysis problems has been made avail-
able on the LBL system by converting three LLL pack-
ages: SAMPP, HIDDEN, and PREPOST. SAMPP is a gen-
eral routine for display of three-dimensional, finite
element models and the results of both static and
dynamic analysis. HIDDEN is Michael Archuleta's en-
hanced implementation of Watkin's visible surface
algorithm. PREP(ST converts SAPIV output to SAMPP
input form. The SAPIV program is already available
at LBL for static and dynamic analysis of structural
systems.
(R. Kinkins and P. Iqbal)

INTERACTIVE INPUT TO GEOTHM

Program GEOTHM is a thermodynamic process pro-
gram for modeling geothermal power plants. Previous-
ly, input design was strictly batch mode and rather
cumbersome. It is now possible to input the design
using program GEOTY in an interactive mode. GEOTY
checks user input for syntax, validity of data, and
completeness of design. The user than has the option
of saving the input data and/or submitting the input
to the 7600 program GEOTHM; GEOTY sets up the control
cards and disposes the job to the 7600 input queue.
At present, the program is limited to 30 plant el-
ements and 6 working fluids. All plant element

parameters have default values reflecting
state-of-the-art design so the user may design a
plant with a minimum amount of input data.
(R. Healey)

PROGRAMMING LANGUAGES—RESEARCH

In response to growing interest in the effect
of programming language characteristics on the costs
of software development and maintenance, more active
participation in national and international language
standardization was undertaken. This included for-
mal membership on the American National Standards
Fortran Committee (X3J3) and election as a member of
the United States delegation to the International
Standards Organization. Results of this participa-
tion included adoption of modern control structures
(IF-THEN-ELSE) in Fortran, development of file con-
cepts, and completion of a revised Fortran standard
proposal for further processing as an American
National Standard and as a basis for international
standardization.

Publication of the Fortran Development News-
letter, For-Word, was continued. Four issues total-
ing about 30 pages were distributed to an average of
1600 addresses.

The LBL Fortran dialect B4TRAN was revised to
incorporate the IF-THEN-ELSE structures of the new
Fortran.
(L. Meissner)

APPLIED MATHEMATICS—RESEARCH

Research is carried out in numerical and ap-
plied mathematics, with special emphasis on elliptic
partial differential equations, fluid flow and com-
bustion, capillary phenomena, and biomathematics.
(N. Albright, P. Bernard, N. Chen, A. Chorin, P.
Concus, S. Doss, C. Fenimore, R. Finn, H. Glaz,
O. Hald, I. Karasalo, S. Knif, R. Kung, G. Nooney,
V. Pereyra, W. Proskurowski, C. Risk, A. Shien,
and G. Sod)

NUMERICAL METHODS FOR ELLIPTIC EQUATIONS

The study of the generalized conjugate gradi-
ent method in combination with fast direct and other
splitting techniques continued. Extensions were

made to nonlinear problems, such as the minimal surface equation, and the method was found to compare favorably with other numerical methods for such problems, thereby increasing further its area of successful application.

Studies continued of the efficient use of fast direct methods for the numerical solution of separable elliptic equations on irregular domains. A method utilizing the capacitance matrix technique was developed to obtain the first several eigenvalues of the discrete Laplace equation. A method for obtaining highly accurate solutions for the Dirichlet problem was developed by combining the usual second order finite difference scheme with the method of deferred corrections, a capacitance matrix technique again being used for solving the resulting systems of algebraic equations. Implicit variants of the capacitance matrix technique were used to develop a method, having only minimal computer storage requirements, that permits efficient solution of Helmholtz's equation on a general plane-bounded region containing a very large number of interior mesh points.

A dynamic alternating-direction, implicit method has been developed for solving general second-order elliptic equations. The method, which relies on a heuristic, automatic choice of acceleration parameters, has been found to be effective for solving linear equations in two and three dimensions and has been extended to strongly nonlinear equations for the two-dimensional case.

Fluid Flow and Combustion

Work continued on the development of numerical and statistical techniques for studying compressible turbulent flow and turbulent combustion phenomena. A coarse graining method, which represents a substantial advance over previously available methods, has been developed. A new version of the vortex method, more accurate any computationally more efficient than previous versions, has also been developed. These two methods are being incorporated into a computer program that should provide a reasonable model of turbulent flow in a cylinder-piston configuration. A random choice method for handling the dynamical effects of exothermic reactions has been developed, and a computer program based on it has been tested successfully.

