Large Science Project Experience at the U.S. Department of Energy

Daniel R. Lehman
Office of Project Assessment
September 14, 2005
www.science.doe.gov/opa
Topics

- Organizational Context
  - Big Government, Big Projects
- Delivering Large Science Projects
  - DOE’s Project Management Process
- Lessons Learned
  - Successful and Not-So Successful Projects
- Final Reflections
U.S. Department of Energy Headquarters

Secretary
Dr. Samuel Bodman
Deputy Secretary*
J. Clay Sell

*The Deputy Secretary also serves as the Chief Operating Officer.

17 Mar 05
Office of Science

Director
Raymond Orbach

Principal Deputy
James Decker

Chief of Staff
Jeffrey Salmon

Deputy for:

Chief Operating Officer
Ralph De Lorenzo

Project Assessment
Daniel Lehman

Berkeley Site Office
Joseph Krupa (A)

Pacific Northwest Site Office
Julie Erickson (A)

Thomas Jefferson Site Office
James Turi

Argonne Site Office
Creig Zook (A)

Stanford Site Office
Bob Wunderlich (A)

Ames Site Office
Roxanne Purucker

Fermi Site Office
Joanna Livengood

Princeton Site Office
Jerry Faul (A)

Brookhaven Site Office
Michael Holland

Fiscal Year

FY 2006 Constant ($B)

Deadlines

Provide Independent Oversight of SC Projects
Provide assistance to SC Line Project Managers
Analyze project execution issues and advise senior SC managers

Approximately 1,000 federal staff and xxxxx contractors complex-wide
National Laboratories
A Less Complex View

Office of Science

$3.3B/Year

Office of Science HQ Program Managers

Office of Science Field Managers

10 National Labs
> 250 Universities

Miracles of Science

6 Major National Advisory Committees

Conscience

Heart and Soul

Eyes and Ears

Brains and Brawn
Office of Science Mission

Our mission is to **deliver** the remarkable discoveries and scientific tools that transform our understanding of energy and matter and advance the national, economic and energy security of the United States.

**Deliver = Project Management**
Department of Energy’s Portfolio of Projects

<table>
<thead>
<tr>
<th>Organization</th>
<th>Total Projects</th>
<th>Total Project Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>NNSA</td>
<td>64</td>
<td>$16.06B</td>
</tr>
<tr>
<td>EM</td>
<td>7</td>
<td>$6.94B</td>
</tr>
<tr>
<td>SC</td>
<td>33</td>
<td>$6.25B</td>
</tr>
<tr>
<td>NE</td>
<td>6</td>
<td>$0.43B</td>
</tr>
<tr>
<td>EE</td>
<td>2</td>
<td>$0.10B</td>
</tr>
<tr>
<td>FE</td>
<td>4</td>
<td>$1.07B</td>
</tr>
<tr>
<td>OE</td>
<td>2</td>
<td>$0.03B</td>
</tr>
<tr>
<td>LM</td>
<td>1</td>
<td>$0.01B</td>
</tr>
<tr>
<td>EH</td>
<td>1</td>
<td>$0.02B</td>
</tr>
<tr>
<td>RW</td>
<td>3</td>
<td>$10.1B</td>
</tr>
<tr>
<td><strong>Sub-Total</strong></td>
<td><strong>123</strong></td>
<td><strong>$41.01B</strong></td>
</tr>
<tr>
<td>EM- Operating Projects</td>
<td>76</td>
<td>$126.04B</td>
</tr>
<tr>
<td><strong>Total DOE</strong></td>
<td><strong>199</strong></td>
<td><strong>$167.05B</strong></td>
</tr>
</tbody>
</table>
Highly visible DOE project failures/cost overruns

High level of scrutiny by key DOE stakeholders (OMB, GAO, IG and Congress)

Specific Congressional direction to improve DOE project performance and project management systems
Establishes DOE Policy for Program and Project Management

Provides Project Management Direction for Acquisition of Capital Assets

Documents Requirements and Guidance for the Planning and Acquisition of Capital Assets

Provides Non-Mandatory Guidance and References
Department of Energy Project Management Process

**Initiation Phase**
- **CD-0**: Approve Mission Need

**Definition Phase**
- **CD-1**: Approve Alternative Selection and Cost Range

**Execution Phase**
- **CD-2**: Approve Performance Baseline
- **CD-3**: Approve Start of Construction

**Transition/Closeout Phase**
- **CD-4**: Approve Start of Operations or Project Closeout

Program funds → Preliminary Engineering and Design funds (PED) → Project funds

Project included in DOE Budget
Dr. Orbach’s philosophy drives SC to:

- Ensure that projects clearly support program research missions
- Verify that projects are adequately defined and staffed before committing significant resources
- Establish project baselines
- Maintain project baselines through formal change control
- Determine a project’s success by measuring performance against the approved baseline
Typical Large DOE Science Project Stakeholders

US DOE Line Management Hierarchy

- Deputy Secretary of Energy
- Under Secretary of Energy
- Director Office of Science
- Office of Science Associate Director
- Office of Science Program Manager
- Federal Project Director
- National Laboratory/Contractor

Oversight

Integrated Project Team

<table>
<thead>
<tr>
<th>Planning &amp; Monitoring</th>
<th>Execution &amp; Reporting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Federal Project Director</td>
<td></td>
</tr>
<tr>
<td>Assisted by:</td>
<td></td>
</tr>
<tr>
<td>Procurement, Financial Systems, Engineering, ES&amp;H, Project Controls</td>
<td></td>
</tr>
<tr>
<td>Contractor Project Manager</td>
<td></td>
</tr>
<tr>
<td>Supported by:</td>
<td></td>
</tr>
<tr>
<td>Laboratory Staff, University Staff, Subcontractors</td>
<td></td>
</tr>
</tbody>
</table>

Advisory Groups

- Office of Science & Technology Policy
- Office of Science Advisory Committees
- Facility User Collaborations
- National Academy of Sciences

Independent Oversight

- Congress (Various Committees)
- Office of Management and Budget (OMB)
- Government Accountability Office (GAO)
- Inspector General (IG)
- Office of Engineering and Construction Management (DOE-OECM)
- SC Office of Project Assessment (SC 1.3)
*The Deputy Secretary also serves as the Chief Operating Officer.
### Project Phase (Critical Decisions) from DOE O 413.3

<table>
<thead>
<tr>
<th>Project Phase</th>
<th>Financial Management Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approve Mission Need (CD-0)</td>
<td>- Ensure preliminary budgetary estimate ranges are reasonable</td>
</tr>
</tbody>
</table>
| Approve Alternative Selection and Cost Range (CD-1) | - Evaluate cost/benefit of alternatives  
- Refine budget profile and cost estimates |
| Approve Performance Baseline (CD-2) | - Evaluate adequacy of project contingency  
- Establish funding profile  
- Establish performance measurement baseline; begin earned value reporting |
| Approve Start of Construction (CD-3) | - Initiate major procurements  
- Control changes affecting cost baseline  
- Manage project contingency |
| Approve Start of Operations (CD-4) | - Assure funding profile supports project end-game strategy  
- Conduct financial closeout |
Office of Science Project Peer Reviews

- Cited as best-practice by OSTP
- Peers are world-class scientists, engineers and managers
- Examines project cost, schedule, funding and management in detail
- Ensures project team is executing according to agreed upon plans
- Informs senior management on status and readiness to proceed to next phase
## Lessons Learned from Selected Office of Science Projects

<table>
<thead>
<tr>
<th>Project</th>
<th>Cost</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spallation Neutron Source (SNS)</td>
<td>$1.4B</td>
<td>ORNL, Oak Ridge, TN</td>
</tr>
<tr>
<td>Advanced Photon Source (APS)</td>
<td>$798.8M</td>
<td>ANL, Chicago, IL</td>
</tr>
<tr>
<td>Continuous Electron Beam Accelerator Facility (CEBAF)</td>
<td>$513.1M</td>
<td>TJNAF, Newport News, VA</td>
</tr>
<tr>
<td>Neutrinos at the Main Injector (NuMI)</td>
<td>$167.8M</td>
<td>Fermilab, Batavia, IL</td>
</tr>
<tr>
<td>Relativistic Heavy Ion Collider (RHIC)</td>
<td>$616.5M</td>
<td>BNL, Brookhaven, NY</td>
</tr>
<tr>
<td>U.S. Large Hadron Collider (U.S. LHC)</td>
<td>$531M</td>
<td>Fermilab, BNL, LBNL</td>
</tr>
<tr>
<td>B-Factory</td>
<td>$177M</td>
<td>SLAC, Menlo Park, CA</td>
</tr>
<tr>
<td>Superconducting Super Collider (SSC)</td>
<td>$11B?</td>
<td>Waxahachie, TX</td>
</tr>
<tr>
<td>(project cancelled)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**Spallation Neutron Source (SNS) – Successful Project**

