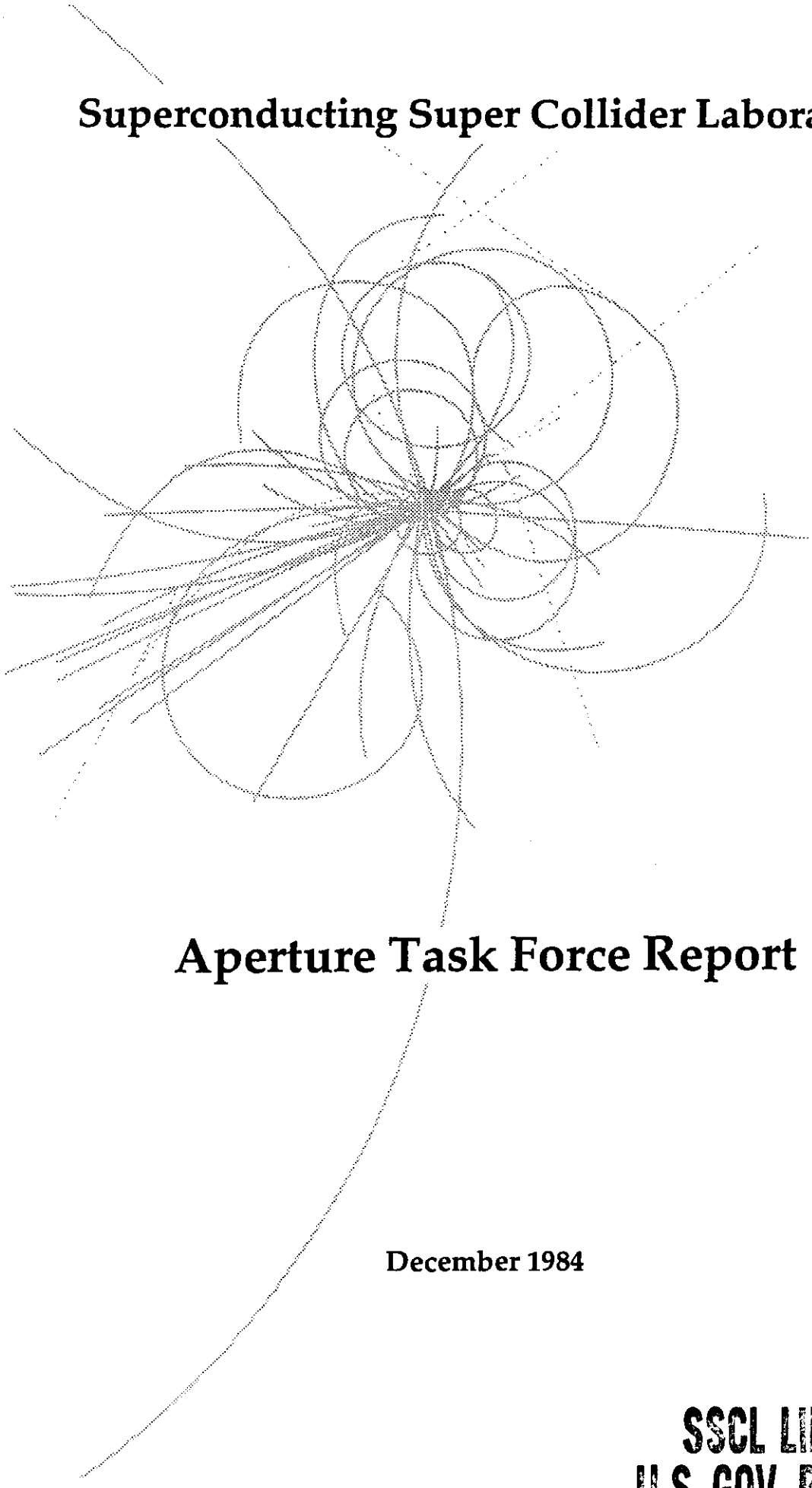
SSC-3

Superconducting Super Collider Laboratory

SSC-3



Aperture Task Force Report

December 1984

SSCL LIBRARY
U.S. GOV. PROPERTY

APERTURE TASK FORCE REPORT

DECEMBER 17, 1984

I. Introduction

The SSC Aperture Workshop held on Nov. 5-9, 1984 at LBL has identified the most immediate work that needed to be done in order to make a preliminary aperture evaluation by next spring. (ref. SSC-TR-2001, SSC Aperture Workshop Summary). The Workshop proposed an action plan, complete with time schedule and job assignments, to carry out the work. An Aperture Task Force that consists of the coordinators of the working groups (groups A to G) was formed after the Workshop to coordinate the execution of the action plan. The Task Force therefore consists of:

A. Test Lattices	Ernest Courant
B. Aperture Requirements	Don Edwards
C. Magnet Errors	Gene Fisk
D. Format, Database, Network and Lattice Codes	Steve Peggs
E. Improving Tracking/Lattice Codes	Alex Dragt
F. Analytic Screening	Christoph Leemann
G. Experiments	Helen Edwards

Since the Workshop, the task force has coordinated the continued work by the workshop participants according to the action plan. For example, a database is set up at the Central Design Group; various

tracking and lattice programs are being improved; analytic techniques for aperture evaluation are being reviewed; aperture related operational features as well as possible experiments are being studied. During this time, two group meetings took place, one at BNL on 12/3-5 by Group A, and one at LBL on 12/3-5 by Group C.; in each meeting, concrete advances were made. The action plan is being carried out satisfactorily. However, the work load in the coming few months still remains heavy to say the least.

To review this progress and to focus further on what needs to be done next, a task force meeting was called on 12/17 at LBL. The main outcome of the meeting was a renewed action plan for the coming few months. It is of crucial importance that we keep the momentum going.

