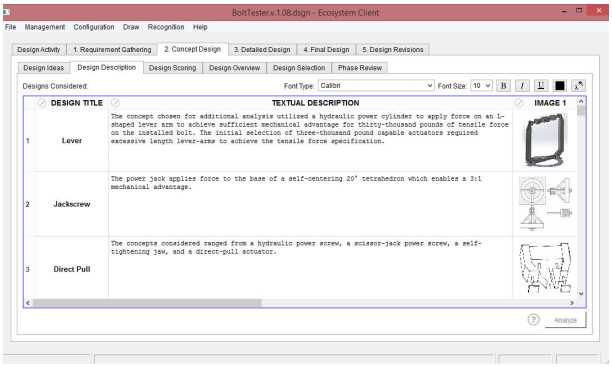
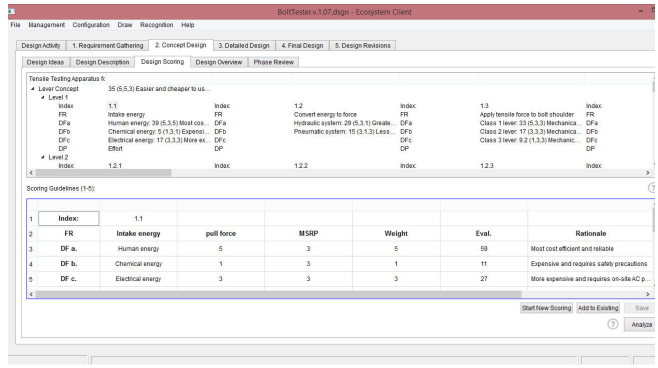
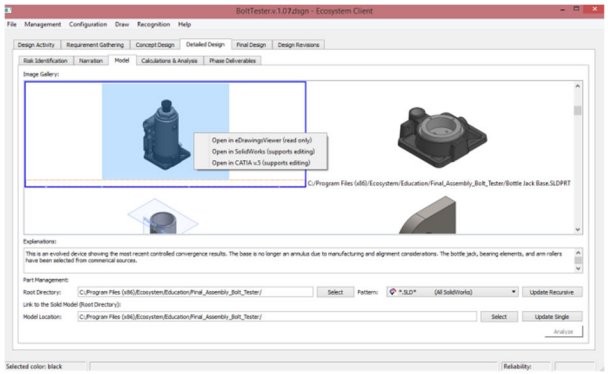
Ecosystem for Design Assessment and Verification 1.20

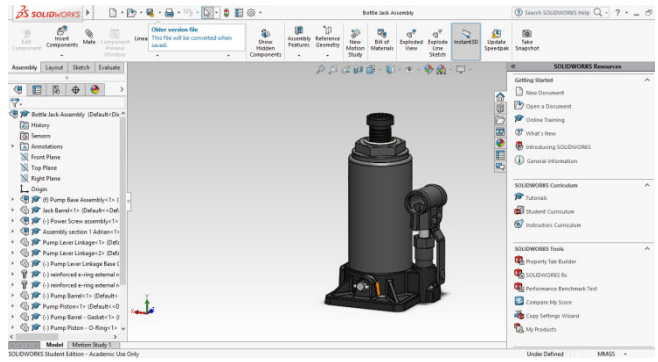
User Manual

(Designer Version)









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The Ecosystem for Design Assessment and Verification is protected by U.S. Patent US 9,923,949 B2 and US 10,853,536 B1. There are additional patents pending (16/182,389, 17/942,329).

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Chapter 1: Getting Started

Common

To get quickly up to speed with the Ecosystem, we recommend the following:

1. Look through the User Manual.
2. Load the examples, by selecting

   Help → Load Examples,

   and step through the tabs.
3. By stepping through the example(s) most similar to your design project at hand, you may quickly develop insight into what you need to do for your project.

Capstone

1. Set up the centralized repository to store the master design journal (see Appendix B).
2. Access the Team Definition tab under the Project menu.
3. If you need to configure the tab layout (e.g., for making more efficient use of the Ecosystem for your particular needs), you do it through the Tab Configuration under the Configuration menu.
4. Start populating the tabs of the Requirement Gathering phase with appropriate content.
5. Systematically execute the design process.

- Populate the tabs in the order listed.

Formula or BAJA SAE

1. Presumably, you already have:

(a) Your shared repository (e.g., Google Drive, OneDrive or Dropbox) set up.

(b) The design files comprising your vehicle design in the shared repository.

(c) Configured the sync application on your laptops to sync up with the shared repository.

- If not, refer to Appendix B.

2. Load in the example with the check list for tech inspection at the Formula or BAJA competitions.
3. Through the Tab Configuration under the Configuration menu unselect tabs as you see fit.
4. Save the modified example under a new name into your local root (the directory sync-ed up with the root of the shared repository).
5. Load your SolidWorks master assembly into the Model tab under Detailed Design.
6. Populate the Design Idea and Design Description tabs under Concept Design with content.
7. For further information, refer to Appendix I.

The Ecosystem is primarily intended as a *design decision support tool*. It does provide a report card with objective assessment of the design work against ABET-compliant learning outcomes, and provides some capabilities for assessment against engineering requirements. The score card is intended as a reference (guideline) supporting the overall assessment done by the instructor.

The Ecosystem is not intended as a complement to Google Docs. We assume tasks are delegated amongst team members in traditional fashion. For further information, refer to Appendix B.

The Ecosystem provides a collection of tools for guiding designers through the design process and avoiding oversights. Designers are at liberty of choosing the tools they consider most useful for their particular application (trimming the SW down to suit their needs). The default layout contains a fairly comprehensive overview over the available tools. But to attain the desired balance between expediency and thoroughness, the user has the ability to deselect tabs at will.

The Ecosystem is presented to benefit design engineers. The archived design information is loaded into the Ecosystem SW, but stored externally. *The Ecosystem does not attempt to archive users' design information internally, let alone communicate back to the vendor*.

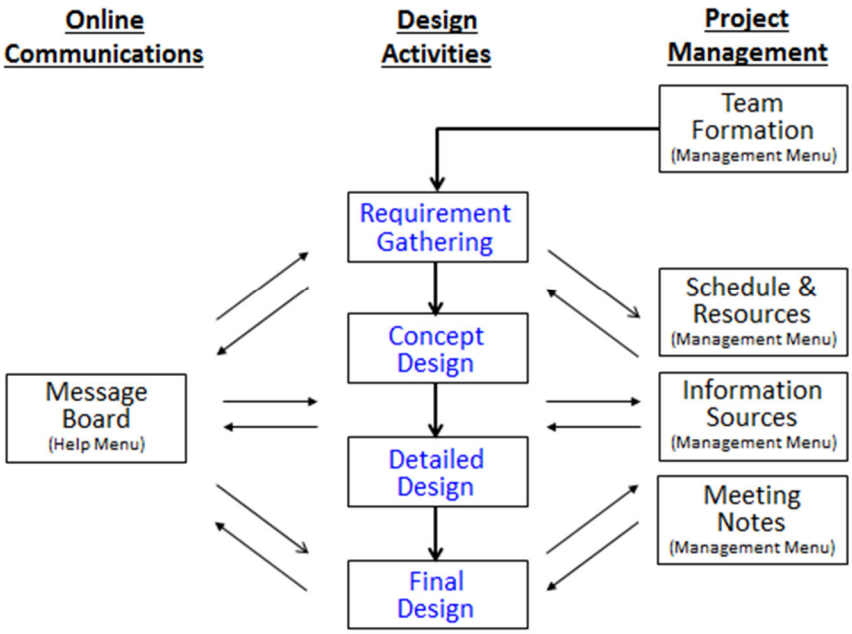


Figure 1: Typical design flow through the Ecosystem. The Project Management facilities are accessed through the Management section in the main menu.

Chapter 2: Introduction

The Ecosystem 1.20 supports a fairly generic, yet comprehensive, process for engineering design. Our goal is to provide most of the tools needed for effective team communications and design in an engineering capstone program (starting with mechanical and/or aerospace engineering). However, designers are not required to use all the tools provided. Designers can select the tools they want to use, to attain the desired balance between efficiency and thoroughness.

Primary Benefits

1. *The Ecosystem for Design Assessment and Verification can guide designers through the design process, in a structured fashion, support the learning of proper design techniques, and help eliminate design oversights (productivity interruptions).*
- To this effect, the Ecosystem provides friendly, real-time advisories, which are also aimed at stimulating creativity.
- The Ecosystem supports assessment against learning outcomes 1 - 7 issued by the Accreditation Board for Engineering and Technology (ABET), Inc. (1).
- The Ecosystem can help academic departments compile data needed for ABET reporting (reduce work load on academic administrators and design instructors).
2. *The Ecosystem offers automatic & objective assessment (scoring) of the design activities relative to the design process.*
- It provides real-time feedback to the designers.
- The students and instructor can avoid spending time on elementary oversights, and instead focus on higher-level learning and problem solving.
- Despite the automation, the Ecosystem does in no way diminish the engineering judgement developed throughout the learning experience.
- To this effect, the Ecosystem offers a systematic way of capturing the rationale supporting engineering decisions throughout the design process.
- The objective score card is intended as a reference (guideline) supporting the overall assessment done by the instructor.
3. *Automatic generation of nicely formatted project reports (a professional looking starting point).*
- The Ecosystem report may be submission ready after only minor modifications.
- The recommended submission format involves Word-compatible html.
4. *The Ecosystem provides multiple features aimed at facilitating communications within design teams or with external stakeholders.*
- Seamless access to design files stored on Google Drive, Dropbox or OneDrive.
5. *For student teams, the Ecosystem can greatly facilitate project and part management.*
- For this purpose, the Ecosystem provides the student teams with tabs for risk identification, scheduling & resource planning, bill of material, parts & assembly, manufacturing options, cost summary, and more.
- The Ecosystem offers seamless interfaces with development tools, such as SolidWorks, CATIA and the e-Drawings Viewer.
6. *The Ecosystem offers an electronic journal of the comprehensive design history.*

Additional Benefits to Designers Working on Top-Down Designs

The Ecosystem provides facilities for

1. *Systematically collecting the customer's definition of the design objectives.*
2. *Transforming the client input into solid customer requirements.*
3. *Translating the customer requirements into strong engineering requirements.*
4. *Succinctly formulating concept solution alternatives (textual description and images).*
5. *Conducting objective analysis of the concept solution candidates.*
- The solution candidates are scored both on basis of technical merit, with respect to the engineering requirements, as well as of the associated importance to the customer.
6. *Requirement tracking and critical parameter management (full transparency and traceability).*

Additional Benefits to Designers Working on Improving Existing Designs

- Many of the project and part management facilities mentioned above benefit such design teams.
- Similarly, the electronic capture of the comprehensive design history can provide great help with regards to knowledge transfer.
- But in addition, the Ecosystem 1.20 SW offers the following benefits to teams of students participating in design competitions:

1. *Design decision support.*

- Systematic capture of rationale for design decisions, gate review deliverables and comments, etc.

2. *Facilities for presenting design work in organized fashion to the judges at competitions.*

- In case of Formula or BAJA SAE, the Ecosystem can help student teams prepare content for the design reports, cost reports and business presentations.
- The judges are expecting students to present their design work in organized fashion and articulate the rationale for design decisions made.

3. *Knowledge Transfer: Facilities for running recursive searches with real-time visualization.*

- This can greatly help students assigned to specific sub-teams to get up to speed.

4. *Facilities for reverse engineering of results from previous competitions.*

- The functional decomposition can be used to break down the score results, determine level of improvement in specific categories, and identify design objectives for next year's competition.

- For further information, refer to Appendix H or to
  http://www.imagars.com/reasons-for-adoption-oregon-institute-of-technology/

Table 1: The Ecosystem's primary benefits to designers, supervisors and sponsors. *Well organized and thorough reports may contribute to good grades for many capstone programs*.

Designers (Students)	Supervisors (Instructors)	Sponsors
• Learning of proper design techniques). • Helps with productivity, planning and team work. • Greatly helps in terms of keeping things organized. • Automation of many administrative tasks. • Editable progress reports	• Guarantees all students go through same design process. • Having SW teach key concepts and methodology, and identify elementary oversights, frees up instructor bandwidth. • Standardized progress reports are easy to grade. • Objective score cards: ABET learning outcome (guideline) - Easy to demonstrate compliance, and report results back	• Ability to informally track progress without excessive handholding (e.g., through the online message board). • Formal progress reports.

Intended Audience

Ver. 1.20 of the Ecosystem for Design Assessment and Verification is aimed at

1. *Students of engineering design (capstone) classes and their instructors.*

- For the capstone design students, the Ecosystem offers a formal framework for teaching proper design techniques.
- The Ecosystem provides the students with an edge (efficiency improvements) over carrying out the functional decomposition using Excel sheets (or a similar tool).

2. *Student design teams, such as the ones participating in the Formula SAE, BAJA SAE, solar race car or rocket design competitions.*

- Here, the Ecosystem can be a part of a complete, low-cost solution for team design.
- The Ecosystem offers a project management framework to teams that don't already have a very formal mechanism in place.
- The Ecosystem provides a framework for point analysis (functional decomposition) yielding better results (better improvements in ranking) than functional decomposition carried out using Excel sheets.
- Given the Ecosystem's degree of alignment with the NASA Product Life Cycle model, the teams participating in CubeSat or the Aero SAE competitions may be interested.

While initially tailored towards mechanical and aerospace design ("component" design), the Ecosystem entails a generic paradigm for learning and team design, and can be extended to many other fields of engineering design.
In particular, the approach for systematically capturing the customer requirements, for translating the customer requirements into engineering requirements, and defining the objective function apply to engineering design in general.
The utility to aerospace engineers is, in part, based on the bi-directional traceability associated with the functional decomposition outlined in Chapter 5.

Intended Usage

1. This User Manual is, first and foremost, intended as a learning tool. It is envisioned as a comprehensive resource that allows designers to get quickly up to speed on the Ecosystem, and reap its benefits, even within a time frame corresponding to a single academic semester.
2. In case of student designers, it is recommended that they prepare a formatted score card, by selecting

   File → Preview & Print Score Card …,

   and turn in, along with their other project deliverables.

- This score card can be one of the guidelines used by the instructor, along with other criteria, to assess the students' overall performance.

3. For Formula or SAE, or the case of large capstone projects, comprising of multiple sub-systems, we recommend creating a separate e-design notebook file for each sub-system.

Terminology

Table 2 summarizes the definition of some of the primary terms used in this Manual.

Table 2: Definition of the primary terms used in the Manual.

Term	Definition
Constraint	An unattached performance requirement specifying a parameter limit which should not be exceeded.
Customer Requirement	Customer needs not necessarily in measurable engineering language
Design Feature	A generic term that can refer to parts of any scope. Design features can refer to assemblies, subassemblies or individual parts.
Design Parameter	A specified constraint against which the system will be designed. Lower level design specifications that are required in order to deliver the Functional Requirements.
e-Design Notebook	A collection of electronic design files specific to each phase in the design process. The tutorial examples, which ship with the Ecosystem SW, provide examples of e-design notebooks.
End User	The end user can be an internal or an external customer. The end user is drawn out separately for ease of categorization of the engineering requirements (to make sure the end user's voice gets heard). If the customer meets the definition of an end user, you want to categorize the customer as such, even though this may also be an external customer.
External Customer	External customer is a stakeholder outside the organization.
Functional Requirement	A requirement that defines function or behavior of a specific collection of objects. May or may not be measurable.
Internal Customer	External customer is a stakeholder internal to the organization.
Manufacturing Method	A mean by which part(s) get manufactured.
Non-Functional Requirement	Requirement that specifies criteria that can be used to judge the operation of a system, rather than specific behaviors.
Performance Requirement	A requirement involving parameters reflecting measurable performance with respect to an associated functional requirement.
Product Design Specification (PDS)	Document created during the problem definition activity very early in the design process. It details the requirements that must be met in order for the product or process to be successful.
System Requirement	System requirements are all of the requirements at the *system level* that describe the functions which the system as a whole should fulfill to satisfy stakeholder needs and requirements.

Chapter 3: Installation and Examples

The Installation Process

The installation process for Ver. 1.20 of the Ecosystem for Design Assessment and Verification resembles that of many other Windows applications. Figure 1 presents the welcome dialog.

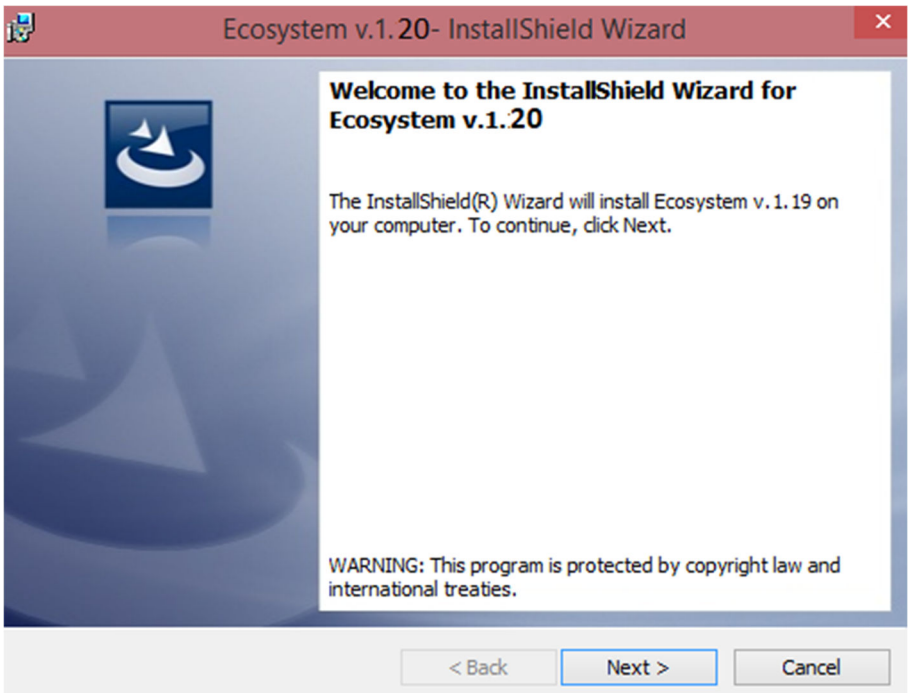


Figure 2: The welcome dialog.

The Tutorial Samples

Traditional Component Design - Bolt Tester

The first tutorial sample carries the user through the complete design of a bolt tester. This is a well thought out, contextual example with sound logical relations throughout each design phase. The bolt tester example comes with a complete e-design notebooks, associated graphics, part and assembly files. This example was extracted from the capstone design project completed by Emily Bedell, Alex Filinov, Robert Jones, Alysia Strickland and John W. Vinti in the Mechanical Systems Design (ME537) class at Portland State University in 2014 (2). The bolt tester is a meaningful test case showing verifiable engineering skills. It enables meaningful assessment (scoring) of the design activities relative to the design process.
Figure 6 – Figure 78 outline the pages of the e-design notebook mostly from the bolt tester example. This example can be loaded by selecting

Help → Load Examples → Traditional Component Design → Bolt Tester

in the top menu. *Note the consistency between the part cost listed in the Bill of Material tab and the associated manufacturing cost listed in the tab for the Manufacturing Options*.

Traditional Component Design - Go Kart Lifting Stand

The Go Kart Lifting Stand was an actual capstone design project completed by Austin Greene, Jeffrey Williamson, Adam Falcone, Jesse Majoros, Nick Vanklompenberg and Jake Waterman,

students in the Department of Mechanical and Materials Engineering at the Portland State University, during the 2015 - 2016 academic year. The purpose of this example is to

1. Demonstrate application of the Ecosystem framework to a practical student design project.
2. Demonstrate how the Ecosystem can capture, and account for all the design parcels involved.
3. Demonstrate the Ecosystem offers enough flexibility to make it of practical use.

Traditional Component Design – Spacer Cart

The purpose of the third example, the spacer cart project, is to demonstrate

1. Application of the Ecosystem to a design project consisting of multiple subsystems.
2. How all the customer requirements can be formulated in terms of quantitative engineering requirements.
3. Working interface between PDFs in the Part and Assembly tab and a PDF Reader (assuming the PDF Reader is properly installed).

The spacer cart is also an actual capstone project from the Department of Mechanical and Materials Engineering at the Portland State University, completed during the 2016 – 2017 academic year. *Note the consistency between the part cost listed in the Bill of Material tab and the associated manufacturing cost listed in the tab for the Manufacturing Options*.

Configuration Management – Business Jet

The third example, adopted from the Department of Aerospace Engineering and Mechanics at the University of Minnesota, *shows how the Ecosystem framework can be applied to large-scale design projects involving conceptual design* of a business jet. Here there is *no detailed or final design*. The goal is to compare and contrast super-sonic business jets to traditional sub-sonic jets. The customer requirements are fairly simple: Both jets need to be able to fly across the Pacific (from Los Angeles to Tokyo) and carry 10 passengers. The example shows how the Ecosystem framework can be used to produce solid engineering requirements from simple customer requirements.

Aerospace Applications – Electronic Fuel Feed System

The Electronic Fuel Feed System was an actual capstone design project completed by Jorden Roland, Johnny Froehlich, John Talik, Rawand Rasheed, Mimi Shang and James Luce, students in the Department of Mechanical and Materials Engineering at the Portland State University, during the 2016 - 2017 academic year. The project was sponsored by the Portland State Aerospace Society (PSAS). For the purpose of decreasing the weight of its rocket, and attaining higher altitudes, the PSAS team wanted to adopt a solution utilizing an electric motor for compressing the fuel from the tank prior to injection into the engine. The purpose of the Electric Feed System (EFS) example is to

1. Demonstrate application of the Ecosystem to a student design project involving aerospace engineering.
2. Demonstrate utility of the Ecosystem to rocket design teams.

Biomedical Applications – Quail Egg Embryo Extractor

The Quail Egg Embryo Extractor was an actual capstone design project conducted by Alex Arnold, Josh Lake, Robert Lesanovsky, Anne Ng, Samuel Rasmussen and Sam Sanford, students in the Department of Mechanical and Materials Engineering at the Portland State University, during the 2015 - 2016 academic year. The purpose of this example is to

1. Demonstrate application of the Ecosystem framework to a practical student design project.
2. Demonstrate application of the Ecosystem to a cross-functional project involving biomedical design.

Civil Engineering – Small Earth Dam

This is an actual capstone project from the Dept. of Civil and Environmental Engineering at the New Mexico State University. The project demonstrates how the Ecosystem can be applied to

1. A civil design project, mostly involving problem formulation and concept design.
2. Cite references (from the Information Sources tab), Figures and Tables from the main text:

[EPA 2012] United States Environmental Protection Agency, Particulate Matter, 2012, http://www.epa.gov/airquality/particlepollution/.

Electrical Engineering – Telemetry System for BAJA SAE

The BAJA SAE telemetry system is an actual capstone project from New Mexico State University. This example demonstrates how the Ecosystem can be applied to

1. a project where the system-level requirements are fairly well defined beforehand.
2. design an embedded hardware system (to a hybrid electrical / mechanical design).
3. a design consisting of a few subsystems.
4. flexible scoring of designs at the sub-system level (by pasting scoring tables, say from MS Word, into the text editor in the Design Overview tab of the Ecosystem).
5. assess severity vs. likelihood of risk items (again, by pasting tables, say from MS Word, into the Ecosystem).

Table 3: Overview over the examples accompanying the Ecosystem 1.20 SW.

Example	Purpose
Bolt Tester	1. Demonstrate rigorous application of the design process to an actual student project involving component design. 2. Demonstrate assessment of verifiable engineering skills.
Go Kart Lifting Stand	4. Demonstrate application of the Ecosystem framework to a practical student design project. 5. Demonstrate the Ecosystem can capture, and account for all the design parcels involved. 6. Demonstrate the Ecosystem offers enough flexible to make it of practical use.
Spacer Cart	1. Demonstrate application of the Ecosystem to a design project consisting of multiple subsystems. 2. Demonstrate how all the customer requirements can be formulated in terms of quantitative engineering requirements. 3. Demonstrate of working interface between PDFs in the Part and Assembly tab and a PDF Reader (assuming the PDF Reader is properly installed).
Business Jet	Demonstrate application of the Ecosystem framework to a student design project involving configuration management (high-level design, no detailed or final design)
Electronic Fuel Feed System	1. Demonstrate application of the Ecosystem to a student design project involving aerospace engineering. 2. Demonstrate utility of the Ecosystem to rocket design teams.
Quail Egg Embryo Extractor	1. Demonstrate application of the Ecosystem framework to a practical student design project. 2. Demonstrate application of the Ecosystem to a cross-functional project involving biomedical design.
Small Earth Dam	Demonstrate application to civil engineering hydraulics project
Telemetry for BAJA SAE	Demonstrate application to the design of embedded hardware
BAJA SAE	• Help BAJA and Formula SAE teams get ready for competition, by checking their vehicles against the checklist used by tech inspectors, prior to heading for competition. • Facilitate early identification of oversights and cost savings. • Enable teams to address oversights in the comfort of their labs.
Formula SAE	

Chapter 4: User Interface and Main Dialog

The Main Dialog

Orientation, Design Phase Selection and the First Steps

The user can select the design phase of interest by simply clicking on it in the main dialog (see Figure 3). To get up to speed with the Ecosystem SW, the user can hover over the icons of interest and access the guiding instructions.

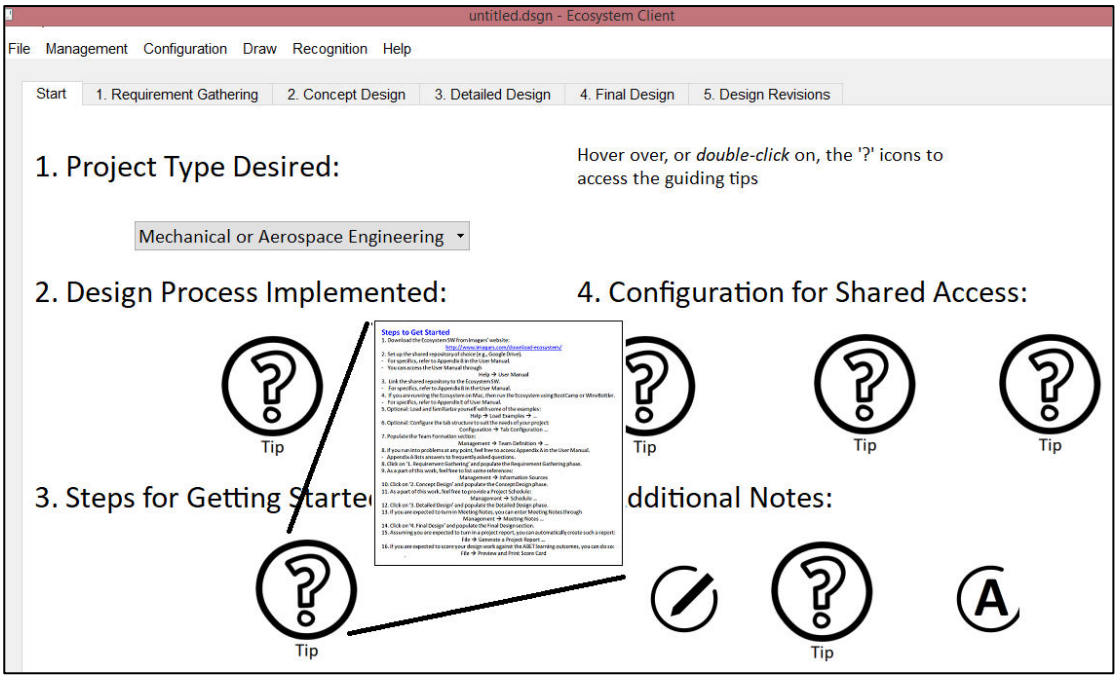


Figure 3: Design phase selection. The question mark provides access to a pop-up image summarizing the typical design flow, applications to capstone programs, or to larger design teams, such as Formula or BAJA SAE. For any given design phase, the scoring of individual objectives is activated by pressing the 'Score Objective' button in the main dialog.

The File Menu

New Project

The 'New Project' menu allows the user to start a new design from scratch. It clears the content of the e-design notebook.

New Sketch

The 'New Sketch' menu clears the content of the canvas in the 'Sketches' tab of the 'Conceptual Design' phase.

Load Project …

The 'Load Project …' menu provides the user with the means to select an e-design (.dsgn) notebook file and load into the Ecosystem application. The link to the working directory is dynamically updated.

Load Sketch …

The 'Load Sketch …' menu provides the user with the ability to load a sketch, e.g., a raster-scan

image into the canvas in the 'Sketches' tab of the 'Conceptual Design' phase.

Save

The Save menu provides the user with the ability to save the content of the e-design (.dsgn) notebook file presently open. The Ecosystem automatically saves the designer's work every 25 sec into a file titled "AutoSavedDesignFile.dsgn", which is located in the same directory as the design file saved by the user. The auto-saved design content can be recovered by selecting

Help → Recover Design

from the main menu.

Save Project As …

This menu allows the user to save the design content, that has been entered into the Ecosystem application, as an e-design notebook file.

The images are stored separately in a local directory (/img/) relative to the directory hosting the e-design notebook file. *When the e-design notebook file is copied onto a centralized server, such as a Google Drive, it is of paramount importance also to copy the content associated with the /img/ directory*.

Save Sketch As …

The 'Save Sketch As …' enables the user to save the content of the canvas in the 'Sketches' tab of the 'Conceptual Design' phase as a raster-scan image (in bitmap (BMP) or JPG format), as Scalable Vector Graphics (SVG) or in the Portable Document Format (PDF).

Generate Project Report …

The Ecosystem provides facilities for automatically exporting the active design content (the active e-design notebook) into a formatted project report, which can be presented directly to fellow team mates, to an instructor, team lead, a student design lead or to the project sponsor, if desired. Hence, there is no need for double entry. Ver. 1.20 of the Ecosystem supports exporting into the Open Document Format (ODF), the HyperText Markup Language (HTML) or PDF. The HTML documents can be opened up in MS Word[1] and edited at will. We recommend the OpenOffice Writer for opening up, and editing, the ODF files. The formatted project report includes all the tables and images from the original e-design notebook (see Figure 4).

Note that the nicely formatted, auto-generated HTML files can be opened up in MS Word, and saved as .docx files, retaining the nice formatting. Once information has been entered into the Ecosystem, students can turn in nicely formatted reports with minimal effort.

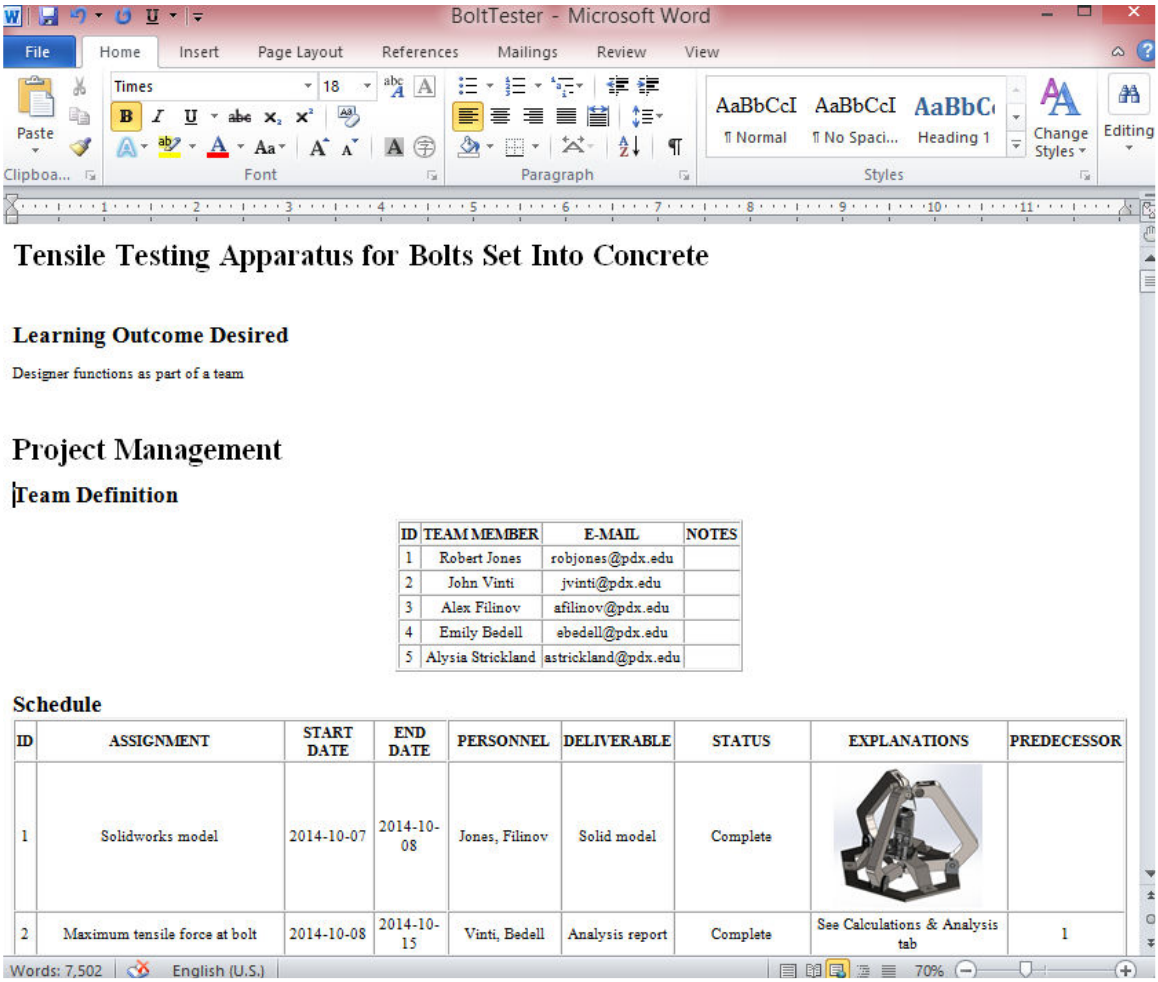
View ABET Score Card …

The 'View Score Card …' menu allows the user to view the comprehensive score card for all of the learning outcomes (see Figure 5). Here the scores for each learning outcome are aggregated across the design phases. For each design tab analyzed, the user earns points in relation to the quality of the design activities with respect to the design process. The Score Card presents up-to-date overview of the scores. The scores are updated for each design tab analyzed. The system can assess the scores anywhere along the process (much before the user completes the entire design process).

Save ABET Score Card (as CSV) …

The Ecosystem provides users with the ability to save the content of an ABET scoring report as a CSV file. Academic administrators or design instructors can import the CSV into Excel. The ABET scoring reports from different design teams can comprise separate sub-tabs in a single Excel file.

[1] In MS Office 2010 or subsequent versions.



BoltTester - Microsoft Word

Tensile Testing Apparatus for Bolts Set Into Concrete

Learning Outcome Desired

Designer functions as part of a team

Project Management

Team Definition

ID	TEAM MEMBER	E-MAIL	NOTES
1	Robert Jones	robjones@pdx.edu	
2	John Vinti	jvinti@pdx.edu	
3	Alex Filinov	afilinov@pdx.edu	
4	Emily Bedell	ebedell@pdx.edu	
5	Alysia Strickland	astrickland@pdx.edu	

Schedule

ID	ASSIGNMENT	START DATE	END DATE	PERSONNEL	DELIVERABLE	STATUS	EXPLANATIONS	PREDECESSOR
1	Solidworks model	2014-10-07	2014-10-08	Jones, Filinov	Solid model	Complete		
2	Maximum tensile force at bolt	2014-10-08	2014-10-15	Vinti, Bedell	Analysis report	Complete	See Calculations & Analysis tab	1

Figure 4: Section from the formatted project report corresponding to the bolt tester example.

Preview & Print ABET Score Card (as PDF) …

The Preview & Print Score Card menu allows the user to preview the formatted score card, adjust zoom settings, page orientation, page layout, page setup as well as to print the score card (see Figure 5). Sometimes, the user needs to adjust the scroll through the list of the printer devices available, to identify the PDF device. It may be obscured from the initial view, but still available.

Preview & Print Meeting Notes …

The Preview & Print Meeting Notes menu allows the user to preview the formatted meeting notes. This mechanism was introduced to enable the user to quickly generate meeting notes in a PDF format suitable for presentation to a capstone instructor or supervisor.

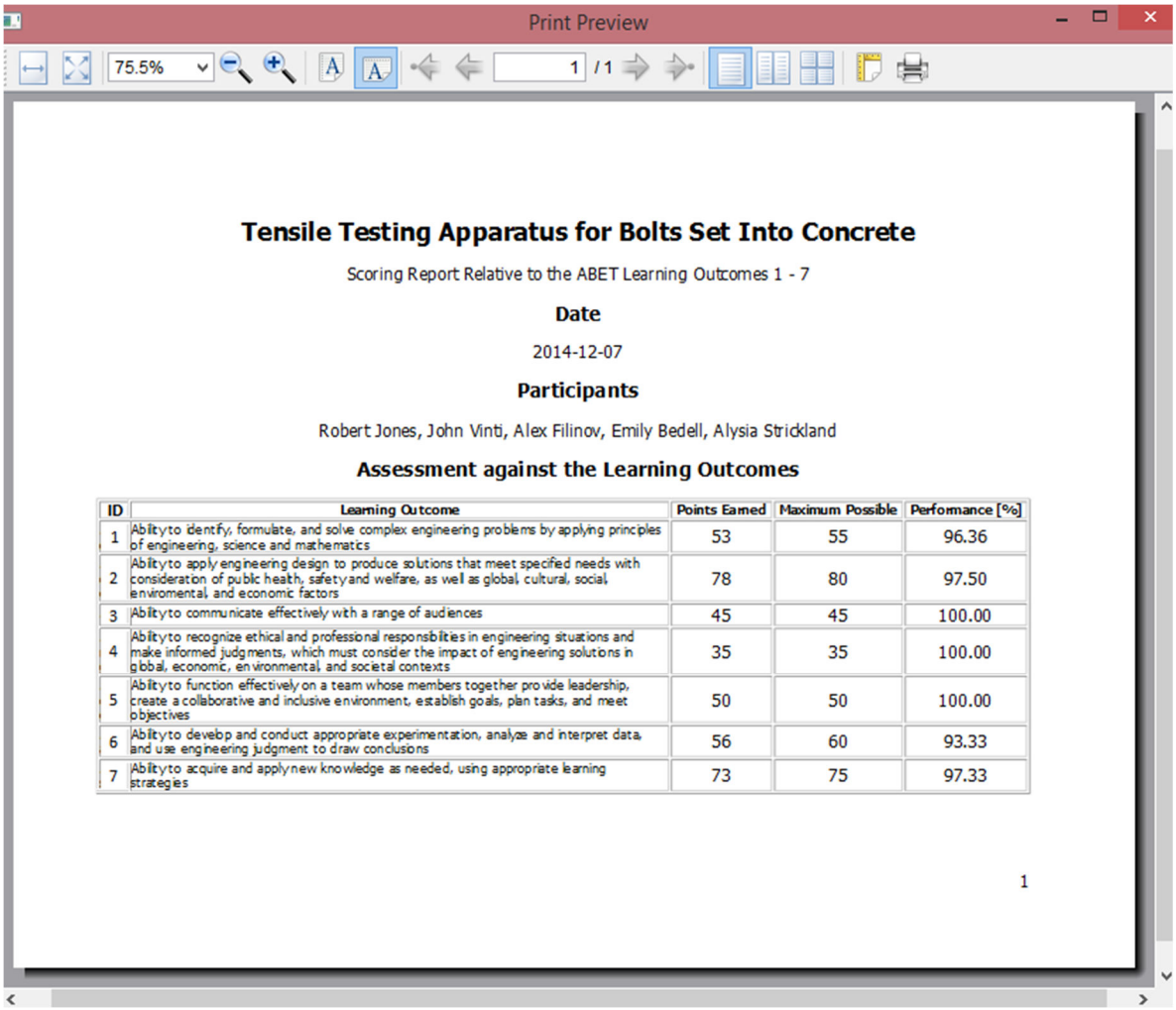
Exit

This option in the sub-menu allows the user to Exit the Ecosystem application.

