THE WARE LAB

JOSEPH F. WARE, JR. ADVANCED ENGINEERING LAB

ANNUAL REPORT 2021–2022

COLLEGE OF ENGINEERING
JOSEPH F. WARE JR.
ADVANCED ENGINEERING LAB
VIRGINIA TECH

eng.vt.edu/warelab

Executive Summary

This annual report summarizes activities at Virginia Tech's *Joseph F. Ware, Jr. Advanced Engineering Lab* housed in the College of Engineering for academic year 2021-22. The report includes sections on lab expenditures, student demographics, and competition activities. This year 557 Virginia Tech students completed all safety requirements needed for lab entry.

Lab expenditures for maintenance and repair of the truck and trailers amounted to $21,800, including extensive repairs of our existing goose-neck trailer ($17,200). Fuel expenditures for trips to competitions totaled $9500 and equipment and material expenditures amounted to $38,400 including the purchase of a new goose-neck trailer ($23,200). The grand total for all lab expenditures for 2021-22 was $69,700.

In addition, many Ware Lab teams met the challenge by excelling at competition events. *Baja SAE* earned 5th out of 93 at their SAE (*Society of Automotive Engineers*) sponsored event in Cookeville, Tennessee. *Concrete Canoe* took 2nd place in their regional AISC (*American Society of Civil Engineers*) event at Virginia Military Institute in Lexington, Virginia and *Design Build Fly* earned 5th out of 97 at their Wichita Kansas AIAA (*American Institute of Aeronautics and Astronautics*) event. Also, our *Hybrid Electric Vehicle Team* placed 4th out of 11 pre-screened teams in the final year (Year 4) of the EcoCAR Mobility Challenge in Yuma, Arizona.

Ware Lab teams must raise the majority of their funds through sponsorship from corporate supporters such and Swearingen, General Motors, Monoflow, Yamaha, and Lockheed Martin. Collectively, our teams raised more than $181,000 in in-kind and monetary contributions. In addition, Virginia Tech's *Student Engineer's Council* (SEC) contributed $37,600 to Ware Lab teams this year alone! Our teams simply could not compete in world class competition events without this generous support.

Virginia Tech served as host for the AISC (*American Institute of Steel Construction*) *National Steel Bridge Competition.* Our own Virginia Tech *Steel Bridge* team earned a slot at the event by capturing first place in all categories at their regional event in Lexington, Virginia. Our team placed in the top 50% at the national competition against the nation's top universities and colleges in the field.

This report also has demographics on team academic levels, academic majors, gender, ethnicity along with demographic trends. A new section illustrating Ware Lab team posters has been added in Appendix A. These posters demonstrate the high degree of dedication necessary for teams to be competitive at regional and international events.

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Introduction

The Joseph F Ware, Jr. Advanced Engineering Lab at Virginia Tech (aka *Ware Lab*) is an undergraduate design facility housed within Virginia Tech's College of Engineering in the Military Building on the main campus. The facility is home to ten undergraduate teams from various departments within the college. Ware Lab staff consists of:

- Dr. Keith Thompson - Director
- Dewey Spangler, PE - Manager
- Phillip Ratcliff - Assistant Manager

The Ware Lab spans over of 10,000 square feet of space divided into four main areas. Each area requires varying levels of safety certification as specified in the *Ware Lab General Policy Manual*. These areas include:

1. General Areas
   a) First floor – (Room 100, 104, 106 through 114, 117) – Fig. 1.
   b) Basement – (Room 18) – Fig. 2.
2. Machine Shop – (Room 101) – Fig. 1.
3. Welding Shop – (Room 102) – Fig. 1.
4. Administrative Areas – (Room 101A, 101AA, 103, 105) - Fig. 1

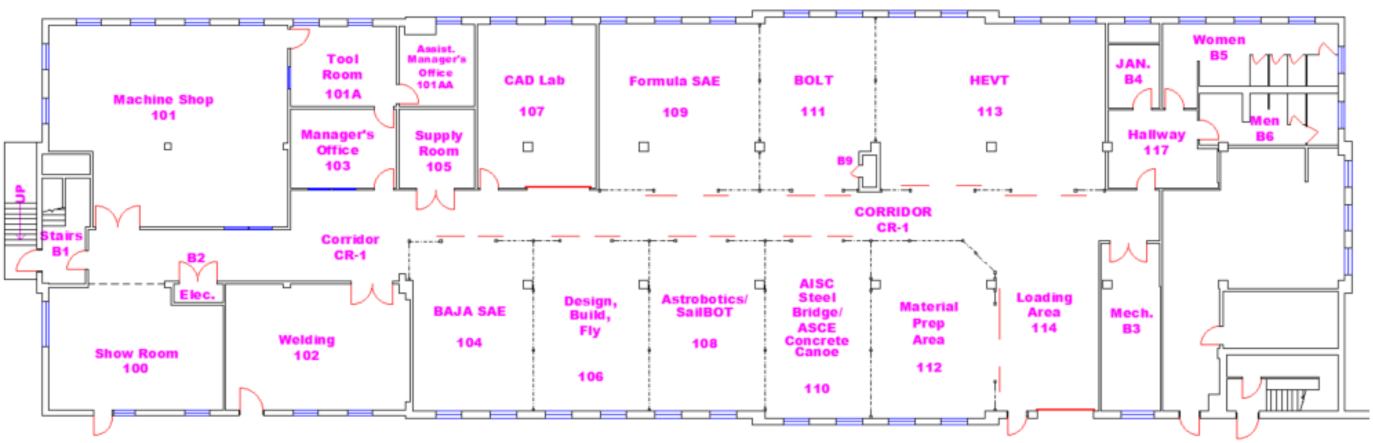


Figure 1 – Ware Lab Main Floor.

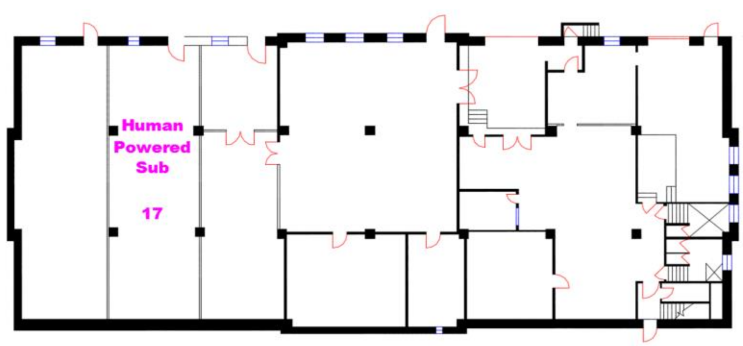


Figure 2 – Ware Lab Human Powered Submarine Bay.

Faculty Advisors, Team Leads, and Team Safety Officers for 2021-22

557 students from various academic departments completed the Ware Lab general survey this year. Table 1 is a list of WL faculty advisors and Table 2 lists student team leadership. The last column in Table 2 indicates each team's safety officer. These students are responsible for insuring that team members conduct themselves in a safe manor according to provisions in the Ware Lab Policy Manual. In Appendix A Ware Lab team posters are displayed showing the level of sophistication our design team are engaged in.

Table 1 – Ware Lab Faculty Advisors for 2021-22

Ware Lab Team	Faculty Advisor	Academic Department
Astrobotics	Kevin Shinpaugh	Aerospace and Ocean Engineering
Baja SAE	Jared Bryson	Mechanical Engineering
BOLT	Rick Clark	Mechanical Engineering
BOLT	Author Ball	Electrical and Computer Engineering
Concrete Canoe	David Mokarem	Civil and Environmental Engineering
Design Build Fly	Rakesh Kapania	Aerospace and Ocean Engineering
Formula SAE	Rick Clark	Mechanical Engineering
Hybrid Electric Vehicle	Doug Nelson	Mechanical Engineering
Human Powered Sub	Christine Gilbert	Aerospace and Ocean Engineering
SailBOT	Stefano Brizzolara	Aerospace and Ocean Engineering
Steel Bridge Team	Matt Eatherton	Civil and Environmental Engineering

Table 2 – Ware Lab Team Leads and Safety Officers for 2021-22

Ware Lab Team	Team Lead(s)	Role	Safety Officer
Astrobotics	Gea Anderson	Team Lead	Gea Anderson
	Thomas Giattino	Mechanical Team Lead	
	Madeline Pedersen	Project Manager	
	Henry Forsyth	Electrical lead	
Baja SAE	Nick Kreuscher	Co-Captain	Dhietmar Curz
	Dhietmar Cruz	Co-Captain	
Battery Operated Land Transport (BOLT)	Alex Surdam	Senior Team Lead	Alex Surdam
	Yanni Kousidis	Senior Team Lead	
	Will Gessner	EV Team Lead	
	Erin Cox	Junior Team Lead	
Concrete Canoe (CTT)	Nawras Zalzala	Co-Team Lead	Nawras Zalzala
	Rachel Johnson	Co-Team Lead	
	Kathy Bruckner	Co-Team Lead	
Design Build Fly (DBF)	Lemuel Hook	Chief Engineer	Lemuel Hook
	Aidan Sprague	Project Manager	
Formula SAE (FSAE)	Max Kreuscher	Co-Team Lead	Matt Kreuscher
	Brandon Pieroni	Co-Team Lead/Chassis Lead	
	Nick Dilauro	EV Powertrain Lead	
	Ben Simons	EV Project Manager	
Hybrid Electric Vehicle Team (HEVT)	Will Hom	Project Manager	Will Honicky
	Candy Li	Engineering Manager	
	Dillon Scott	PSI Manager	

	Will Honicky	Safety Lead	
	Nick Newton	Controls Lead	
	Tom Tase	Connected and Automated Vehicles	
	David Schlingloff	Propulsion Systems Integration Lead	
	Kristen Harrell	CAVs Lead	
	Justin Wu	Controls Manager	
	Stephen Prisament	Communications	
Human Powered Sub (HPS)	James Duval	President	James Duval
	Shane Carroll	Head of Design	
	Nathan Hayes	Vice President	
	Oscar Johansson	Treasurer	
	Mary Claire Armistead	Sponsor Relations	-
	Hannaneh Shadabi	Event Coordinator	
SailBOT	Jay Provost	Team Lead	Jay Provost
Steel Bridge (SBT)	Chris Padgett	Co-Captain	Chris Padgett
	Gavin Harwell	Co-Captain	
	Jack Grondine	Co-Captain	
	Justice Foster	Co-Captain	

Team Competition Results and Annual Budgets

Table 3 is a summary of team rankings at various regional and international competition events throughout North America for 2021-22. VT Concrete Canoe Team took 2nd place in their ASCE regional event and Baja SAE won 5th place at their international SAE event in Clarksville, Tennessee. Also, DBF earned top 5% in their event in Wichita Kansa out of 97 finalists (Figure 3) and HEVT was a top five team at their Year 4 (completion year) event in Yuma, Arizona.

