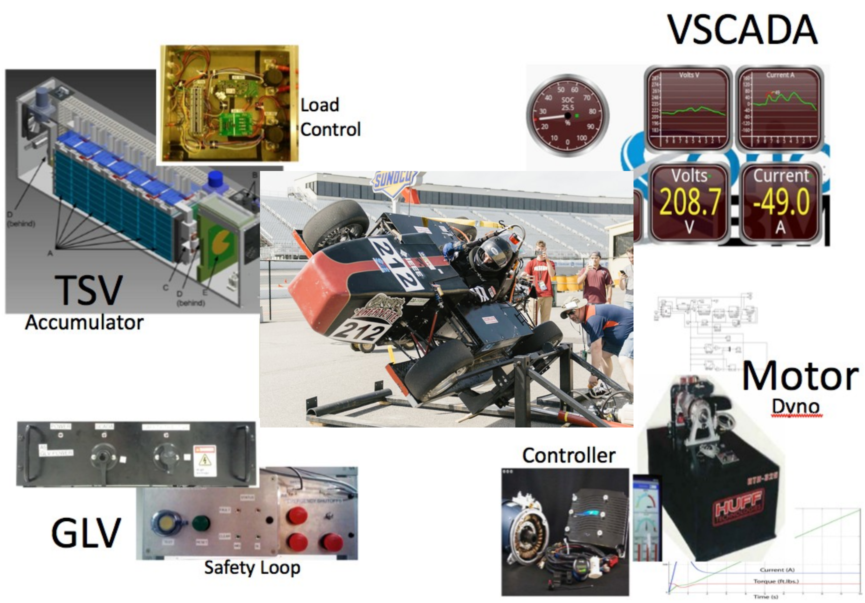
LFEV-2021

Lafayette Formula Electric Vehicle
Statement of Work



PRELIMINARY DRAFT

Lafayette College

Electrical and Computer Engineering Department

&

Mechanical Engineering Department

18 August 2020

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Scope

The Lafayette College Engineering Division is pleased to propose the design, fabrication, and testing of an electric race car that shall be suitable for entry into the Formula Hybrid competition held at the end of April 2021 at New Hampshire Motor Speedway, Loudon, NH, USA.

> *Students who will be participating in the competition in the Spring must contact their instructors during or before the first week of Spring classes to request an absence for the dates of the competition.*

Requirements

LFEV-2021 shall design, build, and test a competition ready electric race car comprising an integrated set of subsystems that meet the following requirements:

- **Competition Requirements –** A central goal of the LFEV-2021 project is to successfully enter a car in the 2021 Formula Hybrid competition. To that end, all the rules specified by the competition website must be met to completely or the car will be disqualified from the competition.
- **GPRXXX: General Project Technical Requirements –** Beyond the technical and management requirements specified by the competition, Lafayette College Engineering adds a set of practice and safety technical requirements that must be met by all projects, including this one. A detailed list of these general project technical requirements is given in Appendix A.

Meeting all requirements is the highest priority for a design engineer. Unfortunately, requirements are sometimes in conflict with each other. Should requirements seem in conflict based on a given design, as a general principle the design should be changed so that both requirements are met, if reasonable to do so. If it is not possible or reasonable to change the design to meet both of the conflicting requirements, the team shall work with Lafayette engineering professors, possibly in conjunction with the Formula Hybrid organization authorities and Lafayette administrative departments (Public Safety, Plant Operations, etc…), to resolve the conflict.

Compliance with established technical requirements must be proved by analysis, demonstration, or inspection. Compliance results must be documented with the system, either in competition “forms”, a formal test reports, or at the competition itself. Based on results from these reports, the technical compliance grade is calculated.

The team must conduct detailed study and analysis of all the Formula Hybrid rules and ECE/ME requirements described herein. It is impossible to be successful in this project without learning the requirements and rules.

Read The Rules

Deliverables

The output of an engineering project is defined by a set of deliverables. The deliverable items from a project can be physical hardware (e.g. working device, tools, and supporting hardware, etc...), or data items (e.g. written or oral reports, computer code, etc…).

The project must produce the following categories of deliverables.

- **Team Competition Deliverables –** The most important deliverable of the LFEV project is the competition-ready car itself. Along with the car, entry in the Formula Hybrid competition requires the production of various paper deliverables, including forms and other documents described on the competition website. All members of the LFEV-2021 team must work together to produce the car along with competition deliverables described on the Formula Hybrid rules.
- **TDXXX: Team Project Deliverables –** The Lafayette College Engineering departments require Senior Project courses to produce additional team deliverables beyond what is required by the competition itself. All members of the team must work together to produce the project deliverables described herein.
- **IDXXX: Individual Project Deliverables –** The Lafayette College Engineering departments require individual students in Senior Project courses to produce individual deliverables in addition to their responsibilities to the team deliverables. Each student on the team must work independently to produce the individual deliverables described herein.

All deliverables must meet all applicable requirements. Incorrect or incomplete deliverables will be rejected. The team must develop a process to review deliverables before submission to make sure they are complete and of high quality. Faculty can assist with this Quality Assurance process, but faculty does not have the capacity to do detailed review of every deliverable. The team must review its own work to ensure quality and be able to demonstrate that this QA review has been conducted effectively. NEXT YEAR'S TEAM DEPENDS ON THE QUALITY OF THIS YEAR'S DELIVERABLES!

All data items, reports, and forms shall be in compliance with and delivered per GPR001. **Specifically, delivery is required both to the web site and by notification to all the course instructors by email.** Small deliverables can be copied as attachments; larger deliverables are best sent as links into the website.

Successful delivery of an item requires that the faculty reviewer accept the item. **Posting to the website and emailing a data item (or link) to instructors does not imply it is accepted.** If a data item is rejected because it failed to be complete or of high quality it must be re-submitted.

No partial credit is given for unacceptable deliverables. Status reports are not accepted late. Other late deliverables are penalized 10% per day for the first three days, then 10% per week. Fractional days or weeks are rounded up.

Deliverable Due Dates

Data Item	Description	Due Date
	Individual Student Deliverables	
ID001	Statement of Individual Goals	19 October
ID002	Weekly Individual Status Report	Noon Monday every week of classes starting week 2 (August 24th)
ID003	Individual Memos, Quizzes, and Surveys	As Reqd
	Team Presentations and Reports	
TD001	Conceptual and Preliminary Design Study	21 September
TD002	Design Proposal	19 October
TD003	Safety Plan and Review	Before hardware work is allowed. No later than 3 December 2020
TD004	Weekly Team Status Report and Presentation	3PM Monday every week of classes starting week 2.
TD005	Five Minute Status Presentation	Fall: 9/21, 10/19, 11/16 Spring: TBD
TD006	Design Reviews	Approx Weekly
TD007	Mid-year Progress Report	3 December
TD008	Mid-year Presentation	Prior to 3 December
TD009	Spring Update Report	Mid Spring
TD010	Final Design Report	FDD
TD011	Final Presentation	FDD
TD012	Project Video	FDD
TD013	Posters and Poster Sessions	End of Fall and Spring

	Test Plans and Reports	
TD014	Subsystem Test Plans and Reports	As Reqd by Schedule
TD015	Top Level Laboratory Test Plan and Report	Plan by 3 December. Report by ECD.
TD016	On-Road Test Plan and Report	Plan by 3 December. Report by FDD.
	Documentation Deliverables	
TD017	Project Website	FDD (with weekly updates)
TD018	Final Purchasing Report	FDD
TD019	Users Manuals and Training Videos	FDD
TD020	Maintenance Manual	FDD
TD021	Final Delivery Checklist	FDD
	Competition Deliverables (Formula Hybrid Specific)	
CD001	Competition Forms and Deliverables	As Required by Competition Rules

Electromechanical Completion Date *(**ECD**) is the last day of classes prior to Spring Break.*

Final Delivery Date *(**FDD**) is the last day of classes in the Spring Term.*

Individual Student Deliverables

The following deliverables must be provided by every student in the team. Students are expected to work independently on these individual deliverables. These individual deliverables are submitted to faculty just like ordinary assignments given in academic classes. Typically, Moodle forms will be provided for these assignments.

ID001: Statement of Individual Goals

Recognizing that a team functions more effectively if each individual understands their role, goals, and milestones of achievement, each of the team members should craft a document stating their role, planned tasks, deliverables, and other contributions that are expected of them as a team member. Please be as specific as possible about near- and long-term goals, referencing specific work breakdown tasks in the project plan. Also describe leadership or service roles within the team, or relevant sub-team, and growth potential as a student (e.g. technologies and tools you intend to learn).

Individual goal statements should be approximately 1 page per team member, separately written by each individual student and submitted to Faculty for review and comment.

ID002: Weekly Individual Progress Report

Every student in the class is required to deliver their own *Individual Progress Report* (IPR). The IPR shall be delivered to an agreed location for review by faculty (typically a Moodle form). The IPR is concerned primarily with completed tasks that appear in the project plan.

The IPR must identify specific tasks from the project plan that have been **100% completed** by that specific student in the previous week, and specific plan tasks intended to be 100% completed by them next week. Any overdue plan tasks shall be identified, their consequences presented, and a mitigation plan given. Tasks must be specific and measurable (per “SMART” principles) and part of the work plan.

Comment only very briefly about ongoing incomplete work. There’s no reason to report work you are doing that is outside the plan – if your work is truly relevant to the project, convince the team to change the plan so your work is “counted”.

ID003: Individual Memos, Quizzes, and Surveys

Throughout the semester, faculty will specify various extra assignments to be completed by students individually. These will include short reports, quizzes, and surveys to assess each student in technical and non-technical areas. Individual students will work independently on these assignments and submit them separately.

Team *Presentation and Report Deliverables*

The following presentations and reports are produced by the team working together. Even if the detailed production of these reports is delegated to a subset of team members, the team as-a-whole remains accountable for them.

All written reports, presentations slides, and supporting material, along with any meeting minutes and action items must be delivered to faculty and posted to the project website per GPR001.

