SSC UNDERGROUND TECHNOLOGY ADVISORY PANEL

UTAP

REPORT

Recommendations following the Meetings of September 18-19, 1989 held in DeSoto, Texas

SUPERCONDUCTING SUPER COLLIDER LABORATORY

UNIVERSITIES RESEARCH ASSOCIATION

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Recommendations following the Meetings of September 18-19, 1989 held in DeSoto, Texas

By

The Underground Technology Advisory Panel (UTAP)

To

Mr. Robert Crawley and Dr. Timothy Toohig

Superconducting Super Collider Laboratory

October 11, 1989

SSC UNDERGROUND TECHNOLOGY ADVISORY PANEL

Thomas D. O'Rourke, Chairman
10 Twin Glens Road Ithaca, New York 14850 607-272-4029

October 11, 1989

Mr. Robert E. Crawley
Dr. Timothy Toohig
Superconducting Super Collider Laboratory
2550 Beckleymeade Avenue, Suite 260
Dallas, TX 75237

Re: Report entitled "Recommendations to the Superconducting Super Collider Laboratory Following the Meetings of 18-19 September, 1989"

Gentlemen,

On behalf of the Underground Technology Advisory Panel (UTAP), I am submitting a final copy of the referenced report. A draft copy of the report was issued on 23 September, 1989, and was circulated among UTAP members for comment. The final report includes changes and refinements to the draft report, as recommended by UTAP members.

We are pleased to assist you. We all look forward to future activity and involvement in the Superconducting Super Collider.

Sincerely,

Tom O'Rourke

T. D. O'Rourke

TDO:kjs
enc.

TABLE OF CONTENTS

	Page
INTRODUCTION	1
GEOTECHNICAL PROGRAM	1
PRESENTATION OF GEOTECHNICAL INFORMATION	3
STARTUP TUNNEL	4
GROUNDWATER AND SUBSIDENCE MONITORING	8
LOCATION OF THE RING	9
TUNNEL AND SPECIAL TUNNEL AREAS	10
EXPERIMENTAL HALLS	12

INTRODUCTION

This report summarizes recommendations made by the Underground Technology Advisory Panel (UTAP) to the Superconducting Super Collider (SSC) Laboratory, subsequent to meetings held on September 18 and 19, 1989. The panel was convened at the request of Mr. Robert Crawley, Deputy Manager of the Conventional Construction Division for the SSC. A list of UTAP members and meeting agenda are appended to this report. The meeting was held at the Holiday Inn, DeSoto, TX, during which time presentations were made by members of the SSC Laboratory staff on the Texas site geology, site exploration, ring placement, experimental halls, and main beam tunnels and shafts. Information conveyed at the meetings is in the public domain, and has been collected and filed as part of the SSC Laboratory Notes which are available through the SSC Laboratory.

Recommendations pertaining to the geotechnical program, presentation of geotechnical information, startup tunnel, groundwater and subsidence monitoring, location of the ring, tunnel and special tunnel areas, and experimental halls are summarized under the headings which follow.

GEOTECHNICAL PROGRAM

The panel believes that the site exploration program currently in progress should be continued along the lines recommended by the Earth Technology Corporation (ERTC). This effort will involve 40 to 45 additional borings beyond those now completed, including a sufficient number to allot one to every shaft, five or six at the injector tunnel, three at each of the large halls, two at medium halls, plus several special borings at the postulated

faults and at contact zones intersecting the running tunnel.

For economy, it will be helpful to utilize electric logging records rather than core recovery in the Austin Chalk. Emphasis should be placed on the Eagle Ford Shale (EFS) and Taylor Marl in sampling for testing. Consistent with the recommendations in the UTAP report of May 22, 1989, Atterberg limits and natural water contents should be determined for the EFS, particularly in its upper portions. Continuing emphasis should be placed on contacts between the Austin Chalk and EFS, as well as the delineation of normal faults which intersect the ring and experimental halls. The location and approximate thickness of bentonitic seams in Austin Chalk should be noted, with samples of the bentonite tested for Atterberg limits and natural water content.

The information gathered to date indicates that the in-situ Austin Chalk and EFS are relatively impervious, and that no accumulations of gas, such as hydrogen sulfide, have been encountered. Nevertheless, it would be prudent to sample the groundwater at locations of relatively high flow, such as brecciated fault zones, to test for chemical constituents. In addition, it is advisable to probe for gas at selected locations, particularly in zones where pyrite (iron sulfide) has been recorded in the existing core logs.

