MY THOUGHTS ON NASA, ACADEMIA, AND TECHNOLOGY DEVELOPMENT

PLANETARY SCIENCE TECHNOLOGY PANEL

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The University of Michigan
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DISCLAIMER

The following opinions are mine alone. They should not be considered the views of the University of Michigan.
I will also report on the views of other academics.

Who am I?

Professor of Aerospace Engineering at Michigan
Expert in electric propulsion (EP) and plasma physics
Ph.D. from Princeton
Michigan faculty member since January 1992
Founder and director of the Plasmadynamics and Electric Propulsion Laboratory at Michigan
AIAA Fellow
Graduated 27 Ph.D. students and 11 M.S.

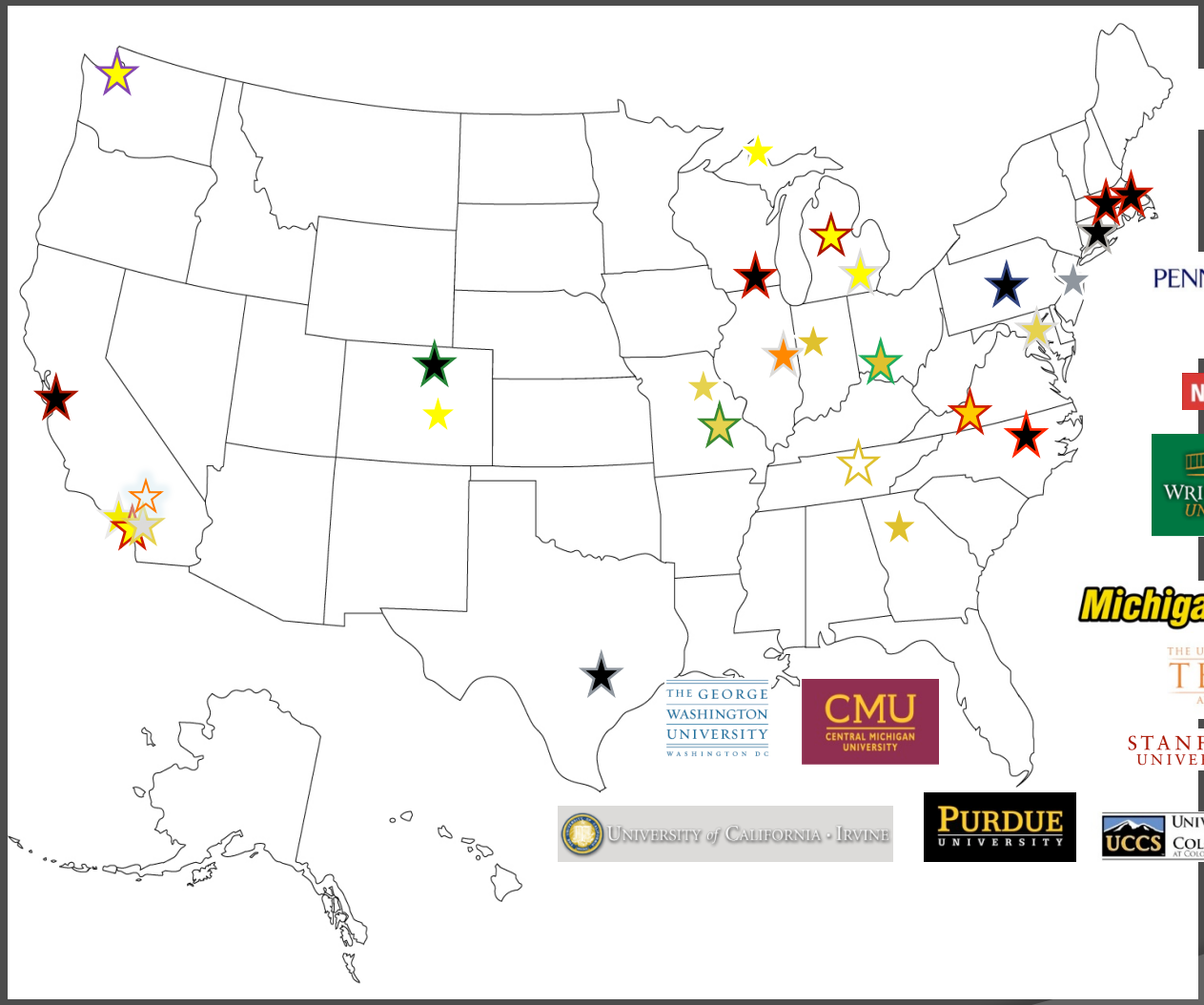
The Landscape

- NASA proposes to engage in technology development on a massive scale
- NASA will work on high-risk, high-payoff technology; NIAC-2
- NASA acknowledges the need to engage academia
- NASA is proposing to increase graduate students funding – workforce infusion

