High Energy Density Physics: What's Happening?

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Office of Fusion Energy Sciences
Presented to FESAC
March 2, 2007

PRE-DECISIONAL

Key Points

- Interagency Task Force on HEDP report to be issued shortly (estimate by 3/31/07)
- Federal stewardship of high energy density laboratory plasma physics (HEDLP) needs to be improved
- OFES and NNSA ICF Office are establishing a joint program in High Energy Density Laboratory Plasmas (HEDLP) to address this issue
  - The joint program will provide stewardship of HEDLP while maintaining the interdisciplinary nature of this area of science
- An Advisory Committee for the joint program will be established
- Details of program management and execution plan are being developed and in discussion with NNSA

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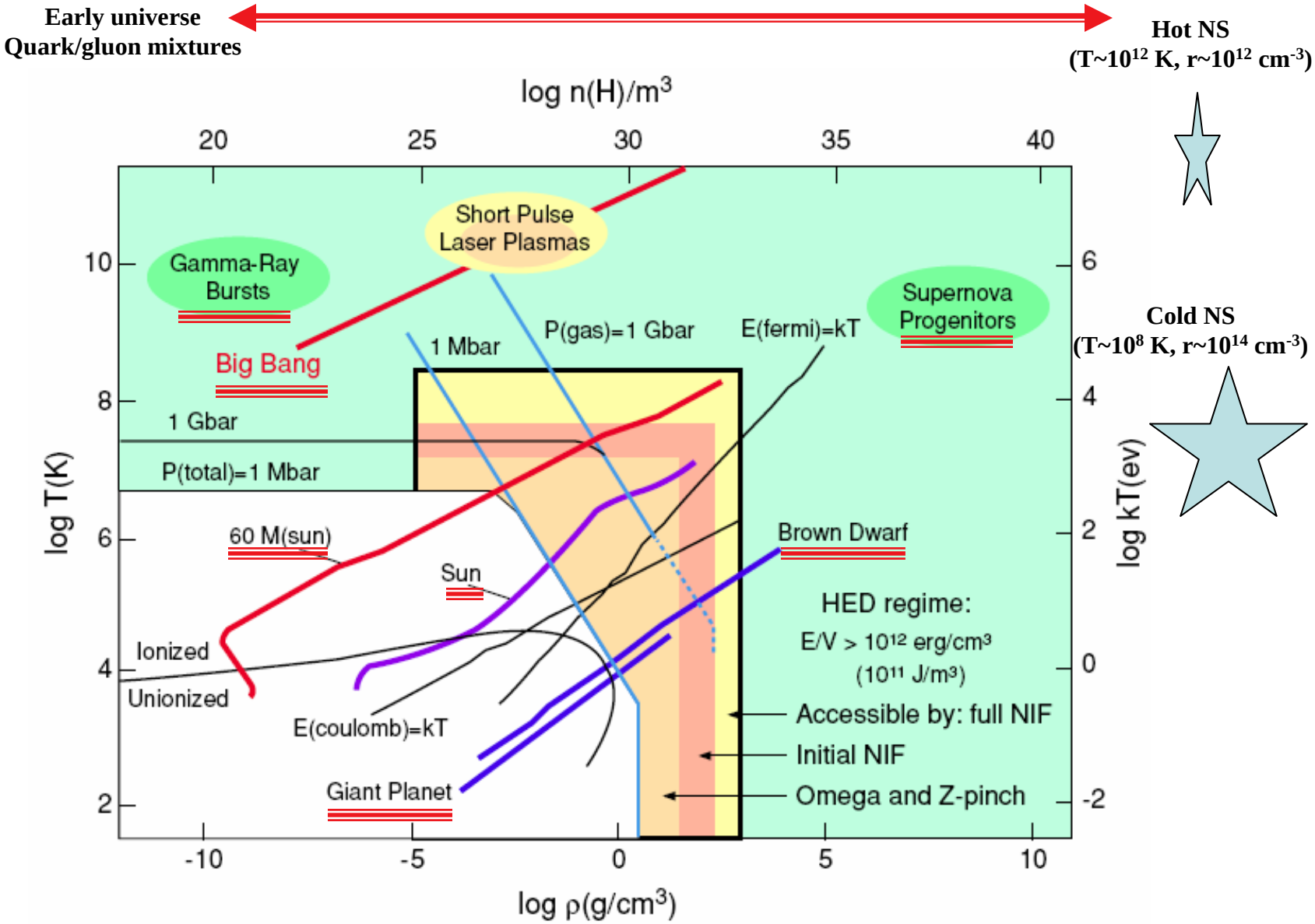
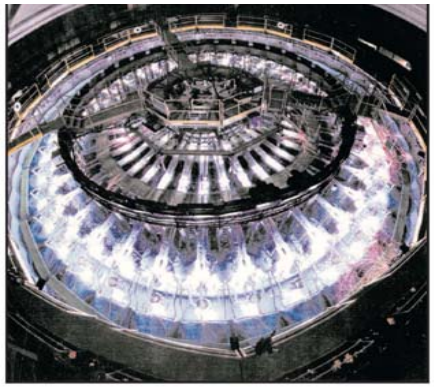
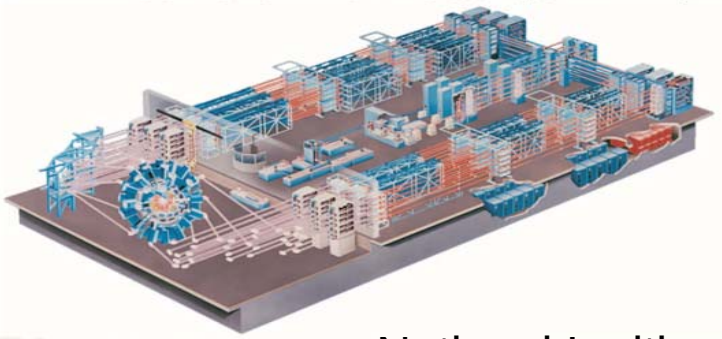
HEDP: Exciting Physics with Potentially Immense Payoffs



