U.S. Department of Energy

Office of Science

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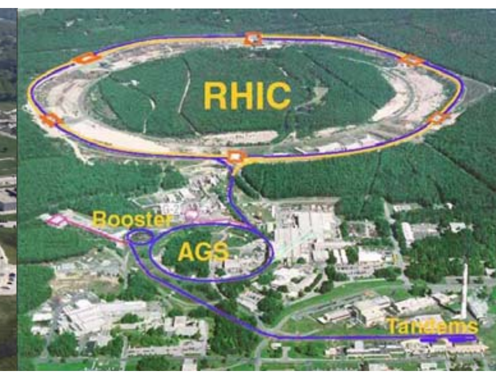
Large Science Project Experience at the U.S. Department of Energy



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

THE GOVERNMENT OF THE UNITED STATES

THE CONSTITUTION

LEGISLATIVE BRANCH

THE CONGRESS

SENATE HOUSE

ARCHITECT OF THE CAPITAL
UNITED STATES BOTANIC GARDE
GNERAL ACCOUNTING OFFICE
GOVERNMENT PRINTING OFFICE
LIBRARY OF CONGRESS
CONGRESSIONAL BUDGET OFFICE

EXECUTIVE BRANCH

THE PRESIDENT

THE VICE PRESIDENT

EXECUTIVE OFFICE OF THE PRESIDENT

WHITE HOUSE OFFICE
OFFICE OF THE VICE PRESIDENT
COUNCIL OF ECONOMIC ADVISERS
COUNCIL OF ENVIRONMENTAL QUALITY
NATIONAL SECURITY COUNCIL
OFFICE OF MANAGEMENT AND BUDGET
OFFICE OF NATIONAL DRUG CONTROL POLICY
OFFICE OF POLICY DEVELOPMENT
OFFICE OF ADMINISTRATION
OFFICE OF THE U.S. TRADE REPRESENTATIVE

OFFICE OF SCIENCE AND TECHNOLOGY POLICY

JUDICIAL BRANCH

THE SUPREME COURT OF THE UNITED STATES

UNITED STATES COURT OF APPEALS
UNITED STATES DISTRICT COURTS
TERRITORIAL COURTS
UNITED STATES COURT OF INTERNATIONAL TRADE
UNITED STATES COURT OF FEDERAL CLAIMES
UNITED STATES COURT OF APPEALS FOR THE ARMED FORCES
UNITED STATES TAX COURT
UNITED STATES COURT OF APPEALS FOR VETERANS CLAIMS
ADMINISTRATIVE OFFICE OF THE UNITED STATES COURTS
FEDERAL JUDICIAL CETNER
UNITED STATES SENTENCING COMMISSIONING

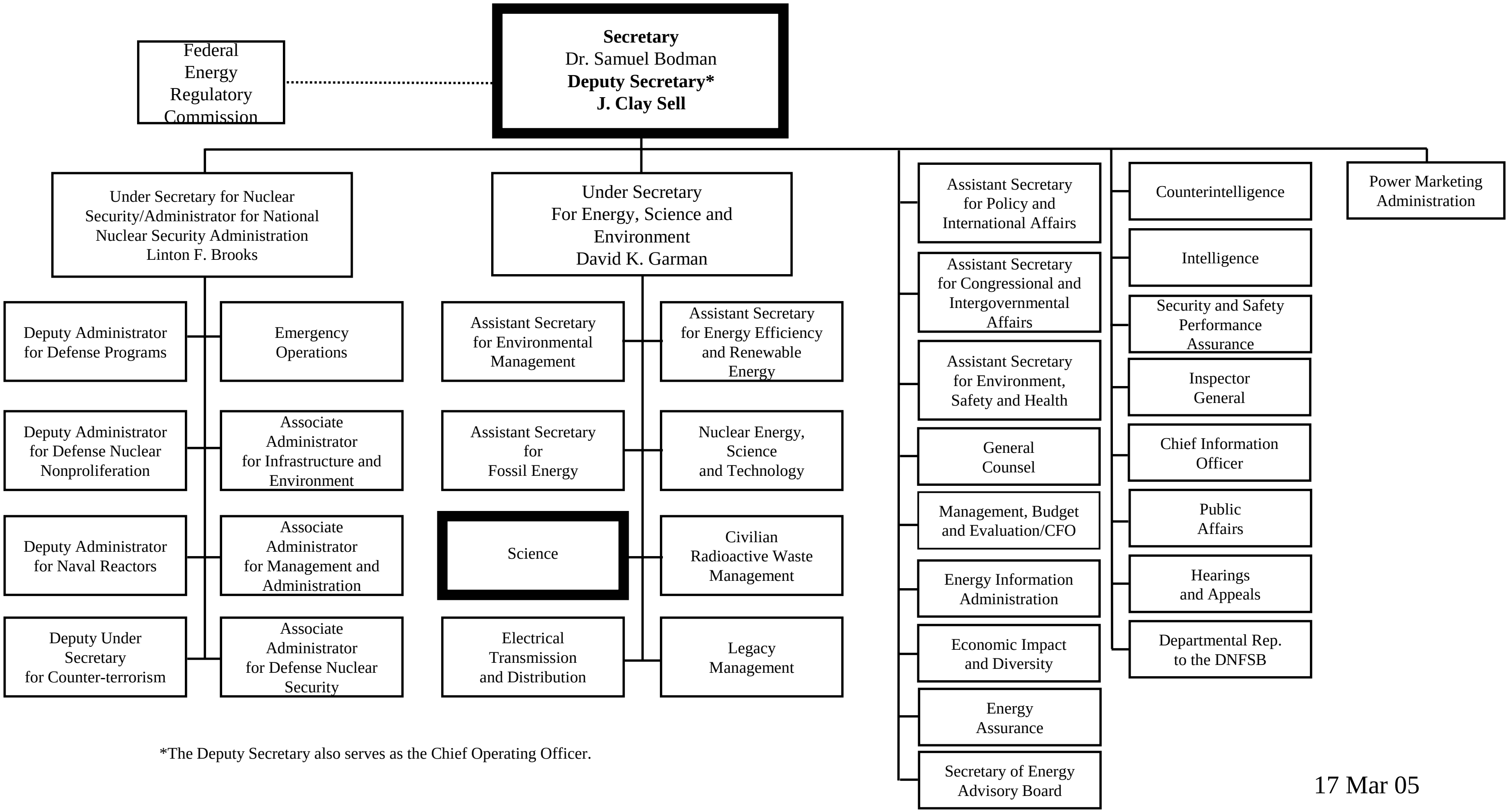
DEPARTMENTS

DEPARTMENT OF AGRICULTURE
DEPARTMENT OF COMMERCE
DEPARTMENT OF DEFENSE
DEPARTMENT OF EDUCATION
DEPARTMENT OF ENERGY
DEPARTMENT OF HEALTH AND HUMAN SERVICES
DEPARTMENT OF HOMELAND SECURITY
DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT
DEPARTMENT OF THE INTERIOR
DEPARTMENT OF JUSTICE
DEPARTMENT OF LABOR
DEPARTMENT OF STATE
DEPARTMENT OF TRANPORTATION
DEPARTMENT OF THE TREASURY
DEPARTMENT OF VETERANS AFFAIRS

