Status and Issues

Steve Peggs

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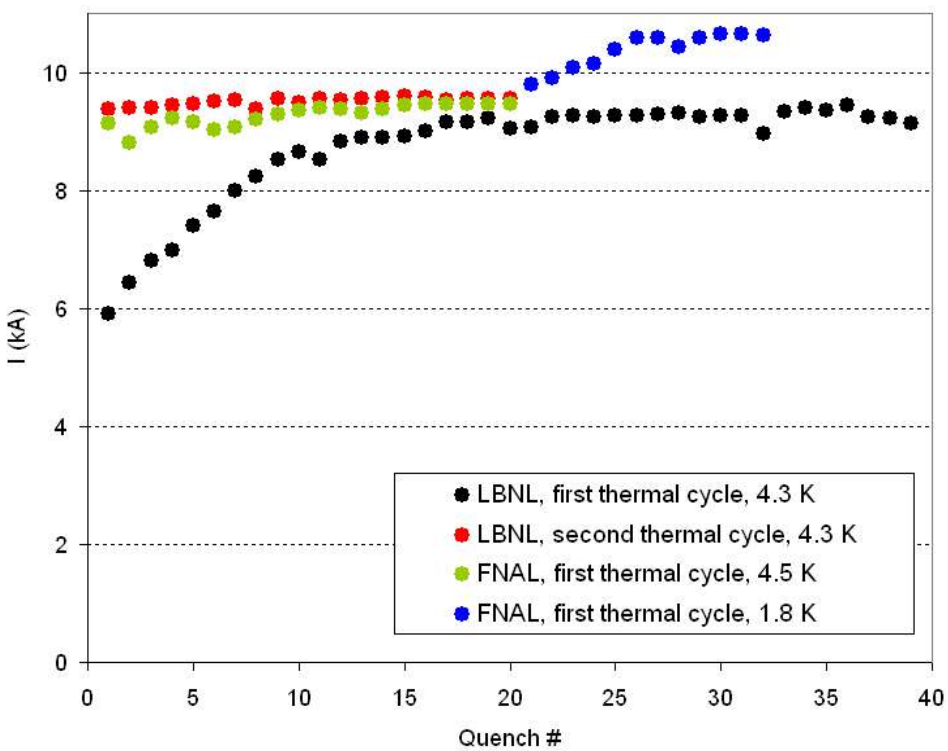
Magnet highlights

Subscale Quadrupole SQ02 achieved 97% of its short sample limit after extensive testing at LBNL and FNAL

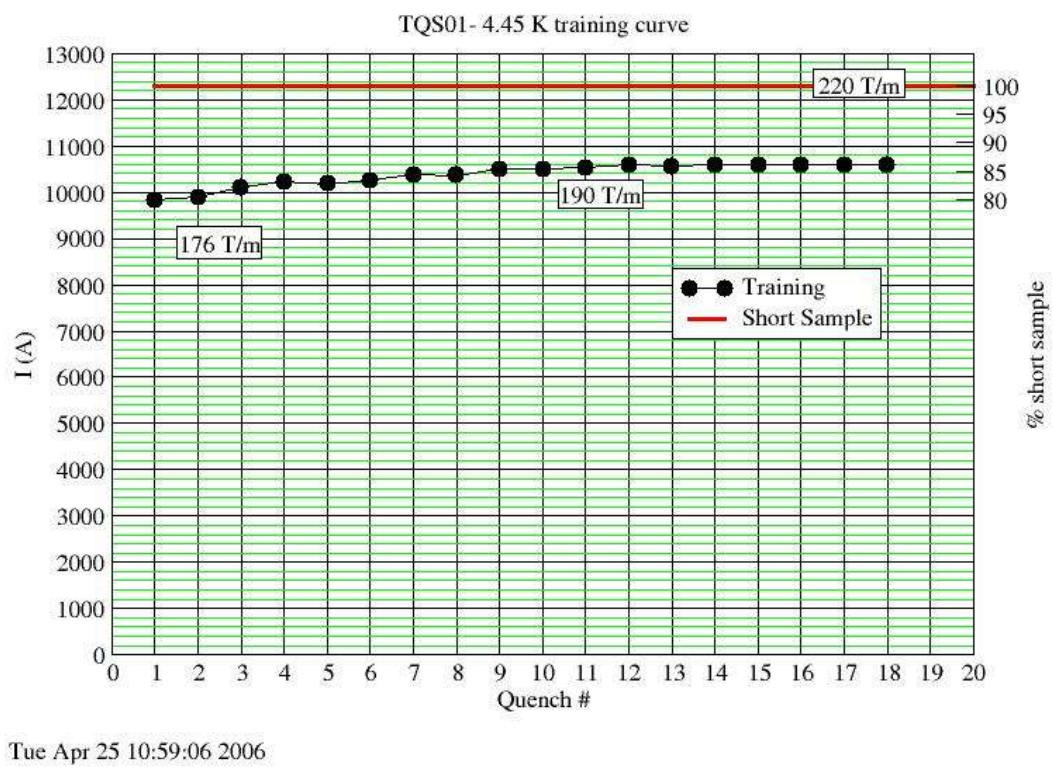
Technical Quadrupole TQS01 recently reached 87% of its short sample limit. The 13% shortfall is under investigation

Great success for the world's first large bore (90 mm) Nb_3Sn magnet!