Management Menu

Team Definition

The purpose of the Team Definition dialog is to capture standard administrative functions, such as the project title, the date on which the design activity is completed, and the names and contacting information for the participating team members. The Team Definition dialog from



Print Preview

Tensile Testing Apparatus for Bolts Set Into Concrete

Scoring Report Relative to the ABET Learning Outcomes 1 - 7

Date

2014-12-07

Participants

Robert Jones, John Vinti, Alex Filinov, Emily Bedell, Alysia Strickland

Assessment against the Learning Outcomes

ID	Learning Outcome	Points Earned	Maximum Possible	Performance [%]
1	Ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science and mathematics	53	55	96.36
2	Ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety and welfare, as well as global, cultural, social, enviromental, and economic factors	78	80	97.50
3	Ability to communicate effectively with a range of audiences	45	45	100.00
4	Ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts	35	35	100.00
5	Ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives	50	50	100.00
6	Ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions	56	60	93.33
7	Ability to acquire and apply new knowledge as needed, using appropriate learning strategies	73	75	97.33

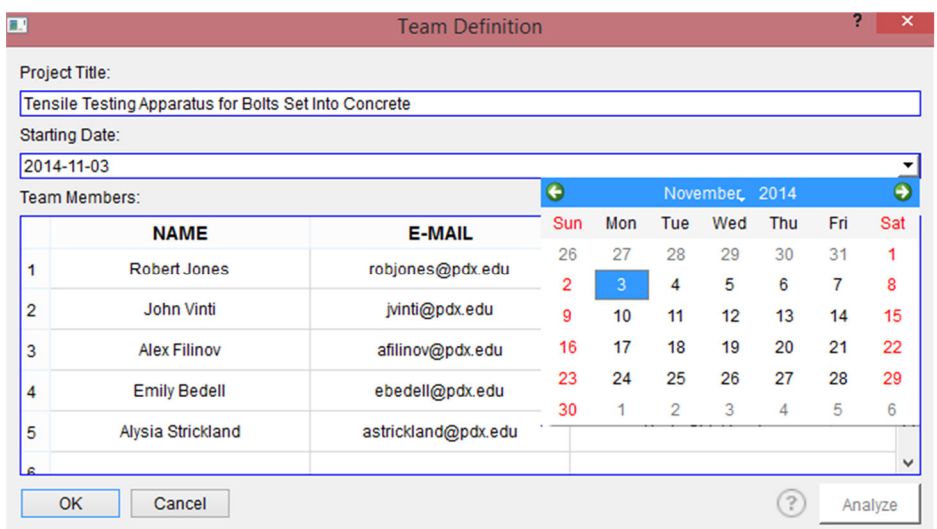
1

Figure 5: Formatted score card (from the Preview & Print Score Card menu).

The bolt tester example is presented in Figure 6. The fields where user input is expected are highlighted in blue.

Schedule

In the dialog for Schedule & Resource Allocation, team members specify the assignments comprising the project along with the associated timeline. Appropriately, start and end dates should reflect effective management of the time available for the design project. The deliverable is typically a formal



Team Definition

Project Title: Tensile Testing Apparatus for Bolts Set Into Concrete

Starting Date: 2014-11-03

Team Members:

	NAME	E-MAIL
1	Robert Jones	robjones@pdx.edu
2	John Vinti	jvinti@pdx.edu
3	Alex Filinov	afilinov@pdx.edu
4	Emily Bedell	ebedell@pdx.edu
5	Alysia Strickland	astrickland@pdx.edu

November, 2014

Sun	Mon	Tue	Wed	Thu	Fri	Sat
26	27	28	29	30	31	1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	1	2	3	4	5	6

OK Cancel Analyze

Figure 6: Team Definition tab for the bolt tester example.

document or a physical object. The explanation column can contain an illustrative figure. To load in a figure, simply double-click on the Explanations column. To delete the figure, simply click on it and hit the 'Delete' button. Note the row height has been automatically adjusted to fit the content.

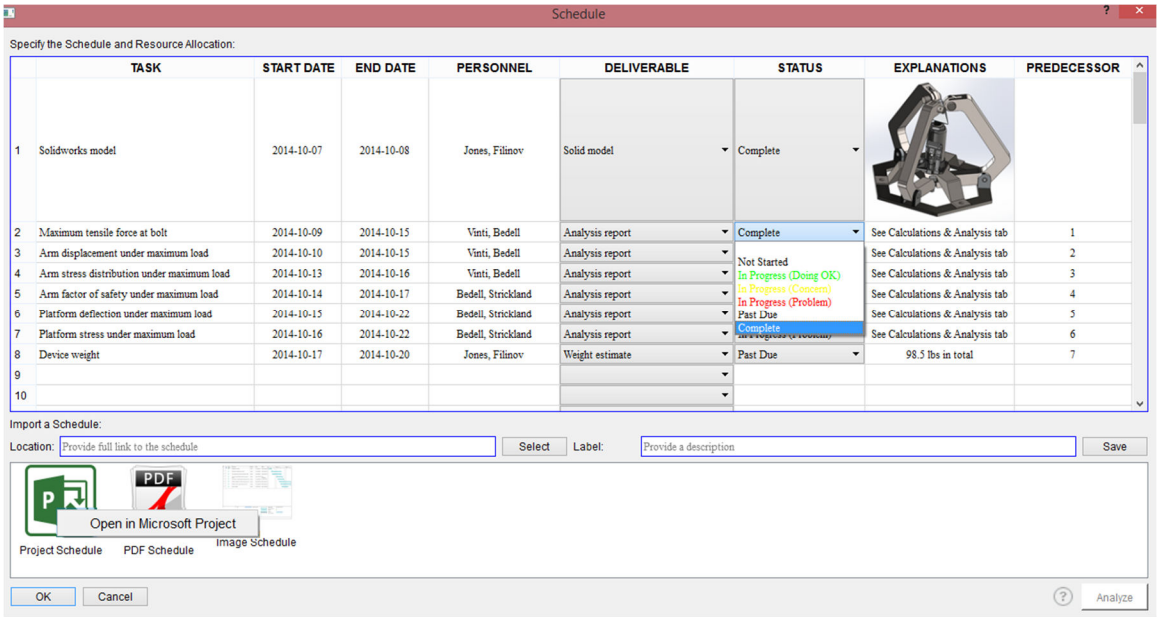


Figure 7: Schedule dialog from the bolt tester example (top).

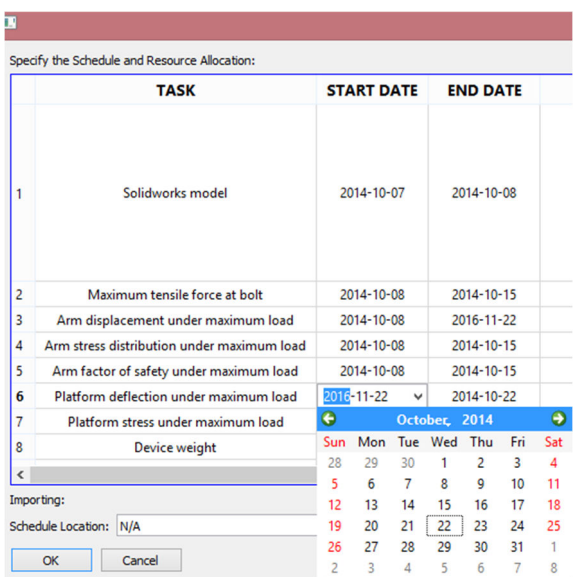


Figure 8: The calendar pop-up in Schedule dialog.

Information Sources

Qualitative needs and quantitative requirements can be contained in a number of source documents. For any given project, numerous organizations may provide relevant guidance in the form of documented standards or accepted practices. It is prudent to run through search for applicable material. Future efforts aimed at automating database keyword searches are planned to elucidate potential sources of guidance. Standards are typically provided from industry organizations, but government regulations and laws may also play a role. Obviously, it behooves any designer to mind regulations and statues to the letter. Ignorance has never been, nor will be an acceptable excuse for negligent violations of law. For organized reference and appropriate credit the entry of standards, regulations, books, website sources and miscellaneous media in the "Information Sources" tab is encouraged.

Once content has been added to the reference list, using the 'Add to References' button, it can be removed simply by clicking on (selecting) the proper row and pressing the 'Delete' button. Once the content of the e-design notebook gets exported into an automatically generated report, the reference list is listed as a part of the Appendix.

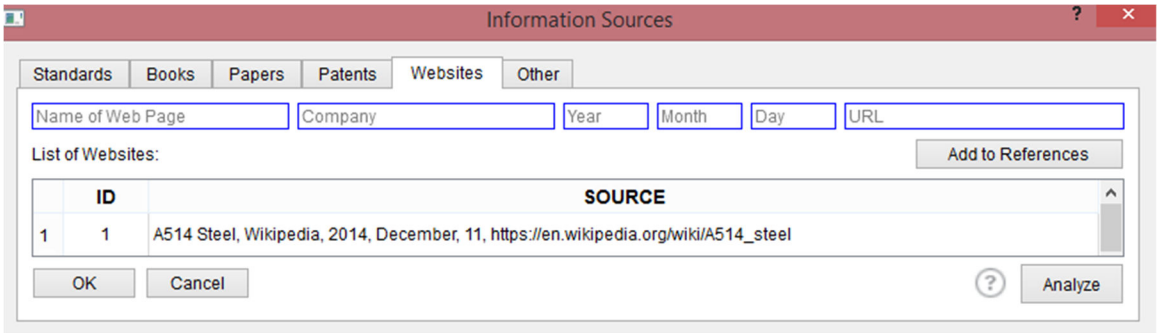


Figure 9: The reference list from the example on the bolt tester.

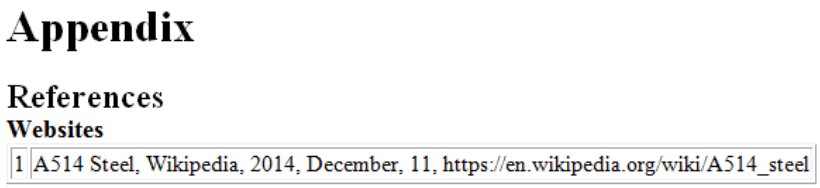


Figure 10: The reference list from the example on the bolt tester (after exporting into an automatically generated report).

Meeting Notes

An important feature of the Ecosystem is provision for immersive design activity, including necessary interaction between team members and the instructor. Capitalizing on the culture of electronic communications, commentary and contributions can be provided and recorded in the tab for Meeting Notes to assist in the assessment of team dynamics and facilitating meaningful discussion, as shown in Figure 11. The content of the Meeting Notes dialog can be exported into an Appendix of the automatically generated report (see Figure 12). To load the record back into the main menu, simply double-click on the record of interest. If you inadvertently insert an incorrect record, and you wish to delete it from the Meeting Archive, simply right-click on the row and select 'Delete Row'.

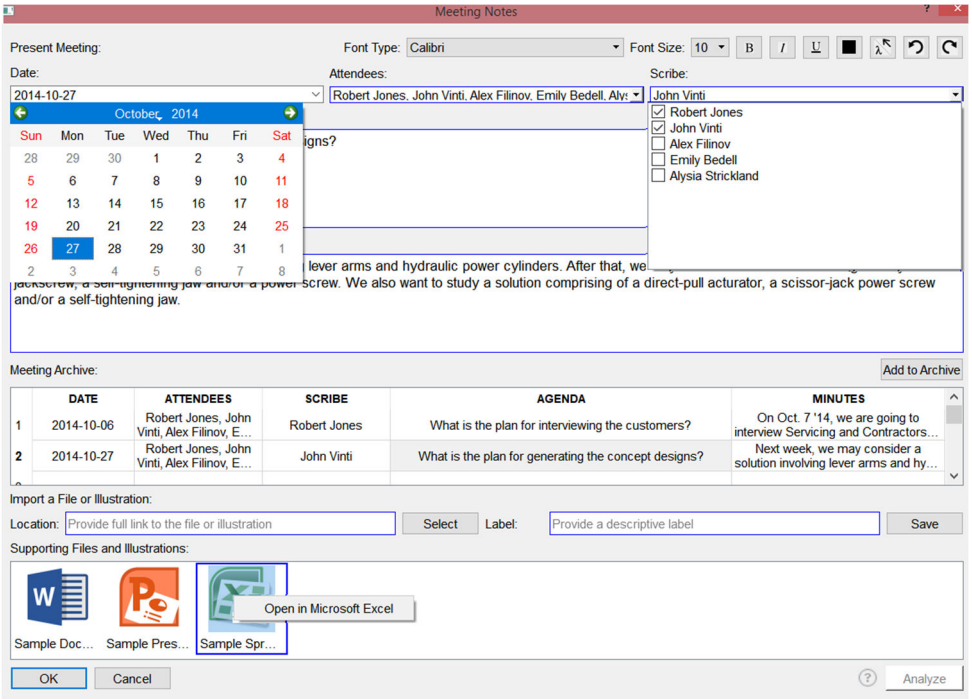


Figure 11: The dialog for Meeting Notes from the example involving the bolt tester.

Meeting Notes

DATE	ATTENDEES	SCRIBE	AGENDA	MINUTES
2014-10-06	Robert Jones, John Vinti, Alex Filinov, Emily Bedell, Alysia Strickland	Robert Jones	What is the plan for interviewing the customers?	On Oct. 7 '14, we are going to interview Servicing and Contractors. On Oct. 9 '14, we are going to interview the Regulatory Agencies and Marketing. On Oct. 11 '14, we are going to interview the Engineering Consultants and the Accountants.
2014-10-27	Robert Jones, John Vinti, Alex Filinov, Emily Bedell, Alysia Strickland	John Vinti	What is the plan for generating the concept designs?	Next week, we may consider a solution involving lever arms and hydraulic power cylinders. After that, we may look into a solution consisting of a hydraulic jackscrew, a self-tightening jaw and/or a power screw. We also want to study a solution comprising of a direct-pull acturator, a scissor-jack power screw and/or a self-tightening jaw.

Figure 12: The Meeting Notes dialog from the example involving the bolt tester (after exporting into the automatically generated report).

Alternative Application: Using the Meeting Notes as a Design Log

Alternatively, the Meeting Notes tab can be used as a running design log. You can use the Meeting Notes tab to keep track of design activities by date (register a date-stamped log).

Configuration

Tab Configuration

The Ecosystem 1.20 SW was designed with flexibility in mind. To this end, the Ecosystem provides the mechanism shown in Figure 13 for hiding the Ecosystem tabs not considered necessary for a particular capstone program. This tab provides the Ecosystem with the ability to attain the desired trade-off between nimbleness (efficiency) and thoroughness. The tabs marked under 'DESELECT?' are hidden, upon the user pressing the 'OK' button. 'Reset to Defaults' restores the original configuration. The default configuration lists the full set of tabs. The user can pair down the selection to the extent desired.
Note that designers do not need to complete the tabs in the order listed. Out-of-order execution is permitted (but not necessarily recommended).

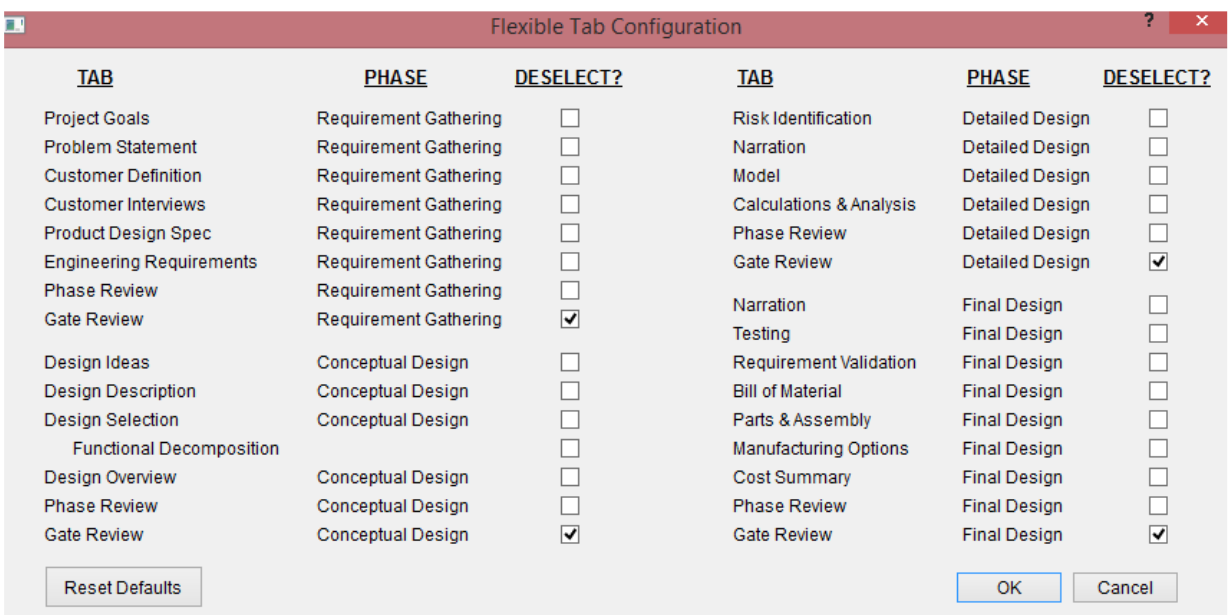


Figure 13: The Tab Configuration dialogue in case of the bolt tester example.

Auto Save

Through the Auto Save menu, shown in Figure 14, the user has the ability to disable the auto save, if desired. The auto saving is enabled, by default.

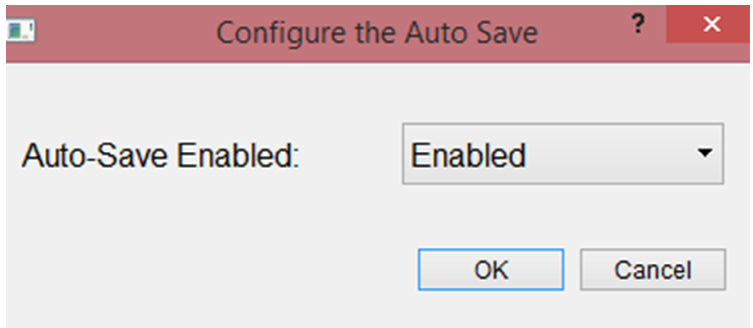


Figure 14: Configuration of the Auto Save menu.

Project Type

Through the Project Type menu, shown in Figure 15, jthe user has the ability to specify the project type of choice. The project type is set to "Mechanical or Aerospace Engineering" by default.

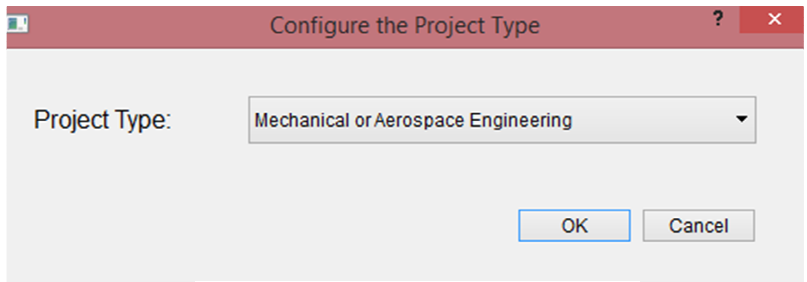


Figure 15: Project Type menu.

Shared Root Directory

Through the Configure the Root Directory menu, shown in Figure 18, the user has the ability to specify the local root directory to the shared repository, shown in Figure 17.

Feasibility Threshold (If Functional Decomposition Enabled)

- When the functional decomposition has been enabled through the Tab Configuration menu, the Current Feasibility Threshold specifies the threshold above which the cumulative score of a given design concept is considered feasible.
- The dialog for the Feasibility Threshold in Ver. 1.20 of the Ecosystem, presented in , offers a recommended value for the Feasibility Threshold, which is automatically populated based on the number of input arguments to the objective function, per the specifications in the 'Requirement Analysis' tab of the 'Requirement Gathering' phase.
- The user is not allowed to change this recommended value.
- This recommended value becomes the initial default for the Current Feasibility Threshold, which the user is then allowed to adjust, based on his or her engineering discretion.

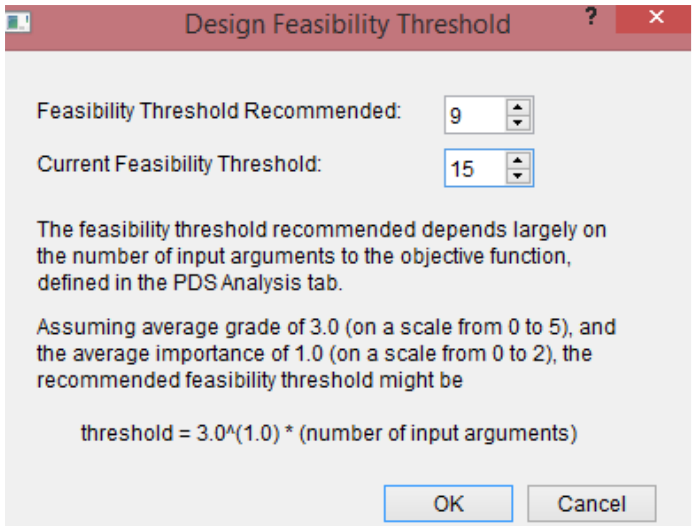


Figure 16: Thresholds for establishing design feasibility for the sample test case (case of three input parameters to the objective function).

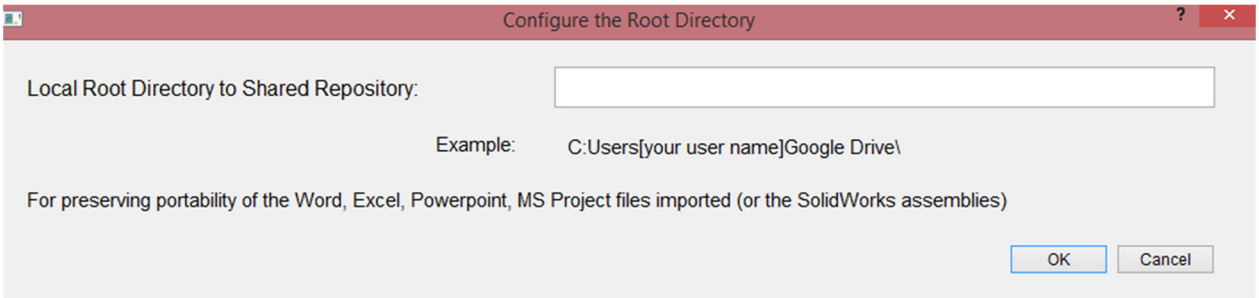


Figure 18: Menu for configuring the local root directory to the shared repository shown in Figure 17.

The Draw Menu (If Design Idea Tab Active)

The Draw Menu comprises of the following menu options:

1. Zoom In
2. Zoom 100%
3. Zoom Out
4. Undo
5. Redo
6. Bring to Front
7. Send to Back
8. Area Selection
9. Move, Resize
10. Draw a Shape
11. Default Pen
12. Stylus Pen

These are all graphics operations restricted to the canvas in the 'Sketches' tab of the 'Conceptual Design' phase. These operations are modeled after corresponding operations in the SketchRec 3.0 software from Imagars. For further information, refer to (3).

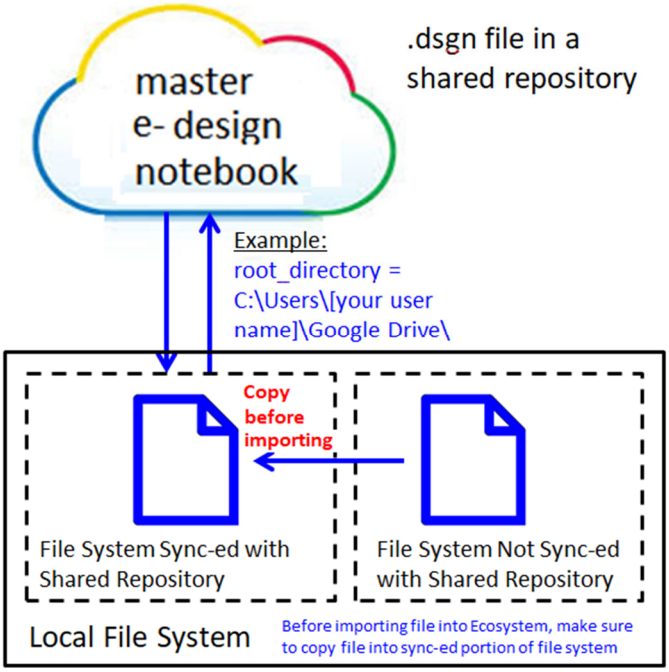


Figure 17: To make files imported into the Ecosystem available for shared access, they need to be copied into the portion of the file system that is sync-ed with the shared repository.

The Recognition Menu (If Design Idea Tab Active)

Recognize as Text

For the 'Sketches' tab in the 'Conceptual Design' phase, this menu option launches the cursive handwriting recognition on the content of the area highlighted using the area selection tool. For attaining the highest overall accuracy, the user is advised to launch the cursive handwriting recognition prior to the graphics recognition (3).

Recognize as Graphics …

For the 'Sketches' tab in the 'Conceptual Design' phase, this menu option provides the user with the means of launching recognition of graphical objects, on the content of the canvas highlighted using the area selection tool. If no area is highlighted, the graphics recognition is applied to the entire content of the canvas. The Ecosystem contains intelligence allowing it to discard the text objects already recognized during the graphics recognition (and hence avoid double-detection of the text objects) (3).

Recognized Contour …

For the 'Sketches' tab in the 'Conceptual Design' phase, the 'Recognized Contour …' menu allows the user to specify the contour thickness for the recognized objects rendered onto the canvas (3).

The Help Menu

About

Figure 19 presents the 'About' menu for Ver. 1.20 of the Ecosystem for Design Assessment and Verification.

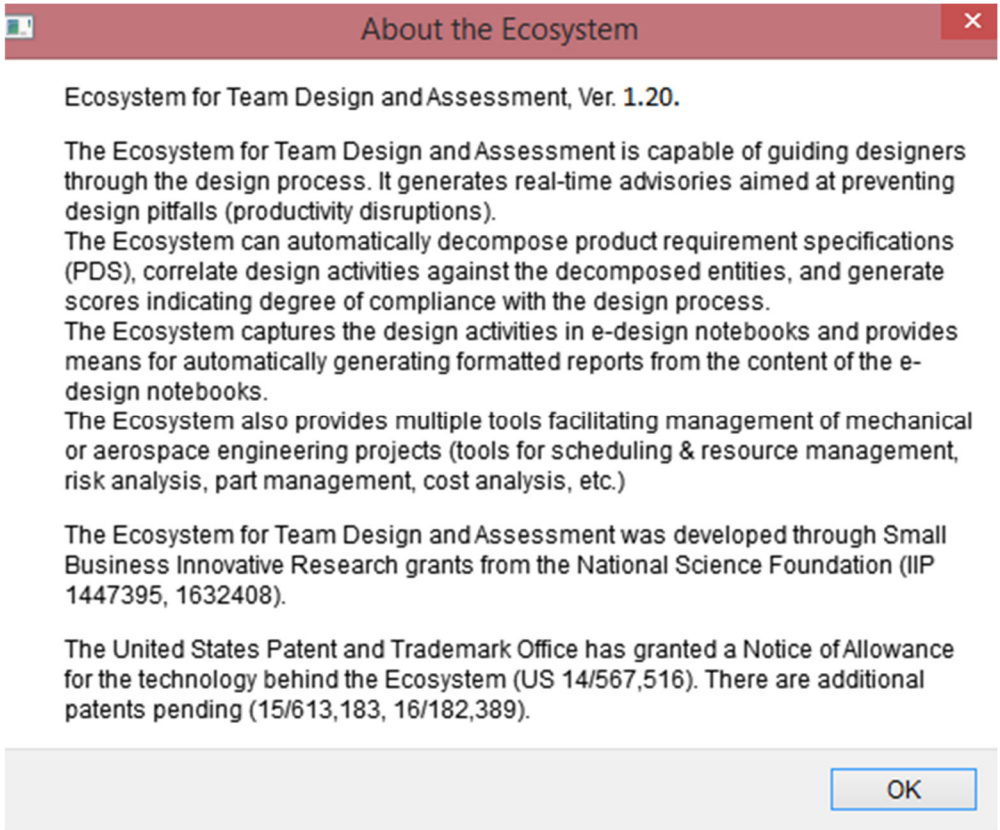


Figure 19: The 'About' menu for Ver. 1.20 of the Ecosystem for Design Assessment and Verification.

User Manual

This User Manual for the Ecosystem is available online:

http://www.imagars.com/UserManual-Ecosystem-1.20.pdf

It is also accessible locally through the Education folder (Load Examples … takes you there).

Load Examples

This menu option provides the user with direct access to the examples provided with the Ecosystem application (the e-design notebook files corresponding to the bolt tester sample).

Recover Design

The Recover Design option offers means for recovering auto-saved design data corresponding to the most recent Ecosystem design session.

License Key

The license dialog is accessed by selecting ‘Help’ in the main menu, and then ‘License Key’.

Message Board

This Message Board is available through:

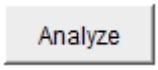
http://www.ecosystem.imagars.com/

Note about Active Assessment vs. the ‘Zombie’ Button

As a matter of standard practice, each design tab in the Ecosystem has a button titled ‘Analyze’ on the lower right side. Upon the user pressing this button, the Ecosystem applies its automatic assessment and scoring mechanism to the content of that design phase.

In the Ecosystem 1.20 software, some of the design tabs do not have active analysis associated with them. Hence, the user should not expect any alerts for these tabs. To prevent misunderstanding, the ‘Analysis’ button for these tabs has been grayed out in Version 1.20 (see Figure 20).

ACTIVE ASSESSMENT



INACTIVE (‘ZOMBIE’) ASSESSMENT

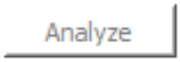


Figure 20: Comparison of ‘Analyze’ buttons representing active vs. inactive assessment.

Note about Auto-Populated vs. Manually Populated Columns

For the purpose of explaining how the auto-population works, the table and tree columns have been labeled with the icons shown in Figure 21.

MANUAL INPUT

AUTO- POPULATION

Figure 21: Icons for columns, where the user is expected to manually enter data (left), and where the design content is auto-populated.

Note about Support for International Keyboards

The Ecosystem support character encodings from international keyboards. Once the user, say, selects a Korean keyboard, the user can enter Korean characters directly into the Ecosystem. The Korean characters get stored in the e-design notebook files with proper encoding, and can be loaded back into the Ecosystem, and visualized properly (as shown in Figure 22).

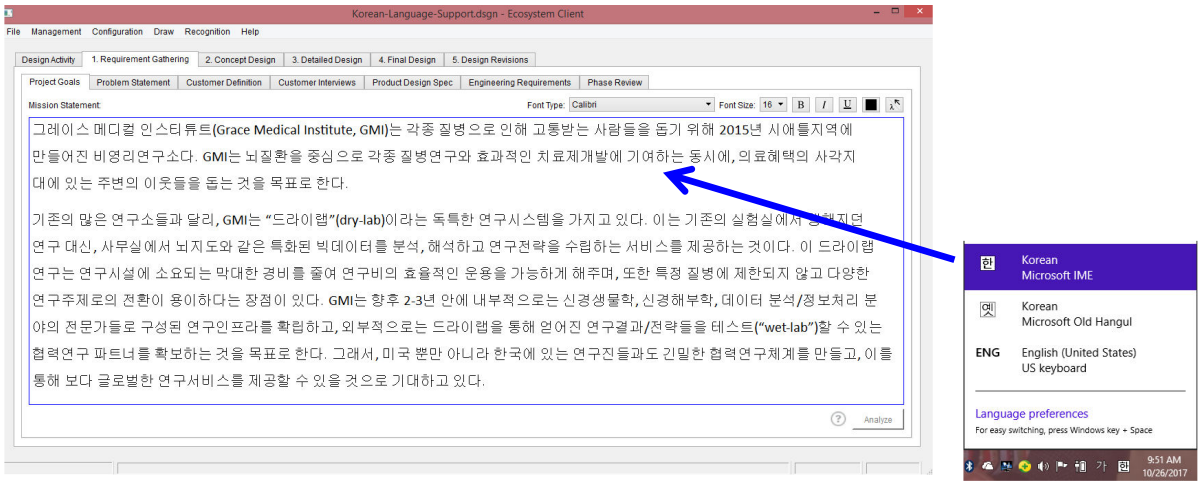


Figure 22: Users can easily switch to foreign keyboards. The Ecosystem supports the codecs involved and creates composite symbols, by combining key strokes, as/if necessary.

Note about Overwrite Prevention

The Ecosystem applies file locking in an effort to help with overwrite prevention. If another user were to modify the e-design notebook file, simultaneous to you modifying your e-design notebook file, the system can identify that the e-design notebook file has been changed, and that your edits need to be merged with the ones from other users, when the time comes to save your edits. Figure 23 summarizes the merging process.

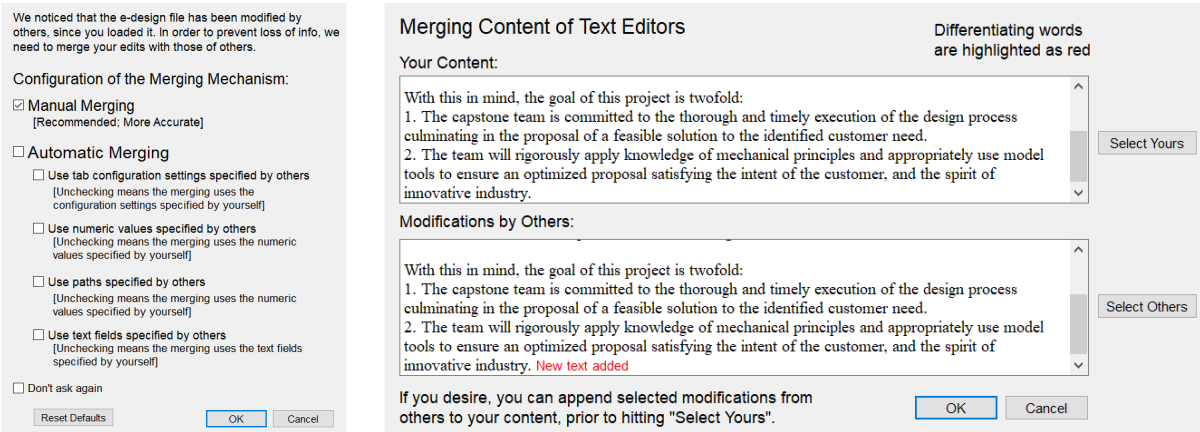


Figure 23: File merging for overwrite prevention.

Chapter 5: Requirement Gathering

The coverage in this Chapter assumes the default tab configuration. Where appropriate, the bolt tester example has been modified to highlight the ability of the Ecosystem to generate meaningful alerts. For additional specifics, refer to the placeholder text and pop-up tips.

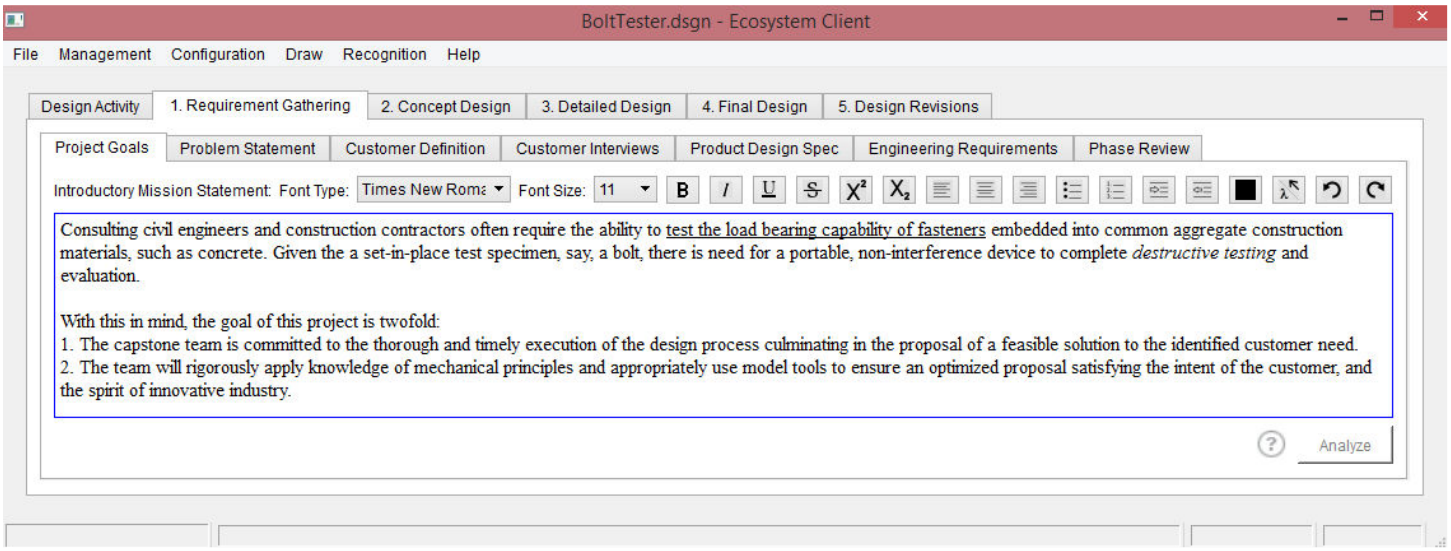


Figure 24: The Project Goals for the bolt tester example (from the Requirement Gathering phase).