TD001: Conceptual and Preliminary Design Study

The purpose of the report is to provide a high-level description of your team's selected problem or the process to select the problem that identifies the main motivation for the problem, estimated resources needed, and timeline for completion. This is the first of a series of documents that will communicate the team's decisions regarding the subject, goals, scope, and resources needed for the project. This document will also present a high-level project plan. While not exhaustive, the following lists some of the areas that should be addressed in the document:

- ***Motivation for project:*** Who benefits? What are the implications of the project's success?
- ***Description of current state of the art:*** What is missing from the current products/systems?
- **Your team's proposed contributions to the state of the art:** Making use of proper resources (scientific journals, patents, prior design reports).
- ***Planned Approach:*** What are the design objectives? In your defined design space, how are you navigating towards a well-defined and realizable design. Include functional decompositions, conceptual designs, proof of concept studies, initial prototypes or other preliminary products of your initial design activities. Also, provide information about the creation/identification of engineering metrics and specifications for your design, including information about your design's subsystems and their interactions. How have you evaluated the appropriateness of these constraints?
- ***Roles and Responsibilities:*** How have you organized your team structure to meet the goals defined in your planned approach? How will you evaluate/refine/adapt roles on a team effectively?
- ***Team Schedule:*** What is your defined timeline (including both internal and external deliverables) and how are identified milestones in the planned approach being measured?
- ***Required Resources:*** What are the size, space, budget, and types of equipment that are foreseeably needed based on your design space?
- S***takeholders or External partnerships:*** Who will you consult with during the design process. How will those relationships be established and what feedback will be sought?

This is a preliminary document and, as such, is not expected to contain detailed information on the finer operational aspects of your design. It is expected that this document will form the basis for subsequent reports and would make a logical starting place for the next report, so careful thought and execution can be a big-time saver later in the process.

TD002: Design Proposal

The purpose of the Design Proposal document is to present your chosen design problem, lay out the proposed goals and scope of the work, and describe your team's' internal structure, timeline, and resource needs to achieve those goals. This proposal should also describe your design objectives as well as the metrics and constraints that define your design space. The proposal should detail how your chosen design problem fits within the state-of-the-art and should show evidence of your design thinking strategies and how they influenced your chosen design. This document builds upon your previous reports and continues to communicate your team's decisions regarding the subject, goals, scope, and resources needed for your project. However, you should view this report as a stand-alone document that fully communicates your design intentions, such that a reader of this document would not have to refer back to prior reports to get a full understanding of your design problem. As such, the following list contains subjects that should be addressed in this report; however, new sections may be included that are germane to your group's project and current timeline.

- ***Abstract***
- ***Team Mission Statement***
- ***Motivation for project:*** Who benefits? What are the implications of the project's success? You must consider the implications of all of the following factors as they pertain to the design and the stakeholders involved:
    - health/safety/welfare
    - global/cultural/social
    - environmental
    - economic
- ***Description of current state of the art:*** What is missing from the current products/systems? What are your team's proposed contributions to the state of the art? Please make use of proper resources and references (scientific journals, patents, prior design reports).
- ***Planned Approach:*** What are your project's design objectives? In your design space, how does your well-defined and realizable design achieve those objectives? Provide information about the engineering metrics and specifications for your design, including information about your design's subsystems and their interactions. How have you evaluated the appropriateness of these constraints and benchmarked your proposed design against them? To demonstrate evidence of the design activities your team has undertaken to date. also include as appropriate:

  - functional decompositions
  - proof-of-concept studies
  - engineering analysis
  - initial prototypes
- ***Roles and Responsibilities:*** How have you organized your team structure to collaboratively meet the goals defined in your planned approach? How have you refined/adapted roles on the team during the design process? How have you evaluated individual contributions while maintaining a respectful environment that values all team members?
- ***Work Breakdown:*** What is the list of specific outcomes that will be accomplished in the project? You must show that the top-level list of tasks comprises 100% of the project (no part of the project is 'left out'). For convenience you may enumerate sub-tasks that make up a single top-level task, but in any such hierarchical breakdown, be sure that any list of sub tasks comprises 100% of the task they subdivide (no part 'left out'). In addition to following the 100% rule, all tasks must be defined according to "SMART" principles and describe <u>outcomes</u>, not mere processes. All tasks in the plan must be
  - **S**pecific **–** Scope of the task clearly defined.
  - **M**easurable **–** It's possible to determine if a task outcome is "done".
  - **A**chievable **–** Reasonable to achieve in the scope of the project.
  - **R**elevant **–** Directly contributes to a required deliverable.
  - **T**ime Based **–** Able to be scheduled.

  Do not list vague, unbounded, unmeasurable *process* tasks like "design circuit" or "investigate problem". Tasks should describe concrete outcomes. Examples of correct "SMART" tasks are: item ordered, part fabricated, deliverable accepted, etc…
- ***Team Schedule*** Based on the Work Breakdown you have created, what is the timeline for completing major milestones and generating both internal and external deliverables. How are identified milestones in the planned approach being measured? How will you track your progress on your previously defined timeline?
- ***Required Resources*** What are the size, space, and types of equipment that are foreseeably needed based on your design proposal? How have these requirements changed as your design is taking shape? You must supply a well-justified request for your operating budget supported by your planned approach.
- ***Stakeholders or External partnerships*** Who have you consulted with during the design process? How are those relationships/feedback influencing your design process and your proposed design?

- ***Risk and Hazard Identification Management*** Identify risks and hazards that will need to be addressed on your way to a completed design. You should include at least one risk assessment matrix and the associated mitigation plan for that risk.

TD003: Safety Plan and Review

In consideration of the hazards present in this project, ***the project team must adopt and implement a safety plan before any physical work is begun that would put people or property at risk.*** The safety plan must document the processes, constraints, and equipment that will be used to ensure the safety of all participants and the preservation of property.

The Safety Plan is a written document that meets the requirements of GPR001.

The best safety plans include detailed processes for accomplishing tasks safely (do this), rather than only listing negative rules (don't do that).

Faculty must approve the safety plan. After approval, the plan must be posted in all work areas.

Important aspects of the final plan must be presented to the entire team for review as part of a weekly status meeting.

The safety plan must consider all significant hazards present in the project, including, but not limited to:

- electrical hazards
- hazards of rotating machinery
- shop tool hazards
- pinch and entrapment hazards
- chemical hazards
- burn hazards
- heavy object lifting hazards
- welding and soldering hazards
- hazards of operating motor vehicles
- RF and laser hazards
- ionizing radiation hazards
- viral pandemic hazards

See the detailed project requirements and GPR005 for additional safety related requirements that must be considered by the plan.

TD004: Weekly Team Status Report and Presentation

A weekly, project wide status report must be presented live at the Monday status meeting. The project status report shall include the following items:

- ***Announcements and general business for the Full Team:*** Information that is relevant to the entire team, as well as overall project problems, decisions, and other team-wide issues should be discussed at the weekly team meeting.

- ***An overall project schedule review:*** Work breakdown tasks completed, underway, and overdue shall be identified. Percent complete statistics are presented. Mitigation for overdue tasks shall be discussed and actions generated. Upcoming tasks due next week should be highlighted.
- ***Action Item Review:*** A discussion of any action items outstanding from meetings or reviews that were conducted previously.
- ***A cost report:*** that shows expenditures to date broken down by budget categories and compared with budgetary limits. Any over-budget items shall be identified, their consequences presented, and a mitigation actions generated. A copy of every purchase request issued that week shall be included as supporting material.
- ***A receiving report:*** shall be included, identifying every item received, with delivery delay, and noting any ordered items not yet received.

When the project safety plan is ready for review it should be presented at a weekly status meeting.

In addition to these required items, if time is available, subsystem teams can discuss their subsystem progress with the overall group. Emphasis should be on items of interest to other subsystems or overall system performance.

The weekly status report presentation slides, supporting material, along with any meeting minutes and generated action items shall be posted on the website by midnight Monday.

Progress reports are not accepted late.

TD005: “Five-minute” Status Presentation

Representatives of the team must present a brief status updates to other Senior Project teams. These occur about three times a semester. The presentations must be no less than four minutes and no longer than five minutes. Specific requirements, formatting and submission instructions will be provided by faculty.

TD006: Design Reviews

Individual students, subsystem teams, and the entire team can conduct design reviews. Design reviews shall be scheduled, typically one or two per week. Reviews can be scheduled any time participants are available, not only during scheduled class time. These reviews are a multi-disciplined technical and/or management reviews of the design of a specific aspect of the project.

Reviews should be attended by relevant faculty and whatever students can contribute. These generally are not full-team reviews. Students should attend only reviews where they can contribute as a qualified participant – not to “just watch”. To be a qualified participant, you don’t necessarily need to be directly involved with the aspect being reviewed, but you should have a working knowledge of the subject and have something useful to contribute to what is being discussed.

Students will receive extra grade credit for their participation in reviews, either as presenters or as reviewers. Therefore, it’s important that students become qualified participants in as many reviews as possible.

Unlike ordinary presentations, where the audience remains respectfully silent till a final Q&A period, design reviews require continual audience participation. The audience is expected to criticize the design in real time throughout the presentation, finding flaws and issues that could jeopardize compliance to requirements. Reviewers can ask the presenter to “jump ahead, backward, or drill down with more detail”. Presenters need to be ready to address whatever questions arise.

While it’s still important to be respectful, effort must be made to find problems and speak out about them at the design review. Everyone should feel good about errors discovered during design reviews.

It is important that detailed minutes and action items are kept so that the issues discovered are reliably fixed.

Deliverable review materials include background documents prepared prior to the review, the interactive design review itself, slideshow file from any live presentation, demonstration software and data from any demos, and meeting minutes and action items from the live review. These items are expected to be posted on the web site immediately.

Test-plans and reviews are only required for complex subsystems. Consult with faculty and the rest of the team to decide if a certain subsystem is complex enough to merit formal review and testing.

All complex subsystems and system functional components must be reviewed at some point in the project. The team is encouraged to have as many subsystem design reviews as possible. Experience has shown that un-reviewed complex designs do not work well when implemented. Time spent in reviews make designs better. Review it and do it right the first time; otherwise be forced to do it over.