The attendants of the meeting were Alex Chao (chairman), Ernest Courant, Dave Douglas (representing Alex Dragt), Don Edwards, Helen Edwards, Gene Fisk, Christoph Leemann, Peter Limon, Steve Peggs, and Jack Peterson (secretary). The agenda of the meeting was:

8:10 - 8:15 AM	Agenda
8:15 - 9:45	Progress Reports A, B, C
9:45 - 10:15	Break
10:15 - 12:15	Progress Reports D, E, F, G
12:15 - 1:15	Lunch
1:15 - 1:45	First Draft of Action Plan
1:45 - 4:30	Details of Action Plans by Groups

II. Review of Working Group Activities

Group A Review, Test Lattices

Ernest Courant

The Test Lattice Working Group had a sub-workshop at BNL on 3-5 December. The results were:

1) Simplification of the standard arc lattices in the interest of convenience and speed:

   a) centering of the bend magnets between the quads. Corrective-element positions are symmetric.

   b) standardization of half-cell lengths:

      100 meters for 6.5 Tesla (Design A) cases

      110 meters for 5 Tesla (Design B) cases

      145 meters for 3 Tesla (Design C) cases

2) Dave Johnson and Al Garren have worked out the parameters for these lattices in forms usable by the MAD, Synch, and PATRICIA (via Synch) programs. These lattices are now stored in the database at the CDG.

3) For linear calculations, a one-piece bend magnet per half cell can be used. For non-linear calculations and for misalignment and error analysis, each bend magnet is (so far, tentative) divided into 10-meter pieces.

4) Insertion properties:

   a) the dispersion killer occupies 2 cells, in which the bend-magnet disposition depends on the phase advance.

   b) matching section

c) phase shifter (trombone) consists of 3 cells and is 600 meters in length. The test lattices contain two trombones (antisymmetric) per insertion. This two-trombone version is esthetically attractive and affords computational and operational (H. Edwards) simplification, but probably greater cost in hardware and real estate.

d) crossing point assumes 20 meters free space on each side, a β^* of 1 meter, but other details are not included in the simplified test lattices. If bending is needed (in either plane), the resultant dispersion can be compensated in the dispersion-killer section.