Our Steel Bridge team won first place in all categories at the AISC regional event in Lexington, Virginia. Categories included: stiffness, construction speed, efficiency, economy, aesthetics, and constructability. The team's performance insured them a spot in the AISC national event hosted by Virginia Tech this year. Our Virginia Tech team scored in the top 50% against the nation's best steel bridge competition teams!

Table 3 – Ware Lab Team Competition Results for 2021-22

Team	Competition	Location	Ranking
Astrobotics	NASA Robotic Mining Completion	Meritt Island, FL	Did not attend.
Baja SAE	Baja SAE Tennessee	Tennessee Tech, TN	1st in *Suspension and Traction*. 8th in *Maneuverability*. 4th in *Endurance*. **5th overall out of 93**
Baja SAE	Baja SAE Rochester	Rochester, NY	26th out of 88
BOLT	AHRMA Varsity Challenge	Millville, NJ	Did not complete.
Concrete Canoe	ASCE Virginias Regional	Virginia Military Institute, VA	2nd out of 6
DBF	AIAA Design/Build/Fly	Wichita, KS	5th out of 97 (see *Figure 3)*
Formula SAE	Formula SAE Michigan (IC)	Brooklyn, MI	Disqualified
HEVT	EcoCAR Mobility Challenge - Year 4	Yuma, AZ	4th out of 11
HPS	Mate ROV	Memphis, TN	No competition this year.
SailBOT	International Robotic Sailing Regatta	Worchester MA	2nd out of 4
Steel Bridge	AISC Virginias Regional	Virginia Military Institute, VA	1th out of 6
Steel Bridge	AISC National Finals	Virginia Tech, VA	19th out of 34

Figure 3 - Virginia Tech's Design Build Fly team in Wichita Kansas. DBF has place in the top 5th position at five international events over its history competing against over 90 universities and colleges.

Table 4 is a summary of Ware Lab team budgets for this year. Ware Lab teams reported over $360,300 in corporate, private, and university contributions for 2021-22. Expenditures totaled $238,120 for a net positive balance of $122,420 for all teams in the facility. Table 5 lists major corporate and SEC (*Student Engineer's Council*) contributions for this year. Ware Lab teams depend heavily on support from many private sector companies such as *General Motors, Lockheed Martin,* and *Monoflow* for support. In addition to corporate contributions, *SEC* support is critical in allowing teams to maintain funds for competition registration fees, equipment, materials, tooling, and traveling expenses. Combined corporate and SEC support totaled $218,000 in 2021-22!

Table 4 – Ware Lab Team Sponsorships and Expenditures for 2021-22

Team	Corporate	Private	Virginia Tech	Total	Expenditures	Net
Astrobotics	$0	$0	$0	**$0**	$3,804	**($3,804)**
Baja SAE	$35,000	$4,625	$8,457	**$48,080**	$36,320	**$11,800**
BOLT	$41,000	$0	$6,700	**$47,700**	$34,000	**$13,700**
CCT	$1,500	$0	$2,811	**$4,311**	$4,075	**$236**
DBF	$10,500	$2,500	$15,450	**$28,450**	$20,263	**$8,187**
Formula SAE	$53,500	$91,900	$5,160	**$150,560**	$79,313	**$71,247**
HEVT	$32,433	$10	$9,778	**$42,223**	$29,795	**$12,428**
HPS	$7,000	$0	$10,700	**$17,700**	$10,087	**$7,613**
SailBOT	$300	$0	$3,710	**$4,010**	$3,960	**$250**
Steel Bridge	$0	$475	$16,787	**$17,262**	$16,503	**$759**
Total	**$181,233**	**$99,510**	**$79,553**	**$360,296**	**$238,120**	**$122,416**

Table 5 – Major Corporate/SEC Sponsorship for 2021-22

	Baja SAE	BOLT	CCT	DBF	Formula SAE	HEVT	HPS	SailBOT	SBT	Totals
Swearingen	$15,000									**$15,000**
General Motors	$10,000	$10,000			$10,000	$7,260				**$37,260**
Lockheed Martin	$5,000	$5,000		$5,000			$5,000			**$20,000**
Toyota	$5,000									**$5,000**
Yamaha		$26,000								**$26,000**
Kokosing			$1,000							**$1,000**
Arcosa			$500							**$500**
Leidos, Serra Nevada				$5,500						**$5,500**
Monoflow					$35,000					**$35,000**
AKG					$8,500					**$8,500**
Argonne National Labs						$20,173				**$20,173**
FORD						$5,000				**$5,000**
Flying-S							$2,000			**$2,000**
Collision Plus								$300		**$300**
SEC	$3,960	$2,200	$2,310	$5,240	$4,600	$1,780	$7,000	$3,710	$6,800	**$37,600**
Total	**$38,960**	**$43,200**	**$3,810**	**$15,740**	**$58,100**	**$34,213**	**$14,000**	**$4,010**	**$6,800**	**$218,833**

General Motors Visit to Ware Lab

In April of 2022, representatives from General Motors visited our automotive based teams to discuss team progress and future funding (Figure 4). On hand was GM's lead talent scout for Virginia Tech, Keith Van Houten and GM engineer Marissa Spallucci, who served as co-lead for VT Formula SAE in 2018-19. In addition to team meetings, GM staff conducted multiple technical sessions on the main campus in areas of EV propulsion, lean manufacturing, and hybrid vehicle design.

Figure 4 – GM's Keith Van Houten (foreground) and Marissa Spallucci (center) visit with Baja SAE (left). Baja team leads discusse CVT drive train design with GM visitors (right).

ASCE National Steel Bridge Competition

Article by *Courtney Sakry*, Virginia Tech College of Engineering

Virginia Tech welcomed hundreds of engineering students from across North America to its Blacksburg campus May 27-28 for the National Student Steel Bridge Competition. Virginia Tech's hosting duties were announced at the 2019 Student Steel Bridge Competition at Southern Illinois University. Because of COVID-19, the event was canceled in 2020 and 2021.

The main competition and awards banquet took place in the Beamer-Lawson Indoor Practice Facility (see Figure 5). Turf that normally is covered with footballs and cleats was transformed to hold steel beams and hard hats, and the aesthetics judging area of the competition was located in the concourse of Lane Stadium. During the two-day event, participants had the opportunity to socialize, explore campus, and take in the famous Hokie Stone architecture.

Figure 5 - Virginia Tech Steel Bridge team members before the national competition. Photo credit Peter Means, College of Engineering.

The Student Steel Bridge Competition is sponsored by the American Institute of Steel Construction, which works with host schools to plan the regional events and national finals. Top teams made up of undergraduate and graduate students from over 20 regional events qualified to compete at the national finals in Blacksburg. The competition challenges student teams to develop a 1/10 th scale-model steel bridge. The bridge layout starts ahead of the build and includes a thorough plan for efficient assembly under timed construction at the competition (Figure 6). Once it is built, each bridge is load tested and weighed (Figure 7). The competing teams are judged in seven categories: construction speed, lightness, aesthetics, stiffness, cost estimate, economy, and efficiency.

> “The steel bridge competition is a unique growing experience for students because it presents them with an uncomfortable problem to solve, one which their professor does not have the answer to,” said Zachary Coleman, a graduate student in the Charles E. Via, Jr. Department of Civil and Environmental Engineering (CEE) who helped organize the event.

Coleman competed in the steel bridge competition as an undergraduate student a few years ago and said the experience was an opportunity for significant personal growth. “For many students, this competition is the first time they must leverage their engineering judgement, research skills, and ingenuity to work toward a solution as a team,” he said. For this year’s event, Coleman was one of three graduate students from CEE who led the planning and organization. Ten other graduate students and multiple staff members also pitched in.

While some of the planning was done in 2019 prior to the national finals' cancellation, in 2020, much of it had to be reorganized as contracts had lapsed and organizers within the CEE and athletics departments had changed. Matthew Eatherton, faculty lead organizer and advisor for Virginia Tech’s steel bridge team, was pleasantly surprised by how well the event was received.

> “I went into the planning process for the Student Steel Bridge Competition National Finals thinking about the opportunity it posed to show off Virginia Tech and our department to top undergraduate students and their faculty advisors from 34 universities in North America,” said Eatherton. “What I didn’t expect was how well the organizing team came together and how many compliments I got about the high quality of the event. It was a great experience.”

Figure 6 - Students from the Virginia Tech steel bridge team compete in the national finals. Photo credit - Peter Means, College of Engineering.

