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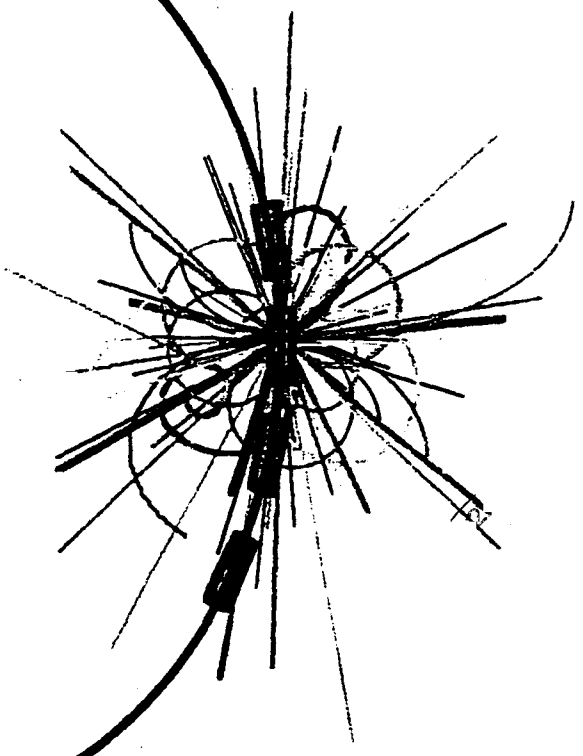
SSC UNDERGROUND TECHNOLOGY ADVISORY PANEL



UTAP

REPORT

Recommendations Following the Meeting of January 18-19, 1993 Held at the SSC Laboratory, Dallas, Texas

SUPERCONDUCTING SUPER COLLIDER LABORATORY

UNIVERSITIES RESEARCH ASSOCIATION

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By

The Underground Technology Advisory Panel (UTAP)

To

Mr. Jon Ives and
Dr. Timothy E. Toohig

Superconducting Super Collider Laboratory

February 9, 1993

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INTRODUCTION

This report summarizes recommendations made by the Underground Technology Advisory Panel (UTAP) to the Superconducting Super Collider (SSC) Laboratory after meetings held on January 18-19, 1993. The Panel was convened at the request of Mr. Jon Ives, Associate Director, Conventional Construction Division (CCD), and Dr. Timothy E. Toohig, Construction Coordinator, CCD, for the SSC. A list of UTAP members and meeting agenda are appended to this report. The meeting was held at the SSC Laboratory, Dallas, TX, during which time presentations were made by members of the SSC Laboratory staff and the Architect-Engineer/Construction Manager (A-E/CM) on the project organization, applied geodesy, design and construction status, management issues, site investigations, instrumented test sections, design of the Interaction Region (IR) halls, tunnel requirements, groundwater flow modeling, and corrosion considerations. Information conveyed at the meetings is in the public domain, and is collected and filed as part of the SSC Laboratory Notes which are available through the SSC Laboratory.

In preparation for the meeting, UTAP members received copies of reports prepared by Parsons Brinckerhoff/Morrison Knudsen (PB/MK), the A-E/CM for the SSC project. The following materials were received in advance by UTAP members:

- PB/MK 90% Title II submittal for the experimental halls, including:
  - Report and Drawings for the IR5 GEM Detector
  - Report and Drawings for the IR8 SDC Detector
  - Geotechnical Design Summary Report
  - Specifications
- SSC N15 to N10 "Basic Tunnel" (including West Utility Straight) Design Requirements, 11/3/92. SSC Document Control Number Y16-00188
- Ltr #92 6431 CC 0002 CENF, to Mr. Gilbert from Jon Ives, entitled "PB/MK Groundwater Modeling for East Campus Experimental Halls and Collider Tunnel"
- Tieback Testing Program, Status Report No. 8, 12/16/92

Before the meetings, members of the Panel on 17 January toured the sites of the N15 Magnet Delivery and N15 Tunnel, N25 Tunnel, tieback testing program, and IR-5 and IR-8 Halls. The field inspections afforded by these visits have helped the Panel in understanding the in-situ nature of the rock and its performance during construction operations, as well as the surface topography and drainage characteristics of the IR hall sites.

On 18 January, a meeting was convened at which UTAP members were able to discuss aspects of the project with senior SSC Laboratory managers. In addition to UTAP, those present at the meeting were R. Schwitters, E. Siskin, J. Rees, G. Robertson, J. Ives, and T. Toohig of the SSC Laboratory. Discussions during this meeting were of benefit to UTAP, and helped the Panel obtain an integrated view of the SSC project.

The report is organized to address issues covered in the agenda for the 18-19 January meeting, and to comment on several additional items not specifically identified in the agenda, but nonetheless brought to the attention of UTAP by discussions during the meeting. The report covers management issues which pertain to Integrated Project Schedule, contracting strategy for IR-5 and IR-8 Halls, verification of tunnel location, survey needs for long-term settlement, technology transfer for infrastructure and environmental applications, and the SSC role in tunneling technology development. The report covers technical issues with observations and recommendations made in conjunction with site visits, tieback testing program, S-30 shaft instrumentation results, laboratory test results for Taylor Marl, design and construction of IR halls, groundwater monitoring program, shaft linings, and Austin Chalk corrosion control.

