Plasma Science as a Part of NSF/Engineering's Mission

Phillip R. Westmoreland

Program Director, Combustion, Fire, and Plasma Systems

Chemical, Bioengineering, Environmental, and Transport Division (CBET)

Directorate of Engineering

U.S. National Science Foundation

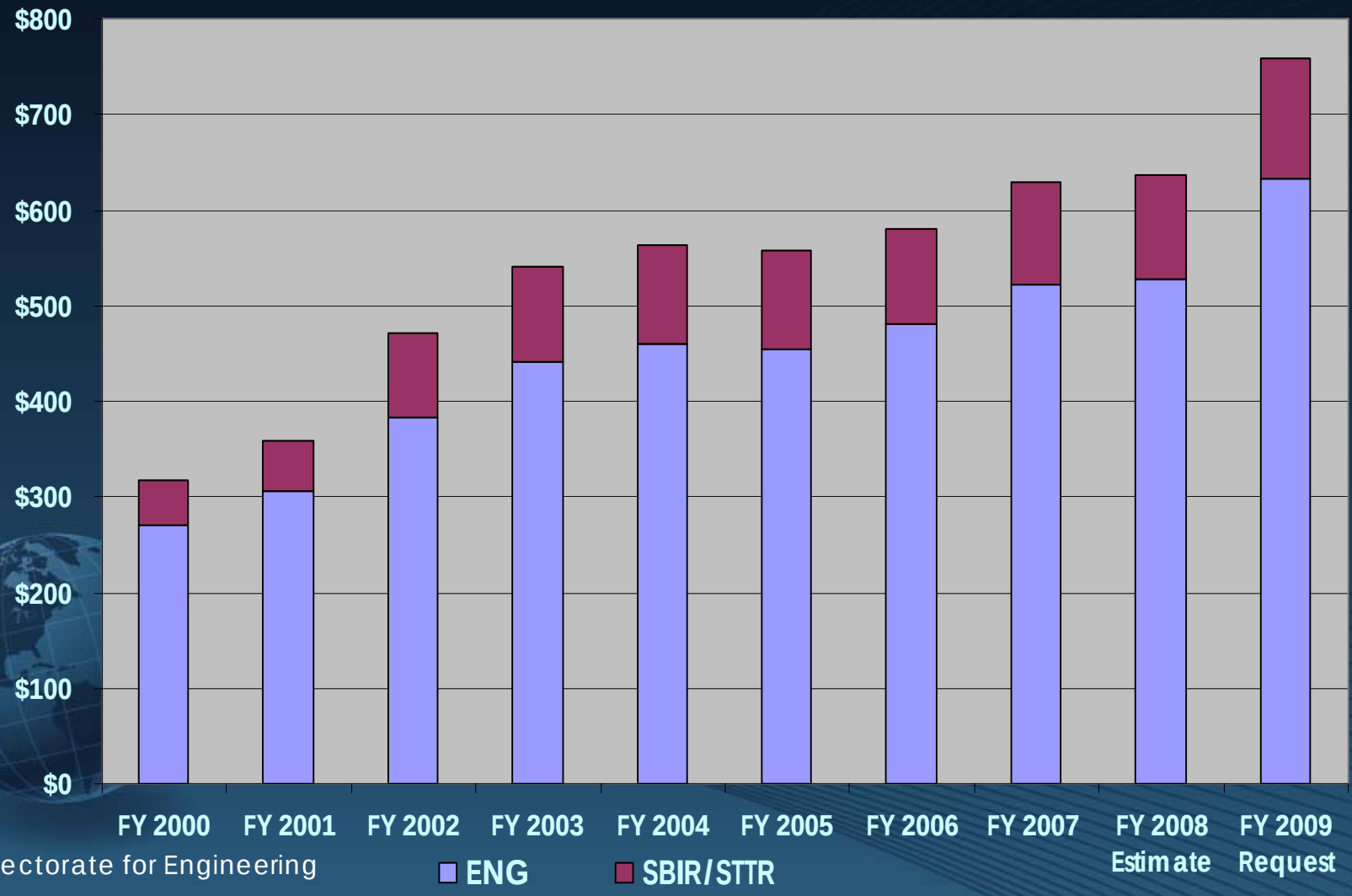
pwestmor@nsf.gov

National Academies Plasma Science Committee, Keck Center, Washington DC, October 9, 2008