Subscale quad SQ02



Technical quad TQS01

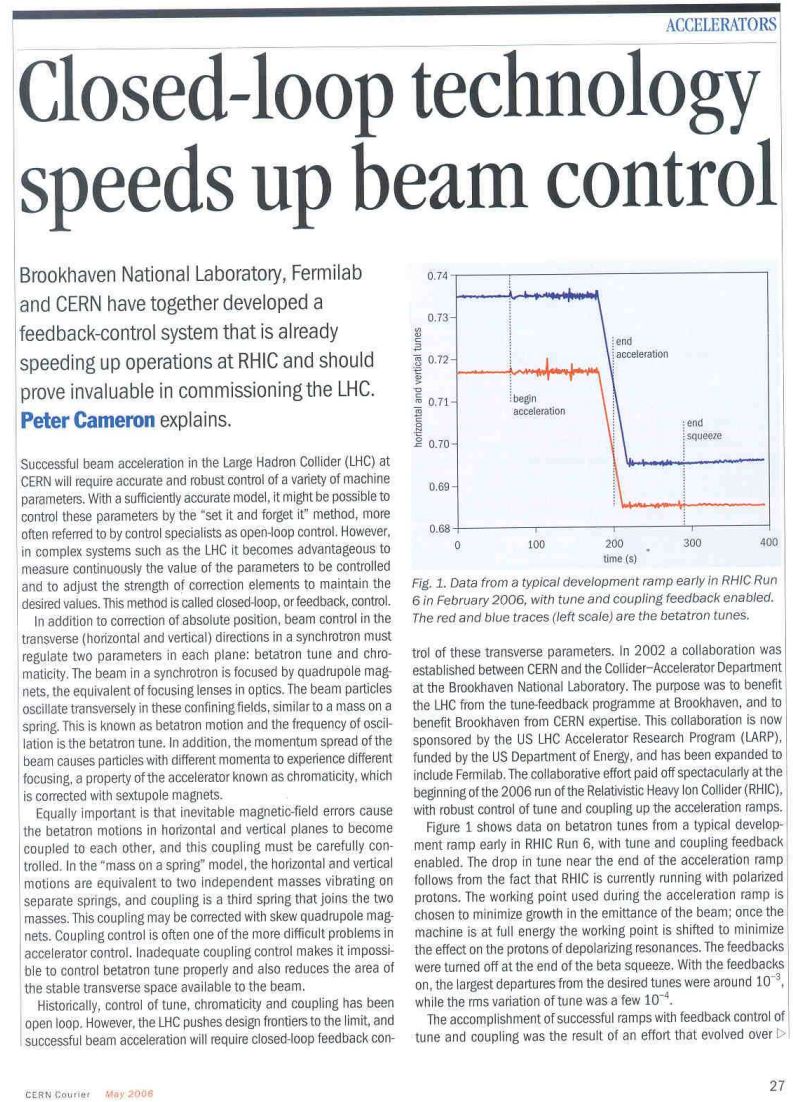


An Accelerator Systems highlight

Simultaneous tune and coupling feedback was demonstrated in RHIC - a world first!

Thanks to work by physicists and engineers from BNL, CERN and FNAL.

This paves the way towards the ultimate goal of chromaticity feedback during snap-back at the beginning of the LHC energy ramp.



ACCELERATORS

Closed-loop technology speeds up beam control

Brookhaven National Laboratory, Fermilab and CERN have together developed a feedback-control system that is already speeding up operations at RHIC and should prove invaluable in commissioning the LHC. **Peter Cameron** explains.

Successful beam acceleration in the Large Hadron Collider (LHC) at CERN will require accurate and robust control of a variety of machine parameters. With a sufficiently accurate model, it might be possible to control these parameters by the "set it and forget it" method, more often referred to by control specialists as open-loop control. However, in complex systems such as the LHC it becomes advantageous to measure continuously the value of the parameters to be controlled and to adjust the strength of correction elements to maintain the desired values. This method is called closed-loop, or feedback, control.

