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Propulsion Research and Academic Programs at the University of Alabama in Huntsville

PRC Strategic Plan- 2019

AIAA Paper 2019-3891

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UAH Propulsion Research Center

THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

Objectives:

- Present PRC Recent Achievements and 2019 PRC Strategic Plan

Scope:

I. Introduction

II. Academic Infrastructure

III. PRC Summary

IV 2019 PRC Strategic Plan

The University of Alabama in Huntsville (UAH)

UAH Research Institute Groundbreaking

Major General Francis Morrow, Dr. Werner von Braun, and Alabama Governor John Patterson
December 20, 1962

- 1961, Alabama legislature granted $3 million to seed the UAH Research Institute which grew into the University of Alabama in Huntsville
- 1991, UAH Forms a Propulsion Research Center to focus propulsion activities into one research business unit
- In 2018, UAH Achieves
  - 9,700 Students in Spring 2018
  - $84 million of research expenditures (FY18)
  - Ranked 5th in Federally-financed Aero and Aero/Astro Engineering
  - 11th NASA R&D Expenditures
  - 28th DoD R&D Expenditures
  - In top 25 by the NSF
  - 72 Ph.D.'s. and 582 Master's, 1,319 Undergraduate Degrees, in AY 18-19

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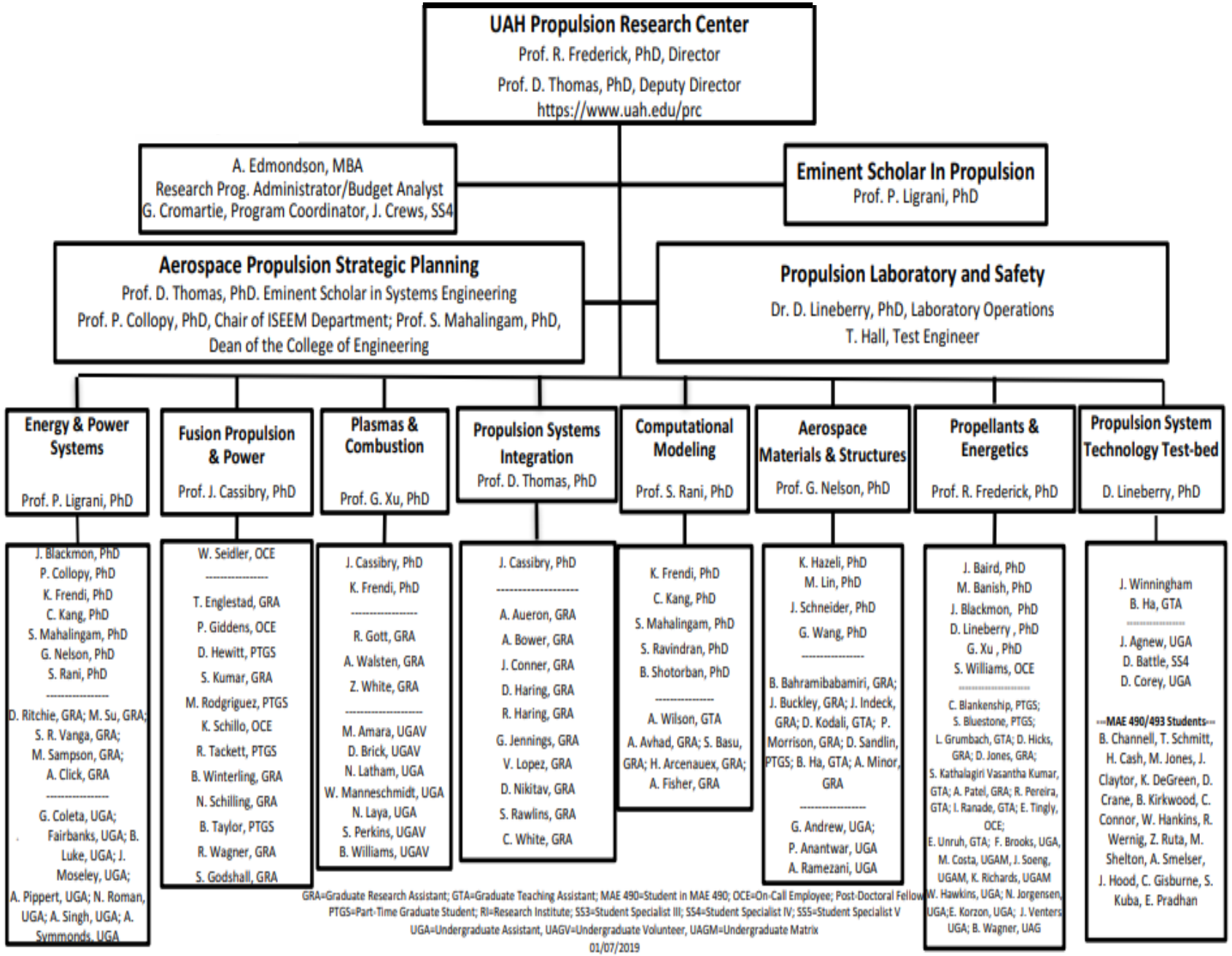
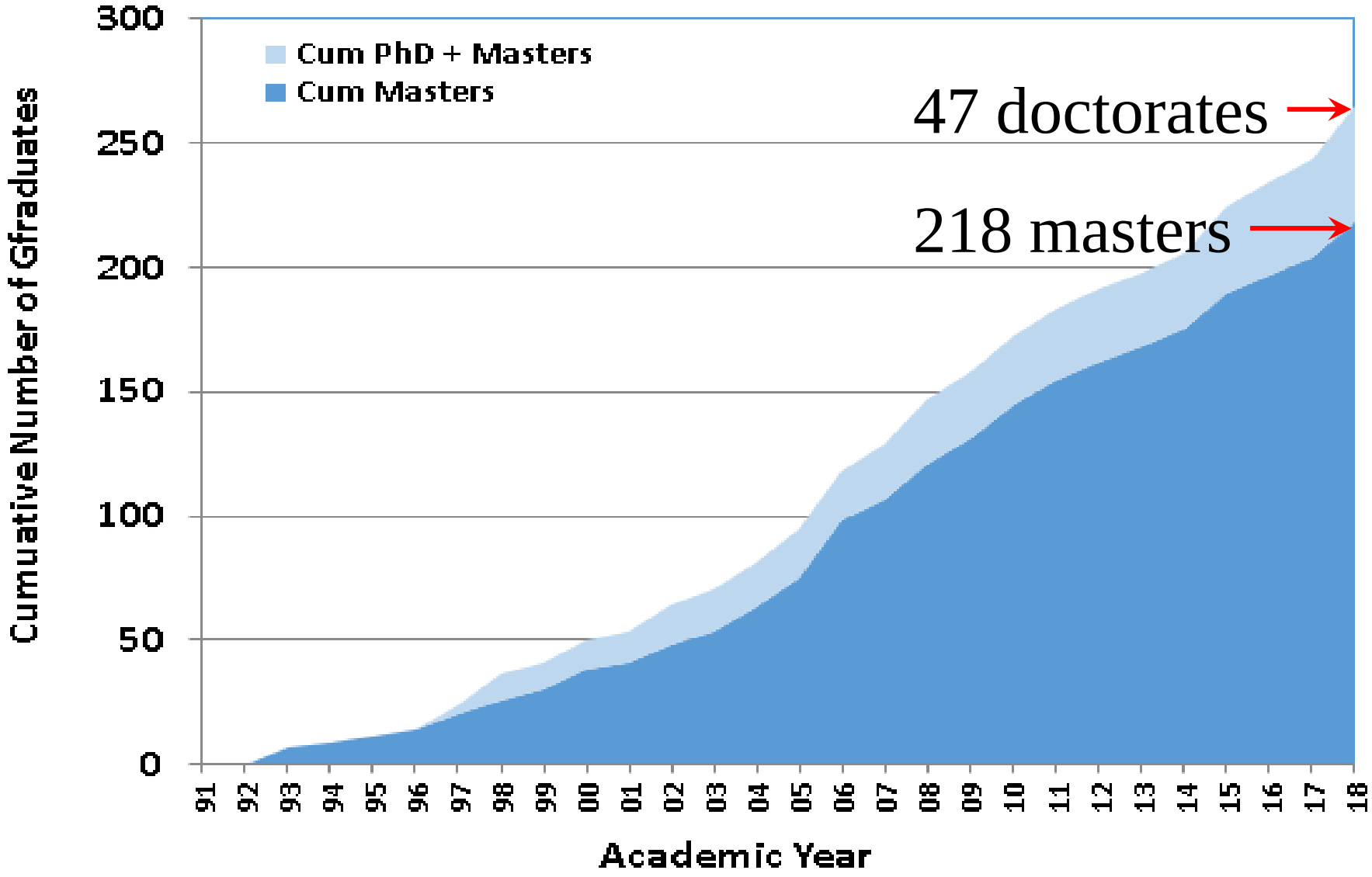
PRC Mission and Strategy

