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PRELIMINARY COST ESTIMATE FOR A 300 GEV CASCADE SYNCHROTRON

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Preliminary Cost Estimate for a 300 Bev Cascade Synchrotron

by M.H. Blewett

1. Introduction:

One cannot, of course, make any sort of detailed cost estimate until a fairly comprehensive design study has been completed. However, a first approximation can be made by scaling the general order of magnitude of costs of components of already existing machines. For this study, the machine design has been assumed to be that outlined in Report SL-10.* Furthermore, it has been assumed that the 10-Bev Booster magnet is pulsed at 10 cps and that the injector for the Booster Ring is a 100 Mev Linac, similar to the Brookhaven design. Costs for the Booster machine were scaled from those outlined (admittedly very rough figures) in MURA Report 467.** General costs and those of most of the accelerator components of the Main Ring are based on experience with the Brookhaven, A.G.S.

No attempt has been made to take into account possible increases in costs due to inflation or due to differences in locality. Most of the prices were based on those prevailing in the period 1955-59 (and in the Northeastern states).

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* SL-10 A Proton Synchrotron for 300 Gev by Matthew Sands. Synchrotron Laboratory, California Institute of Technology, September 1960.

** MURA - 467 A High Repetition Rate 15 Bev Alternating Gradient Synchrotron by M.H. Blewett, E.D. Courant, H.W. Fulbright, F.C. Shoemaker, A.V. Tollestrup, and T.A. Welton, June 1959. Midwestern Universities Research Association, Madison, Wisconsin.

Nor has any attempt been made to estimate the costs of equipment needed for an experimental program. A rough rule-of-thumb for the yearly costs of the experimental program and operation of an already existing accelerator is about 25 percent of the machine's construction cost. The experimental budget would have to start its existence well before the completion of the accelerator.

2. <u>General Costs</u>

For any accelerator in this general energy range, there will be certain costs that will be more or less independent of the design of the machine. These will include offices and laboratories, general utilities, salaries and general overhead expenses.

<u>A. Salaries and Overhead:</u> $24 million

In Appendix I is given a tentative outline of staff requirements. This is based, chiefly, on the number of persons who built the Brookhaven A.G.S., extrapolated to cover the amount of work to be done for completion of the proposed project over a period of about 8 years.

The professional staff turns out to be just a little more than twice the professional staff that built the A.G.S. Other personnel have been estimated on a proportionate basis. Thus, one is led to a peak staff for building the accelerator (if it were to be built at an existing laboratory such as BNL) of about 350 - 375. The addition of another 100 persons to take care of the necessary facilities required by the building of a separate laboratory on an undeveloped site may well be an underestimate. It has been picked merely as a minimum round number.

It is assumed that the staff builds up over the 8-years construction period as shown in Appendix I and that an overall average for salaries, administration and overhead is about $10,000 per person per year.

<u>B. General Buildings and Utilities:</u> $26 million

(1) Experimental area: $3 million.
This figure represents a cost of about $30 per sq. ft. for an area roughly that of the present covered area for experiments (including an addition under construction) at Brookhaven. At Brookhaven, a future

experimental building is planned, at a different location at the machine's circumference, for the large bubble chamber. Such a cost is, for the purpose of this estimate, considered to belong in an experimental program budget.

(2) Movable Shielding: $5 million.

This amount is for approximately 5 times the present movable shielding at Brookhaven (14,000 tons of double-density concrete). Admittedly, this figure has little justification. Some sort of planning for experimental areas and facilities must be done before one can make a better estimate.

(3)	Offices, Laboratories, Control Rooms, etc., i.e. "machine" buildings	$4-1/2 million
(4)	General buildings (administration, cafeteria, warehouses, etc.)	1-1/2 million
(5)	Water for magnet cooling and other component cooling	5 million
(6)	General utilities, landscaping and roads	3 million

The latter figure may be low, because it does not include costs due to inaccessability of an undeveloped site.

(7) Architectural Engineering Fees $4 million

This figure is roughly 10 percent of the cost of the buildings mentioned above, plus the machine tunnels.

3. Accelerator Components

A. Linac and Booster Ring: $21 million

Most of the items in this breakdown are directly scaled from the 20 cps machine described in MURA - 467, with the injector linac assumed to be of half the length and the magnet ring of two-thirds the length. The major addition was an increase in the cost of the foundations and surveying (assumed to be almost $1 million) that would be due to difficult terrain conditions in California.* The magnet tunnel was assumed to be

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* See SL Report CTSL-11 - Hulsizer and Tollestrup - " Magnet Positioning Problems for a 300 Gev Proton Synchrotron" October 1960.

about 18 ft. by 18 ft. in cross-section.