Project Goals

The Project Goals tab prompts the user to input the team's mission statement. This should be completed in the form for a brief narrative statement and worded as if it were the project's written introduction. A sample statement is shown in Figure 24.

The user can enter special characters into the Ecosystem as follows:

1. The user can select the font of interest and simply start typing.
   - You, for example, can type in Greek characters, once you have selected the fonts SWGrekc, SWGreks or Symbol.
2. The user can select special characters from the character map in Figure 24 and Figure 25.
   - Once you have selected the character sequence of interest, you can click on 'To clipboard', close the character map and then past the sequence into the text editor using Ctrl+V.
3. The user can switch to a new key board, by clicking on the proper application in the bottom row of the Windows user interface (see Figure 26) and then type directly into the text editor.
   - This works even without modifying the font type selected in Figure 24.

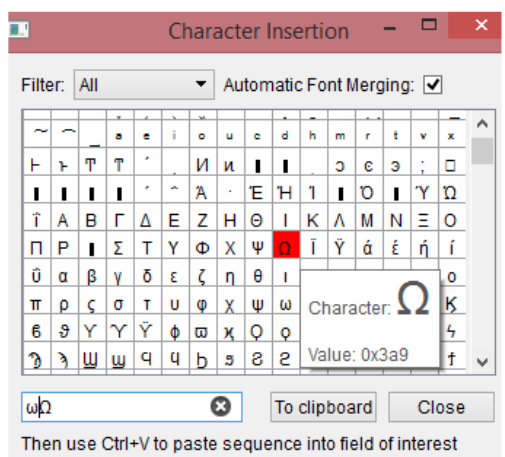


Figure 25: Special character insertion.

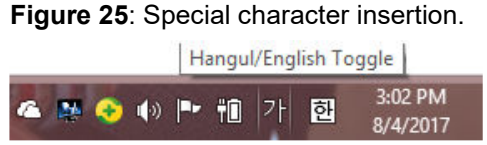


Figure 26: Windows keyboard toggle.

Problem Statement

The Problem Statement narrative is intended to represent the big-picture overview of the customer needs. As exemplified in Figure 27, the language of the problem statement should reflect the nature of the customer need, and a description of the design's intended use. How does the project sponsor or end users formulate the problem? Here, subjective language is acceptable. Once you have captured the problem formulation, in the exact language of the sponsor, you can go back and ask specific questions aimed at clarifying the customer requirements and the associated importance. You can delete an archived illustration, simply by clicking on it and hitting the 'Delete' button.

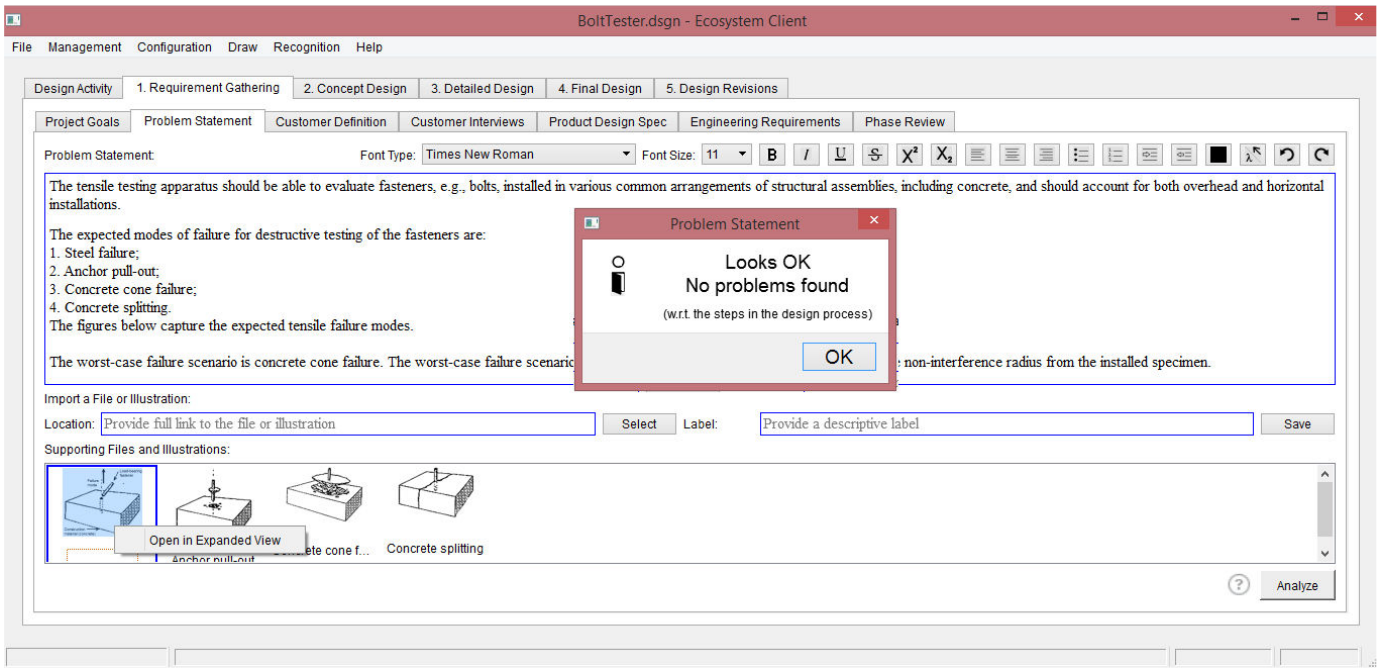


Figure 27: The Problem Definition tab for the bolt tester example.

Customer Definition

Customer definition and analysis is fundamental to successful completion of the PDS. As shown in Figure 28, customer identification involves exploring all parties that have a say in, or are affected by the design decisions made. Customers are categorized as external (those outside the design organization), internal (those within the design (or company) organization) or as end users. The end user can be an external or internal customer. The end user is drawn out separately for ease of categorization of the engineering requirements (to make sure the end user's voice gets heard). If a customer meets the definition of an end user, you want to categorize the customer as such, even though this may also be an external customer.

In order to provide the traceability expected (one of the primary utilities of the Ecosystem), all customer requirements need to have a source. One way or another, we want to be able to trace each requirement to a source (customer) and tell why it is important. The source or interpretation of the customers' needs can sometimes be accomplished by defining a new, internal customer capturing the source or interpretation of other stakeholders. The purpose of capturing the stakeholder motivation is to facilitate comprehension of the facts collected. It also helps form an understanding of what to expect throughout the course of the project. If preferred, you can use the Motivation column to articulate the customer's role.

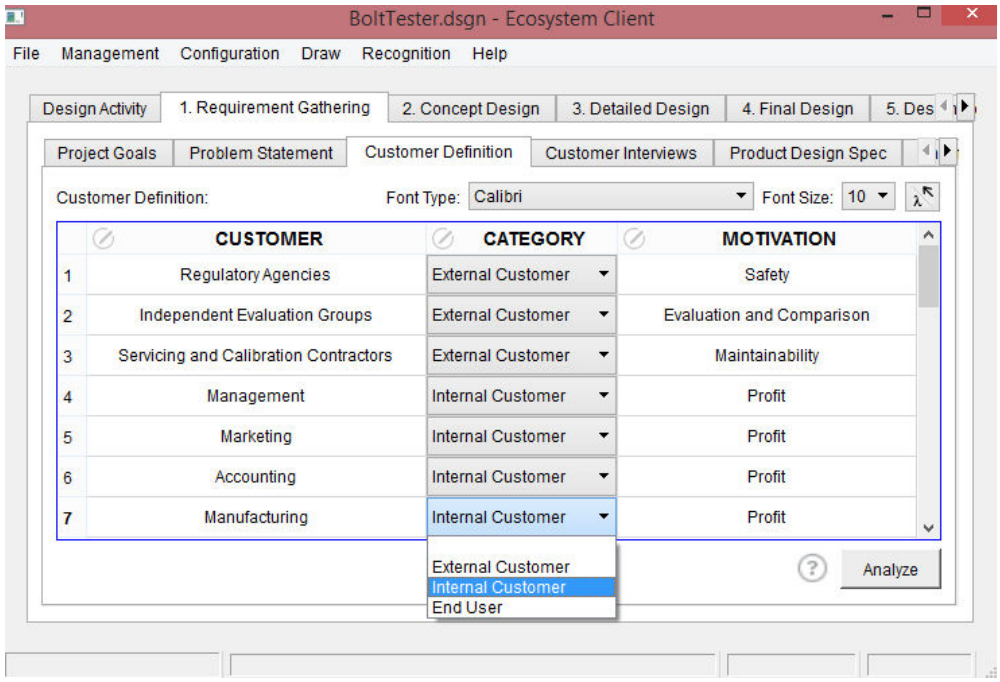


Figure 28: The Customer Definition tab for the bolt tester example.

Customer Interviews

It is important to diligently capture the conversations with the customers, preferably in verbatim language. This decreases the chance of interpretations down the road. Figure 29 presents a snapshot from the example on the quail egg embryo extractor. The interview log can be exported into an Appendix of the automatically generated report, as shown in Figure 30. The content of the drop-down menu for Customer Interviewed is automatically populated based on customers specified in the Customer Definition tab.

Questions to Ask Customer

Here you can list the questions to ask the customer. These should be specific questions addressing factors such as function, size (dimension), cost, performance, safety or the environment. The goal is to clarify the customer requirements.

Customer Response

Here you can list the customer response (the Voice of the Customer). It is important to diligently capture the conversations with the customers, preferably in verbatim language (regardless of whether or not it is tangible or measurable). This decreases the chance of interpretations down the road.

Customer Requirements Extracted

Here we are expecting numeric input for the IDEAL, MIN and MAX values (still ',', '.' and 'Inf' are accepted). As opposed to leaving the MIN and MAX fields empty, we suggest entering, say, 0 for the MIN and 'Inf' for the MAX.

Archived Interview Records

You can press the "Save" button to archive an interview record. If you wish to restore cleared content, you can simply double-click on the record of interest. If you inadvertently inserted an incorrect record, and you wish to delete it, you can simply right-click on the row and elect "Delete Row". If you want to edit an existing record, load it into the fields above, save the revised record, and then delete the original record using the right-clicking mechanism. Alternatively, you can single-click on a given record and hover with the mouse, to quickly view the complete content. The Notes section helps capture the history of the customer requirements. One way or another, people should be able to tell why a particular customer requirement is important, and where it came from. For general meeting minutes (material not directly addressing the customer requirements), we suggest you use the "Meeting Notes" facility.

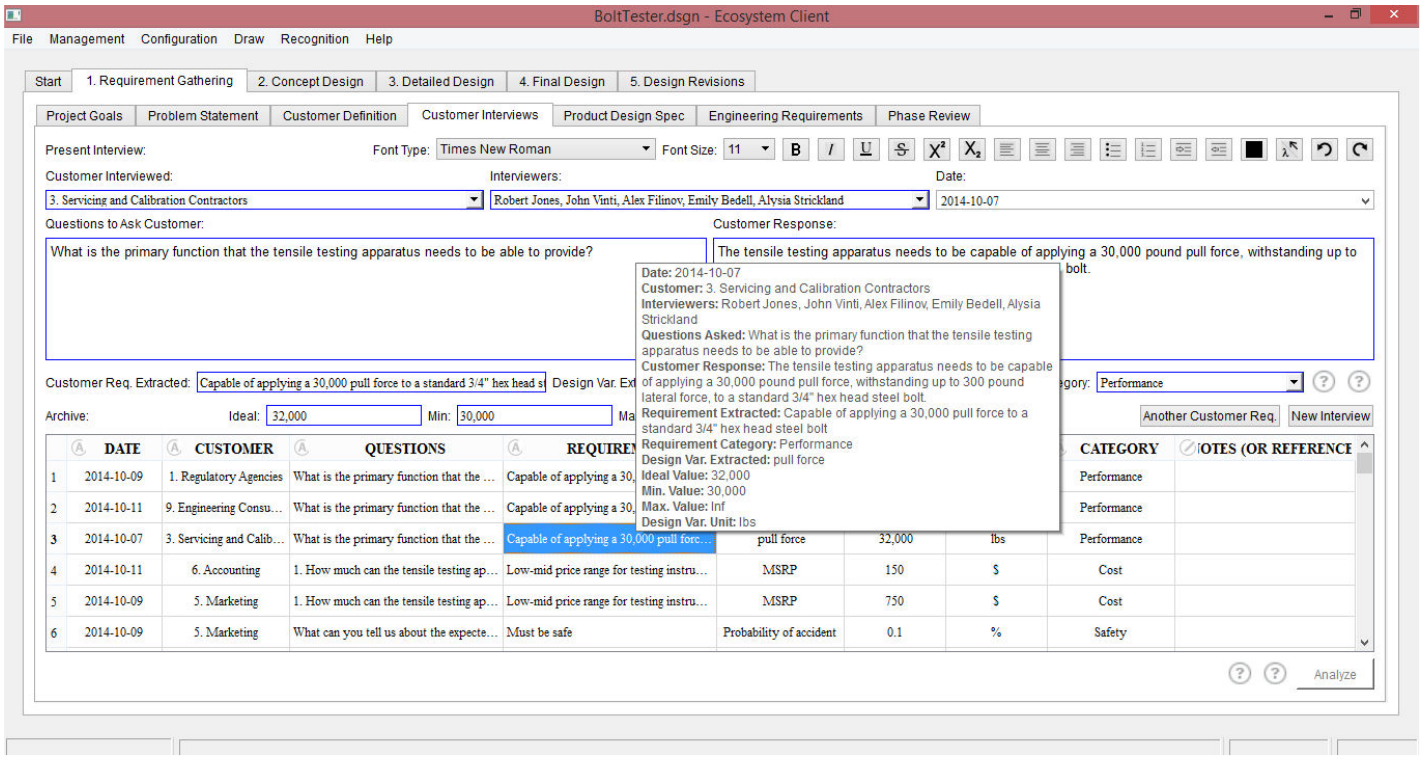


Figure 29: Customer interview tab from the bolt tester example.

Customer Interviews

DATE	CUSTOMER	INTERVIEWER	QUESTIONS	RESPONSE
2014-10-09	1. Regulatory Agencies	Robert Jones, John Vinti, Alex Filinov, Emily Bedell, Alysia Strickland	What is the primary function that the tensile testing apparatus needs to be able to provide?	The tensile testing apparatus needs to be capable of applying a 30,000 pound pull force, withstanding up to 300 pound lateral force, to a standard 3/4" hex head steel bolt.
2014-10-11	9. Engineering Consultants	Robert Jones, John Vinti, Alex Filinov, Emily Bedell, Alysia Strickland	What is the primary function that the tensile testing apparatus needs to be able to provide?	The tensile testing apparatus needs to be capable of applying a 30,000 pound pull force, withstanding up to 300 pound lateral force, to a standard 3/4" hex head steel bolt.
2014-10-07	3. Servicing and Calibration Contractors	Robert Jones, John Vinti, Alex Filinov, Emily Bedell, Alysia Strickland	What is the primary function that the tensile testing apparatus needs to be able to provide?	The tensile testing apparatus needs to be capable of applying a 30,000 pound pull force, withstanding up to 300 pound lateral force, to a standard 3/4" hex head steel bolt.
2014-10-11	6. Accounting	Robert Jones, John Vinti, Alex Filinov, Emily Bedell, Alysia Strickland	1. How much can the tensile testing apparatus cost? 2. What is the cost range for the Bill of Material?	1. The tensile testing apparatus is targeted for low-to-mid price range. 2. The MSRP cannot exceed $1,000.
2014-10-09	5. Marketing	Robert Jones, John Vinti, Alex Filinov, Emily Bedell, Alysia Strickland	1. How much can the tensile testing apparatus cost? 2. What is the cost range for the Bill of Material?	1. The tensile testing apparatus is targeted for low-to-mid price range. 2. The MSRP cannot exceed $1,000.

Figure 30: The customer interview log after exporting into an automatically generated report.

Product Design Spec

Similar to the House of Quality, the Product Design Spec associates the customer needs with the product function. The PDS tab allows the designer to view the dependence between the customer requirements extracted and the associated engineering requirements. The customer requirements are extracted from individual customer interview records and automatically fed into the PDS tab along with the corresponding requirement category, design variables (targets), and associated MIN, IDEAL and MAX values. Both the customer and engineering requirements are uneditable. To modify a customer, or an associated engineering, requirement, the designer needs to go back to the source (the customer interview tab) and modify there. The column to the right of Figure 31 represents the Voice of the Customer, and is also auto-populated. The customers are referenced in terms of the row numbers in which they appear in the Customer Definition tab. To delete a new Customer or Engineering Requirement, simply employ the right-clicking mechanism. When Customer 10 is omitted from Customer Requirement 3, the Ecosystem issues the alert shown in Figure 32.

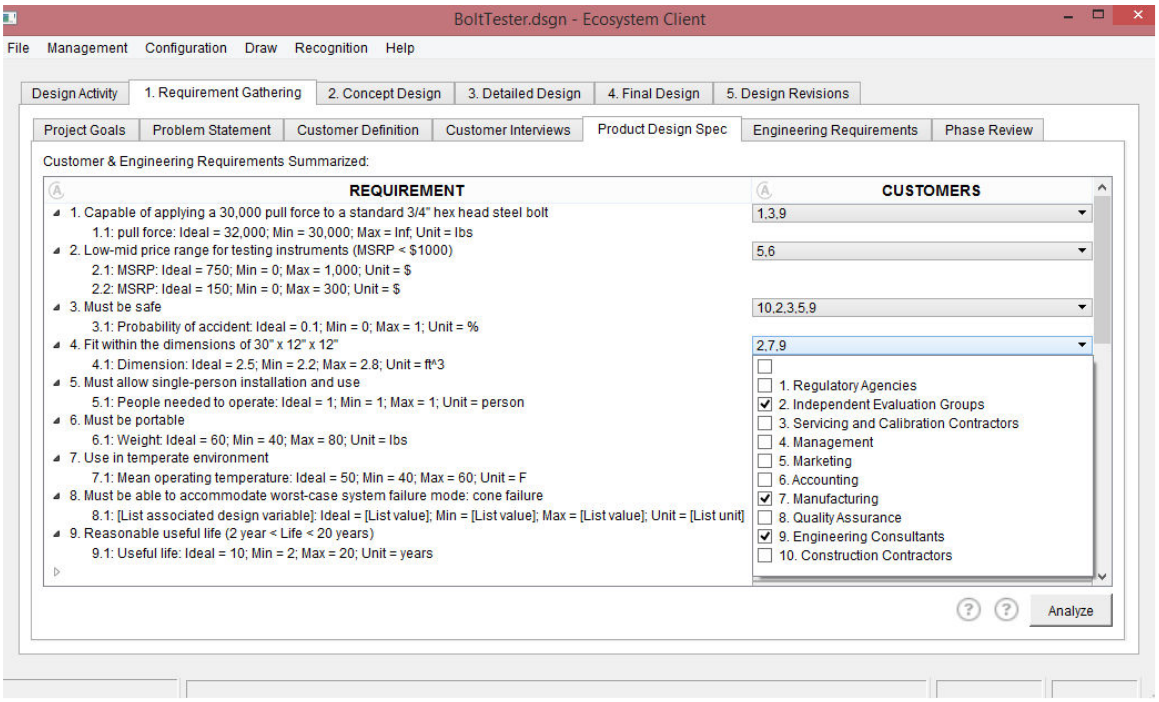


Figure 31: The Product Design Spec (customer need) tab from the bolt tester example.

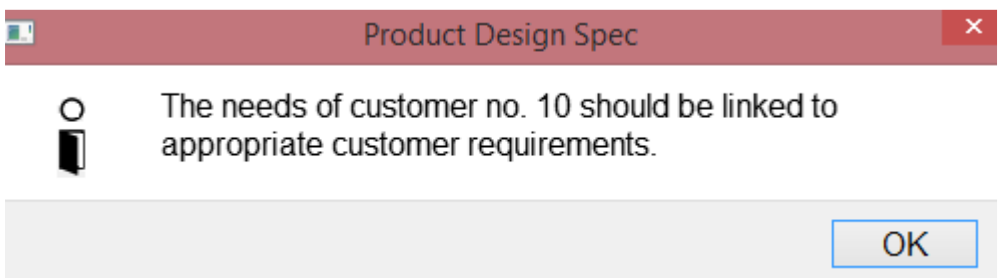


Figure 32: Alert issued by the Ecosystem when Customer 10 is omitted from Requirement 3.

Engineering Requirements

The engineering requirements associated with a given customer requirement are supposed to offer a numeric representation of the customer requirement. To this effect, the Engineering Requirement tab formulates the design challenge in terms of an optimization problem. The design variables (targets) and the associated MIN, IDEAL and MAX values are auto-populated based on corresponding entries from the Customer Interview tab.

The Engineering Requirement tab, shown in Figure 33, allows the designer to complete the definition of the objective function for the functional decomposition. The Ecosystem 1.20 SW employs a power-law objective:

$$\text{Objective} = \sum_{i=1}^{n} \text{Requirement}[\text{i}]^{(\text{Significance}[\text{i}])}$$

The assignment of the importance values is made by the designer, but reflect the priority assigned to the requirement by the customers listed in Figure 31. The significance levels characterize the designer's suitability assessment of the requirements in the fitness function. *Since the functional decomposition is presented as an optional tool, we recommend including all the design variables in the objective function*. This ensures they are accounted for in the weight selection (House of Quality) and the simpler design selection methods.

Note the following:

- "Significance" represents the exponent in the objective function for the function decomposition.
  - It should be assigned based on customer or market input.
- "Importance" denotes the importance assigned to specific customer requirements in the determination of the weights for the design selection.
  - See the House-of-Quality matrix in the Design Selection tab).
- If an Engineering Requirement needs to be modified, the Customer Interview tab is the right place.
  - The information flow is supposed to be uni-directional.
  - Bi-directional information flow can lead to conflicts.
- The text editor in Figure 33 can be used to specify qualitative requirements, constraints, and/or to list test related considerations.
- If you have a qualitative requirement, you can formulate it by specifying a customer requirement, and even a design variable, but omit the values for IDEAL, MIN and MAX.
- If you have a vague customer requirement, such as 'The device must be light', and there is not an opportunity to ask the customer for clarifications, we advise the designer to list numbers considered appropriate along with corresponding explanations under the 'Designer Notes' section.
- If you have a qualitative requirement, such as for 'in-house manufacturing', we suggest you list 'manufacturing' as the Design Var. Extracted, 'in-house' under Ideal and 'N/A' as the unit.

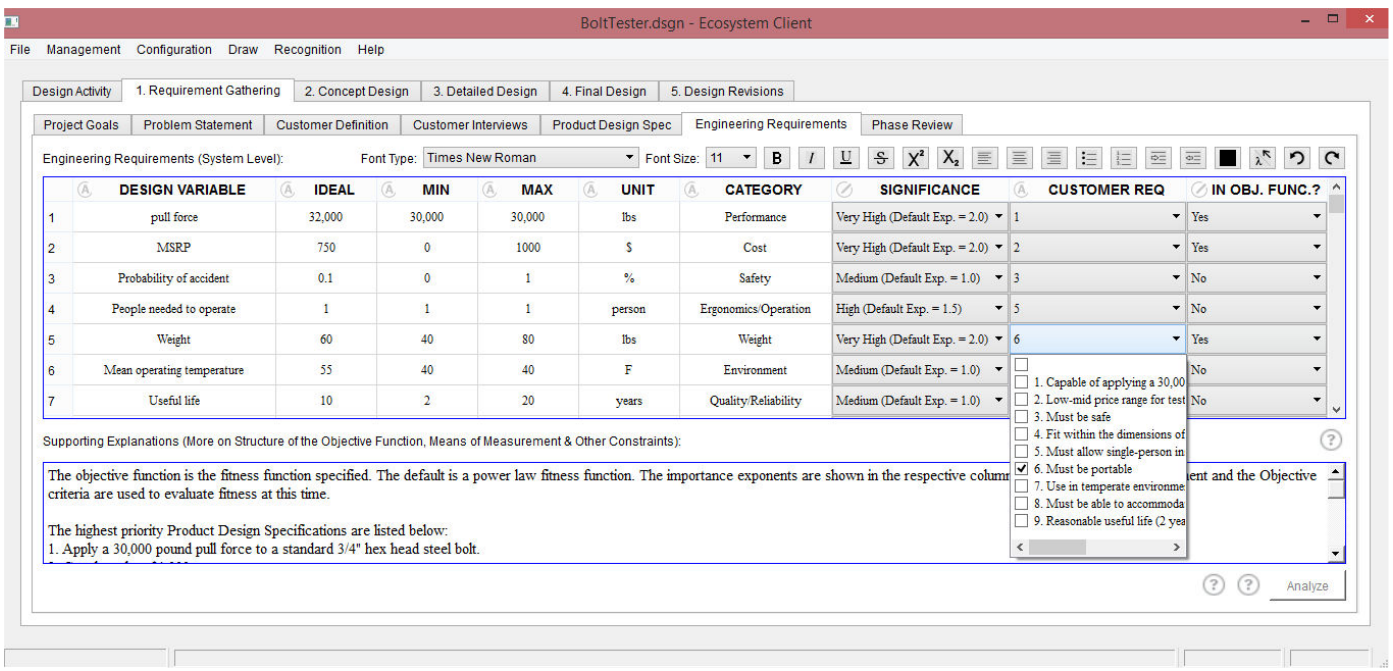


Figure 33: The Engineering Requirements tab from the bolt tester example.

Phase Review

The purpose of the Phase Review tab is to concisely specify the deliverables comprising the design point at the end of the Requirement Gathering phase. The expected output from the Requirement Gathering phase is a complete listing of the customer and engineering requirements. But being a flexible design paradigm, the Ecosystem leaves it up to the designer to choose the tools best suited to accomplish the goal for the project at hand. You can either specify the location or double-click on the Location column an click on the Path (or image) desired. In this way, you can import images into the Location column. Similarly, you can delete an inserted image through a single click by pressing the 'Delete' button. To avoid moving

content around, you can insert or delete rows through simple right-clicking. The COMPLETED column for the default deliverables is auto-populated, in accordance with the content provided. The Explanation column is, in part, intended for capturing test related observations from the early design phases. Before moving on to the next design phase, we encourage you to list test related observations from the Requirement Gathering phase. Finally, by referencing the Deliverables in the Schedule dialog, you can assign a date to the Deliverables listed.

Gate Review

The purpose of the Gate Review tab is to concisely specify the deliverables corresponding to phase review at the end of the Requirement Gathering phase, indicate the level of completion, and capture the associated explanations. In the Notes section, the user can also list the level of completion of specific requirements, or comment on changes in the requirements. The Gate Review tab is excluded from the default tab configuration, but can be enabled through the “Tab Configuration …” menu. The Ecosystem 1.20 SW supports formatting of individual cells in the Gate Review tab.

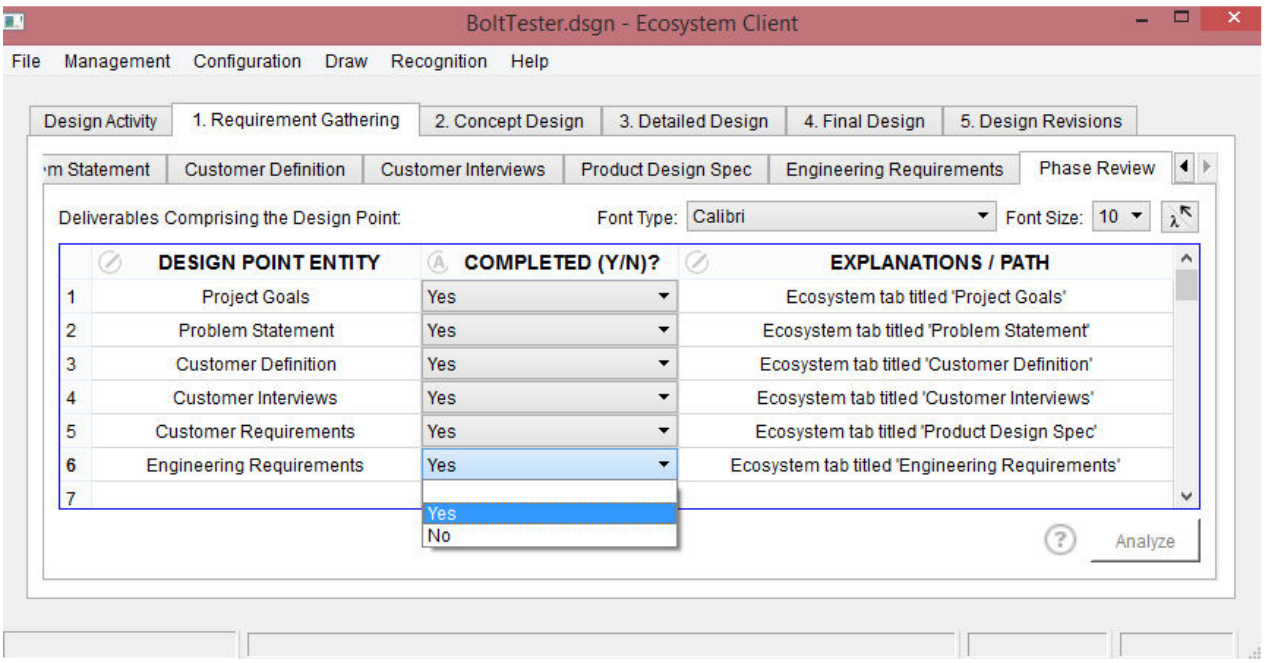


Figure 34: The Phase Deliverables tab from the Requirement Gathering phase.

Chapter 6: Concept Design

Design Ideas

The intent of the Design Idea interface is to allow rapid brainstorming and concept ideation without the cumbersome Windows-Icons-Menus-Pointer (WIMP) graphical interface of solid modeling software (4). While powerful for detailed or final design, solid modeling software may not be ideal for conceptual design, and may impede progress rather than promote. Efforts in the Concept Design phase should emphasize rapid and abundant concept generation and communication followed by thorough investigations of fitness and feasibility.

Features of Interest

- Touch-screen interface supporting stylus input (3).
- Mouse-drawing capabilities for platforms not supporting stylus input (3).
- High-accuracy cursive handwriting recognition (3).
- Automatic graphics recognition (3).
- Great touch-up capabilities (3).
- Ability to jointly recognize graphics & text, without complications (3).
- Automatic loading of images onto the canvas, immediately upon listing an image in the import field (before archiving).
- Zooming and panning using the mouse wheel (3).
- Auto-archiving of design ideas in the Design Description tab, based on the design titles, design description and images provided at the Design Idea stage.

Sample Behavior

INPUT

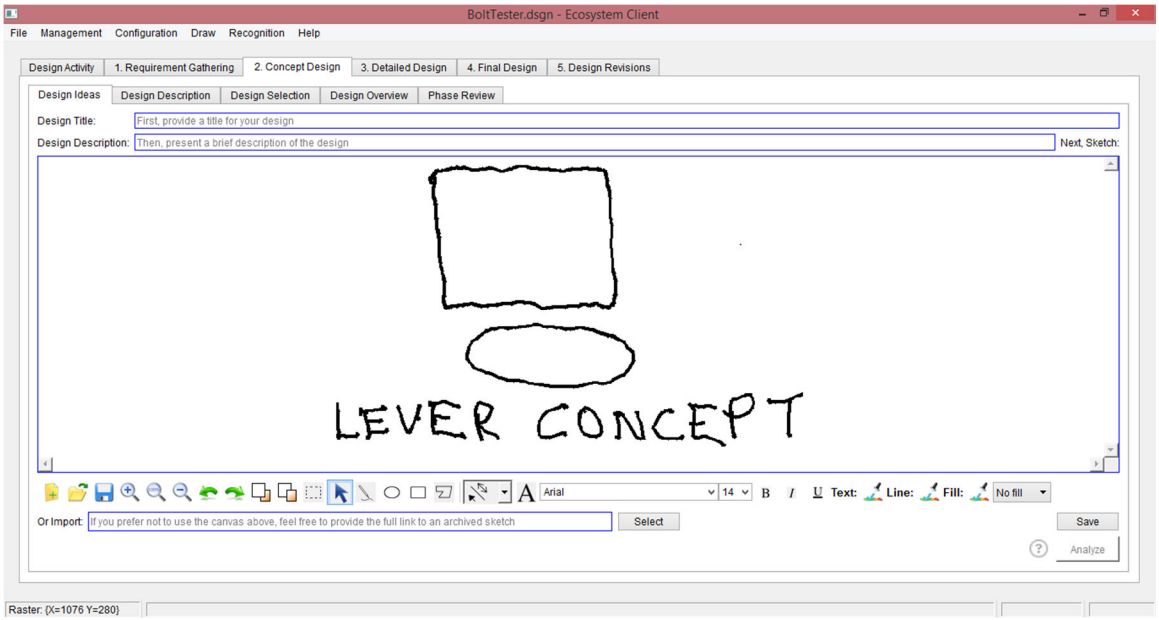
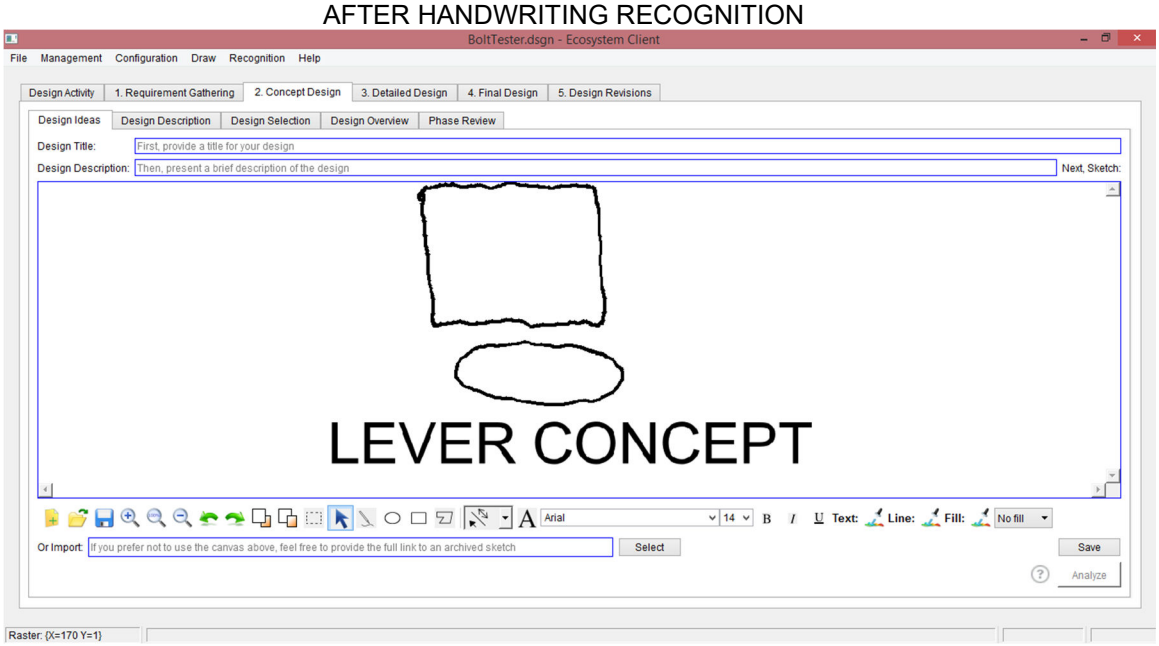


Figure 35: The Ecosystem Ver. 1.20 offers cursive handwriting recognition with high accuracy, graphics recognition as well as great touch-up capabilities.

AFTER HANDWRITING RECOGNITION



AFTER GRAPHICS RECOGNITION (AND MINOR TOUCH-UP)

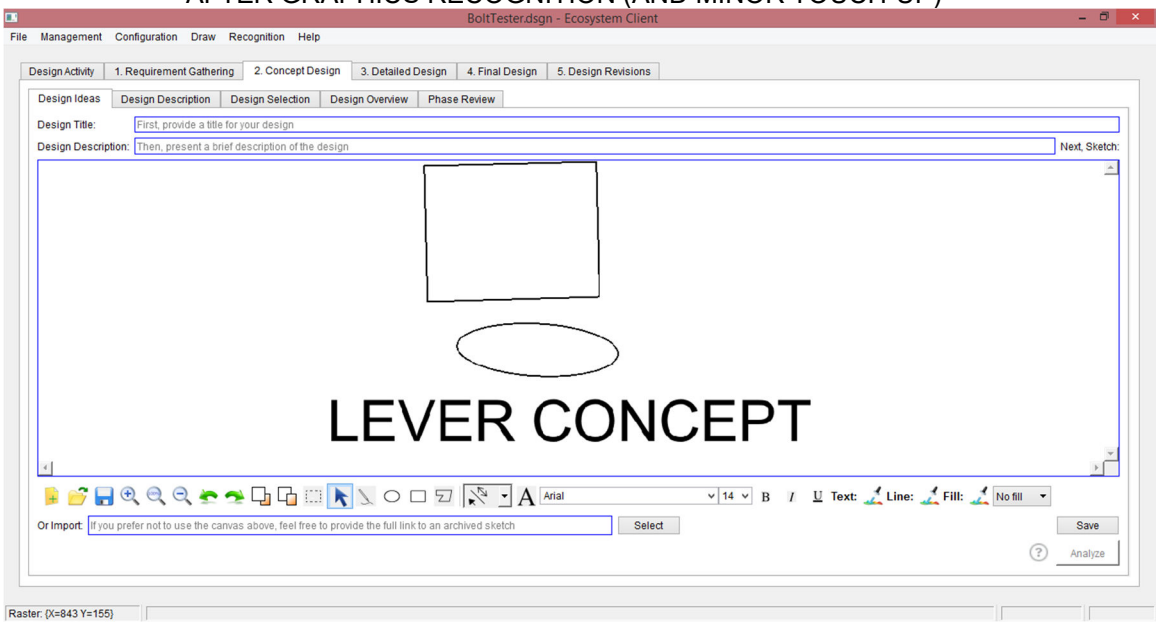


Figure 36: The Ecosystem Ver. 1.20 offers cursive handwriting recognition with high accuracy, graphics recognition as well as great touch-up capabilities.