Many different kinds of reviews and demos can be conducted. These include:

- ***Top-Level system reviews:*** Periodically, the team should conduct an overall review that scrutinizes the top-level system design. The top level mechanical model and electromechanical block diagram should be reviewed, possibly “drilling down” to find system-level deficiencies in subsystem function or interfaces. Any time the system design is significantly changed, an overall review is required.
- ***Subsystem Critical Design Reviews:*** Once the design of a complex subsystem has been decided, this design should undergo critical review. For efficient review to be possible, the designer must be ready with complete and legible design documentation. For mechanical designs this includes a high-level assembly view, parts breakdown, and a live CAD model that is up to date and complete. For electrical designs a high-level block diagram, parts breakdown, and detailed schematics should be available. For software reviews, a top-level block diagram, module/object breakdown, and fully commented code listings should be presented. Software reviews require the presentation of a Maintainability Plan per GPR007. In all cases, analysis and simulation results should be available to prove the correctness of the design.

- ***Subsystem Acceptance Reviews:*** Prior to declaring any subsystem *finished*, its function must be demonstrated in a subsystem test report, subject to a review, and the completion signed off by the rest of the team. Any concerns that arise from the review must be addressed (and testing repeated) for a subsystem to be considered fully finished.
- ***Management reviews:*** Periodic management reviews shall be scheduled as needed (no less than monthly) for a detailed review of the project from a management perspective. Only team members dedicated to management roles need to attend these reviews. The main goal of these reviews is to make necessary changes in the schedule and work breakdown to adapt the plan continuously in response to issues that have developed.
- ***A live system state demonstration:*** The team should conduct a system state demonstration using live hardware and software that shows all the system states and the events that cause transitions between states. Along with the demo, the presentation must describe exactly where system state information will be maintained in hardware and/or software, what the state information consists of, and how the information required for state transitions is communicated among different locations. The system state demonstration must include a live demo of all faults and exceptions, showing how these asynchronous events change system states and how the driver and support crew are informed of these faults.
- ***User interface demonstrations:*** with live computer interactivity that implements as much as possible the final look, feel, and functionality of every user interface. It is desirable that the state demonstration be integrated with the UI demonstration.
- ***Communication link demonstration:*** that proves reliable operation of any wireless or wired communication links to every subsystem.

All materials presented or referenced at a review, including meeting minutes and action items must be posted on the website prior to the next weekly status letter.

TD007: Mid-Year Progress Report

The purpose of this report is to give a summary of your project to date, including all that you have accomplished in the first semester. This document builds upon your design proposal and continues to communicate your team’s decisions regarding the subject, goals, scope for your project but also details the current state of the project, accomplishments to date and an updated plan for the project completion. This report can reference the design proposal such that some information from that earlier document can be summarized or included by citation. The following list contains subjects that should be addressed in this report; however, new sections may be included that are germane to your group’s project and current timeline.

- ***Clear and concise problem statement***
- ***Design Pathway and Progress***
  - Motivation

  - Summary of Project Selection Process
  - Stakeholder Engagement
  - Placement of current effort in a larger societal and technological context including consideration of the health/safety/welfare of the stakeholders as well as any global/cultural/social, environmental, economic implications your successful design might have
  - Development and justification of appropriate engineering specifications to which you are designing to
  - First Semester Accomplishments (a non-exhaustive list)
  - Experimentation
  - Prototypes
  - Proof-of-Concepts
  - Software Development
  - Other benchmarking tools used to evaluate your design against your specifications
- ***Revised Plan:*** Explicit steps toward final goals based on current scope with a well- defined team schedule. Define end-of-project success for your team based on your current progress.
- ***Team Self Examination:***
  - How are your progressing on your team process and overall goals?
  - How have your team structure, roles and responsibilities faired so far?
  - Have you made any changes to team structure/operation or project scope?
- ***Budget Update:*** Summary of current spending referenced to accomplishments to date and an updated budget projection for the future based on current scope/goals

TD008: Mid-Year Progress Presentation

A live mid-year presentation shall be scheduled and conducted prior to the end of Fall Term. Engineering faculty and guests shall be invited to the ~~final~~mid-year presentation. This live presentation shall include

- A high-level introduction to the overall project goals
- A high-level introduction to the design
- Content from the Mid-Year Progress Report
- Brief “drill downs” into technical details of complex subsystems of interest.
- Demonstrations of working subsystems.
- Q&A

TD009: Spring Update Report

This is an update document that presents the state of the project at mid-spring semester and plans to correct any deficits or issues. The format is like the Mid-Year Progress Report (TD007).

TD010: Final Design Report

The purpose of this report is to: A) present an overview and set of specifications for the project B) summarize the work on the project that has been done on the project so far both physical and computational, C) describe the testing program that was used to evaluate the effectiveness of the design, and D) provide any information and/or recommendations necessary to allow another team of engineers to either reproduce or continue your work . It is expected that sections will draw from previous reports, in particular the Mid-Year Progress Report, the Prototype Specification Report, and the Prototype Testing Report. However, the information presented must be updated to include any changes/advancements since the prior reports were issued. This document should form a comprehensive report of the entire project.

- ***Clear and concise problem statement***
- ***Design Pathway and Progress***
  - Motivation
  - Summary of Project Selection Process
  - Stakeholder Engagement
  - Placement of current effort in a larger societal and technological context including consideration of the health/safety/welfare of the stakeholders as well as any global/cultural/social, environmental, economic implications your successful design might have.
  - Project Organization
- ***Engineering Specifications:*** a set of the most significant specifications and critical requirements that govern the design of your project.
  - Specification Table/Functional Decomposition
  - Description of methodologies to determine design specifications
  - Any refinement of the relevant engineering design specifications discovered during prototype design or testing
- ***Current state of the project (Accomplishments)***
  - Description of current Prototypes/Proof-of-Concepts/Fabrication plans
  - Sub-system integration
  - Experimentation, Test-plans, procedures, other benchmarking tools for measuring the quality of your current solution as determined by your engineering specifications

    - How well does your current design meet the specifications as laid out in the prototype specification report?
- ***Test Results and Design Modifications***
    - Describe how the completed testing results will influence changes to your current statement of work and next prototype development, if needed.
- ***Final Budget Update:*** -1) Summary of total project spending referenced to the current state of the project 2) Theoretical budget to reach a final prototype, if needed.

TD011: Final Presentation

A live final presentation and demo shall be scheduled and conducted prior to FDD. Engineering faculty and guests shall be invited to the final presentation. This live presentation shall include

- A high-level introduction to the overall project goals
- A high-level introduction to the design
- Content from the Final Design Report
- Brief "drill downs" into technical details of complex subsystems of interest.
- The Project Video
- Live Project Demonstration
- Lessons Learned
- Q&A

TD012: Project Video

In addition to any training videos produced for the User's Manual, the team should produce an additional video that tells the story of their design experience.

The video should include a project introduction and summary. There should be a collage of clips from the development process, a high-level demonstration of the capabilities of the system, and a brief conclusion that includes lessons learned and advice to a future team. If possible, every member of the team should have a brief appearance. The video should be engaging, memorable, and professionally produced with titles, tasteful effects, and music.

If the team participates in any competition, or describes their work in a conference, this participation should be documented as part of the video.

The video shall include clips from the design and development process that spans the duration of the project. For this reason, it's necessary to work on capturing this video *throughout* the project. This video is shown as part of the final presentation and is posted on the website for reference by future teams.

The video should be about 10 minutes in length.

The video shall meet the detailed requirements of GPR001.

TD013: Posters and Poster Sessions

Typically, there are two poster sessions, one in the Fall and one in the Spring. Major sections of the project shall be documented as attractive and interesting summary posters displayed during these sessions.

These posters shall be delivered to the web site in electronic form per GPR001. In addition, the posters shall be physically printed in a large full color format and displayed in poster sessions for review. Detailed printing requirements will be provided by the division prior to the session.

The purpose of the poster session is to provide the Lafayette faculty, staff, and community an opportunity to interact with your projects. It's a chance for interested folks to celebrate your current state of achievement and ask questions about your process and progress. It is also an opportunity for you to practice your presentation skills in a different environment, speaking one-on-one or to small groups of people who have a great variation in technical background, including folks with no technical background. Finally, it is a chance to get direct feedback from others interested in your project and to have more of an interactive discussion.

The overall senior design team should have multiple posters that together tell a complete story. These posters should be created by separate 3-4 person groups (one group per poster).

It's important that the poster quickly and effectively conveys a main aspect of the project. As a minimum each poster should include a prominent:

- Title
- List of Authors
- Author Affiliations (Lafayette College ECE, ME, etc…)

Use pictures, simple diagrams, and graphs. Avoid lots of fine text; everything on the poster should be readable from 10 feet away. Word count should be 300 - 800 words. Use scalable vector graphics or high-resolution raster to make sure your images and other graphics don't become "pixelated" when printed in large format.

There are many good online resources for poster design. Study them! It is highly recommended that students submit drafts of the posters to instructors one week prior to the poster session for a quality review. The final poster should be complete and submitted to print ample time prior to the session.

Team ***Test Plans and Test Report Deliverables***

The overall system and all complex subsystems should be tested to prove that they meet specified requirements. In commercial industry, the customer or end-user for a system usually will not accept and pay for a system unless it is accompanied by certified testing that proves requirements were met.

Testing is guided by two documents: a **test plan** and a **test report**.

For each requirement or deliverable, the test plan must specify how compliance with that requirement or quality of deliverable will be demonstrated. Executing the plan results in data that is included in the test report.

Test-plans and reports are only required for complex subsystems. Consult with faculty and the rest of the team to decide if a certain subsystem is complex enough to merit formal review and testing.

End users and faculty should be invited to witnesses testing, but are not required to.

Test Reports determine the grade for project success.

