ABSTRACT
The goal of this paper is to demonstrate the advantages of implementing an alternative technical review technique in an engineering design course. Historically formal design reviews associated with the Cornerstone Design course have utilized a Power Point type of presentation for evaluation of a design project status. A case study will be presented involving the use of a project summary report for a comprehensive design project review based on a Toyota management communication tool known as the “A3 Report”. The objectives for utilizing the this report format as an alternative to the presentation format were to require project team members to integrate their individual sub-system designs into their final system proposal, identify the critical aspects of their design, and prepare for detailed questions regarding their design. Conclusions and recommendations from the perspective of both the instructors and the students will be presented, including points of concern with the implementation.

CORNERSTONE DESIGN COURSE BACKGROUND
Cornerstone Design Project Lab is a two credit hour Mechanical Engineering course offered at the Rochester Institute of Technology in the third year of a five year program. Students meet four hours a week for ten weeks. The Project Summary Report developed from the A3 report format discussed within this paper was initially implemented in two sections of the course in the fall of 2008.

The course description is given below for reference [1]:  
“This course gives students an opportunity to apply foundation courses in mechanical engineering to the solution of an open-ended design problem. Students will learn about project definition, concept development, feasibility assessment, managing design parameter tradeoffs using engineering analysis, and developing a preliminary design drawing package. Teams of students will develop their concept through the stage of working drawings. The course is intended to prepare students for future Mechanical Engineering and multidisciplinary design courses.”

Prior to registering for the Cornerstone Design course, students are required to have taken core Mechanical Engineering courses including Engineering Design Graphics, Statics, Mechanics, Thermodynamics, and Fluid Mechanics. In addition to these courses, each student is also required to have completed at least one co-op block of work experience. The reason for the course requirements and the timing of the course offering is to introduce students to an open-ended design problem that is addressed in a project-group setting. This course reinforces the core concepts of mechanical engineering while showing how they can be integrated together. The main goals of the Cornerstone Design course are to:

- Apply the theory of the core Mechanical Engineering courses in a real-world engineering design context
- Introduce students to a structured and logical design process
- Expose students to design tools and processes that address different stages of the design process
- Convey the importance of customer requirements
- Teach students how to utilize the web-based project management tools available to them
- Show the importance of team work and understanding group dynamic challenges associated with working in a large team (5-7 students).
- Work with students to develop presentation material appropriate for the target audience

The course textbook currently used is “Engineering Design” by Dym and Little [2]. A web-based project management environment called the “Engineering Design Guide and Environment”, or EDGE, is also heavily utilized in this course. EDGE¹ was developed to help student teams collaborate on

¹ The EDGE site, https://edge.rit.edu, is extensible and undergoing continual improvements. All statements regarding EDGE are current as of 2009.
design projects. The entire course syllabus, calendar of class meeting topics, course deliverables and grading breakdown are posted on the EDGE website. Cornerstone Design is typically the students’ first introduction to the EDGE environment. Subsequent courses such as Design Project Management and Senior Design exclusively use the EDGE web site for project management. The introduction to the layout, content, and benefits of the EDGE website has proven to be valuable in acclimating students to the environment prior to their upper-level classes.

Groups of five to seven students are randomly assigned to design a solar powered residential hot water and space heating system. Each group must interview a fictional homeowner family from varying locations within the USA to determine the specific needs of their client in order to deliver a system design that is acceptable from a technical and economic standpoint. Recommended project team sub-system roles include analyzing the following critical system areas:

- Foundation
- Structure
- Building Thermal
- Architecture
- Hydronics
- Solar Thermal
- Integration

Throughout the course many different design tools and processes are discussed and utilized. Several of these design tools include affinity diagrams, objective trees, pairwise comparisons, weighted voting, brainstorming, functional black boxes and morphological charts. Information derived from these tools is presented in three group deliverables throughout the course; a customer needs assessment, a preliminary design review, and a final project review.

