U.S. Department of Energy's
Office of Science

Experiences from the Large Hadron Collider

Burning Plasma Physics Advisory Committee (BPPAC) Meeting

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OUTLINE

- Overview of the LHC
- CERN Experience
- U.S. LHC Construction Project
  - Management Approach
  - Success/Challenges
  - Lessons Learned
- Summary

WHAT IS THE LHC?

- Particle physics facility at CERN
  (highest energy -14TeV & luminosity - $10^{34}cm^{-2}s^{-1}$)
- Thousands of superconducting magnets (8.3T @1.8K, largest superconducting installation)
- Existing and new infrastructure
  (27km tunnel ~100m underground)
- Four large detectors
  (ATLAS, CMS, ALICE, LHC-B)
- World's largest accelerator and detectors and among the biggest scientific collaborations

IMPORTANCE OF LHC

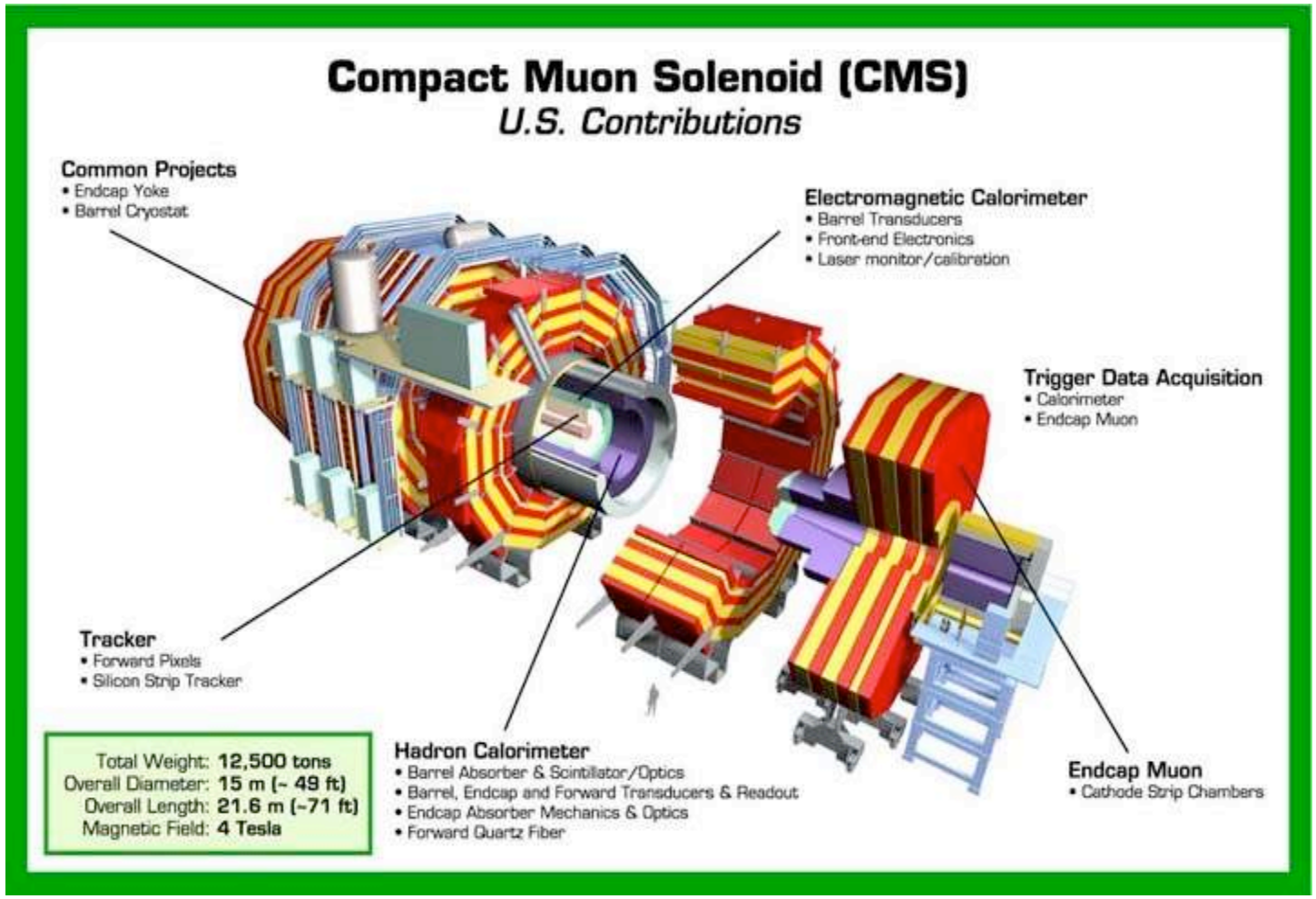
High Energy Physics Advisory Panel Long Range Planning Report recognized the standing of the LHC physics program….