Tunnels, Foundations and Survey	$3 million
Linac (100 Mev) and injection system	4 million
Magnet: Cores and auxiliary hardware	2-1/2 million
(cross-section ≡ B.N.L. - A.G.S.)	
Coils and connecting bus	1-1/2 million
Magnet Power Supply (chokes and condensors, etc.)	3 million
RF System and Ejector	3 million

This is one of the most questionable of estimates and is, again, based on MURA-467 where, admittedly, there was poor justification for the numbers.

Vacuum System	$1 million
Controls and wiring	1 million
Models, Design and Testing Equipment	2 million

In the original proposal for the 300-Bev Cascade Synchrotron, the Booster ring was assumed to be pulsed only once per second and with a 50-Mev injector. The cost of such a machine can be more nearly directly scaled from existing machines and the reductions in costs over the above, readily listed. The Linac and injection system would be roughly half, the magnet cores about two-thirds, the magnet power supply about one-third, the RF system about one-sixth, the vacuum system about two-thirds, and the models and testing, one-half or less. This would give a total reduction of about $10 million.

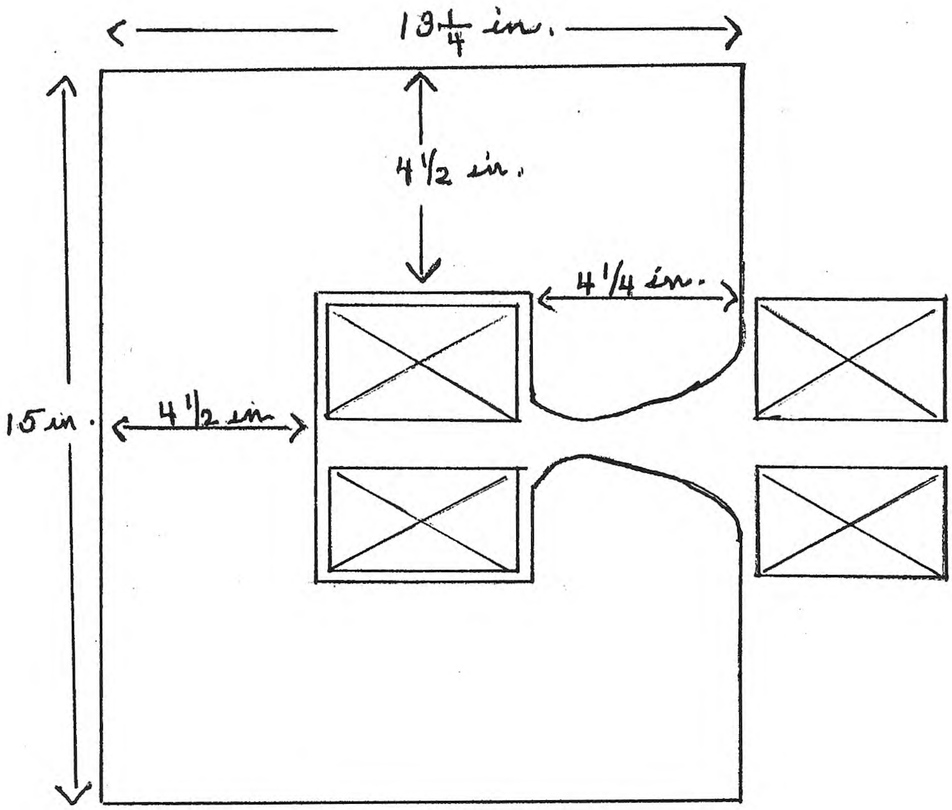
B. Main Ring: $54 million

(1) Tunnels, Foundation and Survey: $15 million

It is assumed that this tunnel has about half the cross-sectional area of the booster magnet tunnel, i.e., about 12 ft. by 12 ft. with about the same cost per cubic foot (about $2). Thus, the tunnel cost is about $11 million and the estimate for foundation and survey about $4 million. The latter may be an underestimate and would be dependent upon the method of support and/or the need for continuous rapid surveying.

(2) Magnet cores, coils, and auxiliary hardware: $13 million.

A tentative outline of the magnet cross-section is given below. This assumes a magnetic aperture about 1/3 (in each direction) of the Brookhaven A.G.S., but a current density in the coils that would be about the same.



