June 2018

Introduction to Engineering Design Processes

Requirements & Design Specs

"For every problem, there is a solution that is simple, plausible, and wrong."
– *H.L. Mencken*

Learning Objectives

By the end of this module, you will have a basic under-standing of the following:

- Basic Engineering Design Processes
- Differences between requirements & design specifications
- Problem analysis for requirements specifications
- Organization of specifications
- Style in specifications
- Content for specifications

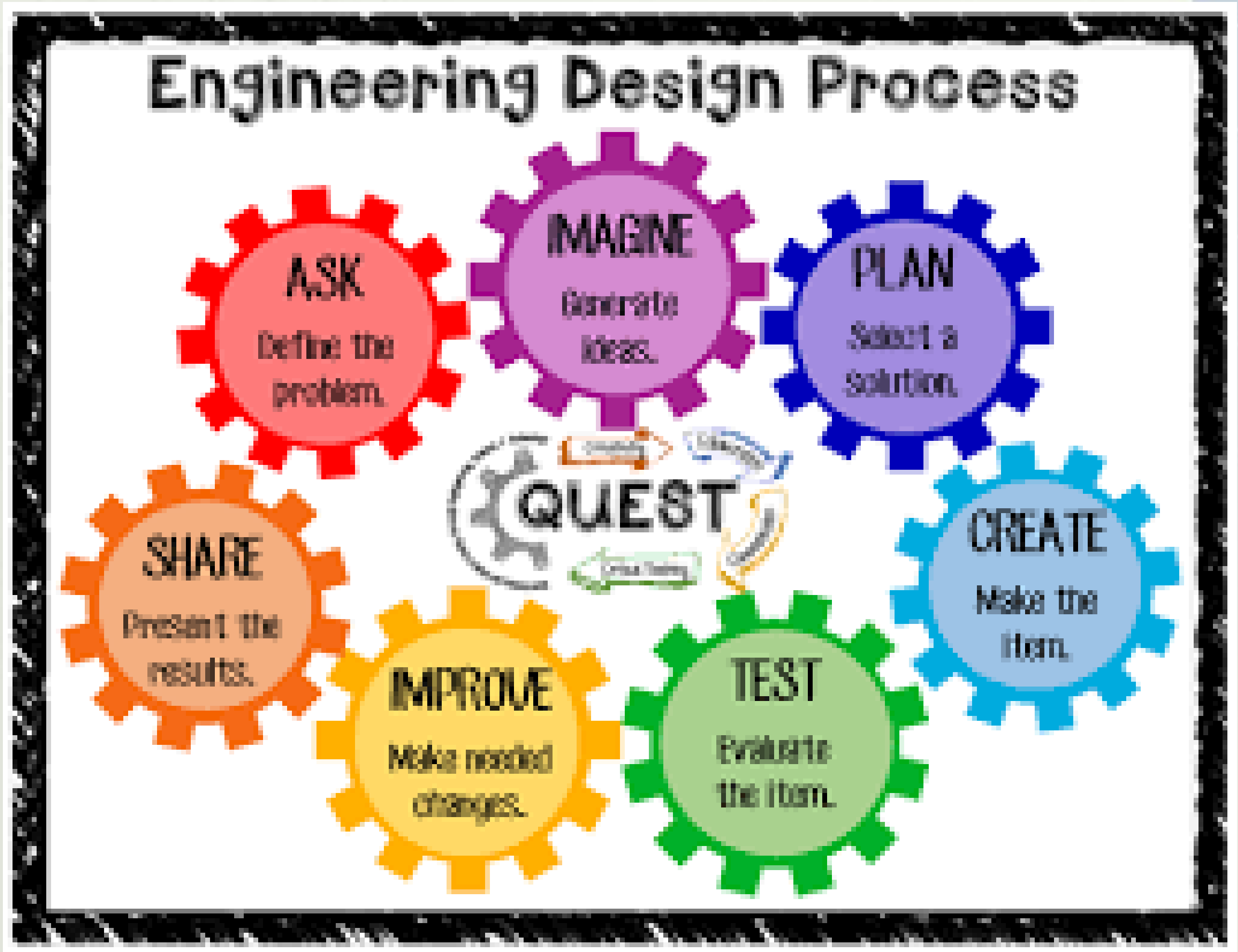
A Multiverse of Engineering Design

- The Canadian Engineering Accreditation Board (CEAB) considers Engineering Design to be one of the most important things we can teach in Engineering Schools.
- But is there really an Engineering Design Process that goes beyond the general process for problem solving?