5) Sextupole schemes are to be decided next (lumped versus distributed, number of families). For this, the November workshop decisions still apply. At a later stage, details may depend on the size of the superconductor filament. Injection energy may also be a factor.

6) Orbit-correction scheme needs to be worked out in specific terms. A fast, proven, and practical algorithm should be used.

Group B Review, Aperture Requirements and Magnet Evaluation

Don Edwards

1) Tevatron aperture experiment, involving a local sextupole perturbation. A pertinent tracking calculation, suggested by Lambertson, was carried out by Al Russell. Its preliminary results were sent to Chao and Lambertson. A more complete investigation is under way.

2) The Tevatron lattice has been made available in the MAD format, as requested. It includes correction elements (concentric quad, sextupole, and octupole windings). The MAD version runs at FNAL.

3) A mechanism for recording aperture-related problems at the Tevatron has been installed. The operators are aware of the SSC interests. Nothing has shown up as yet.

Group C Review, Magnetic Errors

Gene Fisk

The working group met at LBL on 3-5 December to review existing magnetic-error data and to organize a final report to be assembled in January.

Existing data from magnetic measurements from both cosine-type and superferric magnets were reviewed. Also, methods of estimating the magnetic errors of new designs were discussed. There was some debate as to the conductor-placement errors to be projected for the superferric magnets when in production. The work on projected errors is continuing.

The outline of the final report, which lists the contents and the responsible authors, is given in Appendix 1.

Another result of the meeting is a list of the projected multipole errors at 1-cm radius for magnet Designs A (4-cm inner coil diameter) and B (5-cm), based on $r^{-1/2}$ scaling from the Tevatron and CBA magnet measurements. Figure 1 is a plot of these projections by Fisk and Wanderer.

Lundy, Reardon, and Taylor have proposed magnet Design D which is a merger of Reference Designs A and B. Its design specifications (interim) are:

