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[HEPAP] [1971-1973], Guidelines for High Energy Physics for the 70's, meeting agenda, minutes, budget

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Privileged

April 30, 1971

PRIVILEGED

Dr. Edward David
Science Advisor to the President
Office of Science and Technology
Washington, D. C.

Dear Ed:

In accordance with your request we are attaching a set of guidelines for high energy physics for the 70's conforming to the funding patterns you specified. We have chosen as a starting point a level of funding for FY'73 that would halt the precipitous loss of personnel from the field and permit utilization of the existing facilities at approximately three-fourths of optimum level.

This report is not the traditional "promises and needs" document prepared by a panel of participants in the field; rather it is an attempt to fit into the budgetary limitations a program which we believe to be most productive. It obviously reflects our personal prejudices. We would have projected a much larger effort if we had been asked to exploit the opportunities of the field with the talent available today.

We hope you will find this material useful.

With personal regards,

Val L. Fitch

Val L. Fitch

Wolfgang K. H. Panofsky

Wolfgang K. H. Panofsky

Victor F. Weisskopf

Victor F. Weisskopf

PRIVILEGED April 30, 1971

GUIDELINES FOR HIGH ENERGY PHYSICS IN THE 70's

INTRODUCTION

As requested, we have prepared and herein present a set of alternative guidelines for high energy physics, its program and its support. "High Energy Physics" is defined as the part of experimental and theoretical elementary particle physics research concerned with phenomena studied at incident particle energies of 1 GeV or higher.

By design, large accelerator laboratories are National Facilities* used by both university teams of user groups and by resident researchers. The number of centers at which accelerators are operating at or near the frontiers of the field is contracting; in contrast the number of high energy physics "user" research teams at university laboratories not having a home accelerator has grown. This report encompasses the support both of the large accelerator laboratories and of the user community.

This report is in four sections. In the first section we develop a set of criteria for maintaining U.S. "leadership" in this most fundamental science, recognizing the economic pressures facing the Nation. The maintenance of truly innovative research and the creation of the most advanced equipment was taken as a necessity to be purchased where necessary at the price of comprehensiveness of facilities and program. The criteria herein will cause those in the field to weigh carefully the priorities in the light of resources available; these guidelines should also induce caution on the part of those who consider budget reductions without realizing that the productivity of high energy physics will vary steeply with the degree of financial support.

In the second section we consider the base figure for FY'73 from which our projections emanate. The drop in support from FY'70 to FY'72 in

*See Appendix B.

the face of new facilities becoming available makes the support provided in the latter year untenable as a base figure. Utilization of existing facilities in FY'72 will have dropped to only 60% of optimum; manpower losses have been drastic and would deteriorate further if FY'72 funding would be used as a reference point. We therefore have analyzed alternative base points for FY'72 (see Base Point Determination for FY'73, Section B) and found that total new obligations below $250 million (1973 dollars) would be so detrimental to the field that we have not included it among the plans analyzed.

In the third section we project the distribution of funds in three alternative funding schemes in the years following FY'73. The analysis starts from a FY'73 funding level of $250 million; this is considered to be a minimum requirement to meet our criteria. As charged, we consider the distribution of funds in the years ahead on the basis of 5% more real buying power available each year, on the basis of constant support over the years, and on the basis of "real dollar" support declining at the rate of 5% per year. We are assuming that these growth rates apply to the annual new obligational authority of the high energy physics program, irrespective of the "color of money," that is, irrespective of whether the funds involved are operating monies or capital funds, or which agency supports the work.

In the fourth section we discuss the consequences to high energy physics which would ensue as constrained by each of the three alternative funding plans. *Common to all of them is the recognition that the total number of high energy accelerators available to the Nation will have to be reduced.* The main differences among the effects of the three plans is for how long work may continue during planning and preparation for the eventual consolidation of facilities and how great an exploitation of capital investment may yet be realized from existing facilities eventually to be shut down.

A summary of the past achievements of elementary particle physics, of its promises and goals in the next decade, of the status of the world's family of high energy accelerators and of the interaction of high energy physics with other sciences and endeavors through its technical and social aspects is appended to this report.

In preparing these long-range guidelines for high energy physics we have recognized that the 1965 Presidential Guidelines for Policy* have been overtaken by actual events. The fact that the actual budget figures deviated so much from the ones in the 1965 Guidelines has caused a bad disequilibrium in the high energy physics program. Past experience has shown that inefficiency will result if there is no systematic planning of the funding *with some degree of commitment* to the established planning budget over at least a period of five years.** We note that the lead time between inception of even a simple experiment in high energy physics and its final publication is usually in excess of three years. Each laboratory finds it difficult to allocate funds for innovation in the absence of reliable funding projections. The guidelines which we propose here are made in the expectation that they can and will be implemented.

It has not been easy to design a viable program for the future health of this vital field of science in the face of the recent decline

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*Congress: Joint Committee on Atomic Energy, High Energy Physics Program: Report on National Policy and Background Information, February, 1965, 89th Congress, 1st Session, Committee Print.

**There are many examples which illustrate the problems generated if long-range planning commitment is lacking. For instance, the construction and development of the ZGS accelerator at Argonne National Laboratory followed the framework of the Presidential Guidelines of 1965. Today it is an investment whose exploitation contributes to the overload on our present budget. The construction of the ancillary 12-ft. bubble chamber at the Argonne Laboratory made sense only if a similar, or bigger chamber would have been built at the Brookhaven National Laboratory, as was anticipated in the 1965 Guidelines. Since actual funding prevented this second chamber from being realized, we are today caught with only one big bubble chamber located at the wrong laboratory. As another example, the "conversion program" at the Brookhaven National Laboratory increased the intensity of its large accelerator, the AGS, and was intended to permit exploitation of that accelerator by a wider community; it is just such fuller exploitation which is not possible with current funds.

in support, which will result in a loss of about 10% of its manpower during the next fiscal year alone. The guidelines proposed herein do not represent a program for high energy physics which lives up to the foreseeable opportunities; rather they constitute what we consider to be the best use of funds available within the constraints presented.

A. CONDITIONS FOR A COMPETITIVE PROGRAM OF HIGH ENERGY PHYSICS FOR THE 70's

In this section we establish policy criteria essential for the future health of high energy physics in the United States. Then we describe basic implementing assumptions for meeting these policy criteria on a minimal basis. Finally, we discuss funding implications of these assumptions.

1. Policy Criteria

We are proceeding from the assumption that high energy physics together with modern astronomy (these being justly viewed as the most fundamental areas in the physical sciences) will remain activities in which the United States will wish to maintain leadership. "Leadership" does not mean preeminence in all conceivable sub-fields of the science, but it does mean that the new, highly important results in the field should continue to originate predominantly in the United States.

High energy physics will remain an expensive undertaking whether it is practiced from a position of world leadership or not, and its financial support will continue to be the responsibility of the U.S. Government. However, the contribution of high energy physics to the vitality of all of American science will be enormously greater if leadership is maintained so that most of the exciting results originate at home. In contrast, Soviet Union high energy physics research has produced very few new and exciting results; still it has been bought at high cost.

The following, then, are general criteria which flow from this basic policy:

(a) Productivity. The over-all long-term funding level should be such that the rate of important discoveries will not substantially decrease. We note that, in the past, high energy physics has yielded results which have profoundly affected man's thinking about the basic nature of the physical world once every 3 to 5 years. (See Appendix A)

(b) Need for Innovation. The scientific facilities at high energy laboratories must be kept modern and at a high technical level and must continually strive for advances in technology. Once new improvements are implemented, they should be adequately exploited. Performance should be upgraded and ancillary installations incorporated whenever it can be scientifically and technically justified. (The preceding remarks apply to all laboratories until a decision for phasing down a particular laboratory has been reached.) For this reason we assume that U.S. technology aimed at new types of particle detection, at new methods of beam handling, and at various new approaches to particle acceleration must remain in a healthy state.

We have assumed that the National Accelerator Laboratory (NAL) now under construction is likely to be the last large national high energy physics installation supported exclusively by the United States. We anticipate, however, that a further very large step in primary accelerator energy will eventually be taken; it probably will be done on an international scale* with the U.S. as a major participant; this is a further reason for maintaining excellence in accelerator technology.

(c) Breadth of Activity. Nationwide university participation in high energy physics research should continue to involve approximately as many "using" universities as at present, even if the number

*The Brookhaven National Laboratory is a highly qualified contender for the location of such an international machine.

of high energy accelerator centers available to them will contract. Creative contributions to the field have in the past originated in "user" universities as well as at the National Laboratories and are expected to continue to do so; it is essential to maintain this diversity of original thought. Moreover, since high energy physics is the critical frontier area of physics and since knowledge in the field undergoes a complete revolution every 5 to 10 years, we consider it essential to creative *teaching* that members of the physics faculties of the major universities maintain an active involvement in the field.

The technical nature of university participation in work at the national centers is becoming more difficult and the incentive to educate large numbers of graduate students in high energy physics, for the time being, is decreasing. These two negative factors tend to shrink the university community of high energy physicists in the coming years. We must counteract this trend by funding adequate to maintain a sufficient and healthy influx of new, young talent.

(d) Centralization of Research. It is inevitable under the imposed budget constraints that eventually the number of large accelerator centers will contract. The decision to close down any accelerator should be made on the basis of decreasing scientific interest relative to higher priority programs and on the basis of a lack of *uniqueness* of the facility.

The term "uniqueness" should be interpreted with care. Although technically there could be an overlap in opportunities between higher and lower energy proton accelerators, in practice higher energy accelerators do not generally provide ancillary facilities for lower energy experiments. At these lower energies, systematic and precise exploitation of processes in strong and weak interactions is best done by runs of high statistical accuracy requiring large amounts of running time.

If a shutdown decision is made, the following conditions must be met:

(i) Shutdown decisions should be made with adequate lead time and with planning to minimize adverse impact.

(ii) Extra capital funds should be provided so that, where possible, important experiments can be accommodated at remaining accelerators (but for which space or specialized facilities such as lower energy beams, spectrometers, etc. may not exist there).

(iii) If a decision is made to close an accelerator, then 3 to 4 years of subsequent operation of that accelerator should be supported at reduced funding. During this time long runs requiring a minimum of beam changes can be contemplated to obtain data with high statistical significance; operation can be continued very effectively without significant capital improvements, making use of the investments of the past.*

(iv) Shutdown of an accelerator does not necessarily imply closing of the laboratory in question.

(e) Distribution of Facilities. Some reasonable regional balance of facilities should be maintained. Although in an enterprise as expensive as high energy physics one would like to think of each major accelerator as being a truly national facility, as a practical matter, concentration of users from the universities tends to have a regional bias.

*We note that had the Princeton-Pennsylvania Accelerator, now slated for closing, been permitted to continue operating for two more years or so, the Country's return in terms of research results from its approximately $50 million capital investment in that facility would have been greatly increased.

(f) Manpower. The total manpower in high energy physics has been decreasing drastically during the past three years as a result of budget reductions. Since 1969, the number of people working in high energy physics has dropped more than 20%, even with the new establishment and development of NAL. In FY'72 *alone* the total headcount of people working in high energy physics in the AEC's laboratories and in the university user groups will decrease by about 730 people, which is 10% of the *present* total. This type of decrease can not continue without irreparable damage to the science. *Opportunities for young people to enter the field must be maintained.*

2. Implementing Assumptions.

In consonance with the general policy criteria enumerated above, we list several specific assumptions basic to all the alternative funding schemes described in the next section.

(a) Utilizing Existing Facilities. The Country's investment in its accelerator facilities must be well exploited. Therefore:

(i) Operating accelerators should be supported at a level to permit exploitation at a rate of *at least* 75% of that optimally possible. We note that all accelerator laboratories have large "hard core" costs so that the scientific output increases at a much greater rate than the corresponding increase in support.

(ii) The facilities should continue to be modernized and ancillary facilities kept on the highest technical level until a decision for phasing down has been reached.

(iii) NAL should carry out a productive research program up to the very highest energies technically feasible.

(b) Upgrading of Existing Facilities.

(i) Funding should be provided to upgrade the Brookhaven National Laboratory into a superconducting Alternating Gradient Synchrotron yielding a beam energy approaching 100 GeV, or, alternately, for a proton storage ring facility.

(ii) Funding should be provided to permit SLAC to be upgraded in energy and duty cycle via a combined program of increased klystron power and beam recirculation. Expansion of the electron storage ring program should be encouraged if, in time, results so warrant.

(iii) Funding should be provided for NAL (1) to amplify its ancillary facilities, beams and large detecting systems such as bubble chambers, and (2) either to add an intersecting storage ring or to exploit possibilities for upgrading the energy of the accelerator itself.

(iv) Funding should be provided to expand the target areas of the Cornell electron accelerator and upgrade its energy.

(v) *At this time* we see no compelling reason to include funds for construction of a complete superconducting conversion for SLAC nor for construction of an accelerator based on the "electron ring accelerator" (ERA) principle being explored by LRL. Feasibility of neither technique applied to an accelerator in the 100 GeV region is clear to date; if the promise increases, the program might be modified.

(c) Closing of Existing Facilities. *Under the imposed budgetary restraints,* some smaller accelerators will have to be shut down.

(i) CEA. It is assumed that the Cambridge Electron Accelerator will continue as a colliding beam facilities only and will not resume a general electron-photon physics

program. It will continue operation until other electron-positron colliding beam facilities have become available, which, by virtue of superior intensity and energy, would make the CEA program obsolete.

(ii) ZGS and the Bevatron. Candidates for shutdown during this decade are the Bevatron accelerator at the Lawrence Radiation Laboratory and the ZGS accelerator at Argonne National Laboratory. Both of these machines operate in a range of proton energy below that of the AGS at Brookhaven, and, of course, NAL. However, both LRL and ANL are engaged in well established, scientifically productive, long-range programs supporting a substantial part of the user community; cutting them off on a short-term basis without advance planning would be enormously damaging and wasteful.

(iii) The LRL Bevatron. The Lawrence Radiation Laboratory has maintained a tradition of leadership in high energy physics since pre-war times; it is part of the educational and academic activities of the University of California in addition to supporting large user programs. Even if the Bevatron were to cease operations, the high energy physics research program at LRL should continue to maintain its educational involvement in a user program at NAL, SLAC, and BNL and as a source of advanced accelerator and particle detector technology. Should it be decided to terminate its operation, the Bevatron should be run at reduced cost for several years, supporting a smaller number of experiments each of which requires very large amounts of high intensity running time.

Should the current ERA technology prove promising in the future a new evaluation, in view of this development, should be made.

(iv) The ZGS. The ZGS accelerator at Argonne National Laboratory presents a picture of much recent investment: Several improvement programs with the ZGS have been initiated but have not as yet been used for high energy physics. For instance, the largest operating bubble chamber in the world is at ANL but has yet to enter into regular use for physics. A new vacuum chamber for the ZGS, made of titanium, has been procured but has not yet been installed. The 2 GeV Cornell Synchrotron has been transferred to the ZGS to operate as a booster ring to increase the intensity of the machine but has not yet been put into operation. The ZGS has an extensive complex of secondary beams to support a multitude of users.

The ZGS accelerator itself has had a troublesome history. Its design energy of 12 GeV was set to "beat" the Russians' 10 GeV accelerator at Dubna; yet the Brookhaven AGS reached 30 GeV before the Argonne ZGS came into operation. The ZGS reached its design intensity only after protracted delays. Currently the main coil of the accelerator has failed and is under repair. However, with this latter exception the recent operating history and productivity have been excellent.

Once a decision has been made to terminate operation of the ZGS the same argument given in relation to the Bevatron applies here also, i.e., operation at reduced cost for protracted high intensity running will be useful. However, unlike LRL, we are not proposing that a high energy program be maintained at ANL after the ZGS has ceased operations.

Needless to say, these detailed assumptions may have to be modified in the light of changing scientific developments. For instance, the decisions on proton storage rings at NAL or BNL (see 2b (i) and (iii)) should depend on the success of the ISR at CERN as well as the over-all programs of these laboratories. Moreover, decisions concerning the lower energy proton accelerators can clearly not be made until NAL operation is firmly established.

3. Funding Implications of the Planning Assumptions

(a) The general operating level of the operating accelerators must be increased to permit more adequate exploitation. Specifically, Brookhaven's operating funds must be increased substantially to permit utilization of the AGS conversion program now being completed. Operating funds for SLAC's storage rings are to be provided. NAL operating funds must expand rapidly during the next three years.

(b) Equipment obligations for the operating laboratories should be increased considerably. Substantial add-on funds will be required to permit adequate exploitation of NAL; funds for NAL equipment have been low relative to those at other accelerators in the early stages of development.

We note that major laboratories require about $1 million per year of equipment funding as part of the ongoing experimental program without constructing any new facilities; this circumstance is a consequence of the fiscal rules of the agencies. Equipment funding, therefore, has a "hard core" not related to an increase in experimental opportunities.

(c) LRL's Bevatron and Argonne's ZGS will be curtailed in operation at a time controlled by the specified budget level and will continue to operate in such a mode for about 3 years thereafter. LRL will continue in the foreseeable future as a strong center of educationally related high energy physics user research and of accelerator technology. Funding provided for that purpose corresponds to a moderate increase over the present "high energy research" costs of LRL (as distinct from the present cost of accelerator and facilities operations).

(d) Direct support of accelerator "users" at the universities should scale with the support of the laboratories. Support of the programs of "user" groups involves both the direct funding at the universities as well as technical support through the National Facilities; the latter is considerably larger than the former in terms of actual cost.

(e) Accelerator improvement funds should be more than doubled* relative to the current level since those funds support activities which by their nature are classified as "construction" which are essential to modernize the facilities.

(f) The emphasis on innovation in the policy criteria implies that a substantial fraction (near 20%) of the total high energy physics budget should be in the form of new construction obligations. We note that from FY'60 through FY'70 25.8% of the entire high energy physics budget was dedicated to construction.

B. BASE POINT DETERMINATION FOR FY'73

In drawing up projections in accordance with the above principles, we discovered soon the impossibility of doing so consistently with our assumptions if we were to start in FY'73 with the amount allocated to high energy physics in FY'72, escalated by 6% (which we assumed to be the inflationary increase between the two fiscal years). Figure 1 shows the transition in various sub-categories from the escalated FY'72 level to FY'73 levels of constant funding, $250 million and $280 million, respectively.

1. Utilization

The degree of "utilization" or "exploitation" of high energy physics installations has recently been extensively reviewed. These are difficult terms to define with precision in a field of endeavor whose output - basic research - is impossible to measure quantitatively. What *is* easy to measure is the fraction of the available time over which budgetary restraints permit

*Accelerator Improvement Funds were cut nearly in half in FY'72.

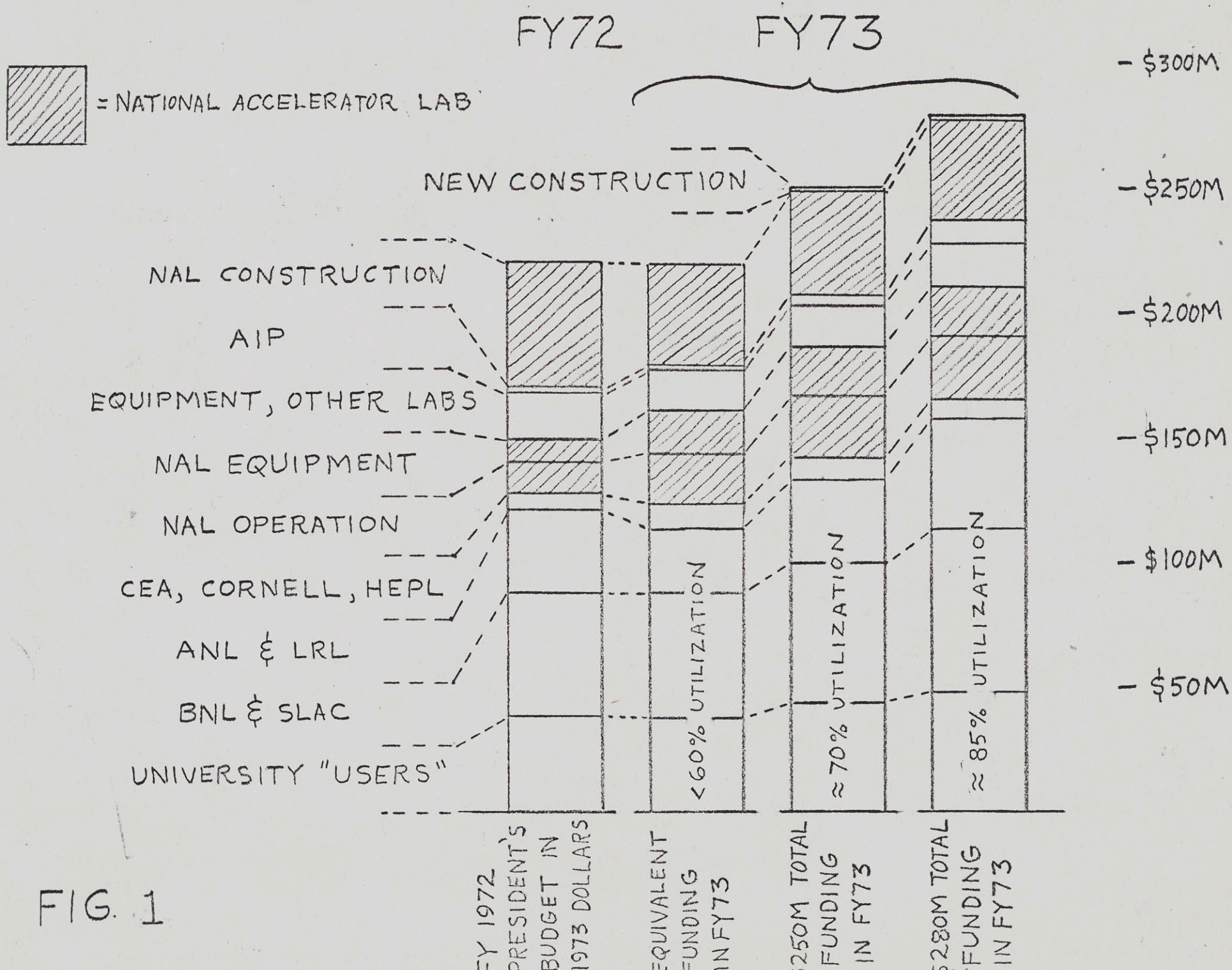

FY72
FY73
= NATIONAL ACCELERATOR LAB
NEW CONSTRUCTION
NAL CONSTRUCTION
AIP
EQUIPMENT, OTHER LABS
NAL EQUIPMENT
NAL OPERATION
CEA, CORNELL, HEPL
ANL & LRL
BNL & SLAC
UNIVERSITY "USERS"
$300M
$250M
$200M
$150M
$100M
$50M
FY 1972 PRESIDENT'S BUDGET IN 1973 DOLLARS
EQUIVALENT FUNDING IN FY73
<60% UTILIZATION
$250M TOTAL FUNDING IN FY73
≈70% UTILIZATION
$280M TOTAL FUNDING IN FY73
≈85% UTILIZATION

FIG. 1

the *accelerator* to be used for research, and how costs would vary with different degrees of machine "on-time". Each laboratory attempts to maximize research output by dividing its available operating funds among (1) accelerator operation and maintenance, (2) the "care and feeding" of ancillary facilities, (3) the direct support of the research itself and, finally, (4) development of new accelerators and new particle detection technology. How to make this division in an optimal way takes a great deal of judgment, but if we assume that laboratory management does a good job, then research output and accelerator operation time will generally be proportional to one another. In this report we therefore identify the "percent utilization" of the Nation's high energy laboratories with the percent of the total time the accelerators are scheduled to be "on the air" relative to the maximum operating time possible in the face of necessary maintenance shut-down. Identifying "utilization" with accelerator use also implies that the government agencies are matching their direct support between University "users" and the laboratories in an optimal way. The following general facts emerge from the "utilization" studies:

(a) If the FY'73 budget corresponds to the President's Budget for FY'72 except for the price-escalation adjustment, the average utilization of the Nation's remaining high energy physics facilities even after the PPA shutdown is less than 60%.

(b) The degree of exploitation of the facilities varies roughly twice as fast as that of the funding supporting them.

2. Manpower in High Energy Physics

Figure 2 shows the decline of total manpower in the Nation's high energy physics program from FY'67 through FY'72; total personnel loss will have been 20% in the last three of these years. The total number of Ph.D's employed in the field has dropped by 80 during the last two years despite substantial production of new Ph.D's.

If funding in FY'73 were held to (escalated) FY'72 levels, this drastic decline would *not* be halted, let alone reversed. The reason is that all operating laboratories have attempted, during the last years of declining real budgets, to protect their personnel as much as possible by cutting procurements of materials and outside services disproportionately; also special plans involving shortened work weeks, deferred salary adjustments, enforced vacations, etc. have been instituted as stop-gaps. Hiring of new, young talent into continuing positions has all but stopped. All such measures decrease efficiency and cannot be sustained as regular operating procedures.

In Figure 2 we are making predictions for high energy physics manpower under two alternative funding assumptions for FY'73; a level continuing the FY'72 level (escalated by 6% to $221 million), line A in Figure 2, and a total level of $250 million in all budget categories, line B in Figure 2. The corresponding manpower levels were arrived at by surveying the manpower estimates for FY'73 of three major laboratories (SLAC, LRL and BNL) corresponding to their budget requests for that year. The manpower extensions beyond FY'73, (lines 1, 2 and 3) were based on evaluations of earlier manpower changes with support, assuming that the variation of manpower with budget level would scale the same way for the balance of the period under study. We conclude that a total level of $250 million will *barely reverse the decreasing manpower trend.*

3. National Accelerator Laboratory

In addition to the utilization and manpower situations we have to face the costs associated with the National Accelerator Laboratory which is expected to generate its first beam this year. Operating costs at NAL will have to increase and at the same time efficient utilization of NAL is impossible unless a substantial increase in equipment funding (an estimated increase of $12 million) is made available to NAL for FY'73.

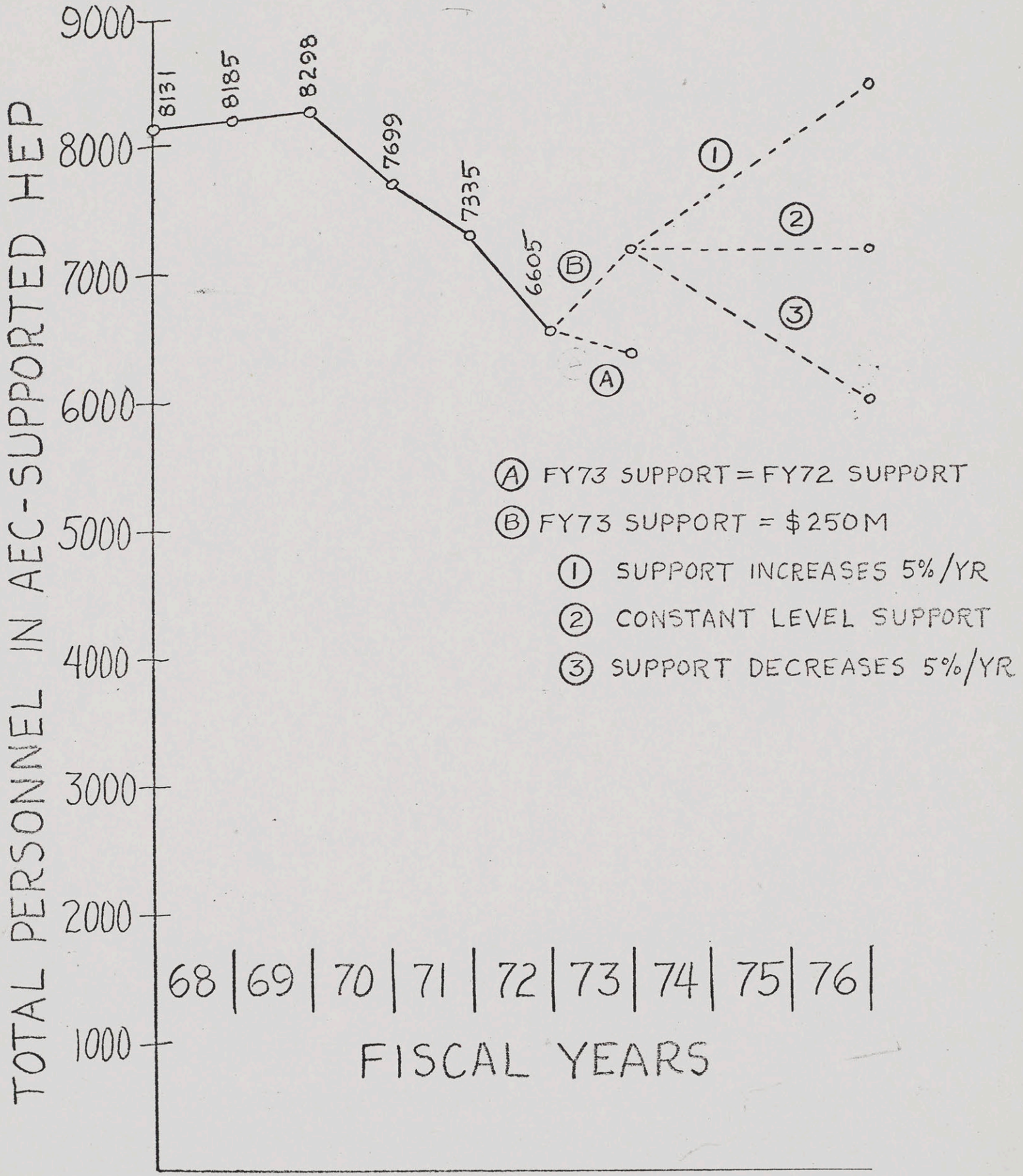

TOTAL PERSONNEL IN AEC-SUPPORTED HEP
9000
8000
7000
6000
5000
4000
3000
2000
1000
8131
8185
8298
7699
7335
6605
B
A
1
2
3
68
69
70
71
72
73
74
75
76
FISCAL YEARS
A FY73 SUPPORT = FY72 SUPPORT
B FY73 SUPPORT = $250M
1 SUPPORT INCREASES 5%/YR
2 CONSTANT LEVEL SUPPORT
3 SUPPORT DECREASES 5%/YR

FIG. 2

At this time we assume that the new obligational authority for FY'73 for NAL construction will be held to $42.0 million (which is the expected cost during that year) rather than the $51 million which is the balance of the not-yet-obligated amount for the total project.

4. Discussion

In view of all these circumstances, an increase of well over $30 million above the value corresponding to the *escalated* FY'72 funding level for high energy physics would be required for FY'73 to approach the 75% utilization guideline. Because of the steepness of the utilization vs. funding curves, lower utilization would be a very poor use of the country's resources. If, therefore, a FY'73 starting point roughly corresponding to FY'72 funding were adopted, the decline of manpower would continue and the difficult choice would have to be made either to use the *existing and the new facilities very inefficiently* or to decide on an *immediate shutdown* of one or two additional accelerators. Such precipitous actions seem exceedingly unwise. Both the Bevatron and the ZGS accelerators currently support productive and important experiments: Many improvements and innovations were introduced lately. An *immediate* cutback in the operations of either of these accelerators would waste large investments and would be a severe blow to the health of the entire field. We do not consider such an action as a responsible choice.

We therefore have based our three projections on new obligations of $250 million for FY'73 covering all budget categories for the entire high energy physics program, and it is these curves which we are including with this report. This $250 million figure is *still below* the computed figure corresponding to 75% utilization. (Analysis gives 70%.)

We have also analyzed the situation starting with a base of $280 million (see Figure 1). Using the same kind of analysis we find

APPENDIX A

PAST ACHIEVEMENTS OF HIGH ENERGY PHYSICS RESEARCH AND GOALS FOR THE NEXT DECADE

1. HIGHLIGHTS OF HIGH ENERGY PHYSICS RESEARCH

High energy physics aims to explore the nature of the physical universe to the smallest possible dimensions. Man's knowledge about our world is bounded on both the infinitesimal and the cosmic ends of the scale. Research in both areas continues to provide new insights and understanding of man's physical environment. Regularly, as both knowledge and techniques advance, discoveries greatly change man's view of his world.

The following table lists the most startling and profound observations and discoveries of high energy physicists over the past 25 years.

DATE	DISCOVERY	EXPLORATION
1947	Lamb shift: "g-2" of the electron	Limits of quantum electro-dynamics*
1947	Properties of the Pion*	Pion-nucleon interactions
1952	Bubble Chamber* for investigation of strange particles*	Interactions of strange particles
1954	Composite nature of the nucleon*	Electron scattering and nucleon spectroscopy
1955	Anti-proton*	Matter/Anti-matter symmetry
1956	Violation of parity conservation*	Weak interactions
1961	Hadron symetries (SU^3)* and discovery of omega-minus (1964)	Whole hadron spectroscopy
1962	A second neutrino	Search for new leptons
1964	Violation of CP conservation	Search for T violation
1968	Point structure within hadrons	Deep inelastic scattering and e^-e^+ storage rings

*Work leading to Nobel Prizes.

A brief outline of the significance of each of these discoveries follows:

The development of the theory of quantum electrodynamics in 1946 opened a whole new all-inclusive way of understanding electromagnetic interactions. It predicted with uncanny accuracy the "Lamb shift" in atomic structure and provided an extremely precise quantification of the magnetic moment ("g-2") of the electron.

The pion (pi-meson) had been predicted in the late 1930's to be the "glue" holding the neutrons and protons together in the atomic nucleus. The discovery of the pion in 1947 led to hopes that the new and strange "strong force" (or "nuclear force") would soon be understood; the properties of the new particles were rapidly explored.

Strange particles had indeed been observed in nature but just in the form of unaccounted-for particles discovered in cosmic rays.

In the constant shower of cosmic rays, physicists had earlier discovered the existence of unknown and bewildering "strange" elementary particles. It was not until 1953 and the advent of the new generation of accelerators, with energies high enough to produce the new particles under controlled laboratory conditions, that the full extent of the "strangeness" of these particles was realized. The strange particles were found to be produced copiously using high energy beams of the new accelerators, yet their decays were of a weak nature. Since both production and decay seemed to involve similar particles, it was puzzling why they took place with such drastically different strengths. What was eventually discovered was the existence of a new conserved quantity in nature. This new quantum number, "strangeness", went far to explain the peculiar interactions of the strange particles in the 1950's. However, the full and rather deep implications of the strangeness quantum number were yet to come 10 years later with the discovery of SU(3) symmetry.

The new accelerators also probed smaller distances than had been explored before. In probing the proton by various scattering experiments, physicists found that the suspected point-like nature of the proton was not there;

instead, the proton was an extended structure with a definite size. This result was first obtained by electron scattering experiments. In addition excited levels of the proton, or proton resonances, were found, further implying a compound structure.

When the Bevatron at the University of California became operational in 1954, an opportunity to test the concept of anti-matter symmetry was presented. The positron (anti-electron) had been discovered in cosmic rays in the late 1930's, opening the possibility of the existence of a complete anti-matter world, symmetric to the known particle spectrum. With the higher energy available at the Bevatron, one could hope to produce the first strongly interacting Fermian anti-particles seen in nature, anti-protons. Indeed, anti-protons were so produced, and as time has progressed most other elementary anti-particles have been found.

In 1964 at the AGS, the anti-deuteron was produced, strongly indicating the possibility of complete anti-particle symmetry through the elements.

In the mid-1950's the bubble chamber was invented, a device which proved to be invaluable in examining in detail the production and decays of what then amounted to 30 elementary particles. One such bubble chamber built in 1956 is still operating in the SLAC beam today. The bubble chamber was instrumental in precipitating, through measurements of unprecedented precision, perhaps the most profound discovery of the decade of the 50's, parity violation.

In 1956 it was shown that parity, i.e., right-left symmetry, was violated in the weak interactions. This discovery was truly momentous since physics from its inception had always assumed that nature could not distinguish right-handed and left-handed systems. The incorporation of this astounding fact into the framework of the weak interactions led to the inclusion of the neutrino and muon in the fundamental equations of particle physics in a beautifully symmetric fashion. These equations were then suggestive of more general forms ultimately leading to the inclusion of the weak interactions as essential reflections of the basic structure of matter in symmetry schemes of recent times.

In 1962 an elaborate experiment proved that contrary to the previous picture there was not just one neutrino in the world but indeed there were two - adding to the list of leptons (electrons, muons, etc.) in the list of elementary particles. This has led to extensive experimental searching for yet further leptons - the question of the role of a multiplicity of leptons in nature remains one of the great open problems in physics.

In 1964, approximately eight years after the discovery of parity violation, another fundamental symmetry principle was found to be violated: Time reversal invariance (or "CP conservation"). The forces driving processes in the forward and backward direction in time were determined not to be necessarily equal: An extremely weak violation was found, the full implication of which has yet to be resolved. Physicists have gained a great deal of insight through the investigation of such basic symmetry principles, and will continue to test established laws to the limits of obtainable precision.

As high energy physics entered the 1960's, the particle explosion really began. New bubble chamber and counter techniques, and the invention of spark chambers, permitted much more extensive and precise experiments to be performed. It seemed that each new experiment discovered at least one new "particle".

By 1965 over a hundred such entities were claimed to exist; a new nuclear physics had evolved. After considerable theoretical effort in the late 1950's and early 1960's, it was found in 1961 that a strong pattern was evident in the mass spectrum of these "particles". This pattern took mathematical expression through group theoretical approaches. In particular, the group (or symmetry) SU(3) had profound predictive power in describing not only the particle spectrum, but particle interactions as well. One great success of SU(3) was the prediction of one "omega-minus" meson, the first strangeness-3 object. This prediction was spectacularly verified in 1964. One of the important insights gained in the last decade was the recognition that those hundreds of "particles" are, in fact, short-lived excited states or resonances of the proton or of the meson. The great variety of particles was recognized as being a series of different manifestations of only two entities which must be endowed with some kind of internal structure so as to be able to appear in different excited states.

Another dramatic implication of SU(3) was the idea of "quarks" - new ultra-basic elementary particles. The idea was that all known particles with strong interaction are composite objects, the constituents being quarks. It represents a primitive example of an internal structure in nucleons or mesons. With the quark concept, many particle properties were explained in a surprisingly simple way. However "quarks" have thus far eluded all efforts to determine whether they exist as independent entities.

New experiments at SLAC involving the scattering of electrons from protons at energies higher than ever before appear to have uncovered another inner layer of matter. The additional available energy (and intensity) have yielded new results implying the existence of elementary point-like constituents in the proton; these may or may not be the quarks predicted from the SU(3) particle spectra. Experiments done with storage ring facilities in Europe have obtained similar results.

This brief historical outline amply documents that the rate of truly profound discoveries in elementary particle physics has by no means decreased -- the field is still wide open. However, the total impact of these fundamental revelations on our thinking and understanding of the natural world cannot be evaluated until a more comprehensive synthesis of theoretical ideas emerges.

2. GOALS OF HIGH ENERGY PHYSICS RESEARCH FOR THE NEXT DECADE

If high energy physics is pursued as projected in this report, one may reasonably expect that new discoveries will continue at a rate comparable to the past. The NAL facility and the CERN intersecting storage rings will provide opportunities to study phenomena in the energy range of several hundred to a thousand GeV. Increased electron energies and in particular the availability of powerful electron-positron storage rings will open up new insights into the subnuclear phenomena from an entirely different aspect. The improved facilities and detection devices at lower energies will allow much more penetrating studies than before in the energy range from a few to 30 GeV.

Obviously, it is impossible to predict what these discoveries will be, but one may try to define the general direction of further progress in high energy research as it appears to develop today. It should be noted, however, that predictions made in the past of goals and results in high energy physics always have turned out to be much too conservative when the energy range was extended by a factor of ten. Each time, Nature turned out to be by far richer than anticipated.

A goal which might be reached in the next decade would be to obtain full or partial answers to the following questions:

(a) At even higher excited states of hadrons (protons and mesons) will the regularities observed at present energies continue?

(b) Will the character of the reactions between colliding hadrons at higher energies remain similar to the one observed so far, or will it show some unexpected new features?

(c) Will there be any new evidence elucidating the internal structure of hadrons?

(d) Is there a "field" which carries weak interactions, analogous to the electromagnetic field carrying electric interactions?

(e) How are the sources of weak interactions distributed within a hadron?

(f) What is the behavior of weak interactions at higher energies?

(g) Is there any deeper reason for the recently discovered CP-violation in weak interactions?

(h) Will the electron exhibit effects coming from its finite size or its internal structure?

(i) Is there a way to understand the reason for the existence of the heavy electron (i.e. the muon), and is there more than one type of heavy electron?

(j) Why do charged particles, hadrons or electrons, always have charges which are integer multiples of the electronic charge?

(k) Can we understand the forces which bind the neutrons and protons in the nucleus in terms of the particles and interactions of high energy physics?

(l) Is there any deeper connection between, or a common origin of, the four fundamental interactions -- strong, electromagnetic, weak and gravitational?

The first question (a) refers to some puzzling regularities found in the properties of excited states, the most important being an approximate proportionality between the angular momentum and the square of their mass (the so-called Regge-behavior). So far, no generally accepted explanation is known. A better knowledge of the high-energy resonances certainly would help to get more insight into the internal structure of the fundamental constituents of matter. Such knowledge would also be most relevent to the study of the early history of the Universe, when matter was under conditions in which these excited states must have played an essential role.

The second question (b) refers to the effects of collisions between particles at high energies. Some, but not all, of these reactions seem to reach "asymptotic" character at presently available energies; that is, they do not seem to change much when the energy of collision surpasses a certain critical value. Is this asymptotic character true or only apparent at lower energies? Are we allowed to extrapolate from our present knowledge to higher energies or will we observe some vary different effects? It may be that the inner layer of matter indicated by the SIAC experiments will manifest itself by some new phenomena appearing at higher energies.

This leads us to question (c) which concerns one of the central goals of this field, namely, to get some evidence on the substructure of the proton or the meson. Further high energy studies with the new accelerators will, no doubt, shed new light upon the nature of the mysterious quarks as subunits of hadrons. Are they real particles? Can they be separated from hadrons? Do they really carry those fractional charges which present evidence ascribes to them, namely, 2/3 or 1/3 of an electronic charge?

The questions (d) through (g) refer to the nature of the weak interaction. This interaction is responsible for certain types of radioactivity, namely, the emission of electrons and neutrinos by nuclear particles. The weak

interactions are still a great puzzle. The laws governing their behavior at presently available energies are well-known and seemingly simple, but they exhibit a number of very strange properties and phenomena. One is the existence of the neutrino, the mysterious, massless and chargeless particle which interacts with matter only by weak interactions. Another is the violation of symmetry between right and left, and a recently discovered tiny violation of symmetry between particle and antiparticle (CP-violation). Neutrinos are among the decay products of mesons, and this fact has been used to produce pure high-energy neutrino beams at proton accelerators, producing meson beams which subsequently decay into neutrinos. Such neutrino beams are research tools of unique value for the study of weak interactions. The projected neutrino beam at NAL will be used to investigate the behavior of weak interactions at very high energies. Question (d) refers to a possible detection of a weak interaction field by finding the quantum of this field (in analogy to the light quantum in electromagnetic interactions). This quantum is usually referred to as the hypothetical "intermediate boson". Many reasons point to the expectation that, if it exists, this quantum would be produced by the newly-available energies.

Question (e) points to another problem which may be solved soon: It is the question of the distribution of weak interaction sources within the hadrons, and it will be answered by experiments with high energy neutrino beams planned at NAL. It will be interesting to see whether these sources are also seemingly pointlike and identifiable with the apparent quarks observed in other experiments. The Question (f) refers to the behavior of weak interactions at very high energies. Will they stay weak? Will they become stronger and more similar to other interactions? Will we find any clue as to the deeper reason for the violation of the CP-symmetry? Will this violation be enhanced at higher energies, will it appear in different phenomena?

Questions (h), (i) and (j) deal with the nature of electricity. The laws governing the interaction of electrons with the electromagnetic field are very well-known and their theory seems to be in good shape. This theory is based upon the assumption of a point-like electron without any spatial extension. So far, no limit to the validity of this theory has been found.

Will experiments with higher energy find some deviations? Will these deviations point to some finite dimensions or to some internal structure of the electron? Today, the only evidence for something peculiar with the electron structure is the existence of the heavy electron (muon, misnamed mu-meson). So far, no difference with the ordinary electron except the mass has been found. The higher energy beams may discover finer features in which it differs from the ordinary electron, and which may give us a clue to the reason of its existence. Another question poses itself here: Are there still heavier varieties of the electron? Present experience cannot exclude them; the improved beams and detection devices may find these still heavier electrons or prove their absence. There may be an unending series of electrons of different masses as there are hadrons; this possibility has not yet been confirmed nor excluded. Is there a different neutrino connected with each variety of electrons as there is with the presently known varieties? It is possible that a new world of phenomena may appear "within" the electron, parallel to what we have found within the proton.

Question (j) refers to the puzzling fact that all particles so far known and directly observed carry electric charges which are exact integer multiples of a very definite charge, the electronic charge unit, even if they are so fundamentally different as the electron and the proton. (The hypothetical quarks with possibly fractional charges have not been directly observed.) We have no idea why this is so, and why the electron-charge is as big as it is. The famous numerical relation $e^2/\hbar c = 1/137$ ($\hbar$ = Plancks constant, c= light velocity) has not yet been explained, neither the numerical value of the ratio of the proton mass M to the electron mass m: $M/m = 1830$. Certainly the large mass of the proton is connected with the fact that the proton is a source of strong interaction, the electron is not. The explanation of this mass ratio is one of the major aims of particle physics. It should be pointed out that the large value of this ratio is a basic condition for the existence of a well-defined chemical structure in molecules. If atomic nuclei would not be more than a thousand times heavier than electrons, their position within the molecule would not be well localized. Let it be remembered that the existence of life is predicated upon the structural properties of macromolecules.