- The PRC was established to provide an environment that connects the academic research community with the needs and concerns of the propulsion community, while promoting an interdisciplinary approach to solving propulsion problems.
- Collaborative Research Groups: Academia, Industry, Government
- Integrate a High-Quality Education with Scholarly Research Activity
  - Seek those externally funded efforts that would provide graduate students with material for theses and dissertations
  - Provide hands-on research opportunities and laboratories for the students
  - Develop new courses in propulsion and energy



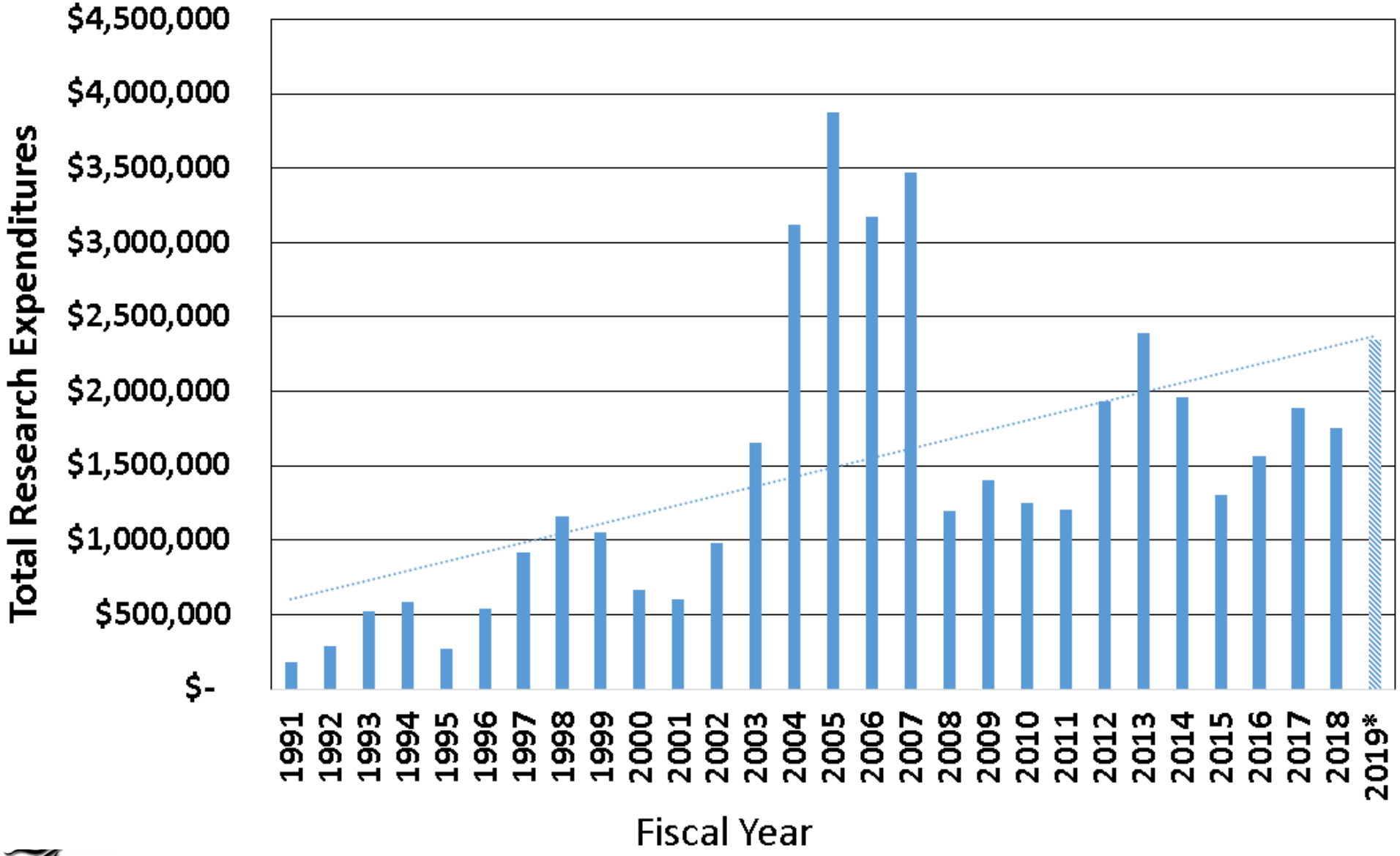
GRA=Graduate Research Assistant; GTA=Graduate Teaching Assistant; MAE 490=Student in MAE 490; OCE=On-Call Employee; Post-Doctoral Fellow
PTGS=Part-Time Graduate Student; RI=Research Institute; SS3=Student Specialist III; SS4=Student Specialist IV; SS5=Student Specialist V
UGA=Undergraduate Assistant, UAGV=Undergraduate Volunteer, UAGM=Undergraduate Matrix
01/07/2019

