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Propulsion Research and Academic Programs at the University of Alabama in Huntsville - - PRC Graduate Student Production History

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The UAH Propulsion Research Center (PRC) is in its 29th 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 that are associated with the PRC. The emphasis this year is describing the graduate student production supported by the PRC over the past 29 years. This assessment identified over 270 theses and dissertations into 9 different propulsion categories. The results accumulated into 207 master's and 67 Ph.D.s with the highest production rate being 21 degrees per year in 2010. The documents are distributed into categories representing conventional propulsion, advanced propulsion, missile design, air-breathing propulsion, Propulsion Testing, and Propulsion Systems Engineering. About 83% of the graduates are estimated to be U.S. citizens and there was a 20% female graduation rate. For the current year the total research expenditures from fifteen different agencies are anticipated to rise to $3.3 million which is a 33% compared to last year. PRC researchers published over 130 papers last year. The UAH student launch team placed 3rd in the NASA Student Launch national competition this year. The PRC continues to be a resource to accomplish high-quality research, education, and workforce development in propulsion and energy.

I. Introduction

THE Propulsion Research Center (PRC) marked its 29th year as a University of Alabama in Huntsville (UAH) research organization in 2020. This paper is part of a series of annual updates about PRC strategic goals, research activities, research capabilities, and history. The past PRC overview papers include a summary of the first 13 years of operations in 2004[1], a 25th anniversary review in 2016[2], an overview of nine technical research areas in 2017[4], a description of fifteen laboratories in 2018[5], and our most recent strategic plan in 2019[5]. This paper highlights PRC student thesis and dissertation production covering the last 29 years. There is an analysis of the main technical areas focused on in each thesis, production rates, and other overall metrics. The paper also summarizes recent PRC research metrics and academic programs at the Mechanical and Aerospace Engineering Department at the University of Alabama in Huntsville where most of these degrees have been supervised.

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, small business, and the aerospace industry also collaborate with the

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PRC. This environment produces leading-edge research results and scholarly activity leading to new discoveries and significant workforce development.

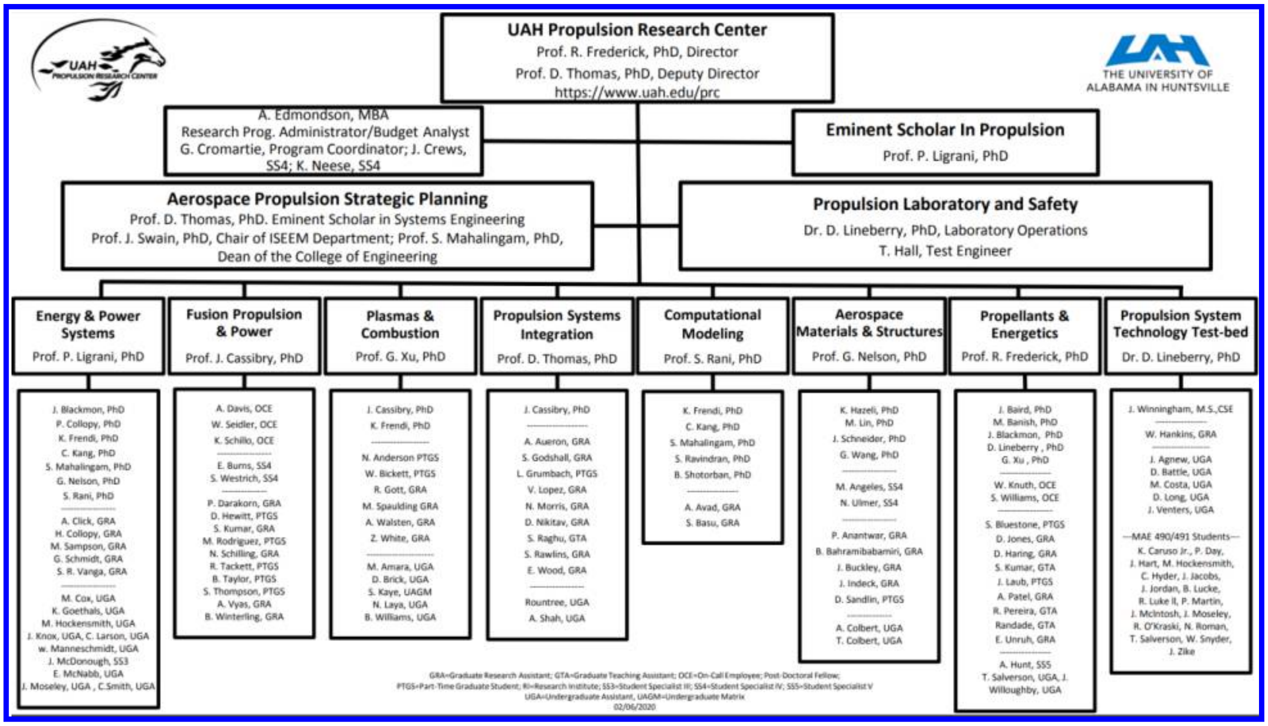


Fig. 1. The 2020 PRC Organization Chart.

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

The PRC Center Director, Dr. Robert Frederick, oversees all operations and leads a research group in Propellants and Energetics. The PRC Deputy Director, Dr. L. Dale Thomas, advises in strategic planning and is also the Eminent Scholar in Industrial and Systems Engineering, the Director of the Alabama Space Grant Consortiums, and leader of his own Propulsion Systems Integration research team. The Eminent Scholar in Propulsion, Dr. Philip Ligrani, holds a named chair that resides in the Department of Mechanical and Aerospace Engineering. As the Eminent Scholar, he leads his own world-class research team in Energy and Power Systems and promotes the overall academic quality of research in the center.

The PRC staff includes Program Administrators/Budget Analysts who manage administrative/fiscal items, a Senior Researcher, Dr. David Lineberry, who directs Laboratory Projects, Safety, and Testing, and a Test Engineer, Mr. Anthony Hall, who oversees laboratory operations at the UAH Johnson Research Center. Figure 1 also shows eight technical 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 a point of contact. Participating faculty principal investigators, staff, graduate students, and undergraduate students who are active in projects or in independent research are also shown in each area. The research areas emphasize the participation of graduate and undergraduate research assistants.

