Organizing a Formula SAE® Team
By Alan Gruner

Preface:
When a few university professors got together 20 years ago to start a very informal SAE student design competition then known as Mini Indy, I doubt that any of them expected their efforts would change the world of motor racing and the lives of thousands of young men and women. Today this program, renamed Formula SAE ®, has become the world championship for college engineering students, and the training program for race car engineers and designers around the world. Teams from as far away as Korea, Japan and Mexico travel to the suburbs of Detroit each May for the big event. Satellite events have begun in the United Kingdom and Australia. Each year as many as 4,000 students are members of Formula SAE teams at universities around the world. Nearly 2,000 make the trip to the competition itself.

The impact of this program on these student engineers is significant - even life-changing. Because of their experience, many will be hired into fast track jobs in the auto industry. Others will catch the dream and go to work for the top racing teams in CART, Formula 1, IRL and other racing series. Nearly all will look back on Formula SAE as the most challenging and rewarding of their college experiences.

How strongly does Formula SAE touch those involved in it? Ask Alan Gruner, team captain of the Michigan State team in 1995, and now a systems analyst with an e-business company in California. Alan was so affected by his Formula SAE experience that he sat down and wrote the equivalent of an English term paper on getting started in Formula SAE, then posted his work on the web as a resource for all those future engineers who accept the challenge to get involved. As a result of his Formula SAE experience, he has also become an avid autocrosser.

With Alan's permission, we offer his suggestions from the SAE Motorsports Engineering website. To make this an even more useful resource, we're encouraging others who have gone through the Formula SAE experience to add to Alan's work - to share their suggestions and their stories. Our goal is to make this a living resource to everyone who starts down the road to build a Formula SAE car and make it to the big show. Good luck!

Introduction
Congratulations! If you are reading this, it means that you have committed to being involved in some way with the Formula SAE competition. This manual is primarily for students though it will be valuable to other team stakeholders as well. It is recommended that you read through the whole document. All the topics covered are here for a reason. Most everything here has been learned the hard way.

Purpose
This manual is being written to help Formula SAE teams organize and successfully complete their car projects. It was originally written to help my old Formula team document the problems that were encountered and solutions that we devised for them. A great deal of knowledge was graduating with team members every year. Knowledge about how to get things done at a university, what are reasonable goals for a team, and where to find resources had to be learned from scratch by incoming officers and team members. This second edition is designed to help new teams successfully launch a new FSAE™ program or improve an existing one. It is my hope that FSAE™ teams will expand and refine these ideas as they learn more. My aim is to provide guidance in the process issues of organizing people, money and other resources for the purpose of competing in Formula SAE. There are a lot of good books on the technical aspects of vehicle design. I am not going to duplicate the content here.

This document is divided into roughly two sections. The first section deals with how to run the organization and includes topics like fund raising and recruiting. The second section deals with some design lessons learned the hard way, design and construction hints, and preparation for the competition. Reading both sections is recommended as many issues and problems that come up in the project are intertwined.

Disclaimer
The information and opinions presented are gleaned from organization management texts and my own experience working on three FSAE cars and managing the construction of one of them during my tenure at Michigan State University. It also comes from stories shared with me by many different teams. Much of this is a subjective interpretation of my experience in the management end of a Formula project. I am human and fully capable of missing something. I expect people will disagree with some of the ideas presented. The opinions expressed are my own and do not reflect those of any organization I am now or have been affiliated with.

Part I: Organizational Topics

Where to Begin

The natural inclination of any FSAE^{TM} group is to begin by focusing on what car to build. While it is important to be thinking about design issues and ideas, in the early meetings you will probably not be able to create a definitive plan. Unless you have designed and built complete automobiles before, you should not make definitive decisions yet. There will be plenty of dialog and thought given to the car design without making it a priority yet.

Students usually think the biggest problems will be technical. We embark on an FSAE project with grand visions of a fast, exciting racecar and can't wait to get started designing and building it. What you find out right away, particularly if you are in a leadership position, is that the largest problems to overcome have less to do with actual hands-on design, construction, and driving of a racecar. The three largest problems you will have are membership, money and university bureaucracy. How well you deal with them will ultimately determine how well you can design and build your car. Engineers generally do not like to spend lots of energy on these types of activities; however, this three-headed dragon is going to face you in every job you ever have. To be an effective engineer, manager, marketer or whatever it is you plan on doing, you will have to deal effectively with these things. One of the reasons companies recruit heavily out of the Formula SAE is the experience that students get managing these problems.

The most important concerted action for an FSAE team to start with is finding SPONSORSHIP! The best idea and design will remain just that unless there is money to pay for them. The point of the FSAE competition is to build an actual functioning vehicle. Money and material donations are what make it happen. Ideas and strategies for securing cash, material, and service donations are discussed in detail in the sponsorship section.

The second activity that needs to be undertaken is developing and implementing a recruiting and selection plan. By the time an FSAE car is built, tested, prepared, polished, documented, presented and raced, several person years' worth of volunteer student labor has been spent to make it happen. All the work that needs to be done will not happen without people to do it.
The last thing that is crucial to begin from the very first meeting is the learning process. To build a competitive car means that you will have to develop a working knowledge of subjects like vehicle dynamics, heat transfer, material science, mechanics and fluids in excess of what is required to pass your classes. Furthermore, many of you will develop managerial skills that exceed what's taught in many MBA programs. You will have to be reading and consulting with experts continually to get where you need to be.

Sponsorship

Running an FSAE project is expensive. To build a brand-new car from scratch can take $60,000 in cash, materials and services easily. This kind of support won't come from membership dues and selling T-shirts. A sponsorship campaign needs to start as early as possible, preferably near the beginning of the calendar year before the year you intend to compete.

What often happens is that one or two people get stuck with the task of approaching sponsors at the beginning of the academic year. This works but is not the most effective. People can quickly get bogged down. Important opportunities slip away because there is not enough time for one or two persons to pursue them and pass classes.

A system for organizing and dividing the workload among a larger group is important. Spreading the sponsorship work gives people an appreciation of how much work is involved raising the money. Until you do it, you do not understand how much work is involved. It is common that contributions of the people involved in fund raising and sponsor relations are under-appreciated by the team.

Let me start by defining what I mean by sponsorship. Sponsorship is donations of cash, materials, parts, services and technical expertise to your FSAE team. To run a successful sponsorship campaign, you will have to become salespeople for the team. Some of you may not be excited about the prospect of being a salesperson; however, we all constantly try to persuade people to support our ideas or join in what we are doing. This is no different. You are trying to get people excited about the project you are working on. It is fun once you've done it for a while. Sponsors are looking for something in return for their donations. Treat them as valued customers in a business. Deliver what they are looking for and they will keep coming back to sponsor the team in the future. It will also put each of you on the team in a position to obtain things that will really matter to you later, like great jobs, high salaries, and interesting work.