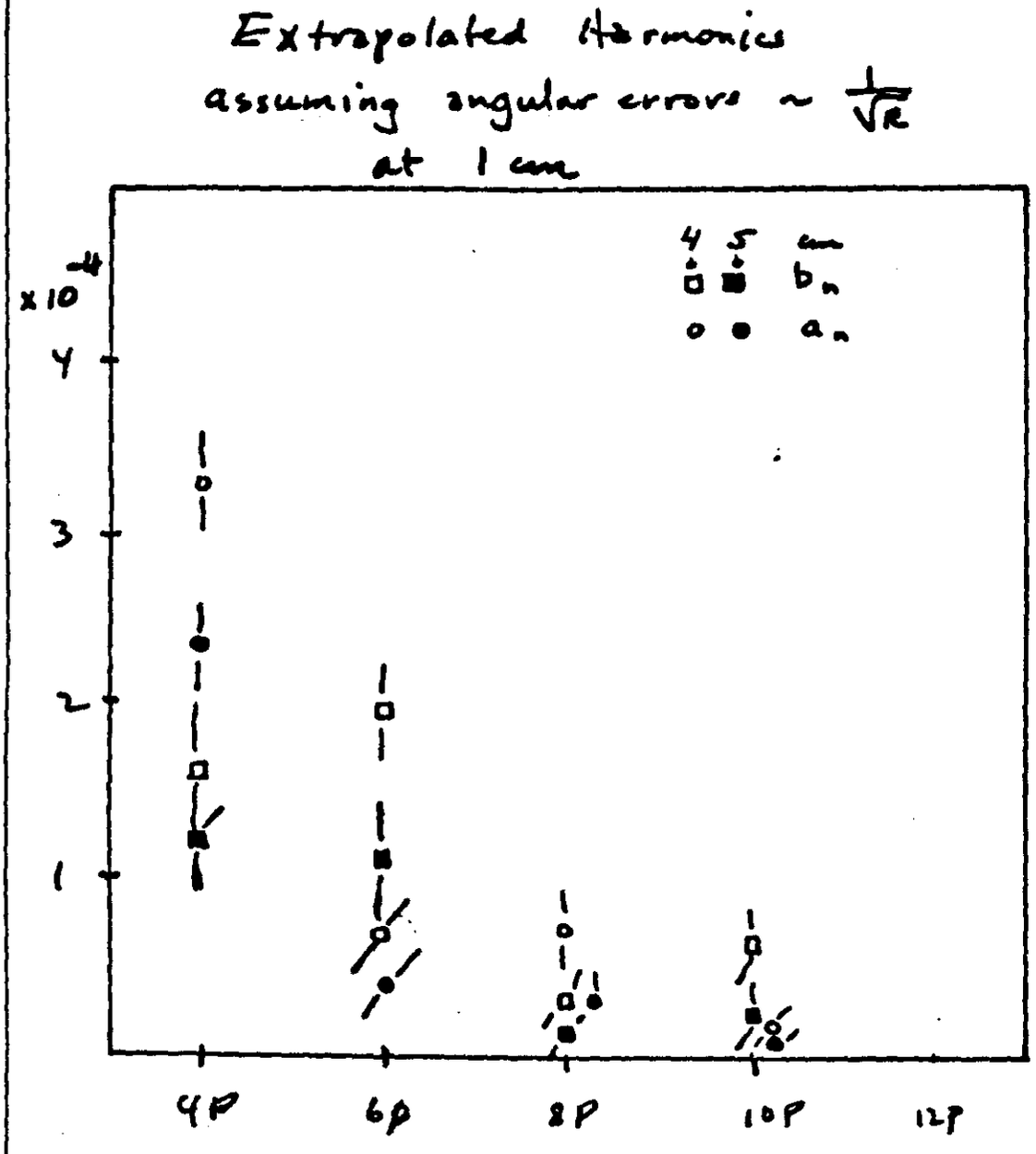


Figure 1. Projected rms variations of magnetic multipoles at 1 cm for Designs A and B, based on TEVATRON and CBA magnet measurements.

4.0 cm inner-coil diameter
6.0 Tesla* minimum (6.5T design goal)
*with 15% operating margin to
short sample of cable
1-in-1 collared coils
cold iron
length set by Design A machine requirements

Group D Review, Data Base, Networks, and Lattice Codes

Steve Peggs

1) Data Base and Hardware

The CDG has been assigned to the VAX-780 GEN. Although competition from the other users has not been serious in the past, there are indications that it is becoming a problem. A 500-megabyte disk is the exclusive domain of the CDG data base and other SSC institutions.

LBL has provided strong support in the acquisition of MACSYMA (symbolic manipulator), FLECS (structured FORTRAN preprocessor), GKS (Graphical Kernel System), Macintosh terminal software, and other such items. Graphics terminals, printers, and work stations are in place or on order.

The data base is now not totally "write-protected", but the new operating system (VMS 4.0) is expected to solve the problem.

The usable contents of the data base now include 6 test lattices ($60^{o}/90^{o}$ lattices for designs A, B, & C) from group A and the TEVATRON lattice from group B.

2) Networks

Five inter-computer networks are in use at LBL (or coming soon):

DECNET is strong and easy to use. Links with FNAL, SLAC, and ANL have been made with only minor problems.

MILNET has strong links to LBL, unused so far.

TYMNET is incoming only at present, outgoing soon. Needs KERMIT software for file transfer. Used successfully by TAC and U. of Maryland.

BITNET coming in December or January. CESR tried BITNET/DECNET gateway at SLAC unsuccessfully.

MFENET for CRAY-XMP use. Currently being improved. Network contacts are possible from ANL, BNL, CESR, FNAL, Maryland, SLAC, and TAC.

The CDG is acquiring professional help for these network systems.

3) Programs and Standard Formats

DIMAT - translation to standard format is being undertaken at CDG with Servranckx cooperation.

TRANSPORT - only in "stand-alone" version. No modification in sight. It can be accessed through MAD. The MAD lattice function module is TRANSPORT based.

SYNCH - modification planned after VAX version is running.

MARYLIE, Z, and PATRICIA - work is in progress by the authors.

AGS, MAGIC/COMFORT, TEVLAT - no plans at present.