In nuclear physics we have learned to use the force which holds the protons and neutrons together in the nucleus - yet we know only little about the nature of this force. Question (k) asks for a better exploration: A theory of nuclear forces based on the pion only as "carrier" of this force has not been too satisfactory; will the other particles of high energy physics and their behavior aid our understanding?

Finally, we face question (l) concerning the relations between the four types of interaction. The existence, side-by-side, of the weak, electromagnetic and strong interactions, along with gravity, must be regarded as a preliminary view of nature. Some connections, in particular between weak and electromagnetic interactions, are expected to show up when we penetrate deeper into the structure of the particles by subjecting them to hitherto unattained energies.

The above list of goals in high energy research is certainly incomplete and by necessity inaccurate. It is a conservative extrapolation from today's knowledge. From past experience we have good reasons to expect that any conservative prediction and extrapolation of research results in high energy physics will be wrong when the energy range is extended by a large amount. Human imagination always lags far behind reality. We therefore should anticipate that completely new and unexpected natural phenomena will be discovered during the coming decade, in view of which the perspectives presented here will look naive and unimaginative. High energy physics is an experimental science. The behavior of matter is explored under completely novel conditions. The field has all the excitements of new discoveries in a virgin land. It will take much time and effort before we can produce a rational map of this new land; it will be the hoped-for fundamental insights into the basic structure of matter.

APPENDIX B

THE STATUS OF HIGH-ENERGY ACCELERATORS

1. U. S. FACILITIES

The National facilities in the United States at which large accelerators are operating at or near the frontiers of the field are:

- NAL: The National Accelerator Laboratory under construction at Batavia, Illinois, with its 200-GeV proton accelerator.
- BNL: Brookhaven National Laboratory at Long Island, New York, with its 33-GeV proton accelerator, the AGS.
- SLAC: The Stanford Linear Accelerator Center at Stanford University, California, with its 22-GeV electron accelerator.
- ANL: Argonne National Laboratory outside Chicago, Illinois, with its 13-GeV proton accelerator, the ZGS.
- LRL: The Lawrence Radiation Laboratory at the University of California, Berkeley, California, with its 6-GeV proton accelerator, the BEVATRON.

The Princeton-Pennsylvania Accelerator, PPA, at Princeton University is being shut down. The Cambridge Electron Accelerator, CEA, in Massachusetts is being converted to an innovative storage ring facility. The 10-GeV electron accelerator at Cornell is operated as a University accelerator with limited outside use. The High Energy Physics Laboratory (HEPL) at Stanford is discontinuing use of its linear electron accelerator for physics research and is initiating construction of a machine using superconducting microwave technology.

2. THE ACCELERATORS OF THE WORLD

The attached chart lists the large accelerators and storage rings throughout the world that are now operating, are being constructed, or are authorized for construction. For the sake of comparison, these high-energy physics facilities are grouped into the three geographical regions shown, and are also grouped by types of machine. The chart lists only those accelerators having a primary beam energy greater than 3 GeV. Although this energy cut-off point is arbitrary, the omission of the smaller accelerators does not significantly alter the generally balanced distribution of accelerators that is shown among the U.S., Western Europe, and the USSR.

It should be noted, however, that this balanced geographical distribution does not accurately reflect the research productivity of the three regions. In the case of the USSR, the research programs at the Russian laboratories have characteristically lagged behind those of the U.S. and of Western Europe. This is partly attributable to the lack of sophisticated technological support (such as inferior computer hardware and software), and perhaps also to more subtle factors: there tends to be excessive separation between experimentalists and theorists; Soviet accelerators have lagged in particle intensity; at times the work has been excessively programmatic rather than innovative.

There are strong indications that the USSR is correcting some of these difficulties in the operation of its 76-GeV accelerator at Serpukhov (currently the highest energy operating accelerator in the world). Scientists from Western Europe and from the U.S. have joined Russian physicists in a number of collaborative experiments, and several noteworthy results have already been attained from this work. On the whole, however, it remains true that, while the lead in accelerator energy has been seesawing between East and West, the USSR has been responsible for a surprisingly small amount of the fundamental experimental results that have so transformed the field during the past 20 years. On the other hand, the Soviets have contributed notably to the accelerator art: New principles of acceleration have been discovered in the USSR, and storage ring technology has been advanced substantially at Novosibirsk.

LARGE ACCERATORS & STORAGE RINGS

OPERATING [IN CONSTRUCTION] (AUTHORIZED)

	U.S.	WESTERN EUROPE	USSR
PROTON ACCELERATORS	[NAL - 200+GeV] BROOKHAVEN - 33 GeV ARGONNE - 13 GeV BERKELEY - 6 GeV	(CERN - 300 GeV) CERN - 28 GeV NIMROD, U.K. - 7 GeV	SERPUKHOV - 76 GeV DUBNA - 10 GeV MOSCOW - 6 GeV
ELECTRON ACCELERATORS	SLAC - 22 GeV CAMBRIDGE - 6 GeV CORNELL - 10 GeV	DESY - 7 GeV DARESBURY - 4 GeV	YEREVAN - 6 GeV
PROTON STORAGE RINGS		CERN - 28 GeV	[NOVOSIBIRSK - 24 GeV]
ELECTRON STORAGE RINGS	[CAMBRIDGE - 3.5 GeV] [SLAC - 2.5 GeV]	ORSAY - 0.55 GeV FRASCATI - 1.5 GeV (ORSAY - 1.5 GeV) [DESY - 3.5 GeV]	NOVOSIBIRSK - 0.75 GeV [NOVOSIBIRSK - 0.75 GeV] [KHARKOV - 2.5 GeV] [NOVOSIBIRSK - 3.5 GeV] (NOVOSIBIRSK - 8 GeV)

In contrast, the research productivity of Western Europe has been very high - experimental results from the CERN 28 GeV proton accelerator have been competitive with work originating from the Brookhaven 33 GeV machine, and the DESY electron synchrotron in Hamburg has easily out-produced its counterpart in Cambridge, USA. In one critical area of research - the important studies that can be carried out only with colliding beam storage rings - the Western European effort is already well ahead of that of the United States both in electron and proton storage rings.

This situation is indicated on the lower half of the attached chart, where the striking disparity between the U.S. and the rest of the world in storage ring activities is clearly illustrated. Western Europe has just started operation of a proton colliding beam facility with 25 GeV in both beams, which represents an important unique facility for the whole world. A similar facility based upon some new and untried technical ideas is under construction in Novosibirsk. In Western Europe and Russia there are six high energy electron colliding beam devices and one proton colliding beam facility just coming into operation. In this country we have only a relatively modest effort just now starting to undergo tests at the Cambridge Electron Accelerator and one other facility under construction at SLAC. This large asymmetry in the effort between the U.S. and the rest of the world has occurred despite the fact that the very first colliding beam device was operated in this country nearly twelve years ago in a Princeton-Stanford collaboration. The small U.S. effort in this key area is being carried out in a rather catch-as-catch-can manner. At Cambridge, the existing research program with the 6 GeV CEA accelerator has been stopped completely, and the laboratory's resources have been turned to converting the machine into a 3.5 GeV storage ring device of moderate luminosity ("luminosity" is a measure of attainable interaction rates, and therefore a major determining factor in the kinds of experiments that can sensibly be attempted). The CEA colliding beam energy can be raised in energy at moderate cost. At SLAC, a portion of the existing budget is being diverted over each of three separate years in order to construct a storage ring of high luminosity that will be competitive with European and Soviet machines that are now operating or under construction.

It is our assessment that, in the future, the electron colliding beam activity should be better supported in this country. The rings now under construction at SLAC and the new facilities projected at SLAC, which will include the possibility of colliding beam work at still higher energies, will help restore the balance in activity. Depending on the success of the colliding proton beams at CERN, the development programs which are proposed NAL and BNL would permit this country to move into this area of research at much higher energies.

3. HIGH ENERGY PHYSICS AND INTERNATIONAL RELATIONS

a) General Observations

High energy physics plays a unique role among the sciences on the international scene for a number of reasons:

- High energy physics is sufficiently remote from current application so that neither military nor commercial secrecy impedes communications.

- High energy physics requires technological efforts of large magnitude so that international collaboration in this field provides much insight into the working methods of other nations.

- High energy physics is expensive; thus rapid international communication is essential for all participants to avoid wasteful planning due to ignorance of plans and results obtained elsewhere.

- As the scale of the tools of high energy physics increases, international cooperation may be the only feasible means of reaching the highest energies.

- There is a sense of community among high energy physicists of all nations; many high energy physicists play a prominent role in advising their respective governments; thus a valuable communication channel results.

- High energy physics is sufficiently prominent in the public eye so that collaboration constitutes an important symbol of international good will.

Stemming from this unique role of high energy physics in the furtherance of international relations a number of significant steps have been taken.

b) Western Europe and Japan

Collaboration with Western Europe in high energy physics has been excellent throughout the postwar period. Americans have played a major role in the original inception of CERN, the Western European laboratory in Switzerland which pools the resources of twelve member nations. Cooperation took place during the design period during which the AGS at Brookhaven and the CERN Proton Synchrotron proceeded along similar schedules, and throughout the utilization period of the CERN accelerator which began in 1959. A very large number of American visitors participate as individuals in the work of CERN. Conversely, an even larger number of West European high energy physicists have participated as visitors at U.S. laboratories, their visits extending usually over one-to-three-year periods. It is interesting to note that the net "trade balance" in high energy physics has been favorable to the U.S., that is, there was more West European travel to the U.S. than in the opposite direction.

There is now an intensification of collaboration in high energy physics with Japan, implementing the U.S./Japanese Agreement on Science Collaboration. Reciprocal meetings have been arranged and there is extensive consultation in connection with Japan's new accelerator program.

c) USSR

Collaboration with the Soviet Union has been unusually extensive relative to such efforts in the other sciences. U. S. visitors were given access to Soviet facilities first in 1956 after the 10-GeV laboratory at Dubna, USSR, came into operation. The organization of the Dubna laboratory was patterned after that of CERN, that is, it is under the control of a Council composed of representatives of the Soviet Bloc nations. China participated initially but withdrew after the Sino-Soviet split deepened.

Collaboration between the U. S. and the Soviet Union in high energy physics was formalized in a series of bilateral memorandum agreements dealing with peaceful uses of atomic energy between the United States

Atomic Energy Commission and the Soviet State Committee for the Utilization of Atomic Energy. Two of these agreements, one dated July 29, 1968, and one February 10, 1970, specifically provided for lessened formality in U.S./USSR relations in high energy physics and permitted that exchanges of scientific workers could be arranged on a Laboratory-to-Laboratory level and that reciprocity should be interpreted as applying only over a protracted period of time. These agreements, singling out high energy physics for less formal treatment, culminated a series of discussions which had started on November 30, 1963 between the Chairman of the U.S. Atomic Energy Commission and the Chairman of the Soviet State Committee.

Implementation of these special agreements has been only moderately successful; there has been frequent reciprocal participation in meetings, and extensive visits and lectures up to a period of one month have taken place. However longer collaborative experimental efforts have been very rare until quite recently. The impediment has partially been the imposition of extensive governmental review in spite of the pledge of informality and also due to the restrictions on the use of foreign currency by both sides: the exchange agreements provide that in general the sending parties pay all expenses.

The situation has improved considerably with international participation in the work of the Serpukhov 76-GeV proton accelerator in 1968; since this is currently the highest energy operating accelerator in the world, the incentive for Western participation increased. Agreements were signed first by CERN and then by France with the Soviet State Committee to provide Western equipment in exchange for experimental access to the unique Serpukhov machine. These agreements have been very successful; West European teams have worked at Serpukhov since it reached initial operation and many joint publications have resulted. Substantial contributions in terms of specialized facilities to Serpukhov have been made by the CERN group and a large bubble chamber designed and produced by the French is currently undergoing final testing at Serpukhov. After extensive preliminary discussion, a special Annex to the U.S./USSR Memorandum of Agreement was signed November 30, 1970, to provide for U.S. access to the Serpukhov accelerator. This agreement is worded

reciprocally such that Soviet physicists can participate in work at NAL. The first experiment involving a U.S. (UCLA-SLAC-Naval Postgraduate School, Monterey) team with a Soviet Bloc (Soviet-Polish) team has just been completed successfully and proposals from Soviet groups are being entertained at NAL.

d) Multilateral Activity

The High Energy Commission of the International Union for Pure and Applied Physics has been the principal agent for sponsoring and organizing a continuing series of meetings involving Western Europe, Japan, The USSR and the U.S.A. These sponsored meetings have dealt on a cyclic basis with new results in experimental and theoretical high energy physics, accelerator technology and high energy photon and electron interactions, respectively. The meetings have been growing steadily and have constituted an important means of international communication and of pooling and collating recently obtained results.

Another sympton of increasing collaboration and communication in high energy physics has been an annual meeting of Laboratory Directors of the USSR, Western Europe and the U.S.A. This series was first started as a bi-lateral set of informal meetings between the USSR and Western Europe but, at the request of the Soviets, was expanded three years ago to include U.S. representation also. The next meeting of this series will be held this coming fall.

Thus far none of these international arrangements have included actual responsibility for large joint construction projects involving the U.S.A. Informal discussions have been held under various auspices including that of the Academies of Science for a possible large "intercontinental" accelerator, but none of these discussions has led to concrete plans. The last such discussion formally arranged was held at the International Atomic Energy Agency (IAEA) in Vienna in 1966. This subject will probably be reopened at the Laboratory Director's meeting to be held in Switzerland this year. There is little question that should there be another very large step in accelerator energy it is most likely that it will be under-taken on a truly international basis.

APPENDIX C

HIGH ENERGY PHYSICS AS A SOURCE FOR APPLIED TECHNOLOGY

High energy physics and astrophysics, subjects which involve the study of the very small and of the very large, respectively, are generally recognized as the frontier fields of physical science -- fields in which the investigators are engaged in probing into completely unknown realms and attempting to understand the laws which govern the behavior of all matter in our universe. Despite these "noble" objectives, it is reasonable to inquire whether, in fact, the frontier of knowledge has been pushed so far afield that what is subsequently learned can have little or no impact on human affairs. And, in view of the resources that are devoted to the exploration of these fields, the practitioners should be continually challenged to answer the question: To what extent are these resources going toward contributing to the well being of man in a cultural as well as a material sense?

Frontier activities of this nature have always stimulated the highest order of intellectual pursuit. These fields tend to draw the most able students, each student aspiring to contribute in a profound way to man's understanding of his environment and universe. The result is an unparalleled educational incentive to our young people. More than this, the creative spirit which is nourished by frontier science affects the entire way of thinking in our culture and the standards by which its creations are judged. As noted by Polanyi*

> "The scientific method was devised precisely for the purpose of elucidating the nature of things under more carefully controlled conditions and by more rigorous criteria than are present in situations created by practical problems. These conditions and criteria can be discovered only by taking a purely scientific interest in the matter, which again can exist only in minds educated in the appreciation of scientific value. Such sensibility cannot be switched on at will for purposes alien to its inherent passion."

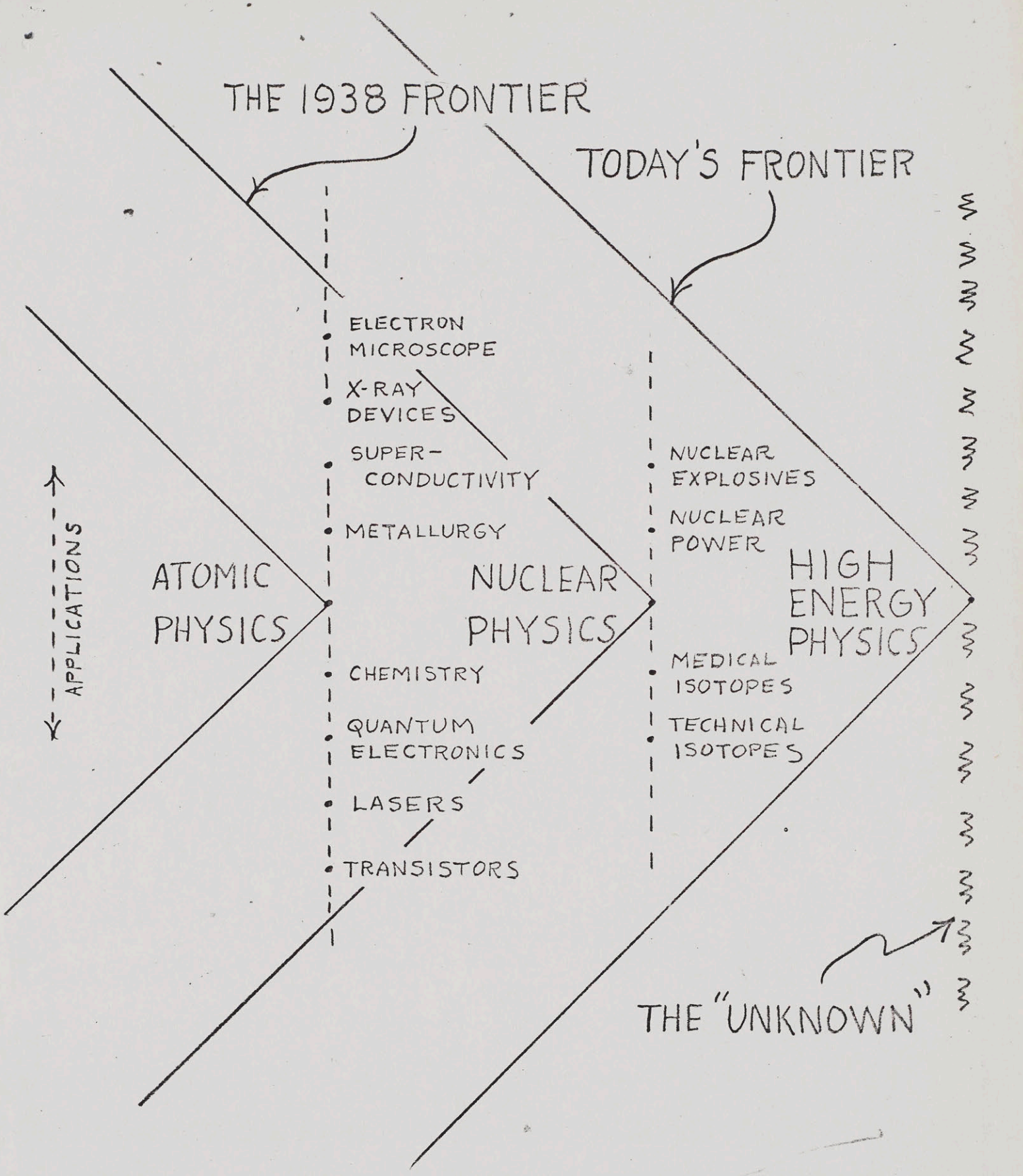
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*K. Polanyi, Personal Knowledge, University of Chicago Press, 1958, p. 182.

The contributions of basic science to our culture and to our material well-being cannot be separated. While Newton's Laws of Motion are apparently quite adequate to meet the challenges of our day-to-day lives, we must recognize that, for example, the synthesis of new drugs and the invention of the fabrics in the clothes we wear both depend on the detailed knowledge of molecules -- only quantum mechanics generates such insight. Newton's Laws of Motion are only an approximation to Quantum Mechanical Laws, these were invented to explain apparently esoteric features of optical spectra defying other explanations.

The applications of quantum mechanics to solids led to many developments such as the invention of the transistor which, in turn, has led to a vast technology, including computers. It is interesting to note that one of the inventors of the transistor has recently made a major contribution to the theory of superconductivity. Another contributor was originally trained as a high energy particle theorist. Along the same lines a recent Nobel Prize winner in biology made his first notable contribution in science in the application of quantum mechanics to scattering problems in particle physics. The electronic circuits invented by nuclear physicists to record radioactive decay processes were later taken over by the computer industry. The strong focusing principle -- invented to make feasible the construction of ultra-high energy accelerators -- led one practitioner to ask whether the same idea might be used profitably in the electron microscope. The result is an instrument with substantially improved resolution. High-power transmitting tubes now used in communications were originally developed to propel particles in accelerators. Special relativity is now "handbook" information used in the design of such tubes.

These examples illustrate an ubiquitous feature of science, the magnitude of which is difficult for the non-scientist to appreciate: that is the degree to which ideas, techniques, and instruments conceived or invented to meet the challenges in basic science are utilized to meet the problems in applied fields of science and technology. The magnitude of this process is difficult to appreciate unless one is deeply involved in the subject.


THE 1938 FRONTIER
TODAY'S FRONTIER
ELECTRON MICROSCOPE
X-RAY DEVICES
SUPER-CONDUCTIVITY
METALLURGY
CHEMISTRY
QUANTUM ELECTRONICS
LASERS
TRANSISTORS
NUCLEAR EXPLOSIVES
NUCLEAR POWER
MEDICAL ISOTOPES
TECHNICAL ISOTOPES
APPLICATIONS
ATOMIC PHYSICS
NUCLEAR PHYSICS
HIGH ENERGY PHYSICS
THE "UNKNOWN"

The main point is -- the challenges of the completely unknown, such as are encountered in high energy physics and astrophysics, by their very nature, force completely unconventional thinking and unconventional approaches to problems. These new approaches and techniques are then used in many fields of endeavor.

Highly innovative technological by-products such as these result because a frontier field like high energy physics attracts highly capable practitioners who are dissatisfied with being limited by the "state of the art". It is thus useless to ask "could such generally valuable tools like strong focusing systems, the klystron tubes, the binary scaling pair, etc. be developed more cheaply if direct support had been given toward that end?" Maybe so in principle but history is replete with examples where the "brute force" push toward invention did not bring the answer. This story, repeated over and over again, has been eloquently described in the words of the industrial scientist H. B. G. Casimir, Director of Holland's Philipps Research Laboratories:

> "I have heard statements that the role of academic research in innovation is slight. It is about the most blatant piece of nonsense which it has been my fortune to stumble upon.
>
> "Certainly, one might speculate idly whether transistors might have been discovered by people who had not been trained in and had not contributed to wave mechanics or the theory of electrons in solids. It so happened that inventors of transistors were versed in and contributed to the quantum theory of solids.
>
> "One might ask whether basic circuits in computers might have been found by people who wanted to build computers. As it happens, they were discovered in the 30's by physicists dealing with the counting of nuclear particles because they were interested in nuclear physics.
>
> "One might ask whether there would be nuclear power because poeple wanted new power sources or whether the urge to have new power would have led to the discovery of the nucleus. Perhaps - only it didn't happen that way, and there were the Curies and Rutherford and Fermi and a few others.
>
> "One might ask whether an electronic industry could exist without the previous discovery of electrons by people like Thomson and H. A. Lorentz. Again, it didn't happen that way.

"One might ask even whether induction coils in motor cars might have been made by enterprises which wanted to make motor transport and whether then they would have stumbled on the laws of induction. But the laws of induction had been found by Faraday many decades before that.

"Or whether, in an urge to provide better communication, one might have found electromagnetic waves. They weren't found that way. They were found by Hertz who emphasized the beauty of physics and who based his work on the theoretical considerations of Maxwell. I think there is hardly any example of 20th century innovation which is not indebted in this way to basic scientific thought."

The above examples of "applications" of high energy physics and other basic research are not applications of <u>results</u> of the research, rather, they are applications of the <u>tools</u> of such work. In considering the applications of the <u>results</u> of high energy physics, we have to consider another feature of basic science. It is the intrinsic <u>unpredictability</u> of what will be learned; or, given a particular goal, the intrinsic unpredictability of what the shortest route to that goal will be.

A few years ago, during the course of some investigations on the interactions of subnuclear kaons, it was discovered, completely by accident, that stopping subnuclear muons would catalyze the fusion of two deuterium atoms to form helium. The controlled fusion process has long been the subject of extensive investigation as a clean energy source of almost unlimited potential. Here, completely unexpectedly, was discovered a new way of producing fusion. While it turned out that the muon catalysis does not work as a power source (it misses by a cat's whisker because the muon gets captured by the helium and cannot continue to catalyze further fusions) the community is now alert to the possibility that a particle, still undiscovered, may work successfully as a catalyzer.

The thrust of the story is: High energy physics came close to solving the fusion power problem, and in a way no one could have possibly invented -- if he were directly addressing the problem of controlled fusion.

Ultimately the expectation of applications stemming from the results of high energy physics research must rest on <u>history</u>. High energy physics is the present trail blazer along a path previously cleared by what is now

nuclear physics, and nuclear physics was preceded along this path by atomic physics. When these earlier fields were the frontier, applications then too seemed unlikely if not impossible. But the attached diagram shows us graphically what has actually happened: applications have come only after the basic facts of a new realm have been explored and established.

Essentially all technologically related products have been generated along a pattern like the one described. Louis Rosen has demonstrated* convincingly that the annual production of goods and services associated with particle accelerators is about 2 billion dollars -- including isotope production, nondestructive testing, radiation processing, power reactor applications, medical treatment, and polymerization by radiation. No one would have conceivably predicted such a volume of activity when accelerators entered particle physics research in the 1930's.

Currently the U.S. has a negative world trade balance in all commodities combined. In contrast the U.S. has a large excess in the balance of payments in the products of technology. This technology was derived from earlier discoveries in basic research. Technology continually needs the nourishment and stimulus derived from the discoveries at the frontier. Thus even this foreign trade argument strongly points that we must maintain leadership in basic research.

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*Louis Rosen: "Relevance of Particle Accelerators to National Goals", 1971 Particle Accelerator Conference, March 1, 1971, Chicago, Illinois.

that such a starting point corresponds to an 80% to 90% utilization of the Nation's high energy physics facilities.*

We therefore recommend that $250 million be considered an absolute minimum for FY'73 to meet the conditions of (a) reasonable exploitation of the facilities now at hand, (b) halting the decline in high energy physics manpower, and (c) a reasonably effective transition of the National Accelerator Laboratory into a productive physics program.

C. PROJECTIONS OF ALTERNATIVE FUNDING SCHEMES

In this section graphs (Figures 3, 4 and 5) are included to show the timetables of funding distribution to accomplish the goals described.

In these projections we analyze a five-year budget program of constant buying power (Figure 4) and alternatively we analyze excursions about this assumption at a total funding growth rate of -5% and +5% per annum (Figures 3 and 5, respectively). We identify illustrative distribution of funds over various budget categories, including both operating and capital items. These alternative plans differ considerably in terms of accomplishment and vigor of the program and the number of physicists which can be accommodated: The number of surviving national laboratories is the same for all these projections by the end of the decade.

The starting points of these plans were taken to be $250 million of new obligational authority for FY'73. (For reasons discussed in Section B, we recommend at least this figure as a *minimum* starting value.)

*Program projections from a $280 million FY'73 base are available but for the sake of brevity are not included in this report.

FIG. 3 - 5%/YR. DECLINE

(IN FIXED 1973 DOLLARS)

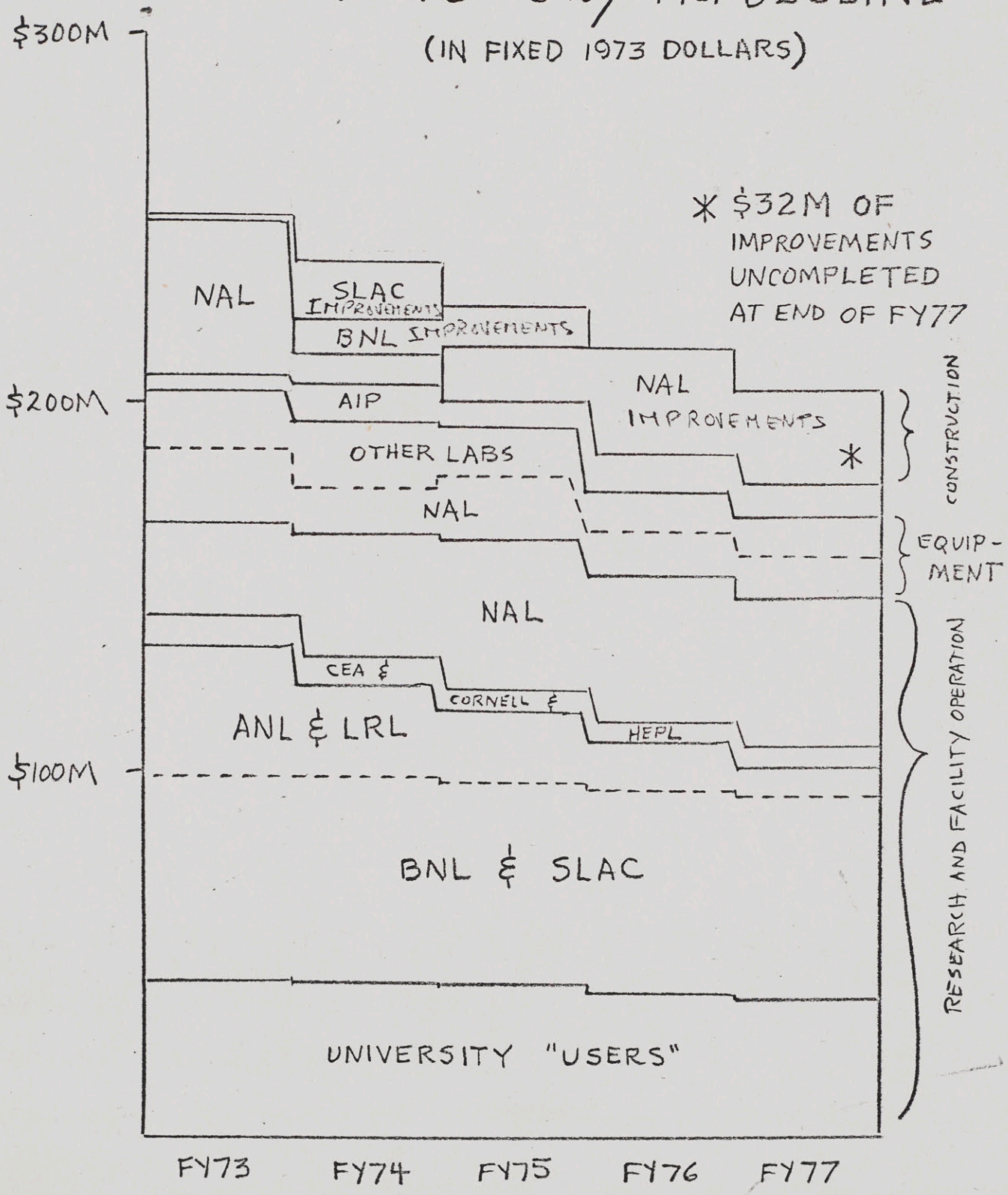


FIG. 4 - LEVEL SUPPORT

(IN FIXED 1973 DOLLARS)

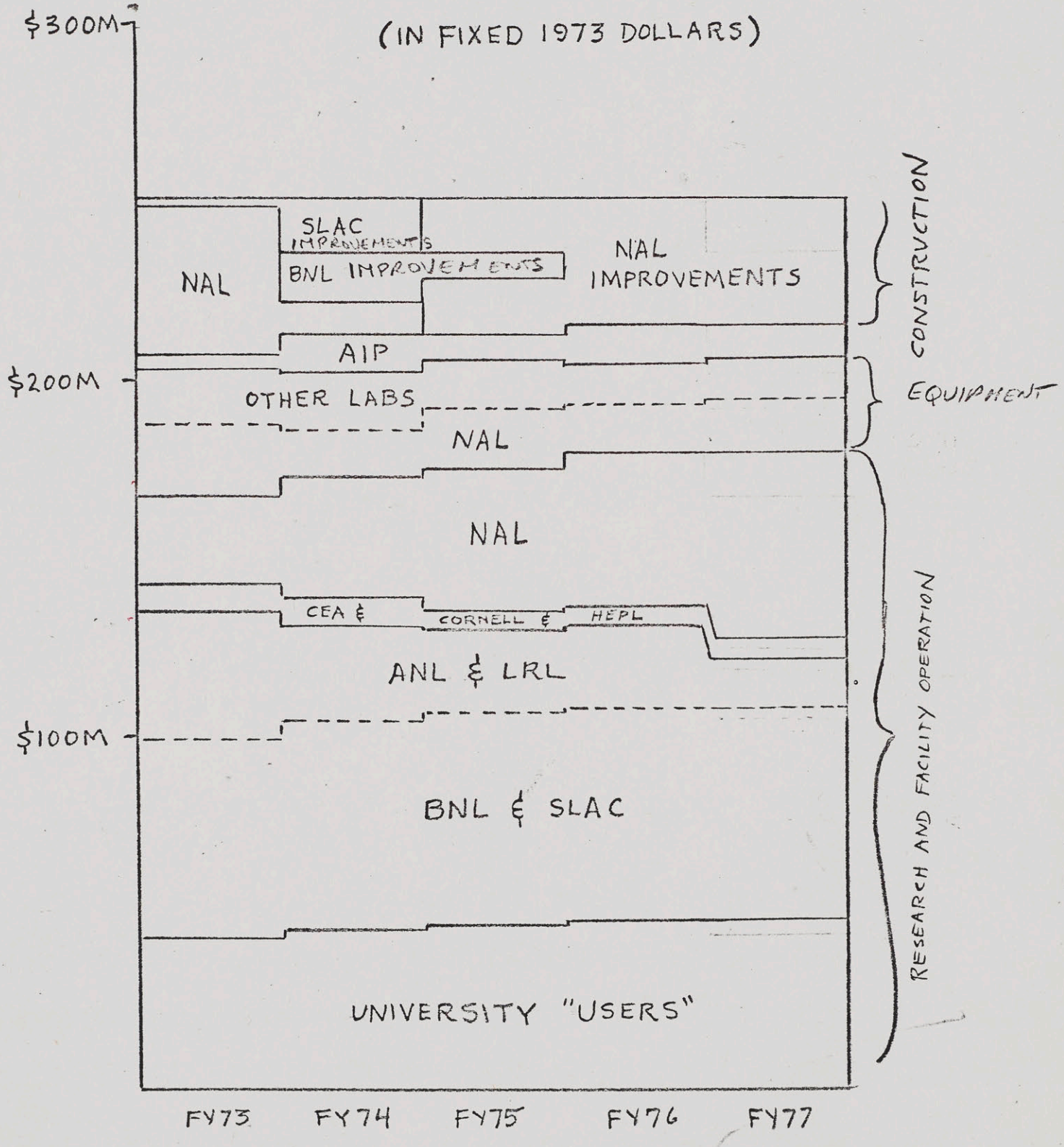
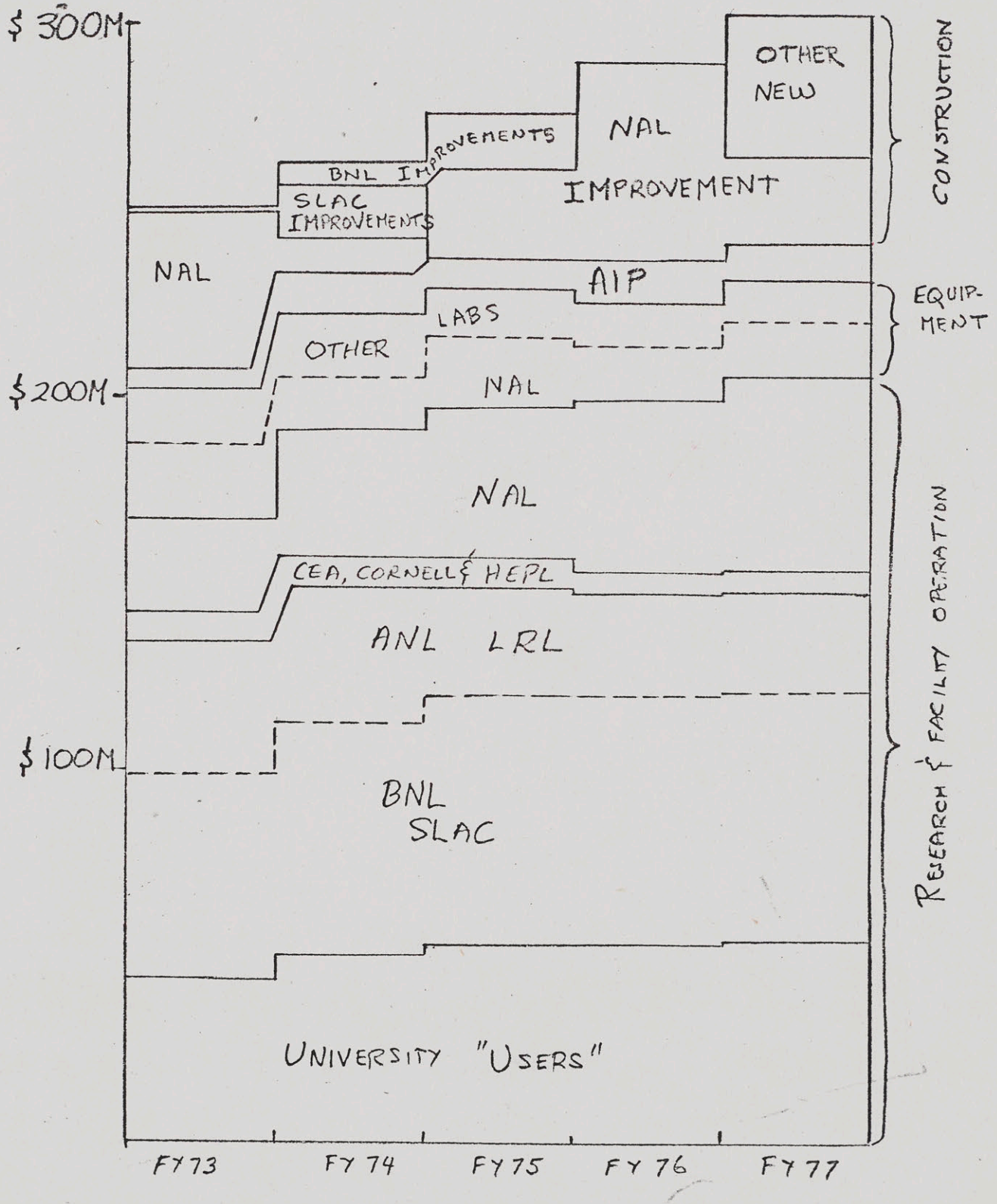


FIG 5 — 5%/YR. GROWTH
(IN FIXED 1973 DOLLARS)



The extended figures as given are in "1973 dollars." We have made no effort to preguess any escalation due to inflation.

Only a minimum number of new on-AEC-site buildings is included in the projections and only on an austere basis.

The *capital* costs of large computer installations at AEC centers are not included in our considerations; such large computers generally also serve programs other than high energy physics. *Operating* costs of such computers allocated to high energy physics are, however, included in our figures.

The cost of participation in an international venture aiming toward an "intercontinental" accelerator is not specifically included.

The *details* of these projections (including the dates of accelerator phase-downs) should not be interpreted as recommendations; actual circumstances such as recent discoveries or technological progress should control decisions of the agencies within the general framework of these projections.

High energy physics, like any frontier science, has a history of startling developments leading to new avenues of thought and unforeseen opportunities. *The projections of this report do not provide specific contingency funds for the unknown.*

D. ANALYSIS OF THE CONSEQUENCES OF THE ALTERNATE PLANS

Under all the growth rates projected four major accelerators above 3 GeV (CEA, PPA, ZGS and the Bevatron) will have ceased operation by the end of the decade covered by the plans.

1. Decreasing Funding Projection (Figure 3)

We consider the program with decreasing real funding at a rate of about 5% per year highly unsatisfactory for a number of reasons:

(a) The number of scientists involved in high energy physics would decrease over the next decade. Practically no young

people would be able to enter the field because of lack of positions and opportunities. The effect of this shrinking and aging process would be disastrous to the creativity of U.S. particle physics and therefore to basic science as a whole.

(b) The various capital improvement projects would be stretched out over an unconscionably long time; for instance, NAL could not acquire a proton intersecting storage ring facility or reach higher energies until near the end of the decade.

(c) The reduction of operating level and operating period for the ZGS and the Bevatron would preclude sensible realization of potential physics remaining to be done there with little further investment. In addition, the two "surviving laboratories" now in operation (BNL and SLAC) could not reach even 75% utilization, much less adequately exploit their newly constructed facilities.

(d) The equipment figures would shrink eventually by 20% below the AEC program request figures. This would perpetuate some of the present problems brought on by insufficient equipment funding. Equipment funding is the one item where the disparity with Western Europe is most glaring; therefore this 20% shrinkage would be damaging to over-all productivity and competitiveness.

(e) NAL operations would be held to a marginal figure which is considerably lower than that projected at the time the machine was authorized.

2. Level Funding Projection

The zero growth pattern in real dollars would meet most of the criteria given in the beginning of this study and would complete the various capital programs indicated during this decade. However, the

program has no flexibility for accommodating new ideas or expanded programs, either instrumental or originating from new physical results. Construction funding is only 18.5% of the total as compared to the 25.8% of the last decade. If, for instance, either the ERA or the superconducting linear accelerator technique were to become sufficiently promising to be included in the program, other subjects would have to be displaced. Similarly, equipment would be cut by 10% below the request figures which would limit new experimental opportunities but still permit provision of equipment above the "hard core" costs of the laboratories discussed above. The rate of innovation would be slow and also the degree of utilization is still far below optimum.

The "zero growth" program presumably implies, after initial transition, a "zero population growth" of the number of high energy physicists. This will involve major hardships to the profession since the average age of the practitioners of high energy physics is quite low; therefore stopping the growth implies only minimal opportunities for a new generation. The effect would be damaging to the quality of the U.S. particle physics similar to that under the declining funding plan. However, the result would show up somewhat later in time.

3. Increasing Funding Projection

The program corresponding to 5% annual growth would permit the innovation necessary to retain facilities reasonably competitive on an international scale and would obligate funds for the now clearly envisaged construction activities by FY'76. In this projection, construction for innovative research remains at about 20% of the total support. Most important, this program would ameliorate the present disastrous manpower drain, providing for some growth of the scientific population in the field and thereby providing opportunities for young people to enter it. While under this program, four accelerators would have been closed; operating levels of the surviving accelerators would eventually correspond to exploitation above the 75% level. Should new ideas be introduced into the program, or should

participation in a large-scale international venture become a reality during the coming decade, some adjustments could be made at this funding level without traumatic effects on the balance of the program.

4. Summary

We conclude that only a *minimum* level of total funding for FY'73 of $250 million for high energy physics and a growth rate of well above zero and approaching 5% per year in *real* dollars will support a program meeting the specified criteria.

During the seventies NAL will have come into initial and expanded operation, but four high energy accelerators will have been lost. It is hoped that such a program will -

Retain pre-eminence in research at the highest proton energies.

Retain leadership in electron energy and in research in the electron-photon field.

Regain competitiveness in storage ring physics.

Maintain opportunities for technical innovation.

Halt the loss of personnel from the field and provide some limited opportunities for young people to enter the field.

Permit reasonably efficient although not complete exploitation of accelerator facilities.

Continue the creative involvement between the universities and the National Laboratories.

With this program there is a reasonable chance that U.S. high energy physics will remain qualitatively in a fully competitive position. Nevertheless, we expect that the share of data generated in the U.S. will be a decreasing fraction of the total, due to the qualitative and quantitative increase of facilities and physicists abroad and due to the shrinking

number of facilities and the fiscal limitations of the operations at home. However such a program, substantially less ambitious than that projected in 1965, hopefully can continue the impressive record of discoveries in U.S. laboratories which have profoundly affected man's view of the physical world.

ENC I

ENCLOSURE I

PAST ACHIEVEMENTS OF HIGH ENERGY PHYSICS RESEARCH
AND GOALS FOR THE NEXT DECADE**

1. HIGHLIGHTS OF HIGH ENERGY PHYSICS RESEARCH

High energy physics aims to explore the nature of the physical universe to the smallest possible dimensions. Man's knowledge about our world is bounded on both the infinitesimal and the cosmic ends of the scale. Research in both areas continues to provide new insights and understanding of man's physical environment. Regularly, as both knowledge and techniques advance, discoveries greatly change man's view of his world.

The following table lists the most startling and profound observations and discoveries of high energy physicists over the past 25 years.

DATE	DISCOVERY	EXPLORATION
1947	Lamb shift: "g-2" of the electron	Limits of quantum electro-dynamics*
1947	Properties of the Pion*	Pion-nucleon interactions
1952	Bubble Chamber* for investigation of strange particles*	Interactions of strange particles
1954	Composite nature of the nucleon*	Electron scattering and nucleon spectroscopy
1955	Anti-proton*	Matter/Anti-matter symmetry
1956	Violation of parity conservation*	Weak interactions
1961	Hadron symetries (SU^3)* and discovery of omega-minus (1964)	Whole hadron spectroscopy
1962	A second neutrino	Search for new leptons
1964	Violation of CP conservation	Search for T violation
1968	Point structure within hadrons	Deep inelastic scattering and e^-e^+ storage rings

*Work leading to Nobel Prizes.

**Prepared by W. K. H. Panofsky and V. F. Weisskopf.

A brief outline of the significance of each of these discoveries follows:

The development of the theory of quantum electrodynamics in 1946 opened a whole new all-inclusive way of understanding electromagnetic interactions. It predicted with uncanny accuracy the "Lamb shift" in atomic structure and provided an extremely precise quantification of the magnetic moment ("g-2") of the electron.

The pion (pi-meson) had been predicted in the late 1930's to be the "glue" holding the neutrons and protons together in the atomic nucleus. The discovery of the pion in 1947 led to hopes that the new and strange "strong force" (or "nuclear force") would soon be understood; the properties of the new particles were rapidly explored.

Strange particles had indeed been observed in nature but just in the form of unaccounted-for particles discovered in cosmic rays.

In the constant shower of cosmic rays, physicists had earlier discovered the existence of unknown and bewildering "strange" elementary particles. It was not until 1953 and the advent of the new generation of accelerators, with energies high enough to produce the new particles under controlled laboratory conditions, that the full extent of the "strangeness" of these particles was realized. The strange particles were found to be produced copiously using high energy beams of the new accelerators, yet their decays were of a weak nature. Since both production and decay seemed to involve similar particles, it was puzzling why they took place with such drastically different strengths. What was eventually discovered was the existence of a new conserved quantity in nature. This new quantum number, "strangeness", went far to explain the peculiar interactions of the strange particles in the 1950's. However, the full and rather deep implications of the strangeness quantum number were yet to come 10 years later with the discovery of SU(3) symmetry.