B. PRC Graduate Student Production Summary

The first overall metric presented is graduate student production. The total master's degree production for the PRC since its inception is now 200 and the total Ph.D. production is 60. During the 2019 academic year (fall 2019 through summer 2020), four PhD's [172],[173],[174],[293] and six master's degrees [27],[30],[276],[308],[309],[320] have been completed. Most of the students who receive advanced degrees are in the UAH School of Mechanical &

Aerospace Engineering (MAE). Section III of this paper entitled “PRC Graduate Student Production History,” is the focus of this year’s paper, and will present further detailed analysis.

The doctoral dissertations covered areas such as modeling solid fuel development for ramjet engines, heat transfer experiments for ablative cooling materials for use in warm gas thrusters, and modeling and simulation for Magneto-inertial Fusion Propulsion. Master’s theses that involved topics such as space force development, liquid rocket injector pulsation, radiation shielding for pulse-fusion propulsion, heat transfer for turbomachinery cooling applications, and propulsion systems engineering. Section III of this paper entitled “PRC Graduate Student Production History,” is the focus of this year’s paper, and will present further analysis.

C. PRC Research Expenditure Summary

Figure 2 shows the annual research expenditures from external sources for the Propulsion Research Center since its inception in FY 1991 through a projection of FY 2020. The average annual expenditure level of the entire period is $1.6 million dollars per year. The periodic “surges” in funding generally represent the growth and completion of significant research programs or with a particular major sponsor. The projection of $3,300,000 for FY 20 shows a 33% increase over last year and is an overall result of increased funding of several team members. The overall research portfolio has increased by 160% in the past five years from $1.3 million to $3.3 million. The research expenditure numbers do not include cost shares, internal university research funds, state provided operating funds, or UAH Foundation investments into the PRC.

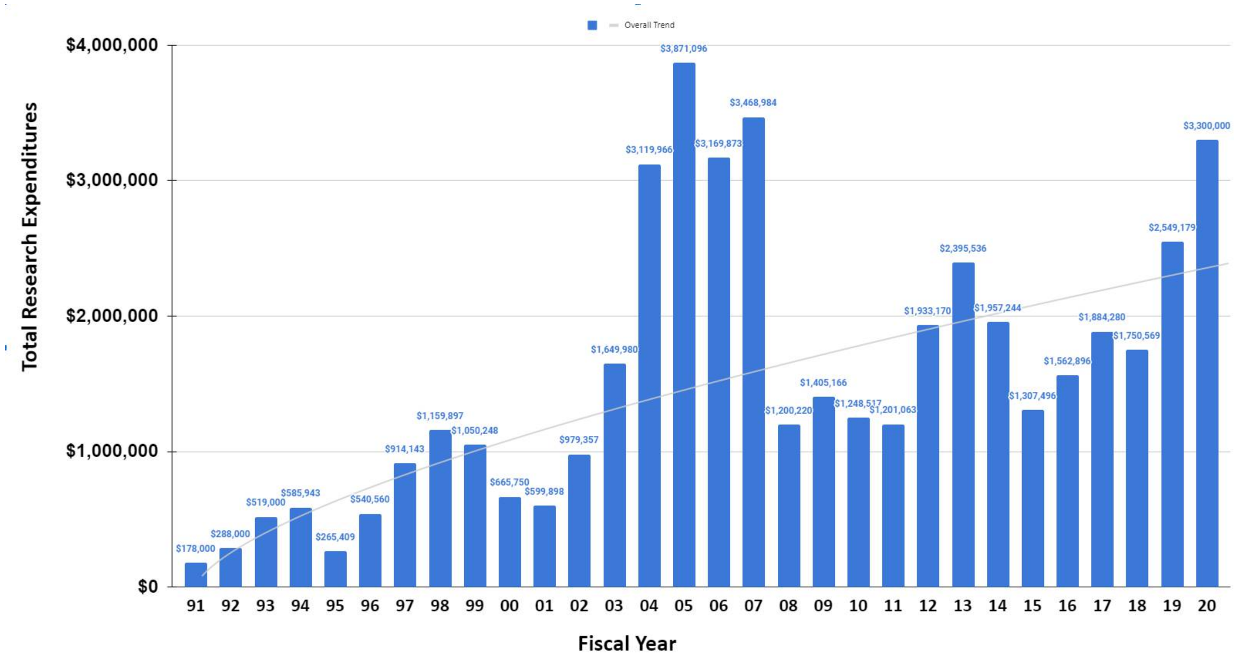


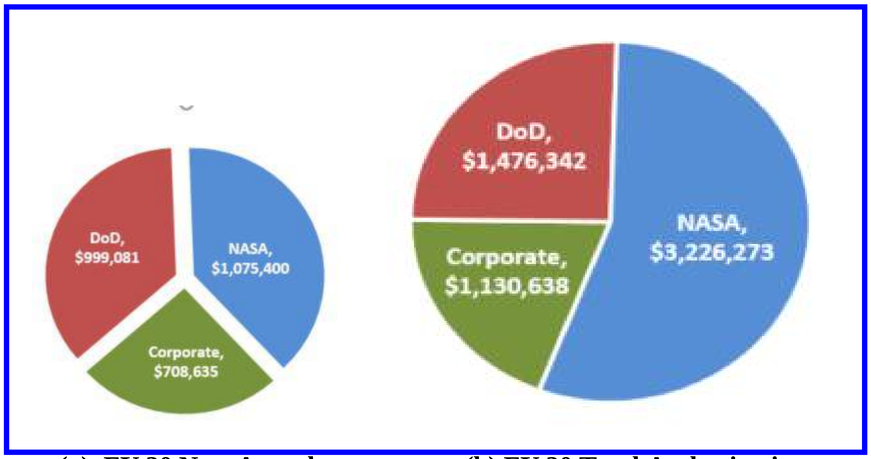
Fig. 2. Research expenditures distribution by FY.