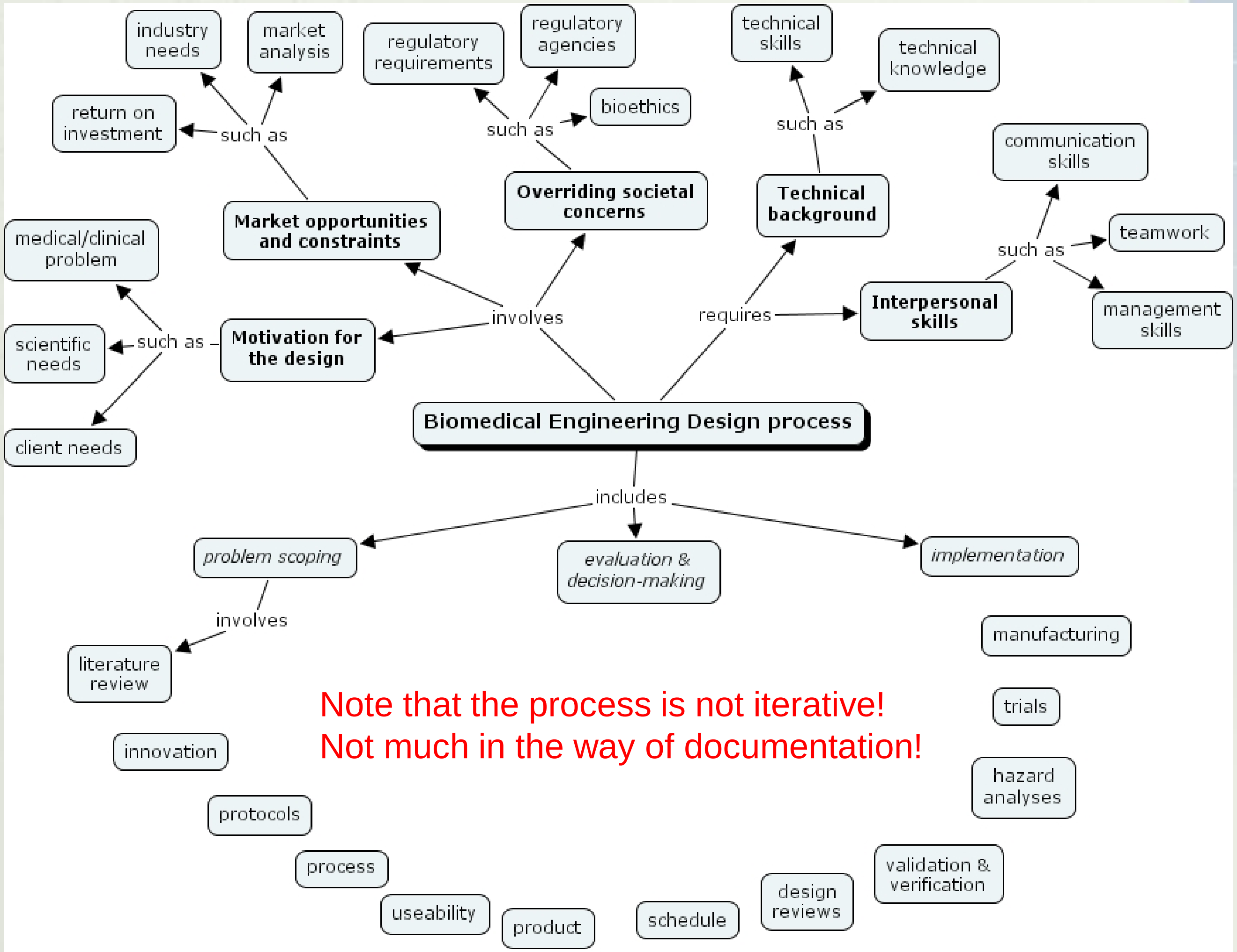
1. Ask a question
2. Define the problem
3. Generate possible solutions
4. Make one of the solutions
5. Test the solution
6. Repeat as required

- I hope that your ENSC 405W/440 project enables you to come up with your own unique and personal design processes!

Kindergarten Design Process



Post-Doc Design Process



Note that the process is not iterative!
Not much in the way of documentation!

	DEFINITION	ANALYSIS	DESIGN	PROGRAM/BUILD	SYSTEM TEST	ACCEPTANCE	IMPLEMENTATION
ACTIVITIES	• BUSINESS QUALIFICATION PROPOSAL • ORDER REVIEW	• FUNCTIONAL SPECIFICATION	• SYSTEM DESIGN	• MODULE DESIGN • CODING/BUILDING • MODULE TEST	• TESTING • INTEGRATION	• ACCEPTANCE • TEST PROCEDURE	• OPERATION • WARRANTY • POST-PROJECT REVIEW

Docucentric (ENSC 405W/440) Design Process

← PROJECT MANAGEMENT →

← REVIEWS →

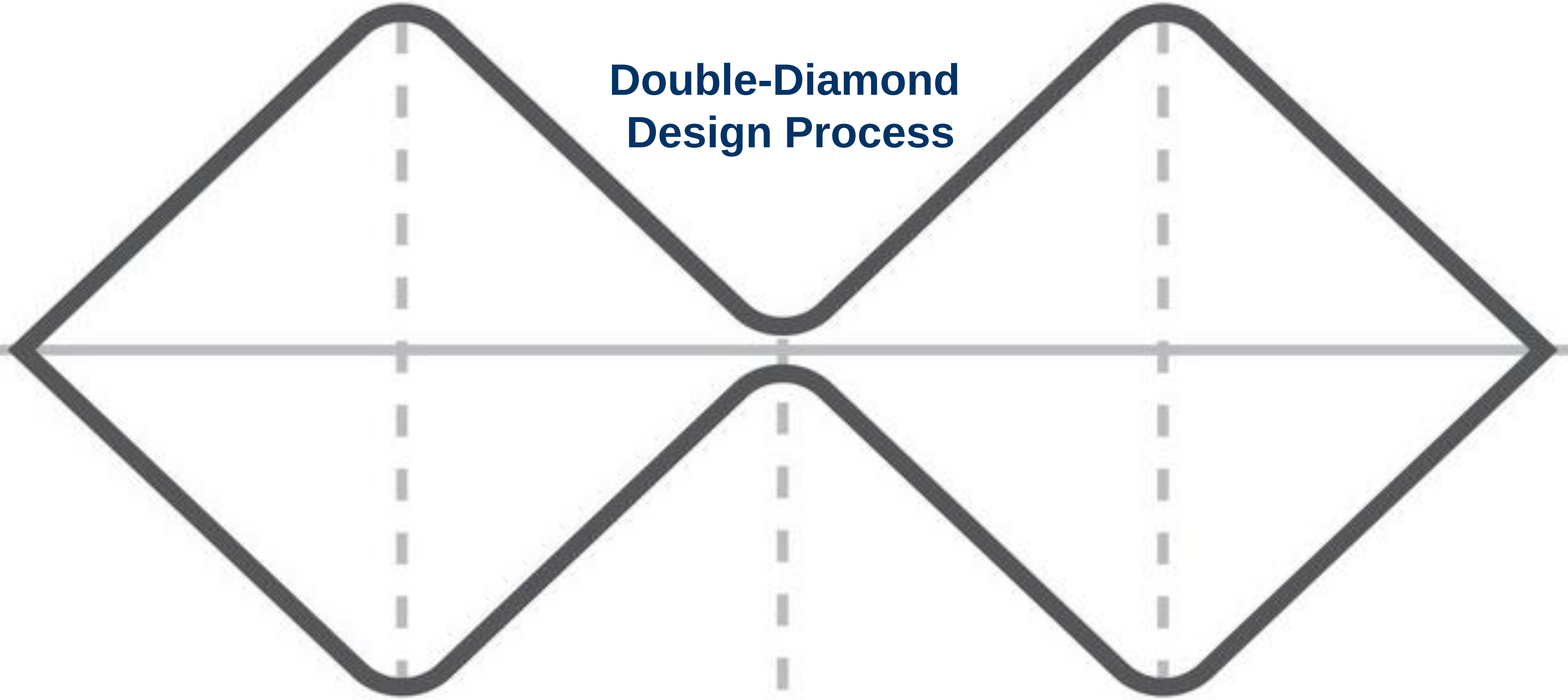
X 2 ← STATUS REPORTS →

← DOCUMENTATION → ← USER TRAINING →

Is this process iterative?