Group E. Tracking Programs

Dave Douglas (for Alex Dragt)

Attempts to install tracking codes on the CRAY-XMP have been frustrated by compiler and code-development problems. The MARYLIE group at TAC/U.Md. found that compiler errors have been preventing proper program execution. However, MARYLIE is now working somewhat on the XMP. F. Dell (BNL) reported some inconsistencies in taking PATRICIA from the CRAY-1S to the CRAY-XMP -- possibly due to the same compiler problem. Plans for improving PATRIS and implementing PATRIS on CRAY-XMP are being initiated.

DIMAT is not yet available on the XMP because of a minor modification that is not yet complete.

The status of RACETRACK is not clear -- presumably not now available on the XMP.

Consequently, most of the effort has been on program development and no new tracking results are available at present, other than some preliminary tracking of FODO cells with DIMAT and an old version of PATRICIA now beginning at CDG (B. Leemann and D. Douglas).

Concerning program development, the improvement of existing kick codes has been discussed a great deal. Some progress is being made.

a) PATRICIA. There is a question of which version to build on. A collaboration with Wiedemann on modifying PATRICIA for SSC is under way. The PATRICIA family at present is non-symplectic with respect to synchrotron oscillations. Several possible modifications have been proposed and are under study.

b) Lie algebraic codes. Development has been interrupted by the XMP compiler problems. Decapole kicks are now available in MARYLIE.

We propose (1) to continue on the schedule (see pages 70, 71 of the SSC Aperture Workshop Summary, SSC-TR-2001) paying close attention so as to avoid the XMP compiler problems, (2) to continue the parallel development of at least the standard tracking codes DIMAT, PATRICIA, and MARYLIE, and (3) begin tracking studies insofar as possible with the existing codes.

E.g., use MARYLIE for a perfect machine.

use "old" PATRICIA for a machine with errors, but without synchrotron oscillations.

use DIMAT for full (but slow) simulation.

Group F Review, Analytical Screening

Christoph Leemann

Efforts in the following areas were recommended at the Aperture Workshop:

1) Construction of phase-space "Invariant curves" and tune dependence on amplitude to provide "pre-tracking" judgment of lattice configurations and to facilitate presentation of tracking results.
2) Development of "higher-order" correction schemes -- i.e., correction beyond that of trim quads and chromaticity sextupoles.
3) Resonance analysis - determine resonant amplitudes, resonance widths and overlap, and assess stability.

Most of our activity has been with "invariant curves". First and second-order versions for systematic and random magnetic multipoles are in progress. These calculations will be connected to other codes, such as PATRICIA. The PATRIS version of PATRICIA has a first-order version built in for regular and skew sextupoles and octupoles for symmetrically placed

elements. The extension to arbitrary multipole orders and random strengths has been straightforward. Higher-order approaches ("super convergence") also have begun. Tangible results to be available in late January, possibly to be reported at the Sardinia Conference.

The development of higher-order correction schemes is about to begin. The first step will be an upgrade of the HARMON program, and an assessment of HARMON for further upgrading.

We have had no activity yet in the area of resonance analysis, which is not urgent and has lowest priority.

Group G, Machine Experiments

Helen Edwards

Three experiments are under consideration at the Tevatron:

1) To check experimentally F. Willeke's aperture analysis, (FNAL-1220, Study of Tevatron Non-Linear Acceptance by Computer Simulation, Nov. 1983).
2) A 1/3 resonance, as discussed at the workshop. It probably can be done, but more studies are needed to evaluate the real significance of such an experiment.
3) A non-linear lens, as discussed by Cornacchia and Evans (BNL 5160, Effects of Magnetic Non-Linearities on a Stored Proton Beam and Their Implications for Superconducting Storage Rings, Oct. 1982). This would be more complicated than (2) because a mixture of non-linearities is involved. This experiment should

be carried out (a) at injection and at high energy, (b) at normal β and low β, (c) with one bunch (no interest in coasting beams because of RF-cavity complications).

Chao mentioned that we could also consider doing dynamic-aperture experiments on SPEAR if we have a proposal accepted by SLAC.