Virginia Tech not only hosted this year’s event, but also contributed its own steel bridge team, made up of five CEE students who competed and several others who helped in the behind-the-scenes planning and design of the bridge. Tech’s team earned a spot at nationals by placing first in all seven categories at its regional competition in April. While the team didn’t place in the top spots at the national event, it was still a learning experience for all that were involved.

“I cannot think of a better educational experience to help prepare students for careers in design and to help them develop independent thinking,” Coleman said.

Figure 7 – This year’s steel bridge during load testing at the Ware Lab. Bridges are subjected to six load cases during competition similar to actual civil engineering structures.

BOLT High Voltage Testing

Ware Lab team members that are exposed to high voltages (>50V) during testing must complete additional EHS safety training and wear necessary personal protective equipment (PPE). The BOLT 4 all-electric motorcycle (Figure 8) uses an EV powertrain with output in excess of 600 volts. Battery array probing involves potential exposure to full voltages, requiring students to be fully insulated during testing. The bike and tester are restricted to a “no-go” zone marked by pilons and an orange chain during high voltage testing, per OSHAA regulations.

Figure 8 – BOLT EV leads during high voltage testing of the 2022 BOLT 4 vehicle.

Ware Lab Facility Tours

Ware Lab tours are provided to visiting families, student groups, and the general public. Table 6 is a summary of tours for this year with over 500 people visiting from K12 schools, summer engineering camps, along with students who have been accepted to the college of engineering. Ware Lab and AEDL jointly hosted a Virginia Tech alumni event and a college wide open house (Figures 9 and 10).

Table 6 – Ware Lab Tours for 2021-22

Organization/Group	Number
4H Junior Leadership Program	42
Accepted Students	8
Alumni Open House	35
Autodesk VP	3
Black College Institute Event	98
CIA Representatives	8
Clark Foundation	10
COE Open House	55
Donor Tours (Ut Prosim Weekend)	10
EHS middle school - Wythe County, VA	19
Elementary Schools	15
Hokie Ambassadors	80
Prospective Students	65
Representatives from NAVSEA - Dahlgren	6
Science Museum of Western Virginia - K to 5	20
Turner Ashby High School, Bridgewater, VA	20
VT STEM Team	17
Women's Preview Weekend	45
Total	**556**

Figure 9 – Ware Lab teams Baja SAE (left) and BOLT during the College of Engineering open house for 2021-22 (Photo Credit – Peter Means, VT COE)

Figure 10 – AEDL Teams OLVT (left) and Rocketry at VT at College of Engineering open house. (Photo Credit – Peter Means, VT COE)

New Ware Lab Equipment

In 2022 Ware Lab purchased a new 30 foot fully enclosed goose neck trailer for $23,000 from Anchor Sales in Salem, Virginia (Figure 11, left) to be used by Ware Lab teams needing transport of vehicles and equipment to competition events. With this purchase our lab fleet now consists of two goose-neck and three ball-hitch trailers (Figure 11, right). Virginia Tech and student team logos will be added to the new trailer in 2022-23.

Figure 11 – New goose neck trailer (left). Ware Lab trailer fleet (right)

Ware Lab Demographics

Ethnicity, gender, academic level, major, academic credit and transfer information is gathered each year when students complete the general admissions survey. Completion of this survey is one of several items needed in order to receive a lab badge. Summaries of collected data are shown in Tables 7 through 11. Figure 12 discusses how students learned about the Ware Lab and Figure 13 shows the square footage allocated to each team on a percentage basis. Most students discovered Ware Lab via team information sessions. Team access to the greater lab area and machine shop are shown in Figures 14 and 15 with Formula and Baja SAE using the facility over 60% of the time. Based on collected data, trends in these demographic areas are shown in Figures 16 through 19.

Table 7 – Gender and Ethnicity

Gender	Ethnicity	Total	Percent (lab total of 557)
Female	African American	4	1%
	Asian	16	3%
	Hispanic	4	1%
	Other	4	1%
	White	53	10%
	White, Asian	1	<1%
Male	African American	16	3%
	American Indian	1	<1%
	Asian	99	18%
	White, Asian	3	1%
	Hispanic	29	5%
	Middle Eastern	1	<1%
	Mixed	4	1%
	Other	6	1%
	Pacific Islander	1	<1%
	White	314	56%
	White, Hispanic	1	<1%

Table 8 – Academic Level

Academic Level	Ware Lab Team	Number	Percent (lab total of 557)
Freshman	Astrobotics	5	**30%**
	Baja SAE	40	
	BOLT	12	
	DBF	33	
	Formula SAE	51	
	HEVT	3	
	HPS	8	
	SailBOT	9	
	Steel Bridge	7	
Sophomore	Astrobotics	3	**26%**
	Baja SAE	16	
	BOLT	14	
	DBF	18	
	Formula SAE	63	

	HEVT	8	
	HPS	7	
	SailBOT	12	
	Steel Bridge	4	
Junior	Astrobotics	4	**27%**
	Baja SAE	17	
	BOLT	19	
	DBF	19	
	Formula SAE	41	
	HEVT	22	
	HPS	15	
	SailBOT	7	
	Steel Bridge	7	
Senior	Astrobotics	2	**15%**
	Baja SAE	12	
	BOLT	12	
	Concrete Canoe	3	
	DBF	4	
	Formula SAE	18	
	HEVT	18	
	HPS	14	
	SailBOT	1	
	Steel Bridge	1	
Grad Student	Formula SAE	2	**1%**
	HEVT	5	
	HPS	1	

Table 9 – Academic Majors

Academic Major	Ware Lab Team	Number	Percent (lab total of 557)
AOE	Baja SAE	4	**17%**
	BOLT	2	
	Concrete Canoe	1	
	DBF	41	
	Formula SAE	15	
	HPS	20	
	SailBOT	11	
BEAM	DBF	1	**<1%**
Business	Baja SAE	1	**<1%**
CEE	Baja SAE	2	**3%**
	Concrete Canoe	2	
	DBF	1	
	Steel Bridge	14	
CEM	Baja SAE	1	**<1%**
	Formula SAE	1	
Communications	HEVT	1	**<1%**
CS	Astrobotics	2	**6%**

	Baja SAE	5	
	BOLT	4	
	DBF	2	
	Formula SAE	6	
	HEVT	8	
	HPS	2	
	SailBOT	5	
ECE	Astrobotics	5	**15%**
	Baja SAE	1	
	BOLT	24	
	DBF	2	
	Formula SAE	26	
	HEVT	14	
	HPS	5	
	SailBOT	5	
ENGE	Astrobotics	2	**10%**
	Baja SAE	15	
	BOLT	2	
	DBF	11	
	Formula SAE	17	
	HPS	4	
	SailBOT	2	
	Steel Bridge	2	
Industrial Design	DBF	1	**<1%**
ISE	Baja SAE	2	**4%**
	BOLT	2	
	DBF	4	
	Formula SAE	9	
	HEVT	1	
	SailBOT	1	
	Steel Bridge	2	
ME	Astrobotics	4	**43%**
	Baja SAE	49	
	BOLT	24	
	DBF	10	
	Formula SAE	97	
	HEVT	35	
	HPS	14	
	SailBOT	5	
	Steel Bridge	1	
MINE	Astrobotics	1	**<1%**
	Formula SAE	1	
MSE	DBF	1	**1%**
	Formula SAE	2	
Nanomedicine	Baja SAE	2	**<1%**

Table 10 – Academic Credit

Role	Ware Lab Team	Number	Percent (lab total of 557)
Graduate Research	HEVT	4	**<1%**
Independent Study	Astrobotics	2	**10%**
	BOLT	5	
	Formula SAE	8	
	HEVT	32	
	HPS	8	
	SailBOT	1	
Senior Design	Baja SAE	8	**9%**
	BOLT	11	
	Formula SAE	17	
	HEVT	15	
Undergrad Research	Astrobotics	2	**<1%**
Volunteer	Astrobotics	10	**80%**
	Baja SAE	77	
	BOLT	41	
	Concrete Canoe	3	
	DBF	74	
	Formula SAE	148	
	HEVT	6	
	HPS	37	
	SailBOT	28	
	Steel Bridge	20	

Table 11 – Transfer-Student Population

College or University	How did you discover Ware Lab?	Major	Team
Blue Ridge Community College (CC)	Word-of-mouth	ME	Baja SAE
Bryn Athyn College	Team Info Session	ECE	Formula SAE
Drexel University	Team Info Session	ECE	BOLT
Longwood University	Online	CEE	Steel Bridge
NC State	Team Info Session	ME	DBF
New River CC	Gobblerfest	ME	Formula SAE
New River CC	Online	ME	Formula SAE
New River CC	Word-of-mouth	ME	Formula SAE
New York Institute of Technology	Lab Tour	ME	Formula SAE
Northern Virginia CC	Gobblerfest	AOE	Formula SAE
Northern Virginia CC	Gobblerfest	AOE	Formula SAE
Northern Virginia CC	Gobblerfest	AOE	DBF
Northern Virginia CC	Team Info Session	ME	HEVT
Penn State University	Word-of-mouth	ME	Formula SAE
Piedmont Virginia CC	Gobblerfest	ME	Formula SAE
Piedmont Virginia CC	Word-of-mouth	ISE	Formula SAE
Piedmont Virginia CC	Word-of-mouth	ME	Formula SAE
RPI	Team Info Session	ISE	Formula SAE
St. Petersburg College	Online	ISE	Formula SAE
Thomas Nelson CC	Lab Tour	ME	Baja SAE
Thomas Nelson CC	Team Info Session	ECE	HEVT
Thomas Nelson CC	Word-of-mouth	ME	Baja SAE
Tidewater CC	Word-of-mouth	ME	Formula SAE

Virginia Western CC	Lab Tour	ME	Baja SAE
Virginia Western CC	Lab Tour	ME	BOLT
Virginia Western CC	Team Info Session	AOE	SailBOT
Virginia Western CC	Word-of-mouth	AOE	SailBOT
Virginia Western CC	Word-of-mouth	CEE	Baja SAE

