Discussion of the DOE 20-year Roadmap

John Corlett
LBNL

ANL Theory Institute on Production of Bright Electron Beams
25 September 2003

Outline of talk

- DOE Basic Energy Sciences (BES) Strategic Planning
- Basic Energy Sciences Advisory Committee (BESAC) subcommittee on 20-year facilities roadmap
- BESAC subcommittee report
    - Cross-cutting needs
- BES facility needs for 2005 and beyond

DOE & SC Strategic Planning

Department of Energy

(Office of Science)

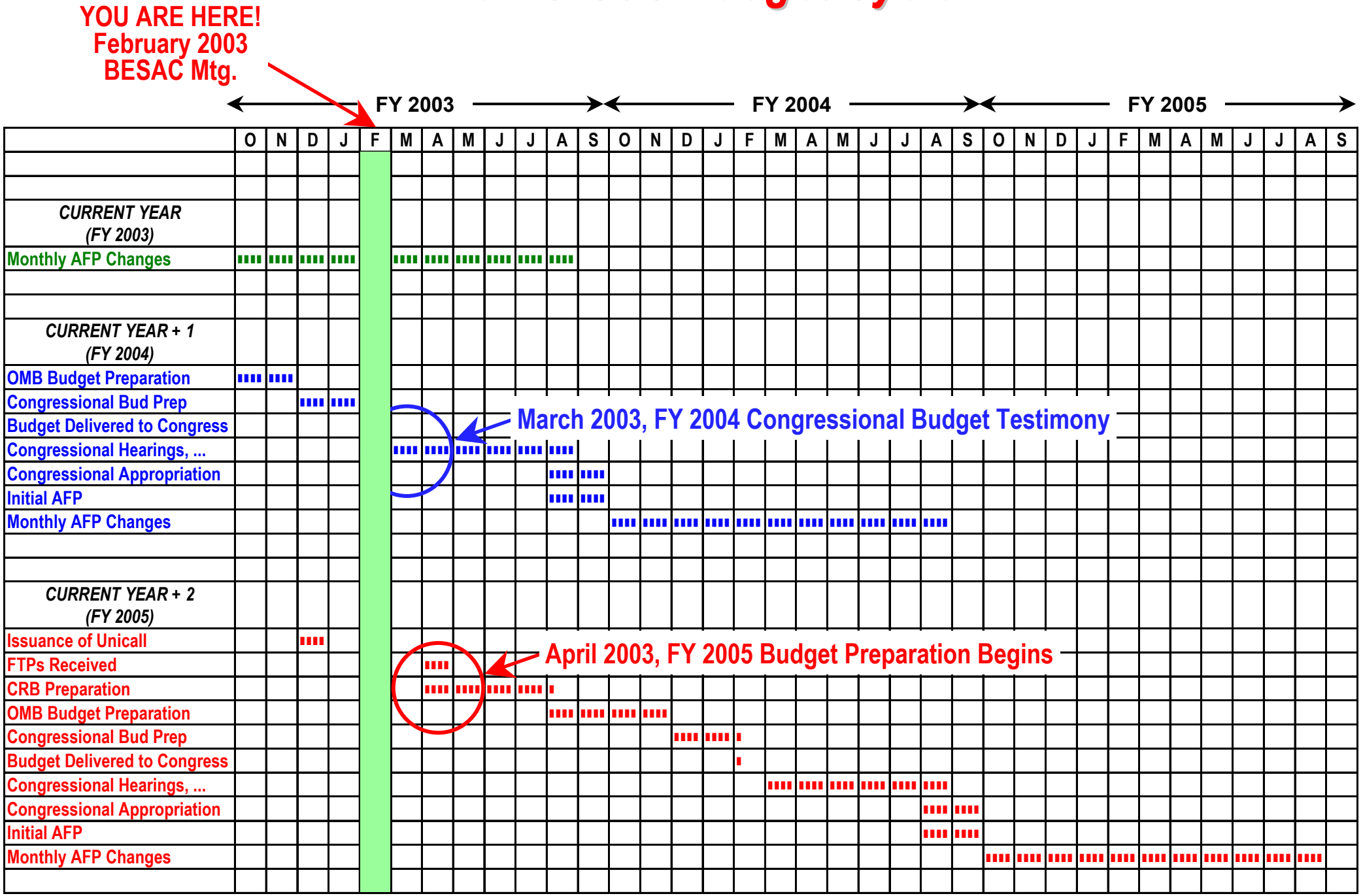
- 25-year time horizon
- Organized around 15-20 goals, with several relevant to SC including scientific research, science facilities, and a number of crosscutting management goals

