**Rice University Collaborative Capstone Design** 

**Documentation Instructions**

*Specification Sheets*

**Why you do it**

Engineered products are defined by their specifications. A product’s specifications provide a quantitative measure of the performance of a product as measured by well-defined, objective testing methods. It should always be possible for an impartial observer to determine whether a product is meeting its specs. Products that fall out of spec may require warranty repairs, costing the manufacturer significant expenses.

In the real world, specification documents can contain many hundreds or thousands of items. Those are the just the “customer-facing” specs. There may be many more internal specs dealing with subsystems of the overall product. It is obviously impractical for a capstone project to utilize so many specs. However, designing to specs is one of the key activities of practicing engineers. Accordingly, there are multiple “design review” presentations throughout the year in which your project will be judged against intermediate specs determined by your team and approved by the course faculty.

The intermediate technical objectives that the team commits to achieving at various points in the year might more properly be called milestones. Rather than break out “milestones” and “specs” as separate entities, in this course we will refer to both milestones and specs for simplicity as “specs”. In this course you will submit multiple versions of Specification Sheets throughout the year covering your team’s milestones and the achievement of your project’s technical specs.

**How objectives work in this course**

In this course the *majority* of team points come from achieving specifications as listed in your Specification Sheets. This high point value is to ensure that teams are focused on achieving technical progress throughout the year. The Specifications are determined by the team itself (with approval from faculty) so the team should be working towards goals that they have determined to be most important.

There are multiple Specification Sheets, located in the HOQ tab of the [Product Development Worksheet](https://docs.google.com/a/rice.edu/spreadsheets/d/1wXd78_Pymxw4x21ZKadqleBBKnLrZlVW1aBzi6foCi8/edit?usp=sharing). Each Specification Sheet reflects a different phase of the project and is submitted at a different point in the school year. Roughly speaking, each team should have, by the end of Fall semester, a “proof of concept” -- some core element of their project that works at some level. Then, by about Spring Break, teams should have their subsystems working and beginning to be integrated into a system. Then, by the Design Showcase the team should have a well-revised and well-tested system that meets most of its specs and that, ideally, can be demonstrated to an audience. Then by the end of the semester the system should be complete and meeting all of its specs. There are multiple opportunities to revise specs along the way, although the team has to justify if they de-commit from major specs.

The various Specification Sheets are:

* **Cycle 1: Target Specifications.** These are a first pass at the the final, customer-facing specs your project will meet. These should be submitted as part of the Design Foundation Document assignment. The Target Specifications are also a forecast of the performance the team expects to achieve from its system by the end of the school year.
* **Cycle 2: High Priority Specifications**. These are specs associated with the aspects of your project that need to be done soonest. Potential reasons for doing them early in the project: they are high risk; they are critical to the success of the project; or they are on the critical path of your project. The team’s performance in meeting the High Priority Specifications will be judged at the end of fall semester in the Fall Design Review Presentation.
* **Cycle 3: Functional Specifications.** These are specs associated with having the various subsystems of your project working to some degree, and beginning integration of your final overall system. This reflects where the project should be by this point -- the (hopefully) final device assembled, with many aspects working already, and ready to be tested / debugged. The team’s performance in meeting the Functional Specifications will be judged near the middle of Spring Semester in the Functional Prototype Review Presentation.
* **Cycle 5: Final Specifications.** These are the final specs that your system will be judged against. They are submitted at the end of Cycle 3 and evaluated at the end of the school year.

The process for Spec evaluation is as follows.

1. Cycle 1 -- Final specs. These are submitted in Cycle 1 and graded along with the other sections of the Design Foundation Document. Along with the Customer Needs section, the Final Specs section should provide guidance throughout the project.
2. High Priority Specs and Fall Design Review -- You will submit these specs in the middle of Cycle 2. Submit a hardcopy version in the OEDK on the due date. (You can submit a softcopy instead to your course faculty member(s) if they prefer.) Course faculty will review the sheets and return them promptly for revisions, which will be due about a week later. The spec sheets will then be graded according to the rubric below, and will be worth a relatively small number of points for Design Cycle 2.   
     