	DEFINITION	ANALYSIS	DESIGN	PROGRAM/BUILD	SYSTEM TEST	ACCEPTANCE	IMPLEMENTATION
OBJECTIVES	SYSTEM REQUIREMENTS	WHAT THE SYSTEM WILL DO	HOW SYSTEM WILL WORK	WHY SYSTEM WILL WORK	SYSTEM WORKS	HANDSHAKE & FINAL PAYMENT	COMPLETION
BENEFITS	• QUALIFIED PROSPECT • TECHNICAL & MANAGEMENT PERSONNEL ACCEPTANCE	• WELL-DEFINED SYSTEM • CREDIBILITY	• TECHNICAL DEFINITION	• TESTED MODULES	• INTEGRATED SYSTEM	• MAINTAINABILITY • USER SATISFACTION	• OPERATION INTEGRITY • STATISTICS • FEEDBACK • HISTORY
OUTPUT DOCUMENTS	• REQUIREMENTS ANALYSIS DOCUMENT • PROPOSAL • PRELIMINARY PROJECT PLAN	• FUNCTIONAL SPECIFICATION • WORK STATEMENT • ESTIMATES • PROJECT PLAN • TOP LEVEL DESIGN • DEVELOPMENT PROPOSAL	• DESIGN SPECIFICATION • ACCEPTANCE TEST PLAN • REVISED ESTIMATES • REVISED PROJECT PLAN	• MODULE DESIGN • SYSTEM TEST PLAN • TECHNICAL MANUAL • OPERATOR'S MANUAL • USER'S MANUAL • PROJECT LEADER SIGN OFF	• PROJECT MANAGER SIGN OFF • DEMO • POSTER	• TEST RESULTS • USER SIGN OFF • INVOICE TO WIGHTON FUND	• POST-PROJECT CRITIQUE • USER SUPPORT PLAN • PROPOSAL FOR DEFINITION OF NEXT PROJECT

Double-Diamond Design Process



Discover

Initial Ideas or Inspiration & Establishment of User Needs

Market Research
User Research
Design Research
Technology Research
Interviews & Insights Gathering
Observation & Shadowing
Empathic Modelling
Information Management

Define

Interpretation & Alignment of Findings to Project Objectives

Information Analysis
Synthesis & Identification
Project Refinement
Project Management
Project Sign-off

Develop

Design-Led Concepts & Proposals Iterated & Assessed

Ideation
Multi-Disciplinary Working
Visual Management & Progress
Testing & Prototyping
Review & Improvement

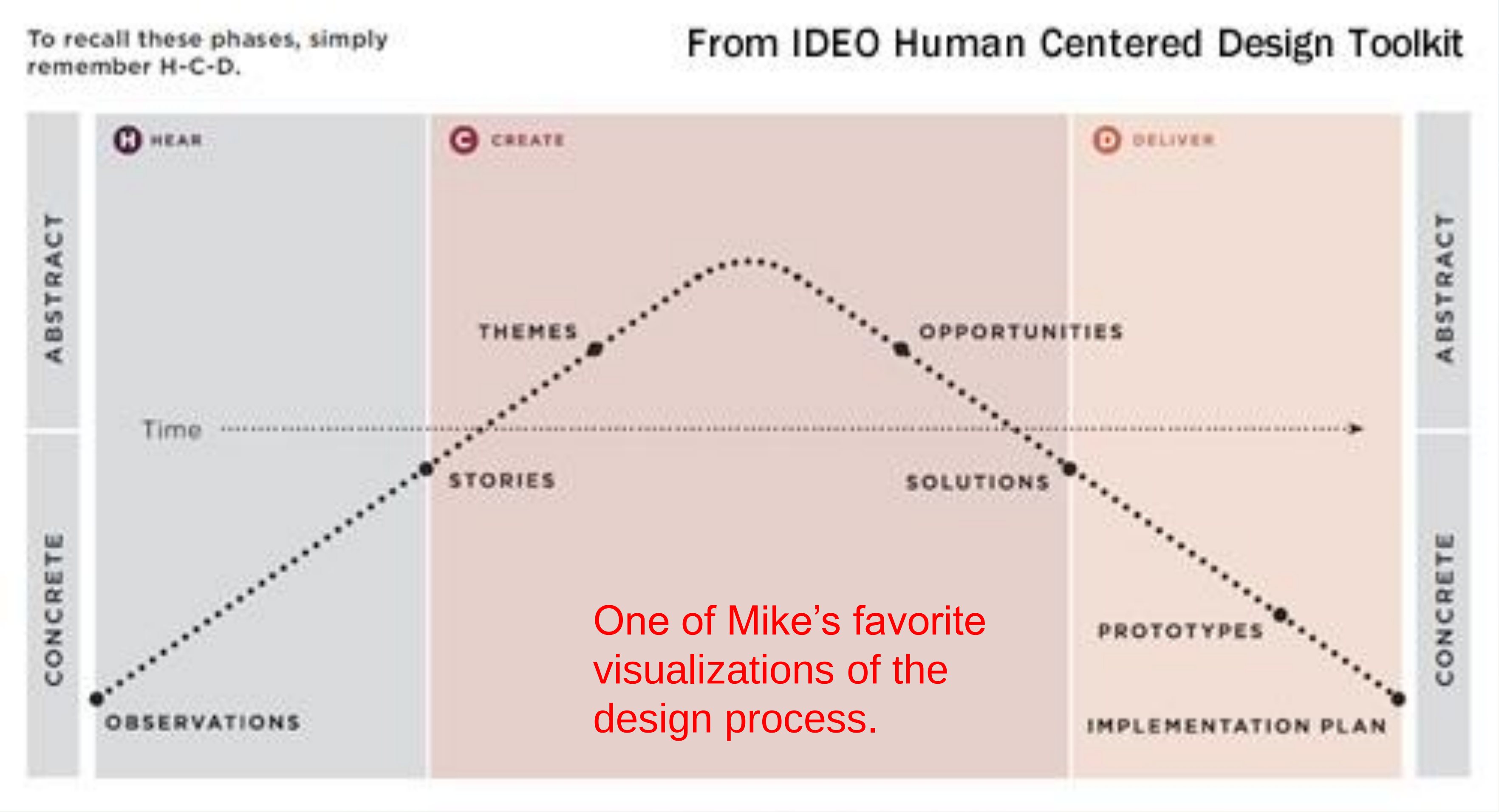
Deliver

Process Outcome(s) Finalised & Implemented

Final Testing & Approval
Production
Launch of Outcome(s)
Evaluation & Further Feedback
Future Work