**Purpose:**
To provide neutron beams with up to 10 times more intensity than any other source in the world (1.4 million watts of beam power on the target)

**Total Project Cost:**
$1.4 billion

**Start/End Dates:**
August 1996/June 2006 (forecast)

**Operating Costs:**
~ $160 million per year

**Features:**
- 80 acre site
- 400 permanent staff
- Initial suite of 24 instruments for material science investigations

**Information:** [www.sns.gov](http://www.sns.gov)
SNS Lessons Learned

- Strong, visible program advocacy and strongly supported mission need
- Lab management team has a “project” mentality
- Project execution is not rocket science, but requires attention and discipline
- Early planning for operations and commissioning/pre-operations
- Multi-lab partnerships add another dimension
- Long-range upgrade strategy established early between DOE and Lab
Purpose:
One of only three third-generation, hard x-ray synchrotron radiation light sources in the world to study the structure and properties of materials

Total Project Cost:
$798.8 million

Start/End Dates:
May 1988/August 1996

Features:
• 1,104-meter (0.7 mi) circumference
• 7 GeV
• 450 permanent staff
• 68 beamlines for experimental research

Information: www.aps.anl.gov
APS Lessons Learned

- Expert reviews built confidence in estimates
- Safety program defined early
- Early user input included in facility requirements
- Project Team drove the project schedules
- Proactive cost savings program enhanced contingency
- Management control systems implemented early, and appropriately revised as project evolved
- Expectations were defined and consistently communicated across the project team
Continuous Electron Beam Accelerator Facility (CEBAF)

Successful Project

**Purpose:**
To understand how nuclear matter is formed from the more elementary particles (quarks).
First superconducting electron accelerator built.

**Total Project Cost:**
$513.1 million

**Start/End Dates:**
February 1987/August 1994

**Features:**
- 7/8 mile circular tunnel
- 2,200 magnets in 58 varieties
- 550 permanent staff

**Information:** www.jlab.org
CEBAF Lessons Learned

- Effective DOE-Contractor “Partnership”
- Strong Leadership and Senior Management
- Competent and Experienced Staff
- Integrated Planning – Project Management; Science; ES&H; and Business Systems
- Adequate Checks and Balances – Independent Reviews
- Proactive Attention to Problem Identification, Tracking and Resolution
Neutrinos at the Main Injector (NuMI) – Problems Encountered

**Purpose:**
NuMI uses a particle accelerator at Fermilab, near Chicago, to produce an intense beam of neutrinos that travels 450 miles to the MINOS detector in Minnesota.

**Total Project Cost:**
$167.8M

**Start/End Dates:**
March 1997/February 2005

**Features:**
- 6,000-ton steel detector located ½ mile underground in Soudan iron ore mine
- NuMI tunnel at Fermilab is ¾ mile long and 300 ft deep at the near detector

**Information:**
www.numi.fnal.gov
NuMI Tunnel Issues

- Demands of engineering and constructing underground beamlines underestimated
- Series of serious safety incidents
- Matrix management poorly suited to supervision of NuMI project contract
- Escalating civil construction market in Chicago region
NuMI Lessons Learned

- Before starting the project, make sure a dedicated, competent, and proven management organization is in place.
- Prior to baselining, allow for sufficient pre-planning and design to ensure that key technical issues and risks are well understood.
- Prior to starting construction, be aware of the message of the incoming bids.
- Correct deficiencies as soon as they arise.
Relativistic Heavy Ion Collider (RHIC) – Successful Project

**Purpose:**
To study the fundamental properties of matter from elementary atomic particles to the evolution of the universe

**Total Project Cost:**
$600 million

**Start/End Dates:**
July 1990/August 1999

**Operating Costs:**
~ $130 million per year

**Features:**
• Two crisscrossing rings in a tunnel 2.4 miles in circumference
• 1,740 superconducting magnets
• Four experiments: BRAHMS, PHENIX, PHOBOS and STAR

**Information:** www.bnl.gov/rhic
Purpose:
To collide two counter rotating proton beams, at a center-of-mass collision energy of 14 TeV. U.S. participates in construction of the accelerator and design, fabrication and operation of the CMS and ATLAS detectors.

