This was a difficult year for War Eagle Motorsports. The car was not completed in time to compete in Formula SAE Michigan. A cracked engine block limited our performance at Formula SAE Lincoln. Concern over the engine and an obscure operating oversight lead to limited performance at Formula Student Germany. After our win in 2016, we leapt off in several new technical directions – and ran into several new technical problems. We received a sharp reminder of the higher level of project management skills required of a larger team with a higher tech.

We built a good car. Full monocoque, full aero, new engine. It showed quality – a 3rd place in Skidpad at Lincoln – only the 12th time in the 22-year history of War Eagle Motorsports that we have achieved a podium finish in a running event. But the learning curve to remain and improve as one of the top Formula teams is rough and unforgiving. After this year, we know a lot more about its pitfalls.

FSAE/FS Background

Almost every major North American engineering college fields a Formula team for the SAE competitions in either Michigan or Nebraska, or the Formula Student competition in Canada. Overseas competitions are held in Australia, Austria, Brazil, England, Germany, Hungary, India, Italy, Japan, Netherlands, and Spain. Approximately 800 teams worldwide compete in Formula SAE/Formula Student, making it the largest motorsports manufacturers’ series in the world. Formula began as Formula SAE in 1981. Some overseas competitions are affiliated with SAE, and those that are not are known as Formula Student – all are part of the World Formula Student Organization. Most FSAE/FS cars are powered by combustion engines, though electric cars have a division in Nebraska and in most overseas competitions. There is a Formula SAE Hybrid competition in New Hampshire. Formula Student Germany has a Driverless division.

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 combustion teams are subject only to a 710-cc engine displacement limit, a 20 mm diameter intake restriction, wing span and placement limits, and absolute adherence to the letter and spirit of a thick set of safety rules. The goal 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/FS 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 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 (this is an FSAE/FS combustion class record) can do 0 to 60 mph in 2.9 s.

FSAE/FS 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); Skidpad (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/FS 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. They aren’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, with most of the overseas competitions beginning in the 21st century. Auburn has competed since 1996, placing 1st in 2016 in Nebraska, 2nd in 2013 in Nebraska, 3rd in 2004 in Michigan, 3rd in 2007 in California, 4th in 2003 in Australia, 5th in 2003 in Michigan, 6th in 2006 in California, 7th in 2014 in Michigan, 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, computer and software, electrical engineers, industrial engineers, and managers in marketing, management, finance, and accounting). Team alumni are widely sought after, with professional racing and the automotive manufacturing industry working hard to retain first dibs.
FSAE/FS 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:
It was a scrambled year of positions and responsibilities for WEMS. Many personalities played a leading role, including:

Nathan Baker  Bryan Golden  Maverick Pierce
Nick Boehm  Leigh Higby  Taylor Sanford
Jonathan Box  Steven Hough  Evan Stegner
Drew Campbell  Matt Huffman  Josh Trammell
Shawn Chen  Jacob Hyder  Garrett Vickery
Stuart Coats  Daniel Maddux  Woody Weicker
Alex Conrado  Andrew McCooy  Hunter Wilkinson
Jack Crouch  Harrison McCrorie  Payson Williams
Trey Danks  Logan Melson  Matt Zeng
Trevor Dimock  Michael Moritz
Dylan Gabriel  Isabel Perry

In addition, we were joined by Dominik Emonts and Riccardo Engels, interning with WEMS from the University of Applied Sciences, Aachen (Germany), and by Maxime Fagon, interning with WEMS from École d'Ingénieurs Sigma-Clermont (France).

The win in 2016 left WEMS exhausted (after a long season, ending late) and exhilarated. OK, and a little cocky. We felt it was time for a new concept. Over many years, we had incrementally developed a hybrid chassis of a carbon fiber tub mated to a tubular space frame in the rear, using the engine as a stressed member. With the 2017 year, we chose the more difficult path of a full monocoque, enclosing the engine. In
2016 we made our first attempt at aerodynamic package, using front and rear elements. This year, we expanded the aerodynamic planform to the extent of the Rules, enhancing the front and rear sets, and adding a full under-tray and side sets between the wheels.