D. PRC Current Research Funding

This section highlights the sponsors and funding award distributions for the first three quarters of FY20. The PRC currently manages these external funds in 66 separate research accounts. The PRC has received $2,783,126 in new awards during the first three-quarters of FY20. Table 1 below shows the distribution of new funding of $2,783,116. This is added to ongoing authorization from previous FY’s of $3,050,137 to a total of $5,833,253. With research expenditures to date of $2,524,477, the current net authorizations are $3,308,776.

Table 1. PRC Funding and Expenditure Summary (Oct. 1, 2019 through June 30, 2020)

	New Funds	Ongoing Authorizations	Total Authorizations
Corporate	$ 708,635.15	$ 422,002.37	$ 1,130,637.52
DoD	$ 999,081.00	$ 477,261.46	$ 1,476,342.46
NASA	$ 1,075,400.00	$ 2,150,873.20	$ 3,226,273.20
Total	**$ 2,783,116.15**	**$ 3,050,137.03**	**$ 5,833,253.18**
		Total Spending (7/31/20)	$ (2,524,476.74)
		Net Authorizations	**$ 3,308,776.44**



(a) FY 20 New Awards **(b) FY 20 Total Authorizations**

Fig. 3, PRC Funding distribution by source for first three quarters of FY 20,

Figure 3 illustrates the distribution of new funds and total authorizations. Figure 4a shows funds for FY20 are evenly split between DOD and NASA with a slightly lower portion from corporate sponsors. Figure 4b shows that a significant amount of multi-year funding comes from NASA. This increases the NASA sector to over half of the current total research authorizations.

Several agencies, companies, and universities provide support for PRC research. Table 2 below shows a listing of recent sponsors (from past 5 years). The sponsors are listed according to the type of agency providing the funds. New sponsors this year include the FBI, Torch Technologies, and Northrup Grumman.

A. PRC Recent Publications

PRC researchers and students have produced over 130 publications since January 2019. Table 3 below shows the citations from the past year grouped by the technical areas and researchers. 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.

Table 2 – PRC Sponsors from FY17 to Present

Federal Government	State Government
• NASA Alabama Space Grant Consortium, • NASA Headquarters, • NASA Goddard Spaceflight Center, • NASA Marshall Spaceflight Center (MSFC), • The Missile Defense Agency (MDA), • U.S. Army Space and Missile Defense Command (SMDC)	• State of Alabama **Academic** • United States Air Force Academy
Corporate	
• Aerojet Rocketdyne, • Barber-Nichols, Inc., • Boeing, • C3 Propulsion, • CFD Research, • Combustion Research & Flow Tech., Inc., • Earth to Sky LLC, • ERC, Inc., • Department of the Air Force (USAF), • FBI, • Gloyer-Taylor Laboratories (GTL), • HyperJet Fusion Corporation	• Hyperion Technology, • Hyper V Technologies, • Jacobs, • IHI Corporation, • Manufacturing Technical Solutions (MTS), • McConnell Jones Lanier & Murphy LLP, • Science and Technology Applications, LLC, • Solar Turbines, Inc., • Northrop Grumman Corporation • TGV Rockets, Inc., • Varian Medical Systems, Incorporated, • Vector (formerly Garvey Spacecraft Corp).

Table 3– PRC Recent PRC Publications

Area/Researcher	Recent Publications
<u>Energy and Power Systems</u> Dr. Phillip T. Ligrani	[26], [53], [54], [55], [56], [57], [58], [59], [60], [61], [62], [63], [64], [65], [66], [67], [68], [69], [70], [71], [72], [73], [74], [75], [76]
<u>Fusion Propulsion & Power</u> Dr. Jason Cassibry	[11],[12],[13],[14],[15],[16],[17],[18],[19],[20],[21],[22],[23],[24]
<u>Plasmas and Combustion</u> Dr. Gabe Xu	[129], [130], [131], [132], [133]
<u>Propulsion Systems Integration</u> Dr. L. Dale Thomas	[26], [68], [106], [107], [108], [109], [110], [111], [112], [113], [114], [115], [116], [117], [118], [119], [120], [121], [122], [123], [124], [125], [126], [127], [128],
<u>Computational Modeling</u> Dr. Sarma Rani Dr. C-K Kang,	 [93], [94] [41], [42], [43], [44], [45], [46], [47], [48], [49], [50], [51], [52],
<u>Aerospace Materials & Structures</u> Dr. George Nelson, Dr. Kavan Hazeli Dr. Judy Schneider Dr. Gang Wang	 [77], [78], [79], [80], [81], [82], [83], [84], [85], [86], [87], [88], [89], [90], [91], [92] [32], [33], [34], [35], [36] [95], [96], [97], [98], [99], [100], [101], [102], [103], [104], [105] [134], [135], [136], [137]
<u>Propellants, Energetics, Safety, and Overviews</u> Dr. Robert A. Frederick, Jr. Dr. Daniel Jones Dr. James K. Baird	 [8], [25], [26], [27], [28], [29], [30], [31], [37], [38], [68], [114], [128] [37], [38], [39], [40] [1], [7], [8], [25]
<u>Propulsion System Techy and Testbed</u> Dr. David Lineberry	[28], [31]

II. Academic Infrastructure

B. Mechanical & Aerospace 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 1410 undergraduate students in fall 2019 and has current enrollment expectations of 1425 in fall 2020. The undergraduate AE program now represents over half the undergraduate population, at almost 750 students. As Fig. 5 shows, the ME cohort has grown steadily at several percent per year. However, the growth in BSAE students, starting in 2015, has reshaped our undergraduate profile. The UAH BSAE and BSME programs are, respectively, the largest and third-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 increasing slowly since 2015 and is expected to be over 180 students in the Fall 2020 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.