Test plans must specify the following:

- What ***Measurements, Analysis, or Inspection*** will be made as part of demonstrating the requirement has been met.
  - ***Measurements*** **–** an explicit test, experiment, or demonstration can be used to prove compliance with a certain requirement by acquiring new empirical (measurements). The comprehensive results of any measurements conducted as part of a test is included in the plan, along with date and time of the test, the pass/fail criteria, uncertainty, pass/fail result, witness name, and witness signature. Empirical tests must be accompanied by an error analysis.
  - ***Analysis*** **–** demonstrate compliance by reasoning from known facts. Analysis can be used cited research results in conjunction with the documented results of measurements, subsystem QA testing, along with generally accepted technical principles to prove system level requirements are met. Analysis memos and relevant data are attached to the report.
  - ***Inspection*** **–**compliance is made evident by directly examining the system. Photographs with detailed annotations or other evidence gathered in an inspection is included in the report.
- What ~~the~~ ***Pass/Fail criteria*** will decide if the requirement has been met.
  - The plan must be unambiguous with respect to the criteria used for determining if a measurement or inspection has met the relevant requirements.
  - In the case of requirements based on measuring some quantity, sufficient number of measurement samples with sufficiently low uncertainty must be acquired such that a test is unlikely to pass through random chance. Pass criteria for empirical results must have at least 90% statistical confidence.

Test reports should include:

- What is being tested (device name, version number, build state, serial number, etc.…)
- Who did the testing (names, affiliations, etc...)
- When the testing was accomplished (dates and times)
- Measured data from the tests, both in human readable form and machine readable data files, if available.
- Photographs of any measurement setups
- Inspection photographs (test by inspection). The photos shall be annotated in a way that explains for each photo exactly what requirements are shown as satisfied and why.
- Relevant calculations and analysis (show your work) for analysis tests.
- Pass fail determinations for measurement tests (based on 90% confidence).

The report should use automation as appropriate to streamline work and improve accuracy. For example, it is often convenient to create the report in the form of a computer spreadsheet automating statistical calculations, pass/fail determinations, plots, etc…

The report gathers all test results. The report comprises the accumulated results of testing per the test plans and other related data. It shall adhere to the documentation standards of GPR001. If the test reports include some handwritten content, they shall be scanned and preserved in electronic form. The original paper must be disposed of per GPR012.

All test plans and reports must be delivered to the web site and faculty per GPR001.

TD014: Subsystem Test Plans and Reports

Prior to declaring any complex subsystem finished, its function must be measured and evaluated according to a subsystem test plan, and these results recorded in a subsystem test report, subject to a review, and the completion signed off by the rest of the team during a Subsystem Acceptance Review.

Test-plans and reviews are only required for complex subsystems. Consult with faculty and the rest of the team to decide if a certain subsystem is complex enough to merit formal review and testing.

If multiple copies of a certain type of subsystem are required, it is often prudent to fully test one unit before the other units are put into production. Eventually all the copies must be tested. The final subsystem test report should include a record of the testing of each and every instance (serial number) of the subsystem type.

TD015: Top-Level Laboratory Test Plan and Report

The Top-Level Laboratory Test Plan (LTP) is a document that describes how the car electromechanical systems, as a whole, will be tested and demonstrated prior to integration into a moving vehicle. Laboratory testing is typically conducted in the dynamometer room (AEC 401). An integrated set of electromechanical subsystems (motor, controller, safety loop, “CarMan”, batteries, SCADA, cooling, dashboard, etc…) are tested to demonstrate operational safety, and compliance with as many requirements as can be demonstrated in a laboratory test.

Laboratory Test Report (LTR) is a document that documents the results of the execution of the Lab Test Plan (LTP). The report should include measured test data, inspection reports, and analysis memos that demonstrate compliance with all specifications.

TD016: Dynamic Test Plan and Report

The Dynamic Test Plan (DTP) is a document that describes how the car as a whole will be tested and demonstrated prior to competition to show compliance with all Formula Hybrid competition rules, as well as the successful integration of all subsystems into the car.

Dynamic testing may occur “on road” on Lafayette College grounds (typically the Metzgar Field parking area).

Dynamic Test Report (DTR) is a document that documents the results of the execution of the Dynamic Test Plan. The report should include measured test data, inspection reports, and analysis memos that demonstrate compliance with all specifications.

***Team* Documentation Deliverables**

The following documentation data items are required by Final Delivery Date (FDD).
These items must meet GPR001.

TD017: Project Web Site

A project web site is required per GPR001 and GPR012. All project deliverable data items shall be posted on the site.

The content of this site shall be professionally presented and organized. Timely updates of the site are required. The site must serve the real time needs of the project, but also must be left as a useful resource for reference in the years to come. Content on the site must remain available for at least 10 years.

Content on the site must be visible over the Internet by the general public using a standard browser. The main content should be largely static, with portable formats (e.g. PDF, TXT, XML) used exclusively for presenting information to guarantee compatibility with future viewing software. In addition, all source code, CAD files, original documents in native and binary format (e.g. .docx, .xlsx, .c, .v, .m, etc…) shall be archived within the web site along with installation links for toolchains.

It is highly recommended that software toolchains be deployed in virutal machines allowing the entire toolchain with libraries to be preserved as a VM file included on the website.

The latest version of each design file must be identified, with older versions remaining available for reference. Version numbers and IDs must be clearly marked.

The use of supplemental "cloud storage" services (e.g. Google Drive, Dropbox, GitHub, etc.…) are permitted only if the main website includes prominent, easy to find, index links to content on these services. Content not indexed by the web site effectively does not exist.

At the end of the project, before FDD, copies of the Web Site shall be produced and physically delivered on USB Flash Drive individually to to each of the course instructors, both ECE and ME. The Flash Drive copy <u>must have a physical copy of every document and file</u> (not just a link to the cloud). Everything from the cloud must be copied onto the Flash Drive, including all Google Drives, DropBoxes, VM Images, CAD Libraries, Network Shares, Git Repositories, etc.….

TD018: Final Purchasing Report

This report shall document every purchase by the project. Tables shall be provided that showing each purchase request, what items were purchased in that request, when the items were received, and any returns/refunds.

Summary tables shall be provided that give purchasing totals broken down by budget categories, by week, and by task group. Statistics shall be calculated for delivery elapsed time, delivery cost, sales tax, and other items of interest.

TD019: User’s Manual and Training Videos

A Users Manual is a section of the web site that documents the end-user operation of each major subsystem and the system, as a whole. This should be a high-level document that contains an annotated drawing of the physical system, annotated screen shots of all user interface screens, annotated drawings of any physical control panels, indicator buttons, power switches, and other controls. The user’s manual must include a simplified block diagram, explains all operational procedures and techniques needed to operate the system is a safe and effective manner, including “getting started”, “FAQ”, detailed explanations of all functions and controls, and user level troubleshooting, calibration and maintenance.

As an alternative to a written User Manual section, training videos can be created that teach the viewer the basics of how to operate the subsystem correctly and safely. Videos shall meet the requirements of GPR001.

TD020: Maintenance Manual

The Maintenance Manual shall be a section of the web site that unifies and indexes all low-level documentation (CAD Drawings, schematics, source code, test results, etc…) for the system. All schematics, parts list, pinouts of all connectors, the signal assignments of all cables, the semantics of all interfaces (hardware and software), block diagrams, state diagrams, source code trees, and other low level information must be documented within this manual.

Along with design documentation, Maintenance Manual should include

- ***Principles of Operation*** documents that explains the unique technical principles and details of subsystem and system operation.
- ***Errata*** documents that list know problems and limitations (either patched or unpatched) in implemented designs.
- ***Maintenance and Calibration*** procedures that must be conducted by expert maintainers (not end users).
- ***Troubleshooting*** flowcharts and suggestions for expert maintainers.

TD021: Final Delivery Checklist

This document contains a list of all team deliverable items (TD001 through TD021) along with the required due date, and the actual date on which they were completely delivered, and the name of a responsible individual (student) who checked that the deliverable has been properly delivered.

For all test reports (TD014,15, and 16), a compliance percentage should be calculated as the number of tests passed divided by the total number of tests. This percentage should appear next to each test report listed in the checklist along with the due date and delivered date.

For competition deliverables, the competition score normalized to 100% shall be calculated as the ratio of awarded points divided by available points. In this calculation bonus points are not included as available, so it is possible to have greater than 100%. Omitted or skipped deliverables should be listed with 0%.

In addition, this document will contain a detailed checklist of all items that need to be completed to satisfy the requirements of GPR012. Dates completed and responsible individuals should be listed for each of these items.

Appendix A – General Project Requirements

The following requirements apply to all Senior Design Projects.

GPR001: Documentation

Complete and accurate documentation must be provided with all projects. These documents shall include documents for mechanical and electrical fabrication, test results, software development kits, maintenance manual, user manual, and specification compliance matrices, and technical papers. All documentation shall be accumulated in electronic form, centralized in a project web site, and thoroughly indexed.

Data items with privacy concerns (e.g. individual status letters) are delivered to course instructors and posted to a private area (e.g. Moodle). All other data items shall be delivered both to the course instructors and to the project web site. In the case of moderate sized PDF documents, the document should be emailed to course instructors and posted on the course web site. For larger deliverables, email notice may be sent to course instructors along with a URL of the deliverable as placed on the web site.

Text documents shall be formatted using a word processor in a professional style.

1. All drawings shall be complete in accordance with the standards established in ME210 and ECE491. In addition, drawings must
    a. Be legible and neat – freehand sketches are unacceptable
    b. Exactly and unambiguously describe the most recent version of the part or assembly, including any bug fixes or improvements
    c. Give all critical dimensions with units
    d. Specify all materials
    e. Have a Lafayette or project specific border with completed title block that includes correct names, dates, part name, number, etc.…
    f. Include the name of a specific individual requesting the part, with their full name, email, and phone number.
    g. Parts must have a unique part number. Assembly drawings and BOMs should use these part numbers consistently.
    h. A part drawing should show the part number somewhere in the title block, the part number should be included in the drawing file name, and the part number should be marked on the part itself at some inconspicuous location using an indelible marker, metal stamp, or other permanent marking system.
    i. Any drawing submitted to the Lafayette Engineering Machine Shop for fabrication must be approved and signed by the designer, the team project engineer, and relevant faculty. “Rough” sketches without approval signatures may not be submitted to the shop.
2. Final drawings of fabricated parts must be indexed and archived on the project web site in PDF form. It should be possible to click on a drawing and open it directly without needing to download and unzip an archive.

