LHC Accelerator Project

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Fermilab

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Outline

LHC Technical Overview
Non-member state contributions
Schedule
Management
  • CERN management structure
  • Management of the US 3-Lab Project
  • Coordination between US Labs and CERN
Extending the US-CERN collaboration
The LHC construction involves almost all of the CERN complex:

- Significant upgrades to the injectors (Linac through SPS)
- Dismantling existing LEP $e^+e^-$ collider.
- Installation of four large 1.9 K refrigeration systems.
- New SPS to LHC beam transfer lines.
- Major civil construction
  - SPS to LHC beam transfer lines.
  - Modifications to existing LEP/LHC tunnel.
  - New collision halls for ATLAS and CMS.
- New superconducting accelerator in the existing LEP/LHC tunnel.
  - ~7,000 superconducting magnets of ~15 different types.
  - Superconducting RF system.
  - >60 km of high vacuum system.
  - State-of-the-art beam instrumentation and controls systems.

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### LHC Main Magnets

<table>
<thead>
<tr>
<th>Name</th>
<th>Quantity</th>
<th>Purpose</th>
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<tbody>
<tr>
<td>MB</td>
<td>1232</td>
<td>Main dipoles</td>
</tr>
<tr>
<td>MQ</td>
<td>400</td>
<td>Main lattice quadrupoles</td>
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<tr>
<td>MSCB</td>
<td>376</td>
<td>Combined chromaticity/ closed orbit correctors</td>
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<tr>
<td>MCS</td>
<td>2464</td>
<td>Dipole spool sextupole for persistent currents at injection</td>
</tr>
<tr>
<td>MCDO</td>
<td>1232</td>
<td>Dipole spool octupole/decapole for persistent currents</td>
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<tr>
<td>MO</td>
<td>336</td>
<td>Landau octupole for instability control</td>
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<tr>
<td>MQT</td>
<td>256</td>
<td>Trim quad for lattice correction</td>
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<tr>
<td>MCB</td>
<td>266</td>
<td>Orbit correction dipoles</td>
</tr>
<tr>
<td>MQM</td>
<td>100</td>
<td>Dispersion suppressor quadrupoles</td>
</tr>
<tr>
<td>MQY</td>
<td>20</td>
<td>Enlarged aperture quadrupoles</td>
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</table>
LHC Magnet System
Main Dipole Production
International Participation

Construction of LHC involves modest, but significant contributions from outside the 20 CERN member countries:

- CERN ~ 90%
- United States ~ 5%
- Japan ~ 5%
- Russia ~ 5%
- Canada ~ 5%
- India ~ 5%

This is, however, clearly CERN’s project, which the US and other non-member states are helping to build. It is not (yet) a truly global collaboration.
Non-Member State Contributions
United States

IR Final Focus Systems: Points 1, 2, 5, 8
- US-built quadrupoles (FNAL)
- Japanese-built quadrupoles (KEK)
- CERN-provided correctors
- Cryostats for all quadrupole assemblies (FNAL)
- US-built beam separation dipoles (BNL)
- US-built IR feed boxes (LBNL)
- US-built specialized absorbers (LBNL)

RF Region: Point 4
- Beam separation dipoles (BNL)

Wire and Cable for Main Magnets:
- Measurement of SC wire & cable (BNL)
- Cable production support (LBNL)

Accelerator physics (all 3 labs - complete)

Project management and oversight (FNAL)
IR Quadrupoles (FNAL)

Scope

Fermilab:
Designs, fabricates and tests the MQXB quadrupole magnet
Designs, fabricates, assembles and tests the LMQXXx and LQXXx Cryostats
Designs and procures portions of the Interconnect Kits, providing integration support for each
Provides Engineering and Test support for the DFBX
Provides Alignment and Energy Deposition Support for the inner triplet region
IR Quadrupoles are well into production.

- First complete Q2 (2 MQXB magnets) is a great success.
- Second Q2 is complete, to be tested soon.
- 5 more MQXB complete ... half the production.
- 5 MQXA delivered from KEK ... more on the way.
Non-Member State Contributions
Japan (KEK)

>9 of 18 IR quads (produced by Toshiba to KEK’s design) are done. Performance matches that of FNAL quads.
Beam Separation Dipoles (BNL)

D1 - IR 2 and 8
D2 - IR 1, 2, 5 and 8
D3 - IR 4
D4 - IR 4
Beam separation dipoles well into production.

D1 - Construction and testing of all 5 D1’s is complete.
   - Two are at CERN, remaining 3 are being prepared to ship.

