WAR EAGLE MOTORSPORTS

FORMULA SAE TEAM

<u>Race Report</u>

Formula SAE, 13-16 May 2015, Brooklyn, Michigan

Auburn's Formula SAE team campaigned a fine racecar in the 2015 FSAE Michigan Competition at Michigan International Speedway, making Design Finals and heading for another top-ten finish. But with five laps to go in the Endurance Race, a suspension control arm failed, stopping the car and leaving us with a DNF.

The car is a continuation up the difficult technical curve that we are following – hybrid carbon composite/space frame, large engine, non-aero, built for acceleration, weight less than 400 lb. This year saw great emphasis on internal aerodynamics (cooling and intake), isotropic and non-isotropic structural optimization, and weight reduction. New technical areas for us were a formal approach to acoustics design, and incorporation of electronic throttle control into our increasingly electro-mechanical racecar.

Devastating though the Endurance failure is (and indicative of the difficult path of light-weight design we are taking to improved performance), the team trained a new cadre of leadership, and continued its tradition of building a better car every year.

FSAE Background

Almost every major North American engineering college fields a Formula SAE team for competition in either Michigan or Nebraska, or in the related Formula Hybrid competition in New Hampshire. Overseas competitions are held in Australia, Austria, Brazil, England, Germany, Italy, Japan, and Spain. Approximately 500 teams worldwide compete in Formula SAE, making it the largest motorsports manufacturers series in the world. The Michigan Competition at Michigan International Speedway (MIS) in Brooklyn (an hour west of Detroit) has by far the longest history and the caché of the "World Series of Intercollegiate Engineering". FSAE-MI is the premier event in engineering student design competition. Michigan entries are limited to 120, and these usually sell out within a day (this year - 10 minutes). The 2015 Michigan Competition included entries from 36 U.S. States (top participating states were: Michigan – 14 cars; Florida – 8 cars; and Pennsylvania – 7 cars), as well as 24½ cars from 9 other countries: Austria (1); Brazil (1); Canada (15); Germany (½); Mexico (1); Poland (1); Singapore (1); South Korea (1); and Venezuela (3). [The ½ car represents cooperation between Oregon State University and the Duale Hochschule Baden-Württemberg - Ravensburg (DHBW-R - Germany) in a single entry]. European participation was down a bit this year owing to an FSAE rule change (regarding allowable aerodynamic appliances) that most European teams did not have time to adjust to.

Each college starts every year from a blank sheet of paper to design and build a single-seat, open-wheel autocross car, the lightest ones getting to below 400 pounds curb weight. The teams are subject only to a 610 cc engine displacement limit, a 20 mm diameter intake restriction, and absolute adherence to the letter and spirit of a thick set of safety rules. The goal of the Competition is to design and build a prototype for the weekend autocross enthusiast. The teams must demonstrate their prototype cost and manufacturability and sell their design to an investment audience, as well as proving their machine's abilities on the racetrack. Designs are judged by a who's who of race engineering professionals, with strong support from top engineers in the racing and automotive manufacturing industries. Although FSAE cars do bear a certain resemblance (due to requirements for: open-wheel architecture; at least four wheels; minimum wheelbase; minimum wheel size; working suspension), design judges and qualified automotive engineers never fail to express surprise at the design diversity from team to team and from year to year. Apparently, the perfect design in this ultra-competitive discipline has yet to be identified. Or perhaps it's that each design is only an expression of each team's goals and philosophy, and success can come in many different forms. The resulting cars are amazing – Auburn's best accelerating car can do 0 to 60 mph in 2.7 s.

FSAE competitions are 3½ day affairs, beginning with an opening half day for the hyper-exacting Technical Inspection. Cars not passing Tech that day may try again, throughout the Competition, but suffer from getting further and further behind on the rest of the schedule. The next day presents additional inspection issues: checking tilt (no leaks at 45°, no rollover at 60°); noise (110 dB(C) max); and brakes (four wheel lockup from speed). Also on this day are the static events that make up 32.5% of the points: Design (explanation of the technology and design process to a judging panel); Presentation (selling the merits of the design as a product to an investment panel); and Cost (proving the reported manufacturing cost estimate). The second full day sees the cars running in: Acceleration (time to 75 m); Skid Pad (time on a 50 ft. diameter circle); and Autocross (what the cars are made for – usually a 1 km course) – another 27.5% of the points. The final day is reserved for Endurance - 22 km of lapping on a course similar to the Autocross course, with one stop for a driver change. Endurance includes a measurement of Fuel Efficiency (a function of the product of average lap time and total fuel consumed), and Endurance time plus Efficiency comprise the last 40% of the points (30% for Endurance, 10% for Fuel Efficiency). Only about one third of the entries are typically able to complete the Endurance Race, and thus get any Endurance/Efficiency points at all.