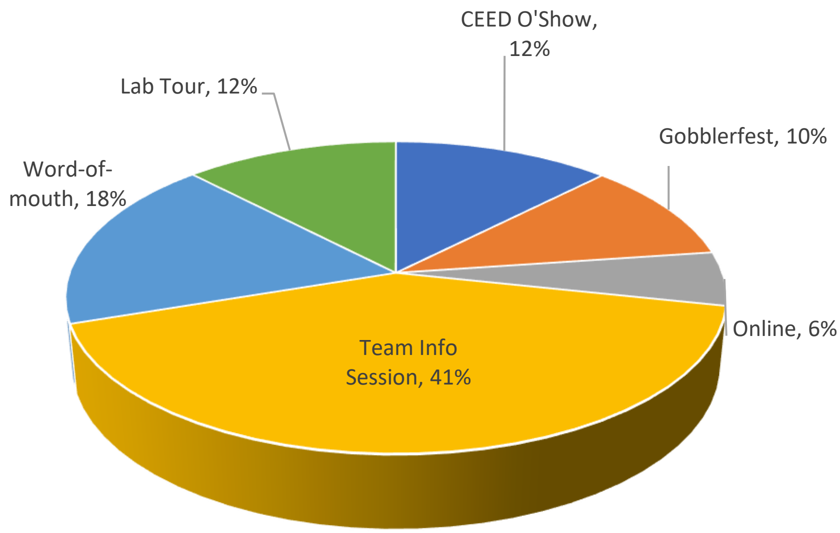


Figure 12 – "How did you learn about Ware Lab?" (out of lab total of 557)

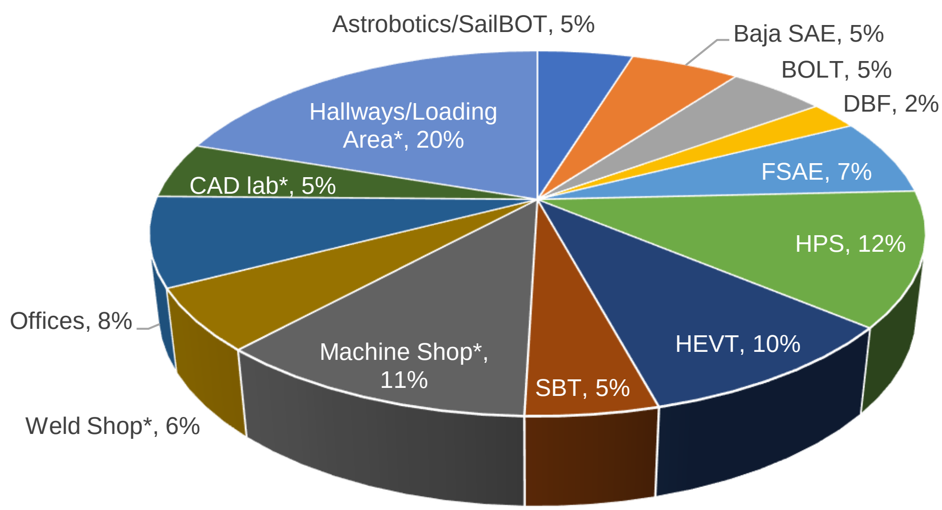


Figure 13 – Lab Square Footage based on total of 10,100 ft^2
*Denotes common-use area.

Team Lab Access

Students have access to the general areas and machine shop after hours via the *Hokie Card* swipe system. Figures 14 and 15 provide a summary of student access to these areas based a team breakdown. Formula SAE utilized the general Ware Lab area the most at 44% and Baja SAE used the machine shop the most at 47%.

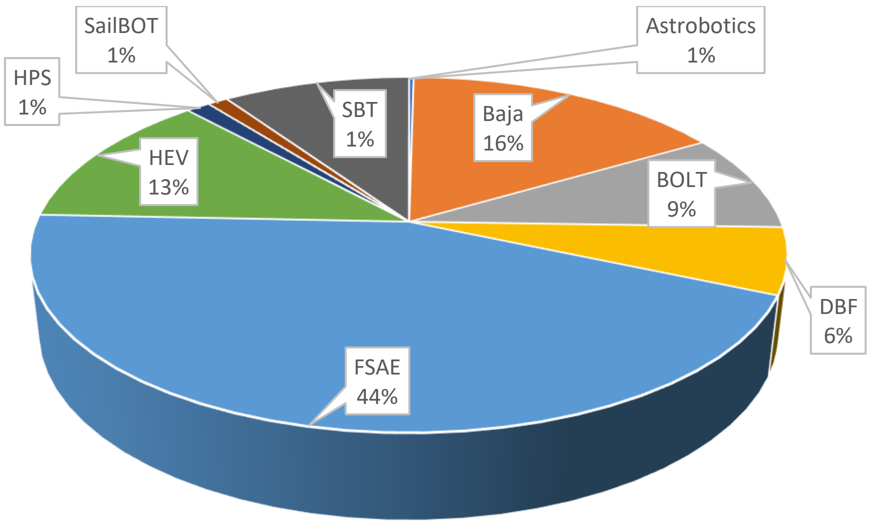


Figure 14 – Team Access to General Ware Lab Area (% 4255 card swipes).

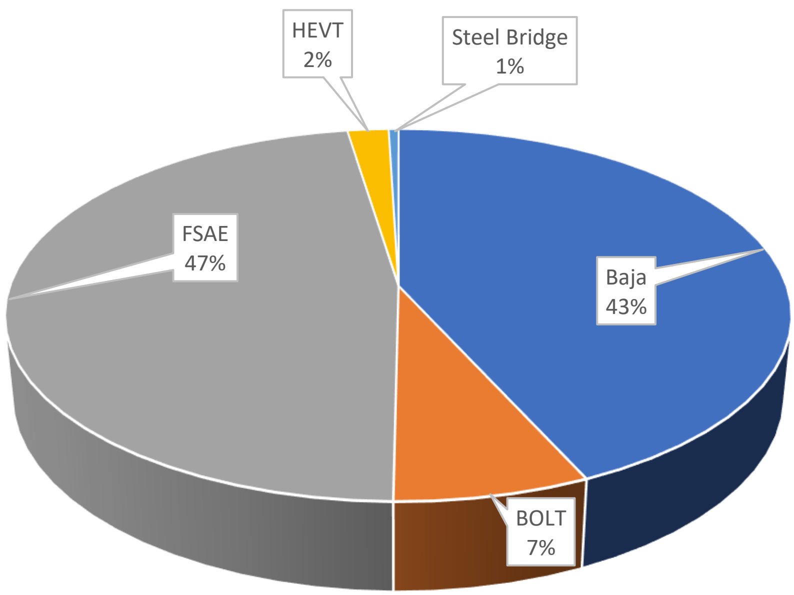


Figure 15 – Team Access to Ware Lab Machine Shop (% 6562 card swipes).

Demographic Trends

Since 2012, students using the Ware Lab have completed a survey indicating academic level, major, and team affiliation. Based on collected data, trends in these areas are shown in Figures 16 through 18. Figure 19 shows trends for Ware Lab gender and ethnicity, staring in 2014.

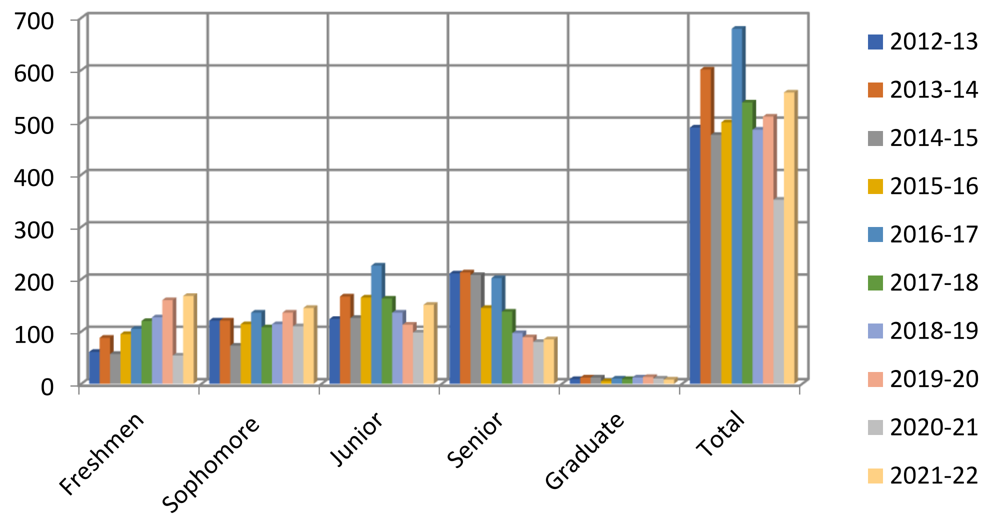


Figure 16 – Academic Levels (student number).