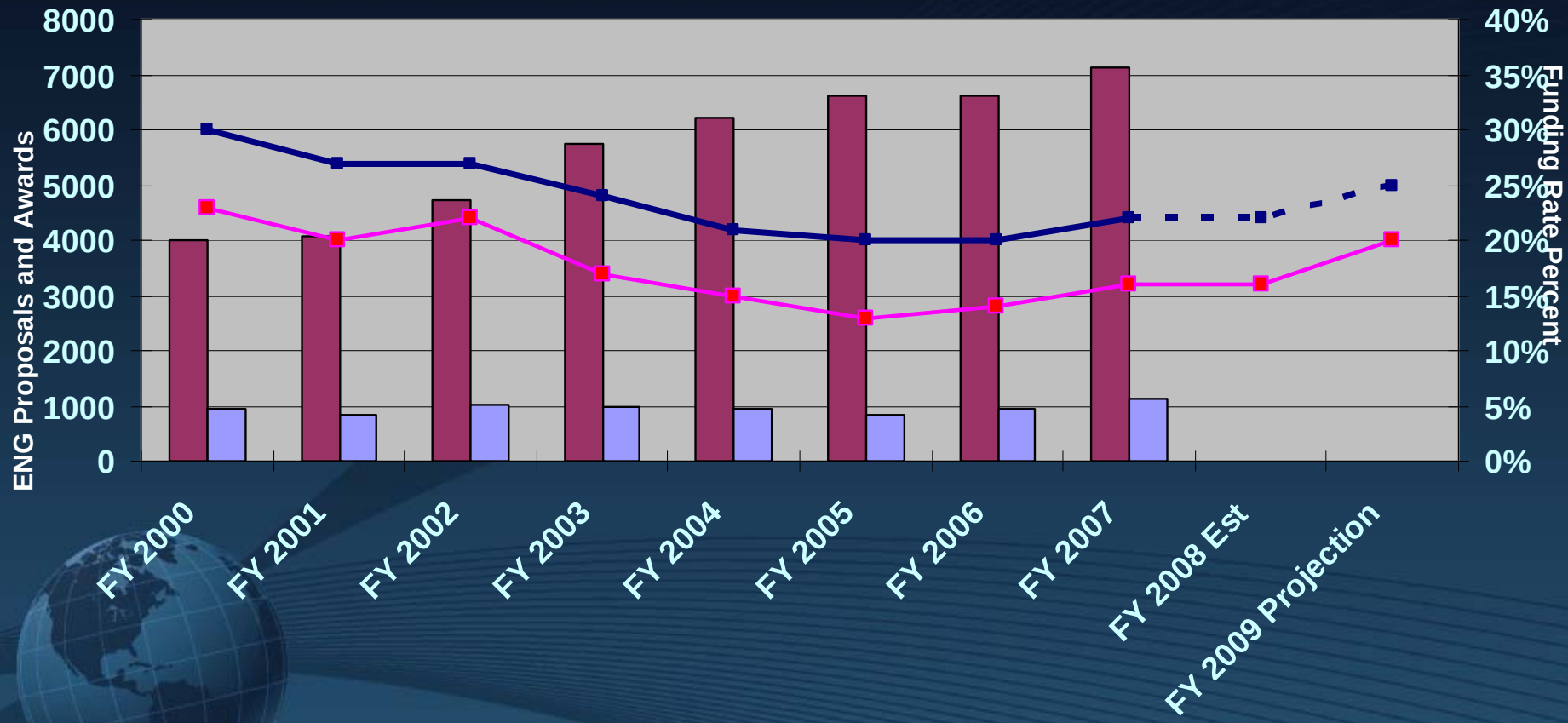
NSF is about fundamental knowledge, but the science in NSF/ENG is driven by problem-solving.

- Plasma processing and diagnostics are commercially, technologically, and scientifically important.
- Both combustion and plasma research are within the ENG/CFP program.
  - The engineering science of combustion and of plasmas has great overlap.
  - All science for technological use of plasmas is relevant for the program.
  - Flames themselves are thermal plasmas, sometimes containing particulates.
  - Among their applications, flames or conventional plasmas may be used for material synthesis or for surface treatment.

ENG and SBIR/STTR Budgets ($M)



Funding Rates of Research Grants



Combustion, Fire, and Plasma program: Core budget is $4.7 million per year.