The customer needs assessment verifies that the project group understands the unique customer requirements for their particular client. The format for evaluating each project team’s customer needs assessment incorporates an interview-style discussion between the instructor and the project team.

For the preliminary design review (PDR), each student is expected to have completed a preliminary analysis of multiple design options for their respective subsystem in preparation for a meeting with the homeowner and the building contractor. Historically, this presentation has been given with Power Point slides. Questions were addressed at the completion of the presentation.

In the past, the final project review consisted of two parts: a formal presentation referenced as the critical design review (CDR) and a technical report. Teams typically expanded on the first Power Point presentation from the PDR to include a comprehensive analysis of the final selected design for the subsequent CDR. In addition to the CDR, teams were required to electronically submit a detailed technical report, justifying their final design system.

**Motivation for an Alternate Final Project Review Format**

Upon reflection of the final CDR project summary, it was determined that the two methods (presentation and technical report) of documenting the final system design both had potential areas for improvement. The CDR did not present a significant challenge to project teams since they typically performed limited reworks of the PDR presentation to incorporate final design modifications. Additionally, the technical report left team members working independently on their subsystem documentation with very little integration towards the final comprehensive design.

With these concerns in mind, it was decided that an alternative final project evaluation method would be pursued. By their third year, students typically have had significant Power Point exposure. No change to the presentation style was implemented for the PDR, since it is a useful and common communication tool that is heavily used in industry. Based on Edward Tufte’s “The Cognitive Style of PowerPoint: Pitching Out Corrupts Within” [3], an alternative was investigated for the final project assessment.

Tufte’s recommendation is to use an A3 paper handout folded in half to create a four page pamphlet. This handout can effectively show images, data graphics and text. He goes on to suggest that this paper handout can provide the same content as 50 to 250 typical Power Point slides. Based on this concept, a modification for the final project assessment was presented to the department head who suggested looking into the A3 Report format as used by Toyota [4].

**A3 Report Background**

The Toyota A3 report is an efficient communication tool used by engineering design teams to convey large amounts of information in a well-organized manner to management. Depending on the audience and the design stage the team is currently in, there are several different formats of A3 reports that can be used with customers, colleagues, and management. One of the key features of the A3 report is the format standardization that is expected when generating and reviewing the document. There is a very structured layout for the A3 report that typically utilizes one side of an A3 size paper. Typical topics covered in an A3 status report include background information, clearly stated objectives, the implementation approach, the current total effect, issues and resolution actions as shown in Figure 1.
The instructors identified three major motivations for utilizing a report format with similarities to the A3 report format as a final project evaluation tool.

Firstly, the A3 report is more representative of a real-world design review setting where there is greater interaction and personal accountability for each team member to address their part of the project. Toyota has developed the A3 report as a management communication tool which can be used for a comprehensive design project review. Exposing students to proven real-world design tools utilized in highly successful companies is a powerful argument that legitimizes the approach.

Secondly, past design reviews for this course utilized a PowerPoint type of presentation for evaluation of a project status. Introducing students to an alternative project review process was intended to address the “death by PowerPoint” syndrome most engineers experience throughout their careers. PowerPoint presentations are often an inefficient use of time due to their bloated size, inclusion of extraneous data, number of slides, and the presenters’ habit of reading the slides to an audience.

Thirdly, a final goal of utilizing the A3 report as an alternative to typical presentations was to force teams to work closely, identify the critical aspects of their design, and prepare for detailed questions regarding their design. A natural outcome of using the A3 report is that each team member must substantiate the value of the information they are suggesting be included in the report to fellow team members. Due to the strict limitation on the available space in an A3 report, all report information included must be critical to the communication of the project status.

Ultimately the very structured layout of the A3 report did not exactly lend itself for direct implementation into the class. A Project Summary Report (PSR) was developed to take advantage of the clear benefits associated with the A3 report, but modified to meet the demands of the course.

