U.S. DEPARTMENT OF ENERGY | Office of Science

Comments from DOE's Office of Science

Superconducting Particle Accelerator
Forum of the Americas
December 11, 2013

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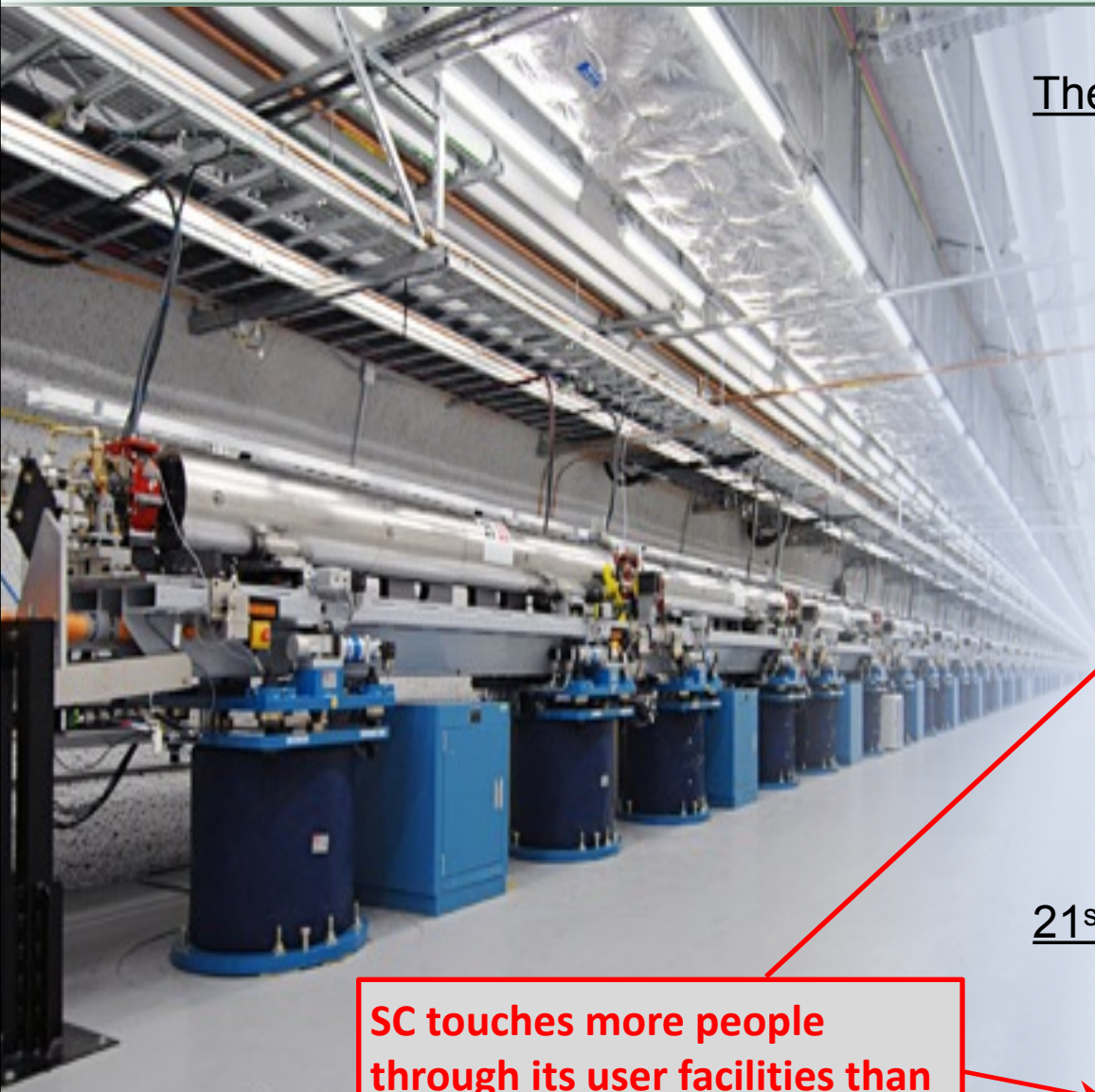
Acting Director, Office of Science, U.S. Department of Energy
http://www.science.energy.gov/sc-2/presentations-and-testimony/