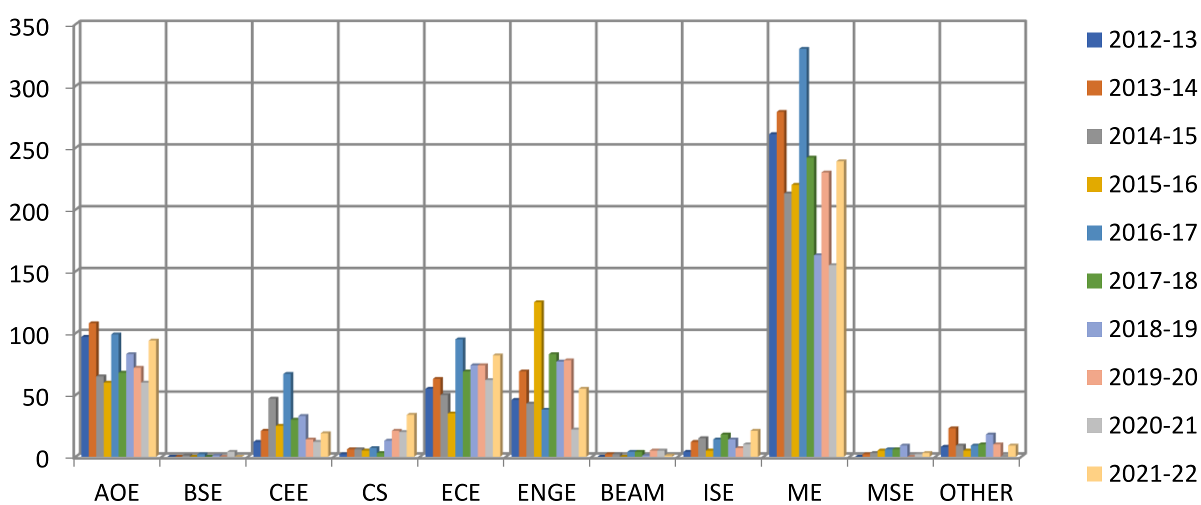


Figure 17 – Academic Majors (student number).

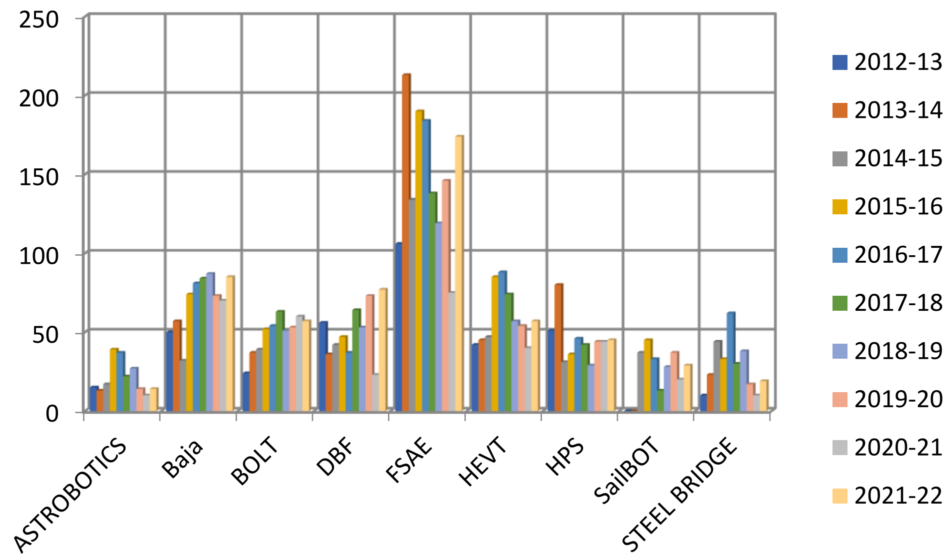


Figure 18 – Teams (student number).

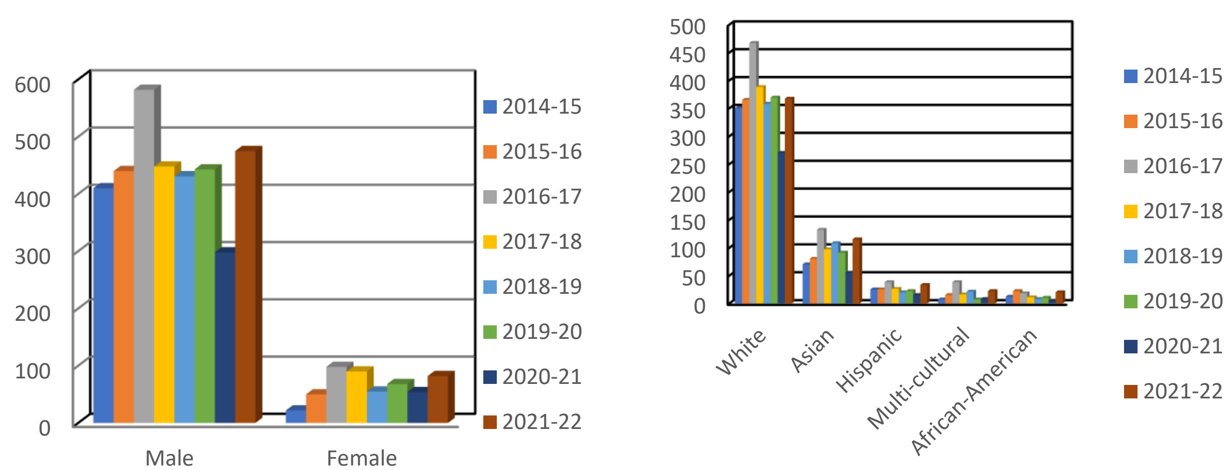


Figure 19 – Gender (left), Ethnicity (right) in student numbers.

Lab Expenditures

Tables 12 and 13 include truck/trailer expenditures for general maintenance and fuel, respectively. In spite of COVID 19 restrictions, many teams were allowed to travel to destinations throughout the United States to represent Virginia Tech at world class competitions using the lab's truck and trailer fleet. Table 14 is a list of Ware Lab general material, equipment, and maintenance expenditures including the extensive repair of our existing goose neck trailer and the purchase of a new goose neck trailer, increasing our fleet to 5 trailers in all. In total, Ware Lab spent $59,700 in order to ensure team success at national and regional competition events in 2021-22.

Table 12 – Truck/Trailer Maintenance

Vendor	Total
Anchor Sales	$686
Auto Experts	$3,849
Blacksburg Auto Parts	$258
Pro-Line Trailers	$17200 (gooseneck trailer repair)
Total	**$21,821**

Table 13 – Fuel Expenditures

Vendor	Total
7-Eleven	$145
Andrew's Fastbreak	$100
Aplus	$145
Blacksburg Auto Parts (DEF fuel treatment)	$122
C.C. Food Mart	$80
Casey's General Store	$285
Express Store	$150
Fastop	$111
Fleet Services	$3,799
Flying J	$317
Kroger	$29
Little General	$143
Love's	$1,122
Marathon Petro	$135
Midway Shell	$134
Pilot	$920
Quiktrip	$219
Rutter's	$258
Sheetz	$427
Shell	$104
Site Mart	$200
Speedway	$236
Super USA	$180
Tmart	$127
Total	**$9,487**

Table 14 – Miscellaneous Expenditures

Vendor	Total
Airgas	$440
Alro Steel	$967
Amazon	$1,063
Anchor Sales	$23,235 (goose-neck trailer purchase)
Arc3	$2,674
Dominion Air	$4,607
Guy Brown	$1,557
Homestead Materials	$88
McMaster-Carr	$88
Monitronics International	$320
MSC	$2,250
Original Frameworks	$500
Sanico	$482
The Supply Room	$134
Total	**$38,405**

Conclusion

This annual report for the *Joseph F. Ware Advanced Engineering Design Lab* for 2021-22 includes competition results, student demographics, outreach events and lab expenditures. Undergraduates from multiple majors comprise teams that design, manufacture and compete top tier projects.

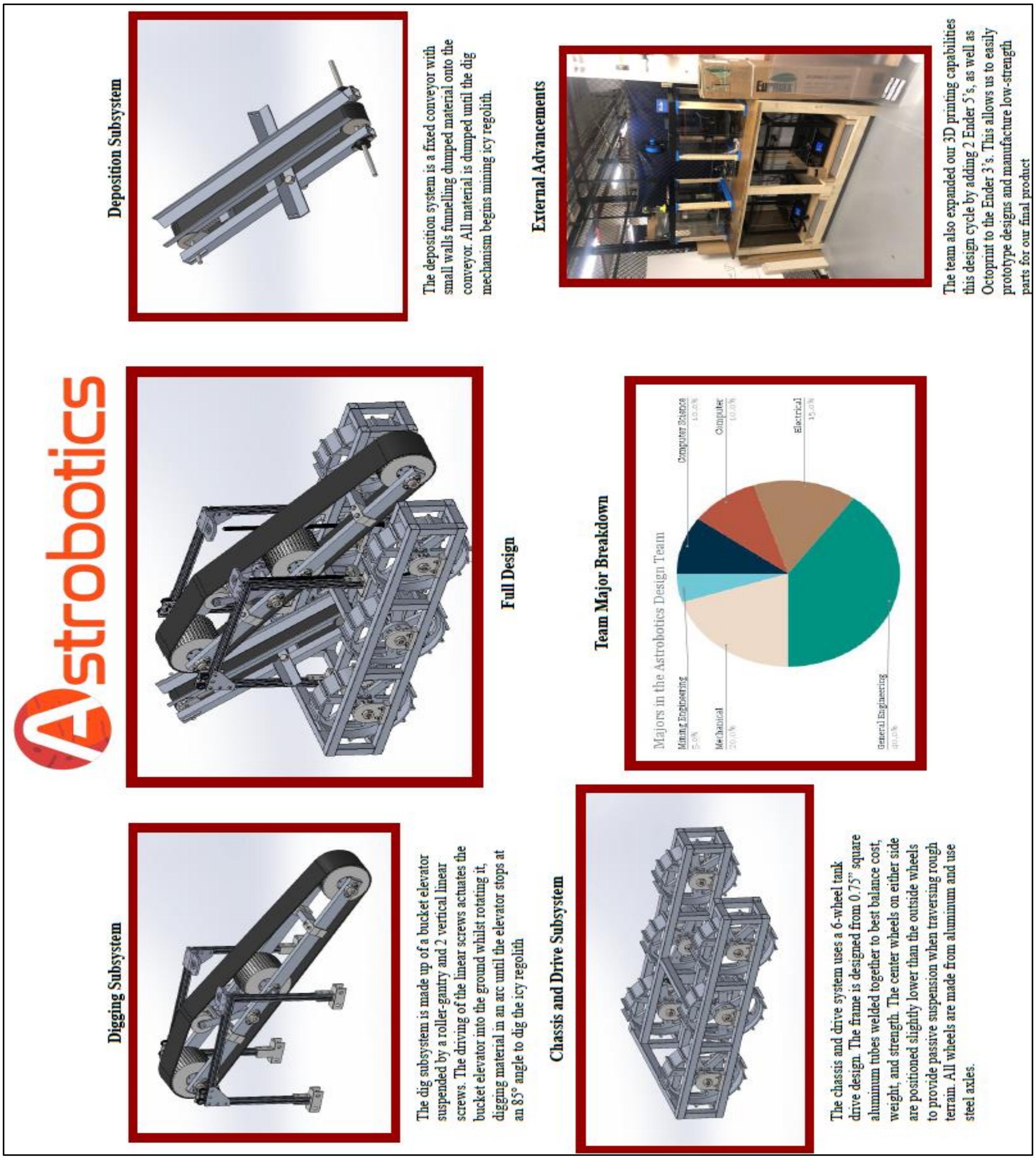
Demographic trends indicate that, in this year, the third largest number of students (557) completed EHS training since 2012. EHS training is necessary in order to work in the Ware Lab facility. A total of 58 students received machine shop training with 14 students completing advanced Hurco CNC orientation. 23 students received hot work certification and 21 passed truck/trailer driver orientation which is necessary to operate our fleet vehicles.

