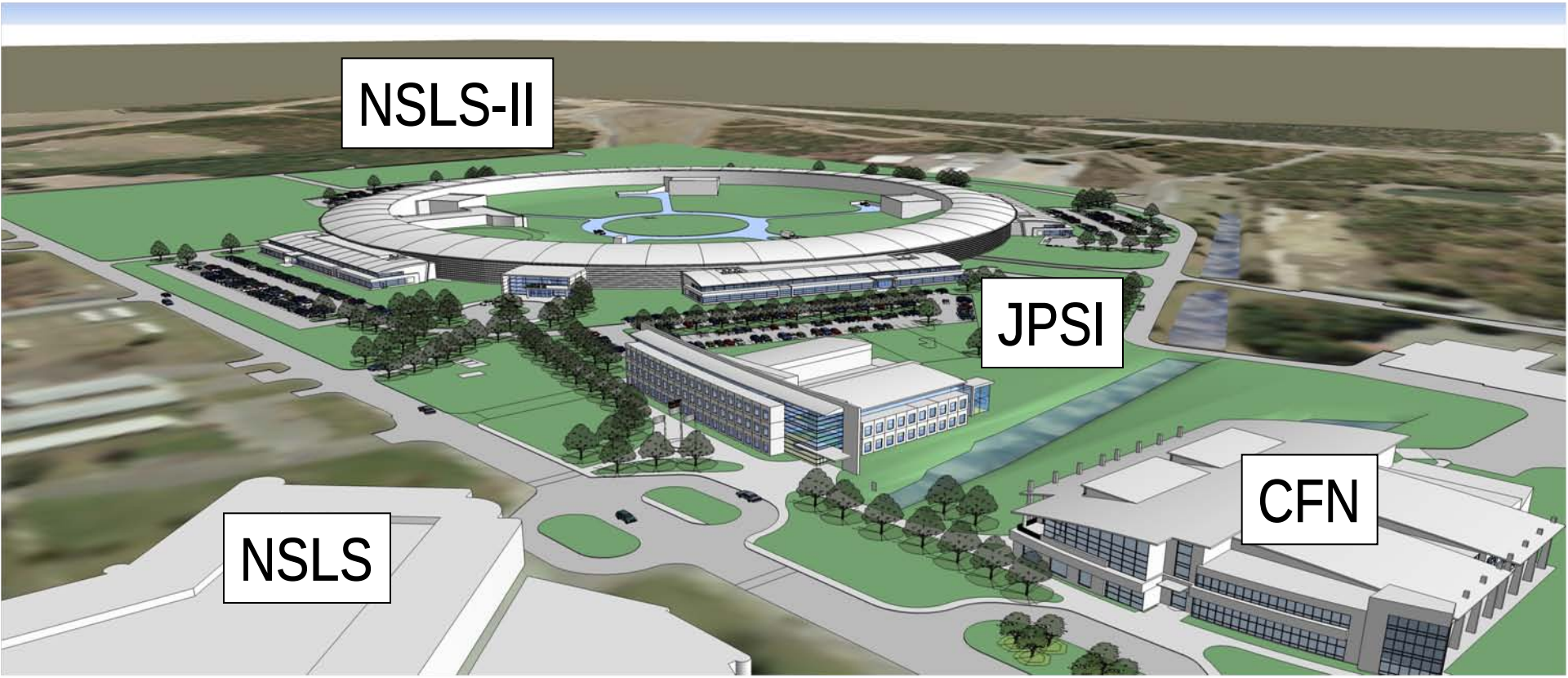
NSLS, NSLS-II and JPSI



Chi-Chang Kao
National Synchrotron Light Source Chairman
Joint Photon Sciences Institute Director

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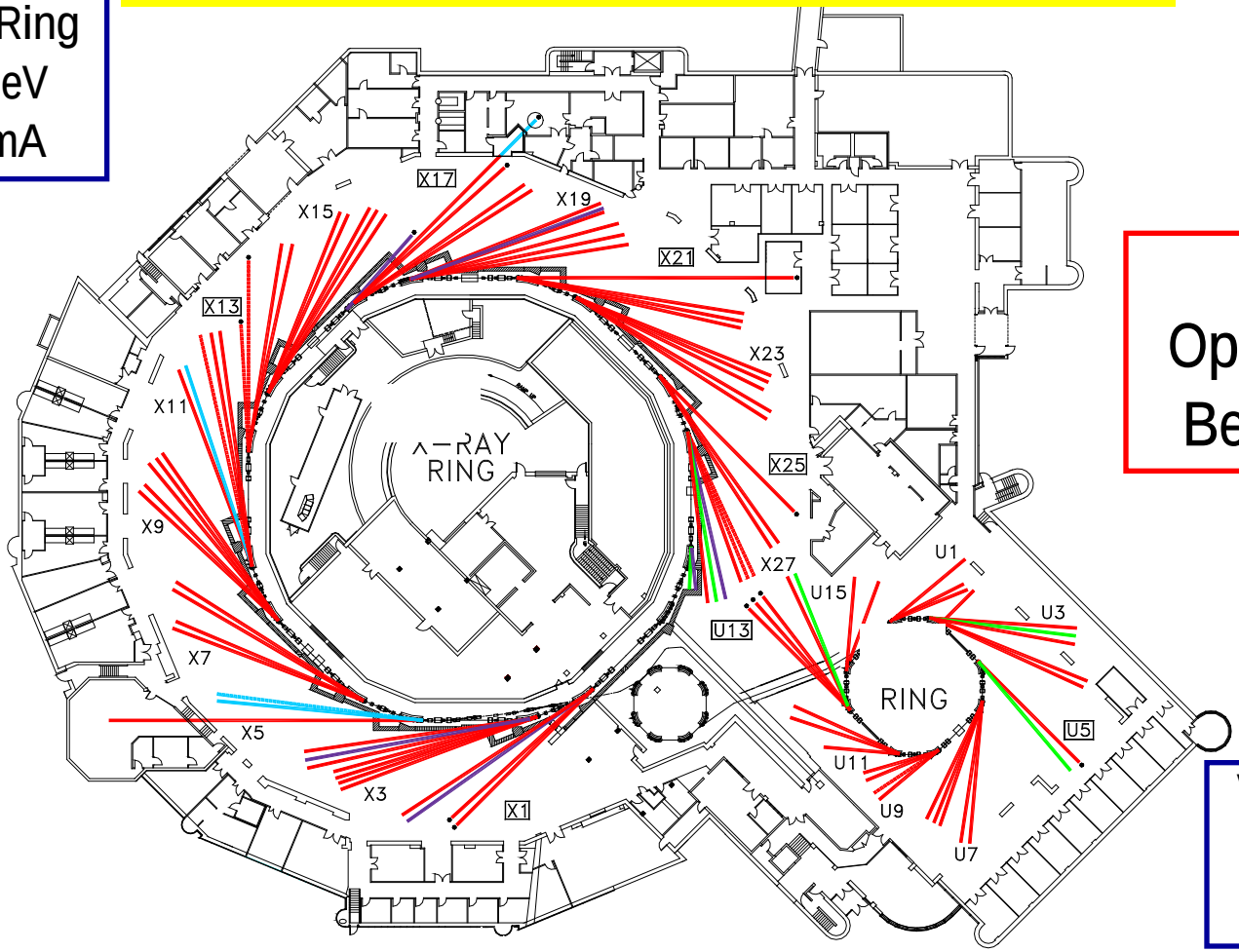
National Synchrotron Light Source

Supports ~2200 users annually

X-Ray Ring
2.8 GeV
275 mA



64
Operational
Beamlines

VUV/IR Ring
800 MeV
1000 mA

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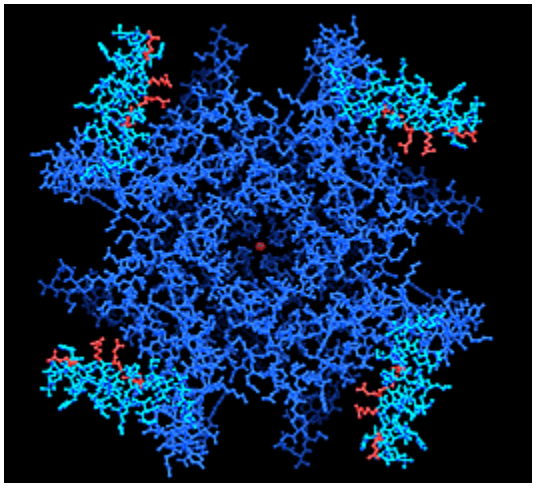
NSLS: More Than Two Decades of Excellence

> 400 academic, industrial, government institutions

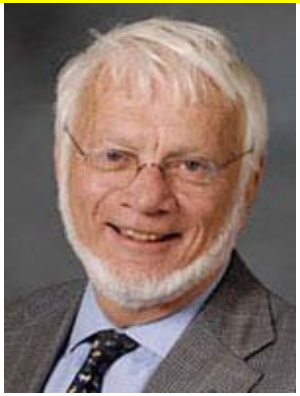
~ 1000 publications per year (~ 250 in premier journals)