The MAE full-time faculty count now stands at 26. Twenty are tenure-track, two are non-tenured Clinical Associate Professors, and four are full-time lecturers. MAE also employs around eight adjunct instructors each term from the Huntsville engineering and research community. In fall of 2019, a new junior faculty member joined MAE in the area of control of autonomous flying vehicles, and a new full-time lecturer is joining in fall 2020. The COVID-19 pandemic has affected the Department in several ways. Hiring of two Assistant Professors was cancelled in spring 2020, and the fall 2020 enrollment, while expected to grow slightly, will certainly deviate from the growth curve of recent years. Finally, the circumstances have required a shift to an online mode of instruction in most of our courses.

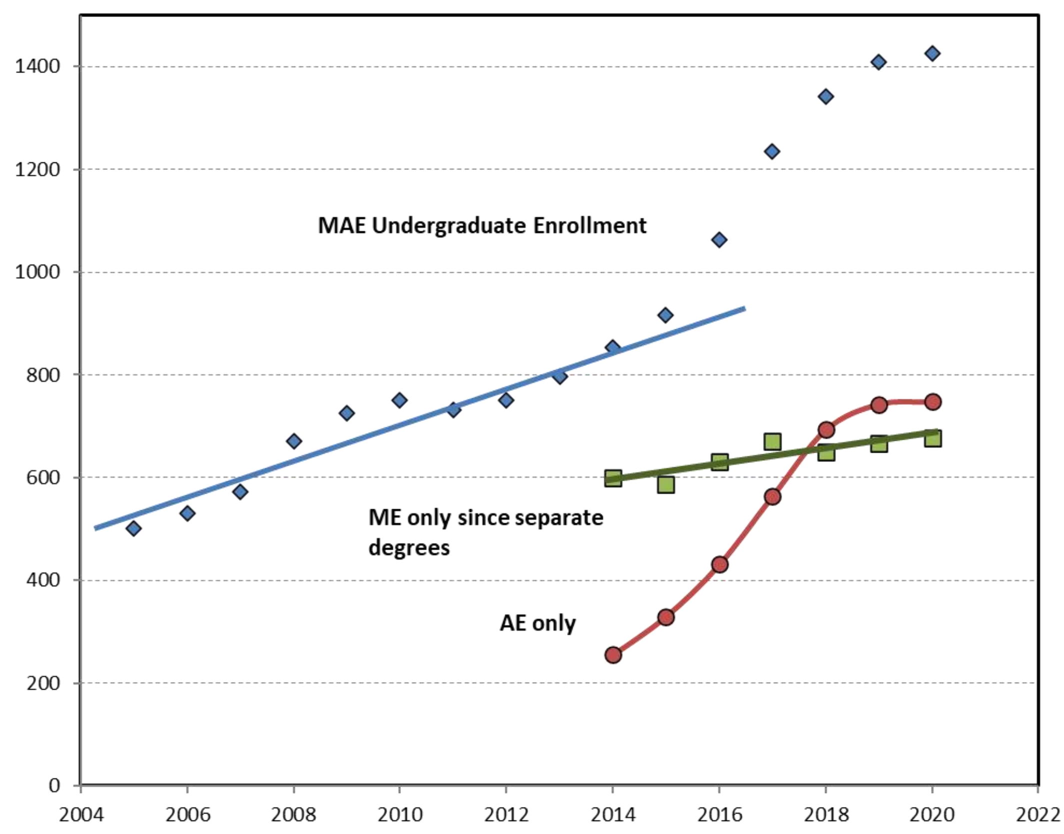


Fig. 5. UAH undergraduate enrollment trends in the Department of Mechanical and Aerospace Engineering. MAE is total enrollment. ME and AE are the separate degree programs.

C. Propulsion-Related Courses

Tables 3 and 4 show several propulsion-related classes offered at UAH in Mechanical and Aerospace Engineering. The dual-level courses in Table 3 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 to meet their program requirements.

It is significant to note the Rocket Propulsion I has doubled in enrollment since 2015-16 and is expected to increase next year. Introduction to Electric Propulsion is an elective course that is offered every two years. 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 rocket design course enrollment has been capped due to ensure safety due to limited staffing and resources to support the course. The increasing totals in the dual level classes of Table 1 show how the overall MAE student growth is increasing propulsion-related class enrollment.

Table 4 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 thorough review and evaluation of 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 combining 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 3. UAH undergraduate and graduate (dual level) course enrollments s related to propulsion and energy by academic year (AY).

Dual-Level Undergraduate/Graduate	AY 15-16	AY 16-17	AY 17-18	AY 18-19	AY 19-20-
MAE 440/540 Rocket Propulsion I	55	34	67	79	110
MAE 441/541 Airbreathing Prop.	17	38	33	38	61
MAE 444/544 – Intro. To Electric Propulsion.	22	-	20	-	27
MAE 468/568–Elem. of Spacecraft Des,	56	62	87	99	122
MAE 490/491– Rocket Design	56	38	40	40	40

Table 4. UAH graduate propulsion and energy courses and enrollments by Academic Year (AY).

UAH Graduate Course	AY 15 - 16	AY 16-17	AY 17 - 18	AY 18-19	AY 19-20
MAE 620-Compressible Flow	21	11	30	26	14
MAE 640–Rocket Propulsion II	-	21	-	29	-
MAE 64 -Adv. Solid Rocket Propulsion	22	-	15	-	23
MAE 645 – Combustion I	6	-	19	-	13
MAE 695/795–ST: Adv. Readings in Prop.	7	3	2	3	5
MAE 695: ST Intro to Nuclear Propulsion	-	22	-	26	-
MAE 695-ST: Comb. Instab. 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: Intro. to Fusion Propulsion	11	-	16	-	17

III. PRC Graduate Student Production History – Special Focus

The special focus of this year's paper is on PRC graduate student production from 1991 to the present. The scope of this work was to collect the student data, categorize each thesis and dissertation, verify the citation and advisor, verify the graduation year, categorize into technical areas, and make first estimates of associated data. In the next year we plan to review this approach and also re-connect with the graduates to verify and collect additional data from them.

