DOE/SF/00515--T88

DE89 012454

INSTITUTIONAL PLAN

FY1989-FY1994

Under Contract with the
Department of Energy
Contract DE-AC03-76SF00515

December 1988

STANFORD LINEAR ACCELERATOR CENTER

Stanford University • Stanford, California

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SECTION I DIRECTOR'S STATEMENT

A. INTRODUCTION

High energy physics began at SLAC in 1966 with the delivery of the first beam from the two-mile linear accelerator. In 1988 the first beams from the SLC were delivered, and the first physics results from SLC are expected in 1989. SLAC has remained a vital institution during these past 23 years by adding new accelerator facilities that gave new opportunities for frontier research to our scientific staff and our users. The SLC continues this tradition, and promises another decade of frontier research at the laboratory. However, our circumstances are quite different from what they were more than 20 years ago. Experiments have gotten longer, collaborations have gotten larger, new accelerator facilities take longer to design and build, the world high energy physics community has gotten stronger, and budgetary constraints have gotten tighter. The continued success of SLAC depends both on the quality of the physics that we do and our ability to continue to develop new opportunities for research at our laboratory.

This Institutional Plan describes the anticipated program at SLAC during the period from FY1989 through FY1994, with one section (Section IV) devoted to a longer range 15-year projection of possible laboratory activities out to the early years of the next century. In this first section, the Director's Statement, we will attempt to summarize all of the most important aspects of the Institutional Plan in a general way, with more detailed discussions to follow in subsequent sections. The intent here, then, is to introduce the main elements of the Plan, to describe the international scene in particle physics research in order to provide a context for the discussion, to describe briefly SLAC's present facilities and program, and to indicate the main directions of future research and development activities.

B. SUMMARY

The general outlines of the SLAC program for the five-year period FY89-94 are clear from the scientific point of view. However, there is considerable uncertainty from the fiscal point of view, coming both from the general budget climate and from uncertainties about the impact of SSC funding on the rest of the High Energy Physics program. We base our plans on the assumption that the electron research direction, which has been so important in the past and is complementary to much of what can be done with proton accelerators, will continue to be viewed as important in the future. The main elements of our program can be summarized as follows:

1. **SLC** The machine should be brought to full performance for physics research. This will require much effort to improve the performance of various

systems of the facility that now limit the peak luminosity and reliability. A large fraction of the laboratory's financial and technical resources must be devoted to this effort.

The SLD detector must be completed, for its vastly larger capabilities to analyze complex final states compared to the Mark II detector are required to do justice to the physics potential of the machine.

The polarization project should be completed and R&D on higher polarization of sources should be aggressively pursued.

2. TeV Linear Collider (TLC) R&D for a higher energy linear collider should also be aggressively pursued. The optimum schedule should aim for a completed conceptual design report in time for the FY94 budget cycle. The R&D program should be coordinated with other regions interested in this type of machine to assure that all the relevant technical issues are adequately addressed. Our present thinking is that the facility should have an initial operating capability of about 500 GeV in the center of mass, with the potential to increase to 1.0 TeV with the addition of more advanced RF power sources.

3. Storage Rings The present cycle of high energy physics experiments on SPEAR should be brought to completion, and if the Beijing facility approaches its design goals, the SPEAR machine should be turned over to full-time use as a dedicated synchrotron light source in FY91 or FY92.

The PEP storage ring should be kept in operation as a high energy physics tool through the period of this plan (1994). Nuclear physics with gas-jet targets should be encouraged if such a physics research program seems sufficiently promising. Parasitic and limited dedicated use of PEP as a synchrotron light source should be encouraged. We will also consider a continuing improvement program and possible construction of a dedicated injector for the PEP ring in order to decouple it from the main SLAC linac.

Our exploration of the weak interactions of the tau, charm and bottom particles has left numerous open questions that can be addressed most effectively by high-luminosity machines specifically directed to these questions. A decision should be made in the next year or two on the desirability of a new storage ring project such as an asymmetric-ring *B* factory or a tau-charm factory.

4. SSC. We should assist the SSC construction project by being available to fabricate components of this accelerator where SLAC's unique technical capabilities are needed (RF systems, for example). We anticipate that SLAC will

serve as a base for the fabrication of first-round SSC detector facilities as part of an appropriate collaboration.

5. Other We must preserve our flexibility to respond to special options in physics at SLAC or at other places where our facilities or expertise can make unique contributions. We should assist other laboratories in the development of future electron accelerators where appropriate (linac injectors for electrons, for example).

C. THE CONTEXT

In 1966 physics with electrons was looked upon by the largest part of the high energy physics community as something of an aberration and a backwater. Since that time, those who chose to ignore the views of the majority and to pursue their own research directions with electrons have been amply rewarded. Indeed, electron-positron physics has come to be so highly thought of that we are no longer alone as the premier electron laboratory in the world. There is competition now, and there will be more in the future. Also, the success of the $S\bar{p}\bar{p}S$ at CERN has generated a great deal of enthusiasm for very large proton colliders, and indeed the SSC is now the centerpiece of the U.S. high energy physics construction program.

In the following paragraphs we give a brief overview of the international scene in particle-physics research.

1. SSC The consensus of the U.S. high energy physics community is that the SSC should be our major initiative for the immediate future. The odds seem to be on the side of approval, but the project will perhaps go somewhat slower than its protagonists hope. If the project is approved, we are not likely to see the approval of any other multi-hundred-million dollar construction proposals until the time when the rate of SSC expenditures begins to decrease. On the presently proposed schedule, that begins to happen about 1994. Thus the earliest time another very large accelerator project could begin in the U.S. is around the mid-90's.

2. Fermilab Fermilab has now brought the Tevatron collider into operation, and we expect to see physics results from the CDF detector soon, and from D0 in 1990 or so. The Fermilab management puts a high priority on maintaining the fixed-target program as well as the colliding-beam program, and the large number of users involved in the fixed-target program will give them considerable influence in the competition for resources. Fermilab has proposed an improvement program for the Tevatron collider that would eventually raise its luminosity to about $10^{31} \text{ cm}^{-2} \text{ s}^{-1}$.

3. Brookhaven The management of Brookhaven appears to be moving towards converting the laboratory to a nuclear physics facility, the centerpiece of which would be the Relativistic Heavy Ion Collider. They have a high energy program that is now centered on rare kaon decay experiments and some neutrino experiments. Because of the attractiveness of the rare kaon decays, this program will probably continue for the next four or five years.

4. Cornell The current luminosity of the CESR facility is $10^{32} \text{ cm}^{-2} \text{ s}^{-1}$. The view of the Cornell staff is that the present machine may be capable of getting up to luminosities as large as $2 - 5 \times 10^{32}$, but cannot go further. They are thinking about a new B factory, but have not come to any decision on what kind or on whether they want to pursue a project like this. A new machine of very high luminosity would probably be quite expensive.

5. Europe Between LEP and HERA and their detectors, Europe is probably spending \$2 - 2.5 billion on new facilities in the decade of the '80s. LEP is scheduled to turn on in July 1989, and it looks as though the detectors will also be ready by about that time. The design luminosity of LEP at the Z^0 is 2×10^{31} (peak), and scheduled operations are approximately 3,000 hours per year. Operating time is limited by both dollars and SPS time because of incompatibility between the LEP program and the $p\bar{p}$ colliding-beam program. Using DESY experience for the ratio of peak to average luminosity in a storage ring that has to be filled and ramped to operating energy, one can expect a yield from LEP at design luminosity of about $1.1 \times 10^6 Z^0$ per year. It will probably be at 10% to 20% of design luminosity at the end of the first year.

R&D on LEP II is being pursued vigorously and successfully. They expect to begin adding superconducting RF cavities to the LEP machine in 1992, and their present plans are to bring the machine to an energy of about 170 GeV by 1994. The pace of the energy increase program is limited more by money than by the status of the R&D program.

There has been considerable discussion at CERN about the possibility of getting polarized beams in LEP. However, almost all of the accelerator physics community believe that the likelihood is extremely small that beam polarization can be maintained in the colliding-beam configuration at high luminosity in a machine as large as LEP. CERN is installing polarimeters as part of the construction project, but no spin rotators. They will look at transverse polarization in the machine and see whether that can be maintained in the colliding-beam mode.

For the longer term future, CERN favors the Large Hadron Collider (LHC), with the CERN Linear Collider (CLIC) as a fall-back position if SSC gets a fast start. The presumed energy of the LEP hadron collider oscillates a bit as optimism on getting very high fields in superconducting magnets waxes and wanes. An 8-tesla field would give about 14 TeV in the center of mass. CERN is talking about a two-ring machine with a luminosity of about $10^{34} - 10^{35}$. The CLIC project is still in the early R&D stage, and the stated goal is approximately 2 TeV in the center of mass of the electron-positron system. Which way CERN goes depends somewhat on the future of the SSC. If the SSC is approved soon, they may drop the LHC idea and turn toward the CLIC project.

DESY expects to start operating the HERA electron-proton collider sometime in 1990. DESY is in a unique position and will have no competition in electron-proton collisions for the foreseeable future. They have not begun to think seriously about what comes next, but it wouldn't be surprising if they began to think about linear colliders in the early 1990s, after the enormous pressure on the laboratory to finish the e - p machine has been relieved.

6. The Soviet Union The UNK proton machine at Serpukhov is scheduled to begin operating in 1992 as a fixed-target machine. The next stage of this facility will be a *pp* collider at 6.0 TeV in the center of mass.

The Novosibirsk group has been interested in electron-positron colliders for many years and has had an active program in R&D on linear colliders going for about as long as SLAC has. The Soviet Politbureau has recently "approved" a project for a 2 TeV electron-positron linear collider to be located at Serpukhov, but it is not really clear what this approval means. It certainly does mean that if there is any linear collider built in the Soviet Union it will not be built at Novosibirsk. There is also a set of R&D milestones that must be met by the Novosibirsk group before final approval is granted. It is interesting to note that the project is to start in the next five-year plan rather than in the present one.

The Novosibirsk group intends to improve their existing storage rings to keep high energy research alive at Novosibirsk. They talk about improving both the VEPP II-M ring and the VEPP IV ring to give them high luminosities, with the VEPP II-M ring serving as a Φ factory and the VEPP-IV machine serving as a B factory. The schedule and funding for these upgrades is not clear.

7. China The Institute of High Energy Physics at Beijing has just recently completed its improved version of the SPEAR storage ring (BEPC). The BEPC is designed to have a luminosity of about a factor of 5 greater than SPEAR in the energy range up to about 2.8 GeV per beam. We believe they will make their design goals, although it may take several years to get there. The accelerator physicists at

Beijing have expressed some interest in collaborating with SLAC on linear collider R&D. No firm plans have as yet been formulated.

8. Japan The Tristan electron-positron collider has started working; as we have come to expect from the Japanese, it had a beautiful and fast turn-on. Both luminosity and energy are low compared to design values (the maximum energy now is 60 GeV in the center of mass). They are starting to install superconducting cavities on the Tristan machine and expect to be able to get up to 70 GeV in the center of mass in two or three years. Their power bill at the higher energy will be quite large (approximately \$60 million per year), but the Laboratory is well-funded.

Japanese industry is very interested in participating in SSC construction, but the Japanese accelerator physicists in general seem to prefer a linear collider that they believe may be able to be built in Japan. They are looking at an energy of around 1 TeV in the center of mass, and they already have a site laid out in Tsukuba which is 90% on government-owned land. SLAC has a formal collaboration with KEK on linear collider R&D.