INTEGRATED PROJECT SCHEDULE

The Panel received an excellent briefing, in some detail, on the current

status and working of the Integrated Project Schedule (IPS). The IPS has been in operation for some months and has progressed to a very respectable tool, as was demonstrated by the briefing and the samples of report documents. A review of the November 1992 CCD report, the most recent, reflects the detail and cross-referencing of information and activities involved.

While the IPS is proving, as predicted, to be a valuable management tool, it still needs continuous application of lessons learned and experiences in use at various levels. Specific examples of management action as a result of IPS reviews were given, with emphasis on problem areas. As might be expected of a system as large and complicated as the IPS, there are still growing pains. With conventional construction in high gear in design and actual field work, there is particular need for more rapid responses to problem areas identified in IPS analyses.

CONTRACTING STRATEGY FOR IR-5 AND IR-8 HALLS

The similarity in scope, schedule, and requirements of the construction contracts for the IR-5 and IR-8 Experimental Halls raises the possibility that there may be economies or efficiency resulting if both were performed by one contractor, which would result in lower bids and lower final costs. The A-E/CM proposes to call for bids whereby the bidder will bid on IR-5 and/or IR-8 individually, and may offer a total bid price for the combination of both IR-5 and IR-8 bid packages. The Panel believes that this approach is a proper, and likely cost-effective, contracting strategy for these two construction contracts. Similar procedures have been used on other projects, and the approach should be well understood by prospective bidders. It is important to recognize that the invitation for bids (IFB) should contain instructions as to how the reduced amount in the combined bid price will be allocated among the individual

construction items in each of the IR-5 and IR-8 bid packages.

Consideration is being given to calling for proposals subject to negotiation, rather than firm price bids. It is expected that lower contract prices and final costs could be achieved through negotiations with the contractor, allowing variation from the terms, conditions, and specifications of the invitation for proposals (IFP). It should be recognized that the IFP would need to set forth specific terms establishing criteria to govern eligibility for negotiation, the form of the final contract, how negotiations would be conducted, number of proposals, and range of dollar value of proposals to be considered before selection is made.

Underground construction in the United States is performed almost exclusively by contractors who submit the lowest, unqualified, fixed price bids in response to invitations for bids which include highly detailed plans and specifications. Underground contractors are, of course, familiar with the process and are comfortable with it. The Panel would be surprised if there was not substantial interest from contractors for the bids solicited for these structures on the conventional basis.

Many in the American underground contracting community are suspicious about procedures in which contracts are awarded based upon what may be subjective criteria, even though these procedures are widely employed elsewhere in the world. For example, the Associated General Contractors (AGC) have, for a long time, actively opposed the use of such contracting procedures.

While it is quite probable that an ostensible lower quote could be obtained by calling for proposals, this contracting method is not commonly used in federally-funded contracts, and time could be lost in obtaining clearances or agreements that would permit negotiation. It is also quite possible that protests or allegations of unfair handling made by unsuccessful proposers could

jeopardize achieving a lower cost negotiated contract, and time lost in achieving a contract could delay the IR-5 and IR-8 contracts, and possibly others dependent on completion of IR-5 and IR-8 facilities.

The Panel recommends that the IR-5 and IR-8 contracts be pursued by taking fixed price bids in the conventional manner, including permitting a bid for the IR-5 and IR-8 combination. The Panel also recognizes that some modifications to the permanent tieback system may occur during construction, based on the results of the monitoring instrumentation system. This factor must be reflected in the form of contract, and additional recommendations in this regard are noted under the section on design and construction of IR halls.

VERIFICATION OF TUNNEL LOCATION

A survey network has been designed and put into place by the A-E/CM to control the construction contract operations. The survey has extended monuments into the tunnels. As tunnel excavation proceeds, surveys will be carried forward with monuments being established on either side of the tunnel every 500 feet. This survey network and monument system are used by the contractor to control the work, and by the CM to check and verify the correct location of facilities. The SSC Laboratory will use the network later for locating laboratory equipment.

It has been intended that the control network procedures, and location of monuments, would be verified by the SSC Laboratory. Apparently, there has been some difficulty in clarifying responsibilities and communicating what actions are necessary to verify the A-E/CM system and network, and to verify specific locations of the tunnels as work progresses. Tunnel construction has already started, so it is essential that verification be performed as soon as possible to avoid delay in construction and to make adjustments, should the verification

process disclose the need for changes.

It appears that the responsibility for verification is with the Applied Geodesy group. Although Applied Geodesy is aware of its responsibility, it represents itself as having insufficient resources to perform the verification in a manner which can keep pace with construction.

The Panel has not attempted to review the requirements nor the resources available. The Panel discussed briefly with representatives of PMO its support of the efforts of CCD and the A-E/CM in urging early firm assignment of responsibility, formulation of approved procedures, and allocation of adequate resources. It is the Panel's understanding that CCD and Accelerator Systems Division (ASD) will confer on this issue and try to clarify resource needs and allocations.