2003 Nobel prize in Chemistry

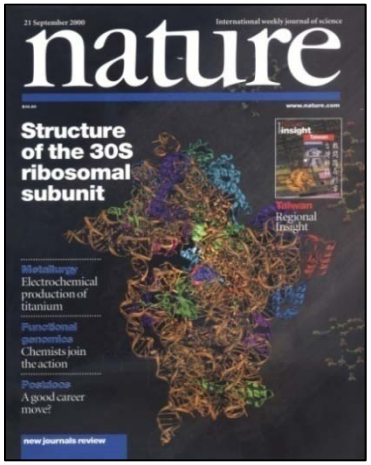


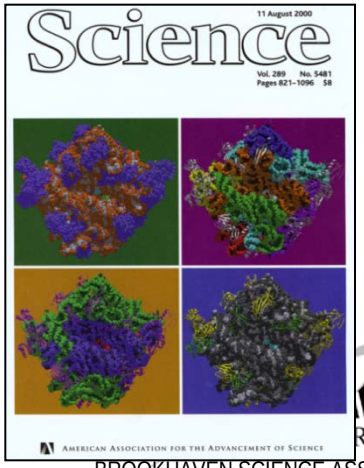
2009 Nobel prize in Chemistry

Venkatraman Ramakrishnan



Thomas Steitz





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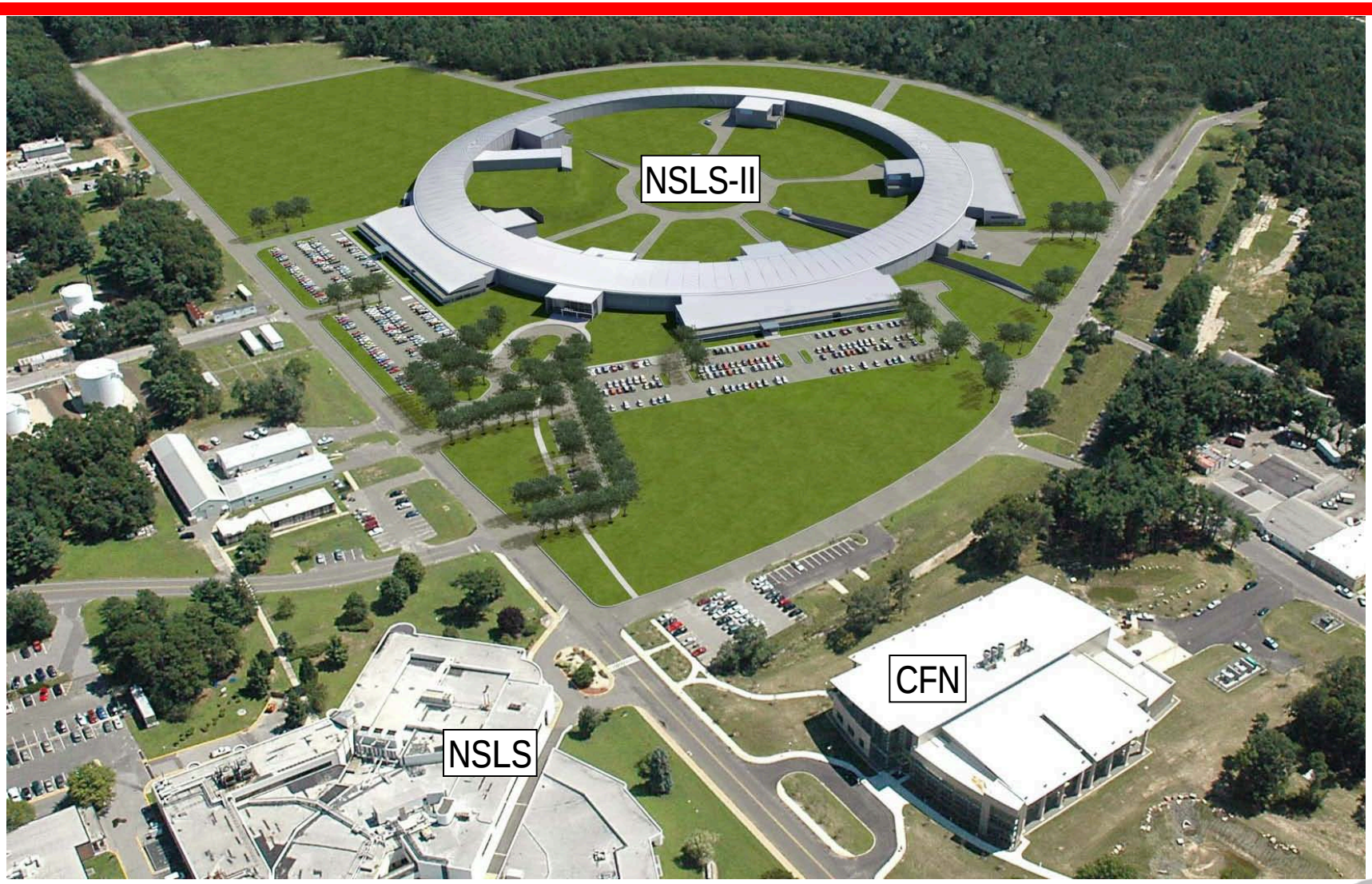
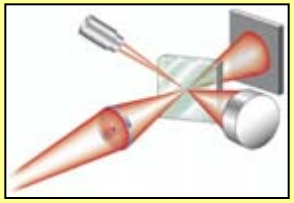
NSLS-II Project

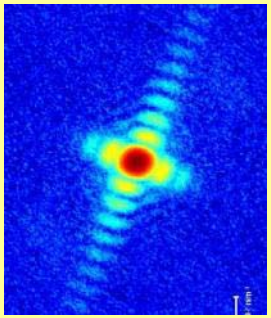


High-Level Description of NSLS-II

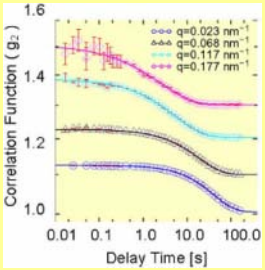
New Capabilities



Nanoprobes



Diffraction Imaging



Coherent Dynamics

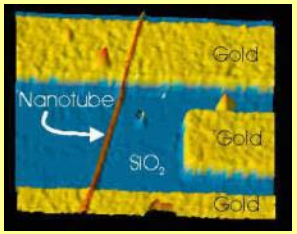
Highly optimized x-ray synchrotron delivering:

- extremely high brightness and flux
  - brighter than any other synchrotron worldwide
  - > 10,000x brighter than NSLS
- exceptional beam stability
- suite of advanced instruments, optics, and detectors that capitalize on these special capabilities

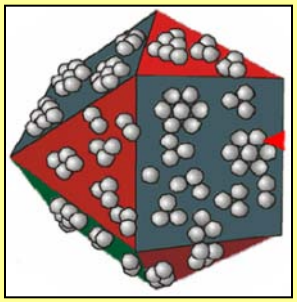
Together, these enable:

- *~ 1 nm spatial resolution*
- ~ 0.1 meV energy resolution
- single atom sensitivity

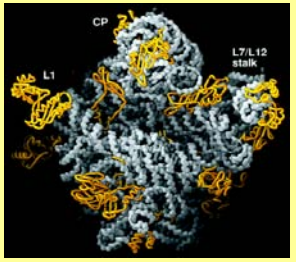
New Science



Nanoscience



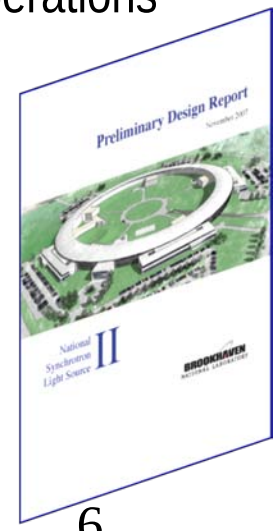
Nanocatalysis

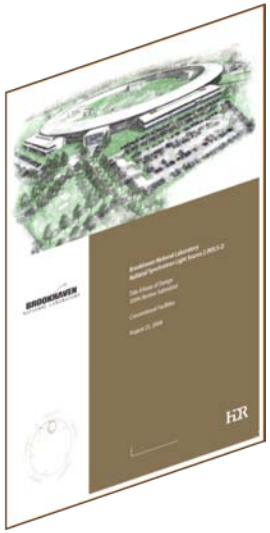


Life Science

Key Project Milestones

Aug 2005	CD-0, Approve Mission Need	(Complete)
Jul 2007	CD-1, Approve Alternative Selection and Cost Range	(Complete)
Jan 2008	CD-2, Approve Performance Baseline	(Complete)
Jan 2009	CD-3, Approve Start of Construction	(Complete)
Feb 2009	Contract Award for Ring Building	(Complete)
Aug 2009	Contract Award for Storage Ring Magnets	(Complete)
Mar 2010	Contract Award for Booster System	
Feb 2011	1st Pentant Ring Building Beneficial Occupancy; Begin Accelerator Installation	
Feb 2012	Beneficial Occupancy of Experimental Floor	
Oct 2013	Start Accelerator Commissioning	
Jun 2014	*Early Project Completion; Ring Available to Beamlines*	
Jun 2015	CD-4, Approve Start of Operations	