9. General The part of the world program that is most important to SLAC is that connected with future e^+e^- facilities. We have been very successful in convincing the rest of the world that linear colliders are the only way to go for high energy machines in the future, and the Europeans, the Russians, and the Japanese are as interested in future high energy e^+e^- machines as we are. The Russians may even have some kind of a lead with the "Project Approval" granted by the Politbureau. There will be an intense worldwide program of R&D in the next few years, probably leading to the approval of some design. SLAC is at present "ahead" in the R&D race, but there are no secrets in accelerator R&D, and so the rest of the world will soon know as much as we do. There may be room for more than one linear collider in the world program, for linear colliders are by their nature single interaction region machines. If one wants to add multiple interaction regions, it really means luminosity sharing rather than simultaneous use by more than one user of the same machine pulse. Since a large part of the cost of a linear collider is connected with its power source, and luminosity sharing simply means increased power if each facility is to reach a critical luminosity, there is a good rationale for more than one of these machines.

On other electron-positron frontiers, the KEK machine will soon get both its energy and luminosity up, and many people (SIN, Frascati, DESY, Cornell, UCLA, KEK, SLAC) are talking about B factories, though no one is as yet committed to build one.

D. THE SLAC PROGRAM

1. **SLC** The SLC is the main thrust of the Laboratory program. The machine is an innovation in accelerator technology, and because of this it is perhaps not unexpected that we have encountered early problems in establishing a reliable operating regime. The design luminosity of the machine is $6 \times 10^{30} \text{ cm}^{-2} \text{ sec}^{-1}$ and this translates into a design yield at the Z^0 peak of 2×10^6 Z^0 s per year, taking running time and efficiency factors into account. Design luminosity is the same as LEP's at the Z^0 , but the SLC should have a higher luminosity than LEP at energies below the Z^0 if the physics is such as to warrant significant running at lower energies. The practical minimum for SLC lower energy is probably about 60 GeV in the center of mass, while because of the excellent performance of our new klystrons the upper limit energy is probably around 120 GeV in the center of mass (some power supplies in the arcs and final focus would have to be modified to reach that high energy). The addition of more klystrons to the linac could push the maximum energy to something between 130 and 140 GeV should the physics warrant an extension to these higher energies.

As mentioned above, the SLC is a new kind of machine, and our experience to date indicates that it will require a large sustained effort to bring it to design performance. We hope for an integrated yield of a few thousand Z^0 s in FY89, and roughly 50,000 Z^0 s in FY90. Meeting these luminosity goals will require improving the performance of some components of the SLC. The Technical Division at SLAC has already developed a long list of improvement projects.

The initial physics program, which will resume in February 1989, is centered on the Mark II detector collaboration. The detector is well tested, most of its new components and its new software having been used at the PEP storage ring and thus being well tuned up. We can reasonably hope that the physics results will follow closely on the accumulation of data.

The SLD detector is designed to include three-dimensional vertex detection, particle identification and hadron calorimetry, thus giving this facility much greater capabilities than the Mark II detector. The SLD fabrication is proceeding well, and its schedule seems to be paced more by finances than by technical considerations. The SLD is presently scheduled to replace the Mark II at the SLC in 1990 or 1991.

Besides the detector itself, the SLD requires the use of superconducting final focus quadrupoles, which are being fabricated jointly by Fermilab and SLAC. Responsibility for supervising the "superquad" program has been given to the SLD collaboration.

An important part of the physics program of the SLC is research using longitudinally polarized electron beams. SLAC has run polarized beams in the linac in the past, and we are quite confident that polarizations of up to 45% can be achieved with the existing source technology. A program to develop sources capable of 90% polarization is ongoing in collaboration with some outside institutions. A collaboration involving SLAC groups and various user groups has been set up to carry out the polarization project. The polarization project is also paced by available funding.

2. PEP AND SPEAR PEP began operation in 1980 and has produced a large body of physics results. A major review of the long-term PEP program was conducted by SLAC's Experimental Program Advisory Committee (EPAC) in 1986, and the result of that review was a recommendation, which the Laboratory accepted, to increase the PEP luminosity for operation at one collision point. The one collision point is occupied by an improved TPC, and the goal of the TPC run is the accumulation of about $1 - 2 \text{ fb}^{-1}$.

The PEP storage ring is now unique in its energy range. This factor was considered by the EPAC in recommending approval of the experiment. The priority areas of study are B physics, QCD, and two-gamma physics. It is likely that the run will not continue beyond the 2 fb^{-1} level unless some very new physics is turned up, and it is probable that the highest potential for new physics is in the $C = +1$ states, which have not been studied well in two-gamma physics to date.

The PEP improvement program is now complete, and tests show that the lattice functions as designed. The measured luminosity on the improved PEP is about 5×10^{31} and could possibly be increased to as much as 1×10^{32} . The goal of the TPC collaboration run will take 500 to 1000 days at a 50% running efficiency. This is a realistic goal only if we can run PEP simultaneously with the SLC, using a quick switching scheme. If we can run PEP simultaneously with SLC, then we might accumulate the desired integrated luminosity in three to four years. Tests of "quick switch" operation have already begun in the Fall of 1988.

SPEAR operations began in 1972, and SPEAR is still doing important high energy physics work. While there is much left to do, it is probable that within a few years the BEPC at Beijing will be operating above SPEAR's present luminosity in the Ψ / D region. The Mark III collaboration now running at SPEAR involves a significant number of people who are also collaborating in either the Mark II or SLD projects at the SLC. Thus it is not likely that SPEAR will remain a competitive facility for more than a few years. Note also that if SPEAR is to be productive during the next few years, simultaneous operation along with the SLC is required here as well as at PEP.

Alternative uses of the PEP facility are being discussed in the High Energy Physics, Nuclear Physics, and Synchrotron Radiation areas. SSRL already uses half of the SPEAR running time in a dedicated mode, and would like to have more. These other options will be discussed later in this Plan.

3. TLC If SLAC is to remain a vital and viable High Energy Physics laboratory beyond the useful lifetime of the SLC project, a new frontier facility is required. The obvious direction to go is toward an advanced linear collider of appropriately high energy. A potential site has been identified on Stanford lands which allows a machine with a total length of 8-10 kilometers to be constructed. Experiments over the past few years on high-gradient accelerator systems indicate that it is possible to sustain accelerating gradients, at least in a single cell, of more than 200 MeV per meter at RF frequencies about four times the present SLAC frequency. If this gradient can be reliably sustained in a long system, we could achieve a total energy of about 1.0 TeV on the Stanford site, reserving sufficient space for a final focus system and other passive systems. The present linac alignment could be used with an extended tunnel for a 600 GeV machine.

Two committees have been established to investigate the scientific interest, define the technical feasibility, and outline the R&D goals of such a project. The first stage of the work of the physics committee is completed, and a report on luminosity requirements and the physics potential of machines in the 0.5 to 1.0 TeV center-of-mass energy range has been written.

The second committee has been looking into the accelerator issues and finds (as might be expected) that the higher the energy and the higher the luminosity required, the further such a machine is from a simple extension of present technology. Much of the work on tolerances, damping rings, accelerator systems, final focus, etc., that has been done makes it clear that such a machine may be possible if suitable high-power RF sources can be developed. A clear conclusion of our group and other groups around the world that are interested in linear colliders is that the next machine should be a conventional linac structure at high frequency with a new technology RF source. Laser acceleration, plasma acceleration, and wakefield acceleration are presently just too far from practicality to be seriously considered for a machine where construction would start within the next decade.

The big cost items in such a facility will be the main accelerator, power sources, and housings. SLAC has begun a significant hardware R&D program in the source and accelerator areas, and we have a collaboration in place with Lawrence Livermore Laboratory on high-frequency, high-power RF sources. The particular direction we are pursuing is one that combines the induction linac technology of Livermore with our klystron technology in order to bunch

kiloampere beams at MeV energies and extract many hundreds of megawatts of RF power with high efficiency. Recent results have demonstrated peak power output of 200 MW at 11.4 GHz, and an accelerating gradient of 130 MeV/m in a 30 cm.-long structure.

Considering the demands on our staff from the SLC program, the earliest time by which we could prepare a credible conceptual design report on the TLC is perhaps 1992. This goal can be achieved only with additional funds devoted to the R&D program. In the international arena, we have a formal collaboration with Japan, are discussing one with the Soviet Union, and have an effective but informal collaboration with Europe. An international workshop was held at SLAC in November 1988 to exchange information and plan future activities.

During the next few years we must also intensively review the physics justification and the choice of energy for the TLC. An intriguing possibility is an "extensible machine," built initially at a lower than TeV energy, but with the potential to add power or length to eventually reach the TeV scale. There is reason to believe that there are very interesting possibilities at 100 GeV (with 100 - 1000 times the SLC luminosity), 500 GeV and 1.0 TeV. These options will have to be carefully evaluated in consultation with the broad high-energy physics community.

4. OTHER MACHINES The presently planned SLC, PEP, SPEAR, and TLC programs all taken together conspire to make SLAC a single interaction region HEP laboratory (SLC) during the mid-1990's unless we create new opportunities. These new opportunities could come from significant new discoveries on our existing storage rings that would extend their life, or from a new project that fills some special need in High Energy Physics. Examples of possible projects include facilities such as a *B* factory, a tau-charm factory, or a nonaccelerator experiment that could be constructed at SLAC.

In the area of *B*-meson factories, there are several ideas circulating at present. One of these is called an asymmetric *B* factory — a high-intensity low-energy storage ring (about 2 GeV) colliding at a single interaction point with PEP (at about 12 GeV) operating in a multibunch mode. The whole system would run at the $\Upsilon(4S)$ resonance. This asymmetric-ring *B* factory is described in more detail in the "Initiatives" section of this Plan.

A tau-charm factory would be a storage ring of about the energy of SPEAR, but with a luminosity 100 or more times larger. A study is in progress to assess the physics potential and technical risk of such a machine. The rationale and present planning for this tau-charm factory are described in more detail in the "Initiatives" section of this Plan.

There are no specific suggestions for nonaccelerator experiments at present, but there have been such in the past.

5. SSC INVOLVEMENT The SSC project, if it goes ahead, is likely to have a strong impact on the SLAC program. SLAC would be interested in developing certain components for the SSC machine, particularly in such areas of special competence as vacuum and RF systems. In addition, the involvement of SLAC physicists in the development and construction of one of the first-round detection systems for the SSC is an important possibility.

As one of the large labs, SLAC does have the infrastructure to support the construction of a large detector for the SSC. There are few places where such a facility could be built. The SSC itself, during its construction period, will obviously not have the shops, assembly space, etc., required to build large detectors, and so fabrication of these things will have to be outside. Presumably the mode of operation would be that some consortium of universities and laboratories submits a successful proposal for an SSC detector, that SLAC is part of that proposal, and that SLAC is designated as home-base for fabrication and testing of some major part of the detector complex.