- Typically two CAREER Awards at $400,000 for five years.
- Conferences, workshops, panels, REU supplements, SGER ~$200,000.
- About $4.1 million to unsolicited and other proposals (new and continuing) with typical sizes $280K to 300K (3-yr duration).
- You might extrapolate to about $15 million with an active total of 40-50 research awards, but...

CFP actually funds about $25 million of activity through 93 awards.

- In addition to awards from base funding:
  - PI's win awards through NSF solicitations like ITR ($1.8 million, 5 yr), NER ($100K, 1 yr), and NIRT ($1-1.2 million, 4 yr).
  - Participate in NSF/DOE Plasma Research solicitation.
  - Other awards are co-funded with other programs or by special division or directorate funds.
- CFP's plasma-research portfolio includes 31 awards totaling $6.7 million.

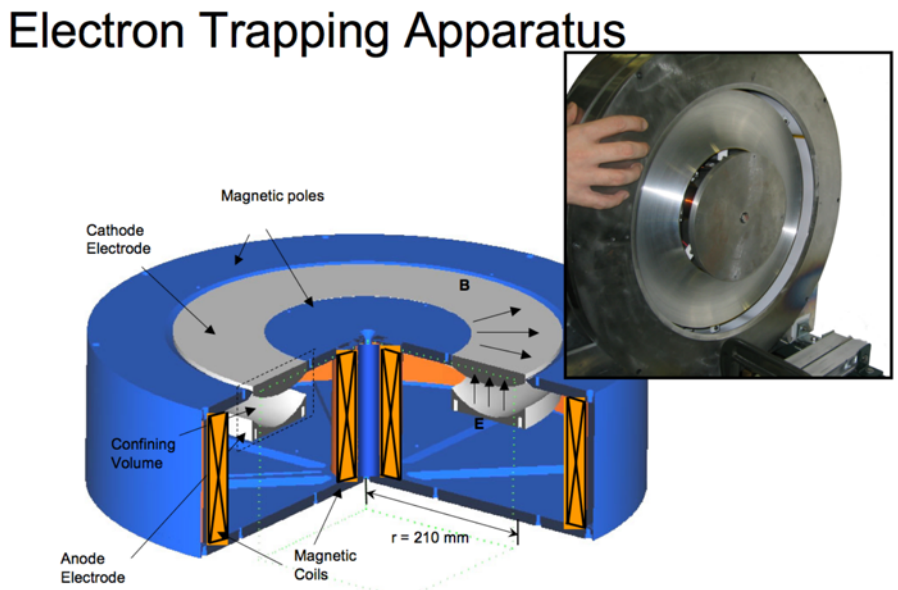
A wide range of plasma-research topics…

Title	Principal Investigator	Organization
Collaborative Research: GOALI: Nanocrystal Formation and Morphology in Nonthermal Plasmas	Michael Zachariah Uwe Kortshagen	Univ. Maryland College Park Univ. Minnesota-Twin Cities
Collaborative Research: Plasma-Surface Interactions in Hydrogen Plasma-Induced Transitions from Carbon Nanotubes to Diamond Nanostructures	Dimitrios Maroudas Eray Aydil	Univ. Massachusetts Amherst Univ. Minnesota-Twin Cities
Collaborative Research: A Diagnostic and Modeling Investigation of Pulsed PECVD	Lax Raja Colin Wolden	Univ. Texas at Austin Colorado School of Mines
Collaborative: Plasma deposition of thin films on nanowires and particles	Themis Matsoukas Farzad Mashayek	Penn State Univ. Univ. Illinois at Chicago
The Power Balance of Plasmas at Extreme High Pressure	James Lawler	Univ. Wisconsin-Madison
Toward Fundamental Understanding: Correlating the Gas-Phase, Surface, and Gas-Surface Interface in Halogenated Plasma Systems	Ellen Fisher	Colorado State Univ.
Quantifying Plasma-Surface Interactions: Charge Exchange, Energy Losses, Fragmentation, and Reactions	Konstas Giapis	Caltech
Fundamental Physical and Chemical Investigations of Electron-Beam Plasmas	Ted Dibble	SUNY Coll. of Env. Sci. and Forestry
Systematic Studies of Plasma Reactions on Dynamic Surfaces Using a Novel Rotating Substrate	Vince Donnelly	Univ. of Houston
Ion and Neutral Velocity Distributions in Multi-Ion Plasma Sheaths	Earl Scime	West Virginia Univ.
Spectroscopic Diagnostics for Low Temperature Industrial Plasmas	Amy Wendt	Univ. Wisconsin-Madison
Influence of superequilibrium and metastable species on nonequilibrium plasma combustion kinetics	Walter Lempert	Ohio State Univ.
Modeling Nanodusty Plasmas	Steven Girshick	Univ. Minnesota-Twin Cities
Nanoparticle Detection Using Microplasma	Jeffrey Hopwood	Tufts Univ.
Effect of ion flows on heating and instabilities in weakly coupled dusty plasmas	Edward Thomas	Auburn Univ.
Role of Excited Species in Plasma-Enhanced Combustion	David Miller	Drexel Univ.
High-Resolution Laser Diagnostics and Modeling of Single-Walled Carbon Nanotube Synthesis by Plasma-Enhanced CVD	Robert Lucht	Purdue Univ.