GETTING BUY IN – UTILIZING AN AFFINITY DIAGRAM

None of the students had any dealings with the A3 type of report format prior to this course. The instructors wanted the focus for the final technical review to be on technical content rather than on the newly introduced PSR format. To alleviate the concerns associated with learning the PSR format, each of the classes was lead through an affinity diagramming session to engage team members in the development of a class PSR template.

Affinity diagrams, also known as the KJ method after its creator Jiro Kawakita, are a way of organizing a collected set of data [5]. Affinity diagrams are typically used if there are a large number of ideas, complex issues, or if it is necessary to reach agreement in a group setting. A procedure for preparing an affinity diagram is presented in “Quality Toolbox” [5][p96] and summarized below:

1. Record each item with marking pens on separate sticky notes. Randomly spread notes on a large work surface so all notes are visible to everyone. The entire team gathers around the notes and participates in the next steps.
2. It is very important that no one talk during this step. Look for ideas that seem to be related in some way. Place them side by side. Repeat until all notes are grouped. It’s okay to have “loners” that don’t seem to fit a group. It’s alright to move a note someone else has already made. If a note seems to belong in two groups, make a second note.
3. You can talk now. Participants can discuss the shape of the chart, any surprising patterns, and especially reasons for moving controversial notes. A few more changes may be made. When ideas are grouped, select a heading for the group. Look for a note in each grouping that captures the meaning of the group. Place it at the top of the group. If there is no such note, write one. Often it is useful to write or highlight this note in a different color.
4. Combine groups into supergroups if appropriate.

To implement affinity diagramming within the classes, each student was given a stack of Post-It® notes. They were asked to think of what information they felt should be included in the report format and to record each idea on separate notes. While the students worked on brainstorming ideas, a large version of the paper, front and back, was drawn on the white board. After several minutes of generating ideas, students were asked to place their Post-It® notes on the white board as shown in Figure 2. The class discussed main topic ideas that were generated through the Post-It® notes as well as the order in which they should be presented. Each of the classes conducted this exercise independently and captured the results of the group
exercise. The two classes developed near identical lists of information to be included in the final PSR format. From this exercise, a template was created using Microsoft Publisher for use by the teams (Appendix A).

Figure 2: Student Affinity Diagramming White Board Activity

The reaction from the students to incorporating the affinity diagram tool into the introduction of the PSR format was very positive. The students felt quite confident that they knew what should be included in the report after completing the exercise. An additional benefit of the activity was that it provided the opportunity to introduce the affinity diagram brainstorming tool to the teams.

IMPLEMENTATION SUMMARY

The PSR discussion utilized in class drew from the A3 report premise discussed in the Toyota Way Fieldbook. Because of the novelty of the approach with respect to the students and the scope of the project, the adapted template allowed teams to consolidate the critical aspects of their design onto an 11” x 17” sized paper, front and back. The electronic version of the report was submitted 24 hours prior to the discussion. Printouts were generated at the final project review for all participants.

The premise of the discussion was that teams were pitching their design to their technical supervisor. Two teams at a time met with the instructors in a classroom with a central table and many chairs. Questions were interjected throughout the meeting as individual team members discussed their subsystem design. Due to the physical size limitations of the report format, students needed to know what they should discuss, and not fall back on reading a slide. Where space issues did not allow all information to be presented appropriately, teams were encouraged to bring supplemental information, either in printed form or referenced electronically on a provided team website. Each team had one hour to provide complete coverage of their final system design.

The final technical discussion was held after the class completed their course evaluation forms so no official feedback from students was collected. As discussed before, this was the first time that the PSR format had been implemented within the course. An informal discussion took place immediately following the final technical review to evaluate the students’ thoughts on how it suited the deliverable. Both instructors were surprised by the overwhelmingly enthusiastic response to the new format. Students commented that the limited space required them to work together as a group and restrict the information presented to the critical aspects of the design. Images, graphs, and tables were prominent in the PSR since they are able to convey a large amount of information in a small space.