Office of Science

- 5 to 10-year time horizon
- Organized around compelling, exciting science, with additional focus on facilities and science management

http://www.science.doe.gov/bes/besac/BESAC_Dehmer_02-25-03.ppt

The DOE/SC Budget Cycle



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Background

- Summer 2002 – Ray Orbach requests that each Associate Director (AD) of the Office of Science (SC) develop a 20-year plan for facilities using input from Advisory Committees, NRC studies, community workshops, etc.

- November 2002 – The five SC ADs present a total of 53 upgrades and new facilities to Ray Orbach

SC staff put together the list of new facilities

- December 2002 – Ray Orbach charges each Advisory Committee with assessing these plans by March 2003.

- December 2002 – A BESAC Subcommittee is formed in response to the charge to BESAC. The Subcommittee is co-chaired by Geri Richmond and Sunil Sinha.

- February 2003 – BESAC Subcommittee meets to hear 11 proposals from BES facilities

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Included in the BES Plan Were 11 New/Upgraded Facilities

11 Facilities

- **Neutron Scattering Facilities**
  - *SNS – Power upgrade*
  - *SNS – Second target station*
  - *HFIR – Second guide hall*
- **Photon Scattering Facilities**
  - *LCLS*
  - *LCLS upgrade*
  - *Linac-based femtosecond source*
  - *NSLS upgrade*
  - *APS upgrade*
  - *ALS upgrade*
  - *Green-field XFEL*
- **Electron Scattering Facilities**
  - *TEAM*

Some Supporting Material

- **Neutron Scattering – recent background**
  - *BESAC Russell, Birgeneau, Aeppli, Crow, Plummer reports*
  - *OSTP IWG report*
- **Photon Scattering – recent background**
  - *BESAC Birgeneau/Shen report*
  - *BESAC Leone report*
  - *Many BESAC discussions on LCLS*
- **Electron Scattering – recent background**
  - *BESAC Stringer report*

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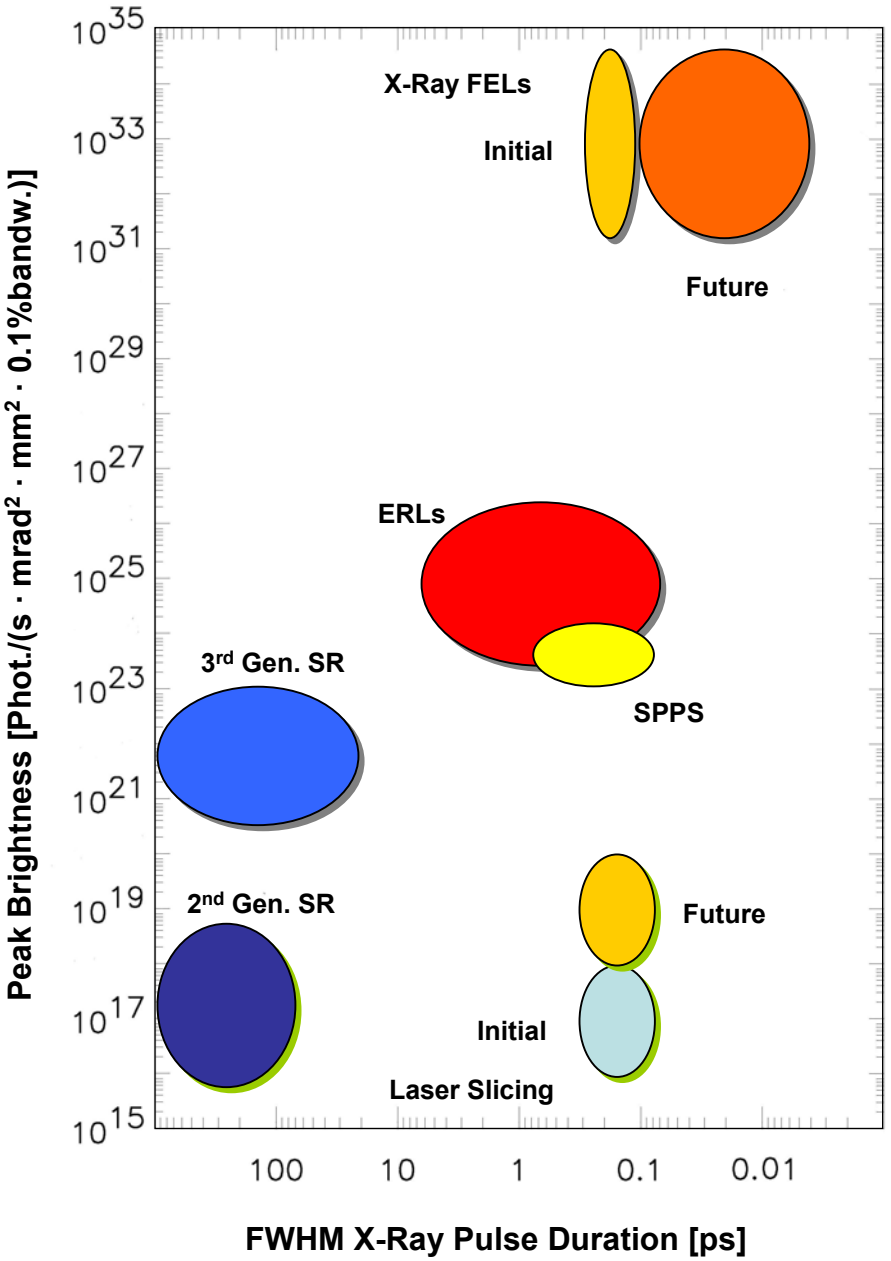
Current and Proposed Light Sources