The new accelerators also probed smaller distances than had been explored before. In probing the proton by various scattering experiments, physicists found that the suspected point-like nature of the proton was not there;

instead, the proton was an extended structure with a definite size. This result was first obtained by electron scattering experiments. In addition excited levels of the proton, or proton resonances, were found, further implying a compound structure.

When the Bevatron at the University of California became operational in 1954, an opportunity to test the concept of anti-matter symmetry was presented. The positron (anti-electron) had been discovered in cosmic rays in the late 1930's, opening the possibility of the existence of a complete anti-matter world, symmetric to the known particle spectrum. With the higher energy available at the Bevatron, one could hope to produce the first strongly interacting Fermian anti-particles seen in nature, anti-protons. Indeed, anti-protons were so produced, and as time has progressed most other elementary anti-particles have been found.

In 1964 at the AGS, the anti-deuteron was produced, strongly indicating the possibility of complete anti-particle symmetry through the elements.

In the mid-1950's the bubble chamber was invented, a device which proved to be invaluable in examining in detail the production and decays of what then amounted to 30 elementary particles. One such bubble chamber built in 1956 is still operating in the SLAC beam today. The bubble chamber was instrumental in precipitating, through measurements of unprecedented precision, perhaps the most profound discovery of the decade of the 50's, parity violation.

In 1956 it was shown that parity, i.e., right-left symmetry, was violated in the weak interactions. This discovery was truly momentous since physics from its inception had always assumed that nature could not distinguish right-handed and left-handed systems. The incorporation of this astounding fact into the framework of the weak interactions led to the inclusion of the neutrino and muon in the fundamental equations of particle physics in a beautifully symmetric fashion. These equations were then suggestive of more general forms ultimately leading to the inclusion of the weak interactions as essential reflections of the basic structure of matter in symmetry schemes of recent times.

In 1962 an elaborate experiment proved that contrary to the previous picture there was not just one neutrino in the world but indeed there were two - adding to the list of leptons (electrons, muons, etc.) in the list of elementary particles. This has led to extensive experimental searching for yet further leptons - the question of the role of a multiplicity of leptons in nature remains one of the great open problems in physics.

In 1964, approximately eight years after the discovery of parity violation, another fundamental symmetry principle was found to be violated: Time reversal invariance (or "CP conservation"). The forces driving processes in the forward and backward direction in time were determined not to be necessarily equal: An extremely weak violation was found, the full implication of which has yet to be resolved. Physicists have gained a great deal of insight through the investigation of such basic symmetry principles, and will continue to test established laws to the limits of obtainable precision.

As high energy physics entered the 1960's, the particle explosion really began. New bubble chamber and counter techniques, and the invention of spark chambers, permitted much more extensive and precise experiments to be performed. It seemed that each new experiment discovered at least one new "particle".

By 1965 over a hundred such entities were claimed to exist; a new nuclear physics had evolved. After considerable theoretical effort in the late 1950's and early 1960's, it was found in 1961 that a strong pattern was evident in the mass spectrum of these "particles". This pattern took mathematical expression through group theoretical approaches. In particular, the group (or symmetry) SU(3) had profound predictive power in describing not only the particle spectrum, but particle interactions as well. One great success of SU(3) was the prediction of one "omega-minus" meson, the first strangeness-3 object. This prediction was spectacularly verified in 1964. One of the important insights gained in the last decade was the recognition that those hundreds of "particles" are, in fact, short-lived excited states or resonances of the proton or of the meson. The great variety of particles was recognized as being a series of different manifestations of only two entities which must be endowed with some kind of internal structure so as to be able to appear in different excited states.

Another dramatic implication of SU(3) was the idea of "quarks" - new ultra-basic elementary particles. The idea was that all known particles with strong interaction are composite objects, the constituents being quarks. It represents a primitive example of an internal structure in nucleons or mesons. With the quark concept, many particle properties were explained in a surprisingly simple way. However "quarks" have thus far eluded all efforts to determine whether they exist as independent entities.

New experiments at SLAC involving the scattering of electrons from protons at energies higher than ever before appear to have uncovered another inner layer of matter. The additional available energy (and intensity) have yielded new results implying the existence of elementary point-like constituents in the proton; these may or may not be the quarks predicted from the SU(3) particle spectra. Experiments done with storage ring facilities in Europe have obtained similar results.

This brief historical outline amply documents that the rate of truly profound discoveries in elementary particle physics has by no means decreased -- the field is still wide open. However, the total impact of these fundamental revelations on our thinking and understanding of the natural world cannot be evaluated until a more comprehensive synthesis of theoretical ideas emerges.

2. GOALS OF HIGH ENERGY PHYSICS RESEARCH FOR THE NEXT DECADE

If high energy physics is pursued as projected in this report, one may reasonably expect that new discoveries will continue at a rate comparable to the past. The NAL facility and the CERN intersecting storage rings will provide opportunities to study phenomena in the energy range of several hundred to a thousand GeV. Increased electron energies and in particular the availability of powerful electron-positron storage rings will open up new insights into the subnuclear phenomena from an entirely different aspect. The improved facilities and detection devices at lower energies will allow much more penetrating studies than before in the energy range from a few to 30 GeV.

Obviously, it is impossible to predict what these discoveries will be, but one may try to define the general direction of further progress in high energy research as it appears to develop today. It should be noted, however, that predictions made in the past of goals and results in high energy physics always have turned out to be much too conservative when the energy range was extended by a factor of ten. Each time, Nature turned out to be by far richer than anticipated.

A goal which might be reached in the next decade would be to obtain full or partial answers to the following questions:

(a) At even higher excited states of hadrons (protons and mesons) will the regularities observed at present energies continue?

(b) Will the character of the reactions between colliding hadrons at higher energies remain similar to the one observed so far, or will it show some unexpected new features?

(c) Will there be any new evidence elucidating the internal structure of hadrons?

(d) Is there a "field" which carries weak interactions, analogous to the electromagnetic field carrying electric interactions?

(e) How are the sources of weak interactions distributed within a hadron?

(f) What is the behavior of weak interactions at higher energies?

(g) Is there any deeper reason for the recently discovered CP-violation in weak interactions?

(h) Will the electron exhibit effects coming from its finite size or its internal structure?

(i) Is there a way to understand the reason for the existence of the heavy electron (i.e. the muon), and is there more than one type of heavy electron?

(j) Why do charged particles, hadrons or electrons, always have charges which are integer multiples of the electronic charge?

(k) Can we understand the forces which bind the neutrons and protons in the nucleus in terms of the particles and interactions of high energy physics?

(l) Is there any deeper connection between, or a common origin of, the four fundamental interactions -- strong, electromagnetic, weak and gravitational?

The first question (a) refers to some puzzling regularities found in the properties of excited states, the most important being an approximate proportionality between the angular momentum and the square of their mass (the so-called Regge-behavior). So far, no generally accepted explanation is known. A better knowledge of the high-energy resonances certainly would help to get more insight into the internal structure of the fundamental constituents of matter. Such knowledge would also be most relevent to the study of the early history of the Universe, when matter was under conditions in which these excited states must have played an essential role.

The second question (b) refers to the effects of collisions between particles at high energies. Some, but not all, of these reactions seem to reach "asymptotic" character at presently available energies; that is, they do not seem to change much when the energy of collision surpasses a certain critical value. Is this asymptotic character true or only apparent at lower energies? Are we allowed to extrapolate from our present knowledge to higher energies or will we observe some very different effects? It may be that the inner layer of matter indicated by the SLAC experiments will manifest itself by some new phenomena appearing at higher energies.

This leads us to question (c) which concerns one of the central goals of this field, namely, to get some evidence on the substructure of the proton or the meson. Further high energy studies with the new accelerators will, no doubt, shed new light upon the nature of the mysterious quarks as subunits of hadrons. Are they real particles? Can they be separated from hadrons? Do they really carry those fractional charges which present evidence ascribes to them, namely, 2/3 or 1/3 of an electronic charge?

The questions (d) through (g) refer to the nature of the weak interaction. This interaction is responsible for certain types of radioactivity, namely, the emission of electrons and neutrinos by nuclear particles. The weak

interactions are still a great puzzle. The laws governing their behavior at presently available energies are well-known and seemingly simple, but they exhibit a number of very strange properties and phenomena. One is the existence of the neutrino, the mysterious, massless and chargeless particle which interacts with matter only by weak interactions. Another is the violation of symmetry between right and left, and a recently discovered tiny violation of symmetry between particle and antiparticle (CP-violation). Neutrinos are among the decay products of mesons, and this fact has been used to produce pure high-energy neutrino beams at proton accelerators, producing meson beams which subsequently decay into neutrinos. Such neutrino beams are research tools of unique value for the study of weak interactions. The projected neutrino beam at NAL will be used to investigate the behavior of weak interactions at very high energies. Question (d) refers to a possible detection of a weak interaction field by finding the quantum of this field (in analogy to the light quantum in electromagnetic interactions). This quantum is usually referred to as the hypothetical "intermediate boson". Many reasons point to the expectation that, if it exists, this quantum would be produced by the newly-available energies.

Question (e) points to another problem which may be solved soon: It is the question of the distribution of weak interaction sources within the hadrons, and it will be answered by experiments with high energy neutrino beams planned at NAL. It will be interesting to see whether these sources are also seemingly pointlike and identifiable with the apparent quarks observed in other experiments. The Question (f) refers to the behavior of weak interactions at very high energies. Will they stay weak? Will they become stronger and more similar to other interactions? Will we find any clue as to the deeper reason for the violation of the CP-symmetry? Will this violation be enhanced at higher energies, will it appear in different phenomena?

Questions (h), (i) and (j) deal with the nature of electricity. The laws governing the interaction of electrons with the electromagnetic field are very well-known and their theory seems to be in good shape. This theory is based upon the assumption of a point-like electron without any spatial extension. So far, no limit to the validity of this theory has been found.

Will experiments with higher energy find some deviations? Will these deviations point to some finite dimensions or to some internal structure of the electron? Today, the only evidence for something peculiar with the electron structure is the existence of the heavy electron (muon, misnamed mu-meson). So far, no difference with the ordinary electron except the mass has been found. The higher energy beams may discover finer features in which it differs from the ordinary electron, and which may give us a clue to the reason of its existence. Another question poses itself here: Are there still heavier varieties of the electron? Present experience cannot exclude them; the improved beams and detection devices may find these still heavier electrons or prove their absence. There may be an unending series of electrons of different masses as there are hadrons; this possibility has not yet been confirmed nor excluded. Is there a different neutrino connected with each variety of electrons as there is with the presently known varieties? It is possible that a new world of phenomena may appear "within" the electron, parallel to what we have found within the proton.

Question (j) refers to the puzzling fact that all particles so far known and directly observed carry electric charges which are exact integer multiples of a very definite charge, the electronic charge unit, even if they are so fundamentally different as the electron and the proton. (The hypothetical quarks with possibly fractional charges have not been directly observed.) We have no idea why this is so, and why the electron-charge is as big as it is. The famous numerical relation $e^2/\hbar c = 1/137$ ($\hbar$ = Plancks constant, c= light velocity) has not yet been explained, neither the numerical value of the ratio of the proton mass M to the electron mass m: $M/m = 1830$. Certainly the large mass of the proton is connected with the fact that the proton is a source of strong interaction, the electron is not. The explanation of this mass ratio is one of the major aims of particle physics. It should be pointed out that the large value of this ratio is a basic condition for the existence of a well-defined chemical structure in molecules. If atomic nuclei would not be more than a thousand times heavier than electrons, their position within the molecule would not be well localized. Let it be remembered that the existence of life is predicated upon the structural properties of macromolecules.

In nuclear physics we have learned to use the force which holds the protons and neutrons together in the nucleus - yet we know only little about the nature of this force. Question (k) asks for a better exploration: A theory of nuclear forces based on the pion only as "carrier" of this force has not been too satisfactory; will the other particles of high energy physics and their behavior aid our understanding?

Finally, we face question (l) concerning the relations between the four types of interaction. The existence, side-by-side, of the weak, electromagnetic and strong interactions, along with gravity, must be regarded as a preliminary view of nature. Some connections, presently unknown, are expected to show up when we penetrate deeper into the structure of the particles by subjecting them to hitherto unattained energies.

The above list of goals in high energy research is certainly incomplete and by necessity inaccurate. It is a conservative extrapolation from today's knowledge. From past experience we have good reasons to expect that any conservative prediction and extrapolation of research results in high energy physics will be wrong when the energy range is extended by a large amount. Human imagination always lags far behind reality. We therefore should anticipate that completely new and unexpected natural phenomena will be discovered during the coming decade, in view of which the perspectives presented here will look naive and unimaginative. High energy physics is an experimental science. The behavior of matter is explored under completely novel conditions. The field has all the excitements of new discoveries in a virgin land. It will take much time and effort before we can produce a rational map of this new land; it will be the hoped-for fundamental insights into the basic structure of matter.

ENCLOSURE II

COLLIDING BEAMS VS. BEAMS ON STATIONARY TARGETS: COMPETING TOOLS FOR ELEMENTARY PARTICLE PHYSICS*

ENC II

High energy accelerators have been the primary tools in advancing elementary particle physics ever since J. J. Thompson discovered the electron using what in modern terms might well be called the first accelerator. Although many of the qualitative findings, including the discovery of new unstable particles, originated from cosmic ray studies, quantitative measurements have required accelerators as particle sources. In fact, as the energies of accelerators have pushed to higher and higher values the relative importance of cosmic rays as a tool for the study of any aspect of elementary particle physics has all but disappeared, although study of cosmic ray physics remains an important activity in its own right as a diagnostic tool of the cosmos.

Figure 1 shows the state of the accelerators in the world in an admittedly oversimplified manner by plotting their energy and intensity: the power of accelerators cannot be measured by one, or even two, parameters. Particle energy remains, of course, the foremost quantity of interest, but intensity, beam quality and geometry and many other factors determine the usefulness of these instruments to the experimental physicist. The chart shows that the National Accelerator Laboratory currently holds the world's record in energy (300 GeV) and aspires to further increasing values; the collaborative international laboratory at Geneva (CERN) has an accelerator under construction aiming at similar energies. These two machines are proton machines; the energy record for electrons is held by SLAC (22 GeV) with the aspiration of expanding the energy to about 50 GeV by a recirculation scheme.

*Paper given October 16, 1972 at the National Academy of Sciences.

Elementary particle physics has been exceedingly productive throughout this century, and it is fair to say that the time interval between new discoveries in this field which have changed man's basic view of nature has not given any indication of stretching out. Yet the magnitude of the tools and the concomitant cost of operating them have grown steadily, and the question is being raised with increasing frequency as to when and how this evolution might stop. As shown in Figure 2 the trend in the increase of accelerator energy has not stopped. New inventions have sustained an almost exponential increase in energy of one decade every six years even though the scaling laws pertaining to each type of accelerator have in the past forced a leveling off of the energy attainable by any one method. This increase in energy has been bought at a serious social cost: Because of the high price of each accelerator the total number of installations worldwide which operate at the frontiers of the field has been steadily decreasing. Therefore elementary particle physicists at academic and other institutions have had to carry out their experimental observations away from home. Yet the consensus remains that involvement of academic physicists within the field should be maintained or even strengthened despite this difficulty: Elementary particle physics, since it is among the most basic of the sciences, remains an essential ingredient of the educational program in physics at major universities.

A possible departure from the pattern outlined above has been introduced by the emergence of colliding-beam techniques. It has been recognized for a very long time that the threshold for a reaction among particles to occur is set by the "center-of-mass energy," that is, by the energy measured in that frame in which the center-of-mass of the coliding system is at rest. At highly relativistic particle energies the center-of-mass energy increases only with the square root of the energy (as measured in the laboratory) of the particle that bombards a stationary target; the rest of the energy is converted into the kinetic energy of motion of the center-of-mass of the combined system. The relationship between the center-of-mass energy and the laboratory energy

of particle beams striking stationary targets is shown in Figure 3. Clearly this decreasing efficiency in terms of center-of-mass energy could be circumvented by two beams colliding with one another from opposite directions. This idea is an old one; it is in fact difficult to document how it originated. However, the question here is not that of the idea but of its execution. The problem is that the density of particle beams is vastly inferior to that or ordinary condensed matter and is in fact comparable to that of practically attainable vacua; thus the reaction rates in colliding-beam experiments are apt to be very much lower than those encountered when particle beams strike stationary targets. Quantitatively this factor is measured by a quantity which colliding-beam physicists call the "luminosity." This is the number by which one multiplies the cross section of the reaction under investigation in order to obtain the reaction rate. Luminosity is therefore generally measured in units of cm^{-2} sec^{-1}.

During the last decade there have been many developments which have demonstrated that the luminosities of colliding-beam devices can reach a range practical for important elementary particle physics experiments. The first such demonstration was made in the Stanford-Princeton collaboration, in which two electron beams, each up to 550 MeV, were made to collide in the common section between two magnetic storage rings arranged in a figure eight patter. This installation resulted in a pioneering demonstration that quantum electrodynamics remained valid up to energies that were previously unattainable. The most important and also most amtitious single step in colliding-beam technology was taken in Europe at CERN in their ISR (Intersecting Storage Ring) project which became operational in 1970. In this installation particles are injected into two rings at an energy of 26 GeV from CERN's proton synchrotron; the energy in each ring can be slightly raised above that value by increasing the magnetic field. When two 30 GeV beams collide in one of the six interaction regions of that machine (interaction regions are formed by intersections between straight sections of each ring), the energy in the center-of-mass of the colliding protons (60 GeV) is equivalent to that produced by a beam of 1900 GeV striking a stationary target. The luminosity of this installation has reached a figure somewhat below 10^{30} cm^{-2} sec^{-1}. Since the total cross section for

reactions at very high energies between colliding protons is somewhere near 10^{-25} cm^2, the total interaction rate is in the neighborhood of 10^5 reactions per second. This figure in itself is of course not fully persuasive as to the usefulness of the installation, since not all the reactions produced would be of equivalent interest; for instance, reactions involving large momentum transfer are in general the most sensitive probe of unknown features of strongly interacting particles, but the cross sections decrease steeply with an increase in this quantity. Practical limits set by the art of particle detection would also reduce the number of observed events per second below this figure. Nevertheless the results obtained with the ISR installation thus far have amply demonstrated the exciting possibilities of colliding-beam techniques. Many experiments reported from the ISR have yielded important new knowledge on high energy reaction phenomenology and on the behavior of cross sections governing pairs of particles at these exceedingly high energies. Moreover, searches for new particles and for qualitatively new phenomena have been carried out in this installation which set a lower limit on what might be observable in the future.

Several colliding-beam installations other than the original Princeton-Stanford storage rings and the powerful ISR have also been built. Figure 4 tabulates the worldwide status of these storage ring facilities. Note that the CERN ISR and the SLAC installation SPEAR hold the current record in energy and luminosity for protons and electrons, respectively; the future evolution of colliding-beam devices will be discussed shortly.

There are, of course, many differences other than center-of-mass energy and attainable data rate which distinguish the kinds of physics which can be done with conventional accelerators producing beams striking stationary targets from those possible at colliding-beam installations. Conventional accelerators with stationary targets permit not only the study of primary interactions between the beam particles and the constituents of the target, but they are also "factories" of secondary beams of unstable particles. These secondary beams are frequently at least as valuable as the primary beam in studying elementary particle interactions of a well-identified nature. The

availability of secondary beams means that a "conventional" accelerator can service a very large number of experimental stations and thus support a larger community of particle physics experiments; in contrast the number of experiments at a colliding-beam facility is generally restricted to the number of "interaction regions."

The use of conventional accelerators in which either primary or secondary beams strike material targets (usually liquid hydrogen) introduces a complicating factor: since baryons (protons and neutrons or one of their strange partners like the lambda) are conserved in any elementary particle process, the struck proton in the collision will either be present in the final state, or else it will have changed into such a baryon. Accordingly, in reactions in which, for instance, a pair of pions of opposite charge is created in the collision, a nucleon will also be present; therefore the final state is a 3-body rather than a 2-body system. Thus the interaction between two pions in isolation cannot be studied with a conventional accelerator. In contrast, when, for instance, electrons and positrons collide in a storage-ring arrangement, these two particles annihilate into purely electromagnetic energy known as a "virtual photon." This virtual photon is at rest in the laboratory and can re-materialize into any combination of particles in the final state which obey the conservation laws applicable to that situation. Specifically the virtual photon is neutral, has spin 1, and has negative intrinsic parity. According to the conservation laws this permits, for example, a pair of positive and negative pions or kaons to be formed in the final state, or one of the so-called vector mesons to be created (these generally decay into pairs of pions or kaons). These objects are thus made available in the laboratory without the disturbing influence of a nucleon, so the interaction between pairs of unstable particles can be studied under conditions of much greater simplicity than is possible with conventional accelerators. Not only is the absence of a hadron a simplifying factor, but also the well-defined quantum numbers of the initial state simplify analysis of the unknown final state interaction, since the number of spectroscopic "states" in the final state is constrained.

"Conventional" accelerators and storage rings need not be separate installations; on the contrary, a conventional accelerator can serve the dual purpose

of injecting particles into a storage ring and of supporting a research program in its own right. This is the case at SLAC which is shown in Figure 5. Here the two-mile accelerator operates both at the energy and intensity frontier of electron machines, but also injects electrons and positrons into a colliding-beam storage ring called SPEAR; this device operates at present also at the highest luminosity and energy of existing electron colliding-beam installations. Similarly, the CERN international laboratory at Geneva operates the ISR and its injecting proton synchrotron as a system of separate research tools.

To summarize, we find that conventional accelerators producing beams striking stationary targets and storage rings producing colliding beams have both assets and deficiencies for high energy particle physics. Generally the conventional accelerators yield much higher intensities and produce useful secondary beams; whereas storage rings can produce much higher center-of-mass energies and can produce states of interaction that are easier to analyze in terms of fundamental questions. Thus normally one would conclude that both of these accelerator types have their proper area of usefulness and both should be developed further. This statement implies that there are no technological or financial limits towards pursuing either or both directions; in practice both of these limits are, of course, very real. Technology alone at this time does not impose any substantial basic upper bound on the performance of conventional accelerators. The "alternating gradient synchrotron" using conventional magnets can in principle be extended to any arbitrary energy provided that limits of real estate or the taxpayers' tolerance do not intervene. Once development of reliable superconducting magnets has been completed their substitution would reduce the required space but not necessarily the cost of an accelerator installation. There are technological limits governing the intensity attainable by proton synchrotrons and electron linacs; these in part derive from the characteristics of practical injection systems, in part from radioactivity and the problem of designing targets for very intense beams, and also in part from certain factors set by beam orbit dynamics which limit the intensity of beams which can be accelerated. However, ultimately both the energy and intensity limits of conventional accelerators appear financial rather than physical.

The intensity limitations on storage rings, in contrast, are more fundamental. In a storage ring the two beams which are destined to collide in the interaction regions must be stored in a magnetic guide field for a period of time measured in minutes or hours. This poses extreme requirements on vacuum technology; moreover, in the case of electrons, energy is radiated during the storage process, requiring very high radiofrequency power to compensate for this loss. However, most basic is the fact that such stored beams must be stable, and it has been the history of each new generation of storage rings that new sources of instability have been discovered whenever a new design entered the test phase. There are many such instabilities: those associated with the storage of a single beam, and those associated with the interaction between the colliding beams. Single-beam instabilities can in principle be controlled by feedback mechanisms, although in practice this can be exceedingly difficult. The interaction between the beams produces modifications of the focusing conditions confining each beam; if such shifts become too large this produces instabilities which are in principle difficult, if not impossible, to prevent. Such beam-beam instabilities thus set a limit to the practically attainable luminosity of storage rings. Several inventions have been made in recent times which advance this limit substantially, but even so it is clear that the interaction rates of storage ring-colliding-beam installations will always be many orders of magnitude below those attainable in interactions of the primary beam found in conventional accelerators with a stationary target. However, the interaction rates become quite comparable if colliding-beam installations are compared with the use of secondary beams from conventional accelerators.

Figure 6 attempts to make a more quantitative comparison between the performance of storage rings and that of conventional accelerators, albeit in a highly oversimplified way. The chart plots the "effective luminosity" of the installation in question against the center-of-mass energy. The luminosity of a conventional accelerator depends, of course, on the thickness of the target actually employed, and we assume in this chart that such a target is a 1-meter-long vessel of liquid hydrogen. The chart also assumes that the efficiency for detecting

the products of reactions produced in both colliding-beam devices and conventional accelerators is 100%, that is, that all the reaction products are seen. Note that the chart spans a range of approximately 20 decades in luminosity, while the installations shown in the chart range some two decades in center-of-mass energy (which would be four decades in laboratory energy for conventional accelerators!).

The chart shows inside a dashed rectangle a series of installations which are at present under active discussion for the future. Such studies are being carried out both on the West Coast with emphasis both on electron-positron and lepton-proton storage rings, and on the East Coast with emphasis on proton-proton storage rings; similar studies are in progress in Europe. These studies project the storage-ring art for protons and electrons well beyond that available at the ISR at CERN and the SPEAR electron-positron ring at SLAC. These studies have been encouraged by the very high productivity experienced with the ISR installation and the successful initial turn-on of SPEAR. You will note that the center-of-mass energy in the most ambitious of these studies might reach as high as 400 GeV; this is the same center-of-mass energy as that obtained when a beam of 80,000 GeV protons strikes a stationary target, clearly an impossible goal for ordinary means of acceleration. In looking to the future the primary problem is therefore whether such very large storage rings can in fact be built at a useful luminosity, and from this arises the question "What is a useful luminosity?"

The question of minimum useable luminosity is of course associated with the projected areas of interest on which high energy physics might focus in this ultra-high-energy region. Adequate discussion of this topic would lead much too far afield. However for illustration let me place an overlay on Figure 6 which shows the minimum luminosity required to produce a counting rate of 1 count/hour for processes driven by the three dominant forms of interaction in elementary particle physics: the electromagnetic interaction, the weak interaction, and the interaction among strongly interacting particles

known as hadrons. The cross section for the electromagnetic interaction between two charged particles which leads to point-like end products is expected to decrease inversely as the square of the center-of-mass energy; the validity of the theory which predicts this behavior has been demonstrated thus far over the full range of energy studied to date. Moreover studies of the reaction

$$e^+ + e^- \rightarrow \text{any combination of hadrons}$$

over the range of energies accessible to electron-positron storage rings to date have shown that the cross section for this process decreases with energy no faster than that of the point-like process (such as $e^+ + e^- \rightarrow \mu^+ + \mu^-$) and exceeds it in magnitude.*

The weak interaction is expected to exhibit a cross section which increases linearly with the square of the center-of-mass energy, and the chart indicates that at energy near 100 GeV the weak and the electromagnetic cross sections might cross over.** It is, of course, generally recognized that no cross section in nature can increase indefinitely with energy, and that something has to "go wrong" with the theory before the so-called "unitarity limit" for quantum mechanics is reached. Therefore particle physicists confidently expect that the Fermi theory of weak interactions in which four spin one-half particles are assumed to interact at a mathematical point will not remain valid to indefinitely high energies; eventually this interaction will have to be carried by some kind of mediating particle.

The total cross section derived from strong interactions is expected to remain roughly constant, as is also shown on the chart.*** However the

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*The reference electromagnetic cross section used in the chart is that of the reaction $e^+ + e^- \rightarrow \mu^+ + \mu^-$

**The reference weak interaction cross section used in the chart is that of the reaction

$$e^- + p \rightarrow \text{neutrino plus any combination of hadrons}$$

***The reference "strong" cross section used is the total cross section for the reaction

$$p + P \rightarrow \text{anything}$$

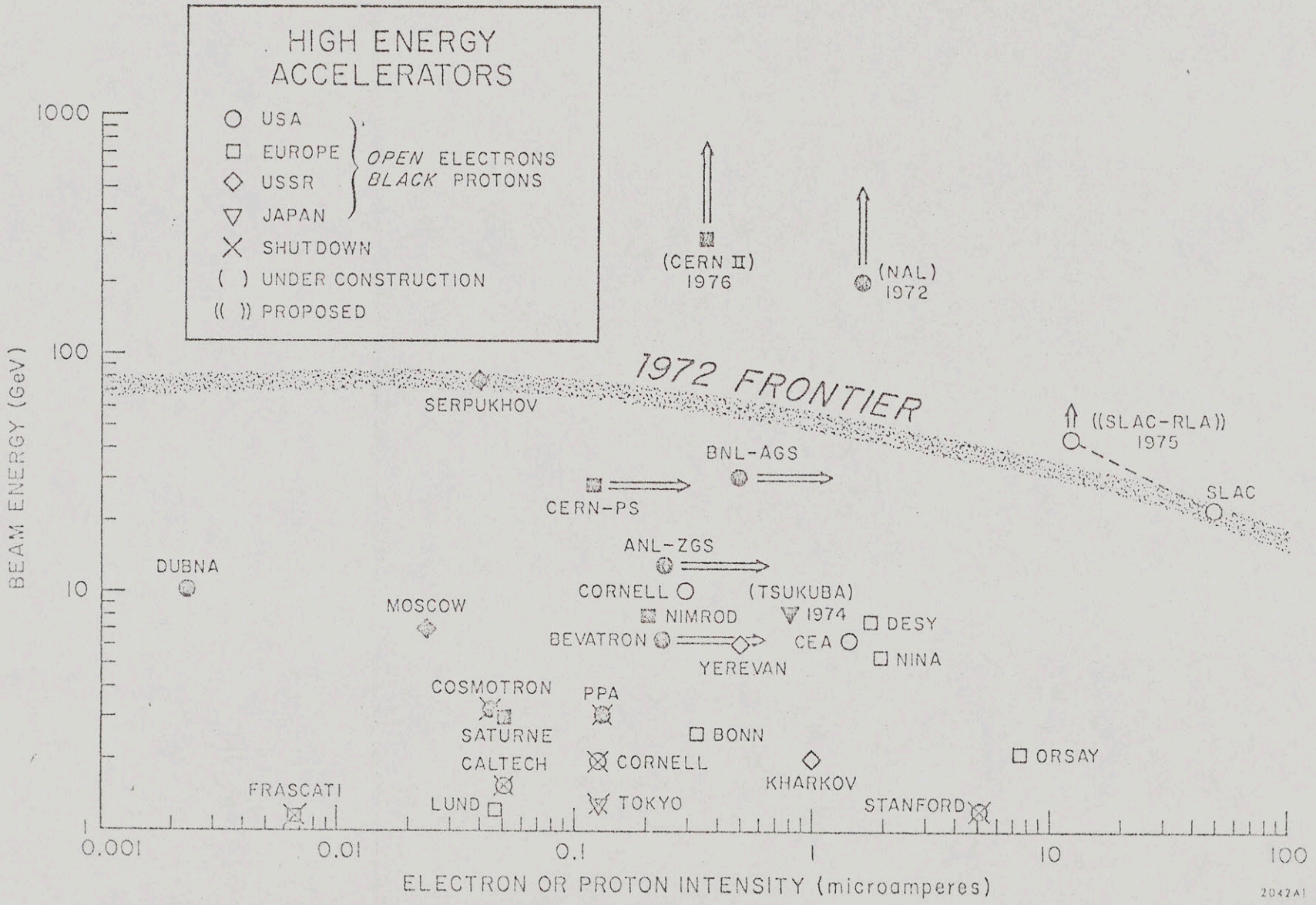
partial cross sections of greatest interest are much smaller: these involve large transfers of momentum among the colliding particles; the chart shows that partial cross sections of as low as 10^{-10} times the magnitude of the total cross section might be accessible to measurement at storage rings whose luminosities are adequate for the observation of the weak and electromagnetic interactions. One might speculate that at corresponding momentum transfers the strong interaction cross sections approach those of weak and electromagnetic interactions at energies in the center-of-mass near 100 GeV.

It appears plausible, therefore, that near a center-of-mass-energy near 100 GeV (which is an energy nobody dreamed of reaching in the laboratory until a relatively short time ago), the basic distinction between weak, strong and electromagnetic interactions might lose meaning, at least as far as signifying magnitudes of cross sections is concerned. There are some members of the theoretical community who are optimistic that work at these extremely high energies will lead to the discovery of unifying principles which will combine their understanding of these different forms of interactions, which have thus far been treated in an essentially separate manner; unification of weak and electromagnetic interactions has already been attempted with some success. Whether this highly ambitious goal will in fact be reached with such installations is of course for the future to decide; even from a more simplistic point of view it is clear, however, that storage rings permit in principle an enormous extension of the kinematic parameters accessible to experimenters that is simply not possible by any other means.

This chart should, however, induce some caution; in the "exciting" region at which these curves converge a luminosity of 10^{32} cm^{-2} sec^{-1} would yield only a few counts per hour, and this value should thus be considered a practical minimum objective for storage-ring installations. Orbit theorists are optimistic that such luminosity values can be obtained; the SPEAR storage ring at SLAC is now only 1 order of magnitude short of this goal, while the ISR operates currently 2 orders of magnitude below this value.

Some rough economic comparisons might also be useful. Without going into detail it appears that the generation of super storage rings will cost less than the NAL accelerator, now in its final test phase near Chicago, or the CERN-II accelerator, now under construction at Geneva. It is certain that the cost will be about an order of magnitude below that of any follow-on conventional accelerator installation exceeding 1,000 GeV in energy.

Let me summarize: The evolution of sources of high-energy particles for use in elementary particle physics is now approaching a fork in the road. One path leads to "conventional" accelerators of higher and higher energy, and the other leads to "super-storage-rings" which promise attainment of center-of-mass energies and access to new physics, hitherto unimaginable, but which require advances in luminosity in order to be practically useful. Considering these facts and the expectation that the second path promises advances at lower cost, it will be pursued in the future with increasing enthusiasm. Whether another step along the former path will be taken, either in the United States or abroad, is a matter of intensive current discussion, in particular in the Soviet Union. I hope, however, that I have presented an over-view which has been persuasive in showing that the field of elementary particles is very far from being "run dry," either in terms of expected fundamental findings or in terms of available technology to provide the tools.


HIGH ENERGY ACCELERATORS
USA
EUROPE
USSR
JAPAN
OPEN ELECTRONS
BLACK PROTONS
SHUTDOWN
( ) UNDER CONSTRUCTION
(( )) PROPOSED
(CERN II) 1976
(NAL) 1972
1972 FRONTIER
((SLAC-RLA)) 1975
SLAC
SERPUKHOV
BNL-AGS
CERN-PS
ANL-ZGS
DUBNA
CORNELL
(TSUKUBA)
MOSCOW
NIMROD
1974
DESY
BEVATRON
CEA
NINA
YEREVAN
COSMOTRON
PPA
SATURNE
BONN
CALTECH
CORNELL
ORSAY
KHARKOV
FRASCATI
LUND
TOKYO
STANFORD
1000
100
10
1
0.001
0.01
0.1
1
10
100
BEAM ENERGY (GeV)
ELECTRON OR PROTON INTENSITY (microamperes)
2042A1

II. Fig. 1

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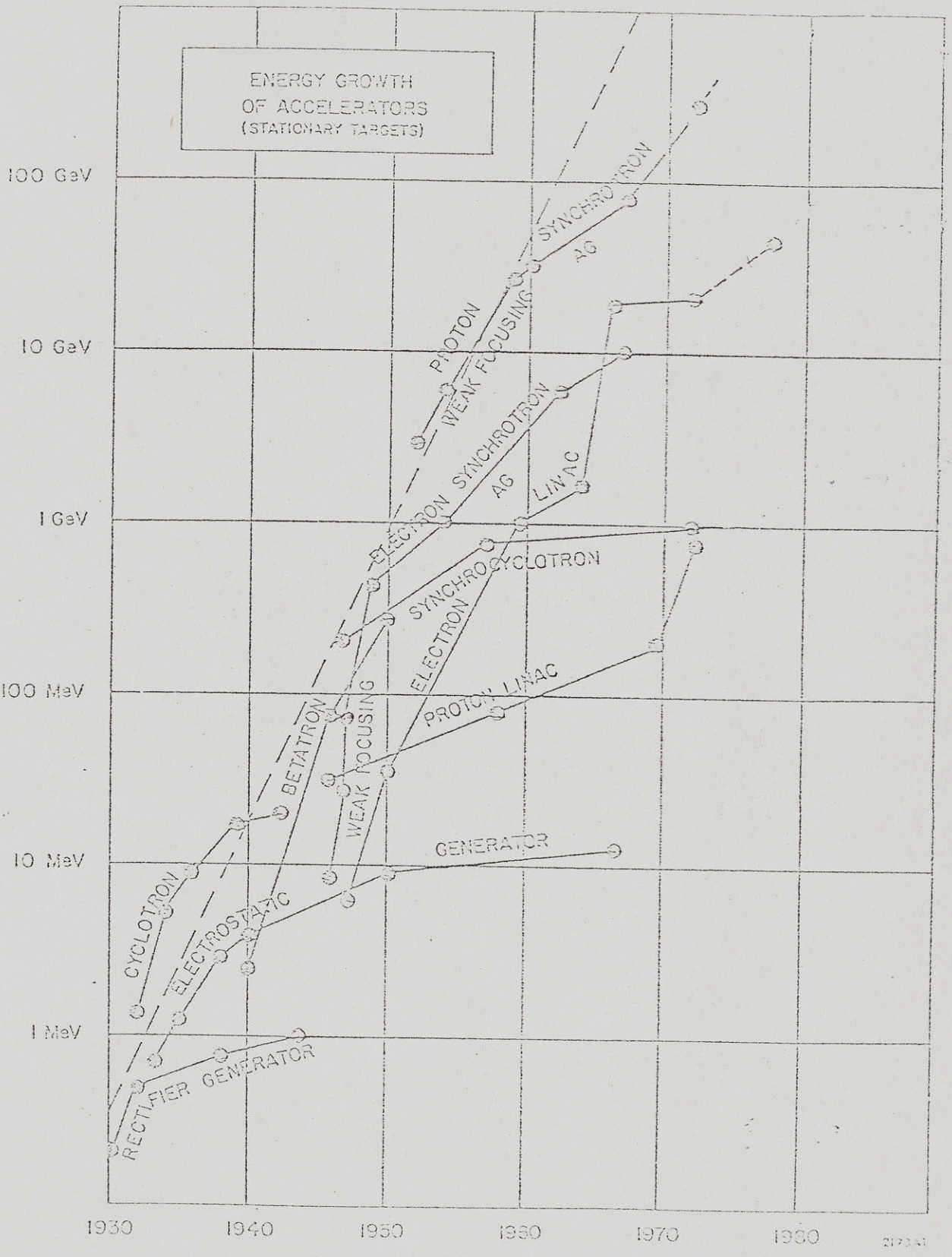
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II. Fig. 1. Energy vs intensity of high-energy accelerators. The facilities shown in Fig. 1 are described more fully in the following table.

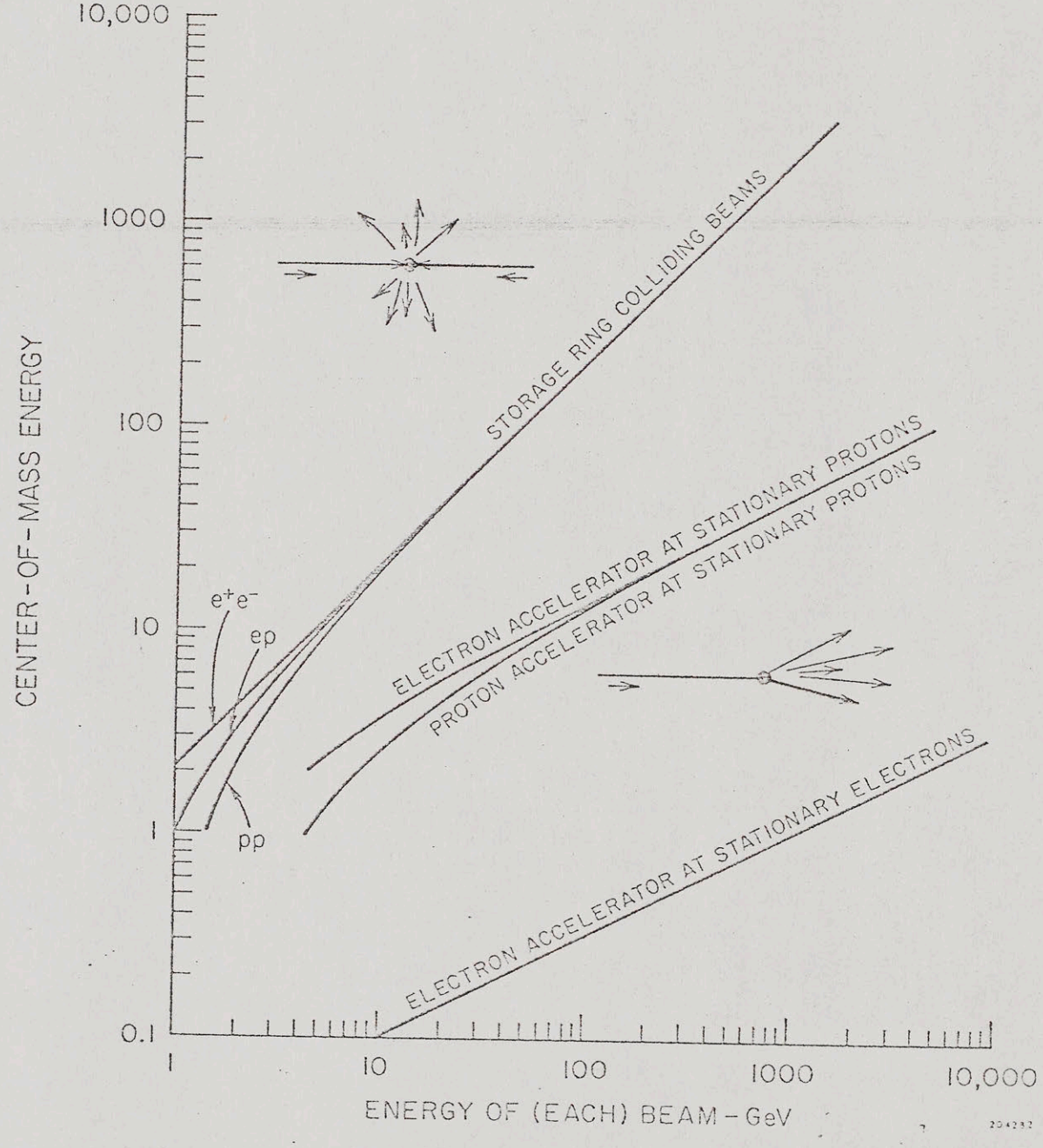
Machine	Energy (GeV)	Fig. 1 Name	Institution	Location	Remarks
Electron Synchrotron	1	Frascati	Laboratori Nazionali del CNEN	Rome, Italy	Shut down
	1	Lund	University of Lund	Lund, Sweden	
	1	Tokyo	Tokyo University	Tokyo, Japan	Shut down
	1.5	CalTech	Cal Tech	Pasadena, California	Shut down
	2	Cornell	Cornell University	Ithaca, New York	Shut down
	2.5	Bonn	University of Bonn	Bonn, W. Germany	
	4	NINA	Daresbury Nuclear Physics Lab.	Daresbury, U. K.	
	6	Yerevan	Yerevan Physical Institute	Yerevan, USSR	
	6	CEA	Cambridge Electron Accelerator	Boston, Mass.	
	7	DESY	Deutsches Elektronen-Synchrotron	Hamburg, W. Germany	
	10	Cornell	Cornell University	Ithaca, New York	
Electron Linac	1	Stanford	High-Energy Physics Lab., Stanford	Stanford, California	Shut down
	2	Kharkov	Physico-Technical Institute	Kharkov, USSR	
	2	Orsay	University of Paris	Orsay, France	
	22	SLAC	SLAC, Stanford University	Stanford, California	
	50	SLAC-RLA	SLAC, Stanford University	Stanford, California	Under design

II. Fig. 1. (Continued)

Machine	Energy (GeV)	Fig. 1 Name	Institution	Location	Remarks
Proton Synchrotron	3	Cosmotron	Brookhaven National Laboratory	Upton, L.I., N.Y.	Shut down
	3	Saturne	Centre D'Etudes Nuclieres	Saclay, France	
	3	PPA	Princeton-Pennsylvania Accel.	Princeton, N. J.	Shut down
	6	Bevatron	LBL, U. of Cal., Berkeley	Berkeley, Cal.	
	7	Moscow	Instit. of Exper. & Theor. Phys.	Moscow, USSR	
	7	Nimrod	Rutherford Lab.	Harwell, U. K.	
	8	Tsukuba	National Lab for High-Energy Phys.	Tsukuba, Japan	Ready in 1974
	10	Dubna	Joint Instit. for Nuclear Research	Dubna, USSR	
	12	ANL-ZGS	Argonne National Lab.	Chicago, Illinois	
	28	CERN-PS	European Organ. for Nuclear Res.	Geneva, Switzerland	
	30	BNL-AGS	Brookhaven National Laboratory	Upton, L.I., N.Y.	
	76	Serpukhov	Instit. for High Energy Phys.	Serpukhov, USSR	
	200	NAL	National Accelerator Lab.	Batavia, Illinois	Ready in 1972
	300	CERN II	European Organ. for Nuclear Res.	Geneva, Switzerland	Ready in 1976


ENERGY GROWTH
OF ACCELERATORS
(STATIONARY TARGETS)
100 GeV
10 GeV
1 GeV
100 MeV
10 MeV
1 MeV
1930
1940
1950
1960
1970
1980
PROTON
WEAK FOCUSING
SYNCHROTRON
AG
ELECTRON SYNCHROTRON
AG
LINAC
SYNCHRO-CYCLOTRON
ELECTRON LINAC
PROTON LINAC
BETATRON
WEAK FOCUSING
GENERATOR
CYCLOTRON
ELECTROSTATIC
RECTIFIER GENERATOR

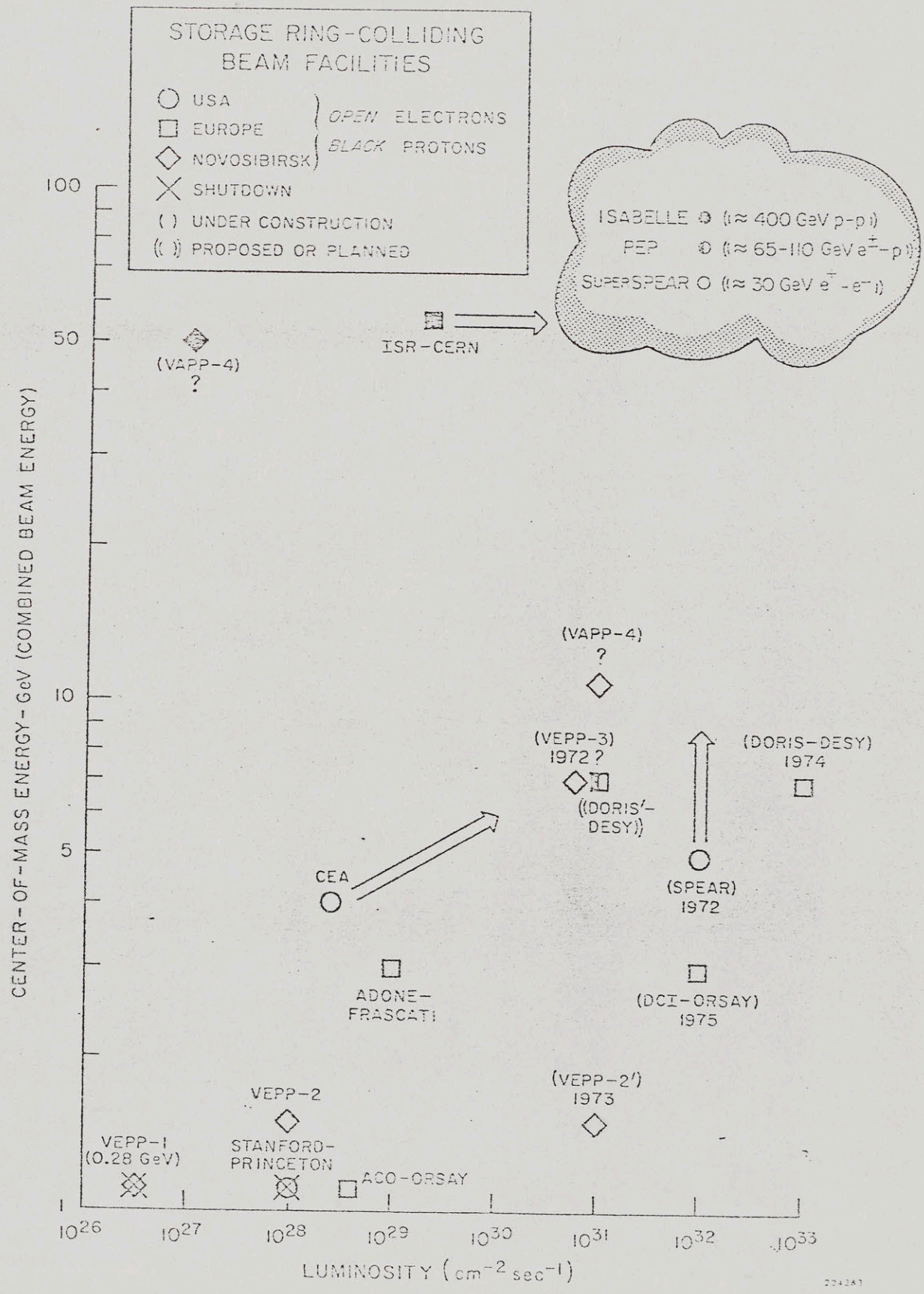
II. Fig. 2


10,000
1000
100
10
1
0.1
CENTER-OF-MASS ENERGY
STORAGE RING COLLIDING BEAMS
ELECTRON ACCELERATOR AT STATIONARY PROTONS
PROTON ACCELERATOR AT STATIONARY PROTONS
ELECTRON ACCELERATOR AT STATIONARY ELECTRONS
e+e-
ep
pp
1
10
100
1000
10,000
ENERGY OF (EACH) BEAM - GeV
204232

II. Fig. 3



II - Fig. 4


STORAGE RING-COLLIDING BEAM FACILITIES
USA
EUROPE
NOVOSIBIRSK
OPEN ELECTRONS
BLACK PROTONS
SHUTDOWN
( ) UNDER CONSTRUCTION
(( )) PROPOSED OR PLANNED
ISABELLE (≈ 400 GeV p-p)
PEP (≈ 65-110 GeV e±-p)
SUPERSPEAR (≈ 30 GeV e⁻-e⁻)
ISR-CERN
(VAPP-4) ?
(VAPP-4) ?
(VEPP-3) 1972 ?
((DORIS'-DESY))
(DORIS-DESY) 1974
CEA
(SPEAR) 1972
ADONE-FRASCATI
(DCI-ORSAY) 1975
(VEPP-2') 1973
VEPP-2
VEPP-1 (0.28 GeV)
STANFORD-PRINCETON
ACO-ORSAY
100
50
10
5
1
CENTER-OF-MASS ENERGY - GeV (COMBINED BEAM ENERGY)
10²⁶
10²⁷
10²⁸
10²⁹
10³⁰
10³¹
10³²
10³³
LUMINOSITY (cm⁻² sec⁻¹)

II. Fig. 5

II. Fig. 5. Center-of-mass energy vs. luminosity for storage-ring colliding-beam facilities. The facilities shown in Fig. 5 are described more fully in the following table.