http://www.jonathanclegg.com/blog/wp-content/uploads/2014/06/DoubleDiamond.jpg

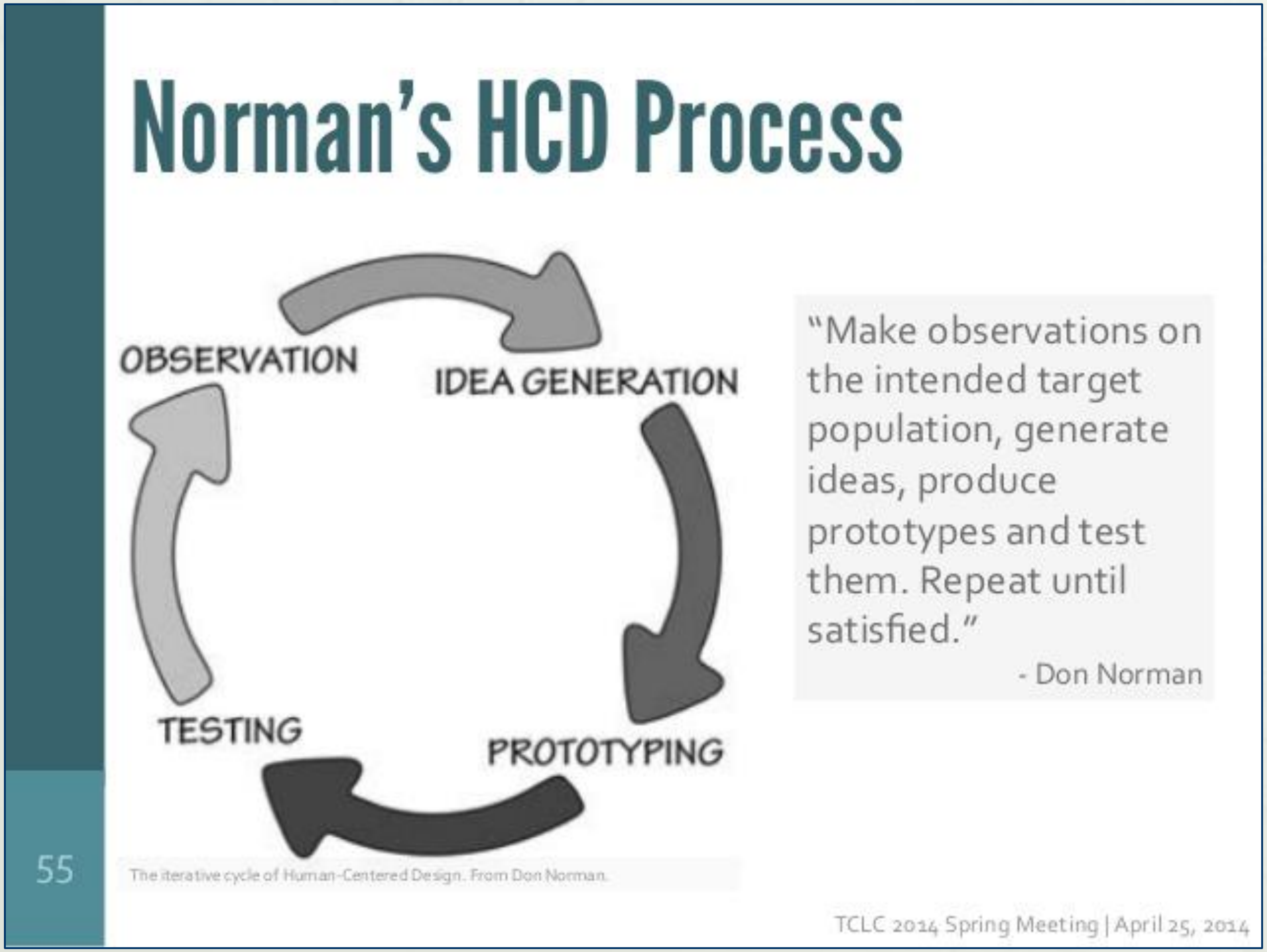
IDEO.org Human Centred Design



One of Mike's favorite visualizations of the design process.

http://www.melodiesinmarketing.com/wp-content/uploads/2009/07/ideo-human-centered-design-process-graph.jpg