INDEPENDENT ESTABLISHMENTS AND GOVERNMENT CORPORATIONS

AFRICAN DEVELOPMENT FOUNDATION
CENTRAL INTELLIGENCE AGENCY
COMMODITY FUTURES TRADING COMMISSION
CONSUMER PRODUCT SAFETY COMMISSION
CORPORATION FOR NATIONAL/COMMUNITY SERVICE
DEFENSE NUCLEAR FACILITIES SAFETY BOARD
ENVIRONMENTAL PROTECTION AGENCY
EQUAL EMPLOYMENT OPPORTURNITY COMMISSION
EXPORT-IMPORT BANK OF THE U.S.
FARM CREDIT ADMINISTRATION
FEDERAL COMMUNICATIONS COMMISSION
FEDERAL DEPOSIT INSURACE CORPORATION
FEDERAL ELECTION COMMISSION
FEDERAL HOUSING FINANCE BOARD
FEDERAL LABOR RELATIONS AUTHORITY
FEDERAL MARITIME COMMISSION
FEDERAL MEDIATION AND CONCILIATION SERVICE
FEDERAL MINE SAFETY AND HEALTH REVIEW COMMISION
FEDERAL RESERVE SYSTEM
FEDERAL RETIREMENT THRIFT INVESTMENT BOARD
FEDERAL TRADE COMMISSION
GENERAL SERVICES ADMINISTRATION
INTER-AMERICAL FOUNDATION
MERIT SYSTEMS PROTECTION BOARD
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
NATONAL ARCHIVES AND RECORDS ADMINISTRATION
NATIONAL CAPITAL PLANNING COMMISSION
NATIONAL CREDIT UNION ADMINISTRATION
NATIONAL FOUNDATION OF THE ARTS AND THE HUMANTIES
NATIONAL LABOR RELATIONS BOARD
NATIONAL MEDIATION BOARD
NATIONAL RAILROAD PASSENGER CORPORATION (AMTRAK)
NATIONAL SCIENCE FOUNDATION
NATIONAL TRANSPORTATION SAFETY BOARD
NUCLEAR REGULATORY COMMISSION
OCCUPATIONAL SAFETY AND HEALTH REVIEW COMMISION
OFFICE OF GOVERNMENT ETHICS
OFFIC EOF PERSONNEL MANAGEMENT
OFFICE OF SPECIAL COUNSEL
OVERSEARS PRIVATE INVESTMENT CORPORATION
PEACE CORPS
POSTAL RATE COMMISSION
RAILROAD RETIREMENT BOARD
SECURITIES AND EXCHANGE COMMISSION
SELECTIVE SERVICE SYSTEM
SMALL BUSINESS ADMINISTRATION
SOCIAL SECURITY ADMINISTRATION
TENNESSEE VALLEY AUTHORITY
TRADE AND DEVELOPMENT AGENCY
U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT
U.S. COMMISSION ON CIVIL RIGHTS
U.S. INTERNATIONAL TRADE COMMISSION
U.S. POSTAL SERVICE
PENSION BENEFIT GUARANTY CORPORATION

U.S. Department of Energy Headquarters



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

17 Mar 05

Office of Science

Budget and Planning
Ralph De Lorenzo

Director — *Raymond Orbach*
Principal Deputy — *James Decker*
Chief of Staff — *Jeffrey Salmon*

Deputy for

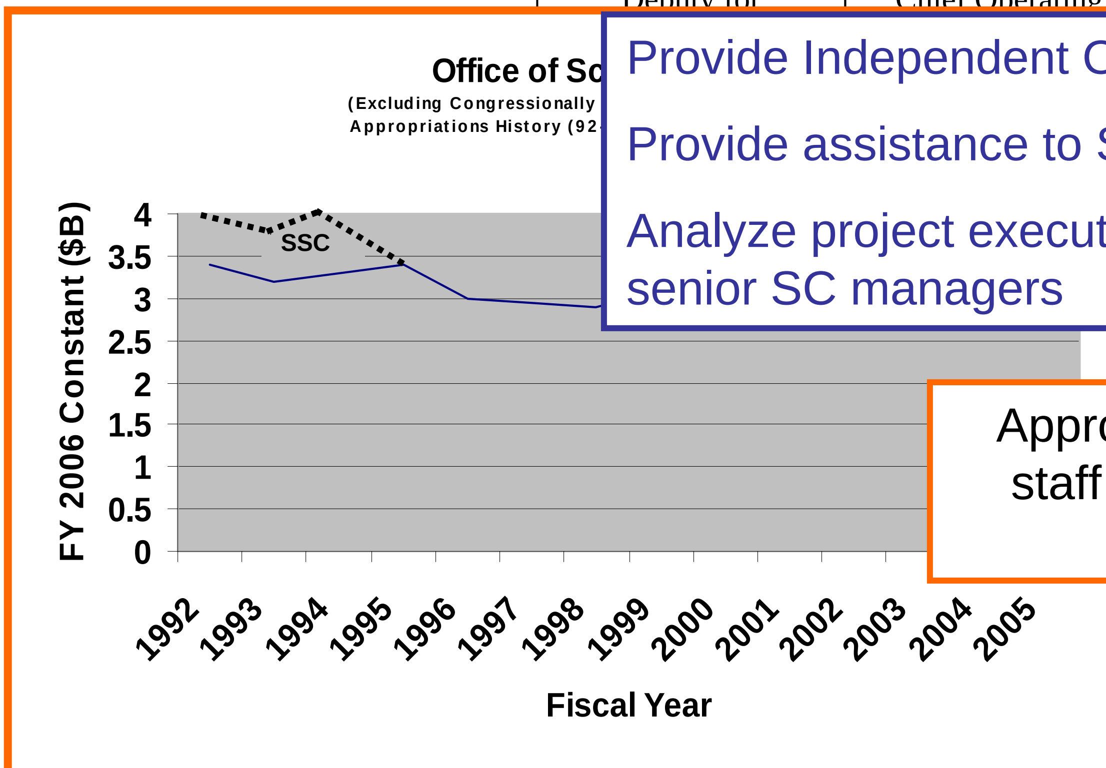
Chief Operating

Project Assessment
Daniel Lehman

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

Center

Science Education & Workforce Development
Raymond Orbach (A)

Site Office
Creig Zook (A)

Berkeley Site Office
Joseph Krupa (A)

Brookhaven Site Office
Michael Holland

Fermi Site Office
Joanna Livengood

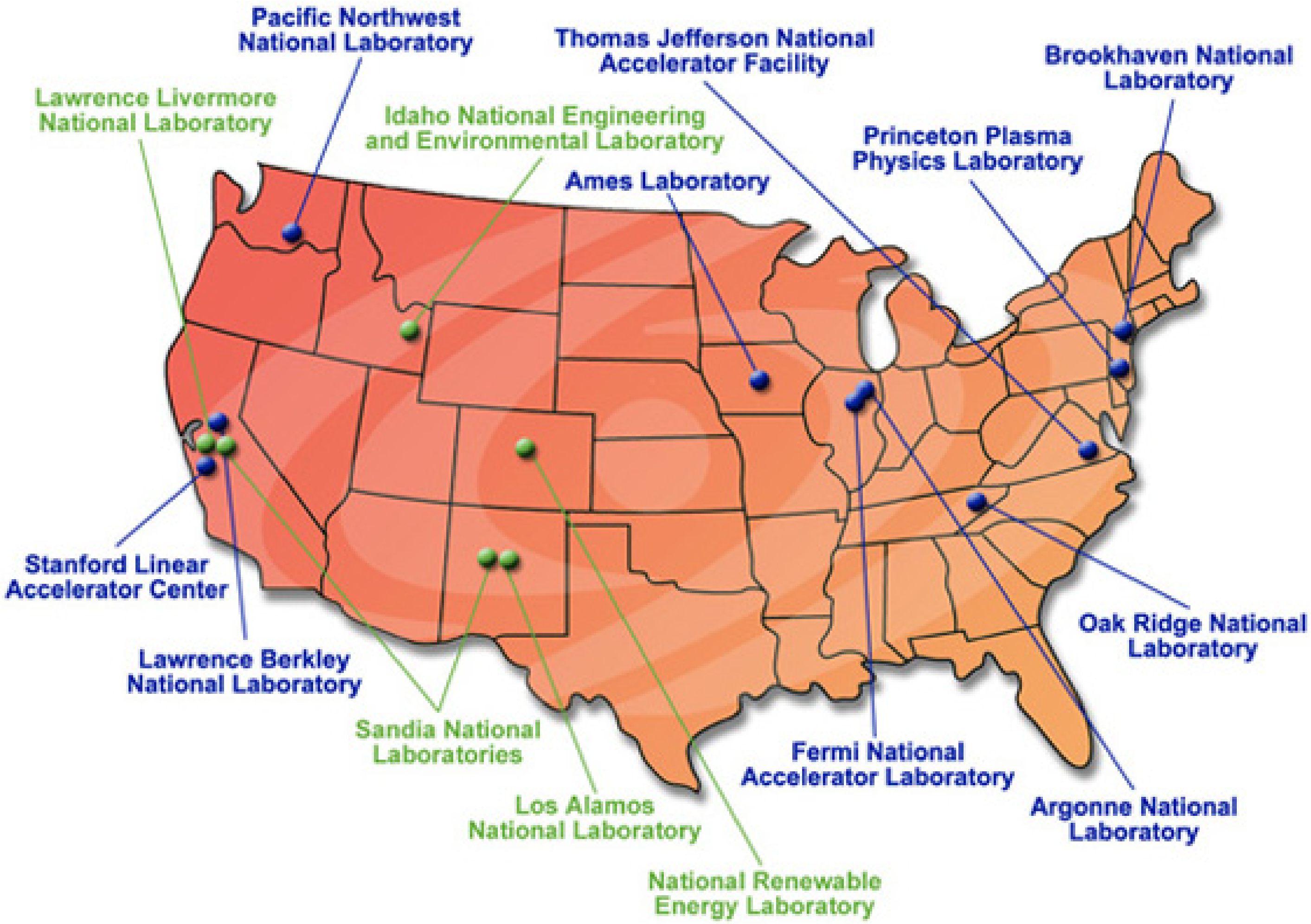
Pacific Northwest Site Office
Julie Erickson (A)