In addition to correction of absolute position, beam control in the transverse (horizontal and vertical) directions in a synchrotron must regulate two parameters in each plane: betatron tune and chromaticity. The beam in a synchrotron is focused by quadrupole magnets, the equivalent of focusing lenses in optics. The beam particles oscillate transversely in these confining fields, similar to a mass on a spring. This is known as betatron motion and the frequency of oscillation is the betatron tune. In addition, the momentum spread of the beam causes particles with different momenta to experience different focusing, a property of the accelerator known as chromaticity, which is corrected with sextupole magnets.

Equally important is that inevitable magnetic-field errors cause the betatron motions in horizontal and vertical planes to become coupled to each other, and this coupling must be carefully controlled. In the "mass on a spring" model, the horizontal and vertical motions are equivalent to two independent masses vibrating on separate springs, and coupling is a third spring that joins the two masses. This coupling may be corrected with skew quadrupole magnets. Coupling control is often one of the more difficult problems in accelerator control. Inadequate coupling control makes it impossible to control betatron tune properly and also reduces the area of the stable transverse space available to the beam.

Historically, control of tune, chromaticity and coupling has been open loop. However, the LHC pushes design frontiers to the limit, and successful beam acceleration will require closed-loop feedback control of these transverse parameters. In 2002 a collaboration was established between CERN and the Collider–Accelerator Department at the Brookhaven National Laboratory. The purpose was to benefit the LHC from the tune-feedback programme at Brookhaven, and to benefit Brookhaven from CERN expertise. This collaboration is now sponsored by the US LHC Accelerator Research Program (LARP), funded by the US Department of Energy, and has been expanded to include Fermilab. The collaborative effort paid off spectacularly at the beginning of the 2006 run of the Relativistic Heavy Ion Collider (RHIC), with robust control of tune and coupling up the acceleration ramps.

Figure 1 shows data on betatron tunes from a typical development ramp early in RHIC Run 6, with tune and coupling feedback enabled. The drop in tune near the end of the acceleration ramp follows from the fact that RHIC is currently running with polarized protons. The working point used during the acceleration ramp is chosen to minimize growth in the emittance of the beam; once the machine is at full energy the working point is shifted to minimize the effect on the protons of depolarizing resonances. The feedbacks were turned off at the end of the beta squeeze. With the feedbacks on, the largest departures from the desired tunes were around 10^{-3}, while the rms variation of tune was a few 10^{-4}.

The accomplishment of successful ramps with feedback control of tune and coupling was the result of an effort that evolved over ▷

Fig. 1. Data from a typical development ramp early in RHIC Run 6 in February 2006, with tune and coupling feedback enabled. The red and blue traces (left scale) are the betatron tunes.

CERN Courier May 2006 27

CERN Courier, May 2006

Q3 budget re-tune

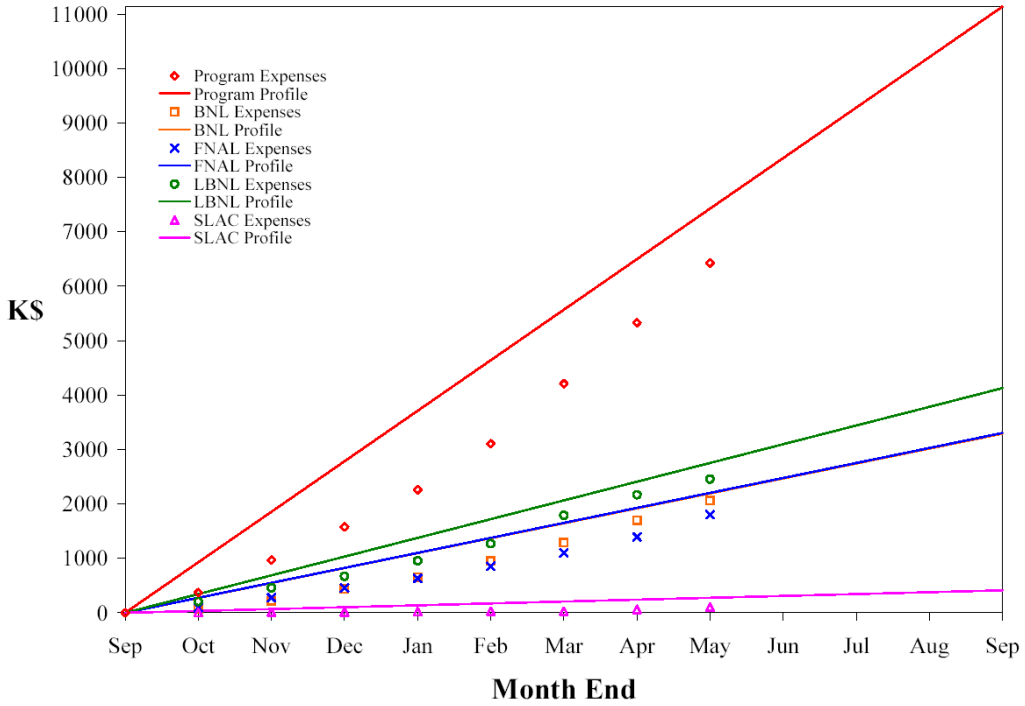
	BNL $k	FNAL $k	LBNL $k	SLAC $k	Unallocated $k	Total $k
Current allocation	2130	2410	2980	780	2700	11000
Requested allocation	3264	3300	4086	350	0	11000
Requested increment	1134	890	1106	-430	-2700	0