continue with the CERN LHC. The LHC will be the centerpiece of the world program in particle physics when it begins operation during the second half of this decade. With an energy seven times that of the Tevatron, it will revolutionize our understanding of TeV scale physics.

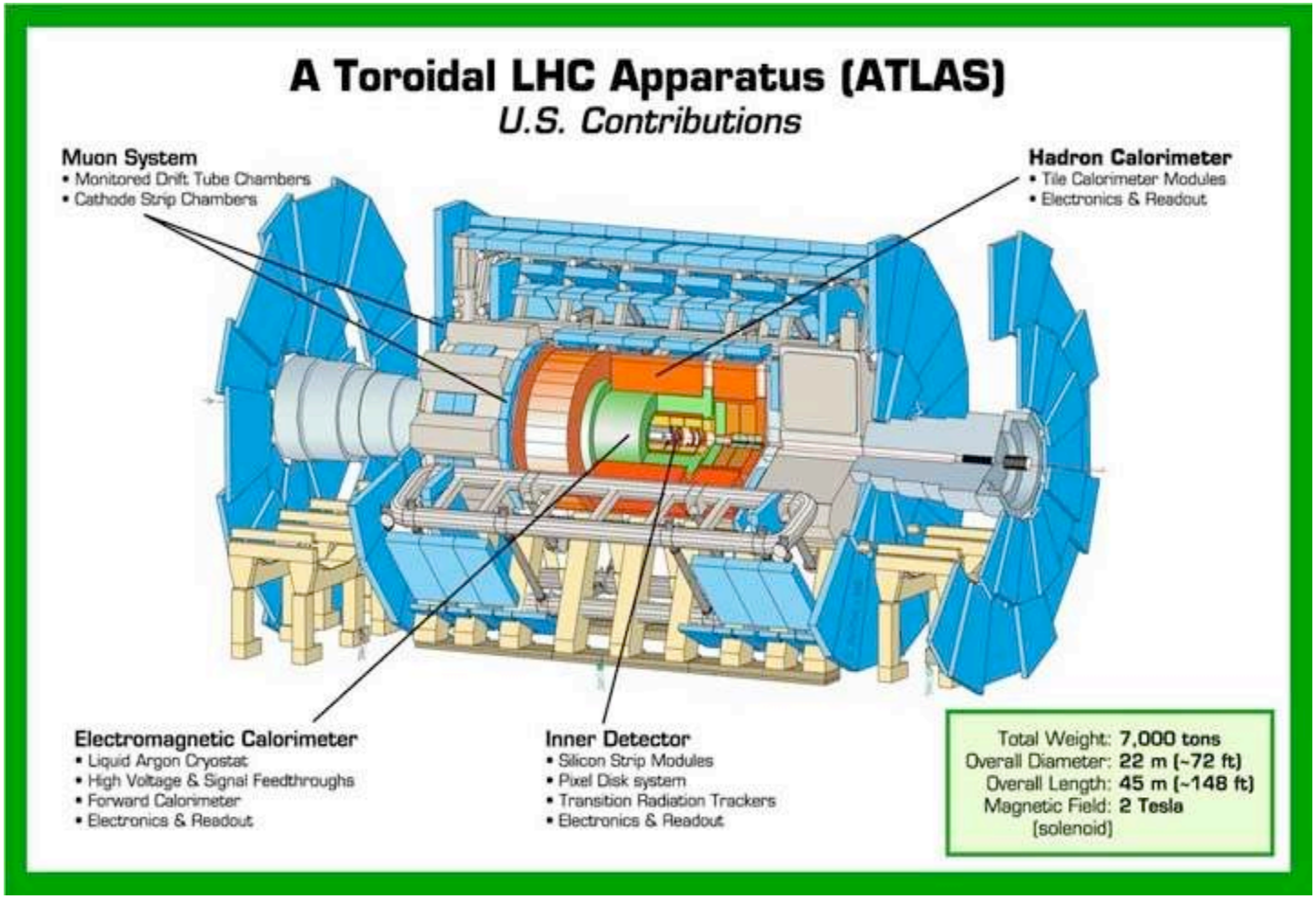
CERN MEMBER STATES

LHC MACHINE

CMS EXPERIMENT



ATLAS EXEPERIMENT



CHALLENGES

news

CERN puts research on hold to build collider

Alison Abbott, Munich

CERN, the European particle-physics laboratory in Geneva, Switzerland, is to shelve most of its medium-term research plans in a bid to ensure the completion of its main project — the construction of the Large Hadron Collider (LHC).

Under a retrenchment plan agreed on 21 June between the laboratory's management and its governing council, physicists at CERN will generate practically no fresh experimental data during 2005. Some researchers have already expressed fears about the impact of this data drought on the laboratory.

Cost overruns totalling SFr850 million (US$570 million) on the LHC's SFr2.6-billion construction cost were exposed last autumn (see *Nature* **413**, 557; 2001). Council members, whose governments foot CERN's bill, were angry that its director, Luciano Maiani, had known about the problem for months but had not informed them.

In September, Maiani set up internal task forces to consider improvements in CERN's management and to find ways of saving money to pay for completion of the LHC. CERN's council, meanwhile, established an external review committee, chaired by Robert Aymar, director of ITER, the international project to build an experimental magnetic fusion reactor.

Cost cutting: the Proton Synchrotron (above) and Super Proton Synchrotron will be shut down for all of 2005.

Both processes reached similar conclusions, and CERN's council has now accepted Maiani's plan to implement these by streamlining the laboratory's management, winding down small research projects and adjusting the LHC construction plan.

The LHC, which physicists hope will find the Higgs boson, will not now come on line until 2007, two years later than originally planned. Loans have been arranged to extend the period of payment for the LHC until 2009.

CERN EXTERNAL REVIEW

- External Committee (R. Aymar) recommended changes and efficiency improvements:
  - organization, project structure, and manpower planning
  - contingency, accounting, earned value
- CERN program reduced and debt repayment extended.
- LHC grows from ~50% to ~75% of CERN program.
- Start-up of the facilities revised from 2005 to 2007.