6. OTHER SCIENCES We are now host to both a Nuclear Physics program and a Synchrotron Radiation program. At present, we have a program called NPAS (Nuclear Physics At SLAC) which is funded by the Nuclear Physics part of the DOE and supports the operation of the linac using the nuclear physics injector at Sector 25 for runs with energies up to 8 GeV and taking about 90 – 180 shifts per year. When this program began several years ago, it was made clear to the nuclear physicists that this would have to be a finite-term program, for when the SLC was operational and our budget was at the point where we could run SLC for a significant fraction of the time, there would be a conflict over use of the linac, and SLC would take priority. We have reached that situation at the present time. It may be possible to resume operation with the nuclear physics injector within two years or so if demand for beams to SLC, PEP and SPEAR slacken and permit windows of time in the calendar.

There is also a new proposal (independent of the existing NPAS program) that has been put forth to do nuclear physics at PEP with a gas-jet target. We have received the final version of the letter of intent and have analyzed it for impact. The major questions are compatibility with other modes of PEP operation (HEP and synchrotron radiation) and funding. A workshop will be held in January 1989 to review the project. If this proposal is compatible with other uses (i.e., can run parasitically) it would be a sensible thing to do. SLAC will endorse the project only

with support from the nuclear physics community, which seems in fact to be developing.

The issues involving the Stanford Synchrotron Radiation Laboratory (SSRL) are more complex. SSRL already uses SPEAR half time in a dedicated mode and wants the rest of it. They are building a special injector for SPEAR that will completely decouple the facility from the linac for synchrotron radiation operation. They are also interested in the use of PEP both in a parasitic and a dedicated mode, and a recent test run indicates that PEP in dedicated operation is capable of beam parameters beyond those of the proposed Advanced Photon Source (though for a more limited number of users) that is to be built at Argonne if Congress approves. Our present agreement with SSRL only gives them the right to 50% use of SPEAR and says that two to three months of dedicated runs on PEP are feasible. The agreement is on a full cost-recovery basis, and we have a complicated algorithm that allocates both storage ring costs and linac costs to the synchrotron radiation program.

SSRL is here, is productive, and has a large user community. SSRL believes that there is a long-range future for synchrotron radiation work using both SPEAR and PEP. PEP is unique in its capability now, and will probably remain so even after the new generation of sources turns on. (ALS, a 1.5 GeV ring at LBL now under construction; APS, a 7.0 GeV ring mentioned above; and an upgrade to the BNL 2.0 GeV ring.) PEP's energy and emittance make it more powerful than any of these, but the number of experimental stations is more limited than can be provided on the new facilities. PEP might well be better than merely competitive in both the dedicated and parasitic modes.

The SPEAR storage ring is presently a unique high energy physics facility. However, as noted previously, it will be superceded when the Beijing machine approaches its design goals. This will probably happen within the next one to three years, which coincides with the time of completion of the present cycle of approved SPEAR HEP experiments. Thus we have begun planning for a transition of SPEAR to a fully dedicated synchrotron light source in FY1991 or FY1992.

If, as it seems, synchrotron radiation work with the SLAC storage rings will be highly productive for the long term, then the institutional arrangements between SLAC and SSRL should be reviewed. The present arrangements were developed when SSRL was a smaller operation and may no longer be appropriate. The University and the laboratories have begun the review process.

SECTION II LABORATORY MISSION

The Stanford Linear Accelerator Center is dedicated to research in high energy particle physics and to the development of new techniques in high energy accelerators and experimental apparatus. The Center is operated as a National Facility so that scientists from universities and research centers throughout the world may participate in the high energy research program.

The mission of SLAC can be summarized as follows:

1. To provide the accelerators, detectors, and support necessary for physicists from SLAC and other institutions to carry out experimental and theoretical research in high energy physics.
2. To develop new detection techniques that allow new kinds of experiments to be done.
3. To improve the capabilities of existing accelerators and to develop the conceptual framework and technology needed for the next generation of accelerators.
4. To assist scientists in other disciplines to exploit the special opportunities that may arise from our high energy physics facilities and our expertise in accelerators.

SECTION III SPECIAL ISSUES

A. PLANT FUNDING

Funding at SLAC for the purpose of plant improvements has been very limited over the years. The level of annual funding for general plant projects (GPP) and accelerator improvement projects (AIP) has been less than one percent of the present value of the investment in the Lab facilities. In the last few years, SLAC has included in its budget request line-item-construction projects to replace the PCB transformers and to add a building for offices and laboratories, but they have not yet been funded. In order for the Laboratory to maintain and enhance its scientific effectiveness and productivity, an increase in the level of plant funding line-item construction, GPP, and AIP) is necessary to improve the SLC, to replace the PCB transformers, to maintain and improve the other facilities, and to provide additional space for the staff and outside users.

1. **AIP** The SLC is the main thrust of the Laboratory program. Since the machine is an innovation in accelerator technology, based on the early operating experience, many near-term improvements to various systems of the facility will be needed to achieve the desired reliability and design luminosity. In the longer term, energy upgrade or other improvements necessitated by the future direction of the physics program will be needed to enhance the performance and productivity of the SLAC machines. Increased funding in AIP will provide the financial resources required.

2. **GPP** SLAC has an increasing requirement for GPP funds for technical facilities necessitated by the evolving research programs; for additional office and light lab space to alleviate overcrowding and improve productivity; for environmental-related projects, many of which are required by federal or state regulations; and for maintenance of its aging physical plant, most of which was constructed 25 years ago. As funding has been inadequate to meet the requirements, the pool of backlog projects keeps growing. The Lab needs an increased level of GPP funding to ensure effective operation.

B. POWER

Electric power continues to be a significant and increasing fraction of SLAC's operating costs. While in the last two years SLAC has benefitted from favorable world power costs which have resulted in stable rates from SLAC's two suppliers of electric power: WAPA (Western Area Power Administration) and PG&E (Pacific

Gas & Electric), it is not clear how long the current rates will hold. PG&E rate is typically higher than WAPA's and is currently at a 40% premium. SLAC's power consumption is expected to increase by about 10% annually over the next few years, and if the "SLC Upgrade to 180 pps" project requested for FY90 is funded, power usage will go up another 20% in FY92.

Regardless of the future rate increases and programmatic changes, it is clear that it will be in SLAC's interest to continue to press for the most favorable contractual arrangements with WAPA and PG&E. A most desirable outcome from future negotiations would be to obtain an increase in overall allocation of power from WAPA above the present 45.9MW. Such an increase, however, should not be obtained at the cost of frequent "brownouts" at SLAC since brownouts are extremely detrimental to the Laboratory's research program. One possibility is that such an increase might come as a result of the completion of the Northwest Intertie. Other possibilities will be explored as favorable opportunities arise.

SECTION IV LABORATORY STRATEGIC VIEW

In this section, we set out briefly a view of how the SLAC laboratory may develop during the next 15 years. Note that much of the information that is given here is also discussed in more detail in Section I of this Plan, "Director's Statement", and in Section VI, "Initiatives". The intent here, then, is to give a concise overview of a desirable course of development of the laboratory during the period up to the early years of the next century.

We begin with a caveat that is customary but nonetheless important. It is difficult to plan a decade or more ahead in a field of science that evolves as rapidly as high energy physics. Not only is the advance of physics itself hard to predict, but there are also major uncertainties in funding patterns and in the development of the next generation of large accelerator facilities. Thus we may be able to speak with some confidence about the early part of the projection period, but our view of the Laboratory's program at the turn of the century is necessarily seen through a cloudy crystal ball.

SLC Given the richness of the physics at the Z^0 we expect the SLC to continue to operate productively for particle-physics research throughout the decade of the 90's. The initial Mark II detector at the SLC will be replaced in 1990 or 1991 by the LEP-competitive SLD detector system. In addition, a polarized electron beam at the SLC will become available at about the same time. We also expect that operational experience with the SLC and the improvement program now under way will result in incremental increases in luminosity toward the design goal of 6×10^{30} .

ADVANCED LINEAR COLLIDERS The central focus of the advanced accelerator R&D at SLAC is on the development of electron-positron linear colliders, and this emphasis is expected to continue through the period of this forecast. The prospects for the next-generation linear collider (the TLC) are discussed in some detail in the "Initiatives" section of this Plan (Section VI). We can visualize a phased construction program for the TLC in which a machine of about 8 kilometers total length is sited on existing Stanford University land, with an initial energy of about 500 GeV in the center-of-mass, and an eventual energy of 1 TeV as more powerful sources of RF are developed. As noted in Section VI, it is our definite intention to work toward the development of a specific proposal for the TLC, with the proposal to be ready perhaps as early as 1992.

In the longer term, we foresee a continuing bright future for e^+e^- linear colliders. There appears to be simply no alternative for very high energy e^+e^- collisions, and the simplicity and cleanliness of the electron-positron

annihilation process make it increasingly attractive for experiments as the energy scale goes up. For these reasons, we expect an evolutionary development of the linear collider idea that will lead to a machine of very high energy in the early years of the next century. For the sake of discussion, we choose 10 TeV in the center-of-mass as a starting point. Such a machine would have a physics reach well beyond that of the SSC for most classes of experiments, and the other advantages noted above would make it an incredibly powerful probe of the nature of matter. SLAC plans to play a central role in this evolutionary development.

STORAGE RINGS It seems likely that the SPEAR storage ring will eventually be dedicated wholly to synchrotron radiation research after the close of its present high energy physics program. This may occur as early as 1990 or 1991. One possibility for continued exploration of the very rich SPEAR energy region would be a new two-ring Tau-Charm factory, which is described in Section VI of this Plan.

The case of the PEP storage ring is more difficult to foresee. PEP appears to have a productive particle-physics research program ahead of it for the next three to five years if, as expected, its operation can be efficiently interleaved with the continuing operation of the SLC. As described elsewhere in this Plan, PEP has also been shown to be an exceptionally bright source of synchrotron radiation, and may well prove to be an important element in the national program of synchrotron radiation research. Another possibility is that PEP will be used in conjunction with a smaller ring to form an asymmetric ring *B* factory, as described in Section VI. These possibilities, together with other proposed nuclear physics and particle physics projects, make it likely that the PEP ring will continue in operation at SLAC through the decade of the 1990's, and perhaps beyond.

SSC INVOLVEMENT For planning purposes, we shall assume that the SSC program goes ahead on a schedule that has this new laboratory ready by about 1997, and that SLAC will have a significant role to play in this work. Specifically, SLAC could logically act as the home base for the construction of one of the very large detection systems that will be developed for use at the SSC. This would presumably represent the effort of a collaborative group of several hundred physicists from many different institutions. SLAC's technical infrastructure of large shops and skilled personnel would obviously be well-suited to such work. Similarly, SLAC's facilities and people might be called upon to fabricate some of the hardware for the SSC itself, particularly in our areas of special competence such as RF systems and ultrahigh vacuum systems. These matters were also discussed in Section I of this Plan.

SECTION V SCIENTIFIC PROGRAM AT SLAC

In the last twenty years our understanding of particle physics, of the fundamental nature of energy and matter, has undergone a revolution. The hundred or more hadrons thought to be elementary particles in the 1960's are now known to be made up of just a few different kinds of quarks. These quarks comprise one family of elementary particles. The electron, muon, tau and their neutrinos comprise a second family, the leptons. The third family of elementary particles are the force-carrying particles: the photon which carries the electromagnetic force, the $W^\pm$ and Z^0 particles which carry the weak force, and the gluon which carries the strong force. SLAC contributed substantially to this revolution. The major examples are the first substantial evidence and then the definitive proof of the quark nature of hadrons; the discoveries of the charmonium and charmed meson families of particles, thus proving the existence of the charmed quark; the discovery of the tau lepton and its neutrino; the first demonstration of the existence of hadron jets; and the study of electro-weak interference.