A team researched our records and those of the library and compiled a database of over 400 entries which also included non-thesis master's degrees, thesis master's degrees, and PhD dissertations. The selection of the degrees has some subjectivity as the PRC supports these thesis and dissertations to varying degrees through contracts and use of facilities. For this exercise we have included the broadest array of associated degrees to fully populate the database, and we plan to refine the analysis in the coming year.

Figure 6 shows a compilation of the cumulative number of Master's theses and PH.D. dissertations completed each calendar year. The total number of degrees is 274 including 207 master's and 67 Ph.Ds. Having 75% of the degrees being Master's degrees stems from two main factors. First, they are shorter in duration. Second, since aerospace funding is typically not multi-year, it is easier to support students for master's degrees than for the longer periods required for PhD's.

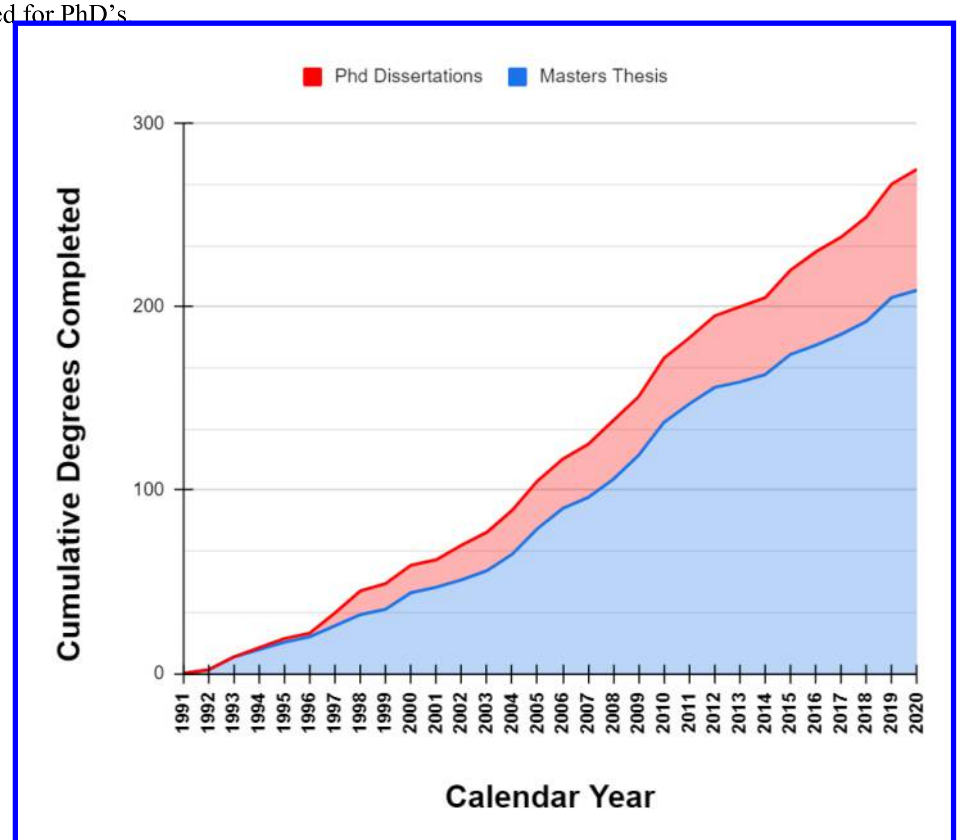


Fig. 6 – Cumulative number of master's and PhD. degrees completed

Figure 7 shows the detail on the rate of completion for each calendar year. The figure illustrates the dynamic nature of degree production. It should also be noted that the completion of a PhD may represent three to five years of work ahead of the actual graduation year. The highest year in 2010 produced 21 degrees. It is also noted that there has been a more sustained and consistent production of PhD over the last few years.