Review Summary

A summary of the reviews presented by the seven Working-group Coordinators is given in tabular form (group/task/status) in Appendix 2. Some action items are identified.

III. Next Plans

The plans described below by each coordinator are to be supplemented by the table in Appendix 2, which is an effort by the ATF as a whole.

Group A Plans, Lattices

Courant

1) Development of test lattices for the cosine magnet design D.
2) Define the orbit correction procedures in the test lattices in collaboration with group F.
3) Determine the sextupole locations and strengths in the test lattices again with group F.
4) As a lower priority, develop the realistic lattices.

Group B Plans, Aperture Requirements

D. Edwards

1) Development of strategy and procedure for initial operation - i.e., first-turn, closed-orbit determination, corrections, etc.
2) Development of a model for halo development, background environment, and quenching of magnets due to energy deposition.
3) Improvement of Tevatron operational information.
4) The VAX11/785 + FPS164 is a flexible, local resource, especially if CRAY-XMP remains a problem.
5) Attempts at using the CRAY-XMP.
6) Aperture requirements at high energy and high luminosity.
7) Tracking of clustered-IR lattices by Gelfand
8) Calculation of invariant curves by Michelotti.

Group C Plans, Magnet Errors

Fisk

The planned action is to assemble in January a report on magnet errors as outlined in Appendix 1.

Group D. Plans, Data Base, Networks, Lattice Programs

Peggs

1) Data Base
   a) improve protection
   b) modify existing test lattices to Carey-Iselin format
   c) acquire standard magnet-error data sets
   d) investigate the adoption of a standard random-number generator
   e) start an irregular Data Base Newsletter
   f) investigate the utility of an electronic mail system
   g) ponder desirability of a CDG-dedicated VAX, or micro-VAXes.

2) Networks

a) investigate several network problems, with the help from a network expert, to be identified.

b) consider encouraging the adoption of DECNET, or, alternatively, MILNET

3) Lattice Programs

a) I/O translators between programs.

b) a workshop is scheduled for March to evaluate, demonstrate, and select lattice-design programs.

c) 3 1/3 people have been assigned urgent tasks in making the system operational.

<u>Group E Plans, Tracking</u>

Douglas

1) Better coordination of tracking efforts

2) Start tracking calculations on cases listed in the November summary. The present code capabilities are shown in Table 1.

3) Short-term code development necessary for initial tracking:

a) adapting all of the present codes to standard format (Peggs, maybe by 2/1/85)

b) codes to XMP (assuming XMP compiler problem is fixed soon): MARYLIE (Dragt), "old" PATRICIA (Dell), RACETRACK (B. Leeman, Kramer), DIMAT (Douglas)

c) ensure that "old" PATRICIA is symplectic with respect to off-momentum (Dell, B. Leemann)

d) investigate RACETRACK status (B. Leemann, Kramer) by 1/1/85

e) enlarge arrays where necessary: DIMAT (Servranckx, Douglas)

4) The long-term code development program is outlined in Table 2.

5) Meeting on PATRICIA developments around 1/20, and a kick-code review meeting in February before the next ATF meeting.

Table 1. Present Tracking-Code Capabilities

Code and People	Problem							
	Perfect FODO		FODO with mult		Perfect Lattice w/ simple IR		Lattice with simple IR and mult	
	$\nu_s=0$	$\nu_s\neq0$	$\nu_s=0$	$\nu_s\neq0$	$\nu_s=0$	$\nu_s\neq0$	$\nu_s=0$	$\nu_s\neq0$
"Old" PATRICIA GFD, BTL	x 0		x 0		x 0		x 0	
DIMAT DD, BTL	x 0	x 0	x 0	x 0	x 0	x 0	x 0	x 0
MARYLIE AD & CO, DD, MF	x	x	x	x	x	x	?	?
RACETRACK (0?) BTL, SK	x	x	x	x	x	x	x	x

x : can do without orbit errors. Do first.
0 : can do with orbit errors. Do second.