Sponsorship takes various forms. The easiest type of sponsorship to get is material and parts donations. For many parts and material makers, sponsoring student projects is a good deal. Several the FSAE students will be making supplier decisions for their employers after graduating. Sponsors get to create a positive image of their company in your mind and familiarize you with their product line. For companies with new products to promote, FSAE provides a forum to get their stuff on display in front of students and auto industry people as well. The FSAE event is sponsored and organized by a consortium of GM, Ford and Chrysler. The competition is crawling with designers, engineers, researchers, purchasing managers and executives of these three and their first-tier suppliers. Companies also like to help because students have a reputation for using things in new and inventive ways. (They often don't work, but that isn't the point.) This can help stimulate interest in new uses for existing products. Often this kind of donation is relatively painless for sponsors. When I started working on my first Formula car in 1994, it was made from pre-impregnated carbon-fiber cloth. I was told it was about to be scrapped because it did not pass the inspections to be certified for military aircraft use. Instead of scrapping it, the sponsor gave it to the Michigan State University Formula team to build a racecar. It was more than adequate for the job and the sponsor got a rolling billboard for the product. In another example along the same lines, I'm told there is a Formula team in the northwestern United States that builds its cars with large amounts of machined aluminum because Boeing lets the students to go through their scrap bins.

A harder type of sponsorship to procure is services like machining, welding, or painting. Most companies and professionals are busy. The time they spend with you is time that they are not getting paid for. However, this doesn't mean people won't help. This project is cool. Often that is enough to get people involved. Their motivations are like those of part suppliers. Helping you out creates a positive image of the company among ambitious aspiring engineers and managers, it familiarizes you with their services and capabilities, and the car gives a chance for their handiwork to be displayed in front of potential customers.

Before approaching anyone about advice or services, remember his or her time is worth money. You must do your homework ahead of time, so you don't waste time or materials. Be clear exactly what you are looking for. Typically, technical help is given, and services are performed during downtime from paid projects. You must be ready to accommodate odd schedules and delays.

The hardest type of sponsorship to get is cash donations. Treat your cash donors like gods. Unlike parts and materials (which can be donated out of existing inventory), technical help (which is a matter someone taking time to talk), and services (which can be performed during downtime from paid projects), cash comes directly out of someone's pocket. Small companies are generally cash poor and cannot afford to contribute. When organizations have cash, it is watched carefully by accountants. Someone high-ranking must authorize donations.

Every college and university are supported to some extent by tax dollars and tuition. However, the rest of its money comes from contributions, endowments, and research projects. The same people in industry who can help you with your Formula car support much of the research your professors do. Every university has professionals and offices dedicated to fund raising. Ask for help.

Funding is a sensitive issue in any organization. It is important to start with your faculty advisors and work as much as possible through your department (ME, EE, MSM, etc.). These people are also vital to your project. You do not want to embarrass them or step on toes at the university. If they don't have time to help directly, they are often aware of who can help you design sponsorship proposals and develop strategies.

When asking for help with your fund-raising campaign, remember that no one is going to do this for you. The actual legwork of identifying, contacting and following up with potential and returning sponsors is going to have to be done by the team. You are looking for people who can guide you and save you months of trial and error.

There are some bare minimum things that you will need to begin your campaign. First you need a budget that reflects the total cost of the project. Be sure to include entry fees, food, transportation and hotel accommodations in the budget. The next things you need are attractive pictures of a car to include with funding proposals. Prints are expensive for this purpose. Color copies work well. People like to see what their money will be spent on. If you have not built a car yet, create a drawing of one. Group photos of the team with a car are also good, assuming the team is more than 3 or 4 people. Once sponsors have committed cash, materials, or services and you've received them, about 60% of your fund-raising work is done. You need to maintain a good relationship with your sponsors so you will have their continuing support. You need their enthusiasm for your project, future contributions to the team, and even job offers for team members. It takes an ongoing effort. Sponsors will tell you one of the biggest frustrations of contributing to student groups is that once a contribution has been made, they never hear from anyone again until the next request for more donations. Start a newsletter for your sponsors and other interested parties. The newsletter needs to go out regularly, at a minimum of every quarter. It should be short. Most of the people you are sending it to are busy and have a lot to read. Two or three pages are good. The newsletter should include, but not be limited to, updates on the progress of the car, announcement of new sponsors, and exciting things happening at the university. The point is to maintain contact with them over the course of the project and make them want to stay involved. You should also start and maintain an interesting World Wide Web site for the team, updated with new content often to keep people coming back to look at it.

A good sponsorship campaign doesn't just happen. It takes time and practice. Often when a member gets to the point of being a good fundraiser, he or she graduates, and the knowledge is no longer available. The team can benefit from having one or two sophomore or junior students involved each year who can carry forward the team's collective knowledge about fund raising. It is wise to keep organized and detailed records of which companies were approached, who you talked to in each company, and what results were obtained. Don't make future teams go down the same dead ends. If some organization or person cannot or will not contribute, make note of it. It makes the team and the university look stupid if the same questions and/or requests come each year no matter how many times someone says no.

Recruiting, Selection and Retention

The most powerful tool that you have for recruiting new members of the team is an existing car. Many people have been recruited by parking a car in the lobby of a school's engineering building with a sign announcing the first meeting. This is one of the simplest and most effective methods. You can enhance the effectiveness of this display by putting out brochures about the car that outline the program including membership information and names, phone numbers and e-mail addresses of the team leaders. People who want to get involved can't necessarily make it to the first meeting. Don't exclude these people by saving membership information for the first meeting.

A car in the lobby of the engineering building should not be the only recruiting method. It only attracts people who see it. In a lot of colleges, this limits the team to juniors and seniors in engineering disciplines. This is a good group to have, but it is important to get freshmen and sophomores involved also. As was alluded to earlier, a fair amount of knowledge and experience graduates with senior members every spring. For the good of the organization, you need to have people around for as many years as possible. To recruit freshmen, universities often help. They hold student organization fairs during their welcome week. To participate takes some preparation. Generally, these events are planned over the summer and the prime locations at the fair go to the groups that have someone on campus in the summer. Contact your student life or equivalent office for details on how to get involved.

Another good place to find members is other student organizations. SAE is unique; only a few organizations do a lot of hands-on work. Ask other organizations like SWE, IEEE, and NSBE if you can make a short presentation about the project at one of their meetings.

Most people working on the project will be mechanical engineers. This is appropriate because much of the work falls into the mechanical engineering realm. However, it is worth getting a diversity of engineering and other majors involved. At a minimum you want to have a cadre of electrical engineers. The electrical system usually is not very complicated for the average EE, but it can be very complicated for an ME. It is also common to want to explore electronic control systems for various functions like shifting. People with non-engineering majors can make valuable contributions too. Logistics management majors from your business college are trained in finding suppliers and costing out manufacturing processes. Accountants are a valuable addition to any team. Some person(s) needs to make sure the project stays on budget and crunch all the numbers for the cost report. You might as well take advantage of accounting systems developed for this purpose and bring in students who want experience in this field.

You also want to recruit graduate students. They have access to things that are not available to undergraduates, are generally resourceful and reliable, and are likely to have a few years of work experience. There is no substitute for work experience. If you can involve a grad student who is working for the team faculty advisor, it can be a good deal for everyone.