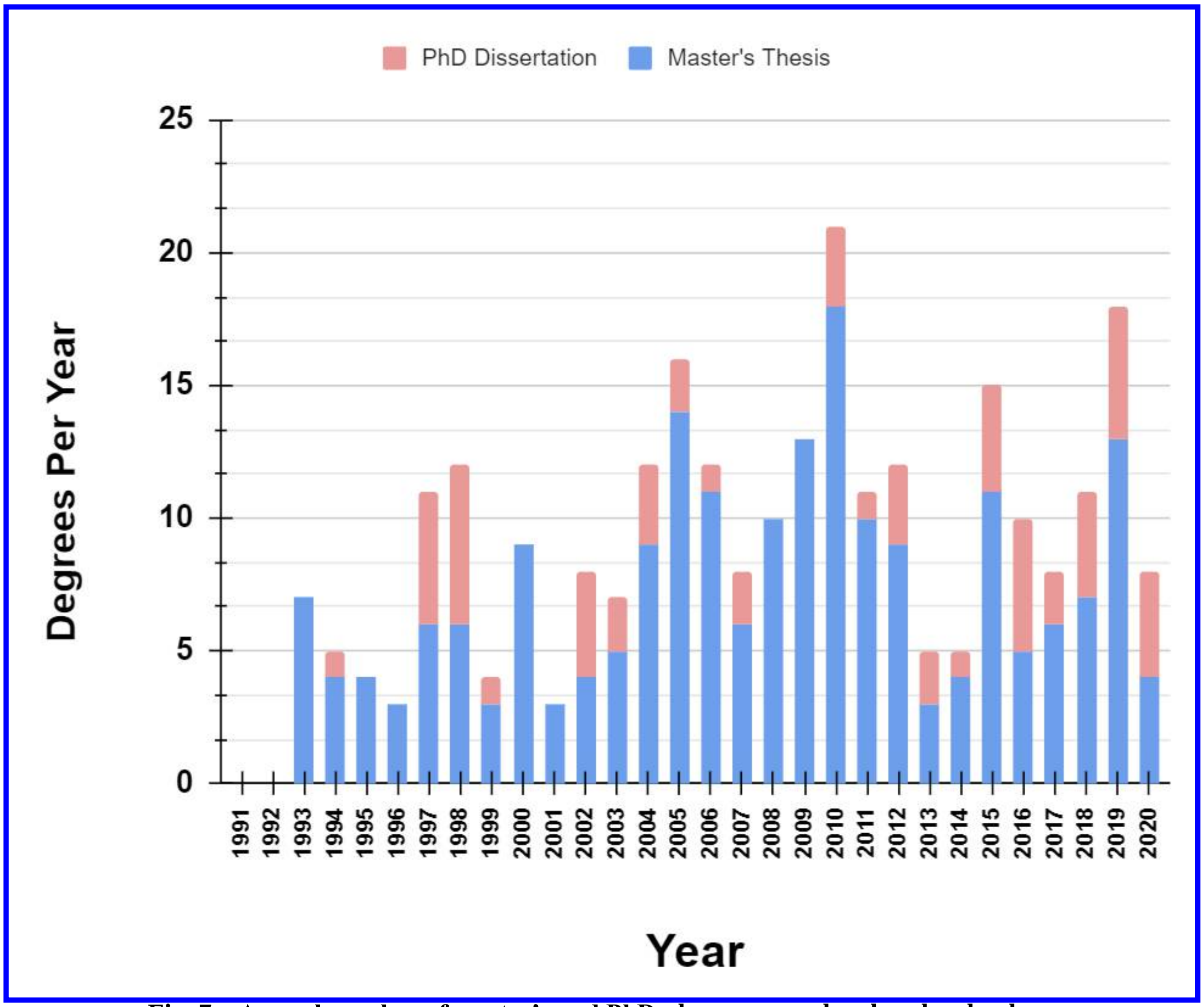


Fig. 7 – Annual number of master's and PhD. degrees completed each calendar year

For a further analysis, each thesis and dissertation was tagged with a technical area that is descriptive of the topic of the work. Table 5 shows the areas and the citations of the thesis and dissertations associated with the areas. The categorization is somewhat subjective, but gives insights into the broad areas of education and research supported by the PRC over the past 29 years. The first three categories are the conventional areas of solid, liquid, and hybrid propulsion. Advanced propulsion which includes electric, nuclear, fusion, solar, and others. Air-Breathing propulsion includes working heat transfer for rotating machinery, wind tunnel work and other areas related to air-breathing propulsion. Propulsion systems engineering includes topics related to system performance trades, costs, reliability, and reducing complexity of systems. Propulsion testing and safety are related to studies of measurement uncertainty and development of new test methods or diagnostic methods. Missile design relates to work related to missile performance. Propulsion-related covers the balance and includes CFD studies, structural work and other items that do not fit neatly into the previous categories.

Table 5. Technical Categories of PRC Master's Thesis and Ph.D. Dissertations from 1991 to present.

Technical Area	Master's	PhD's
Solid Propulsion	[138], [139] [140], [141] [142], [143], [144], [145][146], [147], [148], [149], [150], [151], [152] [153], [154], [155], [156], [157], [158], [159], [160], [161], [162], [163], [164], [165], [166], [167]	[168], [169], [170] [171], [172], [173], [174]
Liquid Propulsion	[175], [176], [177], [178], [179], [180], [181], [182], [183], [184], [185], [186], [187], [188], [189], [190], [191], [192], [193], [194], [195], [196], [197], [198], [199], [200], [201], [202], [203], [204], [205], [206], [207], [208], [209], [210], [211], [212], [213], [214], [215], [216], [217], [218], [219]	[220], [221], [222], [223], [224], [225], [226], [227], [228], [229], [230], [231], [232]
Hybrid Propulsion	[233], [234], [235], [236], [237], [238], [239]	[240], [241]
Advanced Propulsion	[242], [243], [244], [245], [246], [247], [248], [249], [250], [251], [252], [253], [254], [255], [256], [257], [258], [259], [260], [261], [262], [263], [264], [265], [266], [267], [268], [269], [270], [271], [272], [273], [274], [275], [276]	[277], [278], [279], [280], [281], [282], [283], [284], [285], [286], [287], [288], [289], [290], [291], [292], [293]
Air-Breathing Propulsion	[294], [295], [296], [297], [298], [299], [300], [301], [302], [303], [304], [305], [306], [307], [308], [309], [310]	[311], [312], [313], [314], [315], [316]
Propulsion Systems Engineering	[317], [318], [319]	[321]
Propulsion Testing and Safety	[322], [323], [324], [325], [326], [327], [328], [329], [330], [331], [332], [333], [334], [335], [167], [336]	[337], [338]
Missile Design	[339], [340], [341], [342], [343], [344], [345], [346], [347], [348], [349], [350]	[351], [352], [353]
Propulsion-Related	[354], [355], [356], [357], [358], [359], [360], [361], [362], [363], [364], [365], [366], [367], [368], [369], [370], [371], [372], [373], [374], [375], [376], [377], [378], [379], [380], [381], [382], [383], [384], [385], [386], [387], [388], [389], [390], [391], [392], [393], [394], [395], [396], [397], [398]	[399], [400], [401], [402], [403], [404], [405], [405], [406], [407], [408], [409] [410]

Figures 8 and 9 show the distribution of master's and PhD. Degrees in the technical areas. The distribution of the technical areas is relatively constituent between the two figures. The combination of solid, liquid, and hybrid propulsion comprises about a third of the degrees in both categories. Advanced propulsion is another significant area covered by the theses and dissertations with a greater percentage at the dissertation level. Our strategic plan last year recommended more emphasis in the advanced propulsion area for the future. The air-breathing component has grown substantially in the last 5 years with the addition of Dr. Ligrani, Emener Scholar in Propulsion. The propulsion systems engineering is also growing with Dr. L. Dale Thomas joining UAH as the Eminent Scholar in Industrial and Systems Engineering.