Challenges

- NASA's track record in academia for technology development spotty
  - Prometheus, JIMO, Bush "41" and "43" Mars initiatives
- Rapid changes in research priorities deadly for academics
- Academia may not consider NASA to be a good partner
- Academics will be suspicious of NASA and its long-term commitment

U.S. Academic Programs in EP
27 Institutions – 35 Professors



MIT
Mizzou University of Missouri
WPI
Yale UNIVERSITY
PRINCETON UNIVERSITY
PENNSTATE
VT
GT
NC STATE UNIVERSITY
VANDERBILT UNIVERSITY
WRIGHT STATE UNIVERSITY
MICHIGAN
ILLINOIS
MichiganTech
MISSOURI S&T University of Science & Technology
THE UNIVERSITY of WISCONSIN MADISON
THE UNIVERSITY OF TEXAS AT AUSTIN
STANFORD UNIVERSITY
UNIVERSITY of WASHINGTON
Colorado State University
UCCS UNIVERSITY OF COLORADO AT COLORADO SPRINGS
Ucla
USC
CALTECH

Methodology – Survey

1) List of EP projects and type (modeling vs. experimental);
2) Head count of undergraduates, graduate students, postdocs, and research scientists engaged in EP research;
3) Capacity – "How much larger a group could you manage?"; and
4) Thoughts on the following items:
   - *Investment levels*
   - *EP technology development challenges*
   - *Other items. What are we missing in our discussion?*

	# research scientist	# postdocs	# grads	# undergrads	grads desired
Responders	**4**	**7**	**65**	**53**	**80**
All - some based on website	***5***	***12***	***110***	***71***	***135***

23% growth

Sample Projects

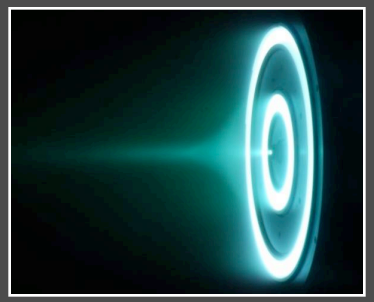
Institution	Project	Experiment	Modeling
MIT	Divergent Cusped Field Thruster	✓	✓
	Electrospray Propulsion	✓	✓
WPI	Flows in micro/nano nozzles and plumes		✓
	Plasma and gaseous microjets	✓	
	EEDF in hollow cathode plume	✓	
Georgia Tech	Field emission from carbon nanotubes	✓	
	ion focusing in discharge channel of a Hall Effect Thruster	✓	
	Concentric Channel Hall Thruster	✓	
	Increasing propellant residence time in Hall Thruster	✓	
	Dual-use Propulsion system for responsive space	✓	
	Hall Thruster Thermal Analysis	✓	
	Ambient Atmosphere Ion Thruster	✓	
Missouri S&T	Heavy-gas FRC plasmas	✓	
	Dual-mode ionic liquid propulsion	✓	✓
	Boron Nitride surface roughness/erosion studies for HETs	✓	
Michigan	Michigan AFRL Center for Excellence in EP		✓
	Ion Thruster Microwave plasma cathode	✓	
	Ion Thruster magnetic cusp collection studies	✓	
	Microwave plasma thruster	✓	
	50-cm ion thruster discharge chamber study	✓	
	Nested Channel Hall Thrusters	✓	
	Nanoparticle field emission thruster	✓	✓
	Hall Thruster Electron physics studies	✓	✓
	Neutral Gas in Hall Thruster Discharge Channel	✓	
	Magnetic Nozzle Detachment in RF plasma	✓	
	Time-resolved Plasma Diagnostics	✓	
	Erosion studies of Hall Thruster Discharge Channel	✓	
Wright State	NEXT ion engine PIC/MCC		✓
Illinois	Gallium Electromagnetic Thruster	✓	
	Microcavity discharge thruster	✓	✓

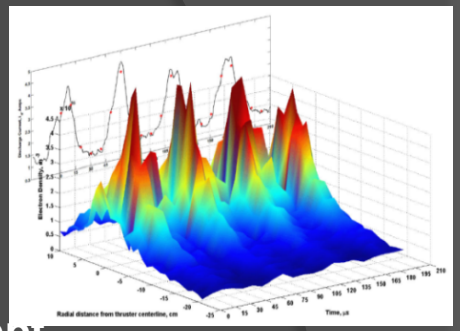
>70 EP-Related Projects (75%) Primarily Experimental