Once you have gotten a group of people together, you need to retain them. This is one of the hardest jobs of leadership. No matter what you do, you are going to have a lot of turnover. The project is demanding. Many people cannot sustain the effort due to academic or other life commitments. Some people don't like it or don't want to work hard. Others don't feel welcome and quit. One common problem happens when several experienced members, returning from a previous team, have an established close working relationship which leaves new people feeling left out. This is often seen at early work sessions and driving events. The old hands tend to dive in and do things while the newbies hover at the edges. Another thing that discourages new members is that the hands-on fun stuff usually isn't ready to start at the beginning of the school year. What does need to be done at the beginning of an academic year is grunt work like cleaning work areas and sorting parts. If you can get your new members to share in these chores, they will begin to feel included in the project and team spirit will begin to develop between new and returning members. The time when your new members will get excited about the work itself is when you start designing and building stuff.

One key to retaining people is to give them some realistic expectations up front. They need to know that in the early stages there is grunt work to be done but it gets more interesting. They need to know that a high level of personal commitment is expected. More than 10 hours per week is normal. They should also know that shoddy work is not going to be accepted. A "D is for diploma" attitude won't fly.

Another key to keeping people is to have fun. Unless you are starting completely from scratch, one of your first activities as a group should be to take the old cars out and run them around a parking lot. Once you have gotten a taste of what these cars can do, it is hard to walk away. When someone comes back from his or her first drive, s/he is usually grinning from ear to ear and ready to work.

Don't take your old cars apart. You need them as recruiting, retention, and motivational tools. You also need them as driver training tools and test beds for new ideas. If you are starting from scratch, try to cut a deal with a local go-cart track for seat time to gain driving experience. Also, contact your nearest SCCA chapter and find where autocrosses are being held nearby. In many autocrosses you can take your streetcar out for runs around the course. Remember the rules say you are designing your FSAE car for these nonprofessional autocrossers. Learn as much as you can from them.

The last key to retaining members is your group process. Since this is a volunteer group, all members need to know their ideas are getting a fair hearing, even if the decision is to do something different. Nothing drives people away faster than feeling ignored. You must be careful not to let a few people dominate discussions.

The officers of the group, Project Leader, Chief Engineer, Treasurer, Secretary, or whatever titles your team uses, are generally chosen by election. When selecting for other key posts, you may want to use another method. Finding effective leaders for the different subsystems groups is vital to the success of the project. The leaders must be extremely hard working, have excellent people skills, and be knowledgeable in the areas they are leading. The chassis group leader needs to understand structures. The power-train leader needs to understand engines, fluids, and heat transfer. To find this kind of knowledge requires screening. Possible methods include having the elected officers screen qualifications and select the subsystem leaders or creating requirements for the positions and letting the members vote to choose between those who meet the qualifications. However, you do it, you need people who can work closely with each other. Personality conflicts among the leadership are extremely detrimental to the team.

One of the unfortunate facts of life is that people are forced for many reasons to drop out of the project or cannot be around at a crucial time. It is critically important that for each key position and on each subproject, there be someone ready to step in and take over. This is called succession planning. For each key person, you need to identify someone who can replace him or her. Make sure the person you have chosen is working closely enough with the key person to know the strategy, the plan, and what must be done next at any given time.

Learning

In classes we are generally given clearly defined problems that include all the data needed to solve them and that have narrowly defined ranges of "right" answers. On this project you will be continually presented with problems that are ambiguous. There will be many solutions that will work and no "right" answers. You will not have all the information you need. This is where you start learning real engineering and management skills. If you don't know something, you must go learn it. The real world is ambiguous; start getting comfortable with it. Engineering is not a science. It is the art of finding solutions and making good choices. Science only provides the paints and brushes you will use.

Goal Setting

Goal setting is an area where many teams get themselves into trouble. Typically, they make plans that are far too ambitious for the available resources. It is easy to do. By the time students fully understand the enormity of the project, they graduate. One of the reasons for this manual is to impress upon all the new people just how big a project this is. The Big 3 (Ford, General Motors, Chrysler) and their competitors (Toyota, Honda, Mitsubishi, Volkswagen, Renault, Fiat, Hyundai, Kia, etc.) take a minimum of 22 months to bring a new or revised car to market. This is 22 months of full-time work by large teams of experienced engineers and technicians who have been building cars for a long time. Many of them are world leaders in their professions. The OEMs also invest several billion dollars in the process.

Some of you may be thinking, legitimately, that you are not trying to build something as complex as a normal production car. While an FSAE may be simpler in terms of the number of parts, the process of creating it is the same. The main difference is that design compromises are all biased toward dynamic performance.

Depending on how well organized you are, you will have 9 to 18 months and a few thousand dollars to build a new car. Furthermore, you will be doing all the work with part-time student volunteers who are learning the processes as they go along and whose top priority must be to pass their classes.

Most professional race teams buy chassis, engines and other components from professional vendors who have been designing and building them a long time. They then spend thousands of hours and ungodly amounts of money testing and tuning what they have purchased to make them competitive. The people testing and tuning have also been doing it for a long time. This is not to discourage you, but to help you understand how much is involved in racecar design, construction and tuning. The good news is you are competing against other colleges and universities and not against professional race teams. The money, talent and other resource constraints of these other schools are like yours. They will have to pull off just as many miracles to get to the competition. The challenge you face is to do the best job you can with what you have.

The first step is to establish goals up front and put them in writing. It is easy to have people with very different ideas about the goals trying to build a car together, and this can and does erupt into destructive conflict. Making a list of goals that everyone agrees to helps diffuse these conflicts. It also helps to keep the team focused. It is very easy to get off track when you get into the details of the project. Revisiting the written goals periodically helps keep it all in perspective.
FSAE attracts people with different goals and motivation. Some students will want to build the most technically advanced (a.k.a. the "coolest") car, cost, time and other considerations be damned. They will want a carbon fiber monocoque chassis, turbo-charged engines, complex electronic control systems, and aerodynamic wings, basically all the tricks and gadgets of Formula One or Indy Cars. They see it built by inexperienced students in nine months with a few thousand dollars. Other students want to get their hands dirty and learn by doing. They are satisfied with overcoming the challenge of something technically demanding like FSAE. Among the last group, which is usually dominant, are those who want to win.

Each of these goals is legitimate and can lead to a satisfying experience. However, you must decide as a group what you want as a team. Building a top-ten contender takes a different commitment of time, money and other resources than being the team with the first fuzzy-logic-computer-controlled-metal-matrix-composite-self-lubricating muffler bearings.

Absolute Necessities

To run a Formula SAE team, there are many things that are nice to have. It would be great to have all the resources of Chrysler Technology Center or GM's Milford Proving Ground. Things like big offices, brand new workstations with the latest design tools loaded, a staff of dedicated fabricators and technicians waiting to turn your latest drawings into three-dimensional reality, and a million-dollar budget. You are not going to have that. You will have a few thousand dollars, your own ingenuity, and a group of other students who are as crazy as you are. You must create miracles repeatedly to get this project done. There are six minimum necessities that you must have to make this project work. In order of importance, they are:

- Commitment and Faith
- People
- Money
- Workspace
- Good Relationships with Faculty Advisors and your College
- Machine Shop and Welding Facilities

Trying to run the project without these is nearly impossible.