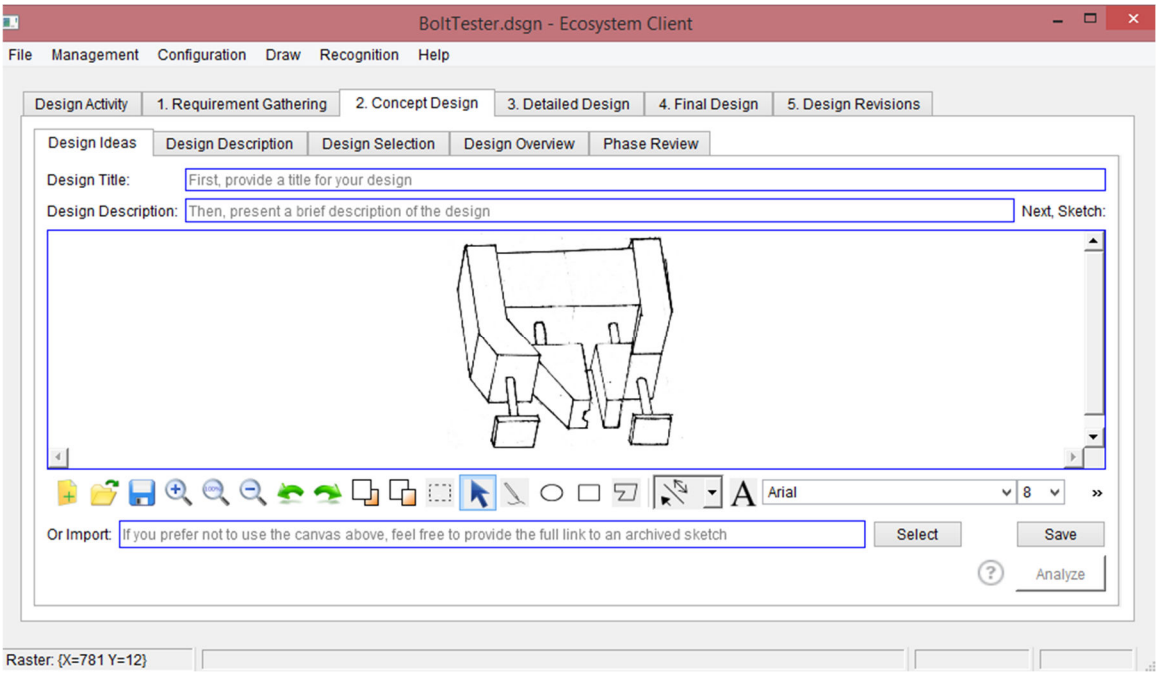


Figure 37: The Sketches tab from the bolt tester example (no zooming).

Further Specifics

- You can press the 'Save' button to move to the next design idea.
- The ideas are archived in the Design Description tab on the next page.
- There, you can use nice text editors to properly format the design description.
- To sketch your design idea on the canvas, use the mouse-based drawing tools or a stylus.
- To invoke the handwriting or graphics recognition, simply highlight the contours of interest using the selection tool and click on 'Recognition' followed by 'Recognize as text' or 'Recognize as Graphics ...' from the main menu.
- The User Manual for SketchRec 3.0 can be accessed through http://www.imagars.com/UserManual-SketchRec-3.0.pdf
- Note that in the text entry mode, you need to double-click on the canvas before start typing.

Designs Description

Next, we complete the description of the designs considered. The Designs Considered tab, shown in Figure 38, provides textual description of the designs considered. The Ecosystem 1.20 provides the user with the ability to import up to 5 images. If your project involves improvement of an existing design, you can list the reference design as the first design idea. To avoid moving content around, you can insert or delete a row by right-clicking on the corresponding title or image column. To insert an image, simply right-click on the cell where you want to have it inserted, and select ‘Insert Image’. To view an image in expanded view, simply double-click on your image of interest.

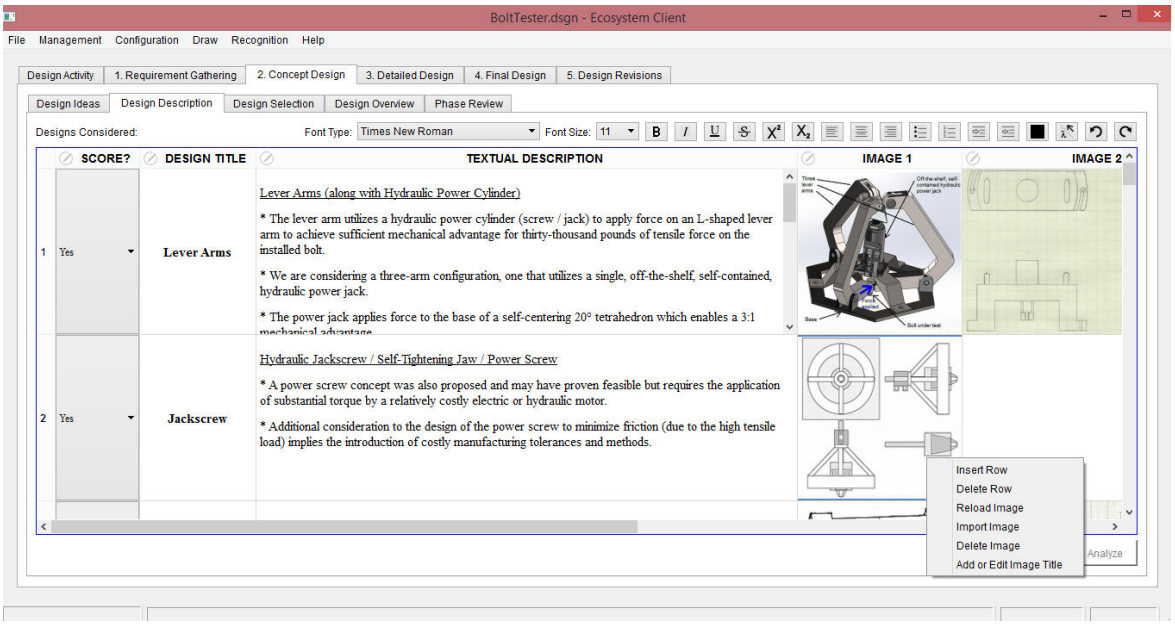


Figure 38: Designs Considered for the bolt tester example.

Design Selection

The Design Selection tab provides access to a House of Quality table for weight selection, three methods for design selection as well as of a listing of the concept design elected for detailed design along with associated confidence specification and rationale. The tree design selection methods comprise of

1. Scoring matrix (simplest).
2. Decision matrix with weights.
3. Functional decomposition.

Scoring Matrix

The Scoring matrix scores the designs relative to a reference (datum). While the reference can in general be external, e.g., consist of a standard or an existing product, we here assume it is internal, i.e., one of the design ideas from the Design Description tab. Figure 39 provides sample population of a Scoring matrix. First, one of the designs is selected as a reference. All the design targets for this design are then automatically assigned the grade 0. Next, the design targets for the other designs are ranked relative to the reference (datum), in accordance with Table 4. Note, if you double-click on '?' icon for the scoring matrix, you can keep it open in a separate side window, while you model your design work accordingly.

Grade	Number
Better	+1
Same	0
Worse	-1

Table 4: Grading scheme for the Scoring matrix.

Design	1 Reference?	2 PDS Criteria: Wall Clearance	Bolt Clearance	Max Load	Adapt-ability	Effec-tiveness	Weight	Cost	3 Total
Design A	Yes	0	0	0	0	0	0	0	0
Design B	No	0	-1	-1	+1	0	-1	0	-2
Design C	No	0	+1	-1	+1	+1	-1	-1	0
Design D	No	+1	+1	+1	0	0	-1	-1	+1
Design E	No	0	0	+1	+1	+1	+1	-1	+3
Design F	No	-1	-1	-1	0	0	-1	+1	-3

auto-populated

auto-populated

Figure 39: Sample population for a Scoring matrix.

House of Quality

Most of the elements in the House of Quality matrix are auto-populated, in accordance with specifications from the Customer Interview tab. Figure 40 lists the sequence expected for the user input. The goal is to determine the weights to be used for the design selection in Figure 41. As noted above, "Importance" denotes the importance assigned to specific customer requirements in the determination of the weights for the design selection. Again, if you double-click on '?' icon for the House of Quality matrix, you can keep it open in a separate side window, while you model your design work accordingly.

House of Quality (1)

Customer Needs	Customer	Customer Importance	Engineering Requirements (Design Targets)				
			Weight	Volume	Power	Safety (MTBF)	Durability
Easy to control or use	1	6	0	7	0	0	0
Easy to move wet leaves	1	9	0	0	9	0	0
Portable	1	9	9	7	0	0	0
Low manufacturing and operating cost	1	7	0	0	9	5	8
		Absolute Importance:	81	105	144	35	56
		Weight:	0.19	0.25	0.34	0.08	0.13
		MIN:	20	10	2.0	1	2
		IDEAL:	40	20	4.0	3	10
		MAX:	60	30	7.0	Inf	Inf
		UNIT:	lbs.	gallon	hp	hours	years

(2) (3)

Auto-populated

Auto-populated

* Purple: Values accounted for in the objective function.
* Gray: Values not accounted for in the objective function.

Figure 40: Auto-populated items, along with the sequence of typical population for the House of Quality table.

Decision Matrix

The Decision matrix formulates a simple method for concept design selection, one that utilizes the weights from the House of Quality along with subjective scores indicating - on the range of 1 - 10 - how well given concept solutions fulfill specific design targets. The SCORES column is automatically computed, once you have populated the last purple cell for a given row. The scores are computed using a simple weighted average formula (not related to the objective function used for the functional decomposition). The auto-computation extends to the scores in the House of Quality matrix. If the latter scores are modified, both the weights and the final scores in the Design Selection matrix will automatically reflect the change. Figure 41 provides illustration of the default table configuration for the Design Selection tab (a combination of the House of Quality and Design Selection matrices).

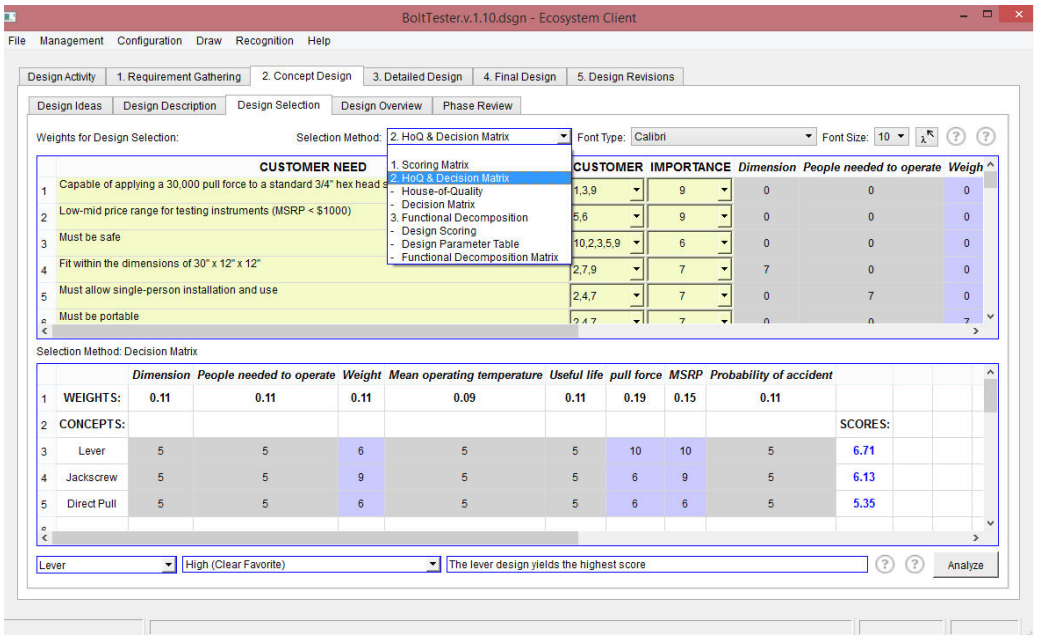


Figure 41: Design Selection tab from the bolt tester example (default configuration).

Functional Decomposition

Through the Functional Decomposition, design concepts can be decomposed into sub-requirements and associated design features and design parameters. The function decomposition enables designers to break complex designs into sub-systems, and define interfaces, without description of the physical attributes. The Functional Decomposition is an analytical technique, one enabling objective comparison of concept design solutions. Each level of the Functional Decomposition allows higher fidelity determination in accordance with the importance ratings provided in the Requirement Gathering tab. Each concept presented is scored, using the table beneath the 'Scoring Guidelines'. Here subjective assessment of fitness in the context of the functional requirements is provided in the columns adjacent to the concept title. The assessment value is automatically calculated in the next empty column in accordance with the objective function.

This approach to the functional decomposition resembles the morphological matrices, the quality function deployment (QFD) decision matrices and the Pugh matrices from the design literature.

Note that detailed functional decomposition may not be needed for all projects. For smaller projects, you can simply move on to the Design Selection. There, you can assign weights based on a House-of-Quality matrix, provided in the Design Selection tab, along with associated subjective (Level 0) scores for the design variables.

Features of Interest

- Generic paradigm (no limit to the number of inputs supported by the objective functions).
- Automatic evaluation of the objective function.
- Automatic population of column headings.
- Editable items in the decomposition tree.

Background on the Objective Function

In Ver. 1.20 of the Ecosystem, each design concept and each design feature are evaluated according to an objective function which has the form

$$\text{Objective} = \sum_{i=1}^{n} \text{Requirement}[\text{i}]^{(\text{Significance}[\text{i}])}$$

Background on the Decomposition Levels

- Level 0 refers to the concept as a whole (think "concept").
- Level 1 refers to any meaningful subdivision of that concept (think "assembly").
- Level 2 refers to anything that makes sense subordinate to that assembly (think "sub-assembly").
- You can continue breaking down the design in this way until you get to the individual parts (at Level *N*).

Background on the Scoring Rules

- The scoring should reflect, in relative terms (on a scale from 1 to 5), how easy it is to attain a given functional requirement.
- A score lower than 5, for a given FR, does not mean the FR is not important. Even with a score lower than 5, the concept solution may still be able to deliver on the requirement. It simply means that meeting the requirement may not be quite as easy. With this said,
- Grade 5 typically refers to "Excellent".
- Grade 4 typically refers to "Good".
- Grade 3 typically refers to "Adequate".
- Grade 2 typically refers typically to "Poor".
- Grade 1 typically refers to "Inferior" or even "Useless".

Sample Decomposition Process

Figure 42 - Figure 49 capture an abbreviated tour through the decomposition process. The tour starts with the user clicking on the 'Start New Scoring' button. The Ecosystem guides the students through the process by issuing advisories, most of which are fairly self-explanatory.

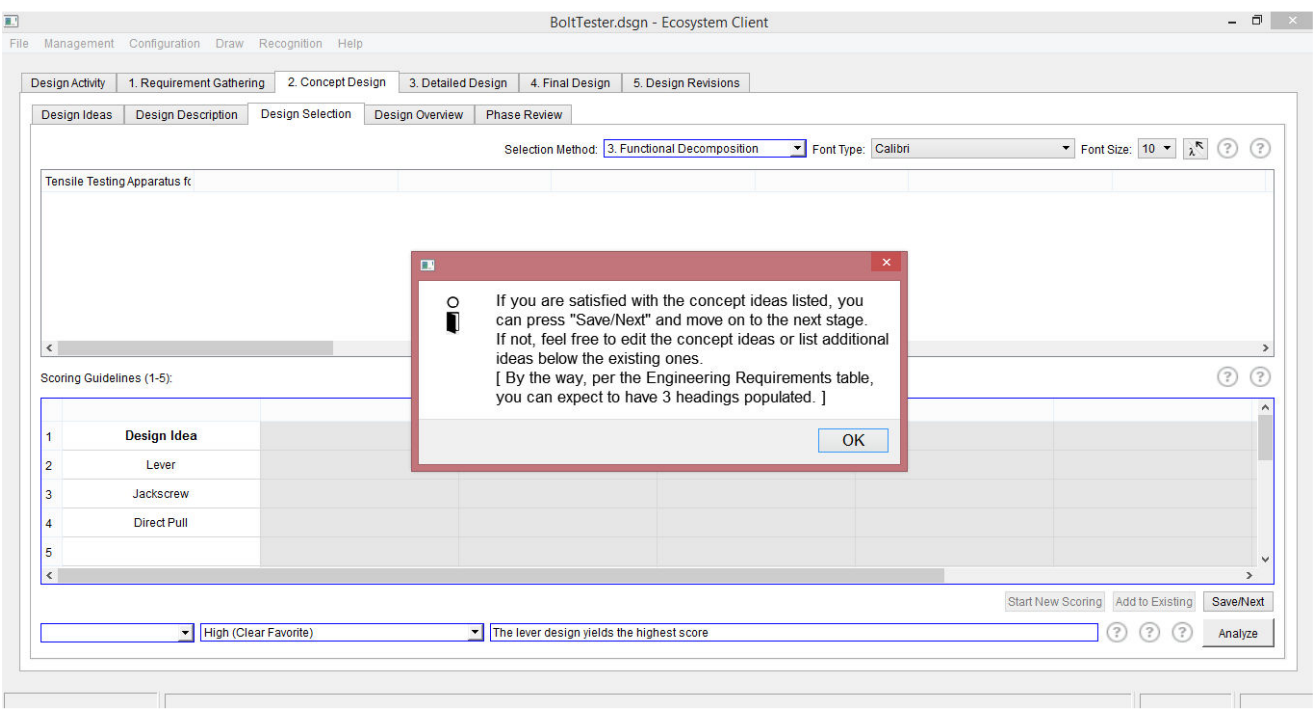


Figure 42: Scoring table at the beginning of the decomposition tour (just after pressing 'Start New Scoring').

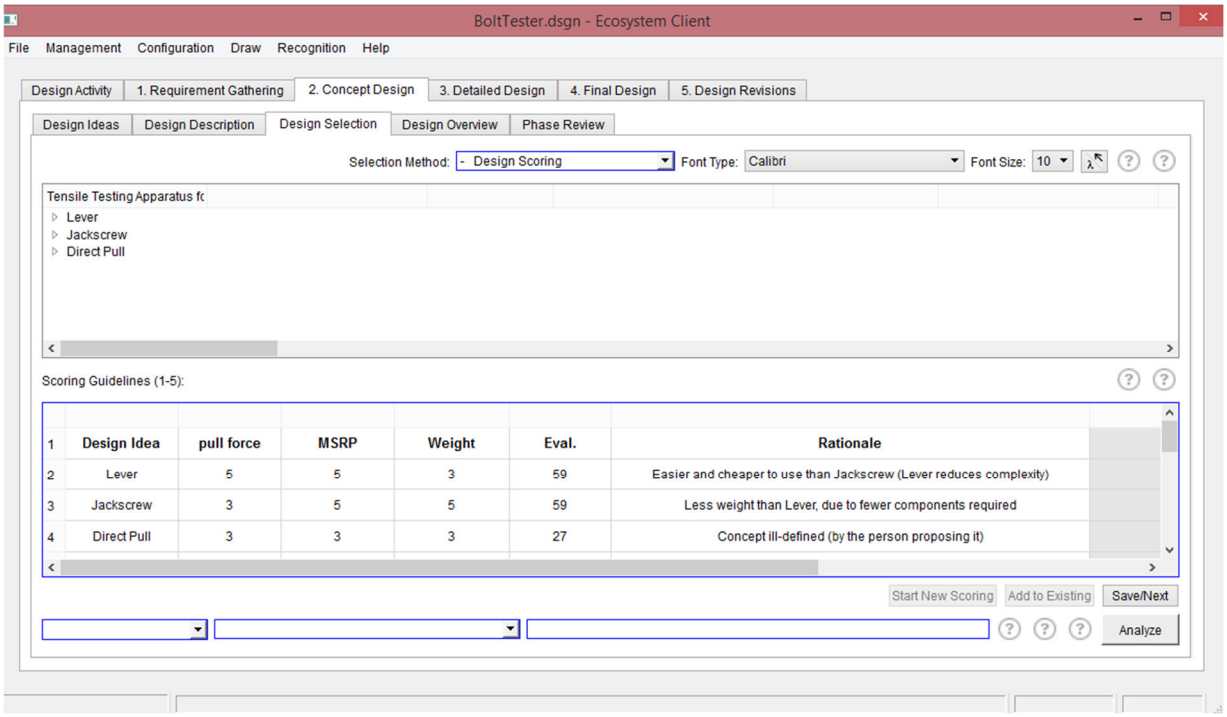


Figure 43: After assigning subjective scores to each high-level design concept. The header was automatically populated and the objective function automatically evaluated.

The rationale provided should shed light on what the numbers mean, in the context provided (i.e, clarify the reason for the assignment). If you did some rapid prototyping of your concept designs, and can report on test related observations, you are welcome to list these in the rationale column.

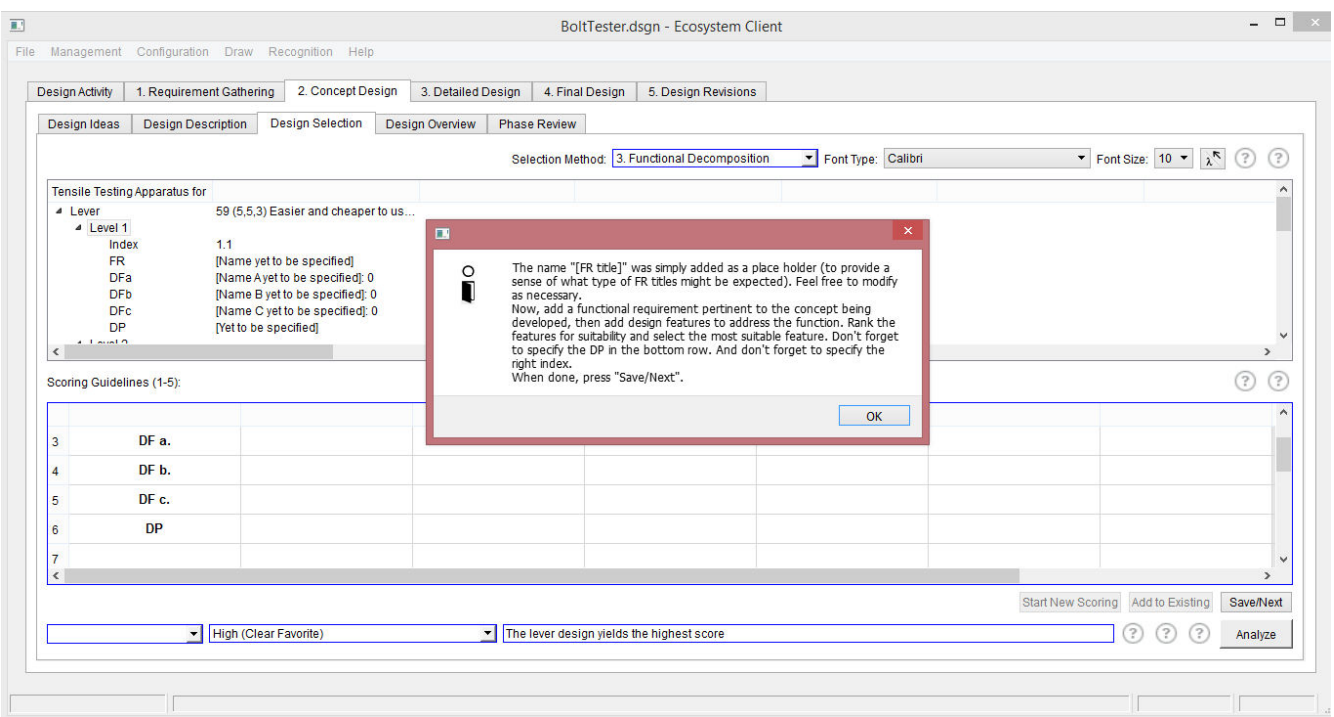


Figure 44: Before scoring the first Level 1 functional requirement.

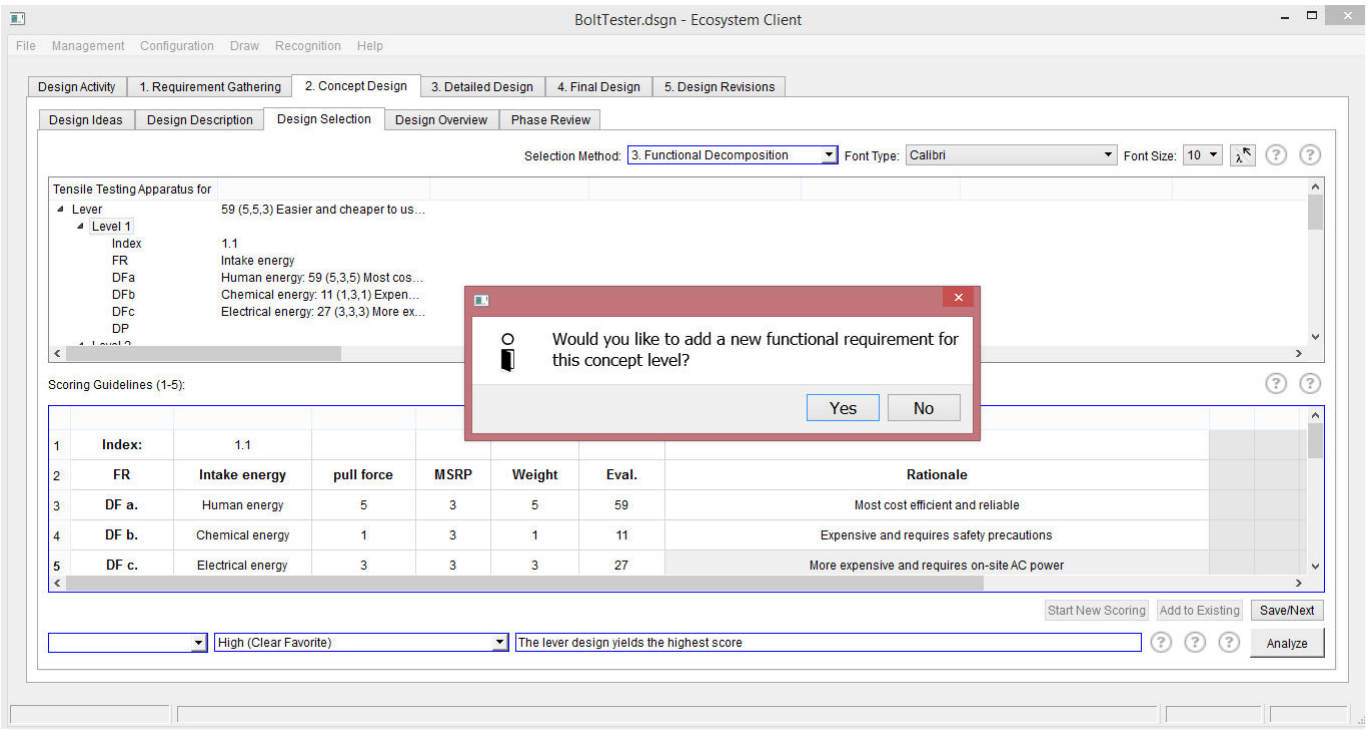


Figure 45: After scoring the first Level 1 functional requirement.

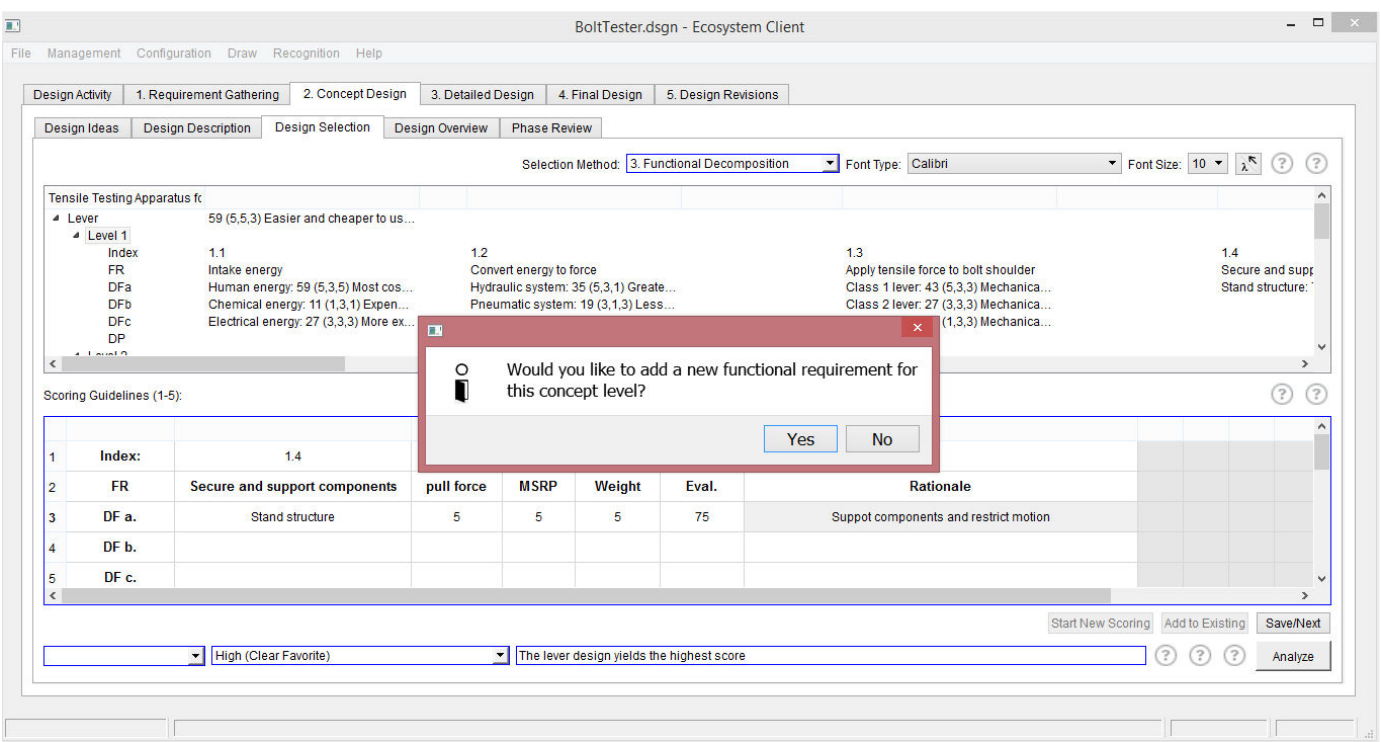


Figure 46: After scoring the last Level 1 functional requirement (FR 1.4).

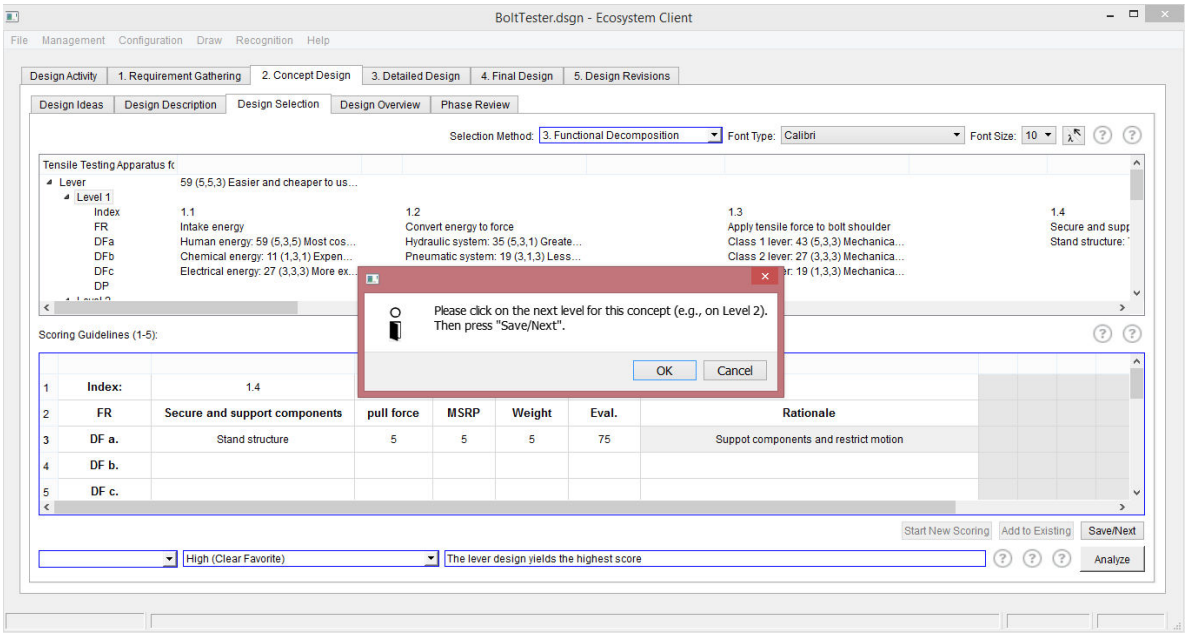


Figure 47: Guiding message at the beginning of the Level 2 decomposition.

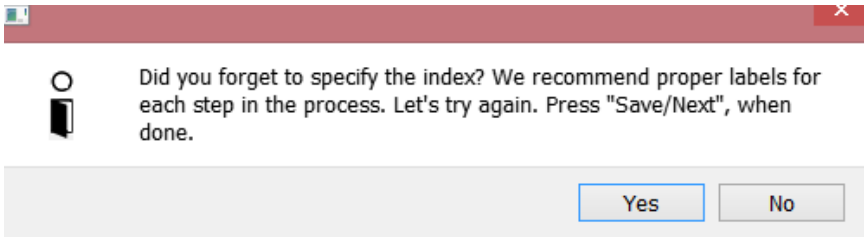


Figure 48: Guiding advisory issued when the user forgot to specify the index for any given FR.

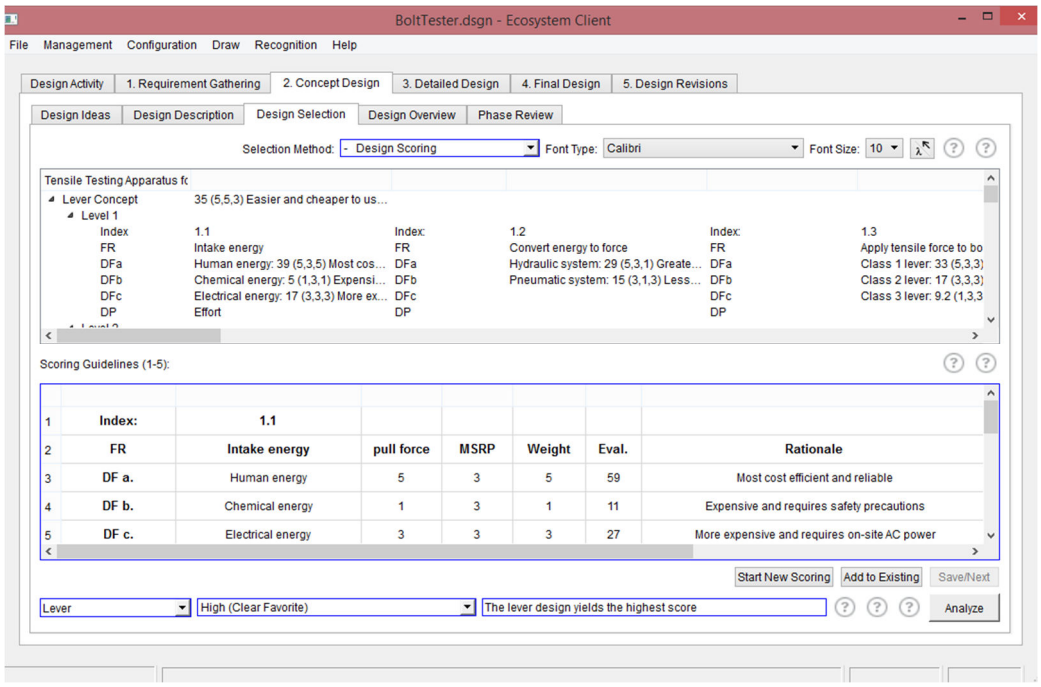


Figure 49: Snippet from the scoring table at the end of the decomposition tour. FR 1.1 was loaded back into the table for the Scoring Guidelines by double-clicking on the main tree.

Editing Existing Scoring Results

Adding New Decomposition Entities

First press ‘Add to Existing’, per Figure 50. Then, for the Concept of interest, click on the Level under which you want to add the new item. Then press ‘Next/Save’. Make sure to pick an Index consistent with the existing labeling.

Deleting Decomposition Entities

To delete an element, simply right-click on the index for the grouping you want to delete, and elect ‘Delete Element’.

Add New Concept

To add a new concept to existing decomposition, simply right-click on one of the existing concepts, and elect ‘Add New Concept’. The new concept will appear at the bottom of the tree.

Delete Concept

To delete a concept, simply right-click on the concept name of interest, and elect ‘Delete Concept’.

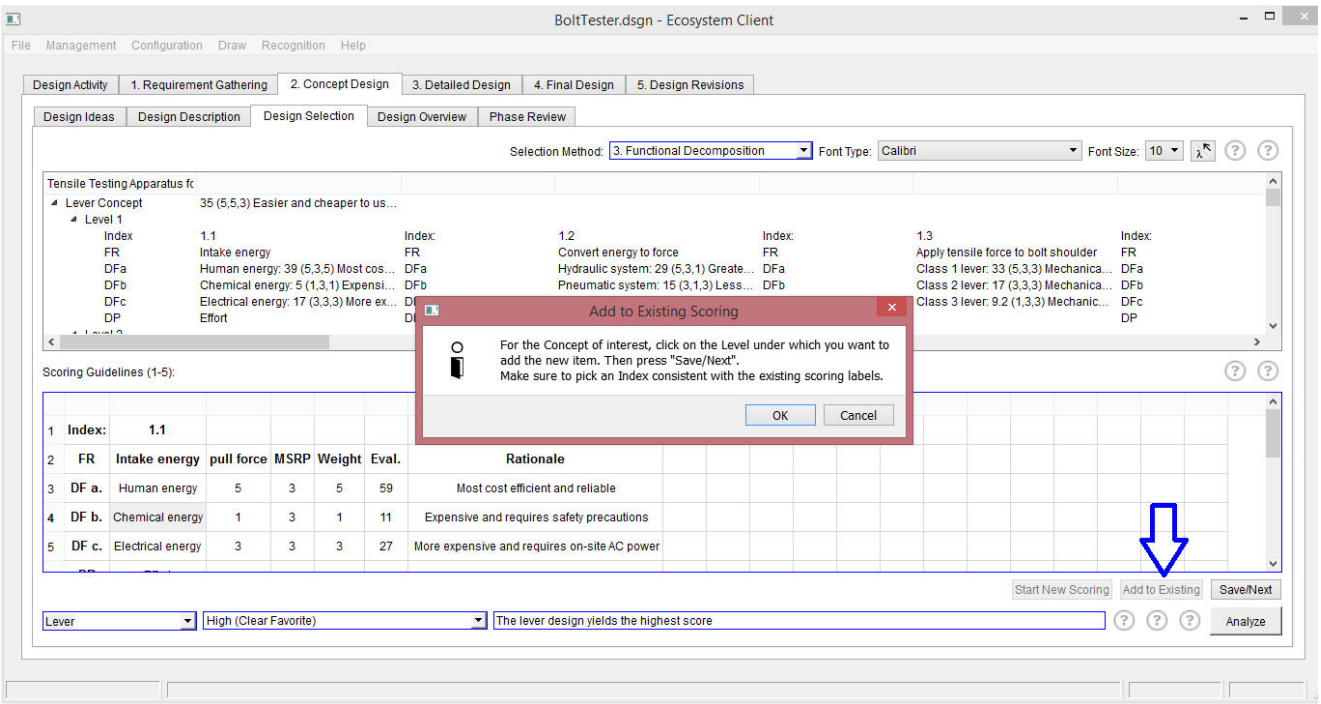


Figure 50: ‘Add to Existing’ enables designers to add new entities to existing scoring results.