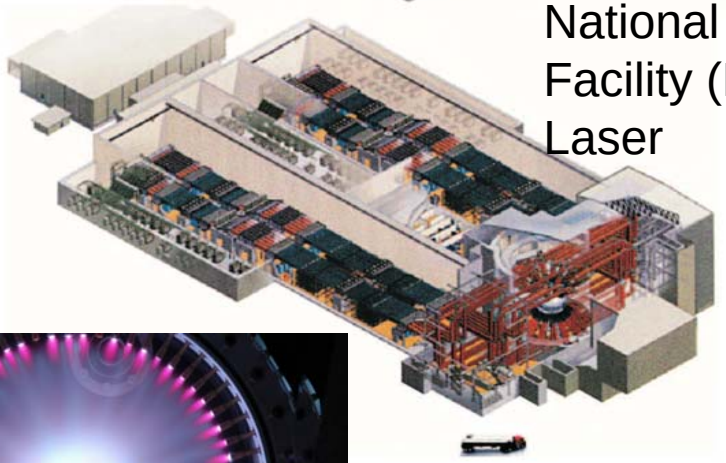
Current and future facilities open new frontiers in experimental high energy density science

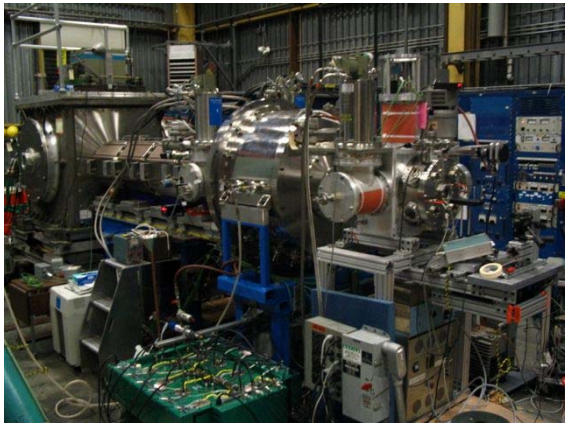
20 MA SNL Z-pinch Facility



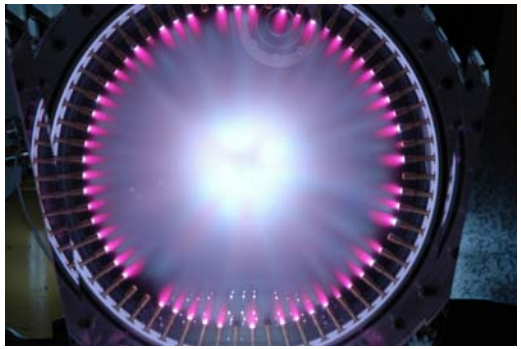


National Ignition Facility (NIF) 2 MJ Laser





Heavy Ion Beam Experimental Facility (NDCX) at LBNL



