CONVENTIONAL FACILITY REQUIREMENTS FOR THE SUPERCONDUCTING SUPER COLLIDER

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Background

In February, Parsons-Brinckerhoff was charged with the mission of defining the conventional facilities requirements for the SSC reference design. This was to be done on a generic basis, that is, the location criteria was to be such that it could be assigned to any of a number of suitable sites throughout the United States. Certain anomalies must be faced from the outset when developing a physical plant on a non-physical site. Nevertheless, it was possible to develop a plan for the conventional facilities. This was achieved with a great deal of guidance and patience from Jim Sanford of Brookhaven and Tim Toohig of Fermilab.

A number of important questions were raised. What kind of criteria apply which may relate to the suitability of future site selections? What are some of the loads, some of the services, some of the types of construction, some of the types of materials, some of the labor force needs that must be determined?

The design was developed to a preconceptual level which means in effect, identifying one feasible and economic solution to the conventinal facilities problem in coordination with the technical facilities SSC working group. No significant attempt was made to refine the results, or to optimize them. To start quickly and to build on existing practices, Fermilab, SLAC in California, and Brookhaven on Long Island were used as laboratory models.

The Site

A median site model was developed to deal with the question of a non-physical site. By definition a median site is a location which would represent an attractive location for siting the SSC. It is not a difficult site, nor is it the most favorable site. Instead, it represents those sets of conditions which one would hope to find that constitute the broad middle range of suitability for the siting of an SSC machine.

The accelerator is assumed to be a gravitationally horizontal planar ring. While there are options for the machine to be able to somewhat follow terrain variation, such a machine was not a part of the initial mission. Environmental sensitivity was built into the design since, in all cases, such sensitivity is here today in every way. Another goal was to maximize the operating efficiency. These conditions have been integrated on a just pass basis, into the design that is discussed here.

The median site reflected conditions expected on an attractive site. With the type of capital investment that the facility represents, it would be foolhardy to set out to locate such a machine in an adverse location because of the enormous cost consequences that result. So a favorable site may be taken as synonymous with a realistic site.

The purpose of the preconceptual design is to have a basis to realistically define costs and schedule for the conventional facilities. For that reason a demographic character is ascribed to the site. That character involves such points as establishing the fact that there would be a major regional city within reasonable driving distance. The city would not only provide the labor force, housing, and an international airport but also cultural facilities, university facilities, and other types of research support. These amenities would help make for a suitable location for a laboratory with three thousand or so people involved in this type of intellectual and research activity. Proximity to public services and facilities was important. Electric power supply, natural gas supply, highways, railroads, and other public services had to be given some definition in the median design. Of course there are costs associated with getting the necessary services on to the site. This estimate could be extrapolated to a real site at some time in the future. A climate had to be assigned because climate greatly affects the operating cost and the type of facility required for the SSC. Climate, topography, and geology have a great deal to do with the cost of the facility. For example, a fairly flat site with a lot of rain will have drainage problems and that adds to the cost of operation, the cost of construction, and to the difficulty of construction as well. This meant there had to be a realistic combination of criteria between climate and certain other physical characteristics.

Dick Lundy noted that these facilities consume a considerable amount of power, perhaps 100 megawatts or more. The primary supply thus must not only be subtstantial but also should be backed up by a fairly stiff grid. The vast majority of the power used passes through the system and is then taken off and rejected through cooling towers or other means. Therefore, climate is reflected in the amount of effort and cost that has to be invested in heat rejection.

Next consider the physical characteristics that were assumed for the area. As was noted earlier there were three magnet designs, A, B, and C, that reflect in three different physical plant sizes. These would cover an area that may be thirty to fifty miles on a side. However, within that rectangle, the surface-located components of the Laboratory may only occupy seven hundred acres of land and the subsurface facilities may require another seven hundred to twelve hundred acres of subsurface easements. Construction easements in an area where a cut and cover tunnel was used would require an area approximate to one quarter of a mile wide, centered on the main ring alignment. This means a deep tunnel might be more appropriate in a populated area. Dick Lundy's figure showing the ring superimposed on Washington, D.C. illustrates the vast area that would be influenced by the siting of the facility.

Rights-of-way and real estate represent a major consideration for the SSC. There is a natural desire to have a flat site for the SSC. At the same time the median site couldn't be unrealistically flat because Mother Nature just didn't arrange land and climate that way. Some relief has been incorporated and the relief leads to drainage and to drainage ways. Vegetation preservation requirements as well as seismicity were considered. The median site was given a seismic characteristic of zone one which means that there could be some seismic activity but not sufficient to create a significant design consideration. In hindsight, the influence of a more restrictive seismic siting condition would have little influence on the facility cost because of the nature of the facilities themselves. A broad range of geologic types was incorporated in the median site. Air quality and solar access conditions were added since DOE facilities require that both active and passive solar energy conservation be a consideration. Finally, the Los Alamos Laboratory Site Atlas for the SSC was reviewed. They had assembled some six or seven preliminary proposals from different states that have come forward to indicate that they would be willing hosts for the SSC. That also provided a certain amount of basic information.