Virginia Tech's College of Engineering spent over $46,000 to cover costs associated with truck/trailer maintenance and repair, fuel, and machine/welding supplies. A new goose-neck trailer costing $23,200 was also purchased, increasing our fleet to five trailers.

Ware Lab team members met the challenge of completing project goals and succeeding at sponsored events. Many Ware Lab teams exceeded expectations with top competition performances at world class, international events. Baja, Steel Bridge, Concrete Canoe, DBF, and HEVT earned top five positions at sponsor events throughout North America. Due to the dedication of these teams, the *Joseph F. Ware, Jr. Advanced Engineering Lab* continues to be an exciting and vibrant place for undergraduate competition-based projects in Virginia Tech's College of Engineering.

Appendix A – Ware Lab Team Posters for 2021-22

Astrobotics



Baja SAE

Baja SAE

Faculty Advisor: Jared Bryson
e-CVT Project: Raunak Ahmed, Alex Coonin, Dhietmar Cruz Herbas, Nick Kreuscher
Custom Brake System: Ryan Barolo, Bryan Meldrum
Dynamometer Redesign: Jack Blazek, Destiny Mason, Matthew Shealy

VIRGINIA TECH

e-CVT Project

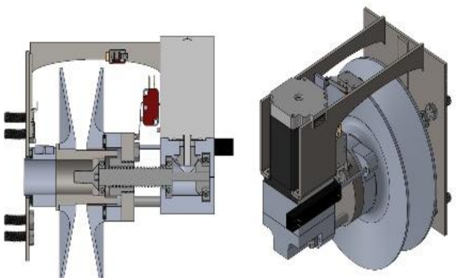
Problem Statement

- Design and manufacture an electronic Continuously Variable Transmission (e-CVT) for an off-road vehicle

Key Target Specifications

- Follows Baja SAE competition rules
- Improve acceleration performance
- Maintain engine's peak power performance

Final Design



Validation Results

- Meets 5 out of 8 Marginal Specifications
- Does not weigh unreasonably more than a CVTech Primary

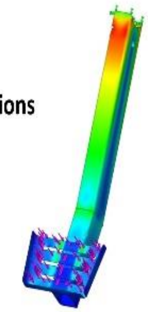
Conclusion

- Tuning an e-CVT is quicker than a conventional mechanical CVT previously used by the team
- An e-CVT can lead to a better testing suite for future cars as well as a higher performing transmission overall

Custom Brake System

Problem Statement

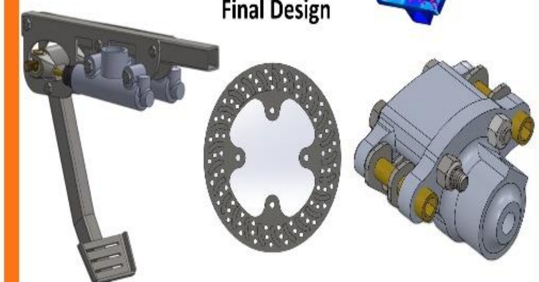
- Design a custom hydraulic braking system for the vehicle
  - Improve serviceability
  - Reduce weight
  - Improve handling



Key Target Specifications

- Follows Baja SAE competition rules
- Brake pedal feel
- Structural integrity
- Time to bleed the system

Final Design



Validation Results

- Meets all 14 marginal specifications
- Meets 4 Ideal specifications
- Properly functions and stops the car

Conclusion

- Bias bar and larger master cylinders are beneficial and worth pursuing in future years
- Use of differently sized calipers in the front and rear can improve brake performance

Dynamometer Redesign

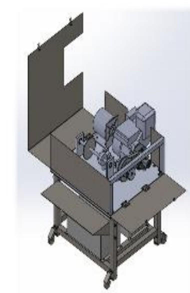
Problem Statement

- Design and manufacture a small engine and CVT dynamometer for Baja SAE application
  - Safety of users
  - Benchmark CVTs and engines
  - Reduce downtime

Key Target Specifications

- Rules compliant (EHS, OSHA, Baja SAE)
- Multiple methods to stop the dynamometer
- React predictably when power is lost

Final Design



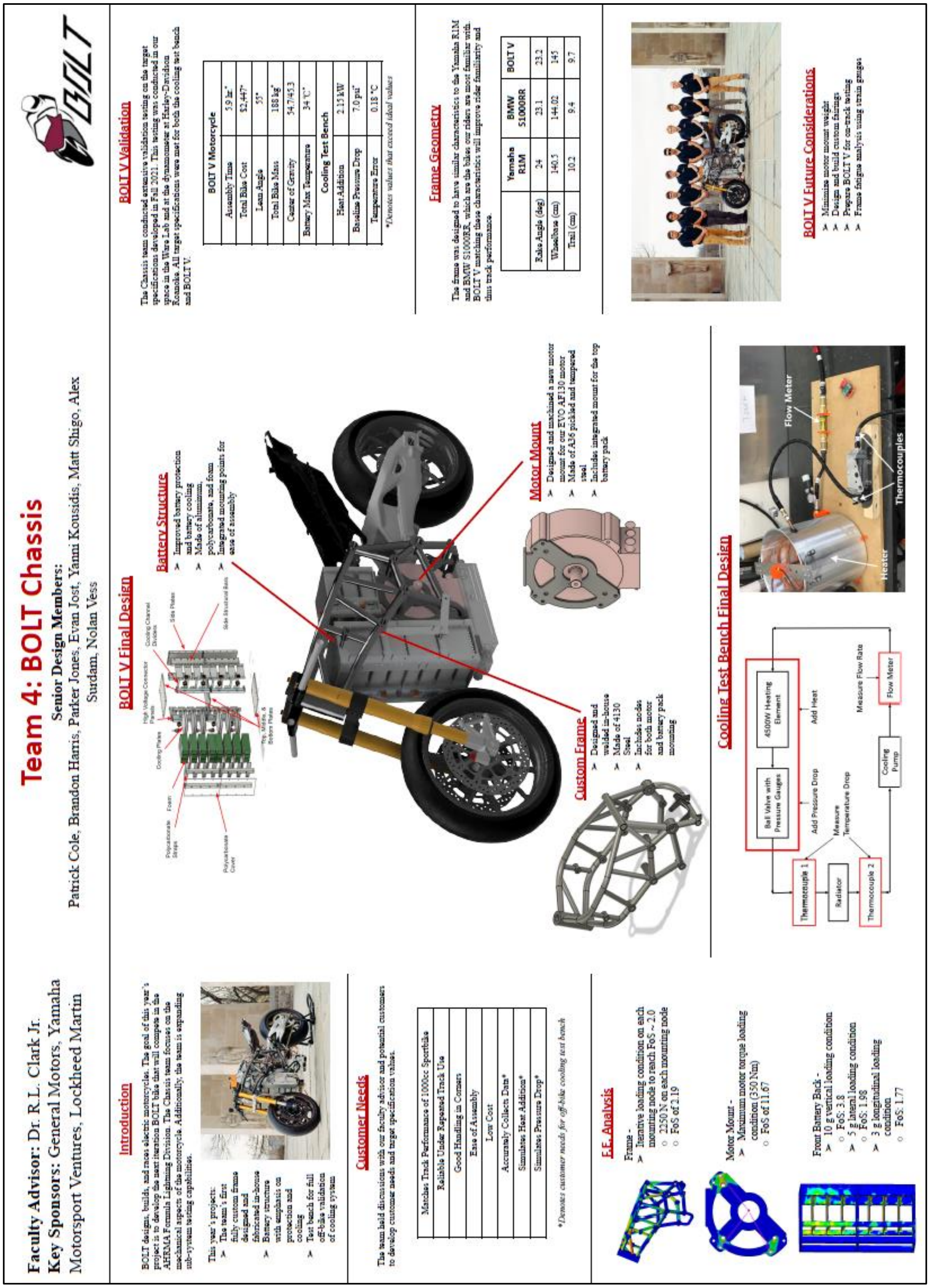
Validation Results

- Of the tests that have been completed, the product meets both marginal and ideal values
- 8 specifications left to validate

Conclusion

- The new design is more structurally stable and does not rest on deployable casters during operation
- Linearly actuated engine mount allows different designs of CVTs to be tested

Battery Operated Land Transport (BOLT)



Team 4: BOLT Powertrain-Controls

Senior Design Members:
Will Gessner, Robin Ahlers, Matthew Ruhlman, Nathan Guy, Jared Mann
Faculty Advisor: Dr. R.L. Clark Jr.
Key Sponsors: General Motors, Yamaha Motorsport Ventures, Lockheed Martin

Problem Statement and Motivation/Background

The goal of BOLT is to design, construct and race a high-performance electric motorcycle. BOLT V is our fifth generation of motorcycle. We compete in the American Historic Racing Motorcycle Association's Formula Lightning class. The powertrain and controls subteams seek to maximize both power and reliability of our motorcycles on the track. Powertrain focuses on the high voltage electrical system and drivetrain while controls handles the low voltage communications system.