3. Students may not submit un-reviewed “sketches” to the machine shop for fabrication. All drawings must be prepared according to GPR001 standards, archived on the web site in PDF format, and bear multiple review signatures along with the name, email, and cell phone number of the responsible individual BEFORE being submitted to the machine shop.
4. All original paper documents should be scanned and stored electronically. The original should be disposed of per GPR012.
5. Test reports for mechanical systems, hardware and software must show the date/time of testing, name and signature of the tester, and name/signature of any witnesses.
6. For all electronic PCB designs the following fabrication documents are required: dated, and numbered schematics or mechanical drawings on Lafayette College drawing format, circuit net-lists, bills of materials, artwork, assembly drawings, and all other files and instructions necessary for CAM or manual manufacturing. The source files for fabricating PCBs and editing linked schematics shall be clearly identified and preserved.
7. For all mechanical assemblies the following fabrication documents are required: mechanical drawings on Lafayette College drawing format, bills of materials, assembly drawings, and all other files and instructions necessary for CNC or manual manufacturing and assembly. The GCode source files or *.dxf files for fabricating parts on the CNC tools shall be clearly identified and preserved.
8. Documentation must be provided both for original designs and for any subcontracted designs. For purchased vendor components within the design, all vendor manuals and documentation shall be retained with the system. Proper mechanical drawings are required for fabricated mechanical parts. Manufacturers data sheets and interface drawings are required for all purchased components.
9. For software and firmware designs: Source code, and executable binaries for all applications; Verilog, constraints and configuration bitstreams for FPGAs; and ROM image files in commonly accepted JED or HEX formats for all PLDs.
10. Videos may be posted on YouTube or other cloud services, but a physical copy of the video in a file format that plays reliably on most PC/MAC/Linux computers must be included as part of the website archive.
11. All documentation must be provided and delivered in electronic form. Emailing a description of a document along with a URL into the project web site is an acceptable and desirable form of delivery. The use of standard and portable document formats (e.g. PDF, TXT), must be used so that the documentation can be viewed on any computer without the need for proprietary applications. Nevertheless, along with a viewable PDF version of every document, the original source format of the document (.docx, .vsd, etc.…) must be archived on the site. The documentation must be arranged in an organized and professional manner on the project web site. Although documents, photos, and videos may be posted temporarily on Google or YouTube or other cloud services for convenience, it’s important that the team archive the original files on college controlled networks (eg, the project web site) as well as on non-volatile media delivered to the course instructors.

12. To promote the College in general and the ECE Department in particular, documentation, hardware, and software shall be marked with the name of the college (using the official logo) along with the words “Electrical and Computer Engineering” in a similar sized font. All circuit boards, major assemblies, enclosures, racks, and any significant hardware subsystem, as well as all software modules, files, “About” screens, “splash screens” shall be so marked. In addition, the names of project team members may be added in a professional and tasteful way to titling on documentation, hardware, and software.

GPR002: Purchasing and Budget

1. **No expenditures will be approved till the project has developed a detailed budget.** All purchases must fit within pre-established budget constraints.
2. Any direct item to be purchased must be requested on a Lafayette Engineering Department Purchase Request form. An engineering professor must approve all requests.
3. Purchase requests must be archived on the web site.
4. The team shall keep a binder or spreadsheet with all approved purchase request forms. These should be tracked by the team against orders and received material. It is recommended that a single individual or small group be assigned for managing material procurement.
5. The college’s purchasing agent will not accept unapproved requests, nor will they accept requests that are not on the standard form. Purchasing requests may be entered only on certain days. Basis for approval will be the degree to which the expense fits with the project plan of record. In general, overnight shipping will not be approved.
6. Running totals of costs incurred should be updated daily or even in real time if necessary, especially when approaching critical limits or deadlines. Updated cost reports and budgets shall accompany requests for major purchases.
7. Received material without special safety considerations may be stored in the empty cabinets and shelves in senior design spaces as approved by faculty. It is the responsibility of the team to receive, inventory, and preserve the stock of received material.
8. In exceptional situations certain “big ticket” items must be purchased for the project with funds that are outside the general project budget.
9. Non-budget funding for such items may be sought from the Engineering Division subject to the approval of Engineering faculty and department chairman. All such requests much be accompanied by written justification.

GPR004: Hazmats

Hazardous materials should be avoided in designs. If use of a hazardous material is essential to the function of the design and there is no non-hazardous alternative, the use of the hazardous material must comply with the Lafayette College Chemical Hygiene Plan.

All materials used in electronic circuit fabrication must meet 2002/95/EC RoHS directives. NiCd or Lead-Acid batteries may not be used in new designs.

Any liquids: water, coolant, brake fluid, resin etc. must be stored in properly labeled containers. Liquids that degrade over time must also be marked with the date received. All materials used on the car must have the accompanying MSDS information stored both on-line and physically in the workspace.

Any portion of the design or prototype that is discarded must be discarded according to the Lafayette College Chemical Hygiene plan. Also, projects should discard the collected electronic waste in an ecological-friendly manner as per the 2002/96/EC WEEE directive, either by ecological disposal or by reuse/refurbishment of the collected waste.

GPR005: Safety and Good Practice

All work shall comply with good industry practice that enhances reliability and maintainability. Students ARE EXPECTED to know ALL the rules and practices listed below. The separation of some of the rules into electrical and mechanical work is for easier identification only. These practices include such items as

General

1. Project activities must adhere to the general Lafayette College safety policy, possibly augmented by any Engineering Department or Laboratory safety rules.
2. A project team member must be designated project safety officer. It shall be the project safety officer's responsibility to ensure that all activities adhere to the project safety plan.
3. Students may not work, or be in the laboratory, machine shop/project rooms while others work, when impaired. Impairment includes being under the influence of alcohol or drugs (including prescription or over-the-counter medication), exhaustion, sleep deprivation or any other condition that adversely affects one's judgment.
4. Any project that develops AC RMS or DC potential differences greater than 30 Volts between any two points within the design (other than at the unmodified mains input side of a UL listed commercial power supply) must adopt and implement an electrical safety plan before any circuits are powered. The safety plan must document the processes, design constraints, and equipment that will be used to ensure the safety of all participants. Faculty must approve the safety plan. The plan must be posted in the work area.
5. Safety glasses must be worn by everyone in mechanical work areas.
6. All work areas must be kept clean.
7. In the event of an emergency call public safety immediately by dialing 4444 (610-330- 4444 from a cell phone) and be prepared to give the following information:
    - Building name
    - Room number
    - Type of emergency (e.g. fire, injury, chemical release)

    Emergencies include but are not limited to:

    - Deep lacerations
    - Loss of consciousness (for any reason)

- Sickness from fumes (from known or unknown sources)
- Electrical shock (even if the person remains conscious)
- Accidental ingestion (even without symptoms)
- Eye injures such as impact to the eye (even without symptoms)
- Chemical burns

8. As soon as possible after an incident has occurred, students involved must report the incident to their faculty advisor. The faculty advisor will report the incident to the head of the department.
9. Color coded wiring in accordance with applicable industry standard color codes (e.g. NFPA 79 or UL508 for power wiring, EIA/TIA 568 for network wiring, etc. …)
10. Wire and cable must be marked with gauge and temperature rating.
11. Clear labeling of all controls and indicators.
12. An obvious and clearly labeled system-wide power shutdown switch.
13. Silkscreen on PCBs that includes reference designators, noted power supply voltages and other critical signals. Silkscreen must show a Lafayette College logo, leopard paw icon, the words “Made in USA”, the words “Electrical and Computer Engineering”, assembly number and revision, and designated locations for serial numbers to be attached or written. PCB bottom copper should have text indicating the board part number and rev.
14. Fuses shall be mounted in UL listed sockets or holders and at least 5 spares must be included with system delivery; breakers shall be resettable. All are readily accessible per maintainability requirements.
15. Service loops must be included on all cable harnesses.
16. Access panels to must be provided on enclosures that contain components that require routine access.
17. Software/firmware developed must adhere to the principles and practice established in Lafayette College course CS205. Source code must be maintained under configuration control.
18. FPGA Logic shall be defined in HDL according to the rules and guidelines established in Lafayette College course ECE221.
19. Embedded computer processors shall have reset buttons. These buttons must be readily acceptable for maintenance, but not so easy to hit that they degrade reliability.
20. Major, visible enclosures shall have pilot lights, indicators, meters, displays, and other features that allow observers to be able to tell what is “going on” within the box without need for extra equipment.
21. Power LEDs shall be green. Red LEDs shall be reserved for error or exception conditions. Yellow and blue LEDs are used for status indications. Microprocessors shall have a “heartbeat” LED that blinks when working code is running.
22. All measurement indicators shall be labeled with units.