36% ($4.0M) in FY06 goes to Accelerator Systems

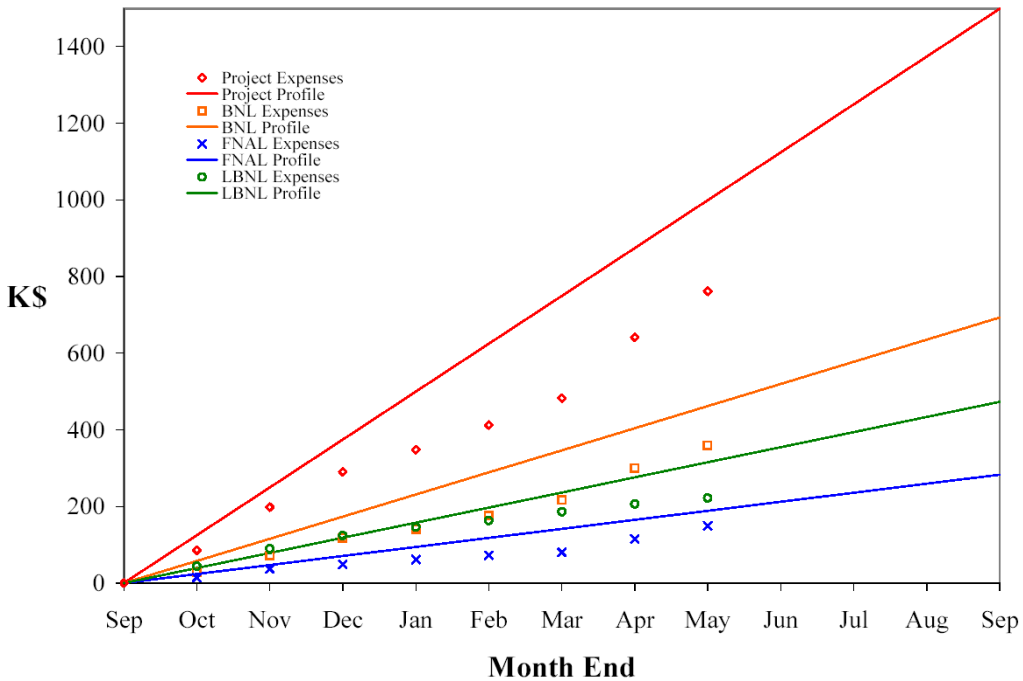
52% ($5.7M) goes to Superconducting Magnet R&D

- More accurate re-distribution of "Toohig Fellowship" money
- Allocation of "Management Contingency" to many Tasks, mainly in small allotments.
- Decrease in funds to "Rotatable Collimators" at SLAC, reflecting a late start in engineering on the first prototype.
- Increase in funding to the "Long Racetrack" activity at BNL