Selected borings at each potential experimental hall should be carried below the proposed subgrade to a depth equal to the base width of the hall. These relatively deep borings will be especially useful for acquiring data and projecting excavation stability and detector settlement performance at halls underlain by EFS.

All boreholes should be utilized to the maximum extent practical for instrumentation to be used for construction monitoring. Caution should be exercised with each borehole that penetrates a tunnel or chamber. In these

situations each completed borehole should be thoroughly grouted, with a record of the grouting procedures kept on file.

The topic of geotechnical site investigations for underground projects is addressed in a report published through the U.S. National Committee on Tunneling Technology.[1] On the basis of an in-depth review of 100 case histories, information was collected for the purpose of planning and conducting effective geotechnical site investigations. It was concluded that expenditures for geotechnical exploration should be, on average, three percent of the estimated project cost to provide effective results and diminish the level of construction claims arising from changed conditions during tunneling. The scope and magnitude of the site exploration program must fit the specific site conditions and project design problems.

PRESENTATION OF GEOTECHNICAL INFORMATION

Geotechnical data tabulation should be on a computerized scheme which is consistent with overall project data storage procedures. Furthermore, stick diagrams of the style utilized by ERTC should be continued and expanded to show geophysical and synoptic structural information. This would be included in the geotechnical data report.

For engineering purposes, it is of great importance to develop a detailed geologic longitudinal section along the tunnel alignment at drafting scales such as 1 in. equals 250 to 500 ft horizontal and 1 in. equals 4 to 10 ft vertical. This should show the proposed tunnel and hall openings as they will be intersected. All of the key developed engineering data should be shown

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[1]Subcommittee on Geotechnical Site Investigations, "Geotechnical Site Investigations for Underground Projects," U.S. National Committee on Tunneling Technology, National Academy Press, Washington, D.C., Vols. 1 and 2, 1984.

numerically or in symbol form at borings, including position of samples and cores, core recovery, RQD, moisture content, strengths, identification properties, in-situ test location, and test results. This profile would be made on a series of sheets, each with appropriate match lines. If the sheets are limited to 20 or 24 in. high, they would only show the lowermost 100 to 200 ft of the borings.

Larger natural scale cross-sections should be drawn in more detail through the halls and at other locations where the boring information is concentrated and where there may be major stability problems. Cross-sections also should be drawn at each location of intersecting tunnels and boots.

The geotechnical data report must be complete and comprehensive. The interpretive report should be developed so that there is no need for the designers or bidders to spend unnecessary effort digesting or interpreting the background data.

STARTUP TUNNEL

To comply with congressional legislation, there is an opportunity to begin actual construction in FY 1990 with a 2.7-mi.-long startup tunnel. A suitable place for the startup tunnel is between shaft locations E1 and F1.

Such a project can provide substantial benefits for the SSC. It allows for early construction of main beam tunnel for timely cryogenic and physics shakedown efforts. It can provide critically important information on rock properties at the interface between Austin Chalk and EFS and on the in-situ performance of EFS, particularly with respect to excavation stability and machine settlement at the large detector halls. It exposes the chalk and shale in-situ, thereby providing prospective contractors the ability to review

the site and information collected during construction. This review will clarify many uncertainties with respect to rock performance and appropriate construction methods, and should be reflected in reduced contingencies during bidding for future tunnel and experimental hall sections. The project can be used to encourage innovative tunneling by inviting technical proposals from prospective contractors utilizing a contract package which will stimulate new developments. Promoting innovative construction with the SSC carries a certain prestige and national importance because it supports efforts for the U.S. to be more competitive internationally.

The panel urges that this opportunity be seized, and that a substantial instrumentation, testing, and evaluation program be included in both the current geotechnical exploration and construction contract. With a well planned geotechnical program, it will be possible to obtain realistic in-situ data on the performance of the EFS and its transition from the Austin Chalk. Consistent with the recommendations in the May 22, 1989 UTAP report, the shafts should be utilized as the equivalent of large over-coring holes with adjacent inclinometers measuring radial displacement, in the lower material, while heave points in the base of the shafts reveal the effects of released vertical load. The complete program would include hand-cut samples of EFS with high quality specialist laboratory testing to determine volume change characteristics and time effects on volume change.

