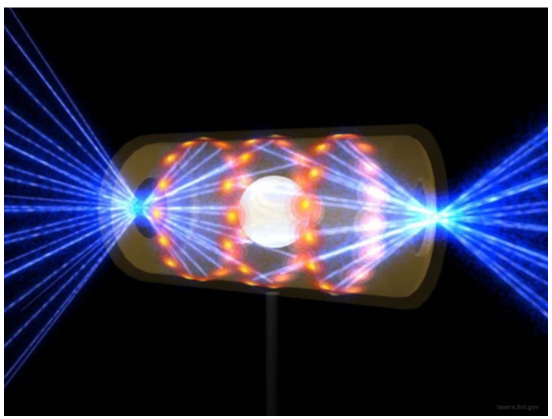
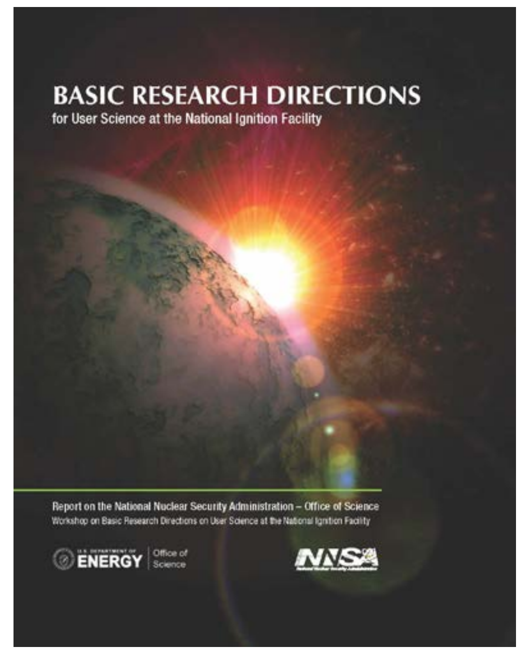
"Basic Research Directions Workshop on User Science at the National Ignition Facility" – An NNSA/SC Workshop

John Sarrao





Scientific opportunities in high energy density (HED) science are recognized

The importance of access to NNSA facilities is emphasized in these reports- NIF is developing processes and infrastructure to support the fundamental science mission

"NIF Science" Workshop
May 9-12, 2011

Workshop Chairs:

Kim Budil, LLNL
John Sarrao, LANL
Michael Wiescher, Notre Dame

Jim Glownia, Office of Science
Mike Kreisler, NNSA

Panel Chairs:

Laboratory Astrophysics:
Paul Drake (Michigan)

Nuclear Physics:
Bill Goldstein (LLNL), Rich Petrasso (MIT), Michael Wiescher (Notre Dame)

Materials in Extremes & Planetary Physics:
Rus Hemley (Carnegie)

Beams & Plasma Physics:
Chan Joshi (UCLA), Warren Mori (UCLA), Margaret Murnane (Boulder), Alan Wootton

Cross-Cut/Facility User Issues:
Roger Falcone (Berkeley)

Plenary Speakers:

Bill Brinkman, Don Cook, Steve Koonin
Chris Keane
Patricia Dehmer, Ralph Schneider

NNSA National Nuclear Security Administration

Basic Research Directions Workshop on User Science at the National Ignition Facility

U.S. DEPARTMENT OF ENERGY | Office of Science

Workshop Goals

Summarize key aspects of the current state of scientific research and understanding in relevant fields;

Define a set of related Science Grand Challenges;

Identify a set of Proposed Research Directions that address broad scientific uses of the NIF; and

Provide a preferred facility governance process, including responsibilities of key individuals, the process for user access and allocation of NIF facility time and resources, and other policies and procedures relevant to facility users;

Consider an exciting new facility … and remember the past

Unprecedented environment for science

- Matter temperatures exceeding 10^8 K;
- Densities of ~ 10^3 g/cm^3;
- Pressures greater than 10^{11} atmospheres;
- Radiation temperatures exceeding 10^6 K;
- Neutron densities as high as 10^{26}/cm^3.