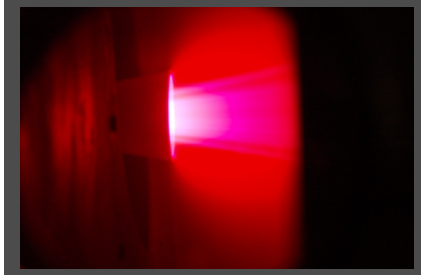
Institution	Project	Experiment	Modeling
Caltech	Cathode Physics for Electric Propulsion	✓	
Colorado State	CRDS diagnostic development	✓	
	Sputter yield characterization	✓	
	Hollow Cathode plasma measurements	✓	
	Ion optics and grid erosion in ion thrusters		✓
Wisconsin	Advanced Helicon Thruster Performance	✓	
UC at Colorado Springs	Liquid Droplet Thrusters	✓	✓
	Radiometric force production	✓	✓
Michigan Tech	Re-generable Field Emission Cathodes for Low-power EP	✓	
	Xenon, Bismuth, and alternate metal Hall Thrusters	✓	
	Hall Thruster thermal modeling		✓
	Electron Dynamics in Hall-effect accelerator	✓	
	annular Field-reversed Configuration plasma	✓	
	Carbon nanotubes for sputter erosion resistance	✓	
Stanford	Physics of Divergent Cusped Thrusters	✓	✓
	Coaxial Plasma Accelerator	✓	
Washington	Electrodeless Lorentz Force Thruster	✓	✓
Princeton	Segmented Electrode Hall Thruster	✓	
	Cylindrical Hall Thruster	✓	
	High Frequency oscillations in Hall Thrusters	✓	
	Near-Anode Processes in Hall Thrusters	✓	
	Secondary Electron Emission	✓	
	Ferroelectric Plasma Sources	✓	
	Magnetic Nozzle Acceleration and Detachment	✓	
	Lithium Lorentz Force Acceleration and Detachment	✓	
	Plasma Heating using Beating Electrostatic Waves	✓	
	Conical Theta Pinch Faraday Accelerator with RF Assisted Discharge	✓	
UT Austin	Plasma Actuators for supersonic/hypersonic flow	✓	✓
UCLA	Plasma Actuators	✓	✓
University of Missouri at Columbia	Ferroelectric Plasma Thruster	✓	
George Washington University	Micro-Vacuum Arc Thruster	✓	
	Hall Thruster 1D Kinetic Code		✓

Sample Efforts

Michigan/AFRL Center of Excellence in Electric Propulsion (MACEEP) — Michigan (Lead), Colorado State, Michigan Tech, Penn State, Washington, UCLA, MSNW



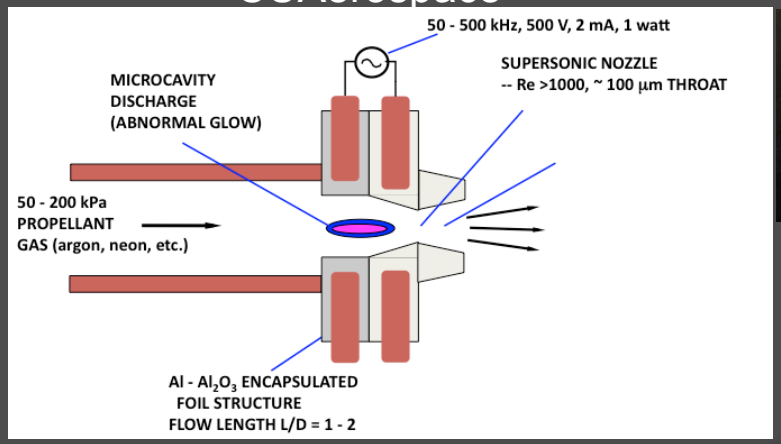


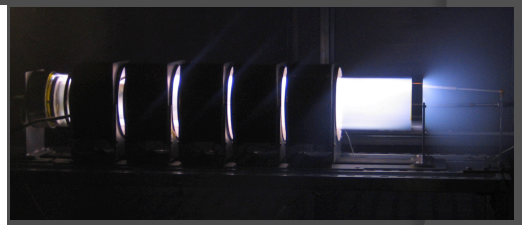


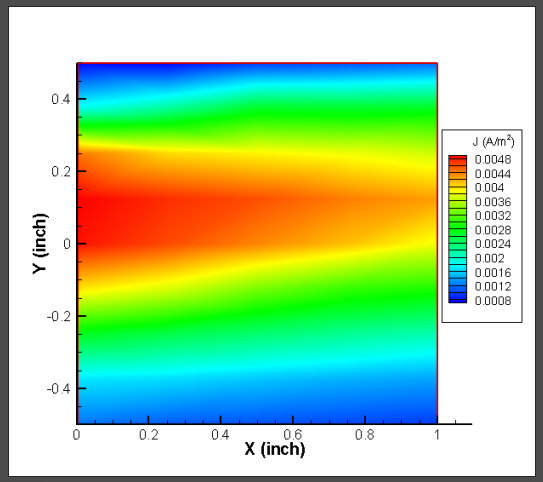
Magnetic Mirroring-Based Divergent Cusped Concept — Princeton, MIT, Stanford, George Washington