Capillary Phenomena

Work continued on the capillary free surface problem and improved analytic estimates for the shape of pendent liquid drops were obtained.

The stability of capillary surfaces in inverted containers was studied for rotationally symmetric cases in which the surface does not include the axis of symmetry. New results were obtained on the limiting form of the suitable boundary conditions for neutral stability for perfectly wetting liquids.

A comparative study of numerical techniques for solving the capillary free surface problem, including the possibility of corner singularities, continued. As part of this study, capillary surfaces on elliptical domains were investigated numerically, and the results were compared with analytical estimates derived previously.

Biomathematics

Work was completed on developing and studying a model of skeletal dynamics. This model describes and simulates the movement of material between blood and bone, and within bone, under various conditions including osseous growth and aging. The model, which uses the density of apatite crystals as an independent variable, enables the study of the retention of ingested radioactive elements, such as strontium, and allows evaluation of mineral replacement therapy including the effects of dietary fluorine.

Mathematical Software and Consulting

Improvements and new additions were made to the mathematical software library in the areas of the numerical solution of ordinary and partial differential equations, linear algebra, and optimization. Consulting services in the above and other areas of numerical analysis, and in applied mathematics, were provided to LBL staff members and other computer center users. The project of preparing brief tutorial reports covering major areas in computational techniques continued.

Educational Programs and Visiting Staff

The Computer Science and Applied Mathematics Department provides supervision of graduate students

in the master's and doctoral programs in applied mathematics and computer science at UCB. Three doctoral candidates (P. Bernard, S. Doss, and H. Glaz) completed their theses in mathematics, and five completed the master's requirements in computer science and engineering (D. Brown, P. Chan, S. Chan, D. Chow, and K. Halvey). Two professors (A. Chorin, and M. Stonebraker) share joint UCB/LBL appointments, providing a rich exchange of ideas and experience.

This year our staff includes several post-doctoral appointees and visitors who are contributing extensively to computer science and applied mathematics research projects. They are N. Chen, R. Finn, O. Hald, I. Karasalo, F. Marchat, F. Montalvo, V. Pereyes, W. Proskurowski, and C. Risk. LBL's unique facilities and expertise provide an excellent training milieu, and this program is expected to grow in the future.

The Department sponsors a weekly Computer Science colloquium, a monthly Applied Mathematics seminar, and the annual Berkeley Workshop on Distributed Data Management and Computer Networks.

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CSAM ABBREVIATIONS

ABAG	Association of Bay Area Governments
AES	Administration for Environment and Safety
ALIGN	Modular simulation and correction program
ANL	Argonne National Laboratory
ANSI	American National Standards Institute
APACHE	Streamer chamber vertex finding program
APPAR	Data base developed by Systems Sciences, Inc.
AQCR	Air Quality Control Regions
ARCS	SPEAR MARK II drift chamber program
ARPANET	Advanced Research Projects Agency Computer Network (international)
ASCII	American Standard Code for Information Interchange
ASTOG	General purpose photo composition system
BARB	Document preparation program
BBN	Bolt, Berenek, and Newman
BCPL	Basic Command Programming Language
BDMS	Berkeley Data-Base Management System
BEA	Bureau of Economic Analysis
BG/ED	Census Block Group/Enumeration District
BIS	Bibliographic Information System
BNL	Brookhaven National Laboratory
BROWSE	Interactive Information retrieval system
B4TRN	LBL Fortran dialect program
CARTE	LBL Thematic Mapping System
CCD	Census County Division
CDC	Control Data Corporation
CERCDC	California Energy Resources Conservation and Development Commission
CETA	Comprehensive Employment and Training Act
CHART	An interactive analysis and display program for tabular data
CICERO	A scanning and measuring system for the COBWEB system
COBWEB	A computer-controlled, bubble chamber measuring system
COENDA	County Energy Data Base
COM	Computer Output Microfilm
CPI	Consumer Price Index
CPMG	Computer Assisted Project Planning and Management with Graphics
CPS	Current Population Survey
CPU	Central processing unit
CSAM	Computer Science and Applied Mathematics
CTR	Controlled Thermonuclear Reaction
CUPID	A high-level graphics query language for INGRES
CWHS	Continuous Work Histroy Sample
Data Base	A collection of any computer-accessible information
DCN	Distributed Computer Network project
DDL	Data-Base Definition Language
DEC	Digital Equipment Corporation
DECNET	DEC Network subsystem
DOIT	General command language interpreter
DOL-ETA	Department of Labor-Employment and Training Administration
EGUN	Electron trajectory program
EIS	Environmental Information Systems
ERDA	Energy Research and Development Administration
ERGON	A data summary and display system
ESARS	Employment Security Automated Reporting System
ESCAR	Experimental Superconducting Accelerator Ring