Princeton Site Office
Jerry Faul (A)

Stanford Site Office
Bob Wunderlich (A)

Thomas Jefferson Site Office
James Turi

National Laboratories



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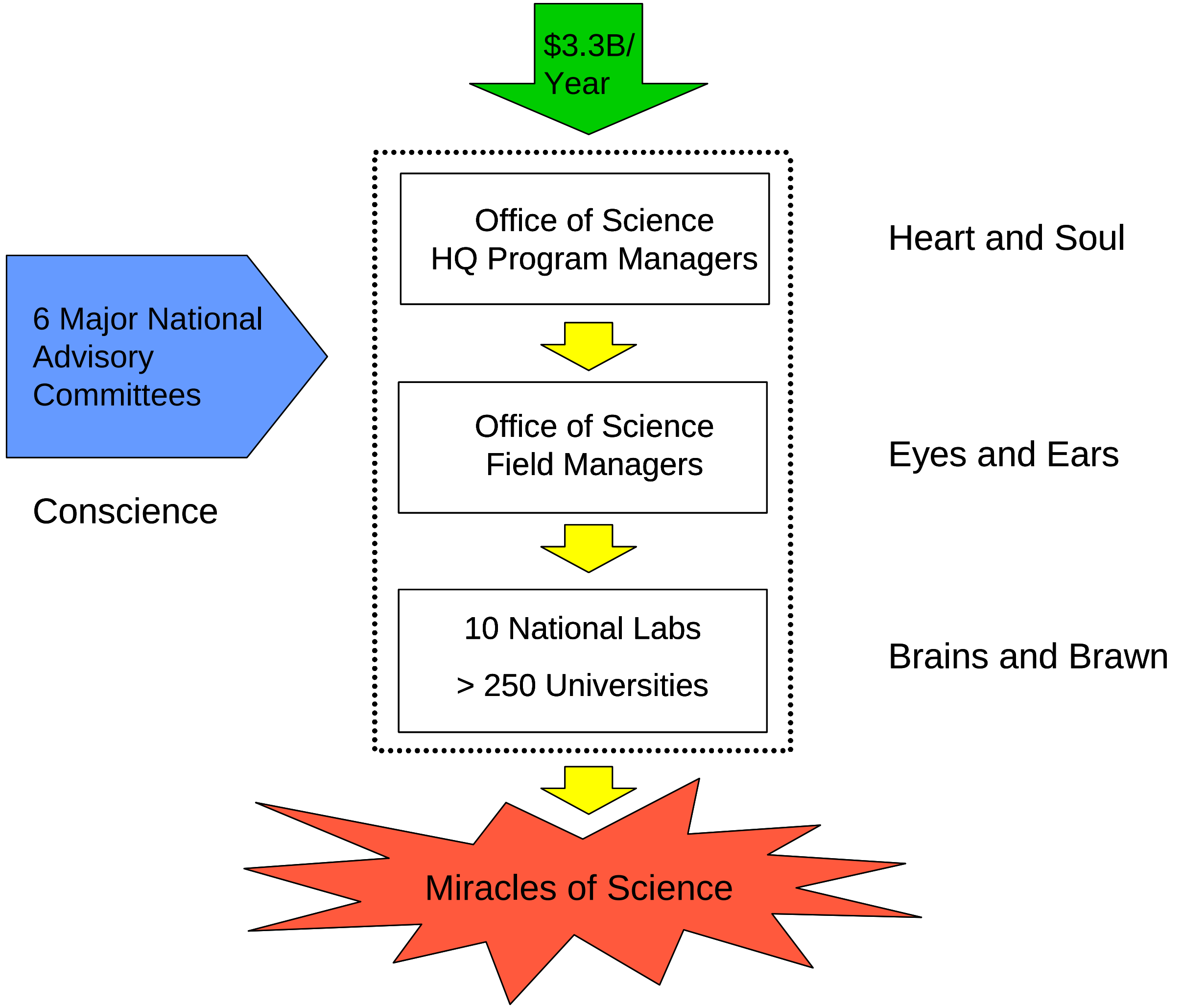
A Less Complex View



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

Organization	Total Projects	Total Project Cost
NNSA	64	$ 16.06B
EM	7	$ 6.94B
SC	33	$ 6.25B
NE	6	$ 0.43B
EE	2	$ 0.10B
FE	4	$ 1.07B
OE	2	$ 0.03B
LM	1	$ 0.01B
EH	1	$ 0.02B
RW	3	$ 10.1B
Sub-Total	123	$ 41.01B
EM- Operating Projects	76	$ 126.04B
Total DOE	199	$ 167.05B