This leads to a coil cross-section about 4 inches by 2-1/4 inches. Scaled from the A.G.S. the magnet's minimum gap is just a little over 3/4 inch and the pole tip width is about 4-1/4 inch. Other magnet dimensions might be as shown in the figure. Approximate weights are, then, about 6000 tons of steel and about 1400 tons of copper.
Thus the estimates are:

for cores and aux. hdwe.	\$6 million
for coils and connecting bus	7 million

(3) Magnet Power Supply and aux. equip. \$3 million

The stored energy of the main-ring magnet will probably be just a little higher than the Brookhaven A.G.S. The actual power requirements have not been calculated, but it is assumed that a generator-set, similar to that for the A.G.S., would be used. However, a somewhat higher cost has been assumed.

(4) RF System: $8 million

Without a definite design for this component, this figure is purely a guess. It is, to some extent, based on the Princeton experience where a 100-kv station is said to cost about $100,000. If 100 or more of such stations were built, the mass production might result in a 20 to 25 percent reduction.

(5) Vacuum System: $6 million

It has been assumed that the vacuum chambers, although smaller in cross-section, would probably cost about the same, per unit length, as the chambers in the A.G.S., but that about a 50-percent saving (per unit length) could be made in the number of pumps, valves, gauges, etc.

(6) Controls and Wiring: $5 million

This figure, again, is merely a guess until further design work is complete. With such large distances, there must be almost complete automation.

(7) Models, Design, and Testing Equipment: $4 million

4. Summary of Costs

A. General:		
Salaries and Overhead		$24 million
General Buildings and Utilities		26 million
B. Accelerator Components:		
Injector and Booster Ring		21 million
Main Ring		54 million
	Total	$125 million

Appendix I: A Tentative Breakdown of Professional Staff (peak load) for Design and Construction.

1. Administrative: (Subtotal 13)

Chairman - senior physicist

Deputy Chairman - senior physicist

Chief Design Engineer

Administrative Aides - 1 physicist, 1 engineer

Construction Manager

Finance officer

Aide shared by construction manager and finance officer

Personnel recruiter

Purchasing officers (2)

Expediters (2)

2. Theoretical (subtotal 3)

1 senior physicist

2 physicists (or 1 physicist, 1 applied mathematician)

3. Magnets

1 senior physicist

(a) Cores and coils (subtotal 19)

4 physicists

6 junior physicists

6 mechanical engineers

1 electrical engineer

2 electronic engineers

(b) Magnet power (subtotal 7)

1 senior power engineer

4 power engineers

2 electronic engineers

(c) Survey (subtotal 4)

1 chief surveyor

3 surveyor engineers

4. Linac and injection system between linac and booster ring (subtotal 12)

1 senior physicist

4 physicists

3 mechanical engineers

4 electrical and electronic engineers

5. Transfer from booster to main ring (subtotal 4)

2 physicists

1 mechanical engineer

1 electronic engineer

6. RF systems and beam observing equipment (subtotal 16)

1 senior physicist

2 physicists

1 senior electronic engineer

10 electrical - electronic - engineers

2 mechanical engineers

7. Vacuum (subtotal 2)

1 mechanical engineer

1 electrical engineer

8. Controls (subtotal 10)

2 physicists

2 mechanical engineers

6 electrical - electronic - engineers

9. Buildings and Utilities (subtotal 7)

1 senior architectural engineer

4 civil engineers

2 electrical engineers

It is assumed that the major design work on the buildings would be done by an architectural - engineering firm and the above 7 persons would be only liason and continuing staff.

B. Other Staff:

Designers and draftsmen	50
Machinists	20
Senior Technicians	20
General technicians	150
Clerical, secretarial computers	30
Other (Maintenance, police and firemen, general administration, stock keepers, librarian, etc.)	100
Staff Grand Total	470

C. Suggested Buildup of Personnel:

1st year: 15 percent of peak (probably 25 percent of professional)

2nd year: 30 percent of peak (probably 50 percent of professional)

3rd year: 50 percent of peak (probably 70 percent of professional)

4th year: 75 percent of peak (probably 100 percent of professional)

5th year: 90 percent of peak

6th year: 100 percent of peak

7th year: 90 percent of peak

8th year: 70 percent of peak

Beginning in the 5th or 6th year of construction some work will have to be started on the equipment for the experimental program and the total staff will probably increase. The lower percentages given for the 7th and 8th years assumes that the rest of the staff is working on these items, but is carried by the experimental budget.