All of this led to the marvelous median site for the SSC shown in Fig. 1. Now the topography and the highways really don't exist anywhere except on the drawing and in the minds of the creator, but they illustrate the factors that are important in a reasonable site for the SSC. The sort of site illustrated is one where there is a crest in the topography with drainage coming away from the high ground. Notice that there is an interstate highway as well as a public service corridor. This corridor contains not only the interstate but also a 230 KV power line and a railroad right-of-way. Parenthetically, off the map where the branch line railroad joins the main line railroad there is a natural gas pipeline. Again, that is characteristic of what one finds today in public utilities. There is a state highway serving the north-south axis as well as a county road on the site. There are also various farm roads and other graded accesses that are not shown on the site plan but are in fact included in the utilization of this site when the machine is superimposed on it. The spirit is to not pave what one doesn't have to pave when the facility is put into place. Later it will turn out that the access roads that are put in are really minimal in nature and are only to get to those areas where there is a high service demand for access.

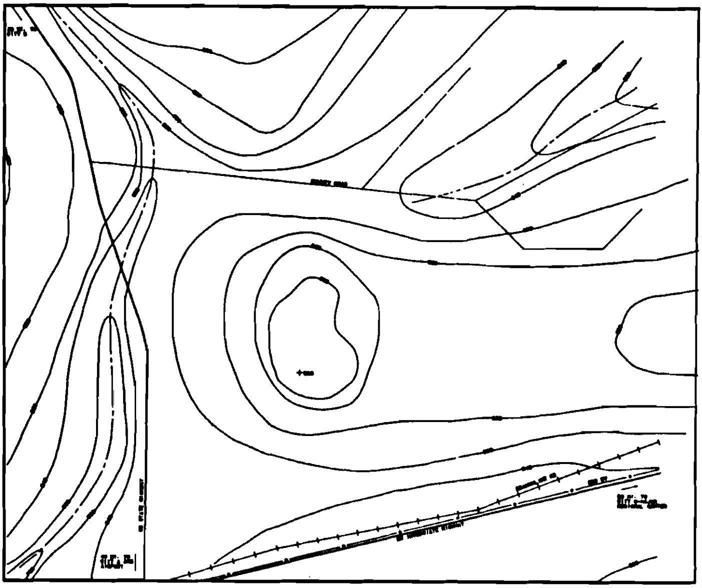


Fig. 1. Map of the SSC median site.

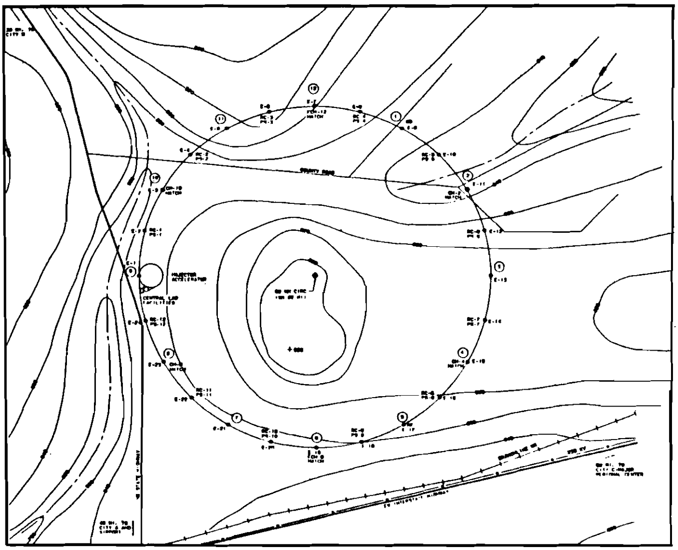


Fig. 2. The median site with the SSC imposed on it.

Looking at this, one asks the question, "How do we go about the matter of locating an SSC in this area?" A number of influences have to be considered. For scale the injector is essentially the same size as the Fermilab Doubler that was described this morning. The high-energy booster is about 20,000 feet around. Figure 2 shows the A design with the 6.5 tesla magnets. This results in a 90 kilometer circumference ring. Design B would have a 113 kilometer ring and the largest one would be 165 kilometers for design C. The injector and the central lab are at nine o'clock (on a clock oriented with twelve toward the north). The beam dump is off at one o'clock while the rf facility is at five o'clock. In addition to that, four developed experimental locations are shown, namely the collision halls at two, four, eight, and at ten o'clock and provision for future collision halls indicated at twelve and six o'clock. There are also refrigeration stations, power stations, accesses and exits, and a variety of other elements that are required to make the system whole. Figure 3 shows a site profile. It is important to realize that this is a much distorted scale profile, the total length on the horizontal is about 56 miles, while the total elevation difference in the vertical is about 180 feet.