Office of Science



The Frontiers of Science

- Supporting research that led to over 100 Nobel Prizes during the past 6 decades—more than 20 in the past 10 years
- Supporting 25,000 Ph.D. scientists, graduate students, undergraduates, engineers, and support staff at more than 300 institutions
- Providing 45% of Federal support of basic research in the physical and energy related sciences and key components of the Nation's basic research in biology and computing

21st Century Tools of Science

- Providing the world's largest collection of scientific user facilities to over 29,000 users each year

SC touches more people through its user facilities than it does through direct funding

Office of Science Budget by Research & Facilities

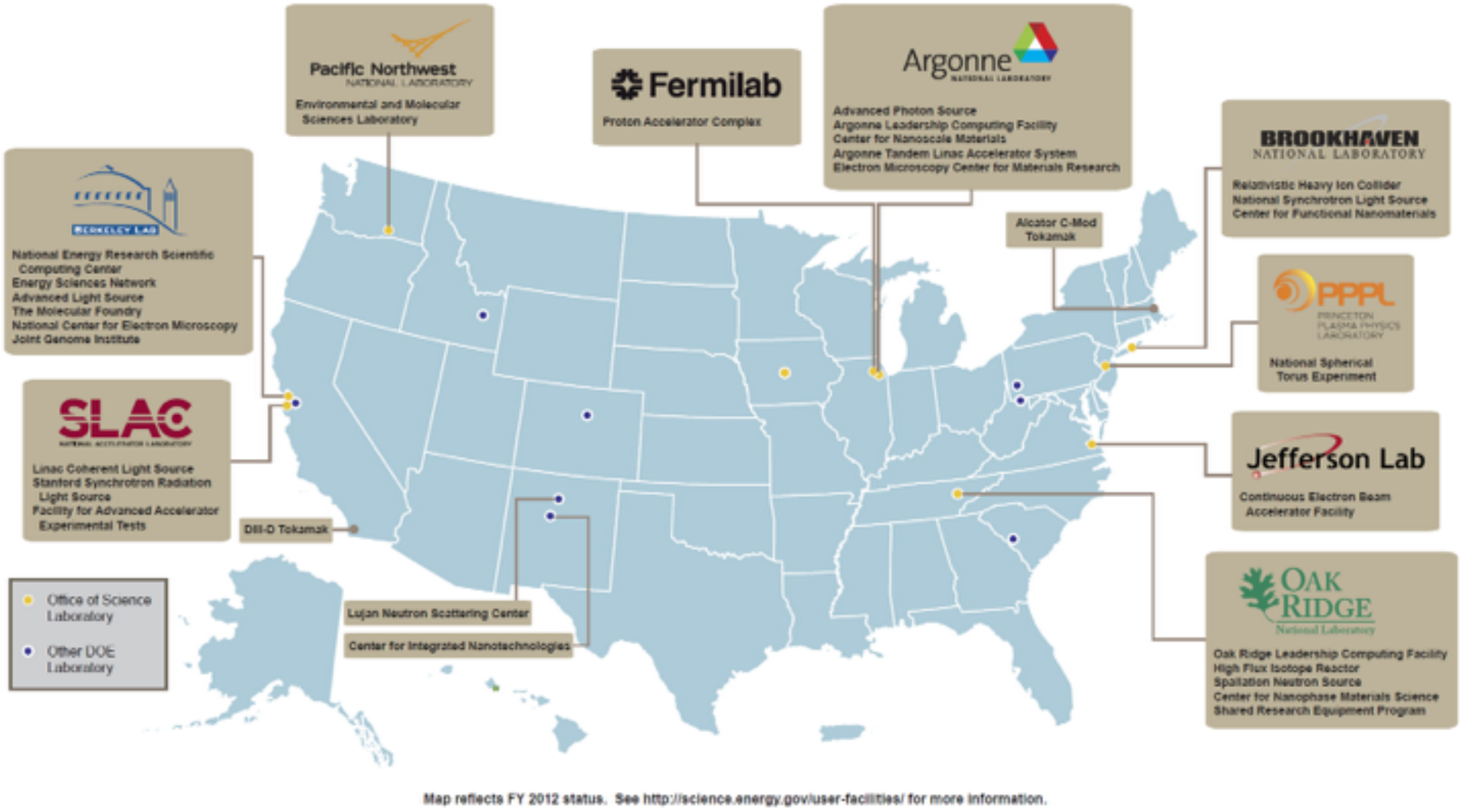
>40% of SC funding is provided to the scientific user facilities

User facilities address needs of the scientific community not met by other government agencies, public organizations, private entities, or international bodies.