Design Parameter Table

The purpose of the Design Parameter table, shown in Figure 52, is to shed light on the reason for the existence of given design parameters, so that one can trace the existence of the design parameters back to particular customers. The design parameters, and most of the other content in the Design Parameter table, are auto-populated from the functional decomposition. In the Notes section, you can offer clarifications as to why given design parameters exist.

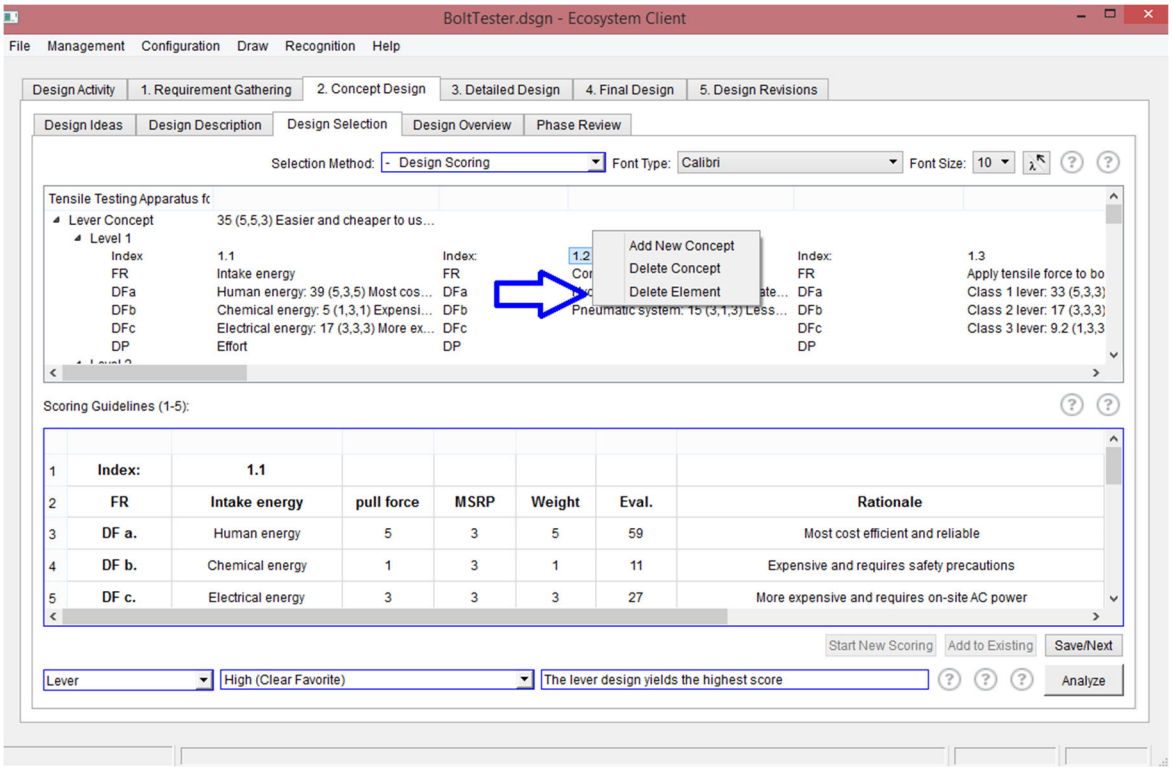


Figure 51: 'Delete Element' allows designers to delete an element from existing scoring results.

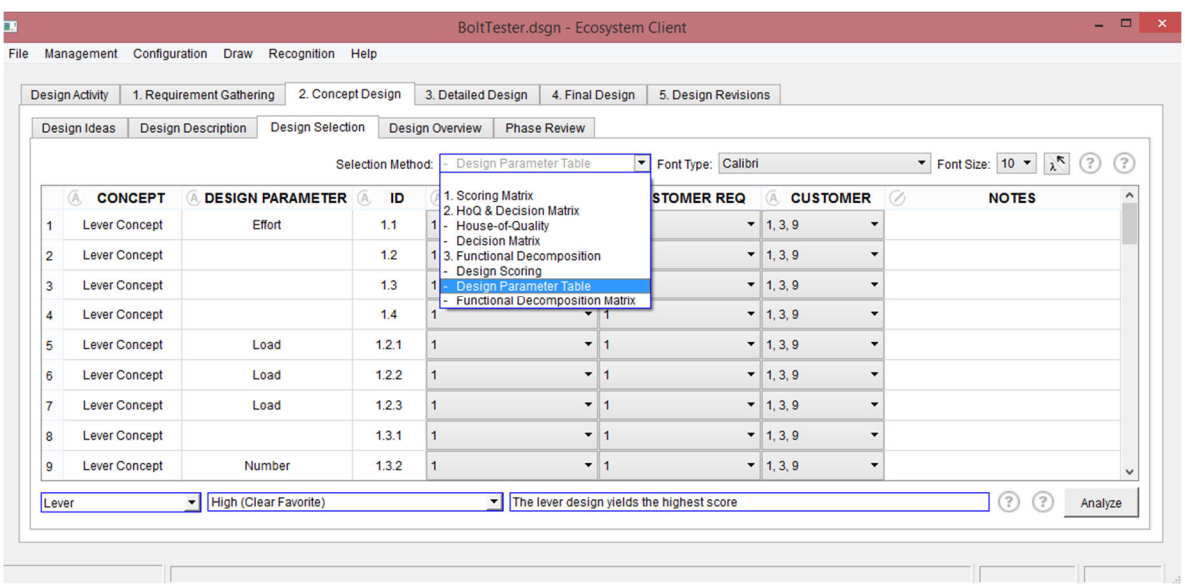


Figure 52: The Design Parameter table for the bolt tester example.

Functional Decomposition Matrix

Figure 53 provides an illustration of the Functional Decomposition matrix for the bolt tester example. The weights are auto-populated from the House-of-Quality matrix, but the scores on the purple background auto-populated from the functional decomposition. The purple background represents design targets included in the objective function for the functional decomposition (in the Engineering Requirement tab). Note that the default configuration assumes all the design targets are included in the objective function.

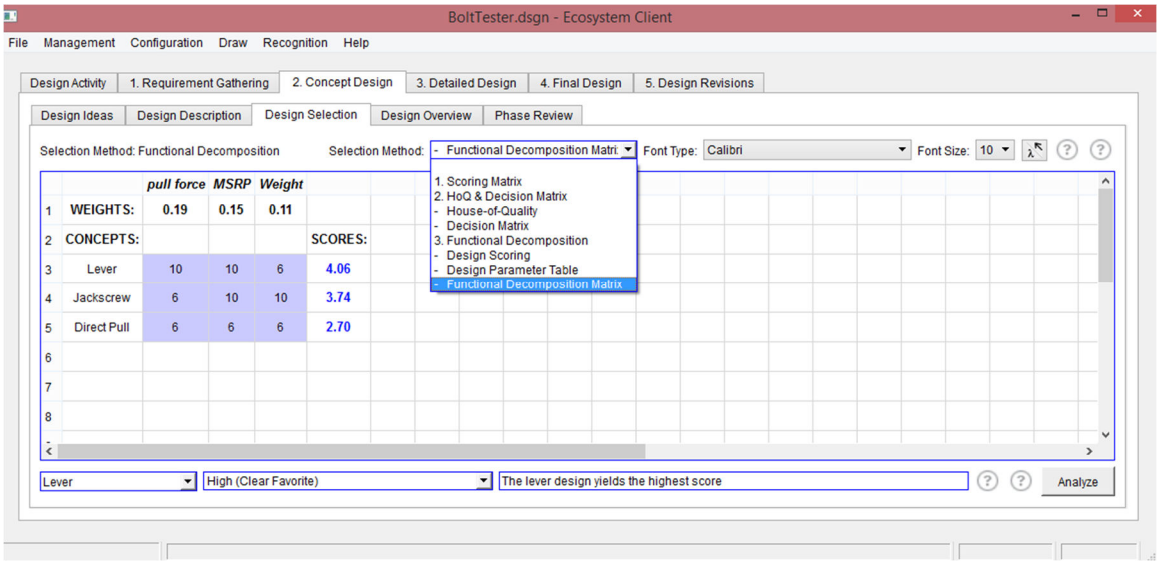


Figure 53: Functional Decomposition matrix from the bolt tester example (single table display).

Concept Design Selected

Here you can simply list the design with the highest overall score.

Design Overview

The purpose of the Design Overview tab is twofold:

1. To capture narration outlining further specifics (context) related to the designs considered.
2. To provide a venue for conduct comparison between the different design selection methods considered.

In the narration, designers can reflect on the requirements, further compare and contrast the solution candidates considered, or summarize the decisions made. If designers completed some mock-up models, for example using glue, paper, wood or Styrofoam, to develop a sense of how well things fit together, designers can comment on the integration in the narration. Alternatively, they can specify a new design idea in the Design Description tab titled "Integration" and add the pertinent text and pictures.

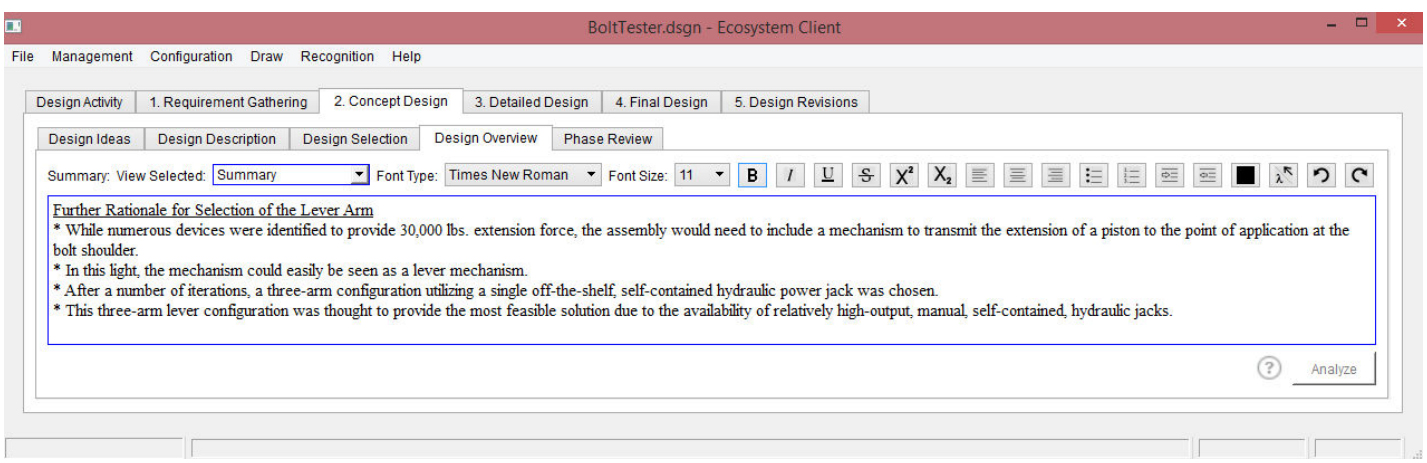


Figure 54: The Design Overview tab for the bolt tester example.

Phase Review

The purpose of the Phase Review tab, shown in Figure 55, is to concisely specify the deliverables comprising the design point at the end of the Concept Design phase. The expected

deliverable from the Concept Design phase is a complete conceptual model of the design. It can consist of a functional model along with supporting sketches and description. Before moving on to the Detailed Design, we encourage you to list test related observations from the Concept Design phase. By referencing the Deliverables in the Schedule dialog, you can assign a date to the design point entities listed.

Gate Review

The purpose of the Gate Review tab, shown in Figure 56, is to concisely specify the deliverables corresponding to phase review at the end of the Concept Design phase, indicate the level of completion, and capture the associated explanations.

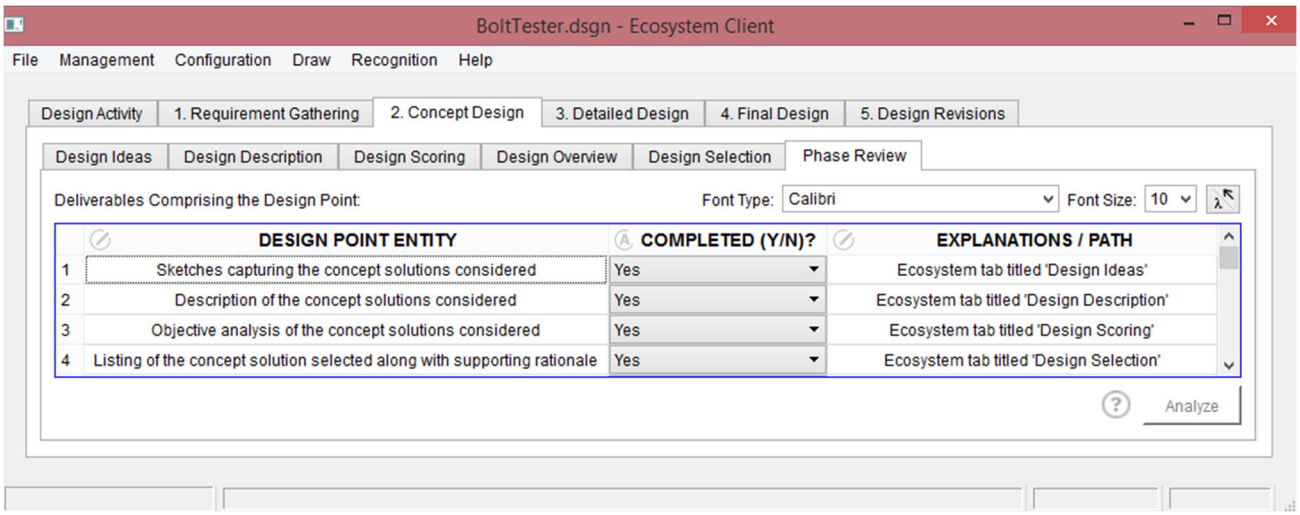


Figure 55: The Phase Review tab from the Concept Design phase.

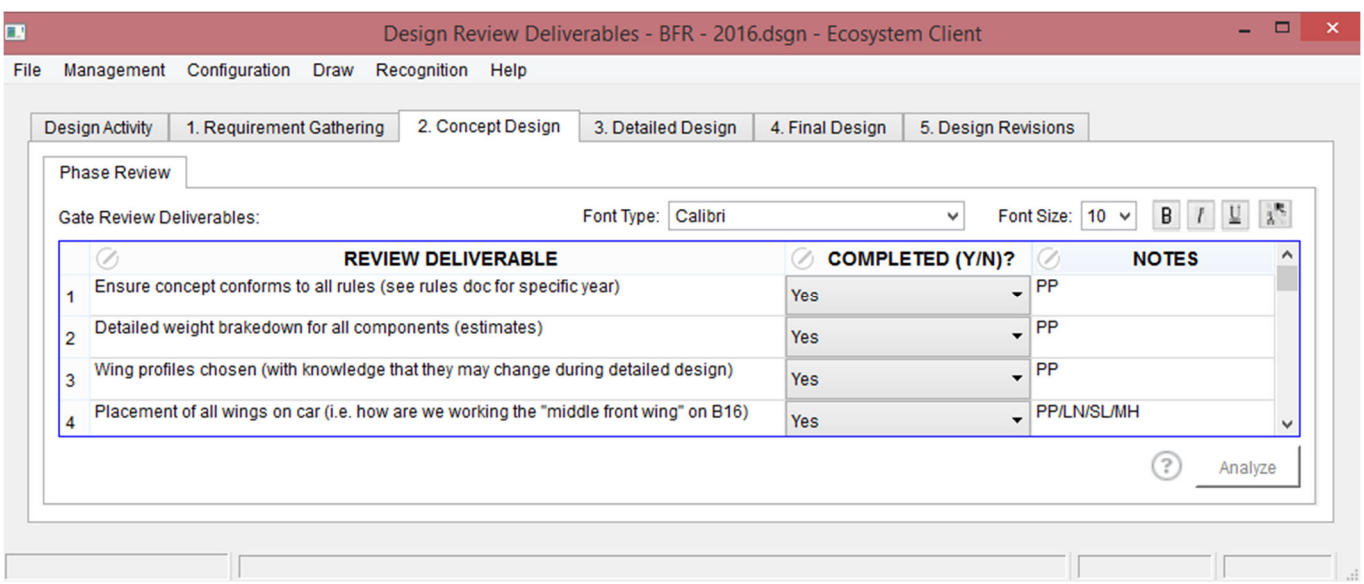


Figure 56: Phase Review tab capturing design review deliverables from a student race car design team.

Chapter 7: Detailed Design

Risk Identification

The purpose of the Risk Identification tab, presented in Figure 57, is to provide facilities for identification, analysis, management (tracking) and mitigation of the risk factors pertinent to the design. Each risk factor is associated with a part, at least one design feature and at least one requirement. The user is expected to specify the severity of the risk factors as well as a mitigation method.

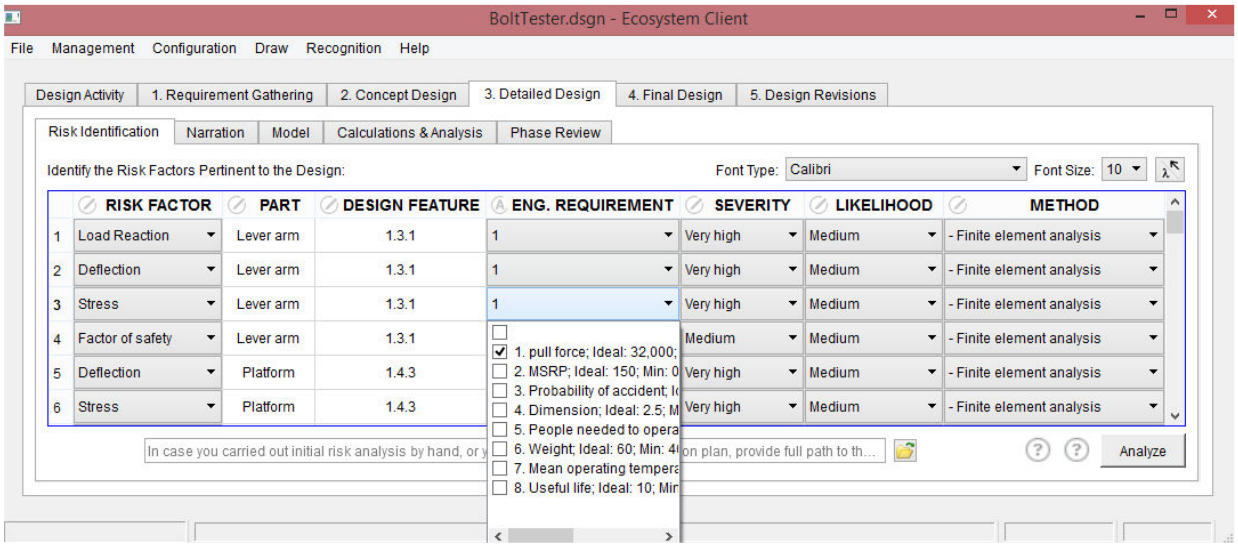


Figure 57: Risk Identification tab for the bolt tester example (from the Detailed Design phase).

Figure 58 provides an example of a meaningful alert provided by the Ecosystem.

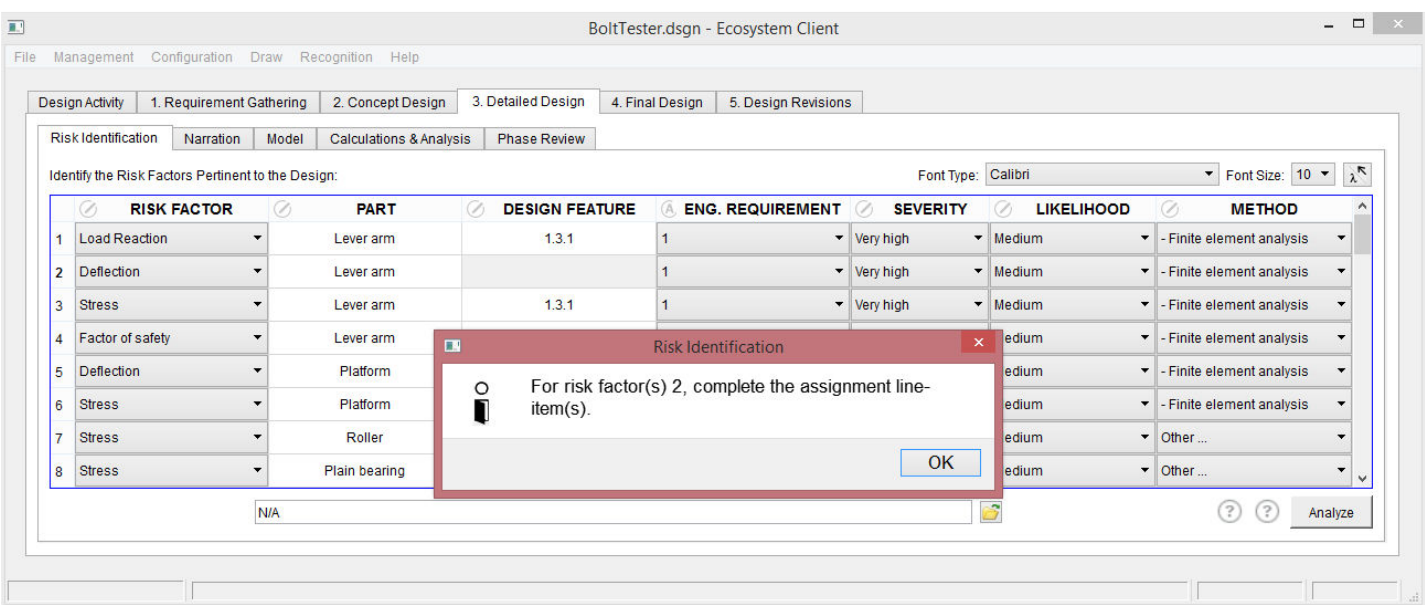


Figure 58: Sample alert from the Risk Identification tab.

Narration

The Narration tab, shown in Figure 59 for the bolt tester, provides the user with the opportunity to expand on the implementation and disclose big picture findings. Here you can expand on the decision made and provide rationale. Note that the engineering requirements should be the primary reference for the detailed design (more so than anything else).

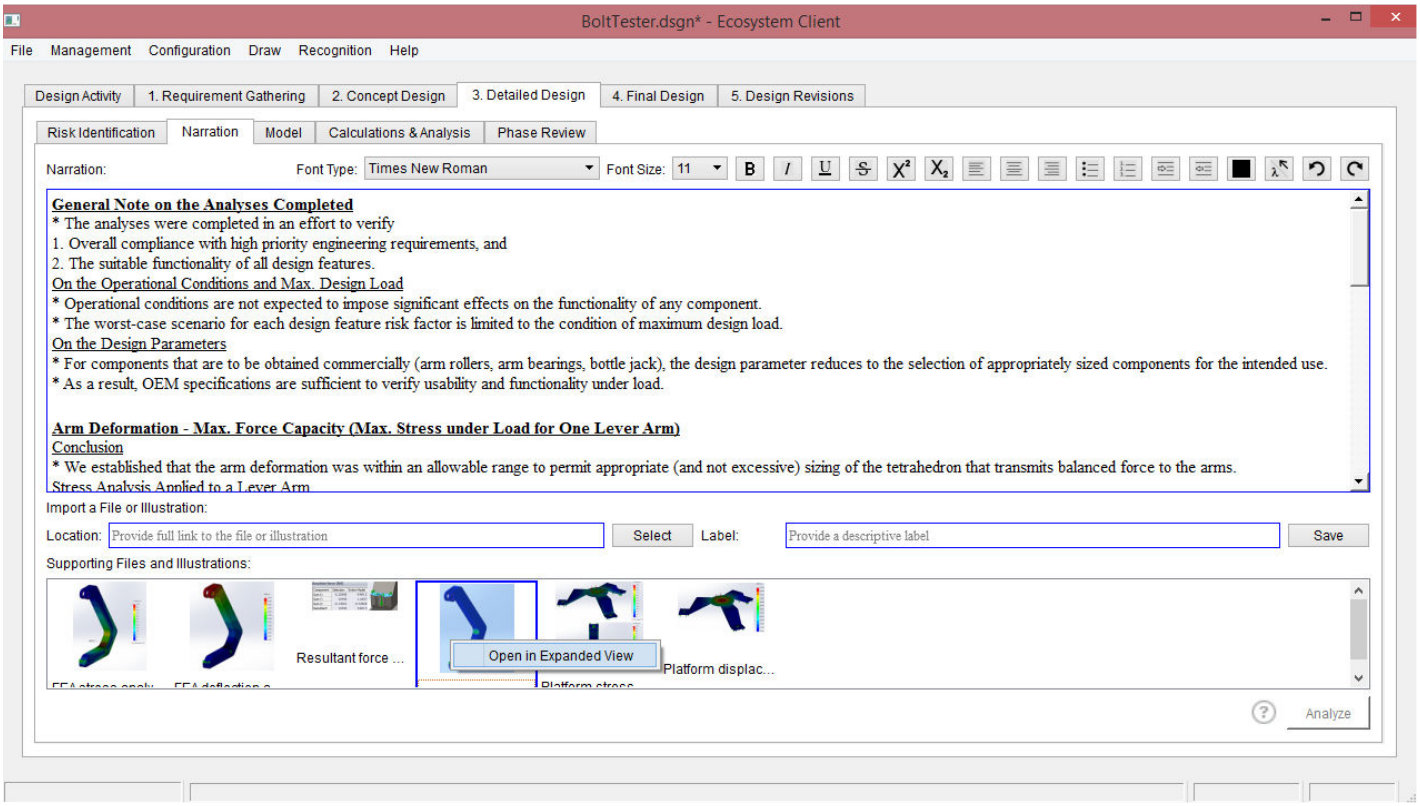


Figure 59: The Narration tab for the bolt tester example (from the Detailed Design phase).

Model

Features of Interest

- Automatic importing of components associated with a SolidWorks assembly.
- Automatic visualization of meta-data (mass properties) of SolidWorks components.
- Automatic image extraction and visualization (based on recursive file search).
- Ability to automatically visualize both the part and ability files comprising a solid model.
- Visualization support for SolidWorks (visualization of part files, of assembly files or of both part and assembly files), PTC Creo, CATIA v.5, AutoCAD and Unigraphics NX drawing files.
- Through a double-click, the Ecosystem furnishes the user with the ability to open up the assembly or part files of interest in the e-Drawings Viewer for thorough inspection in 3D.
- Two databases of Solidworks part and assembly files (common components) are included.
  - Hence, users may not need to design components from scratch.
  - Additional CAD drawings (3D models) may be available from McMaster – Carr free of charge: http://www.mcmaster.com/help/drawingsandmodels.asp

Importing Components and Visualizing Meta-Data from a SolidWorks Assembly

The Model tab allows designers to import SolidWorks assemblies, and visualize meta-data (mostly related to the mass properties), as shown in Figure 60. While the Ecosystem is design

to support the importing of any SolidWorks assembly, the automatic requirement verification of weight and dimension assumes the designer imports the master assembly. Once the master assembly has been imported, we recommend the designer invokes the automatic verification of weight and dimensions by enabling the checkbox titled “Master Assembly Ready for Assessment”.

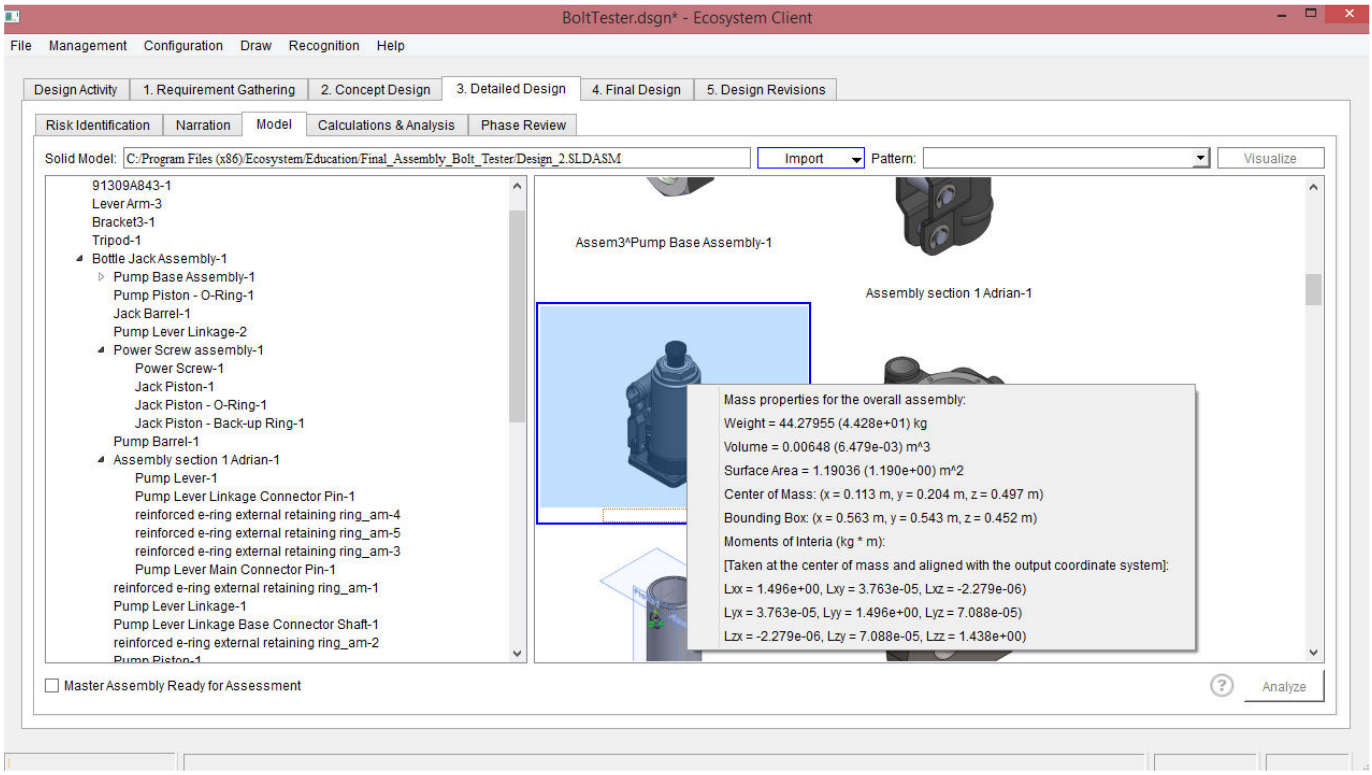


Figure 60: Master assembly from the bolt tester project imported into the Ecosystem.

Importing and Visualizing Parts or Assemblies from a Root Directory

The model tab is also the place for archiving and visualizing the parts & assemblies comprising the solid model. It provides seamless interface to the e-Drawings Viewer, SolidWorks or CATIA, for thorough inspection of part or assembly files of interest in 3D, or even for editing.

The e-Drawings Viewer can be installed for free from[2]

www.edrawingsviewer.com/ed/download.htm.

Upon the user specifying the ‘Root Directory’ for the search under ‘Part Management’ in Figure 61, as well as the ‘Pattern’ of interest, the user simply needs to press ‘Update Recursive to launch the recursive file search. Even if the design team kept the design files in multiple directories, the common root directory can be specified (as long as these directories were hosted as a part of a single file system). In the unlikely case, the design files were distributed across different file systems, the recursive search could be repeated for each file system.

The automatic image extraction can handle SolidWorks 2017 or versions. Separate algorithms are used to extract images from SolidWorks 2014 (or earlier) vs. from SolidWorks 2015 (or later).

[2] Upon installation, opt for ‘eDrawings Viewer only’ as well as ‘All of the above, plus support for SolidWorks shader data’. The total file size should be 242.7 MB.

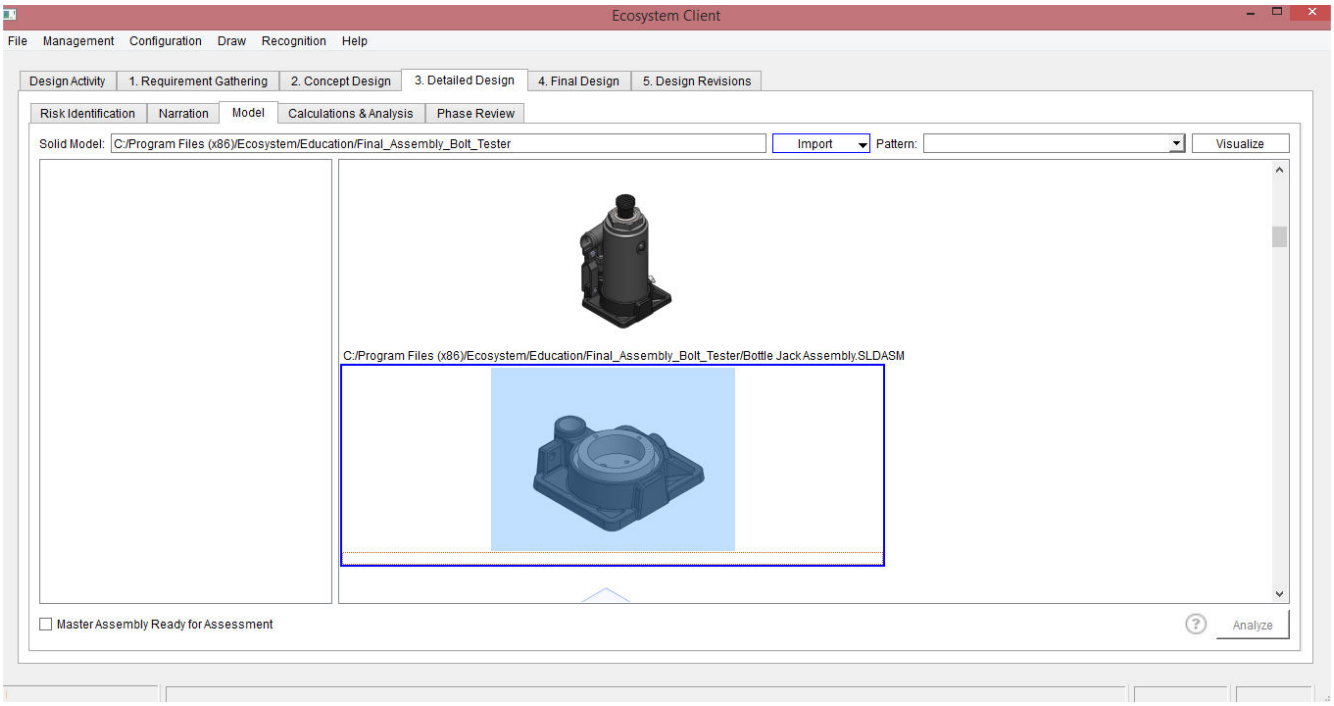


Figure 61: The Model tab for the bolt tester example (from the Detailed Design phase).

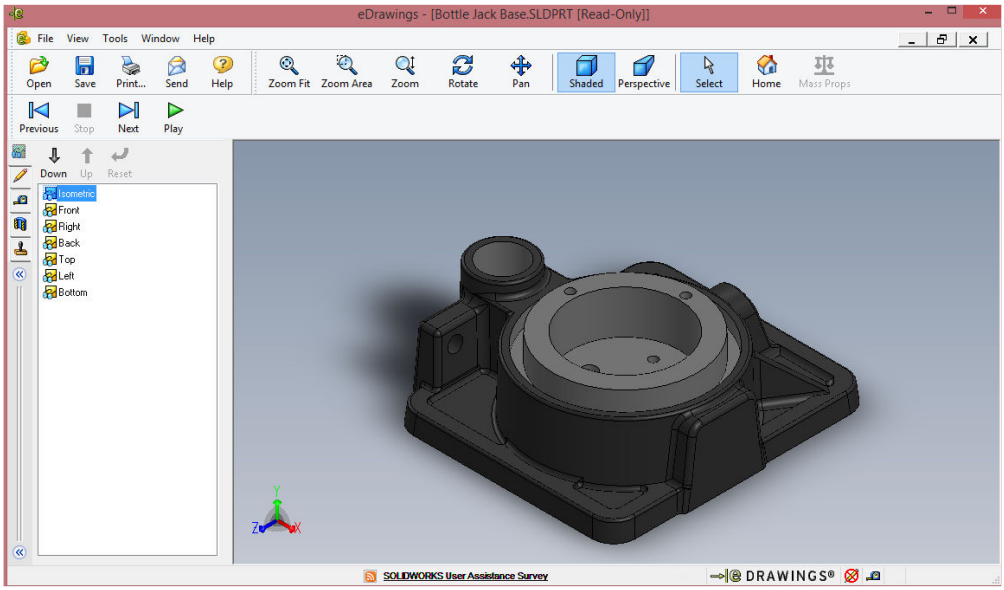


Figure 62: SolidWorks part and assembly files can be opened up in the (free) e-Drawings Viewer, upon double-clicking on the thumbnails in the Model tab, for thorough 3D review. Part and assembly files from PTC Creo and AutoCAD can be visualized in a similar fashion. The Ecosystem also provides automatic visualization support for CATIA v.5.

More on the Interface with SolidWorks and CATIA v.5

In case the designer wishes to modify a design file of interest, the designer can right-click on a search hit of interest. This brings up the context menu shown in Figure 63. Figure 64 presents a design file in SolidWorks that has been launched through this mean.