For geologic groups, a sufficient amount of each major geologic group was identified to obtain a significant measure of what construction methods, costs, and time could be expected in sites that would be receptive to an SSC. Figure 4 characterizes the geology by sector. The north part of the site has both igneous and sedimentary rock varying in hardness from hard to soft. These could be either granites or basalts on the one hand or shales or limestones in the sedimentary group. At the deep point the tunnels are 100 feet down. There are problems with access shafts and construction logistics in deep tunnels. Typically the access shafts could be 32 feet in diameter and cost $3000 to $4000 a foot. A sufficient amount of such ground was incorporated to get a representative sample of the costs, the difficulties, and the time that it takes to construct in such ground. A collision hall facility was assigned to each one of the geologic groups to get a representative sample of what it would mean to have that type of major underground facility located in each of these groups. The east side of the site consisted of sand, silt, clays, and gravels. This is the type of alluvial out wash that is found in many parts of the country, for example, along the foothills of major mountain ranges where over time the material has been washed down from the mountains and settled out in the valleys. Gradations like this can give a variety of construction problems depending upon how they are mixed. The south end of the site consists of firm clay. This could be the type of material one would find in ancient lake bottom deposits. It can be excellent for construction but it can also have some problems. Finally, there is glacial till on the west side where the injector is. An excellent example can be found by going to the window at Fermilab and looking outside. Glacial till is the result of materials left behind by receding

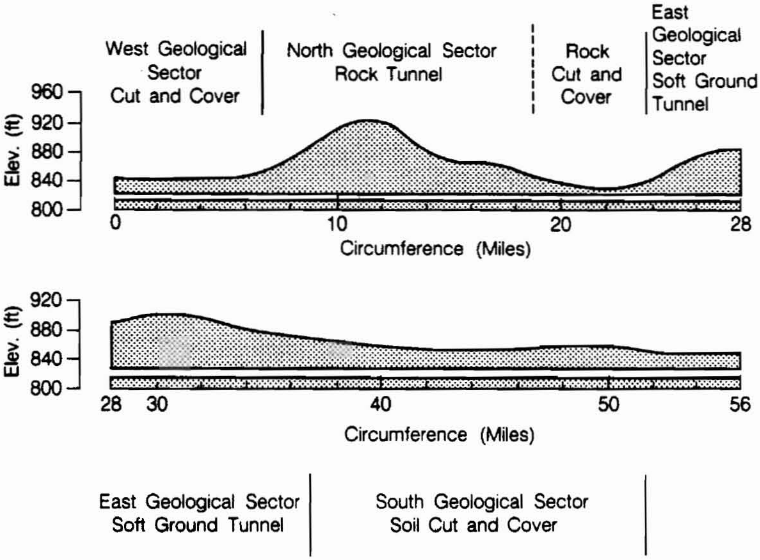


Fig. 3. Distorted profile of site to show angulation of the median site. The elevation difference is on the order of 100 feet which the total horizontal axis extends for 56 miles.

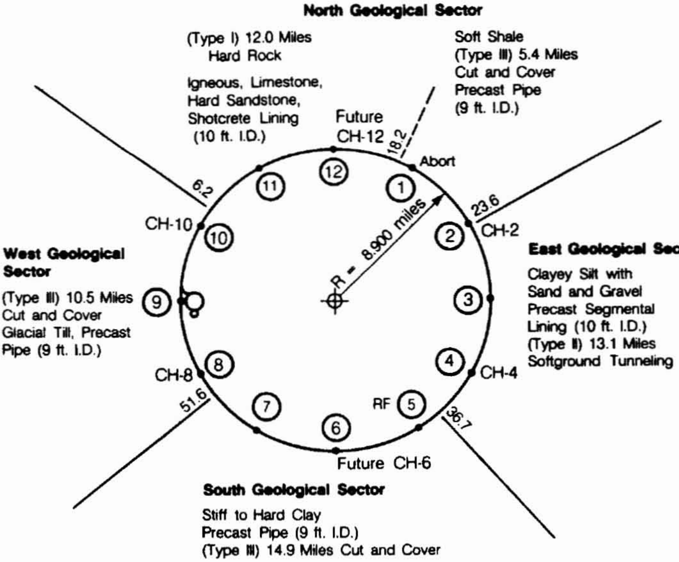


Fig. 4. Geologic character and main ring tunnel types.

glaciers and can be quite variable in conditions. Characteristically it has relatively flat topography and is relatively easy to excavate unless boulder fields, peat areas, or water pockets are encountered.