Instrumentation may include piezometers, inclinometers at the shafts and extensometers in advance of the tunnel and probably directly over the tunnel axis. In addition, there may be convergence measurements in the mined openings, strain gage measurements on appropriate tunnel supports, and heave point observations in the bases of the shafts.

The geotechnical site exploration program for the startup tunnel should include borings positioned at approximately 1000-ft centers along the line of the running tunnel, one at each of the end shafts, and two each at intersections with the boots, or adit tunnels, from the shafts. There would be a total of 25 to 30 borings. For the schedule that was outlined in the meeting of September 18, it will be necessary to give priority to these borings over the general exploration program. As suggested above, coring and sampling for the running tunnel should be economized using downhole geophysical logging. In addition, there must be extensive sampling and associated testing of EFS.

Borings at the intersections of the main beam tunnel and adits should be planned and performed after completing the shaft and running tunnel borings, so as to position them at the best locations to define discontinuities at the intersections. Borings in the pre-contract exploration should be utilized to the maximum extent for instrumentation for contract monitoring.

The exact legislative requirements of the tunnel must be checked to be sure that the tunnel contract is designed in accordance with the intent of the legislation, both as to the end product and the schedule allowed or required for initiation of tunnel construction.

Time constraints dictate a tunnel as simple and clean as possible, e.g., free of appendages or recesses, special supports, and of unusual or special features. It would be desirable, for instance, to specify an "over-size" tunnel which could accommodate equipment otherwise to be put in niches or alcoves. This tunnel could be modified later if the simplified tunnel omits anything subsequently found to be necessary.

Although a tunnel design should normally be performed by the A-E/CM, the delay in selecting and contracting with the A-E/CM (estimated April or May,

1990) will make it necessary for the M & O to begin at once with the formulation of the general scope and engineering criteria. The M & O should form a separate group for this specific purpose if done in-house, or enter into a subcontract with an outside firm to carry the design through the preliminary engineering stage.

It would be advantageous if an arrangement were negotiated with the A-E/CM as soon as selection is made, without waiting until the full contract is finally negotiated and notice to proceed given. This arrangement could be a separate subcontract or an agreement as to the scope of services required and a method of payment related to terms of the full contract when it is made official.

It should be recognized that there will be severe demands on SSC Laboratory personnel and consultants engaged in the site exploration, interpretation of geotechnical data, evaluation of design factors, and development of engineering criteria for the startup tunnel. The need to establish an instrumentation program and to create a contractual framework which stimulates innovation will place further demands on the technical team, both in terms of the subtlety and detail with which the work must be pursued. There is little or no time for delay. The panel believes that the SSC Laboratory staff and their contractors will have to act decisively and cohesively.

Milestones must be established, in extraordinary detail, and early accomplishments and slippages need to be spotlighted. All elements and factions must be made to understand that the schedule is critical and those who delay will be held accountable. The SSC Laboratory, U.S. Department of Energy, and Texas National Research Laboratory Commission (TNRLC) need to be involved in this scheduling process. Their roles in accomplishing individual tasks, as

well as overall help, must be clearly detailed in the total schedule. Given the benefits of such an undertaking, there should be ample encouragement for marshalling the necessary resources and proceeding with dispatch to accomplish the goal.

GROUNDWATER AND SUBSIDENCE MONITORING

There is the potential for subsidence caused by groundwater removal to affect the long-term operation of the SSC. Such subsidence can occur when an aquifer, such as the Woodbine Formation, is overpumped for an extended period of time. There are numerous records of this happening, particularly in the southwestern U.S. The settlement can begin within a few years or less if the overdraft is large and continuous. The settlements usually are a matter of feet and sometimes tens of feet. Well known examples are found in California, Arizona, and Texas.

A program should be organized to establish a firm benchmark grid in the area of the SSC which would be checked annually. Contact should be made with local U.S. Coastal and Geodetic Survey personnel with the pertinent records of the agency collected and reviewed. A groundwater study should be performed which identifies aquifers and aquicludes underlying the project, and determines their respective depths. Information already acquired by the TNRLC will be helpful in this process. Existing water wells near the SSC should be identified, and the static levels and volumes pumped from the wells should be measured annually. Small diameter observation holes should be drilled and cased to measure water levels. It would be helpful to estimate what the demand from the aquifers will be over the next 5, 10, 15, and 20 years, and to evaluate the effect of the SSC on the demand. Demand estimates should be

revised every other year. If possible, the source and amount of recharge to the aquifers also should be estimated.