As a result of this revolution, particle physics is now moving in two broad directions. First, we can now look for answers to very basic questions. What determines the properties of the elementary particles? How many different kinds are there? Are all the forces in nature simply different aspects of a single, truly fundamental force? The second broad direction is the study and precise measurement of the properties of the quarks, leptons and force-carrying particles, that is, the further exploration of the "standard model" of particle physics. SLAC is now poised to pursue particle physics research in both these directions using three different electron-positron colliders and the linac itself. The discussion of the Scientific Program at SLAC that follows will address several aspects of this very interrelated effort:

- The Stanford Linear Collider (SLC) will be used for electron-positron annihilation experiments in the 100 GeV energy range, initially at the Z^0 mass of 93 GeV. In this new electron-positron energy range, we seek the clues for answering the more basic questions. The SLC will provide the physics world with the first entrance into this energy regime.
- The PEP electron-positron circular collider operates in the 20 to 30 GeV energy range. This machine, and its sister machine PETRA in Germany, have already provided a tremendous amount of information on the known quarks and leptons, particularly the bottom and charm quarks and the tau lepton. With the conversion of PETRA to an injector for HERA, PEP is now the only e^+e^- storage ring operating in this energy range. The improvement of PEP will

allow further exploration and more precise measurement of these particles. Experiments using a gas jet target and a new detector are in proposal now. They allow studies in electronuclear physics and high energy physics processes, and are expected to be fully compatible with other PEP activities.

- The SPEAR electron-positron circular collider operates in the 3 to 7 GeV energy range. SPEAR experiments continue to provide the most complete information on the charm quark, and a good deal of information on the lighter quarks and on the leptons.
- Physics of a TeV linear collider will be studied as a continuing effort to support future e^+e^- goals at very high energies. Study groups at SLAC have made preliminary reports available to the physics community at the SNOWMASS 88 workshops.
- B -meson physics or tau and charm physics using future small storage rings at SLAC are possible. A study of the potential for B -meson studies in an "asymmetric B -factory" using PEP beams colliding with a 2 GeV storage ring beam, at high luminosity, has been underway. The center-of-mass energies near the upsilon (4S) result in B -mesons moving in a laboratory detector. The resulting displaced vertices of decaying B -mesons enhance detector capabilities. Also, studies of high luminosity e^+e^- collisions in the energy range 1.5 to 2.5 GeV to produce tau mesons and charmed mesons copiously are underway. Neither the asymmetric B -factory nor the tau/charm factory has gone beyond the preliminary study stage. One of these, but probably not both, may become laboratory supported projects. In either case, a new detector would be required to exploit the high luminosity machines with modern detector capabilities.
- The LINAC is not only an injector for the three colliders but can also provide particle beams for fixed-target experiments and for testing apparatus. As part of the SLC construction project the maximum energy of the LINAC will be increased to 50 GeV.
- Detector research and development work over the next few years will place heavy emphasis on devices to capitalize on access to the new SLC energy range. Research on detectors for the SSC environment will expand significantly.
- Accelerator research and development work seeks to improve the capabilities and efficiencies of existing accelerators and investigate the optimal parameters for future machines.

- Nuclear Physics at SLAC is a relatively small program that exploits existing SLAC research facilities with only nominal incremental expenditures of resources.
- Progress in particle physics is the result of the continuing interplay between new experimental results and particle physics theory. The Theoretical Physics Group at SLAC seeks to orchestrate and facilitate this critical interaction.
- Leadership in new directions for High Energy Physics computing will continue.

A. PHYSICS WITH THE SLC

The SLC will operate at center-of-mass energies up to 100 GeV; this energy could eventually be increased to about 140 GeV. SLC experiments seek answers to the new basic questions:

- What sets the masses of the different elementary particles? Is the Higgs hypothesis correct, and can the Higgs particles be found? If the Higgs hypothesis is wrong, what replaces it?
- Are there more quark or lepton generations? Why do these particles form generations?
- Are the quarks and leptons elementary or composite?
- Are new theoretical ideas like supersymmetry correct?
- Can the strong and electro-weak interactions be unified?

SLC experiments will also provide detailed studies and further exploration of the standard model:

- Properties of the charm and bottom quarks.
- Properties of the top quark if its mass is less than about 45 GeV/c².
- Parameters of the electro-weak unified theory.
- Properties of the known leptons.

The Z^0 and Its Decay Modes The great power of SLC physics comes primarily from the copious production in electron-positron annihilation of the Z^0 vector boson, the neutral carrier of the weak interactions. Of equal importance, the Z^0 sample is pure, unlike Z^0 production from hadron collisions. (The existence of the Z^0 was established in 1983 at the CERN $\bar{p}p$ collider, and its mass is close to the predicted value of 93 GeV/c².) Indeed, the yield of multihadron events should exhibit an enormous peak at the Z^0 resonance. The hadron/electromagnetic muon-pair ratio R is expected to increase from a value around 5 at present energies to about 3000 at the Z^0 mass.

The Z^0 is expected to decay into pairs of all the fundamental leptons and quarks whose masses are less than 1/2 that of the Z^0 .

$$e^+e^- \rightarrow Z^0 \rightarrow e^+e^-, \mu^+\mu^-, \tau^+\tau^-, \nu_e\bar{\nu}_e, \nu_\mu\bar{\nu}_\mu, \nu_\tau\bar{\nu}_\tau, \dots \quad (1)$$

$$\rightarrow Z^0 \rightarrow u\bar{u}, d\bar{d}, s\bar{s}, c\bar{c}, b\bar{b} \dots$$

This crucial property of the Z^0 allows the detailed study of the standard model properties of the known quarks and leptons, and it allows definitive explorations of new physics ideas. For example, it allows the definitive establishment of the existence of the top quark and of massive neutral leptons, if these masses are less than about 45 GeV/c².

New Phenomena An often considered and controversial aspect of the standard model is the Higgs boson. The conjectured boson (or bosons) is responsible for the origin of mass in the standard model, and understanding its properties could lead to a fundamentally important understanding of the mass spectrum of particles. If light enough, Higgs bosons could be seen in the decays of the Z^0 to the Higgs and lepton pairs, for example.

Supersymmetric and grand unified field theories of the fundamental particles are attractive ideas, but so far there is no verification of such ideas. Indeed present experimenters have set lower limits on the masses of the new particles predicted by these theories. The higher energy of the SLC provides the next definitive testing ground for them.

Heavy leptons, neutral as well as charged, or any new particles that carry weak charge, may also exist in the final states. There have been no comprehensive and definitive searches for neutral heavy leptons because the only known general method for producing them is

$$e^+ + e^- \rightarrow Z^0 \rightarrow l^0 + \bar{l}^0$$

a reaction which can be studied fully at the SLC. Indeed, the most important discoveries may well come from effects which today are only speculations or are unknown.

Standard Model Studies In the decays of the Z^0 , described in Equation (1) above, each cross section is roughly proportional to the available phase space. The resulting large sample of all these decays allows detailed studies such as the measurement of branching fractions and of the angular distributions of the charge asymmetries. Deviations from the predicted universality among the three generations of quarks and leptons would point to a problem in the standard model.

The Z^0 is a prolific source of quark-pairs of all flavors that are not too massive to be energetically excluded. Decays of the Z^0 into quark-antiquark pairs of different flavors will be seen through fragmentation into collimated jets of hadrons. The multihadron decays should be a particularly good source of gluon jets radiated from the primary quarks, and should allow a thorough study of the QCD properties of quarks and gluons. Although some QCD predictions will be tested at lower energy machines, extension of these measurements to higher energies will be an important test of QCD ideas.

Polarization Studies Neutral-current processes are inherently parity-violating and are expected to exhibit large polarization-dependent effects. Annihilation of longitudinal polarized electrons on unpolarized positrons in the collider will permit the investigation of the full set of spin-dependent effects and allow very accurate measurements of many neutral-current parameters. Intense beams of longitudinal polarized electrons can be made available at SLAC, and the SLC is designed to preserve the polarization. LINAC beams with polarizations of 50% have already been used, and beams of higher polarization are a good future prospect.

Polarization asymmetry measurements complement the branching ratios and charge-asymmetry measurements for the different lepton and quark types. The accuracy of $\sin^2\theta_w$ will improve an order of magnitude over present low energy measurements, and the polarization information will contribute significantly to this improvement.

B. PARTICLE PHYSICS USING PEP

The PEP storage ring began operation in 1980 and has served six major experiments. Its maximum center-of-mass energy is 36 GeV, but operations have been concentrated at 29 GeV, its maximum luminosity point, since turn-on. The luminosity of PEP is now being increased and it will operate in the 20-30 GeV

range. Experiments at PEP and PETRA have explored a broad range of physics, but there is much more work to be done. This future physics requires either more sophisticated and powerful PEP detectors such as the upgraded TPC, with its new secondary vertex inner chamber, or more specialized detectors such as one which could distinguish and measure photons with great precision.

Hadronic Physics This topic itself divides up into several areas that are being intensively pursued at PEP. While there have been many studies of three-jet events at PEP and PETRA there is a great need for much more data in order to understand the physics of these events in detail and to test the theory of quantum chromodynamics (QCD) in model-independent ways. There is a large class of topics that do not require the partition of the multihadron events into two- or three-jet events. For example there is strong interest in the mechanics of the hadronization process. Here one is asking whether charge or flavor, or both, are conserved locally within a jet, or whether the conservation is achieved globally. Another example is the question of how baryons are produced in the hadronization chain. What hyperons are produced? Are baryons emitted "first" in the chain, or in a statistical manner? Is baryon number conserved locally or globally?

Studies of B -Meson Physics Hadronic events containing leptons are very suitable for studying the properties of b -quark production and decay. PEP and PETRA detectors have already obtained useful measurements of $D_b(z)$ the fragmentation function of the b -quark. More extensive and better information is needed to discriminate among different shapes for $D_b(z)$, and thus to understand in detail how the b -quark produces hadronic final states. Detailed comparisons of b -quark events with light-quark events probe the difference between the fragmentation of heavy and light quarks. Since the b -quark decays with significant probability to the c quark, the semileptonic decay chain of b and c starting from a $b\bar{b}$ pair yields multilepton events. Such events provide information on $b\bar{b}$ mixing and on many other aspects of b -quark physics.

Studies of Charmed Particles at PEP The study of the production of D -mesons at PEP energies will continue. Mixing in the $D\bar{D}$ system is of interest. There is also the challenge of finding out how to study charmed baryon production in the PEP energy range, a very interesting subject because we do not understand the production of ordinary baryons in electron-positron collisions.

Studies of τ Physics Measurement of the τ single-charged-particle branching fraction yields $86 \pm 1\%$. Yet adding up the measured single-charged-particle decay modes yields only about 78%. Tagged tau events can be used to study this significant disagreement.

Two-Photon Physics The two-virtual-photon reactions

$$e^+ + e^- \rightarrow e^+ + e^- + \gamma_V + \gamma_V$$

$$\gamma_V + \gamma_V \rightarrow e^+ + e^-, \mu^+ + \mu^-, \tau^+ + \tau^-, \text{ hadrons}$$

are attracting growing interest. The lepton-pair reactions offer new tests of QED and of the point-particle nature and propagator of the τ . The reaction leading to hadron production allows measurement of the total cross section of $\sigma_{\gamma\gamma \rightarrow \text{hadrons}}$, single-particle inclusive distributions, production of exclusive hadron pairs at high P_T , the production of hadron jets by photon-photon reactions, and the exclusive production of resonances. Deep-inelastic $\gamma e^\pm$ scattering can also be studied given a sufficiently large acceptance. These measurements provide tests of QCD.