"Foremost among my credentials for undertaking this task are that I'm trained as a theoretical physicist, which gives me license to poke my nose into anybody's business." 10/4/99

Gather ~100 people from ~49 institutions in 6 countries to

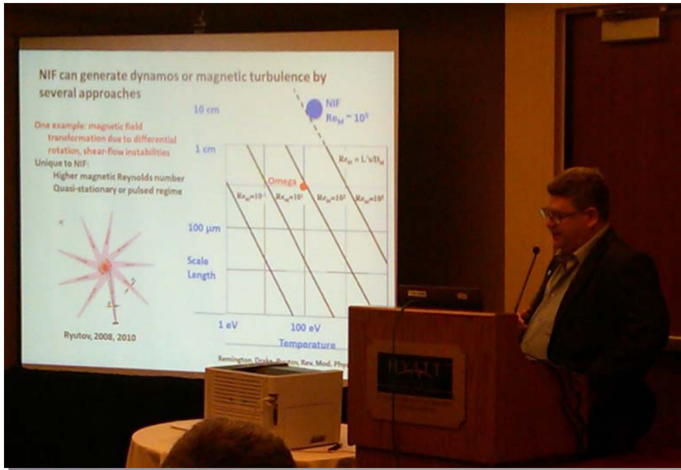
- Define discipline-specific challenges (The Problem)

- that NIF can address (The Solution)

- on a decadal scale (The Path to Success)

- that will make a difference for science (The Impact)

In Laboratory Astrophysics, Nuclear Physics, Materials and Planetary Physics, and Beam and Plasma Physics



Title of Panel
Title of Priority Research Direction

Discipline Specific Challenge

Decadal-scale “grand challenge”

NIF enabled Innovation

“Big idea” realized by new capability

What new tools/techniques/platforms/diagnostics need to be developed to address the challenge?

Challenges for experimental integration/ model validation

Research Directions

What can be done to address the challenge in the near term?
What scientific breakthroughs need to be achieved?

Outcome and Potential Impact

Broader impact/what does success look like

Sixteen Priority Research Directions emerged from Panel Deliberations

Panels	Priority Research Directions
1. Laboratory Astrophysics	1.1 Simulating Astrochemistry: The Origins and Evolution of Interstellar Dust and Prebiotic Molecules
	1.2 Explanation for the Ubiquity and Properties of Cosmic Magnetic Fields and the Origin of Cosmic Rays
	1.3 Radiative Hydrodynamics of Stellar Birth and Explosive Stellar Death
	1.4 Atomic Physics of Ionized Plasmas
2. Nuclear Physics	2.1 Stellar and Big Bang Nucleosynthesis in Plasma Environments
	2.2 Formation of the Heavy Elements and Role of Reactions on Excited Nuclear States
	2.3 Thermonuclear Hydrodynamics and Transport
3. Materials at Extremes and Planetary Physics	3.1 Quantum Matter to Star Matter
	3.2 Elements at Atomic Pressures
	3.3 Kilovolt Chemistry
	3.4 Pathways to Extreme States
	3.5 Exploring Planets at NIF
4. Beam and Plasma Physics	4.1 Formation of and Particle Acceleration in Collisionless Shocks
	4.2 Active Control of the Flow of Radiation and Particles in HEDP
	4.3 Ultraintense Beam Generation and Transport in HED Plasma
	4.4 Complex Plasma States in Extreme Laser Fields

