AN ABSTRACT OF THE THESIS OF

Trenton J. Carpenter for the degree of Master of Science in Mechanical Engineering

presented on June 13, 2011.

Title: Global Distributed Design of a Formula SAE Race Car

Abstract approved:

Robert K. Paasch

Future engineers need to be competitive in today's expanding global industries. They must have capabilities beyond standard engineering practice. In an attempt to develop students capable of working in a globally distributed design and manufacturing environment, Oregon State University (OSU) and Duale Hochschule Baden-Württemberg Ravensburg (DHBW) have developed a senior capstone design project in which students design, build, test and race two identical Formula SAE race cars as a fully collaborative effort. The main intention of this project was to develop an innovative educational experience for students entering into today's globalized engineering society. In order to accomplish that goal, the project's team management structure had to be developed to allow the project to be sustainable year-to-year and yet highly functional. Data exchange and communication tools were developed to allow students to accomplish their everyday tasks as a member of a distributed design team. Finally global supply chain issues were addressed through the creation and implementation of a custom part information tool allowing parts to be distributed to the two schools. After three years of developing collaboration tools and procedures, students were able to learn and apply practical skills beyond the classroom in an

international engineering setting. Ultimately, students participating in this project would become highly desirable engineering graduates through their experience working as a member of an internationally distributed design and manufacturing team. This paper discusses the steps taken to develop the management, data and communication tools necessary for OSU and DHBW to work collaboratively on a Formula SAE racing vehicle. This paper was also intended as an outline for other schools; it conveys the lessons learned and the requirements necessary for universities to collaborate on student engineering projects.

Global Distributed Design of a Formula SAE Race Car

by

Trenton J. Carpenter

A THESIS

submitted to

Oregon State University

in partial fulfillment of

the requirements for the

degree of

Master of Science

Presented June 13, 2011

Commencement June 2012

Master of Science thesis of Trenton J. Carpenter presented on June 13, 2011

APPROVED:

Major Professor, representing Mechanical Engineering

Head of the School of Mechanical, Industrial, and Manufacturing Engineering

Dean of the Graduate School

I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Trenton J. Carpenter, Author

ACKNOWLEDGMENTS

The creation and success of the Global Formula Racing team was by no means the individual work of this author but rather the combined efforts of many. In such a large and involved project, it is difficult to clearly define where one’s responsibility ends and other’s begin. This author would like to acknowledge the following individuals for their equal and invaluable contributions:

Dr. Robert Paasch

Dr. Thomas Nickel

Dr. Belinda Batten

Bernd Johne

Michael Johne

Leanne Lai

Bill Murray

Tino Papaccio

Chris Patton

Christian Schramm

Daniel Segler

Special thanks must go to Leanne Lai, OSU’s MIME computer support technician. None of this could have been possible without her unwavering support and hours upon hours of volunteered time.

TABLE OF CONTENTS

LIST OF FIGURES

1 Introduction

As global product design and development continues to expand in today's society, it is no longer enough for graduating engineers to simply have engineering, business and technology skills, [1], [2], [3], [4], [5], [6]. In order for future engineers to be competitive in expanding global industries they must have skills to communicate technical information across international borders and to understand cultural differences and international regulations. They must be able to work as a team regardless of the members' geographic location [7], [8]. In an attempt to develop students capable of working in a globally distributed design and manufacturing environment, the advisors for the Formula Society of Automotive Engineers (SAE) racing teams from Oregon State University (OSU), a Land Grant University from the United States and Duale Hochschule Baden-Württemberg Ravensburg (DHBW), a Cooperative State University from Germany, have developed a senior capstone design project in which students design, build, test and race two identical Formula SAE race cars as a fully collaborative effort. In this project the schools' two Formula SAE teams would combine forces to become the Global Formula Racing (GFR) team.

Formula SAE is a collegiate student design competition organized by SAE International® in which student teams design, build and race an open wheeled Formula style race car according to rules published by SAE International [9]. The concept behind Formula SAE is that a fictional manufacturing company has contract a design team to develop a small Formula-style race car [10]. This prototype design would then be evaluated for its quality of design, marketability, manufacturability, cost and racing performance.

Designing and manufacturing two identical Formula SAE race cars with a distributed design team of students located in two countries, separated by an ocean and nine time zones, would prove to be a considerable challenge. Academic schedules, global team management, international communication, software integration, global supply chain and interpersonal cultural differences all had to be taken into account for the project to be a success. Data exchange tools, interpersonal communication tools, protocols and purpose-made training material for their use, and standardized management processes all had to be developed before students could begin working together effectively.

Several years prior to the creation of GFR, OSU and DHBW participated separately in Formula SAE competitions for their undergraduate student's "senior capstone" projects. These projects were meant to give students the opportunity to put what they had learned in the classroom into practice on real world engineering problems. Combining the "real world" elements of design, manufacturing, testing and racing a Formula SAE race car with the global elements of distributed design teams, international supply chain and international team management, students on the GFR team project would get a truly unique educational experience in global distributed design and manufacturing.

Before a collaborative effort could begin, many questions had to be answered. What was the purpose of collaborating? What advantages could be achieved that would outweigh the added complications? How likely would a successful venture be? Ultimately, any collaborative effort would be more complex than a localized effort [2]. With the addition of a global collaboration; a management structure, product logistics, data exchange and communication, complexity would increase and introduce risk to the project’s success. So why collaborate?

The answers have been many and varied. The most prominent of which has been the ability to leverage the specialized capabilities of multiple entities into one consolidated effort. Other reasons may be to divide workload in order to increase efficiency, increase credibility, to create a feeling of community [11]. Or, the creation of a collaboration could be simply for the benefit of the educational experience, as many institutions have already done [1], [6], [7], [12], [13], [14], [15], [16], [17], [18], [19], [20], [21]. Whatever the reasons, the benefits had to be greater than the complications or risks for a joint venture to have been considered a viable endeavor.

In the case of OSU and DHBW, the main goal of a collaboration was to create an innovative educational experience for students in global distributed design, manufacturing and team management. In addition, students would be able to leverage the unique capabilities of each university’s Formula SAE team, giving a combined team more expertise and broadening their reach to manufacturers and suppliers.

This paper discusses many of the important issues the team faced while developing this collaboration; the creation of requirements/prerequisites for two universities to begin a collaboration, how to structure and manage an international team of students, and the development of the data, communication and supply chain tools students would use in their every day collaborative tasks. The goal of this paper was to give insight into how to approach the development of a student based collaborative design and manufacturing project such as the one created by the GFR team.

2 Collaboration Prerequisites

Many logistical details had to align for a partnership between two universities to function. The leaders of the GFR team determined that the following prerequisites would be necessary for two or more schools to begin collaborating on a complex student project such as a Formula SAE race car.

1. Relations, Purpose & Trust- there would need to be some pre-established relations between institutions prior to the creation of official agreements to collaborate. A purpose for the collaboration would need to be clearly defined and agreed upon by all collaborating parties. Finally, establishment of trust and understanding between faculty and department administrators, at each school and between schools, would be essential for long-term agreements.

2. Official Agreement- Contractual agreements would need to be put into place in order to ensure the needs, liabilities and commitments of each party were clearly outlined and agreed upon. Each side would have to understand the needs of all other parties while negotiating these contracts. Institutions may have very distinct differences in areas such as; legal liabilities, academic requirements and financial accounting. In addition, each party would need to agree to the scope, purpose and main goals of the project upon which the students would be working. All parties would need to come to a consensus of the contracts which outlined these requirements.

3. Departmental Support- A collaboration would need committed administrative support from all institutions. Without full and continued support from all institutions' Department Heads, the project Faculty Advisors and any other supporting faculty,

a partnership would inevitably lose direction or become embroiled in bureaucracy. These head individuals would need to be involved in the "Official Agreement" process outlined in prerequisite 2.

4. Compatible Schedules- All institutions would need compatible yearly academic schedules which would allow students to work simultaneously on a single project timeline. If the project were to begin at different times for each participating group, relationships between design teams would not be created and proper communication between groups would not develop. The side starting late would inevitably not be able to make up the knowledge deficit.

5. Marriage of Equals- Each partner would need to have equally strong and complementary strengths. It must be a "marriage of equals" or one side would be left supporting the other and the complications of a joint venture would quickly outweigh the benefits. In the case where responsibilities of partners would not be equal, it would be recommended to follow a "host-participant" structure akin to the one outlined in [14], [15], [16].

6. Technical Compatibility- Software compatibility would need to exist for effective day-to-day design work. Specifically related to vehicle design; computer aided design (CAD), product data management (PDM), finite element analysis (FEA), suspension analysis, engine simulation, computational fluid dynamic (CFD) software, and all other software where data exchanged would occur, would need to be compatible. The importance of this aspect, amount of time to install, implement, maintain year-to-year and amount of administrative support should not be overlooked or underestimated.

