AC 2010-933: A SIMPLIFIED DOCUMENTATION CONTROL SYSTEM FOR USE WITH A CAPSTONE SENIOR DESIGN PROGRAM

Peter Schmidt, University of North Carolina, Charlotte

Deborah Sharer, University of North Carolina, Charlotte

Nabila (Nan) BouSaba, University of North Carolina, Charlotte

Daniel Hoch, University of North Carolina, Charlotte

James Conrad, University of North Carolina, Charlotte

Bruce Gehrig, University of North Carolina, Charlotte

Steve Patterson, University of North Carolina, Charlotte

A Simplified System of Document Control for a Capstone Senior Design Program

Abstract

Modern Enterprise Resource Planning (ERP) systems have grown from document control systems pioneered, developed and perfected by engineering organizations over the past 100 years. The idea of having controlled and correct information available at the fingertips of any employee has revolutionized the entire business world, and contributed to the vast productivity increases seen in the workplace in recent decades. As a part of a comprehensive capstone engineering experience, exposure to documentation control is used to prepare graduating seniors for typical of duties they will encounter in the modern workplace, but that are not covered in traditional engineering curricula. This work describes a basic documentation control system used in a multidisciplinary program to train students in information control processes and procedures that are expected of practicing engineers. Work in an organization with global reach increases the importance of real time document and information control and sensitivity to the requirements of a modern Enterprise Resource Planning (ERP) system should position the students exiting the program to be more competitive in the workplace. This work describes a simple but effective system of required documentation, naming conventions, release structure and revision controls that enable student teams to track documentation changes during the life of their capstone project, along with the rationale for any implemented changes. Additionally, the students learn to keep secure, controlled document archives and to standardize document production for presentation to instructors, other faculty, external mentors and other program stakeholders. This program has been designed for migration to an open source ERP system, and the early stages of that migration will also be discussed.

Document Control Rationale

The earliest known examples that could be labeled as engineering drawings date from the time of the ancient Egyptians, from about 1500 B.C.[1]. The simple drawing of a shaduf shown in Ref. [1], with a human operator for scale, could be used to reproduce this simple machine for lifting irrigation water. Euclid formalized geometry around the year 320 B.C., in a way that allowed for the use of drawings as analytical tools.[2]

As engineering entered the Renaissance, investigators who possessed artistic skill began laying the ground work for formalized engineering documentation by drawing not just items used for simple agriculture, manufacturing, architectural and building trades, but drawing complex working devices with some faithful scale as adjunct tools for calculations. The items created by “court engineers” were largely military in nature. [3]

In the late 18th and early 19th centuries, Gaspard Monge, a French military engineer, pioneered the development of descriptive geometry.[4] Monge’s teachings were brought to the United States in 1807 via the Military academy in West Point, New York.

Needs of the industrial revolution prompted designers and engineers to adopt individual methods of tracking changes in documentation throughout the 19th and early 20th centuries. In the early 20th century, the largest user of manufactured goods in the country, the United States Armed Forces, began to consider standards for engineering documentation and specifications. A large body of Military specifications and drawings were generated, for products as diverse as tooth paste to capacitors [5].

These documents were maintained by the federal government, with revision control processes and archiving defined ultimately by DoD-STD-100.

Several Engineering societies had already published drawing standards, ASME, ANSI and IEEE to name a few. Ultimately the government began to use specifications and drawing practices defined by practitioners and unified as a national standard. Drawing and drafting practices were unified under the ANSI/ASME Y14.100 series of documents.

As documentation systems move to all electronic formats, such as the one used by Northrop-Grumman to design the B-2 Spirit bomber, and the common practice in the automotive industry for CAD models of complex sheet metal parts to be the “Master” for inspection, standards are being issued, such as ANSI Y14.41, to assure that documentation remains accessible and useful to future engineering practitioners.

Modern Enterprise Resource Planning Systems

Business systems have developed from engineering document control practices and systems design methodology [6]. Business Enterprise Resource Planning (ERP) Systems such as SAP[7] and Al Fresco[8] are two examples of this type of activity, scaled for large, international organizations with proprietary code and support to open source code and flexible support options.

Off shoring of some engineering functions is a reality in the modern workplace. This distribution of engineering effort requires a system of document maintenance that is accessible from anywhere in the world, at any time of day. Students exposed to documentation control theory and practice as undergraduates should have an advantage in the modern workplace where distributed engineering functions and document generation and use predominate.