Some of the Office of Science User Facilities

NuMI Beamline, FNAL; NERSC Computing Center, LBNL; NSTX, PPPL; STAR Detector, RHIC, BNL; APS, ANL; SNS SC linac, ORNL; NSLS-II, BNL,

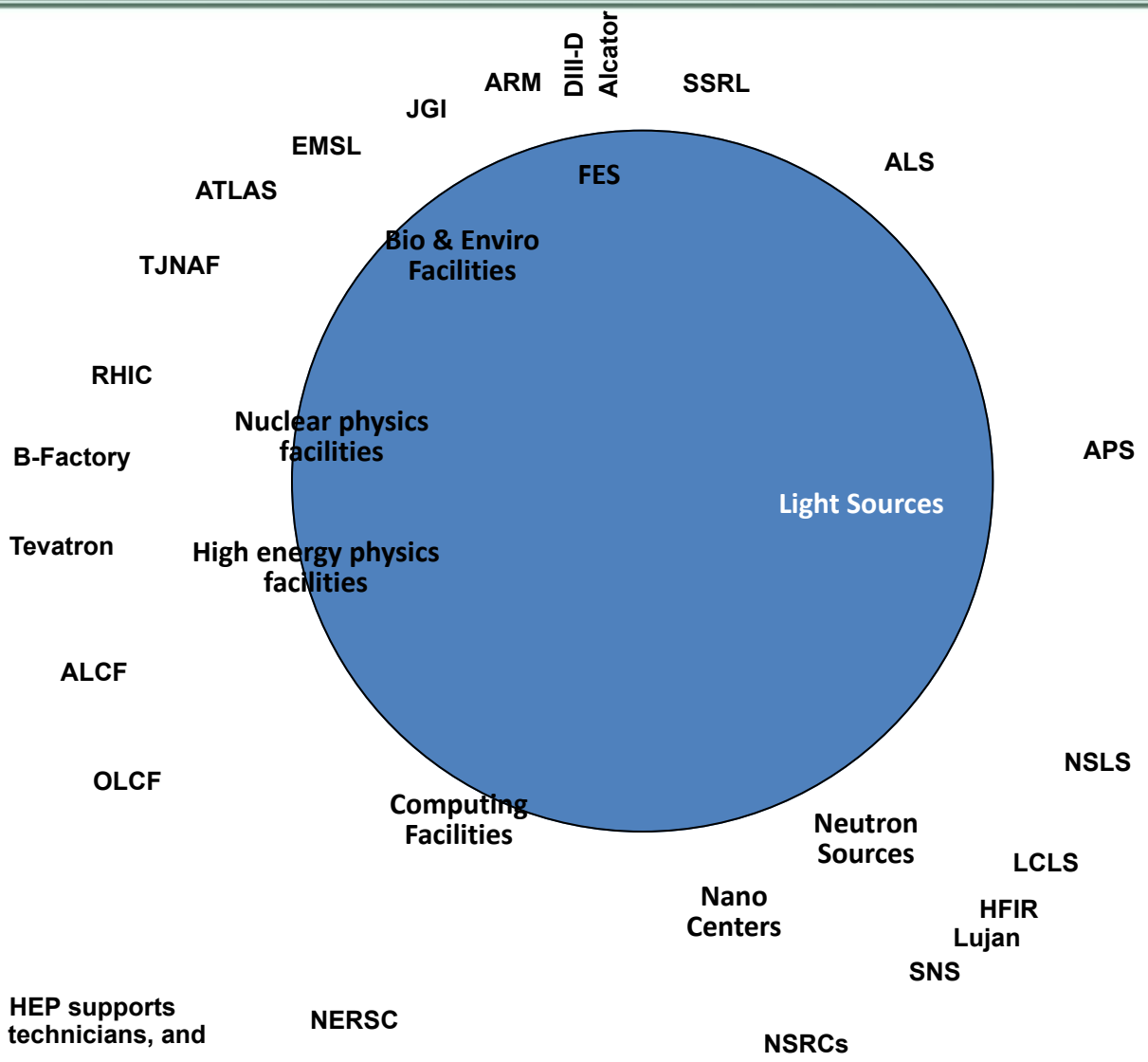
SC User Facilities and the DOE Laboratories