The Tunnels

To house the main ring, a tunnel must be provided with at least twenty feet of soil cover to provide for the necessary radiation protection. In addition to that, there is an additional radiation requirement for soil embankment to the outside of the ring where a muon shield should normally extend out about 270 feet. Thus, if a fill condition exists below the beam line, a fair amount of earth must be carried along. The most difficult feature to work with here is the scale. A ring 56 miles around has 300,000 feet of tunnels and a 165 kilometer or 103 mile ring has 550,000 feet of tunnels. This is a very major construction undertaking so that when one talks about moving a little bit of dirt per foot of tunnel, one is really talking about moving a lot of dirt overall. With this geologic and topographic mix, roughly 55 per cent of the site would be constructed by the cut and cover tunneling technique. The remaining 45 per cent would be evenly split between rock tunneling and soft ground tunneling. Figure 4 also summarizes the mix of the tunnels. The mix of tunneling methods doesn't have much influence on the cost. The sectors are long enough so they would individually constitute suitable construction projects. Typically the lengths of rock tunnels are such that a new tunnel boring machine would be fully amortized by the end of the construction. The cut and cover tunnel has a 9 foot inside diameter while the mined tunnel sections have a 10 foot inside diameter. When working on this project scale, particularly with underground work, the speed of construction becomes a major parameter because that is where the money is. The 10 foot mined tunnel size provides the driving tolerances to achieve near maximum driving rates. Essentially a 9 foot envelope is required within the tunnel to satisfy the technical facilities requirements to provide the continuity of the alignment space which is required for the beam. This 9 foot parameter is thus obtained at minimum cost by this approach. All of this tunneling information then leads to a construction program, a schedule, and a cost estimate.

The least costly technique for tunneling is cut and cover where, for this project, cut and cover would run $600 to $700 a foot for the ideal burial depths. The most expensive tunneling occurs at the interfaces between different geologic groups in the mined rock tunnels where costs could run to $1600/foot. The main ring housing averaged about $1050/foot without utilities. These estimates are in line with experience at PEP and also recent experience in Europe.

Figure 5 shows what the cross section might look like for the cut and cover case. There are several enclosure materials that could work but a precast pipe has been used here. It is estimated that 400 feet of pipe a day could be installed in a trench and back filled using a forward projection pipe laying technique. That's moving fast, but that's what can be done if a contractor sets up not just a pipeline operation but in fact, a production operation.

Observing the tunnel cross section, the primary device in the enclosure is the beam magnet package which is placed along the inside surface of the tunnel, to the right in this view. The injector, also in a tunnel, is located on the inside of the main ring with a magnet package mounted along the outside surface of the housing. If this were design B, there would be a double magnet package. The utilities are kept on one side. They include a helium gas line, water for heat rejection as well as fire protection, and 480 volt power inside the tunnel. The 480 volt power goes into mini power centers that are set out at 100 meter intervals. At those points it is broken down into 120 volts, a 408 V welding circuit and some other housekeeping circuits. The other side of the tunnel has communications and fire alarm circuits. This cross section provides for both a place for a person in a lay down space to work along the beam line, as well as a way of moving about by an electric-powered cart. Obviously the space inside must be used efficiently. The size of the interior space was determined both by considering the size that would be economic to construct as well as the size necessary on a functional basis to provide for what goes on inside the tunnel. Notice that there is sufficient room for two way traffic.

If a shotcrete lined rock tunnel was used it would not be a water tight tunnel, but it also would not be a wet one. The same general configuration would be used but a 10 foot ID tunnel would be used to provide the 9 foot clearance envelope. The soft ground tunnel would be very similar except the tunnel would be of precast concrete tunnel liners jacked into place and sealed without any further finish. Considering each one of these types of tunnels from the point of view of the supply of the various materials that will be required and doing some extrapolation of lengths and size, it is clear some very significant supply contracts will be required to make this project go. Figure 6 illustrates what the inside of the tunnel might look like when all facilities are in place. This is not too different from the photographs of the existing Fermilab facilities.

Other Underground Features

Around the main ring there's more than just a tunnel, even though the tunnel is the major cost feature. There are also twelve refrigeration compressor stations equally spaced around

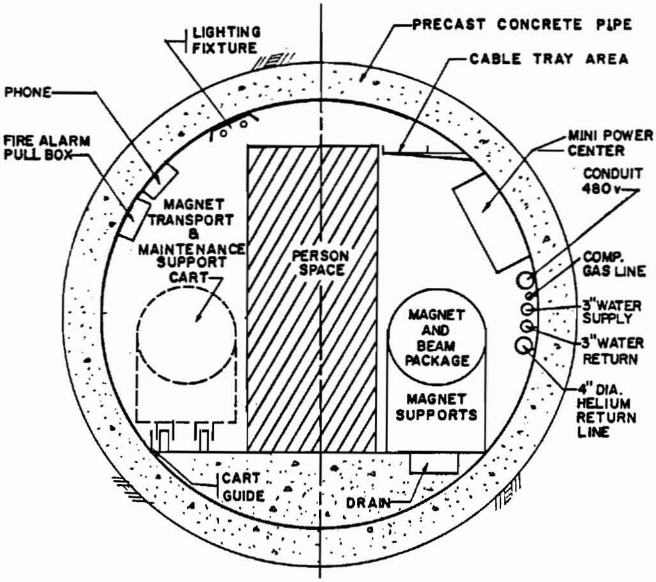


Fig. 5. Tunnel cross section for the cut and cover technique. The inner diameter is 9 feet.