Table 2. Long-Term Code-Development Program

Problem	Program/People			
	RACETRACK	DIMAT	"New" PATRICIA	MARYLIE
Vectorization	BL,SK,RM	DD,MF,RH	BL,HW,RH,GFD	OK
Provide Documentation	SK,BL	OK	OK	AD,DD,LH FN,RR
Orbit Errors	SK,BL	OK	HW	AD,LH FN,RR
Multipoles	OK	OK	HW	AD,DD,MF FN,RR,LH
Symplecticity	OK (check)	DD,MF (speed up)	HW,DD,MF	OK

BL : Beat Leeman
AD : Alex Dragt
SK : Steve Kramer
RH : Ruth Hinkins
HW : Helmut Wiedemann
MF : Miguel Furman
GFD : Fritz Dell
LH : Liam Healy
RR : Robert Ryne

AR : Al Russel
NG : Norman Gelfand
AG : Al Garren
DJ : Dave Johnson
DN : Dave Nueffer
SH : Sam Heifetz
DD : Dave Douglas
FN : Fillipo Neri

FNAL People : AR, NG

Lattice People : AG, DJ, DN, SH

Group F Plans, Analytic Screening

Leemann

1) Complete implementation and use of first and second-order analysis.
   a) coding and checking complete by 1/15
   b) use on simple FODO-cell lattices by 1/1
   c) Lie algebraic versions started around 1/15
2) Development of specific plans for orbit and dispersion corrections. Progress to be reviewed in meetings in early January, then early February
3) The progress of higher-order invariant curves will be reviewed late in January. An outlook for continuation will be developed.
4) Resonance analysis needs more attention soon (Mel Month, Chris Leeman, Sandro Ruggiero).
5) New directions will be considered. Suggestions are welcome. Helen Edwards asked when beam-beam interactions will be included.

Group F Plans, Machine Experiments

H. Edwards

1) There is a problem in finding adequate time for SSC-related experiments in the TEVATRON/DOUBLER schedule of operations.
2) We need theoretical help in developing specific plans.
3) We are enthusiastic about hardware preparation for possible machine experiments.

At present, the TEVATRON and SPEAR proposals of November are still valid, but more details will be provided in a report by the next ATF meeting.

IV. Future Coordinator Meeting

Approximately February 15, 1985. The present action plan will be reviewed. The task force members will coordinate the work for his/her working group to achieve the assigned tasks. The CDG will provide help where needed.

Notes by A. Chao
C. Leeman
J. M. Peterson

APPENDIX 1.

Group C Report Outline

SSC Magnet Errors

A. Superferric Magnets

To be included:

Who		
HEF	(1)	Drawings of magnet cross section, with principal dimensions and sketch of superconductor assembly.
SP	(2)	Tables of measured multipoles of TAC-1, -2, ...
SP	(3)	Tables of multipole sensitivities to likely magnet-parameter variations at 0.15, 2.2, and 3 Tesla.
SP	(4)	Summary tables of final predicted multipoles at 0.15, 2.2, and 3 Tesla (a) systematic multipole strengths at 1 cm, up to 18-pole (b) random multipole strengths at 1 cm, up to 14 pole (c) fluctuations expected in Bdl (d) effects of second bore Statements of assumptions used.
WAW	(5)	Consequences of additional (pole-face) windings.
SP	(6)	Scaling of errors with aperture.
SP	(7)	Persistent current effects (in the text).

B. Cosθ Magnets

To be included:

PW/CT HEF	(1)	Drawings of Design A and Design B magnet cross sections, with principal dimensions.
PW	(2)	Table and figure on measured multipoles (Collins/Wanderer plot)
PW	(3)	Comparison of measurements with three models of conductor placement effects.
RM PW/JCH HEF	(4)	Tables of random multipoles due to placement error up to 14-pole for Designs A and B (at injection and B_{max} if necessary). State assumptions.

PW (5) Table of systematic multipoles b_1, b_2, b_3, b_4, b_6, and b_8 in the two-in-one dipole magnet due to iron saturation effects. (The prediction of b_2 is topic for future discussion). State assumptions.