Thus experiments at the upgraded PEP electron-positron collider will emphasize the second broad direction of present-day particle physics, the further exploration of the standard model.

Studies with Gas Jet Targets in PEP Interest in electronuclear scattering studies using a single PEP beam and a gas jet target has increased significantly. Workshops held by potential users of gas targets have been held at SLAC in January 1988, and will be again in January 1989, to consolidate ideas into a potential program of physics studies. The moderately high energies of the PEP ring (beam energies ≤ 14.5 GeV) allow investigation at the quark level of various properties of nuclei. Studies have shown that gas jet targets are compatible with other uses of PEP, so that substantial running time for these experiments should be available in future years.

C. PARTICLE PHYSICS USING SPEAR

SPEAR operates in the center-of-mass energy region up to 7.4 GeV. Since 1972, experimental work at SPEAR and at the similar German storage ring DORIS has established much of the fundamental physics in this energy region, greatly contributing to the establishment of the standard model of particle physics. DORIS is now operating at higher energy, therefore SPEAR will provide the only access to this important energy region until the Chinese storage ring, BEPC, is fully operational.

The pioneering work at SPEAR includes the discoveries of the psi-particle family, charmed mesons, hadronic jets, and the tau lepton. The present and future physics programs at SPEAR build upon these foundations and look into many open areas in the standard model. Some of these areas are:

The Psi Particle Family Although we know a good deal about ψ and χ states of the charmonium family, there remains much more to be learned. For example, the radiative decay modes of the ψ and ψ' are the best place to look for possible bound states of gluons, and the Mark III detector's accumulation of several million such decays is turning up interesting structure. Strong interest in the ψ family comes from the theoretical expectation that the $c\bar{c}$ system can be studied in an approximately nonrelativistic framework, which means that it should be possible to study the quark-quark interaction in this system in great detail.

D-Mesons, F-Mesons, and Charmed Baryons There are still many aspects of the physics of the D -mesons that remain to be studied in detail and understood. These include the semileptonic decay modes of the D particularly the Cabibbo-suppressed modes, the different lifetimes of $D^\pm$ and D^0 , and the nonleptonic decay modes of higher multiplicity. The F -meson has been identified and its mass measured, but there remain questions about its weak decay branching ratios. Our knowledge of charmed baryons has been increasing quite slowly because it is difficult to study them at proton accelerators. The best experimental method for producing and studying them is in electron-positron collisions in the 4.0 to 5.5 GeV energy range, but there has not yet been time in the SPEAR physics program to operate extensively in that energy range.

Other Standard Model Physics The electron-positron total hadronic cross section in the 4.0 to 5.0 GeV energy region exhibits a complex structure with at least three peaks. These peaks are thought to be related to higher mass states in the $c\bar{c}$ system, but this hypothesis has not been seriously tested. The physics of this region remains to be thoroughly explored. The physics of τ lepton decays, mentioned in the PEP physics section, is also being explored at SPEAR. A challenging problem is to study the hypothesized decay process $F \rightarrow \tau + \nu$.

Although the emphasis in SPEAR physics is in the areas just mentioned, the very high quality and large statistics of the data obtained at SPEAR allow the search for unexpected new phenomena in the 3 to 5 or 6 GeV energy region. The prime example is the discovery in ψ decays of a narrow resonant structure at about 2.2 GeV/ c^2 mass. This structure which is found in data from the Mark II detector has not been explained to date.

D. FIXED-TARGET PHYSICS AT SLAC

The LINAC is not heavily used for particle physics experiments at the present time due to financial constraints. The presently accessible energy region has been fairly well explored, and while there are still specialized high energy physics experiments that use it (about one per year), its primary uses for the past five years have been to supply test beams for apparatus development and to serve us as

injector into our electron-positron colliders. Recently a new injector has been added to the LINAC at about the 80% point, and high-intensity, low-energy beams can be obtained with this new injector for use in nuclear structure experiments. The LINAC will offer more experimental opportunities when 50 GeV beams are available. But the increasing priority given to the collider program combined with overall financial pressures have decreased the support available for fixed-target experiments at SLAC well below the available opportunities. Indeed, the financial restrictions have discouraged many physicists from planning any future fixed-target experiments at SLAC.

There are a number of physics experiments that could use the End Station A facilities at SLAC. These depend on the SLAC machine remaining the highest energy and intensity electron accelerator in the world. The proton accelerators at Fermilab and CERN can produce electron, positron, and photon beams of higher energy, but the intensities are very much less, and the beams have significantly larger inherent phase space. Some of the interesting experiments which could be done include:

- Precise QCD studies of the quark-gluon structure of the proton and of nuclei using elastic and inelastic electron scattering.
- A measurement of the electro-weak parity violation in electron-electron scattering to obtain a better low energy measurement of $\sin^2\theta_W$ interactions involving only leptons.
- A search for electron to muon conversion at high energy indicating violation of lepton conservation.
- A search for light scalar objects which couple to leptons.
- Polarized beam polarized target inelastic scattering. Recent developments in the understanding of spin content of nucleons have stimulated considerable interest.

E. DETECTOR RESEARCH AND DEVELOPMENT

SLAC continues to be a leader in developing experimental apparatus and techniques germane to particle physics. The End Station A spectrometers and the Mark I detector at SPEAR are examples of detector facilities with which major discoveries were made. Indeed, the Mark I detector became the prototype for most colliding-beam detectors built since. Other examples of innovation from the past include the streamer chamber, the hybrid facility based on the rapid-cycling 40-

inch bubble chamber, the multiparticle spectrometer facility LASS, and high spatial precision drift chambers.

The present and near-term detector research and development work at SLAC lies in four areas:

- The micron-sized cross section of the SLC beams offers tremendous opportunity for the detection of secondary vertices from the decay of short-lived particles. Therefore SLAC physicists and their collaborators on SLC experiments are developing three types of secondary vertex detectors: a high pressure, high spatial precision drift chamber; a silicon-strip semiconductor particle detector using a specially designed VLSI preamplifier-multiplexer; and a CCD (charge-carrier-device) semiconductor detector which directly measures space-points on a particle track.
- A Cerenkov Ring Imaging Detector (CRID) system is being developed for the SLD detector for the SLC.
- The SLD detector will also incorporate several advances in its electronic and data acquisition systems. New VLSI analog and digital chips have been specially designed, optical fibre readout is being extensively used, and an integrated concept is being used to design the 2000 MIPS data acquisition system.
- Growing activity in R&D for SSC includes silicon pixel tracking devices, radiation hardness studies in tracking and ring-imaging techniques, customized electronics in integrated circuits, and computing.

F. ACCELERATOR RESEARCH AND DEVELOPMENT

The general objective of this program is to study the physics and technology necessary for the eventual realization of future linear colliders in the TeV energy range. A near-term objective is to identify the areas in both accelerator theory and technology that need further development and to do theoretical and experimental studies to advance our knowledge in these areas.

As various technologies are developed, several accelerator experiments or demonstrations will be proposed and executed. A final focus test beam facility, using the SLC beam as an input, will demonstrate the large demagnification

optics which can focus a flat beam, one with a large ratio between the horizontal and vertical emittances, to a sub-micron spot size. This beam line will also be used to develop and demonstrate ultra precise beam instrumentation and alignment techniques.

By the middle of this five-year plan, a conceptual design report for a TeV Linear Collider will be prepared based on the R&D programs described below. At that time, a construction proposal will be submitted with the goal of a construction start in FY1994.

Work is in progress on accelerator physics and technology issues for future linear colliders in the following areas:

Parameter Optimization Choice of optimum parameters for realizable machine designs with appropriate luminosities at several center-of-mass energies. Designs will be based both on present-day technology limits and on reasonable future extrapolations.

Accelerating Structures and RF Sources Optimization of accelerating structure geometry taking into account accelerating gradient, longitudinal and transverse wakefields, and breakdown field limits. An experimental program to study breakdown limits at different RF frequencies is continuing. This program has two parallel paths, the study of novel damped wakefield structures, including experimental verification of performance, and engineering analysis to evaluate mass production technologies.

RF Sources Advanced RF sources capable of producing very high peak power (hundreds of megawatts) at higher frequencies (10 to 20 GHz) than existing high peak power sources are being studied both theoretically and experimentally. The theoretical studies involve further development of computer codes which simulate beam behavior in a high current, space charge dominated environment, and tests of these codes are part of our experimental R&D program.

Several development programs are in progress and will continue in the area of high peak RF power generation, they are:

- Development of existing klystron technology to higher frequency and power.
- Experiments with RF pulse compression which compress longer pulses to shorter, higher peak powers.

- Relativistic Klystrons, or new technology approaches to the production of RF power, are a major part of the ongoing program in collaboration with other laboratories. The relativistic klystron program is described in more detail below.

Beam Dynamics The study of transverse emittance growth with dependence on alignment tolerances and magnet jitter due to ground motion; amelioration of transverse wakefield effects using Landau damping; scaling of these effects as a function of RF frequency, accelerating gradient, bunch length, and focussing lattice. The preservation of flat beams, i.e., beams with a large ratio between horizontal and vertical sizes, multi-bunch stability and longitudinal bunch compression are all areas which are under active study.

Low Emittance Sources The design of damping rings for minimum emittance, the limitations due to instabilities both for single and multi-bunch designs and the minimum practical impedance for the total vacuum system. Investigation of other low emittance sources such as laser photocathode radio frequency guns.

Final Focus Design of the optics required to produce sub-micron transverse beam sizes at the collision point. Non-conventional techniques such as the use of plasma lenses or intense fields produced by a laser beam are being investigated.

Beam-Beam Physics Detailed study of disruption and beamstrahlung due to megagauss fields in intense colliding electron-positron bunches. Computer simulations of the collision physics, including quantum effects, have been developed and are being updated to include multiple bunch trains crossing at small angles.

In the area of technology development, several projects are in development or being planned. First, a new RF Power Source "the Relativistic Klystron" is being developed by a SLAC, LLNL collaboration. The device combines the pulsed power induction linac technology of Livermore Laboratory with the klystron expertise of SLAC. Several approaches to the conversion of large fractions of the gigawatts of beam power to radio frequency power are being studied both theoretically and experimentally. Our goal is to develop short pulses, 50 to 100 nanoseconds, of high peak power at high frequencies. Twenty nanosecond pulses of 200 MW at 11.4 GHz have already been demonstrated. Second, a full scale test setup of a three stage binary pulse compressor is under construction and will be capable of compressing a 400 nanosecond klystron pulse to 50 nanoseconds to produce eight times the peak power.

G. NUCLEAR PHYSICS AT SLAC (NPAS)

NPAS is a program of nuclear structure physics based on intense electron beams covering a range of beam energies from 1 GeV to about 8 GeV. Electron beams are available from the Nuclear Physics Injector (NPI) facility accelerating beams in the last portion of the LINAC.

These beams and the End Station A spectrometer facilities are ideally suited for a class of experiments to measure the internal structure of nucleons and nuclei in an energy range where the behavior of individual quarks may be important.