23. Wiring connections shall be insulated with heat shrink tubing or other rugged material. Electrical tape may not be used for insulating wire connections.
24. Circuits must be enclosed either by fully grounded metal enclosures, or fully insulated non-metal enclosures. PCBs may not be mounted directly to the outer walls of enclosures with nut/bolts pairs and loose standoffs. The use of an internal "chassis plate" for mounting electrical parts is encouraged.
25. Nut/Bolt fastener pairs may not be used within electrical assemblies. Use captive fasteners: PEM press fit fasters, threaded holes, clip nuts, or similar.
26. All fasteners should include suitable flat washers and lock washers.
27. Every enclosure must be labeled both externally and internally. All cables and wiring harnesses must be labeled. Labeling must be consistent with the ICD.
28. Every cable between assemblies shall have at least one dedicated current return within that cable. These returns shall carry all the return current for signals in that cable. Chassis ground may not carry return current except in a fault condition.
29. Cables and wires shall connect to assemblies and boards by means of suitable connectors. The use of stripped wire into "screw terminals" is strongly discouraged, especially for wire/board interfaces.
30. Connectors must use strain reliefs to prevent mechanical stress on the pin-wire connection.
31. Connectors must be in accessible locations with sufficient "hand grip" room.
32. Crimped pins must be assembled using a proper crimping tool. The wire size and type must be compatible with the pin.
33. Current drain analysis must be provided for all power supplies. Each supply voltage must have a current rating with a 50% safety factor over the anticipated peak current.
34. All resistors or other parts dissipating more than 25 milliwatts shall be identified and analysis shall be provided that shows all such parts are properly rated for peak and average power dissipation and have a proper heat sink and fan, if necessary, that provides adequate cooling over the ambient temperature range.
35. Fans should be protected with grilles and filters. EMI analysis must consider the fan opening and specify EMI tight grillework if necessary.
36. Components must be cooled such that the temperatures of accessible surfaces are no greater than 60° C. If normally closed assemblies contain parts that may be hotter than 60° C and those assemblies have a cover or access panel or other enclosing structure that may be opened during routine maintenance, a "Caution HOT" label shall be affixed on the cover.
37. Power dissipation rating of parts shall be 50% overrated over the required temperature range.
38. Working voltage of capacitors shall be 25% overrated above the peak voltage anticipated, including all expected glitches, spikes, and tolerance limits.
39. Project activities must adhere to the general Lafayette College safety policy, possibly augmented by any Engineering Department or Laboratory safety rules.
40. Any project that develops AC RMS or DC potential differences greater than 30 Volts between any two points within the design (other than at the unmodified mains input side of a UL listed commercial power supply) must adopt and implement an electrical safety plan before any circuits are powered. The safety

plan must document the processes, design constraints, and equipment that will be used to ensure the safety of all participants. Faculty must approve the safety plan.

41. All equipment developed must comply with applicable national standards. Installations of electric conductors and equipment that connect to a building main supply of electricity must be designed, constructed, operated and maintained in accordance to The National Electric Code (NEC) ANSI/NFPA 70.
42. Any interconnection with the Lafayette College power grid is subject to the approval of Plant Operations. Any interconnection with the Lafayette College campus computer network is subject to the approval of the Information Technology Services department.
43. Use and design of lasers shall be in accordance with American National Standards Institute (ANSI) Z136.1-2000, "American National Standard for Safe Use of Lasers". Only low power Class I, II and Class IIIa (<5 mW) lasers should be used. If project requirements necessitate higher power, the project must develop and implement a laser safety plan before any laser work begins. The safety plan must document the processes, design constraints, and equipment that will be used to ensure the safety of all participants.
44. All projects that involve RF power of any level must be designed to ensure that participants are not exposed to RF in excess of the recommended exposure limits adopted by the FCC (most recently in 1996, but note the proposed rule change in 2003). If project requirements necessitate radiated RF power in excess of 100 mW, the project must develop and implement an RF exposure safety plan before any high power RF work begins. The safety plan must document the processes, design constraints, and equipment that will be used to ensure the safety of all participants.
45. Projects that contain recognized hazards must develop a project safety plan. Such hazards include but are not limited to high altitude, operation at sea, on lakes, or in rivers or mines, exposure to electrical, chemical, biological, radiological, or psychological hazards.
46. All projects that involve machinery that create hazards such as those created by point of operation, ingoing nip points, rotating parts, flying chips and sparks, etc…, must develop and implement a machinery safety plan before any machinery work begins. At a minimum, the plan must address US Title 29 CFR Part 1910 Occupational Safety and Health Standards, Sub Part O, Machinery and Machine Guarding.
47. Work is primarily performed in the student machine shop under the direct supervision of a technician or faculty advisor weekdays between 8 am- 3:45 pm. 3:45pm -4:00pm is reserved for cleanup. In special cases the students can work in the shop at other times under the direct supervision of a technician or faculty advisor.
48. Work can be performed by students in ME project rooms between 6 am – 12 am. Outside of weekday operating hours (8 am- 4pm) at least 2 students must be in the project area where the work is being performed
49. Students cannot use the tools in the mechanical areas until they have reviewed the procedures with a supervising technician (faculty advisor or shop personnel). A list of the tools and applicable procedures are available at me.lafayette.edu/safety

50. Students will consult with technicians about the manufacturability of designed parts. Dimensioned drawings must be submitted to the supervising technician. In most cases the machine shop staff will complete fabrication after the consultation process.
51. Testing of any prototypes requires a written testing plan and risk assessment be completed and documented by the students and approved by the faculty advisor in advance of the test. A suggested method to assess and document the risks is available on the ME department website.
52. Prototype testing is restricted to the hours of 6 am to 12 am.
53. Parts should be fully finished with no sharp edges of corners.

GPR006: Reliability

The system wide Mean Time Between Failures (MTBF) must be greater than 1000 hours over the system lifetime. Reliability must be demonstrated in the test plan both by analysis and by Inspection. Failures are defined as anything that causes system requirements to be missed. Failures include, but are not limited to, computer software lock-ups, shutdowns caused by overheating, automatic operations stalled by exceptions or requests for human intervention, as well as random component failure.

1. For reliability analysis, the use of MIL-HDBK-217, Bellcore TR-332, or other equivalent techniques are encouraged for the analysis. Every part and subsystem in the full BOM must be explicitly considered in the MTBF analysis.
2. Parts with power dissipation over 25 milliwatts shall be identified and the reliability analysis shall include reliability derating of these components based on the expected dissipation.
3. In addition to the analysis, a reliability inspection shall be conducted during ATP where the system is shown to operate for 24 hours without any obvious failure.

GPR007: Software and Firmware Maintainability

A software maintainability plan must be developed and reviewed for every complex software subsystem. The plan should describe the overall approach to software maintainability and provide thorough answers to the following questions. Evidence must be provided to support assertions.

a. How will the software be installed on new hardware? What happens if the hardware goes obsolete?
b. How are errors and exceptions handled? How are logs viewed? How are exceptions configured and modified as requirements change?
c. How is backup performed? What is the restore procedure?
d. How is a fresh system deployed and validated on new hardware?
e. Are system logs and data files automatically trimmed? On do they grow and require manual trimming or offloading? If so, how is this accomplished?
f. What is the design of the system API and how will this design support ongoing reliable operation, maintenance and expansion?
g. How is system configuration maintained? Will the system auto detect hardware configuration changes or will configuration maintenance be

required? If the latter, what is the consequence of misconfiguration? How will the software function when only some of the system hardware is available? Are demo or simulation stubs available for major hardware?

h. How is system configuration checked? Are tools provided for generating valid configurations?
i. What tool chain will be used? Is the tool suite up-to-date and actively supported? Is the tool suite mature enough to have stable functionality? How is the tool chain installed in a new development system.
j. What third party software will be incorporated into the system? How will this be maintained, upgraded, or patched during the life of the system?
k. How are requirements in GPR007 met?

In addition, software and firmware must meet the following maintainability requirements.

1. All software source code must be maintained under configuration control, either in on-campus or “cloud” repositories. Nevertheless, complete release snapshots must be archived on the project website.
2. The system must start from cold power-up and boot to full operational status without requiring user interaction beyond enabling power and safety procedures.
3. Any PC software must be packaged for installation with a SETUP.EXE, RPM, JAR, “make install” or equivalent installer allowing it to be installed easily on any compatible computer.
4. Configuration parameters, calibration factors, preferences, and options shall not be hard coded within the software source code. It shall be possible to alter these various factors without recompiling software or physically disassembling hardware. Altered configuration parameters must be persistent through power cycling and reboots. The system must have a function to initialize itself with sane (factory default) configuration content if requested.
5. All data and configuration files must be in a generally supported format (e.g. JSON, XML) or the format required by a mature and well supported application (e.g. MySQL database files, Berkeley db, etc…). The use of custom formatted ASCII or binary files for configuration or data storage is not permitted. Files shall be accessible either through removable media or network file transfer or both.
6. Cross references in configuration files shall use human readable text identifiers, not cryptic numeric codes.
7. Log files, data files, and any other files that grow over time shall be automatically trimmed by system software.
8. A scheme for automatic system backup of data storage shall be provided.
9. To the largest extent possible, the use of passwords shall be avoided. If the use of a password is unavoidable for serious security reasons, the password must be archived in a clearly documented location, and the user manual shall explicitly provide a scheme for password recovery.
10. The use of removable media (thumb drives, flash media cards) is permitted for configuration parameters, offline storage, access, and backup. If removable storage is used for configuration, the system must have the inherent capability to operate without media, and to initialize blank media with sane configuration content.

11. Enumerated devices, such as USB, must be automatically discovered by the system and assigned correct port designations such that the system operates correctly after re-enumeration without any interaction or re-programming by the user. Port designations may not be “hard coded” in the software or firmware.
12. Any cell phone software must be packaged and available from an online “App store” for easy installation on any compatible phone without requiring special alterations of the phone such as SDK installation or jailbreaking.

GPR012: Final Disposal of Projects

Projects may be stored for future work, placed on display, or discarded. Time must be included in project schedules for final disposal.

1. If a project is to be stored, all its materials must be collected together in a single location. If possible, these materials should be enclosed in a sealed container, locked cabinet, or secure room that contains only these materials from one project and no other. If certain parts are impractical to store with the bulk of the project materials, these separate parts must be clearly labeled so their association with the stored project is obvious.
2. Projects placed on display may have portions not on display. The undisplayed portions shall be either stored or discarded as described herein.
3. Portions of projects or complete projects that are discarded must be discarded in accordance with Hazmat procedures described herein.
4. Test equipment moved from labs shall be replaced in its original location.
5. Trash, loose wires, scattered components, and other detritus resulting from frenzied development and testing shall be cleaned up.
6. Paper documents that have been scanned per GPR001 shall be recycled.
7. The project web site must be updated constantly with the most recent versions of all documents. The documents on the final web site must match the delivered system. Obsolete documents on the web site shall be removed.