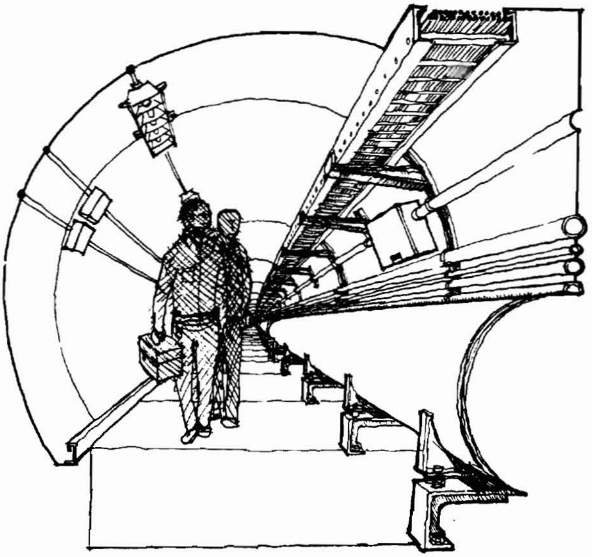


Fig. 6. Perspective view of the main ring tunnel.

the ring with shaft accesses to the tunnel. The power supplies and the refrigeration plants are combined into single stations. There is one radiofrequency facility (rf) in a tunnel enlargement for boosting the beam energy. There is a single beam dump located in a series of short tunnels and underground rooms. The injector facility is at the nine o'clock position located in five miles of tunnel. There are twenty-four tunnel access and exit points around the ring which also provide for ventilation and facilities for moving small equipment in and out. The power is provided from the 230 KV supply to a major substation at the site where it is broken down and distributed around the ring.

Figure 7 illustrates a typical refrigerator/compressor and power station. The typical refrigeration station is a 50 foot by 132 foot building containing a refrigerator/compressor and a power station. Outside there are a couple of additional buildings. There is a shaft going down to the tunnel that has helium facilities and a dewar in it. There is also a tank farm for helium storage. The amount of helium that this whole facility requires is quite remarkable and tests the capacity to produce it. The shafts at the compressor stations are 26 to 30 feet in diameter. The accelerator beam is running on the inside of the tunnel housing so that the passage way is accessible on the outside. Consequently the egress for people is on the outside of the tunnel down an 18 to 20 foot diameter shaft. Double 90 degree dog legs are provided for radiation protection and the cross section is adequate for ventilation of the tunnel.

Figure 8 illustrates a typical collision hall, a very major underground facility. The central hall is some 70-75 feet on a side with a 60 foot ceiling, and a forward and a backward area that are each 40 by 40 feet with a 50 foot ceiling. All of that is buried underground with at least 20 feet of fill on top of it. There is also a bypass tunnel passageway that allows the facilities and personnel in the beam housing to move around the collision hall. There are hatches on the back side of the bypass tunnel by which additional magnets could be lowered down by a cherry picker on to a traveler in the tunnel and moved around the ring if it was necessary to replace one of the magnets. Many of these features have proven to be effective at Fermilab with the B0 and D0 facilities. There is an assembly area at the same floor elevation as the collision hall to give space to lay down components in the course of putting together the experiment. An enormous door, some twenty feet thick, is provided to separate the two areas. At the next level there is a large assembly building for preparation. Access is through a floor opening to the assembly area below. All of this is served by a fifty ton crane. There are a series of offices and floors for the computing area, computer, other equipment, and personnel space on the outside bay of the building. The building is about 120 feet by 300 feet, a fairly large enclosure, but sized to the necessities of one of these research facilities. Recognize that it would probably be at least ten miles from where the

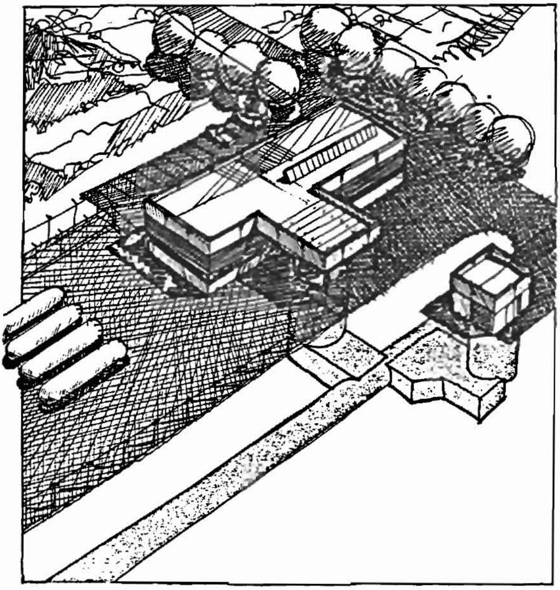


Fig. 7. Aerial view of refrigerator and power supply building.