A number of experiments in which electrons are scattered elastically or inelastically from various nuclear targets have been done with the facility, although the relatively low-duty cycle of the LINAC limits the extent of possible coincidence measurements. Such scattering experiments are of considerable interest in the current state of nuclear physics. Fundamental studies of scattering from the simplest nuclei could absorb the available beam time for several years to come. The recent interest in the behavior of quarks in the nucleons of heavy nuclei (as in the EMC effect) can also be pursued to great advantage with the facility.

The experiments are complementary to electronuclear experiments planned for CEBAF. The higher beam energies available at SLAC make possible studies of nucleon structure at the quark level, a shorter range phenomenon than is observable at CEBAF.

Future directions for nuclear physics studies include electronuclear studies at PEP, using a gas jet target which injects gas into the PEP vacuum at the center of a new detector. A proposal to exploit this capability, called PEGASYS, (for PEP Gas-jet Spectrometer System), has been submitted.

End Station A experiments with fixed targets are possible in the future, including experiments at energies of 30 to 50 GeV as well as polarized electrons using the upgraded beams of the SLC project. These beams cannot run simultaneously with SLC, so must be scheduled at other times. Presently, scheduling of fixed target running at SLAC has been limited by this interference with SLC, and it is anticipated that only limited fixed target running is possible in the next few years.

H. THEORETICAL PHYSICS

The theoretical physicists at SLAC interact vigorously with the world's community of particle theorists; many young theorists are trained or continue their training at SLAC, and many established theorists are visitors here. At the same time the theorists here stay in close contact with SLAC experiments and experimenters and are deeply involved with planning the physics of new facilities such as the SLC.

Theoretical physics research at SLAC involves the two broad directions of particle physics noted at the beginning of this section: a search for answers to the very basic questions of particle physics, and further exploration of the present standard model of particle physics.

Much of the work on the basic questions and issues is concerned with the superstring concept in particle physics. One direction of research has been in the formulation of the theory, understanding its gauge invariances and fundamental couplings. Another has been the use of conformal invariance to understand the properties and symmetries of realistic solutions.

Theoretical research on Standard Model aspects of particle physics covers a variety of topics: the quantum chromodynamics of exclusive hadron reactions and of hadronic jet production, detailed study of the physics of Z^0 production and decay in electron-positron annihilation, examination of CP violation in various models and its experimental consequences, and research on the phenomenology of weak decays. Research extends outside particle physics to, for example, studies of the quantum mechanics of fractional topological charge, of the use of quantum chromodynamics within nuclear physics, and of weakly interacting massive particles within cosmology.

SECTION VI INITIATIVES

In this section we describe the major initiatives that can be foreseen for the SLAC laboratory in the years ahead. There are four such initiatives that presently appear to be most promising for further development and study: (a) R&D leading toward an electron-positron linear collider in the TeV energy range; (b) development of an asymmetric storage-ring facility for the study of B -mesons; (c) development of a SPEAR-sized storage-ring facility of high luminosity for the study of tau leptons and charmed particles; (d) participation as the lead laboratory in the development of a first-round detector for the SSC. Each of these possible SLAC initiatives has been mentioned in earlier sections of this Plan. In the present section we give the rationale for each of these programs and a brief description.

A. LINEAR COLLIDER DEVELOPMENT

The present generation of electron-positron colliders, SLC and LEP, will explore in great detail the electro-weak interactions of quarks and leptons at the threshold of production of the Z^0 and $W^\pm$ gauge bosons. The next generation of electron-positron machines will reach center-of-mass energies at which the interactions between the gauge bosons themselves can be studied. This is important because, in the absence of new phenomena, these interactions would become so strong that they would violate unitarity. Thus new physics of one kind or another must emerge in this regime. A number of ideas have been put forward to explain how this may happen, most notably the injection of the Higgs sector into the theory. It will be the central task of a new, higher energy generation of electron-positron colliders to determine which (if any) of these ideas is correct, and to explore the electro-weak interactions in detail at center-of-mass energies well beyond the masses of the presently known gauge bosons.

The physics opportunities that could be exploited with an e^+e^- linear collider in the energy range up to 1.0 TeV have been studied extensively through Monte Carlo simulations and analysis. The theoretically simple and experimentally clean environment created by e^+e^- annihilation will continue, as before, to facilitate unambiguous discoveries and crisp tests of theory. On the whole, the detectors, triggers, data acquisition systems and analyses that will be required to exploit these new machines are not unduly demanding and for the most part have already been realized. However, it is the higher energy linear colliders themselves that pose still unsolved problems in accelerator physics and technology. It is evident that an extensive R&D program will be needed to develop the linear collider idea to

the high levels of energy and luminosity needed for the next generation of experiments. Such an R&D program is now under way at SLAC and is described in Section V of this Plan.

B. B-MESON FACTORY

An interesting possibility for SLAC would be the construction of an electron-positron colliding-beam facility that would exceed the capabilities of a conventional B-meson factory (such as an upgraded CESR), with particular emphasis on the measurement of CP violation. This facility would make use of the existing PEP ring operating at about 12 GeV in conjunction with a new 2-3 GeV ring in order to produce collisions at the $\Upsilon(4S)$ resonance or slightly above.

The advantage of having unequal beam energies in the collision is that the B-mesons that are produced are moving in the laboratory frame of reference, so that the time structure of the decays can be measured. This is highly desirable for studying the most promising and most interpretable class of CP violation. The 1988 Snowmass Workshop concluded that there was a factor of 6 reduction in the luminosity required to study this class of CP violation using unequal rather than equal beam energies. The Workshop specified that the luminosity range necessary to measure CP violation by this technique would be between 3×10^{32} and $1.2 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$ depending on the values of the Kobayashi-Maskawa matrix, which are still unknown.

The existence of the PEP storage ring is obviously a great advantage in considering an asymmetric-ring B factory of this sort. Work on a feasibility study for this B-meson facility is now underway at SLAC.

C. TAU-CHARM FACTORY

SLAC is presently studying the possibility of constructing a new facility for electron-positron collisions in the center-of-mass energy region from about 3 to 4.2 GeV, with a luminosity of $10^{33} \text{ cm}^{-2} \text{ s}^{-1}$. With such a facility, an enormous range of tau and charm physics could be explored in great detail. As examples of production rates, in a single year this facility could produce $2 \times 10^7 \tau^+ \tau^-$ pairs, or $5 \times 10^7 D^0 \bar{D}^0$ and $4 \times 10^7 D^+ D^-$, or more than 10^{10} psi particles.

As presently conceived, this would be a two-ring circular facility. Particle-physics experiments would be carried out in one interaction region having a microbeta insertion in one straight section. The opposite straight section would contain the RF system, wigglers, and a dispersion-suppression system. The very large luminosity (more than 100 times that of SPEAR) would be obtained by using

many bunches and large current per bunch. This collider would have an associated e^+ and e^- injector that would allow dedicated operation of the facility throughout the full year.

Several other aspects of this possible facility are worth noting. The design of the rings would incorporate features that allow a broad range of accelerator physics activities to be carried out. These include a flexible lattice with individual control of magnet currents, long straight sections and a relatively large beam pipe, and space available for insertion and beam-diagnostic devices. Accelerator physics studies need not be related to improvement of the Tau-Charm Factory itself; decisions on such work would be made by a program committee analogous to the particle-physics program committee.

D. SSC DETECTOR

For planning purposes, we shall assume that the SSC project is authorized and proceeds on a schedule that has this new machine ready for particle physics in the late 1990's. Several SSC Workshops held during the past two years have emphasized the importance of having a complement of detectors ready at or near turn-on time. This means that work on these large detector systems must logically begin rather soon and must be well into the construction phase by the mid-1990's. The rationale for considering SLAC as a possible home base for the design and construction of a large, first-round SSC detector is evident when one considers the lab's infrastructure of shops, engineering support, high-bay assembly space, test beams for checkout and commissioning of subsystems, and so on. The recent alliance that SLAC has made with the semiconductor custom design labs at Stanford would also be a valuable resource.

For these reasons it seems probable that SLAC will join in a collaborative effort with other institutions to propose the design and construction of one of the first-round detection systems for the SSC, with SLAC acting as the lead laboratory. One can visualize, for example, a collaboration of several hundred physicists from some 15 to 20 universities and labs, perhaps mainly but not exclusively from the West Coast. SLAC's recent experience in acting as the home base for the successful development, design and construction of the large SLD detector is an example of the kind of collaborative activity that we would expect. The cost of the SSC detector project would probably be a factor of four or five larger than that of the SLD, but the nature of the collaboration and of the technical activity would be very similar, and the size of the collaborating group would likely be not a great deal larger.

SECTION VII EDUCATION AND TECHNOLOGY TRANSFER PROGRAMS

A. SUPPORT OF SCIENTIFIC AND TECHNICAL EDUCATION

SLAC has several programs aimed at fostering an interest in the scientific and technical areas. Some are set up for those currently pursuing an academic education, while one, the Apprenticeship Program, is designed as an on-the-job training program.

1. PRE-COLLEGE PROGRAMS

Youth Opportunity Program The objective of this program is to provide summer employment for local, disadvantaged youths between the ages of 16 and 22. Employment is provided during the summer and provides the opportunity to young people for exposure to a scientific work environment.

Science Education at SLAC This program is currently in the proposal stages. It would be aimed at high school physics teachers and their students. The program would have two elements: (1) a two-week summer program for high school physics teachers. This part of the program would be designed to improve the teachers' general physics knowledge and their ability to incorporate modern physics concepts and problems into their high school courses. (2) The second part of the program would feature a monthly "Saturday at SLAC" physics day for gifted high school physics students and their teachers.

2. UNDERGRADUATE PROGRAMS

Work Study Program This program provides educational financial support to financially disadvantaged college students, preferably those who are majoring in science programs. SLAC provides two years of part-time employment during the school year and full-time employment during the summer.

Summer Science Program Started about fifteen years ago, the intent of this program is to encourage more minorities, women, and economically disadvantaged to pursue careers in science. It is critical to the student that he/she be committed to the sciences. This is a nine-week learning/work experience. A combination of laboratory work in a research group and lectures are designed to advance the scientific interests of the students. Financial support is shared by SLAC and the Association of Western Universities (50-50). Students are recruited primarily from colleges and universities which are well represented with respect to minority and female enrollment.

3. GRADUATE, POST DOCTORAL, AND FACULTY PROGRAMS

SLAC has several programs geared towards graduate students, post-doctorates, and faculty participation. Our Graduate Student Program provides the Stanford University graduate student the opportunity for a limited term position working in an area of interest which can be used towards thesis work. Graduate students from other institutions participate in various experimental collaborations at SLAC. Our Research Associate Program provides limited term employment for post-doctorate physicists with one of SLAC's experimental or theoretical physics groups.

Members of the SLAC faculty are periodically requested to teach graduate and undergraduate level courses in the Stanford University Physics Department. In addition, the SLAC faculty participate in the graduate training program by serving as advisors to graduate students in the Stanford Physics programs. Six SLAC faculty were involved in teaching Stanford courses during 1988. Teaching assignments are at no cost to the SLAC operating contract because the Physics Department of Stanford University fully reimburses salaries and related costs.

