Crawler Project Report Format and Guidelines

Final report is due 5:00pm on Friday, February 12. The lengths listed are suggestions. There is not a strict page limit, but we believe the main document should not exceed 4000 words. There is no limit on generous, clear illustrations and plots. Between now and the due date, take ample pictures of designs and events so that you have them when you need them!

Here are some guidelines for writing your final report for the crawler project and an outline of what the report should include. The report should be a piece of documentation that you would be proud to turn in to a client who has sponsored your prototype design. Handwritten reports or reports that represent a collection of disconnected sections in different fonts are not acceptable. Although it is natural to divide the work among team members, be sure to allow time for integrating the parts into a consistent whole. You will find that much of the information requested was also part of the design review, so the emphasis is on a clear presentation and not on generating a lot of new results. ME112 is now a "writing in the major" course so your document will be evaluated for clarity and professionalism as well as content.

General guidelines:

(1) Although there is a tendency sometimes to think that spelling, grammar and style matter only in liberal arts classes, it is important that technical documentation be clear and well-written. Misspellings and grammatical errors should be avoided. Unlike the Microsoft Word paperclip, however, we don't really care if you use "that" or "which."

(2) There is a bit of a debate about whether it is appropriate to use the first person ("I" or "we") in technical writing instead of the third person ("The design team", "the crawler"). We don't have a strong preference. If you do write in the third person, however, please minimize use of the passive voice ("Tests were performed and results were collected.") which gets really old after a bit.

(3) Even in the third person, there is no reason to ever use the construction "was done" as in "A series of tests was done." More descriptive verbs exist for whatever you are trying to explain.

(4) Tense should remain consistent within the report or at least within a major section. When discussing your design you need to choose whether to speak about it in the present ("The design possesses...") or the past ("The crawler had a mass of...").

(5) "Optimal" is probably the most abused word in design documentation. It refers to the best solution in a mathematically provable sense. Most designs are not optimal – there is room for improvement. That doesn't mean it isn't a great design, but you should call it something other than optimal. Since the objective of design documentation is to describe what was done and give others some insight into the strengths and weaknesses of the design, honesty and clarity are important.

(6) A number of words with specific technical meanings (like "power," "energy" or "efficiency") also have more casual uses in the English language. Make sure that when you use these terms in design documentation you are consistent with the technical definitions.

(7) When including equations, always define the variables used in a form like: "The energy consumed, E, is calculated as:

$$E = V \cdot i \cdot t$$

where V is the applied voltage, i is the input current and t is the time required to traverse the track."

(8) If you find that a long series of equations disrupts the flow of the text, you can move it to a separate appendix. The basic analyses required to track the flow of power and the application of forces should be in the main body of the report since they are critical information for understanding the design. I any case, you need to explain what the equations are, what they mean and how you used

them. (Don't just dump a bunch of equations in the report.) Along similar lines, cryptic and/or tiny Excel spreadsheets should be avoided.

(9) Reference figures in the text with a caption and a number. For an example of this, please see Figure 1. (Word, Open Office and Latex all provide convenient auto-numbering and cross-referencing for figure captions and major sections.) There is no length limit on figures, so use large, clear figures with descriptive captions and labels highlighting important elements. Don't spend time carefully wrapping text around them. Note also that the figure generally appears after it is mentioned in the text but does not need to come immediately after (scientific article style, not "blog" style).

(10) Where feasible[1], we prefer MKS units with scientific notation and appropriate numbers of significant figures. A leading zero is usually placed before decimal values ("0.3" not ".3") for clarity.

(11) Tables can be very useful for collecting and summarizing information (e.g. various power losses or other performance-related data) in an easily accessible way.