Department of Energy Project Management Legacy

- 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

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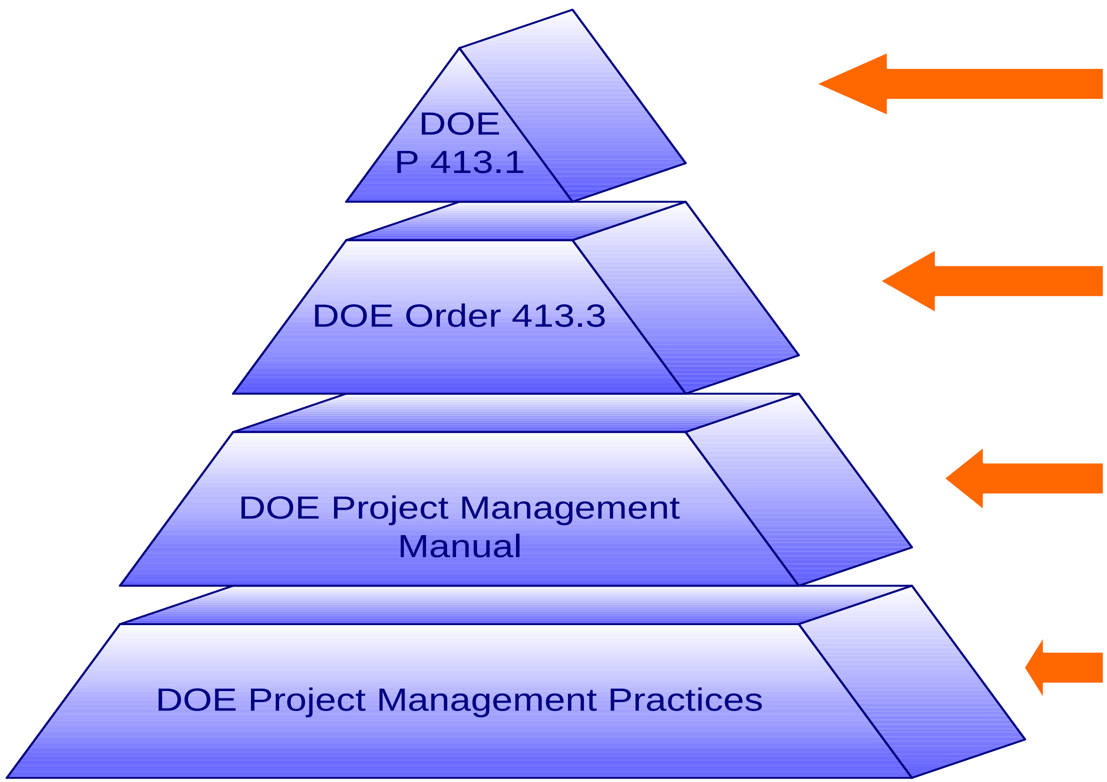
Department of Energy Project Management System



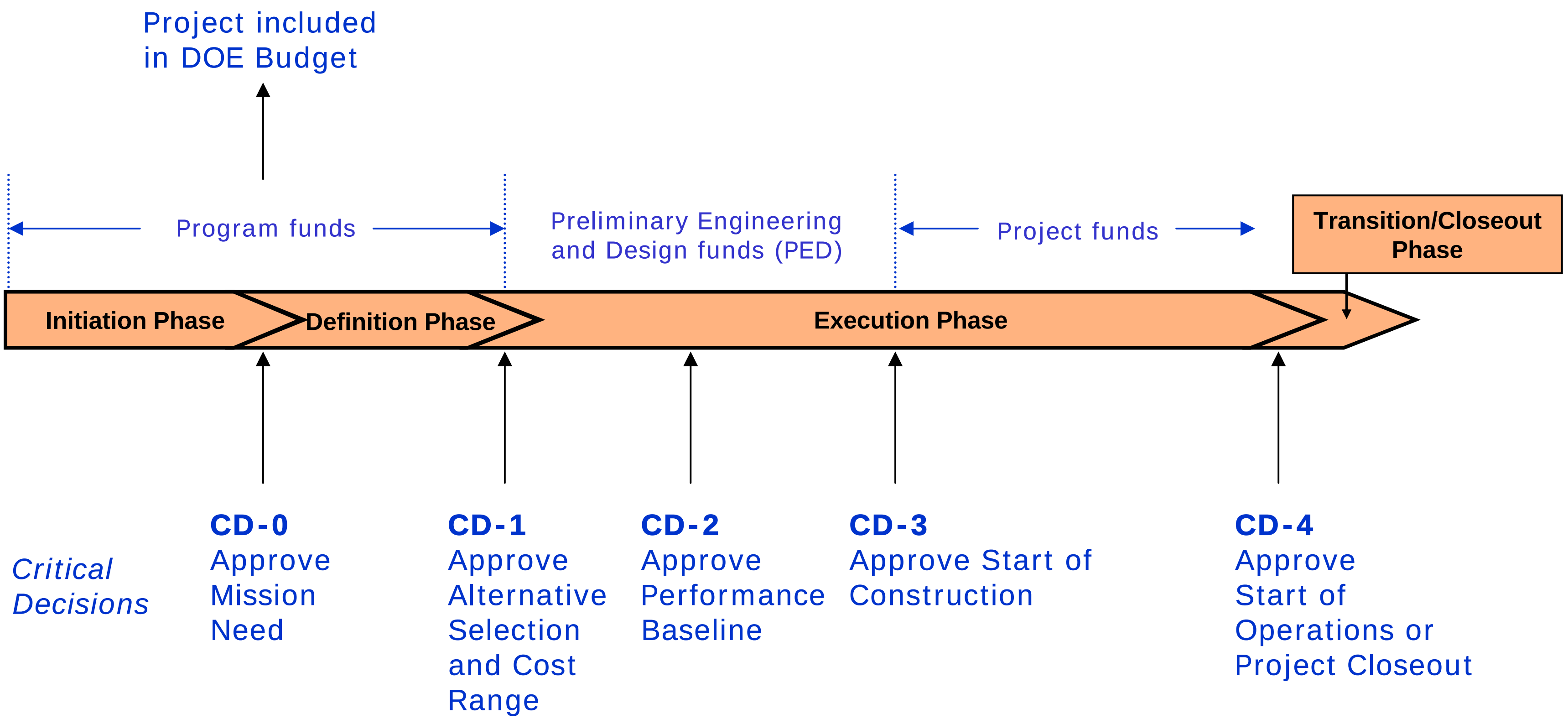
Establishes DOE Policy for Program and Project Management

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



Office of Science
Project Management Philosophy

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

Planning & Monitoring	Execution & Reporting
Federal Project Director	Contractor Project Manager
Assisted by:	Supported by:
Procurement, Financial Systems, Engineering, ES&H, Project Controls	Laboratory Staff, University Staff, Subcontractors

Evaluation/ Advice

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)

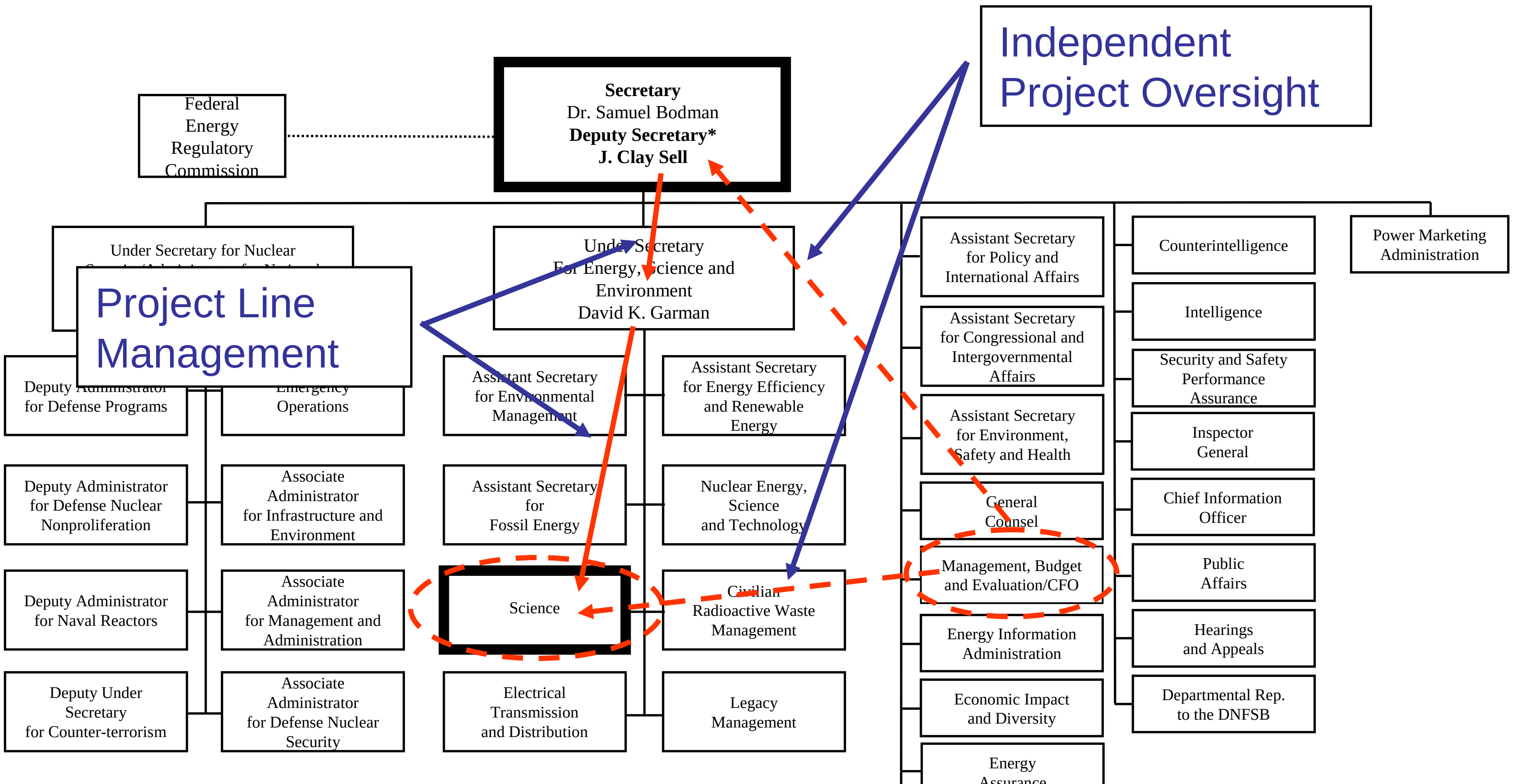
Government Accountability Office (GAO)