Map reflects FY 2012 status. See http://science.energy.gov/user-facilities/ for more information.

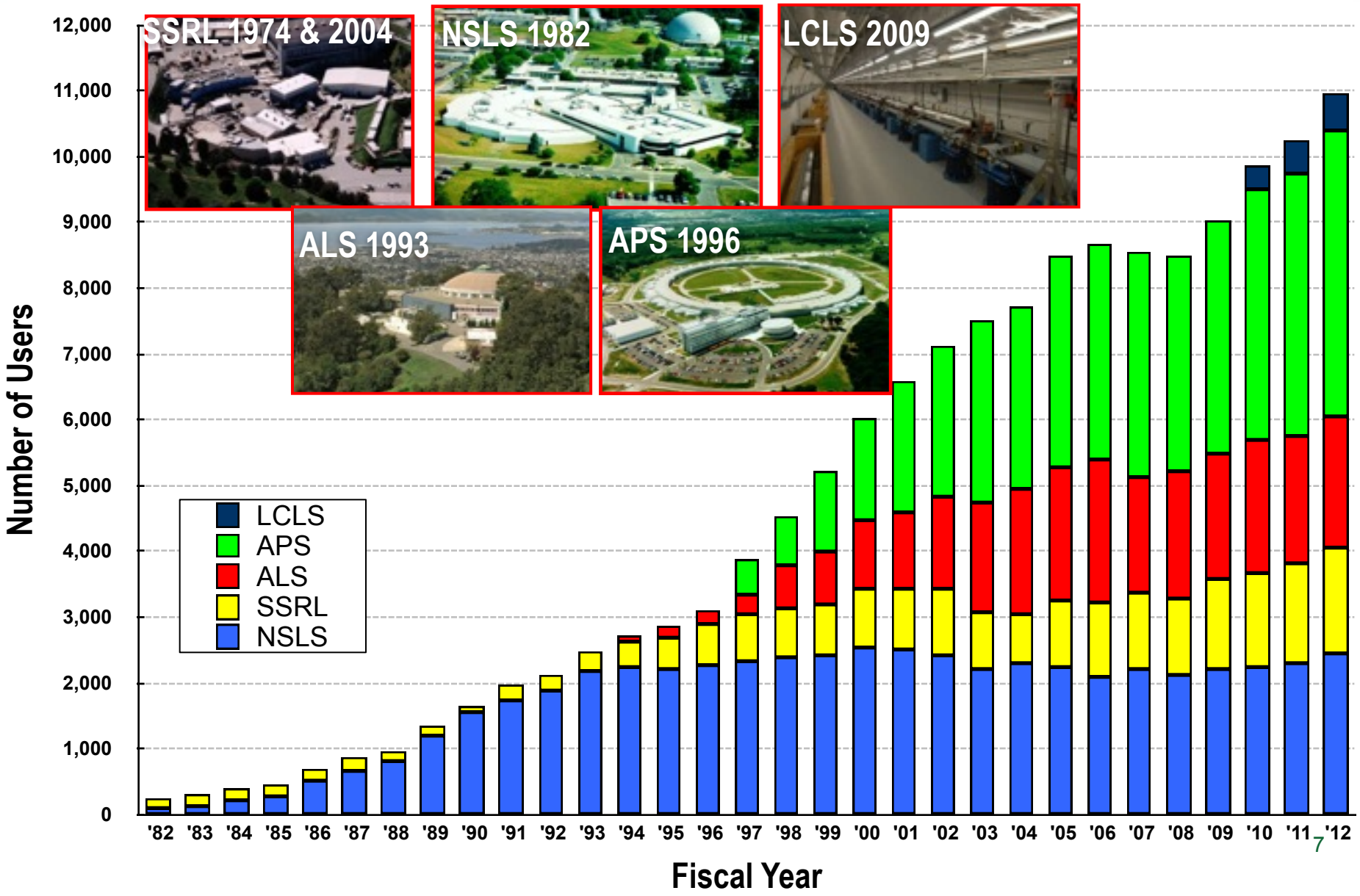
Distribution of Users at the ~30 SC Facilities