SLAC periodically hosts seminars and conferences of special interest to the scientific community. In addition, SLAC hosts an annual Summer Institute. This ten day school is attended by high energy physicists, post-doctorates and beyond, along with many graduate students. There are from 300-350 attendees, of which one-third are graduate students and two-thirds post-doctorates plus faculty/research staff. The ten days are divided into seven days of lectures and three days of a topical conference. In addition to the lectures, there are tours and organized discussions with the speakers. The speakers are scientists from around the world who are invited to talk at the institute regarding their current research. The institute is designed for theorists as well as experimenters.

In addition to the programs described above, the laboratory is actively engaged in programs set up for training and education which would lead towards employment in fields which have not been traditionally filled by minorities or women.

Consortium Program This program was begun at SLAC about ten years ago. SLAC is a founding member of the National Consortium for Graduate Degrees for Minorities in Engineering, Inc., which aims to alleviate the under-representation of minorities and women in the engineering profession. To help support this program, the members contribute annually to the National Consortium which acts as a clearing house to accept applications for scholarships. An employee of SLAC sits on the selection committee and twice a year travels to Notre Dame to select four students to support at SLAC. These students come to SLAC for three summers to

work at a job relevant to their field of interest in engineering. The program pays for their entire graduate program.

Faculty Education Program Currently in the development/proposal stage, this summer program would provide an opportunity to someone currently teaching at another educational institute to spend the summer at SLAC working and learning about physics. He/she would have the opportunity to write a paper to take back to the home institution while learning how a physics laboratory functions. SLAC would solicit proposals from minority colleges.

4. NON-ACADEMIC PROGRAM

Apprenticeship Program This program has been in existence at SLAC for about ten years. It was begun in response to a serious lack of minorities in the crafts areas. SLAC set up a program which is certified by the State of California so that, upon successful completion of the program, the employee would be certified to work outside of SLAC if he/she so chose. This is a four-year training program and the employee is offered a full-time position at SLAC upon completion of the program.

TABLE VII-1 EDUCATIONAL PROGRAM PARTICIPATION FY1988

	Pre- College Students	Under- Graduates	<-----Graduate-----> Students	Post-Doc	Faculty	Total Participants
<u>DOE PROGRAMS:</u>						
Stanford Univ. Graduate Students			61			61
Research Associate				27		27
Youth Opportunity	13					13
Work Study	6					6
Apprenticeship						2
<u>SHARED SUPPORT:</u>						
Summer Science	18					18
Summer Institute			x	x	x	350
Consortium			4			4
Faculty Teaching		x	x			6

B. USER FACILITIES

The Stanford Linear Accelerator Center is a national "designated user" facility operated by Stanford University for the U.S. Department of Energy. SLAC has recently completed construction of a new class of e^+e^- colliding beam machine, the SLC, which has great promise for future particle physics experimentation. The linear collider technique has the potential to be extended in future machines to much higher energies at considerably lower cost than the storage ring methodology which has been used up to now for e^+e^- colliding beam studies. The SLC will operate in the region of 100 GeV and is expected to yield a few thousand Z^0 in FY89 and approximately 50,000 in FY90. The Mark II detector is currently installed at the SLC and will be followed by a LEP- competitive SLD detector system which is under construction.

Two positron-electron colliding beam storage rings, PEP and SPEAR, are in operation at SLAC. PEP has six interaction regions, generates 14.5 GeV per beam and currently utilizes the TPC detector in interaction region 2. SPEAR generates up to 4 GeV per beam and employs the Mark III detector in one of its two interaction regions. Half of the running time of the SPEAR storage ring is devoted to high-intensity single electron beams for the production of x-rays to be used by the SSRL program.

Research with fixed targets is also conducted in End Station A where three large spectrometers are located. Two of the spectrometers, the 1.6 GeV and 8 GeV, are presently in use in the nuclear physics program.

SLAC facilities are available to any qualified user in the United States or overseas, and experiments are approved on the basis of scientific merit. At the present time 572 scientists from 71 institutions including SLAC (36 U.S. and 35 foreign) are members of collaborations performing research in high energy physics and nuclear physics at SLAC. It is expected that outside user participation in the program will continue at a high level.

Proposals for specific experiments should be submitted to the SLAC Experimental Program Advisory Committee (EPAC). There are no user fees and all apparatus and procedures must conform to SLAC safety standards. For further information contact: L.P. Keller, SLAC Experimental Facilities Department.

TABLE VII-2 EXPERIMENTERS AT SLAC [1]

<u>Experimental Area [3]</u>	<u>SLAC [2] Stanford</u>	<u>Other [2] Institutions</u>	<u>Total</u>
SLC	94	275	369
PEP	4	110	114
SPEAR	14	37	51
End Station A			
HEP	0	22	22
NPAS	6	88	94
Misc. Facilities	21	54	75

[1] Data current as of November 1988

[2] The total number of "individual" experimenters is 572. The data above reflect individuals participating in more than one experiment in 153 instances.

[3] Proportion of facilities available during the year is 100%.

C. TECHNOLOGY TRANSFER

SLAC's activities are primarily oriented toward research with the end product being in the form of published information that is presented in seminars, conferences and numerous scientific publications. SLAC's objective for technology transfer is to identify recently developed and/or emerging technology in the laboratory that may have a potential application outside of SLAC, and to promote utilization of the technology in U.S. industry.

SLAC's technology transfer procedures and processes are flexible and we use the services of the Stanford University Office of Technology Licensing (OTL) as a technology transfer broker to supplement our technology transfer effort at the laboratory.

Typically, a public presentation or the publication and dissemination of information relating to our laboratory technology may result in inquiries for additional details on some part of the technology, which might have an advantage for use in applications outside of SLAC. In some cases an on-going relationship is established, with the SLAC originator becoming an advisor or consultant to facilitate the technology transfer. At present, approximately forty SLAC personnel have arrangements with business firms outside of SLAC, typically as a technical consultant or advisor.

SLAC's technology transfer accomplishments include providing technical information relating to klystrons and SLED cavities; SAM, CAMAC, and Fastbus computer system elements; copies of various engineering drawings, and numerous software programs which have been utilized by several industrial firms.

TABLE VII-3 TECHNOLOGY TRANSFER EXPENDITURES AND STAFFING

	-----Then Year Dollars-----				-----FY90 Dollars-----			
	<u>FY87</u>	<u>FY88</u>	<u>FY89</u>	<u>FY90</u>	<u>FY91</u>	<u>FY92</u>	<u>FY93</u>	<u>FY94</u>
FUNDING (\$000)								
ORTA	99	124	140	145	145	145	145	145
Other	<u>811</u>	<u>744</u>	<u>870</u>	<u>955</u>	<u>985</u>	<u>985</u>	<u>985</u>	<u>985</u>
TOTAL	910	868	1,010	1,100	1,130	1,130	1,130	1,130
STAFFING (FTE)								
Professional:								
ORTA	1.2	1.5	1.7	1.7	1.7	1.7	1.7	1.7
Other	<u>3.0</u>	<u>3.0</u>	<u>3.0</u>	<u>3.0</u>	<u>3.0</u>	<u>3.0</u>	<u>3.0</u>	<u>3.0</u>
SUBTOTAL	4.2	4.5	4.7	4.7	4.7	4.7	4.7	4.7
Support	<u>13.0</u>	<u>13.0</u>	<u>15.0</u>	<u>15.0</u>	<u>15.0</u>	<u>15.0</u>	<u>15.0</u>	<u>15.0</u>
TOTAL	17.2	17.5	19.7	19.7	19.7	19.7	19.7	19.7

D. MINORITY AND DISADVANTAGED PROCUREMENT PROGRAM

SLAC intentionally sets very high goals for contractual awards to small, small disadvantaged, woman-owned, and labor surplus firms; and then is very aggressive in attaining these goals. During performance appraisals, each buyer is given a goal of soliciting a minimum of one small disadvantaged business firm in each request for quotation or proposal solicitation. The Purchasing Department has in place a program for monitoring each buyer's performance and utilizes the results as one tool in the yearly salary setting process.

Although SLAC does not maintain a formal list of minority, disadvantaged, woman-owned, or labor surplus firms, we do have access to such lists from the PASS System (a government computerized program maintained by the Small Business Administration), and various other firms and laboratories including Lockheed, LBL, and McDonald-Douglas. Weekly "buyer" meetings are held where we discuss our goals and our success in meeting them. This process has

proven to be very satisfactory for the laboratory and we are justifiably proud of our accomplishments in this area.

Our goal and actual results for FY1988 are as follows:

	(\$ in Millions)	
	<u>Goal</u>	<u>Actual</u>
Total Procurements	\$44	\$53
Minority & Disadvantaged Procurements [1] :		
Small Business	22	25
Disadvantaged Business	2	3
Labor Surplus [2]	1	32
Small Business Set-Aside	4	6
Woman-Owned Businesses	1	2

[1] In many cases individual procurements may be included in more than one category.

[2] Subsequent to goal-setting, three counties in which SLAC engages in much of its procurement activities, were designated as labor surplus areas.

TABLE VII-4 SMALL AND DISADVANTAGED BUSINESS PROCUREMENTS
(\$ in Millions)

	-----FY1987-----		-----FY1988-----	
	<u>Amount</u>	<u>%</u>	<u>Amount</u>	<u>%</u>
Small Business	\$24	53	\$25	47
Small Disadvantaged	3	6	3	6

TABLE VII-5 SUBCONTRACTING AND PROCUREMENTS

(\$ in Millions)

	<u>FY1987</u>	<u>FY1988</u>	<u>FY1989</u>
Subcontracting and Procurement from:			
Universities	\$1	\$3	\$3
All Others	46	51	56

SECTION VIII SITE AND FACILITIES

A. LABORATORY DESCRIPTION

SLAC is located on the San Francisco Peninsula, approximately halfway between San Francisco and San Jose, California. The SLAC site occupies 426 acres of land owned by Stanford University and leased to the DOE.

In 1962 the construction of the Stanford Linear Accelerator Center, and the two-mile-long electron linear accelerator (LINAC), began in the foothills behind the main Stanford University campus. The accelerator and most of the site improvements were completed by 1966. In 1972 the storage ring SPEAR began operation, followed in 1980 by a new matter-antimatter colliding beam machine called PEP. Construction of SLAC's most recent machine, the SLC, began in October of 1983 and was completed in March of 1987.

A second major research facility, the Stanford Synchrotron Radiation Laboratory (SSRL), is located on the SLAC site and receives its funding through the Office of Energy Research, Office of Basic Energy Science of the DOE. SSRL is an independently managed laboratory; however, SLAC retains oversight of the site development aspects of the SSRL operation. SSRL receives dedicated beam time for 50% of the operations shifts on SPEAR and operates in a parasitic mode for additional experimental time on both PEP and SPEAR. (During parasitic operation, the energy and current at PEP and SPEAR are determined by the high energy physics program.) In addition to experimental beams, SLAC supplies numerous services to SSRL including general and administrative support, design and engineering services, as well as ES&H services. SLAC is reimbursed for services and for costs associated with dedicated time on a full cost recovery basis pursuant to an allocation algorithm agreed upon between the Labs.

B. FACILITIES, PLANS, AND OPTIONS

The programmatic assumptions underlying the Laboratory's planned development of facilities during the next five years have been discussed in preceding sections of this document. Because the field of high energy physics continues to evolve rapidly, and due to the existence of major budgetary unknowns, SLAC's site development plans for the latter part of the period are necessarily uncertain.