The Panel supports this type of activity, and also recommends that improved procedures be implemented for the transfer of field survey equipment from Applied Geodesy to the A-E/CM. Field measurement capabilities should be maintained at a level commensurate with the pending construction. It may be advantageous to review the verification responsibilities of the SSC Laboratory to ascertain if some downsizing of Laboratory effort could be achieved such that suitable quality assurance is preserved, at the same time that better resource management is realized.

SURVEY NEEDS FOR LONG-TERM SETTLEMENT

The Panel has recommended in several reports that the geodetic survey resources be utilized to estimate future regional settlements due to groundwater withdrawals from the underlying Woodbine aquifer. Two steps have been suggested:

- Return with a precise elevation survey to the monuments established

several years ago for the initial lattice layout. From this survey, determine any change from the absolute elevations of the original survey points. If this cannot be done, compare current elevation differences between east and west points with the corresponding elevation differences at the time the points were established.

With Texas resource agencies, such as the Bureau of Economic Geology (TBEG), make the best estimate of future additional drawdown in the Woodbine. From this, compute regional settlements caused by consolidation of the Woodbine itself and the overlying fine grained sedimentary aquicludes.

The Panel believes that these two activities represent a prudent and logical approach to monitoring and managing long-term regional settlements.

TECHNOLOGY TRANSFER FOR INFRASTRUCTURE AND ENVIRONMENTAL APPLICATIONS

Underground construction plays a major role in building and renewing transportation, water supply, and waste treatment facilities, particularly in crowded urban and suburban environments. Accordingly, underground construction innovations for the SSC will be of direct benefit in addressing U.S. infrastructure needs. It is important for management to be aware of the civil construction developments, either directly or indirectly supported by the SSC project, which have the potential for spin-off benefits in the areas of infrastructure and environment.

With respect to underground construction, the shaft drilling technology developed by A. H. Beck Foundation, Inc. of San Antonio, TX has introduced a rapid means of sinking shafts which has proved to be accurate and cost-effective. This shaft drilling technology was applied originally at the Exploratory Shaft in support of SSC Laboratory research on ground performance, and now is being used to excavate shafts at many locations around the Collider ring. A triple shield tunnel boring machine (TBM), which allows for continuous excavation by means of a double gripper system, has been supplied at the SSC by the

Robbins Co. of Kent, WA. Although the Panel is aware that this machine has not yet received a full shakedown under actual field conditions, it nevertheless recognizes that the SSC has been a catalyst in stimulating new design concepts with this type of equipment. Such activities result in know-how and expertise which extend well beyond the confines of the project.

Cooling ponds designed for the SSC deserve special consideration because of the innovative way in which they promote circulation of water for maximum heat exchange. The increased efficiency of the ponds is environmentally advantageous in that it circumvents the need for cooling towers, which have undesirable blow down and noise characteristics. The cooling ponds make the landscape more attractive and add value to the environment by promoting natural ecosystems.

SSC ROLE IN TUNNELING TECHNOLOGY DEVELOPMENT

There is opportunity for additional underground technology development. During the UTAP meeting, automated TBM guidance and robotic tunnel lining erection were identified as promising areas which could be encouraged by the SSC Laboratory. There also appears to be an opportunity for applying trenchless construction technology. Trenchless construction is the process of installing underground conduit systems without open excavation, often by means of pipe jacking, microtunneling, horizontal directional drilling, and guided boring. Certain portions of the SSC may provide for the effective use and development of this technology, such as the connections between the Beam Backstop Aborts and the Super Collider Tunnel, the Medium Energy Booster (MEB) test beams, and the transition from MEB to High Energy Booster (HEB). Trenchless construction improvements are directly transferable to the renewal of aging utilities and the installation of conduits in environmentally sensitive areas.

Recently in Japan, there have been trials of TBMs equipped with automatic, computer-controlled steering mechanisms and computer-controlled robot segment erectors and bolters. A presentation was made at the UTAP meeting regarding these systems. Automated steering has the benefit of making the positioning of the TBM independent of the skill of the operator such that unnecessary variations in line and grade can be eliminated. In addition, delays, which result from the need to correct alignment, can be minimized so progress is enhanced. Specialized computer programs need to be written and debugged to ensure that the machine is properly instructed and remains correctly controlled. Automatic steering is likely to be most beneficial in reaches with few changes in line and grade. The primary benefit of automated segment erection and bolting may be the safety of the workers. Manual handling of segments exposes workers to injury. It was estimated that the TBM at the N15 Tunnel could be upgraded to automated steering for a cost on the order of $100,000. Where appropriate, future new TBMs for the SSC could be similarly equipped. The additional cost for an automated segment erector was estimated to be in excess of $250,000. The automated segment erector may be applicable for future SSC tunnels in Taylor Marl, but would not be utilized in Austin Chalk tunneling.

The highly competitive, fixed-price American bidding system provides limited incentive to contractors to include such refinements in their TBMs. The contractor for the N15 Tunnel would have to stop tunneling to install such equipment, and it is not likely that the increased cost would be offset with a commensurate benefit on this job because of its limited length. The contractor will therefore be reluctant to stop work for this purpose. This is unfortunate, because American competitiveness on future work could be enhanced by the expenditure of relatively nominal sums to develop and prove the recommended technologies.