This year, the engine rules changed. FSAE/FS engine power has always been limited by a 20 mm diameter restriction on air downstream of the throttle. In addition, displacement was limited to 610 cc. This limit was raised to 710 cc, since motorcycle manufacturers had been moving up into this range, and the number of engine models close-to but below 610 cc was becoming limited. We cashed in on this change by switching from the Yamaha R6 sportbike engine (I-4, 598 cc) we had used since 2011 to a Yamaha FZ07 (I-2, 698 cc) – a touring bike engine. The FZ07 is lighter than the R6, narrower (for reduced aerodynamic drag), and has a potentially flatter torque curve. Once these major changes (chassis, aero, engine) had filtered through the rest of the design, the answer to the standard question *What did you change?* was *everything*.

It is said that FSAE/FS isn’t really an engineering design competition – it’s a project management competition. We tripped over a few things in that column. One of the major problems was tires. We depended upon availability of a new low-profile tire on 13-inch wheels. This gave us the low outside diameter we needed on a much bigger wheel (more room for improved suspension and brake design) with some very promising tire performance. But delivery kept stretching out, and finally we had to go back to our previous mid-profile tire on a 10-inch wheel, requiring complete redesign of the (very complex) suspension and braking systems, and everything that touched them (like the chassis). The time lost set design way back and put stress on fabrication.

The chassis became an unfortunate series of events. In-kind sponsors cut our plug for us, from which we form a mold, into which the chassis is laid up. Our plug and mold went to another sponsor for curing and were consumed in an autoclave fire. Our machining foam had been used up, and the original plug-cutting sponsor could not interrupt their production to repeat the favor. Furious networking brought us to Symmetrix in Rhode Island, who cut the new plugs (for top mold, bottom mold, nose cone, and the larger aero elements) and looked after us while we were snowed-in. New England experienced an early-spring whole-east-coast blizzard. The new plug came
home, was exhaustively surface-prepped, the mold was laid up and cured, prosthetics were applied to the deformed (due to residual stresses) mold, and the chassis plies and core were laid into it. Somewhere in this intense, laborious, and mind-numbing process, production information was not passed, and the strength plies were laid in twice. The chassis weighed almost twice as much as it was designed to.

The extensive aero design makes a huge difference in the performance of the car, however, puts a huge demand on the team. It doubles the built surface area of the car, and in a way that requires the most skilled fabrication. And given the facilities, personnel, and materials required, this could not begin until after the chassis was finished. We completed all this just at the time of the Michigan competition, which left us no time to test, tune, and train in the car. We have learned over the years that this process does not produce a top performing racecar. With two more competitions coming, it made no sense to expend the team’s energy on an ill-founded Michigan effort, and so we withdrew.

**FSAE Lincoln**

A month later, we were ready for Lincoln. The car was sorted out and turning in some of the best numbers we had ever seen on our test track. Grip was the best ever (because aero). Handling was crisp and predictable. Acceleration was our best ever, which is surprising since the chassis mistake and much-heavier-than-expected aero left us with a curb weight of right at 500 lb. (designed weight was 442).

Lincoln Tech went fine. Tech inspection itself raised a couple of easily-solved issues. Tilt was fine (remember, in 2016 it wasn’t). Noise passed at a phenomenal 104 dB. Brakes – check.

Static events were OK. In Cost, our score of 68.1 out of 100 (always low because our partners give us the opportunity to build a sophisticated car) put us 49th. In Business Presentation, our concept of designing a car for a closed-site racing club attracted a lot of judging questions about the club (‘What can I get with my membership?’) and not so much technically about the car, which probably didn’t help us. Our score of 67.6 did put us 6th in that event, though. In design, we were handicapped by how far off the completed car was from the designed weight. Design judges care a lot about building to the design. This kept us out of Design Finals, and the points bump that entails. We ultimately tied for 7th in Design with 110 points out of 150. In overall static, we stood 12th, 34 points out of the lead.