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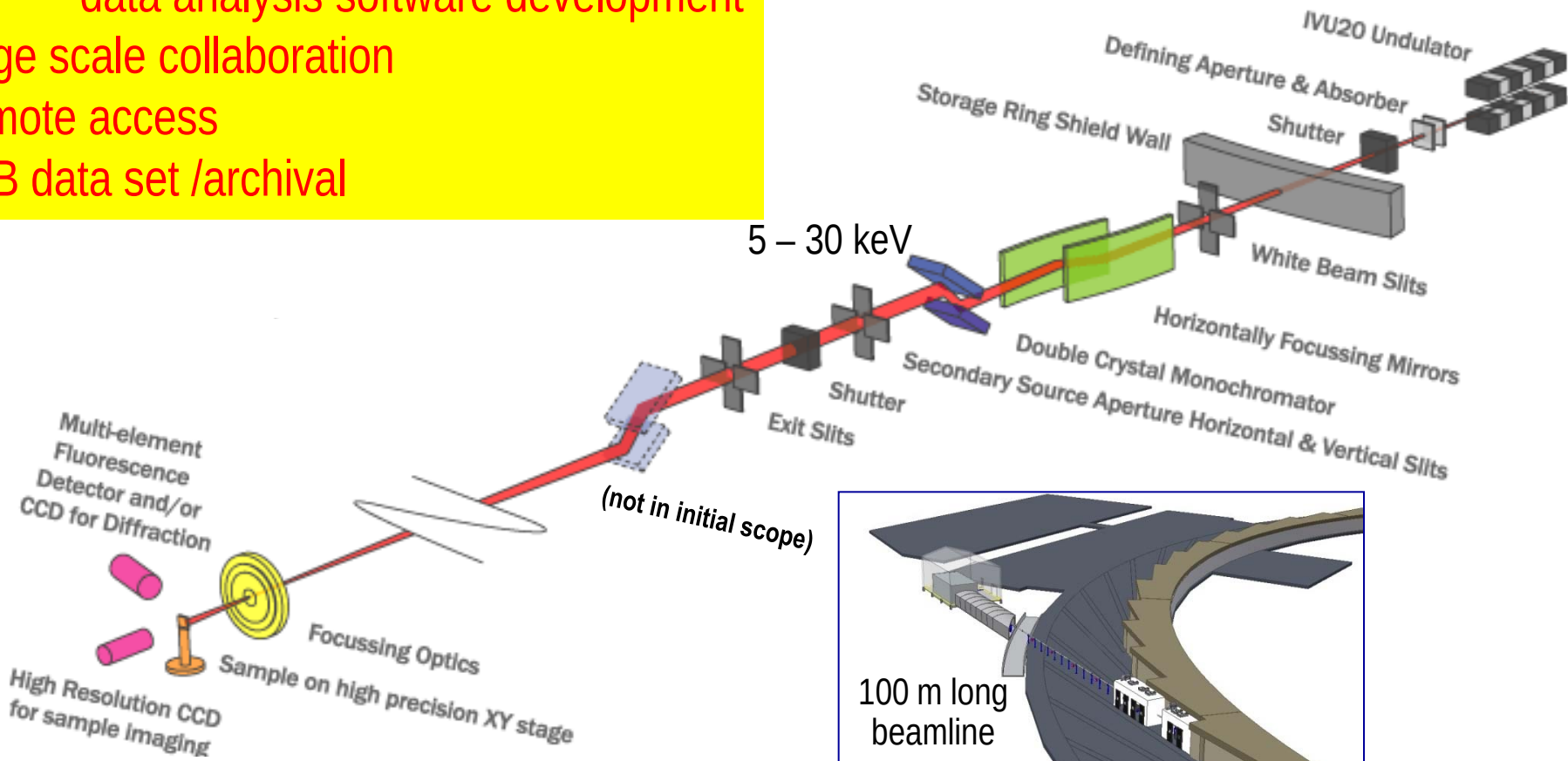
New Scale and Sociology

- 10-20 M capital; ~2M annual operating
- Long term detector/optics/instrument/ data analysis software development
- Large scale collaboration
- Remote access
- ~ TB data set /archival



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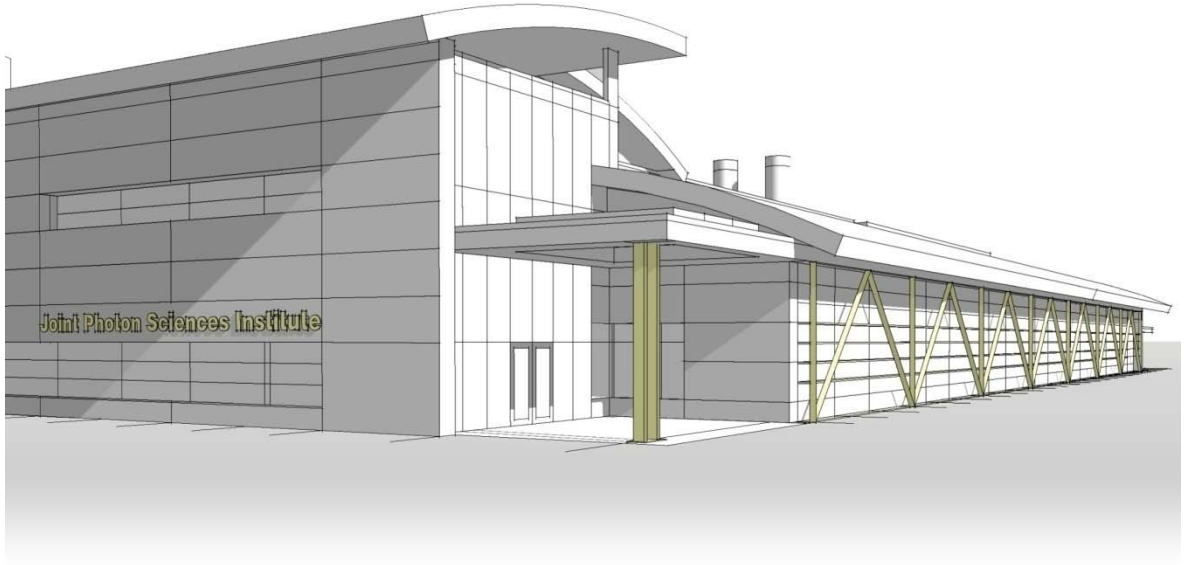
Joint Photon Sciences Institute (JPSI)

- Previous New York State Governor George Pataki committed $30 million for a research building as an incentive to site NSLS-II at BNL - A pledge that led to the establishment the Joint Photon Sciences Institute (JPSI) at Brookhaven National Laboratory (BNL) and Stony Brook University (SBU) in the fall of 2008.



Conceptual design
- 40,000 gross sf
- Office and interaction spaces
- Laboratories
- 5000 sf clean and dry rooms

Funding: NYS has only delivered $10M

Mission of JPSI

The mission of JPSI is to exploit the properties of advanced photon sources to address the most critical scientific and technical problems. In particular, JPSI will explore the opportunities offered by the unprecedented brightness of the National Synchrotron Light Source II (NSLS-II).

- Develop scientific programs that have highest scientific and societal impact
- Develop enabling technology to capitalize on the extraordinary brightness of NSLS-II
- Serve as a gateway for NSLS-II
- Educate and train the next generation of scientists and engineers

Vision of JPSI : From Discovery to Deployment

Discovery Research | Use-inspired Basic Research | Applied Research | Technology Maturation & Deployment

High Risk Science

-Create a vibrant environment
-Develop breakthrough capabilities
-Identify new research areas
-Attract world-class scientists

Applied Research

-Identify pre-competitive industrial R&D
-Match the problems with expertise within government laboratories and universities
-Develop experiments/instruments
-Provide solution