It may be necessary and advantageous to introduce a priced option in the contract documents for future SSC tunneling which would allow a prospective contractor to quote on the expense of technology improvements, such as automatic steering or robotic erection of segments. The option could be judged as value added to the project in terms of better accuracy or safety. It also may be necessary to offer a longer contract performance duration to enable the contractor to obtain and troubleshoot the innovative equipment. Through such options, the SSC Laboratory may be able to encourage improved technologies which ultimately promote a more competitive American industry.

SITE VISITS

Visits were made on 16 January by UTAP members to the sites of the N-15 Magnet Delivery Shaft, N-25 Hammerhead Shaft, IR-5 and IR-8 Experimental Halls, and tieback testing program. At the N-15 Magnet Delivery Shaft, the walls and tunnels show stable behavior of the Eagle Ford Shale (EFS), with no evidence of significant continuing movements. On the basis of experience to date, it appears that EFS will perform in a satisfactory way, provided that adequate advance rates can be maintained by the new Robbins TBM. It will be important to achieve a timely erection of tunnel liners to promote EFS stability. Initial problems with supply of precast concrete liner segments appear to have been solved, avoiding a bottleneck in this regard. As yet, there is little experience with grouting of the liner. It may prove both difficult and unnecessary to inject any significant quantities of grout behind the liner due to the tight fit with the EFS, but this factor is not expected to cause any problems with the tunnel performance.

The N-25 shafts in Austin Chalk have confirmed the very stable nature of this material. The final lining of the shafts and adit has been changed from

cast concrete to shotcrete, and observations to date indicate that the shotcrete is providing a fully adequate liner, as expected. The Contractor for this tunnel segment is in the process of installing a rebuilt Robbins TBM in the starter tunnel, and excavation is expected to start soon. Inspection of the excavated surface of Austin chalk shows no visible degradation of the material since being cut, with every tooth-mark still being sharp and fresh. No significant geomechanics problems are foreseen in this material.

Visits were made to the sites of the IR-5 and IR-8 Halls. Clearing and stripping is underway at one site, exposing a highly plastic clay soil that can be expected to cause trafficability problems, particularly in wet weather. The sites are relatively low-lying, such that control and handling of surface water will require careful attention.

TIEBACK TESTING PROGRAM

Sixteen tieback anchors were installed from October to December 1992. Most were tested to failure, while four anchors were retained for sustained loading to determine long-term creep performance. These tests have been extremely valuable, indeed essential, in delineating key factors controlling anchorage design and allowable bond stresses in the Taylor Marl. Long-term tests now are underway, and will continue for at least three months.

Augering initially was employed for installation, followed in some holes by reaming with an overcutting auger. Later installations used rotary drilling with a tricone bit. Contrary to the original intent, the position of the tie bond zones encompassed only about a 30-ft difference in elevation, at an average depth of about 55 ft. At this level, compressive strength of the marl averaged 350 psi. The tests were affected by various mechanical complications, among them the difficulty of preventing water intrusion into boreholes from the

water-logged weathered marl. Cement grout was poured without applying pressure.

Several important aspects of the testing were discussed at the UTAP meeting, and can be summarized as follows:

- Augered drilling smoothed the walls of the hole, remolded marl on the contact, and yielded failure bond stresses of only 15 psi. This procedure was not considered acceptable for the prototype.

- Rotary drilling yielded failure bond stresses in rapid loading in excess of 45 psi, and seemed to be a maximum of about 60 psi. The use of a reamer after rotary drilling or use of non-shrink grout did not alter the quick test failure bond.

- According to the creep test readings currently available, bond stresses higher than about 35 psi produced unacceptable gradual movements. Tentatively, it was concluded that working bond stresses in the range of about 20 to 22 psi in rotary drilled holes will offer an acceptable safety factor against creep.

In translating these results to the prototype IR-5 and IR-8 Experimental Halls, the following factors should be considered:

- Substantial water inflows from the saturated weathered Taylor Marl adversely affected anchor performance, possibly due to softening and degradation of marl at the hole wall. This factor should be made clear to prospective IR Hall bidders.

- Because of the sensitivity of the grout-to-marl bond strength with respect to the characteristics of the hole wall, it is highly desirable that the IR hall anchors include a component of mechanical interlock with the surrounding marl by using belling or post-grouting installation techniques. In the Panel's judgment, such mechanical interlock will provide a measure of increased reliability.

- At the actual IR hall sites, average marl compressive strength at intended anchor depths increases from a minimum of approximately 350 psi to a maximum almost double that value in the lower elevations of the marl. A 20% allowance for increase in bond strength from the shallow anchors to the deepest anchors is contemplated. This appears to be a conservative allowance, given the doubling of rock strength.

- In terms of empirical evidence, a design bond of 20 psi compared to rock compressive strength of 350 psi is low. Experience elsewhere with similar material suggests that it is possible to obtain design bond, including appropriate safety factor, of roughly 10% of compressive strength, on the order of 35 psi at the shallowest anchors. Instead, this appears to be the creep limit with no safety factor.