7. Social & Cultural Compatibility- A social/cultural understanding and compatibility between partners would need to exist. This would be especially true for international partnerships. Cultural differences, whether they are subtle or distinct, would need to be understood and taught to team members, either by faculty, team leaders or written documentation from previous teams. There would also need to be little-to-no language barrier between the collaborating parties if they were to be highly involved with each other's day-to-day activities.

8. Team Building- Expense and planning would need to be put into face-to-face team building. A webcam would be no substitute for personal interaction. While it would not be critical for the entire team to know each other face-to-face, it would be critical for key team members to know one another. As stated in [18], "social bonding, getting to know the team members and their wider interests, lies at the heart of relationship management and has repercussions for the health of a global supply chain." If a few personal relationships were to exist, the trust and understanding of those individuals would spread to others, allowing virtual teams to quickly become cohesive groups.

With these prerequisites met, the GFR team expected the highest likelihood of a successful collaboration. With these in place, work could move forward onto the development of the team's management structure and tools for students' day-to-day collaborative activities.

3 Project Management

The next step in building the GFR collaboration was to define the team's management structure. It would need to be organized such that it could support the unique demands of an international team of students who would build two FSAE race cars; one in the US and one in Germany. First, the existing management would need to be analyzed in order to determine which aspects needed to be kept, which to change and which to remove or improve. The program would need to be sustainable year-to-year so students could enter and leave the project without the team losing knowledge or capability. The program would need technically proficient leaders to advise the students with their tasks while allowing the students to do their own design work. Since the participating partners of the collaboration were from different countries, the management would also need to be able to address issues associated with cultural differences, time differences, distributed design difficulties and interpersonal conflicts.

Prior to the start of GFR's collaboration, each team had its own unique management structure. At OSU, leadership and advisory rolls were filled by graduate students who were capable of being highly involved in the day-to-day progress of the project. In contrast, at DHBW highly motivated alumni members with fulltime jobs provided guidance to the students through email and weekend workshops. This posed some interesting questions on how to integrate the two groups' responsibilities, considering the main purpose of each was the same, which was to advise and provide technical leadership. Yet, the advisors' roles were inherently different since at OSU, the advisors were students and at DHBW, they were not.

Article A4.1 and A4.2 of the "Formula SAE Rules" [9] convey that "design work and engineering decisions must be conducted by graduate or undergraduate students seeking a degree.” This meant non-student advisors (faculty, alumni and industry professionals) could give sound engineering advice but could not make design decisions for the students. Thus roles had to be clearly defined such that the two management groups could be integrated while not violating the FSAE rules. This structure will be elaborated on further in the paper.

The next problem faced by the management was the year-to-year sustainability of the program. From the simple nature of a senior capstone project, the students working on the project would change every year. At OSU and DHBW it would not be uncommon for ninety percent or more of the seniors to be new and unfamiliar with the project’s details. With such a high turnover rate, the knowledge and capability of the team could dramatically ebb and flow if knowledge was not kept within the team and transferred year-to-year.

Coupled with the high turnover rate, Formula SAE projects require a vast amount of knowledge from the students who engineer the vehicle, develop marketing plans, coordinate purchases, communicate with sponsors and manage the team. It would take several years of experience working with the team for students to become competent enough to manage the project or lead others in a particular discipline. Therefore knowledge transfer was a key requirement for the team and GFR built many modes of knowledge transfer into its organization to help facilitate year-to-year project stability, overcome steep learning curves and develop competent student leaders. These modes include:

- Graduate students employed as teaching assistants to the program, all of which would have several years of experience on the team.

- An advisory committee of highly knowledgeable and experienced mentors who would share their knowledge and experiences with the students.
- Underclassmen included in team and senior level projects in order to allow them to gain experience before they were given major responsibilities.
- Students exchanged between DHBW and OSU to promote team communication, cultural understanding, knowledge of institution's capabilities and gain experience.
- Clear requirements for project documentation built into senior capstone and graduate level projects to prevent "tribal knowledge".

To further the year-to-year stability of the program, the team's management would need to be capable of foreseeing and mitigating potentially damaging decisions which could hurt the program as a whole. An example of which could be inexperienced students choosing to make large changes to the high level design which would require more that a season's worth of work for the whole team. Therefore, the high level project scope for a subsequent season would be determined by the student leaders, faculty advisors and project advisors from the previous season. This group would be defined as a *Steering Committee* for the team.

Finally, a means for maintaining equality between the two sides was needed. To ensure the needs of both schools were maintained, all management levels needed an equal counterpart on the opposite side. This parallel management structure would require all members, top-to-bottom, to communicate with their international counterpart. This would also give each side equal means for negotiation of any disputed matter.

Moreover, this structure would provide a means to manage interpersonal conflicts within the team. As stated in [2], “overcoming cultural risks requires special human skills from the management.” With complementary management on each side, conflicts could be discussed by experienced individuals from both cultural standpoints making fair solutions easier to create with less risk of cultural misunderstanding.

After considering the factors discussed above, the structure of the team began to materialize as seen in Figure 1. The team structure was divided into three main tiers: Upper Management, Student Management, and Student Groups, where each role would be equally represented on each side of the collaboration.

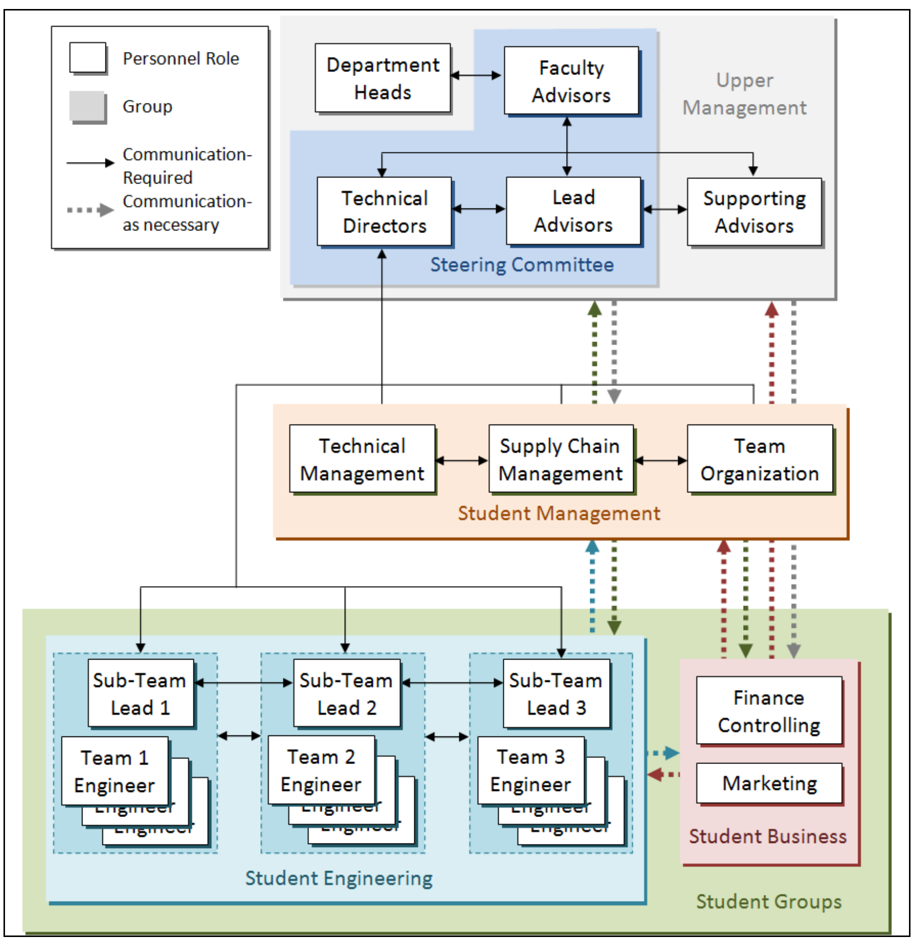


Figure 1: GFR management structure

Steering Committee- This group would be comprised of each school's Faculty Advisor, the student Technical Directors and Project Advisors who are the most involved and experienced with the student project. The Steering Committee would consist of approximately eight individuals but would always have an equal numbers of committee members on each side in order to equally represent the needs of each school. The ultimate purpose of this committee would be to define high level project scope and maintain the welfare and purpose of the collaboration. Decisions would be agreed upon through a majority vote if a consensus could not be reached. High level project goals would be defined by these individuals since the Faculty Advisors understand the needs of the school, the students Technical Directors would have the most up-to-date information on the status of the project and student capability, and the Lead Advisors would provide a wealth of experience and knowledge. It is important to note that while high level project scopes would be defined by the Steering Committee, engineering and business decisions would be made by the students.

Department Heads- These individuals are appointed by the university and lead the schools which support the project teams. These individuals provide school support for the project.