Materials at Extremes and Planetary Physics

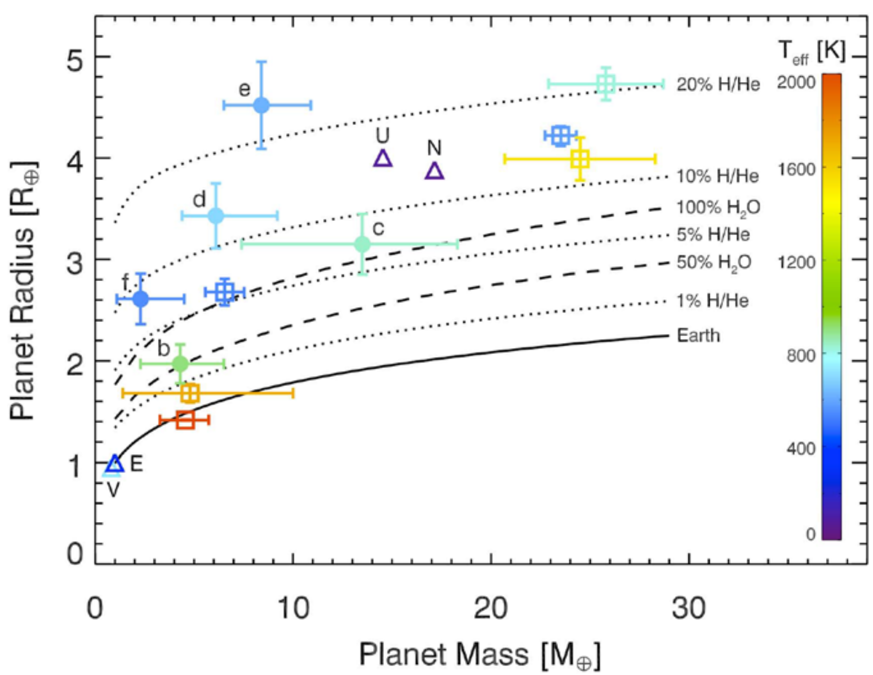
Exploring Exoplanets at NIF

Planets are everywhere. What are they made of?

1/5 of all stars have an ice giant planet.

1/10 of all stars have a earth-like planet.

Need constrained interior models for super-earths, ice giants, gas giants. Up to 10-10^3 Mbar, 10^3 to 10^6 K



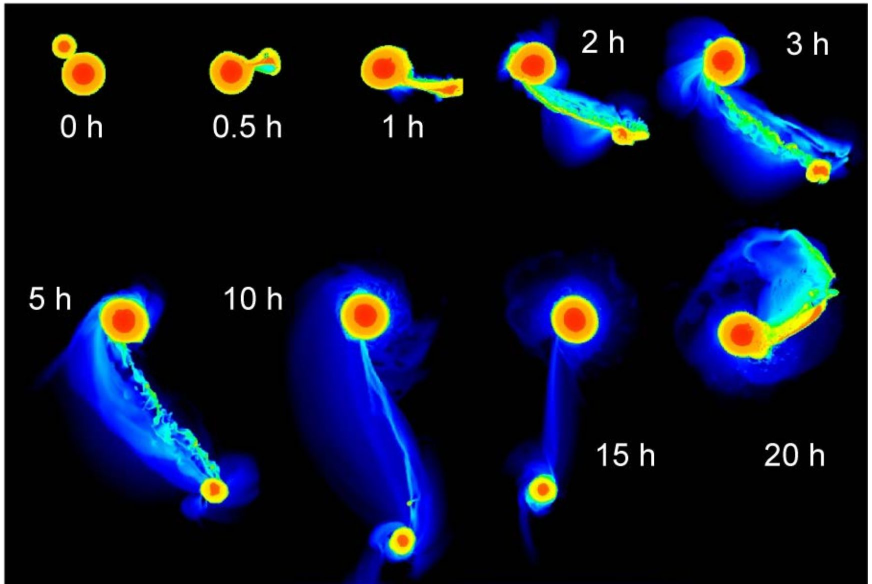
Testing models of planet formation and evolution.

Did Jupiter form by core accretion or gravitational instability? Is Saturn's excess luminosity from He rain?

Need high precision H, H-He EOS.

Origin of the Moon and core formation?