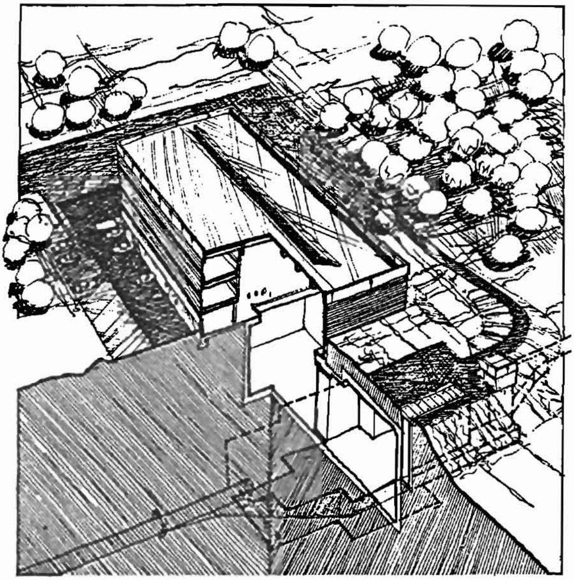


Fig. 8. Aerial view of staging building and cut away of collision hall. The staging building is 125 feet × 300 feet.

experimental area is located to the central laboratory as a result of the scale of the facility. It could be as much as thirty five miles back to the main laboratory from a collision hall on the other side of the ring. That means this has to be essentially a self-sustaining operation. There would probably be people here who would work here and nowhere else if they worked at the site.

Consideration was given to the fact that these buildings may be buried at different depths. Each collision hall was treated in terms of its actual relationship to the geology and the topography.

The Services

The primary power to the facility comes in at 230 KV. From the primary main substation, two 13.8 KV circuits provide power to the main laboratory and the injector. A 69 KV line comes off which loops around the main ring and goes to a series of what are called primary network units which supply the refrigerator compressors and the power stations as well as feeding the collision halls as illustrated in Fig. 9. These contain the power transformers as well as emergency generators for each one of these stations. There is nothing out of the ordinary in any of these systems. The circuit breakers, the switches, and the isolation techniques represent common power practice.

A number of other services are required, such as water, sewage, solid waste disposal, and all the little things that add up to make the place feel like home. Each is provided for in the plan.

Rather than devise a main ring road type of design, the existing graded, perhaps graveled road services were utilized. This also helps from the standpoint of being as good a neighbor as possible by building the machine into an area where the original use of the site could be retained and employed if it was, for instance, used for grazing animals or for other farm purposes. Protective enclosures are provided near the entrances of the tunnel and around the RC/PS areas.

The Central Laboratory Complex

The injector facilities are very similar in size and configuration to the Fermilab accelerator complex. A linear accelerator feeds beam into a low energy booster (LEB) with a "small" ring, three quarters of a mile around. That feeds beam in turn to the high energy booster (HEB) which accelerates the beam to 1 TeV. The LEB has conventional magnets and therefore requires some low conductivity water facilities. The HEB uses superconducting magnets and therefore requires an RC/PS facility.

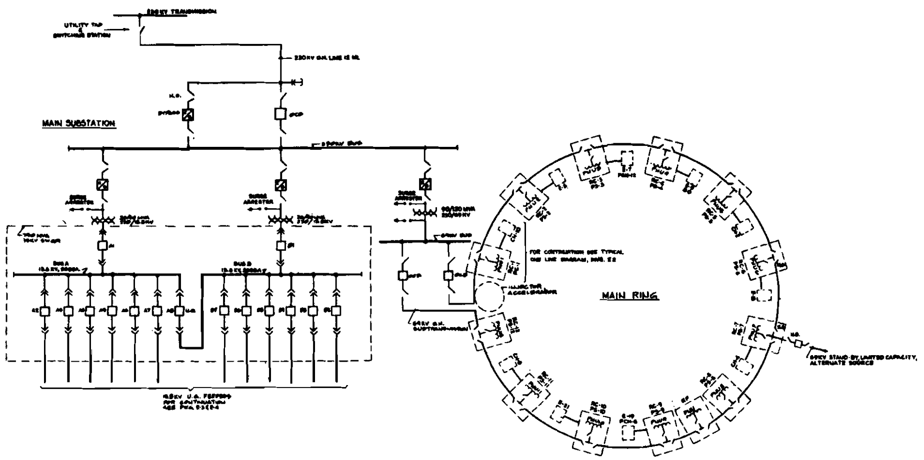


Fig. 9. Main power distribution.