Faculty Advisors- These individuals would be faculty members, one from each school, and would assume departmental responsibility for the team. The Faculty Advisors would ensure that the students would have the tools needed to fulfill their academic requirements while participating in the GFR collaboration. These individuals hold ultimate say in the management's personnel composition to ensure all students have the proper environment to fulfill their academic requirements.

Technical Directors- This role would be filled by two to four of the most experienced students on the team, each with one or more years of experience and strong leadership qualities. They would be charged with high level system engineering decisions and other critical engineering decisions. These individuals would be engaged in daily communication with all levels of management and student designers and thus would also need strong communication skills. These individuals would be expected to have a driving interest in the success of the team and a positive “can do” attitude.

Key knowledge aspects would need to be distributed among these individuals. Specifically for the GFR team, the knowledge and expertise of Technical Directors would need to cover: vehicle dynamics, suspension design and manufacturing, engine tuning, simulation and maintenance, electronic wiring, data acquisition, drivetrain design and manufacturing, brake design, structural composite analysis and manufacturing, vehicle testing, vehicle driver training, CAD structure and management, supply chain management, and team finances.

Ultimately, these individuals oversee the fabrication of the vehicle and monitor build quality. It would also be the Technical Director’s responsibility to supervise students in their tasks and ensure teams were working together properly and communicating regularly.

Lead/Supporting Advisors- This group would be a board of project mentors comprised of individuals, each with one or more years of experience with the team. They could be students, university faculty or industrial professionals. These individuals would provide knowledgeable technical advice on specific topics. Lead Advisors would be those that were the most frequently involved with the students, the most knowledgeable on the project and would have time to commit to be members of the Steering Committee. The group of Lead and Supporting Advisors could be as large as necessary while still being manageable. Their purpose would be to guide student projects with engineering advice while still allowing the students to make their own engineering decisions. These individuals would be in regular communication with the Technical Directors as well as individual students. These individuals would evaluate student performance in their specific topic and provide feedback to faculty advisors.

Technical management- This group would consist of 1-3 individuals per school. These students would ideally have prior experience with the project, but this would not be required. Ultimately, these individuals would need to show strong leadership potential and communication skills. They would communicate critical information between sub-team leads, coordinate group work sessions during both design and manufacturing phases, identify critical deadlines and ensure all team level deadlines were on time. They would communicate daily with the Technical Directors about engineering decisions and team progress. These individuals would also coordinate approval for purchases for products selected by student engineers.

Team Organization- This group of 1-3 students per school would be responsible for coordinating team events, sponsor visits, team clothing, developing marketing plans, coordinating sponsorships, collecting team money, collecting team waivers, maintaining the team website and other public relation venues. This group could be comprised of several smaller sub groups as necessary and would be advised by individuals from the Upper Management.

Supply Chain Management- This group of 2-4 students per side would be exclusively responsible for coordinating part-sourcing for the team. They would be responsible for developing and maintaining tools to help track: part sourcing information, manufacturing processes, international shipping information, taxes and tariffs, for each part. These tools would be provided to the student engineers to fill out the information for their parts and that information would be used by the engineers and team leaders to identify sourcing locations. The Supply Chain Management group and the student engineers would then bear equal responsibility in ensuring that all parts arrive in a timely manner and at their correct destinations. This group would be advised by individuals from the Upper Management.

Subteam Leads- Student subteam leaders would be identified as those showing strong leadership traits within their group and/or those excelling within their group with their day-to-day tasks. Due to these individuals' highly motivated nature, they would naturally know the most about their subteam's project. Technical Directors and Technical Management would communicate system level changes to these individuals and the Subteam Lead would then communicate that information down to their group. They would also be responsible for monitoring the progress of their subteam to ensure it was on task, on time and on budget.

Subteam Members- These students would be tasked to work within small subteams of 2-4 on specific topics defined by the Upper Management. These individuals would be responsible for the design, manufacturing, testing and documenting of their project. Particular care would need to be spent on documentation of their processes and experiences as this would be the direct means for the evaluation of their academic grade and transferring their knowledge year-to-year.

The definition of these positions made the hierarchy of the team and roles of individuals clear to all members involved. With the team's management structure defined, tools could be developed for individuals to begin using. Data management, communication and supply chain tools could be developed such that individuals at each level of the team could have access to appropriate information for their day-to-day tasks.

4 Data Management and Communication

With the team management in place, the next step to developing the collaboration was to put the tools in place that the team would use to communicate, share data and manage their time. As stated in [22], “global organizations can be successful only if they have reliable systems in place that allow speedy access to information in a variety of forms, from data to complex drawings. Global organizations will need information technology (IT) systems that will permit fast, reliable transfer of data to any point on the globe”. This was precisely the GFR team’s need for product data management (PDM) software. With a time frame of 12 weeks to design a race car and 30 weeks to build, test and race two identical copies, time could not be wasted with inefficient data exchange. This meant the GFR team would need fast, reliable transfer of information between its two schools. Moreover, DHBW students spent two of their four terms abroad at one of their employers’ sites elsewhere in Germany or the world. This meant information transfer and communication would need to be possible from anywhere on the globe. Additionally, time could not be spent teaching students to use an overly complicated system, thus the PDM system would need to be simple and easy to learn.

Since CAD data comprised the majority of the team’s product information during the design phase, it was critical that all designing parties had access to the same parts, assemblies and drawings. With nearly one hundred students, all potentially modifying data within the same CAD model simultaneously, files would need to have user permission and file change management to prevent overwritten, deleted or out of date information. Physical geographic separation would need to be considered for users to have adequate connection speeds. Also, the system had to accommodate and work with the different network protocols and firewalls at each university.

After reviewing the resources available to each school, an appropriate CAD software was selected. It was essential that the same version of the CAD software was used regardless of computer or geographic location. Licenses purchased by each university had to give designers access to the same capabilities within the software. Since both schools received their licenses through separate distributors and under different contracts with the software company, coordination of both institutions' IT departments was needed.

Beyond CAD data, all other metadata also had to be managed. This data included any documentation, purchasing, manufacturing information, shipping information, schedules, or pictures, for a given part. Product data management softwares provide data storage, document management, revision/change and access control, project management tools, workflow management tools, and simple interfaces with other software programs. PDM systems come in many configurations [23] and scopes thus GFR had to identify which was best for its use.

With the above information in hand, several requirements for GFR's PDM system were defined:

- Fast, reliable global access to data
- Compatibility with both schools' network and firewall
- Windows OS compatible; "English" and "German" Windows
- Compatible with CAD files & MS Office files
- Multi-user secured access and revision control
- Simple installation and implementation
- Simple to learn and use
- Quality technical support
- Software available in both countries

After evaluating several software packages against the team's requirements, as listed above, a PDM software program was selected.

This PDM software provided a web portal for viewing 3D products and related documents that were stored in the PDM database. This capability allowed data to be accessed and reviewed from anywhere with an internet connection. The PDM software was compatible with Windows and the team's CAD software. It could store and categorize any file type in its database and allowed the user to create links between different files. This meant that a part's metadata could be centralized to the part itself, improving project management and project workflow. The PDM software incorporated decision-support features, easy search and query tools, multi user redlining options and manipulation tools for over 200 different file types with an advanced security and authorization mechanism with data secured in an electronic vault.

With this software, most of the team's needs were met. Although much was unknown about the complexity of its installation and implementation, it was believed that with a partnership between the university and the software developer, those difficulties would be minimal. After several months of discussion with the company, a full partnership was not achieved but the software was acquired.

After several months of work, a very simple deployment of the software was successful within OSU's university network. Due to lack of technical support, a more sophisticated deployment of the software, bridging OSU and DHBW's networks, was not practically possible with the resources available.

Most data exchange systems offered by software companies were, at that time, difficult to install and manage [24]. In Ref. [24], the authors found that the largest factor to cause the implementation of a PDM system to fail was lack of management support, and that PDM integration had to be driven by the company executive. Understanding the technological challenge this presented, the team was determined to find an adequate solution but lacked full school or corporate IT support. From the team's initial failure and limited availability of resources, a different allocation in priorities for the PDM system had to be made.

The team's initial priorities were on the level of integration with the CAD software and what capabilities the PDM software had. Applying the lessons learned from the team's first attempt, the priority changed to ease of installation and quality of company technical support. After, again, evaluating several software packages, a different PDM software package was selected. It met all the team's requirements to some degree or another, but it was selected mainly for its high level of available tech support from the software company. After attending a seminar on the installation process and spending several months installing the software, a successful deployment was made with the software functioning over a web based gateway with data accessible from within either OSU's or DHBW's school networks.

The team had reasonable success with this new PDM software but its main drawback was its complexity. Maintaining and administering the software was beyond the capabilities of the students managing the team. The software was also difficult to use, making its learning curve very steep. Further complicating the situation, the database server was located at OSU and not mirrored at DHBW. This was due to lack of IT resources and the necessity of simple software deployment. This made connection speeds very slow in Germany and sometimes caused data to be lost or corrupt. Students quickly developed an acute dislike for the software and this hindered progress with their project. After using and developing this PDM software for two years, little progress was made toward improvement to its usability. Because of these and other technical complications, use of this software was cancelled. This again stemmed from a lack in the team's IT resources and capabilities.

