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Propulsion Research and Academic Programs at the University of Alabama in Huntsville - PRC Strategic Plan 2019

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The UAH Propulsion Research Center (PRC) is in its 28th year at the University of Alabama in Huntsville (UAH). The mission of the Propulsion Research Center is 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. This paper summarizes recent metrics from academic and research programs. The emphasis this year is describing a PRC Strategic Plan derived from a Strengths-Weaknesses-Opportunities-Threats (SWOT) evaluation for the UAH Propulsion Research Center. This assessment concluded that while the goals within the current strategic plan remain valid, choices must be made regarding which advanced propulsion technologies will guide facility investment, curricula development, and faculty recruitment. Total research expenditures from fifteen different agencies are anticipated to rise to $2.5 million dollars in the 2019 fiscal year. This represents a 40% increase from FY 18 and a doubling of research expenditure over the past five years. PRC researchers published over 80 papers last year. Eight Ph.D., fourteen master's students, and numerous undergraduate students obtained degrees in conjunction with the center in the last year. The PRC continues to be a resource to perform research and workforce development in propulsion and energy.

I. Introduction

THE Propulsion Research Center (PRC) marked its 28th year as a University of Alabama in Huntsville (UAH) research organization in 2019. This paper is part of a series of periodic updates about PRC activities and capabilities. The past PRC overview papers include a summary of the first 13 years of operations,[20] a 25th anniversary review in 2016,[21] an overview of seven technical research areas in 2017,[22] and description of fifteen laboratories in 2018.[23] This paper details provides strategic planning summary for the PRC and summarizes recent metrics from academic and research programs.

A. PRC Mission and Strategy

The mission of the PRC is 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. Individuals and groups within the university collaborate to achieve the PRC's research goals. Researchers from government laboratories, other universities, and the aerospace industry also collaborate with the PRC. This environment produces leading-edge research results and scholarly activity leading to new discoveries and significant workforce development.

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Figure 1 shows the PRC Organization Chart. Research centers at The University of Alabama in Hhuntsville are interdisciplinary business units that focus on specific technical areas. The Propulsion Research Center is an assembly of staff, faculty, and students that work in teams on research projects related to propulsion and energy topics. Each box represents a functional area in the organization. Currently, there are over one hundred faculty, staff, and students associated with PRC research activities.