Inspector General (IG)

Office of Engineering and Construction Management (DOE-OECM)

SC Office of Project Assessment (SC 1.3)

U.S. Department of Energy Headquarters



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

17 Mar 05

Cost is carefully managed at every project phase

Project Phase (Critical Decisions) from DOE O 413.3	Financial Management Activity
Approve Mission Need (CD-0)	▪ Ensure preliminary budgetary estimate ranges are reasonable
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

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

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

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

U.S. Department of Energy

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Advanced Photon Source (APS) – *Successful Project*

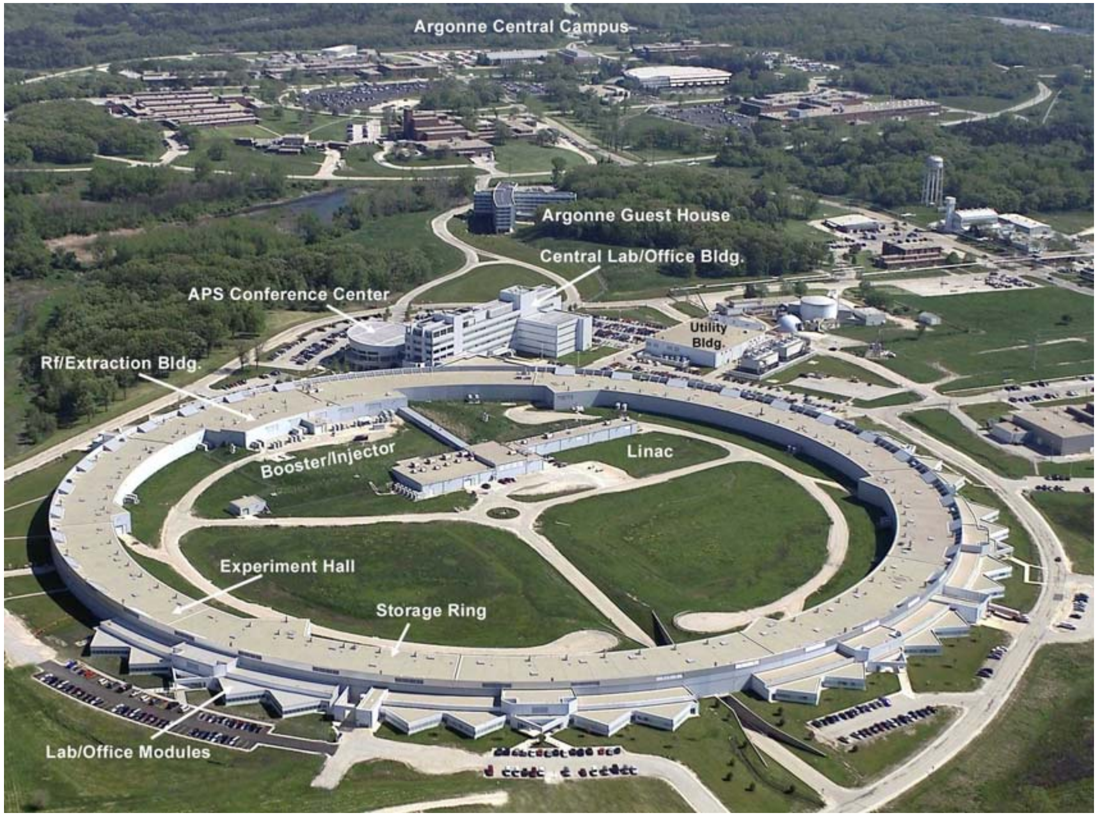
Purpose:
One of only three third-generation, hard x-ray synchrotron radiation light sources in the world to study the structure and properties of materials

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

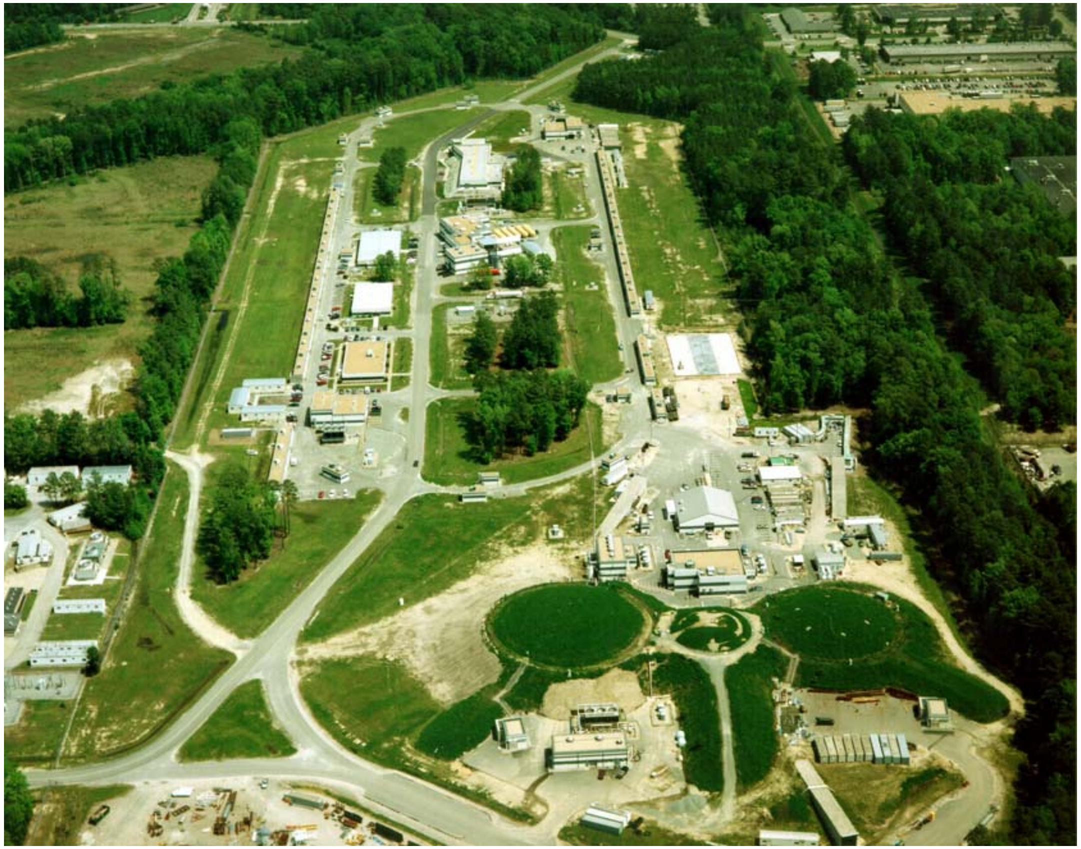
Purpose:
To understand how nuclear matter is formed from the more elementary particles (quarks). First superconducting electron accelerator built.