Coupling the repeated problem of minimal IT resources and the issue with software complexity, the GFR team again reevaluated its requirements for a PDM software. This time complete emphasis was placed on simplicity of installation, administration and use. The team's PDM system was reduced to a web based sharing server for documentation and to a synchronized file sharing server for CAD data and other files not supported by the web based server. By doing this, CAD data was no longer integrated with product meta-data, however this was seen as an acceptable compromise due to the system's simplicity.

Use of Google's suite of integrated web base applications; Email, Documents, Calendar and Sites, was a solution which the GFR team used with great success. Documents could be viewed and edited in real-time by multiple users, from anywhere in the world. Calendars could be made by any individual and shared with the team helping to schedule meetings between dozens of people and different timezones. Websites were an easy way to post progress, presentations and links to important documents. All these features were easy to use made it equally easy for students to learn. Due to its usability, students found these web applications as useful tools rather than a necessary burden.

System administration was necessary for creating accounts and defining permissions to access or change certain features and information. Students were able to manage this without difficulty. Since these features were a service from Google, software installation and maintenance was nonexistent. This fact removed the source of IT problems the team had with previous PDM softwares. However the drawback was that this solution was not a true product data management software. CAD files could not be uploaded while still keeping part-to-part associations, meaning opening a CAD assembly file would not open the part files within the assembly. For this reason, CAD files, and other data files not supported by the Google database, had to have a separate system to share information.

The simplest solution the team could devise for these files, while still allowing fast connection speeds, permission control, and correct CAD file operation, was to keep all files in a Windows folder structure, duplicated on a server at each university, and then use a third party software to synchronize the two servers. Using Windows security settings, permissions were assigned to individual folders based off their contents and the individuals that needed to access that information. This required a clearly defined folder structure to ensure groups of individuals had access to the correct information. The folder hierarchy was built based off an indentured part numbering structure for the vehicle which the team was designing. The indentured part structure can be seen in the Appendix, and the resulting folder structure can be seen in Figure 2. This process had several drawbacks: access was limited to within the universities' networks, folder permissions were not transferred between the two servers and backup and revision control had to be done manually or with a third party software.

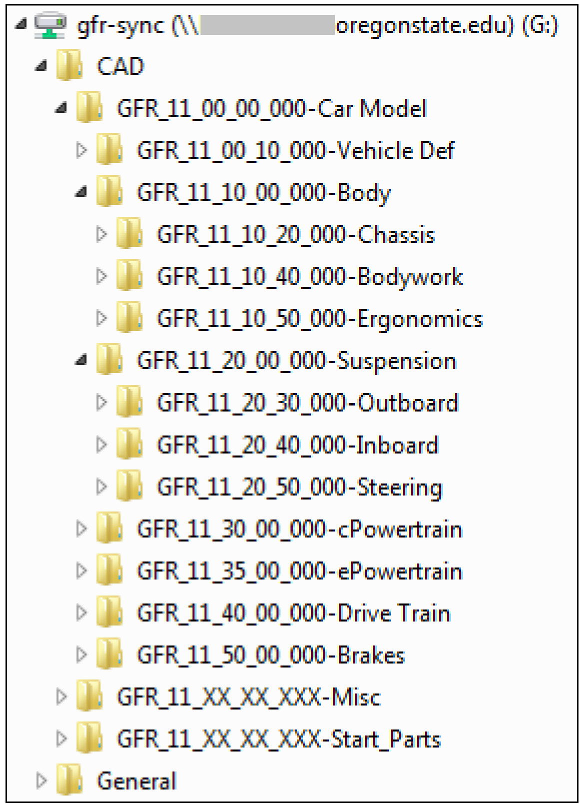


Figure 2: synchronized folder structure from OSU server

In order for part information on the web based system to remain connected with the CAD files on the synchronized drive, some parallelism between the two systems had to be created. Therefore, subteam responsibilities, websites, document folder structures, document names, email groups and email threads were divided or labeled to match an appropriate level of the indentured part numbering system. For example, a part within the Suspension subsystem would have a part number beginning with “GFR_11_20” were “GFR” designated the team, “11” designated the year the part was created and “20” designated the part belonged to the Suspension system. Therefore, website headings, document titles and email threads related to this part would start with the same, “GFR_11_20” designation; or in some cases simply “20”. This way, team structures, file organization, email conversations and even website navigation, were all connected to a part or system of the vehicle.

With this pseudo PDM system functioning and an organizational structure created for it, the next step was to develop protocols for the use of these data and communication tools. As stated in Ref. [1] “communications tooling needs more attention than the engineering tooling.”

Email was a critical form of communication and data exchange for all members on a day-to-day basis. With well defined communication rules set by the team and enforced throughout the collaboration, email became a very effective way of communicating information over the team’s large, complex and geographically distributed community. One of the simplest and useful email rules the team employed was the use of “subteam” mailing lists. All members were assigned to one or more mailing lists depending on their area of responsibility. If any information was communicated about a subject, an email thread was created and discussion began between the necessary parties. The key was to address the email to the particular individuals of interest and to C.C. the subteam mailing list which applied to the topic. By doing this, the whole subteam was aware of the interactions of their members and team leaders were able to follow conversations in the event they needed to intervene. A drawback of this method was possible email “overload”. However, with properly enforced rules on new thread creation, well organized mailing lists and automatic email sorting, email became a very efficient way of communicating for the team.

While email was an effective form of communication, it was not enough to effectively design in a virtual team. Video conferencing became necessary for more in-depth discussions. Weekly internationally meetings, in addition to daily email communication, were a mandatory event to keep teams up-to-date with each other's progress. Scheduling meetings proved to be a constant challenge. Meetings with sometimes a dozen members, stretched across nine time zones (sometimes more), with all members having a unique work or class schedule, was something every member had to understand and compromise with. For this reason it was a common expectation that some meetings would need to take place late in the evening or early in the morning. Each member was required to post their schedule on their Google calendar and share it with their team. By doing this, meeting times could be determined with relative ease.

In order to conduct their conferences, a free internet telecommunication tool was used. All members were required to create an account and team leaders distributed every team member's contact with all other members. This not only provided the team with a means for video conferences, but it was also a convenient way to have impromptu verbal conversations or chats via its instant messenger. For that functionality to work, it was a mandatory requirement for team members to login to the communication software first thing when they sat down to begin working on tasks.

In order for conference calls to be effective, several conferencing rules had to be implemented. Many standard practices for conference calling were available; following any of them would be adequate. For further information on the complications encountered by international student group communication, Ref.'s [16], [25], [26] provided a good frame work to follow. In addition to common conference call practices, it was found that students working in the collaboration routinely needed to be reminded of the following rules.

- If several users were in the same conference and in the same room;
  - Use only one microphone and a set of speakers
  - Or, have all members in the room use their own headsets
  - Never have a combination of the above two scenarios.
- Mute the microphone if not speaking.
- For native English speakers;
  - Speak clearly and PRONUNCIATE.
  - Do not speak slowly, but do not speak quickly, simply speak clearly.
  - Do not use slang.
  - Do not use overly complicated words or sentence structures.
- For non native English speakers,
  - If something is not understood, do not be afraid to stop the conversation and explain in your native language.
  - Do not be afraid to ask for another explanation if something does not make sense.
- If discussing the contents of a document, send the document or a link to its location in the communication software chat window.

With these systems and protocols in place, students would be able to go about their daily collaboration activities once they learned how to use them. Thus, a means for teaching the students to use these systems had to be devised. Since the nature of a capstone design project requires students to document their work, much of the easily knowledge acquired by the team would lie in written documentation. For this reason a team Wiki was created on the team's Google Sites. With this wiki, the team would have a centralized location for team rules and protocols, student reports, testing data, history of the team and any other pertinent information. This would provide students with the means to teach themselves and others about the team, the engineering behind what they would be working on and what members from previous years had learned. Ultimately, the wiki would be a main source for knowledge transfer and would help to alleviate the issue of tribal knowledge and lost year-to-year knowledge.

With data exchange and communications clearly defined, students had the adequate tools for design. The next step in the collaboration was defining how parts would be manufactured and sourced. To accomplish this, a system for global supply chain management had to be created.