Nearly ¾ of users do their work at ASCR or BES facilities



Does not include LHC; HEP supports about 1,700 scientists, technicians, and engineers at the LHC.

Users by Facility at the Light Sources



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BESAC Report on "Future X-Ray Light Sources" and the DOE Actions

Snippets from the BESAC Light Source Report

Patricia Dehmer
Acting Director, Office of Science

Harriet Kung
Director, Office of Basic Energy Sciences

Jim Murphy
Director, BES Scientific User Facility Division

Charge to BESAC on X-ray Light Sources

- On January 2, 2013, Bill Brinkman, then the Director of the Office of Science, issued a charge to the Basic Energy Sciences Advisory Committee (BESAC).
- The charge requested:
  - An **assessment of the grand science challenges** that could best be explored with current and possible future SC light sources.
  - An **evaluation of the effectiveness of the present SC light source portfolio** to meet these grand science challenges.
  - An **enumeration of future light source performance specifications** that would maximize the impact on grand science challenges.
  - **Prioritized recommendations** on which future light source concepts and the technology behind them are best suited to achieve these performance specifications.
  - Identification of **prioritized research and development initiatives** to accelerate the realization of these future light source facilities in a cost effective manner.
- John Hemminger, the Chair of BESAC, served as Chair of a 22 member Subcommittee, which used previous BESAC and BES reports and new input from the x-ray sciences communities to formulate findings and recommendations.
- The final report was accepted by BESAC on July 25, 2013.

BESAC – Findings

- At the present time, the U.S. enjoys a significant leadership role in the x-ray light source community. This is a direct result of the successes of the major facilities managed by BES for the U.S. This leadership position is due to the science successes of the storage ring facilities and the particularly stunning success of the first hard x-ray free electron laser, the Linac Coherent Light Source (LCLS). **However, it is abundantly clear that international activity in the construction of new diffraction limited* storage rings and new free electron laser facilities will seriously challenge U.S. leadership in the decades to come.**

- **The U.S. will no longer hold a leadership role in such facilities unless new unique facilities are developed** as recommended by the BESAC facilities prioritization report.

* *To upgrade an existing storage ring to one that is diffraction limited will require the replacement of the entire lattice to greatly reduce the electron source size and angular divergence in order to maximize the x-ray beam brightness.*

BESAC – Recommendations

- **For free electron lasers:** In spite of the present intensely competitive environment, an exciting window of opportunity exists for the U.S. to provide a revolutionary advance in x-ray science by developing and constructing an unprecedented x-ray light source. This new light source should provide **high repetition rate**, **ultra-bright, transform limited**, **femtosecond x-ray pulses** over a **broad photon energy range** with **full spatial and temporal coherence**. **Stability** and **precision timing** will be critical characteristics of the new light source.
  - ➢ The best approach for a light source would be a linac-based, seeded, free electron laser.
  - ➢ The linac should feed multiple, independently tunable undulators each of which could service multiple endstations.
  - ➢ The new light source must have pulse characteristics and high repetition rate to carry out a broad range of "pump probe" experiments, in addition to a sufficiently broad photon energy range (~0.2 keV to ~5.0 keV).