Particles Stored	Energy Of Each Beam (GeV)	Fig. 5 Name	Institution	Location	Remarks
Electrons + Electrons	0.14	VEPP-1	Institute of Nuclear Physics	Novosibirsk, USSR	Shut down.
	0.55	Stanford-Princeton	High-Energy Phys. Lab, Stanford	Stanford, Cal.	Shut down.
Electrons + Positrons	0.55	ACO-Orsay	Univ. of Paris	Orsay, France	
	0.75	VEPP-2	Institute of Nuclear Physics	Novosibirsk, USSR	
	0.75	VEPP-2'	" " "	"	Ready in 1973.
	1.5	Adone-Frascati	Laboratori Nazionali del CNEN	Rome Italy	
	1.5	DCI-Orsay	Univ. of Paris	Orsay, France	Ready in 1975.
	2.5	SPEAR	SLAC, Stanford Univ.	Stanford, Cal.	Oper. in 1972.
	3.5	CEA	Cambridge Electron Accelerator	Boston, Mass.	
	3.5	VEPP-3	Institute of Nuclear Physics	Novosibirsk, USSR	Ready in 1972?
	3.5	Doris-DESY	Deutsches Elektronen Synchrotron	Hamburg, W. Germ.	Ready in 1974.
	6	VAPP-4	Institute of Nuclear Studies	Novosibirsk, USSR	Date uncertain
	15	SuperSPEAR	SLAC, Stanford Univ.	Stanford, Cal.	Under study.
Electrons + Protons	3.5	Doris-DESY	Deutsches Elektronen Synchrotron	Hamburg, W. Germ.	Under study.
	15 e^- or e^+ / 70 or 200 p	PEP	SLAC, Stanford + LBL, Berkeley	Stan., Berkeley	Under study.
Protons + Protons	28	ISR-CERN	European Organ. for Nuclear Res.	Geneva, Switz.	
	200	ISABELLE	Brookhaven Nat. Lab. + Collab.	Upton, L.I., N.Y.	Under study.
Protons + Antiprotons	24	VAPP-4	Institute of Nuclear Research	Novosibirsk, USSR	Date uncertain.

Fig. 6. Effective luminosity vs. center-of-mass energy for several accelerators and storage rings, existing and under study. The facilities shown are identified in previous figures except for the following:

(a) SuperSPEAR is a study being carried out at SLAC of the possible characteristics and uses of a colliding-beam storage ring that would store beams of electrons and positrons up to energies of 15 GeV (each beam).

(b) PEP is a study being carried out by a collaborative group from SLAC and LBL, Berkeley, on the possible characteristics and uses of a colliding-beam storage ring that would permit collisions between 15 GeV electrons and 15 GeV positrons, or between either of these particles and 70 to 200 GeV protons.

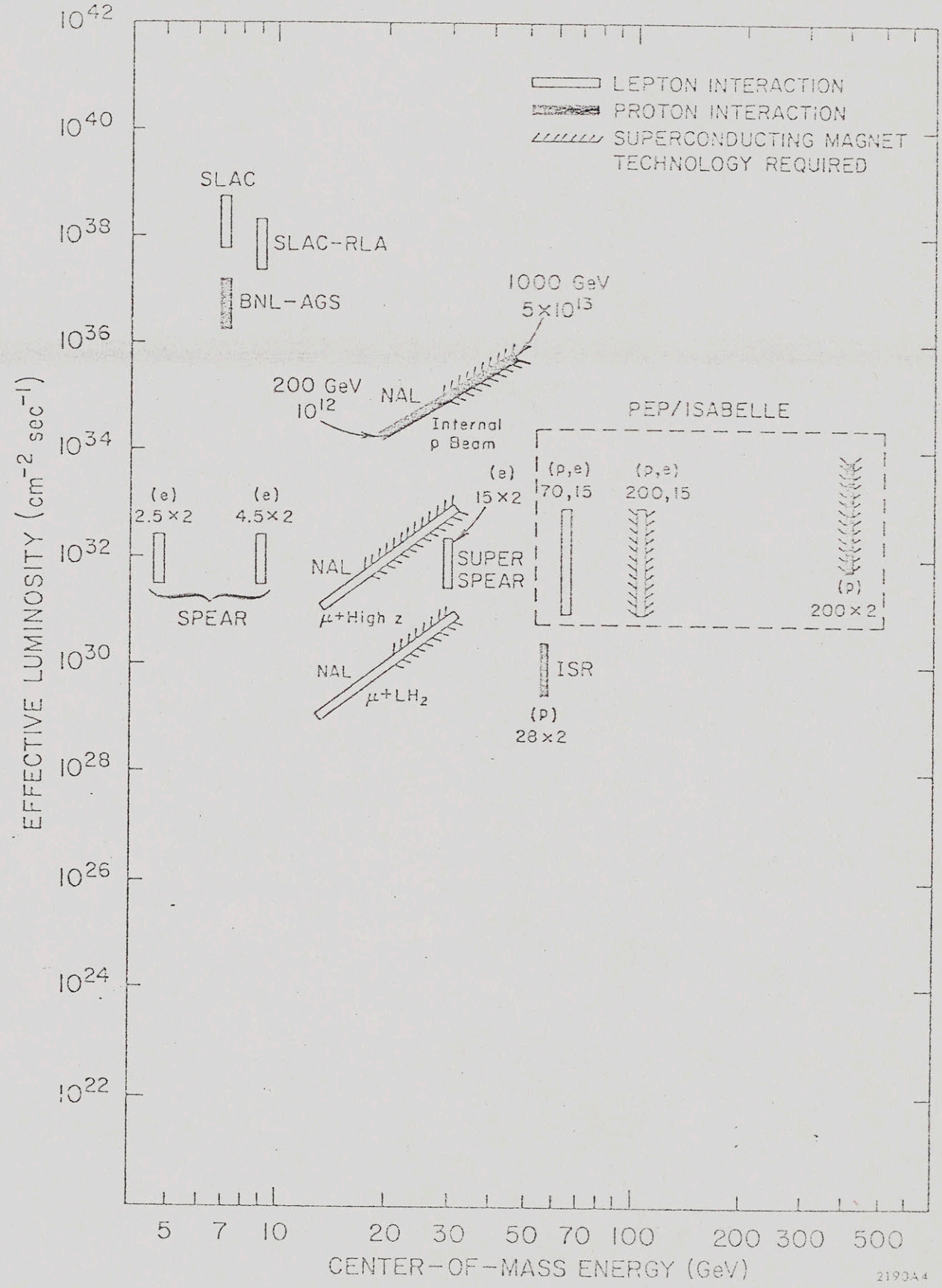
(c) ISABELLE is a study being carried out by a group from Brookhaven National Laboratory and collaborators on the possible characteristics and uses of a colliding-beam storage ring that would permit collisions between beams of protons having energies up tp 200 GeV (each beam).

Figure 6 attempts to display both accelerator and storage-ring installations on a comparable scale. Naturally, such an attempt will involve some oversimplification. The data rates attainable are described by an "effective luminosity"; this is the number by which the cross section (measured in cm^2) of the reaction channel under observation is to be multiplied to arrive at a rate in events per second. This scale replaces the "intensity" figures, in microamperes or in particles per pulse, that are usually displayed for accelerators. It is assumed that the reaction in question is observed at 100% efficiency, and that the detector solid angle collects all the events of interest. To apply this concept to an accelerator, it is assumed that (unless otherwise indicated) a liquid hydrogen target of one-meter length is used. With the exception of the muon-beam entries, all figures refer to primary beams.

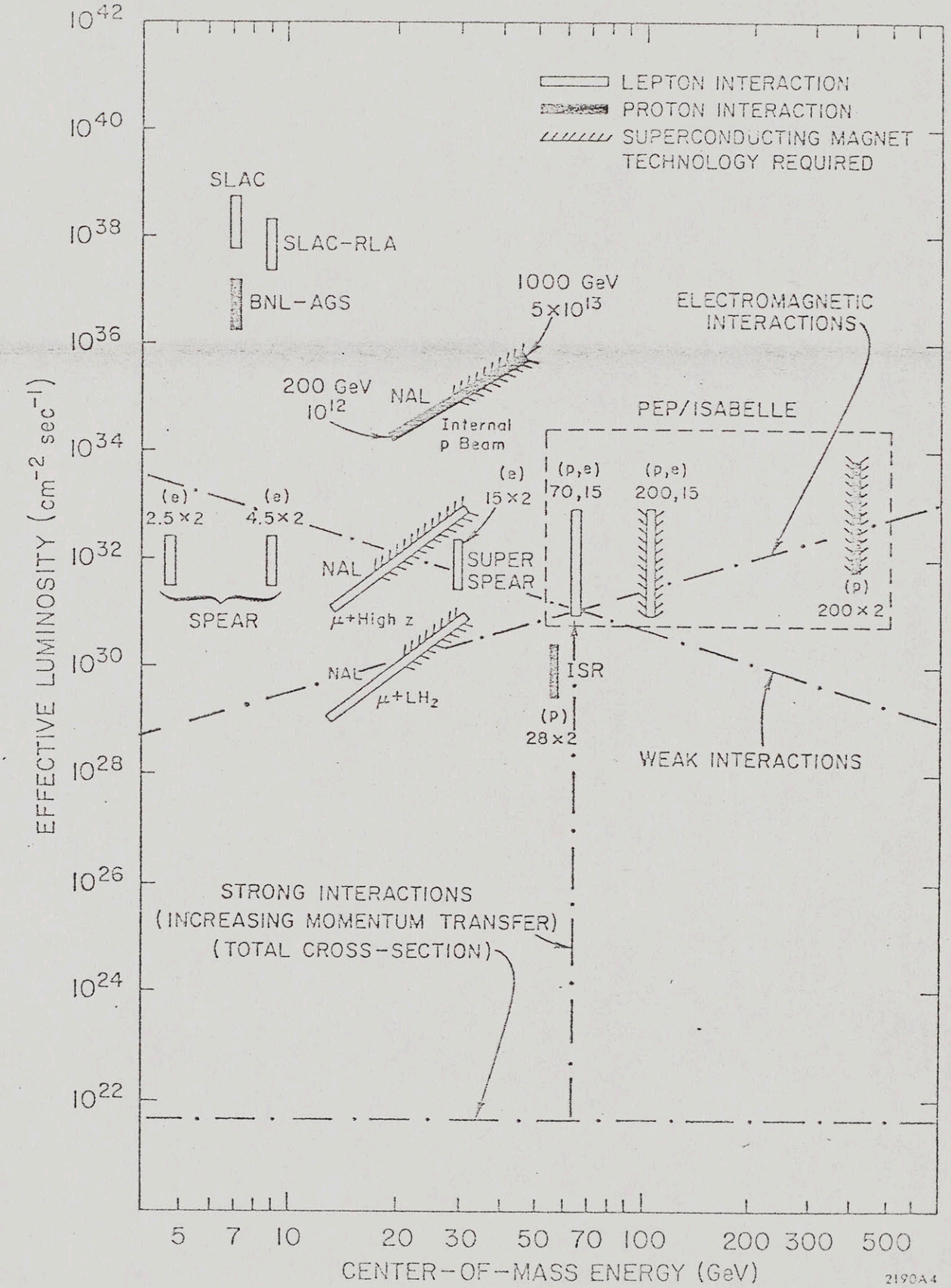
Center-of-mass energies are plotted under the assumption of a stationary proton target in the case of conventional accelerators. Those U.S. accelerators which are operating or are under study, and which have a center-of-mass energy greater than 5 GeV, are listed in the figure. The CERN ISR is shown for comparison with the U.S. colliding-beam storage-ring projects under consideration. CERN II is not explicitly shown, but its performance would be comparable to NAL. NAL performance is shown under a wide range of assumptions; these range from an energy of 200 GeV at 10^{12} protons per pulse (which might be available for physics research by the end of this calendar year) all the way up to an intensity of 5×10^{13} protons per pulse at an energy of 1000 GeV. The latter values are very optimistic assumptions, both in regard to intensity and to the feasibility of the superconducting "doubler" project for NAL.

Since the engineering feasibility of large-scale superconducting magnet technology has not been demonstrated, a special notation is made in the figure to point out those devices that would require such technology.

The dash-dot lines on the figure indicate the luminosities that are required to achieve a counting rate of one event per hour, at the center-of-mass energies shown, for weak, strong, and electromagnetic interactions. The vertical dash-dot line extending upward from the strong-interaction line is meant to point out the increasing luminosities needed for rates of one count per hour for events of increasing momentum transfer.


LEPTON INTERACTION
PROTON INTERACTION
SUPERCONDUCTING MAGNET TECHNOLOGY REQUIRED
SLAC
SLAC-RLA
BNL-AGS
1000 GeV
5×10^13
200 GeV
10^12
NAL
Internal
p Beam
PEP/ISABELLE
(e)
2.5×2
(e)
4.5×2
SPEAR
(e)
15×2
NAL
SUPER
SPEAR
μ+High z
NAL
μ+LH2
(p,e)
70,15
(p,e)
200,15
(p)
200×2
ISR
(p)
28×2
EFFECTIVE LUMINOSITY (cm^-2 sec^-1)
10^42
10^40
10^38
10^36
10^34
10^32
10^30
10^28
10^26
10^24
10^22
5
7
10
20
30
50
70
100
200
300
500
CENTER-OF-MASS ENERGY (GeV)
2190A4

II. Fig. 6



II. Fig. 6 overlay

Enclosure II

LIST OF FIGURES

Note: The captions for Figs. 1, 5 and 6 are given separately, and are placed directly after each of these figures.

2. The energy growth of accelerators from 1930 to the present.

3. Center-of-mass energy vs. beam energy for accelerators and storage rings.

4. Aerial view of the Stanford Linear Accelerator Center, showing the recently completed storage ring, SPEAR.

ENCLOSURE III

COMMITMENT TIMES INVOLVED IN
THE EXPERIMENTAL PROGRAM AT SLAC

ENC III

TIME SPAN OF SELECTED EXPERIMENTS AT SLAC USING ELECTRONIC RECORDING TECHNIQUES

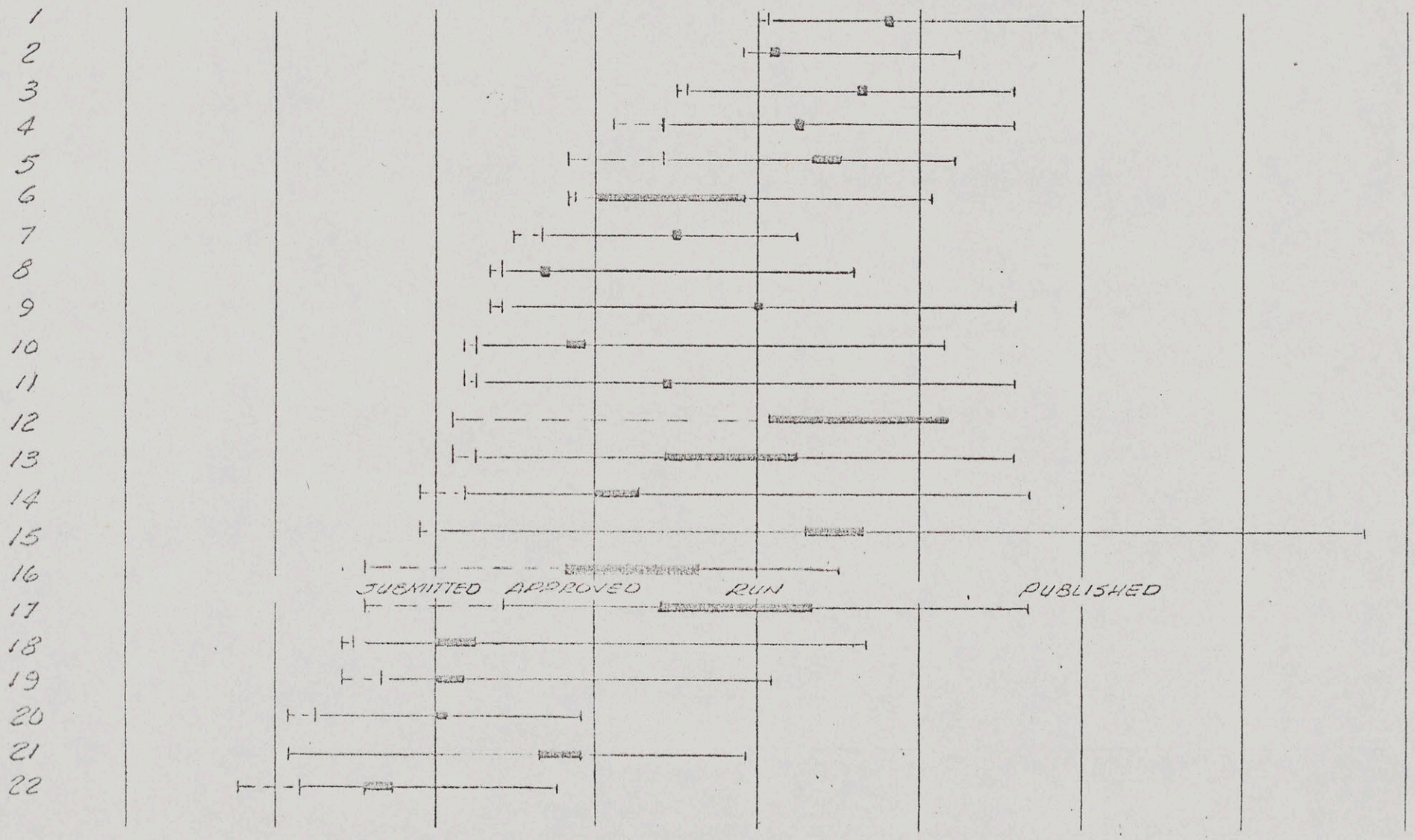


FIG. III - 1

TIME SPAN OF SELECTED EXPERIMENTS[1]

AT SLAC USING ELECTRONIC RECORDING TECHNIQUES

Completed Experiments	Date First Submitted	Date Approved	Date Run First	Date Run End	Accelerator Hours	Institutions[2]	Date[3] Analysis Completed	[3] Date of Publication	Month Interv
1) E-87	Dec 71	Jan 72		Oct 72	584	MIT-SLAC	July 73	Nov 73	24
2) E-86	Nov 71	Nov 71		Jan 72	243	NAL-SLAC	Dec 72	Feb 73	16
3) E-79	June 71	July 71		Aug 72	341	HEPL-Stanford	Feb 73	June 73	25
4) E-76a	Jan 71	May 71		Mar 72	305	UCSB	Mar 73	June 73	30
5) E-74a	Oct 70	May 71	Apr 72	June 72	570	SLAC-Tufts	Dec 72	Feb 73	29
6) E-73 A&B	Oct 70	Nov 70	Dec 70	Nov 71	604	Harvard U of Wisconsin SLAC	July 72	Dec 72	27
7) E-71	June 70	Aug 70		June 71	430	UCSC-SLAC	Dec 71	Feb 72	21
8) E-69	Apr 70	May 70		Aug 70	442	John Hopkins UCLA-SLAC	May 72	June 72	27
9) E-68	Apr 70	May 70		Dec 71	320	U of Wisconsin	Dec 72	June 73	39
10) E-67	Feb 70	Mar 70	Oct 70	Nov 70	361	SLAC	Dec 71	Jan 73	36
11) E-66	Feb 70	Mar 70		May 71	850	SLAC	Feb 73	June 73	41
12) E-65	Jan 70	Dec 71	Jan 72	Feb 72	506	SLAC	Nov 72	Feb 73	37
13) E-64	Jan 70	Mar 70	May 71	Mar 72	1001	UCSC-SLAC Stanford	Oct 72	June 73	42
14) E-61	Nov 69	Feb 70	Dec 70	Mar 71	598	UCSC-SLAC	Mar 73	July 73	45
15) E-60	Nov 69	Dec 69	Apr 72	Aug 72	329	UC-LBL UC-Riverside SLAC	Feb 74	Aug 75	70
16) E-56A	July 69	Oct 70	Oct 70	Aug 71	639	U of Penn UCSC-SLAC	Feb 72	May 72	35
17) E-55	July 69	May 70	May 71	Apr 72	514	Colorado UCSC-SLAC	Jan 73	July 73	49
18) E-53	May 69	Jun 69	Dec 69	Mar 70	179	UCSB	Mar 72	July 72	39
19) E-52	May 69	Aug 69	Dec 69	Feb 70	208	Northwestern Stanford-SLAC	June 71	Dec 71	32

TIME SPAN OF SELECTED EXPERIMENTS[1]

AT SLAC USING ELECTRONIC RECORDING TECHNIQUES

(continued)

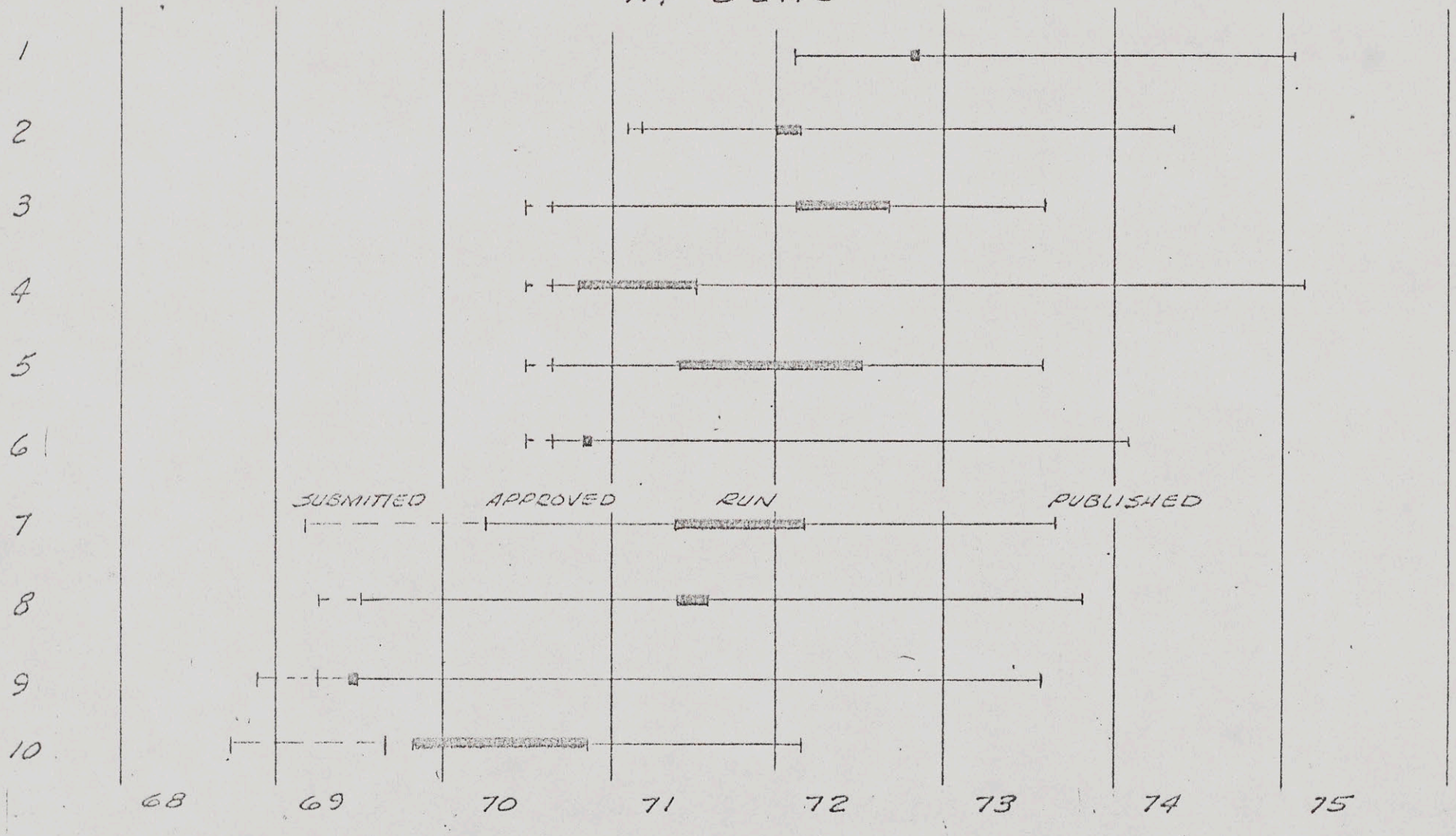
Completed Experiments	Date First Submitted	Date Approved	Date Run First	Date Run End	Accelerator Hours	Institutions[2]	Date Analysis Completed[3]	Date of Publication[3]	Months Interv
20) E-50a	Jan 69	Mar 69	Dec 69	Jan 70	277	Harvard Northwestern SLAC	June 70	Oct 70	22
20) E-50b	Jan 69		Aug 70	Nov 70	378	Harvard Northwestern SLAC	May 71	Oct 71	34
22) E-44	Sept 68	Feb 69	July 69	Aug 69	512	John Hopkins CERN UCLA-SLAC	June 70	Aug 70	24

1) Experiments are those that have most recently completed running at SLAC.

2) If the official spokesman was not available contact was made with anyone with knowledge of the experiment.

3) Obviously dates after this compilation (Nov.72) represent "best guess" for completion of analysis and publication. Publication date means first paper giving results from analysis of all data in a regular scientific journal. Subsequent publications are sometimes issued elaborating further on the results or presenting secondary analysis.

TIME SPAN OF SELECTED BUBBLE CHAMBER EXPERIMENTS AT SLAC



CALENDAR YEAR

FIG. III - 2

TIME SPAN OF SELECTED BUBBLE CHAMBER EXPERIMENTS[1]
AT SLAC

Completed Experiments	Date First Submitted	Date Approved	Date Run First	Date Run End	Pictures (in thousands)	Institutions[2]	Date Analysis Completed[3]	Date of Publication[3]	Months Interval
1) BC-50	Jan 72	Jan 72		Oct 72	339	Duke U of N C	Oct 74	Dec 74	36
2) BC-47	Jan 71	Feb 71	Dec 71	Feb 72	896	UC-LBL SLAC	Oct 73	Mar 74	39
3) BC-42	Jun 70	Aug 70	Feb 72	Aug 72	90[4]	UCSC SLAC	Mar 73	Jun 73	37
4) BC-40	Jun '70	Aug 70	Oct 70	Jun 72	400	MIT	July 74	Jan 75	56
5) BC-38	Jun 70	Aug 70	May 71	Jun 72	414	Florida State U of Pa	Jan 73	Jun 73	37
6) BC-37	Jun 70	Aug 70		Nov 70	132	Yale	July 73	Dec 73	43
7) BC-35	Feb 70	Mar 70	May 71	Feb 72	511	UC-Riverside UC-LBL		July 73	54
8) BC-25	Mar 69	Jun 69	May 71	July 71	454[5]	CIT	Mar 73	Sept 73	55
9) BC-21	Nov 68	Mar 69		Jun 69	267	UC-Riverside	Dec 72	Jun 73	56
10) BC-19	Sept 68	Aug 69	Oct 69	Oct 72	840	Tel-Aviv		Jan 72	41

1) Experiments are those that have most recently completed running at SLAC.

2) If the official spokesman was not available contact was made with anyone with knowledge of the experiment.

3) Obviously dates after this compilation (Nov 72) represent "best guess" for completion of analysis and publication. Publication date means first paper giving result from analysis of all data ih a regular scientific journal. Subsequent publications are sometimes issued elaborating further on the results or presentin secondary analysis.

4) This was a "gated" experiment, it exposed 1 picture for every 300 expansions of the bubble chamber. This would make it almost equivalent to a 27,000,000 picture experiment.

5) This was a "gated" experiment, it exposed 1 picture for every 20 expansions of the bubble chamber. This would make it almost equivalent to a 9,000,000 picture experiment.

FABRICATION AND CHECK-OUT DURATION OF SELECTED SLAC CAPITAL EQUIPMENT PROJECTS

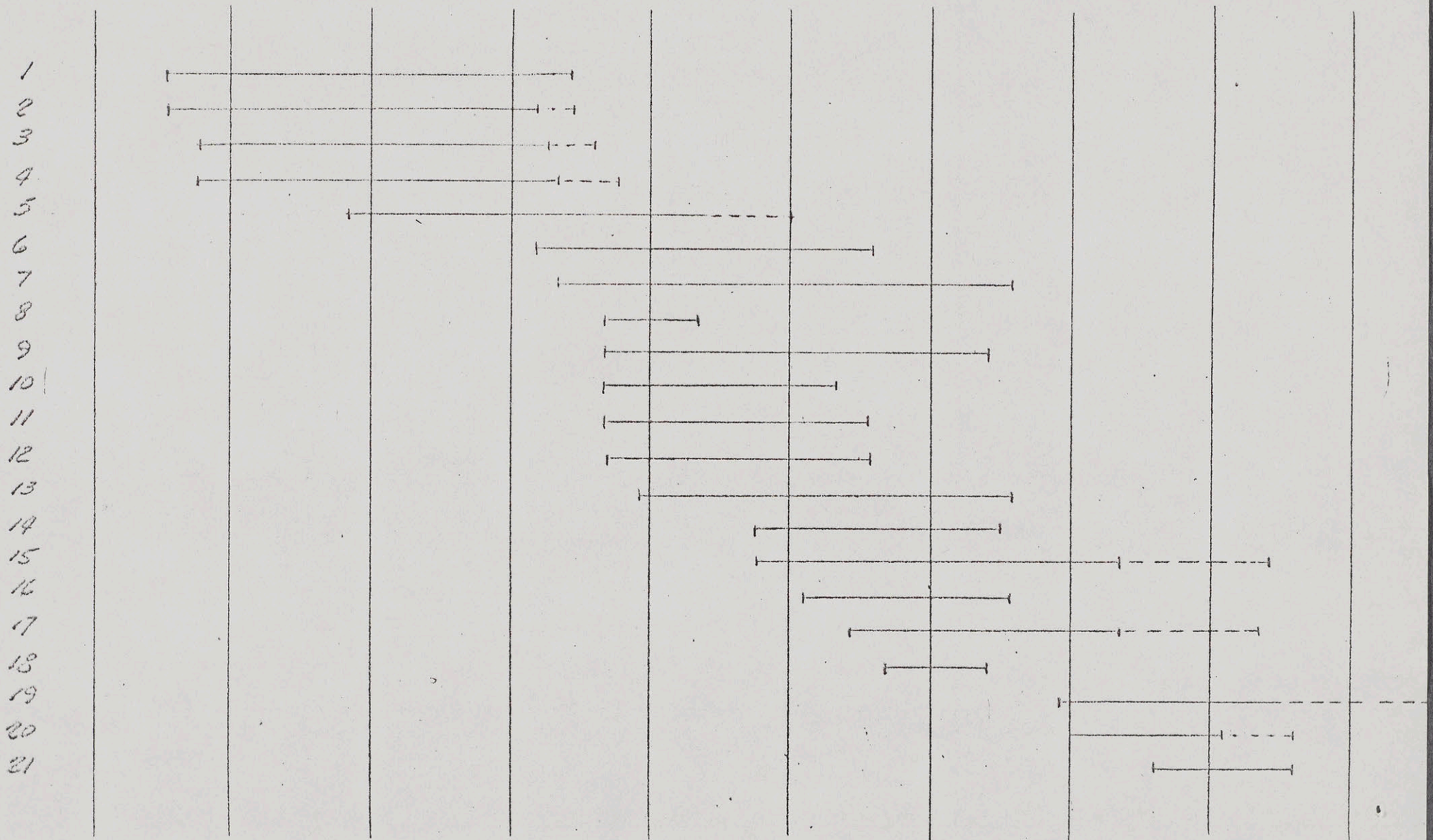


FIG. III-3

Fabrication and Check-out Duration of Selected SLAC Capital Equipment Projects

(Figures Represent Dollars in Thousands)

	TITLE	AMOUNT	PROJECT APPROVED	PROJECT CLOSED	FIRST PHYSICS	MONTHS INTERVAL
1)	1 Meter HBC 40"	$1978	June '65	May '68	April '68	35
2)	Positron Source	257	June '65	Feb. '68	April '68	35
3)	Large Volume Magnet	282	Sept. '65	Mar. '68	June '68	34
4)	1.6 BeV Spectrometer	277	Sept. '65	April '68	Aug. '68	36
5)	Spiral Reader	343	Oct. '66	May '69	Nov. '69	38
6)	Cerenkov Counter	113	Feb. '68	June '70	June '70	29
7)	Graphics Interpretation Fac.	138	April '68	June '71	June '71	39
8)	5.8 MW Power Supply Mod.	178	Sept. '68	Mar. '69	Mar. '69	7
9)	Gooney Bird II	126	Aug. '68	June '70	April '71	33
10)	18 D72 Bending Magnets	145	Aug. '68	Mar. '70	Mar. '70	20
11)	400 KW Power Supply	112	Aug. '68	June '70	June '70	23
12)	35 mm Camera (82" HBC)	91	Aug. '68	Jan. '70	June '70	23
13)	360/91 Additions	359	Nov. '68	June '71	June '71	32
14)	K^{o} Spectrometer Facility	306	Sept. '69	May '71	May '71	21
15)	Rapid Cycling Chamber	321	Sept. '69	April '72	April '73	44
16)	Central Computer Add. II	169	Jan. '70	June '71	continuing	
17)	SPEAR	5260	May '70	April '72	March '73	35
18)	Spectrometer D.A. Syst.-Mod.	104	Aug. '70	April '71	April '71	9
19)	LASS	970	Nov. '71	June '73	July '74	33
20)	Polarized Electron Source	145	Dec. '71	Jan. '73	June '73	19
21)	SPEAR Syst. Improvements	160	July '72	June '73	continuing	

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4/23/73

MINUTES

HIGH ENERGY PHYSICS ADVISORY PANEL

Lawrence Berkeley Laboratory

Berkeley, California

April 2-3, 1973

The agenda for this meeting is attached (p. A1-2).

Participants:

HEPAP

V.F. Weisskopf, Chairman
D.B. Cline
J.W. Cronin
T.H. Fields
L.J. Laslett
F.E. Low
R.R. Rau
B. Richter
J.L. Rosen
J.R. Sanford (Apr. 3)
G.F. Tape
W.A. Wenzel
W.D. Wales, Exec. Secy.

NSF

A. Abashian, Program Dir. for Elementary Particle Physics

AEC

J.M. Teem, Director, Div. of Phys. Res.
W.A. Wallenmeyer, Asst. Dir. for HEP, Div. of Phys. Res.

LBL Presentation

The agenda for the LBL presentation is attached (p. A3). This presentation was made in the Building 50 Auditorium, and was attended by approximately sixty of the Laboratory staff in addition to the members of the Panel. W.A. Wenzel introduced the Berkeley presentation by pointing out that not only was the HEP budget at LBL being reduced in FY 1974, but that the MEP budget was being

cut to less than half its FY 1973 level. This latter cut will reduce the support staff necessary for all (MEP and HEP) particle physics work. The Laboratory plans to run the 184" synchrocyclotron in spite of these cuts.

G.F. Chew reported on the activity of the LBL theory group. The group, which has a budget of $670K annually, consists of four accelerator theorists, seven particle theorists (of whom six are on the UC-Berkeley faculty), three LBL post-docs, and four UC-Berkeley post-docs. These post-doc figures will be reduced to two and two next year.

Current work is being done on dual resonance models, multi-peripheral and eikonal models, weak and electromagnetic currents, strong interaction phenomenology, s-matrix theory and unified gauge models. Chew outlined the theoretical interest in high energy heavy ion experiments. Since many aspects of particle theory treat the elementary particles themselves as composite, these concepts ~~should~~ could perhaps be relevant for baryon numbers greater than 1. Chew felt that the study of heavy ion interactions would increase our understanding of the basic strong interaction. ~~Heavy ions provide additional experimental parameters, which should increase our understanding. Also, since simplicity~~ may be more obvious ~~when levels are closer~~ together, the high level density in nuclei ~~may be of great help.~~

G.H. Trilling outlined the LBL high energy experimental efforts. The funding is split between Bevatron work ($2M), SLAC work ($3M), and work at NAL and elsewhere ($1M). The LBL Program at SLAC has been concentrated, until the past year, on work with the 82" chamber. This work has involved large exposures with the chamber and has resulted in high statistics studies of many strong interaction processes. Recent analyses have been made of K_{π} scattering, $N\pi\pi$ decay of resonances, and Λp elastic and inelastic scattering. The interests of the LBL have recently shifted from the 82" chamber to other facilities at SLAC. The group is now working on experiments with the 40" triggered chamber, the streamer chamber, and with SPEAR. They do not, at present, have any further plans for use of the 82" chamber.

O. Chamberlain reviewed the LBL work at NAL. There are several collaborative experiments in various stages of preparation. A search for magnetic monopoles (NAL #3) will begin in the beam dump of Proton West in late summer. An external muon identifier (NAL #155) is being developed for use in the 15' bubble chamber during neutrino exposures. The first units of this device will be shipped shortly. The beam for a charge exchange experiment (NAL #111) is now being tuned. This experiment, which will run in the summer, will measure the 0° cross sections for $\pi^- p \rightarrow \pi^o n$ and $\pi^- p \rightarrow \eta n$ and will test the predictions of Regge theory at high energies. The set up of an experiment (NAL #61) to measure

polarization in pp, $\pi^- p$, and $\pi^+ p$ elastic scattering should begin by summer. A study of $\pi^- p$ at 200 GeV (NAL #137) in the 30" bubble chamber is underway. Preliminary results indicate that the total cross section is the same as at 60 GeV and that the charged multiplicity distributions are the same as those found in pp collisions.

H.M. Steiner reviewed the Program at the Bevatron. Recent experiments include $\pi^- p \rightarrow$ neutrals, $\pi^- \vec{p} \rightarrow \pi^o n$ to look carefully for an explanation of discrepancies in the phase shift analyses, an η' decay measurement in a streamer chamber, and a study of μ polarization in $K_{\mu 3}^o$. The search for $K^o_L \rightarrow \mu^+ \mu^-$ data is being reanalyzed. A search is being made for evidence of neutral currents in $K^+ \rightarrow \pi^+ \nu\bar{\nu}$ and $\mu^+ \nu\bar{\nu}$. The lambda beta decay experiment has accumulated one thousand events. HEP experiments with heavy ions have included heavy ion fragmentation (of C, N, O) and particle production from p, d, and α. The high energy negative pion yield in the latter appears anomalously high, but may be due to effects from Fermi motion.

Scheduled experiments include a study of $K^o_s \rightarrow \mu^+ \mu^-$, a study of neutral bosons (esp. A^o_2) in the streamer chamber, a study of $\pi p \rightarrow N^* \pi$, an investigation using nuclear energy levels to study particle interactions, pd and pα elastic scattering, continuation of the heavy ion experiments, work with the tagged neutron (from deuteron stripping) beam, and studies of hyper-nuclei. The work

with heavy ions will include an investigation of high energy interaction mechanisms, high energy nuclear physics, searches for exotic nuclei and hyperfragments, experiments of specific interest to cosmic ray and space physics, particle production, biophysics and other studies.

The instrumentation efforts at the Bevatron have developed large, high resolution Ge detectors, are working on Camac systems, multi-wire proportional chambers (with the Fairchild chip developed for the purpose as a result of a national cooperative effort), liquid chambers, fast electronics (300 MHz with MECL III), and polarized targets.

A.H. Rosenfeld reviewed the activities of the particle data group. The effort on "particle properties" includes six from LBL, three from CERN, and three from elsewhere. The group is preparing a compilation of "documents and data." "Documents" will be a list of approved experiments (LBL 91) secured with the cooperation of the scheduling committee secretaries. "Data" will be a list of preprints and publications (LBL 90). LBL 50 will try to summarize, in some uniform format, the data available on tapes and reports. The group had also prepared a preliminary survey of publication statistics (UCID 3599) which compared publication rates at different laboratories. The concensus of HEPAP was that this latter, especially in view of the elasticity of publication, was not a particularly productive enterprise. It will probably not be pursued.