Need physics of giant impacts; melting & vaporization; mixing & phase separation



Materials at Extremes and Planetary Physics

Exploring Exoplanets at NIF

Discipline Specific Challenge

- Interior composition, structure and evolution of planets within and outside the solar system?
- The physics of planetary impacts and their role in shaping planets?
- The formation and diversity of planetary systems; pathways to habitable planets?

NIF enabled Innovation

- Tailored high-precision compression paths: achieve interior conditions of gas and ice giants and super-earths
- Mapping of states achieved during impacts and in interiors
- Large volume (cm-scale) experiments (heterogeneity, mixing, separation)

Research Directions

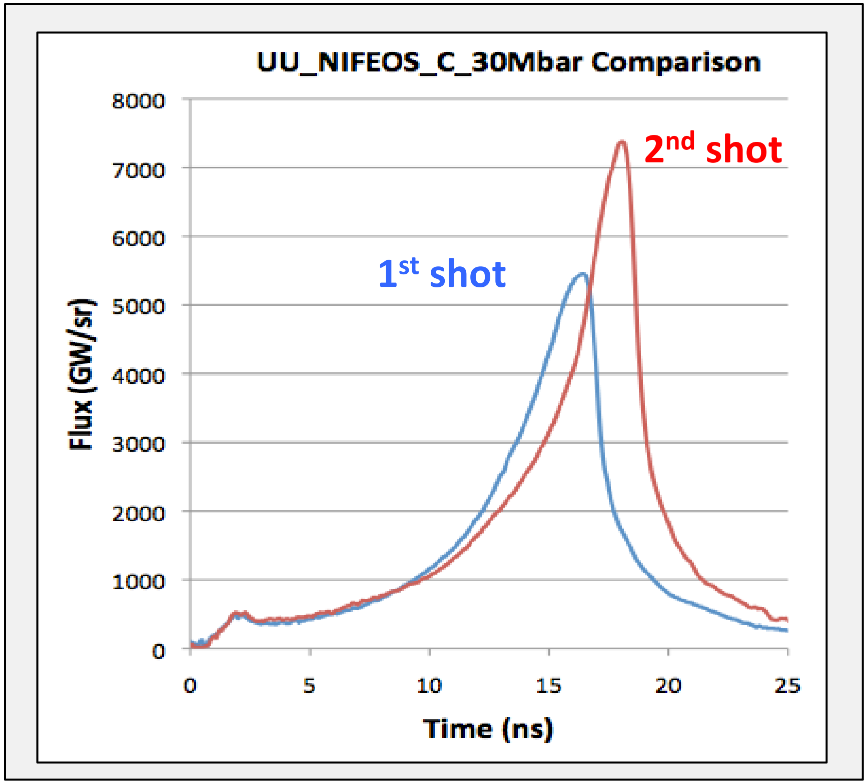
- High precision (2%) EOS measurements: H, H-He mixtures and phase separation
- Crystal structures and bonding through x-ray diffraction and spectroscopy
- Global/multiphase *P-V-T* EOS models of gases, ices, silicates, iron-alloys
- Multiphase hydrodynamics: dynamics of phase mixing and separation