8. The entire design, or some major functional subsystem of the design, must be suitable for continuous, unattended display as a self-contained, active demonstration that would excite the interest of students, faculty, and other ECE Department visitors. Such demonstrations must meet the following requirements:

    - Demonstrations must fit in a compact public area and operate safely and without unreasonable disturbance of its neighbors.
    - In demo mode, computer screens must periodically display the Lafayette ECE logo, list of team members, and a team photo to the extent permitted by the graphics capabilities of the screen, and functional realizability.
    - If powered by building mains, the demonstration shall automatically restart after a power outage. User interaction with the demo is encouraged, but if activated by some passer-by, the demonstration must deactivate automatically after a short delay. The MTTR and MTBF of the demonstration must meet or exceed the project-level Maintainability and Reliability requirements given herein.

Appendix B – Team Management

Teamwork is critical to the success of projects. True teams outperform groups of individuals working independently. How well students work together as a team correlates strongly with project success.

To become a true team, rather than just a working group of individuals, ***the team must establish team performance goals and hold themselves mutually responsible for achieving those goals.***

Three coordinating mechanisms lead to the mutual accountability toward performance that characterizes a true team. These are

- Closed Loop Communication
- Shared Mental Model
- Trust

Team members must communicate with each other to develop a common approach to the problem at hand. This is the Shared Mental Model. A team cannot make progress pulling in different directions. Past experience has shown that excessive reliance on open-loop electronic communication (e.g. email, texting, google apps, etc.…) can be counter-productive. The team must communicate closed-loop, and actively inspect first-hand the work of all team members to hold each other mutually accountable for performance toward the goals using the agreed-on approach.

When team members fail to meet goals, the team structure must adapt to correct the individual. If necessary other people must step up to do the work if the team is to be successful. This can only happen if the team members trust each other and hold each other mutually responsible for achieving goals.

As individuals, team members should strive to develop the “big five” qualities that make them a good team member

- Leadership
- Team Orientation
- Mutual Performance Monitoring
- Backup Behavior
- Adaptability

Leadership doesn’t mean telling people what to do. Rather it means leading by example and setting a positive tone. Leaders have strong Team Orientation, putting the goals of the team ahead of their personal goals. Strong team members pay attention to the work being done by other members of the team through Mutual Performance Monitoring. This monitoring leads to mutual accountability. When the monitoring discovers a shortfall, a good team member will step in and provide Backup Behavior – helping their teammate. Over time, all these characteristics lead to an ability of each good team member to adapt to changing requirements.

Work Breakdown Structure

A key management tool in almost any engineering project is a hierarchical task breakdown (Work Breakdown Structure, or WBS). The Work Breakdown is essentially a TODO list, usually created in hierarchical tree form. An example WBS is shown in the appendix. This breakdown focuses on the outcomes or milestones that must be accomplished to complete the overall project. The WBS should break down the overall project to identify specific, measurable outcomes that will be accomplished. The responsible individual ad due date shall be noted on the WBS for each outcome. The WBS shall follow the **100% rule** and comprise the entire project, including deliverables and management. Definitions of tasks shall be according to “**SMART**” criteria.

https://en.wikipedia.org/wiki/SMART_criteria

The team must place a relentless focus on team performance as measured by completion of SMART goals. Team members must hold each other mutually accountable for achieving the tasks.

It is valuable for the WBS to be printed in large format paper and posted in working areas. The WBS is reviewed weekly, updated as outcomes are completed, and expanded as new goals are discovered. The team should be aware of the lead-time required by the machine shop and other resources, factoring this time into the project schedule.

Schedule

The WBS provides only part of the information needed to successfully plan out the project. It gives you a list of what needs to be done, but does not specify **when** must it be done, or in **what order** it needs to be done. Since proper WBS tasks should be “Time Based”, it should be possible to assign a due date for every task. The ordering of tasks is a degree of freedom in planning, constrained by some tasks that have dependencies (e.g. an item can’t be assembled till the constituent parts are received.)

One typical tool for this analysis is the Gantt Chart. Gantt charts: 1) provide deadlines for each of the tasks listed in the WBS, 2) shows the ordering and possible parallelism of unrelated tasks, and 3) shows the dependency of one task on another. Both the WBS and the Gantt chart are living documents that will need to be updated and maintained throughout the project.

Appendix C – Template Documents

Individual Progress Report

IPR Number [serial number]

Covering period from [Start Date] to [End Date]

Prepared by: [Student Name (s)]

WBS Tasks I completed in the previous week:

[Complete WBS items only. List specific, clear definition of completion that can be checked. Make special note of deliverables accepted or requirements demonstrated successfully.]

WBS Task Completed 1: WBS Item Number, description

WBS Task Completed 2: WBS Item Number, description

D00X Delivered: WBS Item Number, description

…

WBS Tasks I plan to complete next week.

[Complete WBS Items Only. List specific, measurable planned task outcomes along with the responsible individual for each goal.]

Due 1:WBS Item Number, description

Due 2:WBS Item Number, description

…

Overdue WBS Items

[Give consequences and a mitigation plan]

Project Status Report

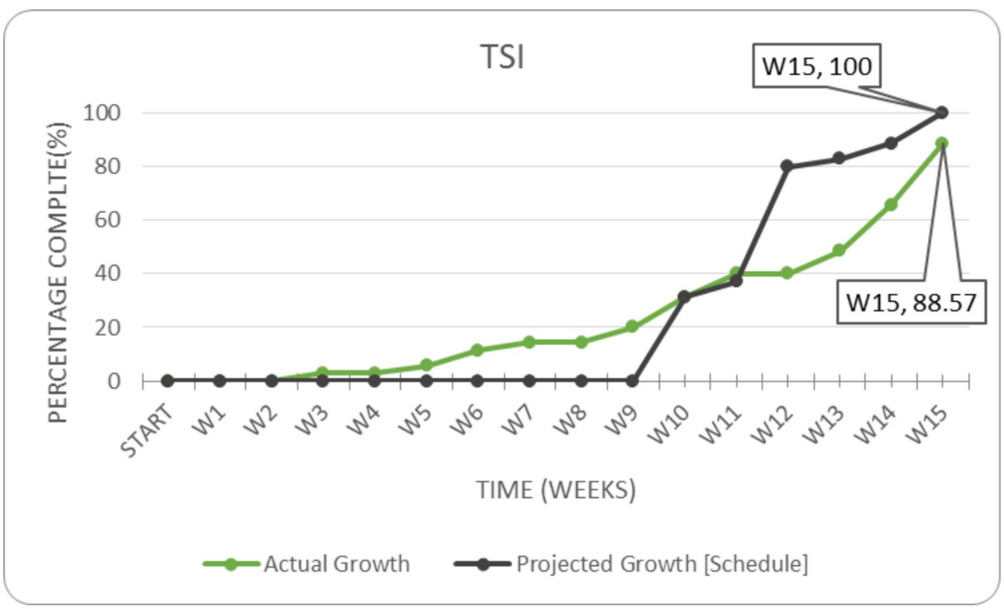
PSR Number [serial number]

Covering period from [Start Date] to [End Date]

Prepared by: [Student Name (s)]

Project Completion Graph:

[Plot overall percent project completion versus time. The time scale should extend from project start to ECD. The completion scale should be 0 – 100%. Include a line indicating ideal completion based on scheduling or estimation. As backup, additional graphs or tables should be given for major sub tasks.]



WBS Tasks Summary from the previous week:

[Summarize the data from the Individual Status letters, giving special emphasis to overdue WBS tasks that require mitigation, backup-behavior, or redesign]

Plan for next week:

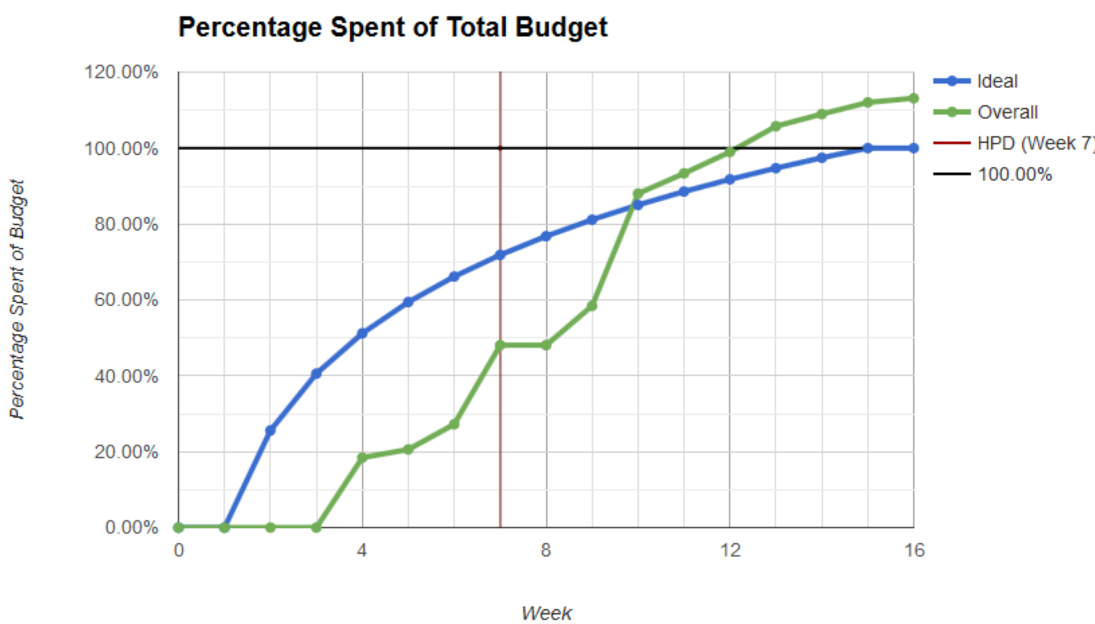
[Summarize the plan for next week, giving special emphasis to WBS tasks due that appear to be at risk]

WBS Changes

[Enumerate new goals or sub-goals to be incorporated into the WBS. Changes must be approved by faculty.]