   Then at the end of Design Cycle 2, in your team’s Fall Design Review presentation, you will demonstrate your project’s performance as compared to the specs you listed previously on the High Priority Specifications Sheet. Performance vs. stated objectives will be worth a large number of points. Performance will determine how many team points you are awarded in the Execution of Design Specifications (Cycle 2) section of the Capstone Documents Grading spreadsheet.
3. Cycle 3 Functional Specifications and Functional Prototype Review -- At the end of Cycle 2 you will submit the next tab from Specifications Sheet -- Cycle 3 Functional Specifications. Your course faculty will grade the document according to the rubric below. A revision of the documents will be due at the beginning of Spring semester. As with Cycle 2, the Spec Sheet itself will be worth a relatively small number of points, but the Functional Prototype Review at the end of Cycle 3 in Spring Semester will be worth a large number of points. Performance will determine how many team points you are awarded in the Execution of Design Specifications (Cycle 3) section of the Capstone Documents Grading spreadsheet.
4. Cycle 5 Final Specifications Final Design Review -- At the end of Cycle 3 you will submit the next tab from Specifications Sheet -- Cycle 5 Final Specifications. Your course faculty will grade the document according to the rubric below. As with Cycles 2 and 3, the Spec Sheet itself will be worth a relatively small number of points, but the Final Design Review at the end of Spring Semester will be worth a large number of points. Performance will determine how many team points you are awarded in the Execution of Design Specifications (Cycle 5) section of the Capstone Documents Grading spreadsheet.

For each Spec Sheet the team must obtain the explicit approval of the course faculty members , and any technical mentors or customers, if appropriate. The team should get an email confirmation of this approval, or, even better, a faculty signature on a hardcopy of each Spec Sheet. The main point is to be able to show unambiguously, during the Review presentations, that there was a set of specs that everyone agreed upon.

**Point values for meeting specs**

Each Spec Sheet (except the Cycle 1 Target Final Specs sheet) also allows the team to allocate their points among the various specs & milestones. The majority of points should be allocated to the most important objectives. Less critical specs, nice-to-have features, etc. should be allocated fewer points. At least 10% of the points for each Design Cycle should be allocated to “stretch goals” –those that are high-risk (in the opinion of the team and the mentor or advisor.) The team and mentor/ customer should discuss and agree on the allocation of points. The course professors have the option of changing the point allocation. For instance, suppose a team was building a web-enabled bread-slicing machine, and that in DC2 there were 1200 points to allocate. The team might allocate 500 points to demonstrating functionality on a hand-driven bread slicer, 400 points to a basic user interface on a standalone PC that has a start & stop button, 150 points to the measurement of the cutting properties of various knives, and 150 points to a mechanism that allows multiple knives to be used simultaneously (the latter being a stretch goal.)

*What if the team discovers they won’t be able to meet the objectives committed to in the previous design cycle?*

There is always some risk when committing to achieving definite objectives by a particular date. In this course the commitment happens about 4-8 weeks in advance of the test. A lot can go wrong in the interim: unforeseen technical roadblocks, unavailability of key parts, teammates who disappear for a week to work on other classes, or -- most commonly -- just an underestimate of the time required. That is the nature of engineering. In the real world, it is sometimes possible to get approval from the customer on reduced specs, slipping of a schedule or re-negotiation of costs as it becomes clearer that the original specs/ schedule/ cost were too optimistic. In this capstone course, the team is allowed to change the Spec Sheet, including point allocations, assuming the team can get approval from the customer/ mentors and the professor. The profs do understand that adversity outside of the team’s control does sometimes occur, and may take that into account when deciding whether to allow teams to de-commit from agreed-upon specs. In the real world, your customer might not be so understanding.

**Writing good specs**

A spec or milestone or objective needs to have an unambiguous way to determine if it is met – an associated test. Sometimes this is easy because it is purely quantitative and obvious how to measure it: “Output power > 100 W”, ”Volume < 1 liter” etc. Sometimes a more “squishy” spec has to be included, such as “intuitive graphical user interface.” In this case one should try to make the test semi-quantitative, as in “At least 80% of all users rate intuitiveness 4 or 5 on a scale of 1-5.”