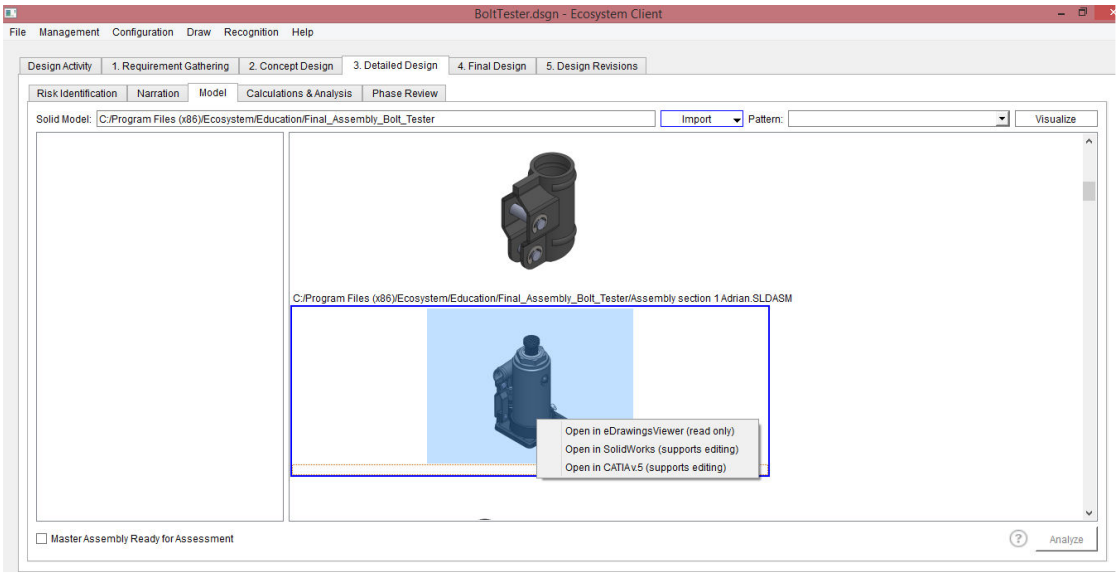


Figure 63: Context menu for manually selecting which development tool to launch from the Ecosystem.

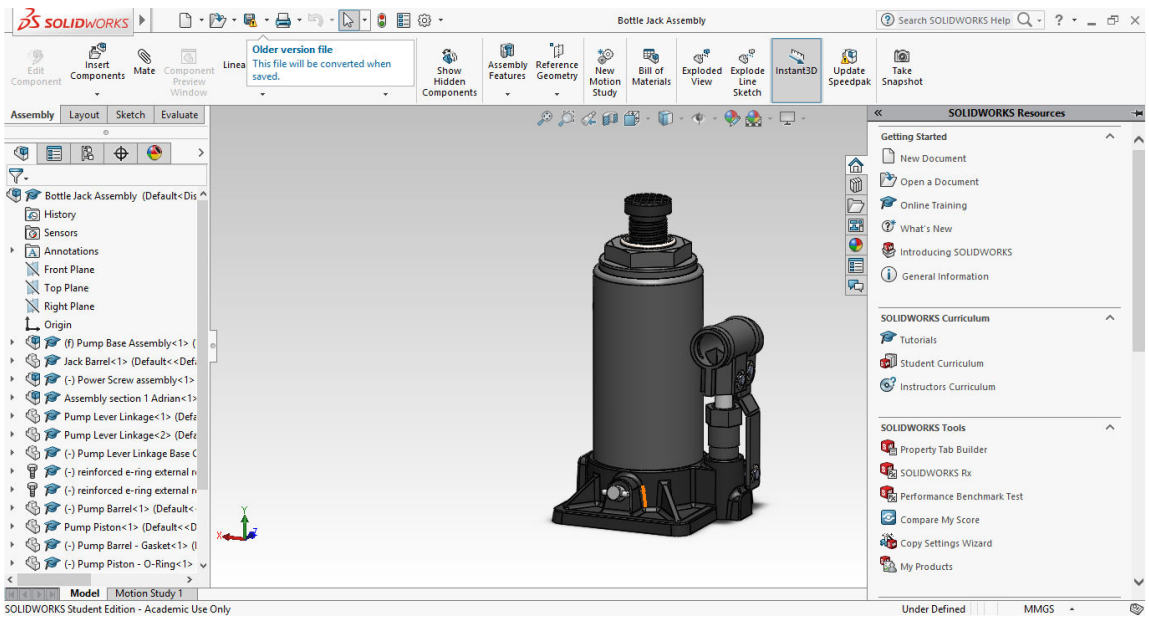


Figure 64: SolidWorks launched from manual selection in the context menu. Here the designer can modify the design file of interest at will.

Backward Compatibility

Table 5 outlines the capabilities of the real-time image extraction in terms of backward compatibility.

Table 5: Capabilities of the real-time image extraction in terms of backward compatibility.

Vendor	Versions	Support
AutoCAD	Back to 2010	Image extraction supported
CATIA	v.5 & v.6	Image extraction supported
NX Unigraphics	Back to 2010	Image extraction supported
PTC Creo	Back to 2010	Image extraction supported
SolidWorks	Pre-2015	Image extraction supported (fast)
	2015 or post	Image extraction supported (slightly slower)

Future Proofing

- For SolidWorks 2015 and later versions, the real-time image extraction utilizes the SolidWorks API.
- We hard code a license key for unlocking the API into our software.
- Being a certified SolidWorks Solution Provider, Imagars can complete a simply web form, for each new release of SolidWorks, get a new license key e-mailed back to us, and plug into the SW.
- Assuming the API to SolidWorks remains largely the same, we have reason to believe that the real-time image extraction will extend to future versions of SolidWorks.

Calculations & Analysis

The purpose of the Calculations & Analysis is to mitigate the risk factors identified. As Figure 65 illustrates for the bolt tester example, the analyses completed correlate directly with the risk factors identified (from Figure 57). If you need to alter the content of these columns, we suggest the designer goes back to the Risk Identification tab and modifies there. In addition, Figure 65 contains two new columns, for 'Analysis Completed' and 'Outcome'. The Analyses Completed column can contain an illustrative figure, a textual explanation or even a simple equation. By simply double-clicking on the 'Analysis Completed', the user can upload an illustrative figure. If issues were discovered during the analysis, the 'Outcome' column is the place for pertinent reporting. In case an analysis was completed, without an corresponding image being readily available for uploading, the user can add a textual explanation or a reference link. The Calculations & Analysis tab also provides means for importing the file capturing the analysis. This could be an output file, e.g., from Matlab or ANSYS.

Features of Interest

Versatile column for "Analysis Completed", one supporting

- the uploading of an image capturing the results,
- the user typing in brief explanation (text),
- the ability to label uploaded images,
- the ability to delete an uploaded image simply by clicking on the image and hitting 'Delete'.
- the ability to a file, e.g., a MS Word file or an Excel sheet containing supporting calculations,
- the user pasting in a link by hand (as a text string),
- dynamic adjustment of the row height to fit the content.

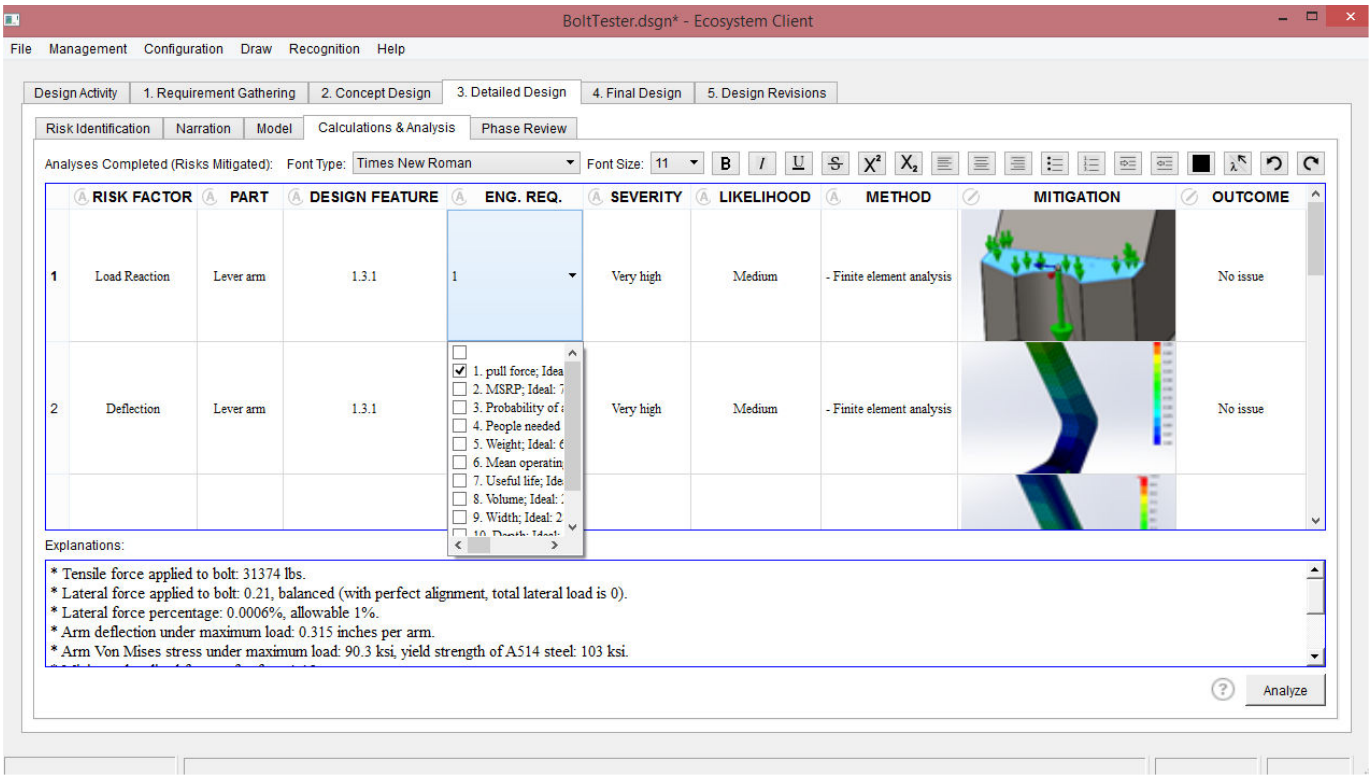


Figure 65: The Calculations & Analysis tab for the bolt tester example.

Phase Review

The purpose of the Deliverables tab, shown in Figure 66, is to concisely specify the deliverables comprising the design point at the end of the Detailed Design phase. The expected deliverable from the Detailed Design phase is a physical manifestation of the design. Sample entities include the solid model, the risks identified, the risk analysis or the project schedule. You are welcome to add more, as/if appropriate for your project. Before moving on to the Final Design, we encourage you to list test related observations from the Detailed Design phase. By referencing the Deliverables in the Schedule dialog, you can assign a date to the Deliverables listed.

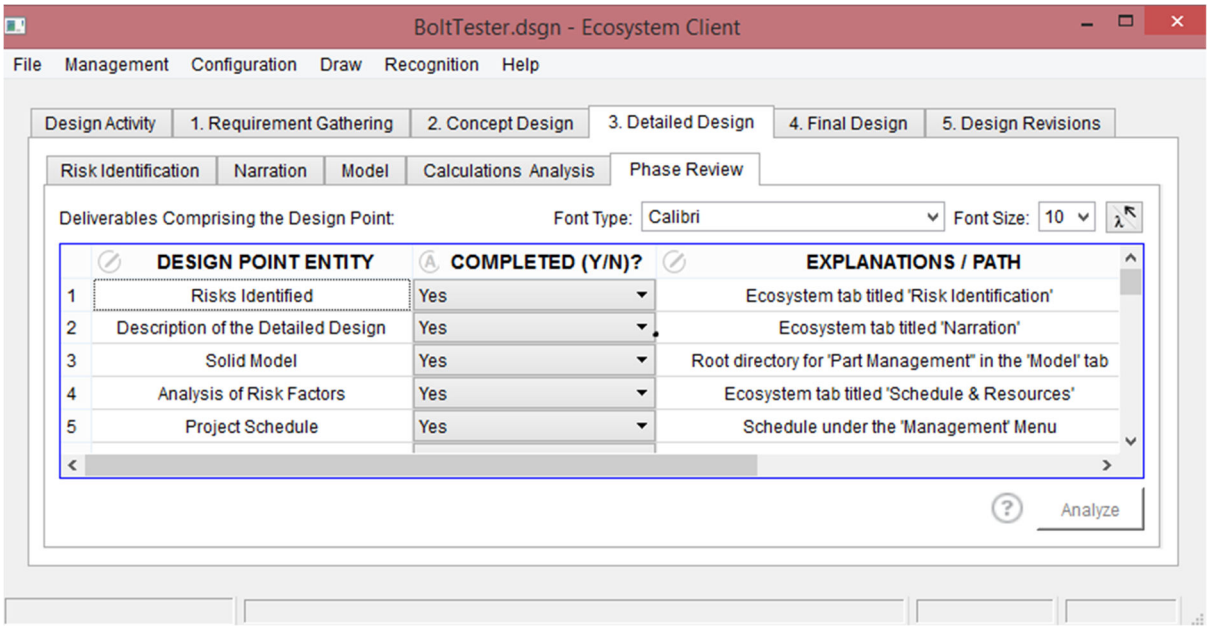


Figure 66: The Phase Review tab from the Detailed Design phase.

Gate Review

The purpose of the Phase Review tab, shown in Figure 67, is to concisely specify the deliverables corresponding to phase review at the end of the Detailed Design phase, indicate the level of completion, and capture the associated explanations. The Notes section can capture comments pertinent to specific Phase Review Deliverables. Or it may contain notes on level of attainment of specific requirements, changes in requirements, etc.

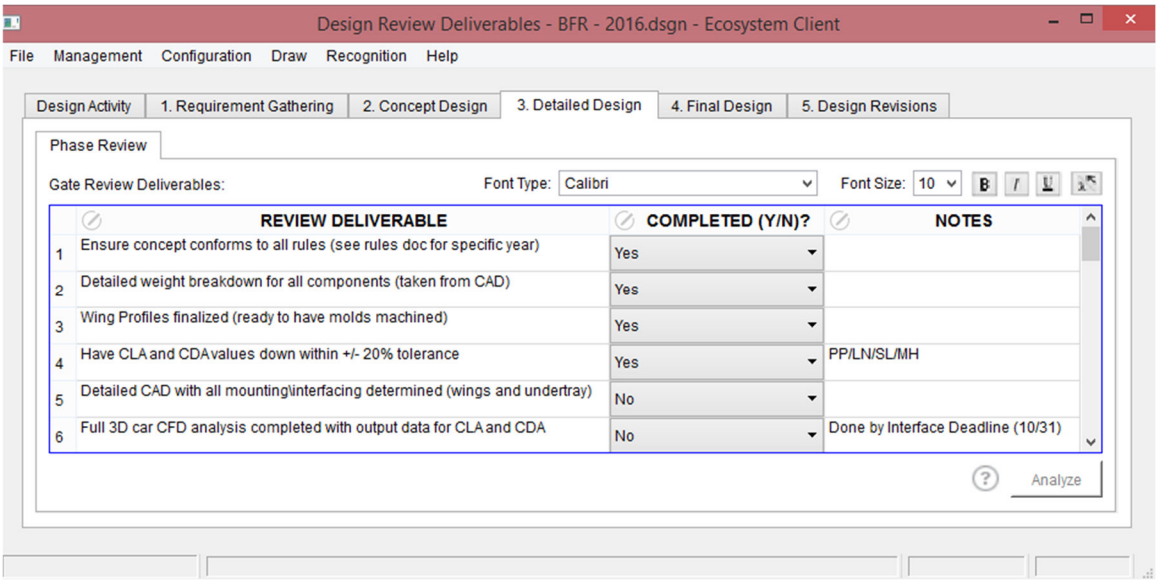


Figure 67: Gate Review tab capturing design review deliverables from a student race car design team.

Chapter 8: Final Design

Narration

The “Narration” tab allows expansion on the overview of process steps completed to date. This tab is materially similar to the “Narration” tab of the Detailed Design phase. It is intended as a general introduction for the final design phase, which is generally thought of as preparation for production.

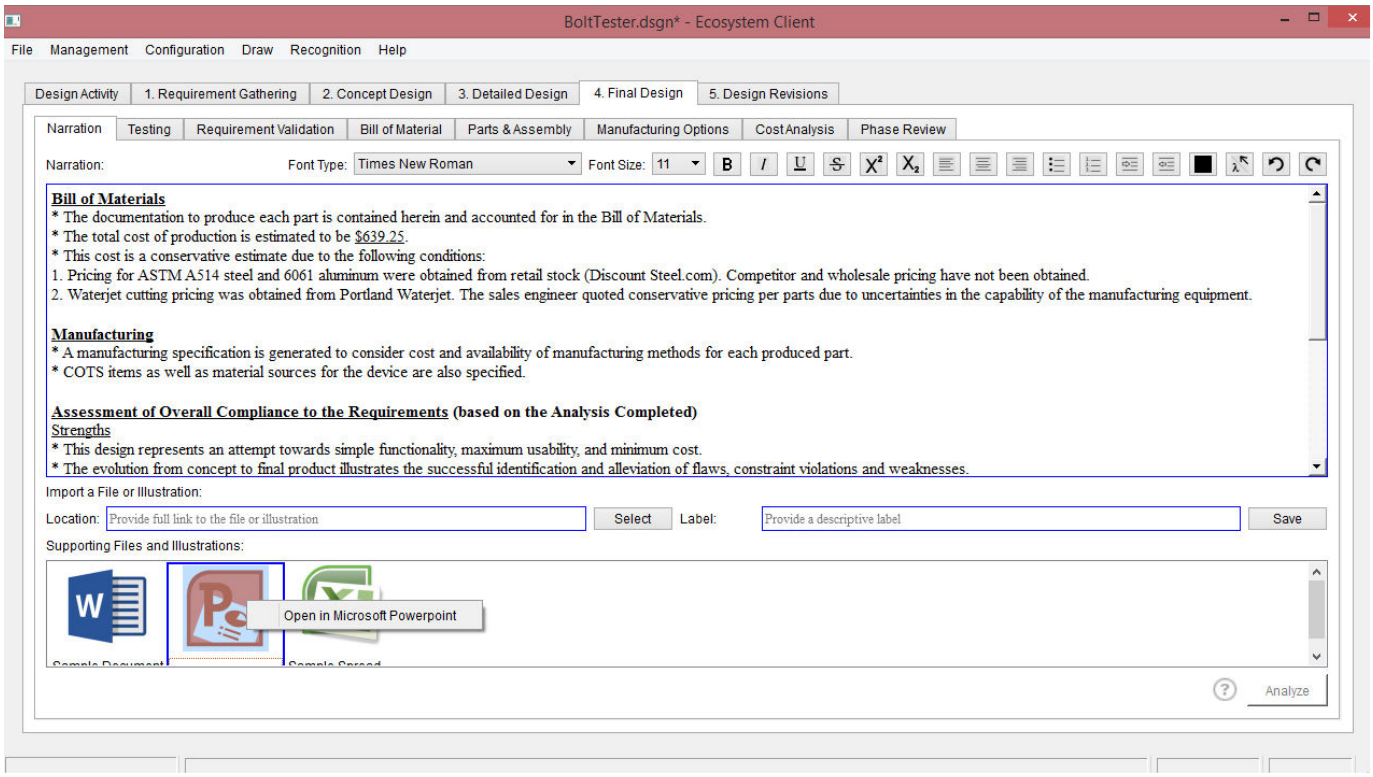


Figure 68: The Narration tab for the bolt tester example (from the Final Design phase).

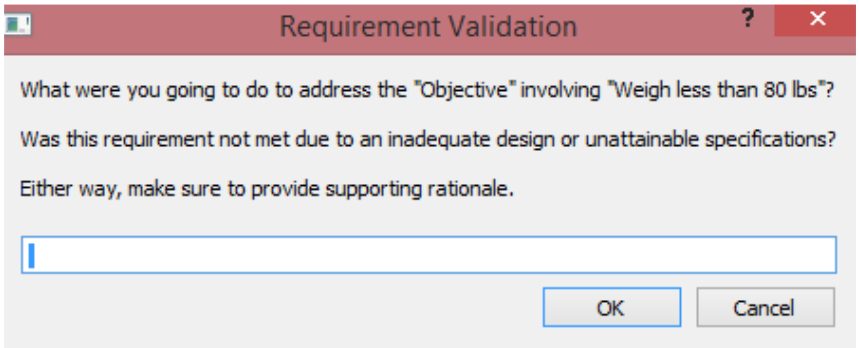


Figure 69: Alert resulting from the fact that the requirement on the bolt tester weight not being satisfied.

Testing

In the Testing tab, the testing assignments needed to validate remaining specifications are listed, along with the requirements and/or risk factors that the tests are designed to address. If

no requirement or risk factor is specified, the justification becomes very important. The justification could involve usability, ergonomic aspects, etc. It is also important to list the design feature that the testing assignments are aimed at. Even though a facility for formal testing is offered in the Final Design phase, you don't need to defer design verification till the Final Design. We encourage you to draw upon, and list here, test related observations from the earlier design phases (e.g., from the phase reviews).

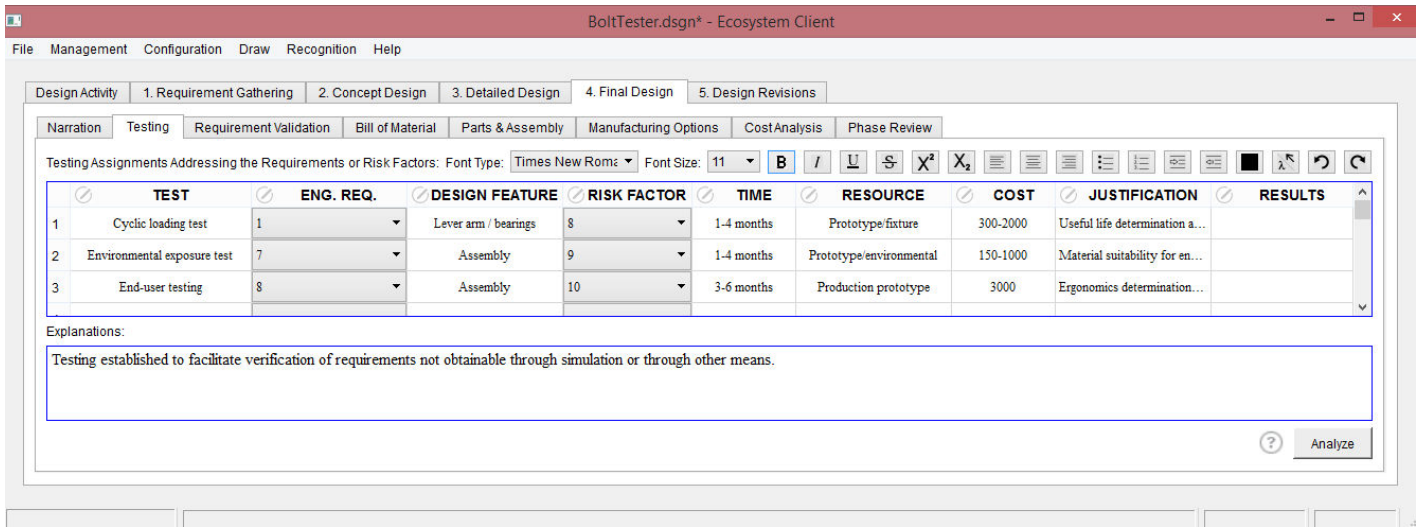


Figure 70: The Testing tab for the bolt tester example (from the Final Design phase).

Requirement Validation

The results from the Detailed Design phase correlate to a binary satisfaction of each requirement in the Requirement Validation tab, as shown in Figure 71. In case of the bolt tester, the objective weight is not satisfied because the weight of the bolt tester is found to be 98.5 lbs. (18.5 lbs. above the limit). When a requirement is deemed Not Satisfied, the Ecosystem automatically issues an alert prompting the user to specify whether this was due to an inadequate design or unattainable specifications (see Figure 69). The METHOD column refers to the method used to validate the requirements. It can, for example, be by testing, through simulation, through analysis, or through some type of similarity comparison.

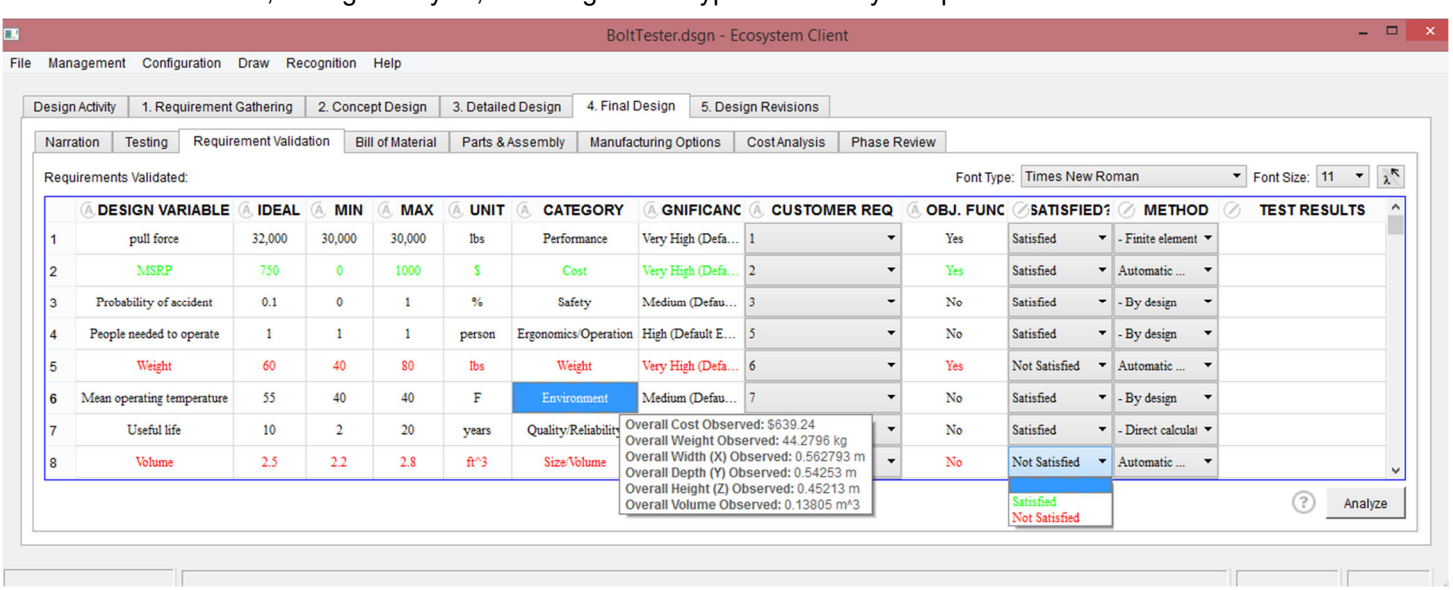


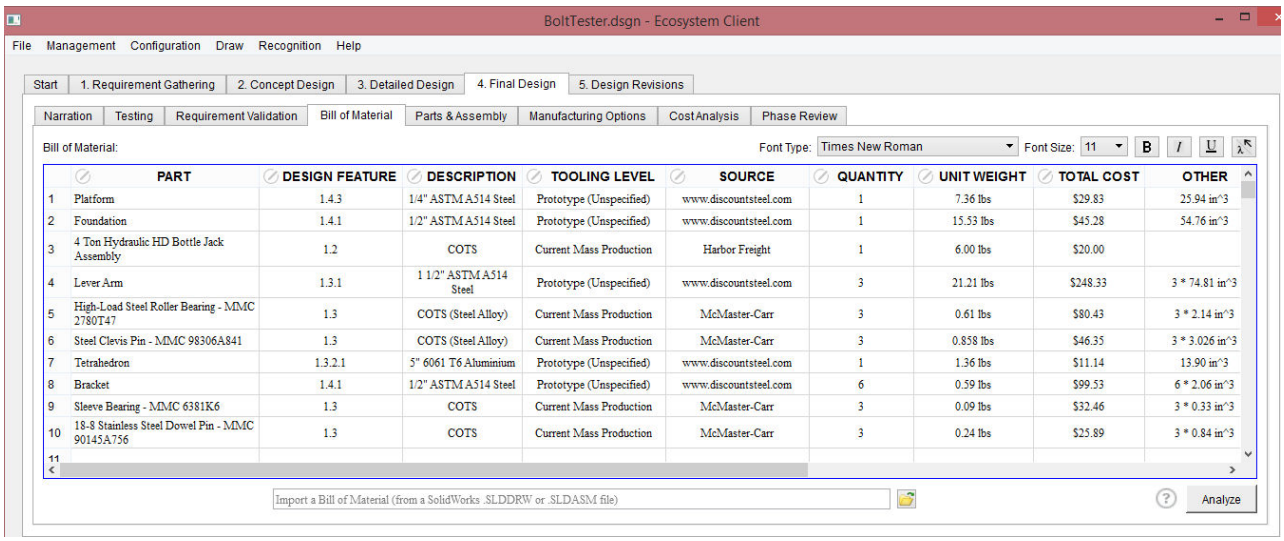
Figure 71: Requirement Validation tab for the bolt tester example (from the Final Design phase).

Bill of Material

The Bill of Material tab, shown in Figure 72, allows input of identifying and accountability attributes for each part comprising the design. It is essential to assign a design feature, material, tooling level and source associated with each part. The Description column can list the material. For definition of the tooling levels, refer to

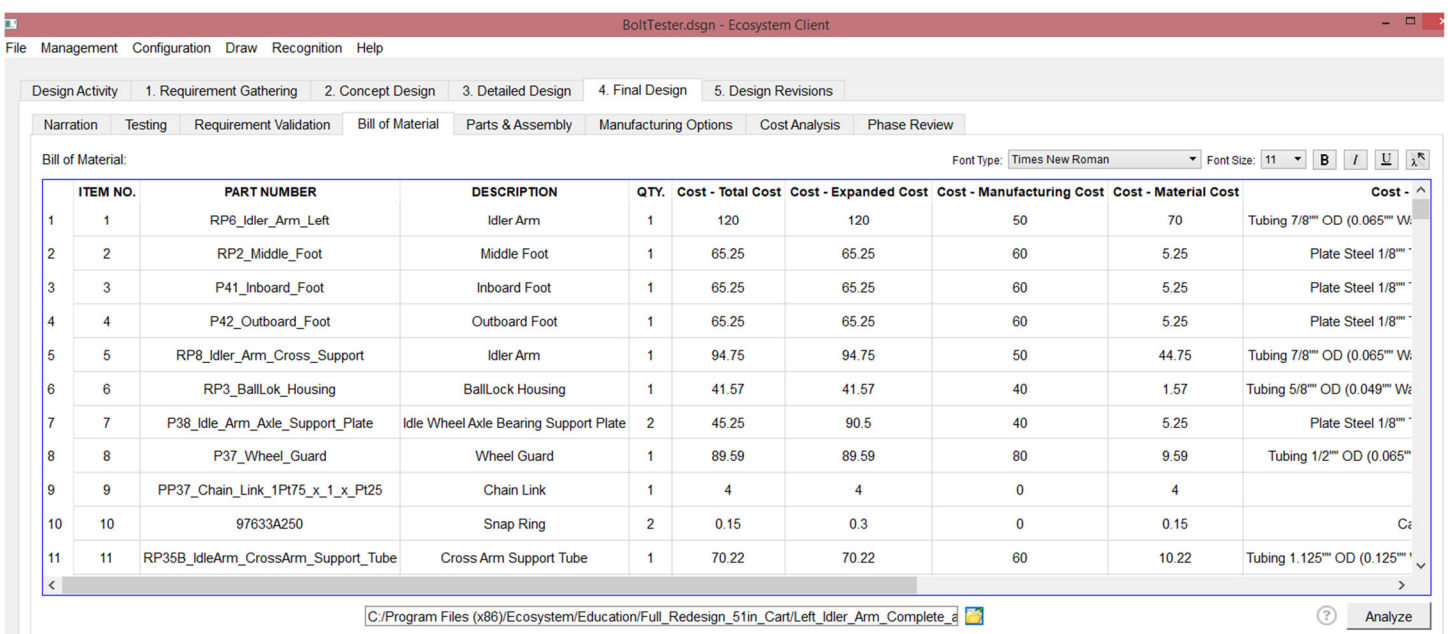
http://www.imagars.com/PartMaturationExpectations.pdf.

Note that the Ecosystem 1.20 SW supports importing of Bill of Materials from both SolidWorks drawing and SolidWorks assembly files, as illustrated in Figure 73. In this case, the column headers are updated to reflect the imported content. Figure 74 presents a sample alert related to automatic verification of a system cost requirement.



	PART	DESIGN FEATURE	DESCRIPTION	TOOLING LEVEL	SOURCE	QUANTITY	UNIT WEIGHT	TOTAL COST	OTHER
1	Platform	1.4.3	1/4" ASTM A514 Steel	Prototype (Unspecified)	www.discountsteel.com	1	7.36 lbs	$29.83	25.94 in^3
2	Foundation	1.4.1	1/2" ASTM A514 Steel	Prototype (Unspecified)	www.discountsteel.com	1	15.53 lbs	$45.28	54.76 in^3
3	4 Ton Hydraulic HD Bottle Jack Assembly	1.2	COTS	Current Mass Production	Harbor Freight	1	6.00 lbs	$20.00	
4	Lever Arm	1.3.1	1 1/2" ASTM A514 Steel	Prototype (Unspecified)	www.discountsteel.com	3	21.21 lbs	$248.33	3 * 74.81 in^3
5	High-Load Steel Roller Bearing - MMC 2780T47	1.3	COTS (Steel Alloy)	Current Mass Production	McMaster-Carr	3	0.61 lbs	$80.43	3 * 2.14 in^3
6	Steel Clevis Pin - MMC 98306A841	1.3	COTS (Steel Alloy)	Current Mass Production	McMaster-Carr	3	0.858 lbs	$46.35	3 * 3.026 in^3
7	Tetrahedron	1.3.2.1	5" 6061 T6 Aluminium	Prototype (Unspecified)	www.discountsteel.com	1	1.36 lbs	$11.14	13.90 in^3
8	Bracket	1.4.1	1/2" ASTM A514 Steel	Prototype (Unspecified)	www.discountsteel.com	6	0.59 lbs	$99.53	6 * 2.06 in^3
9	Sleeve Bearing - MMC 6381K6	1.3	COTS	Current Mass Production	McMaster-Carr	3	0.09 lbs	$32.46	3 * 0.33 in^3
10	18-8 Stainless Steel Dowel Pin - MMC 90145A756	1.3	COTS	Current Mass Production	McMaster-Carr	3	0.24 lbs	$25.89	3 * 0.84 in^3
11									

Figure 72: The Bill of Materials tab for the bolt tester example (from the Final Design phase).



	ITEM NO.	PART NUMBER	DESCRIPTION	QTY.	Cost - Total Cost	Cost - Expanded Cost	Cost - Manufacturing Cost	Cost - Material Cost	Cost -
1	1	RP6_Idler_Arm_Left	Idler Arm	1	120	120	50	70	Tubing 7/8"" OD (0.065"" W
2	2	RP2_Middle_Foot	Middle Foot	1	65.25	65.25	60	5.25	Plate Steel 1/8""
3	3	P41_Inboard_Foot	Inboard Foot	1	65.25	65.25	60	5.25	Plate Steel 1/8""
4	4	P42_Outboard_Foot	Outboard Foot	1	65.25	65.25	60	5.25	Plate Steel 1/8""
5	5	RP8_Idler_Arm_Cross_Support	Idler Arm	1	94.75	94.75	50	44.75	Tubing 7/8"" OD (0.065"" W
6	6	RP3_BallLok_Housing	BallLock Housing	1	41.57	41.57	40	1.57	Tubing 5/8"" OD (0.049"" Wa
7	7	P38_Idle_Arm_Axle_Support_Plate	Idle Wheel Axle Bearing Support Plate	2	45.25	90.5	40	5.25	Plate Steel 1/8""
8	8	P37_Wheel_Guard	Wheel Guard	1	89.59	89.59	80	9.59	Tubing 1/2"" OD (0.065""
9	9	PP37_Chain_Link_1Pt75_x_1_x_Pt25	Chain Link	1	4	4	0	4	
10	10	97633A250	Snap Ring	2	0.15	0.3	0	0.15	Ca
11	11	RP35B_IdleArm_CrossArm_Support_Tube	Cross Arm Support Tube	1	70.22	70.22	60	10.22	Tubing 1.125"" OD (0.125""

Figure 73: Bill of Material imported from a SolidWorks assembly file.

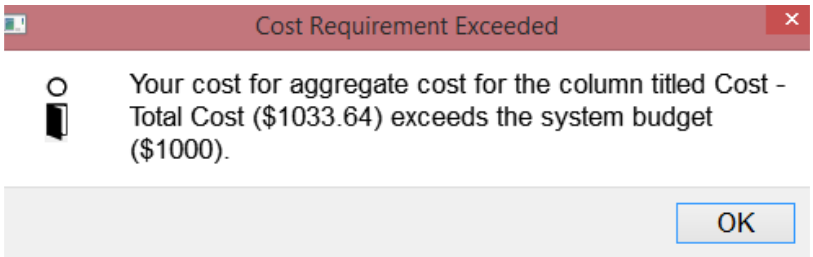


Figure 74: Sample alert resulting from automatic verification of a system cost requirement.

Parts & Assembly

All design features should be accounted for in one way or another in the Parts & Assembly tab, shown in Figure 75. Components that are to be manufactured should have appropriate production documentation provided in graphical form. Parts that are to be purchased should be mentioned with at least one usable source. By right-clicking on a PDF, you should be able to open it up in the Adobe Acrobat Reader (if installed). For enlarged view of a raster image, simply double-click on the image of interest. The user can delete any given image from the list by simply clicking on the image or PDF and hitting the 'Delete' button.