- **For storage rings:** At best the present plans for upgrades of U.S. storage rings will leave the U.S. behind the international community in this area of x-ray science. BES should ensure that U.S. storage ring x-ray sources reclaim their world leadership position. **This will require a careful evaluation of present upgrade plans to determine paths forward that will guarantee that U.S. facilities remain at the cutting edge of x-ray storage ring science.**

BESAC Recommendations

How U.S. and International Light Sources Address the Recommendations

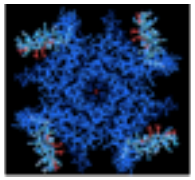
BESAC Recommendations	LCLS-II (Before)	LCLS-II (After)	NGLS	SACLA	EU XFEL	PAL XFEL	SWISS FEL
Seeded & Transform Limited Free Electron Laser		✓	✓	✓	✓	✓	✓
High Rep Rate ~1 MHz		✓	✓				
Broad Spectral Range – at least 0.2-5 keV	✓	✓		✓	✓	✓	✓
Multiple, Tunable Undulators	✓	✓	✓	✓	✓	✓	✓

The new LCLS-II is the *only* FEL addressing all of the BESAC recommendations.

4 Nobel Prizes in Biochemistry with SC Storage Ring Light Sources & the Prospect of Single-Molecule, Single-Shot Imaging with FELs

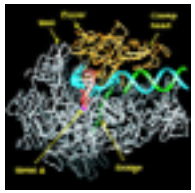
Nobel Prizes with SC storage rings in protein structures

2003	Roderick MacKinnon (Chemistry) for “structural and mechanistic studies of ion channels.”
2006	Roger Kornberg (Chemistry) "for his studies of the molecular basis of eukaryotic transcription.”
2009	Venkatraman Ramakrishnan, Thomas A. Steitz, and Ada E. Yonath (Chemistry) "for studies of the structure and function of the ribosome.”
2012	Robert J. Lefkowitz and Brian K. Kobilka (Chemistry) "for studies of G-protein-coupled receptors.”

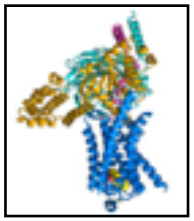


The overall view of a voltage-dependent potassium ion channel.

The 50S subunit at 2.4Å resolution.

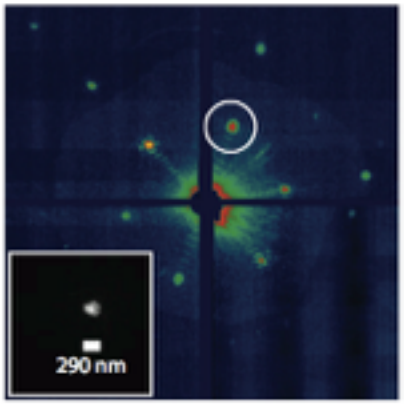


The visualized transcription process.



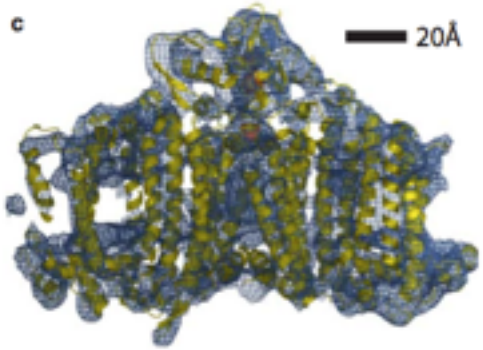
The structure of the β2AR-Gs complex.

Early experiments in single-molecule, single-shot imaging at LCLS



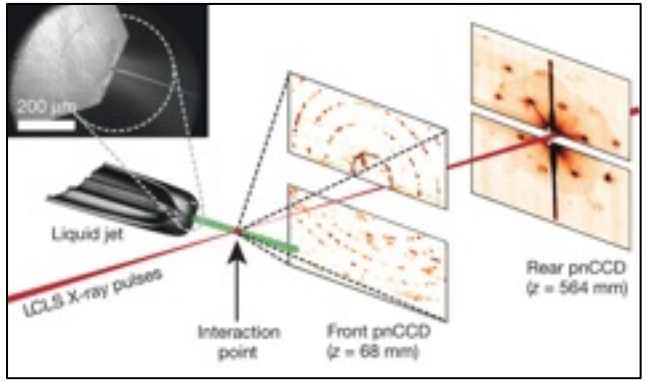
Single Shot Diffraction Pattern

HN Chapman *et al. Nature* **470**, 73-77 (2011)