This project is going to be tough. You can't give up when things get difficult. You must be absolutely committed that, come hell, high water, bureaucratic snafus, reluctant sponsors, broken axles, and blown engines, you are going to finish your car and race at the FSAE in May. You must resolve, no matter how bad things look, you will get there. When you do something ambitious like this, stuff happens. Assuming you all are familiar with Murphy's law, you need to know Murphy is going to come and visit. If fact, Murphy will knock you down and kick you several times. Things go wrong at the worst possible times. Someone who is building a critical part is going to quit the team and disappear with everything needed to finish it. A critical part that a sponsor promised is not going to come because a budget got cut. This is a normal part of life in FSAE. You must be strong enough to recover from it.

The next thing you need is people. It takes dedicated work by a team of people to make one of these projects happen. After talking to many FSAE teams, there seems to be a consensus that you need a core of 8 to 20 people who are absolutely committed to the project. This seems to be critical mass. Beyond that you can have a larger group who are involved in one aspect or another of the project. However, when you try to get large numbers of people involved, coordination of the work can become more complicated than the work itself. On the other hand, very large teams do exist in the world of FSAE.

When you have dedicated people, who know that they are going to build a car no matter what happens, you need money. Raising money is covered in the sponsorship section. Do not start spending in major amounts until you have created an overall plan that everyone has bought into. With commitment, people and money secured, you must have workspace. My impression is that the majority of FSAE teams work in corners of sympathetic professors' labs. Space is a highly politicized issue on most campuses. Do what you need to stay on good terms with the people with whom you share space. If you get kicked out, it takes a long time to find somewhere to move to, time you need to be working on the car.

Good faculty advisors are worth their weight in gold. You are taking on a project that is very difficult and complex technically. It requires the group to find its way through an economic, political, and organizational landscape that is equally complex. You will need advocates in the university. You need guidance from people who have been around long enough to know how to get things done. Faculty members who are willing to take the time to get you through both jungles are truly special people. Treasure them.

Last, you really cannot build a new racecar without a machine shop and welding facilities, or at least access to them. Many schools continue to try. It can't be done very well. If you have enough money, you can hire someone to do it. Budget at least $15,000 if you decide to have all work professionally done.

Safety

Safety is one of the stickiest issues surrounding a Formula SAE team. You are building a racecar. Racecars have a well-deserved reputation for being dangerous. In order to build the car, you will use welders, saws, machine tools and chemicals of all descriptions. Like the car, all these things are safe if used properly, unsafe if used improperly. In the environment of easy lawsuits and substantial jury awards to people who do stupid stuff, there is a lot of justifiable nervousness about letting students anywhere near anything that could possibly hurt them. All it takes is one serious injury to shut down your team for good. There are plenty of people in positions of power who can't understand why you would want to do anything other than just go to classes and graduate. There are also plenty of people who would like to kill student projects because they see them as creating work and problems that they should not have to deal with. Don't give these people any leverage to pull the plug on you. Formula projects have been killed or almost killed many times when people did things that were dangerous, seemed dangerous, or were stupid. Examples I have heard of include driving Formula cars on public roads and driving a Formula car around at night with a headlight duct-taped to the frame. The temptation to do things like this is very strong. DON'T. You are working with stuff that is not idiot proof. Don't be idiots.
It is inevitable that your group is going to attract someone who is a flake. Therefore, safety rules are created. Unfortunately, often you don't spot them until they are in the shop or in the driver's seat. It is almost impossible for a group to be self-policing. Work with the faculty advisors to develop procedures that will limit people's opportunities to hurt themselves.

Group Process

Success in the FSAE is going to depend on effective management of one of the more complex adaptive systems that you will ever encounter: a group of people. Too many engineers assume that individuals can just come together and start working. It is not that simple. To get a project the magnitude of an FSAE car together takes effective teamwork. Effective teams can build societies, pyramids, or fast cars. Ineffective teams waste resources and spoil the potential of their members.

Engineers have a reputation for not having good people skills and being hard to work with. There is a kernel of truth in the stereotype. Fortunately, you don't have to be a "people" person to work effectively with your teammates. However, understanding the basics of group dynamics can help you diagnose problems and see where your own behavior is helping or impeding the progress of the team.

Behavioral psychologists have found that when groups form around work, they go through roughly four stages. They call these forming, norming, storming, and productive. The forming stage is where people come together and begin to get to know each other. Typically, there is a lot of talk about non-work-related stuff. People start learning each other's names and about each other's backgrounds. The norming stage is where many of the formal and informal rules of the group get established. The level of formality between group members, acceptable subjects to talk about, how different ideas are received and evaluated and how different ethnic groups are treated are all things that get laid down, at least on an informal basis, during this stage. The storming stage is where people kick around ideas and visions of what the group might do and how to accomplish them. This is also where the work of the group gets started. The last stage is where most of actual work gets done.

Teams are fragile entities. A lot of things can go wrong and frequently do. Each stage depends on an increasing level of trust and commitment between members. A potential team can get stuck in any of the first three stages and never get to being productive at all. When people leave or join the group, the whole process starts over. This is one of the reasons it is often hard to join an existing team or to integrate a new person. New relationships must be established, and new norms created. You may not want to be bothered by this intangible touchy-feely stuff, but it is the difference between a great team and an average team. Rather than go through a bunch of locker room clichés like, "There is no I in team," just remember that your success depends on how you all work together. No one can do this alone.

There are things that you can do to improve the group process. Start by letting other people talk and listening to them. Listening is an active mental process where you try to understand meaning. This is not the same as hearing which is a physiological recognition that sound is leaving someone's mouth. Argue design questions on quantifiable aspects of the problem. Focus on the problems and don't personalize disagreements. Don't discount something because you don't like the person who thought of it. This is most important. Deliver your pieces of the project on time and on budget. Finally, you must be thick skinned. Not everybody is going to like your ideas. Most people are not shy about letting you know it. If you can't handle criticism or you get mad if the group doesn't do it your way, find another profession.

Leadership

There is no one right way to lead people. There has been a lot of study of what makes good leaders. There is no one set of characteristics that distinguishes good leaders. Leadership is situational. What works any given time may be wrong at another. How you interact effectively with your followers depends on where you are in the group process. In the early stages of the FSAE project, new members need a lot of direction at work sessions and meetings. They don't know where to find tools. They don't know all the tricks to putting something together or taking it apart that you figured out last year. Some of them have never worked on a car before. New members, for the most part, are going to need teaching and close interaction until they start feeling confident about what they are doing. Team leaders need to prepare enough structured activity for early get-togethers, so no one is standing around. A fast way to lose people is to waste their time.

Fairly quickly the leaders will be able to step back more and eventually start delegating things directly. If you delegate too much right away, people are going to get mad at you because they are not ready for it. If you continue to closely supervise people after working with them for six months, they will be equally mad at you because they don't need close supervision anymore. It is a fine balance that you must maintain. I have heard FSAE leaders complain bitterly about new people needing to have their hands held. They looked on this as some sort of weakness. If you find yourself feeling this way, be patient. Your new members will gain confidence if given a chance. On the other hand, if they sense disdain from you, they will quit one by one and soon you'll be down to five people trying to build a car.