Although stirring race results are the immediate goal of any FSAE team, the real product is the teamers themselves. They learn the hard project engineering lessons of teamwork, metric-based overall design, devil-in-the-details machinery design, project planning and scheduling, financial control, supplier interface, communication (written and oral), and how to enhance each ability to make the whole greater than the sum of its parts. Most importantly they learn (and prove that they have) that special moxie that it takes to get a real running product out the door on time, under budget, and up to a demanding – and rigorously measured - performance specification. They learn that a prototype design is just that – a prototype. It isn't ready to race until they learn a whole lot more about how to get the most from what they have just built.

FSAE has been running since 1981. Auburn has competed since 1996, placing 2nd in 2013 in Nebraska, 3rd in 2004 in Michigan, 3rd in 2007 in California, 5th in 2003 in Michigan, 6th in 2006 in California, 7th in Michigan in 2014, and 8th in 2009 in California.

Team members tend to be mechanical engineers, though a spectrum of other engineering and non-engineering disciplines are also represented (given current team interests, there is a push for more aerospace engineers, electrical engineers, industrial engineers, polymer and fiber engineers, and marketing managers). Team alumni are widely sought after, with professional racing and the automotive manufacturing industry working hard to retain first dibs.

FSAE is a real world experience, and is not possible without real world tools, facilities, parts, and supplies. Access to these essentials would not be possible without the generous support of our major sponsors. War Eagle Motorsports is enabled by:

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FSAE Michigan 2015

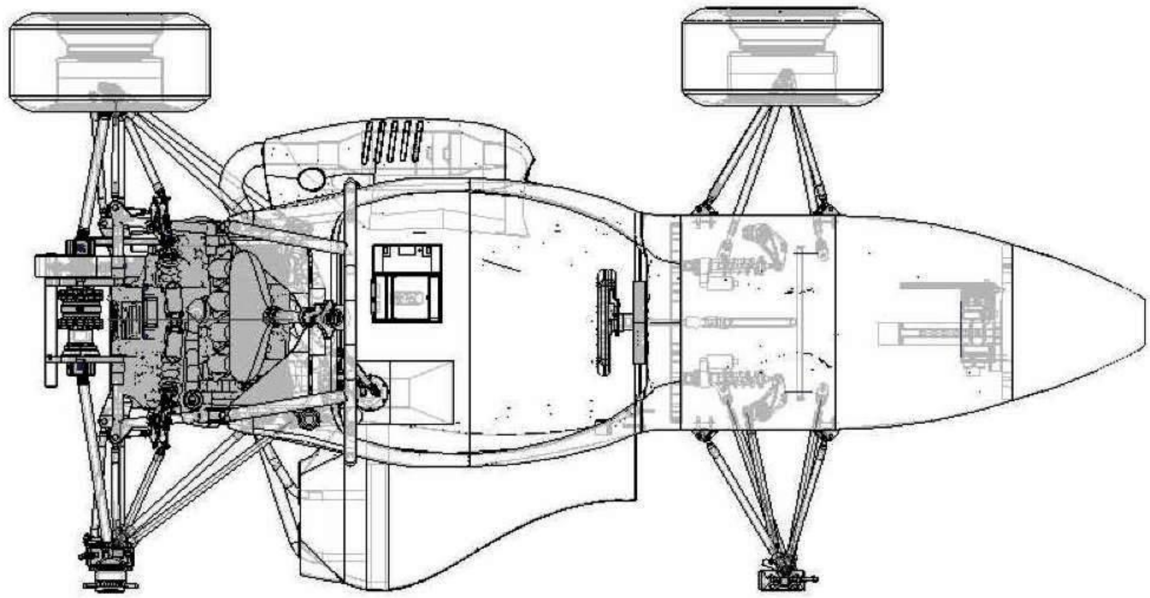
Global Formula Racing (GFR - Oregon State and DHBW-R) repeated their 2014 performance to win, edging out a strong performance by the University of Florida. The top five were filled out by Technische Universität Graz (Austria), Kookmin University (South Korea), and the University of Michigan at Ann Arbor. Completing the top ten were: Virginia Tech, National University of Singapore, University of Michigan at Dearborn, Politechnika Wroclaw (Poland), and Western University (Canada). GFR ran its usual enormous aerodynamics package with a 450 single and 10 in. wheels. Florida had a lot of heritage features (space frame, 13 in. wheels, Honda 600 cc I-4) but really went large on their first-ever aero package. Graz brought a full carbon monocoque, 10 in. wheels, a KTM 450 cc single, and the big wings. Kookmin had no aero package at all, plus space frame, 10 in. wheels, and the I-4. Michigan ran a full monocoque, 10 in. wheels, I-4, and enormous wings. Again, it's not the concept choices, it's the design embodiment and racecar development.