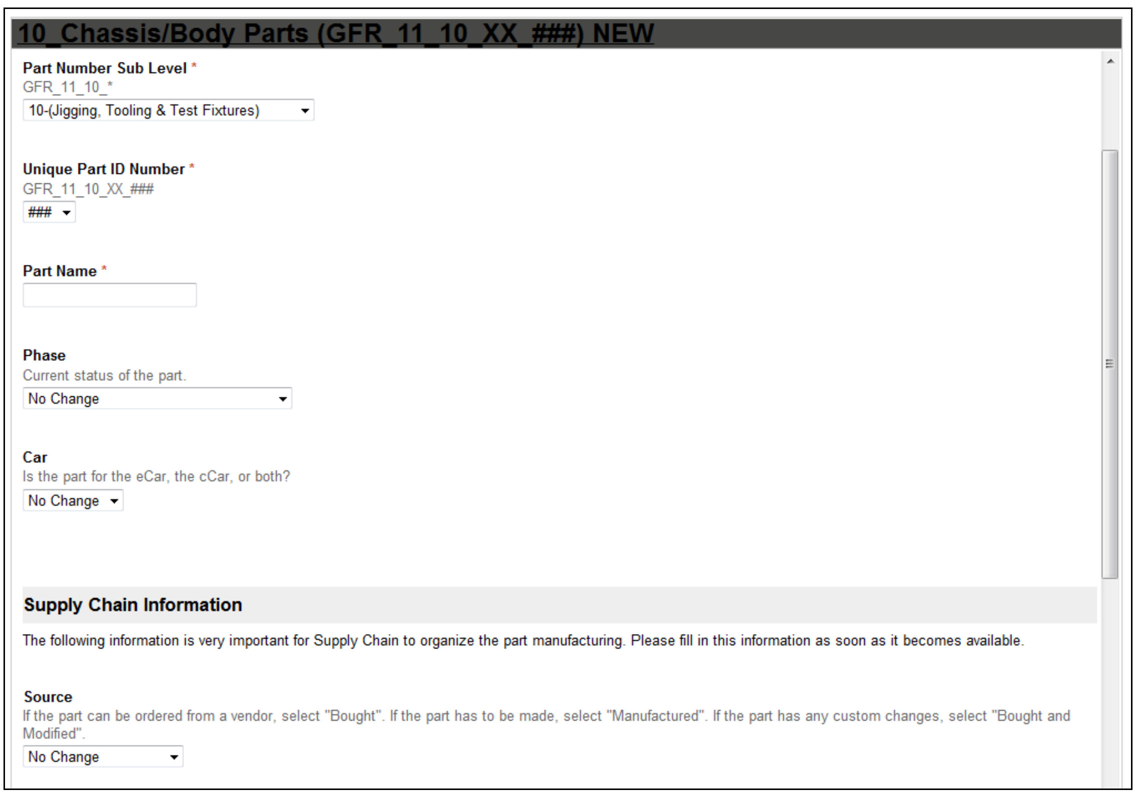
5 Supply Chain Management

Methods for product-sourcing become significantly more complicated once parts can come from two or more countries at once. “Global organizations will have to make effective use of suppliers anywhere in the world to benefit from lower manufacturing costs and proximity to a given construction site” [22]. This meant a well organized supply chain management (SCM) team and tools for their use would be critical during the team’s manufacturing and assembly phases.

Part-sourcing had to begin concurrently with the design phase. Regardless of where a system was being designed, there had to be a source for the part to be purchased or manufactured. For every component, the question had be asked: “buy or manufacture?”; “source in Germany, source in the US, or both?”; “which company to source from?”; “ship components individually or all in one big box?”; “how many shipments to send in each direction?”; “which parts would arrive in which shipment?” All were very simple questions for any individual part or circumstance, but given several hundred or a few thousand parts, the task of answering those questions for each part becomes very complicated. In order to help the process of making these decisions, tools had to be created that allowed: designers to match manufacturers with their designed parts, schedules to be made for manufacturing sequences, and shipments and part orders to be organized in order to save costs.

International considerations beyond simply purchasing parts also had to be taken into account. Costs on the same merchandise could differ greatly from the US to Germany, so research had to be done on each side of the globe to find the best price. Beyond the value on the price tag, international taxes and tariffs also had to be factored into the price. For example, purchased parts from the US that were shipped to to Germany were subject to 19% value added tax plus a 1-5% duty. Student built parts and donated parts were also subject to taxes and duty. The SCM and team leaders had to pay particular attention to these details as not to accumulate unnecessary costs.

To meet these challenges, the GFR team developed its own Google web based tool which tracked all pertinent part information. This "part evaluation" tool allowed team leaders and the SCM team to identify groups of parts that could be manufactured in the same locations based on their manufacturing processes. In addition, parts that could to be sourced from a single company would need to be identified, allowing single consolidated purchases to be made. Finally, the tools had to be simple enough for students to use and administer.



10_Chassis/Body Parts (GFR_11_10_XX_###) NEW

Part Number Sub Level *
GFR_11_10_*
10-(Jigging, Tooling & Test Fixtures)

Unique Part ID Number *
GFR_11_10_XX_###
###

Part Name *

Phase
Current status of the part.
No Change

Car
Is the part for the eCar, the cCar, or both?
No Change

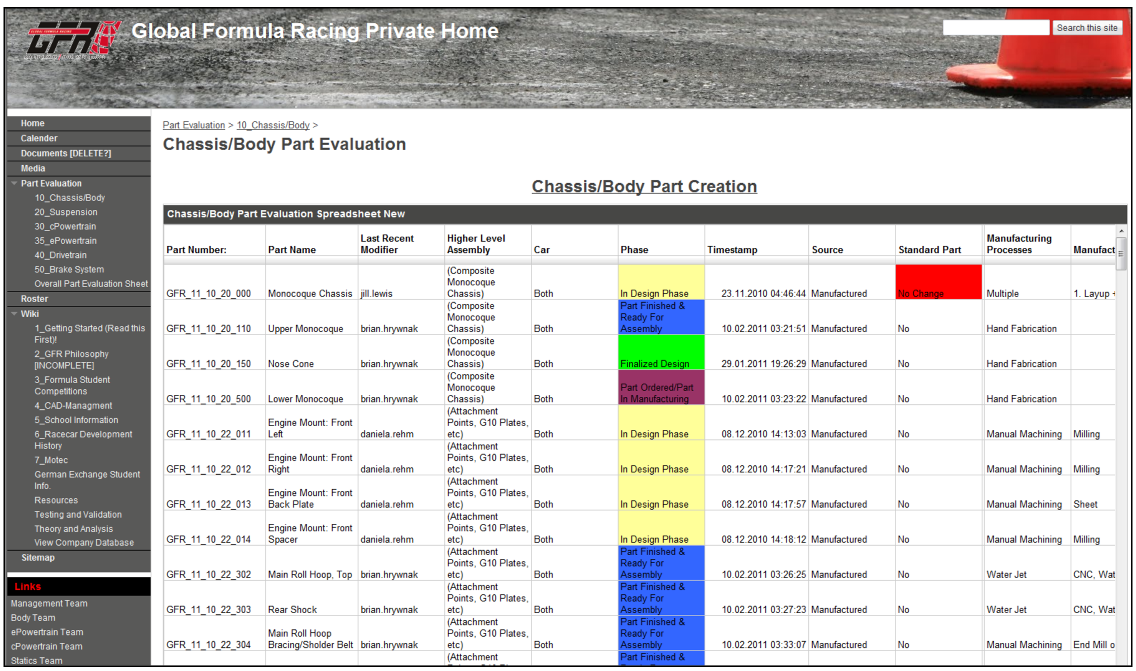
Supply Chain Information

The following information is very important for Supply Chain to organize the part manufacturing. Please fill in this information as soon as it becomes available.

Source
If the part can be ordered from a vendor, select "Bought". If the part has to be made, select "Manufactured". If the part has any custom changes, select "Bought and Modified".
No Change

Figure 3: Part Evaluation Sheet creation form.

For each part, the student responsible would fill out a web based form with the part number and other pertinent information such as; quantities, material, manufacturing procedures, manufacturing location, etc. This form would then automatically populate a subsystem's bill of materials (BOM) list. An example of a part creation form can be seen in Figure 3. This tool would also track the status of parts, indicating the phase of development or production the part was in. This feature provided designers quick visual indications for which parts were falling behind and which were on time. An example of this tool can be seen in Figure 4. Management groups could then use this tool to track progress of all subsystems easily from anywhere in the world due to the system being integrated with in the private GFR team website.