It would be well to have a qualified expert or firm conduct the groundwater and subsidence study and submit a report to the SSC staff showing present groundwater conditions and use. Predictions should be made of what to expect in the future and provisions for continued monitoring of benchmarks and water levels.

LOCATION OF THE RING

It is the understanding of the panel that the location of the ring has been virtually fixed with respect to plan location, dip, and obliquity. There appears to be some latitude, however, with respect to depth. Currently, the elevation of the ring has been set for a minimum depth of 50 ft beneath one or more of three creeks. A higher elevation of the ring would encroach on the 50-ft buffer zone, thereby requiring consideration of backfilling and culvert diversion of surface waters, as discussed in the May 22, 1989 UTAP report. The panel is mindful that such activity would involve environmental considerations, special fee structures for purchase, permits, and costs. Nevertheless, there are benefits associated with raising the ring. Increasing the elevation of the ring would diminish the amount of main beam tunnel within the EFS and reduce problems with invert control, mixed face tunneling, and stability of intersections at boots and shafts. Perhaps the most important effect would be to decrease or eliminate exposure of the EFS at the bases of the large detector halls. This would help in stabilizing the base during construction and in controlling settlements as the detectors are assembled and operated. Even small increments in elevation of 5 to 10 ft can be advantageous from a

geotechnical perspective.

TUNNEL AND SPECIAL TUNNEL AREAS

Leakage criteria for the tunnels will be influenced by the durability, sensitivity, and long-term operational concerns associated with the magnets and electronic equipment. Detailed discussions between conventional facilities and magnet designers should focus on tolerable levels of moisture and the form of optimal moisture control. The panel has not been briefed on the magnet, its electronic components, and their packaging. Nevertheless, it is possible to offer some general guidance, with the understanding that refinements will follow from a more detailed delineation of moisture tolerances and operational requirements.

Most sections of the tunnel will not generate significant water flows, and are not likely to require special protective schemes or a water-tight lining. Water infiltration may be encountered at shafts and fault zones, and criteria should be established for controlling this water on a local basis. It is advisable to focus on the control of local infiltration and avoid the unnecessary complications of applying the local measures to all sections of the tunnel.

The construction of a startup tunnel will force the project to confront at an early stage a number of important problems in underground construction, since this work will intersect the upper weathered and softened portion of the EFS where compressive strengths range from 100 psi at the interface to 500 psi in lower material. Criteria developed should include the following:

- Any shaft carried to the surface provides a downward path for migration of infiltrating waters on the outside of the shaft lining to tunnel structures at depth. A standard detail should be devised

for a seepage cut-off collar in the shaft lining and appropriate drainage outside the wall of the shaft at its base. There probably is a need for a cut-off separating the adit tunnel boot from the base of the shaft itself. All of these procedures tie in to the criteria for acceptable infiltration into the running tunnels, a substantial portion of which may be concentrated at the shaft boot intersection.

- The boot itself will include a special slot-shaped cross-section with high walls, whose dimensions depend on the requirement for magnet insertion from the shaft. This slot-like structure will call for special loading criteria for both initial and final structural support.

- The invert of these special structures and main beam tunnel will be in the shale. Procedures for protecting the shale from slaking and softening, the structural requirements of the invert slab and the drainage trench beneath it, all need to be considered here. These are particularly important since there is a possibility that the startup tunnel would be mined with roadheader or similar device which would have a flat floor and would not be adapted to precast segmented circular lining.

The panel believes that the method of shaft construction and mucking should be left to the contractor, subject to appropriate safety and stability assurances. Savings will be gained by allowing contractors as much flexibility as possible in choosing locations of muck and other construction shafts. Rather than focusing on mucking procedures, it is advisable to concentrate on muck disposal. The pyrite (iron sulfide) crystals and nodules evident in the EFS core logs implies that atmospheric exposure and water infiltration of EFS muck may promote chemical reactions involving dilute sulfuric acid. The leachate from EFS muck disposal areas should be evaluated in context of environmental effects. The panel acknowledges the value of leachate tests currently planned for EFS samples by ERTC, and encourages additional efforts to probe the environmental consequences of EFS spoil.