STUDENT FEEDBACK

To get a better gauge on the students’ feelings regarding the use of the PSR format, a voluntary online survey was conducted several weeks after the end of the course. Out of thirty three students, ten students responded to the survey consisting of the following 5 questions:

1. Based on your experience utilizing the A3 report format, **WOULD YOU RECOMMEND** the A3 report format for a final project review?
   a. Strongly recommend
   b. Recommend
   c. Neutral
   d. Do not recommend
   e. Strongly do not recommend

2. What were the major **STRENGTHS** of utilizing the A3 report format for the final project review?

3. What were the major **WEAKNESSES** of utilizing the A3 report format for the final project review?

4. Now that you have utilized the A3 report format, what **ONE CHANGE** would you suggest concerning the A3 report format?

5. Please provide any **ADDITIONAL COMMENTS** you would like to share concerning your experience with the A3 report format.

The feedback from the students was very informative. Rather than selecting a few favorable comments, all comments received are included below.
With regard to question 1 feedback was very positive, with six students strongly recommending and four students recommending utilizing the A3 report format.

The ten responses to question 2 regarding the strengths of the A3 report were:

- Everything that was vital to the customer was in one convenient location, and that one location was not a 20-page tech memo.
- The A3 report allowed the organization of pertinent engineering material in a visual format. The use of graphics and charts allow the communication of ideas in the same "language" engineers use every day, eg. cad models, charts, diagrams. The function of the A3 Report Document is three fold. It allows designers/team member to organize and consolidate their thoughts, it creates an agenda, and it also serves as an extremely effective visual aid.
- The relatively small size of the A3 forces us (the hardworking students) to include only the information that is absolutely critical to our design. It also provides an attractive single item that conveys most of the important points of the entire project.
- The major strength of the report was its required brevity. With so little space for the report it was essential to have only the most important information on page. This focused the team on what was really important to them and to the potential customer.
- The A3 format exposed us to a presentation method currently being used in industry; it taught us how to tailor our data/information into a clear, concise, and organized presentation without overwhelming the client.
- There had to be a lot of teamwork involved so the A3 report could flow well. Also, the most important details had to come to the surface in such a small amount of space.
- Makes you focus on the important details, and prevents from unnecessary details
- smooth flow between sub sections, highlighted the important points due to the limited space, allowed for a good discussion as design was presented
- It was necessary to make good use of the space provided so it forced us to concentrate on the important information. Also it forced us to have to talk about certain details that could not be included in the report.
- The A3 report format required that all the technical information regarding the project be condensed to the major concepts and conclusions. This allowed the project team to better visualize the interactions between the different components of the project and aided in presentation.

The ten responses to question 3 regarding the weaknesses of the A3 report were:

- The biggest struggle came with trying to decide what exactly needed to be in everyone’s section of the report as well as squeezing it all in.
- When the RIT Baja Team used the A3 Report the largest problem was introducing the idea to the group. Having all of the individuals in the group understand the process without having gone through it is very tough. This relates to not only the entire A3 review concepts and procedures but also the specificity of the items to be posted by team members on the A3. Another critical portion of the review is how the report information is used to move the project forward. This was slightly outside the scope of the cornerstone coursework and also was an area of weakness during the Baja Team implementation.
- While setting up the A3, some team members were forced to subtract information from their section to make room for information from another team member, who insisted that all his information be on the report. But not that big a deal.
- One weakness that I saw in our own report was the lack of clarity on where supporting material can be found. This is not really a general format problem but just one that we ran into.
- The A3 format did present a challenge of how to fit everything that needed to be presented to the customer on the A3 sheet.
- Coordinating enough space for each group member
- Slight limitation with space due to the large size of project. A3 would be good for one component, but for the whole house layout and details, two sheets was still very crowded
- may have been difficult for people to follow along if group was any bigger (seemed to work for our class though)
- It was hard to include relevant details in the report. It did not provide any area for a supporting written report.
- For large, involved projects there was a tendency to sacrifice data for a clean presentation. This was remedied by supporting documentation but personally I believe the A3 report should be an aid for a formal report and not a replacement.