ESTICS	Employment Security Table Independent Cell Structure	MAPEDIT	System for automatic map digitization
ETA	Electron Test Accelerator	MATBOARD	An interactive analysis program designed for managers
FDMF	Flexible Data Management System Facility	MCD	Minor Civil Division
FIPS	Federal Information Processing Standard	MED-X	Master Enumeration District list, extended
FTN4	A FORTRAN comoiler; the primary one at the Computer Center	MIS	Management Information System
FTP	File Transfer Protocol	MIT-LNS	Massachusetts Institute of Technology-Laboratory for Nuclear Science
GBF-DIME	Geographic Base File-Dual Independent Map Encoding	MONITOR	Executive system
GEOTHM	Thermodynamic process program for modeling geothermal power plants	MRUNCFF	Document preparation program
		MSS	Mass Storage System
GEOTY	Interactive program for input to GEOTHM	MTC	Metropolitan Transportation Commission
GFUN3D	Three-dimensional magnetic field calculation program	NASN	National Aerometric Surveillance Network
GISFILE	Integrated comprehensive data base	NBTF	Neutral Beam Test Facility
GLEF	Geothermal Loop Experimental Facility	NCHS	National Center for Health Statistics
GUMPS	A linear programming system with parametric capability	NEDS	National Emmissions Data Source
		NTIS	National Technical Information Service
HEMP	Hydro Elastic Magnetic Plastic program	NYU	New York University
HIF	Heavy Ion Fusion program	OPTIK	Off-line Photocomposition of Text from the IRATE Keyboard
HILAC	Heavy Ion Linear Accelerator		
IDDS	Integrated Data Display Systems	ORBIT	SPEAR MARK II Drift Chamber program
INGRES	A relational data-base management system	ORNL	Oak Ridge National Laboratory
INTERAC	Hierarchical File Management System	PARAP	Population-at-Risk to Air Pollution data base
		PDG	Particle Data Group
IRATE	A special text editing system	PEP	Positron-Electron Project
IRG	LBL's Information Research Group	PICASSO	A general, interactive, graphics modeling program
IWGDE	Interlaboratory Working Group for Data Exchange	PLANET2	Teleconferencing system by the Institute for the Future
KIOWA	Physics display program	PNL	Pacific Northwest Laboratory
LANDSAT	Data utilized by the Land Use Project	POISSON	Magneto-static program
LBLIRI	LBL Interactive Resource Index	POLYVRT	A conversation program between different cartographic data structures
LMPM	Labor Market Projection Model		

CSAM Abbreviations (continued)

PSS	Program Storage system		SQUAW	A kinematic fitting program for SPEAR
QWICK QWERY	A generalized retrieval and report generating system		SRL	Savannah River Laboratory
RAS	Regional Automation System		STOFI	Data management system
REAP	Interactive retrieval system for SEEDIS data		SUPERFISH	A program for calculating the radio frequency of a cavity
RFP	Request for proposal		SURE	Sulfate Regional Experiment
RHEL	Rutherford High Energy Laboratory		SYMAP	Printer-plot mapping program
RIS	Reports Issued System		SYNCH	Synchrotron and orbit properties system
RJE	Remote Job Entry system			
RMIS	Regional Management Information System		SYSTEM 2000	(S2K) A commercial data management system
SAP IV	Structure Analysis Program		TELNET	Virtual terminal protocol for ARPANET
SAROAD	Storeage and Retrieval of Aerometric Data		TFTR	TOKAMAK Fusion Test Reactor study
SCOPE	A standard CDC operating system for 6600 and 7600 computers		TOKAMAK	The Princeton TOKAMAK Fusion Test Reactor
SEEDIS	Socio-Economic-Environmental-Demographic Information System		TORMAC	LBL fusion project
			TRANSPORT	Space-charge code
SESA	State Employment Security Agencies		TRIM	Two-dimensional magnetostatic computer program
SIC	Standard Industry Code		TST	Track Sensitive Target
SIRAP	System of Information Retrieval and Analysis for Planners		TVGP	Three-view Geometry Physics Program
SKED92	System for budget coordination		UCLA	University of California at Los Angeles
SLAC	Stanford Linear Accelerator Center		VFB	Video Frame Buffer
SMSA	Standard Metropolitan Statistical Area		VTX	SPEAR MARK II Drift Chamber program
SNOBOL	A programming language		WDB2	World Data Bank II
SP5B	Bubble chamber film scan table		WOLF	Ion source program
SPEAR	Colliding beam machine		ZING	Map editing program