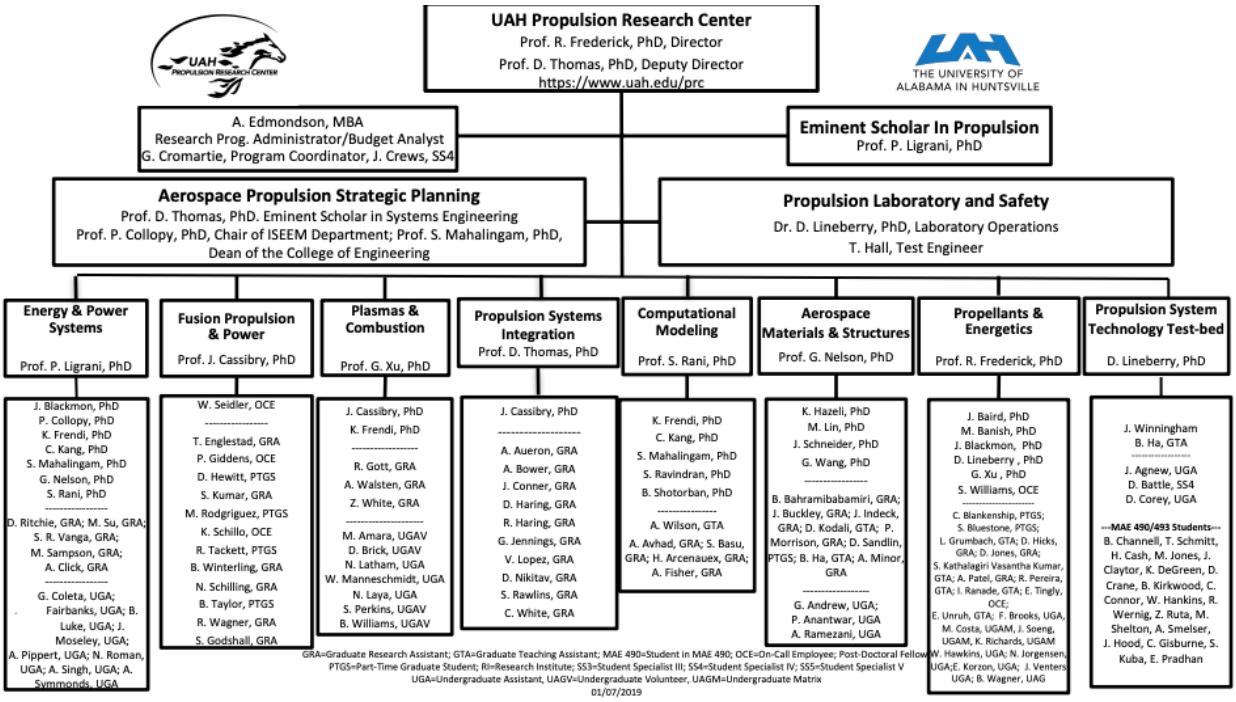

Fig. 1 The PRC Organization Chart.

The PRC Center Director oversees staff that include a Deputy Director that advises in strategic and technical matters, Program Administrators/Budget Analysts who manage administrative/fiscal items, a Senior Researcher who directs Laboratory Projects, Safety, and Testing, and a Test Engineer who oversees laboratory operations at the Johnson Research Center. The Eminent Scholar in Propulsion is a named chair that resides in the Department of Mechanical and Aerospace Engineering. The Eminent Scholar leads his own world-class research and promotes the overall academic quality of research in the center. The organization chart also shows eight topic areas ranging from Energy and Power Systems to Propulsion Systems Technology Test-bed. Each of these eight areas has a lead person/principal investigator, in most cases a faculty member, identified as contact. The names beneath these boxes show participating faculty principal investigators, staff, graduates students, and undergraduate students who are active in projects or independent research in each area.

B. Overall Metrics

Figure 2 shows the cumulative production of advanced degrees for students associated with the Propulsion Research Center from its inception in 1991 to 2019. The total master's degree production is now 218 and the total Ph.D. production is 47. During the 2018 academic year (fall 2018 through summer 2019), fourteen master's students completed advanced degrees. This is a record number of advanced degrees in one year supported by the PRC. Most of the students who receive advanced degrees are in the UAH School of Mechanical & Aerospace Engineering (MAE).

The doctoral dissertations covered areas such as modeling of radiative heat transfer[5], flexible flapping wings[6], fusion propulsion[7,8], electric propulsion[9], controllable solid propellants[10], advanced heat transfer[11], and elastic instabilities/elastic turbulence.[12]

Students also completed master's theses in that involved topics such as aerospace systems engineering,[13,14,15,16] energy and power systems,[17,18] nuclear fusion propulsion,[19] propellants and energetics,[20] additive manufacturing,[21,22] and advanced heat transfer.[23] Three other PRC-supported students achieved non-thesis master's degrees.

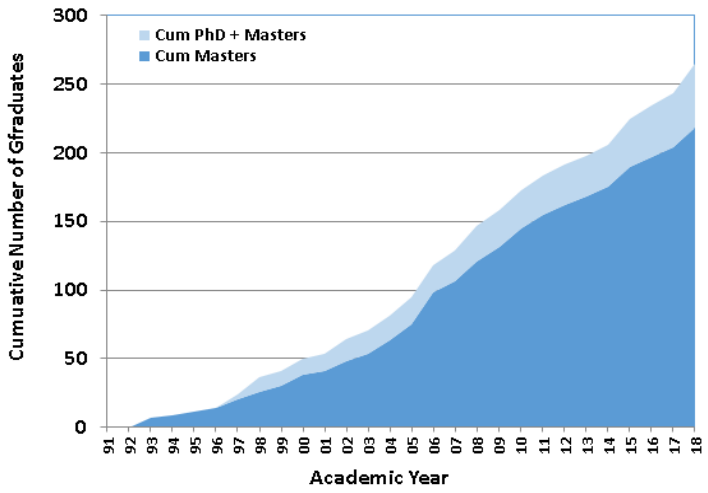

Fig. 2. Cumulative advanced degrees supported by the PRC.

Figure 3 shows the annual research expenditures from external sources for the Propulsion Research Center since its inception in FY 1991 through a projection of FY 2019. The average annual expenditure level of the entire period is $1.5 million dollars per year. The periodic "surges" in funding generally represent the growth and completion of significant research programs with a particular major sponsor.