Implementation

A simplified approach to documentation control is desirable in an academic setting. A simple structure mimics the limited scope that novice engineers encounter when starting their careers. A simple structure also allows for a standardized list of deliverables which facilitate assessment of diverse project work using a common rubric.

This work is targeted as an aid to those who have studied design methodology in an academic setting, or have only been involved in design in a research and development capacity. Acting as instructors for students who may be employed as field, line or application engineers who might interface with a purchasing department, a manufacturing facility or an external consulting organization will require a different skill set when dealing with documentation. This is especially true of any technical professional who is involved with projects that must be designed for a competitive bidding process.

The simple structure must also be flexible. Just as projects undertaken by practicing engineers can differ in scope and focus, multidisciplinary capstone projects vary in discipline specific content. The system must be able to accommodate projects with deliverables that are real and full size, to models of large systems and even software based simulations of control system design.

The basic document list required in the subject capstone program also allows projects to expand their documentation where necessary or desirable. For example, a project that delivers a prototype mechanical device may require a significant number of detail drawings of components, with a basic block diagram explaining function to an unfamiliar user. Software flow charts or pseudo-code may be minimal. Compare this to a project that delivers a software tool. There would be no detail drawings per se, with block diagrams and software descriptors being the bulk of the deliverable documentation.

Infrastructure for document control is implemented in the 4th week of the first semester. After assignment of students to groups is complete, and all projects have been approved by faculty, a list of standard project names is issued and posted on the course website. This standard nomenclature is useful in several ways. Students are introduced to time keeping procedures that may be required in their professional practice, and must account for their time using their standard project name along with the work element that appears on the project schedule the students develop. This nomenclature is also used in submitting assignment to the course website, both as a file naming convention and as an assignment tag for routing to individual grading instructors.

In the 7th week of the first semester, students are given a lecture on document revision / configuration control. Since novice engineers will be entering an existing organization with predefined revision control procedures, senior design faculty in the subject program have provided a structure for revision control, based on the professional experience of the authors. This system mimics practices common in manufacturing, research and development organizations and those used in the design and construction of buildings.

Documents are broken into two simple groups to ease student learning, text documents and graphical documents. While both types of documents feature aspects of the alternate category (written status reports often contain sketches or graphed data), they are separated by the basic type of structure they employ.

Students are provided with templates for their standard text documents, mimicking the structure that will be encountered as a novice practitioner. The appropriate templates are available in the native word processing software used in this particular University, but are simple enough that they can be quickly developed for any word processor.

Students are instructed that text documents should be marked as follows:

- Preliminary, with numerical revisions, starting with P1 (See Fig. 1)
- Original / Issued
- Revised with the proper revision level indicated (See Fig. 2)

Students are instructed that all document versions should be retained in a secure location.

Date	Rev	Author	Comments
15 Aug 2009		Smith	Preliminary, Issued for comments
29 Aug 2009	P1	Smith	Team comments incorporated
5 Sept 2009	P2	Smith	Faculty Mentor Comments incorporated

Figure 1. Example Revision Block for Preliminary Documents

For this course an alphabetical revision scheme is mandated after drawing release; Original, Revision A, Revision B, etc.

Date	Rev	Author	Comments
15 Sept 2009		Smith	Original Issue
2 Oct 2009	A	Smith	Revised to include new capability (CAP015)

Figure 2. Example Revision Block for Issued Documents

An example template for a text document, including the revision block, is included as Appendix 1.

Most student projects will have some engineering drawings associated with their project execution. As in the case of the existing revision control system, students will also be entering an organization with existing systems for assigning part, drawing or assembly numbers to their work product, so a simple implementation has been provided. This document numbering system is also helpful for ABET archiving purposes.

Students are instructed to number their drawings as follows: Project title followed by an under-strike and a 5 digit field starting with _09.

- Tidal_Power_Turbine_09010 would be the 10th drawing produced by the Tidal Power Turbine group.

This type of naming convention is consistent with industry practice of embedding some data about the file in the storage name, and the concept of metadata, where the filename is associated with a tag that points to a database entry with information about the file status and configuration. Here we visually embed the year that the project was started and the project name.

If changes occur and are approved, one would append the alphanumeric character of the revision to the filename.

- Tidal_Power_Turbine_09010A would be revision A of the drawing previously described. Both files should be retained in an archive.