HEF (6) The multipoles in a bore-wound correction coil (a one-paragraph discussion).

PW (7) Sensitivity of a collared coil to placement in an iron yoke (a one-paragraph discussion).

PW (8) The multipoles due to magnet ends (a one-paragraph discussion).

HEF PW (9) The correlation of multipoles (a one-paragraph discussion).

HEF (10) The multipole fields in quadrupole magnets (a one-paragraph discussion).

C. Magnetization Effects in Cosθ Magnets

To be included:

(1) Data on filament-size dependence

WVH (a) Tevatron quadrupoles
WVH (b) 3.2-cm dipoles
WSG (c) LBL dipole comparison with M.A. Green

WSG WVH (2) Tables and graphs of dipole, sextupole, and decapole strengths at 1 cm and at 2/3 inner-coil-radius for filament diameters 2, 6, 8.7, and 20 microns for Design A and 2, 6, 8.7, and 16.5 microns for Design B. To be expressed both in gauss and as multipole coefficients. Magnetization cycle is to be specified.

HEF (3) Fluctuations to be expected from variations in superconducting materials.

WVH (4) Fluctuations to be expected from temperature variations. Include periodicity.

RS WVH (5) Cost considerations of 2-micron filaments.

WVH (6) Comparison of multipole-correction schemes.

The Who list:

HEF	Gene Fisk	SP	Sergio Pissanetsky
WSG	Bill Gilbert	RS	Ron Scanlan
WVH	Bill Hassenzahl	CT	Clyde Taylor
JCH	John Herrera	PW	Peter Wanderer
RM	Bob Meuser	WAW	Bill Wenzel

APPENDIX 2

Summary of the Working-group Reviews

Group	Tasks	Status
A	Test lattices in data base FODO, simple IRs for designs A, B, C	Done
A/B	Magnet alignment errors use 1-in-1 numbers Store in data base	1/10
A	Magnet design D test lattices	2/1
F	Sextupoles, several families	2/1
A/F	Orbit correction procedure in test lattices	2/15
A/F	Lumped sextupoles for error-sextupoles	3/15
A	Realistic lattices	Not urgent
A/B	Clustered IR in test lattices?	Report at next ATF mtg.
B/D	TEVATRON lattices in data base	Done
C	Magnetic-error data store in data base Group C meeting for final report	Underway by Jan/Feb 1/28, 29
B	Documentation of aperture-pertinent Tevatron operation Report needed	Underway 4/1
B	SSC First turn procedure	3/1
B/C	Need for multipole data in both 2-in-1 and 1-in-1? for at least 2 filament sizes	2/15 report by B report by C
C	Multipole data for Design D by extrapolations	2/1

Group	Task	Status
D	Data base various hardware protection system improvement dedicated VAX?	Structure exists Peggs will monitor
D	Networks to SLAC, FNAL, ANL, UM, TAC Networks to CESR, BNL, CERN, DESY Need expert help.	Basically done More work
D	Format Various translators need development	3/1
E	Multipoles in MARYLIE	Going on
E	Work organization Heavy work coming Programming help needed? Which kick codes need development?	Potentially Serious!
E	Code transfer to CRAY-XMP has problem Use CRAY-1S for now?	Peggs will monitor
E	Tracking with existing codes FODO With simple IR With multipole errors	 Underway 2/1 2/15
E	Review of PATRICIA development Mtg. with Wiedemann	1/20
E	Kick-code review meeting	2/10
F	Invariant curves Various techniques Incorporate into tracking/lattice codes	In progress
F	Resonance analysis	Being started
F	Analytic screening for test lattices without errors with multipole errors	 1/15 2/15
G	Need to confirm experimentally Ferdis' tracking results? Use coasting beam? Study.	
G	What is learned from 1/3 resonance expts. at Tevatron? Needs more analysis.	

Group	Task	Status
G	Non-linear lens expt. at Tevatron. Needs more study.	
B/G	Experimental proposals need more details New hardware How much manpower, beam time SPEAR TEVATRON SppS	2/15

0024J