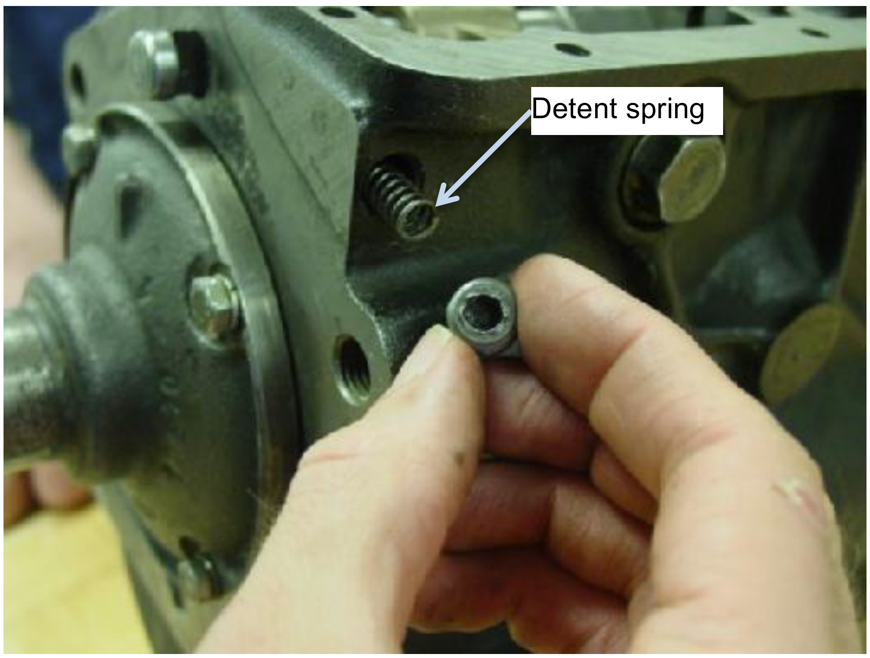

Figure 1. This figure has nothing to do with the crawler project but it is admirably large and clear, and illustrates proper referencing and captioning. In this case we have used Word's "insert caption" feature for numbering.

Report Contents

The following items describe the information that must be in the report, broken down into different sections of the document. Each report should contain all of the following elements.

Title page with team members' names and team name, the project title and the date. We encourage you to include your team photo.

[1] AGMA gear calculations are in English units, so MKS units are not entirely feasible in this case

Executive Summary *(usually 2-3 paragraphs and a figure).*
The summary should be substantive. In other words, if a client only reads the Executive Summary of your document she should have a sense of what was special about your design, how it performed, what key insights you gained, and what comes next.

Summarize important results for easy reference. Don't just write something along the lines of "This report will describe the design, outline the testing results and suggest recommendations," but instead be specific about the main features of the design, the results and your recommendations going forward.

Although Executive Summaries often don't have illustrations, for design documents it is useful to include a clear *gestalt* image – perhaps a clear photo of your design in action? This image can be a duplicate of a figure found later in the report.

Check list:
Everybody on your team needs to be happy with this section. Word-for-word, it's the most important one for clarity and style. Remember, the Executive Summary is the only section that busy executives will read!

Background *(~1 paragraph)*. In this section, discuss what you set out to do, the design requirements and, if necessary, how you interpreted the design requirements. This section should carry your own emphasis and not simply be cut and pasted from the project description.

Basic Description of the Design *(perhaps 2-3 pages exclusive of figures & captions)*.
Explain what your design looks like and why. Pictures are in many cases truly worth a thousand words. While it is perfectly acceptable (and in many cases extremely useful) to discuss concepts you considered and discarded, this section should *not* be a chronological retelling of how you came up with the design. Such historical narratives are fine if you scale Everest or Kilimanjaro, but frustrating for a reader trying to understand your design in its final form. Focus on the important features and explain what they do. To do this well, it is necessary to take a step back and consider why your design works in an absolute sense, not just why this design worked better than other things you tried.

Show the design from multiple views. Label any features that you describe in the text. Often a sketch or even a CAD rendering can be clearer than a photo for explaining certain points. If you find yourself devoting more than a sentence or two describing any feature of the design, that is a sign that you should have another accompanying figure. Figures and captions are excluded in the page count to encourage large, clear images with labels, and explanatory captions.

Among other things, this section should make it clear what your overall transmission ratio is and what its arrangement is. Other key features include:

- What are your drive wheel(s), and where are they (and why)?
- What guides and other provisions are there for stability (and why)?
- Where are you carrying the core drill (and why)?
- How are you depressing the switch?
- How does your design descend after depressing the switch? What changes?