Convergence of dense plasma jets

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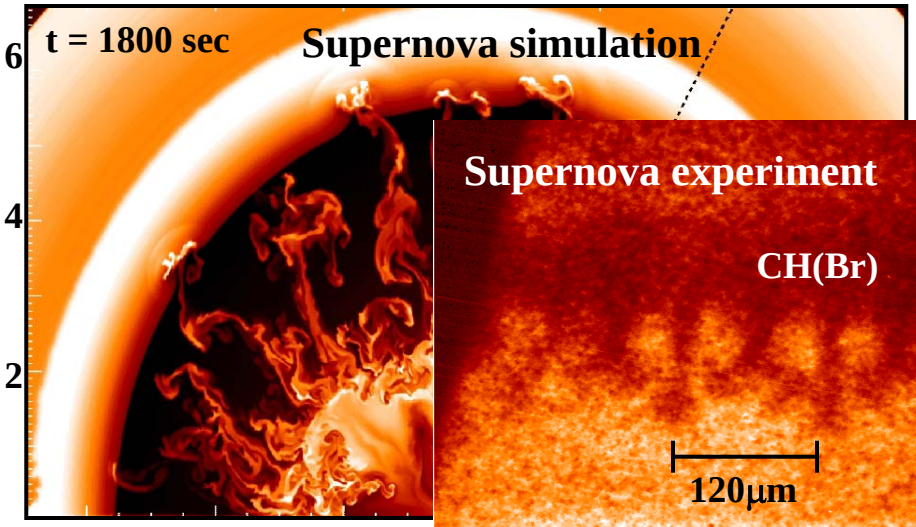
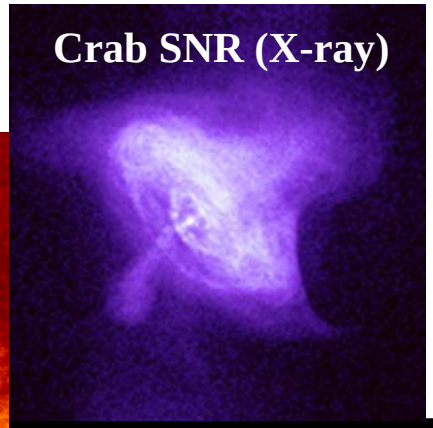
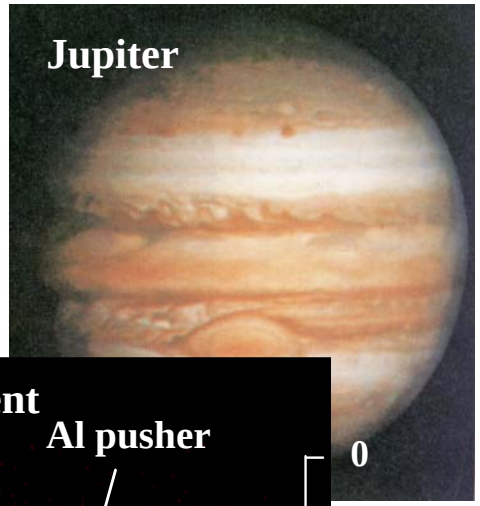
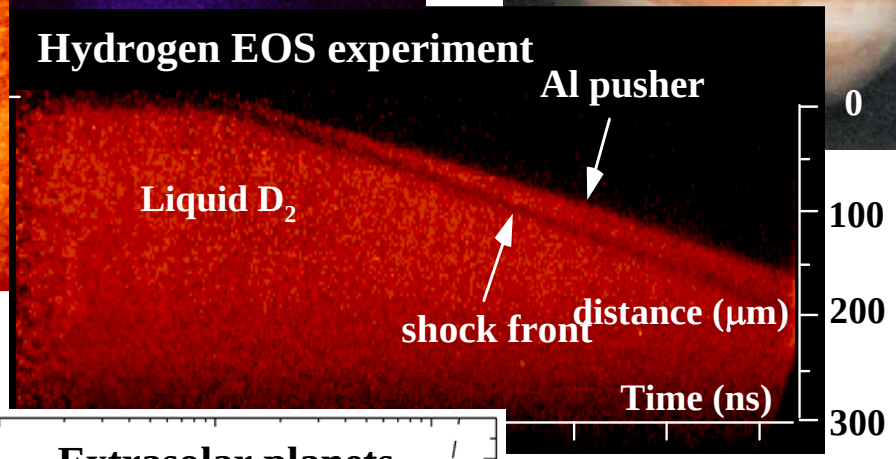
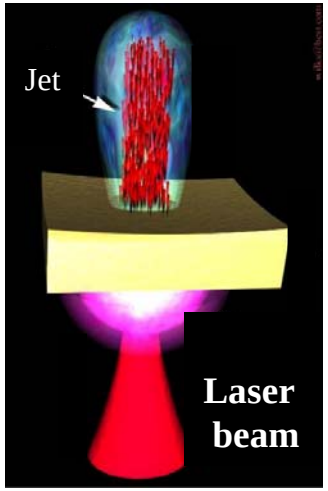
High Energy Density Plasma Science and Astrophysics