- 2nd and 3rd generation Synchrotron Radiation (SR) light sources are today's workhorses. About 150 beamlines are operational with the capability of adding about 50 more at the new sources (ALS, APS). The number of users could reach 10,000.
- The long pulse length – hundreds of picoseconds – of 2nd and 3rd generation sources limits their usefulness for the study of fast processes. Sources that are much more intense and have shorter pulse lengths hold the promise for remarkable new discoveries.
- Energy Recovery Linacs (ERLs) are more intense than SR light sources, have high repetition rates, and can serve many beam lines. ERLs can be optimized for short pulses or high brightness - but it is very challenging to do both.
- X-ray Free Electron Lasers (XFELs) can achieve extreme peak brightness and ultrashort pulse lengths.



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Basic Energy Sciences Advisory Committee

Subcommittee to Assess 20-Year BES Facilities Plans

20-Year BES Facilities Roadmap Workshop

February 22-24, 2002

Doubletree Hotel and Executive Meeting Center
1750 Rockville Pike
Rockville, MD 20852

http://www.science.doe.gov/bes/besac/BESAC_Sinha_Richmond_02-25-03.ppt


Greenfield FELs
John Galayda, SLAC
Kwang-Je Kim, ANL (Presenter)
James Murphy, BNL
BESAC Subcommittee on
BES 20-year Facility Road Map
February 22-24, 2003

Subcommittee Members

- Geri Richmond, U of Oregon (Co-Chair)
- Sunil Sinha, UCSD (Co-Chair)
- Nora Berrah, Western Michigan U. (BESAC)
- Joe Bisognano, Synchrotron Radiation Center, Wisc.
- Collin Broholm, Johns Hopkins (BESAC)
- Phil Bucksbaum, U. of Michigan (BESAC)
- Jack Crow, National Magnetic Lab, Florida
- Pascal Elleaume, European Synchrotron Rad. Fac., France
- Eric Isaacs, Bell Labs/Lucent (BESAC)
- Gabrielle Long, NIST (BESAC)
- Gerhard Materlik, Diamond Light Source Ltd.
- Les Price, ORO
- Kathy Taylor, Retired GM (BESAC)

BESAC committee + advisors

Technical Representatives

- ANL-- Robert Kustom
- BNL-- Jim Murphy
- LBNL-- Howard Padmore
- ORNL-- Norbert Holtkamp
- PNNL-- Ray Doug
- SLAC-- Max Cornacchia
- TJNAF-- Swapan Chattophadhyay

Each Lab represented

Key Points of the Charge

Importance of the science

- the extent to which the proposed facility would answer the most important scientific questions;
- whether there are other ways or other facilities that would be able to answer these questions;
- whether the facility would contribute to many or few areas of research;
- whether construction of the facility will create new synergies within a field or among fields of research;
- what level of demand exists within the scientific community for the facility.