Here are some things to expect as a leader. First, a minority of people in the group will cause most of the problems. It comes with the territory. You will get at least one individual who needs a lot of attention. Another common team dysfunction happens when different groups don't see each other working. Small fragmented subgroups are notorious for assuming that other members or groups are not doing anything. On a regular basis, perhaps weekly, each subgroup should update the team on what they are doing. They should explain what they have done since the last update, what snags they have run into, what they are doing about it and finally their measurable goals for progress by the next update. This approach can do several good things. It communicates that progress is being made, highlights bottlenecks in the process, and gives the team members goals to focus on. It can also bring the power of peer pressure to motivate individual members. There are few things as uncomfortable as standing in front of a bunch of your friends who have been busting their butts on something if you have been spending too much time playing Doom and drinking beer.

Dealing with University Bureaucracy

The bureaucracy at any university can be one of your biggest problems. The systems for purchasing and tracking parts and materials were designed with many goals, but the responsiveness and speed needed for FSAE or other student projects are not usually among them. The bureaucracies are all different, but there are a few guidelines to dealing with your local bureaucrats. First, as students you are only going to be around for a few years. The people who work at the university are going to be there many more. You are going to go away after graduation. The natural tendency for anyone in a bureaucracy is to give top priority to those who can make his or her life most miserable. Slow rules and procedures will get followed unless someone up the command chain says it’s okay to do differently. You need good relationships with faculty and administrators. Second, almost everyone who works in a college or university has been burned, or knows someone who was burned, by a student who lied. It is going to take time to build credibility. Your credibility is fragile. DO NOT engage in unethical behavior. Don't falsify documents. Don't use money for other than its intended purpose. Don't accept money under the table. If you get caught, you will kill your Formula team and taint every other student project. The last thing is to make sure you understand who owns the cars, tools and spares, and what authority you have over the disposition of them. Generally, you will end up with stuff you are not using or don't need. It makes sense to sell or trade for what you do need. Every organization has rules for disposing of things. Don't get yourself into trouble by selling college property without authorization.

PART II: Design, Construction and Preparation

What is a racecar?

This might seem like a stupid question, but it is surprising how many different answers you will get. It is also surprising how often students end up wasting valuable time because they never decided what they are trying to create.

One simple, useful definition is this. A racecar is a vehicle that has nothing on it that is not required by the rules or that does not make it go faster. This definition gives you two important questions to ask about every design decision. Is it required by the rules? Will it make the car go faster? The third question for FSAE is, will it get us more points? Asking these will help when deciding between alternate sets of ideas or solutions.

Common Misconceptions

A common misconception is that one part of your car is most important. Some people will argue that the engine, chassis or suspension is most important. There is no one most important part of the car. A racecar without power is not competitive. A racecar that won't turn is not competitive. A racecar that won't stop is not competitive and is going to injure someone. A racecar that won't last is not competitive. The car is a collection of systems that must be integrated. It must accelerate, brake, and corner well. It must be inexpensive to manufacture. A car is a complex system that solves a complex problem.

Another misconception is that FSAE is a good place to develop new technology. No FSAE team will have the knowledge and resources to develop brand new technology and still meet eligibility requirements for members. You can be innovative. But the place to do it is packaging existing parts and technology. Some teams use new technology developed at their universities. Some teams use new materials or parts that are donated to them by manufacturers who want to showcase their products.

Very little in a modern racecar design is new. The first double-overhead-cam four-valve-head race engine appeared in 1916. The first stressed skin monocoque chassis was built around the same time. Electronic fuel injection was developed in the 1950s. Tubular space frame chassis were state of the art in 1920's aircraft. Composite materials date back to at least the 1940s (several hundred years if you count adobe as a composite material). Experiments with anti-lock brake systems were being carried out in the early 1950s. CNC machining has been around since the early 1970s. Much of what we think about as "high tech" has been around for longer than a lot of you who are reading this. It takes a long time and a lot of development money for technology to reach the point where it is reasonable to put it into a $5500 racecar. The skill that is most important to develop is to be able to use what is available to you. If you are interested in developing really new technology, there are design competitions better suited than FSAE.
A final misconception is that competitiveness in the FSAE comes from having the best car at the competition. Competitiveness comes from having the best combination of car, drivers and presentations. The team with the most points wins the competition. If you want to win, make decisions that add more points to the total at the competition.

Most of the points are available in the driving events. The driver is the biggest variable in determining how well a car will perform. It is no accident that Formula 1, CART and NASCAR drivers are the highest paid professional athletes in the world. In FSAE race preparation, driver training and selection are routinely neglected. At the time of this writing, only a handful of teams have come up with effective ways of getting drivers trained. For a lot of teams, good drivers happen by chance and not by design. Hopefully more teams will develop a systematic approach to driver training and selection.

Lessons Learned the Hard Way

Lesson Number 1 - Make it SIMPLE

Tattoo this on your forehead, put a note on your bathroom mirror, or use it as a meditation mantra. Do whatever it takes to burn it into your brain that you are going to make the car as simple as possible.

First, keep in mind that you will not be able to come up with a completely new design each year and get it built and running in nine months. One key is to reuse any good designs you have from previous years. If you have a system from last year's car that works and works well, use it again. Make minor improvements if appropriate but keep major redesign work at a minimum. Save your time and energy for the systems that were less successful in previous years.

For any system or part that requires major redesign, keep it simple. You realize after you have designed and built a few pieces and systems that it is harder to build something simple than to build something complex. It is easy to make things that are complex and heavy. It is harder to build things that are complex and light. It is hardest of all to build things that are simple and lightweight. To be competitive you make things simple and lightweight.

Simplicity is hard to achieve because it takes the most thought, planning, and design iterations. Simplicity pays handsome rewards. I have read that William Kettering, the head of GM engineering when such landmark designs as the small-block Chevy engine were conceived and developed, had a sign on the wall of his office that said, "Parts left off weigh nothing, cost nothing, and don't cause service problems."

One of the non-technical reasons for keeping designs simple and parts count low is that for a manufacturer there is less inventory to keep track of and inventory = $$$. This becomes important in your Sales Presentation. For you, the racer, it means carrying fewer spares to the track. You want to minimize, not just the total number of parts, but also the number of different kinds of parts.

Another concern is that more pieces take longer to assemble. Assembly time must be counted in the cost report. Longer assembly means more time in the shop building the car and less time driving it. At the competition, things break at the worst times. Often you must tear half the car apart to fix it and there is only an hour until you must be at the starting line. This DOES happen. The more pieces to assemble, the less likely you will make the race. You also have more opportunities to assemble it wrong. You will be embarrassed and could be injured when this happens. I have seen a car fail because students in a hurry forgot to put nuts on the bolts that hold suspension arms on the car!

Lesson Number 2 - Force = Mass x Acceleration (F=MA)

The point of building a racecar is to maximize acceleration in any direction the driver wants to go. Applying simple algebra, we get Acceleration = Force / Mass (A=F/M). F (force) is effectively limited to 80-90 horsepower by the engine intake restrictor. The only unrestricted way to make a faster car is to minimize M (mass). The engine is in many ways the heart of the car. However, the strongest heart can only do so much if the rest of the body is overweight.