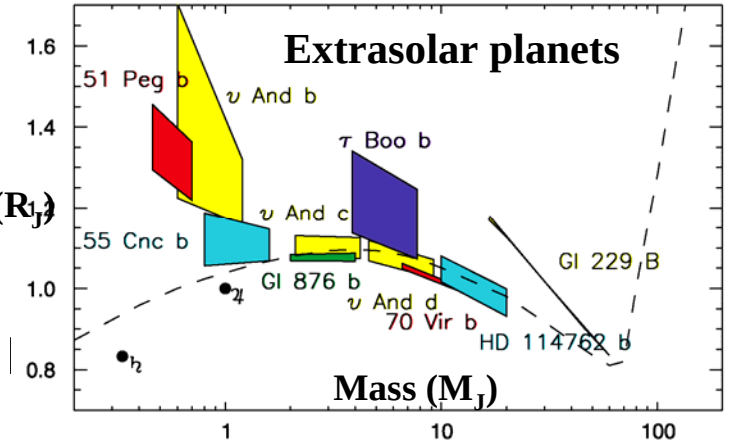








Lab relativistic micro-fireball jet



Many important physics questions can be addressed in the next decade

- How does matter behave under conditions of extreme temperature, pressure, density, and electromagnetic fields?
- Can high yield thermonuclear ignition in the laboratory be used to study aspects of supernova physics and nucleosynthesis?
- Can the transition to turbulence, and the turbulent state, in high energy density systems be understood?
- What is the dynamics of strong shocks interacting with turbulent and inhomogeneous media?
- Can conditions relevant to planetary and stellar interiors, white dwarf envelopes, neutron star atmospheres, and black hole accretion disks be recreated in the laboratory on next-generation HED facilities?