Global Formula Racing Private Home

Home | Calender | Documents [DELETE?] | Media | Part Evaluation | 10_Chassis/Body | 20_Suspension | 30_cPowertrain | 35_ePowertrain | 40_Drivetrain | 50_Brake System | Overall Part Evaluation Sheet | Roster | Wiki | Sitemap

Part Evaluation > 10_Chassis/Body >

Chassis/Body Part Evaluation

Chassis/Body Part Creation

Chassis/Body Part Evaluation Spreadsheet New

Part Number:	Part Name	Last Recent Modifier	Higher Level Assembly	Car	Phase	Timestamp	Source	Standard Part	Manufacturing Processes	Manufact
GFR_11_10_20_000	Monocoque Chassis	jill.lewis	(Composite Monocoque Chassis)	Both	In Design Phase	23.11.2010 04:46:44	Manufactured	No Change	Multiple	1. Layup
GFR_11_10_20_110	Upper Monocoque	brian.hrywnak	(Composite Monocoque Chassis)	Both	Part Finished & Ready For Assembly	10.02.2011 03:21:51	Manufactured	No	Hand Fabrication	
GFR_11_10_20_150	Nose Cone	brian.hrywnak	(Composite Monocoque Chassis)	Both	Finalized Design	29.01.2011 19:26:29	Manufactured	No	Hand Fabrication	
GFR_11_10_20_500	Lower Monocoque	brian.hrywnak	(Composite Monocoque Chassis)	Both	Part Ordered/Part In Manufacturing	10.02.2011 03:23:22	Manufactured	No	Hand Fabrication	
GFR_11_10_22_011	Engine Mount: Front Left	daniela.rehm	(Attachment Points, G10 Plates, etc)	Both	In Design Phase	08.12.2010 14:13:03	Manufactured	No	Manual Machining	Milling
GFR_11_10_22_012	Engine Mount: Front Right	daniela.rehm	(Attachment Points, G10 Plates, etc)	Both	In Design Phase	08.12.2010 14:17:21	Manufactured	No	Manual Machining	Milling
GFR_11_10_22_013	Engine Mount: Front Back Plate	daniela.rehm	(Attachment Points, G10 Plates, etc)	Both	In Design Phase	08.12.2010 14:17:57	Manufactured	No	Manual Machining	Sheet
GFR_11_10_22_014	Engine Mount: Front Spacer	daniela.rehm	(Attachment Points, G10 Plates, etc)	Both	In Design Phase	08.12.2010 14:18:12	Manufactured	No	Manual Machining	Milling
GFR_11_10_22_302	Main Roll Hoop, Top	brian.hrywnak	(Attachment Points, G10 Plates, etc)	Both	Part Finished & Ready For Assembly	10.02.2011 03:26:25	Manufactured	No	Water Jet	CNC, Wat
GFR_11_10_22_303	Rear Shock	brian.hrywnak	(Attachment Points, G10 Plates, etc)	Both	Part Finished & Ready For Assembly	10.02.2011 03:27:23	Manufactured	No	Water Jet	CNC, Wat
GFR_11_10_22_304	Main Roll Hoop Bracing/Sholder Belt	brian.hrywnak	(Attachment Points, G10 Plates, etc)	Both	Part Finished & Ready For Assembly	10.02.2011 03:33:07	Manufactured	No	Manual Machining	End Mill o

Figure 4: Part Evaluation Sheet, embedded within the GFR team website.

Finally, all tools were designed to allow continued development throughout the years. By keeping the tools simple, students could improve usability and functionality year after year, without an enormous learning curve before they can start. Beyond simple improvements, students were allowed to do something rather unique. They were allowed to devise and refine a management system and actually implement the changes on the functioning organization. This provided students a level of educational experience in systems management engineering that was difficult to achieve elsewhere. This ultimately closed the loop on the main goal and purpose of the project; to create a fully collaborative design and manufacturing project with real world implications, all while providing innovative educational experiences for its students.

6 Conclusion

Purpose, support, planning, organization and technical capability; these were all the elements necessary for the Global Formula Racing team to develop a global distributed design project between OSU and DHBW. Both schools joined the venture with clear and open expectations. The project took several years of preparation before its debut and as of 2010, was in its 3rd year of a 5 year collaborative agreement between the universities.

The result of this work was the development of a team management system which allowed students to organize an international engineering team to work as a single unit on a complex engineering design and manufacturing task. This management structure clearly defined the roles and responsibilities for individuals from university administration, down to student engineers. Practical tools were also developed for students to use during their day-to-day engineering activities. These tools included a product data management system that was simple enough for students to manage, maintain and use; a system for communicating complex engineering information between persons distributed around the globe; and finally, a tool for tracking part information across a global supply chain.

In the 2010 Formula SAE season, the GFR team was able to build a unique collaborative venture unlike anything the FSAE racing community had ever seen. They earned 1st place victories in three of the six competitions they attended with their two identically built race cars. While this was a significant note of achievement, the true success lied with the experience the students received from working on the project. Students were faced with the real world, everyday problems of an engineer. Students had to organized and manage their time in conjunction with their local and international peers. Students had to learn and apply technically complicated engineering processes quickly to accomplish their assigned tasks. They learned to communicate technical information and ideas through multimedia, to an international community. They learned how to source and track parts across a global supply chain. Ultimately, as a result of this project, students learned many aspects of how to be engineers within a globally distributed team.

While many aspects of this paper were specific to the GFR team, the intent of this paper was to give a general framework for other universities to follow in order to create their own successful collaborative partnerships. As a result of this project, students were able to not only collaboratively design and build their vehicle, but were able to learn invaluable lessons as an engineer working in an ever-diversifying world. While many difficulties were faced, students learned practical skills beyond the classroom, ultimately making them highly valued engineering graduates.

BIBLIOGRAPHY

[1] Gotel, O.; Kulkarni, V.; Scharff, C.; Neak, L., "Working Across Borders: Overcoming Culturally-Based Technology Challenges in Student Global Software Development," Proceedings of the CSEETW'08, Charleston, SC, USA, April- 14-17, 2008.

[2] Hayes, C.; Pande A.; "What Skills Will Future Engineering Graduates Need in Global Organizations?" ASME Conf. Proc. 2007, 625.

[3] Andersen, A.; Hansen, J., "Engineers of Tomorrow and Beyond Knowledge, Insight and Skills Needed to Work Across Borders," Proceedings of the 2002 American Society for Engineering Education Annual Conference & Exposition, Montreal, Que., Canada, June 16-19, 2002.

[4] Shetty, D.; Choi, S., "Globalization and Product Design Curriculum in Engineering Programs," Proceedings of the 2003 ASEE Annual Conference & Exposition, Nashville, TN, USA, 2003.

[5] Downey, G.; Lucena, J., "Globalization, diversity, leadership, and problem definition in engineering education," Proceedings of the 2007 ICREE, Honolulu, HI, USA, June 24-27, 2007.

[6] Gotel, O.; Scharff, C.; Seng, S., "Preparing Computer Science Students for Global Software Development," Proceedings of the 2006 ASEE/IEEE Frontiers in Education Conference, San Diego, CA, USA, October 28-31, 2006.

[7] Sarker, S.; Sahay, S., "Implications of Space and Time for Distrubuted Work: an Interpretive Study of US-Norwegian Systems Development Teams," European Journal of Information Systems (2004), 13:3-20, 2004.

[8] Coar, K., "The Sun Never Sets On Distributed Development," QUEUE: 32-39, December/January 2003-2004.

[9] SAE International, "2011 Formula SAE® Rules," http://students.sae.org/competitions/formulaseries/rules/2011fsaerules.pdf. 2011.

[10] SAE International, "About Formula SAE," http://students.sae.org/competitions/formulaseries/about.htm

[11] Maienschein, J., "Why Collaborate?" Journal of the History of Biology, 26(2): 167-183, 1993.

[12] Gotel, O.; Kulkarni, V.; Say, M.; Scharff, C.; Thanwadee, S.; Touch, S.; Des, P., "Quality-Driven Competition: Uniting Undergraduates, Graduates and Professionals on Global Software Development Projects," Proceedings of the CSEETW'08, Charleston, SC, USA, April- 14-17, 2008.

[13] Dixon, G., "Teaching Project Management with International Collaboration," Proceedings of the 2007 ASEE Annual Conference and Exposition, Honolulu, HI, USA, June 24-27, 2007.

[14] Giullian, N.; Jensen, G.; McCammon, J.; Brooks, B., "Hosting/Participating in Global Collaborative Pace Projects," Proceedings of the 2007 ASEE Annual Conference and Exposition, Honolulu, HI, USA, June 24-27, 2007.

[15] Webster, M., "Pace Global Vehicle Collaboration," Proceedings of the 2007 ASEE Annual Conference and Exposition, Honolulu, HI, USA, June 24-27, 2007.

[16] Carlson, O.; Webster, M.; Jensen, G; Korth, D., "Multinational Design: Keys to Incorporating Multinational Design," Proceedings of the 2007 ASEE Annual Conference and Exposition, Honolulu, HI, USA, June 24-27, 2007.

[17] Chaturvedi, S.; Crossman, G.; Swart, W.; Betit, J., "Global Engineering in an Interconnected World: An Upper Division General Education Cluster at Old Dominion University," Proceedings of the 2001 ASEE Annual Conference & Exposition, Alburquerque, NM, USA, June 24-27, 2001.

[18] Gotel, O.; Kulkarni, V.; Neak, L.C.; Scharff, C.; Seng, S., "Introducing Global Supply Chains into Software Engineering Education," Proceedings of the Software Engineering Approaches of Offshore and Outsourced Development 2007, Surich, Switzerland, February 5-6, 2007.