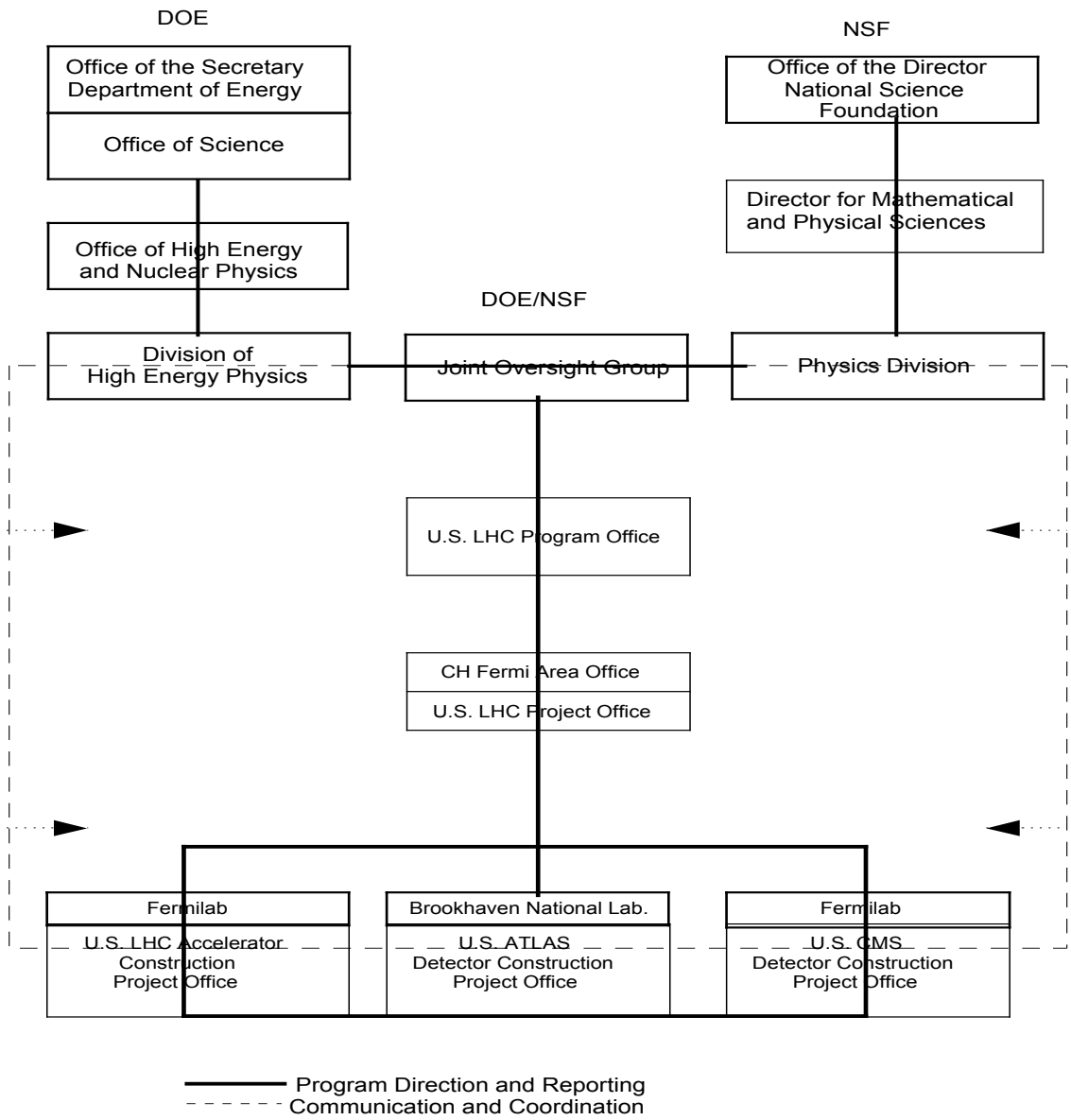
U.S. ROLE

- U.S. is a minority partner in the international LHC project (Europe 82%, DOE/NSF 10%, others 8%)
- NSF and DOE are partners and act as one in the international arena
- Contributions are deliverables
- Overriding control is the congressional cap of $531M

US-CERN RELATIONSHIP

- U.S./CERN–International Agreement defines our capped contribution to construction as $531 million (DOE-$450M and NSF-$81M).
- U.S. construction deliverables are defined in detail:
  - U.S. ATLAS: ATLAS Memorandum of Understanding
  - U.S. CMS: CMS Memorandum of Understanding
  - U.S. Machine: U.S./CERN Implementing Arrangement
- Significant changes approved by DOE/NSF.