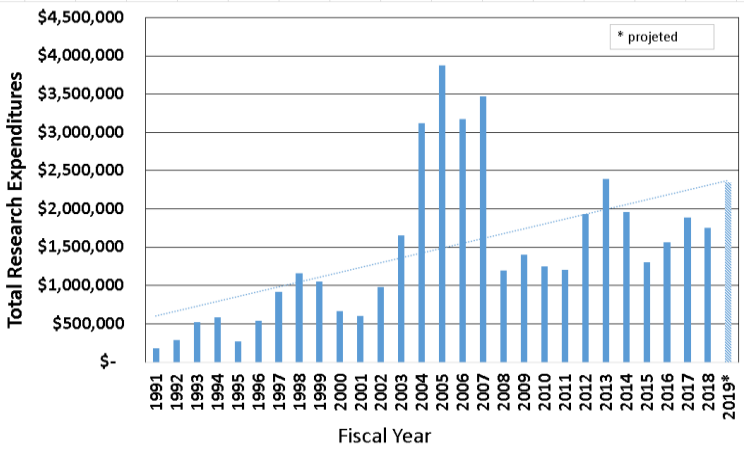

Fig. 3. Research expenditures distribution by FY.

Research expenditures increased about 20% per year in both FY 16 and FY 17. Total expenditures rose from $1.308 million (FY15), to $1.563 million (FY16), to $1,884 million (FY17). FY18's total at $1,750,000 was a 7% decline largely influenced from a funding gap in one major program that is now back in place. The projection of $2,500,00 for FY 19 shows a 40% increase over last year and is an overall result of increased funding of several team members. The overall research portfolio has doubled in the past five years. The research expenditure numbers do not include cost shares, internal university research funds, state provided operating funds, or UAH Foundation investments into the PRC.

C. Current Research Sponsors

This section highlights the sponsors and funding award distributions in FY17, FY18, and FY19 (October 2018 through June 2019). The PRC has received $1,890,090.67 in new awards during the first three quarters of FY19. Since the beginning of FY17, the PRC has received funding from several different agencies. These include Aerojet Rocketdyne, Alabama Space Grant (NASA), Barber-Nichols, Inc., Boeing, C3 Propulsion, Combustion Research & Flow Tech., Inc., Earth to Sky LLC, Department of the Air Force (USAF), Gloyer-Taylor Laboratories (GTL), Hyperion Technology, Hyper V Technologies, Jacobs, IHI Corporation, Manufacturing Technical Solutions (MTS), NASA Headquarters, NASA Goddard Spaceflight Center, NASA Marshall Spaceflight Center (MSFC), McConnell Jones Lanier & Murphy LLP, Science and Technology Applications, LLC, Solar Turbines, Inc., TGV Rockets, Inc., The Missile Defense Agency (MDA), State of Alabama, Varian Medical Systems, Incorporated, and Vector (formerly known as Garvey Spacecraft Corp).

D. Recent Publications

PRC researchers and students have produced over 80 publications in the past year. Many of the papers are multi-author among faculty, students, and research partners. Numerous other contract research reports are not included in the citations below. Several example publications are listed in the bullet list below and indexed by one of our principal investigator authors and the general area of the work shown in Figure 1:

- James K. Baird,[24,25,26,27] Propellants and Energetics
- Jason Cassibry,[28,29,30,31,32,33,34] Fusion Propulsion
- Robert A. Frederick,[35,36,37,38,39,40] Propellants, Energetics, Safety, and PRC Overviews
- Kavan Hazeli,[41,42,43] Materials and Structures
- Philip T. Ligrani,[44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62] Energy and Power Systems
- George Nelson,[63,64,65,66,67,68,69,70,71, 72,73, 74,75,76] Aerospace Materials and Structures
- David Lineberry,[77,78] Propulsion System Technology Testbed
- Sarma Rani,[79,80] Computational Modeling
- C-K Kang, [81,82,83,84,85,86,87,88, 89,90,91,92,93,94] Computational Modeling
- Judy Schneider,[95,96,97,98,99,100] Aerospace Materials and Structures
- L. Dale Thomas,[33,101,102,103] Propulsion Systems Integration

II. Academic Infrastructure

A. Mechanical & Aerospace Engineering

The PRC works primarily in conjunction with faculty and students from The UAH Department of Mechanical and Aerospace Engineering (MAE), The UAH Department of Industrial and Systems Engineering and Engineering Management (ISEEM), and The UAH Department of Chemistry in the College of Science. Working with the faculty and students from these departments on funded research fulfills our strategic priority to support academic achievements. The MAE Department offers Bachelors of Science Programs in both Aerospace Engineering and Mechanical Engineering accredited by the Accreditation Board for Engineering and Technology, Inc. (ABET). At the graduate level, the MAE Department offers Master's and Ph.D. Programs in Aerospace Systems Engineering and Mechanical Engineering.