Outcome and Potential Impact

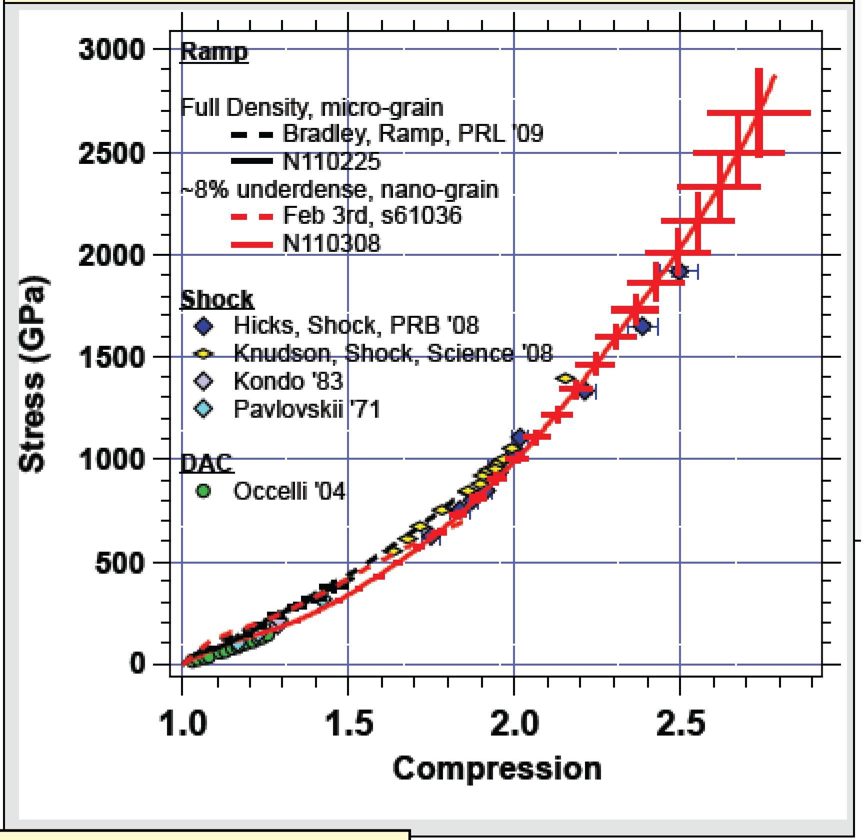
- Origin of giant planets
- Anomalous luminosity of Saturn
- Fundamental properties of the Earth: Origin of the moon, core formation
- Nature of exoplanets
- Change in properties of matter from planets to brown dwarfs to stars

Initial (unprecedented, exciting) data are just the beginning

Carbon compression to ~ 30 Mbar



Tantalum compression to 10's of Mbar

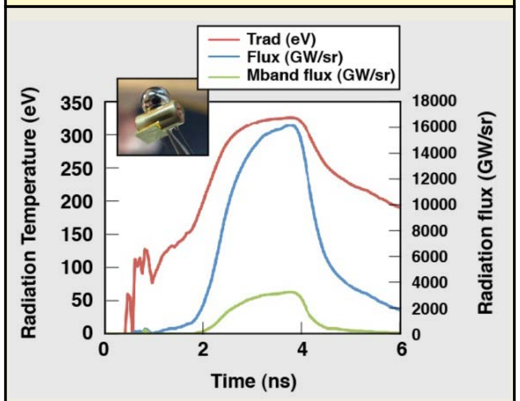


(UC Berkeley, Princeton, LLNL, et al.)

User teams aligned with the priority research directions have already taken data at NIF

Laboratory Astrophysics

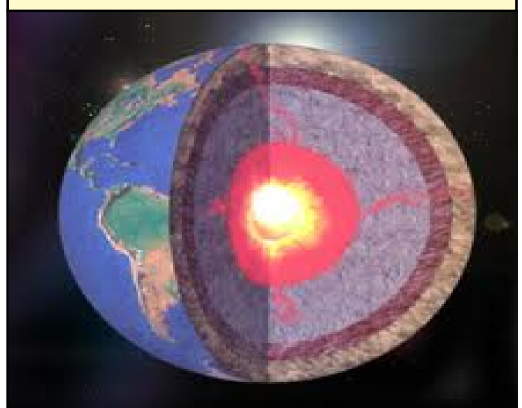
Effect of radiation on supernova hydrodynamics