PRC Advanced Degrees Supported



During the 2018 academic year, fourteen master's students and six doctoral students earned advanced degrees. This is a record number of advanced degrees in one academic year completed at the PRC.

PRC Research Expenditure History



FY 19 shows a 40% increase over last year and the overall research portfolio has doubled in the past five years.

The UAH Aerospace Program

Department of Mechanical & Aerospace Engineering

- **BS in Aerospace Eng. and Mechanical Eng.**
- **MS and PhD in ME and Aerospace Systems Engineering.**
- **BS MAE Undergraduate Enrollment,** 1,342 (AY 18-19). An 8% increase. (has doubled in past 10 years)
- **ME and Aero Graduate Students.** Increased from 158 (AY17-18) to 162 (AY18-19)
- **MAE Degrees (AY18-19):** 178 Undergraduate
  39 Graduate
- **20 tenure-track faculty,** 5 non-tenure-track faculty members, and several part-time instructors teaching in the Mechanical and Aerospace degree programs
- **UAH Ranked among the top 5 federally-funded Aeronautical and Astronautical Engineering Programs**
- **Contact:** Dr. Keith Hollingsworth
  keith.hollingsworth@uah.edu
  Chair: Dept. of Mech. and Aero. Eng.

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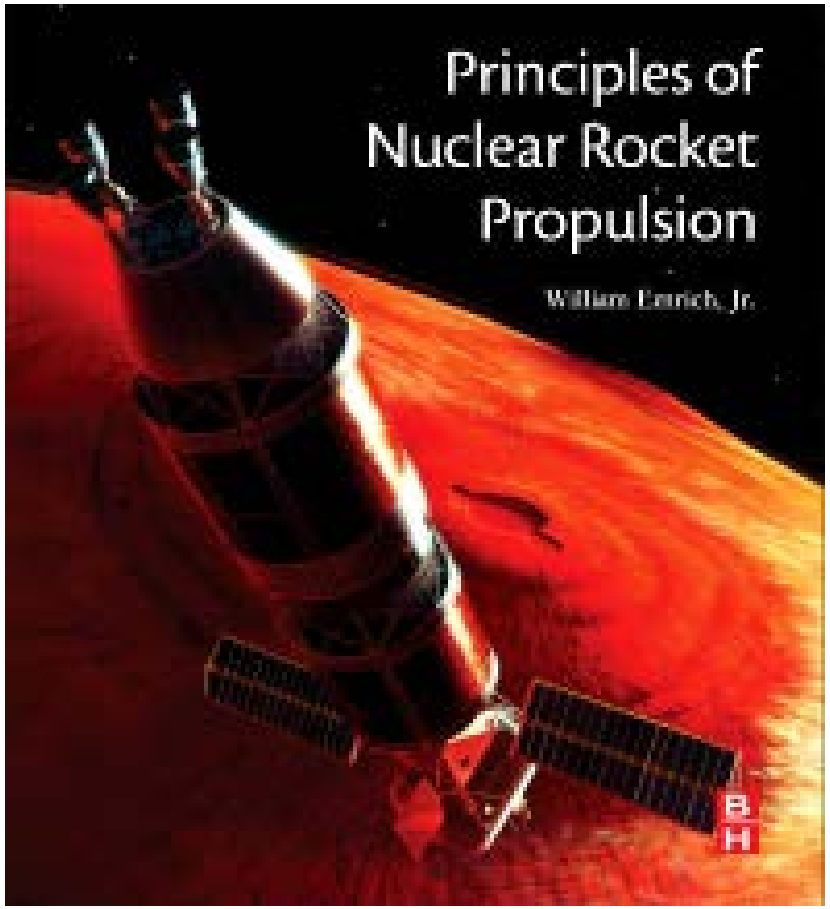
UAH Propulsion and Energy Courses