H.A. Grunder reported on the status of accelerator and facilities at the Bevatron. The new 50 MeV injector from BNL, now being installed and tested, should give more intensity. The Bevatron now has a 25% duty cycle with intensity modulations of less than 3/1 in the spill. The deuteron beam can be used to provide a tagged ($\Delta p/p \sim 0.7\%$) or untagged ($\Delta p/p \sim 3\%$) neutron beam of momentum up to 3 GeV/c. The 500 MeV/c stopping K beam is capable of providing 10^5 K^+/3 x 10^{12} protons. The streamer chamber facility has one experiment completed, one in progress, and about three more being planned. The heavy ion intensity at present is 10^{12} d/pulse, 10^{10} α/pulse, and much lower intensities for heavier species. The Bevalac will permit beams of 10^{10} nuclei/pulse through neon, 5 x 10^8 argon/pulse, and 10^5 iron/pulse. Grunder believes that polarized beams of protons and deuterons, as well as useful beam microstructure (bursts of less than 10ms) could be readily accomplished.

T. Elioff outlined the goals and status of the PEP study. He divided his discussion into PEP proper, superconductivity, and a mini-project. PEP would permit a look in the energy region where weak interactions are presently expected to approach the strength of electromagnetic interactions. The device will provide 100 GeV in the C.M. for ep interactions and 30 GeV in the C.M. for e^+e^- interactions with a luminosity of $10^{32}/cm^2$-sec. Elioff pointed out that the margin of error in colliding beam devices is small - a

luminosity of less than 10^{31} would not be useful. The work on PEP in the past year has concentrated on developing the accelerator lattice structure, studying the R.F. system and beam-beam interactions, and continuing superconductivity effort. The PEP device, as now conceived, would use conventional magnets for the electrons and positrons, since the magnetic fields are very low, and superconducting magnets for the protons.

The superconductivity work at the Laboratory has been divided between pulsed magnets for a synchrotron and D.C. magnets for beam lines. A one meter D.C. dipole and an eight-inch bore D.C. quadrupole are now in operation on the Bevatron experimental floor. A number of pulsed dipoles have been constructed with wire containing 10μ filaments. One cycle/sec at 35kG has been achieved in a model 3" diameter and 16" long. Effort is now being placed on achieving field uniformity and maintaining such uniformity from magnet to magnet. Two "identical" dipoles, now being completed, will be used to test the uniformity of fabrication techniques.

Since PEP is not likely to be funded in the immediate future, a "mini-project," which would both serve as a way-station on which to focus effort and result in a useful device for physics, is being studied. The device being considered is a small (4 GeV) superconducting ring which would be constructed in the Bevatron experimental area. This ring would provide a real test of the application of

superconducting technology to a synchrotron, and permit storage ring tests. In addition, primarily because of the much better vacuum system (compared to the Bevatron) much heavier ions could be accelerated to high energies (uranium to 300 MeV/nucleon). Thus the device would nicely complement the super-Hilac and the Bevalac. The costs of this "mini-project" are estimated to be on the order of $3 million.

D. Keefe reviewed the status of LBL work on ERA. The ERA originally seemed the most promising of the collective acceleration effects. A great deal of understanding has been acquired to date. However, present theory indicates that the gain for protons would be limited to less than 80MV/meter. This would provide large compaction factors for linear accelerators, but appears to offer no advantages for super-high energies.

L.T. Kerth outlined the LBL computer situation. The Laboratory, as recommended by HEPAP, has set up regional HEP computer service with non-lab types on advisory committees. The present computer complement, after releasing one 6600 to NAL, is a 6600, a 6200, a 7600, and interfaces. The use(last year) was divided between LBL (total of 43%, of which physics accounted for 30%) and non-LBL (total 57%, including 8% for HEP and AEC and 45% for other federal agencies). The operating costs of the facility are supported by recharge to users. At present, the 7600 is running at 60-70% saturation. Improvements in hardware are being made to overcome

the present bind in I/O capability, which is 90% saturated. Users from inside and outside the Laboratory are now treated uniformly, provided federal funding is involved. The current rates are about $800/CPU hour on the 7600. The 7600 is about four times as fast as the 6600 for the LBL job mix.

Discussion of LBL Presentation

The Panel discussed the statistical survey of publications which had been presented. It was the concensus that the dissemination of grossly oversimplified research indices, such as cost/publication, could very easily lead to misinterpretation. Although there was some recognition that some measure of research might be useful, no measurement which might be appropriate was suggested.

Some Panel members voiced concern about the future prospects for ERA research. Although it appears that the research might lead to very effective devices for accelerating heavy ions to intermediate energies, the fact that it is no longer of prospective use for high energy physics makes its financial support from HEP funds questionable, especially when funds in this field are being severely stretched to cover an expanding energy range. On the other hand, it was pointed out that accelerator technology has traditionally been done in high energy physics, and that research on projects like ERA contributed heavily to the "spin-off" which is often used to help justify work in this field. Concern was voiced that HEP budget

restrictions might force LBL to cut off ERA research before it was possible to demonstrate the utility of the device to scientists in other fields which might eventually provide funding. It does not appear that this problem can be resolved by a committee such as HEPAP which is concerned solely with high energy physics.

The discussion of the overall program at the Bevatron floundered on the same sort of problem as did the ERA discussion. The Bevatron is moving into an inter-disciplinary area, where running with the Bevalac for nuclear physics and biological research is expected to displace a part of the particle physics work which formerly exclusively occupied the accelerator time. The Panel recognized that their competence did not extend to these new areas. However, concern was voiced that HEP funds were being stretched to include some fraction of this work.

The Panel was quite concerned about the future of high energy physics at the Bevatron, especially since so large a fraction of the LBL research staff which formerly used the Bevatron has now shifted to experimental work at other accelerators. The contrast between the LBL policy, which permits scientists to work wherever they are inclined, and the much more restrictive policy on outside research by in-house physicists at other laboratories, was noted by the Panel.

Experimental Facilities Survey

The concensus was that corrected copies of the beam and facilities survey which R.R. Rau had presented at the previous HEPAP meeting

should be given broad distribution, and should be updated once a year. Rau agreed to have R.H. Phillips sent out table #1 (summary of funded beams). We will try to encourage the particle data group to take up this task on a continuing basis.

SLAC 82" Bubble Chamber

The Panel discussed the SLAC proposal to shut down the 82" chamber by next January. There does not seem to be a strong future program developing from the present users of this device. The users of the BNL 80" chamber are not pushing hard for more conventional pictures, but are enthusiastic about the prospects for a track-sensitive target, for which the SLAC chamber is unsuited. It was also pointed out that the 3" wall of the 82" chamber makes it unsuitable for use in a hybrid mode. (The SLAC 40" and 15" chambers, which are more versatile in this respect, are in large demand and will continue in operation). It appears that the high analysis costs of bare chamber pictures has effectively dried up the demand originally projected for multi-million picture experiments. The Panel decided that the SLAC proposal was quite reasonable in the circumstances and that, assuming no major change in demand, the chamber should be phased out.

Foreign High Energy Physics

W.A. Wallenmeyer showed a graph of funding in U.S. and Western Europe over the past decade (p. A4). The Panel commented on the ominous implications of the diverge of the two curves. Some members

suggested that the shortage of funding made it imperative to concentrate available resources at the high energy laboratories. The damaging effect this would have on university users was noted. There appeared to be general agreement that some colliding beam project such as ISABELLE or PEP must be built if the U.S. program is to remain competitive. V.F. Weisskopf closed this discussion by noting that Europe is not taking over in high energy physics. He suggested that the European curve is behind the U.S. curve, and that if we give up work in this field, they will not sustain it. He stated that the life of high energy physics in the world depends on U.S. choices, and that the field will die if we do not keep up our effort.

NAL Review

J.R. Sanford presented a review of the current status of NAL. He reported that March has been the best month of operation thus far. There has been steady work at 300 GeV, with an average intensity of about 1.5×10^{12} p/p. The beam may now be used simultaneously in all four areas. C-0 will be kept in operation indefinitely - investments are now being made in more extensive facilities there. There have been a series of runs to 300 GeV with the H_2 jet target. It is planned to go to 400 GeV on the target and also to use D_2 in it. The laboratory is expecting they will be offered an opportunity to buy this target from the Soviets.

The losses in the splitting stations (electrostatic plane and Lambertson magnets) are now at the 1% level. Typical splitting operation might be 10% for Proton Laboratory, 10% for Meson Laboratory, and 80% for Neutrino Laboratory. Two targets are used in the Proton Laboratory, while one each is used in the Meson and Neutrino Laboratories. The laboratory is now learning the flexibility of the splitting modes. The power level, with all areas operating, has been kept below 50MW.

Accelerator studies during the month concentrated on improving transmission in the main ring. The loss in the main ring has been as low as 10%, but is often much higher. The aperture appears to be about 1¼" x 1½" instead of 1¼" x 3" as expected. Slow extraction is about 85% efficient, while fast extraction efficiency is between 95% and 100%. The ripple (720 Hz and 60 Hz) in the quad. regulator supplies makes the duty factor during flat top about ten percent. The favored solution, bucking supplies, has resulted in an improvement from the original one percent duty factor.

Work is continuing on the linac and booster. The booster aperture, which is restricted to 2-3cm instead of the 10cm expected, is being investigated. Component reliability is still a problem. A recent source of trouble has been fractures in the R.F. cavity insulators. This appears to be caused by alumina of lower purity than expected - new insulators have been ordered. Magnets are continuing to fail

at the rate of greater than one per week, but they are not a major source of downtime. Although most of the failures have occurred with older magnets, two or three of the "super" magnets have failed. These failures appeared to be due to leaks at joints.

The plan for the immediate future is to go to 400 GeV, and do fast extraction while running C-O, 1A, and the 30" bubble chamber. Since the previous experience with this level totals ten hours, some problems might be expected. It is also possible that the higher transients will cause difficulty with the power company, which has agreed only to operation at 300 GeV. In addition, during the summer there may be trouble with total power level and with cooling.

The neutrino area runs consistently with the 30" chamber and neutrino and muon beams. The muon flux (per proton) is low by a factor of five. This problem, due to lack of understanding of beam optics, is being worked on and improvement is in sight. Three target loads will be possible:

1. Dichromatic - muon and #21 (now)
2. Horn - 15' and #1A, but not muons (by summer)
3. Bare target

The by-pass is now used to feed beam to the 30" bubble chamber.

The Proton Laboratory has had beam to two branches. Proton East has a spot size of 2mm. Larger aperture quads are needed, since

halo could cause problems with transmission experiments. Proton Center has a similar spot. The beam dump works satisfactorily. Proton West is several months behind the other two branches. Experiment #100 is being installed in Proton East, and should run in a few months. A lepton search (#87A) is being installed in Proton Center. The R.F. structure is very sharp (1ns on, 20 off) and will be used to do a time-of-flight search for massive particles (#187) made on a target in the switch yard. The Proton Laboratory was designed for 500 GeV, the Neutrino Laboratory, designed for 400 GeV, could probably be hardened for 500 GeV, and the Meson Laboratory has been hardened to 300 GeV.

The Chicago cyclotron magnet (for #98) has been powered. The metal piston for the 15' chamber is nearly done, while a fiberglass piston is being fabricated. Sanford reported that R. Huson, who had gone to the BEPS cooldown, ~~and~~ was optimistic about the prospects for the NAL chamber.

The useful experimental time is now averaging 50-60 hours/ week. The experimental backlog, assuming 2×10^{12} p/p and 50% operation, is about three to four years. Less than ten percent of the approved experiments would be in difficulty (neutrino and muon experiments particularly) if beam intensity remained at its present level. As gears have changed from construction to operations, the laboratory sections have begun to operate smoothly. The present section heads are:

Meson - R. Lundy

Neutrino - R. Orr

Proton-J. Peoples

Three main problems at present are extraction and duty cycle, reliability, and manpower to turn the corner on operating problems. In response to questions on the energy doubler, Sanford pointed out that 1000 GeV could be used easily inside the ring and in the proton area, and, possibly with some hardening, in the neutrino area. The doubler may become very vital to the laboratory's operation if power problems become severe. The present doubler effort consists of about a half dozen people who are now building a few test dipoles. The entire prototype effort is limited to $1.5 million in construction funds. There is also some effort being made to install superconducting bending magnets in the line to the 15' chamber.

Discussion of NAL

D. Cline gave his views on NAL as seen from experimenters' eyes. He pointed out that he had lived at NAL for two and one-half years, and had gone through a depressing era. He felt that during the time B. McDaniel was in charge of accelerator operation a significant improvement was made. During the past six months talented individuals have surfaced and have been given freer rein. People are now getting things done. Their experiment (#1A) now can get eight events/hour and can do good physics with existing beam when the horn is installed. He feels that stability is now

needed more than intensity. He stated that there have been enormous changes in the past year and that the slope is definitely up.

J. Cronin pointed out that the emerging experimental area physicists are extremely good. The Proton Laboratory is running much better, and his (#100) first exposure went extremely well.

J. Sanford reported that although the muon flux was now only a few times 10^3/pulse, a factor of ten improvement would come, within 3-4 months, by improving the load and installing larger aperture quads and dipoles. A second factor of ten, by increasing the proton beam intensity, would come a bit at a time over a longer period. He pointed out that more people were being hired, and that they were beginning to have enough operating technicians. These additions will still leave the laboratory below full capacity, and it may be able to regularly operate only two external laboratories instead of three for a year or two. He pointed out that staff transfers from Argonne had worked quite successfully, but staff from more remote locations were not easily induced to move.

A discussion of extraction difficulties indicated that the adjustable Lambertsons had not resulted in as much improvement as anticipated. However, the problem was not yet well enough understood to permit a rational decision of what step should next be taken.

The Panel expressed concern that NAL might not be in a good position to meet the coming competition from the CERN SPS. They indicated that reliability and intensity ~~should be pushed now rather than~~ are important - first, and energy next. It was pointed out that the summer study and the summer program meeting might resolve some of the problems (muon beam, length of que) with which the Panel was concerned, especially since the past year's operating experience will provide a foundation on which a less academic overview can be based. It was also pointed out that money was available for improving many problems, but, in many cases, designs were not yet available.

Several members of the Panel expressed the opinion that NAL had been, and continued to be, ~~doing~~ done too much "on the cheap" to permit it to do productive physics at a level justified by its scale. They indicated that a change in style was necessary if the laboratory were to remain competitive when CERN's SPS came into operation.

The Energy doubling is desirable & finally attainable but should not be done at the expense of rel. and int. at 300 GeV and at the expense of well equipped exp. areas

Vanderbilt Conference

J.D. Jackson summarized the results presented at the Vanderbilt Conference (p. A5).

HEPAP Closed Sessions

The Panel discussed the shutdown exercises requested by the Controller and the Office of Planning and Analysis, and the DPR's proposed spring agency plan for the next five years. There was

not a great deal of detailed response to the spring agency plan. The discussion of the funding exercises centered on the future role of the Bevatron in high energy physics.

The selection of the next Chairman of the Panel was discussed (Weisskopf is leaving at the end of the year). It was the concensus that S. Drell would be an excellent choice.

Next Meeting

The date for the next meeting was set for June 18-19, 1973. It now appears that this meeting will be at NAL.

LESS ELIMINARY
March 14, 1973

AGENDA

HIGH ENERGY PHYSICS ADVISORY PANEL

Lawrence Berkeley Laboratory
Berkeley, California

April 2-3, 1973

Monday, April 2, 1973

8:45 AM	Agency Presentations (closed)	50-B Conference Room
10:00	LBL Program Review - LBL Staff	Building 50 Auditorium
11:45	Tour of Facilities	
12:30 PM	LUNCH	LBL Cafeteria
1:15	LBL Review (cont'd)	Building 50 Auditorium[1/]
2:30	Discussion of LBL Program - HEPAP, LBL Staff	
3:30	Experimental Facilities Review - R.R. Rau	
4:00	Impact of FY 74 Budget on Program	
4:30	U.S. and Western European HEP Goals	
5:00	End of Afternoon Session	

1/ The meeting may be moved to 50-B Conference Room sometime during the afternoon if using the Auditorium becomes unwieldy.

Monday, April 2, 1973 (cont'd)

6:30 PM	DINNER - HEPAP, LBL Staff	
8:00	"Status of High Energy Physics" - V.F. Weisskopf, HEPAP, and Audience	Building 50 Auditorium

Tuesday, April 3, 1973

9:30 AM	NAL Status - J.R. Sanford	50-B Conference Room
10:00	Discussion of NAL	
11:00	General Topics	
12:00 NOON	LUNCH	LBL Cafeteria
1:00 PM	Agency Presentations (closed)	
5:00 PM	ADJOURN	

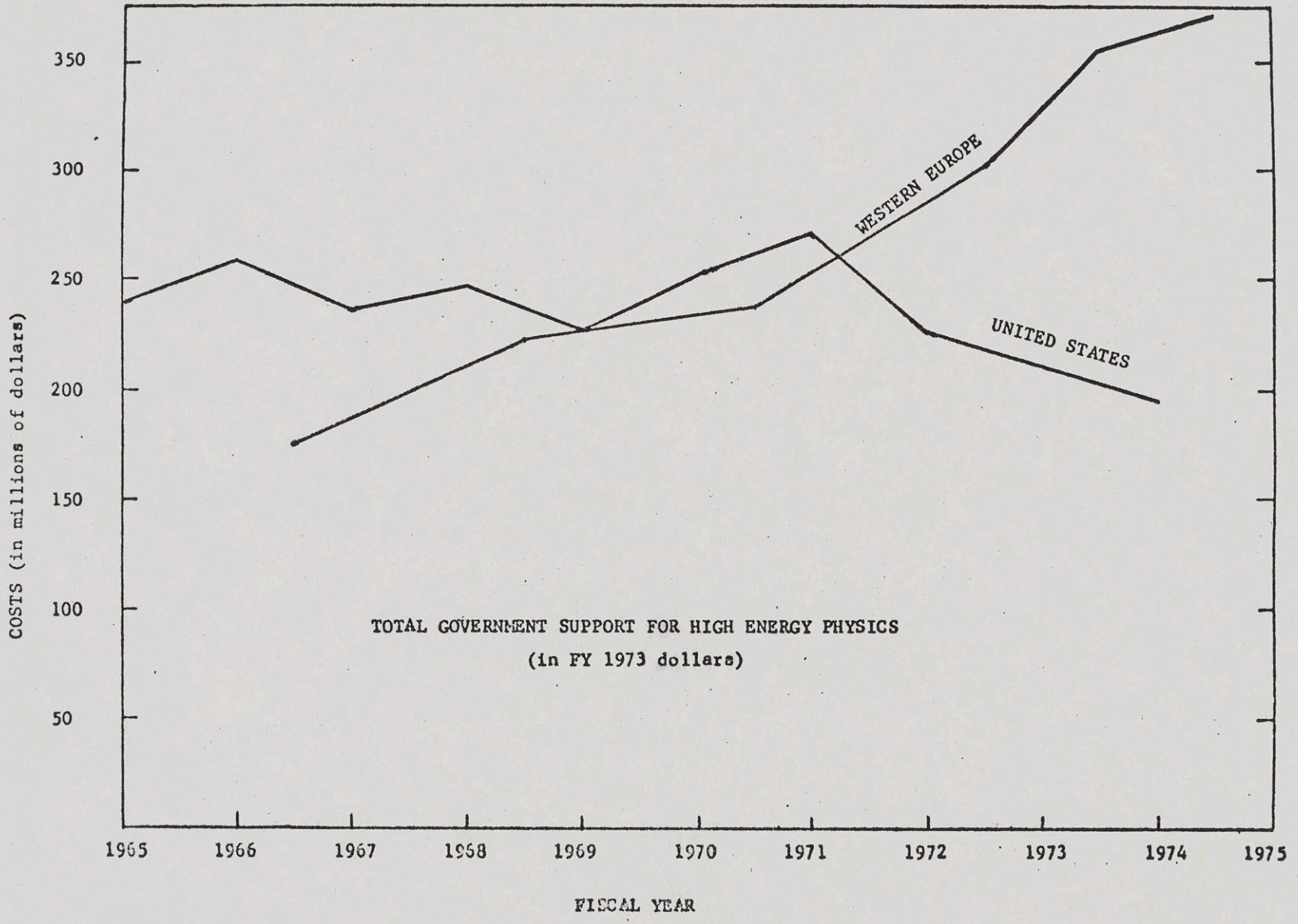
HEPAP MEETING

LAWRENCE BERKELEY LABORATORY

April 2-3, 1973

HOST LABORATORY PRESENTATION, APRIL 2

		Approximate Time
10:00 A.M.	Introduction - E. M. McMillan, W. A. Wenzel	
10:10	Physics Research and Instrumentation	
	Theory - G. F. Chew	15
	Expt. - G. H. Trilling	20
	- O. Chamberlain	15
	- H. M. Steiner	25
	- A. H. Rosenfeld	5
11:40	Accelerator Developments	
	Bevatron - H. A. Grunder	15
	PEP, Etc. - T. Elioff	20
	ERA - D. Keefe	10
12:30 P.M.	LUNCH	
1:15	Tours of Facilities	
	I Superconductivity, Bevatron and ERA	
	or II Data Analysis and Computer Center	
	or III Nuclear Instrumentation and Xenon Chamber	
2:15	Computer Center - L. T. Kerth	
2:30	DISCUSSION	


350
300
250
200
150
100
50
COSTS (in millions of dollars)
WESTERN EUROPE
UNITED STATES
TOTAL GOVERNMENT SUPPORT FOR HIGH ENERGY PHYSICS
(in FY 1973 dollars)
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
FISCAL YEAR

NEW RESULTS, VANDERBILT CONF., MAR 26-28/73

TOTAL CROSS SECTIONS

$\sigma_t(\bar{\pi}p) = 24.0 \pm 0.5$ mb at 205 GeV. (LBL/NAL/UCB)

$\sigma_t(pp) = 43.4 \pm 1.0$ mb at $W = 63$ GeV (PISA/SB)

NAL

100, 200, 300 GeV pp } 30" h.b.c.
200 GeV $\bar{\pi}p$ }

ELASTIC SCATTERING (GAS JET) — $b(t)$, $[\alpha = Re/Im]$

INELASTIC $pp \to pX$ (i) Gas jet, s-dependence at fixed t and x. (Rutgers etc.)
(ii) very small $|t|$ (Col./SB)

PHOTONS AT ~90° IN CMS, LARGE $p_\perp$ $(0.1 < p_\perp < 3)$ (NAL)
EMULSIONS

ISR

LARGE $p_\perp$ PRODUCTION; γ, e^+e^-, .. (CCR)
- CORRELATION OF $\langle n_{ch} \rangle$ WITH π^0 VS. $p_\perp$
- NO OBJECTS DECAYING INTO e^+e^-

CORRELATIONS AT WIDE ANGLES (PISA/SB): $C(\eta_1, \eta_2)$

PARTICLE COMPOSITION VS. $p_\perp$ (BR/SCAND): $\bar{d}/p \sim 10^{-3}$

$p_\perp \sim 2.5$ GeV/c:

π^+, π^-	55-60%
K^+, p	15% each
$\bar{K}$	~10%
$\bar{p}$	~5%

INELASTIC p & YIELDS AT LARGE x (CHLM)
↳ INCLUSIVE & STUDY OF "JET" IN OPPOSITE HEMISPHERE FOR x_1

CHARGED $\pi - \pi^0$ & $\pi^0 - \pi^0$ CORRELATIONS (CERN-H-V)

PRODUCTION RATIOS & $\langle n_i \rangle$ VS. s (BOLOGNA/CERN)

ELASTIC SCATTERING AT $0.5 < |t| < 5$ } (CERN/HARVARD)
INELASTIC p

MULTI PHOTON EVENTS (BNL/ROME)

SLAC

DEEP INELASTIC ELECTRON SCATTERING ON p, n, Z^A (CalTech/SLAC)

INEL. μ SCATT. IN h.b.c. } $\frac{n}{p} \simeq 0.85$ FOR $5 < \omega' < 20$
PHOTON FRAG. REGION $N^+/N^- > 1$ } $A^{1.0}$ DEP. FOR $Q^2 \neq 0$.

OTHER

Conversation with Sild.

1. Resign from Chapt.
Reason not lack of authority.

Reason for auth. 1970-90

New machines, Storage ring
Quarks, structure of Pich
Weak interactions.

Competition with W. Europe.
Will US be leading?
in view of anti-science!

American adventure
your words

220 M, higher than US

Basic support Science,
addl sex-appeal: Europ. collab.

Highly appreciated.

Why do people not separate issues? He is the best director...

First US choosing elections > (Rep!
support it if ~~2 yrs~~ (0-4 yrs what is now, for 2-3 years. Reconsider this summer if not.

Hm

The worst is over, I support Science

What is European Support?

How come Nat so high?

If OMB does not cut, it will be better

Pierre additions don't help, article in N.Y.T. influences Joint committee. I agree with most of his views but

Rey don't!

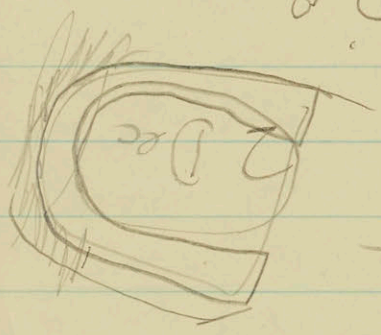
What about CEA?

Is CEA a M.I.T. concept?

No, Harvard, but
common interest.
What do you think
of Herop?

I have stopped 6 Committees
but not HEPAP. It seems helpful
I did not study it carefully.
What do you think?

Useful to AEC, advice
Buffer to community → Planning
Useful to us. Difficulties:
parochial behavior of lab. representatives
can be dealt with.



ENCLOSURE IV

THE SLAC COST INDEX

A History of Cost Escalation at the Stanford Linear Accelerator Center FY1969 - FY1973

In the compilation of these figures cost escalation was determined separately for labor, for klystron and thyratron tubes, with the remainder of the costs escalated according to the wholesale price indices for representative commodities as of January of the respective fiscal year. The SLAC cost indices are referenced to FY1967; this is consistent with the wholesale price index which currently equates the 1967 index to 100.

The result of this effort is summarized in the attached table and thus represents the actual cost escalation experienced at SLAC from FY1969 through FY1972 and an estimate for FY1973 which may be slightly on the conservative side.

The increase in the cost index can be considered generally significant only if the mix of skill levels of the SLAC staff has remained reasonably constant. This is, in fact, the case: During the period covered, the composition of the SLAC staff has remained virtually unchanged.

The major factor in SLAC cost escalation will be seen to be the unit cost of labor. Examination of the detailed figures indicates that roughly two thirds of the labor cost increase is due to direct salary adjustments, while the balance is due to increased staff benefits. During the period covered, labor costs rose from 40% to 64% of total project expenditures.

Two bar charts are attached illustrating SLAC costs and new obligational authority from FY'67 to FY'73, respectively. The charts are shown both in dollars of constant (FY'73) purchasing power computed using the SLAC Cost Index, and in dollars current to the fiscal year tabulated.

ENC IV

12/5/72

SLAC COST INDEX

	FY1967	FY1968	FY1969	FY1970	FY1971	FY1972 [5]	Est. [1] FY1973
Labor Cost Index	100.0	103.2	110.1	115.1	124.0	133.7	146.5
Klystron & Thyratron Cost Index [2]	100.0	92.0	96.0	93.0	134.1	147.2	147.2
Other Materials & Supplies Cost Index	99.0	101.6	104.5	112.9	117.8	121.3	125.9
Composite SLAC Cost Index [3]	99.4	102.3	106.7	113.3	122.9	130.4	140.4
Change in Index From Previous Year	--	2.9	4.4	6.6	11.1	7.5	10.0
Percent Change From Previous Year	--	2.9	4.1	6.1	9.9	6.1 [4]	7.7

1/ These estimates are based upon known labor costs and January 1972 wholesale price indices extrapolated at a conservative 3.8% to January 1973. Recent statistics indicate that the industrial commodities index rose at .4 of 1% monthly from January through June 1972, after which increases diminished steadily through October 1972 when a seasonably adjusted decline of .1 of 1% was reported.

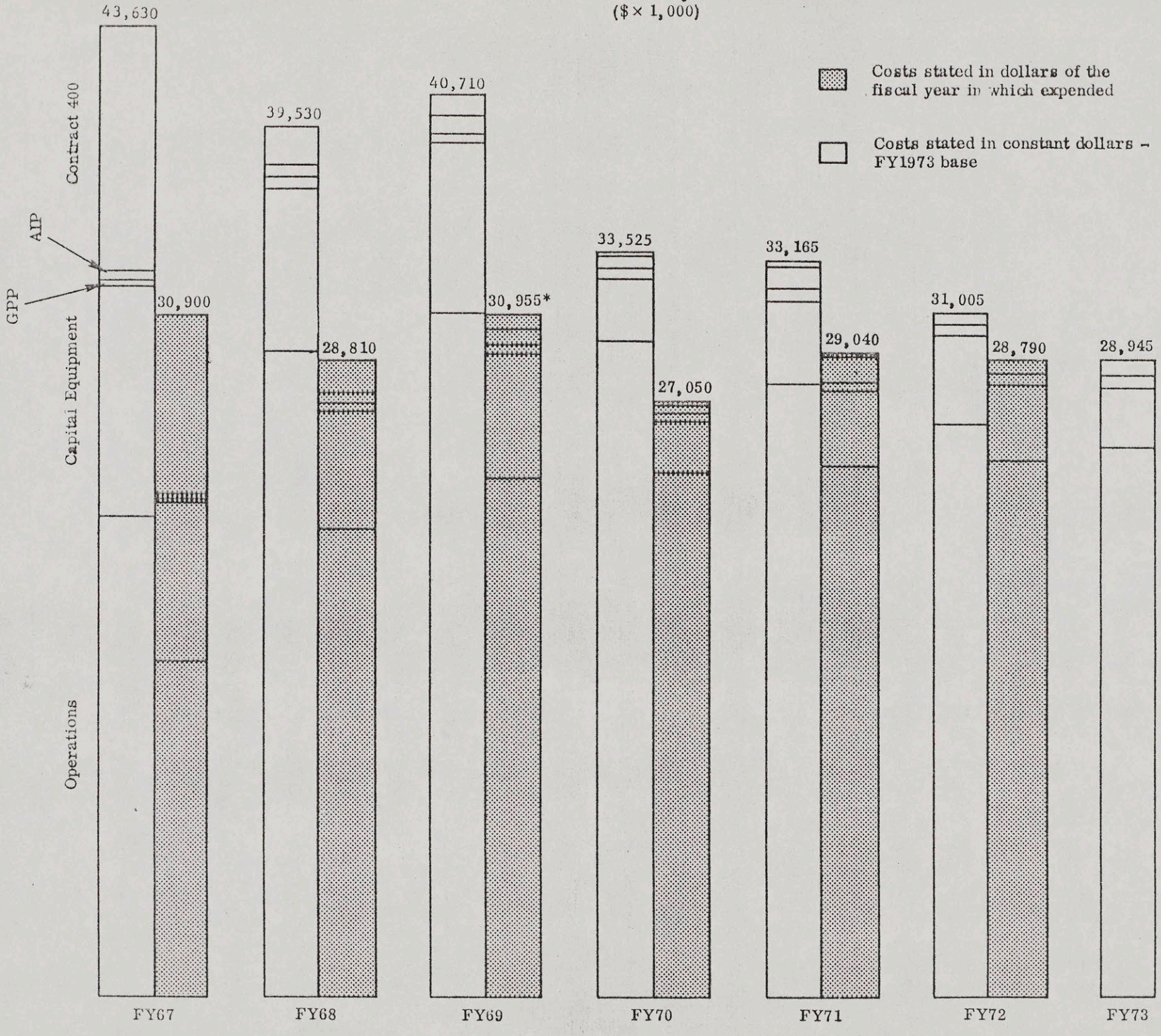
2/ This index is applicable to the 30 MW klystron which was first procured in 1967. The FY1973 entry assumes replacement of failed klystron tubes with 30 MW tubes, not with the proposed 30/60 MW klystrons.

3/ The SLAC Cost Index is computed using the actual per unit cost for labor, klystron and thyratron tubes and Bureau of Labor Statistics monthly wholesale price indices for selected other costs. The slight variance of FY1967 indices from 100 is due to the use of the January index as representative of FY1967 as opposed to the calendar 1967 average as used by the wholesale price indices.

4/ This figure reflects the effects of the special salary administration program instituted at SLAC during FY1972. Without this action FY1972 escalation would have been substantially higher.

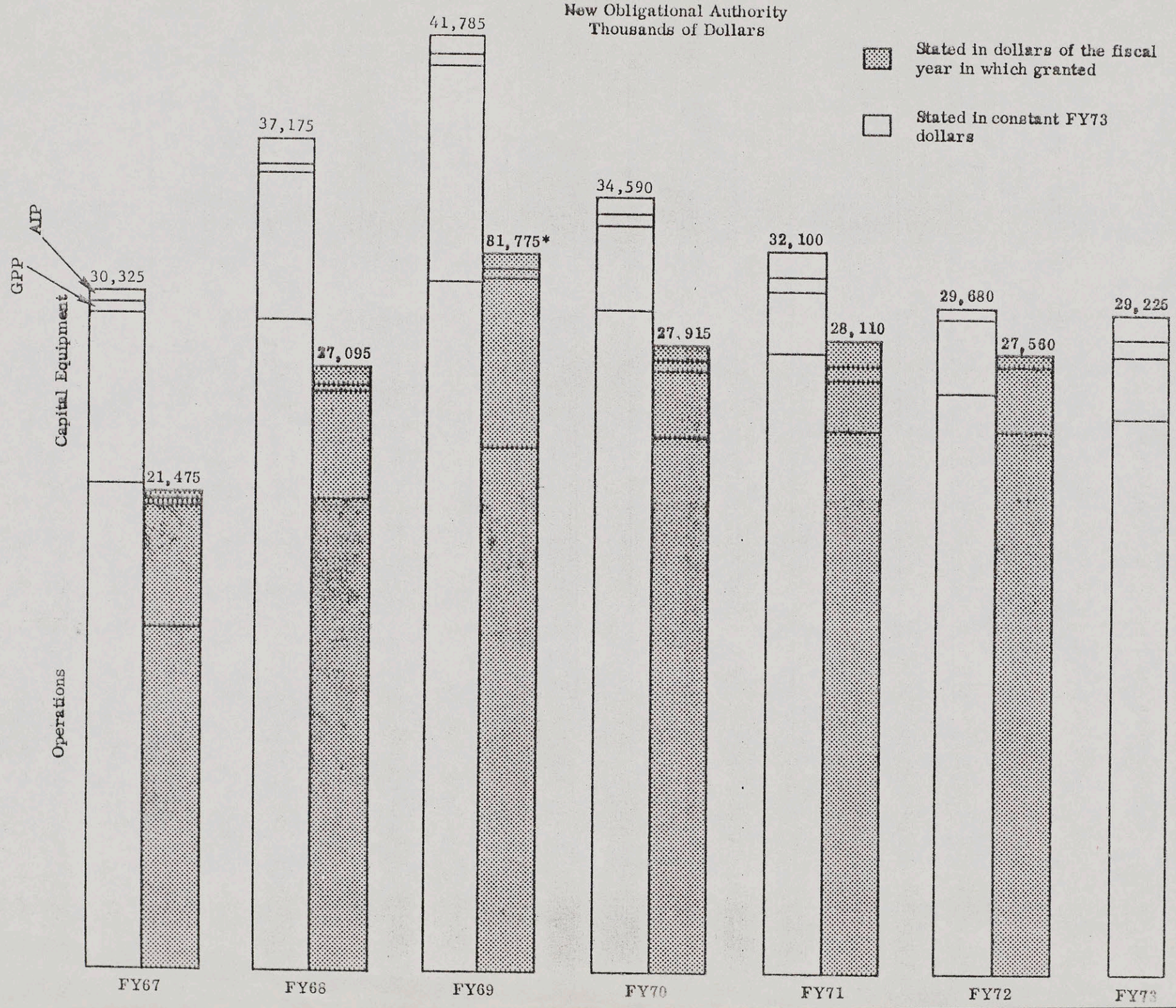
5/ During FY1972 Labor costs were 59% of total, klystron and thyratron costs were 3% of total and other materials and supplies were 38% of total.

SLAC Total Costs by Fiscal Year
($ × 1,000)



*This figure includes $2,813,000 of FY1969 costs associated with the acquisition of the IBM 360/91 computer.

2201B40


New Obligational Authority
Thousands of Dollars
Stated in dollars of the fiscal year in which granted
Stated in constant FY73 dollars
GPP
AIP
Capital Equipment
Operations
30,325
21,475
37,175
27,095
41,785
81,775*
34,590
27,915
32,100
28,110
29,680
27,560
29,225
FY67
FY68
FY69
FY70
FY71
FY72
FY73

PRIVILEGED

April 30, 1971

Backup data for projections presented in "Guidelines for High Energy Physics in the '70's" and description of excursions about those projections.

CONTENTS

Introduction

Figure 1 - FY '73 Alternative Funding Base Points Compared

$250-Million-Based Program

Alternative Growth Charts

Tabulated Data

Legend for Tabulation Entries

$221-Million-Based Program

Alternative Growth Charts

Tabulated Data

Legend for Tabulation Entries

$280-Million-Based Program

Alternative Growth Charts

Tabulated Data

Legend for Tabulation Entries

Manpower Projections

Figure 2 from the Guidelines

Some Source Material

INTRODUCTION

This document provides the backup material used in developing "Guidelines for High Energy Physics in the '70's." The question as to choice of starting value for FY '73 is discussed in Section B of the Guidelines and the distribution in funding categories over three alternative FY '73 levels is illustrated in Figure 1. It is concluded in the Guidelines, partially on the basis of manpower analysis, that the FY '73 starting value of $250 million must be a minimum program for new obligations.

Next, Figures 3, 4, and 5 of the Guidelines are repeated along with tabulated data and legend for the tabulation entries, to explain the $250-million-based program at all three alternative annual growth rates of -5 percent, 0, and +5 percent respectively.

Then follow similar curves, data and legend for a lesser program beginning with an FY '73 new obligation level of $221.5 million (equivalent to the FY '72 President's Budget escalated by 6 percent).

Next is a third set of similar curves, data, and legend for a larger program beginning with an FY '73 new obligation level of $280 million.

This is followed by background information on manpower determinations for Figure 2 of the Guidelines.

Finally, a list of some source material is given.

****

Some further amplification on various tabulation entries is as follows:

1. New construction obligations are blocked out to conform to the projected total obligation schedule and the requirement of a reasonably smooth variation in operating support. A realistic schedule of obligations for construction would of course generate some "bumps" in the curve of total obligations for high energy physics.
2. Note that the availability of new facilities for physics research will lag the charted obligation schedule for these facilities by from one to three years.
3. Line 1 of the tabulations (User Support) is total university user support, with some smoothing. It has been made proportional to the operating support of all the current laboratories. The ratio is based on FY '70 operations.
4. Line 2 of the tabulations (Brookhaven Operations) considers the AGS's present undergoing of a major "conversion" program to improve and extend its facilities. This has entailed prolonged shutdowns for installation of new equipment. This situation makes a quantitative assessment of recent accelerator "utilization" essentially impossible.

Other comments and amplifications on line entries are given directly in the "Tabulation Entries."