4. COMPUTER CENTER

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The principal responsibility of the Computer Center is to provide large-scale computational support to LBL's scientific programs. This includes providing access to an extremely powerful computer (a CDC 7600), to a very large mass storage system (an IBM Photodigital Store, containing 3×10^{11} bits of on-line storage), and to a complete selection of peripheral devices. Large numbers of jobs are processed (more than a million in 1976) with excellent turnaround (about 70 percent completed within 20 min).

A comprehensive set of interactive facilities is offered, including text editing, document preparation, program preparation and submission, several interactive graphics subsystems, and the ability to interact with any job running on the "front-end" (CDC 6600 and 6400) computers. LBL is also a node on the ARPANET, which links more than 100 computer centers (some of them overseas) together. The network carries both interactive and batch traffic between LBL and other centers. Ancillary services provided include a professional consultants' service, on-line user documentation of the entire system, and a wide range of standard products and libraries.

In accordance with the Federal Economy Act, LBL makes its excess computing capacity available to other ERDA laboratories and contractors. The most significant single outside user at year-end was the National Magnetic Fusion Energy program, which received 22 hr/wk of block-time during November and December. In addition, many university physics groups found remote use of LBL's Computer Center to be convenient and economical.

In addition to the normal support tasks, the Computer Center maintains a number of development efforts in both hardware and software.

CDC/IBM CHANNEL ADAPTER

One of the major trends in the world of computing in the past few years has been the emergence of the "plug-compatible peripheral device," a device which is designed to operate with an IBM computer at much less cost than its IBM counterpart. Until quite recently the benefits of this development have been denied to users of Control Data computers. (IBM-compatible peripherals are not CDC-compatible.) In 1976 LBL completed the development of a CDC/IBM Channel Adapter which allows IBM-compatible devices to be used with CDC computers. It is now being used to simplify collaboration with SLAC by allowing the exchange of IBM-compatible, 6250 bpi tapes. (More than 300 tapes were transferred in 1976 with no unrecoverable errors.) The adapter is expected to see wider use in the future on disk systems and mass-storage systems.

PERFORMANCE MANAGEMENT

The major 7600-improvement program begun in 1974 was completed in late 1976, bringing an increase of 20 percent in throughput capacity to the system. The major visible element was an increase in multiprogramming capability (the ability of the system to work on different aspects of several jobs simultaneously) from two to six jobs. Performance measurement instrumentation, which allows dynamic monitoring of the system, was provided for the 7600. A program of improvement in peripheral hardware, partially based on the newly accessible IBM-plug-compatible equipment, was begun. Computer Center staff participated energetically in several forums devoted to this subject, including the annual conferences of CPEUG (Computer Performance Evaluation Users Group) and CMG (Computer Measurement Group).

PEPNET

A new project, PEPNET, which will strengthen the ties between LBL and SLAC, was begun. Two links will be provided: one between LBL and the PEP experimental areas, the other between LBL and SLAC's computer complex. (The existing microwave link will be used as the transmission medium.) Between the two, together with the communications facilities at SLAC, a scientist at either site will have access to