DOE/NSF ORGANIZATION



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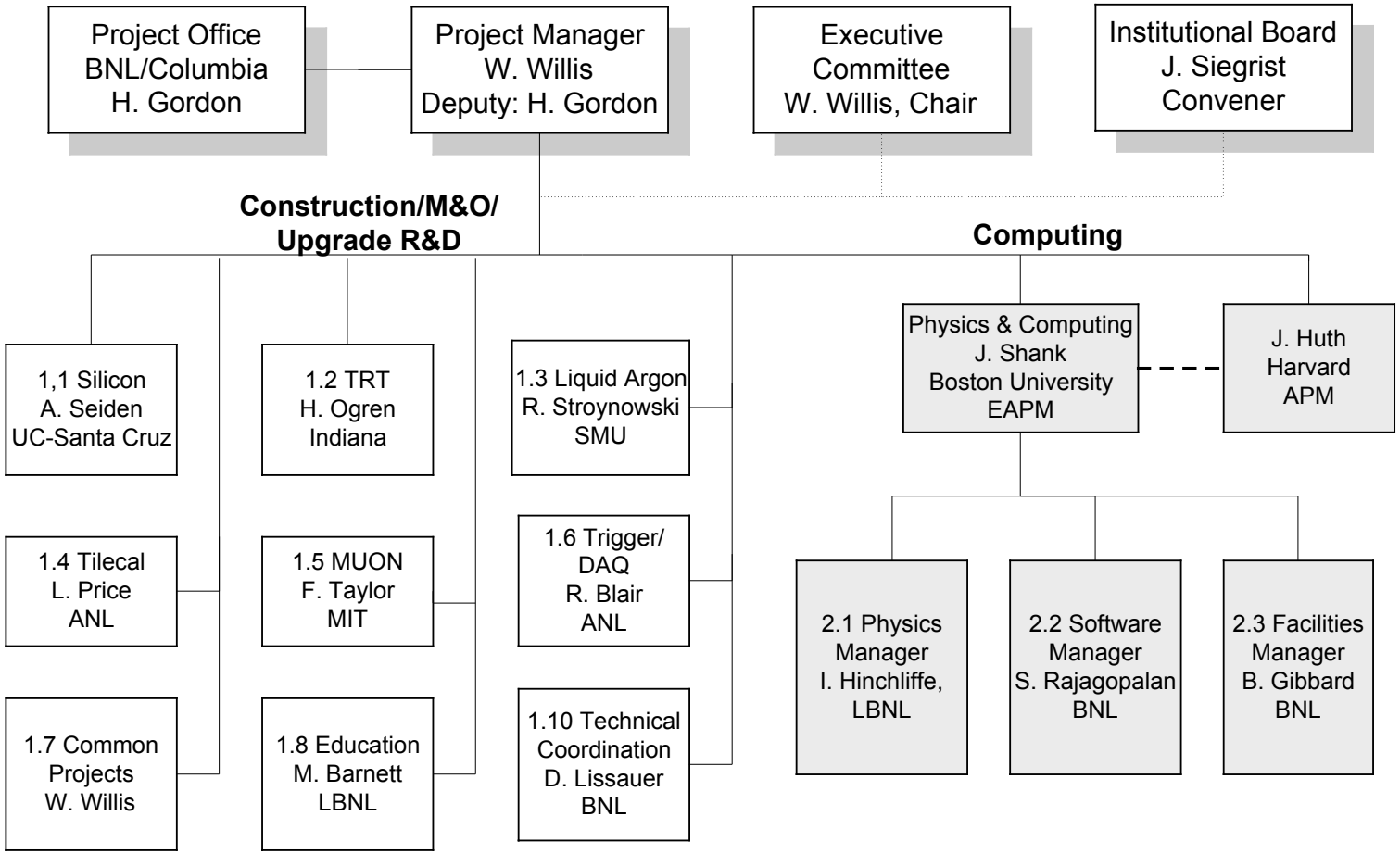
USATLAS ORGANIZATION