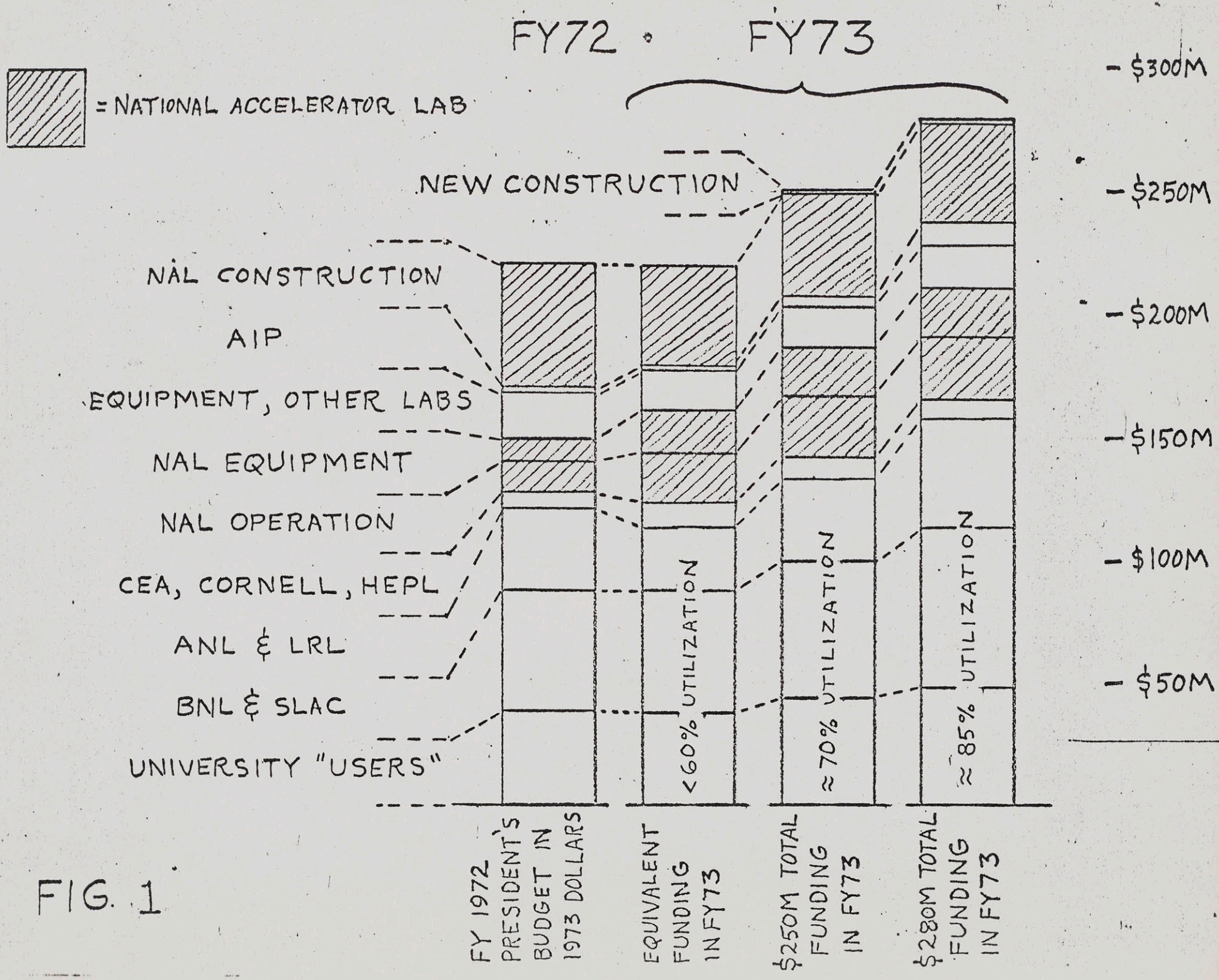

FY72
FY73
= NATIONAL ACCELERATOR LAB
NEW CONSTRUCTION
NAL CONSTRUCTION
AIP
EQUIPMENT, OTHER LABS
NAL EQUIPMENT
NAL OPERATION
CEA, CORNELL, HEPL
ANL & LRL
BNL & SLAC
UNIVERSITY "USERS"
<60% UTILIZATION
≈70% UTILIZATION
≈85% UTILIZATION
$300M
$250M
$200M
$150M
$100M
$50M
FY 1972 PRESIDENT'S BUDGET IN 1973 DOLLARS
EQUIVALENT FUNDING IN FY73
$250M TOTAL FUNDING IN FY73
$280M TOTAL FUNDING IN FY73

FIG. 1

PROJECTION BASED UPON

$250-MILLION-BASED PROGRAM

FIG. 3 - 5%/YR. DECLINE

(IN FIXED 1973 DOLLARS)

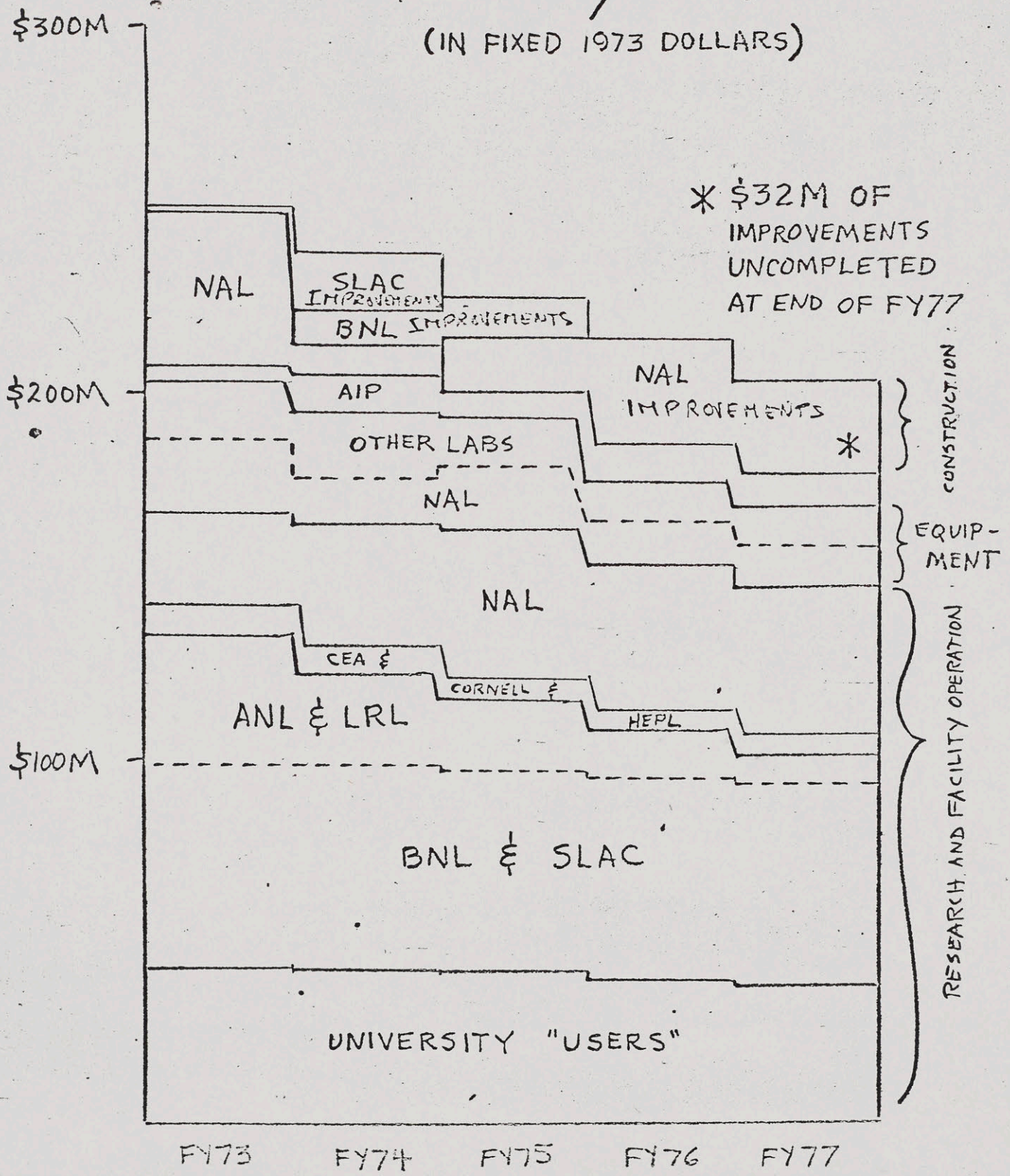


FIG. 4 - LEVEL SUPPORT

(IN FIXED 1973 DOLLARS)

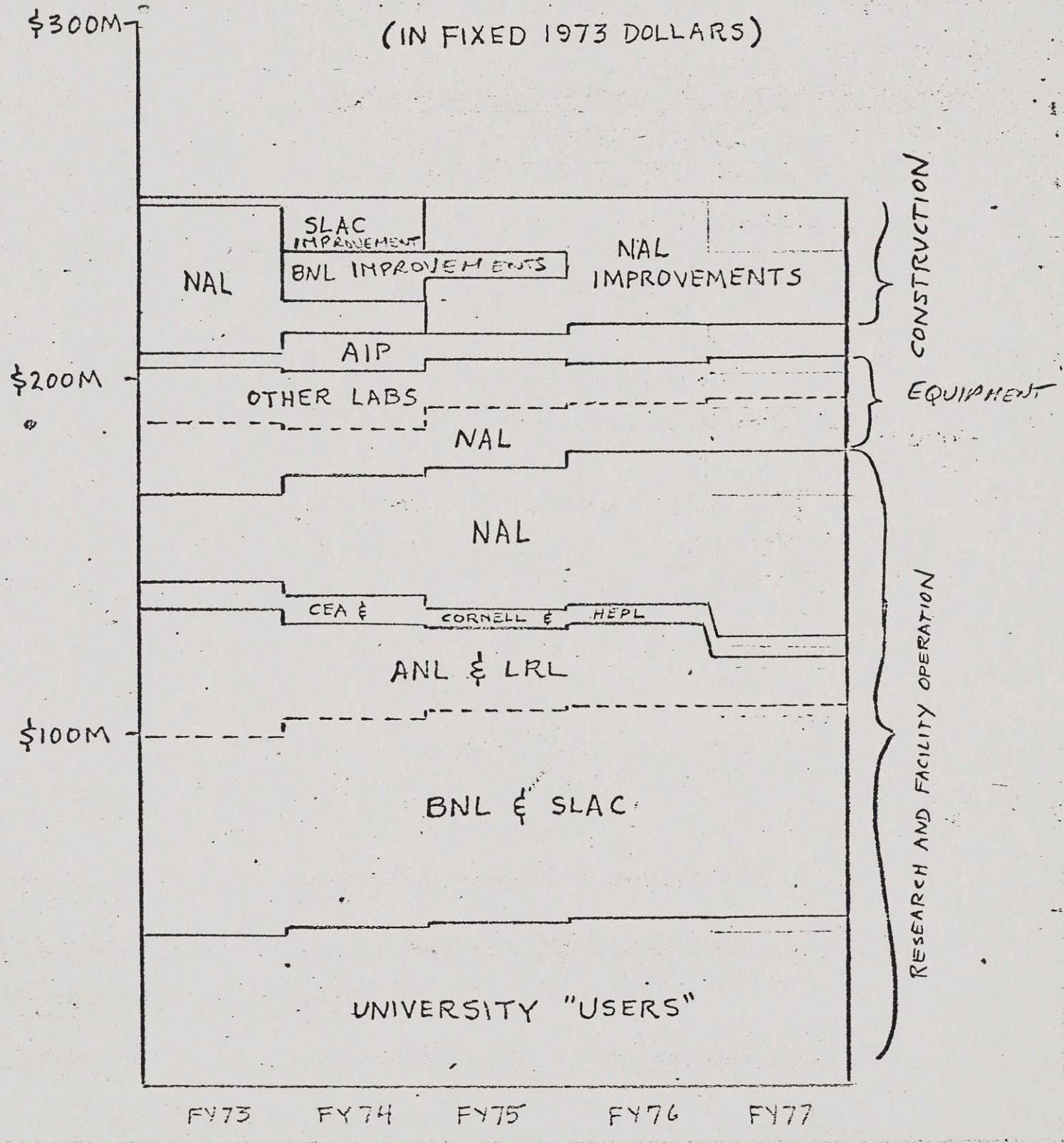
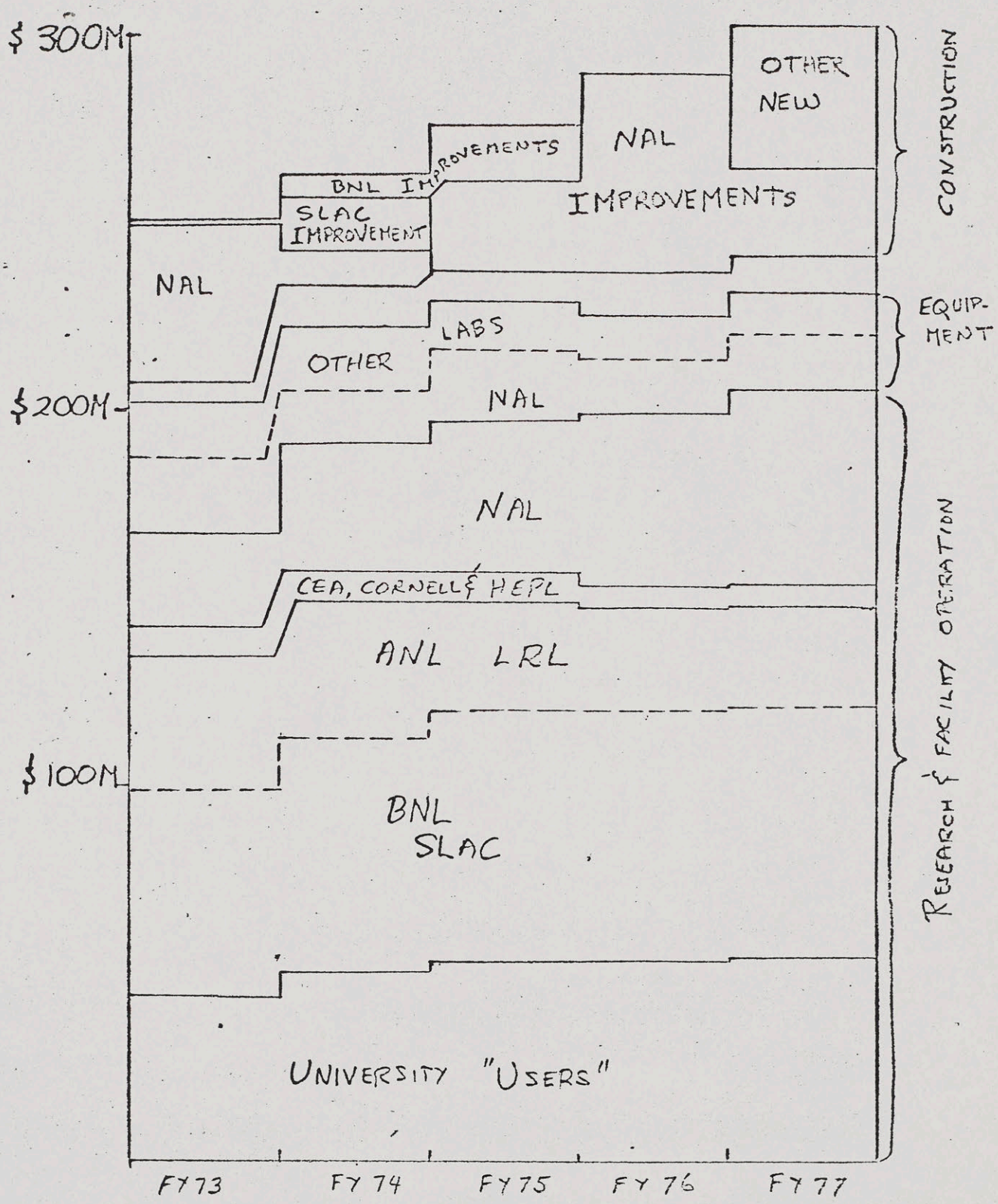


FIG 5 — 5%/YR. GROWTH

(IN FIXED 1973 DOLLARS)



TABULATION FOR $250-MILLION-BASE PROGRAM

LINE No:	5%-/YR. DECLINE					ZERO GROWTH					5%/YR GROWTH				
	FY73	74	75	76	77	FY73	74	75	76	77	FY73	74	75	76	77
1	43.7	43.1	42.6	40.1	38.4	43.7	45.0	45.6	46.7	46.7	43.7	50.0	53.0	53.0	53.8
2	27.0	25.5	25.5	25.5	25.5	27.0	27.0	27.0	27.0	27.0	27.0	30.5	31.5	31.5	31.5
3	28.1	28.1	28.1	28.1	28.1	28.1	29.4	29.4	29.4	29.4	28.1	30.5	31.5	31.5	31.5
4		2.0	2.0	2.0	2.0		2.0	4.0	4.0	4.0		2.0	4.0	4.0	4.0
5	17.8	7.1	7.1			17.8	8.9	8.9	8.9		17.8	17.8	10.7	10.7	10.7
6	17.8	17.8	12.2	12.2	7.4	17.8	17.8	14.0	14.0	14.0	17.8	18.5	18.5	16.8	16.8
7	90.7	80.5	74.9	67.8	63.0	90.7	85.1	83.3	83.3	74.4	90.7	99.3	96.2	94.5	94.5
8	8.0	7.2	6.5	5.5	5.5	8.0	8.0	5.5	5.5	5.5	8.0	8.0	8.0	5.5	5.5
9	24.7	34.0	40.0	40.0	42.0	24.7	34.0	40.0	43.0	52.0	24.7	34.0	40.0	46.0	52.0
10	167.1	164.8	163.0	153.4	146.9	167.1	172.1	174.4	178.5	178.6	167.1	191.3	197.2	199.0	205.8
11	19.8	12.6	17.1	12.0	12.0	19.8	12.6	17.1	13.5	15.0	19.8	14.0	19.0	15.0	15.0
12	15.9	17.0	13.4	10.2	10.2	15.9	17.0	13.4	11.7	11.5	15.9	17.0	13.4	11.7	11.5
13	35.7	29.6	30.5	22.2	22.2	35.7	29.6	30.5	25.2	26.5	35.7	31.0	32.4	26.7	26.5
14	4.2	10.1	7.0	10.5	8.9	4.2	10.6	7.5	11.6	9.4	4.2	10.6	7.5	11.0	9.4
15	42.0	8.9				42.0	8.9				42.0	8.9			
16	1.0	15.0				1.0	15.0				1.0	15.0			
17		9.1	11.4				13.8	6.7				5.7	14.8		
18			13.7	28.2	25.6			30.9	35.3	33.8			23.7	52.7	23.6
19					-32.5					1.7					38.6
20	250.0	237.5	225.6	214.3	203.6	← 250.0 →					259.0	262.5	275.6	289.4	303.7

DATA FOR FIGURE 3 FIGURE 4 FIGURE 5

TABULATION LEGEND FOR $250 MILLION-BASED PROGRAM

Table Entry	Base Assumptions	a. Considerations at -5%/year b. Considerations at level funding c. Considerations at +5%/year
1.	Total university user support, proportional to operating support of all laboratories.	
2.	BNL operations. FY 73 satisfactory utilization. (BNL has been undergoing a major construction program to improve and extend their facilities. This has entailed an unusual influx of construction money and prolonged shutdowns. This past imbalance makes quantitative assessment of accelerator utilization and laboratory program balance impossible within the scope of this study.)	a. Less than satisfactory utilization after FY 73. b. Satisfactory utilization. c. Satisfactory utilization with multiplicity of experiments.
3.	SLAC operations. FY 73 utilization about 72%.	a. 72% utilization. b. 75% utilization. c. Program request level after FY 73 reaching 80% utilization in FY 75 and thereafter.
4.	Increase operating funds to match need of BNL (conversion program) and SLAC (storage ring) to maintain accelerator utilization while increasing breadth (multiplicity) of experimental facility.	
5.	Reduce and eventually terminate ANL high energy physics and ZGS operations.	a. 40% level FY 74 and FY 75 and terminate after FY 75. b. 50% level FY 74, FY 75, FY 76 and terminate after FY 76. c. 60% level in FY 75, FY 76, and FY 77 and terminate after FY 77.
6.	Strengthen LRL high energy user physics. Reduce and eventually terminate Bevatron operations, following ANL schedule but delayed one year.	

7.	Total operation of BNL, SLAC, ANL, LRL. Determined in FY 73 by subtracting equipment, construction, and NAL requirements from budget. Funds proportioned to the four laboratories on the basis of AEC program requests.	
8.	Total operation of CEA, Cornell and HEPL. (Reduce operations and eventually terminate CEA.)	a. Further reduce CEA and terminate after FY 74. b. CEA remains at present reduced level, terminate after FY 74. c. Same as (b) but terminate after FY 75.
9.	NAL operations.	a. AEC program requests, limited to $40 M per year. b. AEC program requests through FY 76, laboratory requests in FY 77. c. Laboratory 5-year requests.
10.	Total operating costs for laboratories and all university users.	
11.	NAL equipment.	a. AEC program requests less 10% for FY 73, FY 74, FY 75; 20% less FY 76 and FY 77. b. AEC program requests, less 10% through FY 76. c. AEC program requests after FY 73.
12.	All other equipment (except large computers); same adjustments as for NAL equipment only 10% of program requests for Bevatron, ANL and CEA during reduced operations.	
13.	Total equipment.	
14.	Accelerator Improvement Projects adjusted from AEC recommendations. (Add essential buildings and increment for SLAC energy increase for FY 73 through FY 76.) No AIP from two years prior to reduced operations.	a. AIP: AEC program requests less 20% for FY 73, 74, 75; thence less 30%. b. AIP: AEC program requests less 20%. c. Same as (b).

15. Complete NAL construction. FY 73 amount (new obligation authority) is set to estimated costs for that year. Balance of obligations to complete are in FY 74.

16. SLAC energy upgrading via recirculation.

17. Brookhaven improvements (cryogenic accelerator or storage ring). $20.5 M assumed from cryogenic accelerator study.

18. Major NAL improvements (storage ring or energy upgrading). $100.0 M assumed from NAL 100 GeV Storage Ring Study. A very preliminary figure.

19. Remainder for exploiting new opportunities (further innovations, additional NAL installations, international accelerator, etc.) OR, if shown as deficit, amount in future years necessary to complete projects under way.

20. Total budget (in fixed 1973 dollars).

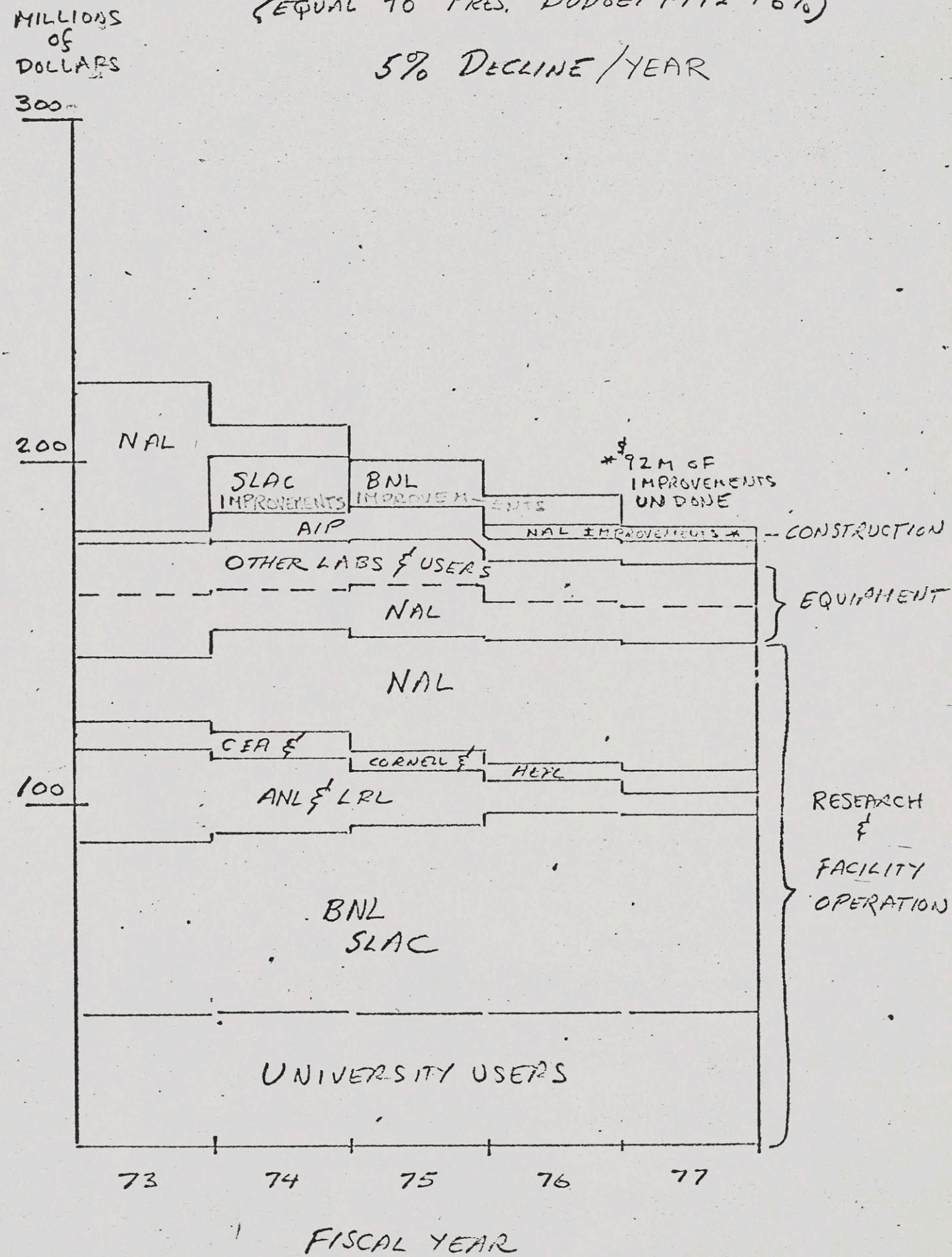
a. 5% decline per year.
b. Level funding.
c. 5% increase per year.

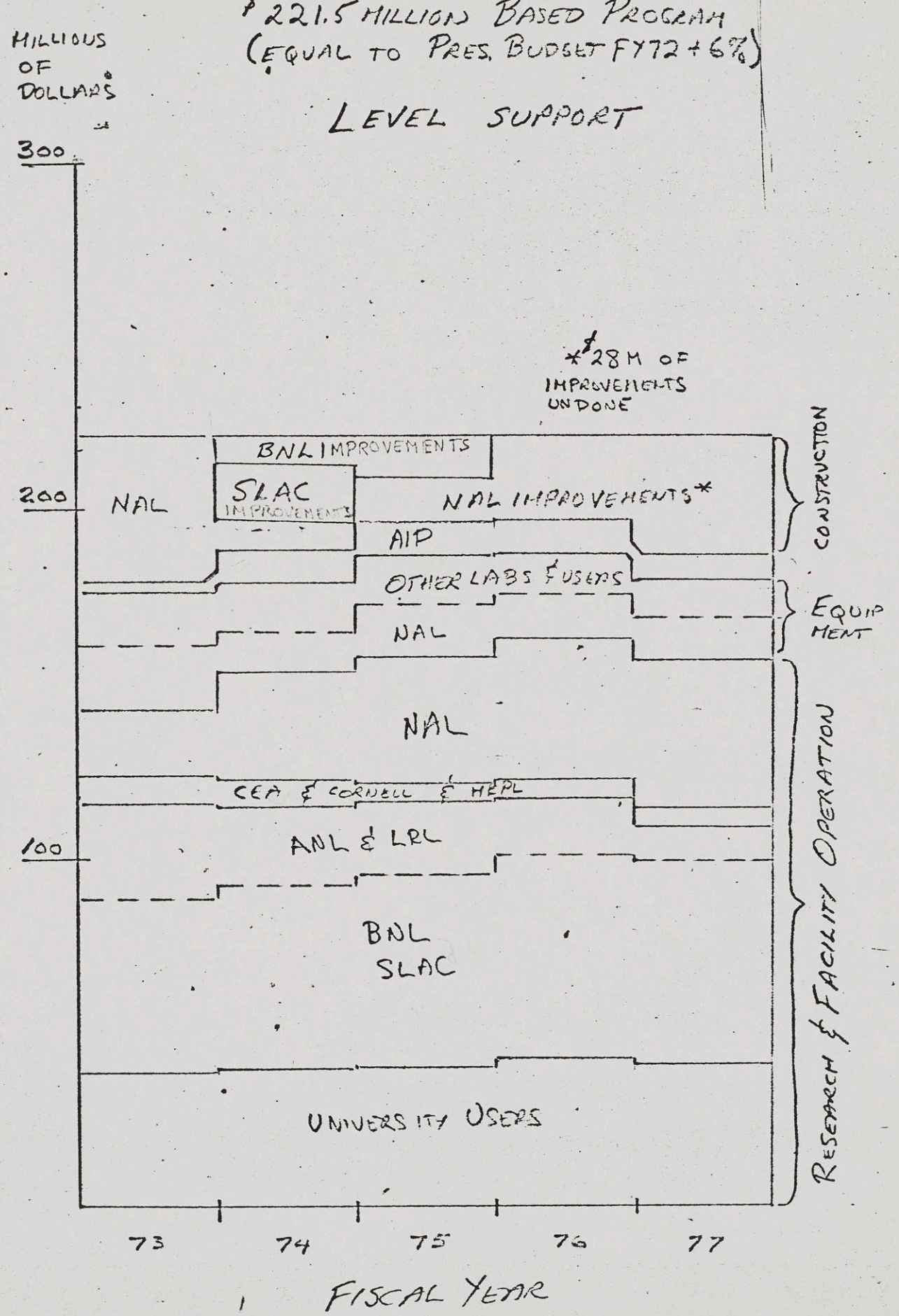
PROJECTIONS BASED UPON

$221-MILLION-BASED PROGRAM

$221.5 MILLION BASED PROGRAM
(EQUAL TO PRES. BUDGET FY72 +6%)

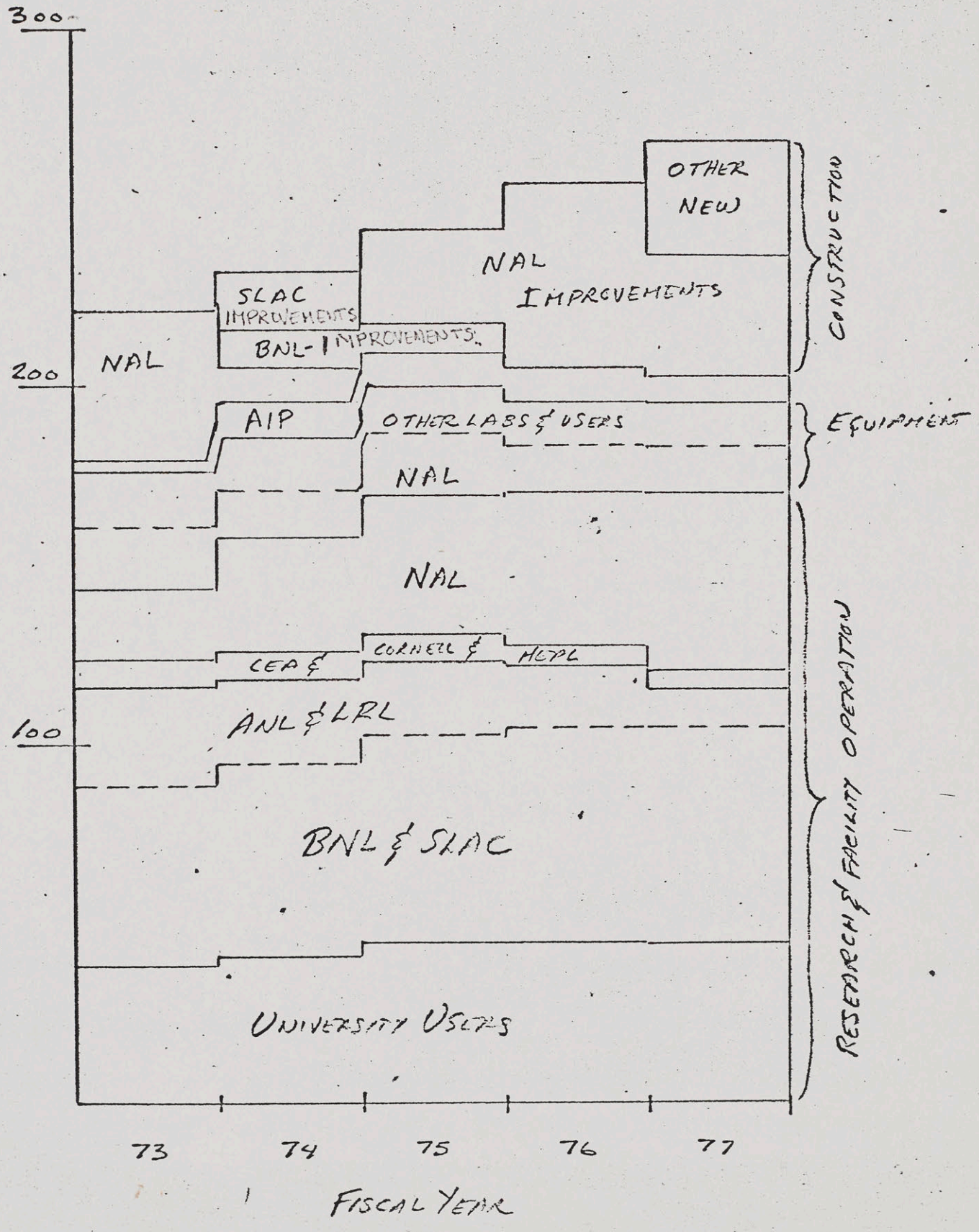
5% DECLINE/YEAR




$221.5 MILLION BASED PROGRAM
(EQUAL TO PRES. BUDGET FY72 + 6%)
LEVEL SUPPORT
MILLIONS OF DOLLARS
300
200
100
*$28M OF IMPROVEMENTS UNDONE
BNL IMPROVEMENTS
NAL
SLAC IMPROVEMENTS
NAL IMPROVEMENTS*
AIP
OTHER LABS & USERS
NAL
NAL
CEA & CORNELL & HEPL
ANL & LRL
BNL
SLAC
UNIVERSITY USERS
CONSTRUCTION
EQUIPMENT
RESEARCH & FACILITY OPERATION
73
74
75
76
77
FISCAL YEAR

$221.5 MILLION BASED PROGRAM
(EQUAL TO PRES. BUDGET FY72 +6%)

5% GROWTH/YEAR



TABULATION FOR #221.5-MILLION-BASE PROGRAM.

LINE NO.	5%/YR. DECLINE					ZERO GROWTH					5%/YR GROWTH				
	FY 73	74	75	76	77	FY 73	74	75	76	77	FY 73	74	75	76	77
1	39.3	39.4	38.8	33.6	38.3	39.3	40.2	40.9	42.8	41.1	39.3	41.3	44.4	44.6	44.5
2	24.2	25.0	26.0	26.0	26.0	24.2	25.0	26.0	26.0	26.0	24.2	25.6	27.0	27.0	27.0
3	25.0	26.0	27.0	28.0	28.0	25.0	26.0	27.0	28.0	28.0	25.0	27.0	29.4	29.4	29.4
4		1.0	2.0	4.0	4.0		1.0	2.0	4.0	4.0		1.0	2.0	4.0	4.0
5	11.8	7.9	3.9			11.8	8.2	8.2	4.1		11.8	8.2	8.2	4.1	
6	15.9	14.3	12.1	9.5	6.8	15.9	14.6	12.4	12.4	9.7	15.9	14.6	12.9	12.9	10.2
7	76.9	74.2	71.0	67.5	64.8	76.9	74.8	74.1	74.5	67.7	76.9	76.9	79.5	77.4	71.1
8	7.8	7.2	5.5	5.5	5.5	7.8	7.8	5.5	5.5	5.5	7.8	7.8	7.8	5.5	5.5
9	19.5	30.0	33.0	36.0	38.0	19.5	31.0	36.0	41.0	43.0	19.5	32.0	38.0	43.0	49.0
10	143.5	150.8	143.3	147.6	146.0	143.5	153.8	158.0	163.8	157.3	143.5	158.0	169.7	170.5	170.1
11	17.4	11.2	15.2	10.5	10.5	17.4	11.2	15.2	12.0	12.0	17.4	12.6	17.1	13.5	13.5
12	15.3	14.1	14.1	12.8	12.8	15.3	14.1	14.1	11.9	10.4	15.3	15.3	13.4	11.7	11.5
13	32.7	25.3	29.3	23.3	23.3	32.7	25.3	29.3	23.9	22.4	32.7	27.9	30.5	25.2	25.0
14	3.3	9.1	9.2	7.7	6.5	3.3	9.1	9.2	9.3	7.9	3.3	9.6	9.7	9.8	8.4
15	42.0	8.9				42.0	8.9				42.0	8.9			
16		16.0					16.0					16.0			
17		.3	13.1	7.1			8.4	12.1				12.2	8.3		
18				4.2	40.0			12.9	24.5	33.9			26.0	50.9	23.1
19					-91.8					-28.7					-42.6
20	221.5	210.4	199.9	159.9	180.4	221.5	221.5	221.5	221.5	221.5	221.5	232.6	244.2	256.4	269.2

TABULATION LEGEND FOR $221 MILLION-BASED PROGRAM

Table Entry	Base Assumptions	a. Considerations at -5%/year b. Considerations at level funding c. Considerations at +5%/year
1.	Total university user support, proportional to operating support of all laboratories.	
2.	BNL operations. FY 73 marginal utilization. (BNL has been undergoing a major construction program to improve and extend their facilities. This has entailed an unusual influx of construction money and prolonged shutdowns. This past imbalance makes quantitative assessment of accelerator utilization and laboratory program balance impossible within the scope of this study.)	a. Slightly improved operation after FY 73. b. Same as (a). c. Improved utilization after FY 74.
3.	SLAC operations. FY 73 utilization about 57%.	a. Approach 70% utilization for FY 75. b. Same as (a). c. Approach 75% utilization after FY 75.
4.	Increase operating funds to match need of BNL (conversion program) and SLAC (storage ring) to maintain accelerator utilization while increasing breadth (multiplicity) of experimental facility.	
5.	Reduce and eventually terminate ANL high energy physics and ZGS operations.	a. 50% level mid FY 73 and FY 75 and terminate mid FY 75. b. 50% level mid FY 73, FY 74, FY 75 and terminate mid FY 76. c. Same as (b).
6.	Strengthen LRL high energy user physics. Reduce and eventually terminate Bevatron operations, following ANL schedule but delayed one year.	

7.	Total operation of BNL, SLAC, ANL, LRL. Determined in FY 73 by subtracting equipment, construction, and NAL requirements from budget. Funds proportioned to the four laboratories on the basis of AEC program requests.	
8.	Total operation of CEA, Cornell and HEPL. (Reduce operations and eventually terminate CEA.)	a. Further reduce CEA and terminate after FY 74. b. CEA at reduced level, terminate after FY 74. c. Same as (b) but terminate after FY 75.
9.	NAL operations.	a. Below AEC program requests. b. Approach AEC program requests in later years. c. Below laboratory 5-year projection.
10.	Total operating costs for laboratories and all university users.	
11.	NAL equipment.	a. AEC recommendations less 20% for FY 73, FY 74, FY 75; 30% less FY 76 and FY 77. b. AEC recommendations less 20%. c. AEC recommendations less 20% in FY 73; following years cut 10%.
12.	All other equipment (except large computers); same adjustments as for NAL equipment only 10% of program requests for Bevatron, ANL and CEA during reduced operations.	
13.	Total equipment.	
14.	Accelerator Improvement Projects adjusted from AEC recommendations. (Add essential buildings and increment for SLAC energy increase for FY 73 through FY 76.) No AIP from two years prior to reduced operations.	a. AIP: AEC recommendations less 30% for FY 73, 74, 75; thence less 40%. b. AIP: AEC recommendations less 30%. c. Same as (b).

16. SLAC energy upgrading via recirculation.

17. Brookhaven improvements (cryogenic accelerator or storage ring). $20.5 M assumed from cryogenic accelerator study.

18. Major NAL improvements (storage ring or energy upgrading). $100.0 M assumed from NAL 100 GeV Storage Ring Study. A very preliminary figure

19. Remainder for exploiting new opportunities (further innovations, additional NAL installations, international accelerator, etc.). OR, if shown as deficit, amount necessary to complete projects under way.

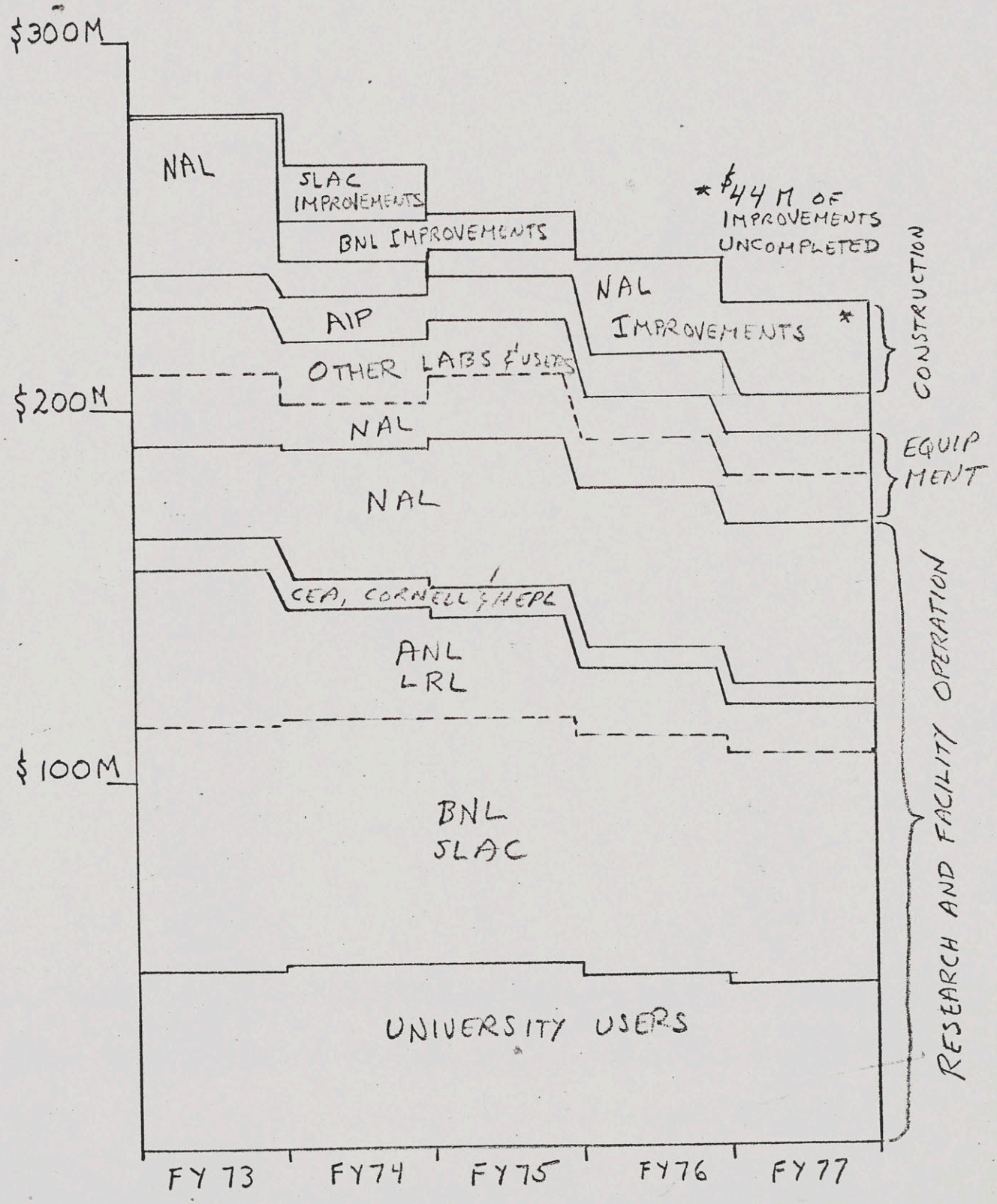
20. Total budget (in fixed 1973 dollars).

a. 5% decline per year.
b. Level funding.
c. 5% increase per year.

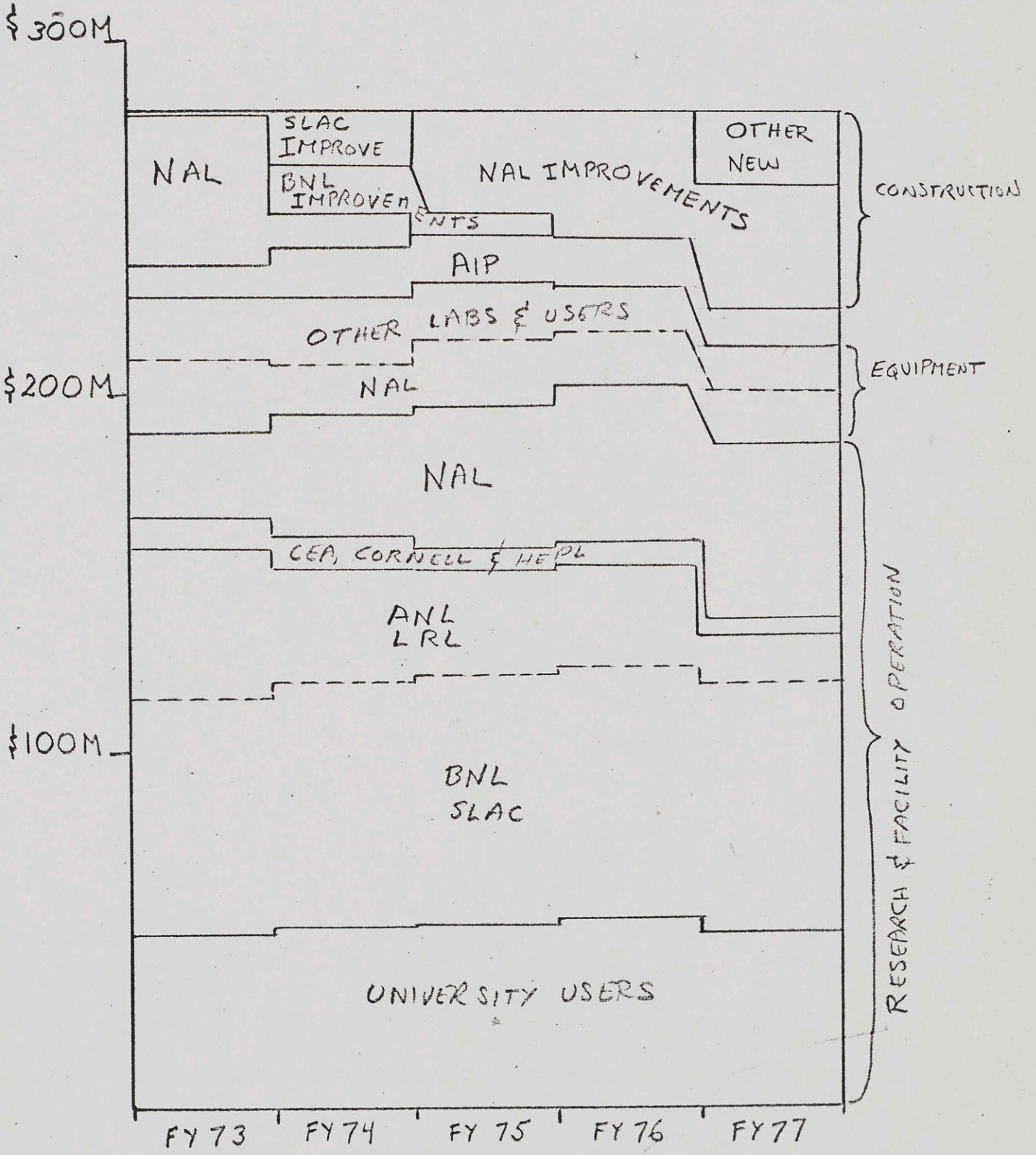
PROJECTIONS BASED UPON

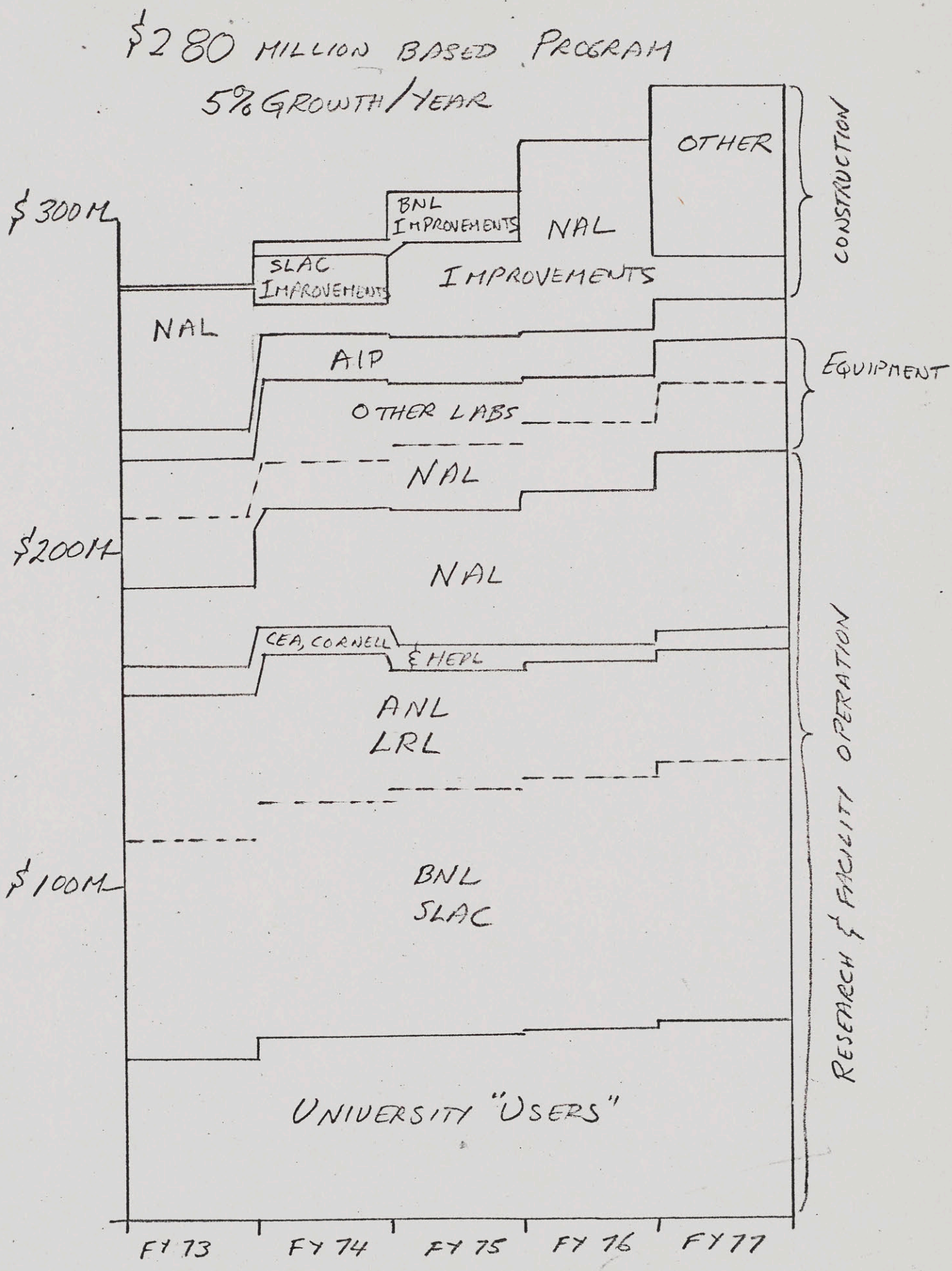
$280-MILLION-BASED PROGRAM

$280 MILLION BASED PROGRAM
5% DECLINE/YEAR



$280 Million Based Program Level Support




$280 MILLION BASED PROGRAM
5% GROWTH/YEAR
$300M
$200M
$100M
OTHER
BNL IMPROVEMENTS
NAL
SLAC IMPROVEMENTS
IMPROVEMENTS
CONSTRUCTION
NAL
AIP
OTHER LABS
EQUIPMENT
NAL
NAL
CEA, CORNELL & HEPL
ANL
LRL
BNL
SLAC
RESEARCH & FACILITY OPERATION
UNIVERSITY "USERS"
FY 73
FY 74
FY 75
FY 76
FY 77

TABULATION FOR $280 MILLION-BASED PROGRAM

	5%/YR. DECLINE					ZERO GROWTH					5%/YR GROWTH				
	FY 73	74	75	76	77	FY 73	74	75	76	77	FY 73	74	75	76	77
1	48.3	49.5	50.3	46.6	44.0	48.3	51.0	51.5	53.1	48.6	48.3	55.9	55.8	57.1	60.1
2	32.6	31.9	31.3	30.7	30.1	32.6	32.6	32.6	32.6	32.6	32.6	33.4	34.2	35.0	35.9
3	33.8	33.1	32.4	31.8	31.2	33.8	33.8	33.8	33.8	33.8	33.8	34.3	34.8	35.3	35.9
4		2.0	3.0	3.0	2.0		2.0	4.0	4.0	4.0		2.0	4.0	5.0	5.0
5	21.4	9.7	9.7				10.7	10.7	10.7		21.4	21.8	13.1	13.1	13.1
6	21.4	21.0	17.7	17.7	12.5	21.4	21.4	18.5	18.5	13.2	21.4	21.8	22.3	20.9	20.9
7	109.2	97.7	94.1	83.2	75.8	109.2	100.5	99.6	99.6	83.6	109.2	113.2	108.4	109.3	110.8
8	8.5	8.0	8.0	5.5	5.5	8.5	8.5	5.5	5.5	5.5	8.5	8.5	8.5	5.5	5.5
9	24.7	34.0	40.0	43.0	43.0	24.7	35.0	40.3	44.8	48.2	24.7	36.0	40.6	46.6	53.4
10	190.7	189.2	192.4	178.3	168.3	190.7	195.0	196.9	203.0	185.9	190.7	213.7	213.3	218.5	229.8
11	19.8	12.6	17.1	13.5	13.5	19.8	14.0	19.0	15.0	15.0	19.8	14.0	19.0	20.0	21.0
12	17.0	17.0	14.5	11.7	11.5	17.0	18.9	16.1	13.0	12.8	17.0	24.0	18.0	13.2	12.8
13	36.8	29.6	31.6	25.2	25.0	36.8	32.9	35.1	28.0	27.8	36.8	38.0	37.0	33.2	33.8
14	9.5	12.6	11.9	12.1	10.3	9.5	13.8	13.0	13.2	11.2	9.5	13.8	14.0	14.2	12.2
15	42.0	8.9				42.0	8.9				42.0	8.9			
16	1.0	15.0				1.0	15.0				1.0	15.0			
17		10.7	9.8				14.4	6.1				4.6	15.9		
18			7.0	24.5	24.5			28.9	35.8	35.3			28.5	58.2	13.3
19					44.0					20.6					51.2
20	280.0	266.0	252.7	240.1	228.1	280.0	280.0	280.0	280.0	280.0	280.0	294.0	308.7	324.1	340.3

4-22-71

TABULATION LEGEND FOR $280 MILLION-BASED PROGRAM

Table Entry	Base Assumptions	a. Considerations at -5%/year b. Considerations at level funding c. Considerations at +5%/year
1.	Total university user support, proportional to operating support of all laboratories.	
2.	BNL operations. FY 73 very satisfactory utilization. (BNL has been undergoing a major construction program to improve and extend their facilities. This has entailed an unusual influx of construction money and prolonged shutdowns. This past imbalance makes quantitative assessment of accelerator utilization and laboratory program balance impossible within the scope of this study.)	a. Increase restriction of accelerator utilization and experiments after FY 73. b. Very satisfactory utilization and multiple experiments. c. Very satisfactory utilization with maximum flexibility for multiple experiments.
3.	SLAC operations. FY 73 utilization about 90%.	a. Declining utilization. b. 90% utilization. c. Approaching optimum utilization and experimental flexibility.
4.	Increase operating funds to match need of BNL (conversion program) and SLAC (storage ring) to maintain accelerator utilization while increasing breadth (multiplicity) of experimental facility.	
5.	Reduce and eventually terminate ANL high energy physics and ZGS operations.	a. 50% level FY 74 and FY 75 and terminate after FY 75. b. 50% level FY 74, FY 75, FY 76 and terminate after FY 76. c. 60% level in FY 75, FY 76, and FY 77 and terminate after FY 77.
6.	Strengthen LRL high energy user physics. Reduce and eventually terminate Bevatron operations, following ANL schedule but delayed one year.	