- It is likely that prospective contractors will plan to enhance the bond strength of their prototype anchors by methods such as multiple belling or post-grouting. Economy would be served if IR hall contracts encouraged specialist bidders to consider installation techniques that provide increased bond capacity. With increased capacity, it is likely that the contractor will request a reduction in the total number of tiebacks, while still achieving the total design capacity. The Panel recommends that some preliminary "scenario analyses" be performed to investigate the degree to which a reduction in the total number of tiebacks would be allowed, if a contractor is able to demonstrate convincingly an increased capacity per installation.

The construction approach discussed at the UTAP meeting was to allow the IR hall contractor to select the method for installing permanent anchors, subject to a performance specification within a fixed-price contract. The A-E/CM will determine the acceptability of the proposed anchor installation by requiring an initial series of tests. At the UTAP meeting, a scenario for initial testing was discussed which involved five tests, two of which would be 72-hour tests. The initial testing would be followed by performance testing of a percentage of the installed anchors. Each production anchor will be proof tested.

Because of the importance of verifying anchor capacity and the critical path nature of the IR hall construction, it seems prudent to devote careful attention to the initial testing program and its contractual ramifications. It would be advantageous to provide a written summary of the initial testing program for review by an outside expert, such as Dr. Stuart Littlejohn, to acquire feedback based on experience with testing and production installation in similar material. Given the low bid basis for contract award, some "what if" scenarios should be considered. Contingencies should be considered for the case in which the contractor fails to achieve the required anchor capacity in the initial testing. Provisions should be available to achieve in a timely way an adequate installation procedure, should difficulties be encountered in the initial testing program.

S-30 TEST SHAFT INSTRUMENTATION RESULTS

The 18-ft-diameter S-30 Shaft was excavated to a depth of 203 ft within Taylor Marl in October 1992. The shaft was instrumented to determine Taylor Marl performance. Results to date were reported at the UTAP meeting. The upper 40 ft of weathered, saturated marl was restrained by a tangent pile wall. Below this, the shaft was lined by shotcrete with rock dowels. Appearance of the unweathered marl was good: massive, homogeneous, lacking weak planes, joints, or bentonitic seams.

Structural performance of the marl was satisfactory. The only anomaly is that convergence of the shaft walls apparently was continuing after construction while inclinometer movements had stopped. Data from Convergence Station No. 1 at approximately 70 ft below ground surface suggest that inward movements were continuing as of the end of November 1992. It would be advantageous to obtain additional readings at the shaft convergence stations to define better the long-term response of the Taylor Marl.

The most important data from S-30 concerns the piezometric response of Taylor Marl. Three double-point piezometers were set with intakes at 100 and 160-ft depths at varying radial positions outside the shaft. Starting with water at the ground surface at Elevation 484 ft, drawdown in the Taylor Marl followed essentially the same path for all piezometers, except for aberrant seal effects in piezometer P3. Drawdown of approximately 40 to 45 ft occurred immediately as the base of the shaft approached the piezometer tips, and was equal in piezometers at both depths and at varying distances. The pattern of piezometric levels indicated little continuing flow into the shaft, either with a vertical or horizontal component. This may be the result of the sealing effect of the shotcrete liner and low permeability of the marl, which delay drawdown in the presence of substantial recharge at the base of the weathered marl.

This limited drawdown is to be compared with much more rapid drainage in Austin Chalk. The piezometer observations should be continued at intervals in the future, and will be a valuable indicator of the difficulty of drainage at the experimental halls.

The piezometer results indicate that the unweathered Taylor Marl drains very slowly. In light of this observation, stability analyses for the IR halls based on the assumption that a fully drained, zero pore pressure condition will be achieved in marl around the IR halls must be reviewed carefully. At best, this condition would require a very long time to achieve. Although the S-30 Shaft is shotcreted, and therefore cannot be compared directly to rock drained by a series of drainholes, the test results nonetheless encourage additional thinking about the adequacy of horizontal drains at a vertical spacing of 60 ft in the walls of the IR halls. The Panel is aware that Austin Chalk at the base of the IR halls may act as an underdrain for Taylor Marl, and that such an undraining condition was not encountered in the S-30 Shaft. It is prudent nevertheless to consider how pore pressures along potential sliding surfaces would affect long-term stability. Because pore pressure conditions are fundamental to the calculation of the total required capacity of the tieback system, the Panel strongly recommends that parametric analyses be performed to assess the impact of having positive pore pressures along potential failure surfaces, compared to the currently assumed zero pore pressure condition.

Some instrumentation in Taylor Marl is planned currently for the S-40 Shaft, which penetrates Austin Chalk at its base. If piezometers were installed adjacent to this shaft, it would be possible to evaluate how effective Austin Chalk is at promoting underdrainage of Taylor Marl. Piezometer measurements at this shaft would improve our understanding of how rapidly and completely pore

pressures dissipate under drainage conditions more consistent with the actual IR hall construction.