BOLT IV races at New Jersey Motorsports Park, 2021

Customer Needs

Safe High Voltage System	1000cc Sportbike Performance
Reliability Under Track Use	Efficient Drivetrain
Data Visibility	Relevant Data Collection
Familiar Feel for Rider	Ease of Assembly

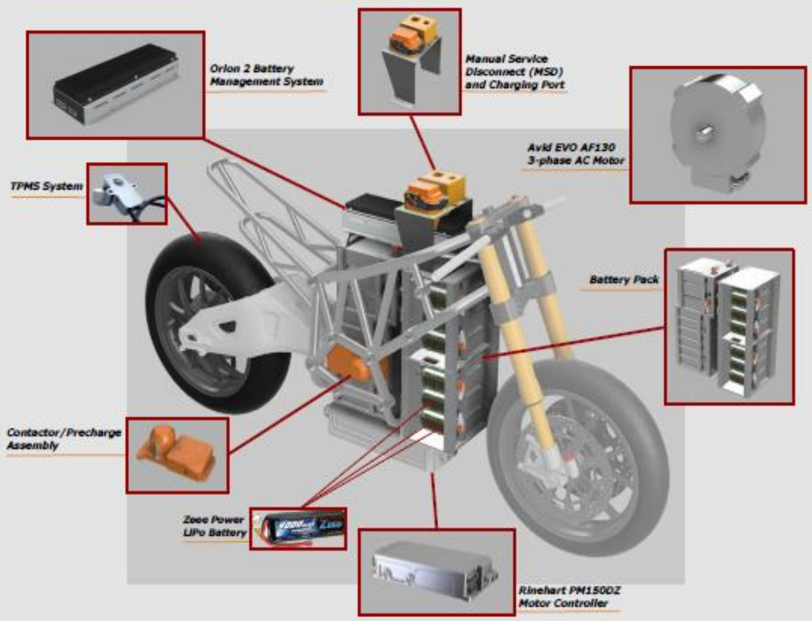
Target Specifications

Eng. Characteristic	Units	Marginal Value	Ideal Value
Battery Max Temperature	°C	80	60
Tire Temperature Error	%	5	2
Wheel Power	kW	90	125
Assembly Time	hours	12	8
Total Bike Mass	kg	216	200
Wheel Torque	Nm	200	300
Peak Voltage	V	600	700
Battery Pack Capacity	kWh	10.5	13

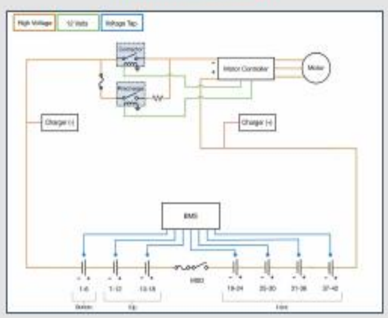
Analytical Methods

- Battery selection optimization calculations
- Battery capacity tests
- Experience with BOLT IV led us to want to improve
  - Wire routing organization
  - Internal battery pack resistance
  - Design for assembly

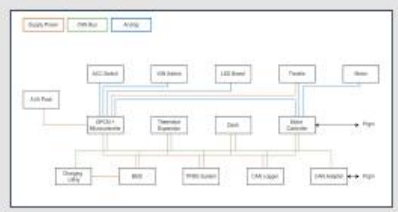
BOLT V System Design



High Voltage System



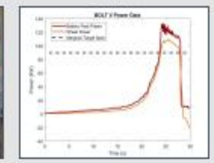
Low Voltage System

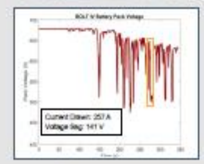


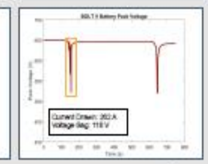
Product Evaluation

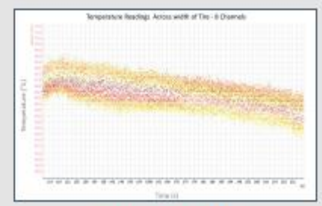
A combination of in-house and dynamometer testing was used to validate BOLT V's design against our target specifications. The dynamometer testing was performed at Harley-Davidson of Roanoke.

Engineering Characteristic	Measured Value
Battery Max Temperature	34 °C
Tire Temperature Error	4 %
Wheel Power	110 kW
Assembly Time	6 hours
Total Bike Mass	188 kg
Wheel Torque	233 Nm
Peak Voltage	634.5 V
Battery Pack Capacity	6 kWh







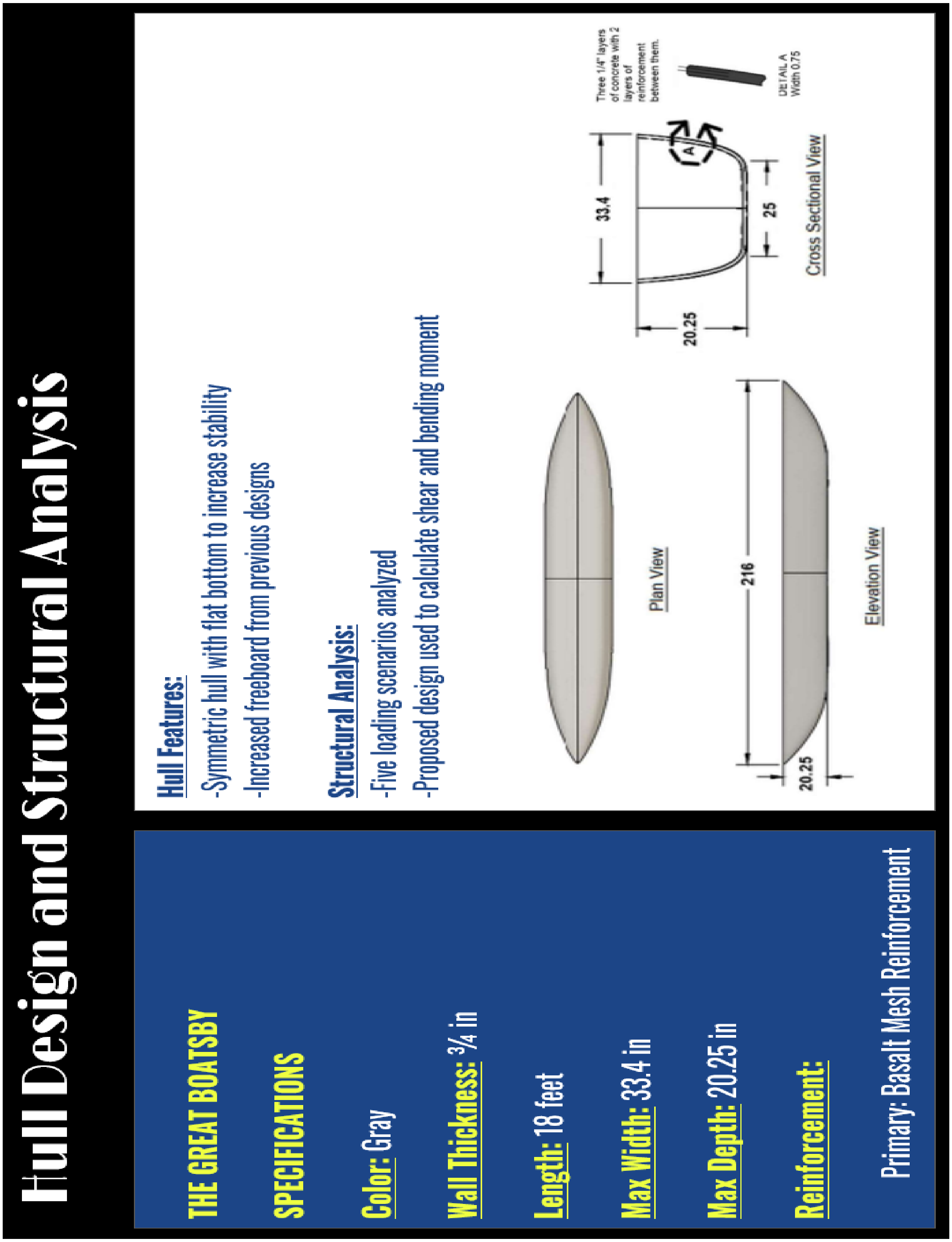


The Future of BOLT V

Next year's BOLT senior design team will continue work on BOLT V by:

- Performing more extensive dynamometer testing on the powertrain
- Preparing the motorcycle for a track environment
- Addressing how to finish a race with BOLT V's limited battery pack capacity

Concrete Canoe (CCT)