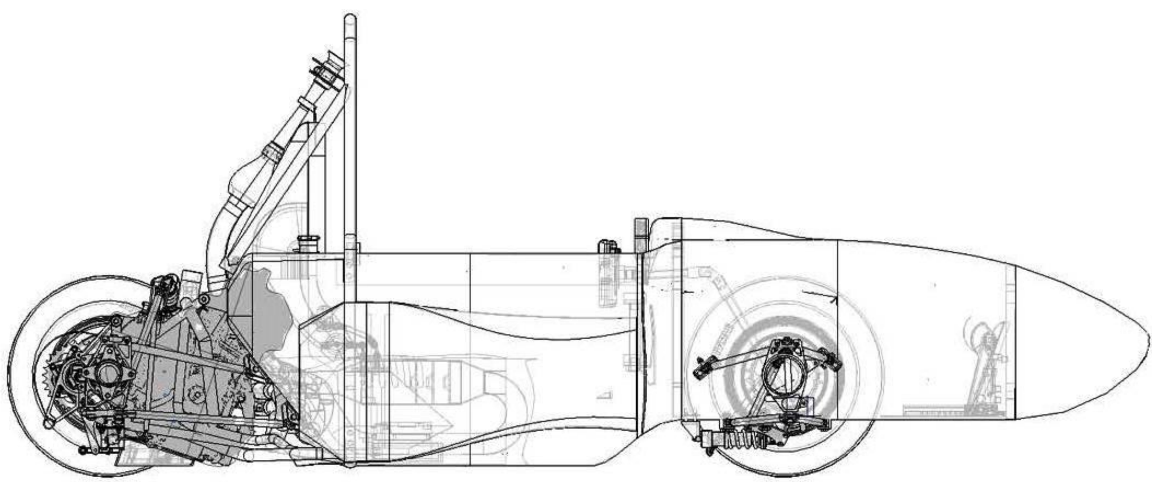
Auburn FSAE 2015

AU/FSAE 2015 was led by Co-Captains Jordan French (also Chassis Chief Engineer) and Jimmy Gordon (also Powertrain Chief Engineer), and Business Manager Cheyenne Johnson. Other designers included Jonathan Ashworth (drivetrain, electronics), Drew Campbell (spaceframe), Davis Edwards (brakes), Daniel Hardin (acoustics), Kyle Kubik (suspension), Tori Moffa (cooling), Michael Moritz (intake), Lee Neidert (steering), Mark Stepnowski (cost, ergonomics), Joe Stitt (fluids), and Josh Trammell (spaceframe). Vital jacks-of-all-trades included: Alex Conrado; Bryan Golden; Hayden Hilmer; Steven Hough; Alex Locker; Robert Odom; Ryan Reeves; Wesley Rocha; Taylor Sanford; and Payson Williams. Joining Formula from the successful 2014 Freshman Baja Team (Faja), in addition to Drew, Michael, and Josh, were: Austin Baker; Nathan Baker; and Donovan Johnson.

After the big shift in 2014 (new tub mold, plus a move to 10 in. wheels - and new wheelsets, and bearings, and brakes, and suspension set up, ad infinitum), the goal for 2015 was to bring back the reliability and robustness of the package. Cooling and Acoustics received their first dedicated lead designers (as the engine power improves with cams, lightening, injection tailoring, intake aero, and tuning, we also make more and more heat, and more and more noise). Fatigue re-entered the process as a guiding design principle. Intake went through another from-scratch design iteration (choosing center intake this time), with restrictor shape and plenum volume iterations. We were chosen as a Bosch-sponsored team, which meant that electronic throttle control fell within our grasp. And our chassis (tub) design process, though using the shape of the 2014 mold, started with the proverbial blank sheet to discover optimal ply schedules, core, and strengthening fiber layouts. The steel space frame (we run a hybrid carbon tub/rear steel space frame) has reduced to little more than an engine bracket, and the rear suspension box is now gone, the rear suspension and drivetrain loads going to the engine block. We continued to refine our electric shifting and reconfigurable display dashboard.