Human-Centred Design Process

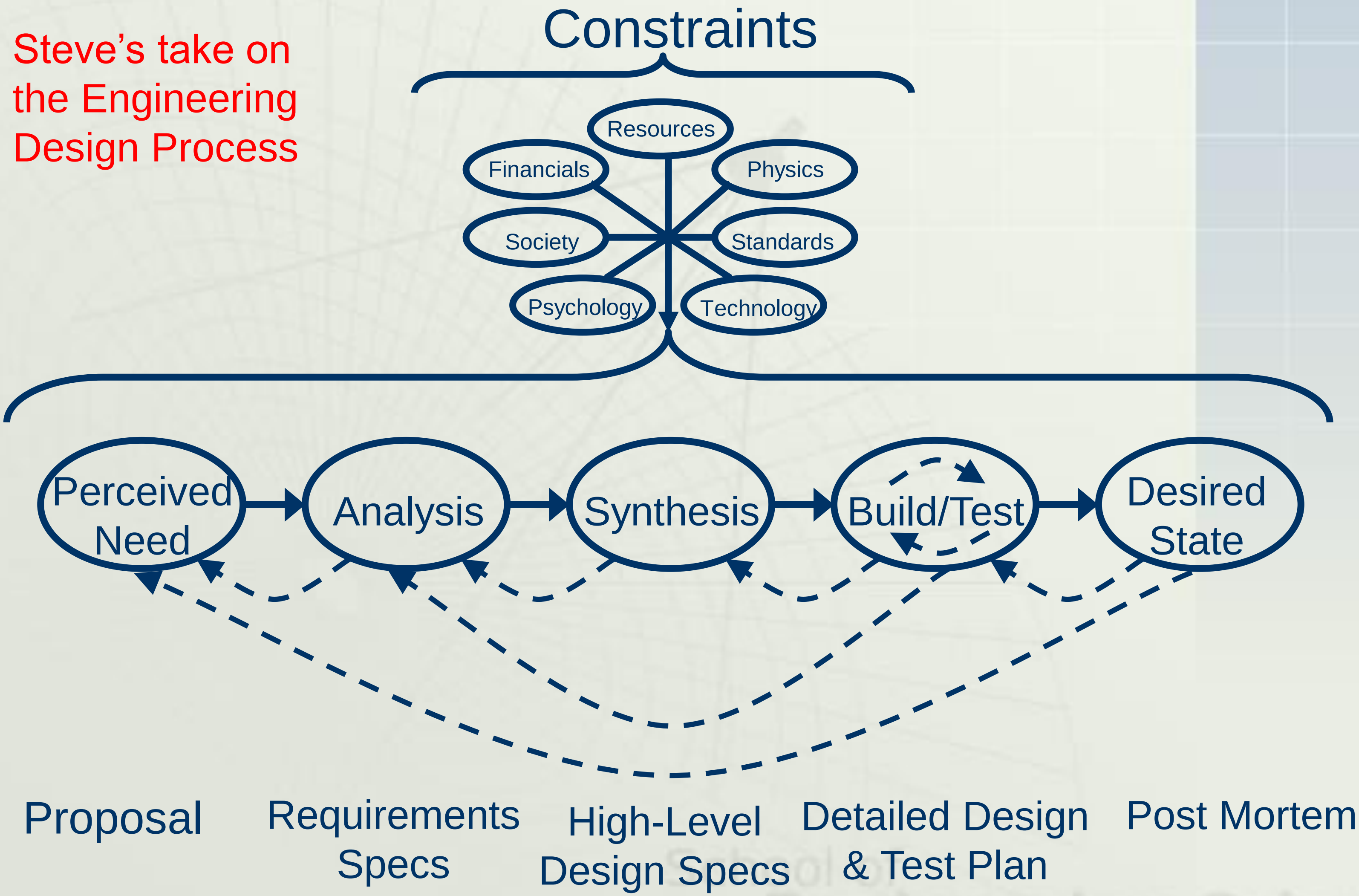


User Interface & Human Factors

http://image.slidesharecdn.com/macdonald-20tclc-202014-ux-20is-20everything-140505140131-phpapp02/95/user-experience-is-everything-and-vice-versa-lessons-for-libraries-and-information-organizations-55-638.jpg?cb=1399317395

Flying Saucer Design Process?

Steve's take on the Engineering Design Process



Map of Design in 405W/440

ENSC 405W:

Problem (Pain)	→	Proposal
Define Requirements	→	Requirements Specs
Create Design	→	Design Specs (prelim)
Assess User	→	UI Appendix & Test Plans
Prepare for 440	→	440 Planning Appendix
Build P-of-C	→	Progress Reports/Poster

ENSC 440 (tentative):

Critique P-of-C Project	→	Project Review
Refine Design	→	Design Specs (additive)
Re-Assess User	→	User Manual
Build Prototype	→	Business Plans & Pitch
Analyze Process	→	Post-Mortem

Engineering Documentation & Roles

Your Activities	→	Your Roles
➢ Proposal	→	Entrepreneur/Sales
➢ Journal/Minutes	→	Professional
➢ Req. Specs.	→	Lawyer
➢ Design Specs.	→	Designer
➢ Building	→	Technician
➢ Post-Mortem	→	Royal Commissioner
➢ Web Site	→	Sales/Technician/Entrepreneur
➢ User Manual	→	Educational Psychologist

Sum these together and you get an **Engineer**

Difference between RS/FS and DS

Requirements Specs = **WHAT?/WHY?**

Example → RS = *Rigid external case*

FS = *To protect circuits*

Design Specs = **HOW/WHY?**

Example →	**Sheet Steel**	→	**Plexiglass**
→	Readily available	→	Readily available
→	Inexpensive	→	Expensive
→	Difficult to fabricate	→	Easy to make
→	Temp. resistant	→	Melts
→	Conductive	→	Non-Conductive
→	Opaque	→	Transparent

Some RS & DS Considerations

- Normal Operating Conditions (Temp., Altitude, Humidity, Interference)
- Power
- Heat Dissipation
- Size & Weight
- Response Times
- Packaging (Device Protec-tion, Aesthetics)
- Reliability
- Sustainability
- Standards (ISO, IEEE, CSA, MilSpec, Medical, etc.)
- Compatibility with Other Systems
- Known System Limitations
- Safety Considerations
- Docs (e.g., User Manual)
- Testing (Test Plan: RS)
- Training of Users
- User Interface
- Ergonomics
- **Et cetera**

Note: Failure to address sustainability and/or safety issues will result in a reduction in grade for the Requirements and/or Design Specification.

Problem Analysis for RS #1

- Collect **all available information** about the project (RFP, RRFP, client or user notes, **RESEARCH**, etc.)

- Identify and **meet with the *real* user** of the proposed system:
  - Minimal requirements of the user
  - Ideal requirements (wish list)

Also meet with the decision makers and determine their requirements (costs and benefits). But watch out for *Analysis Paralysis*