Students are cautioned about this type of file naming structure, and the need for metadata in engineering documentation control systems. The amount of data available in any filename is limited by file naming conventions of the native operating system.

- Windows Vista limits the length of filenames to 260 characters including the volume, path name and with one character occupied by a null terminator.

Students are provided with ANSI standard drawing blocks for use on their projects. Students are required to submit documentation for their design that is shop / fabrication ready. Students are encouraged to review their documentation with staff members skilled in fabrication, such as machinists, electronics technicians and professional programmers in the department.

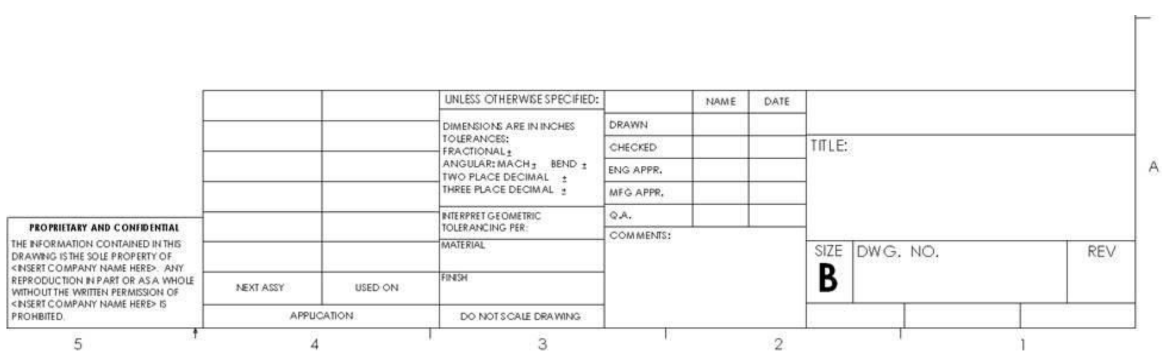

Figure 3. ANSI Standard Title Block

A mix of drawing sheet borders are usually provided as a part of any CAD/CAE software package, and can be customized to the individual class or program with very little effort. Students are introduced to ANSI Y14.100 drawing standards in graphics courses early in their curriculum, and have that system reintroduced and required as a part of their capstone experience. Sizes made available to students, with customized intellectual property verbiage and school / college log are shown in Figure 4.

Letter Size	**Width (in)**	**Width (mm)**	**Length (in)**	**Length (mm)**
A1 (ISO)	23.39	594	33.11	841
A2 (ISO)	16.54	420	23.39	594
A3 (ISO)	11.69	297	16.54	420
A4 (ISO)	8.27	210	11.69	297
A	8 ½	215.9	11	279.4
B	11	279.4	17	431.8
C	17	431.8	22	558.8
D	22	558.8	34	863.6

Figure 4. Standard Drawing Border Sizes

Document List

The following documents comprise the limited system required in the subject capstone program. This list represents minimum deliverable work product, and each project instructor and mentor review and augment this list to fit individual project needs. Alternate common names for documents are listed in parentheses.

- Capability and Requirements Document (Specification and Test Plan)
- Project Plan (Project Schedule and Work Breakdown Structure)
- Conceptual Design Report
- Project Budget
- Bill of Material (Parts List)
- Design Detail Documents (Detail Drawings, Computer Code, Block Diagrams)
- Interface Control Document (Drawing List)

Interface Control Document

Interface control documents are generally a new concept to students with no work experience, and frequently to those with work experience outside the construction industry. This concept is introduced to the students during the lecture given on configuration control.

Normal manufacturing procedure is used as an example to illustrate this concept. Systems or assemblies have part numbers associated with their construction, operation and repair. A typical example is the exploded view seen in the owner's manual of a consumer appliance such as a washing machine or lawn mower, or the example from Leonardo, shown in Figure 5. When an item is constructed or computer code implemented, a document is constructed that defines all the constituent components. This document defines the revision levels of all components, and assures that form, fit and function are maintained. When a component is changed or a subroutine is rewritten, this document is consulted such that form, fit and function are unaffected. Failure to do so can be costly.[9]

Students are provided an example spread sheet with a dual linked list for tracking the revision levels of their documents. This document is organized with tabs for a main assembly, a subassembly and with individual parts. The individual parts appear in multiple assemblies, with the revision level of the individual part tracked in each. This illustrates to the students that changes made at a component level must be checked everywhere that the component is used, so that systems not directly connected with current project work remain functional. An example page from this spreadsheet is included as Appendix 2.