The MAE undergraduate programs consist of accredited components in Mechanical Engineering (ME) and Aerospace Engineering (AE). MAE has continued a high rate of growth and reached 1342 undergraduate students in Fall 2018. The undergraduate AE program now represents over half the undergraduate population, at just under 700 students. As Figure 5 shows, the recent undergraduate growth has been in BSAE students. The UAH BSAE and BSME programs are, respectively, the largest and second largest undergraduate programs on campus, and the MAE department makes up over 1/7 of the total UAH student population. The MAE graduate enrollment has been fairly stable and stands at 162 in the Fall 2018 term. The recent trend has been toward more graduate students in the Aerospace Systems program and fewer in the Mechanical Engineering program. This is a reversal of the opposite trend that was in place from 2008 to 2015. As the MAE research activity grows, the graduate student population shifts more to full-time research-active students.

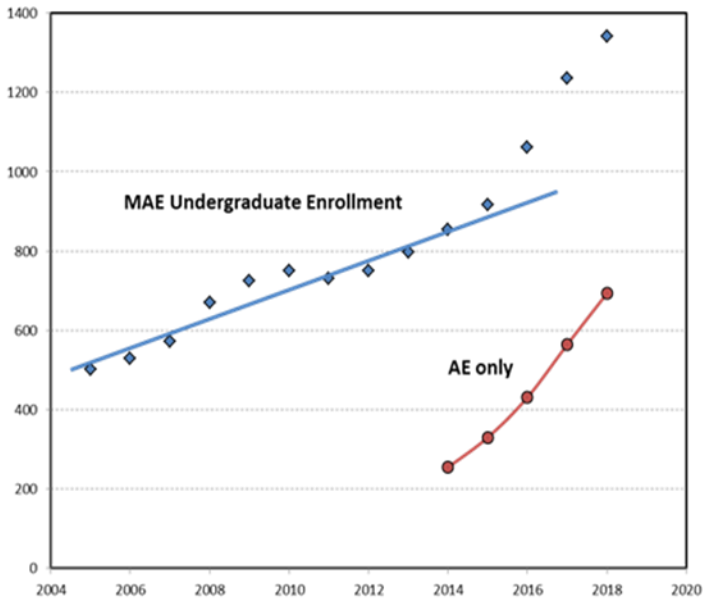

Fig. 4 UAH undergraduate enrollment trends. MAE is total mechanical and aerospace. AE is aerospace only.

The MAE full-time faculty count now stands at 25. Twenty are tenure-track, two are non-tenured Clinical Associate Professors, and three are full-time lecturers. MAE also employs around eight adjunct instructors each term from the Huntsville engineering and research community. This fall a new junior faculty member will join MAE in the area of control of autonomous flying vehicles.

B. Propulsion-Related Courses

Tables 1 and 2 show several propulsion-related classes offered at UAH in Mechanical and Aerospace Engineering. The dual-level courses in Table 1 allow undergraduate and graduate students to learn together. Qualified undergraduates can participate in a Joint Undergraduate Master's Program (JUMP) in which they can simultaneously earn undergraduate and graduate credit for taking up to nine hours of approved graduate-level classes. Undergraduate AE students can choose either Rocket or Airbreathing Propulsion for their program. All undergraduate AE students take Spacecraft Propulsion. Rocket design is a two-semester capstone course where students design, fabricate, and build a sounding rocket with a payload. The increasing totals in the dual level classes of Table 1 show how the student growth is increasing class enrollment.