Analysis Paralysis

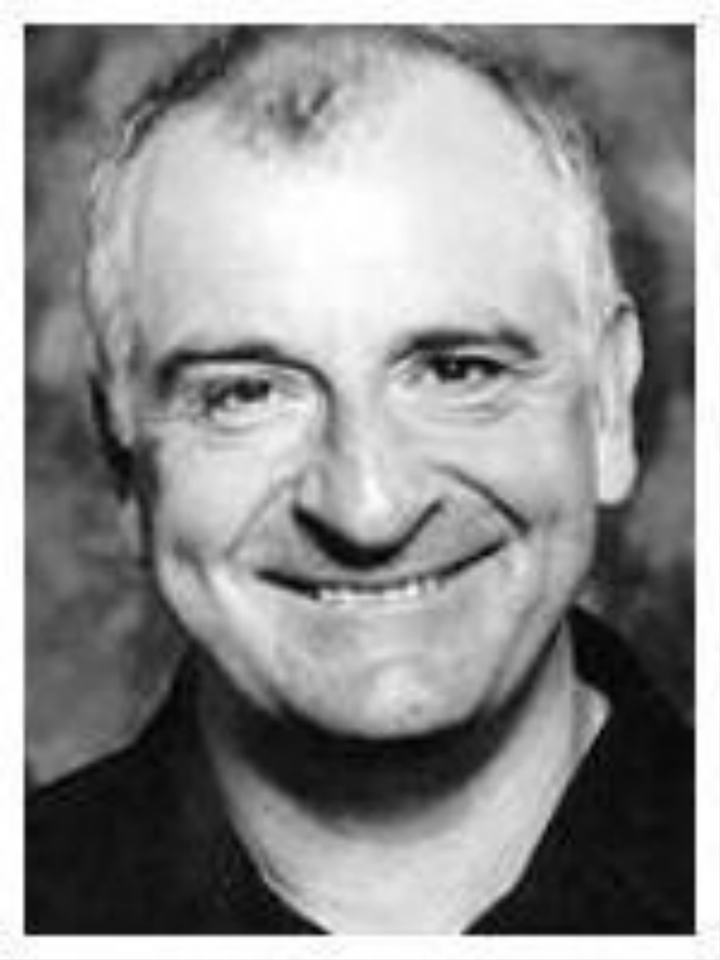
“You could spend an infinite amount of time gathering data to help optimize something that refuses to be optimized any further.”

– *Darrell Mann*

“The usual approach to problem-solving is to identify and remove the cause of the problem. Sometimes this is not possible because the cause cannot be found; because there are too many causes; or because the cause is human nature and cannot be removed. In such cases we are usually paralyzed.”

– *Edward De Bono*

Hmmm . . .



"A common mistake that people make when trying to design something completely foolproof is to underestimate the ingenuity of complete fools."

-- Douglas Adams, author of *A Hitchhiker's Guide to the Galaxy*

Problem Analysis for RS #2

- Analyze the **physical and theoretical phenomena involved in the performance characteristics** of the idea/product.

- Analyze the practicality of the idea to **see if it is marketable** and if you have the facilities and expertise to develop/produce the product. Comprehensive market research is required in the proposal.

- Examine **the system currently being used** to complete the task(s). This will help provide insight into the "real" (rather than the stated) problem and needed functions.

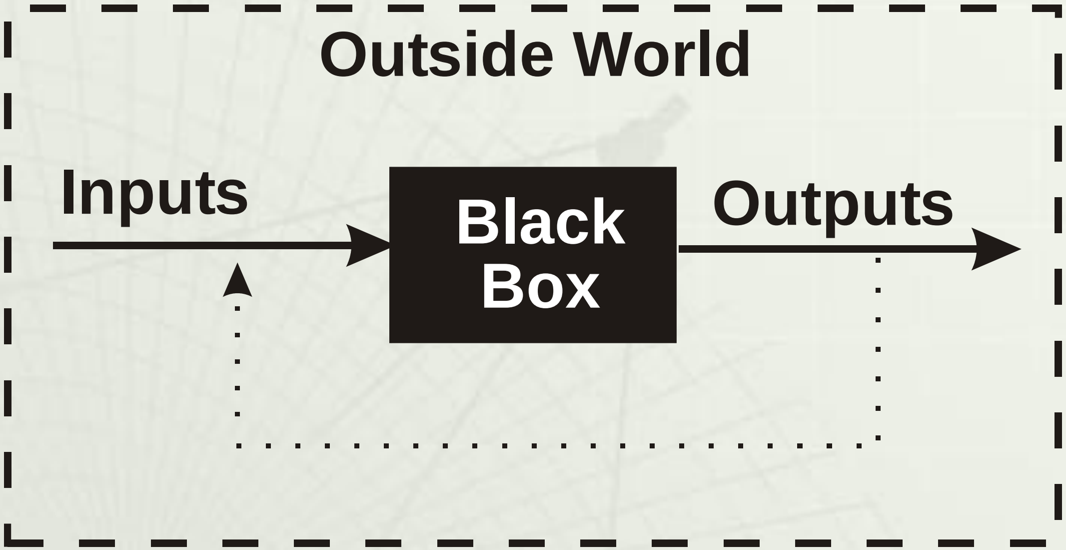
Problem Analysis for RS #3

- Analyze the collected information and define the issues which need to be resolved. During this process, create a **list of questions which need to be answered**.

- **Collect answers to those questions** through surveys, interviews, meetings, tours, observation, and research, and then analyze those answers.

- **Define the system or device conceptually** by working backwards from the output through the processes in order to determine what inputs are required.

Problem Analysis for RS #4



- **Review the definition of the problem and the requirements** with the users of the system.

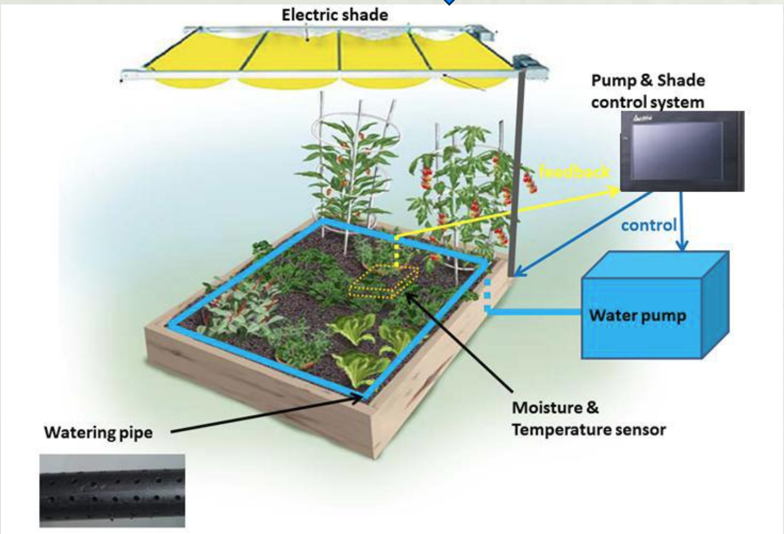
- **Negotiate any changes required and obtain approval**.