The eight responses to question 4 regarding the one change they would make to the A3 report format were:

- The three sections that were on the first page did not take up as much space as the second page; if the second page sections could have spilled over onto the first page, it might have looked a little more even.
The A3 has an extremely streamlined, clear and effective way of organizing the pertinent design information, but it lacks a framework for feedback. Out of the review process there is again another level of narrowing focus and identifying risks. This information exists only in the notes of those present and lacks the formalization and consolidation that the A3 creates. It seems that a formalized follow-up method would be beneficial to group organization and also be more true to a real world scenario.

Up the ante. ONLY ONE SIDE
I think the process should be started sooner. One idea may be to make the preliminary design reviews done similar to the A3 report but with on sheet per system. This would introduce the concept but allow more space for detail that is needed in the initial review.
I would suggest more guidance on how to present with the A3 format which could be supplemented with an actual example of the A3 format in a handout.
The A3 format should be less compartmentalized and allow for more flow from one concept to the next. A single, cohesive representation of the project surrounded by specifics on particular subsystems would contribute to a more unified view of the project. If this was used as a supplementary to a formal report there would be no loss of information and the primary purpose of the A3 report, to condense information, would be better served.
I would not change the A3 report. I thought it was a good use of engineering strengths to portray information.
I don't believe that any changes need to be made to it. It is a very effective tool.

The five responses to question 5 regarding any additional comments were:

- It was really good, from an educational standpoint, to learn about a technical memo format that is actually used out in industry.
- It functions as an excellent framework for any review process, but I think that with a feedback mechanism it would be an exceptionally strong interim project organization tool.
- I liked putting the report together and seeing the entire project on one sheet of paper. It also afforded opportunities to be creative in designing an attractive layout. A3 way to be. Peace.
- I think this is a very effective tool and one that I plan to use in the future.
- Overall, the A3 was interesting to use because power points can be dull and overused. The round table discussion was a great form of design review and allowed for critiquing during presentation of material.

INSTRUCTOR ASSESSMENT

Instructors were pleasantly surprised by the very successful transition of the final report format to the PSR format based on the A3 report. All aspects of the final review improved compared to the preceding course offering, particularly the level of detail, the team integration, and the degree of preparedness.

Several issues and opportunities for improvement were noted by the instructors from the initial implementation of the PSR. One of the dominant issues related to the new format was providing proper citations for the information contained within the report. The condensed format allowed little room for including citations. Some teams provided a separate handout including citations for assumptions, values, and images.

Printing an 11”x 17” double sided report for every attendee was also more paper intensive than typical for the course. This isn’t a major concern, but an unfortunate side effect. The effects were minimized by only having one group sitting in while another group presented. Color copies were produced for the instructors, but black and white copies were provided for every student. The lack of color made some graphs difficult to interpret.

In future iterations of the course, students will be made aware of this situation, and encouraged to make accommodations. Some PSRs were difficult to follow what information belonged to which subsystem. It was noted that teams utilizing a simple border outline delineating the different sections of the PSR were clearer on where sections begin and end.

Both of the instructors feel that the A3 report based format has many benefits to offer as a project communication tool. The key aspects to our implementation of the PSR that led to its success were:

1. Introducing the topic of the A3 report as presented in “The Toyota Way Fieldbook”. This text is made available electronically to the students through the RIT library – improving the possibility that it would be accessed by the students.
2. Developing what should be included in the template as a collective group. Getting buy in from everyone involved made implementation much easier.
3. Having a copier available to make a number of grayscale two sided 11” x 17” printouts for review attendees as well as a limited number of color printouts for instructors.
4. Having the time and location to allow all participants to sit around a table and discuss the final design. In our experience it took a full hour for each group.

It is not our recommendation that the A3 report-based format replace all Power Point presentations. Communication via Power Point presentation still has a significant role in academia as well as industry. There are many opportunities to
incorporate this “tool of industry” into curriculum throughout a student’s time at college.