D2 - Construction of all 9 D2’s is complete.
   - First 4 have been tested and the 5th is under test.

D4 - One cold mass complete.
   - Coils collared for remaining 2.

D3 - All coils wound.
   - Four of six magnets collared.
IR Feed Boxes (LBNL)

Recently signed big contract for feedbox assembly.

• Highly qualified vendor ... near Fermilab.
• Complex assembly ... requires close communication with vendor.
• HTS leads being delivered to Fermilab for testing.
• Vapor cooled lead contract signed.
• Fabrication of lab-provided components has started.

But
• Schedule for completion of the job is tight.
IR Absorbers production assembly nearing completion.

- Last major component - TAN beam tube - being e-beam welded.
- Final assembly and test of TAS is under way.
- Plan to ship all absorbers by June 2003.
Russian In-kind Contributions

**Protocol**

In-kind contribution up to 110 MCHF

**Fund**

CERN contributes one third of value* to a Fund that is dedicated to:
- Support of Russians at CERN
- Contributions to LHC experiments
- Materials & tools for Addenda.

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**Transfer line dipoles – major in-kind contribution**

CERN contributes half of the value.

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Canadian In-kind Contributions

Protocol
In-kind Contribution via TRIUMF*:
- $19M equipment.
- $11M salaries.
  (equiv. to 33 MCHF)

Extension
$11.5 M (equiv. to 12.6 MCHF)

Warm twin-bore quadrupoles for the collimation insertion – a major contribution

Tasks

<table>
<thead>
<tr>
<th>Completed</th>
<th>Underway</th>
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<tr>
<td>Beam dynamics studies</td>
<td>-&quot;-</td>
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<tr>
<td>Instrumentation for SPS</td>
<td>-&quot;-</td>
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<tr>
<td>Power equipment for PS upgrade</td>
<td>-&quot;-</td>
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<tr>
<td>Magnets for PBS and PS linac</td>
<td>-&quot;-</td>
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<tr>
<td>Kickers for PS injection</td>
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<tr>
<td>40 MHz cavity for PS</td>
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<tr>
<td>52 warm twin-aperture quads for collimation insertion</td>
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<tr>
<td>66 kV converters for LHC injection</td>
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<td>PFNs for LHC injection</td>
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<tr>
<td>LHC beam monitoring electronics</td>
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<tr>
<td>Collimation studies</td>
<td>-&quot;-</td>
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</table>

* Values are given in Canadian dollars.
Indian In-kind Contributions

**Protocol**
In-kind Contribution up to 34.4 MCHF.

**Fund**
CERN contributes one half of the value* to a Fund that is dedicated to:
- Support of Indians at CERN.
- Contributions to LHC experiments.
- Occasional purchase of material.

**Addenda (Tasks)**
- Addenda (20)
- Approved [MCHF] 23.96
- Delivered [MCHF] 5.66

**Superconducting sextupole correctors**
*major in-kind contribution*

**Extension (new)**
Approved 26 MCHF

**Fund**
CERN contributes half of the value.

*Values are given by the estimated European value of the In-kind contributions*

P. Bryant
# LHC Project Working Groups

**LHC Sub-projects**

- Archives for non-active working groups.
- Magnet Evaluation Board home page.
- Cryodipole Coordination home page.

<table>
<thead>
<tr>
<th>Working Groups</th>
<th>Chairman</th>
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<tr>
<td>ATWG</td>
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# LHC Project - Sub-projects

**LHC Project Working Groups**

Archives for non-active working groups.

[Home page](Magnet Evaluation Board).

<table>
<thead>
<tr>
<th>Sub-Projects</th>
<th>Leader</th>
<th>Reporting to</th>
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<tbody>
<tr>
<td>LBDS Beam Dump</td>
<td>B. Goddard</td>
<td>xxx</td>
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<tr>
<td>CWG LHC Collimation</td>
<td>R. Assmann</td>
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<td>COMIN LHC Communication Infrastructure</td>
<td>P.S. Anderssen</td>
<td>TCC</td>
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<td>LHC-CP LHC Controls</td>
<td>R. Lauckner</td>
<td>LTC</td>
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<td>SLI SPS as LHC Injector</td>
<td>P. Collier</td>
<td>AB TC</td>
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<td>PS-LHC PS as LHC Pre-Injector</td>
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<td>PS-Ions PS Ions for LHC</td>
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<td>LHCOP LHC Operation</td>
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<td>String2 String 2</td>
<td>R. Saban</td>
<td>TCC/MARIC</td>
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<td>LTI LHC Transfer Lines and Injection</td>
<td>V. Mertens</td>
<td>AB TC</td>
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Governing US-CERN Agreements