University of Michigan

Materials and Planetary Physics

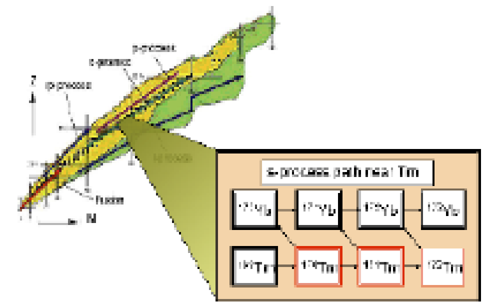
C/Fe equation of state



UC Berkeley; Princeton University

Nuclear Physics

Nucleosynthesis and the s-process

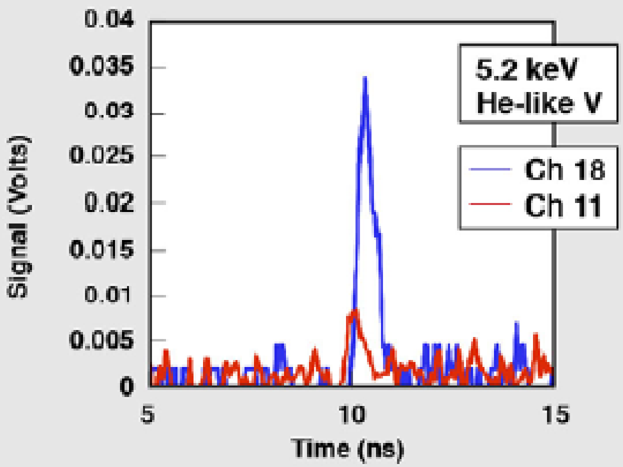


LLNL; LANL; Ohio University

Initial (unprecedented, exciting) data are just the beginning

Laboratory Astrophysics:
Radiation Hydrodynamics

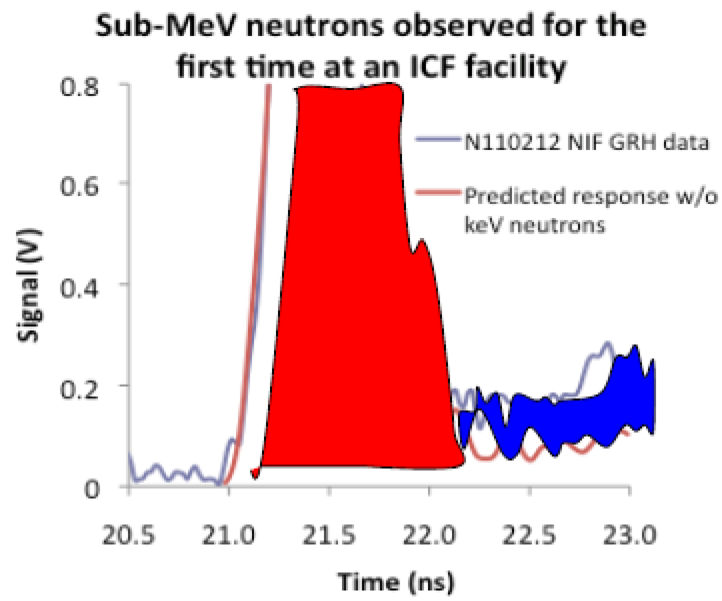
Backlighter development
October 27, 2009



Conversion efficiency of ~0.4% measured in both channels—agrees with expectation

Nuclear Physics:
Nucleosynthesis

Effect of nuclear excited states on the s-process



Governance Models and User Experience were an Important Consideration

Three principles underlie our recommendations:

Make science on NIF successful on long-term timescales

Build a sense of scientific community among NIF users

Utilize best practices and lessons learned from relevant facilities at NIF

(But, don't tell LLNL and NIF how to do their jobs)

Recommendations spanned three principal topics

Policy and Governance

-Develop clearly defined user access policy

-Foster independent advisory bodies

-Address stewardship considerations

Facility Operations

-Address/be realistic about NIF capacity for user science

-Provide access to target fabrication and simulation/design support

-Reward and provide resources to NIF staff for supporting users

Outreach and Education

-Educate the community/Communicate the excitement of NIF science

-Establish users' group

-Grow/foster intellectual centers beyond LLNL

-Create opportunities for young scientists

First NIF User Meeting two weeks ago

Capability gaps

Lab-Astro Panel

- **Facility capabilities**
  - Beam delays up to 10 µs
  - Far off axis (10 cm) laser pointing
  - Induction coils
- **X-ray diagnostics**
  - Large FOV (~cm), ~ µm resolution gated imaging
  - Large aperture, high res spectral x-ray imager
  - Versatile x-ray scattering
  - Diverse x-ray spectroscopy
- **“Optical” diagnostics**
  - Optical interferometry
  - Faraday rotation
  - UV Thomson scattering