A wide range of plasma-research topics…

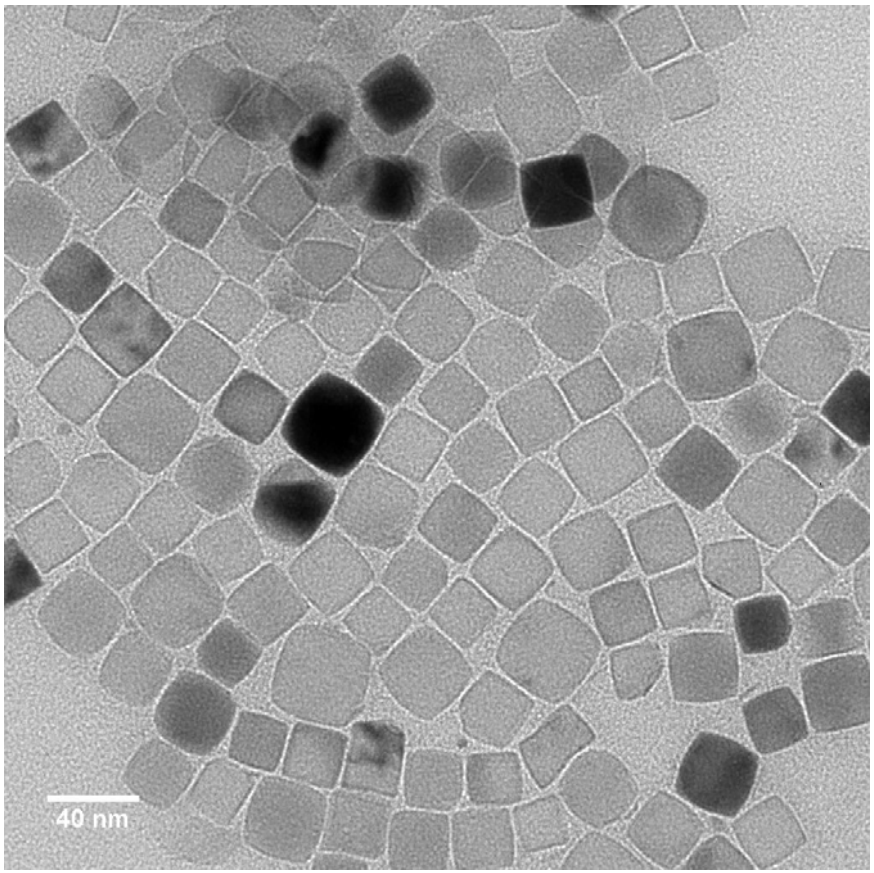
Title	Principal Investigator	Organization
CAREER: Electron Fluid Dynamics in a Hall-effect Accelerator: Using Fundamental Research to Enhance Education and Technology	Brad King	Michigan Tech Univ.
CAREER: Continuous-flow microplasma synthesis of Group IV semiconductor nanoparticles	Mohan Sankaran	Case Western Reserve Univ.
SGER: GOALI: Experimental Studies on Nanoscale Corona Discharges	Junhong Chen	Univ. Wisconsin-Milwaukee
SGER: Development of in situ NMR spectroscopy and in situ MRI as new diagnostic tools for atmospheric-pressure plasmas	Thomas Meersmann	Colorado State Univ.
SGER: The Effects of Temperature and Conductivity on Aqueous-Phase Electrical Discharge	Bruce Locke	Florida State Univ.
Drexel & The University of Orleans--IRES in Plasma Medicine	Alexander Fridman	Drexel Univ.
Student and Participant Support for the 2008 Gordon Research Conference on Plasma Processing Science	Uwe Kortshagen	Univ. Minnesota-Twin Cities
Partial Support for Graduate Summer Institute on Complex Plasmas	Jose Lopez	Saint Peter's College
Student Travel Support for the 2008 Gaseous Electronics Conference (GEC)	Lawrence Overzet	Univ. Texas at Dallas
International Conference on Plasma Medicine ICPM-2 Student support	Alexander Fridman	Drexel Univ.