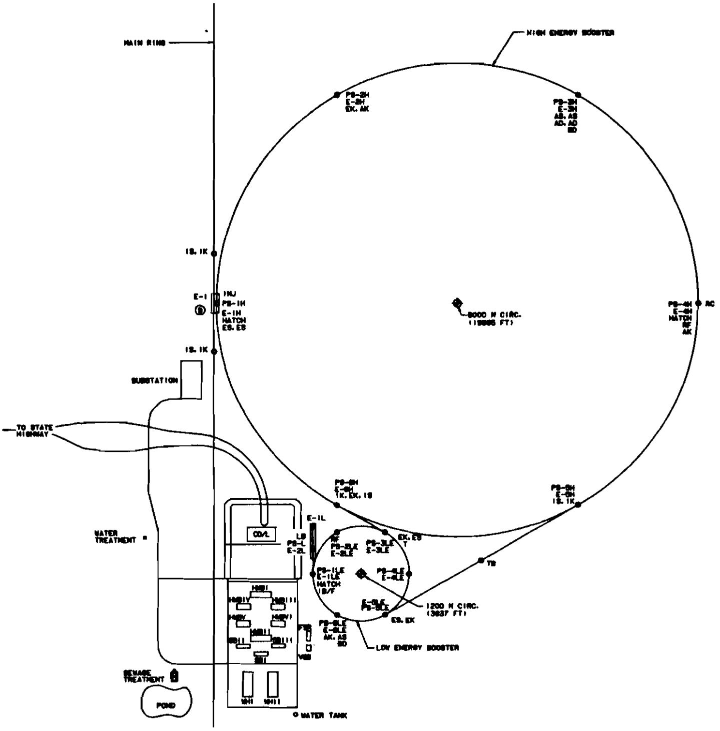


Fig. 10. Central laboratory and injector facilities. The high energy booster is about 6,000 feet in diameter.

The beam is transferred directly from the HEB into the main ring as shown in Fig. 10.

Facilities are required at the central lab campus area to provide sufficient work space and support for some 3000 people, as shown in Fig. 11. There are six assembly buildings, four shop buildings, two service support buildings, and various other kinds of support facilities. Figure 12 shows a conceptual rendering of the major building for the central office and laboratory space. It is laid out on a simple rectangular plan which readily permits expansion. The building is statistically similar to the Fermilab highrise except that a four story building is considered so that a light steel framing approach can be used which is more economic today. There are 380,000 square feet or so of space in this building. Both passive and active solar techniques are employed as a means of exploiting the available solar energy.

The Schedule

Figure 13 shows the schedule, in part, for conventional construction. A period on the order of six years is shown. A detailed schedule of all of the work to be done was put together during the design study. An obligation curve, Fig. 14, was devised from the construction schedule. While it is an ambitious investment program, it is not without precedence in the area of public works construction. About a quarter of a billion dollars a year would be put into civil construction. As an example, a number of transit projects in this country have put that much or more work in place in a one year period.

For the A design (6.5 tesla magnets) the cost of the conventional facilities was put at about 875 million dollars while the B facilities were estimated to be on the order of 1 billion dollars and the C facilities would be on the order of about 1.4 to 1.5 billion dollars. That is just extrapolating on the basis of the median site and the unit prices that came out of the exercise. Those numbers are being reviewed by DOE and they may be changed in the final DOE report.

With all this information, it would be possible to start looking for a site now. Of course, there is still a lot of development to be done and that development may result in further definitions that will modify some of the needs and some of the requirements that will come back into the conventional side. However, it might be prudent to get underway with site selection soon. The lead time that it takes to produce the environmental impact reports and to go through the site selection process with the kind of contest that could be generated in that decision will simply take time. It could well be a time equivalent to the R&D time for the technical facilities.

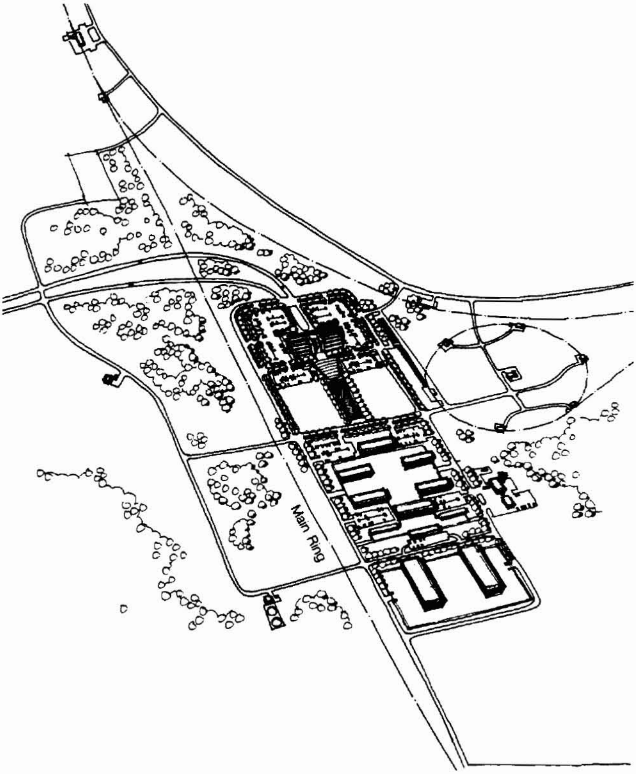


Fig. 11. Aerial view of the central laboratory campus complex. The circle in the foreground is the low energy booster.