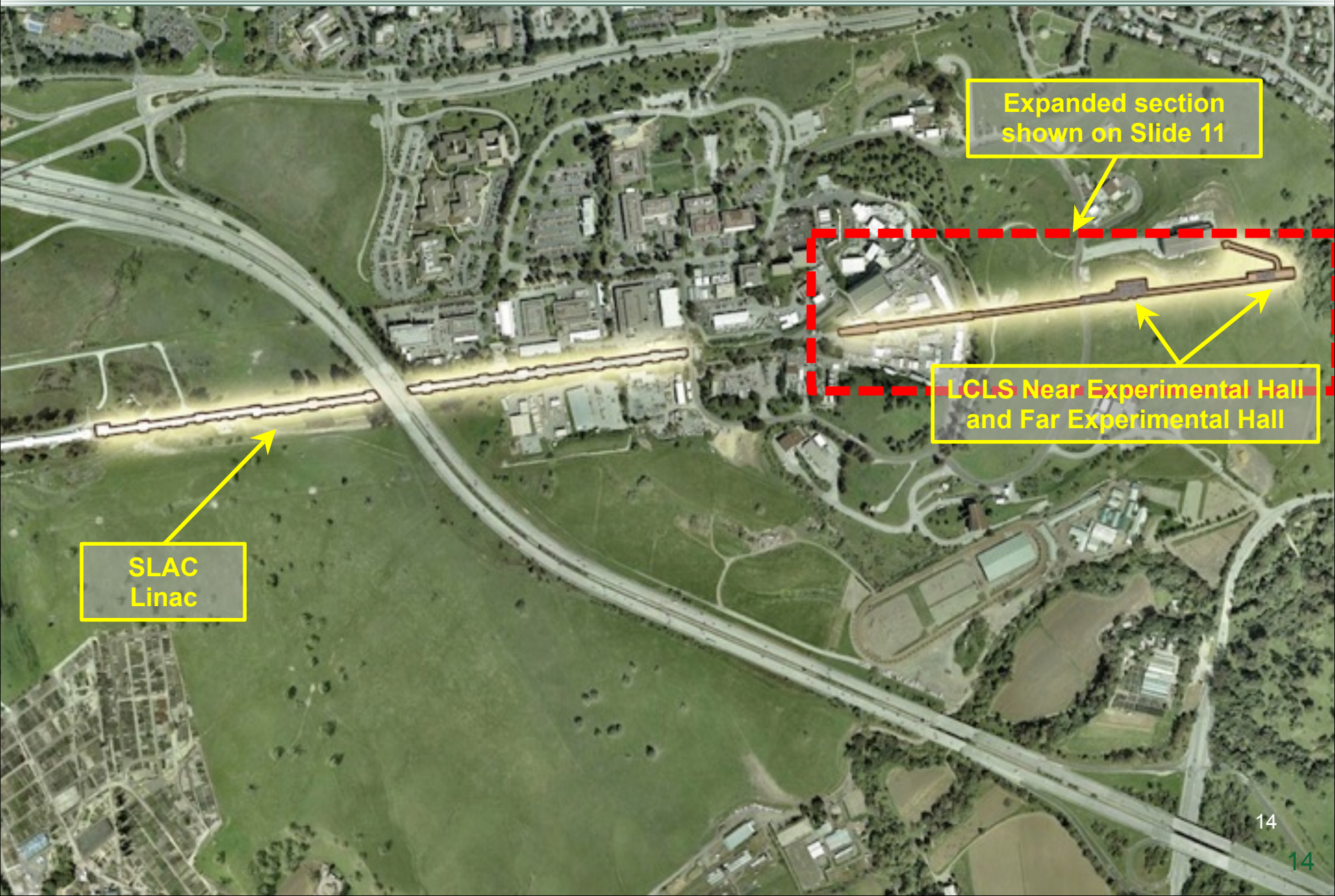
The structure of the β2AR-Gs complex.

Reconstructed Image



The Experiment

The Linac Coherent Light Source at SLAC



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LCLS-II Upgrade After BESAC Report:
New 4 GeV SC linac; 1 soft x-ray & 1 hard x-ray undulator in the existing tunnel