The introduction of alcoves and niches along the main beam tunnel should be evaluated carefully with respect to impact on schedule. Given the

sequential nature of tunneling, excavation and linings for alcoves and niches may add significantly to the time envisioned for main beam tunneling in the conceptual generic design and current study of SSC contracting practices conducted by the U.S. National Committee on Tunneling Technology. Increasing the tunnel diameter may be a suitable alternative to alcoves and niches. A preliminary evaluation was made by members on the panel of cost trade-offs associated with larger size. These estimates show that increments of 3 to 4 ft relative to the 12-ft finished diameter currently proposed may not be cost effective, even when the smaller sized tunnel is constructed with niches and alcoves.

If a circular cross-section is used, it will be advantageous to excavate for the same diameter irrespective of the rock formation in which the tunneling is performed. Sufficient room should be available after excavation in Austin Chalk for initial support, such as bolts and straps, to protrude without encroaching on operational space.

EXPERIMENTAL HALLS

As emphasized in the May 22, 1989 UTAP report, efforts should be concentrated on placing the bottom of the halls at depths less than 200 ft and on minimizing excavation of the halls in EFS or Taylor Marl. In the current ring profile, the chambers are close to, or less than, the recommended 200-ft depth.

Prime factors which need to be considered in choosing between open excavations and chambers in rock for the experimental halls include: 1) cover over the crown of the chamber, 2) stability of chamber and excavation walls, and 3) stability of the excavation bases. With respect to cover, sound rock

equal to one-half to three-fourths or more of the excavation span is desirable. High side walls in Taylor Marl or EFS may require substantial support. In such weak rock, anchorage capacity is low, so that long bolts and large diameter holes are required to develop adequate capacity.

The strength of the marl and shale is low with respect to in-situ stresses, which means that new fractures can develop through the intact rock. Furthermore, EFS and the Taylor Marl contain, in addition to bedding plane weaknesses, joints of intermediate to steep dips that can cause unstable wedges to form. The potential for combinations of failure through intact material <u>and</u> along joints results in increased support requirements. Geotechnical investigations at the experimental hall sites should concentrate on determining joint orientations and on locating zones of shearing and concentrations of natural fractures in the rock mass.

In either open cut or chamber construction, it will be necessary to prevent instability in the EFS that could cause lateral deformation and loss of support of the walls. Moreover, buckling and heaving of EFS in the bottom of the excavation must be constrained. Stabilizing the lower walls could be accomplished by placing bearing surfaces (wall plates) at the side of the excavation and drilling anchors down and out from the chalk into the EFS. To prevent buckling of the floor and to minimize heave, the bottom of the excavation could be tied down with large-diameter dowels that are extended to depths approximately equal to the excavation width. Dry drilling, to prevent introduction of water into the EFS, is recommended. Average pressures applied by tie-downs over the surface of the excavation floor could be on the order of 25 to 50 psi.

The limited access to working space, which accompanies chamber

construction, will drive up the cost of excavation and installation of support. Moreover, there is the need for large pillar widths and substantial wall reinforcement in the Taylor Marl and EFS.

In an open cut, it will be critical that the foundation in EFS be protected from water and covered as soon as excavated. The base slab then should be tied into the underlying material.

Heave of the EFS could be in the range of 6 to 12 in. for an open cut. Recovery of much of the heave would occur with the cover and backfilling operation. Of greatest concern are the residual time-dependent movements which occur after the detectors are installed. The panel views the question of settlements of the heavy detectors of prime importance. Long-term settlement of a detector after construction is the function of a number of factors, including: position of the bearing surface in the geological column; relation of the total gross release of load in construction to the final load applied by the detector; the sequence of this unloading-reloading; heave permitted during construction; and time deformation properties of the EFS. Settlement will be inhibited by protection of the exposed subgrade, denial of water to it, and minimizing the total unloading during excavation. The initial shaft and startup tunnel contract should include measurements to evaluate potential heave and settlement.

Given the uncertainties in the unloading and loading sequence, access to water, and time-dependent performance of the EFS, it seems prudent to design the detectors to accommodate some differential settlement. An array of flat jacks, for example, could be inserted between the main detector components and their mat foundation for differential leveling of the machine to offset variable settlement.