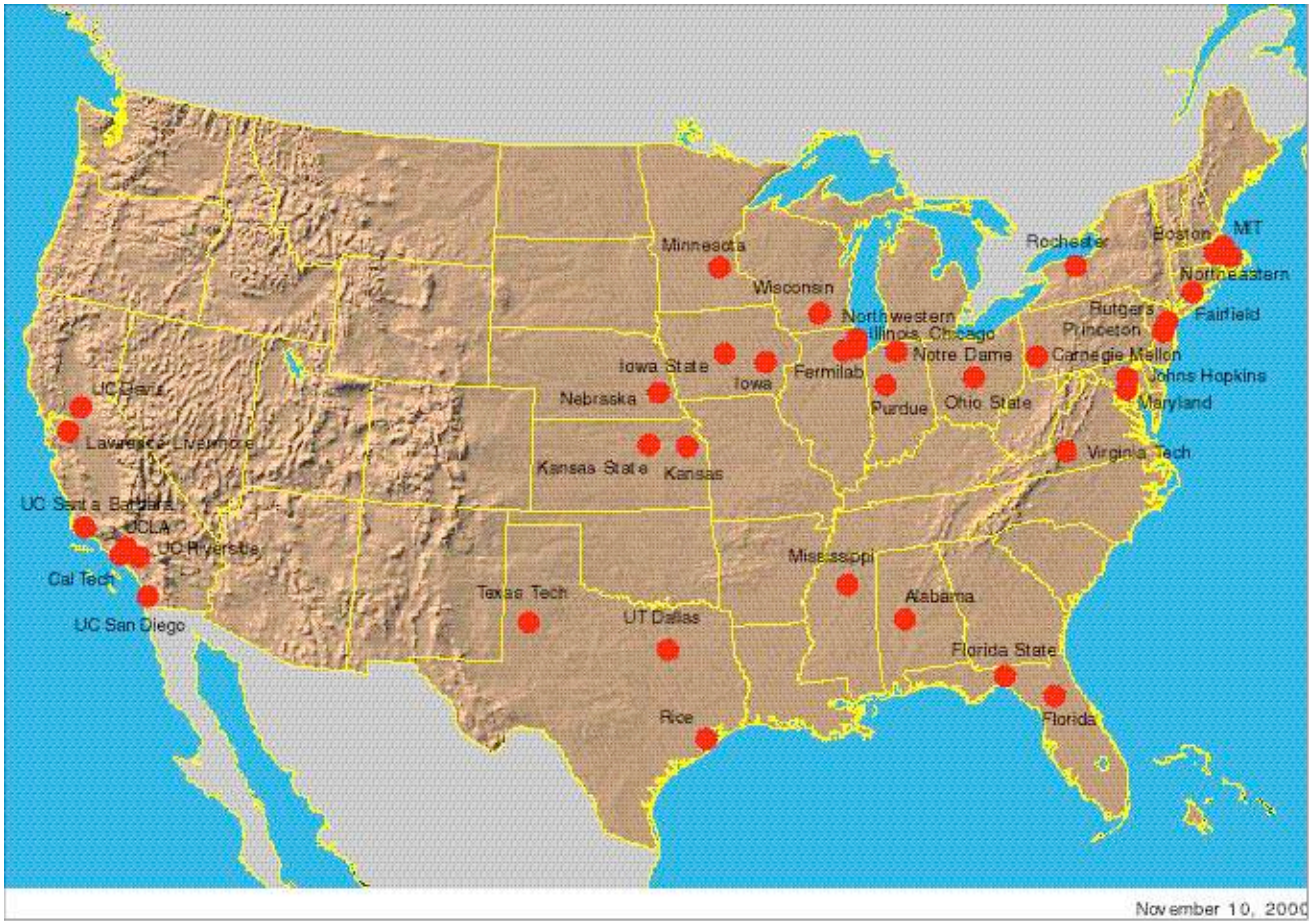
Office of Science

U.S. ATLAS Organization



USCMS

USCMS = 387 members from 38 Institutions



USLHC PROJECTS

- U.S. LHC Accelerator - $200 million (DOE funding only)
  - Fermilab/Brookhaven National Laboratory/Lawrence Berkeley National Laboratory Collaboration - $110 M
  - CERN Direct Purchase from U.S. Industry - $90 M
- U.S. ATLAS Detector Construction – $163.75 million
- U.S. CMS Detector Construction - $167.25 million
- "Base" program support for physicists and infrastructure at labs and universities.

AGENCY OVERSIGHT

- DOE/NSF Joint Agency Approach
  - DOE/NSF MOU addresses joint responsibilities
  - DOE/NSF Joint Oversight Group (U.S. program coordination)
  - U.S. LHC Project Execution Plan & detailed Management Plans
  - Project Reporting and Reviews
    - Extensive formal reporting, quarterly meetings and site visits
    - Regular "Lehman" reviews
- Host/Lead Laboratory Role and Advisory Committees
  - U.S. ATLAS BNL A.D. w/ Project Advisory Panel
  - U.S. CMS FNAL D.D. w/ Project Management Group
  - U.S. LHC Accelerator FNAL A.D. w/ Project Advisory Group

PROJECT BASELINES

Baseline Characteristics (1998)

- Peer Reviewed ("Lehman" Reviews)
- Cost Contingency
  - U.S. LHC Accelerator at ~20%
  - U.S. CMS and U.S. ATLAS at ~40%
- Schedules
  - Construction activities scheduled to end in 2004
  - Set to match LHC schedule of 2005
- Scope/Technical
  - Detailed list of deliverables
  - Scope reduced to create adequate contingency
- Collaboration/project relationships established