LABORATORY TEST RESULTS FOR TAYLOR MARL

The Panel was provided with the results of two recent tests on Taylor Marl performed at the University of Texas at Austin: one drained test, with detailed measurement of volumetric strain, and one undrained test, with pore pressure measurements. Although such results are limited in scope, they nevertheless may be useful as a means of clarifying the failure mechanism of intact marl.

In both cases, the material failed in a brittle manner, at 1% strain in the undrained test and 2% strain in the drained test. The material performed in a contractive mode, with positive pore pressures generated in the undrained test and volume compression in the drained test to failure, followed by dilation after the peak strength was exceeded. Peak compressive strengths were 900 psi drained, and only 370 psi undrained. The calcareous cement in the marl apparently broke at low strain. The grain structure then slumped slightly, and then dilated with continued strain. The residual strengths were low, between about 200 and 250 psi in both tests. Shear pore pressures were very high in the undrained test, almost reaching the 150 psi confining pressure.

During the preparation of this report, a summary of laboratory test results was received in which drained strength parameters were evaluated for Taylor Marl. The Panel is pleased that drained strength data are being acquired, and encourages a careful review of all the drained and undrained test data to develop as clear a picture as possible of the intact, small specimen behavior of the marl. The Panel also encourages careful consideration of the drained strength data relative to the strength parameters that may apply for the in-situ rock mass. Experience with the large-scale performance of heavily overconsolidated

clays and shales has indicated that the operative value of effective cohesion under field conditions may be substantially less than the value derived from laboratory test specimens.

DESIGN AND CONSTRUCTION OF IR HALLS

Design of the total capacity of tieback tendons, which is required to maintain stability of the sidewalls of the IR halls, has been based on limiting equilibrium analyses of potential slide blocks having a geometry which is defined by an inclined planar slide surface and a tension crack at the back of the block. Because these analyses form the basis of design of the permanent tieback system, it is clearly important that they reflect as accurately as possible our current state of knowledge and uncertainty. The Panel offers several recommendations concerning these analyses, and the consequences which may emanate from the analytical results:

- There is uncertainty concerning the values of long-term pore pressures along potential sliding surfaces in Taylor Marl. The assumption of zero pore pressures, as currently used, is optimistic. A series of parametric analyses would be beneficial, using a reasonable range of pore pressures along the potential slide surface in conjunction with effective stress strength parameters, to assess the sensitivity of the tieback design to changes in the assumed pore pressure conditions. The specific importance of this recommendation is to alert the designers to the possible consequences in terms of wall stability and required tieback capacity. If positive pore pressures are monitored in the field, such analyses will help formulate the appropriate remedial action to be taken. Such actions could include the installation of additional tiebacks and/or drilling of additional pressure relief drain holes.

- There is uncertainty concerning the appropriate value of effective cohesion for use in long-term effective stress stability analyses. Currently, a value of 50 psi has been used in the Geotechnical Design Summary Report. The database for this value is limited (7 consolidated drained and 9 consolidated undrained tests), and tests have been conducted only on laboratory scale samples of intact material. There has been no reduction in the cohesion value to account for potential scale effects in the field, swelling effects due to reduced mean normal stress caused by excavation, time rate of loading, and possible presence of fissures. Parametric analyses are

advisable, using a range of cohesion values in conjunction with reasonable pore pressures, to evaluate the sensitivity of the design to uncertainties in the input data on material properties.

- It is not clear that the assumed trapezoidal shape for the potential failure block is the most critical. At the UTAP meeting, the Panel was advised that circular failure surfaces had been analyzed. The Panel encourages this type of analysis of a circular arc failure surface (plus tension crack), again with a view to assessing the sensitivity of the design to variations in the input conditions.

The Panel's recommendations for sensitivity analyses concerning the effects of porewater pressure and effective cohesion are intended to bracket the variations in excavation performance which may occur in the field, and do not necessarily imply that design pressures need to be increased. By providing a better understanding for the consequences of variations in porewater pressure and strength parameters, the sensitivity analyses also point the way for more effective use of field instrumentation as a means of assessing whether conditions in the field conform to those assumed in design.

For IR-5, the design lateral pressures constitute 0.3 times total overburden at the top of the wall, and 0.15 times total overburden at the base of the Taylor Marl at its interface with Austin Chalk. For IR-8 with less marl, the ratio of lateral pressures to total overburden is approximately 0.15 at the top of the wall and 0.09 at the base of the marl, slightly more than half of the pressure ratios assigned at IR-5. The Panel agrees that it is important to apply a larger pressure coefficient at the top of the unweathered marl to limit the potential for extension strains and tension cracking.

As discussed previously, the intended design bond stress of the tiebacks is low compared to the apparent Taylor Marl strength in unconfined compression. Specialist contractors, who are qualified to bid this work, are likely to devise a tieback installation that could increase significantly the nominal bond stress. Specifications should be drafted to encourage a value engineering

proposal or, preferably, an alternative bid that would bring more savings to the SSC Laboratory in the negotiation period. An alternative bid could take the form of installation of fewer, higher capacity ties, thus requiring an increase in flexural capacity of the caisson soldier piles. There should be a specification provision that limits the depth of excavation beneath an installed tier of ties that is based on tie capacity and wall flexural strength. Obviously, the stipulated post-award demonstration testing of the tieback procedure should ensure that progressive overstressing of the bond is not causing a relaxation of the ties. In that regard, routine proof testing should include a requirement for plotting the load versus extension to determine that the bond resistance has not retreated outward along the bonded length.