Lesson Number 3 - Packaging and Integration Drive 90% of Design

One of the most difficult things about designing an FSAE car is thinking of everything that needs to be mounted on the car and then integrating it into the design. This is the first major design and prototyping project many of you have worked on. What often happens to inexperienced teams is that major components are designed and built, then the team starts assembling the car and immediately runs into things needed to make the car work that no one thought of. It can be as simple as nuts, bolts and brackets, or it can be a major system. You must plan where to package all the minor as well as major components. It takes time up front but saves time overall. If you are not thinking about integration issues all through the process of designing and building your car, you will spend countless hours trying to figure out how to mount and package critical things like fuel tanks, intake manifolds, and batteries that could have been packaged easily if more thought had been given to where to put them in the first place. For example, a team finds the perfect location to install a unit, only to realize that this installation will require-moving a frame tube half an inch or more in a non-critical direction. By the time the frame is welded up, it is too late to make such changes. Since most of you are engineers, placing high in the design event carries high prestige. It is important to the future of the team and your career to do well.

Lesson Number 4 - Read the Rules

With amazing regularity, students don't read the rules and design things that must be altered substantially to be legal. These parts almost always become heavy, complicated, expensive and failure prone. Anytime lots of bits and pieces get thrown together at the last minute, the whole car becomes heavy, cluttered and failure prone. Last minute fixes are easy to spot. The design judges do see them and deduct points. It wastes time you could be driving or sleeping, something no Formula team ever gets enough of.

Lesson Number 5 - Allow Enough Time for Details

One of the lesser-understood aspects of designing an FSAE car is that the smallest parts take the largest amount of time. Typically, the major components of the car, the frame, suspension arms, intake and exhaust system, etc., take about 30% of the total time to build the car. The detail work, like pedals, pedal mounts, motor mounts, fuel lines, paint, wheel hubs, instrument panels, differential mounts, half shafts, shifters, wiring, brackets, spacers, fuel line routing, brake line routing, steering wheel mounts, steering column mounts, throttle cable, break light switches, chain guards, and oil seals, take the rest of the time. This is perhaps the most important work. It is said often that God is in the details. Regardless of religious aspects of doing a good job on the details, the details are what separate the best from the also-rans. Time must be budgeted. Well integrated systems and components are a big part of what makes a racecar competitive.

Novice car builders always grossly underestimate the time it takes to have a vehicle on the ground and running well. When I was working on my first FSAE project, an experienced member told me to use the rule of pi when planning any part of the car. The rule of pi states that when you have made your longest possible estimate of time needed to do something, multiply the estimate by pi (3.14) and that is the minimum amount of time that it will take to get it done. It works! Things always happen that you can't plan on. A machine shop is closed at a time when it is supposed to be open. You need data from someone who just found a new boyfriend or girlfriend or, worse, broke up with one. Someone breaks a tool that is critical to your project. Your professor decides to make a course more "challenging." You get called for an interview with your dream company. Your parents see your grades and demand changes. All these things happen to students while trying to finish a simple part.

A misconception of many newbies is you can design, build and install a part and it's done. It is never that simple. A racecar is always a work in progress as is every part on it. It is not unusual to go through three or four iterations of a basic design before you have something good. It is also not unusual on your first three or four projects to get halfway through building a part or system and then think of a substantially better way to solve the problem. It is easy to design something that can't be built with the tools you have. A typical sequence of events goes like this. Design a part. Redesign because you had better idea. Start over because you can't buy the right material for the new design. Redesign because the parts you attach to have changed or you realize you forgot something. Redesign and build, test. Find problems. Make more changes. Retest and make final tweaks. Suddenly, the part you thought was going to take two days to finish has taken two weeks.

Lesson Number 6 - Get the Electronics Working Early

One story I have heard from many teams goes like this. "We had a new engine person this year and/or we started using a new fuel injection system. The engine teams worked hard to design and build an intake and exhaust. When those were done in April, they started hooking up the electronics. We had a lot of problems. The engine didn't run until two weeks ago. It isn't running right and we have had almost no seat time." For some reason, the uninitiated (this included me) tend to think that setting up fuel injection or other engine electronics is going to be easy. It is not. I think we are lulled into this by the relative ease with which you can set up a stereo or a PlayStation. I have never been involved with student-built fuel injection, but I would guess the problems are ten times as complicated as commercially available equipment. Hooking up the wires is relatively easy. However, that is just the beginning of the process. Each wire is connected to a sensor. The sensors must be mounted somewhere. Almost none of the engines commonly available for FSAE were designed with EFI sensors in mind. You are on your own to find a workable placement and build the mounts.

The bigger problem areas are the crank position and (if you are running one) cam position sensors. These usually consist of magnetic or Hall-effect sensors that generate a signal from their proximity to a trigger wheel. The trigger wheel is a piece of metal attached to the crank that has teeth machined on it. Both the sensor and the trigger wheel must fit someplace on the end of the crank where the engine designers didn't leave room for it. This takes a while. This is where you need electrical engineers. Sensors and triggers must be in exactly the right proximity to each other to get a signal the computer can read.

You must start installing, tweaking and debugging the engine electronics as early as is humanly possible. This must start before you have your intake and exhaust systems designed. Teams lucky enough to have a dynamometer need to get the engine installed on it as soon as the engine is in your possession. If you don't have one, build a test stand. It need not be fancy. It just needs to be something you can mount the engine on to run it long before the car is finished. It is going to take quite a while to design and build the final intake and exhaust for your car. Don't wait until they are done to get the engine running; have it running before your school breaks for Christmas/New Year. Create some temporary intake and exhaust manifolds. They don't have to be legal or even practical for the final car. You need to do system debugging.

Assuming your electronics are working correctly, chances are very good the fuel and spark maps are nowhere close to what will start the engine, and have it idled reliably. Again, barring electrical problems, you can plan 20-60 hours of trial and error just to get the engine to start and run reliably when cold or hot. Remember the rule of pi.

Lesson Number 7 - Avoid $2 Part Failures

In Formula SAE, as in other forms of racing, you will see spectacular failure of major components occasionally. Most of the problems that sideline cars come from parts that cost $2 or less. In fact, many spectacular failures start from something simple like a bolt breaking and jamming itself into otherwise perfectly functioning machinery. Many FSAE cars are sidelined when critical junctures of the cooling system come apart. Hose clamps fail regularly, most often because they are improperly installed or reused too many times. Be sure that you are using parts in the manner that they were designed to be used or in a way that will not overtax them. In 1995 an MSU student used a plastic 90-degree pipe designed for garden hoses in the cooling system. It lasted until the last driver in the last event of the weekend had just pulled off the track and shut the engine off. We were lucky. If it had failed one minute sooner, the car would not have finished the event and MSU would have placed closer to fortieth or fiftieth instead of twenty-eighth.

Suggestions to Get You Started

Inventory

One of the smarter solutions that teams use for planning and keeping track of everything that must go on the car is to take an existing car that is race ready and legal and inventory all the parts on it. Start with large items like the chassis, body, engine, control arms, springs and shocks and move down to all the little parts like nuts, bolts, washers, shock mounts, shift lever, brackets, and cables that take the most time to create. Once you have the master list of everything on the car, use it as a guide to create the new vehicle. As the new design comes together, keep referring to the list and check off items as they are finished. Keep asking the questions, "Have we planned for X? Do we know where Y is going?" It will be time consuming to catalog all the parts. However, in the long run it can result in a much better vehicle. Since you must have an inventory of parts for the cost report on your new car, this inventory also becomes the framework for your cost report.

Chassis

It is critical for the chassis to be done early, or at least to be designed and a full-scale model built. Packaging drives 90% of the design decisions. The chassis is the package that everything must fit into.