Hull Design and Structural Analysis

MOLD FABRICATION

3D Model of hull design
CNC Router
Symmetrical hull makes it easier

POUR DAY

Concrete and reinforcement placement
Intense QA/QC procedures

REPURPOSING OLD FOAM BLOCKS

Sustainable and inexpensive
Time intensive
“tetra” stack

FORM FINISHING

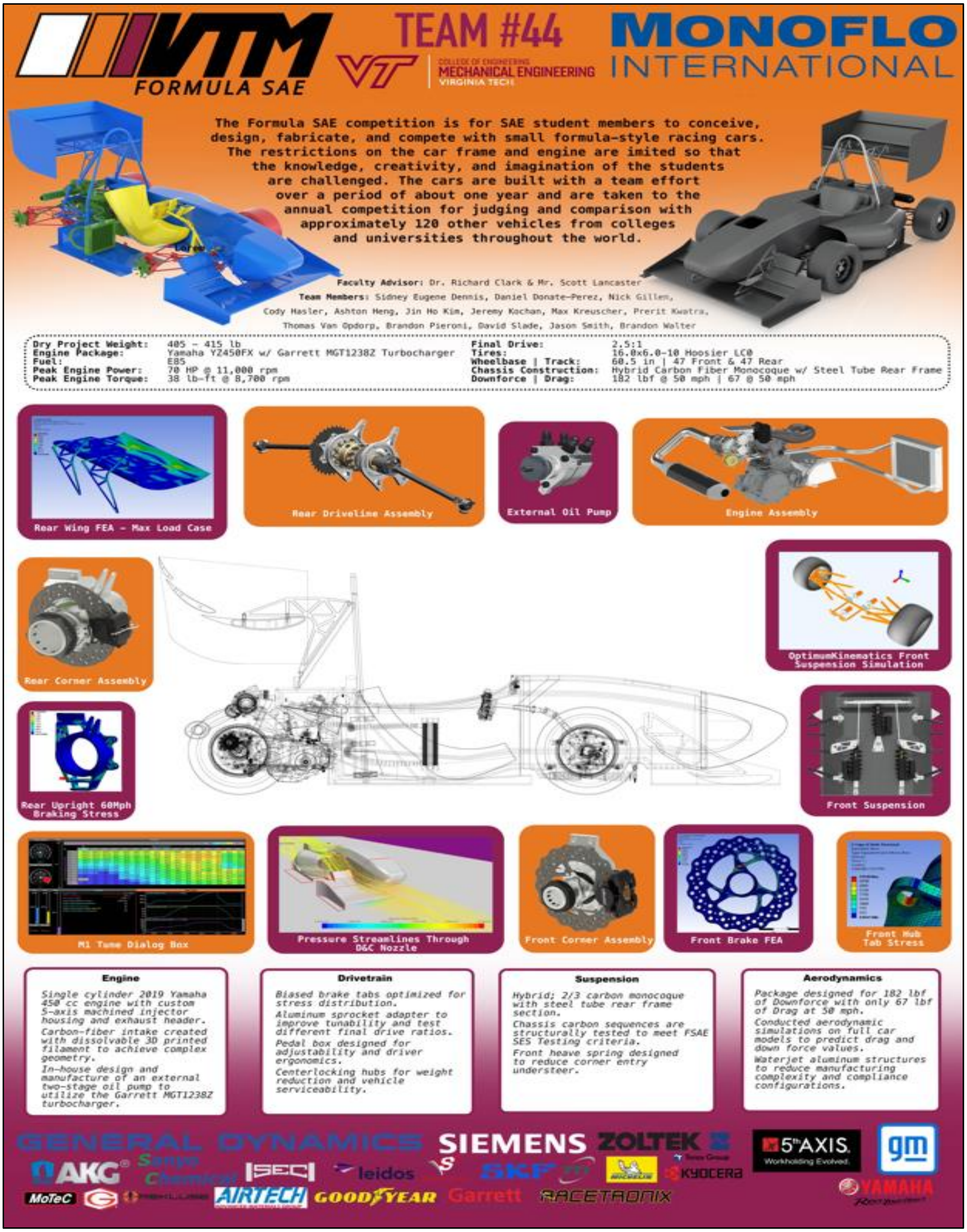
QA/QC measures implemented
Sanding, filling, priming, waterproofing

CURE AND FINISH

28 day cure
Daily monitoring
Sanding and finishing

Design Build Fly (DBF)

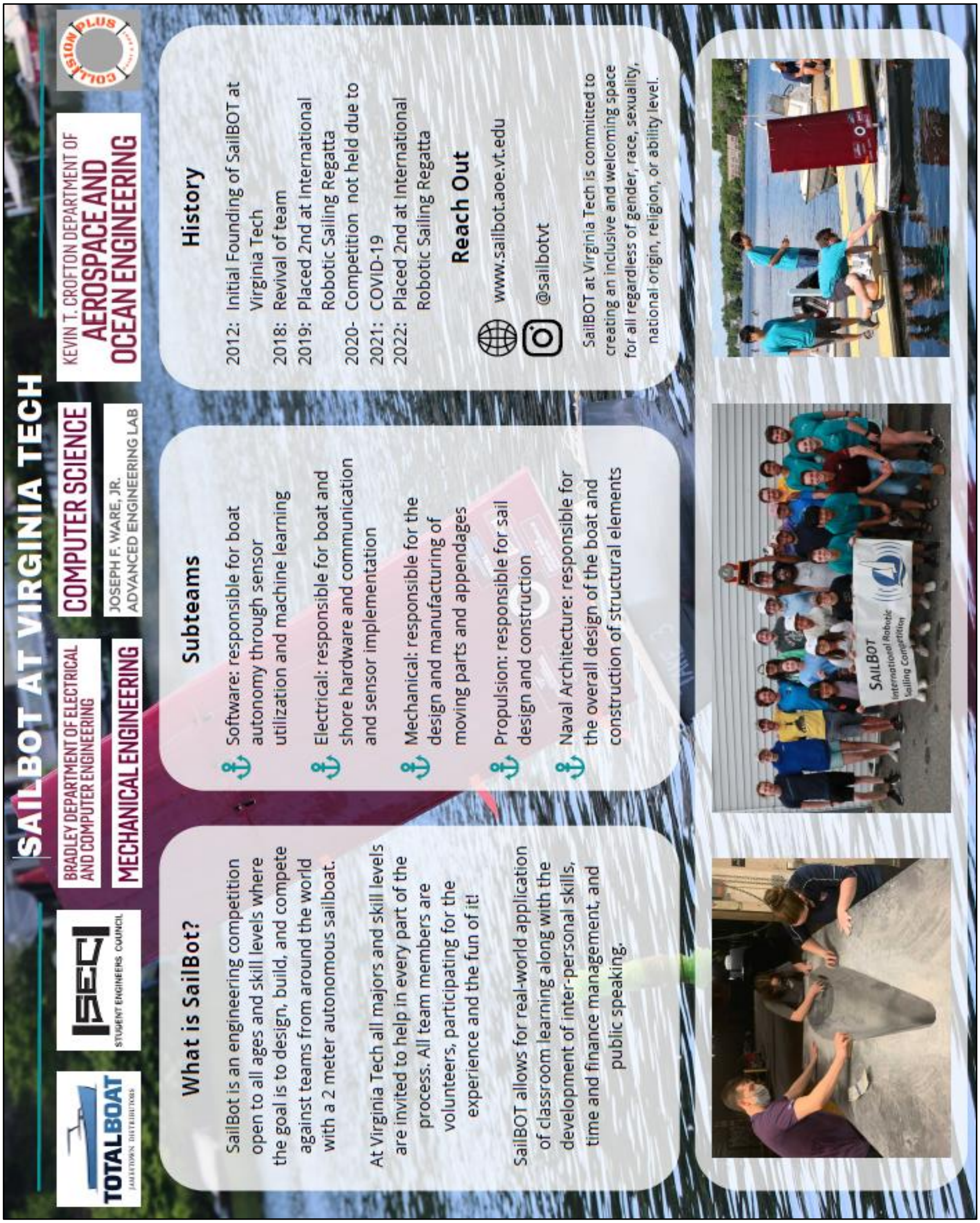
Formula SAE (FSAE)



Hybrid Electric Vehicle Team (HEVT)

Human Powered Sub (HPS)

SailBOT



SAILBOT AT VIRGINIA TECH
TOTALBOAT
JAMESTOWN DISTRIBUTORS
SEC
STUDENT ENGINEERS COUNCIL
BRADLEY DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING
MECHANICAL ENGINEERING
COMPUTER SCIENCE
JOSEPH F. WARE, JR. ADVANCED ENGINEERING LAB
KEVIN T. CROFTON DEPARTMENT OF AEROSPACE AND OCEAN ENGINEERING
COLLISION PLUS
What is SailBot?
SailBot is an engineering competition open to all ages and skill levels where the goal is to design, build, and compete against teams from around the world with a 2 meter autonomous sailboat.
At Virginia Tech all majors and skill levels are invited to help in every part of the process. All team members are volunteers, participating for the experience and the fun of it!
SailBOT allows for real-world application of classroom learning along with the development of inter-personal skills, time and finance management, and public speaking.
Subteams
Software: responsible for boat autonomy through sensor utilization and machine learning
Electrical: responsible for boat and shore hardware and communication and sensor implementation
Mechanical: responsible for the design and manufacturing of moving parts and appendages
Propulsion: responsible for sail design and construction
Naval Architecture: responsible for the overall design of the boat and construction of structural elements
History
2012: Initial Founding of SailBOT at Virginia Tech
2018: Revival of team
2019: Placed 2nd at International Robotic Sailing Regatta
2020-2021: Competition not held due to COVID-19
2022: Placed 2nd at International Robotic Sailing Regatta
Reach Out
www.sailbot.aoe.vt.edu
@sailbotvt
SailBOT at Virginia Tech is commited to creating an inclusive and welcoming space for all regardless of gender, race, sexuality, national origin, religion, or ability level.
SAILBOT International Robotic Sailing Competition

Steel Bridge (SBT)