7.	Total operation of BNL, SLAC, ANL, LRL. Determined in FY 73 by subtracting equipment, construction, and NAL requirements from budget. Funds proportioned to the four laboratories on the basis of AEC program requests for FY 73.	
8.	Total operation of CEA, Cornell and HEPL. Funds of CEA in FY 73 for aggressive storage ring program.	a. Reduce CEA and terminate after FY 74. b. CEA remains at FY 73 level, terminate after FY 74. c. Same as (b) but terminate after FY 75.
9.	NAL operations.	a. AEC program requests, limited to $40 M per year. b. AEC program requests through FY 76, laboratory requests in FY 77. c. Laboratory 5-year projection.
10.	Total operating costs for laboratories and all university users.	
11.	NAL equipment.	a. AEC program requests less 10%. b. AEC program requests, less 10% in FY 73. c. Laboratory request after FY 73.
12.	All other equipment (except large computers); same adjustments as for NAL equipment only 10% of program requests for Bevatron, ANL and CEA during reduced operations.	
13.	Total equipment.	
14.	Accelerator Improvement Projects adjusted from AEC recommendations. (Add essential buildings and increment for SLAC energy increase for FY 73 through FY 76.) 50% AIP two years prior to reduced operations; thereafter none.	a. AIP: AEC program requests less 10%. b. AIP: AEC program requests. c. Same as (b).
15.	Complete NAL construction. FY 73 amount (new obligation authority) is set to estimated costs for that year. Balance of obligations to complete are in FY 74.	

15. Complete NAL construction. FY 73 amount (new obligation authority) is set to estimated costs for that year. Balance of obligations to complete are in FY 74.

16. SLAC energy upgrading via recirculation.

17. Brookhaven improvements (cryogenic accelerator or storage ring). $20.5 M assumed from cryogenic accelerator study.

18. Major NAL improvements (storage ring or energy upgrading). $100.0 M assumed from NAL 100 GeV Storage Ring Study. A very preliminary figure.

19. Remainder for exploiting new opportunities (further innovations, additional NAL installations, international accelerator, etc.) OR, if shown as deficit, amount in future years necessary to complete projects under way.

20. Total budget (in fixed 1973 dollars).

a. 5% decline per year.
b. Level funding.
c. 5% increase per year.

MANPOWER PROJECTIONS

The "headcount" tabulations and projections given in Figure 2 (following) were arrived at as follows:

1. Figures given for FY 68 through FY 71 are actual headcounts.
2. Figure for FY 72 is based on laboratory assessments of personnel cutbacks (reductions in force) under President's proposed budget.
3. Projection A represents further 3 percent reduction in force if FY 73 funding remains the same as escalated FY 72 funding. This was calculated on the assumption that one-third of the vacancies created by attrition (normally 8 percent to 9 percent per year) can be left unfilled.
4. Projection B represents a 600-man restoration in force if FY 73 funding totals $250 million. This figure is based on headcount projections of various laboratories preparing FY 73 budget request submissions.
5. Curves 1 and 3 represent an increase or decrease, respectively, of one man for each $25,000 change in funding level. This is based on actual experience over the past five years.

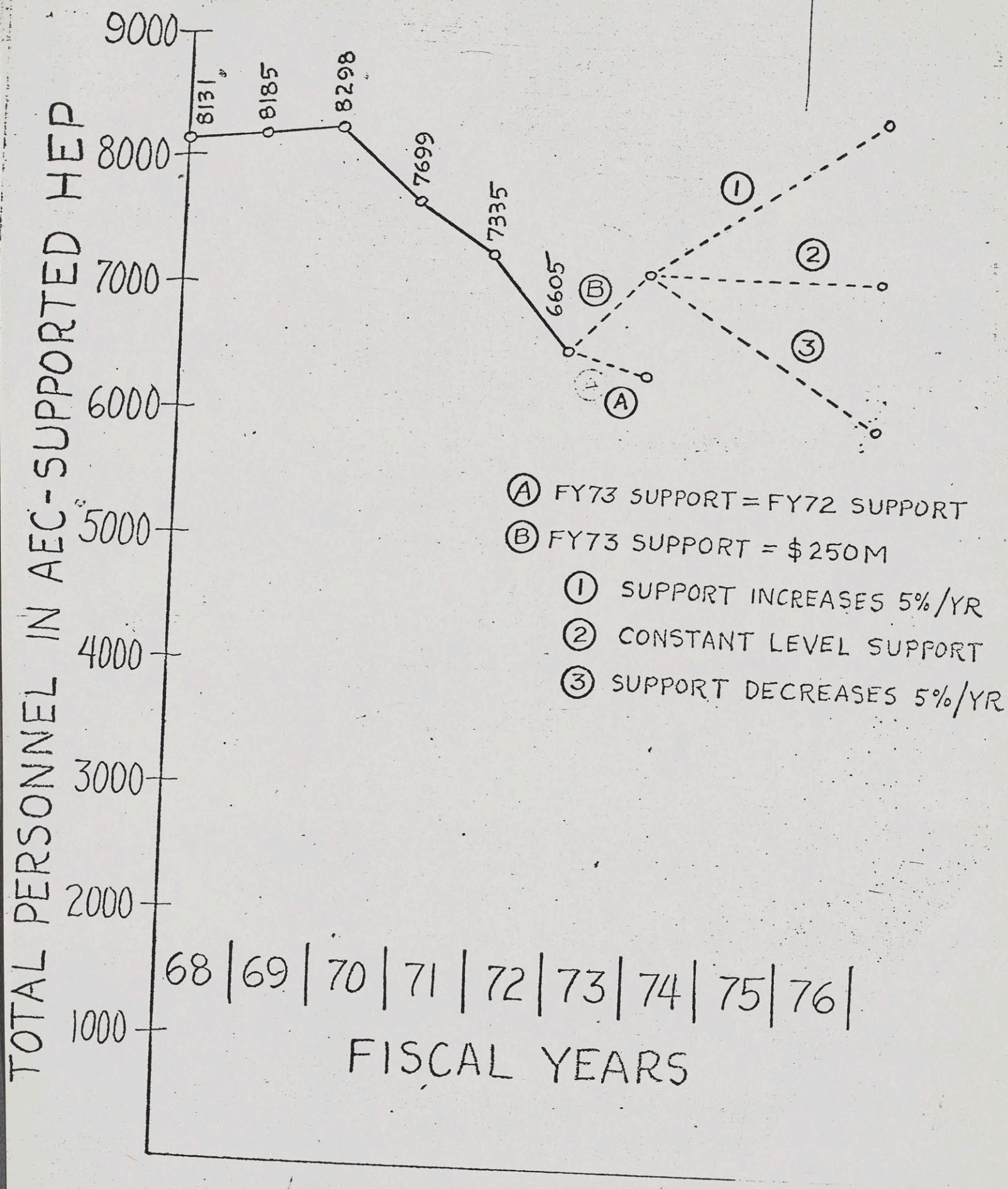

TOTAL PERSONNEL IN AEC-SUPPORTED HEP
9000
8000
7000
6000
5000
4000
3000
2000
1000
8131
8185
8298
7699
7335
6605
B
A
1
2
3
A FY73 SUPPORT = FY72 SUPPORT
B FY73 SUPPORT = $250M
1 SUPPORT INCREASES 5%/YR
2 CONSTANT LEVEL SUPPORT
3 SUPPORT DECREASES 5%/YR
68
69
70
71
72
73
74
75
76
FISCAL YEARS

FIG. 2

SOME SOURCE MATERIAL

1. AEC's "HIGH ENERGY PHYSICS PROJECTIONS, FY 1973-1977," dated 2/10/71. These projections contain laboratory or field "requests" and the "program requests" which latter constitutes the AEC staff projections. These data have been updated where some recent information has become available.

2. "Proton-Proton Colliding-Beam Storage Rings for the National Accelerator Laboratory," Design Study, 1968, NAL, Batavia.

3. "Design Study of a Cold Magnet Synchrotron (CMS)," Brookhaven National Laboratory, October, 1970.

4. "Brookhaven National Laboratory Summer Study on AGS Utilization, 1970," BNL 16000.

5. "Feasibility Study for a Two-Mile Superconducting Accelerator," Internal SLAC Document, Revised December, 1969.

6. "Recirculating SLAC with a Superconducting Section," W. B. Herrmannsfeldt, November, 1970.

7. Proposal to NSF for an Extension of the Experimental Area, Cornell University, 1970.

8. "High Energy Physics FY 72 Impact," AEC, March 5, 1971.

9. "The Manpower Crisis in Physics," L. Grodzins, MIT, January, 1971.

10. FY '73 Budget Projections, H. W. Koch, AIP, January, 1971.

11. AEC-HEPAP Correspondence.

12. AEC-furnished cost and obligation schedules for NAL.

13. "Utilization and Operating Costs of High Energy Accelerators of the AEC," General Accounting Office, 1970.

14. Accelerator utilization analysis by AEC staff from laboratory-furnished data.

15. "High Energy Physics Program: Report on National Policy and Background Information," Joint Committee on Atomic Energy, Feb. 1965, and other JCAE documents.

STANFORD UNIVERSITY

STANFORD LINEAR ACCELERATOR CENTER

Mail Address
SLAC, P. O. Box 4349
Stanford, California 94305

January 15, 1971

Mr. Caspar Weinberger
Deputy Director
Office of Management and Budget
Executive Office Building
Washington, D. C.

Dear Mr. Weinberger:

First I would like to thank you for giving me time for a telephone conversation during this hectic part of the budget cycle. I am confirming here the essence of the remarks I made during the call.

1. There is an enormous disparity between the actual funding of high energy physics and the planning assumptions which were made when those high energy laboratories now operating were created. In 1965 President Johnson submitted to the Congress on the request of the Joint Committee for Atomic Energy a Guideline for Policy for High Energy Physics. Actual funding for FY'71 adjusted to a fixed dollar is below that guideline by more than a factor of two. Total operating costs for high energy physics in fixed dollars have actually been decreasing substantially since 1966, while two large new laboratories (SLAC and NAL) have reached or are reaching the operating state, and a large construction project (BNL) is being completed which greatly increased the research potential of the laboratory.

2. As a result of this funding deficiency all existing high energy facilities in the United States are seriously under-utilized. All high energy accelerator laboratories have large fixed costs. The result is that any additional funding would buy a much more than proportional amount in productivity. I am attaching a graph which illustrates the situation by showing that at SLAC a given percentage increase in funding would buy 2.3 times as much operating time of the accelerator and a corresponding increase in research output. For budget reasons in FY'71 SLAC shuts down its operation for two months out of the year and beyond that, one week out of every four is non-operative. If, as you indicated, FY'72 funding in dollars will be lower by a small amount, then this fact, combined with inflation, means that operations will decrease further. The

SLAC situation is atypical only in that funding pressures never permitted full operation; other laboratories are now similarly under-utilized. A recent report in preparation by the General Accounting Office documents these facts quantitatively for each high energy accelerator.

3. The problem of under-funding of existing facilities became critical during the budget process for the Fiscal Year 1971. As a result it was reluctantly concluded that the logical economic response should be to decrease the total number of laboratories; in consequence it was decided to close the Princeton-Pennsylvania Accelerator, although it was a highly productive installation at that time. This step was taken in the full expectation that the funds freed by this shutdown plus additional funds which might be available in the future would increase the effectiveness of the remaining laboratories. A budgetary decrease for FY'72, combined with inflation, now not only swallows the cost reduction derived from the PPA shutdown, but goes considerably beyond that. As a result the total cost-effectiveness of the remaining laboratories is decreased even further.

4. U.S. funding contrasts sharply with the support of European high energy physics. Western Europe operates a smaller number of accelerators than does the United States but total funding is not only larger but is rising at a substantially higher rate. Consequently the degree of exploitation of corresponding European installations is much greater.

5. The situation for FY'72 is aggravated further by the success achieved by the National Accelerator Laboratory (NAL) at Chicago in advancing its expected completion date by almost one year beyond that originally envisaged, and in expecting to do so at less than estimated cost. Due to this earlier than expected turn-on date the pressure on the scientific community to utilize this machine is advanced also; in consequence the need for operating funds for the groups planning experimental use of the facility has increased. Moreover, the operating cost of NAL itself is increasing substantially in FY'72.

6. It seems to me that the scientific community should not be penalized for its successes such as the early turn-on of the National Accelerator machine. I should like to add that the high energy physics community has an enviable record in constructing accelerators at the highest energies on schedule and within projected budgets. Relative to other technological undertakings supported by the Federal Government this fact is truly exceptional, if you consider that design and construction of new accelerators involve at least as much extrapolation into new technology as is involved in space and military systems.

7. High energy physics is justly proud of many new technological developments it has achieved in the past, yet just such innovations are being actively discouraged by the present funding pattern. Each laboratory finds that if it diverts a small fraction of its resources for innovation it loses many times that amount in terms of current operating efficiency. Moreover, capital equipment funds for high energy physics have been reduced disproportionately in the budgeting process. It is these funds which not only increase future research opportunities but these monies also are needed for support of the ongoing research. Experiments in high energy physics involve such massive installations that many of the costs inherent to the normal experimental program are formally budgeted as capital equipment or accelerator improvement funds.

8. It appears incongruous to decrease high energy physics funding in the face of all these specific circumstances while, as you told me, other basic research funding, in particular that in the NSF, is now taking an upturn. Recent, extremely exciting results in high energy physics need further follow-up to achieve better understanding. Indications are that these results have uncovered another layer of totally new phenomena whose impact is not as yet understood.

I can add to these problems specific to high energy physics a remark on the more common problem of employment: High energy physics has lost already a substantial part of its manpower and the human impact of the reduction in effort implied by the FY'72 pattern is particularly severe since most of the high energy physics laboratories are located in areas which are already impacted by the decrease in technological spending by the government. For example, the unemployment rate in the county where most of the employees of SLAC reside is 7.4%; the actual figure is probably higher and the proportion of technically skilled people within this unemployment figure is much higher yet.

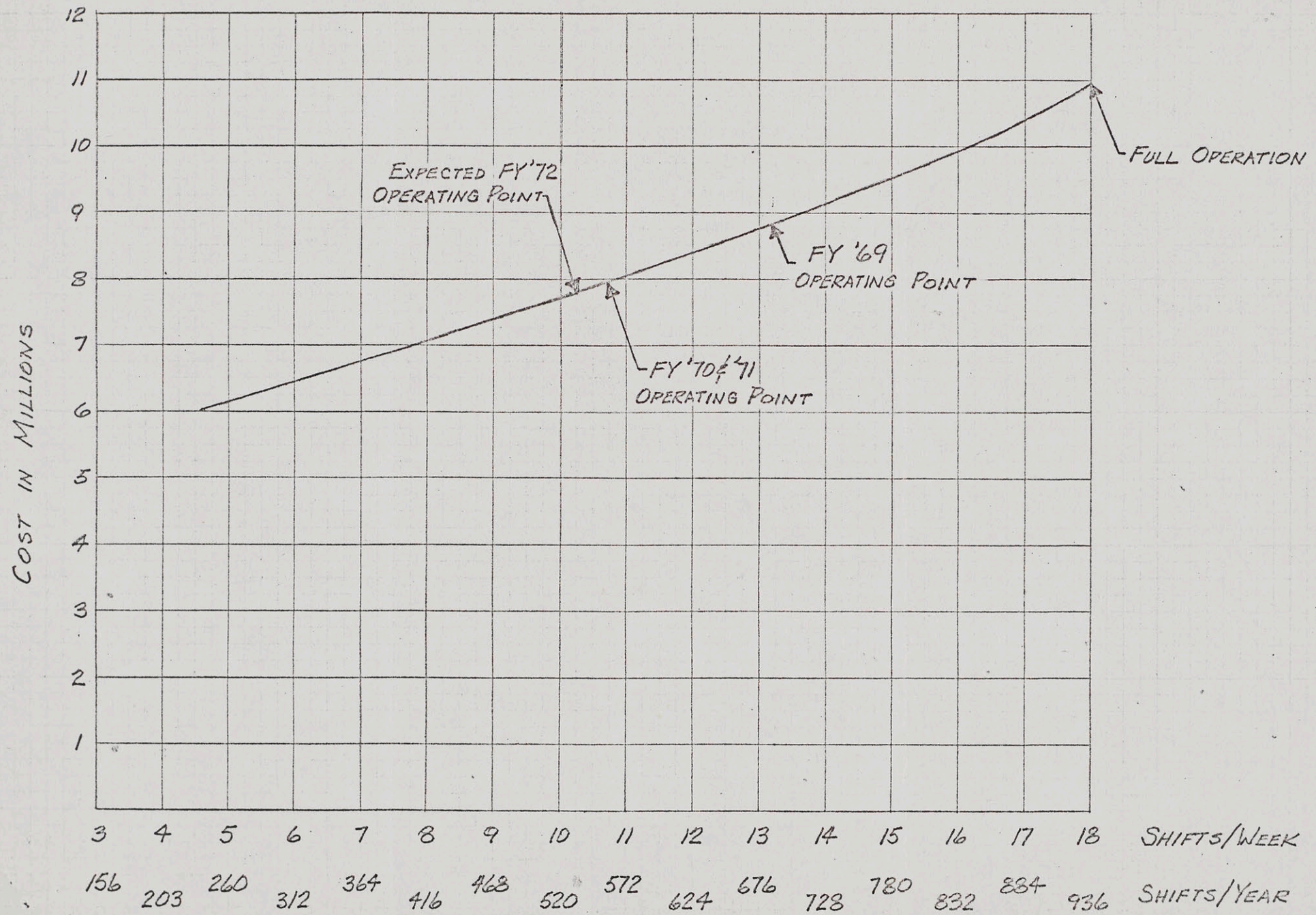
I appreciate very much having had the opportunity of bringing these problems to your attention and was heartened by your remarks that you were willing to entertain at least the possibility of supplementary funds in FY'72 and remedial action for FY'73. I also appreciate that you are willing to discuss these problems with me in person as time permits. I will be in Washington during January 26 and 27, and again later on February 22 and possibly February 16. I will try to arrange an appointment on one of these dates.

With many thanks and best personal regards,

Wolfgang K. H. Panofsky

Wolfgang K. H. Panofsky
Director

Estimated Annual Direct Cost of Machine Operation vs. Number of High Energy Shifts



W. K. H. Panofsky and SLAC Staff
February 1971

HIGH ENERGY PHYSICS AND THE FY'72 PRESIDENT'S REPORT

A Brief Outline of the Challenges and Problems

1. THE SCIENCE

High Energy Physics (the physics of elementary particles at energies above 1 BeV) has become the frontier of elementary particle research as it has evolved over the years. The field is far from being exhausted; new results which modify profoundly man's view of the most basic nature of the physical evidence continue to evolve. The procession of discoveries in elementary particle physics which have in a very real sense introduced new dimensions into physical thought are briefly listed in Attachment I. There is no evidence that the richness of the field in terms of basic discoveries is decreasing; yet a real synthesis of these results in a unifying picture is still eluding us.

As the frontier of elementary particle physics moves to higher energies, the relation of the earlier results to other sciences bares itself; the elementary particle physics of yesterday is the basis of nuclear structure physics of today. The relation of high energy physics to processes in cosmic systems is now beginning to be recognized.

2. LONG RANGE PLANNING VS CURRENT FUNDING

There is an enormous disparity between the actual funding of high energy physics and the planning assumptions which were made when those high energy laboratories now operating were created. In 1965 President Johnson submitted to the Congress on the request of the Joint Committee for Atomic Energy a Guideline for Policy for High Energy Physics. Actual funding for FY'72 adjusted to a fixed dollar is below that guideline by more than a factor of two. Total operating costs for high energy physics in fixed dollars have actually been decreasing substantially since 1966. This decrease has been occurring even while two large new laboratories (SLAC and NAL) have reached or are reaching the operating state and while a large new construction project (BNL) which will greatly increase the research potential of the laboratory is being completed.

Meaningful planning with some degree of commitment is essential for effective pursuit of high energy physics: The time interval between inception of new experiments and final analysis of the data is generally three years. Instrumental innovation, so essential in maintaining the vitality of the field, precedes actual participation in the experimental program by several years.

3. UNDER-UTILIZATION OF FACILITIES

As a result of this funding deficiency all existing high energy facilities in the United States are seriously under-utilized. High energy accelerator laboratories have large fixed costs. The result is that any additional funding would buy a much more than proportional amount in productivity. Figure B in Attachment III in the Appendix illustrates the situation by showing that at SLAC a given percentage increase in funding would buy 2.3 times as much operating time of the accelerator and a corresponding increase in research output. For budget reasons in FY'71, SLAC shuts down its operation for two months out of the year and, beyond that, one week out of every four is non-operative. If, as is indicated, FY'72 funding in dollars will be lower by a small amount, then this fact, combined with inflation, means that operations will decrease further.

Figure B in Attachment III documents how SLAC utilization has evolved in time relative to full capacity. The SLAC situation is atypical only in that funding pressures never permitted full operation; other laboratories are now similarly under-utilized. A recent report in preparation by the General Accounting Office documents these facts quantitatively for each high energy accelerator.

4. ACCELERATOR SHUT-DOWN

The problem of under-funding of existing facilities became critical during the budget process for the Fiscal Year 1971. As a result it was reluctantly concluded that the logical economic response should be to decrease the total number of laboratories; in consequence it was decided to close the Princeton-Pennsylvania Accelerator, although it was a highly productive installation at that time. This step was taken in the full expectation that the funds freed by this shutdown plus additional funds which might be available in the future would increase the effectiveness of the remaining laboratories. The budgetary decrease for FY'72, combined with inflation, now not only swallows the cost reduction derived from the PPA shutdown, but goes considerably beyond that. As a result the total cost-effectiveness of the remaining laboratories is decreased even further. The regular research program at CEA has been terminated in order to make it possible to carry on the development of the highly promising colliding beam "by-pass" facility. All other laboratories are carrying a large backlog of highly competitive experiments.

5. COMPARISON WITH SUPPORT OF EUROPEAN FACILITIES

U.S. funding contrasts sharply with the support of European high energy physics. Western Europe operates a smaller number of accelerators than does the United States but, in contrast, total funding for their operation is not

only larger but is rising at a substantially higher rate. Consequently, the degree of exploitation of corresponding European installations is much greater. Attachment II documents this situation in some detail. The European "300 GeV" accelerator, of cost comparable to that of NAL, is expected to be authorized shortly.

The storage ring (colliding beam) technique, first exploited successfully in the U.S., had been taken over almost entirely by U.S. and USSR laboratories until quite recently; the result is a highly unbalanced situation described in Attachment II.

6. SOVIET HIGH ENERGY PHYSICS

The Soviet high energy proton accelerator at Serpukhov is currently the world's highest energy machine, soon to be surpassed by NAL. The initial results from Serpukhov have been important contributions. Existing technological developments involving storage rings are being carried out at Novosibirsk. With these exceptions, generally speaking, most important high energy physics results continue to originate in the West. No simple budgetary comparison appears feasible.

There is excellent communication between Western and Soviet high energy physicists which is borne out by the fact that many Western European and some U.S. physicists are participating in the work at Serpukhov.

7. IMPACT OF AN EXPECTED EARLY TURN-ON OF THE NAL ACCELERATOR

The situation affecting the programs of the operating high energy laboratories for FY'72 is complicated further by the success achieved by the National Accelerator Laboratory (NAL) at Chicago in advancing its expected completion date by almost one year beyond that originally envisaged, and in expecting to do so at less than estimated cost. Due to this earlier than expected turn-on date the pressure on the scientific community to utilize this machine is advanced also; in consequence the need for operating funds for the groups planning experimental use of the facility has increased. Moreover, the operating cost of NAL itself is increasing substantially in FY'72. It is clear that the early utilization of NAL offers a challenging opportunity.

It seems to me that the scientific community should not be penalized for its successes such as the early turn-on of the National Accelerator machine. I should like to add that the high energy physics community has an enviable record in constructing accelerators at the highest energies on schedule and within projected budgets. Relative to other technological undertakings supported by the Federal Government this fact is truly exceptional, if you consider that design and construction of new accelerators involve at

least as much extrapolation into new technology as is involved in space and military systems.

8. DISCOURAGEMENT OF INNOVATION

High energy physics is justly proud of many new technological developments it has achieved in the past, yet just such innovations are being actively discouraged by the present funding pattern. Each laboratory finds that if it diverts a small fraction of its resources for innovation it loses many times that amount in terms of current operating efficiency.

As documented in Attachment II, capital equipment funds for high energy physics have been reduced disproportionately in the budgeting process. It is these funds which not only increase future research opportunities but which are also needed for support of the ongoing research. Experiments in high energy physics involve such massive installations that many of the costs inherent in the normal experimental program are formally budgeted as capital equipment or accelerator improvements funds.

9. RELATION TO OTHER RESEARCH FUNDING

It appears incongruous to decrease high energy physics funding in the face of all these specific circumstances while other basic research funding, in particular that in the NSF, is now taking an upturn. Recent extremely exciting results in high energy physics need further follow-up to achieve better understanding. As discussed in Attachment I, indications are that these results have uncovered another layer of totally new phenomena whose impact is not as yet understood, but which is expected to have far-reaching importance.

10. IMPACT ON SCIENTIFIC PERSONNEL

I can add to these problems specific to high energy physics a remark on the more common problem of employment: High energy physics has already lost a substantial part of its manpower and the human impact of the reduction in effort implied by the FY'72 pattern is particularly severe, since more of the high energy physics laboratories are located in areas which are already impacted by the decrease in technological spending by the government. The extent of the personnel losses is discussed in Attachment II; an alarming feature is that a substantial fraction of the U.S.-trained Ph.D. physicists have left the United States. Attachment III describes some of the extra-ordinary measures taken at SLAC to avoid excessive lay-offs.

* * * * *

I recommend that, on the basis of the situation outlined, supplementary funds for FY'72 be requested to relieve some of the inequities and inefficiencies generated.

ATTACHMENTS

ATTACHMENT I. Highlights of High Energy Physics Research

ATTACHMENT II. The Effects of Budget Trends on High Energy Physics in the United States

A. Comparison of Present Trend with Prior Plan
B. Comparison of European and United States Support of High Energy Physics
C. Nationwide Loss of Personnel from High Energy Physics
D. Trends in AEC Equipment Obligations for High Energy Physics

ATTACHMENT III. The Effects of Budget Trends on the Stanford Linear Accelerator in Particular

A. Operating Funds
B. Facility Utilization
C. Capital Equipment Acquisition
D. Personnel
E. Program Losses
F. Overall Budget Deduction Program

ATTACHMENT I. HIGHLIGHTS OF HIGH ENERGY PHYSICS RESEARCH

High energy physics aims to explore the nature of the physical universe to the smallest possible dimensions. Man's knowledge about our world is bounded on both the infinitesimal and the cosmic ends of the scale. Research in both areas continues to provide new insights and understanding of man's physical environment. Regularly, as both knowledge and techniques advance, discoveries greatly change man's view of his world.

The following table lists the most startling and profound observations and discoveries of high energy physicists over the past 25 years.

DATE	DISCOVERY	EXPLORATION
1947	Lamb shift: "g-2" of the electron	Limits of quantum electro-dynamics*
1947	Properties of the Pion*	Pion-nucleon interactions
1952	Bubble Chamber* for investigation of strange particles*	Interactions of strange particles
1954	Composite nature of the nucleon*	Electron scattering and nucleon spectroscopy
1955	Anti-proton*	Matter/Anti-matter symmetry
1956	Violation of parity conservation*	Weak interactions
1961	Hadron symmetries (SU^3)* and discovery of omega-minus (1964)	Whole hadron spectroscopy
1962	A second neutrino	Search for new leptons
1964	Violation of CP conservation	Search for T violation
1968	Point structure within hadrons	Deep inelastic scattering and e^-e^+ storage rings

*Work leading to Nobel Prizes.

A brief outline of the significance of each of these discoveries follows:

The development of the theory of quantum electrodynamics in 1946 opened a whole new all-inclusive way of understanding electromagnetic interactions. It predicted with uncanny accuracy the "Lamb shift" in atomic structure and provided an extremely precise quantification of the magnetic moment ("g-2") of the electron.

The pion (pi-meson) had been predicted in the late 1930's to be the "glue" holding the neutrons and protons together in the atomic nucleus.

The discovery of the pion in 1947 led to hopes that the new and strange "strong force" (or "nuclear force") would soon be understood; the properties of the new particles were rapidly explored.

Strange particles had indeed been observed in nature but just in the form of unaccounted-for particles discovered in cosmic rays.

In the constant shower of cosmic rays, physicists had earlier discovered the existence of unknown and bewildering "strange" elementary particles. It was not until 1953 and the advent of the new generation of accelerators, with energies high enough to produce the new particles under controlled laboratory conditions, that the full extent of the "strangeness" of these particles was realized. The strange particles were found to be produced copiously using high energy beams of the new accelerators, yet their decays were of a weak nature. Since both production and decay seemed to involve similar particles it was puzzling why they took place with such drastically different strengths. What was eventually discovered was the existence of a new conserved quantity in nature. This new quantum number, "strangeness," went far to explain the peculiar interactions of the strange particles in the 1950's. However, the full and rather deep implications of the strangeness quantum number were yet to come 10 years later with the discovery of SU(3) symmetry.

The new accelerators also probed smaller distances than had been explored before. In probing the proton by various scattering experiments, physicists found that the suspected point-like nature of the proton was not there; instead, the proton was an extended structure with a definite size. This result was first obtained by electron scattering experiments. In addition excited levels of the proton, or proton resonances, were found, further implying a compound structure.

When the Bevatron at the University of California became operational in 1954, an opportunity to test the concept of anti-matter symmetry was presented. The positron (anti-electron) had been discovered in cosmic rays in the late 1930's, opening the possibility of the existence of a complete anti-matter world, symmetric to the known particle spectrum. With the higher energy available at the Bevatron, one could hope to produce the first strongly interacting Fermian anti-particles seen in nature, anti-protons. Indeed, anti-protons were so produced, and as time has progressed most other elementary anti-particles have been found.

In 1964 at the AGS, the anti-deuteron was produced, strongly indicating the possibility of complete anti-particle symmetry through the elements.

In the mid-1950's the bubble chamber was invented, a device which proved to be invaluable in examining in detail the production and decays of what then amounted to 30 elementary particles. One such bubble chamber built in 1956 is still operating in the SLAC beam today. The bubble chamber was instrumental in precipitating, through measurements of unprecedented precision, perhaps the most profound discovery of the decade of the 50's, parity violation.

In 1956 it was shown that parity, i.e., right-left symmetry, was violated in the weak interactions. This discovery was truly momentous since physics from its inception had always assumed that nature could not distinguish right-handed and left-handed systems. The incorporation of this astounding fact into the framework of the weak interactions led to the inclusion of the neutrino and muon in the fundamental equations of particle physics in a beautifully symmetric fashion. These equations were then suggestive of more general forms ultimately leading to the inclusion of the weak interactions as essential reflections of the basic structure of matter in symmetry schemes of recent times.

In 1962 an elaborate experiment proved that contrary to the previous picture there was not just one neutrino in the world but indeed there were two - adding to the list of leptons (electrons, muons, etc.) in the list of elementary particles. This has led to extensive experimental searching for yet further leptons - the question of the role of a multiplicity of leptons in nature remains one of the great open problems in physics.

In 1964, approximately eight years after the discovery of parity violation, another fundamental symmetry principle was found to be violated: Time reversal invariance (or "CP conservation"). The forces driving processes in the forward and backward direction in time were determined not to be necessarily equal: An extremely weak violation was found, the full implication of which has yet to be resolved. Physicists have gained a great deal of insight through the investigation of such basic symmetry principles, and will continue to test established laws to the limits of obtainable precision.

As high energy physics entered the 1960's, the particle explosion really began. New bubble chamber and counter techniques, and the invention of spark chambers, permitted much more extensive and precise experiments to be performed. It seemed that each new experiment discovered at least one new particle.

By 1965 over a hundred particles were claimed to exist; a new nuclear physics had evolved. After considerable theoretical effort in the late 1950's and early 1960's, it was found in 1961 that a strong pattern was evident in the particle spectrum than extant. This pattern took mathematical expression through group theoretical approaches. In particular, the group (or symmetry) SU(3) had profound predictive power in describing not only the particle spectrum, but particle interactions as well. One great success of SU(3) was the prediction of the "omega-minus" meson, the first strangeness-3 object. This prediction was spectacularly verified in 1964.

Another dramatic implication of SU(3) was the idea of "quarks" - new ultra-basic elementary particles. With the quark concept many particle properties were explained in a rather simple way. Indeed, the accuracy of many calculations of particle properties is difficult to understand in light of the simplicity of the models used. Basically, the idea is that all known particles with strong interaction are composite objects, the constituents being quarks.

New experiments at SLAC involving the scattering of electrons from protons at energies higher than ever before appear to have uncovered another inner layer of matter. The additional available energy (and intensity) have yielded new results implying the existence of elementary point-like constituents in the proton; these may or may not be the quarks predicted from the SU(3) particle spectra. Experiments done with storage ring facilities in Europe have obtained similar results. More experiments are necessary to really prove or disprove these ideas of a new layer of matter. These are presently under way or will be in the near future at SLAC.

The beams of the National Accelerator Laboratory will provide an excellent testing ground for these ideas. Indeed with the much higher energy of NAL, one might actually be able to produce a "quark" in the laboratory. The new storage rings in Europe and the U.S. will add a totally new experimental approach to the field. Then an entire new world in high energy physics may open.

This brief historical outline amply documents that the rate of truly profound discoveries in elementary particle physics has by no means decreased - the field is still wide open. However the total impact of these fundamental revelations on our thinking and understanding of the natural world cannot be evaluated until a more comprehensive synthesis of theoretical ideas emerges.

ATTACHMENT II

THE EFFECTS OF BUDGET TRENDS ON HIGH ENERGY PHYSICS IN THE UNITED STATES

A. Comparison of Present Trend with Prior Planning

On January 26, 1965, the President sent Congress a Report on National Policy for High Energy Physics Program.[1] In that report a program was detailed that would maintain the leadership of the United States in elementary particle physics. Figure 1 strikingly shows the implications of past budgets and further reductions as departures from that program. It is evident that national funding for high energy physics has fallen to less than half of that projected by the 1965 policy planning.

The annual budgets proposed in 1965 are shown on the figure, escalated by the Consumer Price Index over the intervening years. Shown on the same figure are the dollars obligated by high energy physics for the intervening years and the obligation levels contained in the President's Budget for FY1972. The totals shown correspond to the entire program for federally supported high energy physics in the United States.

The U. S. Atomic Energy Commission supports the greater part of this program; the National Science Foundation is the next largest supporter, and a small fraction of support came from the National Aeronautics and Space Administration and the Department of Defense. For example, in the FY1970 budget, about $13.7 million was contributed from the National Science Foundation and about $3 million was shared by the Office of Scientific Research of the Air Force, the Office of Naval Research, and the National Aeronautics and Space Administration. The contribution to high energy physics of the latter three organizations for FY1971 and FY1972 is not included, but is very small.

Some additional support (not indicated) comes from costs shared by the universities, largely in the form of salary contributions, some computer time, some equipment, some reduction in overhead, and the provision of some facilities for their "user groups."

The Atomic Energy Commission is considered to be the "Executive Agent" responsible for coordinating the nation's High Energy Physics Program.

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[1] Congress: Joint Committee on Atomic Energy, High Energy Physics Program: Report on National Policy and Background Information, February, 1965, 89th Congress, 1st Session, Committee Print.

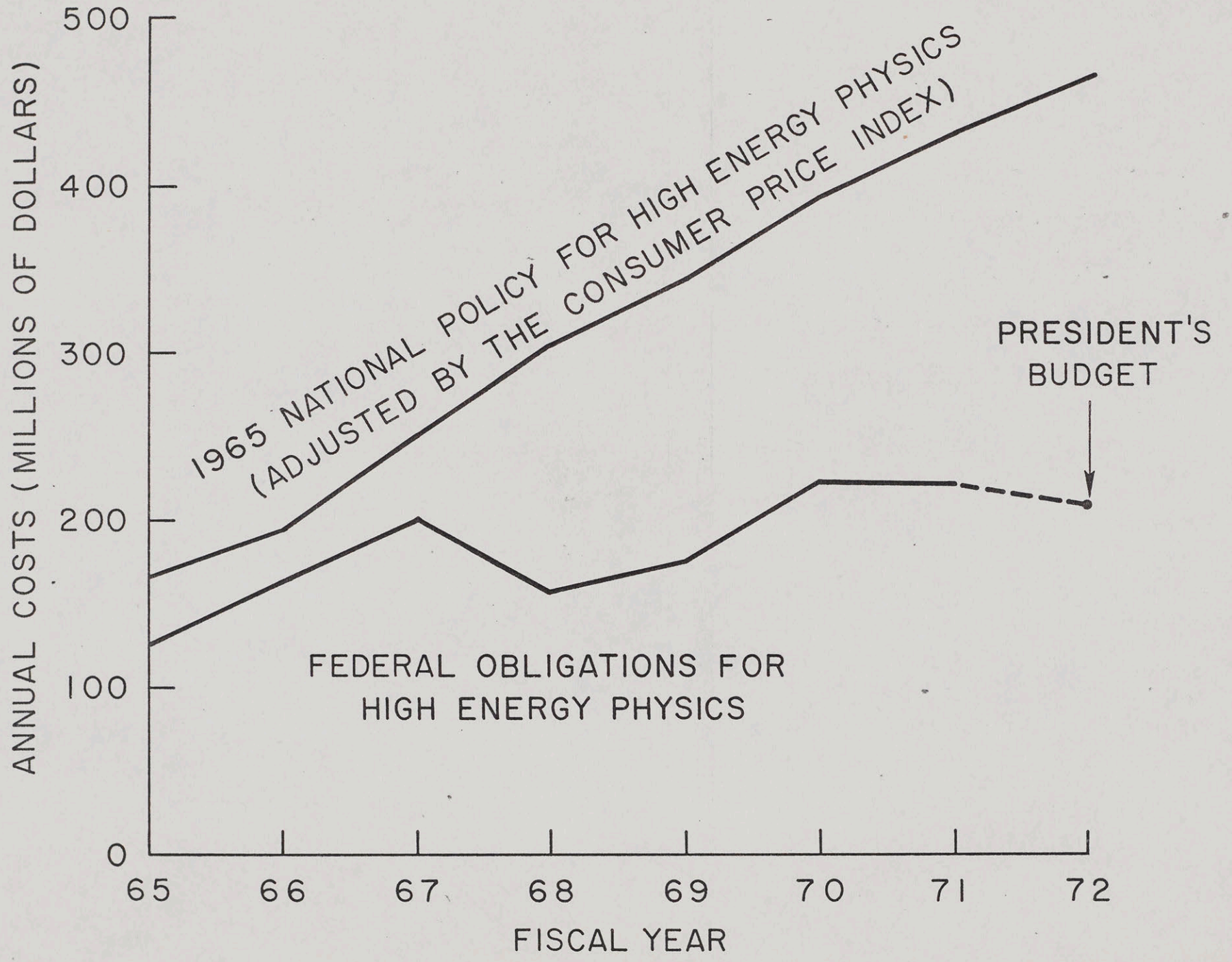

ANNUAL COSTS (MILLIONS OF DOLLARS)
500
400
300
200
100
0
1965 NATIONAL POLICY FOR HIGH ENERGY PHYSICS
(ADJUSTED BY THE CONSUMER PRICE INDEX)
PRESIDENT'S
BUDGET
FEDERAL OBLIGATIONS FOR
HIGH ENERGY PHYSICS
65
66
67
68
69
70
71
72
FISCAL YEAR

FIG. 1

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B. Comparison of European and U. S. Support of High Energy Physics

Until recently the United States has held a fairly clear position of world leadership in elementary particle physics. The European community has been working very actively in high energy physics at an increasing pace. The member countries have established an international laboratory of 3650 people at Geneva, Switzerland, called CERN (European Organization for Nuclear Research). In addition, there are several national laboratories and scores of active user groups at the universities in the various countries.

Figure 2 compares the money spent in Europe in the last few years compared to that obligated by the United States. For a valid comparison, the National Accelerator Laboratory with its 200 GeV accelerator under construction has been listed separately; it is expected to cost about $250,000,000. This laboratory corresponds to a 300 GeV accelerator which the European community is expected to approve within the next few months. It will cost $267,000,000 (at 1970 prices).

Table I attempts to compare the financial support available to the major accelerator centers in the United States and Europe. It can clearly be seen that for corresponding laboratories the United States facilities are at a financial disadvantage by about a factor of two. The total monies available to the United States, even with two additional major centers of activity, is less than that for Europe.