Dual-Level Undergraduate/Graduate	AY 15-16	AY 16-17	AY 17-18	AY 18-19
MAE 440/540 Rocket Propulsion I	55	34	67	79
MAE 441/541 Airbreathing Propulsion	17	38	33	38
MAE 444/544 – Intro. To Electric Propulsion.	22	-	20	-
MAE 468/568 –Elements of Spacecraft Design	56	62	87	99
MAE 490/491– Rocket Design	56	38	40	40

Graduate	AY 15-16	AY 16-17	AY 17-18	AY 18-19
MAE 620-Compressible Flow	21	11	30	26
MAE 640–Rocket Propulsion II	-	21	-	29
MAE 644 Adv. Solid Rocket Propulsion	22	-	15	-
MAE 645 – Combustion I	6	-	19	-
MAE 695/795–ST: Adv. Readings in Propulsion	7	3	2	3
MAE 695: ST Intro to Nuclear Propulsion	-	22	-	26
MAE 695- ST:Comb. Instability in Solid Rockets	15	-	-	--
MAE 695- ST: Liquid Rocket Engineering	20	-	-	-
MAE 681 – Missile Trajectory Analysis	-	-	-	--
MAE 740-Aerothermodynamics	18	-	-	19
MAE 745 Combustion II	-	-	-	-
MAE 754 – Hypersonic Flow	-	11	-	25
MAE 795–ST: Introduction to Fusion Propulsion	11	-	16	-



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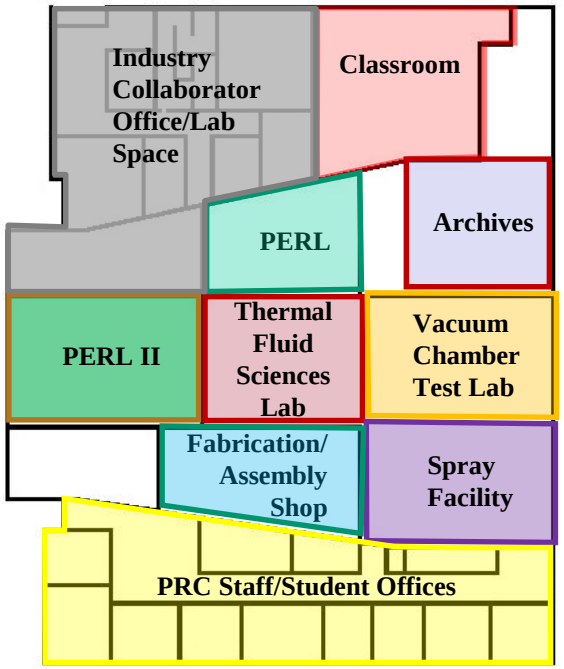
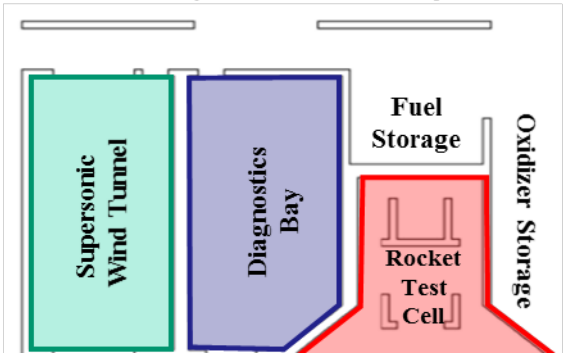
PRC Laboratory Capabilities