Our final drive chain would not stay on the car during short dynamic events. Although this had never happened in practice at home, in the morning before Acceleration, the chain started slipping off, and this could not be cured. We struggled through the morning session (Acceleration and Skidpad), greatly impeded by our full monocoque, which made access to the drivetrain very difficult. We did get the chain to stay on long enough to carefully complete Acceleration. Jacob Hyder and Josh Trammel were the two drivers, pulling a best time of 4.243 s. The winning time was not much better (4.186 s), and so while our time was only good for 6th place, we got 96.18 points
out of 100 for it. In Skidpad, between repairs we had time to put one driver through. Josh Trammell drove to a 5.025 s time, placing 3rd for 62.78 points out of 75. In the afternoon, the drivechain loads in Autocross are much more transient, omnidirectional, and severe. We could not complete the Autocross course without the chain slipping off.

Our chain wraps around a sprocket attached to one face of the differential, which is fixed by two carriers directly to the transmission casing. To get ready for the endurance race on the last day, we built a new differential mounting that was much stiffer laterally (we imagined that our problem was the racking of the differential mounts under lateral load). This was a somewhat heroic undertaking. Under the constraint of the impossible space restriction in the back of the monocoque, we had to create a three-dimensional weldment with the accuracy to keep motorsports drivetrain machinery located and oriented, working in a parking lot under street lamps. By dawn, it was done.

Unfortunately, our efforts were in vain. Drew Campbell started the Endurance Race, trying to be fast, but really babying the car. He got five laps (out of 16) before the chain popped off again. During his time on the track, Drew was looking great and steadily knocking off time. War Eagle Motorsports received a DNF (Did Not Finish) and was towed off the track.

The trip home wasn’t much fun either. An hour out of Lincoln the truck transmission failed. We parked the trailer, scrambled for a U-Haul, and were fortunate to get a lift for a lot of our gear from our friends at Georgia Southern. After the truck’s transmission was replaced in Lincoln, it only got as far as Evansville before the water pump pulley shattered, giving rise to another out-of-town repair and a retrieval trip.

**Formula Student Germany**

Competing in Germany requires elaborate preparation. To make schedule (of both travel time and precision of arrival date), the car and gear must go by air. To go by air, the car must be emptied and dried out of fuel, oil, and fluids. No batteries. Realistically, it takes a week to work the car back up after opening the crate in Germany and restoring the car mechanically. So, with shipping time, it had to go into the crate a week after getting home from Lincoln. That week was spent rebuilding the car, and designing and machining a dead-on, dead stiff differential mounting.
On arrival in Germany, staying with our friends at the Technische Hochschule Mittelhessen in Gießen, we were able to take advantage of Opel’s kindness and work up on their test track in Dudenhofen-Rodgau. There we discovered the root of our problem. We use the motorcycle engine’s rear suspension mounting points – cast directly onto the transmission casing, to mount our drivetrain. On our old engine, the R6, we had studied this mounting over the years, and knew that it was far stronger than we needed it to be. We had not yet been to this depth of analysis on the new engine, the FZ07. The FZ07 is a touring bike and does not see the same rear suspension loads as the R6, a sportbike. So, its transmission case is lighter. And weaker. Our drivetrain mounting was flexing the transmission casing under lateral and torsional loads. In fact, we had actually cracked the block. There, in Germany, about to move down to the race site, there was little we could do. We limited our workup driving and planned to drive the car with care in competition.

Moving to Hockenheim for the race, we found that a few trees had blown down in the FSG campsite in a violent storm the previous week. Under the logical extension that trees are dangerous, the whole FSG camp was moved to a fennel field outside the city. Muddy, treeless, and with limited access, as one might expect an agricultural field to be. But still, it was the FSG camp – always an experience.

Tech at FSG is always a bit mind-blowing. And we got a late number, and so felt some pressure to get through. But everything was more or less fine, and in due course we had our full tech sticker.