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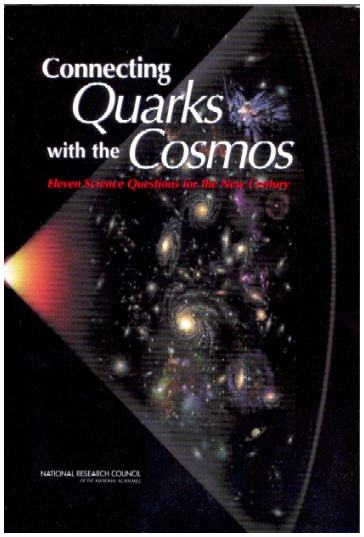
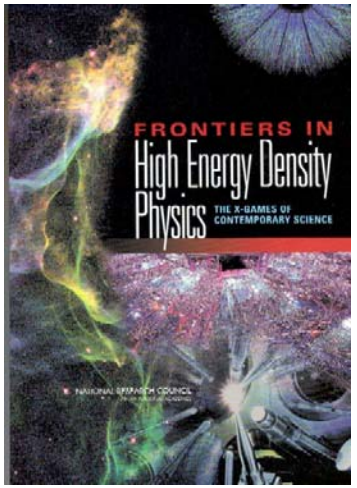
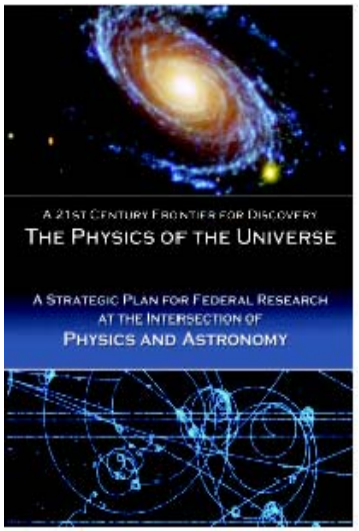
Previous Reports on HEDP



- Turner's NRC Report 2003 "Connecting Quarks with the Cosmos"
- Davidson's NRC Report 2003 "Frontiers in High Energy Density Physics: X-Games of Contemporary Physics"
- Community Workshop Report 2003 on "The Science and Applications of Ultrafast, Ultraintense Lasers"
- Report of the Interagency Working Group on the Physics of the Universe (IWG-POU), "A 21st Century Frontier for Discovery: The Physics of the Universe"
  - HEDP regimes are becoming increasingly accessible in the laboratory
  - Emerging scientific opportunities, and
  - One of the recommendations: "In order to develop a balanced, comprehensive program, NSF will work with DOE, NIST and NASA to develop a science driven roadmap that lays out the major components of a national HEDP program, …."





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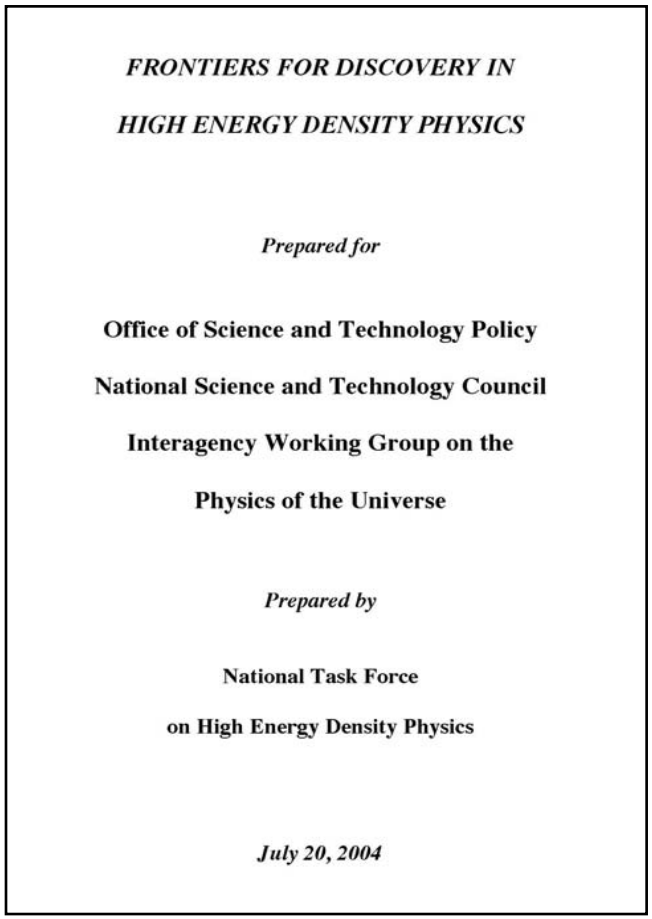
Previous Reports on HEDP