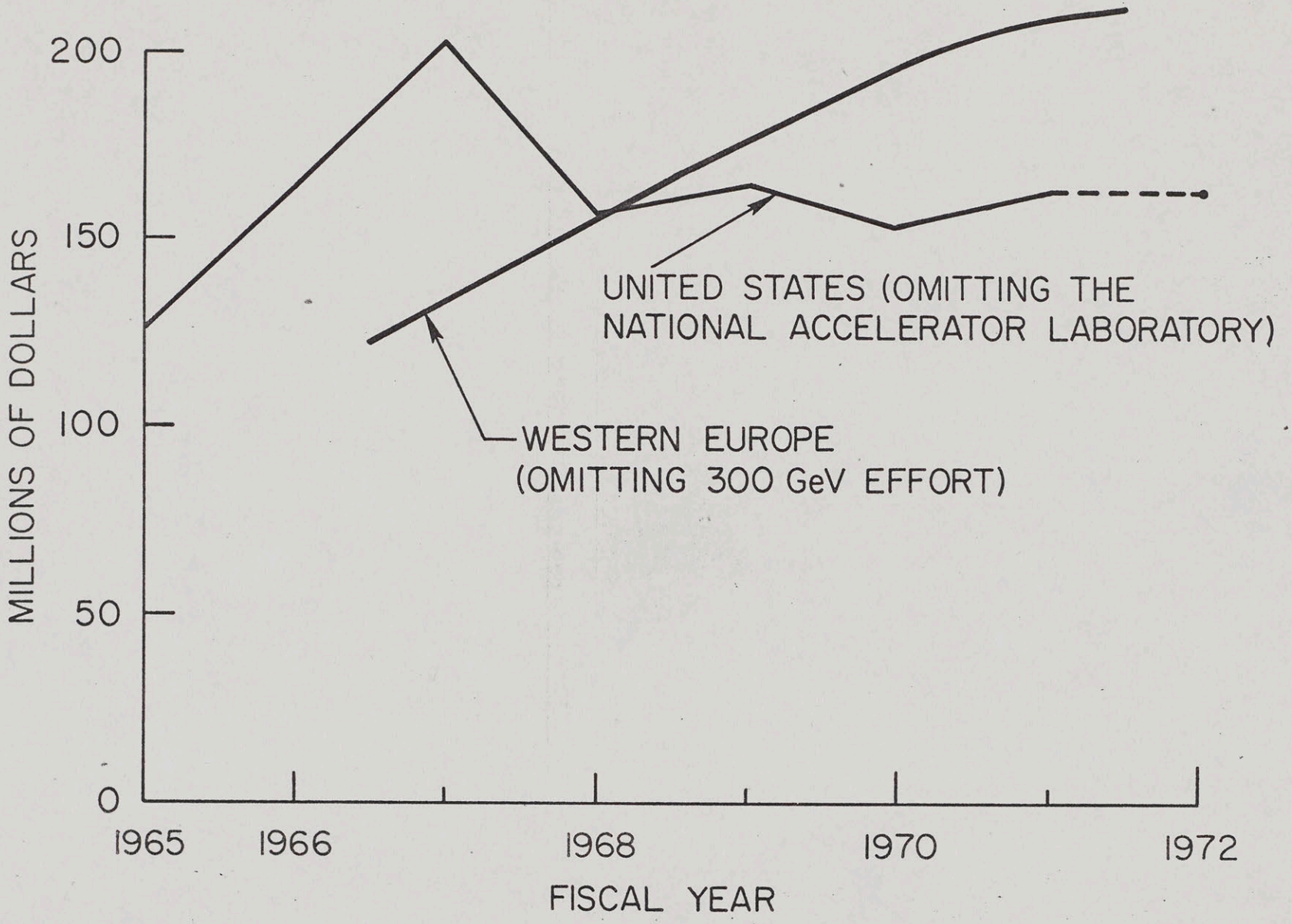
Table II illustrates the future relative positions of the United States vis-a-vis Europe and Russia in Colliding Beam-Storage Ring Projects. This area of research may represent the next frontier in the study of high energy particles. The United States, during past years has continuously been postponing or refusing proposals in this field; during the last years two efforts (CEA and SLAC) have gone forward at the expense of ongoing projects.

In colliding beam facilities, two beams of high energy accelerator particles collide head on, rather than having one beam striking a stationary target (as is customary). In such facilities the following special features accrue:

1. The energy available in the center of mass of the collision is very much larger; as an example, the CERN intersecting storage ring (ISR) which is now undergoing initial tests, will produce a reaction energy which corresponds to an ordinary accelerator of 1800 GeV.

2. If electrons and positrons are used as the colliding particles, not only is high center of mass energy obtained but in addition the reactions are of a particularly simple nature because no strongly interacting particles are present in the initial state; therefore, the reactions are produced by the closest equivalent to a source of "pure energy."

NOTE: The European numbers were hastily gathered from published sources. The accounting systems in the various countries differ widely. There has always been an active scientific interchange between the United States and Western Europe. An attempt is under way by the U.S.A.E.C. Division of Research and the CERN Planning Office to understand and relate the financial aspects of the high energy physics in the two parts of the world. The attempt has been made to compare the total laboratory programs including current construction.



UNITED STATES vs EUROPE EXPENDITURES IN
HIGH ENERGY PHYSICS

FIG 2

1824A5

TABLE I

SUPPORT OF CORRESPONDING ACCELERATOR LABORATORIES (OPERATING ABOVE 3 GeV)

Millions of Dollars [a]

United States		Europe	
AGS - Brookhaven (33 GeV)	$ 26.9	PS, CERN - Geneva (28 GeV)	$ 78.4 [b]
CEA - Harvard/MIT (6 GeV)	2.9	DESY - Germany (6 GeV)	22.0 [c]
Bevatron - Berkeley (6 GeV)	26.7 [d]	Nimrod - United Kingdom (7 GeV)	17.2
Cornell [e] (10 GeV)	2.7	NINA - United Kingdom (4 GeV)	8.3
Total Corresponding Accelerator Support	59.2		125.9
ZGS - Argonne (13 GeV)	19.0	-----	
SLAC - Stanford (22 GeV)	28.2 [f]	-----	
Total Major Accelerator Support	$106.4		$125.9

FOOTNOTES:

a/ This is the total support for the laboratories as can be ascertained. It includes Operating, Capital Equipment, Accelerator Improvement Projects, and General Plant Projects and computers for the U.S. Facilities. The European figures have been hastily gathered from published sources. The U.S. figures represent support for FY1971. The European figures represent support for calendar 1970 except for PS, CERN which are for calendar 1971. European monetary units have been converted at official rates.

b/ Includes several "line items" -- storage rings, the Serpukhov/Saclay collaboration, Big European Bubble Chamber, etc.

c/ Includes $5,900,000 for storage ring construction.

d/ Includes one time cost of $8,700,000 for a large computer and $1,500,000 for ERA development.

e/ Funded by National Science Foundation.

f/ Includes storage ring Spear.

TABLE II

COLLIDING BEAM - STORAGE RING PROJECTS

Location	Beam Energy	Relative Luminosity	Status and Comments	Total Cost (Millions $)
U.S.A.				
CEA, Cambridge	3.5 GeV	30.0	Scheduled operation: 1971	(Modification)
SLAC, Stanford	2.5 GeV	300.0	Scheduled operation: 1972	$ 5
Western Europe				
Frascatti, Italy	1.5 GeV	1.0	Operating	9
Orsay, France	0.55 GeV	0.05	Operating	2
Orsay, France	1.5 GeV	500.0	Proposed	10
DESY, Germany	3.5 GeV	3000.0	Scheduled completion: 1974	20
CERN, Geneva	28.0 GeV	10.0	Scheduled operation: 1971	85
			Total Europe	$126
U.S.S.R.				
Novosibirsk	0.75 GeV	0.1	Operating	
Novosibirsk	0.75 GeV	10.0	Scheduled completion: 1972	
Novosibirsk	3.5 GeV	10.0	Scheduled operation: 1971	
Novosibirsk	6-10 GeV	?	Proposed	
Novosibirsk	24.0 GeV	?	Under construction	
Kharkov	2-3 GeV	30	Under construction	

C. Nationwide Loss of Personnel from High Energy Physics

The reduction in high energy physics support together with increased costs will have a severe effect on the manpower of the national laboratories. A preliminary survey by the Division of Research of the U.S.A.E.C. indicates a reduction in personnel from FY1971 to FY1972 of some 863 people out of under 7000. These people will have to be separated from the laboratories and associated University user groups. This is an especial hardship for these people; the laboratories are generally located in areas of high technical activity and the current unemployment in these areas will make reasonable industrial employment for these specialized individuals difficult.

A case in point is a recent involuntary separation list from the engineering department of one of the major laboratories. It lists seventeen people; they have an average age of 48 years and an average of eleven years experience in that particular laboratory.

Professor Grodzins of Massachusetts Institute of Technology is Chairman of the Economic Concerns Committee for the American Physical Society. He is conducting a man-to-man survey to find out what is happening to the entire physics Ph.D. population of the country. His survey learned that in 1970, there were 1500 new Ph.D.'s looking for positions. He estimated that there were about 1700 experienced physicists looking for positions. Of this 3200 total, about 2000 found positions in the United States in physics jobs. The 1200 remaining did not. Of this 1200, two-thirds were experienced physicists and one-third were new Ph.D.'s. Half of these 1200 found work outside the United States, one-fourth left physics all together, and one-fourth remain unemployed.

Another survey has shown that, contrary to the case for all other Ph.D's, Federal research and development funding is the principal support of the endeavors of physics Ph.D.'s.

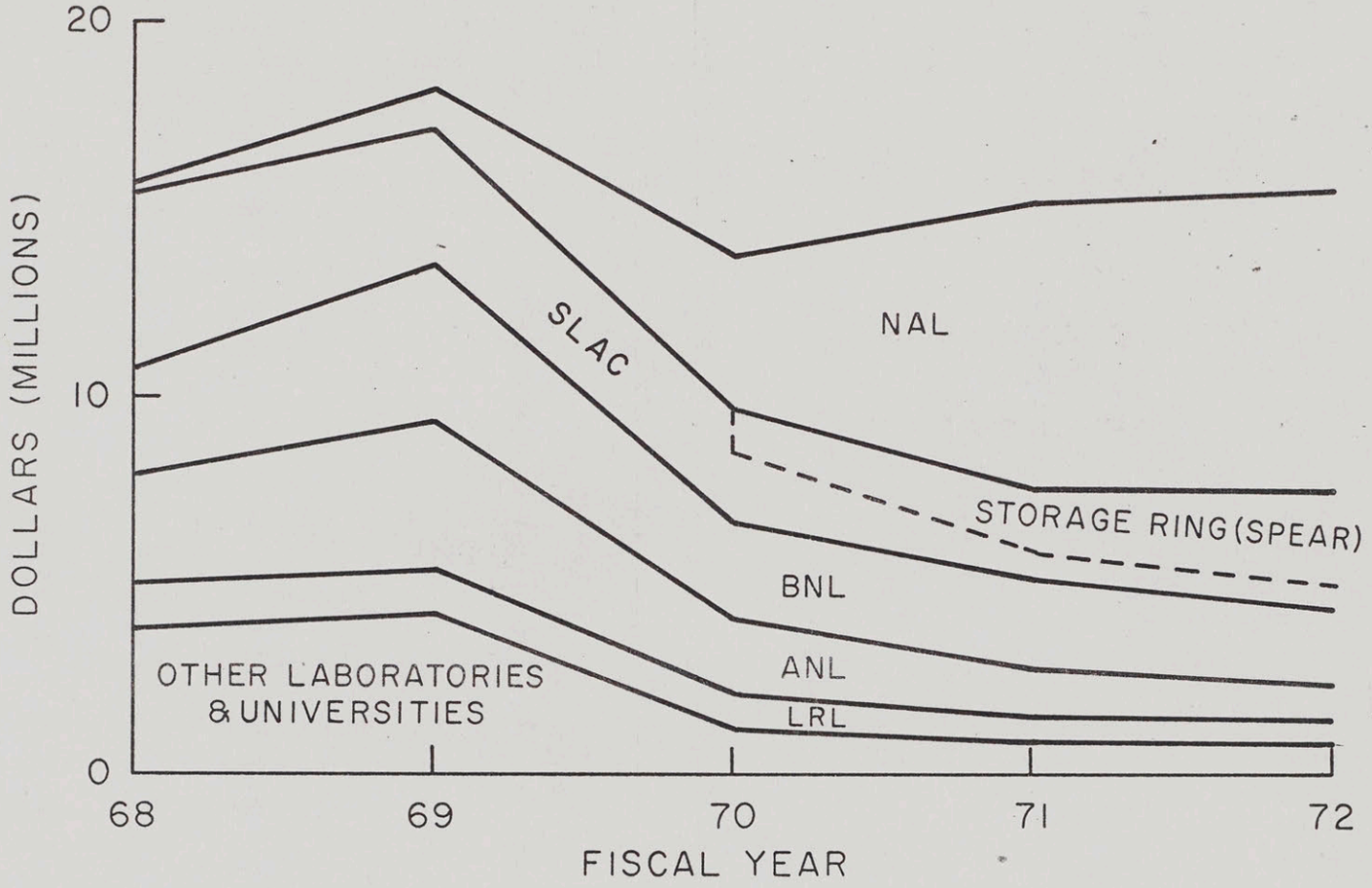
D. Trends in AEC Equipment Obligations for High Energy Physics

Figure 3 graphically illustrates the problems of high energy physics with respect to equipment. It shows the history of equipment obligations to the large AEC high energy physics laboratories (excluding computer purchases).

The money available for equipment for laboratories has decreased in spite of two new major projects being approved: The National Accelerator Laboratory, which must be equipped, and the SLAC Storage Ring, which is being built primarily as equipment.

Maintaining an experiment involves very complex apparatus, such as magnets and separators; the evident stringency has at times restricted the number of experiments that could be run simultaneously, cutting down on the incremental utilization of the accelerator. The equipment stringency has also curtailed the efforts to improve the efficiency of existing equipment, further reducing laboratory utilization. The development of new experimental devices has been curtailed; this inhibits future growth and utilization and efficiency.

The equipment and accelerator improvement funds play a very different role in high energy physics than they do in connection with lower energy ongoing programs. The apparatus of high energy physics is so large that the process of shifting from one experiment to the other as part of the regular ongoing program requires re-installation and re-furbishing of major pieces of equipment. By the current fiscal practices, a substantial part of this ongoing expense - part of the regular experimental program - has to be charged to capital equipment and to construction funds in the accelerator improvement categories. Accordingly only a fraction of those funds budgeted for equipment and accelerator improvements represent actual expansion of new opportunities. Therefore, the selective cutting of equipment and accelerator improvement funds has had a disproportionately large effect on technical innovation and the support of generally new experimental opportunities.



AEC EQUIPMENT OBLIGATIONS

FIG. 3

1824A7

ATTACHMENT III.

EFFECTS OF PROPOSED BUDGET REDUCTIONS ON SLAC IN PARTICULAR

A. Operating Funds. As shown in Figure A, the proposed budget for SLAC for FY72 for the first time provides fewer dollars in operating funds. More significantly, the effects of inflation have been reducing SLAC's real buying power since 1969 with the largest decrease to occur in FY72. Note that in the original Stanford proposal for SLAC, annual operating budgets of between 15 and 20 million dollars were specified for full operation after construction. Escalation since 1957 causes the corresponding figures for the present to be 22 to 28 million dollars.

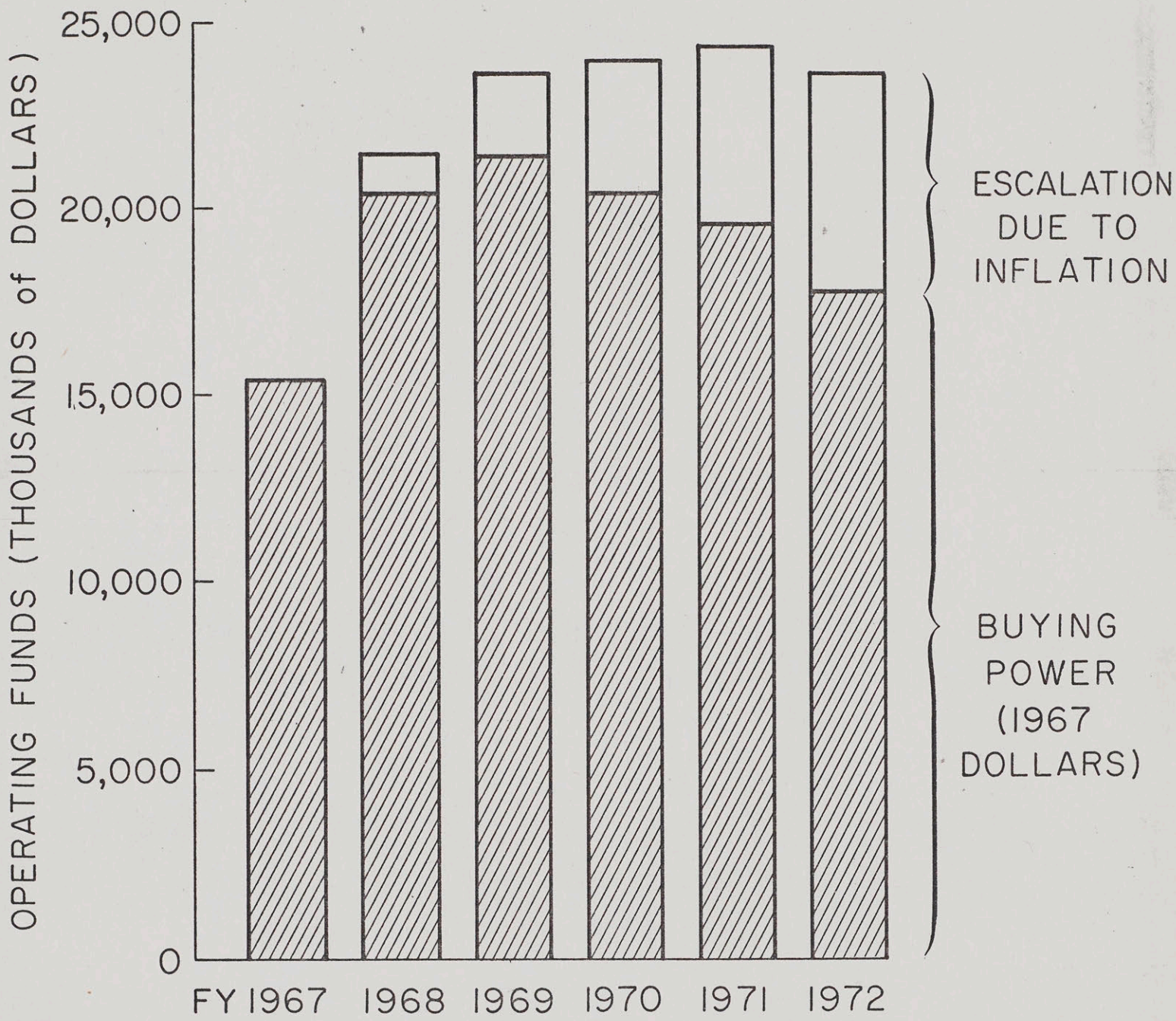
B. Facility Utilization. As shown in Figure B, the amount of use of the two-mile accelerator increased from FY68 to FY69 climbing towards optimum utilization of 936 eight-hour shifts per year. Reduced funds in FY70 and FY71 reversed this trend, decreasing utilization. The proposed FY72 budget will require even further under-utilization to but 57%.

C. Capital Equipment Acquisition. As shown in Figure C, the acquiring of capital equipment for carrying out new research experiments has been decreasing in magnitude since FY69. The proposed budget for FY72 provides for less than $200,000 for capital equipment not related to computer acquisition or storage ring construction. This compares to a high of over $5,000,000 in FY67.

D. Personnel. In mid FY70, anticipation of reduced operating funds initiated efforts to reduce staff, as shown in Figure D. Beginning in FY71, staff was added to begin construction of the SPEAR storage ring. By December of 1971, foreboding of budget cuts initiated another round of staff reduction. Beginning in July 1971, SLAC will establish regular periodic 4-day work weeks for the first half of FY72. Further attrition during FY72 will be capitalized upon.

E. Program Losses. As is shown on Figure E, the levels of funding for SLAC contained in the President's FY 1972 budget are $1.4 million less than is contained in present financial plans for FY 1971. When an estimated loss due to the influence of escalation of $1.4 million is added to this figure, a total loss in buying power of $2.8 million will be experienced in FY 1972 as compared to FY 1971. The impact upon SLAC due to this loss in buying power as developed in the preliminary planning for FY 1972 is severe. The level of accelerator shifts will be reduced by 5% from an FY 1971 level of 560 to an FY 1972 level of approximately 530. Virtually all development programs which are not directly related to approved experimental programs will be cancelled. A very substantial reduction in SLAC's ability to analyze experimental data will be experienced because a preliminary estimate for this activity shows reduction of as much as 25%.

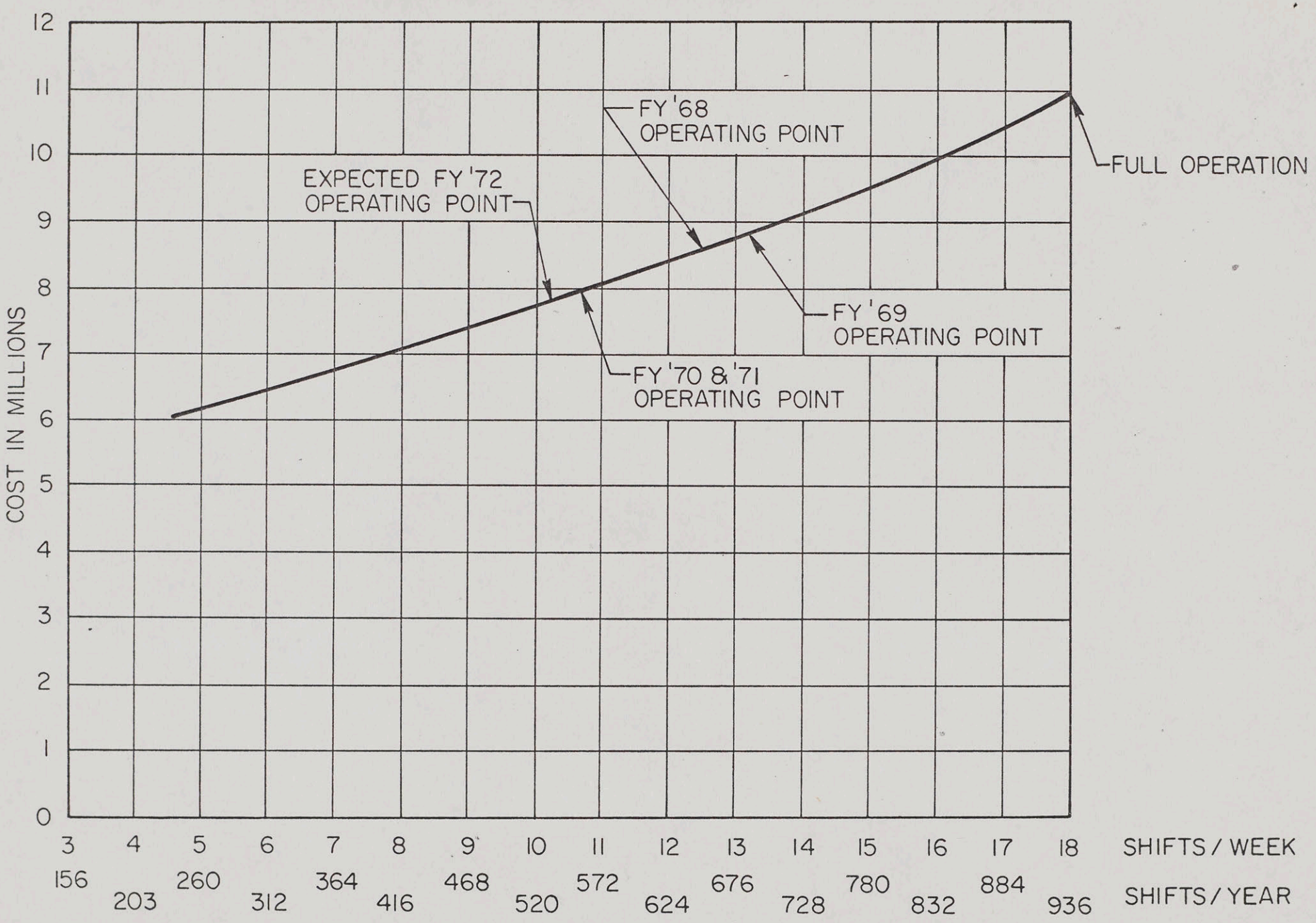
F. Overall Budget Reduction Program. Announcement of cost-reduction programs for FY72 was made in addresses to the staff on February 9, 1971. A copy of that address concludes this attachment.



SLAC OPERATING FUNDS

FIG. A

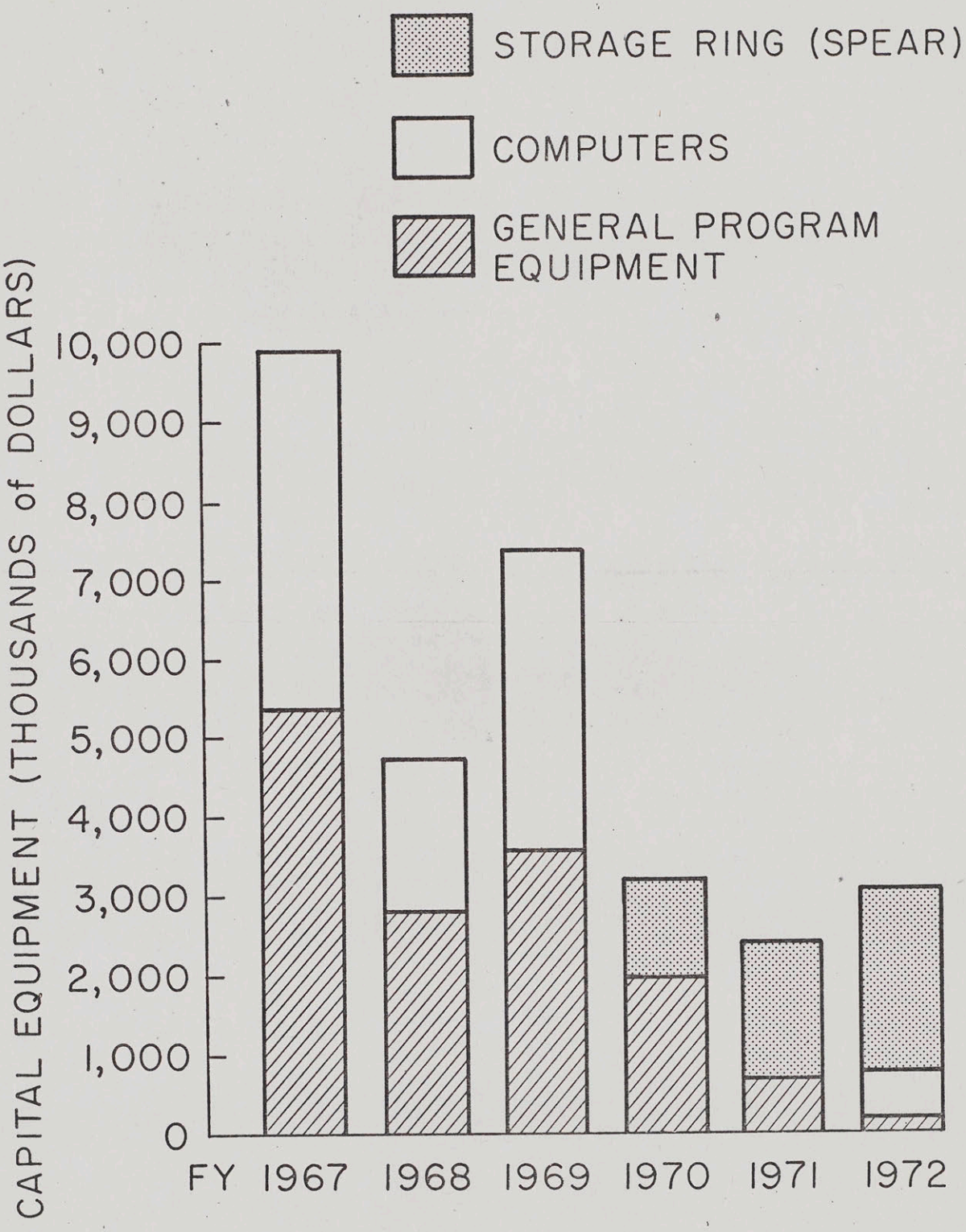
1824A2



ESTIMATED ANNUAL DIRECT COST OF MACHINE OPERATION
vs NUMBER OF HIGH ENERGY SHIFTS

1824A1

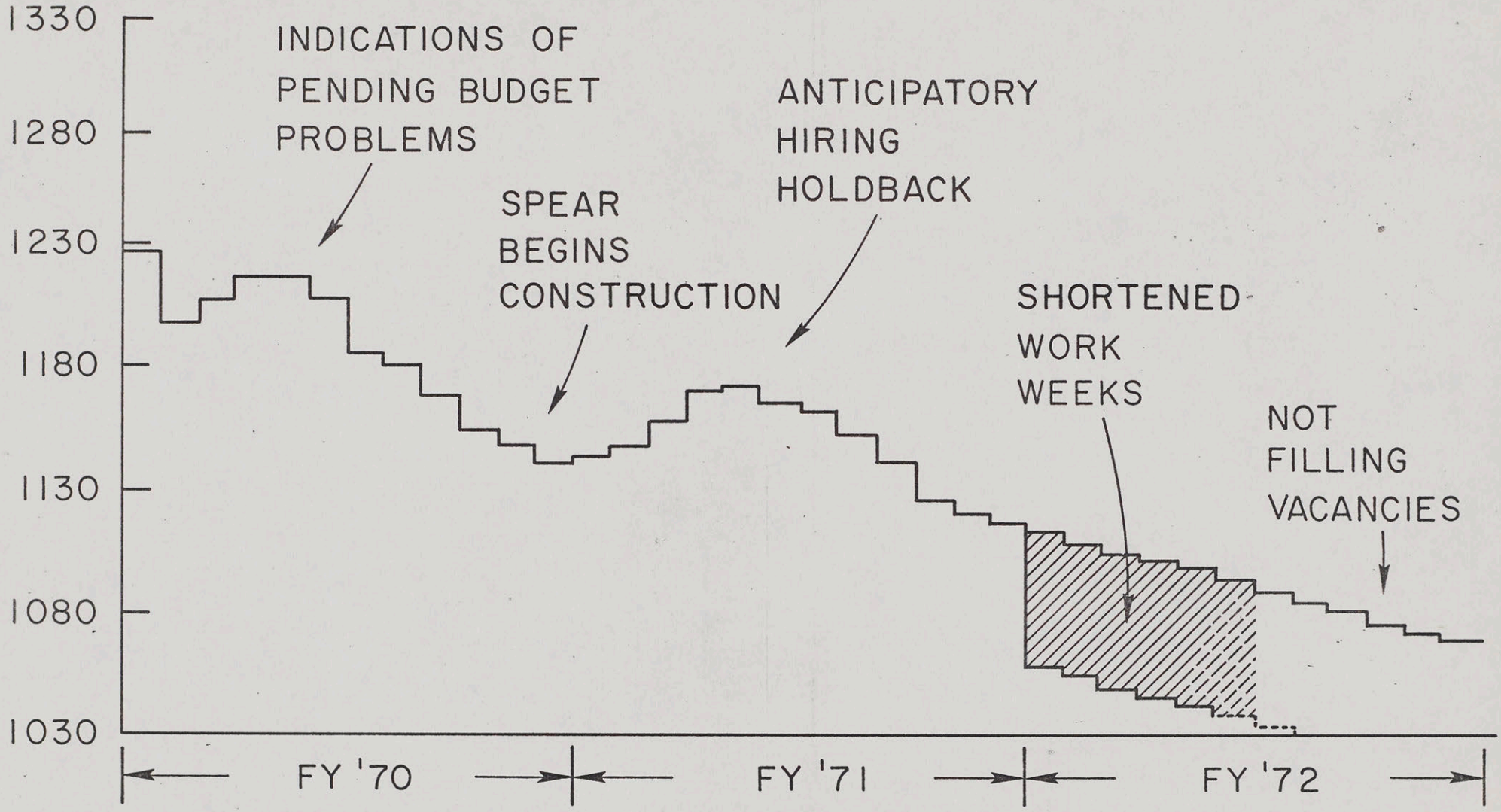
FIG. B



CAPITOL EQUIPMENT OBLIGATIONS

FIG. C

1824 A3



SLAC MANPOWER

FIG. D

1824A4

Estimated Total Costs

Dollars in Thousands

	FY1971	FY1972	Change
Operating	$24,300	$23,600	$ (700)
Equipment:			
Current Year Funds	2,420	3,100	
Prior Year Carryover	2,201	950	
Year-end Carryover	(950)	(150)	
Subtotal	3,671	3,900	229
Accelerator Improvement Projects:			
Current Year Funds	950	475	
Prior Year Carryover	478	200	
Year-end Carryover	(200)	(150)	
Subtotal	1,228	525	(703)
General Plant Projects:			
Current Year Funds	500	500	
Prior Year Carryover	163	50	
Year-end Carryover	(50)	(100)	
Subtotal	613	450	(163)
Total Costs	$29,812	$28,475	(1,337)
Escalation @ 5%			(1,424)
Adjusted Total			$(2,761)

FIGURE E

TALK TO SLAC STAFF ON FEBRUARY 9, 1971 - W. K. H. PANOFSKY

I am talking to you today about SLAC's progress and problems of last year and also to take a look into the future.

The last year has been one of achievement in spite of worsening budget problems. Excellent results have been obtained, both instrumentally and scientifically. Let me review a few of these results.

The accelerator has reached new records - in energy, intensity and power. The energy record now stands at 22.1 GeV, 10% above even the most optimistic design goal; the intensity has now reached a peak of 82 milliamps, more than 1½ times our initial maximum objective, and the average power of the beam is an incredible 880 kilowatts. Such an intensity used to be unimaginable in a high energy accelerator before SLAC entered the scene. I am showing you a 3-minute film sequence to give you some feeling of realism of what such powers mean.

We have increased greatly the multiplicity of beam operations; at times as many as six experiments are running simultaneously. This in turn has made the problem of our operators and maintenance people extremely complicated and I am grateful to all of them for having made this unprecedented mode of operation possible.

On the experimental equipment side there are also several records to report: A recommendation was made by the AEC's High Energy Physics Advisory Panel to concentrate hydrogen bubble chamber picture production at those laboratories which could do so most efficiently, and SLAC as a result has been carrying more than half of the total load of picture production. Although we would have liked to do more, we had set a target of about 4½ million pictures during the last year and this has been achieved. In addition to setting an impressive record in terms of just plain production the bubble chambers have also been used much more flexibly at SLAC than has ever been possible in the past: We have been able to run bubble chambers at record rates: For instance the 40" chamber has run 4 cycles per second in regular production runs. In addition we have developed methods by which bubble chambers are no longer as "blind" as they used to be: In the past all bubble chamber pictures had to be taken at each expansion whether something worth seeing had occurred or not. Now we have combined electronic detectors with bubble chamber operation so that a quick decision can be made after each expansion whether the picture is worth taking or not. Therefore substantial savings in film and in the subsequent data analysis accrue. As a result of all these developments the entire high energy physics community now depends heavily on SLAC for bubble chamber production; less than 20% of the pictures taken here are actually analyzed at SLAC with the rest going all over the world.

The spectrometer complex has evolved considerably during the last year: The different spectrometers have been operated in conjunction with one another and with other instruments so that a much larger variety of experiments became possible. In addition we have reorganized the spectrometer operations so that outside scientists can use the facilities while our own physicists can go their own way with independent experiments.

The streamer chamber has come into its own during the last year: In a single mammoth exposure 2½ million pictures were taken to study a high energy reaction which has been investigated several times before at other laboratories with results not being in agreement with one another. Our streamer chamber has the enormous advantage that this reaction can be looked at without any bias: Whichever way the particles go, they are detected. It is therefore hoped that the analysis of these pictures will settle this long-standing discrepancy.

1970 has been the year in which combinations of large magnets and wire spark chambers have seen intensive use and where it has been demonstrated that these techniques, when carried out at SLAC, can be fully competitive with the rest of the world. It had frequently been assumed previously that, because of the short pulses of the SLAC accelerator, such techniques would not be as productive here as elsewhere - this has been shown to be false; we are expecting to build a more complete wire chamber magnet facility during the next year in addition to the ones now in use.

1970 has also been an exciting year from the point of view of the scientific results themselves. The most profound experimental results have been those from the inelastic scattering program carried out with the large spectrometers in End Station A. It has become clearer and clearer that these results cannot be interpreted unless one assumes that there is another layer of matter even smaller than the proton itself. All theories which have been developed to understand these results have one common feature: They assume that there are point-like substructures - to use Dr. Drell's phrase, "like seeds in the jam" - in the matter which constitutes the proton. Understanding on this point is far from complete; an enormous number of theoretical studies have been induced by these results and more refined experiments are in progress at SLAC and elsewhere.

There has been great progress in studying the production mechanisms of particles not normally occurring in nature using the high energy X-ray beams which SLAC can produce in various ways. SLAC has the unique capability of providing X-ray beams of many different characteristics - high energy, low energy, in wide and narrow energy bands, polarized and not polarized. In a paradoxical way during the last few years SLAC has done such a good job in

covering this entire field that the data generated are so comprehensive that relatively few gaps remain. The data are so good that in making theoretical comparison of these results with those obtained from proton machines, usually inadequacy of the proton data sets the limit on interpretation.

During the second half of last year a new field of work was opened up: A vertical shaft was drilled into the hill behind Beam Dump A, which is where the beam from End Station A was caught. In this hole the same detectors were placed which, over a decade ago, had demonstrated at the Brookhaven National Laboratory that neutrinos, the most penetrating particles which exist in nature, exist in more than one form. The preliminary results from SLAC indicate that what is seen is not compatible with known properties of these neutrinos, but it is too early to tell whether something really new is in the works.

These impressive results have been achieved in spite of the fact that budget pressures have forced us to reduce the number of shifts from 680 during the Fiscal Year 1969 to 561 during Fiscal Years 1970 and 1971, and that we have been forced to reduce the staff by 42 during the last year.

As you may know, President Nixon's budget proposal for Fiscal Year 1972 (July 1, 1971 through June 30, 1972) has been presented to the Congress. The figures show that SLAC will be receiving less money to spend next year than we have had this year. We won't know what Congress will do to the budget proposal until, perhaps, next fall (after over one-third of the money has been spent!). But all indications are that SLAC will without doubt have budget problems.

Not only is SLAC likely to have fewer dollars but in addition these dollars will buy less because of inflation: Labor and materials have cost more by 5% this year, and it is probable that the same will happen next year.

SLAC's funds received from the government are spent in two ways: Money spent outside the laboratory for purchased goods and services, and money spent inside Stanford to pay our staff. Any reductions in either or both of these categories must be made keeping in mind the purpose of SLAC's existence: We exist for the purpose of designing, supporting and carrying out new experiments in elementary particle physics and to develop interpretation and theories relating to such work. Our financial support is affected by how much research we do and how well we do it.

During the budget squeezes of recent years we have continuously decreased outside costs in order to protect the jobs of our own people to the maximum extent possible. For the coming year we plan to continue these efforts to reduce outside costs as much as we can. We are preparing to counter inflation in materials and services costs by spending no more dollars for purchases than we do now. In addition, we will reduce the amount of work to be done next year at SLAC by reducing some of our internal programs. We are also planning to decrease even further the number of hours which the accelerator is operated in order to lower operating costs.

However, the apparent magnitude of our coming budget problem is such that we cannot continue to absorb it all by such techniques without seriously affecting the quality of our work. This means that we must also accept the unpleasant fact that we have to accomplish substantial savings in our payroll next year: We must decrease our "in-house" effort by the equivalent of 100 people working for one year. How can we do this and do the least harm to our staff, to our work and to SLAC's future?

The simple method, following common industrial practice, would be to separate close to 100 people from the payroll. *This we will not do.* Jobs, including those requiring technical skills, are scarce on the Peninsula - unemployment is above 7%, which is much higher than the national average. The quality of our work would suffer. We could shut the laboratory down for enough weeks without pay to balance the budget but we would thereby seriously diminish the scope of our research program. We could decide to freeze all salary increases for an entire year, but this would be unfair to everyone in this time of inflation, and we could not reward excellence of work.

After weighing all these factors we propose to put into effect the following composite plan:

1. Partial Salary Increase Deferral: The normal salary review will be carried out as usual. However, those in higher pay brackets who are granted increases will have the effective date of their increases delayed. Staff Members, Senior Research Associates, Faculty and Directors will begin to receive their increased salaries six months after their regular effective dates. Staff Associates will begin to receive their increased salaries three months after their regular effective dates. Increases for all other employees will not be deferred.

2. Reduction in Force: The number of people on the SLAC payroll will have to be reduced by approximately 40. It is hoped that most of these will be taken care of by not filling jobs which become vacant by the departure of people who leave of their own accord or by transfer to other jobs at Stanford. Hence we hope that the number of involuntary separations will be very small indeed.

3. Shortened Work Weeks: Starting in July, one week of each month will be a 4-day work week; the fifth day of that week will not be a work day or a vacation day. Thus, everyone of us will lose one day's pay each month. (Certain few people in accelerator or research operations or in other essential laboratory functions may be assigned different shortened work weeks to accommodate fixed requirements.) I note that several other organizations in the Bay Area have adopted similar plans.

We are not certain how long we will continue the shortened work week schedule - we estimate six months beginning in July 1971 (a loss of six working days) - but the duration may be shorter or longer - but no longer than the full year.

There is one specific matter which must be considered and which could affect how many months we must continue to have the short work weeks. The way our accounting works, *earned vacation costs money to SLAC when it is not taken.* As an employee accrues vacation, money is held in reserve to pay the employee when he takes the vacation later. If the employee does not take his vacation the additional reserve set aside for his accumulated vacation cannot be used to pay our staff currently. Therefore, if employees in general take less than normal vacation we might have to extend the shortened work week program through more months of the year. On the other hand, if people with a great deal of accrued vacation take more vacation than normal, enough money may be saved that we could resume normal 5-day weeks sooner. Note that the extra day off during the week of only four work days cannot be charged to vacation. In order to be able to plan ahead, we will be asking each employee to fill out a form on which he can estimate the amount of vacation he believes he will take next year. Knowledge of the total vacation our employees anticipate taking will help us to plan how long we will have to live with short work weeks.

The above combination of measures spreads the burden to some extent over the entire staff. All of us will be "out of work" and without pay for several days scattered over the year, and the higher paid members of the staff will receive their raises late. I fervently hope that you will agree with me that this is the best course to take under the present conditions. I greatly welcome your comments and reactions to this plan.

These measures will apply to the next fiscal year - July 1971 through June 1972. To eliminate the further need for such actions I am committed to two steps: First, I will exert all possible effort to secure increases in funding which I believe the success of your efforts in having made this a highly productive laboratory deserves. Second, unless increased funding is assured we will continue to leave voluntary vacancies unfilled whenever we can so that the staff will continue to shrink with the aim of achieving a match between the available funds and the number of fully employed and fairly paid employees.

I am giving you this information to tell you what we are planning to do as early as I possibly can. In spite of these difficult problems the general outlook for SLAC looks extremely good, thanks mainly to the excellent work you all have been doing. As you know, after a long process of persuasion we have received authorization to proceed with building the storage ring - SPEAR - and construction is well advanced. Despite the budget pressures mentioned we hope to keep SPEAR on schedule so that initial beam tests can start by the spring of 1972 and physics research with this new facility can start in the fall.

Going ahead with SPEAR, even in the face of these difficult times, is part of the general policy of SLAC; we will continue to innovate our facilities even at the expense of full exploitation of what we have. There are many other improvement programs for the SLAC accelerator which are under study and some of them will turn into reality not too far from now. Specifically, the program of accelerator energy increase to be achieved by gradually replacing the existing klystrons with higher energy models is now in progress; we therefore can expect a continuing series of energy records for electron beams.

SLAC's main feature continues to be its uniqueness in the world of high energy physics. Although the 200-500 GeV proton accelerator near Chicago is expected to look for its first beam this year, SLAC will continue to be the world's highest energy electron accelerator in the forseeable future. All long range plans of high energy physics which have been developed in studies both within and without the U. S. Government contain the National Accelerator Laboratory and SLAC as the backbone of the program. The future, therefore, looks good.

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF MANAGEMENT AND BUDGET
WASHINGTON, D.C. 20503

February 10, 1971

Dr. Wolfgang K. H. Panofsky
Director
Stanford Linear Accelerator Center
P. O. Box 4349
Stanford, California 94305

Dear Dr. Panofsky:

Thank you very much for your thoughtful letter of January 15. I enjoyed our conversation on the telephone and am impressed that you took the trouble to detail the substance of your views so carefully in writing.

Many of the points you make are clearly correct, and they are the subject of concern in the Government and in OMB. Particularly, we are concerned about the under-utilization of facilities which were built, principally by the Government, at great expense and whose maintenance costs even when not used are substantial. We are also aware of recent discoveries of possibly great importance in the field of high energy physics--made, as I understand it, at the Stanford Center--which it is especially desirable to pursue as quickly as possible. These, and the other points you make, are obviously important, and they suggest that more money could be well spent on high energy physics research.

But this is true of many areas--in basic scientific research and also in dealing with social problems, such as law enforcement and housing, with education, with health care, and with the environment. All these needs are competing together for Government funds along with many others. Spending more on high energy physics necessarily means spending less on something else, and the money could be "well spent" in both areas.

Because we consider high energy physics a most important area of research, we have tried to continue a high level of support for it, even in the face of greatly increased demands for spending on social programs as well as many well-documented complaints about the comparative level of support for research in other basic sciences. Total Government support for high energy physics research continues at a level of approximately $200 million, and although the AEC share of this may have decreased I expect that NSF will pick up more than enough projects to compensate for this out of the generous increase in its research funds. Further, the government makes substantial indirect contributions to high energy physics research through programs supporting universities where the research is done, through aid to students, through tax incentives which encourage contributions to universities by private citizens, and in numerous other ways. I am sure you will agree that it comes out to a great deal of money, though perhaps not as much as you would like--or as I would like, if there were fewer other pressing needs competing for funds.

Taken altogether, I think that high energy physicists should be able to carry on a substantial amount of research with the funds proposed in the budget for this year. In view of competing demand for Government funds, $200 million seems a fair allocation of total resources for this area. However, as I indicated to you over the telephone, my mind is certainly not closed on the subject, and I think I would find a meeting with you most instructive. I hope that you will get in touch with my office and work out an appointment, as you suggest.

With kind personal regards,

Sincerely,

Caspar W. Weinberger
Deputy Director