Table 2 shows a wide array of graduate-level courses related to propulsion. Compressible flow is offered each year. Other graduate courses are offered on two-year cycles as shown in Table 2. The Advanced Reading in Propulsion Course guides Master's and Ph.D. students a through reviewing and evaluating pertinent literature in preparing for their research projects. UAH also has a College of Professional and Continuing Studies (CPCS) which offers a certificate in propulsion by combing three of the following courses: Rocket Propulsion Fundamentals, Advanced Solid Rocket Propulsion, Combustion Instability in Solid Rockets, and Liquid Rocket Engineering. These courses assist professionals who might be transitioning into new technical areas and want to receive advanced material for professional development credit. CPCS offers these courses periodically in person or with on-demand, online learning.

Table 1. UAH undergraduate and graduate (dual level) courses related to propulsion and energy.

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

Table 2. UAH graduate propulsion and energy courses.

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	-

III. People Make the Difference

During the past year, we continued to intentionally maintain and build our relationships with each other and our community. The PRC hosted periodic student mentoring cookout lunches at the lab that included guest speakers and tours of the facilities for guests. Luncheon talks are usually kept short (about 20 minutes) to ensure that we have time to meet new people and interact with each other. We often have participants from our supporting organizations such as security, purchasing, sponsored programs, and accounting. We keep a light atmosphere, celebrate birthdays, and recognize achievements. Our team also meets periodically offsite at local restaurant where we enjoy good food and several members perform music.

Fig. 5 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.

Our PRC Student Association (PRCSA) continued to support outreach events such as Girls Science and Engineering Day, the regional Science Olympiad, and NASA in the Park, a Huntsville tradition. Each year we hold two celebrations honoring our upcoming graduates and all the departments around campus that provide the support that makes our efforts successful. We also have periodic buffet lunches at a local BBQ restaurant where students and faculty perform on their musical instruments. Figure 5 shows the PRC team at our December 2017 Graduate Recognition gathering.

IV. Strategies for the Future

A. Prologue

To plan strategies for the future, it is first necessary to understand the legacy that has been inherited from the past. The UAH PRC came into existence on February 1, 1991 under the directorship of Dr. Clark W. Hawk. Dr. Hugh W. Coleman was recruited and appointed as the Eminent Scholar in Propulsion and added to the faculty at the rank of Professor of Mechanical Engineering in the College of Engineering. Dr. Robert A. Frederick, Jr. joined the PRC to initiate experimental research in solid and hybrid propulsion as an Assistant Professor of Mechanical Engineering. It is also significant to note that Dr. Hawk joined the Mechanical Engineering Faculty as a Professor and was put on a tenure track, meaning he would be called on to lead the center and establish an academic record that would be reviewed by his university peers for the award of tenure in the subsequent years. The Eminent Scholar in Propulsion was endowed in part by Rocketdyne, Aerojet, Martin-Marietta, Thiokol, and Lockheed Missiles and Space Company, which showed strong industry support for the endeavor. An agreement was also put in place to have Dr. Naminosuka Kubota from the Japan Defense Agency serve as a Visiting Scholar in Propulsion in 1992. With Drs. Hawk, Coleman, and Frederick in place, an overall strategy to build the PRC was then implemented. Dr. Hawk had program management strengths and connections with the professional community from his 31 years of experience in propulsion research and technology with the Air Force. Dr. Coleman brought more than 25 years of experience in research fields related to rocket propulsion, along with a wealth of experience in working inside of academic intuitions which would prove valuable for integrating the PRC into the academic world. Dr. Frederick had four years of industrial experience as a solid rocket combustion researcher. Dr. Kubota had over 20 years of experience in solid rocket combustion studies and would become an integral part of building joint programs and bringing students to the university. Hence, the PRC was founded upon the principles of academic rigor, conducting research of value to both government and industry, and international collaboration.[2]

The mission of 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. Collaborating individuals and groups were envisioned as part of the PRC's research goals. This mission would be further accomplished though cooperation with researchers from government laboratories, other universities, and the aerospace industry. The result of this environment would be leading-edge research and scholarly activity in the pursuit of advanced technologies and their applications. These endeavors were also envisioned as a means by which students associated with the PRC could achieve a high-quality education in engineering and related fields. The PRC committed to being an integral part of the UAH academic program. The PRC also declared at its founding that it would only seek those externally funded efforts that would provide graduate students with material for theses and dissertations, or provide supplemental support for undergraduate students. This was a departure from the more classical model of some university research centers that sought to maximize research funding through the hiring of and growth of professional staff.[2]

The PRC held annual external reviews after its founding, and in the second annual review, one reviewer commented, “The PRC must, as a practical matter, be opportunistic, but not lose sight of what it wants to be when it grows up.” When first starting and maintaining a research center one must balance between “getting money” and pressing toward your mission. The most recent strategic plan for the PRC was developed in 2011 to address the strategies for the future at that time. By that time, it had become evident that energy research was highly synergistic with propulsion research, and so the following mission and vision for the PRC addressed both propulsion and energy:

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.