PRC Labs at the Johnson Research Center



PRC's Propulsion Test Facility



Sec.	Propulsion Test Facility (PTF)	Location
A	Rocket Test Cell	UAH Johnson Research Center
B	Supersonic Wind Tunnel Laboratory (SWTL)	UAH Johnson Research Center
	Johnson Research Center	**Location**
C	Charger Rocket Works (Sounding Rockets)	UAH Johnson Research Center
D	Injector Spray Facility	UAH Johnson Research Center
E	Plasma and Electrodynamics Research Lab (PERL)	UAH Johnson Research Center
F	Thermal Fluids Sciences Lab	UAH Johnson Research Center
G	Vacuum Chamber Test Lab	UAH Johnson Research Center
	Other PRC	**Location**
H	High-Pressure Solid Propellant Lab	UAH Materials Science Building
I	Solar Thermal Lab	UAH Werner von Braun Research Hall
	Other UAH	**Location**
J	Adaptive Structures Lab	UAH Technology Hall
K	Advanced Materials and Manufacturing Laboratory	Aerophysics Research Center at Redstone Arsenal
L	Charger 1	Aerophysics Research Center at Redstone Arsenal
M	Complex System Integration Lab (CSIL)	UAH Werner von Braun Research Hall
N	Mechanics of Materials Under Extreme Environments	UAH Optics Building
O	Transport, Reaction, and Energy Conversion Lab	UAH Shelby Center

Propulsion Research Center Vision & Mission

- *Vision*: The PRC will be a major generator of talent and innovative solutions in propulsion and energy related technologies.

- *Mission*: PRC connects the Academic Research community with Industry & Government to advance basic science and technology development related to propulsion and energy.

Strategies for the Future

- SWOT Analysis
  - Strengths
  - Weaknesses
  - Opportunities
  - Threats

- Observations & Recommendations

Strengths

- Collaborations and partnerships.
  - with RSA, MSFC, and Industry.
  - across departments, laboratories, and research centers within UAH.
- Strong curricula in traditional and advanced propulsion and systems engineering.
- Pool of interested and participating students.
- Good facilities and strong analysis and modeling capabilities.

Weaknesses

- Organization not cogent/coherent for PRC research areas.
- Relationships with relevant program managers & policy makers controlling funding in PRC research areas.
- Lack of key accomplishments & publications in *advanced propulsion* technologies.
- Facilities, expertise, and curriculum for *advanced propulsion* & high temperature physics and additive manufacturing.

Opportunities

- Strategic partnerships with Gov't & Industry in energy applications and additive manufacturing.
- Interdisciplinary Materials Science program is being reinvigorated with support from Cross College Collaboration funds and in collaboration with faculty at UA and UAB.
- Air Breathing Propulsion, including scramjet engine technologies and concepts.
- Nuclear Thermal Propulsion.

Threats

- Capabilities, both existing and under development, at other universities are comparable to or better than PRC capabilities in some areas.
- Good opportunities for students creates challenges for graduate student recruitment and retention.
- Competition with industry for limited funding opportunities.

Observations

- PRC good at “traditional” but needs to choose forward path to maintain relevance in evolving technological environment.
  - The environment is dynamic; the PRC must adapt.
- Proximity to RSA, MSFC, & CRP should motivate selection PRC developmental investments.
  - Also offers alliance opportunities for relevant capabilities at other universities.
  - Organizational relationships recognized, but personal relationships among key individuals perceived to be lacking.
- Explore value proposition with area industry.
  - Seek teaming & collaborative arrangements to foster workforce development and basic research. Industry focus is applied research.