Budget Graph:

[Plot overall percentage budget expenditure versus time. The time scale should extend from project start to final delivery date. The budget scale should span from 0 – 100% of the budget allocation. Include a line indicating ideal expenditure based on scheduling or estimation. As backup, additional graphs or tables should be given for major budget categories using actual dollar amounts.]



Cost Summary

[example]

Team	Allocated Budget	Total Spent	Budget Remaining	Percentage Spent
TSI	$1,000	$1,041.67	-$41.67	104.17%
GLV	$1,000	$620.90	$379.10	62.09%
VSCADA	$50	$21.99	$28.01	43.98%
Cell App	$125	$0.00	$125.00	0.00%
Cooling	$600	$511.69	$88.31	85.28%
Interconnect	$1,000	$2,241.52	-$1,241.52	224.15%
Dyno	$50	$0.00	$50.00	0.00%
TSV	$500	$890.43	-$390.43	178.09%
Shipping/Tax	$1,175	$894.55	$280.45	76.13%
Overall	**$5,500**	**$6,222.75**	**-$722.75**	**113.14%**

[List over-budget items. Give consequences and a mitigation plan]

Receiving Report

[List every item received, with delivery delay]

[List any ordered items not yet received]

[List overdue items. Give consequences and a mitigation plan.]

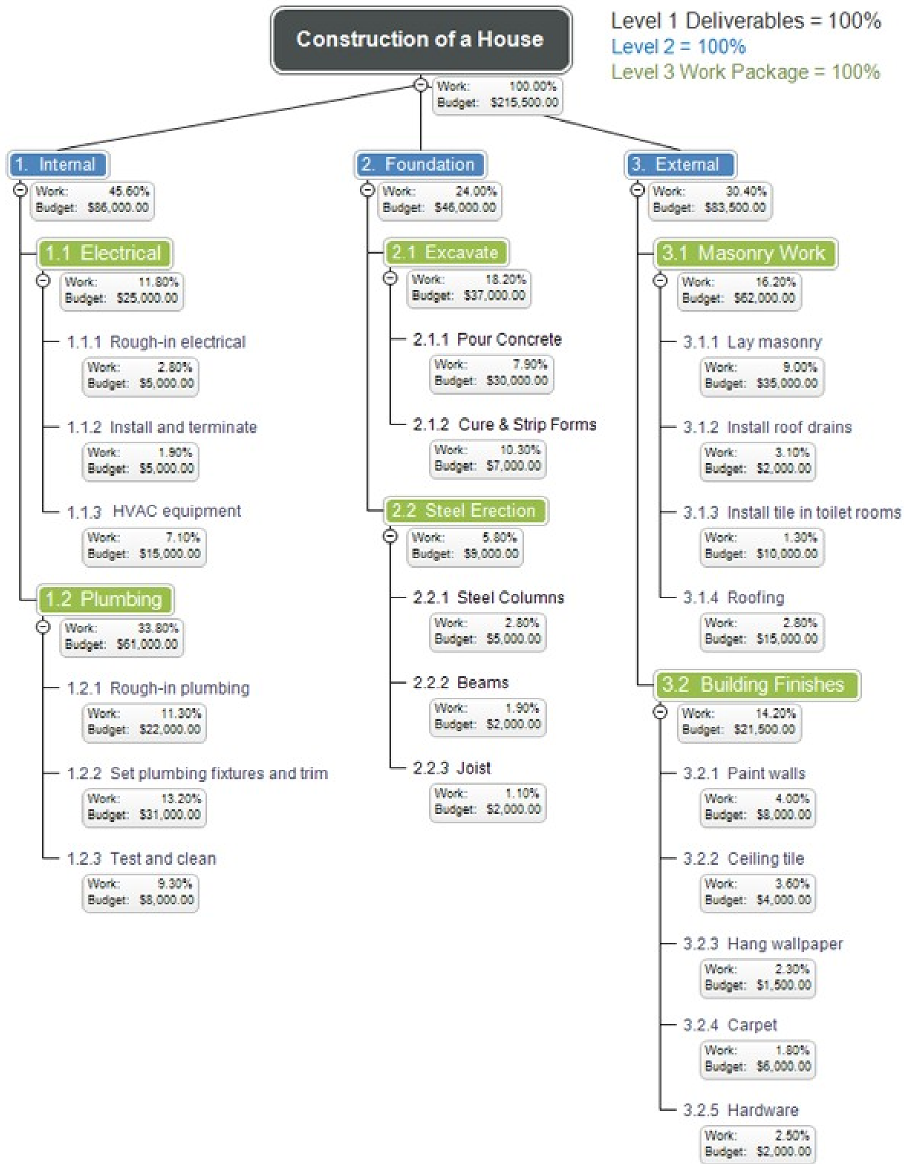
Purchase Requests

[attach all new purchase requests as appendix]

Work Breakdown Structure Example

SMART refers to criteria for setting goals and objectives, namely that these goals are: Specific, Measurable, Attainable, Relevant, and Time-bound. The idea is that every project goal must adhere to the SMART criteria to be effective. Therefore, when planning a project's objectives, each one should be:

- Specific: The goal should target a specific area of improvement or answer a specific need.
- Measurable: The goal must be quantifiable, or at least allow for measurable progress.
- Attainable: The goal should be realistic, based on available resources and existing constraints.
- Relevant: The goal should align with other project objectives to be considered worthwhile.
- Time-bound: The goal must have a deadline or defined end


Construction of a House
Level 1 Deliverables = 100%
Level 2 = 100%
Level 3 Work Package = 100%
Work: 100.00% Budget: $215,500.00
1. Internal
Work: 45.60% Budget: $86,000.00
1.1 Electrical
Work: 11.80% Budget: $25,000.00
1.1.1 Rough-in electrical
Work: 2.80% Budget: $5,000.00
1.1.2 Install and terminate
Work: 1.90% Budget: $5,000.00
1.1.3 HVAC equipment
Work: 7.10% Budget: $15,000.00
1.2 Plumbing
Work: 33.80% Budget: $61,000.00
1.2.1 Rough-in plumbing
Work: 11.30% Budget: $22,000.00
1.2.2 Set plumbing fixtures and trim
Work: 13.20% Budget: $31,000.00
1.2.3 Test and clean
Work: 9.30% Budget: $8,000.00
2. Foundation
Work: 24.00% Budget: $46,000.00
2.1 Excavate
Work: 18.20% Budget: $37,000.00
2.1.1 Pour Concrete
Work: 7.90% Budget: $30,000.00
2.1.2 Cure & Strip Forms
Work: 10.30% Budget: $7,000.00
2.2 Steel Erection
Work: 5.80% Budget: $9,000.00
2.2.1 Steel Columns
Work: 2.80% Budget: $5,000.00
2.2.2 Beams
Work: 1.90% Budget: $2,000.00
2.2.3 Joist
Work: 1.10% Budget: $2,000.00
3. External
Work: 30.40% Budget: $83,500.00
3.1 Masonry Work
Work: 16.20% Budget: $62,000.00
3.1.1 Lay masonry
Work: 9.00% Budget: $35,000.00
3.1.2 Install roof drains
Work: 3.10% Budget: $2,000.00
3.1.3 Install tile in toilet rooms
Work: 1.30% Budget: $10,000.00
3.1.4 Roofing
Work: 2.80% Budget: $15,000.00
3.2 Building Finishes
Work: 14.20% Budget: $21,500.00
3.2.1 Paint walls
Work: 4.00% Budget: $8,000.00
3.2.2 Ceiling tile
Work: 3.60% Budget: $4,000.00
3.2.3 Hang wallpaper
Work: 2.30% Budget: $1,500.00
3.2.4 Carpet
Work: 1.80% Budget: $6,000.00
3.2.5 Hardware
Work: 2.50% Budget: $2,000.00

Gantt chart example

Tasks are listed in the second column. Related tasks can be grouped together into a larger goal. The grouping of the tasks are shown by the indentation of the task name. The arrows show the reliance of one task on another. Notice has this supports the T in SMART criteria.

ID	Task Name	Duration	Start	Finish
1	**Concept Proposal**	**25 days?**	**Mon 1/28/08**	**Thu 2/21/08**
2	Project objectives	9 days?	Mon 1/28/08	Tue 2/5/08
3	Concept developmen	11 days?	Sat 2/2/08	Tue 2/12/08
4	Design concept	7 days?	Sun 2/10/08	Sat 2/16/08
5	Initial math model	14 days?	Sun 2/3/08	Sat 2/16/08
6	Prepare Concept Proposal	6 days	Sat 2/16/08	Thu 2/21/08
7	Concept Proposal	0 days	Thu 2/21/08	Thu 2/21/08
8	**Design proposal**	**19 days?**	**Sun 2/17/08**	**Thu 3/6/08**
9	Finialized math model	15 days?	Sun 2/17/08	Sun 3/2/08
10	Preliminary Inventor Model	14 days	Sun 2/17/08	Sat 3/1/08
11	Design Proposal Prep	7 days	Fri 2/29/08	Thu 3/6/08
12	Design Proposal	0 days	Thu 3/6/08	Thu 3/6/08
13	**Detailed drawings**	**29 days?**	**Sun 3/2/08**	**Mon 4/7/08**
14	Finalized Invento Mod	15 days	Sun 3/2/08	Sun 3/23/08
15	Initial drawings	7 days?	Sat 3/8/08	Fri 3/14/08
16	Create detail drawing	11 days	Sat 3/8/08	Tue 3/25/08
17	Revise drawings	12 days	Wed 3/26/08	Sun 4/6/08
18	Completed detail drawings	0 days	Mon 4/7/08	Mon 4/7/08
19	**Manufacturing**	**33 days?**	**Mon 4/7/08**	**Fri 5/9/08**
20	Purchase Materials/Parts	25 days?	Mon 4/7/08	Thu 5/1/08
21	Machining	26 days	Mon 4/7/08	Fri 5/2/08
22	Testing and tweeking	6 days?	Sun 5/4/08	Fri 5/9/08
23	Final report preperation	14 days	Tue 4/29/08	Mon 5/12/08
24	Race Day	0 days	Mon 5/12/08	Mon 5/12/08