World-class science

High-impact technologies

CFN, NSLS I, II, New York Blue
Instrumentation Division, Source Dev Lab

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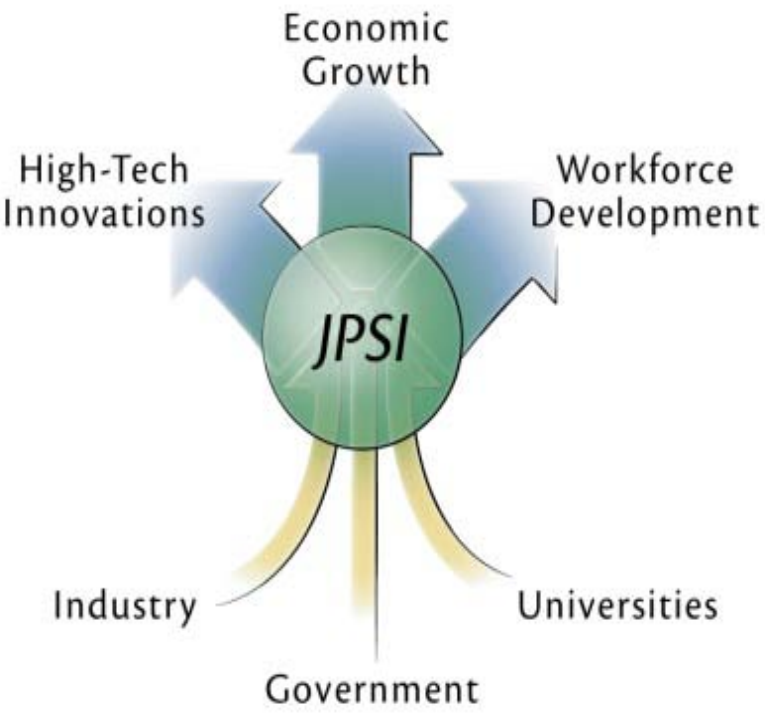
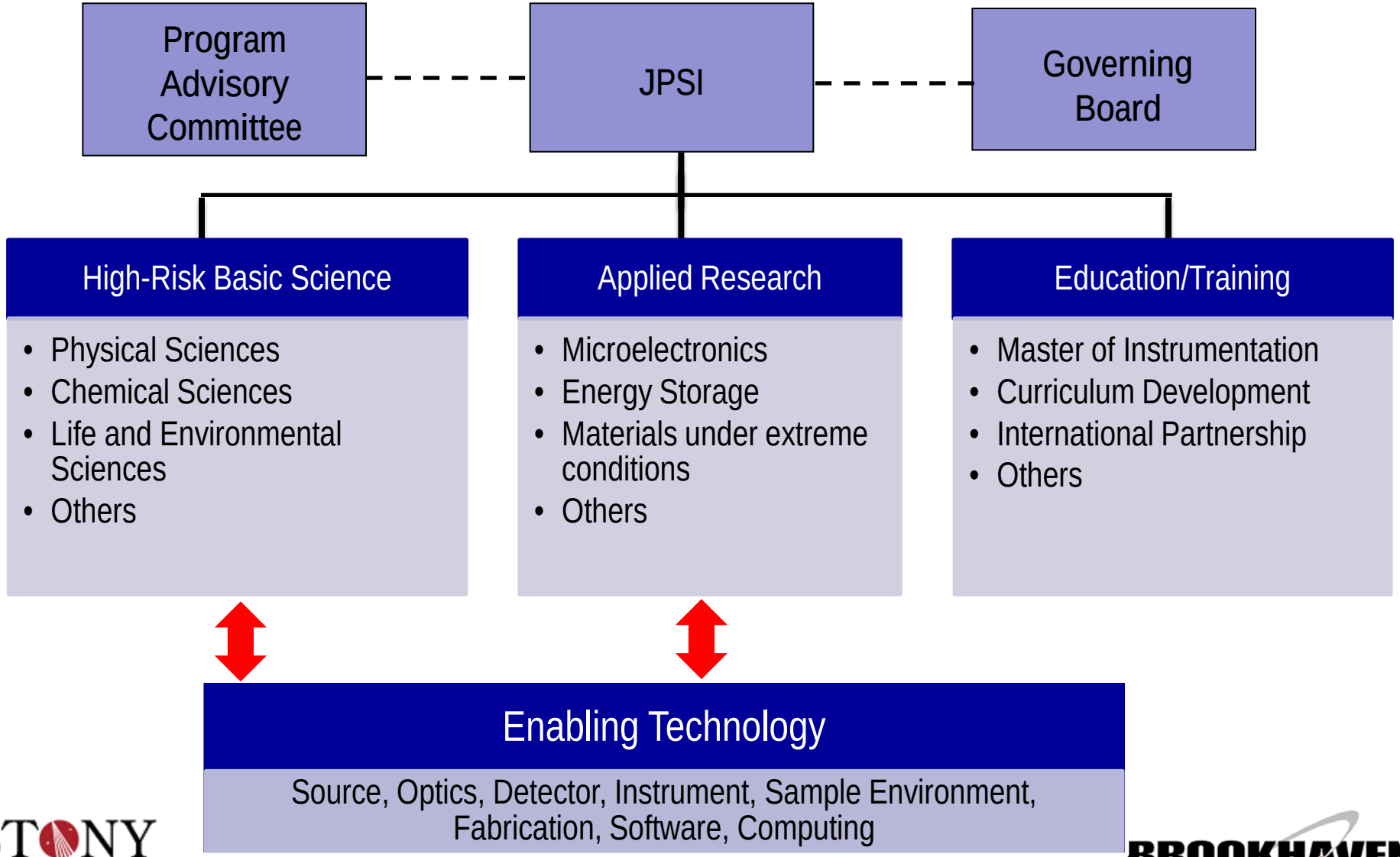
Strategy: New Paradigm of Collaboration for "Small" Sciences

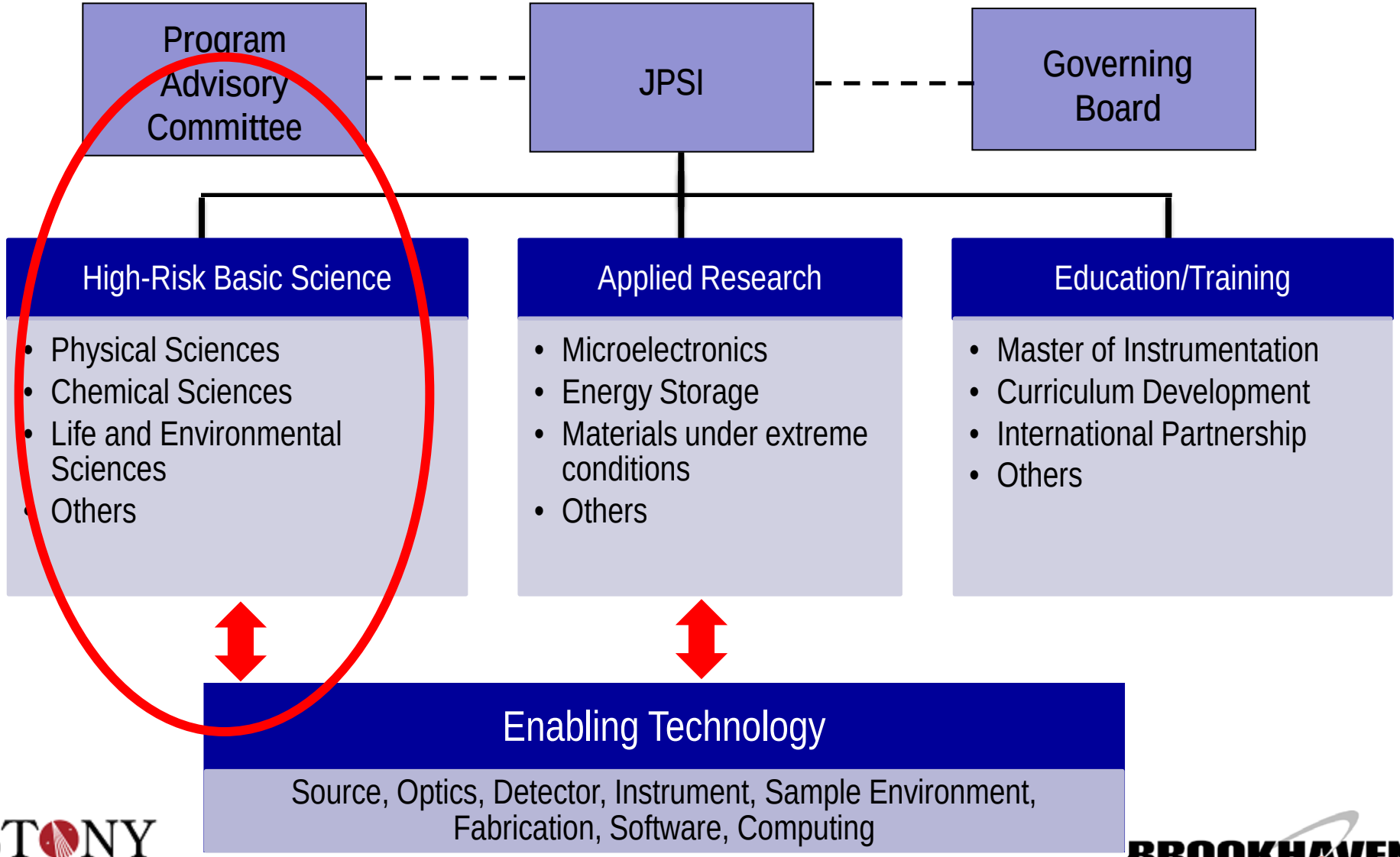
- JPSI catalyzes innovations by facilitating industry, university and government interactions and collaborations
- Leverage investments made by governments in major national user facilities, such as NSLS-II (~$1billion capital, ~$150M annual operating, ~500 staff), to attract the best scientists around the world
- Problem-driven