Categorize as "absolutely central," "important," and "don't know enough yet," according to the potential importance of their contribution.

Readiness of the facility

- whether the concept of the facility has been formally studied in any way;
- the level of confidence that the technical challenges involved in building the facility can be met; the sufficiency of R&D performed to-date to assure technical feasibility of the facility; the extent to which the cost to build and operate the facility is understood.

Categorize according to their readiness as "ready to initiate construction," "significant scientific/engineering challenges to resolve before initiating construction," and "mission and technical requirements not yet fully defined."

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Organization of Facility Types

- ***Light Source Facilities***
- **Neutron Scattering Facilities**
- **Other Facilities**
- ***Cross-cutting issues***

http://www.science.doe.gov/bes/besac/BESAC_Sinha_Richmond_02-25-03.ppt

Light Sources

- Upgrade Initiative
  - Advanced Light Source (ALS)
  - Advanced Photon Source (APS)
  - National Synchrotron Light Source (NSLS)
- New facilities
  - Linac Coherent Light Source (LCLS)
  - LCLS II
  - "Green-field" X-ray Free Electron Laser (XFEL)
  - Linac based Ultrafast X-ray source (LUX)
  - Thomas Jefferson Lab Infrared FEL
  - Coherent Infrared Center at the ALS (CIRCE)
  - APS super storage ring
  - NSLS third generation ring

High priority

Pursue R&D with emphasis on future science opportunities

Develop science agenda and user needs

Develop concept

Develop proposal

http://www.science.doe.gov/bes/besac/BESAC_Sinha_Richmond_02-25-03.ppt

Cross Cutting Issues

- Detectors and other instrumentation
- Electron gun development
- Superconducting short period undulators
- Energy recovery LINAC (ERL) development

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BESAC Subcommittee Workshop Report on 20-Year Basic Energy Sciences Facilities Roadmap

Co-Chaired by:

Geraldine Richmond, BESAC Chair
University of Oregon

and

Sunil Sinha
University of California, San Diego

February 22-24, 2003

Doubletree Hotel and Executive Meeting Center
1750 Rockville Pike
Rockville, MD 20852

http://www.sc.doe.gov/production/bes/BESAC/20year_facilities_report.pdf

Cross Cutting Issues

As scientists across the nation utilize US facilities, they currently experience an urgent need for optimized instrumentation to make best use of the intense X-ray and neutron beams available there. While the 1996 Facility Instrumentation Initiative significantly strengthened the facilities and enabled important advances in science, a large subset of instruments remain inadequate for utilizing the bright beams that are now available. It is therefore time for a new instrumentation initiative to enable advances in detector performance and other advanced instrumentation that will allow scientific breakthroughs. The BESAC Subcommittee recommends that development in the following areas be a priority:

electron gun technology
detector technologies
cutting edge end stations
automation
robotics
energy recovery linacs (ERLs)
superconducting short period undulators

Training of personnel in development of a broad range of scientific instrumentation, and particularly in accelerator design, is an important cross cutting issue that must be effectively addressed.

http://www.sc.doe.gov/production/bes/BESAC/20year_facilities_report.pdf

5. Cross Cutting Issues

Electron Gun Development

The evolution of light sources toward diffraction limited radiation at high energy, to sub-picosecond photon pulse lengths, and with FEL operation places increasingly stringent demands on the three dimensional phase space density of the electron beam. For linear accelerators, these performance requirements translate directly into the necessity of smaller emittance, higher charge bunches generated at the electron gun. In addition, increased repetition rates at the gun allow higher average flux, multiple undulator end stations, and ultimately the generation of storage-ring-class currents in energy recovery linacs. Also, with lowered emittance, the resulting higher gain will enable important cost savings. For example, undulator lengths and electron beam energy could be reduced.

The critical enabling technology to advance linac-based light sources is the electron gun. At low repetition rates, the present RF photocathode technology generates 1 mm-mrad normalized emittance bunches with a charge of a nanocoulomb at 100 Hz repetition rates. For projects such as an LCLS upgrade to higher energy photons or for the “Greenfield” FELs, emittances at the 0.1 mm mrad level will be necessary to increase photon beam energies to 30 keV and above. Repetition rates to tens of kilohertz are envisioned for optimal facility performance. Performance enhancements in RF photocathode guns are crucial to advanced FELs and extended capability undulator sources such as LUX.