The instrumentation program must include sufficient piezometers to demonstrate convincingly that the assumed drainage is achieved on the back of the postulated failure wedge. The inclinometers should be positioned so that changes in the tieback load with the progress of excavation can be evaluated in terms of extension strains in the ground that are occurring behind the bonded length of the ties. Inclinometers should be established at key locations across the tied-back mass of Taylor Marl, preferably near the edge of excavation, just in front of the bonded lengths of critical ties, and immediately behind the anchor zone. A suitable number of inclinometers should be installed to accommodate occasional losses of inclinometer casings because of damage during tieback installation. Sufficient load cells should be installed to evaluate the total load conveyed to a full vertical section of ties, and to provide for verification that adequate anchor loads are being maintained within the tieback population at large.

Statistical methods can be used to select the number of instrumented ties to achieve a prescribed confidence limit that anchor loads exceed a particular

minimum value. As mentioned in the 16 November, 1992 UTAP report, multi-position extensometers can be installed parallel to or at shallow angles across the Taylor Marl/Austin Chalk contact to monitor any concentrated displacement at this location, and to provide direct evidence of rock mass deformation which is transferred to and reflected in the tieback loads.

As previously discussed, there are uncertainties associated with the inferred behavior of Taylor Marl in the field and the appropriate design parameters needed to represent the field behavior. These uncertainties make even more important the planning of the instrumentation program, conscientious monitoring and interpretation of data, and the rapid, systematic response to measured performance. To this end, it is important to review the proposed layout of piezometers and extensometers around the IR halls in light of the sensitivity of the tieback design to changes in the assumed input parameters of pore pressure (monitored by piezometers), and/or reduction in cohesion (evidenced by larger movements than expected, in conjunction with piezometer results).

The design should be as conservative as practical with respect to the capacity of the truss and the upper tiebacks, so as to restrict extension strains that encourage water to enter the unweathered marl. It should be recognized that the truss is a much stiffer element in resisting lateral earth loading than are the ties, which will tend to relax if inward movement of the marl is widespread. Even though the lateral pressure diagram is top-loaded, shear strains in the marl could cause even more of a load transfer upward. In view of this possibility, the working stresses in the chords of the truss should be selected conservatively for the design lateral pressures. It also may be advantageous to measure the loads in select bottom chords of the truss.

Given that the tieback system is permanent, the instrumentation should be designed with long-term measurement capabilities. It will be advantageous to

consider how the accessibility and integrity of instruments will be maintained, and who will acquire the responsibilities for long-term monitoring.

The Panel is mindful that difficulties were encountered during tieback testing and that significant changes were required as testing progressed, even though the program was relatively simple and limited in scope. The Panel urges that the SSC Laboratory adopt a contractual approach to the construction of the IR halls that can adjust to clarifications of Taylor Marl and tieback performance which are signalled by instrumentation and observational data. It is highly advisable that clear provision be made in the IR hall contract documents for the placement of additional tiebacks and pressure-relief drain holes, if required. This provision is consistent with the recommendations on page 17.

GROUNDWATER MONITORING PROGRAM

The Panel heard with interest the proposal of Dr. Allan Dutton of the TBEG, whose focus was monitoring to demonstrate the absence of radiation contamination of groundwater by SSC Laboratory operations. The Panel offers the following comments:

- Detailed measurements of piezometric levels surrounding the underground units indicate that porewater pressures are orderly and predictable, only major lithologic changes are influential, and that erratic jointing does not appear to alter the laminar flow. The Austin Chalk appears to reach equilibrium rapidly, directing flow into the SSC units which serve as a drain or sink to exterior groundwater.

- The general pattern is inflow to the SSC system, <u>not</u> flow passing by or crossing over the system, and thus escaping into the regional groundwater. Radiation contamination of through-flowing groundwater is unlikely. Regardless of this conclusion, there is a need for sampling in monitoring wells to establish baseline water quality in the SSC area of influence, as proposed by the TBEG.

- Besides this baseline study, highly focused in-situ investigations also should be undertaken. These would be positioned where SSC units generate relatively high radiation and/or which correspond with pervious horizons where inflow is relatively heavy. Parts of

the accelerator, such as the Beam Backstop Aborts, may offer opportunities to monitor piezometric levels before and after tunneling to obtain drawdown data for back-analysis of in-situ permeability and flow characteristics. Local access to the Abort areas could be provided for limited mapping of rock fractures to be incorporated in the modeling. Locations of special interest from the perspective of flow horizons include interfaces between Austin Chalk and both EFS and Taylor Marl. At selected locations, piezometers and sampling wells would be concentrated, and both the inflowing seepage and the exterior source water would be sampled for changes in water chemistry and radioactivity.

- Apart from the specific undertakings discussed above, the Panel does not believe that an open-ended program of joint mapping and groundwater sampling is justified, according to the information now available. The Panel also urges that maximum use be made of the piezometric data which have been and will be acquired at locations such as the Exploratory, Magnet Delivery, and S-30 Shafts, as well as the pending IR hall excavations.