FRONTIERS FOR DISCOVERY IN

HIGH ENERGY DENSITY PHYSICS

Prepared for

Office of Science and Technology Policy

National Science and Technology Council

Interagency Working Group on the

Physics of the Universe

Prepared by

National Task Force

on High Energy Density Physics

July 20, 2004

- The IWG-POU chartered a community-based National Task Force on HEDP (NTF-HEDP) to respond to the recommendation. The NTF-HEDP was chaired again by Davidson, and produce a roadmap for the field, “Frontiers for Discovery in HEDP”, 2004.
- The current interagency Task Force on HEDP (TF-HEDP) was chartered IWG-POU to
  - respond to the community-based Davidson’s report, and
  - recommend specific steps needed to move forward on the scientific opportunities identified in HEDP.

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Interagency Task Force on HEDP Sponsor/Members

Sponsor: OSTP (R. Dimeo)

Co-Chairs: C. Keane (DOE/NNSA- ICF/NIF)
D. Kovar (DOE/SC/Nuclear Physics)

Exec. Secretary: F. Thio (DOE/SC/Office of Fusion Energy Sciences)

Members: DOD (S. Ossakow)
DOE/NNSA (R. Schneider, C. Deeney, A. Hauer)
DOE/SC/Basic Energy Sciences (E. Rolfing, M. Casassa)
DOE/SC/Nuclear Physics (J. Simon-Gillo)
DOE/SC/High Energy Physics (R. Staffin, L.K. Len)
NASA (M. Salamon)
NIST (J. Gillaspy, T. Lucatorto)
NSF (J. Dehmer)

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Task Force Charter

- **Advise and assist the Interagency Working Group on the Physics of the Universe (IWG-POU) in developing and implementing a strategic plan for advancing non-defense scientific research in High Energy Density Physics (HEDP).**

- **Provide a forum for discussion of interagency issues in High Energy Density Physics, facilitate interagency coordination, and establish priorities for the development of scientific research capabilities to address the vexing questions and opportunities in this area**

Task Force Charter (cont.)

Functions may include but are not limited to:

1. **Review agency programs and plans for scientific research specifically relevant to research in HEDP.**

2. **Identify and recommend priorities for scientific research in HEDP.**

3. **Develop plans and recommendations for implementing a coordinated, multi-agency research and development agenda in this area.**

4. **Facilitate interagency cooperation and policy development regarding use of scientific facilities.**

5. **Foster the development of the research community and facilitate coordination of HEDP activities across the agencies.**

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Davidson 2004 report defined 15 "scientific thrust areas"

1	**Astrophysical phenomena:**
2	**Fundamental physics of HED astrophysical phenomena:**
3	**Laboratory astrophysics:**
4	**Heavy ion driven HEDP and fusion:**
5	**HED physics with ultrarelativistic electron beams:**
6	**Characterization of quark-gluon plasmas:**
7	**Materials properties:**
8	**Compressible dynamics:**
9	**Radiative hydrodynamics:**
10	**Inertial confinement fusion:**
11	**Laser excitation of matter at the relativistic extreme:**
12	**Attosecond physics:**
13	**Ultrafast, high peak-power x-rays:**
14	**Compact high energy particle acceleration:**
15	**Inertial fusion fast ignition:**

- Thrust areas touch upon many well-established fields of science, such as atomic physics, nuclear physics, plasma physics, high energy physics, astrophysics, materials science, and laser science.