Project management was the usual race against the clock to learn and apply advanced engineering subjects, with the usual clutter of good components force-fit into systems that might need refinement on the design freeze day, October 1st. But it would be fair to say that we substantially met design freeze. We met the drive-by date as well, opening practice early in March, though many of the final systems were not complete on the car at that time, and continued to develop up to race.





Day One.5 – Static Events

This car was well prepared for Tech Inspection, and passed Wednesday night with no problems. Even though we wound up with a high take-a-number (the race-in-the-gate continues to evolve), we were able to roll in late in the day and check everything off. With the exception of the special Tech for Electronic Throttle Control (ETC), that is. ETC was newly allowed for this year. Several teams registered for ETC and filed the necessary reams of pre-competition forms, although Wisconsin and Auburn were the only ones who showed up actually running it. Many additional electronic checks were required to ensure that an electrical gremlin didn't take our car for a wild ride, and a few of these checks required us to go back to our paddock and think about it for a while.

On Thursday, there was actually a minor issue on the Tilt test, but this was easily solved (it was a slight leak at 45° roll – with a vertical center of gravity 8.5 in. above the deck, we weren't likely to have a problem with the 60° rollover check).

Noise, despite our innovative dual-chamber design (one chamber for reflection, one for absorption), was still an issue. FSAE has switched to a dB(C) scale, which includes a lot of inaudible low frequencies that are hard to damp out. And commercial muffler manufacturers aren't much help, because they don't care about the low frequency stuff – only FSAE does. And working to the notoriously high-reading SAE Sound Level Meter didn't help. We were back and forth many times between the Noise Test area and our paddock, adding spark arrestors and tips and bits of packing to try to hold the sound down without choking off the engine. Finally made it, though you could say it was a near-run thing.

Pursuit of the Noise issue left us no time on Thursday to pass Brake Test, though we lined up and ran this first thing on Friday morning, passing easily. We know brakes.

The Cost Event (on Thursday) includes 40 points for the actual prototype cost, 20 points for the Cost Report (turned in a month earlier), 20 for evaluation and inspection at the event, as well as feasibility for volume production, and 20 for the team's on-the-spot solution to cost reduction in a system of the judges' choosing. We had a near-perfect Report (19.59) perfect on-event evaluation (20), and made the full 20 on our cost-reduction solution. But we do have a well-turned out car, and our prototype cost of $15,444 gave us only 16.73 points out of 40, for a total Cost score of 76.32 out of 100, good for 38th place. Kennesaw State University won Cost with a score of 94.70 ($8,576 on reported prototype cost, but only 15.05 on their report – good job, Mark!). The lowest prototype cost was Tennessee Tech with $8,518, and the highest was Worcester Polytechnic Institute with $37,172. Mean cost was $14,308, with a standard deviation of $4,132.

The Presentation Event did not go well. We scored 55.1 points out of 75 to place 39th. The National University of Singapore won the event with the full 75.

The Design Event went very well. We had a sharp-looking, sharply-engineered car, and our engineers knew what they were talking about. The Judges agreed. We were invited into the rarefied air of Design Finals, eventually tying for 4th place with 125 points out of 150. École de Technologie Supérieure won Design (with the full 150 points), followed by the University of Florida and the University of Wisconsin.

Overall static events put us in 6th place with 256.4 points (out of a possible 325). The top five at that point were ETS (283.4), Florida (281.2), Wisconsin (272.2), Universidade Estadual de Campinas (Brazil – 266.2), and the University of Akron (259.2).

Day Two – Short Dynamic Events

Shifting issues bedeviled us all day on Friday. The electrical shifting system was finished late, and therefore not thoroughly tested. It turned out in later analysis that we were asking for limit performance from the purchased parts of the system, when integrated with our shift-without-lift philosophy. In consequence, shifting was unreliable throughout Skidpad, Acceleration, and Autocross. We were perpetually in the wrong gear.

Drew Campbell and Donovan Johnson drove Friday morning in Skidpad and Acceleration – two runs each in each event. In Skidpad, we pulled a best time of 5.737 s to place 21st with 23.89 points out of 50. San Jose State (space frame, 10 in. wheels, I-4, big wings) won Skidpad (50 points) with a time of 5.138 s. In Acceleration, launching in 3rd gear, we had a best time of 4.496 s to place 16th and take 56.73 points. Florida, despite their wings, won Acceleration in 4.113 s for 75 points.

Robert Odom and Josh Trammell drove Autocross Friday afternoon. Showing a lot of skill but still having trouble shifting, Robert and Josh made a best time of 53.971 s on the 1 km course, placing 26th and taking 90.22 points. Oregon State/DHBW-R won Autocross in 46.944 s for 150 points.