Nuclear Physics Panel

- High resolution charged-particle, neutron and gamma spectrometry techniques at low energies
- Capsule designs tailored to mimic thermonuclear reaction plasma environments in stellar and big bang nucleosynthesis
- Capsule designs tailored to mimic neutron spectra in Asymptotic Giant Branch and massive stars that drive s process nucleosynthesis
- Capabilities to load radioactive elements in capsules
- Radiochemical diagnostic capabilities (debris collection) and in-situ counting

On the decadal scale, the opportunity exists to shape the facility and to drive r&d

NIF Science 2020

"NIF Science" is more than just HED science

The broader community wants to engage

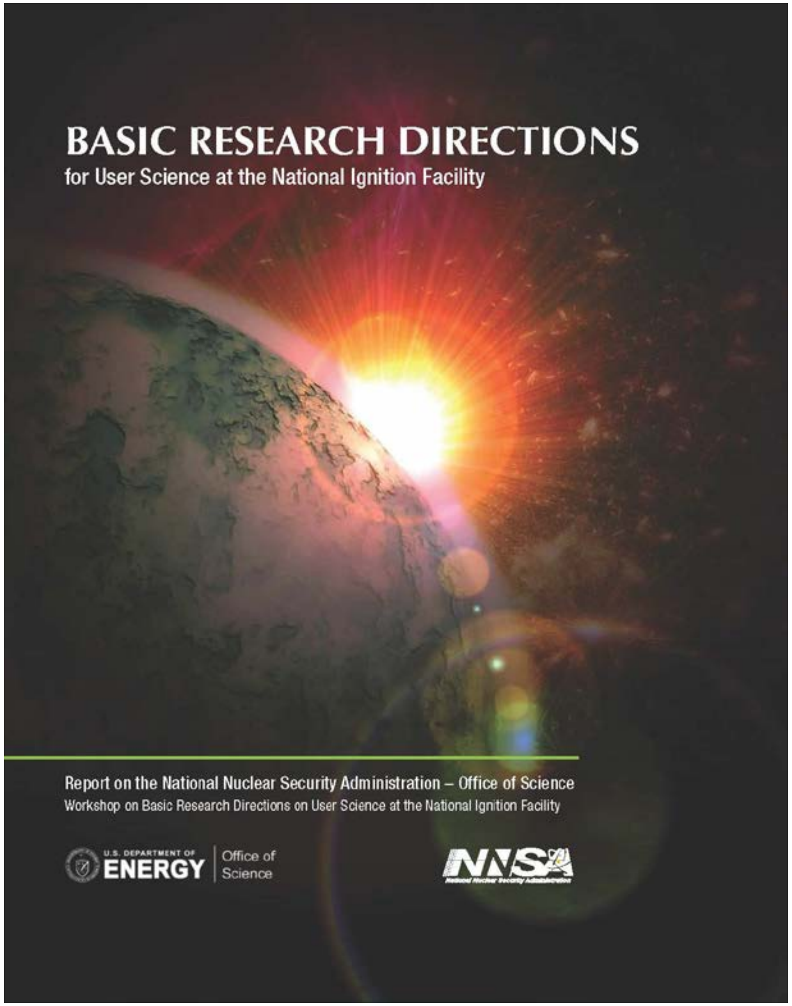
The time to seize the opportunity is now

Exciting possibilities AND development required

Partnering between SC and NNSA is essential for realizing the full potential of NIF Science

SC & other facilities provide models and infrastructure for NIF to emulate

Thank you for your interest!



http://science.energy.gov/~/media/sc-2/pdf/reports/SC-NNSA_BRD_Report_on_NIF_User_Science.pdf