The experimental halls currently are divided into three groups on the basis of size. Design and construction considerations for each size category are summarized briefly under the following subheadings.

Small Experimental Halls, West Side. These halls, which will be approximately 33 ft wide, are located in Austin Chalk. Chamber excavation here is feasible with normal support techniques, such as rock bolts having lengths of 1/3 span and spacings and capacity typical of those normally used in chambers. Shotcrete should be used for support between bolts. It should be noted that the size of the shaft-tunnel intersections located around the ring will be of the same order as that of the small chambers.

Medium Experimental Halls, East Side. These halls, which will be approximately 60 ft wide, are located in Taylor Marl with Austin Chalk near the base. Chambers here will need pillars with widths greater than twice their heights. The 70 to 90 ft of rock cover at the prospective hall locations may be adequate for an arch, but would depend on the depth of weathered marl. Long bolts (1/2 span or more) may be needed to obtain adequate support capacity. Open excavations will require benched and cut back slopes, with the slope angle dependent on the jointing and rock strength.

Further reduction in the excavation depth of the medium halls would decrease rock removal volumes but raise the base above the Austin Chalk, thereby leaving a less desirable surface of marl at the bottom of the experimental hall. The Austin Chalk is likely to provide a relatively stable foundation with little heave or settlement due to excavation and reloading.

Large Experimental Halls, West Side. These halls are located in Austin Chalk with EFS near the invert. Rock cover for the halls is near minimum for chamber construction. The 200-ft depth is compatible with open cut procedures. The ability to use a steep 4V:1H slope in chalk depends closely on the stability of the EFS, as well as the jointing in the chalk. A bench at the top of the experimental hall is recommended. Experience in quarries in the Dallas area should be reviewed and summarized. Any adjustments that can be made to eliminate or reduce excavation into the EFS is desirable, both to improve stability and to minimize movement of the detector foundations.

APPENDIX

SSC UNDERGROUND TECHNOLOGY ADVISORY PANEL

MEETING AGENDA

September 17, 1989

Holiday Inn, 1515 North Beckley, DeSoto, Texas

- Arrive evening and check in; location shown on map.
- Reservations for all members on nights of 17 and 18 of September have been made.
- Telephone 214-224-9100

September 18, 1989 8:30 AM - 5:00 PM

SSC Laboratory, 2550 Beckleymeade Avenue, Suite 260
Dallas, Texas, Telephone 214-709-9921

a) Morning Session - Presentations by SSC Staff

I. TEXAS SITE GEOLOGY
II. UPDATE ON GEOTECHNICAL SITE EXPLORATION
III. UPDATE ON SSC FOOTPRINT
IV. UPDATE ON EXPERIMENTAL HALLS
V. SHAFTS

b) Afternoon Session - Joint Discussion

VI. DISCUSSION OF TECHNICAL ISSUES

- Implications of recent site investigation findings
- Location of SSC ring and its implications for construction
- Design concepts, scheduling, and construction of experimental halls
- Location, construction methods, and scheduling of shafts
- Additional site characterization and geotechnical needs

September 19, 1989 8:30 AM - 12:00 noon

SSC Laboratory, 2550 Beckleymeade Avenue, Dallas, Texas

VII. RECOMMENDATIONS FROM ADVISORS

- Recommendations pertaining to technical issues discussed during September 18 session

ATTENDANCE

UTAP Meeting of September 18-19, 1989
Holiday Inn, DeSoto, Texas

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Dennis Boll	SSC
Dick Briggs	SSC
Edward J. Cording	UTAP Consultant
Robert Crawley	SSC
L. Edwin Garner	BEG
James P. Gould	UTAP Consultant
David Hammond	UTAP Consultant
Ron Hoffman	SSC
David R. Kielsing	TETC
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Jim Larsen	SSC
James A. Lilly	UTAP Consultant
Tracy Lundin	SSC
Robert Matyas	UTAP Consultant
Thomas D. O'Rourke	UTAP Chairman
Gene Perko	SSC
Dwayne Piepenburg	LP&A
John Reinfurt	SSC
Mack Riddle	RTK
Robert K. Tener	SSC
Tim Toohig	SSC
Eugene Waggoner	UTAP Consultant
Matt Werner	TETC

(From attendance sign-up sheet)

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10/12/89