CAREER: Electron Fluid Dynamics in a Hall-Effect Accelerator: Using Fundamental Research to Enhance Education and Technology (King, Michigan Tech)



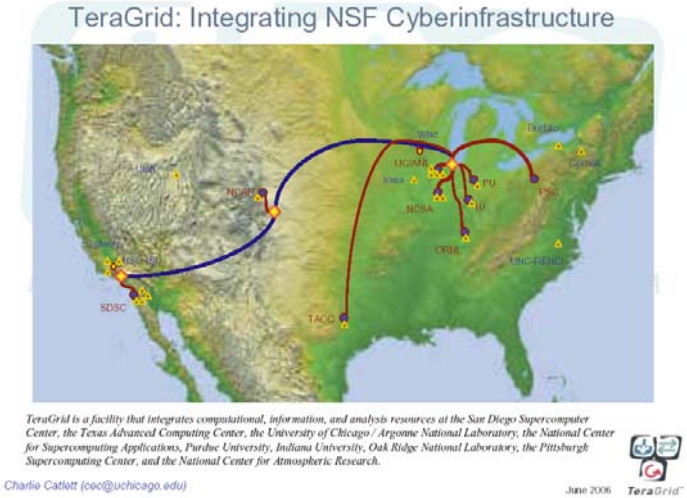
- Project seeks to understand anomalous leak rates of plasma across magnetic field lines in an attempt to account for the discrepancy between observation and theory.
- Investigators have designed, constructed, and tested a novel apparatus for inducing anomalous diffusion in a very controlled manner.

Collaborative Research / GOALI: Nanocrystal Formation and Morphology in Nonthermal Plasmas (Zachariah, Maryland; Kortshagen, Minnesota; Innovalight, Inc.)



- May allow higher-efficiency solar cells.
- Possible cheaper fabrication by solution deposition of conductive films.
- This is apparently the first process that produces silicon crystals of a cubic shape.
- Hypothesis: Anisotropic hydrogen etching of heated Si, initially spherical, transforms particles into nanocubes.

Consider cyberinfrastructure and its applications to plasma science.



- More powerful computing:
  - Grid-based computing
  - "Simulation-Based Engineering and Science"
- Different ways of collecting and processing data.
  - Remote sensor networks and remote experiments.
  - Data workflows (Make data depositories, not data graveyards).
- More effective collaboration and information transfer:
  - Interactive data archives.
  - Threaded discussion.
  - "Virtual organizations" (gateways, hubs, collaboratories).

NSF-wide solicitation: Cyber-enabled Discovery and Innovation (CDI)

- Five-year initiative with minimum of $26M in FY 2009.
  - Minimum of $26M was promised in FY 2008; awarded $40M through 38 awards.
- Intent is to create *potentially transformative* science and engineering research outcomes...
- made possible by innovations and advances in "computational thinking":
    - Computational concepts, methods, models, algorithms, tools
- Emphasis on bold, multidisciplinary activities – must show promise of potentially transformative outcomes in two or more disciplines.