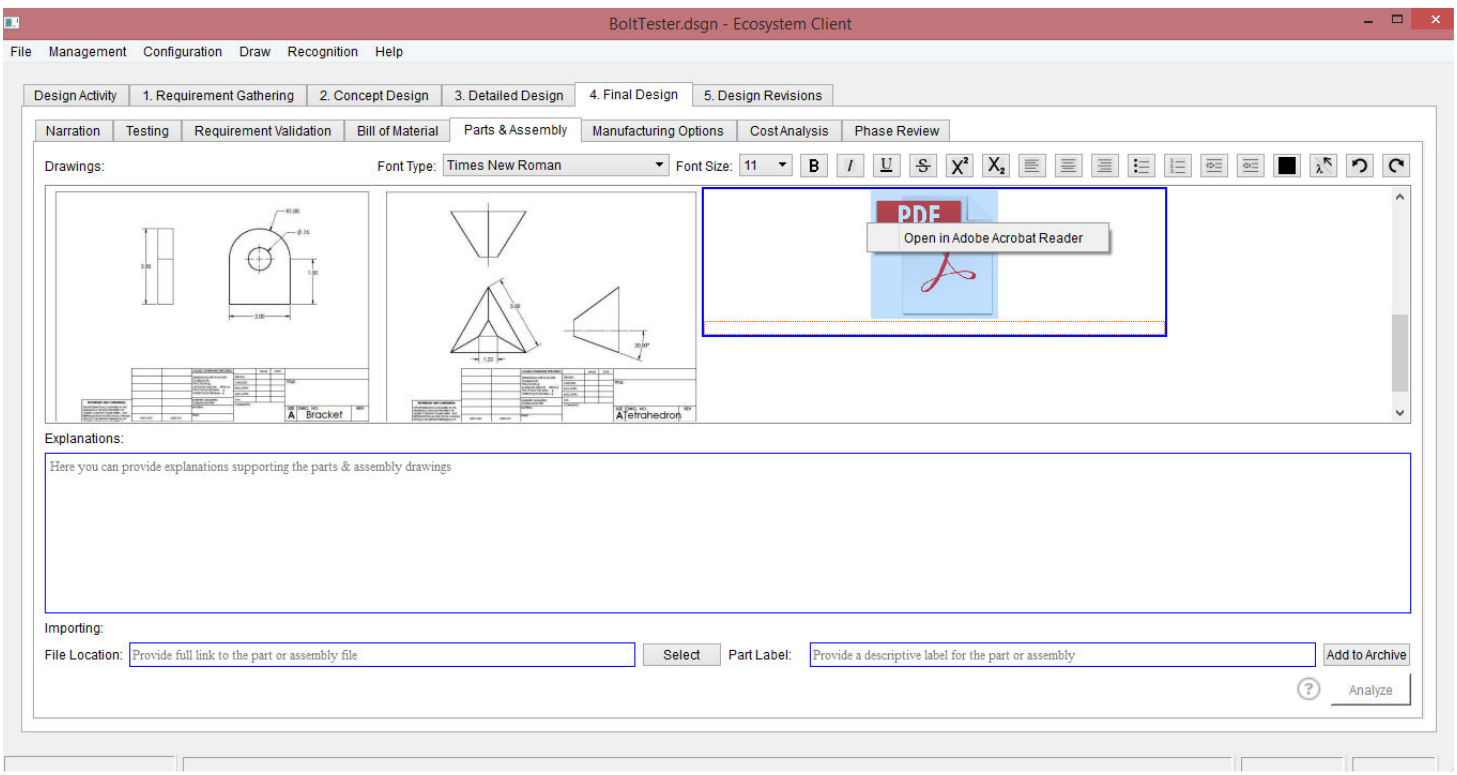


Figure 75: The Parts & Assembly tab for the bolt tester example (from the Final Design phase).

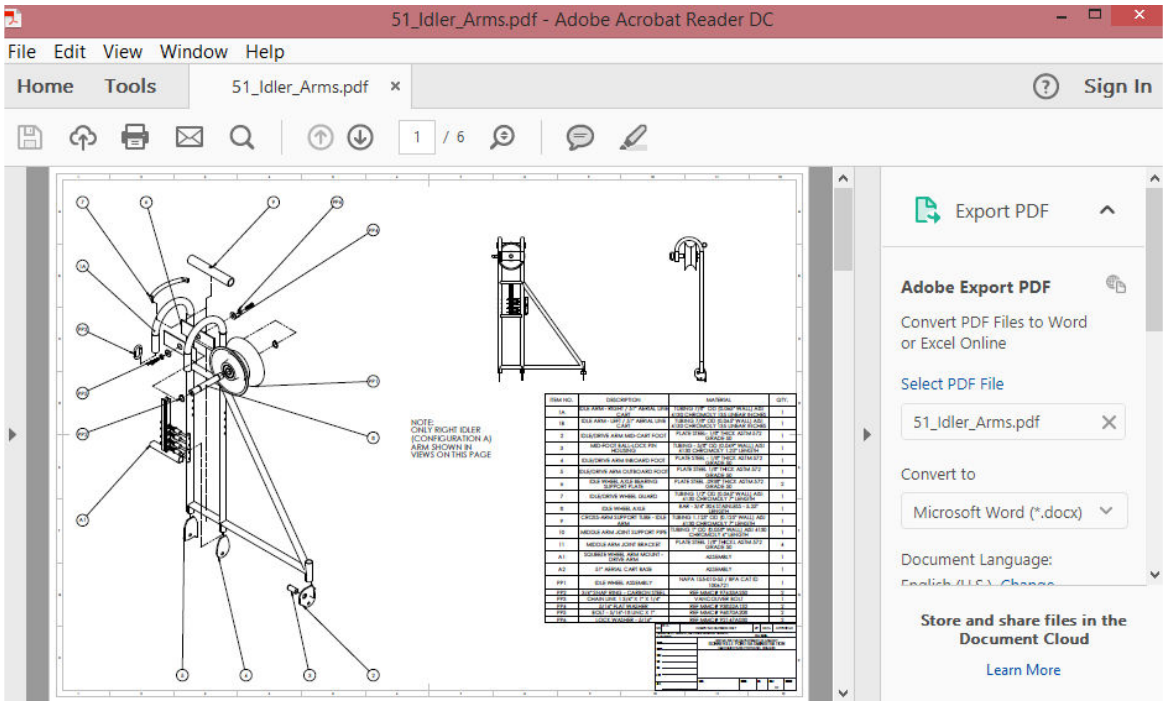


Figure 76: PDF file from the Spacer Cart example accessed through the interface with Adobe Acrobat provided in the Parts & Assembly tab.

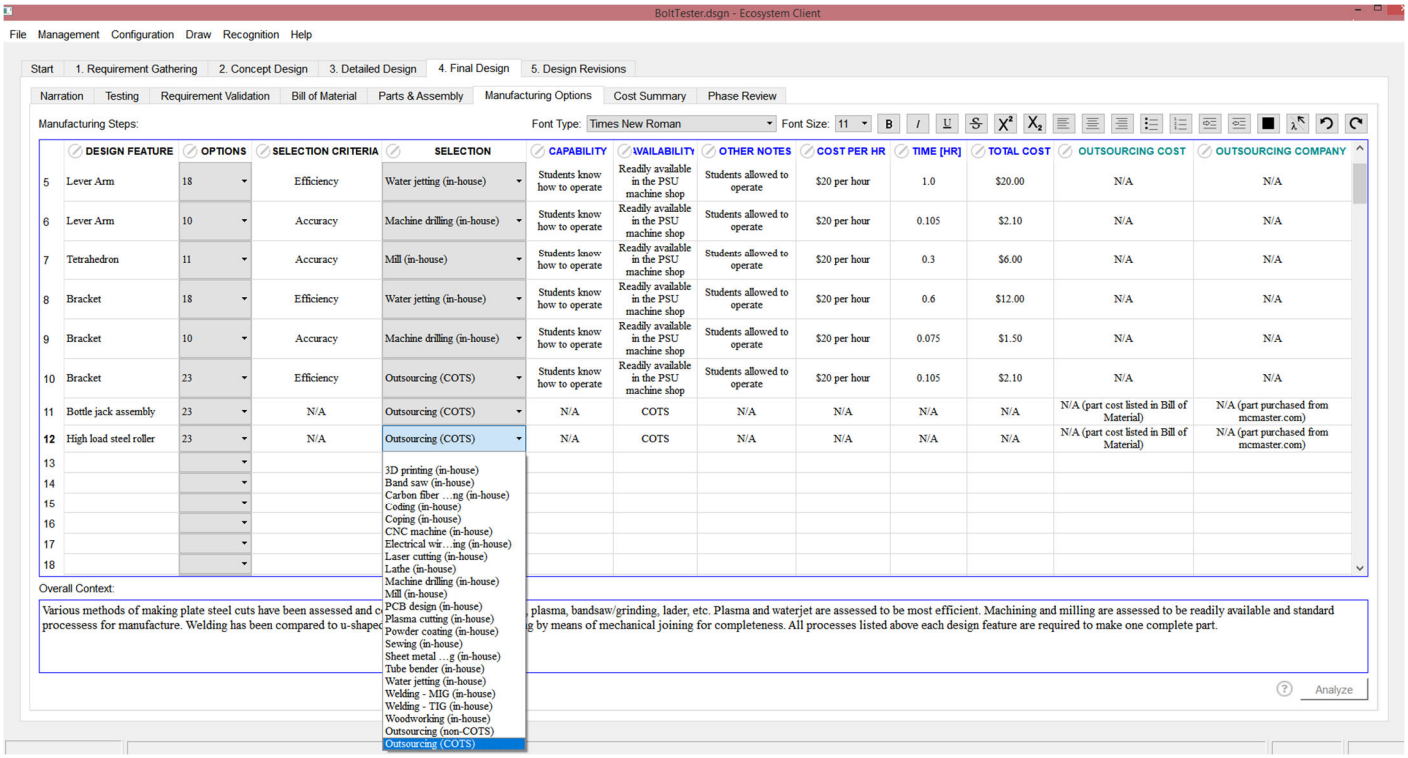
Manufacturing Options

The Ecosystem provides the user with facilities for coordinating plans for manufacturing, both in-house and outsourced manufacturing. In the tab for the Manufacturing Options, shown in Figure 77, the user can specify the manufacturing steps needed for each tab.

The content of the Bill of Material tab should be consistent with the content of the tab for the Manufacturing Options. The Bill of Material should provide full overview of the cost of the parts comprising the design, whereas the tab for the Manufacturing Options should provide full overview of the manufacturing cost. Together, the tabs for the Bill of Material and the Manufacturing Options should provide complete overview of the cost of making the design.

If a given part requires multiple steps, please list the part in multiple lines (preserving the order of operation). Similarly, if a part is partially made in-house vs. partially outsourced, apply same approach (listing each manufacturing step in separate line, preserving the order of operation)

The OPTIONS column refer to the manufacturing methods that can be employed for making the design feature, part or assembly. This refers to the present manufacturing step, if multiple steps are needed. The SELECTION CRITERIA refers to the primary criteria on which selection of the manufacturing method will be based (again, this refers to the present step, if multiple steps are needed). The SELECTION column refers to the manufacturing method selected for the present manufacturing step in making the part. The CAPABILITY refers to the manufacturing capabilities that the operators (students) possess (assuming in-house manufacturing). AVAILABILITY refers to the availability of the equipment needed for in-house manufacturing. OTHER NOTES refer to other notes or restrictions that apply to in-house manufacturing. E.g., are machinists (in-house staff) only allowed to operate the equipment (say, the welding)? COST PER HR refers to the cost per-hour for operating the in-house manufacturing tool. TIME [HR] refers to the time that in-house manufacturing tool needs to be operated to make the design feature, part or assembly (accounting for the number of units manufactured). TOTAL COST refers to the total cost for making the design feature, part or assembly in-house. OUTSOURCING COST refers to the total cost for making the design feature, part or assembly, assuming out-sourcing. OUTSOURCING COMPANY refers to company to which the plan is to outsource the manufacturing of the design feature, part of assembly.



	DESIGN FEATURE	OPTIONS	SELECTION CRITERIA	SELECTION	CAPABILITY	AVAILABILITY	OTHER NOTES	COST PER HR	TIME [HR]	TOTAL COST	OUTSOURCING COST	OUTSOURCING COMPANY
5	Lever Arm	18	Efficiency	Water jetting (in-house)	Students know how to operate	Readily available in the PSU machine shop	Students allowed to operate	$20 per hour	1.0	$20.00	N/A	N/A
6	Lever Arm	10	Accuracy	Machine drilling (in-house)	Students know how to operate	Readily available in the PSU machine shop	Students allowed to operate	$20 per hour	0.105	$2.10	N/A	N/A
7	Tetrahedron	11	Accuracy	Mill (in-house)	Students know how to operate	Readily available in the PSU machine shop	Students allowed to operate	$20 per hour	0.3	$6.00	N/A	N/A
8	Bracket	18	Efficiency	Water jetting (in-house)	Students know how to operate	Readily available in the PSU machine shop	Students allowed to operate	$20 per hour	0.6	$12.00	N/A	N/A
9	Bracket	10	Accuracy	Machine drilling (in-house)	Students know how to operate	Readily available in the PSU machine shop	Students allowed to operate	$20 per hour	0.075	$1.50	N/A	N/A
10	Bracket	23	Efficiency	Outsourcing (COTS)	Students know how to operate	Readily available in the PSU machine shop	Students allowed to operate	$20 per hour	0.105	$2.10	N/A	N/A
11	Bottle jack assembly	23	N/A	Outsourcing (COTS)	N/A	COTS	N/A	N/A	N/A	N/A	N/A (part cost listed in Bill of Material)	N/A (part purchased from mcmaster.com)
12	High load steel roller	23	N/A	Outsourcing (COTS)	N/A	COTS	N/A	N/A	N/A	N/A	N/A (part cost listed in Bill of Material)	N/A (part purchased from mcmaster.com)
13												
14												
15												
16												
17												
18												

3D printing (in-house)
Band saw (in-house)
Carbon fiber …ng (in-house)
Coding (in-house)
Coping (in-house)
CNC machine (in-house)
Electrical wir…ing (in-house)
Laser cutting (in-house)
Lathe (in-house)
Machine drilling (in-house)
Mill (in-house)
PCB design (in-house)
Plasma cutting (in-house)
Powder coating (in-house)
Sewing (in-house)
Sheet metal …g (in-house)
Tube bender (in-house)
Water jetting (in-house)
Welding - MIG (in-house)
Welding - TIG (in-house)
Woodworking (in-house)
Outsourcing (non-COTS)
Outsourcing (COTS)

Various methods of making plate steel cuts have been assessed and c… plasma, bandsaw/grinding, lader, etc. Plasma and waterjet are assessed to be most efficient. Machining and milling are assessed to be readily available and standard processess for manufacture. Welding has been compared to u-shaped… g by means of mechanical joining for completeness. All processes listed above each design feature are required to make one complete part.

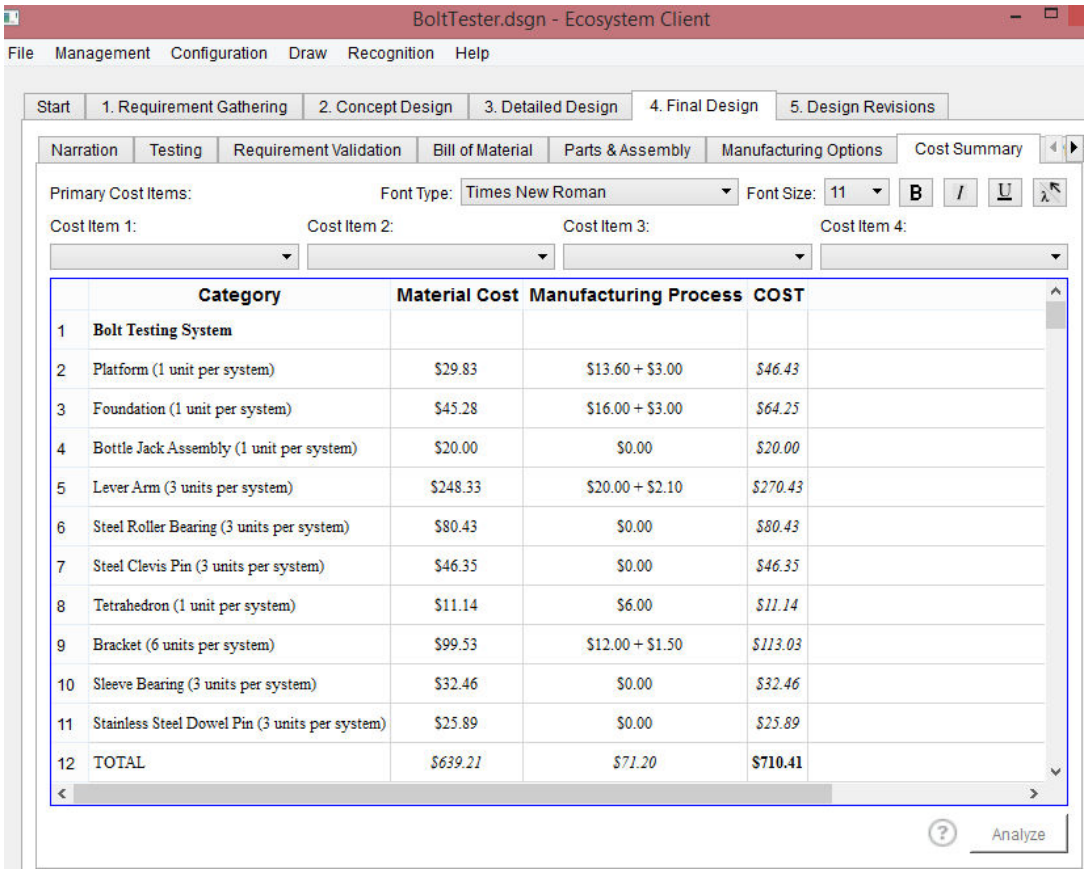
Figure 77: Tab for Manufacturing Options (from the bolt tester example).

Cost Summary

The Cost Summary tab can be used to to present a clear high-level overview of the primary cost items for the design project, as shown in Figure 78 The column headings are dynamically populated, based on the cost items selected.

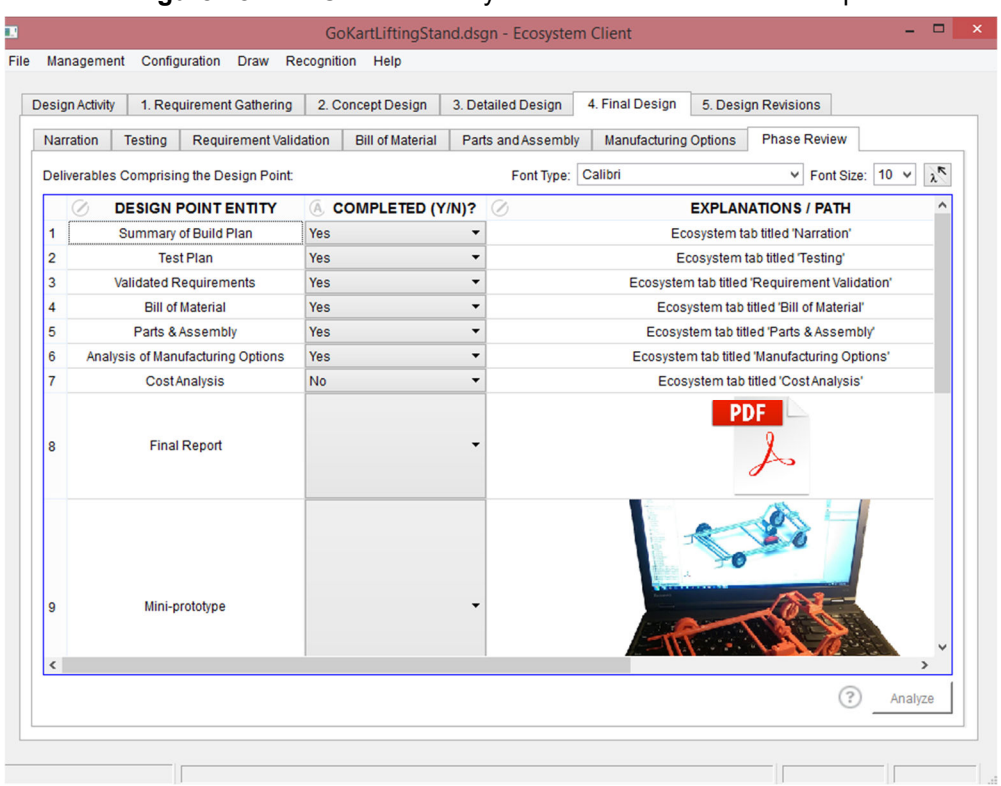
Phase Review

The purpose of the Deliverables tab, shown in Figure 79, is to concisely specify the deliverables comprising the design point at the end of the Final Design phase. To import an image into the Location column, simply double-click on the pertinent cell and specify the link to the image file of interest. To delete and image, simply click on the image and hit the 'Delete' button. By referencing the Deliverables in the Schedule dialog, you can assign a date to the Deliverables listed. Note that the row height has been dynamically adjusted to fit the content.



	Category	Material Cost	Manufacturing Process	COST
1	**Bolt Testing System**			
2	Platform (1 unit per system)	$29.83	$13.60 + $3.00	*$46.43*
3	Foundation (1 unit per system)	$45.28	$16.00 + $3.00	*$64.25*
4	Bottle Jack Assembly (1 unit per system)	$20.00	$0.00	*$20.00*
5	Lever Arm (3 units per system)	$248.33	$20.00 + $2.10	*$270.43*
6	Steel Roller Bearing (3 units per system)	$80.43	$0.00	*$80.43*
7	Steel Clevis Pin (3 units per system)	$46.35	$0.00	*$46.35*
8	Tetrahedron (1 unit per system)	$11.14	$6.00	*$11.14*
9	Bracket (6 units per system)	$99.53	$12.00 + $1.50	*$113.03*
10	Sleeve Bearing (3 units per system)	$32.46	$0.00	*$32.46*
11	Stainless Steel Dowel Pin (3 units per system)	$25.89	$0.00	*$25.89*
12	TOTAL	*$639.21*	*$71.20*	**$710.41**

Figure 78: The Cost Summary tab from the bolt tester example.



	DESIGN POINT ENTITY	COMPLETED (Y/N)?	EXPLANATIONS / PATH
1	Summary of Build Plan	Yes	Ecosystem tab titled 'Narration'
2	Test Plan	Yes	Ecosystem tab titled 'Testing'
3	Validated Requirements	Yes	Ecosystem tab titled 'Requirement Validation'
4	Bill of Material	Yes	Ecosystem tab titled 'Bill of Material'
5	Parts & Assembly	Yes	Ecosystem tab titled 'Parts & Assembly'
6	Analysis of Manufacturing Options	Yes	Ecosystem tab titled 'Manufacturing Options'
7	Cost Analysis	No	Ecosystem tab titled 'Cost Analysis'
8	Final Report		PDF
9	Mini-prototype		

Figure 79: The Deliverables tab from the Final Design phase (from the example for the go kart lifting stand).

Gate Review

The purpose of the Phase Review tab, shown in Figure 80, is to concisely specify the deliverables corresponding to phase review at the end of the Final Design phase, indicate the level of completion, and capture the associated explanations. The Notes section can capture comments pertinent to specific Phase Review Deliverables. Or it may contain notes on level of attainment of specific requirements, changes in requirements, etc.

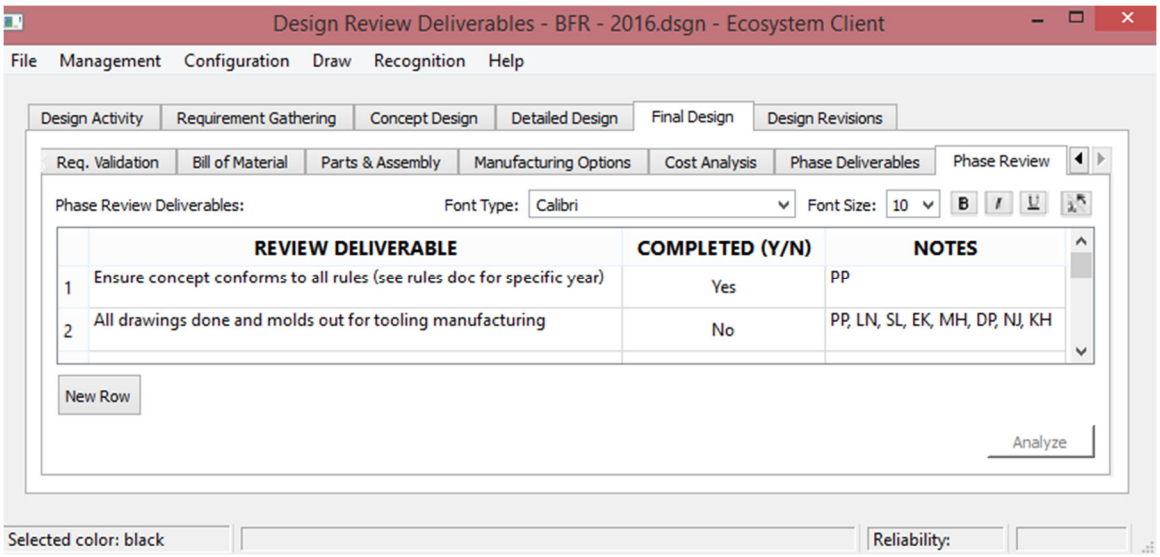


Figure 80: Phase Review tab capturing design review deliverables from a student race car design team.

Chapter 9: Design Modifications

In the Ecosystem ver. 1.20, the Design Modification phase consists of a single table presenting a revision overview. The table provides means for listing the issues identified, up to three solutions alternatives, links to original design file, the revised design file as well as the revision number (see Figure 81).

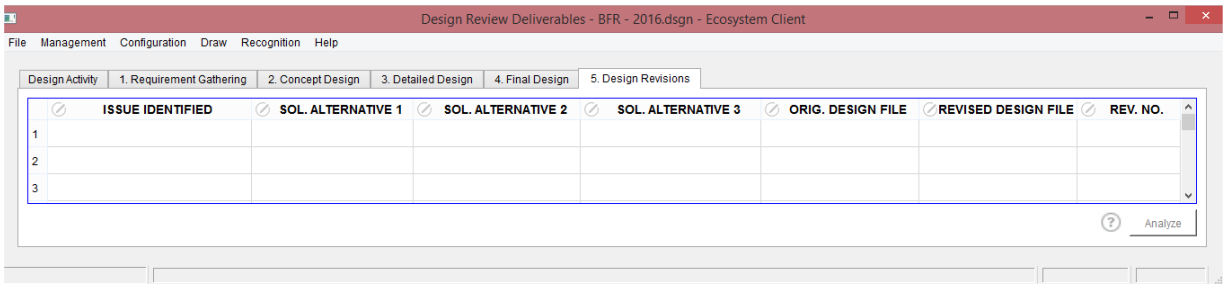


Figure 81: The revision table of the Design Modification phase.

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Appendix A: Frequently Asked Questions

Table 6: Recommended resolutions for problem scenarios that might arise.

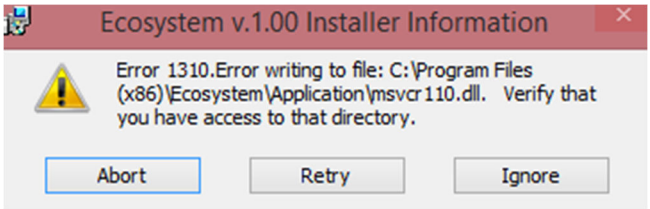
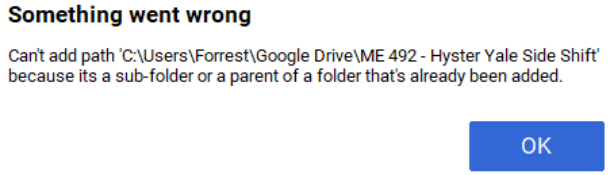
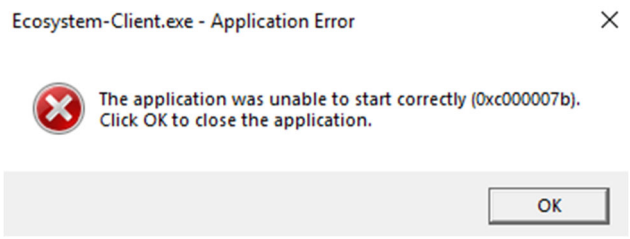
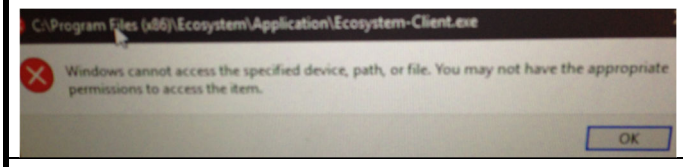
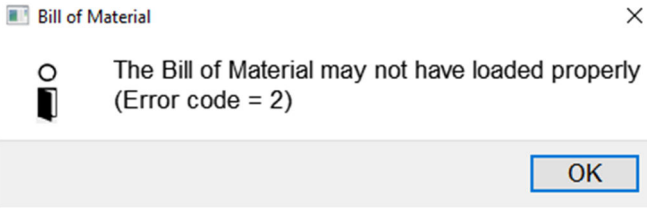
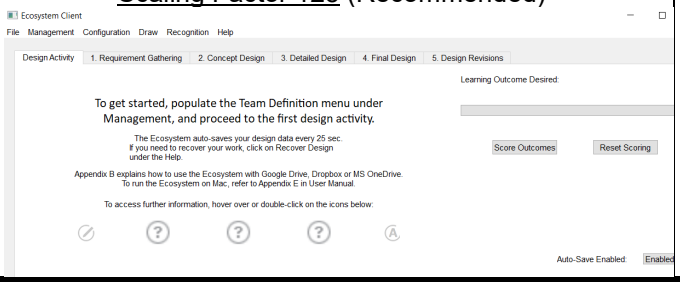
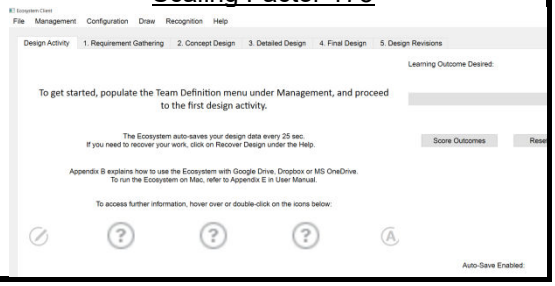
Problem Scenario	Resolution to Consider
Scoring Designs tab of the Conceptual Design phase: Missing headers from the scoring table	• Make sure to populate the column 'In Obj. Func.?' in the Engineering Requirement tab. • The auto-population of the headers in the scoring table of the Scoring Design tab keys off the description for the element with 'Yes' specified in the column for 'In Obj. Func.?' in the Eng. Requirement tab.
Problems with running the Ecosystem under Macintosh	• You may need to install the right libraries via WineTricks (integrated into the WineBottler (5)).
Design file is not loading properly (seems corrupt)	• Revert back to the 'last, good design file' (or consider creating a new one).
Empty placeholders for images in an exported report	• Regenerate the automatically formatted report (re-export into PDF)
	Download the x86 version, per the instructions in the download form.
	Temporarily disable your virus protection SW.
Figures not showing up when accessing exported project reports in ODF or HTML format.	Exported project reports in PDF format should not exhibit this problem.
My license key is not being accepted	Check for empty space(s) at the beginning or the end of the key string.
Stylus input is not working under Windows 10	Install new drivers from http://www.wacom.com/en-de/support/product-support/drivers
Can I run more than one instance of the Ecosystem 1.20 SW concurrently?	No. Simultaneous read and writes may lead to system vulnerabilities.
Ecosystem seems to pause for a few seconds (unexpected delay)	Consider disabling the auto-save. Refer to Chapter 10 for details.
	1. In the Google Backup and Sync application, make sure to select "Google Drive", not "My Laptop (see Figure 87). 2. Simply retry. - This may have been an intermittent connection problem.

Table 7: Recommended resolutions for problem scenarios that might arise (continued).

Problem Scenario	Resolution to Consider
	Install the x86 version of the Visual C++ Redistributable Packages for Visual Studio 2013 (vcredist_x86.exe) https://www.microsoft.com/en-us/download/details.aspx?id=40784 If the problem persists, try installing other Visual C++ Redistributable Packages for Visual Studio, in particular 2012. These Redistributable Packages ship with the Ecosystem 1.20 SW can be located in the installation folder (usually C:\Program Files (x86)\Ecosystem\Application\).
Windows cannot access the specified devices, path or file. You might not have the appropriate permissions to access the item 	This error is likely caused by a complication between user and administrator accounts. For resolution, refer to https://www.youtube.com/watch?v=u6GcpS52wUw
Problem loading in the Bill of Material: 	Error codes 1 and 2 suggest need to install or update the Visual C++ Redistributable Packages for Visual Studio 2013 and 2015. You need *both the x86 and x64 versions*. https://www.microsoft.com/en-us/download/details.aspx?id=40784 https://www.microsoft.com/en-us/download/details.aspx?id=48145
Problem importing SolidWorks assemblies or Bill of Materials into the Ecosystem Error Code = 1, upon importing Bill of Assembly	It is possible that access, or security, restrictions play a role. As fall-back, consider 1. DOS Prompt (*Administrator* Mode) [cd to Application under the Installation folder] `COMObjectFactory.exe /regserver` 2. Launch the Ecosystem as Administrator Type 'Ecosystem' into the Windows search field, right-click on 'Ecosystem – Client' and select 'run as administrator'.
Layout issues under Windows 10 Scaling Factor 125 (Recommended)  Scaling Factor 175 	Consider reducing the "Scaling Factor": - Right-click on Windows icon - Select 'System' and then 'Display' - Set 'Scaling and Layout' to 100%

1. At what point are the requirements considered fully defined?

- The requirements are considered fully defined at the end of the Requirement Gathering phase.
- If the Gate Review for the Requirement Gathering phase is completed, the requirements are considered fully defined after the Gate Review.
- If no Gate Review for the Requirement Gathering phase is conducted, the requirements are considered fully defined upon completion of the Engineering Requirement tab.

2. Does the Ecosystem allow requirements to change, after Gate Review for the Requirement Gathering phase?
3. What should a team do if the sponsor tries to expand the project scope during the course of a capstone project?

- One of the utilities provided by the Ecosystem involves prevention of scope creep.
- To prevent scope creep, we advise teams to have the sponsor sign off on the requirements, and add a note to this effect to the Gate Review tab.
- However, if a requirement were to change later on (not recommended), a note to this effect (explanations) should be added both into the Notes section of the Customer Interview tab and to the Gate Review tab.

4. How to use the Ecosystem in a capstone program where the sponsor expects to receive weekly progress updates?

- Presently, these progress reports can be sent using the Message Board described in Appendix C, or a 3rd party application, such as e-mail.
- The auto-generated project reports may expedite the process of generating content for the progress updates.
- For further information, refer to Figure 4.

5. During the course of a semester, what type of mechanism is available to capstone instructors to monitor the progress of student design teams using the Ecosystem 1.20 SW?

- Instructors can select from at least three options:

(a) Ask their students to submit the exported project journals.
(b) Ask their students to provide them with access to the centralized repository storing the master e-design project journal (e.g., Google Drive or One Drive).
(c) Communicate with their students through the message board ecosystem.imagars.com.

Appendix B: Attaining a Complete Solution at Low Cost

Ver. 1.20 of the Ecosystem for Design Assessment and Verification was developed with deliberate emphasis on its unique capabilities with regards to the design process, in particular in terms of design scoring and assessment.

Yet, the Ecosystem 1.20 can be combined with a number of free software solutions, for team communication and file sharing, to arrive at a complete solution at low cost. Figure 82 captures the core idea. This Chapter further expands on a few such solutions. The coverage is not comprehensive.

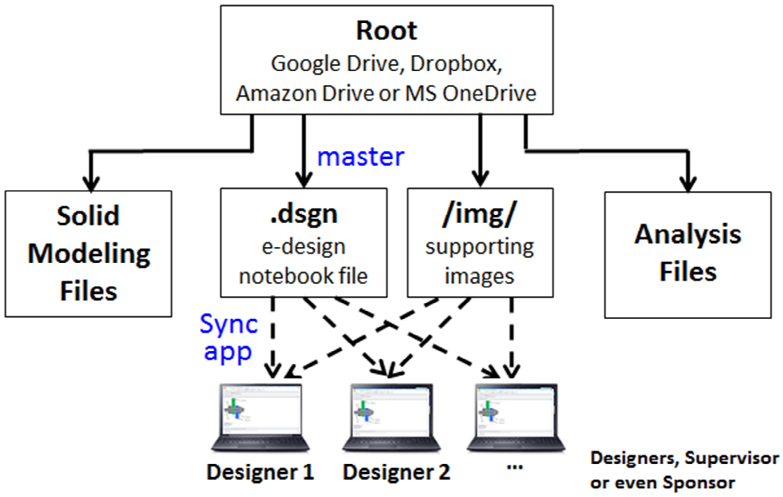


Figure 82: Ecosystem's usage with the Google Drive, Dropbox, Amazon Drive or OneDrive for a typical capstone application.

Note though that the Ecosystem 1.20 is not envisioned as a complement to Google Doc. The design scoring and assessment is considered a core capability of the Ecosystem, not the team communication capabilities.

If you are looking for additional information on how to configure the Ecosystem to your needs, please don't hesitate to contact us at support@imagars.com.

Key Recommendations

1. We recommend delegating tasks and roles amongst team members, with perhaps one team member taking on the role of a scribe.
- Even though the Ecosystem does support it, we do not recommend that designers are concurrently working on the same assignments and modifying the same tabs at the same time.
2. Even though we do support sharing of design files through personal Google accounts, we do recommend creating a dedicated, shared drive (account) for your design project.
- For information on how to efficiently share designs through personal Google accounts, refer to the section titled *Efficient Sharing of Design Files through Personal Google Accounts* below.
3. *When copying an e-design notebook file onto a centralized storage facility, remember to copy the /img/ directory along with its content.*

File Management through Google Drive

- In terms of a file management solution for the student design teams participating in Formula SAE or similar competitions, the Google Drive is a common choice.
- *The Ecosystem provides means for accessing shared files, both e-design notebooks and repositories of archived designs (say, part or assembly files), by mapping the Google Drive onto the local file system* using the Google Drive Sync application.
- In this way, *the user can apply the automatic image extraction and visualization (see Figure 83 - Figure 84), even on files stored on the Google Drive.*
- *Different team members can access and modify on the same files virtually at the same time.*
- *The synchronization is handled automatically.*

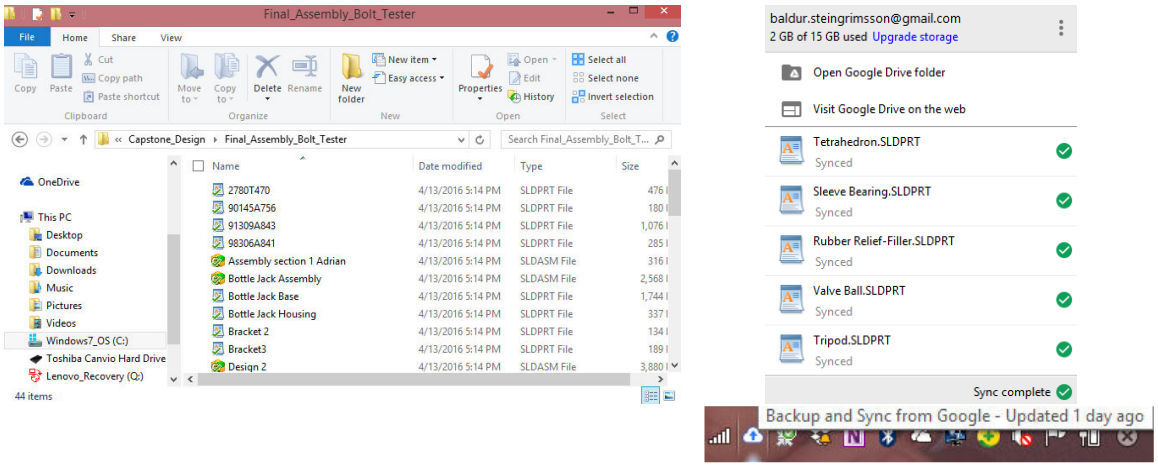


Figure 83: The Backup and Sync application from Google used for team collaboration.