Structure of Specifications

- Letter of Transmittal
- Title Page
- Abstract (RS and DS)
- Table of Contents
- List of Figures
- Glossary
- Body of Document
- Conclusion
- References
- Technical Appendices (includes test plans, user interface design, and 440 planning in design specs)

Organization of Specifications

- System Overview (What and Why)
- Cloud-Shaped Drawing (RS/FS) or Block Diagram (DS)



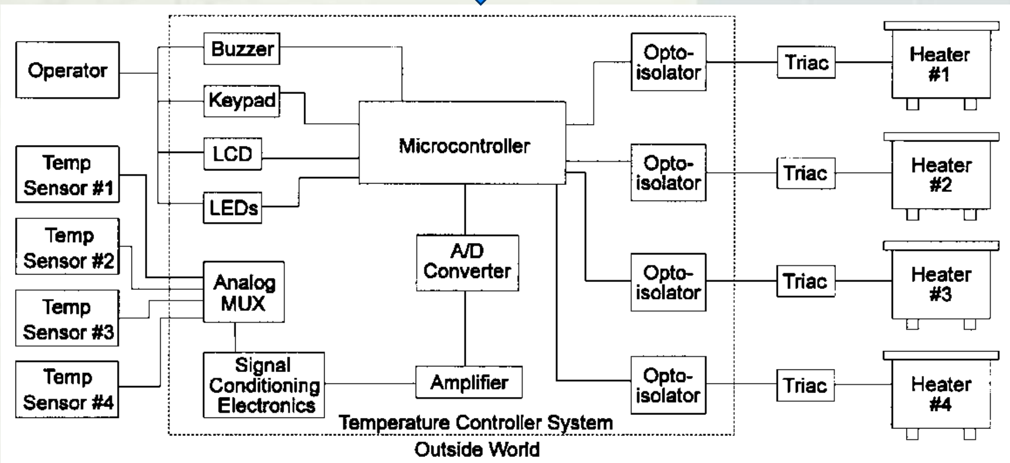


Figure 1: Temperature Controller Block Diagram

Organization of Specifications

- In RS, describe requirements that apply to entire system (usually one paragraph per requirement); in DS, present design choices, and explain **why** you made the choices you did
- Subsections detail subcomponents of system:
  - In RS, describe requirements that apply to subcomponents
  - In DS, explain choices that apply to subcomponents
- Headings numbered and (ideally) match each other:
  - In RS, *2.2.1 Temperature Sensor* outlines the needed requirements
  - In DS, *2.2.1 Temperature Sensor* details a sensor meeting those requirements
- Provide any physics, equations, and theoretical detail needed to support your choices
- Provide description of device limitations (and rationale)
- Distinguish between proof-of-concept, prototype, and production versions.

Style of Specifications

- Typically written in passive voice (although sometimes written using 1st person – "*We*" or "*Acme Inc.*").
- In industry, critical functions listed using "*must*" ("*The device **must** have an MTTF of 6 years*"). **Please don't do this for 405W/440.**
- Use lists, tables, and figures rather than text where possible (see your stereo spec sheet for an example). We do not want text-heavy specs. **Be concise here.**
- In RS, avoid jargon and technical terms as much as possible (Steve should be able to understand it). The RS often forms the basis for a legal contract.
- In DS, include a glossary for the specialized terms.

Sustainability & Safety

- A section (about 1 page each) in both the Requirements and Design Specifications **must** deal with **sustainability and safety** issues related to your device:
  - Covers “cradle to cradle” sustainability cycle for your **proof-of-concept/prototype** device (i.e., how do you intend to recycle, reuse, or repurpose the materials in your project).
    - **Cradle to grave** = Make it, use it, and then discard it.
    - **Cradle to cradle** = Make it, use it, and then repurpose or recycle it.
  - Outlines major sustainability and safety considerations for **production** device.

Appendices to Specifications

- You must include a 1-2 page **Acceptance Test Plan** for the proof-of-concept version of the device/system in the Requirements Spec.
- You must include a 5-10 page appendix detailing the analysis and design of the **User Interface** in the Design Specs.
- You must include a 5-10 page appendix detailing your **Plans** for continuing the project in 440 in the Design Spec.

Sample Acceptance Test Plan

- We want you to provide a high-level acceptance test plan NOT a detailed characterization of the circuit or components
- Design one to fit the specifics of your project.
- Must include a copy as an appendix in your RS.

SFU

Team XXXXX

Test Sheet

Date:

Mechanical Parts	
1- Wheel :	Comments:
Max RPM: 10 ☐ Yes(pass) ☐ No(fail)	
2- Brake:	Comments:
Max force: 20 N ☐ Yes ☐ No	
Deceleration: 1.2 m/S^2 ☐ Yes ☐ No	
Stopping distance: 2 m ☐ Yes ☐ No	
3- Movement of link	Comments:
From 0 to 90 degree ☐ Yes ☐ No	
…	
….	

Electrical Parts	
1- Circuit Output :	Comments:
Volt: 120 V ☐ Yes ☐ No	
Frequency: 60 Hz ☐ Yes ☐ No	
2- Laser Output:	Comments:
Power: 300 mW ☐ Yes ☐ No	
Range: X m ☐ Yes ☐ No	
Detection of movement by sensor ☐ Yes ☐ No	Comments:

ENSC 405W Grading Rubric for Requirements Specification

Criteria	Details	Marks
Introduction/Background	Introduces basic purpose of the project.	**/05%**
Content	Document explains the requirements of the proposed product without excessive design content (i.e., outlines the "what" rather than the "how").	**/10%**
Technical Correctness	Ideas presented represent requirements specifications that must be considered for a marketed product. Specifications are presented using tables, graphs, and figures where possible (rather than over-reliance upon text).	**/15%**
Process Details	Complete analysis of problem. Justification for chosen requirements. Sources of ideas referenced. Specification distinguishes between requirements for current project version and later stages of project (i.e., proof-of-concept, prototype, and production versions). Comprehensively details constraints.	**/20%**
Engineering Standards	Outlines specific engineering standards that apply to the device or system and lists them in the references.	**/10%**
Sustainability/Safety	Issues related to sustainability issues and safety of the device are carefully analyzed. This analysis must cover the "cradle-to-cradle" cycle for the current version of the device and should outline major considerations for a device at the production stage.	**/10%**
Conclusion/References	Summarizes requirements. Includes references for information from other sources.	**/05%**
Presentation/Organization	Document looks like a professional specification. Ideas follow logically.	**/05%**
Format Issues	Includes letter of transmittal, title page, abstract, table of contents, list of figures and tables, glossary, and references. Pages are numbered, figures and tables are introduced, headings are numbered, etc. References and citations are properly formatted.	**/10%**
Correctness/Style	Correct spelling, grammar, and punctuation. Style is clear concise, and coherent. Uses passive voice judiciously.	**/10%**
CEAB Outcomes: Below Standards, Marginal, Meets, Exceeds	8.2 Responsibilities of an Engineer: 8.5 Integration of Standards: 9.2 Sustainability:	