Given the foregoing vision and mission, the strategic goals stated in the 2011 plan included:

Goal 1. Expand Partnerships - Strengthen relationships with key organizations and individuals with which PRC can collaborate and conduct research;

Goal 2. Focus Research Opportunities – Select a few broad areas of research on which PRC can concentrate its resources of time and money;

Goal 3. Promote the PRC – Increase awareness of the PRC's successes and capabilities with key audiences;

Goal 4. Develop People - Keep the educational responsibility of a university in mind by investing to increase the knowledge and skills of faculty and students associated with the PRC;

Goal 5. Enhance the Facility – Maximize the utilization of the real assets to aid in the communication of the world-class research being conducted.

The years since 2011 have witnessed significant progress toward these goals. Recently an effort was undertaken to revisit and update the 2011 PRC Strategic Plan. This strategic planning activity began with a review of the 2011 Strategic Plan and concluded that the mission, vision, and goals remained highly relevant to the current propulsion research environment within which the PRC exists. With that starting point, a SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis was employed in order to determine needed updates.

B. Strengths

The key strengths identified for the PRC included:

- *Collaborations and partnerships.* Consistent with its legacy, the PRC continues to sustain a strong array of collaborations and partnerships with the Department of Defense organizations resident on Redstone Arsenal, with the National Aeronautics and Space Administration's Marshall Space Flight Center, and with local and national Industry of all scales. The PRC also collaborates well within UAH across departments, laboratories, and other research centers.

- *Strong curricula in traditional and advanced propulsion and systems engineering.* The UAH Department of Mechanical and Aerospace Engineering offers courses in traditional solid and liquid propulsion as well as advanced propulsion areas including electric and nuclear thermal propulsion. The UAH Department of Industrial and Systems Engineering and Engineering Management provides courses in traditional systems engineering and in advanced areas including digital engineering and decision systems, with courses in intelligent systems under development.

- *Pool of interested and participating students*. The PRC continues to attract quality students. Interested undergraduate students participate in PRC projects as undergraduate research assistants. Some PRC graduate research assistants matriculate from UAH, but most join the PRC for their graduate studies upon graduation with their BS from other universities across the nation. The PRC also attracts a number of graduate students from around the world.

- *Good facilities and strong analysis and modeling capabilities*. The quality of the facilities is evidenced by the frequency of their use for sponsored research. The facilities not only provide the basis for many research proposals, but also provide students with hands-on experience thereby serving as a strong attraction for students considering joining the PRC research team. The strong modeling capabilities synergistically complement the testing capabilities.

It is observed that these strengths are not logically orthogonal to one another; rather, they are strongly interrelated.

C. Weaknesses

In this SWOT analysis, the key weaknesses of the PRC were identified as:

- *Organization not cogent/coherent for PRC research areas.* As an academic research organization, the PRC is organized by academic discipline rather than by research area. While this organizational scheme is strong for translating research progress into the classroom, it is not the most efficient for managing the interdisciplinary research efforts that tend to epitomize propulsion research.

- *Relationships with relevant program managers & policy makers controlling funding in PRC research areas.* Two of founding leaders of the PRC, while tenure track academicians, were senior personnel with extensive industry and government experience. The PRC benefitted strongly from their relationships during their tenure, and their absences are keenly felt today within the context of strategically identifying and planning for opportunities.

- *Lack of key accomplishments & publications in advanced propulsion technologies.* The UAH PRC has a strong track record in traditional chemical propulsion, both solids and liquid. The track record in advanced propulsion technologies is less impressive.

- *Facilities, expertise, and curriculum for advanced propulsion & high temperature physics and additive manufacturing.* Advanced propulsion research at the PRC is suffering from a vicious cycle of lack of investment in relevant facilities, leading to fewer wins in competitive research proposals, leading to a lack of funds for investment in relevant facilities, and so on. Likewise, the lack of a strong research base in advanced propulsion technologies impedes efforts in faculty recruitment and retention, further exacerbating the problem.