CBB 761-10857
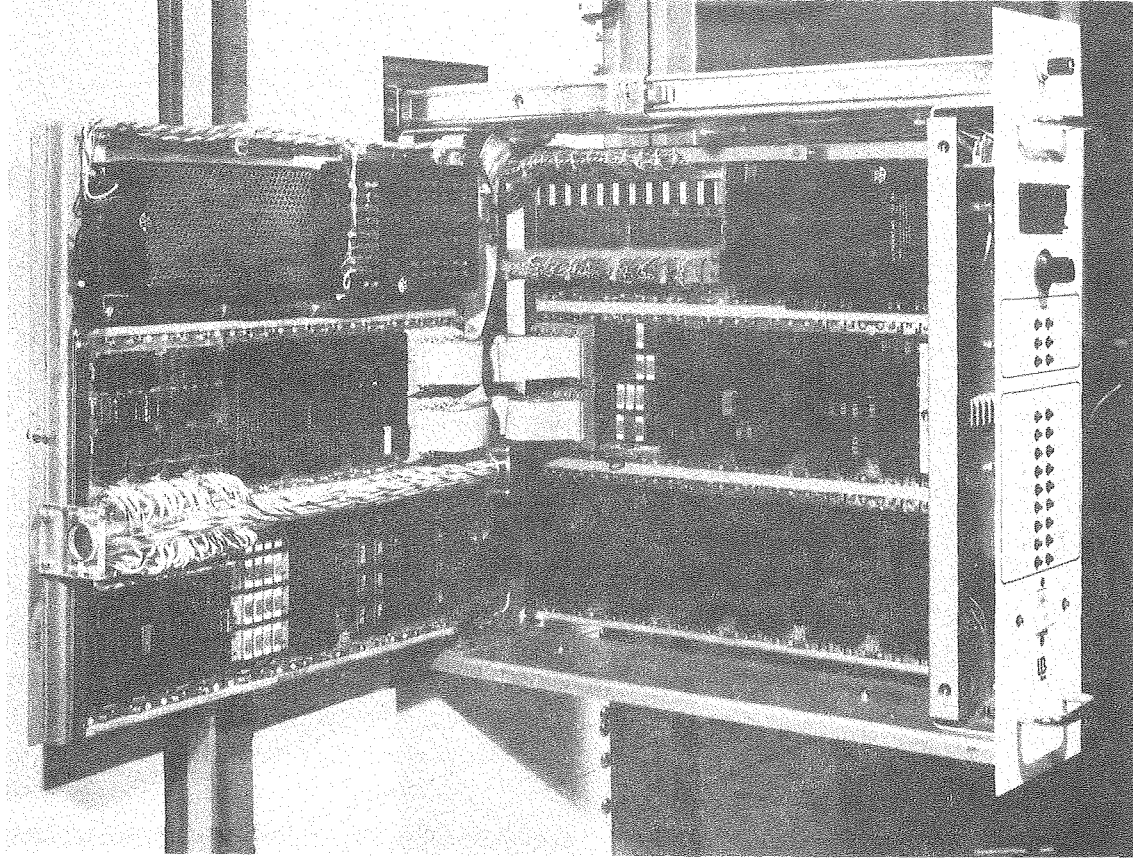
Channel adapter that allows use of IBM equipment with a Control Data computer.

all the capabilities and amenities of both sites. The amount of program conversion which would otherwise have to be done should be at least halved. PEPNET is now being designed, in consultation with the experimental physics community, and will be operational in FY79.

Mass Storage

The Computer Center learned in 1976 that the backbone of its mass storage system, the IBM 1360 Photodigital Store, will not be supported by the manufacturer beyond the end of FY79. Consequently, design has begun on a system that will not only replace the current system but will also remove some of its limitations. In particular, it will provide simultaneous access for both reading and writing of the store for several jobs, and will be accessible from all of the Center's major computers. (The present system allows only a single access, and it must be through one specific computer, the 6600.)

A Users Introduction to BKY

A new training course on use of BKY, the generic name applied to the systems supported by the Computer Center, was completed and given at several remote user sites. It is the culmination of a collaboration between the User Services Group and the U. S. Army Corps of Engineers, Davis, California.

Modern FORTRAN

As predicted in last year's Annual Report (LBL-5363), FTN4 (CDC's standard FORTRAN compiler) became LBL's principal compiler in fact (i.e., usage) as well as intent; by year-end, FTN4 was the most frequently used compiler. (Its predecessor as LBL's most popular compiler, RUN, has not been supported by the manufacturer for several years. It still attracts about 30 percent of the usage, however, and will likely remain in service for some time to come.)

The Inflation Fighters

A new charging algorithm, providing an effective rate decrease of about 17 percent was adopted at year-end.

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