Static events were a little disappointing. Cost gave us our usual 71 points out of 100 to place 42nd. In Business Presentation, the German judges were not impressed at all with our racing club concept, and we were hammered (also having differing opinions among judges), getting only 49.14 points out of 75 to place 36th. In Design, the German judges were even less impressed than the Lincoln judges that we missed our designed weight by so much. We got 80 points out of 150 to place 33rd. One might note that the engineering design bar in FSG is very high.

We gingerly competed in short dynamic events. In Acceleration, our time of 4.406 s (slow for us) placed 24th for 49.13 points out of 75. At FSG, Skid Pad is done on a wet track. The course is watered by an array of rainbirds, with water flying everywhere, and the cars wearing rain tires. Our time of 6.165 s was good for 19th place and 45.90 points out of 75. Autocross, with its transient shock loads coming from everywhere, was our greatest concern. We managed to finish, and our time of 74.597 s was good for 20th place and 58.55 points out of 100 (the winning time was 68.122 s).
Overall, we did not look that bad. Consistency and completion of events is important in Formula. It keeps the point total in the hunt, ready to take advantage of the inevitable carnage in Endurance. We were placed well enough that, given a good Endurance Race, we could finish in the top ten overall.

But we had to finish. Drew Campbell took the first driving shift, trying to stay fast enough to get points without finally wrenching open the transmission casing (if nothing else, that would oil the track and DQ us). In general, he did well, and pulled into driver change to hand over to Daniel Maddux. At driver change, the cars are inspected. If there is anything loose, or especially if anything drips, the cars are DQ’d. A drip was found on the top of one of our wings. We were DQ’d. It turns out that the drip came from the cooling system catch can. It was dripping because it was full of water. It was full because it filled up during the wet Skidpad the day before along with the rain experienced during the events. We don’t see wet skidpads much, and we didn’t think to empty the catch can after that event. Of all the things to end on.

Moving On

We came home to a new shop situation. From its opening in 2012, most of Wiggins Hall belonged to the Mechanical Engineering Department, but our shop was administered (loosely) by the College of Engineering. The College finally turned that space over to the Department. The Department had plans that did not include the somewhat Bohemian sprawl in which we got used to building Formula cars. The Department is converting the space to a multi-project shop and closed it down to clean it out to create this. We lost months of time, much material, convenience, and flexibility. But we hope to gain supervision, training, safety, and machine maintenance.

We salute our seniors as they make the move to the War Eagle Motorsports Alumni Association. Michael Moritz has joined Tandy Engineering in Houston. Michael Bassie is now with Honda in Ohio. Jon Box is with XYZ in Birmingham. Alex Conrado is with Northrop-Grumman in California. Drew Campbell will complete his senior year in ME.
For 2018, we have a new organization. Instead of leaving physical groups in place all year (chassis, powertrain, etc.), we are moving to functional groups – Design, Fabrication, Racing, and Business. Each functional group will organize its own subgroups as best suits its mission. Nick Boehm will be Captain. The Group Leaders will be: Steven Hough (Design); Nathan Baker (Fabrication); Daniel Maddux (Racing); and Payson Williams (Business).

The 2018 design will return to the hybrid chassis of carbon tub and rear space frame. This has served us well, and we now understand why it is more desirable than a full carbon tub – manufacturability, maintainability, and weight, with no loss to rigidity. We will also return to the Yamaha R6. This seems like a retreat to the last good configuration. Really, it is an appreciation of that configuration. To build enough structure into a chassis to make up for the weakness of the FZ07 transmission casing would add much more weight than we save by substituting that engine for the R6. In a curious case of design module interaction, it is the structural aspects of the engine that dictate its choice, as opposed to relying purely on thermodynamic comparisons. It is, after all, a whole car.

We are a good team, coming off a year of very hard knocks. We learned a lot. We made a lot of great engineers, which is why we do this whole Formula thing. We are grateful to you for sticking with us and look forward to a more joyous report in 2018.