As with the strengths, interrelationships are observed between the four foregoing weaknesses – particularly between the first two with each other, and between the last two with each other.

D. Opportunities

Next in the SWOT analysis, the key opportunities for the PRC were identified:

- *Strategic partnerships with gov't & industry in energy applications and additive manufacturing.* Just as the PRC was founded with an inclination for collaboration which has continued strong through its existence, the collaborative environment for the PRC is perhaps now the strongest that it has ever been. The Department of Defense continues to grow its presence on the Redstone Arsenal, with much of that growth including missions and organizations that depend on propulsion and energy technologies. UAH's membership in the Oak Ridge Associated Universities (ORAU) facilitates collaboration with Department of Energy National Laboratories. Furthermore, UAH's proximity to Oak Ridge National Lab and Y-12 also facilitates such collaboration.

- *Interdisciplinary Materials Science program is being reinvigorated*. Cross College Collaboration funds are being used for this reinvigoration and UAH faculty are collaborating with faculty at the University of Alabama (UA, in Tuscaloosa) and the University of Alabama in Birmingham (UAB). This program will provide access to facilities and courses at UA and UAB.

- *Air Breathing Propulsion, including scramjet engine technologies and concepts.* Hypersonic vehicles and hypersonic propulsion research are once again receiving attention from both government and industry organizations.

- *Nuclear Thermal Propulsion.* The NASA exploration near term objective is the Moon, but the longer term objective remains Mars, and NASA established nuclear thermal propulsion (NTP) as the propulsion technology baseline for human missions to Mars in their most recent Design Reference Architecture. NASA has established a NTP Program to mature the technologies needed to safely produce and operate NTP engines and vehicles.

The foregoing opportunities are bases on collaborative relationships as well as advanced manufacturing and advanced propulsion technologies. It is noteworthy that traditional propulsion is not included in this list.

E. Threats

Finally, the SWOT examined the threats:

- *Capabilities, both existing and under development, at other universities are comparable to or better than PRC capabilities in some areas.* This is particularly acute in the area of advanced propulsion technologies.

- *Good opportunities for students creates challenges for graduate student recruitment and retention.* Recall the earlier observation regarding the causative effect of good facilities and student recruitment. As before, this is acute in the area of advanced propulsion technologies.

- *Competition with industry for limited funding opportunities.* In addition to competing with other universities, the PRC must also compete with industry at times for the finite pool of propulsion research funding. This is not a new threat, but it has certainly not diminished since the founding of the PRC.

It is observed that these threats in general could have been written at any time during the life of the PRC. While they typify the environment, that does not mean that they should not be explicitly acknowledged and, to the extent possible, addressed.

F. Assessment

Given the results of this SWOT analysis, it was concluded Goals 2 and 5 warranted update. Recall goals 2 & 5:

Goal 2. Focus Research Opportunities – Select a few broad areas of research on which PRC can concentrate its resources of time and money;

Goal 5. Enhance the Facility – Maximize the utilization of the real assets to aid in the communication of the world-class research being conducted.

The needed update is deemed not to be to the goals themselves, which remain valid as written. Rather, the updates are needed in the plans to address these goals in the future. Specifically, drawing on the strong collaborative relationships enjoyed by the PRC, the PRC will conduct assessments five and ten years into the future to choose the subset of advanced propulsion technologies on which to focus facility investment, curricula development, and faculty recruitment. In congruent fashion, the PRC will explore collaborative relationships with other universities focused on those advanced propulsion technologies not chosen as the PRC priorities, but still of interest to PRC customers and stakeholders. Of course, this plan is fraught with risks, for in choosing some avenues for investment and intentionally de-emphasizing others, the consequences of poor choices are magnified both for investing in areas that fizzle in terms of customer investment as well as not investing in areas that grow disproportionately. Analogous to investing in the stock market, the best that one can do is to make informed choices. That part of the current strategic planning effort is currently underway.

V. Remarks

The UAH PRC stands poised to build upon a rich legacy of research advances in propulsion. Recalling the sage advice offered in an early PRC annual review that "The PRC must, as a practical matter, be opportunistic, but not lose sight of what it wants to be when it grows up," the PRC strategy forward will focus on continuing a legacy of excellence in traditional liquid and solid propulsion and make strategic choices on advanced propulsion technologies in which to invest in pursuit of our Vision and Mission.

VI. Acknowledgements

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