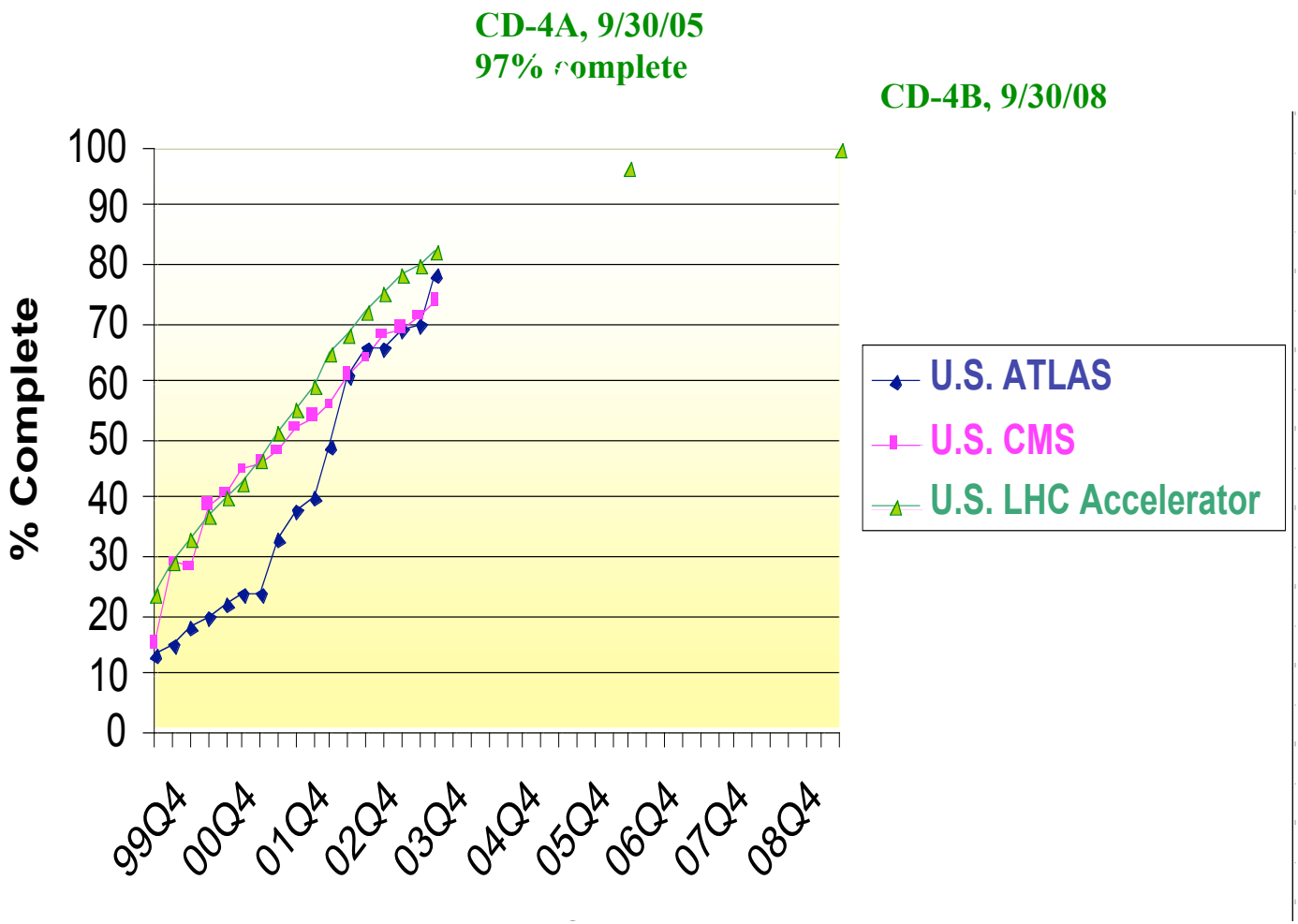
PROJECT HISTORY

- U.S. LHC Accelerator
  - Earned contingency early (>20%), scope additions
  - Struggling to hold contingency at ~20% of ETC
  - CERN purchases from U.S. industry had slow start
- U.S. CMS & U.S. ATLAS
  - Earned contingency early on material contracts
  - Some scope added, holding contingency at 40%
  - Priorities on scope additions established with international collaboration leadership
  - Some schedule delays driven by slow production starts and delivery of parts from collaborators
- Meeting commitments plus scope additions within the cap.