For energy recovery linear accelerators, improvements of injector performance to 100 mA average current at 1 mm mrad emittance will yield photon beam specifications possibly bettering that obtainable in the storage ring approach to 4th generation light sources. The shorter bunch lengths inherent in linac beams, into the femtosecond regime, offer another potential benefit. For an ERL, the current state of the art at 10 mm mrad at 100 pC bunch charge at 10 mA average current (100 MHz repetition rates) needs to be extended to 1 mm mrad at 100 mA (1 GHz repetition rates). The current technology of DC photocathode guns may yield these gains, but work on RF and superconducting RF guns should also be pursued.

These order of magnitude improvements in electron guns (DC, RF, and superconducting RF) will allow qualitative advances in light sources capabilities at reduced costs. They are the highest-leveraged technology for next generation light sources. The BESAC Subcommittee recommends that DOE BES strongly support and coordinate research and development in this unique and critical technology. The strengths and core competencies of Office of Science laboratories (and also across agency boundaries) should be integrated into a comprehensive high performance national electron gun R&D program.

http://www.sc.doe.gov/production/bes/BESAC/20year_facilities_report.pdf

5. Cross Cutting Issues (cont'd)

Energy Recovery Linac (ERL) Development

The DOE BES should take a lead role in the development of the basis for energy recovery linear accelerators (ERL), which may outperform the conventional hard X-ray storage ring sources envisioned for a decade from now in both brightness and short bunches. Given that ERLs might be a competitive technology for 4th generation light sources, the BESAC Subcommittee recommends that DOE BES actively support ERL research and development.

An ERL R&D program would address the following key issues to demonstrate whether or not it is a viable technology for future light sources:

1. Electron gun development (the top priority), as discussed in the electron gun development section of the report.
2. Developing of superconducting RF cavities with sufficient damping for 100 mA beams, both from beam breakup and energy deposition points of view.
3. Energy recovery at high average current and high energy.
4. Energy recovery with the manipulations of phase space envisioned for light source optimization (e.g., bunch compression, transverse deflection, chirping), given the adiabatic antidamping (i.e., increase) of the beam geometric emittance and relative energy spread as the beam is decelerated for energy recovery.
5. Stability of ERL sources, with sufficient diagnostics of ERL performance through the generated photon beam.

In general, the strengths and core competencies of Office of Science laboratories (and across agency boundaries) should be integrated into a comprehensive ERL R&D program.

http://www.sc.doe.gov/production/bes/BESAC/20year_facilities_report.pdf

Additional Important Recommendations:

Workforce for the Future

Looking to the future of DOE facility design, implementation and operation, a highly educated scientific and technological workforce is critical. We recommend that every effort be made to retain our current workforce and to recruit and train the next generation of the best minds to build and exploit the capabilities of these world-class facilities. This includes the training of accelerator physicists. The success of these facilities is determined by the quality of the scientists and engineers that design, operate, and use these facilities. It is imperative that DOE address workforce infrastructure issues on the same level of priority that they address construction and operation issues in order to realize the full range of outstanding opportunities that these future facilities offer.

http://www.sc.doe.gov/production/bes/BESAC/20year_facilities_report.pdf

In April 2003 BES request Light Sources describe their activities given three cases for a new facilities initiative

BES Facility Needs for FY 2005 and Beyond

INSTRUCTIONS:

Describe your highest priority facility needs for FY 2005 and beyond within three funding cases:

1) a 15% increase in operating funds in FY 2005 over those in FY 2004
2) a 25% increase in operating funds in FY 2005
3) additional needs above a 25% increase

Assume that the *FY 2005 increment* would increase 3% per year after FY 2005. For the first two cases, please use the budget figures provided for your facility on the attached table.

Each of the four BES Light Sources proposed the same R&D plan under *case 3*

BES Facility Needs for FY 2005 and Beyond

4. Common R&D Needs ("Case 3")

There are important R&D needs that lie beyond the capability of any one facility but which are common to all. The four DOE light sources propose the following important and mutually beneficial collaborations as part of the upgrade initiative (Case 3). Here is a budget summary

Dollars in Thousands									
Data from President's FY04 Request				INCREMENTS above FY 2004 President's request					
				(Constant FY 04 dollars)					
FY 2002	FY 2003 Request	FY 2004 Request	*Options*	FY 2005	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010
182,759	189,418	199,067	**3) >25%**	**21,400**	**22,000**	**22,700**	**23,400**	**24,100**	**22,000**
Detector R&D				**4,000**	**4,100**	**4,200**	**4,400**	**4,500**	**4,600**
SC Undulator				**2,400**	**2,500**	**2,500**	**2,600**	**2,700**	
Accel Phys				**2,000**	**8,000**	**10,000**	**10,300**	**10,600**	**10,900**

The amounts requested include the combined funding for all four DOE light sources to conduct this R&D, and are in addition to the funds requested for Cases 1 and 2. Funds have been escalated by 3% per year.