SHAFT LININGS

Based on the experience to date of shaft performance in Austin Chalk, it has been suggested that the final lining of shafts in chalk could be changed from cast concrete to shotcrete. It is the Panel's opinion that a cast concrete liner is not required in Austin Chalk from the viewpoint of stability of the rock mass around the shaft. Thus, the issue becomes one of construction ease with respect to placement of shaft fixtures and furnishings, and a contractual issue of whether or not such a change can be satisfactorily negotiated within existing contracts. For drilled shafts in the chalk, in which the dimensional variations in the rock walls will be minimal, shotcrete should provide an excellent finish, to within small tolerances (less than 1 in.), and the Panel recommends that this alternative be pursued. Shafts excavated by roadheader also are likely to have serviceable surfaces after shotcrete placement. For drill-and-blast shafts, it will be more difficult to achieve a smooth finish, and satisfactory results may not be achieved.

AUSTIN CHALK CORROSION CONTROL

Concern has been expressed by some engineers about the potential corrosion of rock dowels and unistrut channels in Austin Chalk. Corrosion concerns have been triggered in part by the relatively low resistivity and high chloride content of some Austin Chalk samples. Expert advice has been sought from Norton Corrosion Ltd., Inc., which indicates that the electrical isolation of dowel and unistrut by a nonmetallic sleeve and washer assembly, coupled with systematic sampling of chalk muck at 500-ft intervals, would be advisable.

The Panel is mindful that corrosion problems with metallic reinforcements have not been part of the local experience with Austin Chalk, and that exposures of chalk on the project have disclosed a generally dry, competent material. Nevertheless, the Panel concurs with the recommendation for inexpensive electrical isolation between dowel and unistrut, similar to the mylar-nylon sleeved washer which was distributed during the UTAP meeting. The unit cost for the washer should be low, and the presence of the washer should add little to the cost of installation.

It is possible that sampling chalk muck at intervals of 500 ft will result in a wide variation of data which may be inconclusive regarding the apparent corrosion potential of the in-situ material. The Panel recommends that sampling be concentrated instead at persistently wet locations and areas of continuing seepage. Sampling at areas where free water is present should disclose characteristics of the potentially worst corrosive environments. Such selective measurements will indicate whether there is a corrosion problem and provide a focused assessment of what corrosion effects, if any, can be anticipated.

APPENDIX A

AGENDA UTAP Meeting
January 17 - 19, 1993
Dallas, Texas

UTAP Members
Melrose Hotel
3015 Oaklawn
Dallas, TX 75219
214-521-5151

January 17, 1993 — Sunday — Site Visit

	Site Visit — Leave from Melrose Hotel 9-10AM (boots and hats will be provided) N15 tunneling, N40 shafts, Pull out tests, IR Halls Sites	Jo Bhore Jim Monsees

January 18, 1993 — Monday — Stoneridge Building 4 Upstairs Conf Rm

8:30–8:40	Introduction and Welcome	Jon Ives
8:40–9:00	Review of Recommendations from Last UTAP Meeting	Jim Monsees Bob Janowski
9:00-9:30	Tunnel Survey, Field Q/A	Rick Wilkin
9:30–10:15	Construction Update	Roy Prince Jo Bhore
10:15-10:30	COFFEE BREAK	
10:30-11:30	Test Sites & Design Data Ground Anchor Testing (30 mins) In Situ Instrumentation Update (45 mins) S30 Data in Marl Exploratory Shaft N15 Utility/Magnet Shafts Hall Instrumentation Program	 Roy Cook Birger Schmidt
11:30-12:00	Project Schedule	Larry Sluiter
12:00–1:00	LUNCH	
1:00-2:00	Executive Session with SSCL Management	Jon Ives
2:00-2:30	TBM Roundup: Overview of committed TBM's	Joe Bhore Jim Monsees
2:30-3:00	New Possibilities for TBM Improvement	Dick Robbins

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January 18, 1993 — Monday, Continued		
3:00-4:30	Status of Experimental Halls Program Status Design Status Construction Contracting Construction Strategy & Schedules	Francis Fong Birger Schmidt Hank Carmean Tom Kirk Gary Sanders
4:30-5:00	UTAP Working Session	
7:00	Gaudiosa with SSCL & PB/MK	

January 19, 1993 — Tuesday — Stoneridge Building 4 Upstairs Conf Rm		
8:30-10:00	West Utility Straight Overview of Technical Requirements HEB/Collider Intersection Collider/Abort Line Intersections Abort Caverns	Tracy Lundin Amanda Elioff
10:00-10:15	BREAK	
10:15-11:00	Ground Water Monitoring Infiltration Estimates Corrosion Concerns	Alan Dutton (TBEG) Birger Schmidt Jim Monsees
11:00-12:00	UTAP Working Session	
12:00-12:30	Executive Session Feedback	

dale montana
1/15/93

ATTENDANCE

UTAP Meeting of 18-19 January, 1993

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*Footnote: Use home FAX for late Friday and weekends

1/25/93