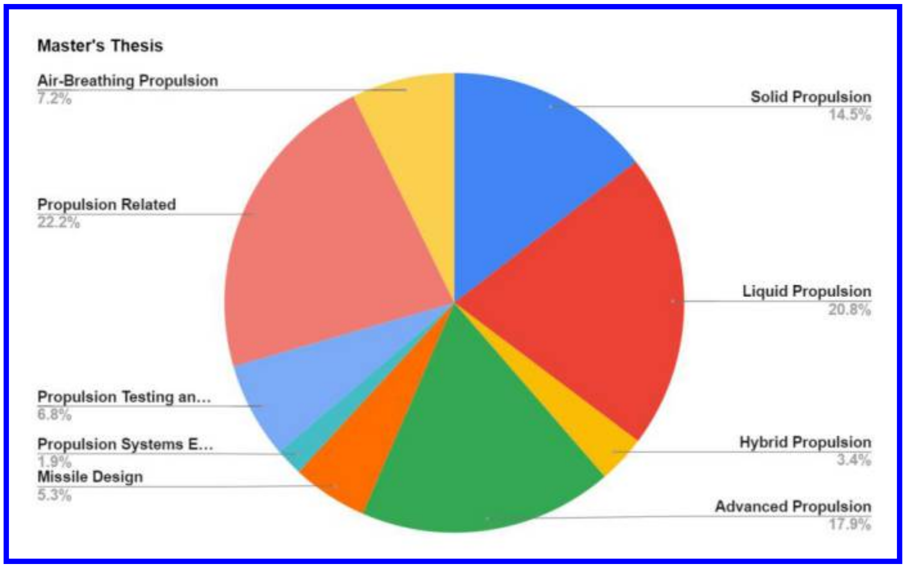


Fig. 8 – Distribution of master's theses completed by technical areas

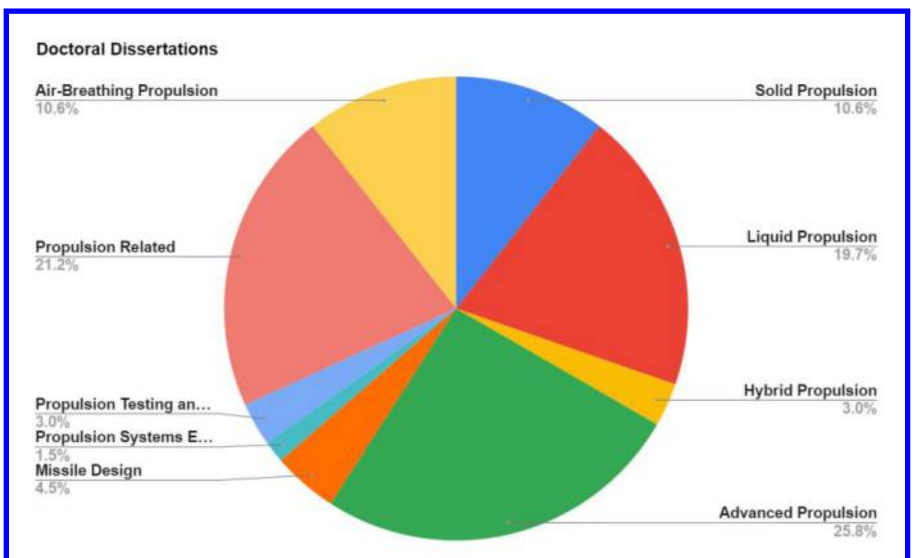


Fig. 9 – Distribution of master's theses completed by technical areas

Figure 9 shows the percentage of advanced degree graduates each year by gender. The overall rate is 20% female and 80% male. Figure 9 shows the annual percentage of graduates who are U.S. citizens. The overall average is 93 percent. The large number of U.S. citizens is partly driven by contracts that require citizenship and the high-density of aerospace work for U.S. citizens in the Huntsville area.