Recommendations

- Meet with key stakeholders at RSA, MSFC, and CRP
  - Identify current capabilities warranting sustainment & investment.
  - Identify 5 and 10 year propulsion & energy environments (programs, technologies, etc.).
  - MDA, SMDC, AMRDEC, MSFC, AR, Dynetics, etc.
- Identify relevant capabilities at other universities and explore teaming & collaborative opportunities, leveraging UAH proximity and other university capabilities.
  - Consider an IUCRC as a vehicle to drive long term collaboration with industry & universities.

People Make the Difference

Propulsion Research Center faculty, staff, students, colleagues, and friends at the fall 2018 Recognition of Graduates Reception. "Keep relationships more important than tasks or problems" – Dr. Robert A. Frederick, Jr., Director, UAH Propulsion Research Center.

PRC Papers at the 2019 Propulsion and Energy Conference

1. Agnew, J. “An Examination of Warp Theory and Technology to Determine the State of the Art and Feasibility, AIAA-2019-4288, August 2019
2. Aueron, A., and Thomas, L.D., “Nuclear Thermal Propulsion Vehicle Scaling and the importance of Densified Propellant,” AIAA-2019-3942, August 2019.
3. Buckley, J., Nelson, G. “Experimental Validation of the X-ray Determined Pore Size Distribution of Porous Hybrid Motor Grains,” AIAA-2019-4097.
4. Frederick, R. A., Thomas, L.D., and Ligrani, P.M., “Propulsion Research and Academic Programs at the University of Alabama in Huntsville – PRC Strategic Plan – 2019,” AIAA Paper 2019-3804, August 2019.
5. Click, A., Ritchie, D., Ligrani, P., Liberatore, F., Patel, R., and Ho, Y. “ Double Wall Cooling of an Effusion Plate with Cross Flow and Impingement Jet Combination Internal Cooling: Comparisons of Main Flow Contraction Ratio Effects”, AIAA-2019-3967, August 2019.
6. Godshall, S., and Frederick, R., “Collaborative Space and Propulsion Education: Leveraging all sectors of the space enterprise to benefit the future U.S. Space and Propulsion Workforce!,” AIAA Paper 2019-3804, August 2019.
7. Jones, D., Frederick, R., “Thermal Analysis Techniques and Autoignition Testing for Solid Polymers: a Review,” AIAA Paper 2019-3983, August 2019.
8. Kumar, S., Cassibry, J. “Round-Trip Mission to Neptune Using Nuclear Fusion Propulsion,” AIAA-2019-4033, August 2019.
9. Ligrani, P. , Click, A., Ritchie, D. , F. Liberatore, F., Patel, R., and Ho, Y. «Effects of Coolant Supply Arrangement on Hot-Side Effusion Performance and Cold-Side Nusselt Numbers at Different Initial Blowing Ratios,” AIAA-2019-3965, August 2010.
10. Nikitaev, D. , “Air and Space Thermal Rocket Engine with Turbojet (ASTRET),” AIAA-2019-4393, August 2019.
11. Patel, A., Frederick, R., “Gas Cooling Generator Technologies for Aerospace Applications,” AIAA Paper 2019-4068.
12. Ranade, I., Frederick, R., “Experimental Study of Swirl Coaxial Injector Hydrodynamics Under High- Frequency Self-Pulsation,” AIAA Paper 2019-4118, August 2019.
13. Schilling, N., Cassibry, J. , “Development of a pulse-recharge magnetic nozzle for PuFF,” AIAA-2019-4284, August 2019.
14. Thomas, L. D., Aueron, A. , Lopez, V. , and Bower, A. , “Virtual Systems Integration Applied to Advanced Space Systems,” AIAA-2019-4053, August 2019.
15. Venters, J., Costa, M., Unruh, E., Lineberry, D., Frederick, R., “Uncertainty Analysis of Experimental Discharge Coefficients in Additively Manufactured Liquid Injector Elements,” AIAA Paper 2019-3932, August 2019.
16. Wagner, R., Westrich, S., Burns, E., and Cassibry, J. “Fusion Research Development at the University of Alabama in Huntsville,” AIAA-2019-4287, August 2019.

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