Our short dynamic event total was 170.8 points (out of a possible 275), 17th best in the field. TU Graz had the best day with 250.0. Heading into Endurance, we were in 11th place overall with 427.2 points. Florida led with 498.1.

Day Three – Endurance and Fuel Efficiency

Historically, only between 33% and 40% of the field finishes the Endurance Race, and thus gets any points at all for Endurance and Fuel Efficiency. These cars are as light as they can be, plenty powerful, and get accelerated, decelerated, and laterally flung awfully hard (keep in mind that the peak coefficient of friction from these racing tires is above 2). 22 km of that treatment is more than most of them can take. And when it blows, it can blow at any one of the very many seams in these student-designed, hand-built prototypes. Also, 40% of the total points come from Endurance and Fuel Efficiency. And so FSAE comes down to Endurance, and Endurance comes down to, well, enduring.

The system is that one driver runs 11 km on a course similar to the Autocross course (often Autocross run backwards, with suitable adjustment of the gates, boxes, slaloms, and other features), and then comes in, shuts the car off, and trades with the second driver, who restarts the car (this is the most dangerous failure point), and completes the second 11 km.

Josh Trammell was our lead-off. Work overnight had helped the shifting, and Josh was running good, consistently faster lap times. But in the fifth lap, during a hard braking maneuver, he felt the pop of the end fitting in one of the pultruded carbon tube suspension links (front left upper rearward) delaminating its tube. The result was increased front compliance, reduced front grip, balance, and ultimately, performance. Josh worked it hard, not losing much time, but he had a cautionary tale to tell Robert Odom, taking over as our clean-up driver. Robert tried to find a balance between nursing the car and running fast, like we needed to. But eventually the fatigue at the suspension joint was too much, and the end fitting pulled out during another hard braking maneuver, pulling the car off the track, and making it impossible to return. In great despair, we had joined the 60 to 67% (actually 65% in this race, or 71% if one counts the cars that crossed the finish line, but ran too slowly to get any points).

Since FSAE rules now allow fuel efficiency to be scored for cars that make it to the driver change in Endurance, we did get 73.6 points (out of 100) in Fuel Efficiency, placing 23rd. GFR won Fuel Efficiency with the full 100.

Conclusions

Adding it all up, our point total (517.9) landed us in 27th place. Not bad for failing Endurance, though this is cold comfort. Playing the point games, even with the deteriorating performance in Endurance, if the final failure had held off for five more laps, a top-ten finish would have been pretty certain. But then playing point games is dissatisfying for the simple reason that the game result did not actually happen. It remains that although we did improve the reliability and robustness in the systems identified at the beginning of the year, we did not improve other systems, and paid for that omission.

But the team does know how far it came this year, what it accomplished, and what it has. We are building very fine Formula SAE cars, and now know how to build them just a little bit finer.

It’s always hard to say goodbye to the good teammates, even though we know that they are ending merely the active stage of their membership in War Eagle Motorsports, and are entering that honorable institution, the War Eagle Motorsports Alumni Association. I.e. we know where to find them. Our best wishes for fair winds and following seas go to: Jordan French, who will begin a Ph.D. program in composite structures at the University of Utah; Jimmy Gordon who has joined SpaceX in McGregor, TX; and Cheyenne Johnson, who has had several good offers, but is still choosing. Jimmy and Jordan completed the Certificate in Automotive Engineering along with their BME’s. Cheyenne, a psychologist, deserves the Certificate, but academic policy interferes.

For 2016, we have a new team organization. Jonathan Ashworth will be Team Captain. The next line in the org chart shows our Divisions: Business (Payson Williams); Chassis (Kyle Kubik); Electronics (Andrew Cookston); and Powertrain (Joe Stitt). The presence of the Electronics Division and Andrew reflects the merger of the Formula SAE Team (Combustion) with Auburn's Formula SAE Electric Team. The latter was a new independent team in 2015, paid a lot of dues, and found that their path forward will be within the combined Formula SAE Team – one team, two cars (though the Ecar will be a multi-year effort, while the Ccar continues to be annual). Plans for the 2016 Ccar call for full-court engineering on the suspension links, their carbon bodies and bonded joints to metallic ends, ultimate load testing, fatigue estimates in the design process, and fatigue monitoring of parts on the car. Also improved shifting (i.e. overhaul of system concept), robust electronics, advances in acoustics, cooling, intake, and oiling, rigorous fluid systems design and environmental management for fluid systems, next–gen metalo-composite suspension links, and … aerodynamics. AU/FSAE will take wing.