COMPLETION STRATEGY

- Complete U.S. deliverables on the original schedule
  - no change to construction commitment of $531 M
  - cost effective, supporting maximum deliverables
  - 97% percent complete by the end of 2005
- Implications of this strategy
  - Deliveries occur well before the physics program begins
- Construction Endgame
  - ~ 3% of the construction work is tied to the LHC start-up schedule, e.g., final installation and computing purchases

PROJECT COMPLETION



SUCCESS/CHALLENGES: *Agency Coordination and Planning*

- DOE and NSF Coordination
  - DOE/NSF Memorandum of Understanding
  - Active, joint agency coordination
- Advance planning for the LHC research program
  - DOE/NSF MOU modified to include the research program to enable joint planning
  - Assigned roles for host labs and U.S. collaboration leadership

SUCCESS/CHALLENGES: *Agency Oversight*

- Reviews & Status Meetings
  - Peer reviews throughout life of the project
    - Goal of no surprises and full transparency
    - Coordinated w/ internal reviews
  - Quarterly Status Meetings
    - Integrated Project Team coordination
    - Issue resolution and follow-up
- Reporting
  - Formal – more than necessary; Informal - constant
  - Some overlap between DOE and NSF

SUCCESS/CHALLENGES: *Community Leadership*

- Project Managers
  - Appointed by host labs with concurrence of the DOE/NSF JOG and the U.S. collaborations
  - Successful managing to the U.S. project baselines and meeting the DOE and NSF project requirements
  - Continuous challenge managing the interface with the international collaboration
- U.S. Collaborators
  - Working with the project management paradigm

SUCCESS/CHALLENGES: *Funding Profile*

- Long term funding commitment for the full $531M
  - Nominally $70 M per year
  - Minor profile changes made after consensus, e.g., annual redistribution between projects
- Controlled by the project managers
  - NSF Cooperative Agreements, DOE Financial Plans and Grant Supplements, and subcontracts
  - Allocations to >70 U.S. collaborating institutions based on MOUs, annual SOWs, and resource loaded schedules controlled by the managers

SUCCESS/CHALLENGES: *Interface Management*

- Technical
  - Requires vigilance but still mixed results
  - U.S. would prefer a stronger CERN role
- Schedule
  - U.S. successful at keeping off the critical paths for the machine and experiments
- Cost
  - U.S. contingency strategy has helped but significant risk still remains

SUCCESS/CHALLENGES: *Coherent U.S. Position*

- U.S. coherent approach essential (project vs. institutes)
  - U.S. Agencies - CERN
  - ATLAS and CMS (Multi-lateral negotiations)
  - Machine (Bi-lateral)
  - U.S. collaborators work through U.S. leadership and directly with international framework
- U.S. LHC Accelerator three lab collaboration
  - Struggles to operate as a single project

LESSONS-LEARNED

- Importance of Planning and Management Systems

- Baseline a project with realistic cost estimates and schedules and adequate contingency to address a substantial fraction of the risk (see GAO report on large science projects).

- Project leaders should implement management systems early, use these systems and revise as needed.

- Project leaders should actively pursue strategies to avoid, transfer, control and mitigate risk factors.

LESSONS-LEARNED

- Project Team, Structure, and Decision-making

- Good working relationships are essential for large projects
- Factorize a large project and align with competent managers
- Roles of team members should be understood and honored
- Decision-making authority should reside with the project manager with obligation to keep others informed
- Transparency in plans and actions engenders trust, confidence, and better quality

SUMMARY

- U.S. LHC is a large science project on track to successful completion in support of the LHC program.
- There are valuable lessons learned from U.S. LHC that are relevant and applicable to other projects.
- The U.S. LHC managers have received significant assistance and advice from the community and are willing to try to help others.