ENSC 405W Grading Rubric for Design Specification

Criteria	Details	Marks
Introduction/Background	Introduces basic purpose of the project.	**/05%**
Content	Document explains the design specifications with appropriate justification for the design approach chosen. Includes descriptions of the physics (or chemistry, biology, geology, meteorology, etc.) underlying the choices.	**/20%**
Technical Correctness	Ideas presented represent design specifications that are expected to be met. Specifications are presented using tables, graphs, and figures where possible (rather than over-reliance upon text). Equations and graphs are used to back up/illustrate the science/engineering underlying the design.	**/20%**
Process Details	Specification distinguishes between design details for present project version and later stages of project (i.e., proof-of-concept, prototype, and production versions). Numbering of design specs matches up with numbering for requirements specs (as necessary and possible).	**/15%**
Test Plan Appendix	Provides a test plan outlining the requirements for the final project version. Project success for ENSC 405W will be measured against this test plan.	**/10%**
User Interface Appendix	Summarizes requirements for the User Interface (based upon the lectures and the concepts outlined in the Donald Norman textbook).	**Graded Separately**
440 Plan Appendix	Analyses progress in 405W and outlines development plans for 440. Includes an updated timeline, budget, market analysis, and changes in scope. Analyses ongoing problems and proposes solutions.	**Graded Separately**
Conclusion/References	Summarizes functionality. Includes references for information sources.	**/05%**
Presentation/Organization	Document looks like a professional specification. Ideas follow logically.	**/05%**
Format Issues	Includes letter of transmittal, title page, abstract, table of contents, list of figures and tables, glossary, and references. Pages are numbered, figures and tables are introduced, headings are numbered, etc. References and citations are properly formatted.	**/10%**
Correctness/Style	Correct spelling, grammar, and punctuation. Style is clear, concise, and coherent. Uses passive voice judiciously.	**/10%**
Comments		

ENSC 405W Grading Rubric for User Interface Design

(5-10 Page Appendix in Design Specifications)

Criteria	Details	Marks
Introduction/Background	Appendix introduces the purpose and scope of the User Interface Design.	/05%
User Analysis	Outlines the required user knowledge and restrictions with respect to the users' prior experience with similar systems or devices and with their physical abilities to use the proposed system or device.	/10%
Technical Analysis	Analysis in the appendix takes into account the "Seven Elements of UI Interaction" (discoverability, feedback, conceptual models, affordances, signifiers, mappings, constraints) outlined in the ENSC 405W lectures and Don Norman's text (*The Design of Everyday Things*). Analysis encompasses both hardware interfaces and software interfaces.	/20%
Engineering Standards	Appendix outlines specific engineering standards that apply to the proposed user interfaces for the device or system.	/10%
Analytical Usability Testing	Appendix details the analytical usability testing undertaken by the designers.	/10%
Empirical Usability Testing	Appendix details completed empirical usability testing with users and/or outlines the methods of testing required for future implementations. Addresses safe and reliable use of the device or system by eliminating or minimizing potential error (slips and mistakes) and enabling error recovery.	/20%
Graphical Presentation	Appendix illustrates concepts and proposed designs using graphics.	/10%
Correctness/Style	Correct spelling, grammar, and punctuation. Style is clear concise, and coherent. Uses passive voice judiciously.	/05%
Conclusion/References	Appendix conclusion succinctly summarizes the current state of the user interfaces and notes what work remains to be undertaken for the prototype. References are provided with respect to standards and other sources of information.	/10%
CEAB Outcomes: Below Standards, Marginal, Meets, Exceeds	1.3 Engineering Science Knowledge: 4.1 Requirement and Constraint Identification: 5.4 Documents and Graphic Generation: 8.2 Responsibilities of an Engineer:	

ENSC 405W Grading Rubric for ENSC 440 Planning Appendix

(5-10 Page Appendix in Design Specifications)

Criteria	Details	Marks
Introduction/Background	Introduces basic purpose of the project. Includes clear project background.	**/05%**
Scope/Risks/Benefits	Clearly outlines 440 project scope. Details both potential risks involved in project and potential benefits flowing from it.	**/10%**
Market/Competition/ Research Rationale	Describes the market for the proposed commercial project and details the current competition. For a research project, the need for the proposed system or device is outlined and current solutions are detailed.	**/10%**
Personnel Management	Details which team members will be assigned to the various tasks in ENSC 440. Also specifically details external resources who will be consulted.	**/15%**
Time Management	Details major processes and milestones of the project. Includes both Gantt and Milestone charts and/or PERT charts as necessary for ENSC 440 (MS Project). Includes contingency planning.	**/15%**
Budgetary Management	Includes a realistic estimate of project costs for ENSC 440. Includes potential funding sources. Allows for contingencies.	**/15%**
Conclusion/References	Summarizes project and motivates readers. Includes references for information from other sources.	**/10%**
Rhetorical Issues	Document is persuasive and demonstrates that the project will be on time and within budget. Clearly considers audience expertise and interests.	**/10%**
Format/Correctness/Style	Pages are numbered, figures and tables are introduced, headings are numbered, etc. References and citations are properly formatted. Correct spelling, grammar, and punctuation. Style is clear, concise, and coherent.	**/10%**
Comments:		

Student Perspectives

“There were several times (usually during conflicts) where we would pull out either our requirements or design specifications and verify how we would implement a certain feature and when we could consider the feature completed.” – Shane Schneider, 1999

“Never underestimate the worth of a finalized design before construction.” – Jeff Robinson, 2000

“My advice is to have each group member read, under-stand and search for inconsistencies in the design spec.” – David Boen, 2001

A Couple More Aphorisms

“If it’s stupid but works, it ain’t stupid.”
– Major Ambler Furry, USAF

“Not everything worth doing is worth doing well.”
–Tracy Kidder

Conclusion

- Your requirements specification is due on Thurs, June 21 by 11:59 PM (difficult to write)
- Your design specification is due on Thur, July 26 by 11:59 PM (long).
- You can use your free late of 3 days on one of the two docs, but not both. 10% day late penalty.
- As usual, please e-mail them to whitmore@sfu.ca as .pdf attachments.