In conducting research for this paper, it was brought to the authors’ attention that the A3 report format has been implemented recently in several classes in the Industrial and Systems Engineering (ISE) department at Rochester Institute of Technology. In the ISE department, the A3 reports focus on Problem Solving and Proposal activities. The A3 report as detailed in this paper was not based on examples or work done in the ISE department. After discussing the implementation of A3 report formats within the classroom there may be an opportunity for future collaboration between the departments. Perhaps more engineering departments are utilizing this style of design review within classes, but the results from a literature review do not support that assessment.

CONCLUSIONS
The PSR format based on the A3 report will continue to be implemented and developed as the final technical design report format in the Cornerstone Design course at the Rochester Institute of Technology. The opportunities for improvement will be addressed in future course offerings and formal student feedback will continue to be gathered and evaluated. The strengthened collaboration between team members and the technical roundtable discussion with immediate feedback were two of the most significant benefits realized by this approach. The use of the PSR also demanded internal group member evaluation for clarity and relevance of all information to be included in the document. Overall, the PSR format benefits were recognized and appreciated by both instructors and students.

ACKNOWLEDGEMENTS
We would like to acknowledge the contributions from all of the students that served as our project guinea pigs. Their honest feedback led us to believe that there was uniqueness in this approach that warranted further discussion. We would also like to acknowledge the valuable discussions and feedback provided by Dr. Andres Carrano from the ISE department at RIT.

REFERENCES
APPENDIX A.1 – Template Generated Through Student Collaboration – Front Side

Project Definition and Description
- Geographic location (city, state)
- Square footage
- Layout
- Homeowner information
- Team number
- Climate
- Additional constraints
- Intro statement (type of climate, summary of critical needs assessment information attained through customer interviews and given information)

System Information
- Architectural
- Structural
- Foundation
- Thermal
- Fluids
- Solar
- Economics

Architectural
- Design achievements
- Exterior 3D view of house
- North
- Panels
- Slope
- Relative amount of windows
- Show slope of land relative to house basement

Structural
- Truss factor of safety (for compression, tension, and bending)
- Truss material & size
- Truss diagram with roof angle identified
- Roofing material
- Venting
- Attic dimensions
- Load capacity (summary of loading conditions used in analysis)
  - Environmental, building material, etc.
- Weight of completed roof
- Max stress
- FPC mounting approach (mounted to roof or additional support structure needed?)
- Hurricane straps
- BOM with cost information in backup material

Foundation
- Foundation fabrication technique (cement blocks, poured concrete, etc.)
- Cross section of wall (identify how design prevents water intrusion, infestation, manages water drainage, reduces heat loss, etc.)
- Dimensions of foundation
- Location of solar thermal system in basement
- Soil type / density
- Footer depth / frost line
- Material thickness and properties
- FOS (for both compression and bending)
- Key calculations
- Estimated house weight
### Building Thermal
- Building Code R-Value requirements/recommendations
- Overall house UA value
- Wall UA value
- Windows UA value
- Attic UA value
- Door UA value
- Basement walls UA value
- Cross section of wall
- Worst-case temperature difference to calculate heat loss
- Return on investment

### Solar Thermal
- FPC angle
- Azimuth angle
- FPC spec
- # of FPC’s
- Recommended maintenance
- Collector size
- Heat Capacity

### Economics
- Total cost of system (FPC’s and Fluids)
- Amount added on Mortgage
- Interest added
- Tax credits (state and federal)
- Auxiliary energy source & cost
- Life cycle cost
- Approximate amount saved through other methods (building thermal maybe?)

### Fluids
- Pump selection & size (refer to total head needed to overcome)
- Fluid selection
- Pipe size & material
- Tank size and selection
- Controller
- Heat exchanger
- Schematic showing location of system
- Costs
- Efficiencies
- What the customer sees
- Maintenance
- BOM with cost information in backup material

### Final Recommendations & Summary
- DHW, SH, Both or Neither
- Life Cycle Savings / # of years
- # FPC’s
- Break Even Point
- Suggested alternative energy (oil, gas, electric)