[19] Damian, D.; Dadwin, A.; Al-Ani, B., "Instructional Design and Assessment Strategies for Teaching Global Software Development: A Framework," Proceedings of the ICSE '06, Shanghai, China, May 20-28, 2006.

[20] Anwar, S., "International Collaboration in Engineering and Technology Education: A Case Study," Proceedings of the 1998 ASEE Annual Conference and Exposition, Seattle, WA, USA, June 28-July 1, 1998.

[21] Lin, Y.; Harby, D.; Jang, D.; Zhen, W., "Teaching Capstone Design in Globalization Environment," Proceedings of the 2004 ASEE Annual Conference & Exposition, Salt Lake City, UT, USA, June 20-23, 2004.

[22] Kini, D.; "Global Project Management- Not Business as Usual" Journal of Management in Engineering, Vol. 16, No. 6, Nov/Dec 2000, pp. 29-33.

[23] Gao, J.; Aziz, H.; Maropoulos, P.; Cheung, W.; "Application of product data management technologies for enterprise integration," International Journal of Computer Integrated Manufacturing, Vol. 16, No. 7-8, pp. 491-500.

[24] Siddiqui, Q.; Burns, N.; Backhouse, C.; "Implementing product data management the first time," International Journal of Computer Integrated Manufacturing, Vol. 17, No. 6, pp. 520-533, Sept 2004.

[25] Janna, W.S.; Hochstein, J.; Phillips, A., "Senior-Freshman Collaboration in a Capstone Design Course," Proceedings of the 2003 ASEE Annual Conference and Exposition, Nachville, TN, June 22-25, 2003.

[26] Li, H.; "Project management team strategy in a global environment," Computing, Communication, Control, and Management, 2009. CCCM 2009. ISECS International Colloquium on , vol.1, no., pp.169-172, 8-9 Aug. 2009.

APPENDIX- Part Numbering Scheme

Part Numbering Scheme

1 2 3 4 5 6

OSU_09_00_00_000_PRD- OSU09 Formula Car

[PartID (Part #)]-[Name/Description]

	No.	IDENTIFIER	Explanation	Examples of Applicable Items	Example of PartID & Name
1	ABC	TEAM ID	If item is unique to a team use a three digit TEAM IDENTIFIER.*	CAD, Reports, Rosters, Meeting Summaries	**OSU_09_20_46_001_CAD- Pensky Shocks** **BRT_09_00_00_001_RST- BART 2009 Team Roster** **BJA_10_75_00_001_CMP- BAJA 2010 Cost Report**
	* See the "TEAM ID" worksheet for specific team identifiers.				
	GEN	GENERAL ID	If item is a general piece of information and does not belog specifically to a team use the GENERAL IDENTIFIER.	Publication and Reference material, Pictures of other teams cars, Manufacturing's Website	**GEN_XX_20_46_002_REF- Testing Shock Characteristics** **GEN_09_XX_XX_001_WEB- FSG Website** **GEN_08_20_36_011_PIC- Stuttgart Upright** **GEN_XX_XX_XX_223_CAD- CA02 Ball Bearings**
2	YY	YEAR NUMBER	If item is unique to the year of the project, use a two digit YEAR NUMBER i.e. "09" signifiying when the project will go to competition.	CAD Data, Competition Documents, Reports, Rosters, Pictures,	OSU_09_00_00_000_CAD- OSU 2009 Formula Car BRT_09_00_00_000_CMP- BART 2009 Design Report
	XX	PLACE HOLDER	If item is not unique to the year of the project, use a PLACE HOLDER of "XX".	Publications & Reference material, Tutorials, Websites, etc.	GEN_XX_30_30_005_REF- Intake Tuning Theory GEN_XX_XX_XX_000_WEB- Linn Gear Co. Website
3	00	TEAM LEVEL	If item belongs to the entire team, use a TEAM LEVEL number of "00".	Team Roster, Team Website, Highest level CAD products, Team Goals, Team Events	BRT_09_00_00_000_RST- Team Roster OSU_09_00_00_000_CAD- OSU 2009 Formula Car BRT_09_00_00_000_CMP- BART 2009 Design Report GEN_XX_00_00_123_REF- Team Management
	##	SUB LEVEL	If item belongs to a particular sub-team or sub-component of the car use the appropriate SUB LEVEL number.**	Sub Component CAD products, Publications related to Sub Component, Sub Team Design Reports	OSU_09_10_00_000_CAD- Monocoque Chassis GEN_XX_30_30_001_REF- Intake Tuning Theory GEN_08_20_26_011_PIC- Picture of Stuttgart Upright
	** See the "SUB LEVEL" worksheet for specific numbers.				
	XX	PLACE HOLDER	If item is not a TEAM LEVEL object or listed as a SUB LEVEL use a PLACE HOLDER of "XX".	General Website, Rules Documents,	GEN_09_XX_XX_000_RUL- FSG Rules GEN_09_XX_XX_000_WEB- FSG Website GEN_XX_XX_XX_023_FRM- SAE Forum
4	00	TEAM LEVEL	If item belongs to the entire team, use a TEAM LEVEL number of "00" i.e. if column 3 is "00", column 4 will be "00"	Team Roster, Team Website, Highest level CAD products, Team Goals, Team Events	BRT_09_00_00_000_RST- Team Roster OSU_09_00_00_000_CAD- OSU 2009 Formula Car BRT_09_00_00_000_CMP- BART 2009 Design Report
	##	SUB LEVEL 2	If item belongs to a higher SUB LEVEL, use its appropriate SUB LEVEL 2 number.**	Items related to sub components i.e. sway bars, shocks, intake, exhaust, pedals, brake calipers, etc. This includes CAD, Publications, Pictures, Websites, etc.	OSU_09_20_46_001_CAD- Pensky Shocks GEN_XX_30_30_001_REF- Intake Tuning Theory GEN_08_20_36_011_PIC- Stuttgart Upright
	** See the "SUB LEVEL" worksheet for specific numbers.				
	XX	PLACE HOLDER	If item is not a TEAM LEVEL object or listed as a SUB LEVEL use a PLACE HOLDER of "XX".	General Website, Rules Documents,	GEN_09_XX_XX_000_RUL- FSG Rules GEN_09_XX_XX_000_WEB- FSG Website GEN_XX_XX_XX_023_FRM- SAE Forum
5	###	UNIQUE NUMBER	All items on the data base must have a unique PartID number. Use a unique three digit number to distinguish similar items.	Any items that have the same identifiers in other levels (1-4, 6)	GEN_XX_20_46_001_REF- Shock Tuning GEN_XX_20_46_002_REF- Testing Shock Characteristics GEN_XX_20_46_003_REF- Designing Custom Shock Valving
6	ABC	ITEM TYPE MODIFIER	All items must have a three letter ITEM TYPE MODIFIER to distinguish what type of information is in the item.***	*ALL ITEMS*	OSU_09_20_46_001_CAD- Pensky Shocks GEN_09_XX_XX_001_WEB- FSG Website GEN_XX_20_46_001_REF- Shock Tuning GEN_08_20_26_011_PIC- Stuttgart Upright
	*** See the "ITEM TYPE MODIFIER" worksheet for specific modifiers.				

Team Identifiers

TEAM ID	Description	Years Effective*
GFR	Global Formula Racing	2010-
OSU	Oregon State University Formula Team	2004-2009
BRT	Berufsakademie Ravensburg Racing Team (BART)	2006-2009
BJA	Oregonstate University Baja Team	2004-
306	OSU ME 306 Class	2008-2009
248	OSU ME 248 Class	

* Years in which data can exist for the specified TEAM ID

00	00	General Team

10	00	Chassis/Body
	10	Jigging, Tooling & Test Fixtures
	20	Composite Monocoque Chassis
	21	Structural Equivalence
	22	Attachment Points, G-10 Plates, etc.
	23	Suspension Pickup Points
	30	Tube Chassis/Rear Structure
	31	Differential Mounting
	40	Body Work
	41	Aero Elements- Cooling/Intake Ducts
	42	Aero Elements- Down Force
	50	Human Factors & Ergonomics
	51	Seat
	52	Steering Wheel
	53	Shifting System
	54	Pedal Assembly
	55	Dash Board
	56	Ergo Manikin
	60	Carbon Fiber Manufacturing
	85	Sensors
	86	Sensors Mounts
	90	Auxiliary Chassis Components

20	00	Suspension
	10	Jigging, Tooling & Test Fixtures
	20	Suspension Definition
	30	Outboard Suspension
	31	Tires
	32	Rims
	33	Wheel Center
	34	Wheel Nut/Fastener
	35	Spindle
	36	Upright
	37	Wheel Assembly
	40	Inboard Suspension
	41	A-Arms (Wishbones)
	42	Push/Pull Rods
	43	Sway Bars
	44	Bell Crank
	45	Springs
	46	Shocks/Damper
	50	Steering System
	51	Steering Link
	52	Steering Housing
	53	Steering Rack
	54	Steering Pinion
	55	Steering Column
	56	Steering Joint
	85	Sensors
	86	Sensor Mounts
	90	Auxiliary Suspension Components