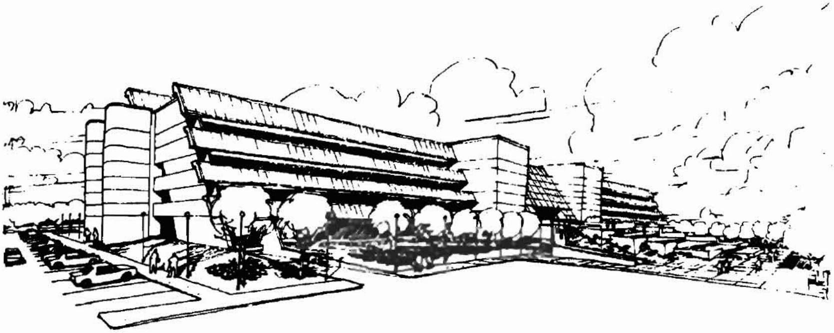
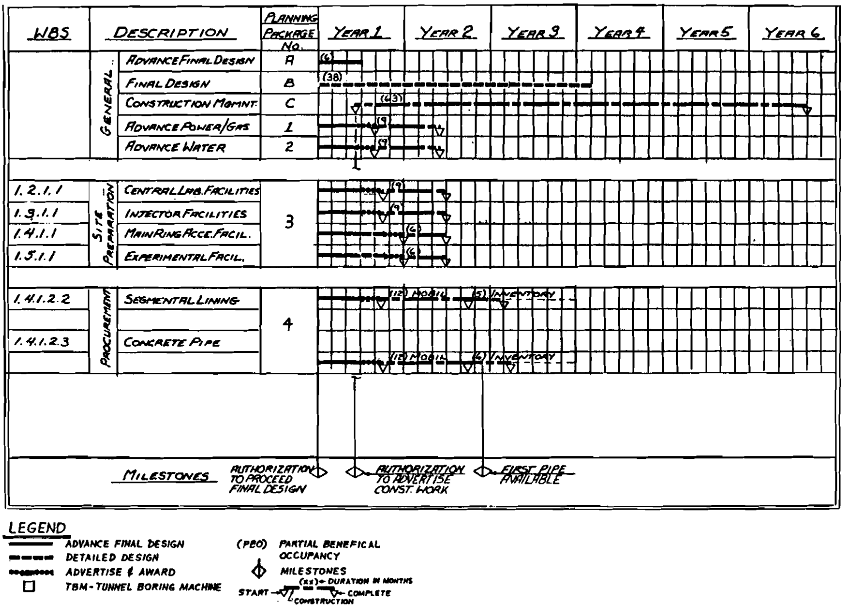


Fig. 12. South facade of the central laboratory.



WBS		Description	Planning Package No.
	General	Advance Final Design	A
		Final Design	B
		Construction Mgmnt.	C
		Advance Power/Gas	1
		Advance Water	2
1.2.1.1	Site Preparation	Central Lab. Facilities	3
1.3.1.1		Injector Facilities	
1.4.1.1		Main Ring Acce. Facil.	
1.5.1.1		Experimental Facil.	
1.4.1.2.2	Procurement	Segmental Lining	4
1.4.1.2.3		Concrete Pipe	

Fig. 13. Project planning and scheduling.

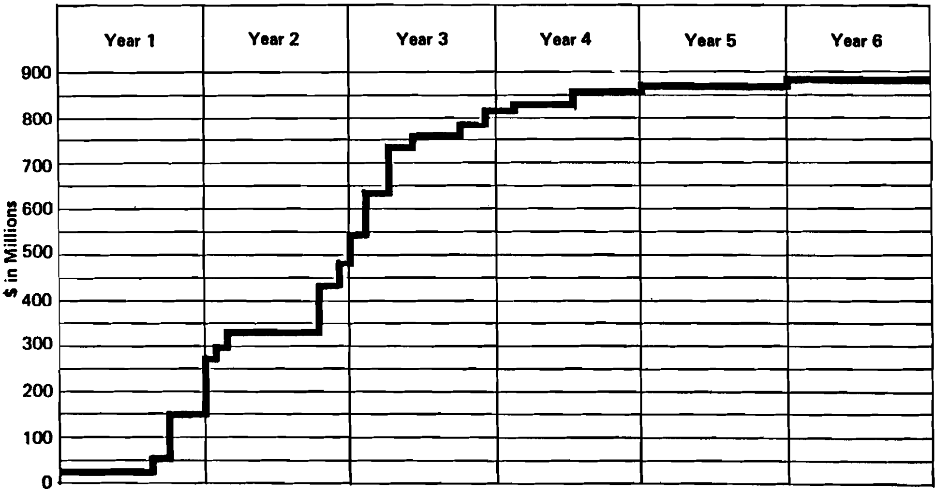


Fig. 14. Obligation curve for the SSC project.

Conclusion

The SSC is a feasible project and its future is possible. Its conventional facilities can be designed and constructed efficiently and cost effectively today, using today's men, materials, and methods. Let us hope that the priorities to be set include the SSC.