INTERNATIONAL CO-OPERATION AGREEMENT
between
THE EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH (CERN)
and
THE DEPARTMENT OF ENERGY
OF THE UNITED STATES OF AMERICA
and
THE NATIONAL SCIENCE FOUNDATION
OF THE UNITED STATES OF AMERICA
concerning
SCIENTIFIC AND TECHNICAL CO-OPERATION
ON LARGE HADRON COLLIDER ACTIVITIES
1997

INTERNATIONAL CO-OPERATION AGREEMENT
CONCERNING
SCIENTIFIC AND TECHNICAL CO-OPERATION
ON LARGE HADRON COLLIDER ACTIVITIES
ACCELERATOR PROTOCOL
between
THE EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH (CERN)
and
THE DEPARTMENT OF ENERGY
OF THE UNITED STATES OF AMERICA
1997

IMPLEMENTING ARRANGEMENT

ACCELERATOR PROTOCOL

THE EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH (CERN)
and
THE DEPARTMENT OF ENERGY
OF THE UNITED STATES OF AMERICA
concerning
SCIENTIFIC AND TECHNICAL CO-OPERATION
ON LARGE HADRON COLLIDER ACTIVITIES
May 2002

Signed by CERN, DOE and NSF

Signed by CERN and US Labs
Management of US Project

Organized as a classic DOE construction project:

- Formal lines of authority and responsibility.
- Established work scope, budget, schedule and contingency.
- Earned value analysis and reporting.
- Change control procedures.
- Etc....
Management of US Project

Special features of a multi-lab project:

- One lab – that with the biggest long-term stake in the program – assigned as Lead Lab
  - Formally puts Director on the hook.
  - Provides backup for Project Manager.
  - Coordination with other Lab Directorates mainly through committee of relevant Deputy/Associate Directors.
  - All 3 Directors sign the Implementing Arrangement to formally commit their labs to the Project.

- Role of Division Heads is also important … They control the people.
Special features of multi-lab project

- Try to have independent work packages at each lab.
- Assign local project manager at each lab. Success depends **strongly** on having the right people for this.
- Need to have a strong Project Office.
  - Define specifications, especially interfaces between US labs and between US and CERN.
  - Coordinate interactions with CERN.
  - Keep regular and close tabs on work at all labs.
Problems specific to a multi-lab project:

- Difficulty of controlling work done at another lab.
- Different motivations of different labs … and tension between what is good for the project and what is good for each lab.
- Competition for the best people with other projects (not necessarily in HEP), which may have higher local priority.
- Difficulty of moving work from one lab to another.
- Local lab manager may be more in thrall to his Division Head than to the Project Manager.
- …

=> Costs are (probably) modestly higher than if all work done within a single lab.
US-CERN Coordination

Special features of International Collaboration.
(Or at least of dealing as a junior partner in someone else’s project.)

- Add formal links to responsible CERN people. *Informal, personal relationships are equally important.*

- Scope and schedule not fully under our control. Our change control procedures have to interact with theirs.

- Mis-match in schedules for completing designs.

  => *Extra contingency must be allowed for “external” changes.*

- No way to move funds between CERN and US labs to deal with changes that draw on contingency… Only “currency” is work scope.
Extending the US-CERN Collaboration

The US responsibility for LHC construction ends with the successful delivery of our equipment to CERN.

We are planning to extend the US-CERN collaboration into the commissioning and operational phases of LHC.

• Commissioning:
  o Commissioning the US-provided hardware systems.
  o Helping commission the LHC as a whole with beam.

• Operational phase:
  We do not plan to take real responsibility for operations; rather we will do R&D to extend the LHC performance for (US) HEP.
    o Machine development studies and fundamental accelerator research.
    o Development of advanced beam diagnostics.
    o R&D for a luminosity upgrade (dominantly advanced SC magnets).
Organization for the Next Phase
Summary

LHC represents an important step towards global collaboration in the construction of large scientific instruments.

- Construction is proceeding towards machine startup in 2007.
- Management systems for US-CERN collaboration are working well.
  - The determination of the people involved to make the collaboration work is just as important as the management systems.
- Multi-lab US Project is generally working well.
  - But this is less efficient than a single lab project.
  - Management relations among the labs must be carefully defined.
  - Strong Project Office is required.
- We are currently working to “invent” the structures to extend the US-CERN collaboration for machine commissioning and R&D to extend the LHC performance as a tool for (US) HEP.