Total Project Cost: (US share only)
$531 million

Start/End Dates:
December 1997/September 2008

Features:
• 27 KM (16.8 mi) circumference tunnel
• US ATLAS group consists of 31 Universities and 3 DOE Labs
• US CMS group consists of 38 institutions

Information:
http://www.ch.doe.gov/offices/FAO/projects/uslhc/index.html
Baseline projects with realistic cost estimates and schedules
Implement management systems early; revise as needed
Actively pursue strategies to avoid, transfer, control and mitigate risk
Give decision-making authority to the project manager with an obligation to keep others informed
Making plans and actions transparent creates trust, confidence, and better quality
Logically subdivide large projects and align with competent managers
Understand and honor roles of team members
**Purpose:**
To create a facility for observing collisions of electrons and positrons with sufficient luminosity to measure the extent to which charge polarity conservation is violated in the decay of B-mesons.

**Total Project Cost:**
$177 million

**Start/End Dates:**
1993/1998

**Features:**
- 3 KM (1.9 mi) linear accelerator
- 2.2 KM (1.4 mi) circular storage ring
- Project was replacement of an existing machine

**Information:**
http://www.slac.stanford.edu
B Factory Lessons Learned

- Use a central project management control system
- Drive the schedule
- Use a vertical not matrix project organization
- Use phased commissioning; bring upstream systems online as early as possible
- Don’t procrastinate on hard decisions
- Use internal and external design reviews to assure quality
- Pay attention to team building
Superconducting Super Collider (SSC) - **Cancelled**

**Purpose:**
To create a particle accelerator with an energy of 20 TeV per beam as a means of capturing a Higgs boson from the planned collisions.

**Total Project Cost:** $10.45 Billion

**Start/End Dates:** September 1987/October 1993

The project was cancelled by Congress in 1993 after 14 miles of tunnel were dug and over 2 billion dollars spent.
SSC Lessons Learned

- Understanding of purpose and benefits not clear
- Growing perception of poor management by DOE and SSCL
- Increasing costs not understood
- Diminishing likelihood for foreign participation
- Recruiting experienced scientists and engineers difficult
- Users sensed very long time before research possible
The project’s purpose and benefits must be clear.

Integrated Project Team and Relationships
- A dedicated, competent, and effective management organization, with adequate resources, must be in place
- Strong Program support is critical
- The laboratory management team must have a project mentality
- There should be a strong DOE/Contractor “partnership”
- Roles of team members should be understood and honored

Early Planning
- Pre-planning and design is critical to ensure that key technical issues and risks are well understood prior to baselining
- The baseline should be well-defined with realistic cost estimates, schedules, and adequate contingency
- Management control systems should be implemented early and revised as the project evolves
- Planning for operations and commissioning/pre-operations should take place early
- A safety program should be defined early
- User input should be included (early) in facility requirements
- A long-range upgrade strategy should be established between DOE and the laboratory

Adequate Checks and Balances
- Expectations should be defined and consistently communicated and managed across the project team; proactive attention should be given to problem identification, tracking, and resolution
- Strong emphasis should be placed on meeting schedules
- Independent reviews should be conducted on a regular basis
Early Planning Strongly Influences Project Outcomes

- **Major Influence**
- **Rapidly Decreasing Influence**
- **Low Influence**

Influence vs. Expenditures

- **Influence**
- **Expenditures**

- **Perform Business Planning**
- **Perform Pre-Project Planning**
- **Execute Project**
- **Operate Facility**

High to Low Influence:

- Large Expenditures
- Small Expenditures
People Make Successful Projects

- All participants and stakeholders must readily recognize the project’s scientific merit and/or need
- Project management (managers) must be highly credible
- Positive relationships must exist among senior project managers
- Good personal relations are essential among customer/owner, contractor, vendors
- There must be a high quality, capable project staff
Understanding the Outcomes of Megaprojects

A Quantitative Analysis of Very Large Civilian Projects

Edward W. Merrow
With Lorraine McDonnell, R. Yilmaz Argüden

March 1988

Supported by the Private Sector Sponsors Program

40 Years RAND

R-3580-PSSP

Historical Review of San Francisco-Oakland Bay Bridge East Span Seismic Retrofit Cost Increases

Final Report

Submitted to the State of California Business, Transportation and Housing Agency
January 28, 2005

Michael Weigt, Managing Partner, The Results Group
John Heintz, Senior Consultant, The Results Group
Hans Blixt, Senior Consultant, The Results Group
Karl Johnson, President, The Results Group

Rand Corporation

40 Years RAND

EXP 016 0001
Closing Thoughts

- Scope definition is important; management is critical; funding is paramount
- Too often, optimistic rather than realistic view of events affecting projects
- Slow to look outside the project for solutions (defensive routines)

- Management, Management, Management!