There are three sets of critical "hard points" that you need for the design. They are the cockpit dimensions and control locations, the engine/powertrain dimensions, and the suspension points. Engine dimensions are the easiest, assuming you have an engine. As soon as the team has formed, put a crew on the job of measuring the engine in every dimension, especially the mounting points. Next, work up measurements for the driver's cockpit. To test ergonomics, a mockup of a cockpit can be something box shaped that various people could sit in to try different positions for the steering wheel, pedals, shifter, and switches. Find an arrangement that is comfortable, makes everything easy to use and puts the driver's weight as low as possible. You will need adjustments for different size people, such as a combination of padding and adjustable pedals. Measure how much room is needed for the driver to move, paying attention to the elbows, knees, and feet.

The suspension points often take the longest to specify. The suspension geometry must balance a lot of conflicting elements and it takes time to get to a workable solution. By the time you have gotten the driving position together, the suspension points need to be ready also. From there you sit down with the rules and your knowledge of structures and play "Connect the Dots."

It is usual for these points to come into conflict. The steering rack regularly appears between the driver's feet or legs. The only thing you can do is compromise. The temptation is to compromise toward the functioning of the machine and away from driver ergonomics. However, if the driver can't use the controls easily, the driver is not going to go as fast. The driver is the biggest variable in dynamic events. Make the job as easy as possible. You must be able to use all the controls, throttle, brakes, shifter and clutch, AT SPEED!

One thing that helps to focus on your task is to have a picture of what the car will look like when it is finished. This is difficult without a frame, but it is possible to guess within about a centimeter where most of the hard points will be and create a picture from that. You can certainly get close enough to begin designing the major structures before all the hard points are set. The sooner people know what the space looks like, the sooner they can eliminate ideas like three-foot-long intake manifolds and focus on something that will fit and do the job.

In 1996, as this is being written, you need to build a $6000, 500-lb. car. You need at least a month of driving to tune and debug it and for the drivers to get seat time. If you want to be a contender for the overall win, this is the price of admission.

Powertrain & Electrical

The powertrain and electrical systems on an FSAE car are straightforward. Everything is based on technology that has been proven over the last 40 to 100 years. Do not underestimate the amount of time it is going to take to make everything work. You will gain a new appreciation for the effort that went into making your daily driver work as well as it does.

The question that the group almost always starts with is, "What kind of engine are we going to use?" It is an important question. The car doesn't go anywhere without an engine. However, there is a lot of work that is independent of the engine that can and must be started while engine decisions are still being made. An engine needs to be connected to a differential. The differential must be connected to C.V. joints and half shafts to get the power to the wheels. If you use a chain or belt to transmit power to the differential, the chain is going to stretch and will need to be adjustable somehow. A sprocket must be attached to the differential. You will have to engineer that. The pieces that connect the differential to the C.V. joint almost always must be designed and built by the team. You can be 99% sure the half shafts will need to be a length not commercially available and the team will have to design and build those also. All these pieces need to be strong enough to transmit the engine torque, and brake torque if you are running inboard brakes, and yet be light and not cost too much. It takes thoughtful design with attention to detail and a lot of precision machining. This attention to detail separates the top teams from the also-rans.

A project that can be started before the engine decisions are finalized is the cooling system: This is VERY important. The racecar that can't cool can't do anything else. The final specs of the system will depend on the engine decisions, but there is plenty of groundwork to be done. Cooling system calculations are no mystery. There are probably a hundred million vehicles on the road each day that don't overheat. However, someone on the team must learn how it is done. Someone must build or borrow a test rig to measure all the relevant temperatures, pressures, and flowrates. If you are using a liquid cooled engine, you must source the heat exchanger or radiator from somewhere. Someone must make sure it is mounted in the chassis in a way that it won't be damaged, has enough cool air coming into it and has somewhere for hot air to escape. Don't make any assumptions that a stock bike radiator will be enough. Countless races have been lost because of this.

One last item, which needs thought and planning, is gear ratios. The final drive ratio is the only one that you can change easily. If your team has the resources to custom configure the internal ratios of the gearbox by the time you read this, congratulations! You have a level of sophistication that exceeds anything I could do. Whether changing internal ratios or just the final drive, the engine torque must be usable to the drivers in whatever event they are driving. There are good books on the subject. One mistake that is often made is gearing the car for the acceleration event only. If you are only going to run one gear set at the competition, optimize it for the endurance event. That is where the most points can be earned, and the most driving will be done.

Suspension

The suspension work begins with determining the suspension geometry. This ultimately determines the mounting points for the steering rack and control arms. There is a lot of work that can be done while the geometry is being worked out. All the parts that the team does not build, such as tires, wheels, springs, shocks and spherical bearings, a.k.a. rod ends, heim joints, uniball joints, must be sourced from somewhere. The challenge is to find parts that are appropriately sized for a car as light as an FSAE. If you copy exactly Formula Fords or other cars with a comparatively high minimum weight, your parts will be oversized for the application. I have seen cars using spherical rod-ends that could support suspension loads in a Chevy Camaro. Rod ends are available in many sizes. Size appropriately. Shocks built for cars weighing 4 to 5 times as much as an FSAE appear regularly. Larger parts are more expensive and add weight. The newest trend is to use high quality mountain bike shocks and springs.

General Hints

Do not make things any larger than needed. Think things carefully through. Remember that your part must stand up to more than just average use. Suspension and frame parts must be able to withstand the occasional jolt from hitting large bumps. Powertrain people need to remember that someone will inevitably spin the engine to 9500 rpm and dump the clutch hoping to do a John Force style burn out. By the way, it doesn't work. FSAE cars rarely have enough torque to get a good pair of slicks smoking.

Remember that racecars are inherently high maintenance machines. It is entirely appropriate to use or design a part that will wear out quickly. This is not an excuse for being shoddy or not doing your homework. It means that parts that wear out regularly like brake pads and disks, suspension bearings and bushings, and drive chains can be sized for a short life between replacement. You must be anal-retentive about checking the whole car each time before it is run. Rebuild or replace anything that is questionable.

A final hint. Where possible, iterate off an existing design. It is much easier to take an existing part or system and analyze the strengths and weaknesses than to start from scratch, especially if this is the first car project a student has worked on. Your school has a lot of tools that can help you figure out where to reduce cost and mass.

Full Scale Model

Creating a lightweight, well-integrated car means packaging everything in three dimensions. To see and think in three dimensions, the solutions used in the auto industry are appropriate for FSAE projects. You can build a full-scale mock-up of everything to see if it all fits, or if you have access to computers with the sophisticated CAD tools that are available, you can generate virtual models of your car. They take more drawing and software expertise, but the function is the same. On complicated projects they save time and money.

Lessons Learned from FSAE Competitions

Static Events

Be visual. You need to communicate a lot of information in a short time. Pictures are worth at least a couple hundred words each. Think of ways to graphically represent what needs to be said.

Cost Analysis & Presentation

The bulk of the work is the cost report. The presentation is to clarify and/or defend things that the judges don't understand. It is mostly reactive for the presenters. The presenters should ideally be the people who compiled the report. Between them, they need to know where everything on the car was included in the cost report. It is hard to argue and negotiate with judges when you are staring at each other saying, "Uh... didn't we report the pedals in the chassis section? Maybe they're in with the brakes." It looks unprofessional. The judges expect you to have your stuff together. They might be inclined to be charitable to college students except that other schools put on the kind of presentation they are used to seeing at their jobs every day.