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

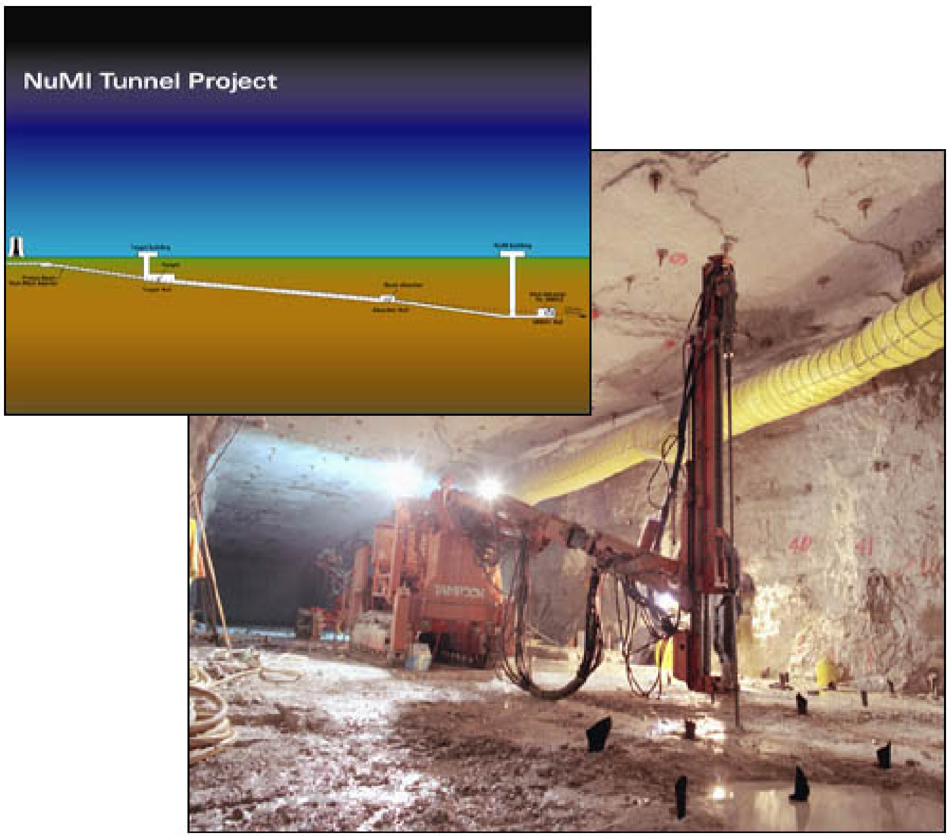
Total Project Cost:
$167.8M

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

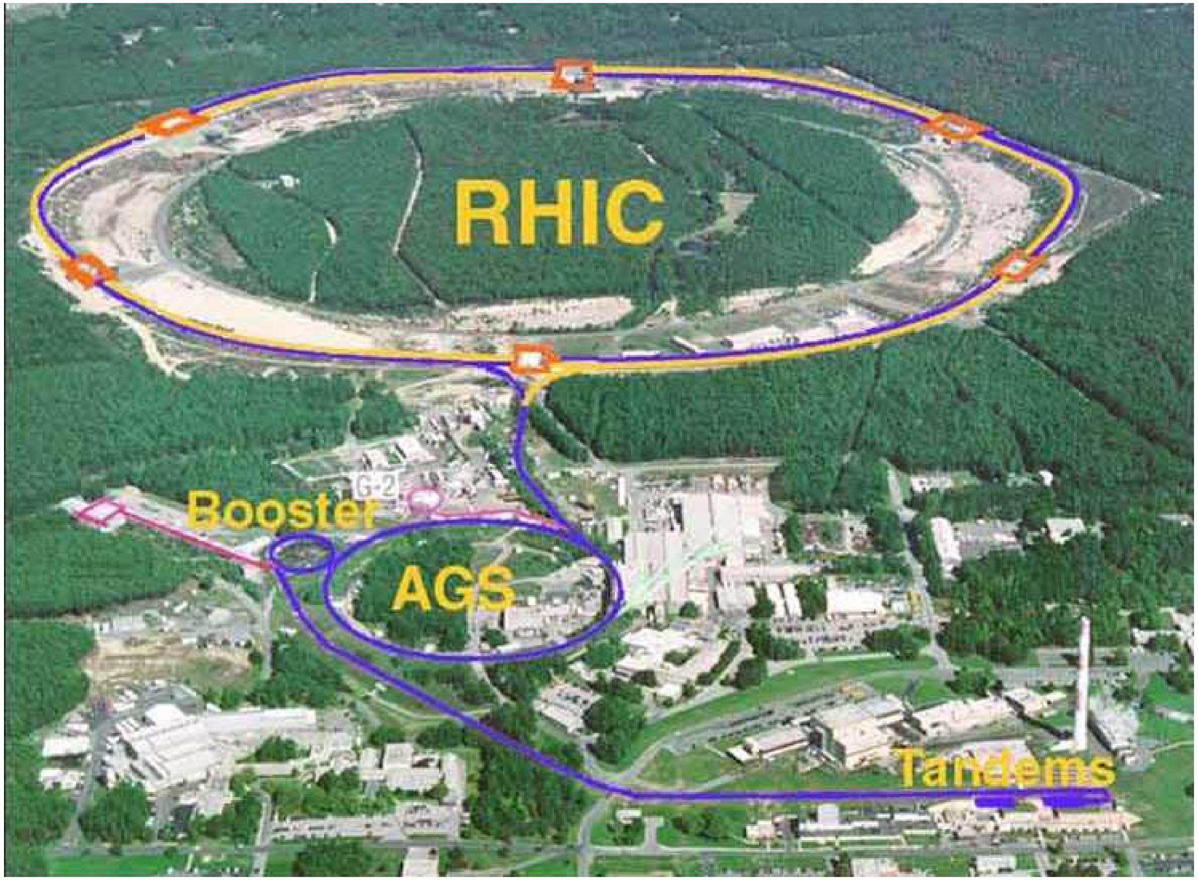
Total Project Cost:
$600 million

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



U.S. Large Hadron Collider Project (U.S. LHC) – *Successful Project*

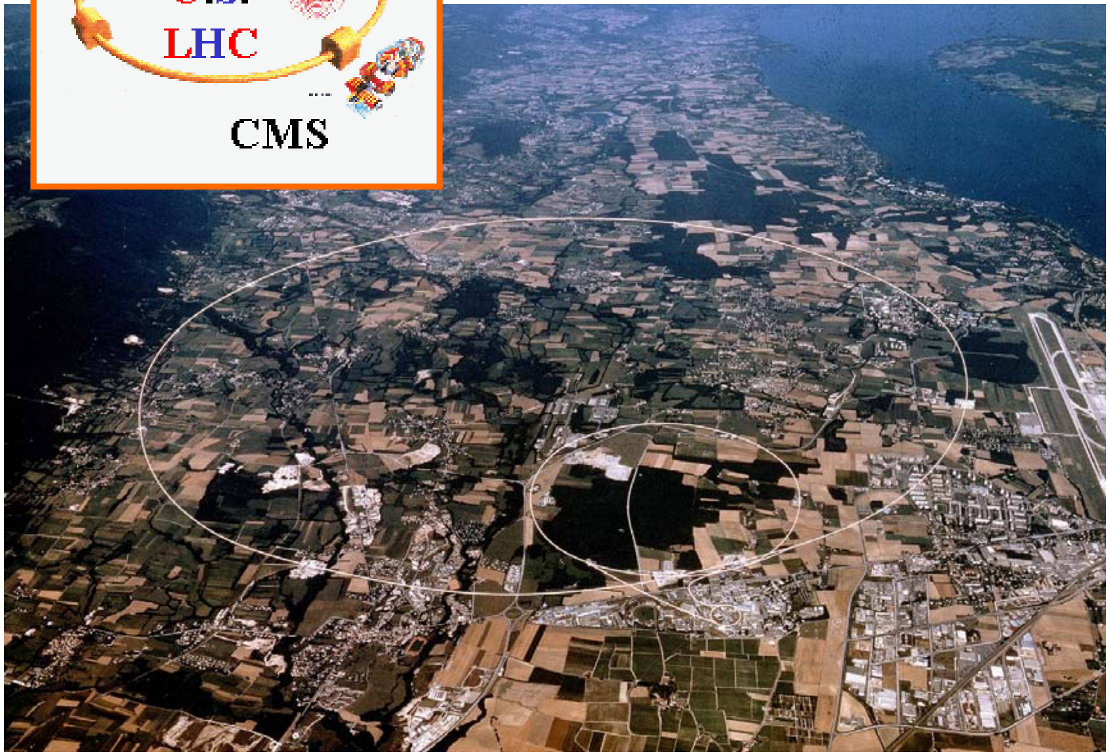
Purpose:
To collide two counter rotating proton beams, at a center-of-mass collision energy of 14 TeV. U.S. participates in construction of the accelerator and design, fabrication and operation of the CMS and ATLAS detectors.