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Federal Research Categories in HEDP

Federal Research Categories	Lead Agencies	Research Examples
Astrophysics	**NASA, NSF**	Astrophysical jets, physics of astrophysical plasmas; neutron star interiors; core-collapse supernovae
HED Nuclear Physics	**NP, NSF**	Physics of quark-gluon plasmas; nuclear astrophysics
High Energy Density Laboratory Plasmas (HEDLP)	**NNSA, FES**	Fundamental studies of hydrodynamics, radiation flow, material properties, fusion burn, and materials under condition of extreme laser, particle and plasma beam irradiation; dense plasmas in ultrahigh fields; laboratory studies of astrophysical plasmas and associated material properties
Ultrafast, Ultraintense Laser Science	**BES, NSF**	Ultraintense x-rays for material science studies; applications of ultraintense lasers to chemistry and materials; advanced accelerators

Davidson research thrusts may be placed into these 4 categories

Federal Research Category	**Research thrust area(s) from the *Frontiers for Discovery in HEDP* report**
Astrophysics	1. Astrophysical phenomena 2. Fundamental physics of HED astrophysical phenomena
HED Nuclear Physics	6. Characterization of quark-gluon plasmas
High Energy Density Laboratory Plasmas	3. Laboratory astrophysics 4. Heavy ion driven HEDP and fusion 5. HED physics with ultrarelativistic electron beams 7. Materials properties 8. Compressible dynamics 9. Radiative hydrodynamics 10. Inertial confinement fusion 15. Inertial fusion fast ignition
Ultrafast, Ultraintense Laser Science	11. Laser excitation of matter at the relativistic extreme 12. Attosecond physics 13. Ultrafast, high peak-power x-rays 14. Compact high energy particle acceleration

The HEDLP Manifold is a Tensor Product of the Subject Areas and the Methods (Tools) to Produce HED Plasmas

- The 11 Thrust Areas spread over the three streams of HEDLP in a program matrix

	Thrust Areas	Laser-Driven	Beam driven	Pulsed-power driven
1	Laboratory astrophysics	x	x	x
2	Heavy ion driven HEDP and fusion		x	
3	HED physics with ultrarelativistic electron beams		x	
4	Materials properties under extreme conditions of temperature and density	x	x	x
5	Compressible dynamics	x		x
6	Radiative hydrodynamics	x	x	x
7	Inertial confinement fusion	x	x	x
8	Inertial fusion fast ignition	x	x	x
9	Plasma jets and dense plasmas in ultrahigh magnetic fields	x	x	x
10	Particles-waves and laser-plasma interactions	x	x	x
11	Fracture mechanics	x		x

Current FES Program in HEDP

- Since its inception in 2004, the FES program in HEDP has sought to move towards a balanced stewardship of HED science relevant to energy applications
  - Laser-driven: fast ignition inertial fusion
  - Particle-beam driven: heavy ion beam driven WDM and fusion
  - Pulsed-power driven: plasma jets and dense plasmas in ultrahigh B field, magneto-inertial fusion
- OFES will continue to provide stewardship for these areas of HEDLP in the joint program
- Supports the SC 20-year Strategic Plan:
  - 2009 Evaluate the feasibility of potential drivers, including heavy ion beams, dense plasma beams, and lasers
  - 2015 Determine the physics limits that constrain the use of IFE drivers in key integrated experiments needed to resolve the scientific issues for IFE and high-energy density physics
- Supports the IPPA 2000 Goal for IFE:
  - Advance the fundamental understanding and predictability of high energy density plasmas

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Plan of Actions

- Details on the management plan for the joint program are in discussion between OFES and NNSA
- An Advisory Committee will be established in consultation also with NSF
- Workshops and Meetings will be organized
- Budget Request for FY 2009 will be prepared for the joint program
- Solicitations will be issued in FY 2008 competing for FY 2009 funds

Summary: Key Points

- Interagency Task Force on HEDP report to be issued shortly (estimate by 3/31/07)
- Federal stewardship of high energy density laboratory plasma physics (HEDLP) needs to be improved
- OFES and NNSA ICF Office are establishing a joint program in High Energy Density Laboratory Plasmas (HEDLP) to address this issue
  - The joint program will provide stewardship of HEDLP while maintaining the interdisciplinary nature of this area of science
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