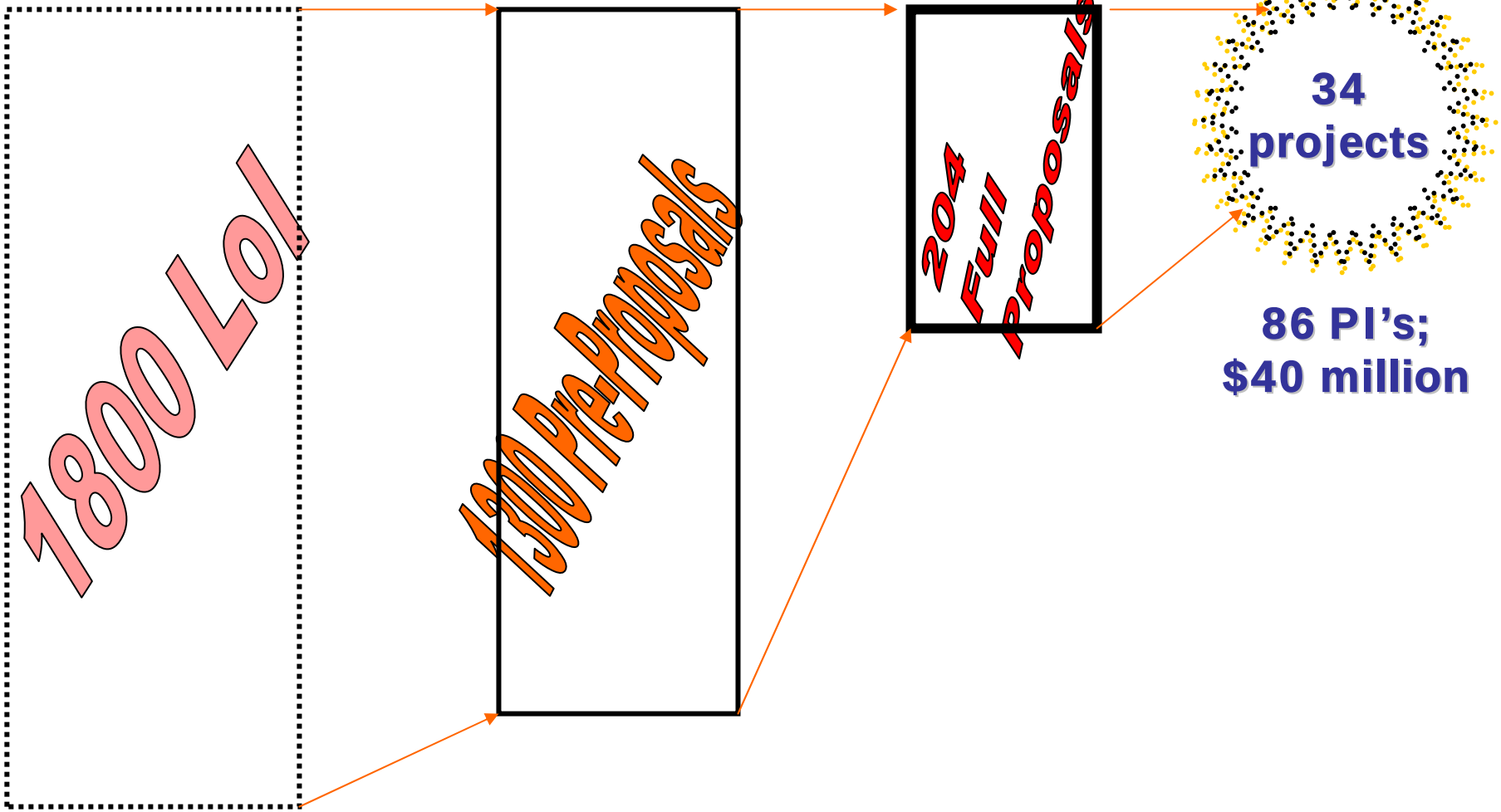
CDI seeks transformative research in the following general themes:

- **From Data to Knowledge:** *enhancing human cognition and generating new knowledge from a wealth of heterogeneous digital data;*
- **Understanding Complexity in Natural, Built, and Social Systems:** *deriving fundamental insights on systems comprising multiple interacting elements;* and
- **Building Virtual Organizations:** *enhancing discovery and innovation by bringing people and resources together across institutional, geographical and cultural boundaries*.

Projects are classified by magnitude of effort, not $.

- Three types are defined:
  - Type I - Level of effort equivalent to ~2 PI's, 2 graduate research assistants, 3 years duration.
  - Type II - Level of effort equivalent to ~3 PI's, 3 GRA's, 1 post-doc, 4 years.
  - Type III - Center-scale level of effort.
- [Type III, center-scale efforts, are not supported in the first or second years of CDI.]

Found and funded some excellent proposals – none yet in plasma science and engineering.



To close:
What opportunities, specifically in this program?

- Encourage stretching across even more disciplinary boundaries.
  - Applying plasma science to diverse technologies.
  - Bridging the computer scientist / engineering scientist gap.
  - Broader opportunities: Linking plasma scientists with materials scientists.
- Encourage new science for systems-level solutions.
- Encourage more representative student populations.