JPSI Organization



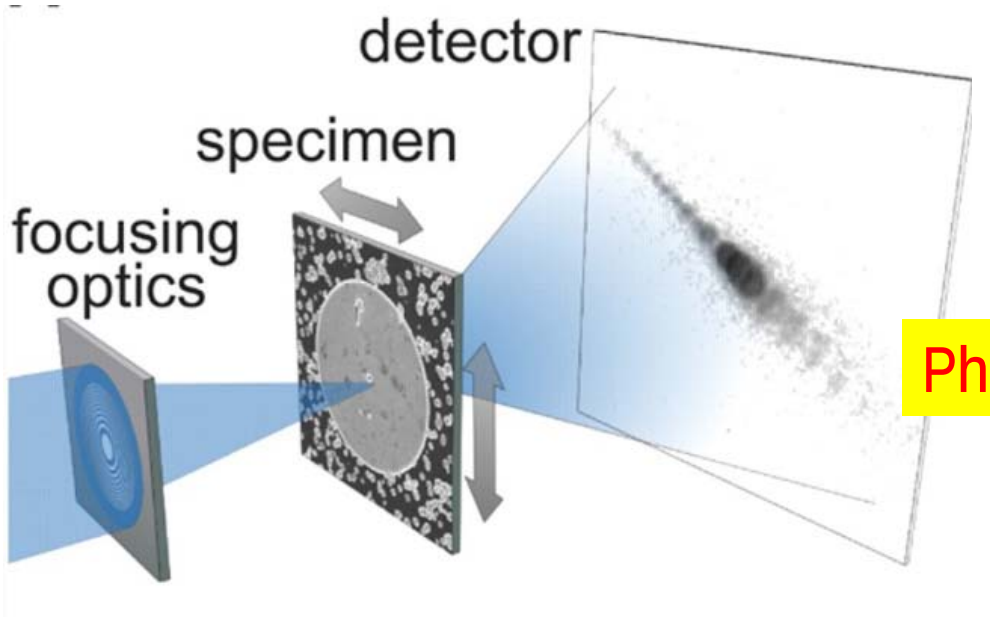
JPSI Organization



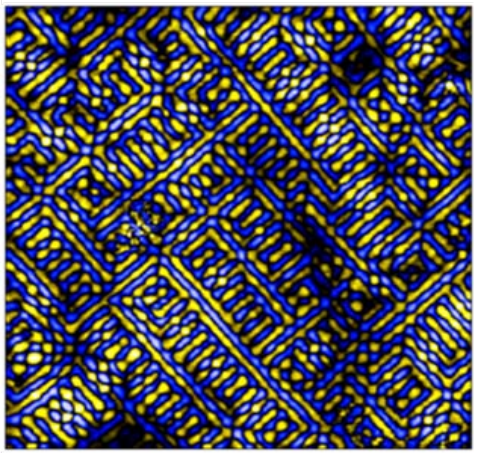
Real-Space Imaging of Electronic Textures in Strongly-Correlated Electron Systems

Goal: To image electronic texture (spin, charge, orbital) in strongly-correlated electron systems, in particular high-temperature superconductors, with ~O(1) nm resolution

Approach:



Phase problem

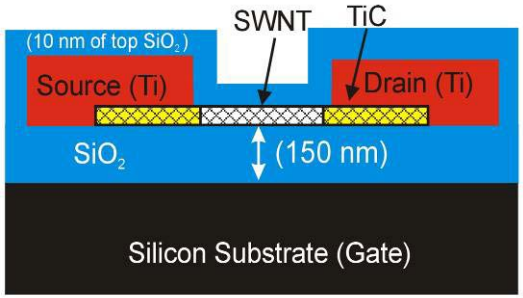


Real space STM image of electronic structure in Bi-1221

P. Thibault *et al.*, Science 321 379 (2008)

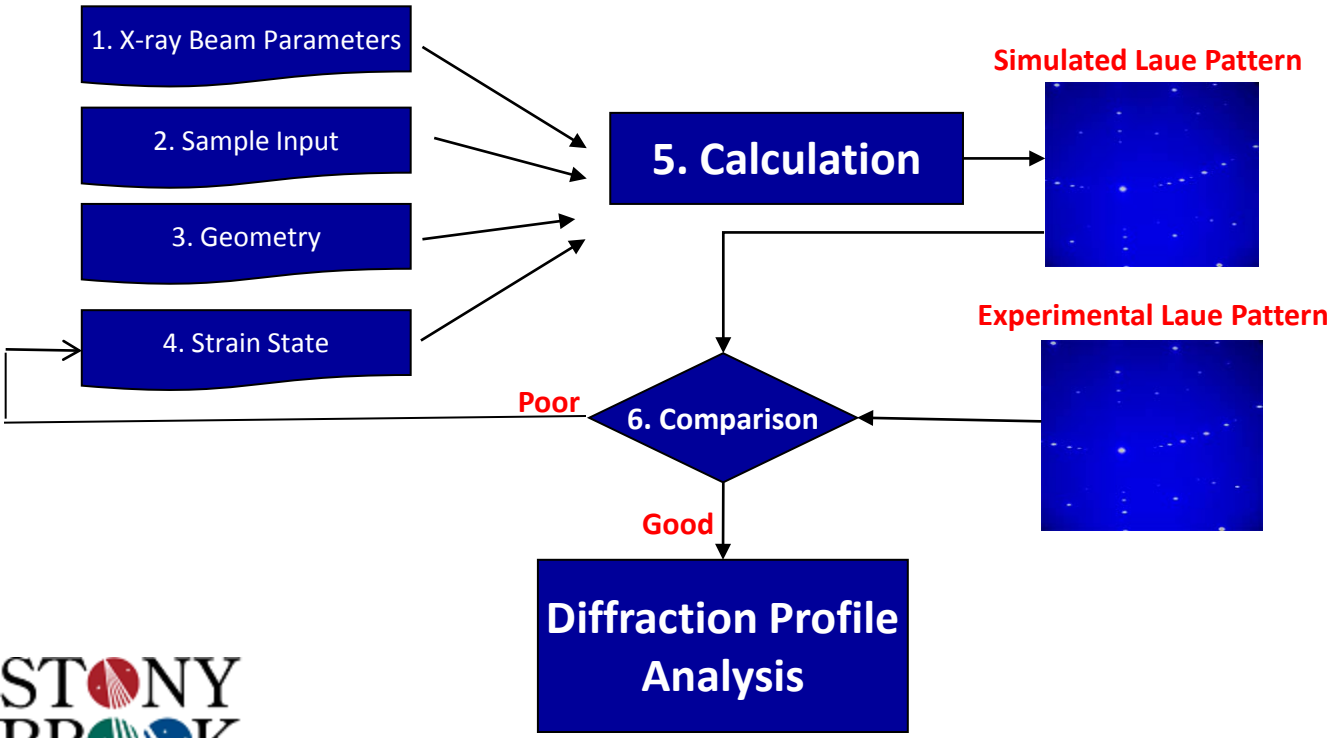
Beyond CMOS: Diffraction from Nanostructures and Materials Development

Goal: To measure nanostructures with arbitrary strain gradient and impurity distribution

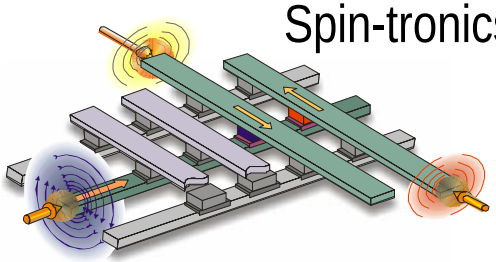


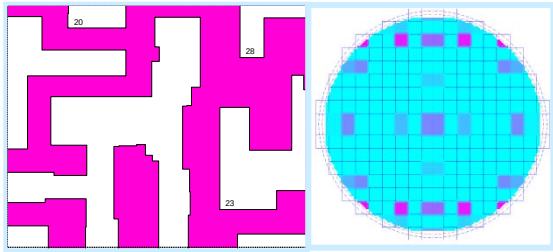
- Diameter
- Chirality
- Orientation
- Impurities

Approach:



Spin-tronics

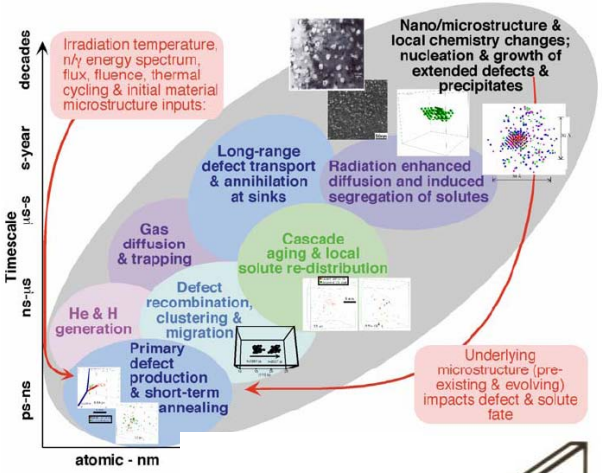




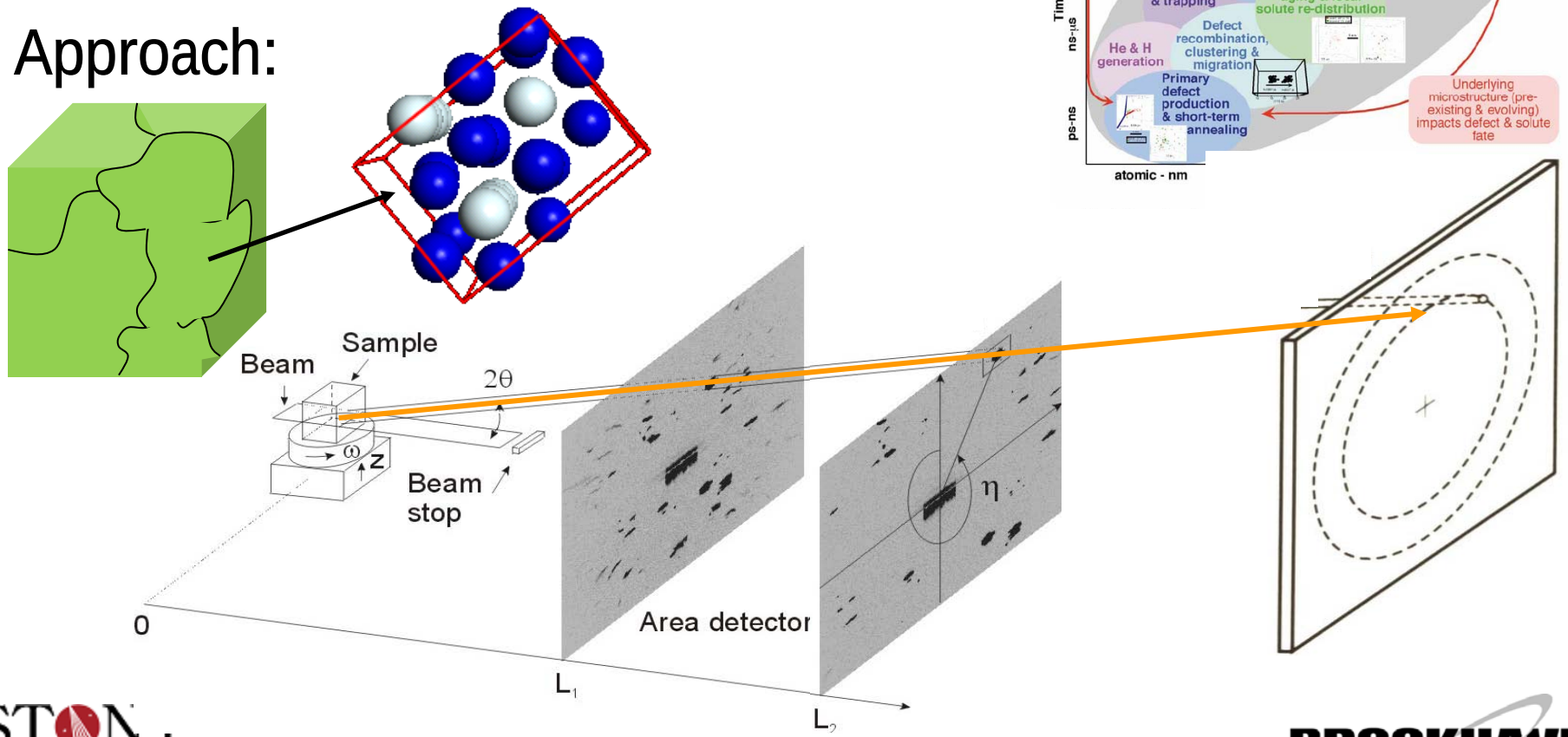
Computationally Global-Optimized Mask

Designer Engineering Materials (Carbon Sequestration): X-ray Diffraction Tomography

Goal: To measure 3D nanoscale structure under high temperature/pressure



Approach:



Margulies, NSLS-II

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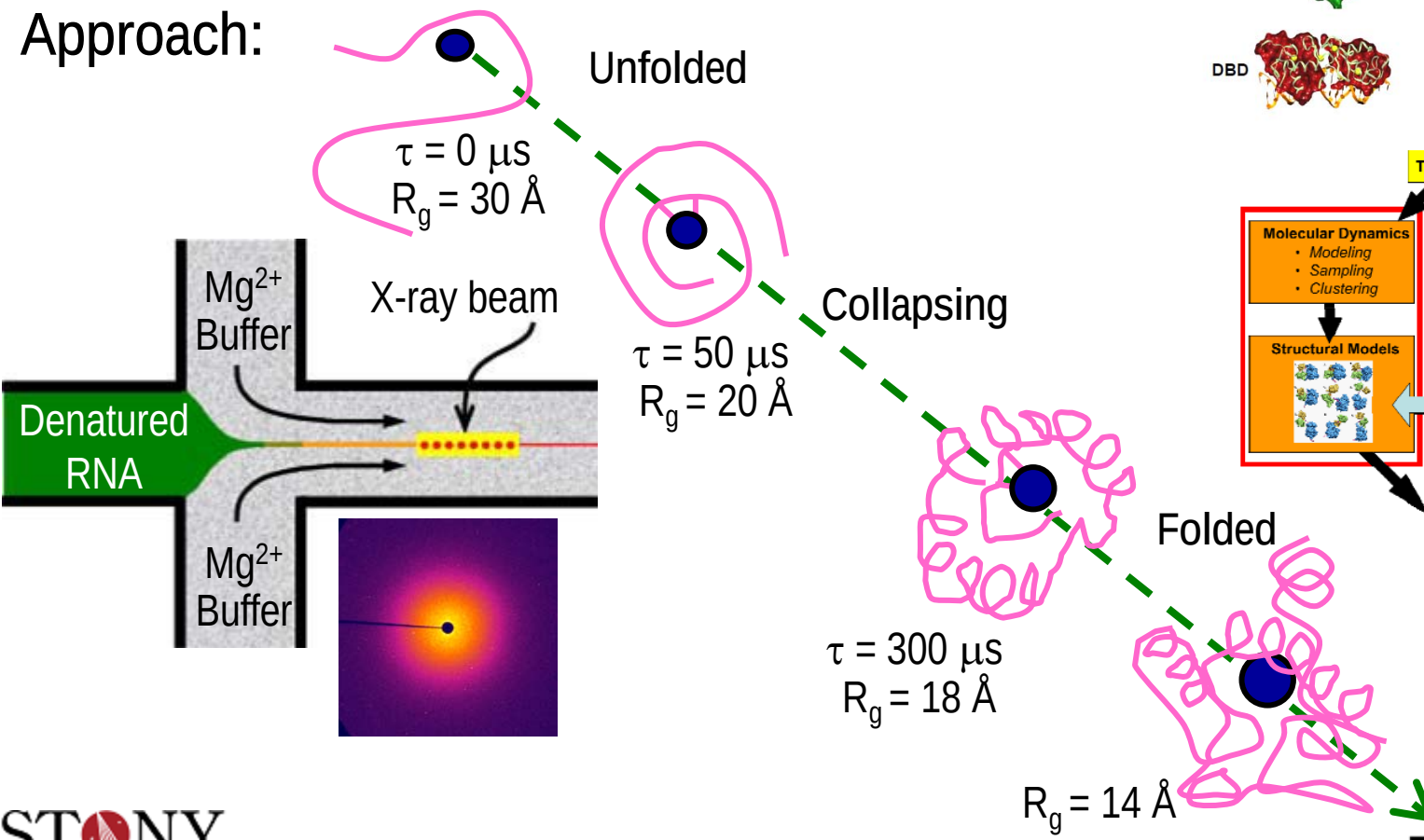
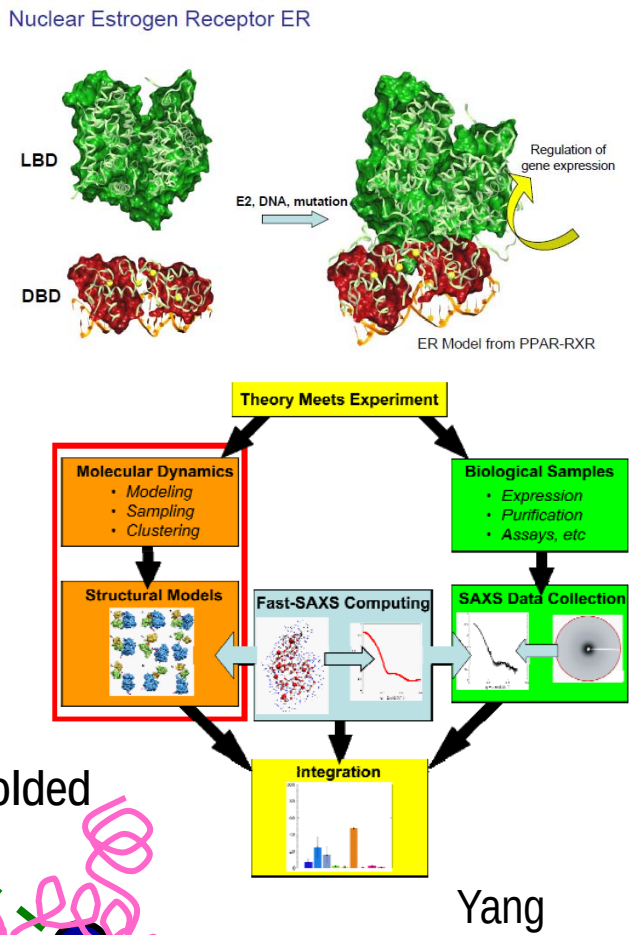
Protein-Folding and High-Throughput Screening