The cost score comes from the price of the car and how easy it is to understand the information. They take specific numbers and compare them to the average or median prices from all the reports for the item. If it is below it is adjusted upward with an associated penalty until they see the car and verify that the item is indeed cheaper. If you don't include an item, then they adjust to the average with a penalty unless they can verify that the car doesn't have something. Even then it is discretionary. There are some things they require on every car. For example, you will be penalized for not including paint for a steel chassis. It can be a $10 item if you put just enough Krylon on to keep the thing from rusting. The judges know what many things should cost. If you deviate from that, then you'd better have documentation in the form of receipts or price quotes from suppliers. Every novice team tries to save money by under reporting assembly time for each subsystem and the whole car. The judges are wise to that scam and won't fall for it.
It is a good idea to begin each section of the report with a short paragraph describing the pieces of the car and how they work, something like, "The brake system has dual master cylinders attached to the pedal through a balance bar mechanism. The pedal is of our own design and construction. The balance bar components were purchased. There are three brake calipers, one on each front wheel and one acting on the differential in the rear..." The goal is to make it clear exactly how the thing is put together. A good test for whether the report is complete enough would be to hand it off to someone not familiar with the car and see if that person understands it and what questions are asked. The easier it is for the judges to read the report and understand what you have done, the higher the score will be. These are relatively easy points to get. It takes time to get a good cost report together. Start it at the beginning of the year.

Since 1995, the cost judges have been running a seminar at the competition on how to prepare a good cost report, and as a result, the quality of the reports submitted has improved dramatically. What was an outstanding report in 1995 became just average two years later. The trend is toward more and more complete documentation. Filling a three-ring binder with a three to five-inch stack of documentation is not uncommon. Try to get logistics management, accounting, and industrial engineering students involved. They will be able to add insight. Anyone reading your report should have no questions as to what any part looks like, who is going to manufacture it, how it will be manufactured, how long it will take to assemble, and how much the materials cost.

Design Competition

The design competition is the most prestigious of all the static events. Winning it gives bragging rights for the year. There is a certain amount of luck to winning the dynamic events. Track conditions change. Things are shortened or rescheduled because of weather. Sometimes slower traffic holds you up. Scoring high in the design presentation will help to make up for problems in other events in the eyes of sponsors and the university.

There are really two things that you are being judged on in the design competition. The first is the actual car itself. The second is how well you understand it.

The first and most important thing in the design event is for the presenters to be assertive. Typically, the judges will come and start looking over the vehicle as a whole and at certain details. A lot of them don't ask questions. They look at what you have done and evaluate it. They are human beings, not gods. They make assumptions about what they see, and their assumptions can be incorrect or right on. They may not see the best thinking or understand why something is the way it is unless you explain it to them. They are also evaluating some 80 plus other cars and may just not have time for the logic of some particularly good idea to leap out at them. Judges also have preferences. They know a lot about what does and what does not work. You must be ready to explain clearly what you designed and why you made those choices for your car. Presentations put together at 4 a.m. on the way to the competition after a week of all-nighters will not get you much.

Once you have a conversation going with the judges, you must demonstrate knowledge and reasoning. The underlying question a judge has is why. Why did you do it that way? What was the thought process? Do you really understand what you have? Engineering is, at its heart, an art form, the art of choosing compromises that best solve the problems presented. It is not only important to intelligently present the advantages of each aspect of the design but to know its limitations as well. The judges want to see that careful thought and analysis went into the decisions made. It is necessary to do your careful thinking about the design decisions up front. How will you explain it to the inquiring mind of someone who has been racing all his/her life? The judges also want to see data. You may have had the most brilliant thought process in the history of mankind to make the design decisions you did. The judges are going to be skeptical unless you can show them real data that proves your point.

Again, it is important to have visual aids. When the car is put together, some of your best work may be buried in the middle of an assembly somewhere. Pictures of how things fit together help a lot. Photographs of the car during construction, exploded assembly drawings, graphs of horsepower and torque can all help to communicate how thoroughly you have thought out your design choices.

You need to have most of the team on hand so the presenters can refer a question to the person who designed and built a particular item. It is also useful for junior members of the team to see and hear everything so they can be better prepared for presentations in future years. You also need to have tools there in case anything needs to be taken off or taken apart to show some particularly ingenious bit of engineering.

Sales presentation

When preparing the sales presentation, think about what you would want to know if you were a customer. If you were a non-professional weekend autocrosser buying one of these cars, what would you want to know about the car? At a minimum, probably performance and price. You would also want to know what it looks like, parts availability, and ease of repair. Think about what else you would want to know and include that information in the presentation.

The concept of the competition is that you are making the sales pitch to a manufacturing company that is considering building and selling 1000 of these racecars. If you are the manufacturer buying a design, what will you want to know? You will ask everything that the non-professional weekend autocrosser would ask because you must sell cars to these people. Additionally, you are going to want to know how difficult it is to build this car, what inventory is required for construction and service, and so on. A manufacturer will want to know the processes used to make your decisions. What computer modeling was done? How much testing has been done? No one wants to buy a design that is going to break regularly or is untested.

When you have thought through the customer side of things, start collecting and organizing the information you will need. Think about what makes your car unique: Your original design features? Your creativity in using readily available, inexpensive parts in new, appropriate and innovative ways? How you saved money, inventory or assembly time by the simplicity of the design of part x or system y?

Finally, as with all the other presentations, be visual! Make sure you have charts, graphs, photos, and spare parts to illustrate the message. Again, make sure the message is clear and the visual aids add to that clarity. It is easy to get caught up in making charts, graphs and photos that look cool and forget about the message. In 1994, MSU showed up with a 4-minute professional video that outlined the processes used to create the car that year. The presentation judges said afterward that their first reaction when they saw that our presenters had a video was, "Oh no." A previous team had shown up with 10 minutes of home movies of their car driving around in circles.

Dynamic Events

The first and most important thing is to be safe. Pay close attention to the officials and corner workers. They will see things you don't. I have seen at least three cars catch on fire where the driver was clueless until s/he was black flagged. In the endurance event, move over in the passing lanes when someone faster is behind you. You will be penalized if you don't. Many places in the overall standings have been lost by drivers' inattention or by big egos in the passing areas. Drive within your limits and the car's limits. Few of us are blessed with natural genius for driving fast like Michael Schumacher or Dale Earnhardt. Don't put yourself, your team or the event staff at risk by trying to get more out or the car than there is.

One of the most heartbreaking and often embarrassing things you see at every FSAE is someone with a great run that ends because of something simple that was overlooked before the car hit the track. You must develop a systematic and consistent way to check all the critical nuts, bolts, hose clamps, fittings and electrical connections each time before the car goes on the track. This is a safety issue. You do not want critical parts of your car, like wheels, falling off when you are at speed. One of the simpler ways to keep track of your preparation is to create a set of checklists for each part and system of the car. This gives you a written record of what has been checked over before you drive, and you don't have to rely on the memory of someone who has not had enough sleep for the last three or four weeks.