If you have many figures and design details of intermediate designs, you can put them in an Appendix section. In this case, refer the reader explicitly to the appendix in the text of your main document ("see Appendix A for additional views of the Version 2 drivetrain.").

Check list:

- Figures are generous and clear (don't skimp on size) with labels pointing out important features Figures have explanatory captions (these can run to two or more lines, Scientific American style) and all figures are numbered sequentially.
- Text refers explicitly to figures by number ("...as seen in Fig. 3, the hyperspace flux capacitor is positioned just below the motor, where its heat softens the tires for better traction.")
- All important features are indicated in figures and described in text
- Key design decisions are noted (rationale, not rationalization!)

Basic Description of Logistics *(1-2 paragraphs)*. You have to install a bolt, ascend the track, depress a bumper, reverse the leads and descend (perhaps with a different voltage). Perhaps you will also contend with the horizontal/inclined transition? Explain briefly how you intend to accomplish this and what features of your design support successful execution.

Analysis of Performance in the Shaft *(several pages depending on how many plots, figures, tables)*
In this section, you should document the energy use obtained during testing and describe how much of the energy was consumed by:

- losses in the motor
- inefficiency of the drivetrain
- rolling resistance of the design
- lifting the mass of your crawler including the "core drill" (bolt).

Guide the reader through the process of analyzing where the power went, and why. You can obtain the necessary information from your motor curves, your actual testing results and additional tests where you apply a known load to your crawler. In describing these losses, you should reference:

- A plot of the characteristics of your motor (speed vs. torque, power vs. current and efficiency vs. current). Use your actual voltage during ascent and indicate where on this plot your motor was operating. You probably want to add a second curve for the descent condition.
- A free body diagram of your design so that the reader can understand where losses come from. If it is more useful to include this in the previous section where you discuss the design, then please do so and give a backward reference. Any forces that contribute directly to your analysis (like rolling resistance) should be clearly labeled. Include the force and moment equilibrium equations so that the reader understands how you estimated force values.

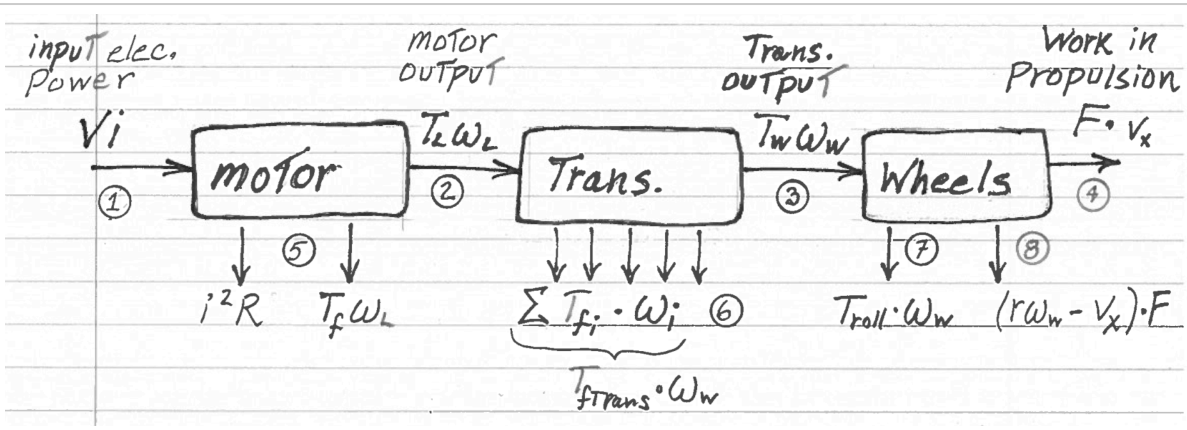

Figure 2. Summary of power flow in a crawler, showing loss terms. (Numbers match labels in accompanying text.) *This example uses a MS Word text box to ensure it does not become separated from its caption. If using Googledocs, insert a 2-cell table, with image in upper cell, caption below.*

If there are lengthy derivations, they should go in an Appendix section (e.g. Appendix B) and you should refer the reader explicitly to it for details. For any equations, you should define terms the first time you use them. Don't assume your reader necessarily knows what "i_nl" is. You don't need to spend a lot of time formatting equations, but they should be clear (as described in the overall guidelines above). Where possible, stick with MKS units. You may want an illustration similar to Figure 2 (but don't just copy it – not all terms may be relevant to you).