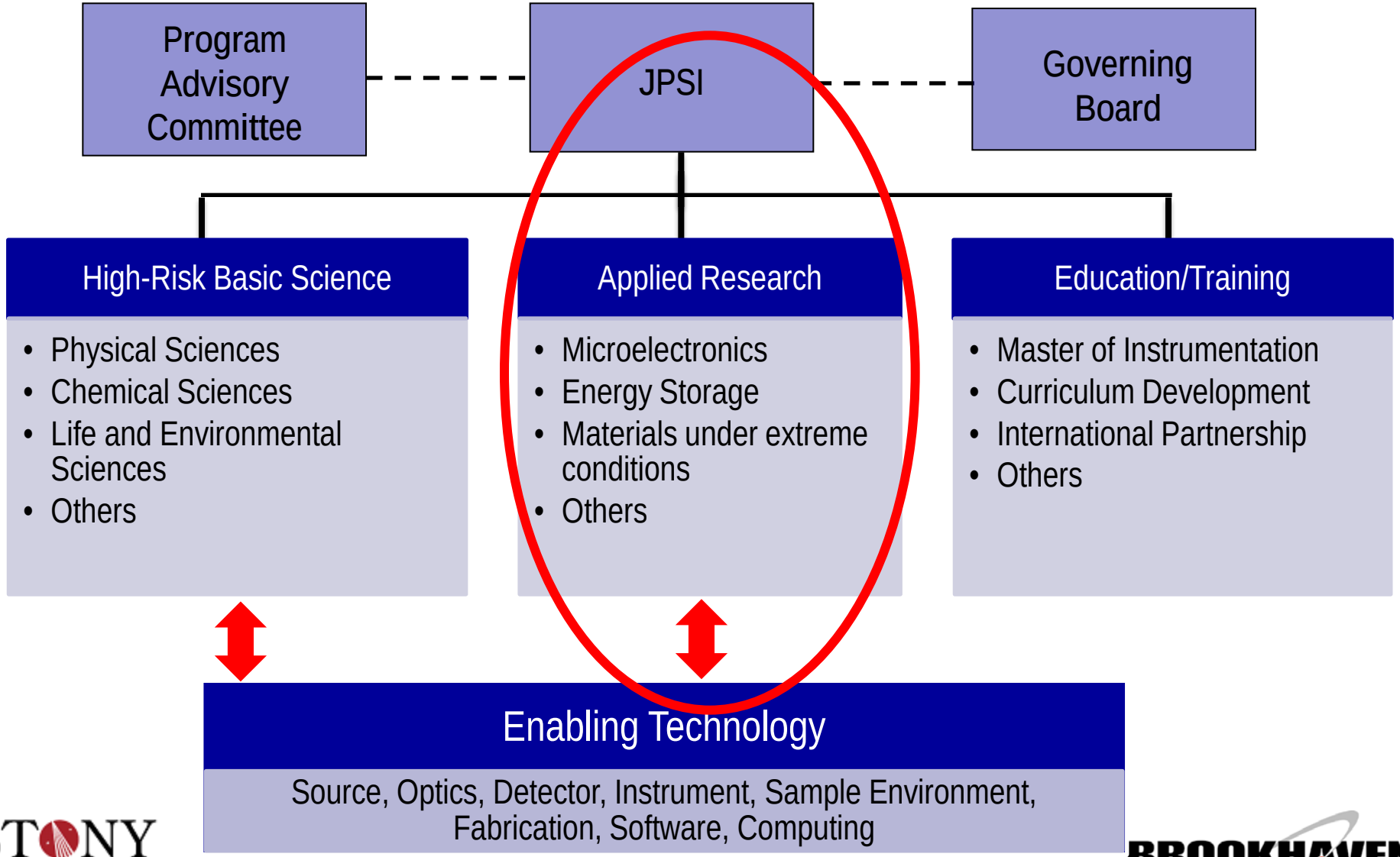
Goal: To improve time-resolution of protein-folding measurement to the time scale of computer simulation

Approach:

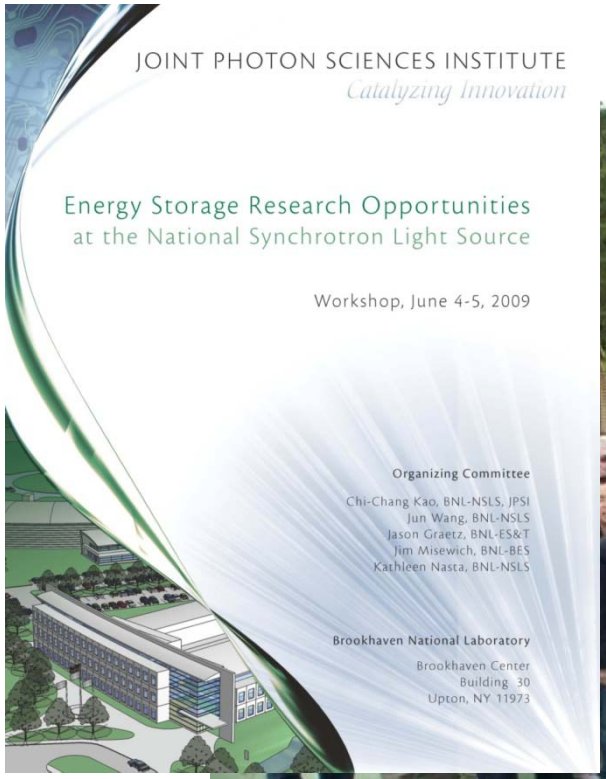




JPSI Organization



JPSI-Sponsored Workshop on Energy Storage
June 4-5, 2009

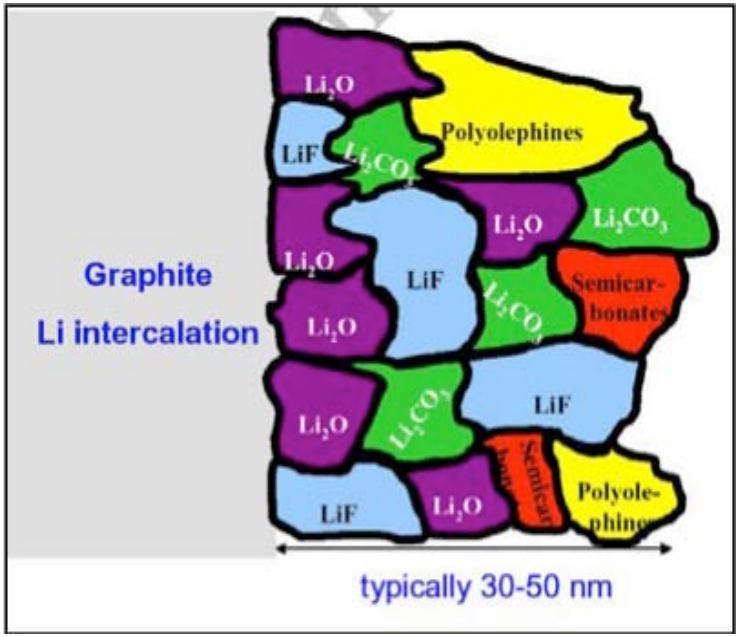


MATRIX			Electrochemical performance	Degradation mechanism during cycling and storage	New material for electrodes	Polymer/liquid electrolytes	Electrolyte Interface (SEI)	Defects	Safety	3D internal structure
Synchrotron Tool	Spectroscopy	EXAFS	Catalyst at interface	Local environment around specific element	Coordination and band length change		Element specific		Decrepitation of materials when hydrogenated	
		XANES	In-situ oxidation state	Range reduction of valence changes	Redox reaction in-situ	Element selective ion complexing	Charge transfer process		Thermal decomposition during heating	
		PES		Electronic energy-band structures			Bulk/surface electronic structure			
		IR Microspectroscopy	Reaction pathway			Identify species present	Identify species present			
	Scattering/ Diffraction	Sing Pow								
		High								
		u-X								
		PDF								
		SAX		change	during cycling	structures in real time at nano to micro scales	nanoparticles/ breakage of larger particles			
		GISAXS/ GIXD	Surface structure			In-situ PEM structural changes	In-situ surface/ interface structure			
		RXS/RXD			Element, charge and orbital ordering phenomena					
	Imaging	Micro-XCT	In-situ particles formation	Breakage 3D imaging during cycling	Morphological changes during cycling		Non-equilibrium Li battery			Micro 3-D **internal structure**
		TXM	Change in near surface morphology	Evolution of surface or interface structure at nano scale	3D elemental distribution at nano scale	Interface structure by phase contrast	3D imaging in nano spatial resolution	Internal 3D structural imaging	Nanostructural and morphological changes during cycling	3-D **internal** structure at submicron to nano scale
		SXM	Chemical states and local structure in micron scale	Oxidation state in micron region	2D composition and oxidation mapping		Local oxidation state change			2D elemental imaging
		Topography	Strain distribution in near surface		Strain distribution			Strain induced by cycling		
		PEEM/LEEM	Surface element		Surface 2D mapping					