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



U.S. LHC Lessons Learned

- 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

B Factory - Successful Project

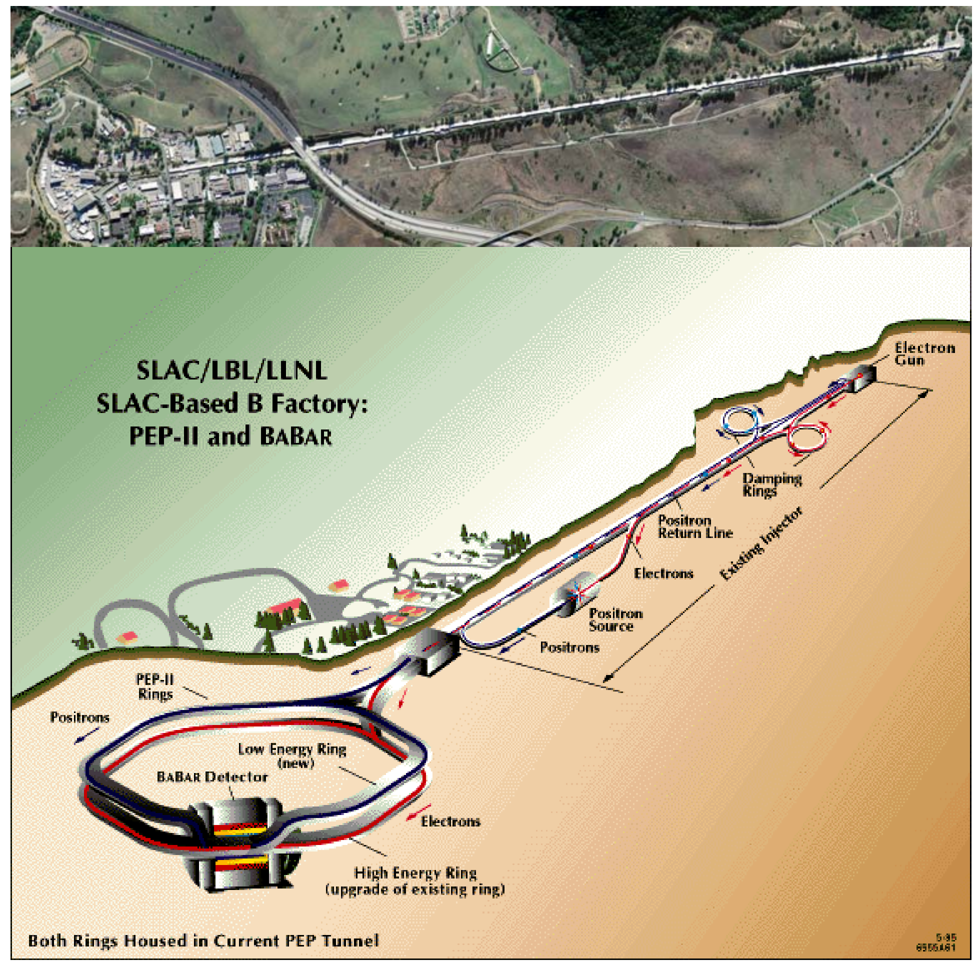
Purpose:
To create a facility for observing collisions of electrons and positrons with sufficient luminosity to measure the extent to which charge polarity conservation is violated in the decay of B-mesons.

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

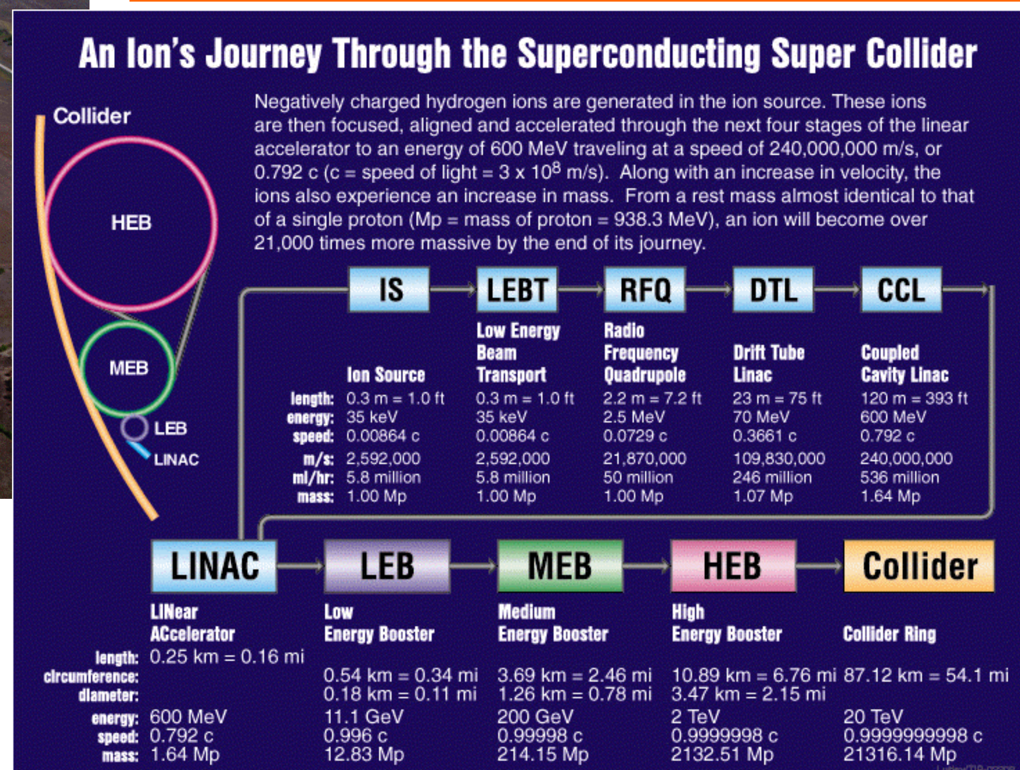
Superconducting Super Collider (SSC) - *Cancelled*