In this course you are allowed to pre-designate “partial credit” for partial achievement of specs. Sometimes this is done in the real world as well – the design team may have some incentive bonus based on performance of the product. Consider the following example: The spec is a 12-lead wireless electrocardiogram system with battery life of 1 week, worth 500 team points. The team, not sure if they could hit the aggressive battery spec, could stipulate 350 team points for achievement of 8 hours of battery life and the full 500 points if the full spec is met. The different levels of goals can be addressed by separate line items in the spreadsheet or simply by noting the point assignment in the appropriate cell in the spreadsheet.

**How to fill out the Spec Sheet**

The Spec Sheets are tabs of the Product Development Worksheet. In each Cycle you submit the appropriate sheet, as described above.

For filling out the Cycle 1 Spec Sheet (TargetSpecs) see the instructions for the Design Foundation Document. Roughly speaking, the Target Specs are your initial guess at the perfomance your system will meet at the end of the year.

For the remaining Spec sheets (Those to be evaluated in Cycles 2, 3, and 5), here is a brief explanation of the fields:

Metric/ Spec #: Enumeration of specs. Use outline numbering (e.g. 1.1, 1.2, 1.2.1 etc. as needed) to keep track of sub-specs.

Need #: every spec needs to have at least one associated Customer Need number from the appropriate tab in the worksheet

Metric/ Spec: the performance spec that will be measured. If the spec is very complicated you can use footnotes or a separate page to provide details.

Units: Units of measured value (not relevant for all specs -- you can put NA if appropriate)

Importance (1-lowest, 5-highest): Your qualitative estimate of how important it is to achieve the spec. This feeds into the risk analyis.

Ideal Value: A target spec that would be most important

Marginal Value: the “barely acceptable” value

Technical Risk/ Complexity (1-lowest, 5-highest): Your qualitative estimate of how difficult or technically risky it will be to achieve the spec.

Risk Index: Simply the product of Importance and Technical Risk scores. This gives you a way of identifying which items require the most attention or highest priority. This information is addressed in the Design Strategy document where, among other things, you will identify the highest risk items and set up your schedule to reduce the risks.

Goal/ objective if no data: If you are working on an intermediate goal or milestone that supports a spec but cannot itself be quantified, then you can include the objective here and assign points to it. E.g. if the spec is “1.1. acceleration 0 to 60 mph in 5 seconds” you might have a goal of “Speed measurement test fixture fully functional.” The more quantitative the goal can be made the better. It is OK to have multiple goals for the same spec. E.g. you could have add another line item also associated with spec 1.1 -- “speed measurement test fixture design completed.”

Points Possible: This is the number of points your team can achieve if the spec is completed. The total Points Possible on each Spec Sheet must match the number shown in the appropriate cell of the Execution of Design Specifications row in the Capstone Documents Grading spreadsheet.

Points Awarded: to be filled out at the various Review presentations, reflecting whether or how well the particular spec was met. The total of Points Awarded will be tracked on the Points Awarded.

Other Customer Needs not addressed by metrics: At the bottom of the spreadsheet is a table where you can list any customer needs that do not have specs attached to them. For each one, you need to provide a rationale. This is to ensure that, during your product design, you don’t inadvertently overlook some key aspect of the design.

**Content of Specifications**

The focus of your specifications in the different sheets should change throughout the year. The Cycle 2 Specs should address the High Priority items -- those your risk analysis has determined need the most attention up-front. One of the high priority items needs to be getting some kind of proof of concept working in fall semester. For Cycle 3 the focus should be on getting working subsystems that can meet some detailed specs that are close to the final specs. For Cycle 5 the entire system should be working and the Cycle 5 Specs should align well with the original Target Specs sheet. Any discrepancies should be discussed with your faculty advisor and your customer or faculty mentor as part of the process of agreeing on Final Specs.

**Review Presentations**

For details on how to prepare for the Review presentations associated with the Spec Sheets, check out the separate document on presentation instructions and associated rubrics.

[Specification Sheet Rubric](https://docs.google.com/a/rice.edu/document/d/1ppZFTxPv4mSABp7BVgyWtTLL90pBW9cA9KkOJRZ8WO4/edit?usp=sharing)

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