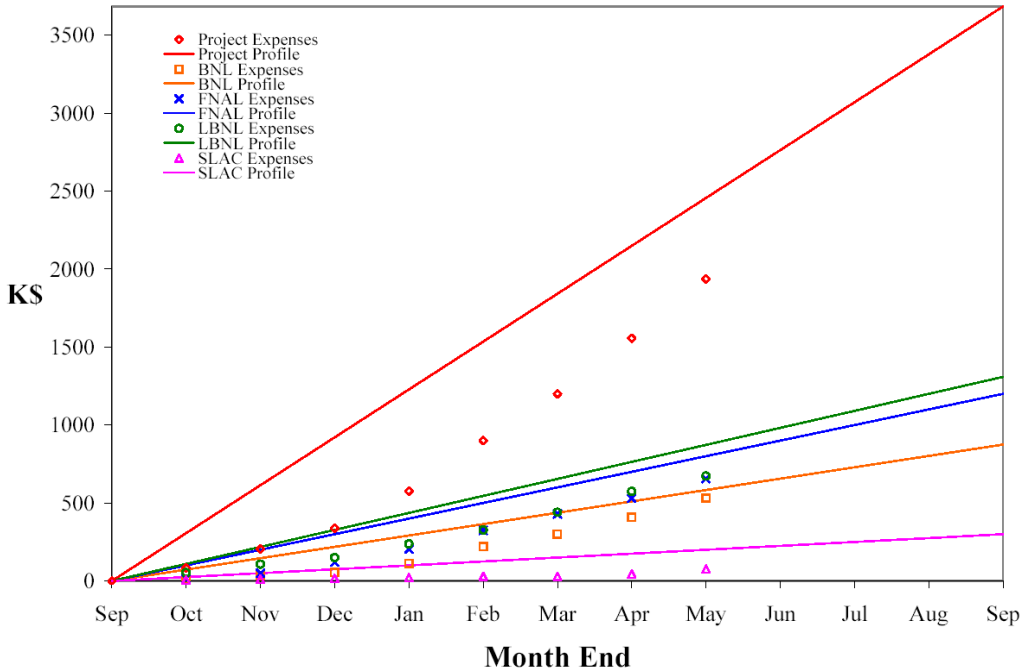
LARP PROGRAM $11,138k FY06 Funding



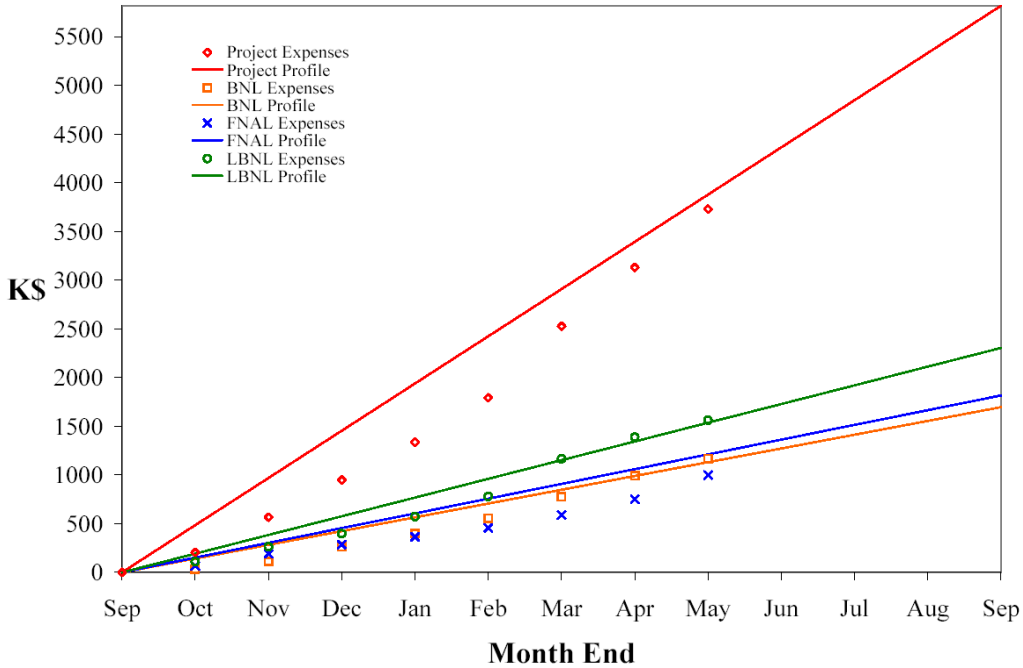
W.B.S. 3.0 PROGRAM MANAGEMENT $1,499k FY06 Funding



W.B.S. 1.0 ACCELERATOR SYSTEMS $3,684k FY06 Funding



W.B.S. 2.0 MAGNET R & D $5,817k FY06 Funding



New head of Magnet R&D

Steve Gourlay was recently promoted to head of AFRD

Jim Kerby will replace him as head of Magnet R&D on July 1

Criteria

- technical & managerial excellence
- ability to take a national view:

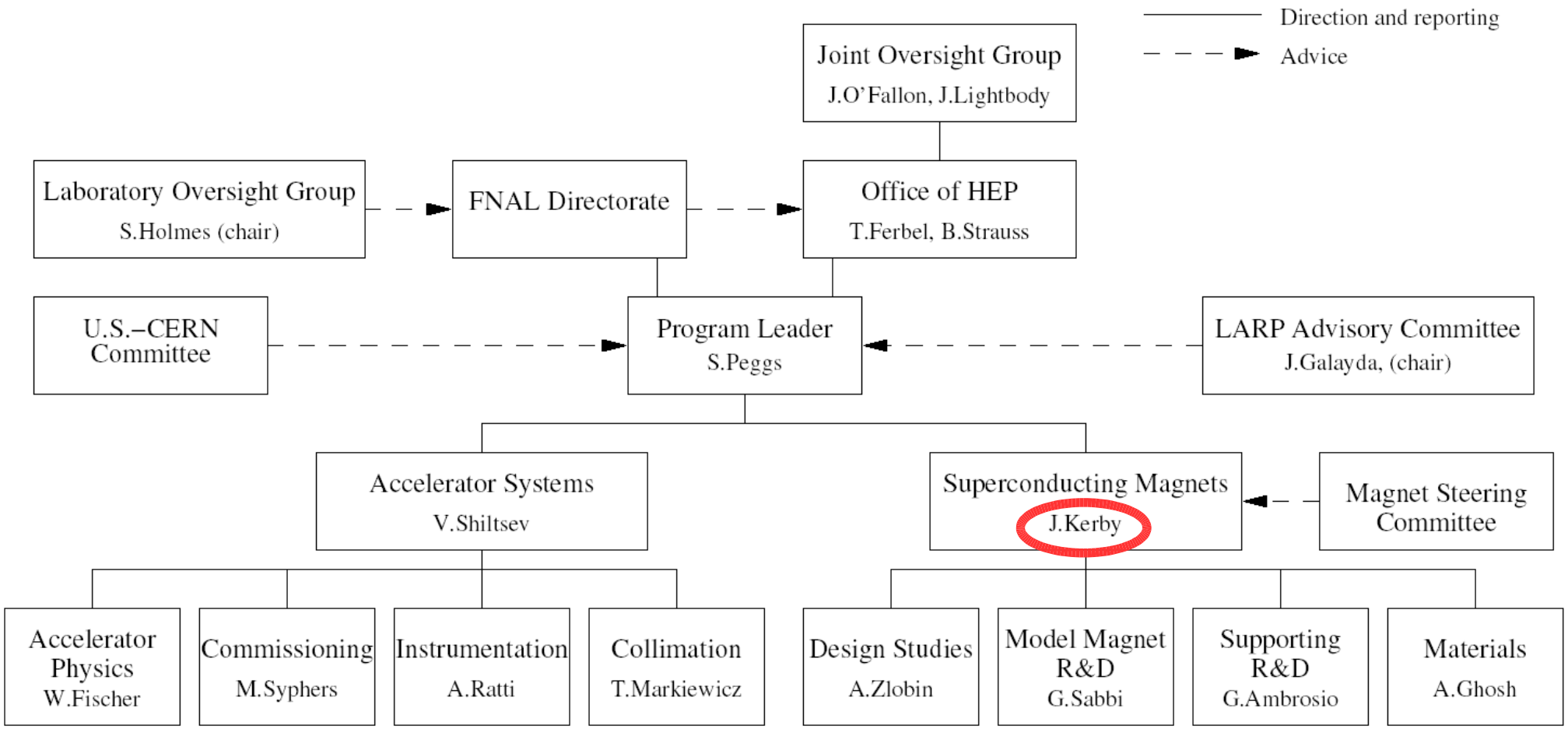
  "... you will represent all partner institutions in interactions within LARP, with DOE, CERN, and other organizations. In this position you must maintain a national view and work to achieve the goals of the program without bias."

- fair distribution between labs on a time averaged basis

Strait	FNAL			->	Aug	04
Gourlay	LBNL			->	June	06
Peggs	BNL	Sept	04	->	Aug	07
Shiltsev	FNAL	July	05	->	June	07
Kerby	FNAL	July	06	->	June	08

US LHC Accelerator Research Program (LARP) Organization Chart

July 1, 2006



LARPAC: J.Galayda (chair), A.Chao, A.Devred, J.Minervini, C.Rode, A.Seryi, K.Wittenburg, A.Yamamoto

LOG: S.Holmes (chair), P.Drell, S.Ozaki, J.Siegrist

MSC: J.Kerby, G.Ambrosio, A.Ghosh, M.Lamm, G.Sabbi, P.Wanderer, A.Zlobin

US–CERN Comm: L.Evans, R.Assmann, R.Bailey, P.Bryant, P.Lebrun, R.Ostojic, L.Rossi, F.Ruggiero, R.Saban, H.Schmickler S.Holmes, S.Gourlay, M.Harrison, J.Kerby, P.Limon, S.Peggs, T.Raubenheimer, V.Shiltsev, V.Yarba

Issues

Change Control Procedure

The Change Control Procedure of the Executive Committee recently approved further consideration of the following major proposed new initiatives for FY07

"Major" means 6 months and/or $100k and/or new scope

Accelerator Systems

a) Instrumentation/AC Dipole (Kopp)

b) Instrumentation/Fast ramped mag. msmt. system (Jain)

c) Acc. Phys./New initiative feasibility studies (Shiltsev)
bundles LER + synchlight + crab cavities

d) Acc. Phys./Beam-beam (Sen)
existing task absorbs new electrons lens activities

Change Control Procedure (2)

Magnet R&D

a) Model Magnet/Long quadrupole LQ ()

b) Model Magnet/High gradient quad engineering design ()

c) Supporting R&D/Short racetrack test fixture SRK (Wanderer)

d) Design Studies/Fast ramped magnet (Wanderer)

e) Materials/Cable evaluation (Ghosh)

EC minutes: "Although necessary, EC approval is not sufficient [to become an approved task] – financial viability within an integrated FY07 budget still needs to be demonstrated".