Advanced Helicon Thruster Characterization — Georgia Tech and Wisconsin

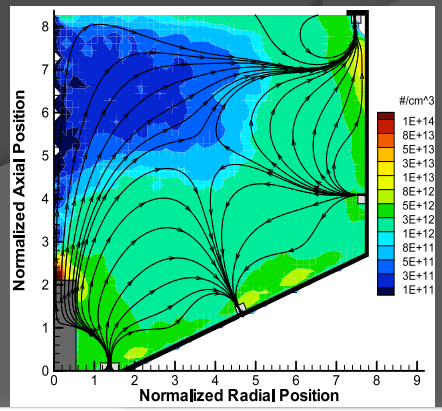
Microcavity Discharge Thruster — Illinois, Texas, CUAerospace







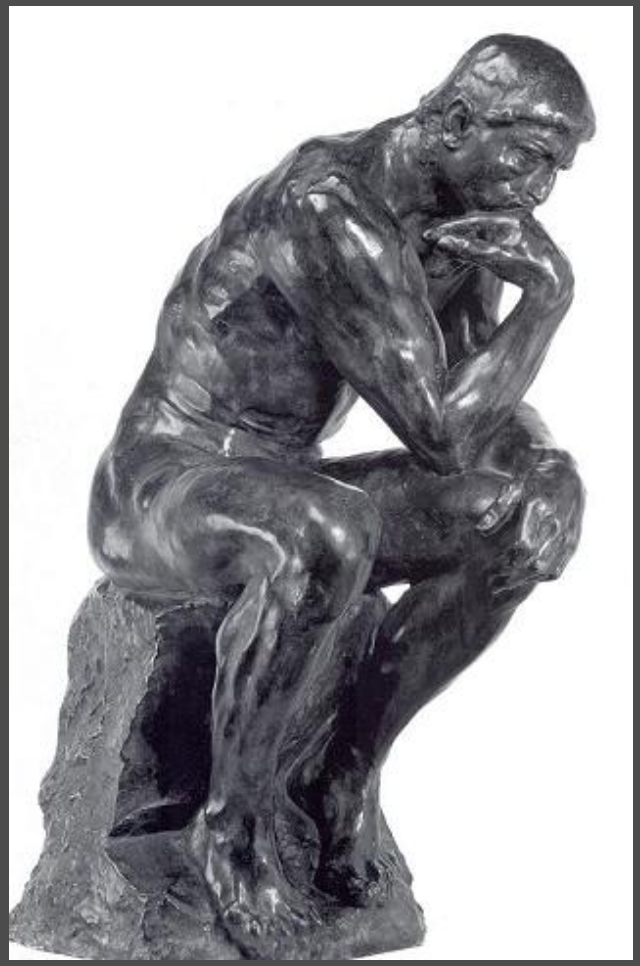
Ion Thruster Discharge Chamber Modeling — Wright State



Ion Beam Neutralization Modeling — USC

What academics think is needed or have identified as challenges…

- *Long-term sustained programs (like they have in Europe/ Japan) are needed in the U.S.*
- *U.S. EP program has fallen behind European/Japanese programs in terms of funding and in coordination*
- *Consideration of systems aspects often missing in academic EP research (too many "pet thrusters?")*
- *No clear path to space missions…lack of sustained support in any one technology…no agency leaders/champions*
- *EP technical challenges of interest to civil space, DOD, and industry largely unknown to academics*
- *Looking to NASA to join the Air Force in providing sustained funding to academic research programs*
- *Lack of consistent sustained support risks loss of heritage and expertise as investigators are drawn to other sources of funding*

Findings and Parting Thoughts

- EP academic community is larger than funding levels and EP job prospects would suggest
  - 28 institutions, 35 professors, ~110 graduate students
  - Estimated non-faculty personnel cost of responders >$4M/yr
  - Total non-faculty personnel cost could approach $7M/yr
  - Not clear how well coupled most of this research is to industry and government EP users/developers
- In spite of the funding and job prospect realities, EP [Space] remains an attractive field to students
- Academia is in desperate need of direction and commitment from the funding agencies and industry
- NASA will have to do a sales job to engage the best in academia….”fool me once….fool me twice…”