- *Identify new collaborative projects*
- *Facilitate collaboration between universities, government laboratories and industries*
- *Joint long-term planning with industry*

Follow up

- New laboratory at NSLS for energy storage research
- Impact on NSLS-II instrument design
- Generate new research ideas
- Submitted joint funding proposals
- Targeted companies in energy storage industry -- A-123, GE, Toyota, etc. – with goal to establish a consortium
- Possible Department of Energy funding

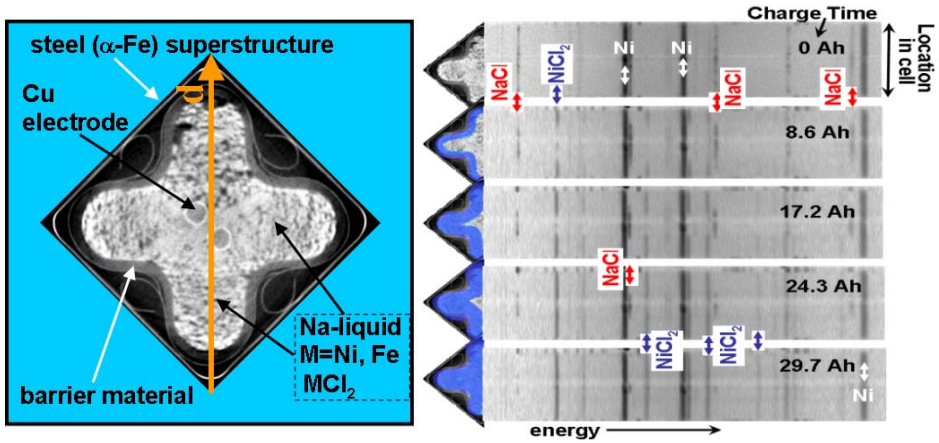


Studying Commercial Batteries in Action

J. Rijssenbeek,[1] M. Vallance,[1] Y. Gao,[1] Z. Zhong[2], N. Jisrawi,[3] I. Ignatov,[3] M. Croft[3]

[1]GE, [2]Brookhaven National Laboratory, [3]Rutgers University

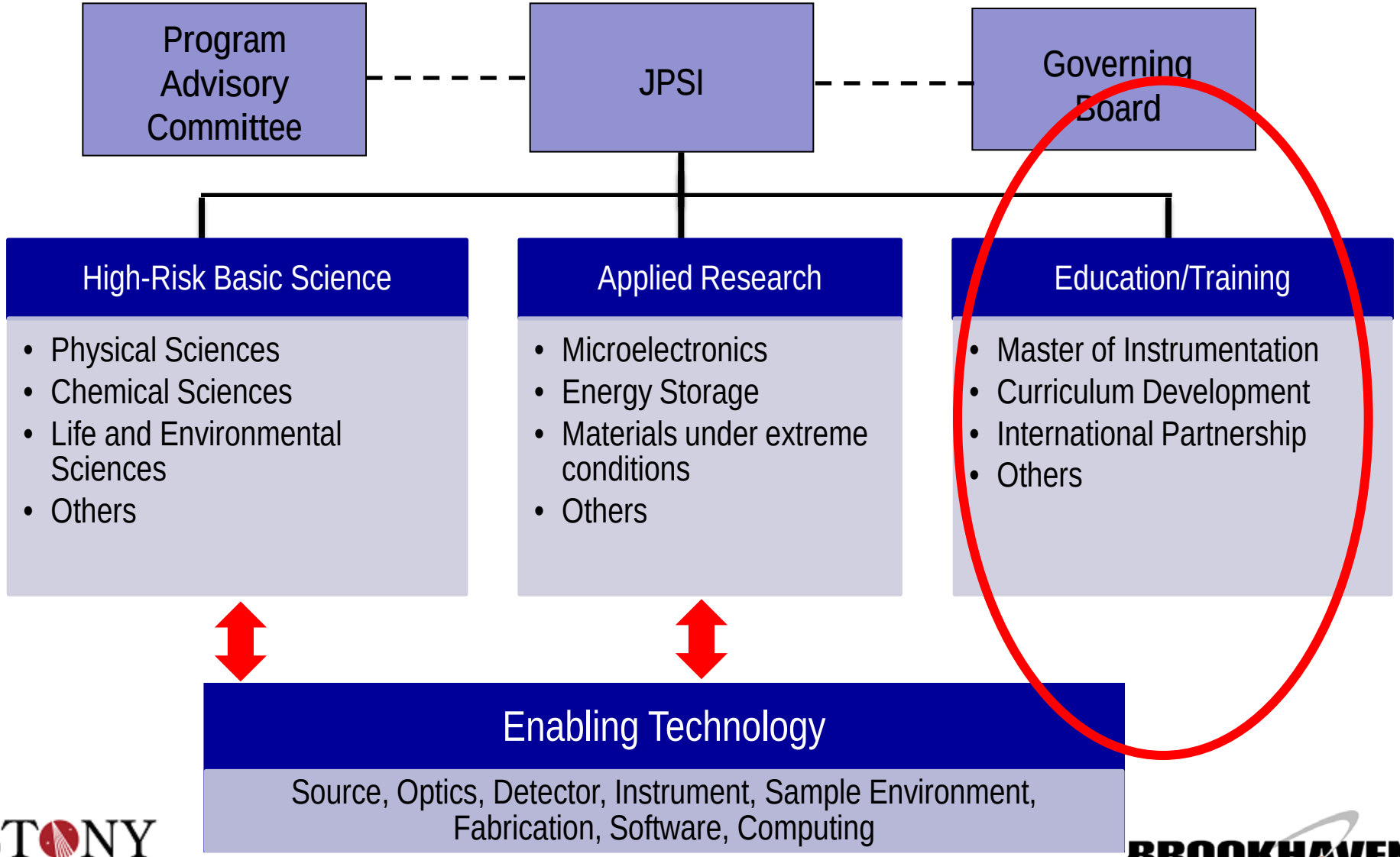
- Energy dispersive x-ray diffraction (EDXRD) provides an excellent platform for 4D-mapping (3D-spatial plus time/charge-state evolution) measurements of the internal electrochemistry of functioning commercial batteries.
- In situ studies were performed on prototypes of batteries designed by GE for hybrid diesel locomotives. EDXRD measurements revealed local electrochemical kinetics in unprecedented levels of detail deep inside of commercial-size batteries.
- GE has recently announced that it will build a 100 Millions manufacturing facility in upstate New York to produce Sodium metal halide battery, and will use EDXDR at the NSLS to improve the performance of them.



Cross-sectional x-ray diffraction patterns taken at various times during charging of a $Na/MCl_2 \Leftrightarrow NaCl/M$ battery

GE chemical engineer Charles Iacovangelo, advanced battery project leader, holds a sodium metal halide battery cell.

JPSI Organization



Education/Outreach Program

- Potential large base of users in universities and industries
- Develop undergraduate- and graduate-level courses in synchrotron science at Stony Brook University, in partnership with minority-serving institutions
- Develop professionals (Masters' level) for SR and industry
- International partnership
- Possible National Science Foundation funding

Bring World-Class Science to Middle and High Schools

- Web conference using Enabling Virtual Organizations (EVO) system to bring synchrotron research to high schools
- Students and teachers participate in research program
- Expand the program to serve schools in under-privileged areas

Summary

- Synchrotron and other advanced light sources are powerful scientific tools with significant government investment globally
- JPSI, through its' interconnected programs, provides a platform for large-scale collaborations between academia, industry and government to tackle grand challenges in science and to solve technological problems with high societal impact
- JPSI will bring world-class talent to Stony Brook University and to Brookhave National Laboratory