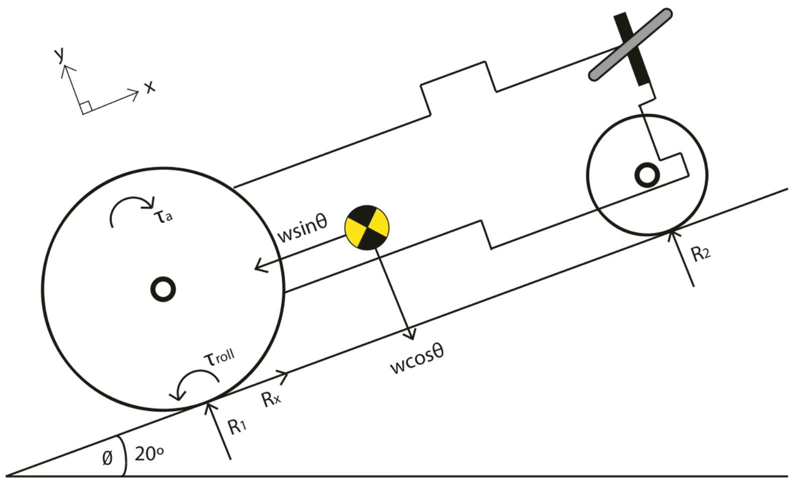

Figure 3. Free-Body Diagram of crawler in the lava tube, showing main normal and tangential reaction forces and rolling resistance (assumed negligible at front wheel). *Ideally this figure should include a couple of dimensions in the x direction.*

Check list:

- Diagram explaining the overall distribution of energy and energy losses
- Equations showing how energy consumption depends on various factors including weight, rolling resistance, motor performance, etc.
- Motor efficiency plot showing where your operating points are for climbing and descending, and equations showing how the efficiency is calculated from measured parameters
- Explanations of main measurements for obtaining terms used to compute energy loss in various parts of the system
- Free body diagrams that are clear and easy to interpret for understanding the relevant forces in your analysis

Strength Estimate *(~1/2 page with reference to Appendix for spreadsheet or Matlab for details)*

By now you should have enough intuition to identify the "worst case gear" in your system. How sturdy is it compared to anticipated loads? You can perform an analysis similar to that shown in Friday sections for a Lego gear mating with a Lego worm using the same material constants.

		PitchDia (inch)	Ftan (lbf)	Vtan (in/s)	Vtan (ft/min)	Kv (AGMA)	Jlewis (15.23)	Sigma_L (psi)
N1_driver	24	0.87912 0879	0.10	210.99	1054.94	1.27	0.39	85.84
N1_driven	8	0.29304 0293	0.30	210.99	1054.94	1.27	0.20	502.15
N2_driver	8	0.29304 0293	0.30	210.99	1054.94	1.27	0.20	502.15
N2_driven	40	1.46520 1465	0.06	210.99	1054.94	1.27	0.45	44.64

Table 1. Example of a table useful for summarizing information, in this case relating to the strength of Lego gears. (We ask only for the "worst case" gear.")

Conclusions (*2/3 page*)
When all is said and done, how did you do? What aspects of the design should we be confident will work as expected? Will your design work for exploring the pyramid?

What changes would you recommend going forward, and why? In particular, what would make the most sense for increasing the efficiency of your crawler? If the motor was not operating at its peak efficiency you might do any or all of the following: use a higher voltage (if not already at 9 volts), increase the gear ratio, reduce weight, reduce forces against the sidewalls and/or reduce the rolling resistance. Which of these would be most effective in your case? How much of a change would you be able to make? Support your assertions quantitatively, referring back to equations in the analysis section if appropriate.

Appendices
Divide the appendix into sections for different major topics (detailed views of various designs, testing, analyses...). Don't just throw a lot of equations or spreadsheet data in the report and call it an appendix – there should be some organization and clarity. Appendices do not contribute to the document word count.

Check list: Make sure that any appendices are explicitly referred to in the corresponding sections of the main report.