There are several factors which bear upon SLAC's site and facilities development during the period of this plan. These include the age and physical

condition of the majority of the SLAC physical plant, emerging environmental and safety concerns, a shortage of office and light laboratory space, and expectations as to needed HEP and nuclear physics experimental facilities at the Laboratory to support frontier research for physicists from SLAC and elsewhere in the world.

There has been a chronic shortage of office and light laboratory space at SLAC which has been accommodated only through overcrowding and the continued use of substandard facilities. The demand for office and light laboratory facilities has further increased with the growing participation of outside users in the large Mark II and SLD collaborations. SLC operation has also intensified the need for light laboratory facilities, as has the increased emphasis on Advanced Accelerator R&D. To alleviate this issue, SLAC has planned a series of General Plant Projects which will expand and renovate existing buildings on the site. In addition, SLAC has submitted a FY1990 Budget Request for construction of a Central Laboratory Expansion, the details of which are contained below in the description of FY1990 line item projects.

As part of SLAC's ongoing GPP program and in addition to space related projects, GPP funds will be utilized on site to upgrade support facilities consistent with programmatic needs and experimental objectives. These projects include such items as the Central Chiller Upgrade, HVAC replacement, LCW Deionization Plant replacement and others. The Laboratory is also continuing its Accelerator Improvement Program which will enhance the capabilities, operating efficiency and safety of the accelerator facilities at SLAC.

The items contained in SLAC's FY1990 Budget Request are:

SLC Upgrade to 180 pps The proposed SLC upgrade to 180 pulses per second will consist of major modifications to three existing subsystems which presently limit the operation of the Linear Accelerator to 120 pps. This upgrade will increase the luminosity of the SLC by a factor of one and one-half, and is equivalent to raising the data-taking capability of the SLC by 50%.

Central Laboratory Expansion The CLE will be a three story structure of 20,000 usable square feet located immediately adjacent to the existing SLC Central Laboratory. The new building will have roughly 13,000 square feet devoted to office space housing about 100 people. The remainder of the structure will include light laboratories, drafting rooms and conference areas. Approximately 70% of the intended occupants will be SLAC employees and 25% of the office area will be for users. The structure will ameliorate the overcrowding and use of substandard office space which has existed at SLAC for a number of years.

Discontinued Use of PCB Transformers This project will replace twenty PCB transformers on the SLAC site with non-PCB units. The effort includes the removal of existing PCB transformers and PCB liquids from SLAC, transportation to an out-of-state disposal site, and the installation of new non-PCB transformers.

In the long term the "facilities" picture becomes somewhat unclear depending on the availability of funding and the future direction of research. SLAC is planning for a new LINAC Injector for PEP which is a 10 GeV "high gradient" accelerator to be located in one of the interaction regions of PEP. The project is anticipated to require approximately two years for completion at an estimated cost of about \$100M.

The Laboratory also intends to work towards the phased construction, on Stanford land, of the TLC which is estimated to cost on the order of one billion dollars. The optimum schedule, as mentioned in Section I, would aim for a completed CDR in time for the FY1994 budget cycle.

SLAC also will make a determination within the next two years on the desirability of pursuing research with a new storage ring facility such as an asymmetric *B*-factory or Tau-Charm factory.

C. FACILITIES RESOURCE REQUIREMENTS

The funding (i.e., resources) needed to implement SLAC's plan for future facilities and funds needed to improve existing facilities are included in Table IX-1 "Laboratory Funding Summary". The funding for major construction projects except for the asymmetric B-factory and the Tau-Charm factory are shown on the following page:

TABLE VIII-1 MAJOR CONSTRUCTION PROJECTS

(\$ in Millions - BA)	<u>TEC</u>	<u>FY87</u>	<u>FY88</u>	<u>FY89</u>	<u>FY90</u>	<u>FY91</u>	<u>FY92</u>	<u>FY93</u>	<u>FY94</u>
FUNDED CONSTRUCTION									
SLC	115.4	1.0							
In-House Energy Management	2.2	0.2	0.4	1.3	0.3				
TOTAL Funded Construction		1.2	0.4	1.3	0.3	0.0	0.0	0.0	0.0
BUDGETED CONSTRUCTION									
PCB Transformers	3.6				2.0	1.6			
Central Lab. Expansion	4.1				4.1				
SLC 180 pps Upgrade	14.1				14.1				
TOTAL Budgeted Construction		0.0	0.0	0.0	20.2	1.6	0.0	0.0	0.0
TOTAL FUNDED AND BUDGETED CONSTRUCTION		1.2	0.4	1.3	20.5	1.6	0.0	0.0	0.0
PROPOSED CONSTRUCTION									
New LINAC Injector for PEP	98.0						58.0	40.0	
TLC PE&D	25.0						10.0	15.0	
TLC Construction [1]	1,000.0								150.0

[1] Funding continues beyond FY94

D. DATA PROCESSING AND TELECOMMUNICATIONS REQUIREMENTS

The SLAC central computer facility is based upon an IBM 3081K dyadic processor with 48 megabytes of memory and a system of peripherals with 46 gigabytes of data storage. The basic operating system on the Central Computer system is IBM VM/SP which has been only slightly modified from IBM's versions. To increase the capacity of the processor, the SLAC computer center operates a small farm of emulators and an IBM 3033, all of which are slaved to the 3081K.

When SLC begins operations for physics, an increase in the capacity of the existing computer system will be needed to process the data. SLAC is therefore augmenting the 3081K with the acquisition of a Class V computer which is expected to be installed by March 1989. The Laboratory will be required to further upgrade the Class V computer in FY90 to accommodate the growth of the Mark II and SLD experiments which are expected to saturate the Central Computer Facility.

Current projections indicate that computer analysis of physics data generated by the Mark II experiment will continue to increase and by FY92 an additional Class V computer will be required to manage the higher demand for storage and processing.

SECTION IX RESOURCE PROJECTIONS

The tables in this section provide a summary of the projected resource requirements. In order to further advance the linear collider technology to design a machine in the TeV energy range, substantial increase in R&D funding in the five-year planning horizon will be necessary. Table IX-1 shows the profile of operating funding required to support an aggressive linear collider R&D program with a goal to start TLC construction in FY94.

In the funding tables, escalation factor of 6.2% is used for FY1990 and constant FY1990 dollars are used for FY1991 and beyond.

TABLE IX-1 LABORATORY FUNDING SUMMARY

(\$ in Millions - BA)	<u>FY87</u>	<u>FY88</u>	<u>FY89</u>	<u>FY90</u>	<u>FY91</u>	<u>FY92</u>	<u>FY93</u>	<u>FY94</u>
DOE Effort	89.7	98.9	107.6	129.3	155.3	168.8	186.2	178.0
Work for Others [1]	2.3	2.1	2.7	2.7	2.7	2.7	2.7	2.7
TOTAL Operating	<u>92.0</u>	<u>101.0</u>	<u>110.3</u>	<u>132.0</u>	<u>158.0</u>	<u>171.5</u>	<u>188.9</u>	<u>180.7</u>
Capital Equipment [2]	18.2	20.3	21.8	30.4	23.0	21.0	19.5	19.5
Accelerator Improvements	2.8	3.2	3.4	6.0	6.0	6.0	6.0	6.0
General Plant Projects	1.7	1.8	2.6	6.5	6.5	6.5	6.5	6.5
Line Item Construction	1.0			20.2	1.6			
In-House Energy Management	0.2	0.4	1.3	0.3				
TOTAL Laboratory Funding	<u>115.9</u>	<u>126.7</u>	<u>139.4</u>	<u>195.4</u>	<u>195.1</u>	<u>205.0</u>	<u>220.9</u>	<u>212.7</u>
Proposed Construction [3]						68.0	55.0	150.0
TOTAL Projected Funding	<u>115.9</u>	<u>126.7</u>	<u>139.4</u>	<u>195.4</u>	<u>195.1</u>	<u>273.0</u>	<u>275.9</u>	<u>362.7</u>

[1] The majority of the work under the SLAC Work For Others program is related to the SLC collaborations; the miscellaneous support for experimenters from other institutions; and the Japanese participation, under the US/Japan Agreement in High Energy Physics, in several research programs at SLAC.

[2] Capital Equipment funding does not include SSC detector involvement.

[3] Neither the B-factory nor the Tau-Charm factory is included in the Proposed Construction funding.

TABLE XI-2 LABORATORY PERSONNEL SUMMARY

(Person Years)	<u>FY87</u>	<u>FY88</u>	<u>FY89</u>	<u>FY90</u>	<u>FY91</u>	<u>FY92</u>	<u>FY93</u>	<u>FY94</u>
DIRECT								
Total Operating	1,068	1,050	1,055	1,145	1,330	1,385	1,450	1,495
Capital Equipment	120	120	140	154	160	150	150	150
Construction	50	30	50	77	97	270	370	670
TOTAL Direct	<u>1,238</u>	<u>1,200</u>	<u>1,245</u>	<u>1,376</u>	<u>1,587</u>	<u>1,805</u>	<u>1,970</u>	<u>2,315</u>
INDIRECT	257	270	275	275	322	337	367	354
TOTAL Laboratory Personnel	1,495	1,470	1,520	1,651	1,909	2,142	2,337	2,669

TABLE IX-3 FUNDING BY MAJOR DOE PROGRAM

(\$ in Millions - BA)

	<u>FY87</u>	<u>FY88</u>	<u>FY89</u>	<u>FY90</u>	<u>FY91</u>	<u>FY92</u>	<u>FY93</u>	<u>FY94</u>
DIRECTOR, OFFICE OF ENERGY RESEARCH								
KA HIGH ENERGY PHYSICS								
Operating	88.2	98.1	106.7	127.3	154.6	166.8	183.7	175.5
Capital Equipment [1]	18.1	20.2	21.8	28.4	19.0	19.0	19.0	19.0
Construction [2]	5.4	5.0	6.0	32.7	14.1	80.5	67.5	162.5
Subtotal KA	<u>111.7</u>	<u>123.3</u>	<u>134.5</u>	<u>188.4</u>	<u>187.7</u>	<u>266.3</u>	<u>270.2</u>	<u>357.0</u>
KB NUCLEAR PHYSICS								
Operating	1.5	0.8	0.9	2.0	0.7	2.0	2.5	2.5
Capital Equipment	0.1	0.1		2.0	4.0	2.0	0.5	0.5
Construction								
Subtotal KB	<u>1.6</u>	<u>0.9</u>	<u>0.9</u>	<u>4.0</u>	<u>4.7</u>	<u>4.0</u>	<u>3.0</u>	<u>3.0</u>
TOTAL Energy Research	113.3	124.2	135.4	192.4	192.4	270.3	273.2	360.0
ASSISTANT SECRETARY, MANAGEMENT & ADMINISTRATION								
WB IN-HOUSE ENERGY MANAGEMENT								
Operating	0.1							
Capital Equipment								
Construction	0.2	0.4	1.3	0.3				
Subtotal WB	<u>0.3</u>	<u>0.4</u>	<u>1.3</u>	<u>0.3</u>	<u>0.0</u>	<u>0.0</u>	<u>0.0</u>	<u>0.0</u>
TOTAL Management & Administration	0.3	0.4	1.3	0.3	0.0	0.0	0.0	0.0

[1] Capital Equipment funding does not include SSC detector involvement.

[2] Neither the B-factory nor the Tau-Charm factory is included in the Construction funding.

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