Aymar, Rossi & Schmickler requests

Rossi requests better magnet communication with LARP.

Response: use/modify 4 mechanisms

1) Collaboration meetings (where are the CERN reps?)
2) Re-invent the CERN-U.S. Committee (see below)
3) Observe at DOE reviews
4) Regular phone and/or video conferences

Aymar/Schmickler request

1) Hard deliverables with documentation (see below)
2) Tracking task performance (semi-annual report)
3) Executive summary of collaboration meeting (done)

Hard deliverables

Four items have been identified by LARP and CERN as "hard deliverables":

- they are crucial to LHC performance
- "plan B" is weak or non-existent.

Would need special protection in the face of a budget shortfall.

1) Luminosity Monitors.
A review held on April 24 noted good progress

2) Tune Feedback.
"Final Design Review" to be held Oct 23

3) Beam and Instrumentation Commissioning.
CERN/LARP vetting procedure needed to ensure excellence

4) Rotatable Collimators.
This longer time scale item is on track, despite a slow start

CERN-U.S. Committee

Hermann Schmickler offers frank and perceptive comments:

"As a first step in re-inventing this [annual CERN-U.S. Committee] meeting I would like to look at the needs of communication beyond the existing communication channels.

1) on the technical side things happen in bilateral communications of the involved parties. This needs occasional follow -up (...), but this works fine in general.

2) The plenary sessions of the collaboration meetings are sufficient to do the politics and administration. NO need to repeat in a second CERN meeting.

3) LARP gets additional input from its advisory panel. OK.

4) Feedback on the management scale from LARP back into CERN works quite well for accelerator systems (through myself), but it does not work ... for the magnet program."

CERN-U.S. Meeting

5) What I feel really missing is an appropriate feedback from US_LARP (technical/scientific and managerial) into our top management ...

... the event as present is obsolete."

LARP will propose to CERN:

1) Formally identify Lucio as Magnet R&D liaison, in parallel to the role that Hermann Schmickler plays for Accelerator Systems

2) Reduce membership on the CERN-U.S. Committee to:

CERN: Evans (co-chair), Lebrun, Myers, Rossi, Schmickler
US: Peggs (co-chair), Holmes, Kerby, Limon, Shiltsev

3) Focus the annual agenda on getting appropriate (technical/scientific and managerial) feedback from LARP into CERN top management. One or 2 hours around a table.

Long stay "commissioners"

Ensuring excellence

- Hardware & IR Commissioning "was" easy
  - Main actors well known from construction project
  - Relatively short term activity ~18 months

- Long stay commissioners
  - Not just Beam, but instrumentation, simulation, ...
  - Broad scope, long term ~ 10 years
  - Prioritization and evaluation by LARP & CERN
  - Youth versus experience
  - Lab neutral
  - "Justice must not only be done, ..."

- Looming crisis ...

University involvement

The involvement of U.S. universities could significantly enhance Accelerator Science at the LHC.

We are groping towards ways in which the DOE funded labs in LARP can work effectively with the (mostly) NSF funded universities that have appropriate talent and resources.

Loose connections are being formed in four potential areas:

1) University of Texas (Kopp). AC Dipole topics.

2) MIT (Barletta, Milner). Demonstration of Optical Stochastic Cooling at the MIT-Bates ring.

3) National High Field Magnet Laboratory (Larbalestier). Material testing and R&D.

4) Texas A&M (McIntyre). Exotic magnets.

LARPAC06 & Santa Rosa

LARPAC 06 comments – Acc Sys

"The LARP research program demonstrates excellent focus, a strong spirit of cooperation and the clear evidence of synergy within the Collaboration."

"The devices [Tune Feedback, Luminosity monitors, Schottky] are also important in that they are at the foundation of the LARP beam commissioning effort. Timely delivery of these critical systems must be made a highest priority of the LARP program."

The documentation and approval plans for each instrument are in a good shape. Indeed there is strong and encouraging evidence for improvement in all aspects of communication and cooperation, within LARP and between LARP and LHC."

"The committee feels that exploration of possibility for US labs to participate in beam and hardware commissioning might have not [been] done exhaustively."