30	00	cPowertrain
	10	Jigging, Tooling & Test Fixtures
	20	Engine
	30	Intake System
	31	Intake Runner(s)
	32	Plenum
	33	Restrictor
	34	Throttle
	35	Air Cleaner
	40	Exhaust System
	41	Exhaust Pipe
	42	Muffler
	50	Fuel System
	51	Fuel Pump (if external)
	52	Fuel Pressure Regulator/Gauge
	53	Fuel Rail
	54	Fuel Injector
	55	Fuel Tank
	56	Spark Plug
	60	Oil System
	61	Oil Pump (if external)
	62	Oil Tank
	63	Overflow (Catch) Bottle
	64	Oil Plumbing
	70	Cooling System
	71	Cooling Pump
	72	Radiator (Cooler)
	73	Overflow (Catch) Bottle
	74	Fan
	75	Water Plumbing
	80	Engine Management & Electrical
	81	Power Regulation (rectifier, fuse, ect)
	82	Ignition
	83	ECU- Engine Control Unit
	84	Power Storage (Battery, Capacitor, etc)
	85	Sensors
	86	Sensor Mounts
	87	Human Feedback (Display, Light, etc)
	89	Data Acquisition Module

35	00	ePowertrain
	10	Jigging, Tooling & Test Fixtures
	20	Motor
	21	Motor Mounting
	25	Controler
	30	Low Voltage System
	32	Low Voltage Battery
	33	Low Voltage Charger
	35	High Voltage Isolation
	50	Battery System
	51	Battery Monitor / Controller
	52	Battery Cell
	53	Contractor (HV Relay)
	55	Battery Contanier
	70	Cooling System
	71	Cooling Pump
	72	Radiator (Cooler)
	73	Overflow (Catch) Bottle
	74	Fan
	75	Water Plumbing
	80	Data Acquisition
	85	Sensors
	86	Sensor Mounts
	89	Data Acquisition Modules
	90	Auxiliary ePowertrain Components
	91	Plugs/Switches/Connectors
	95	Wiring Harness
	96	Wire
	97	Wire Loom

40	00	Drivetrain
	10	Jigging, Tooling & Test Fixtures
	20	Differential
	21	Differential Housing
	22	Pinion Gears
	23	Spider Gears
	24	Spider Gear Axle
	25	Clutch Plates
	30	Sprocket & Chain System
	31	Engine Sprocket (Crown Gear)
	32	Differential Sprocket (Crown Gear)
	33	Chain Tensioning Mechanism
	40	Half Shafts
	41	Drive Shafts
	42	Stub Shafts
	43	CV Housings
	44	CV Tripod
	50	Transmission
	85	Sensors
	86	Sensors Mounts
	90	Auxiliary Drivetrain Components

Item Type Modifiers

No.	ITEM TYPE	Explanation	Examples of Applicable Items	Example of PartID & Name
AQU	Part Acquisition Form	Every physical part weather manufactured or purchased must have a Part Acquisition Form filled out for that part or set of parts.	Engine, Radiator, A-Arms, Spherical Bearings, Deutsch Connecters, etc.	BRT_09_30_00_000_AQU- 2003 Yamaha R6 OSU_09_10_23_000_AQU- A-Arm Clevis
BCF	Boundary Condition Form	If FEA calculations are conducted a BCF must be filled out to document the loading and constraint sceinarios so other students can follow the analysis.	For any FEA calculation	OSU_09_20_43_001_BCF- Sway Bar Link OSU_09_
CAD	COMPUTER AIDED DESIGN	Any computer aided design files. This includes; CATParts, CATAnalysis, IGES, CVR, DXF, ect	All CATIA files, converted geometry files i.e. IGES, Solid Works, ProEngineer, ect	OSU_09_00_00_000_CAD- OSU 2009 Formula Car OSU_09_20_46_001_CAD- Pensky Shocks GEN_XX_XX_XX_223_CAD- CA02 Ball Bearings
CMP	COMPETITION DOCUMENT	Any file created specifically competition.	Competition Design Report, Cost Report, Marketing Presentation, etc.	BRT_09_00_00_000_CMP- BART 2009 Design Report BJA_10_75_00_001_CMP- BAJA 2010 Cost Report
DAT	DATA	Any documents relating to testing, collected data, calculations, programs, ect. This does NOT include CATAnalysis files.	Test resulst, MoTeC data, data in Excel, Matlab programs, hand written calculations, ect	OSU_09_20_00_000_DAT- Weight Transfer Spreed Sheet
DOC	DOCUMENT	All other documents that do not fall into any of the listed catagories.		
DRW	DRAWING	Any drawing created for manufactuing.	Any solid model part or assembly, CATDrawing, DXF, ect.	OSU_09_20_26_100_DRW- Upright Manufactuing Drawing
FRM	FORUMS	Any website that points to a Forum.	Team Forum, SAE Forum, any motorsports forum, ect.	GEN_XX_XX_XX_023_FRM- SAE Forum BRT_XX_00_00_000_FRM-BART Team Forum
PIC	PICTURE	Any Image relevent to the project or team.	Team Photo, Vehicle Components,	OSU_09_00_00_000_PIC- OSU Team Picture GEN_08_20_26_011_PIC- Picture of Stuttgart Upright
PRJ	PROJECT DESCRIPTION	Any project descrition.	Overall Formula project desc., sub-team project desc., "underclassmen" project desc., ect.	BRT_09_10_00_000_PRJ- SA Body OSU_09_10_60_000_PRJ-Human Factors Project Description
REF	REFERENCE MATERIAL	Any piece of literature that could be used for education or reference. Note a website with written reference material is designated with a REF and not a WEB.	Published report, article, text book, website, manual, ect. **Ensure no copy rights are violated.**	GEN_XX_20_46_001_REF- Shock Tuning GEN_XX_20_46_002_REF- Testing Shock Characteristics GEN_XX_20_46_003_REF- Designing Custom Shock Valving
REP	REPORT	This is only for Senior Design Reports or Deploma Theisis Reports.	Seinior Design Reports for ME 418 and ME 419 (OSU) or Final Deploms Theisis Reports (BA)	OSU_09_20_00_000_REP- Suspension Design Report BRT_09_70_00_000_REP- Cost Coltrolling Deplom Thesis
RST	ROSTER	Any roster related to any group of persons in this organization	2009 OSU-BART Formula Team Roster, Sponsor Roster, ect	BRT_09_00_00_000_RST- Team Roster OSU_09_00_00_000_RST-Formula Team Sponsor Roster
RUL	Rules	Any documents relating to the rules of the compentitions, "Codes of Conduct" or safety rules.	SAE Rules, FSG Rules, Team Conduct Rules, Testing Safety Rules, etc	GEN_09_XX_XX_000_RUL- FSG Rules GEN_09_XX_XX_001_RUL-FSG Rules Website BRT_09_00_00_000_RUL- Testing Safety Rules
SCH	SCHEDULE	Any schedules related to any part of this organazation	2008-2009 Design Schedule, Competition Schedule,	OSU_09_30_00_000_SCH- Engine Team Gantt Chart GEN_09_XX_XX_010_SCH- Silverstone Event Schedule
SKL				
SEF	Structural Equivelacy Form	Any evaluated structural equivalence needed to pass rules	Monocoque, square tubing, aluminum tubing, composite bulkhead (anti-intrution plate), etc.	OSU_09_00_00_100_SEF- SAE Structural Eqv Form OSU_09_00_00_101_SEF- Front Bulkhead OSU_09_00_00_001_SEF- Monocoque Chassis
SMY	MEETING SUMMARY	Any document outlining to events of a meeting.	Team meetings, Sub-Teams meetings, meetings with sponsors, workshop summaries, etc	BRT_09_40_20_000_SMY- Workshop 2 Summary
SYS	SYSTEM FUNCTIONS	All documents relating to the protocals and conventions this organization uses in Teamcenter.	Part Number Scheme (this document)	GEN_XX_XX_XX_001_SYS- Part Number Scheme
TUT	TUTORIAL	Any tutorial on any subject. A tutorial (TUT) has a different modifier than a piece of reference material (REF).	ME 306 tutorials, Advanced Catia class, MoTeC tutorials, etc	GEN_XX_XX_XX_012_TUT- Advanced Catia Course GEN_XX_XX_XX_045_TUT- ME 306 CATIA Lesson 3
WEB	WEBSITE	Any website other than a Forum or site used as a REF (reference), see REF for more information.	Team Website, FSG Rules Website, Manufacturer's Website, ect.	GEN_09_XX_XX_001_WEB- FSG Website BRT_09_00_00_000_WEB- BART Team Website