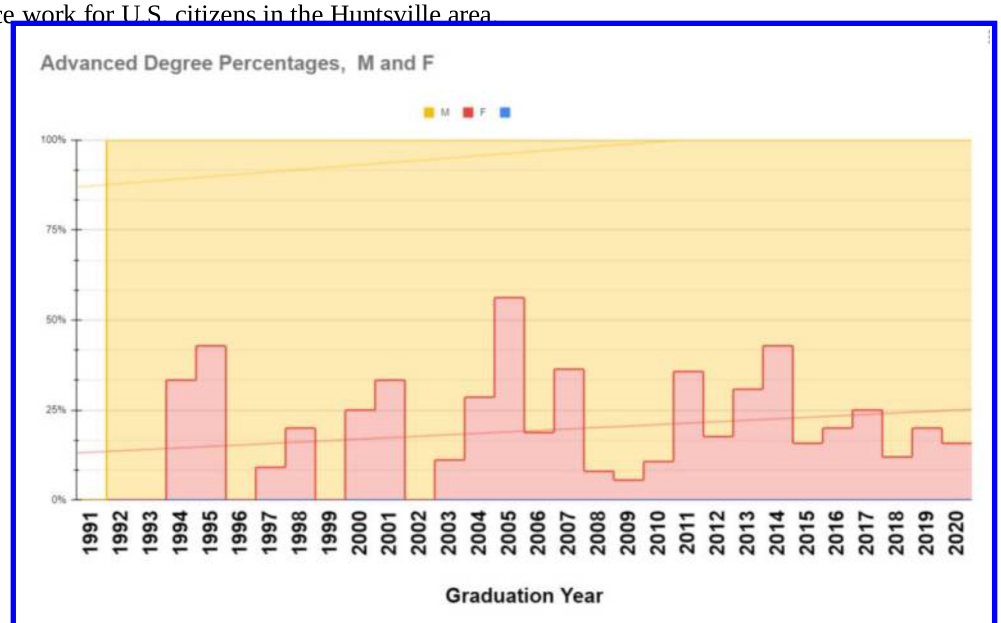


Fig. 10 – Distribution percentage of degrees each year by M – male, F – Female

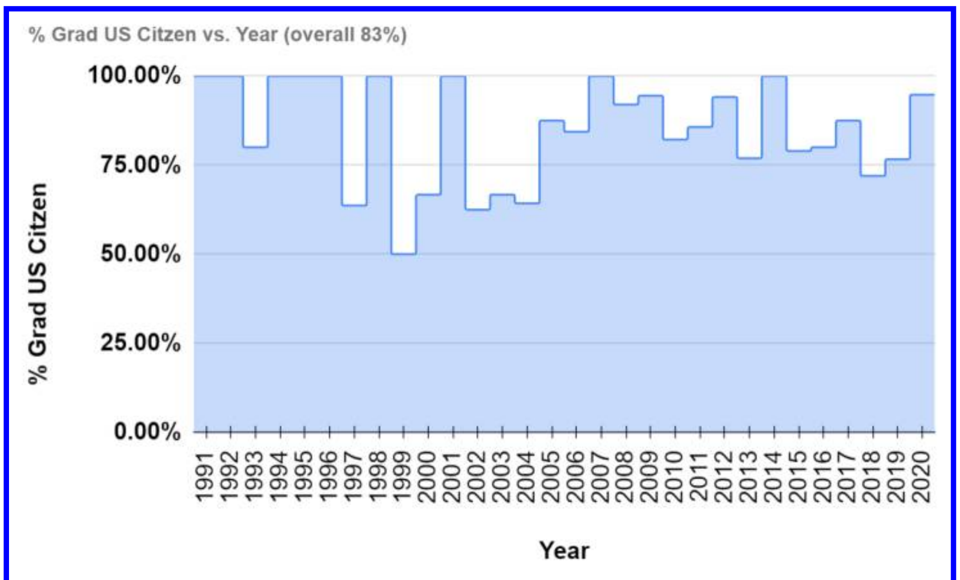


Fig. 11 – Estimated distribution percentage of U.S. citizen degrees each year

IV. Student Launch Initiative

Figure 12 shows the UAH 2020 UAH Student Launch Team with their sounding rocket at our UAH laboratory. This year the team's rocket reached an apogee of 4,454 feet above ground level. The team's goal was 4,500 feet. Originally this launch was a payload demonstration, but due to schedule changes caused by COVID-19, the mission objective was changed to a full flight demonstration of the rocket and payload. The SLI final launch that had previously been set for April 4 at Bragg Farms in Toney, Ala., was scrubbed. The SLI program typically has a very tight schedule, but this year because of the COVID-19 outbreak, in addition to new design and programmatic challenges, the team had to deal with a schedule reduced by an additional month. Completing the design, manufacturing, and testing of both the payload and rocket, and demonstrating the full mission prior to the shutdown was a monumental accomplishment. The team members, their role, and hometown are:

- Nicholas Roman, project manager; senior, aerospace engineering, Cullman, Ala.
- Joshua Jordan, chief engineer; senior, mechanical engineering, Mount Vernon, Wash.
- Peter Martin, vehicle team lead; senior, mechanical engineering, Coopersburg, Penn.
- James Venters, payload team lead; senior, mechanical engineering, Huntsville, Ala.
- Jessy McIntosh, safety officer; senior, mechanical engineering, Beaufort, N.C.
- Maggie Hockensmith, technical writing coordinator and vehicle safety deputy; senior, aerospace engineering, Lexington, Ky.
- Claudia Hyder, payload safety deputy; senior, mechanical engineering, Knoxville, Tenn.
- Patrick Day, project management team; senior, aerospace engineering, Johnson City, Tenn.
- Will Snyder, project management team; senior, aerospace engineering, Cleveland, Ohio
- Rodney L Luke, vehicle team; senior, aerospace engineering, Pleasant Grove, Ala.
- Roman Benetti, vehicle team; senor, aerospace engineering, Woodbury, Minn.
- Rachel O'Kraski, vehicle team; senior, aerospace engineering, Huntsville, Ala.
- Ben Lucke, vehicle team; senior, aerospace engineering, Saint Petersburg, Fla.
- Jeremy Hart, vehicle team; senior, aerospace engineering, Gainesville, Ga.
- Jacob Zilke, vehicle team; senior, aerospace engineering, Wilmington, N.C.
- Joseph Agnew, payload team; senior, mechanical engineering, New Market, Ala.
- Johnathon Jacobs, payload team; senior, aerospace engineering, Valley Head, Ala.
- Thomas Salverson, payload team; senior, mechanical engineering, Gretna, Neb.
- Kevin Caruso, payload team; senior, mechanical engineering, Lawrenceburg, Tenn.
- Jacob Moseley, payload team; senior, aerospace engineering, Gaylesville, Ala.

The UAH team is advised by Dr. David Lineberry, a Research Engineer at the UAH Propulsion Research Center, and mentored by Jason Winningham, who has assisted rocket launches and advised throughout the project. The University of Alabama in Huntsville (UAH) earned first place in project safety and third place overall in competition at a COVID-shortened national 2020 NASA Student Launch.

Fig. 12 –UAH 2020 Student Launch Team

V. People Make the Difference and Comments of COVID -19

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 restaurants where we enjoy good food and several members perform music.

Fig. 13 – Propulsion Research Center faculty, staff, students, colleagues, and friends at the fall 2019 Recognition of Graduates Reception (left) and spring 2020 graduate calibration (COVID-19 Zoom). "Keep relationships more important than tasks or problems" – Dr. Robert A. Frederick, Jr., Director, UAH Propulsion Research Center.

Figure 13 shows the PRC team at our December 2019 and May 2020 Graduate Recognition gatherings. The difference in the left and right photo illustrate the difference that COVID-19 has made on our interactions. In December we stood shoulder to shoulder throwing hats into the air, while in May we all connected through the internet from our remote work sites to maintain social distancing. Our laboratory reopened a few weeks ago has been operating under strict COVID guidelines.

VI. Remarks

The UAH PRC stands poised to build upon a rich legacy of research advances in propulsion. One of our original strategies was to pursue funding support for projects that would support students. The faculty associated with the PRC have followed that vision and could produce 300 graduates with advanced degrees on propulsion topics in the first 30 years (projecting to next year). If we also project 30 years of total expenditures at $50 million, that averages to about $170,000 per degree. The strategy forward will focus on continuing a legacy of excellence in traditional student production in the propulsion arena, equipping the future workforce for success in their future careers.

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