LARPAC 06 comments - Magnets

"The committee first wishes to acknowledge the tremendous efforts being carried out and the good and synergetic team spirit that appears to be developing among the three partners."

"The next major Milestone is the "Support Structure Decision". **Without this down select on schedule there will not be adequate funds for the LQ and HQ programs!!!!**"

"The committee recommends ... only introduce [a different baseline strand than OST RRP 54/61] at a stage which minimizes technical and programmatic risk."

"The committee agrees that testing of cables .... would be a valuable tool for bridging the large gap in scaling from single strand performance to magnet performance ..."

"The committee ... endorse[s] the recommendation ... that the HQ program be treated as a scope contingency ... [O]nly proceed with it if the LQ program is well under way and will not be adversely affected ... .

Santa Rosa responses – Prog. Mgmt.

Action Items – None.

Executive Summary Recommendations.

ES1: Finally, the committee still felt uncomfortable with the lack of formality in the dealings of LARP, and strongly recommended a more effective bookkeeping system for managing expenses and progress on all active tasks, and the addition to the management team of a person who would be responsible for implementing such a system.

Response: The LARP bookkeeping system has proved itself more than adequate during the evolution of the program from $3M per year to $11M per year. The Program Leader receives financial administrative support from fractions of specialists at each of the labs, coordinated by Ron Prwivo at BNL. Monthly financial reports are distributed and analyzed throughout the collaboration. Semi-annual reports describe financial and technical progress and issues at length.

Santa Rosa responses - 2

Management Recommendations.

MGMT1: The committee remains uncomfortable with the level of contingency maintained by LARP management, which is only $200K out of a budget of $11M. Granting that much of the work is R&D, a contingency of order 5–10% would be more prudent, and should be adopted by the program. Any unallocated funds at the end of the fiscal year could be used to bridge budgetary delays that might otherwise halt key activities. This should become part of the planning for LARP management.

Response: LARP does not need a formal contingency because it is a program and not a project. Scope and schedule are contingency, in practice. The initial management reserve of $200k was fully allocated half way through FY06 on the occasion of the (sole) budget trim from version v2b to v2c - see presentation by Peggs - a “first-time” exercise that worked very well. It is prudent to anticipate a more difficult mid-year trim in FY07, and so it makes sense to increase the reserve to the level of 3-5%.

Santa Rosa responses - 3

MGMT2: A mechanism for reconciling task sheets from year to year (what was stopped and what changed in cost or scope) is essential, and would help LARP management, and certainly help LARP reviewers understand progress. As it now stands, the process is essentially discontinuous across fiscal-year boundaries.

Response: We are upgrading and improving the process by which we maintain and develop Task Sheets, in the preparation of the FY07 budget, using the DocDB web based file management system. While Task Sheets focus on a single fiscal year (eg FY07), they are required to include an appropriate amount of information on the out years (eg FY08 and beyond).

Santa Rosa responses - 4

MGMT3: It is recommended that DOE and LARP management review the [organization chart] structure to see if all that "help" is truly needed.

Response: We would be happy to discuss any concrete proposals that the June reviewers may have. A re-optimization of the activities of the CERN-U.S. committee is currently under way. The Laboratory Oversight Group meets only as necessary. The Magnet Steering Committee works very well as a matrix management necessity. The Executive Committee works well.

Santa Rosa responses - 5

MGMT4: There is a change-control procedure in place, although it was unclear whether it has been exercised very much. It appeared that changes could be proposed from the outside without going through the L4 and L2 managers. It is recommended that at least the L2 manager be asked to sign off on any proposed changes before they are raised as an option for discussion.

Response: The LARP Change Control Procedure (CCP) was formally invoked for the first time at the June 5 meeting of the Executive Committee meeting. The CCP considers and approves modifications to the LARP scope (list of tasks) or significant modifications to the schedule or level of funding of existing tasks, at the 6 month or $100k levels. The L2 managers were fully consulted before and during this process.

Santa Rosa responses - 6

MGMT5: if funds for the Toohig Fellowship are not assigned, they should be carried as LARP reserve, and not assigned 25% to each of the four participating Labs. Similarly, management expenses should be written off against the Lab that incurs the expense, and not distributed more or less uniformly. These sorts of issues would be easily resolved if there were a Project Engineer on the management team to take care of budgets, schedules, and change-control matters. We encourage LARP management and DOE to identify a suitable person for this task as soon as possible.

Response: At the time of the budget re-tune in the middle of FY06 it was clear on a lab-by-lab basis how to budget expenses for this years sole Toohig Fellow. Because only about 75% of the total LARP budget was allocated to the collaboration labs at the beginning of FY06, it was easy to use this opportunity to move money between the labs in the budget spreadsheet, without decreasing the actual allocation to any single lab.