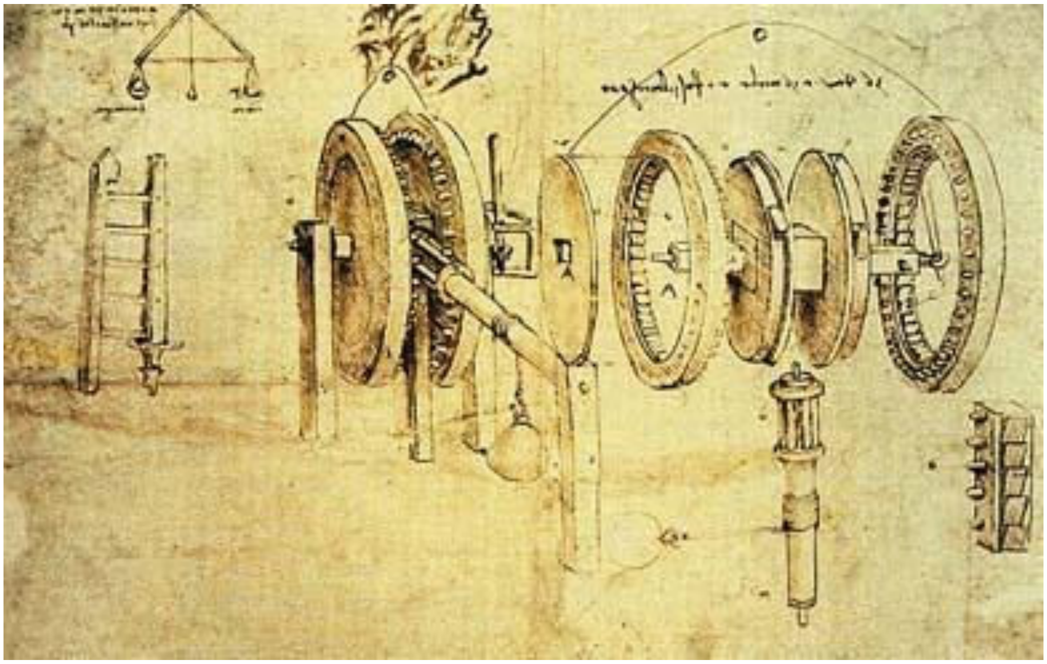

Figure 5. Exploded view by Leonardo

Document Archiving

Students are instructed that project documentation forms a legal record of their work, as a minimum. In some instances, documents are deliverables as a part of a contract with another entity or are maintained by government agencies as records of construction activities. Often, these documents must be stamped by professional engineers prior to final issue of use.

Instructions to archive and save all versions of a document are issued to all student teams. At the same time, the importance and concept of document custodians is also introduced. Project engineers for each group are instructed to hold write privileges for document archives, and are given authority to issue document revisions. Best practice associates a single responsible individual with a document. This is often, but not always, the author of the document. In some cases documents are released for public use containing only the organization as the “author”. In these cases it is good practice if the public document derives from an internal document that has the full set of characteristics. Designation of a responsible individual does not preclude listing contributors or recognizing multiple authors.

It is far simpler to reconstruct lost work from interim work, and all changes should have their rationale captured for the use of future projects or in service work required as a part of maintaining the original project work product.

Project engineers also maintain public archives, viewable by the entire student group, faculty and industry mentors, which hold read-only versions of all documents.

Conclusion / Discussion

A simplified document revision / configuration control system has been presented and detailed. Implementation of this system was first accomplished in a small section of a capstone senior design class and then improved and expanded to a large group of over 200 students.

Student documentation of design information shows distinct signs of improvement over previous years. Students routinely utilize revision control for submitted assignments and updated documents presented for faculty review. Quality and professional appearance of design drawings has markedly improved, replacing what would be generously termed as sketches submitted by previous cadres of students.

As a result of encouragement by the authors, it is common practice for students who wish to be competitive in the end of sequence design competition to have complete drawing and specification packages ready for review by interested judges. One alumnus of the program recently communicated with the corresponding author about the value of the documentation package as an aid during the job search and ensuing interview process prior to beginning full time employment. Anecdotal reactions from industrial sponsors of projects have been positive as well.