Common request from each light source

BES Facility Needs for FY 2005 and Beyond

4.3 Accelerator Physics and Training

We propose an R&D program in accelerator physics studies essential to extending the frontiers of light source capabilities. Targeting critical accelerator physics and enabling technology developments, these programs are aimed at order of magnitude improvements in performance over current capabilities. Four areas are targeted to address the critical issues:

(1) Electron gun/compression systems – novel designs, cathode performance, laser systems, systems integration, and reliability. Goals: low emittance guns < 0.5 mm-mrad at 1 nC, peak current > 1 kA, and high-power gun repetition rates > 10 kHz.

(2) Synchronization of ultrafast x-ray pulses with pump laser systems and development of ultra-stable optical timing systems and diagnostics. Goals: synchronization of10 fs.

(3) Cascaded high-gain harmonic-generation in FEL's. Goals: demonstration of two-stage harmonic generation radiating at less than 200 nm.

(4) Accelerator physics studies, including, FEL modeling, manipulations of phase space, techniques for short-wavelength FEL seeding, diffraction limited rings, positional feedback and diagnostics and permanent magnet lattices. Goals: physics designs for facilities with increased intensity, stability, coherence, and flexibility.

Each of the above items requires significant investment, and following an initial $2M to develop concepts and plans, a sustained budget of $8-10M per year would support an integrated program across multiple laboratories, and state-of-the-art systems providing training of skilled accelerator experts as the workforce of tomorrow.

To support the accelerator R&D request, a white paper commissioned by the Light Source directors is to be submitted to BES

Development of Accelerator Technologies to Enhance the Scientific Reach of National Synchrotron Radiation Facilities

A White Paper

John Corlett (LBNL)
John Galayda (SLAC)
Kwang-Je Kim (ANL)
James Murphy (BNL)

Four areas are targeted initially:

(1) Electron guns - novel designs, cathode studies, laser systems, and reliability. Goals: low emittance guns < 0.5 mm-mrad at 1 nC, peak current > 1 kA, and high-power gun repetition rates > 10 kHz.

(2) Synchronization of ultrafast x-ray pulses with pump laser systems and development of ultra-stable optical timing systems and diagnostics. Goals: synchronization of10 fs.

(3) Cascaded high-gain harmonic-generation in FEL's. Goals: demonstration of two-stage harmonic generation radiating at less than 200 nm.

(4) Accelerator physics studies, including, FEL modeling, manipulations of phase space, techniques for short-wavelength FEL seeding, diffraction limited rings, positional feedback and diagnostics and permanent magnet lattices. Goals: physics designs for facilities with increased intensity, stability, coherence, and flexibility.

Office of Science *Strategic Plan* and *Science Portfolio*

The Office of Basic Energy Sciences is a major research program within the DOE's Office of Science (organizationchart). The Office of Science will issue a new *Strategic Plan* in 2003, and DOE will also substantially revise its Strategic Plan in 2003.

The 20-year plan is not yet released (as of 09/23/02)

Strategic Plan

The schedule for release of the SC Strategic Plan has been changed to mid-September. The scope of the Plan has expanded to include a detailed facilities component spanning a 20-year planning horizon. The facilities component is now being reviewed and approved by SC's advisory committees, DOE senior management, the OMB and congressional staff. Final integration will take place following these reviews, and publication of the full SC Strategic Plan will occur shortly thereafter.

http://www.sc.doe.gov

Summary comments

BES has a plan for facilities that appears to commit funds for facilities through roughly the end of the decade

Longer range plans have been reviewed and prioritized

The DOE 20-year plan is not yet released

Where the BES plans for future light sources fall within this is not public information as yet

The BESAC committee has recognized the importance of accelerator science and technology to the future of BES facilities

The BES light source directors reflect that in a common request for accelerator R&D

The community has an opportunity to increase support for accelerator R&D – white paper in preparation