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

Summary of Lessons Learned

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

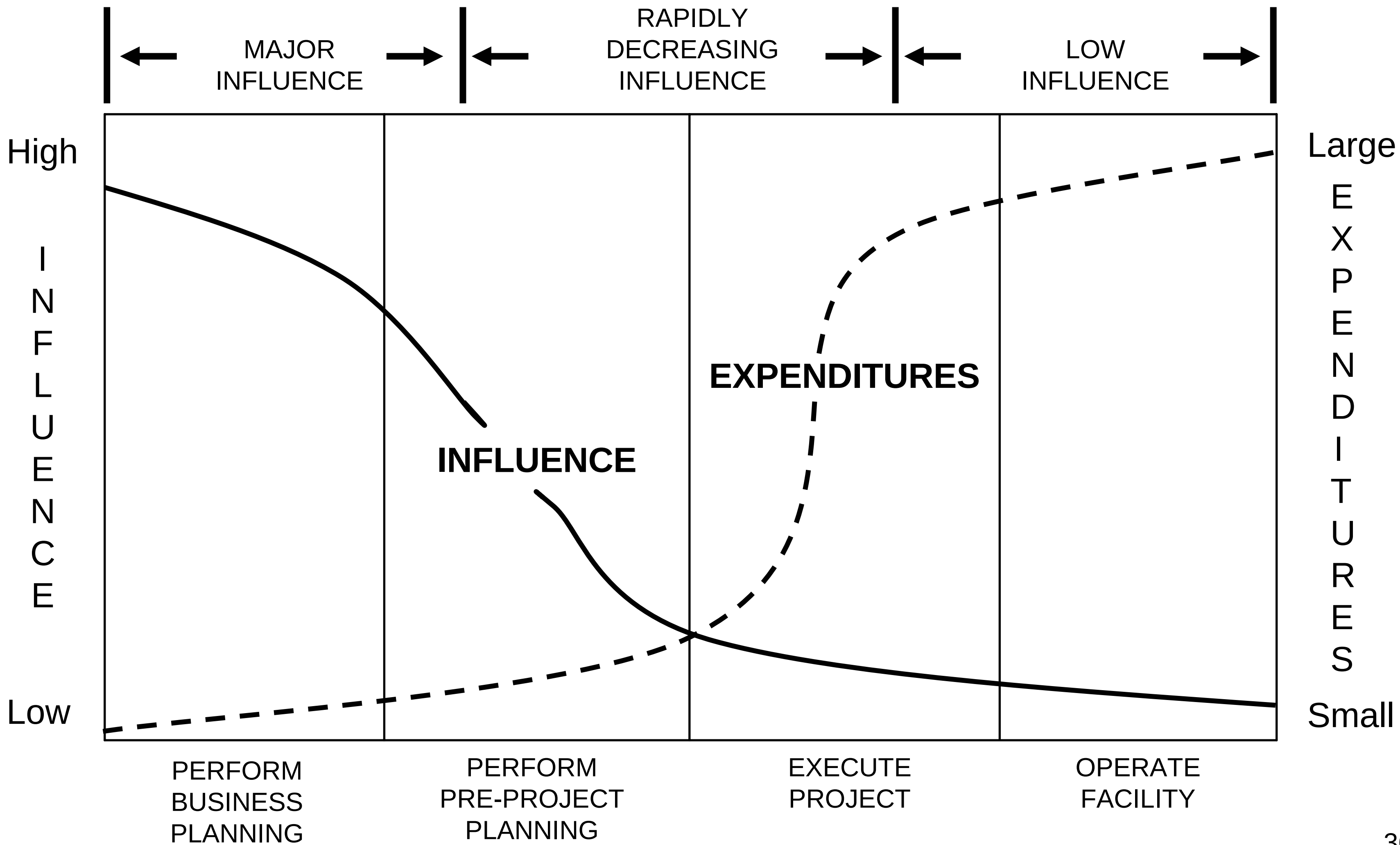
Early Planning

- 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



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

Mega Project Management Studies

Underestimating Costs in Public Works Projects

Error or Lie?

Bent Flyvbjerg, Mette Skamris Holm, and Søren Buhl

This article presents results from the first statistically significant study of cost escalation in transportation infrastructure projects. Based on a sample of 258 transportation infrastructure projects worth US$90 billion and representing different project types, geographical regions, and historical periods, it is found with overwhelming statistical significance that the cost estimates used to decide whether such projects should be built are highly and systematically misleading. Underestimation cannot be explained by error and is best explained by strategic misrepresentation, that is, lying. The policy implications are clear: legislators, administrators, investors, media representatives, and members of the public who value honest numbers should not trust cost estimates and cost-benefit analyses produced by project promoters and their analysts.

Flyvbjerg is a professor of planning with the Department of Development and Planning, Aalborg University, Denmark. He is founder and director of the university's research program on transportation infrastructure planning and was twice a Visiting Fulbright Scholar to the U.S. His latest books are *Rationality and Power* (University of Chicago Press, 1998) and *Making Social Science Matter* (Cambridge University Press, 2001). He is currently working on a book about megaprojects and risk (Cambridge University Press). **Holm** is an assistant professor of planning with the Department of Development and Planning, Aalborg University, and a research associate with the university's research program on transportation infrastructure planning. Her main interest is economic appraisal of projects. **Buhl** is an associate professor with the Department of Mathematics, Aalborg University, and an associate statistician with the university's research program on transportation infrastructure planning.

Journal of the American Planning Association, Vol. 68, No. 3, Summer 2002. © American Planning Association, Chicago, IL.

Comparative studies of actual and estimated costs in transportation infrastructure development are few. Where such studies exist, they are typically single-case studies or they cover a sample of projects too small to allow systematic, statistical analyses (Bruzelius et al., 1998; Fouracre et al., 1990; Hall, 1980; Nijkamp & Ubbels, 1999; Pickrell, 1990; Skamris & Flyvbjerg, 1997; Szyliowicz & Goetz, 1995; Walmsley & Pickett, 1992). To our knowledge, only one study exists that, with a sample of 66 transportation projects, approaches a large-sample study and takes a first step toward valid statistical analysis (Meurwitz, 1973a, 1973b).[1] Despite their many merits in other respects, these studies have not produced statistically valid answers regarding the question of whether one can trust the cost estimates used by decision makers and investors in deciding whether or not to build new transportation infrastructure. Because of the small and uneven samples used in existing studies, different studies even point in opposite directions, and researchers consequently disagree regarding the credibility of cost estimates. Pickrell (1990), for instance, concludes that cost estimates are highly inaccurate, with actual costs being typically much higher than estimated costs, while Nijkamp and Ubbels (1999) claim that cost estimates are rather correct. Below we will see who is right.

The objective of the study reported here was to answer the following questions in a statistically valid manner: How common and how large are differences between actual and estimated costs in transportation infrastructure projects? Are the differences significant? Are they simply random errors? Or is there a statistical pattern to the differences that suggests other explanations? What are the implications for policy and decision making regarding transportation infrastructure development?

R-3560-PSSP

Understanding the Outcomes of Megaprojects

A Quantitative Analysis of Very Large Civilian Projects

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

March 1988

Supported by the
Private Sector Sponsors Program

40 Years 1948-1988

RAND

EXP 016 0001

The Results Group — Strategy • Change • Development

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 Wright, Managing Partner, The Results Group
Sara Tickler, Senior Partner, The Results Group
Matthew Stevens, Senior Consultant, The Results Group
Maureen Perry, Research Librarian, The Results Group
Ellen Moratti, MPP, EM Analytics
Tracy Johnson, P.E. Senior Consultant, URS Corporation
John James, President, James Transportation Group
Darrell Vice, P.E. Senior Engineering Consultant, James Transportation Group
Steve Cox, P.E., S.E. Executive Vice-President, Winder and Kelly Consulting Engineers

819 Sonoma Avenue, Santa Rosa, CA 95404 • 707-577-0818 • www.TheResultsGroup.com

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!**