References

1 Burstall, Aubrey "A history of Mechanical Engineering", M.I.T Press, Cambridge Massachussets, 1965

2 Desmond, Kevin "A timetable of inventions and discoveries from pre-history to the present day", M. Evans, New York, 1986

3 Misa, Thomas J "Leonardo to the internet : technology & culture from the Renaissance to the present", Johns Hopkins University Press, Baltimore, 2004

4 http://www-history.mcs.st-andrews.ac.uk/Biographies/Monge.html (Accessed 4 January 2010)

5 http://www.dscc.dla.mil/Downloads/MilSpec/Docs/MIL-C-25/mil25.pdf (Accessed 4 January 2010)

6 http://www.product-lifecycle-management.com/download/MIL-STD-483A.pdf (Accessed 4 January 2010)

7 http://www.sap.com/ (Accessed 4 January 2010)

8 www.alfresco.com/ (Accessed 4 January 2010)

9 Euler, E.E., Jolly, S.D., and Curtis, H.H. "The Failures of the Mars Climate Orbiter and Mars Polar Lander: A Perspective from the People Involved." Proceedings of Guidance and Control 2001, American Astronautical Society, paper AAS 01-074, 2001.

Appendix 1 - Sample Text Document Template

Xxxxxx Project – Design for Review

Date	Revision	Author	Comments
2010-xx-xx		Yyyyyy	Distributed for Comments
	P1		Comment Incorporated
			Original / Issued
	A		Capability Added (CAP015)

Table of Contents

Overview of this Document

This document describes the design of the Xxxxxx project and of its end-product. The team member who is identified as the Principal Engineer is responsible to maintain this document.

Overview of the Xxxxxx Project

Include in here some detail of the project and end-product. This can be lifted from the Statement of Work.

Specifications

Describe the specification. You will need to refer to the requirements.

System Design

Describe the entire system design. You will need to refer to high-level CAD drawings and schematic block diagrams.

Designs of Subsystem A

Describe the design. You will need to refer to CAD drawings and schematics. Include Algorithms here (if needed).

Designs of Subsystem B

Describe the design. You will need to refer to CAD drawings and schematics. Include Algorithms here (if needed).

Designs of Subsystem C

Describe the design. You will need to refer to CAD drawings and schematics. Include Algorithms here (if needed).

References

1. Statement of work
2. Requirements document
3. Xxxxxx, Document number xxxxxxxxxxxxxxxxxxxxxxx.
4. Web site: www.aaaaaaaa.com
5. Papers
6. Books

Appendix 2 – Sample Interface Control Document

Drawing List XXXX-Demo_09001	Jet Pack Assembly Drawing	
Drawing Number	Title	Revision
XXXX-Demo_09002	Jet Pack Wing Subassembly	J
XXXX-Demo_09003	Jet Pack Engine Subassembly Drawing	
XXXX-Demo_09004	Jet Pack Mounting System Subassembly Drawing	
XXXX-Demo_09005	Jet Pack Fuel System Subassembly System Drawing	
XXXX-Demo_09006	Jet Pack Safety Subsystem Drawing	
XXXX-Demo_09007	Mounting Bolt	B
XXXX-Demo_09008	Sealant	
XXXX-Demo_09009	Hose	
XXXX-Demo_09010	Control Cable Subassembly	
XXXX-Demo_09011		
XXXX-Demo_09012		
XXXX-Demo_09013		
XXXX-Demo_09014		
XXXX-Demo_09015		
XXXX-Demo_09016		
XXXX-Demo_09017		
XXXX-Demo_09018		
XXXX-Demo_09019		

Tab 1

Drawing List	Jet Pack Wing Subassembly	J
XXXX-Demo_09002		
Drawing Number	Title	Revision
XXXX-Demo_09007	Mounting Bolt	B
XXXX-Demo_09011	Main Wing Spar	
XXXX-Demo_09012	Chord Support	
XXXX-Demo_09013	Wing Skin Panel	F
XXXX-Demo_09014	Cable Routing Grommet	
XXXX-Demo_09015	Hinge	
XXXX-Demo_09016	Pin	
XXXX-Demo_09017	Lubricant	
XXXX-Demo_09018	Cable Routing Fastener	
Used on		
XXXX-Demo_09001	Jet Pack Assembly Drawing	

Tab 2

Drawing Number	Title	Revision
XXXX-Demo_09007	Mounting Bolt	B

Used on

XXXX-Demo_09001	Jet Pack Assembly Drawing
XXXX-Demo_09002	Jet Pack Wing Subassembly

Tab 3