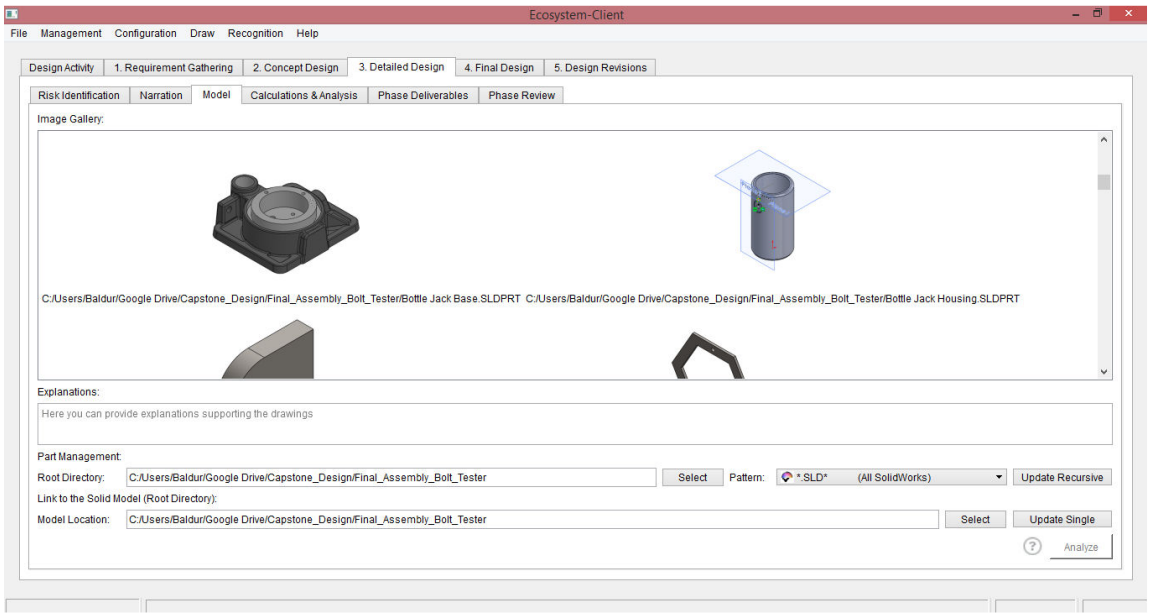


Figure 84: Real-time image extraction and visualization applied to design files stored on a Google Drive (and mapped to the local file system using the Google Drive Sync application).

Installation Procedure

1. Download the application for synchronization with the Google Drive
   https://tools.google.com/dlpage/drive/index.html?hl=en
2. Select “Personal” and “Backup and Sync”.
3. Follow the installation steps.

Procedure for Setting up a New (Empty) Project File

1. Start up the Ecosystem SW.
2. Click on “Save Project As …” and save the project into the local folder corresponding to the shared drive.
3. The local folder may be called

   C:\Program Files\Google Drive\Capstone_Design\

or

   C:\Users\[Your_Name]\Google Drive\Capstone_Design\

Efficient Sharing of Design Files through Personal Google Accounts

For the purpose of efficiently sharing (large) designs through personal Google accounts, we recommend the following:

1. A team lead installs the Google sync application and logs into his or her personal account.
2. The team lead creates a directory, say, for Formula2019, in his or her personal Google Drive and shares just that one folder with other team members (and, if desired, the faculty adviser).
- See Figure 85.
3. The team lead configures his/her Google sync application only to sync this one folder.
- If you have problems logging in (get a 400 error), you can try signing in through a web browser.
4. The team members also install the Google sync application.
5. Shared folder may appear under "My Shared Folders" on the team members' Google Drives.
6. Team members access their Google Drives through a web browser, click on the folder that was shared (located under "My Shared Folders") and opt for "*Add to My Drive*".
- See Figure 86.
7. The team members now should be able to configure the Google sync application such as to sync the one folder that the team lead shared with them.

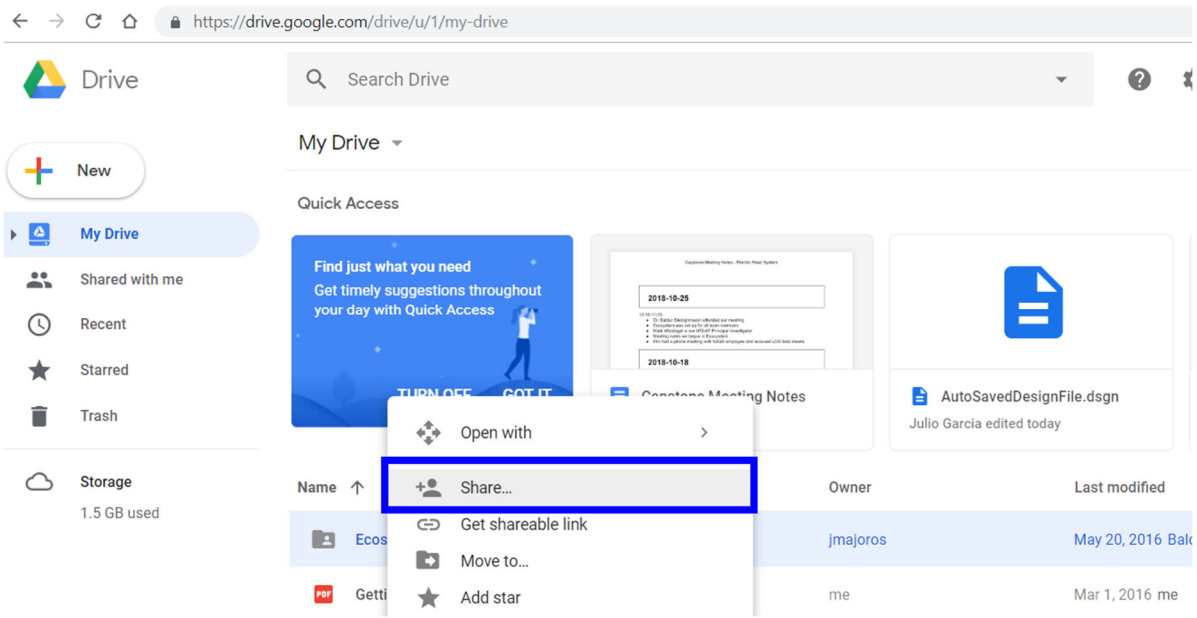


Figure 85: Sharing of a project folder through a Google Drive.

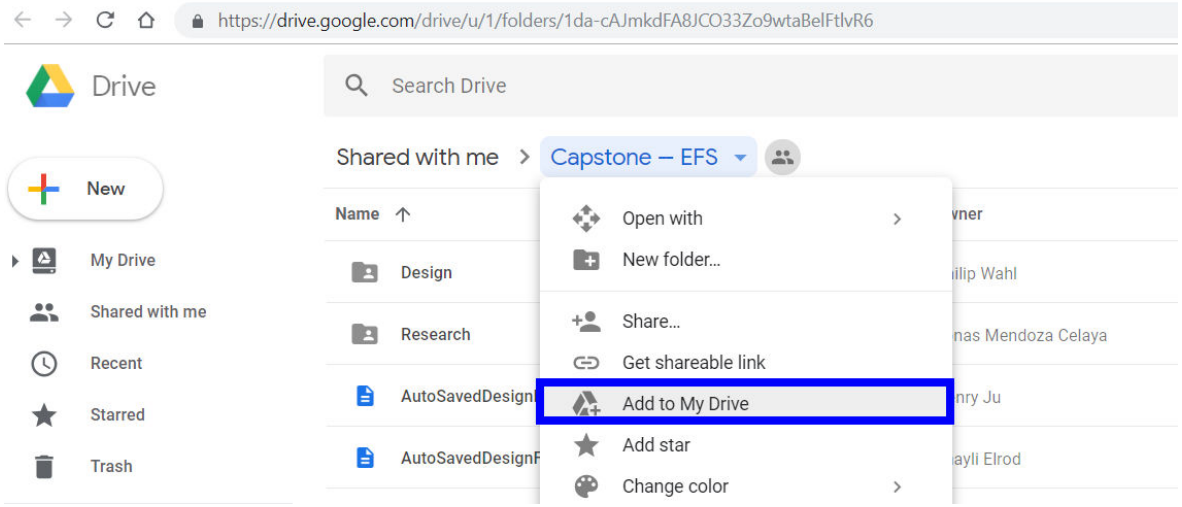


Figure 86: Adding a shared Drive to a personal Drive, in order to access through the Google Sync application.

Selection of the Folders to Be Synced

1. Click the Google Cloud icon .
- On a Mac, the icon is usually in the menu bar at the top right of the screen.
- On a PC, the icon is usually in the taskbar at the bottom right of the screen.
2. In the top right, click More > **Preferences**.
3. Click on the **Google Drive** icon (on the right side).
4. Select the folders you want to sync (see Figure 87).

Note that you do not need to click on the **My Laptop** icon.

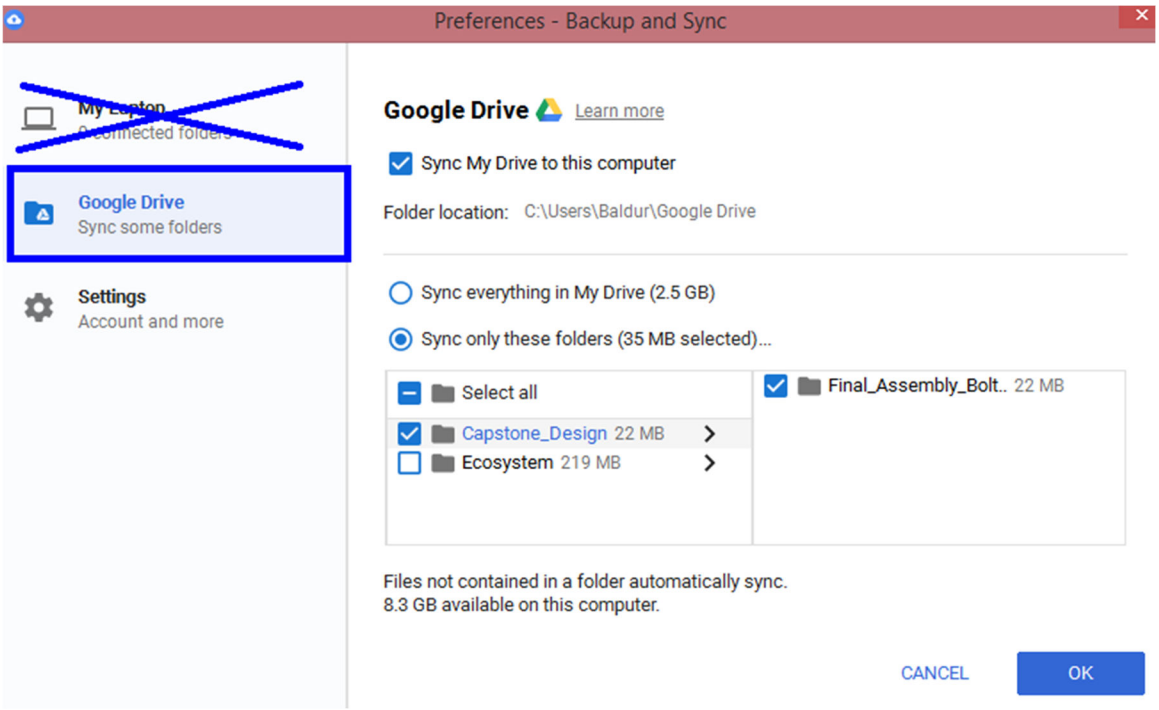


Figure 87: Selection of the folders to be sync-ed with the Google Drive.

Configurations for Near-Instantaneous Uploads and Downloads

To ensure near-instantaneous uploads and downloads, when team members are modifying the same files at the same time,

1. Click the Google Cloud icon .
- On a Mac, the icon is usually in the menu bar at the top right of the screen.
- On a PC, the icon is usually in the taskbar at the bottom right of the screen.
2. In the top right, click More > **Preferences**.
3. Click on **Settings**.
4. Click on **Network Settings**.
5. Make sure both the "Download Rate" and "Upload Rate" is set to **Don't limit** (see Figure 88).

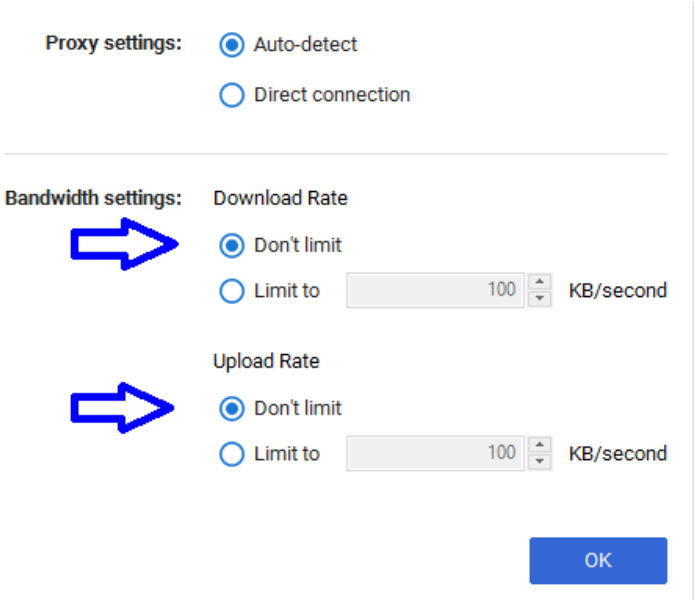


Figure 88: The Backup and Sync application from Google configured for near-instantaneous uploads and downloads.

Concurrent Edits

The Backup and Sync application provides automatic version control, as illustrated in Figure 89. Older file versions are automatically kept for 30 days.

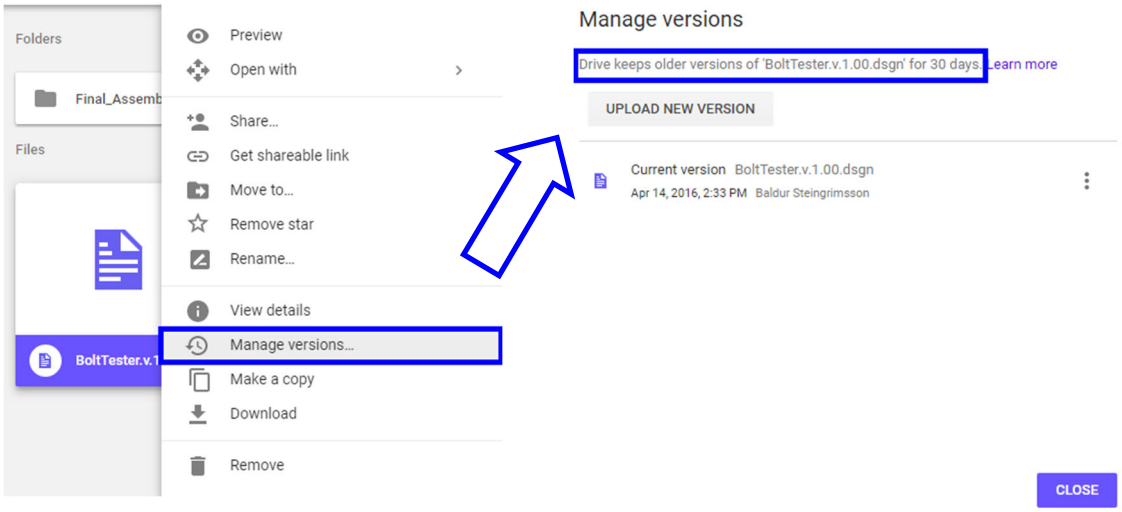


Figure 89: Automatic version control provided by the Backup and Sync application from Google.

File Management through Dropbox

- The Dropbox can be used similarly to host shared design files.
- As for the Google Drive, the synchronization is handled automatically (see Figure 90).
- *Hence, different team members can access and modify on the same files virtually at the same time.*

Procedure

1. Download the Dropbox application from
   https://www.dropbox.com/downloading

2. Run the Dropbox installer

DropboxInstaller.exe

3. Follow the installation steps.

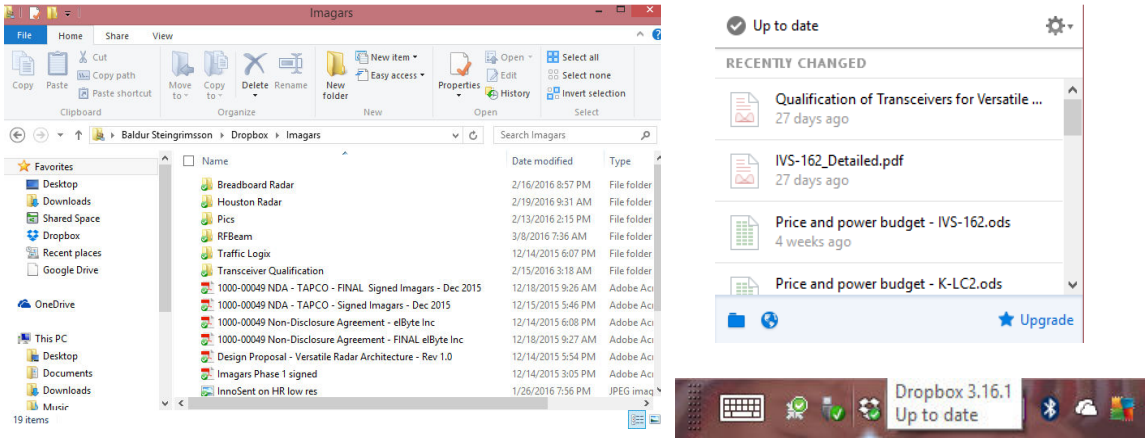


Figure 90: Snapshots from usage of Dropbox for team collaboration on an actual design project.

Concurrent Edits

- Dropbox provides ability similar to Figure 89 for viewing the file history.
- Version control is handled through time stamps.
- For further information, refer to

https://www.dropbox.com/help/business/badge-collaborate

File Management through OneDrive

- The OneDrive can be used similarly to host shared design files.
- As for the Google Drive and Dropbox, the synchronization is handled automatically.
- *Hence, different team members can access and modify on the same files virtually at the same time.*

Procedure

1. Download the OneDrive sync client from

https://onedrive.live.com/about/en-us/download/

2. Run the installer for the OneDrive sync client

OneDriveSetup.exe

3. Follow the installation steps.
4. You can typically access your mapped folder through the following path:

C:/Users/[your-user-name] /OneDrive/

Figure 91 provides sample results from a search applied to design files stored in a centralized archive, but mapped to a local folder, and synchronized using the OneDrive sync client.

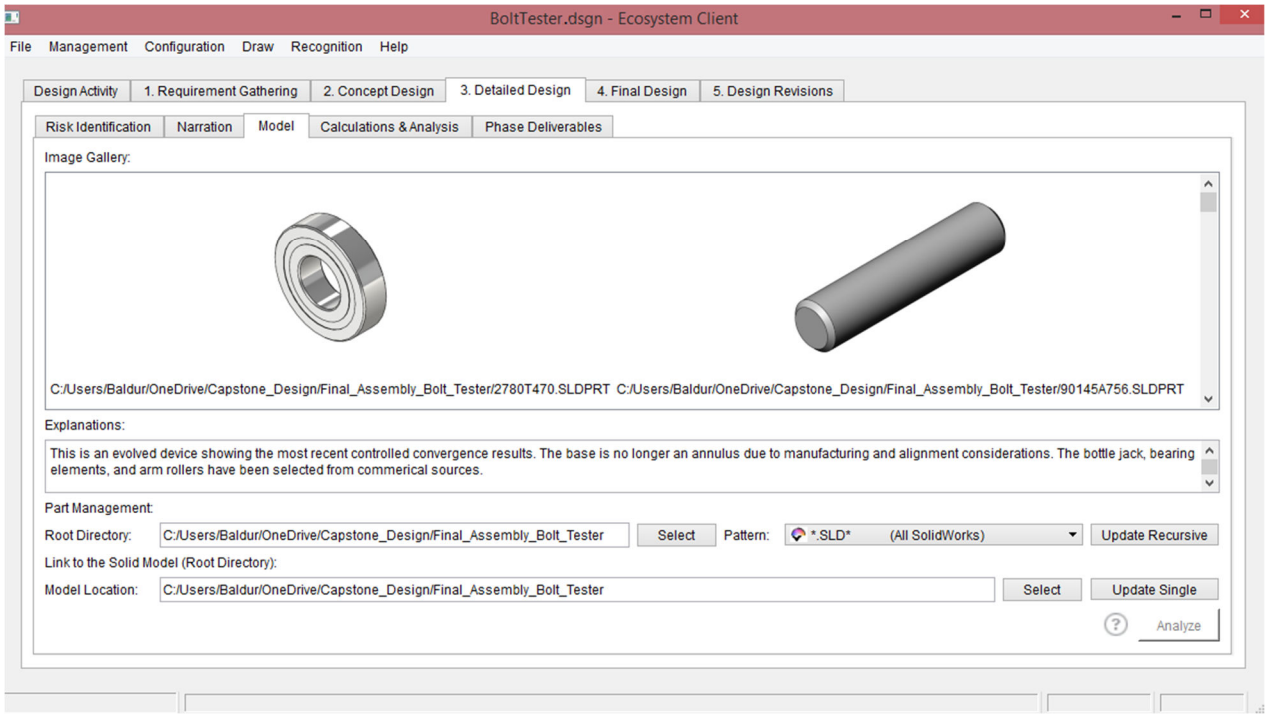


Figure 91: Real-time image extraction and visualization applied to design files stored on a MS OneDrive (and mapped to the local file system using the OneDrive sync client).

File Management through Amazon Drive

- The Google Drive, the Dropbox, the MS OneDrive, the Amazon Drive or the Discord Drive can be used to host shared design files.
- As before, the synchronization is handled automatically.
- In case of the Amazon Drive, the application handling the synchronization can be downloaded from

https://www.amazon.com/clouddrive

File Management through Discord Drive

- The Google Drive, the Dropbox, the MS OneDrive, the Amazon Drive or the Discord Drive can be used to host shared design files, as noted above.
- In case of the Discord Drive, the application handling the synchronization can be downloaded from

https://discord.com/

File Management through GitHub

- The GitHub provides advantage, such as ability to track versions.
- Using the Ecosystem SW with the GitHub is easy:

1. Sign in to the GitHub or register for a new account

https://github.com/

2. Search for your project or start a new project.
3. Select 'Upload files' for uploading your master e-design project journal file into the project root.
4. Once you have added images to your project, make sure also to upload your /img/ folder beneath the project root.

Other Options for File Management

Users can also achieve their goals for assignment delegation and distributed file management using a number of other software solutions. MediaFire, RapidShare, ShareFile and YouSendIt are dedicated to sending and hosting large files in a corporate context (6). Box, Dropbox, Minus, SkyDrive and SugarSync are more general, personal use file storage serves that have mass distribution as an adjunct feature (6).

Recommended Platform for Team Communications

- Imagars' message board

  www.ecosystem.imagars.com

  is the recommended platform for team communications.
- Team members are advised to register for an account by accessing the 'Register' function in the main message board menu
- For now, we recommend stand-alone usage of the message board.
- The message board can be accessed from a browser running in parallel with the Ecosystem client.

Appendix C: Message Board

General Overview

- The message board can be accessed through

  http://www.ecosystem.imagars.com/
- The purpose is to facilitate effective communications between team members, between project teams and Imagars, or between instructors and Imagars.
- The message board may provide a more organized framework for dialogue than a litany of e-mails (and better means for archival?).

Structure

- The message board channels are organized as follows:

  University name – Course name – Semester
- For a given course, there is an additional channel, with restricted access, for communications with the instructor.
- For an illustration, refer to Figure 92.

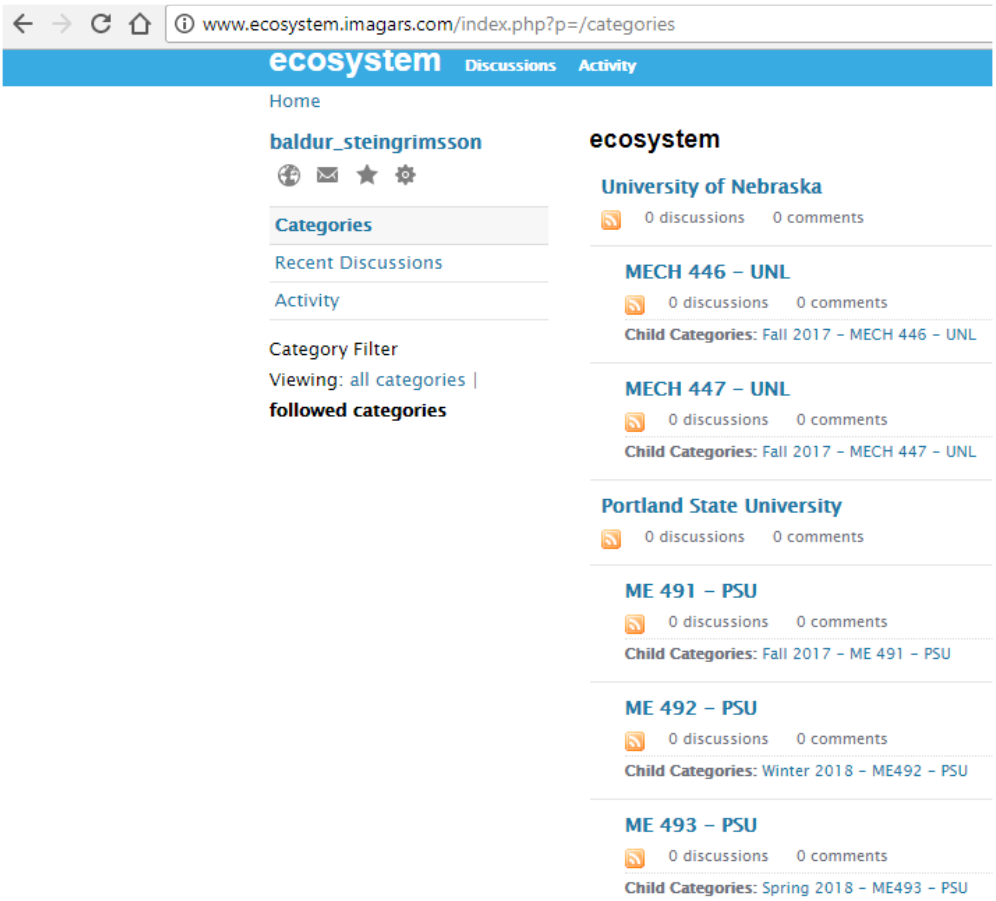


Figure 92: Structure of discussion threads in the message board (Member view).

Roles and Permissions

- Table 8 summarizes the role of different participants in the message board.
- Instructors are typically provided with Moderator access.

Table 8: Roles of different participants in the message board.

Participant	Role
Guest	Guests can only view content. Anyone browsing the site, who is not signed in, is considered to be a "Guest".
Unconfirmed	Users must confirm their e-mails before becoming full members. They get assigned to this role.
Applicant	Users who have applied for membership, but have not yet been accepted. They have same permissions.
Member	Members can participate in discussions. Privacy is ensured by configuring custom member roles for each university.
Moderator	Moderators have permission to edit most content.
Administrator	Administrators have permission to do anything.

Security and Privacy

- The message board has been configured as PRIVATE.
  - This means that only signed-in users are able to see content in a community.
- Imagars ensures privacy by defining custom member roles for each participating university.
  - These roles are configured such that students taking a particular class at a particular university in a given year only have member access to discussion thread(s) for that class.
- The Vanilla message board is fairly powerful, in this regard. For assurance, refer to https://blog.vanillaforums.com/help/how-to-restrict-forum-content-by-role/

E-mail Notifications

- Member can configure their notification preferences through the Edit Profile menu.
- To enable e-mail notifications, once logged in, select

→ Edit Profile → Notification Preferences.

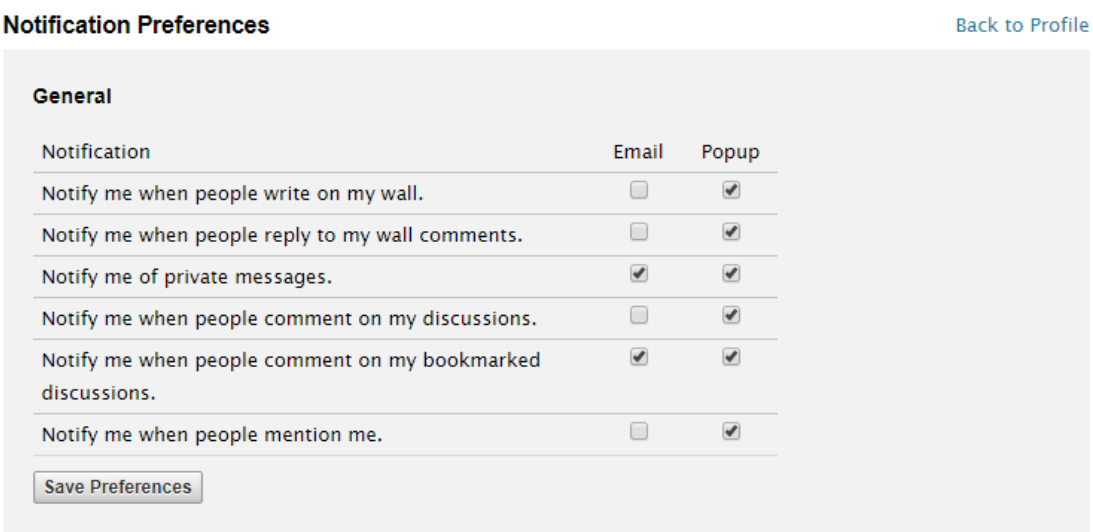


Figure 93: Notification preferences available to members.

Signing Up

- With the access being set to PRIVATE, the sign-up process is very straight forward.
- Upon accessing the message board, unregistered users are directed to the sign-up sheet (see Figure 94).
- Upon completing the application form, Applicants are provided with fairly good viewing capabilities.

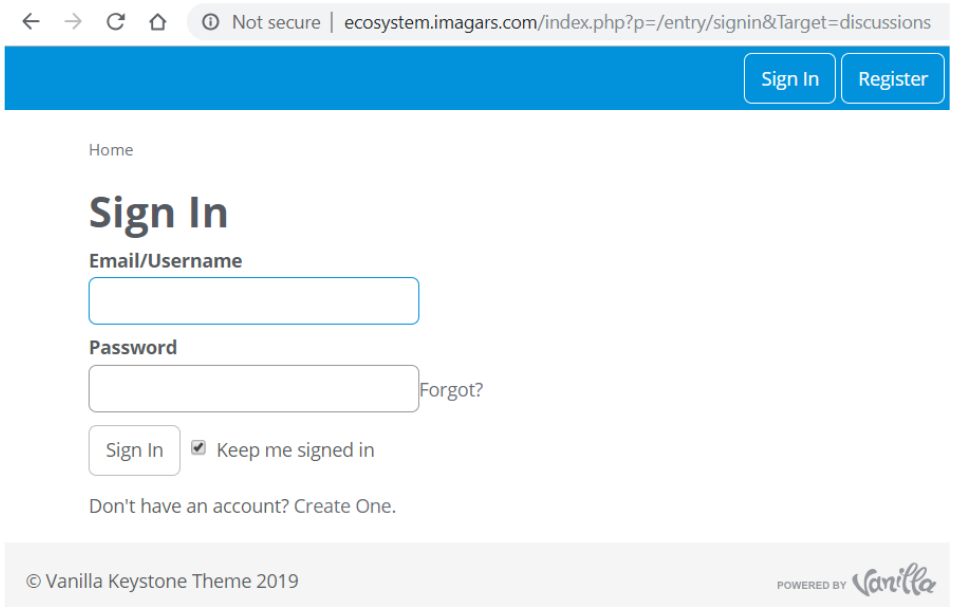


Figure 94: Point of entry for unregistered users.

Appendix D: Learning Management Systems

Usage of the Ecosystem with Canvas

- The interface for Canvas resembles that of content management systems such as Wordpress.
- We presently assume the Ecosystem is used separately from Canvas, but that data (reports) from the Ecosystem is imported into Canvas as necessary.
- Students can import both the electronic project journals (the .dsgn files) and the formatted reports (the .pdf, .html or .odf files) into Canvas[3].
- Canvas allows users to import content:
  https://community.canvaslms.com/docs/DOC-12935
- Data from Student Information Systems (SIS) can be uploaded in CSV format:
  https://community.canvaslms.com/docs/DOC-12585-4214164118

Usage of the Ecosystem with Blackboard

- We presently assume the Ecosystem is used separately from Blackboard, but that data (reports) from the Ecosystem is imported into Blackboard, in a fashion similar to Canvas.
- Students can import both the e-design notebooks (the .dsgn files) and the formatted reports (the .pdf, .html or .odf files) into Blackboard.

Usage of the Ecosystem with Moodle

- We presently assume the Ecosystem is used separately from Moodle, but that data (reports) from the Ecosystem is imported into Moodle, in a fashion similar to Canvas or Blackboard.

Usage of the Ecosystem with Desire2Learn (D2L)

- We presently assume the Ecosystem is used separately from D2L, but that data (reports) from the Ecosystem is imported into D2L, such as described above.

[3] The Ecosystem is primarily intended for project-based design classes (capstone), where students generate design reports and submit. Canvas handles report management for college and university classes. By having students upload the original project journals (.dsgn files) and/or exported reports into the Ecosystem, one does not need an automated interface between the Ecosystem and Canvas.

Appendix E: Support for Macintosh

There are a few ways for Mac users to run the Ecosystem (7):

1. Through the Boot Camp dual booting mechanism (recommended).
2. Through a Virtual Machine, like VmWare Fusion, if installed.
3. Using the WineBottler, per Figure 95 (8).
4. Using the CodeWeavers' CrossOver Mac.
5. Using a Remote Desktop.

During the testing phase, the Ecosystem 1.20 SW was installed and run under Macintosh, using the Boot Camp, per instructions from

https://support.apple.com/boot-camp

No problems were observed.

The WineBottler is a free Mac application which can be downloaded from (8)

http://winebottler.kronenberg.org/

Instructions on how to run Windows applications on Mac, using the WineBottler, are listed in (5)
http://www.makeuseof.com/tag/sleeping-with-the-enemy-running-windows-programs-on-your-mac-using-winebottler/

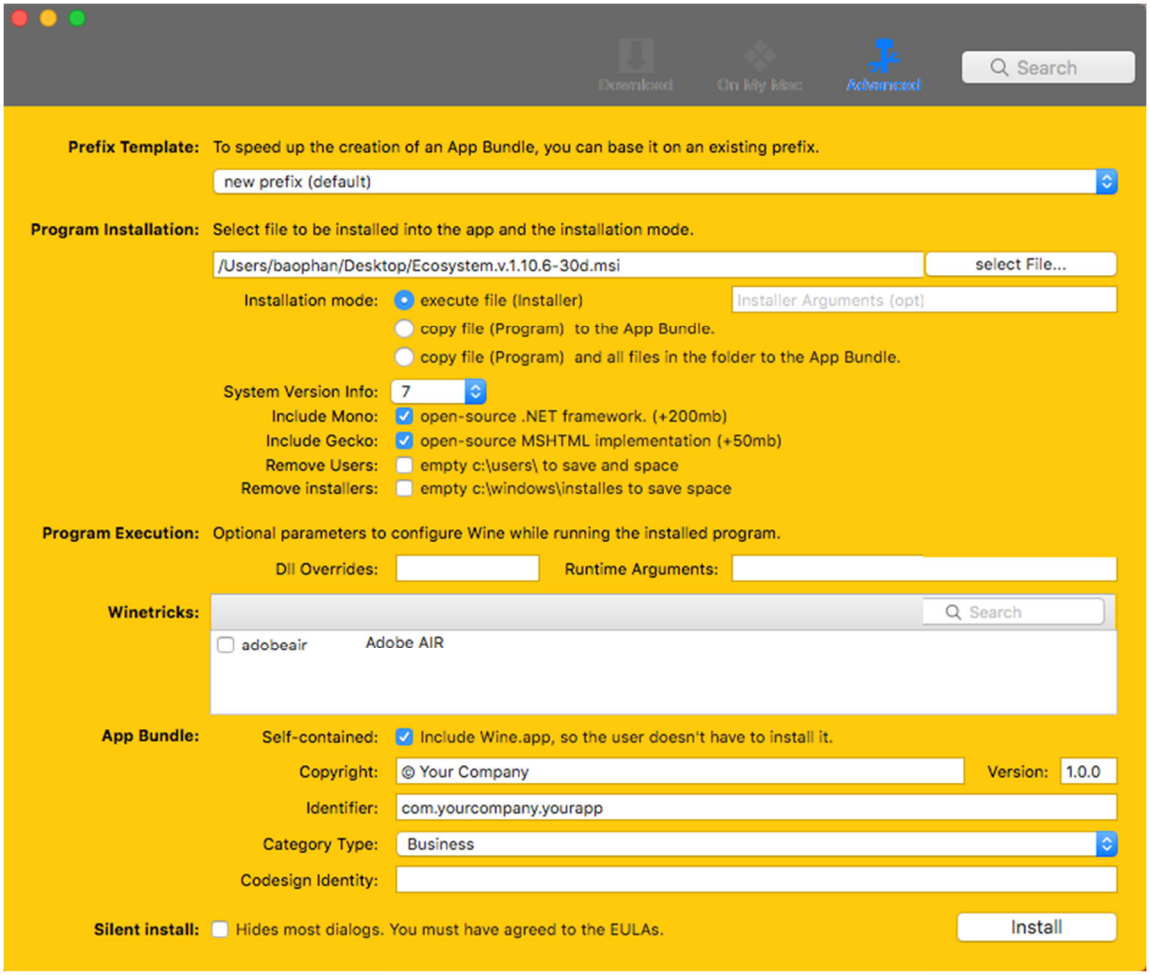


Figure 95: Sample configuration for installing Ecosystem 1.10 SW on Machintosh using the Wine Bottler.

Appendix F: Distance Education

The Ecosystem can be effectively applied in classes involving distance education. Such applications would rely on 3rd party solutions, such as Webex (9) or Skype (10), for screen sharing.

Appendix G: Identification of Functional and Performance Requirements Illustrated

The identification of the functional and performance requirements consists of the following key steps:

1. Hone in on the right key words.
- Look for key words that describe the function that will be delivered.
2. Ask the relevant questions.
- The functional requirements address the function that the design must provide.
- Therefore, ask: ”What must it do?”
- The performance requirements address how well the design must do it.
3. Enter the results into the Ecosystem.
- See Figure 33.

The following is a problem definition for a kart stand for kart racers. The key words of interest are highlighted in blue.

> Kart racing is a variant of open-wheel motorsport with small, open, four-wheeled vehicles called karts. They are raced on scaled-down demanding pavement circuits. The karts themselves weigh 200lbs and must be transported to the race complex by a transportation vehicle. A mechanism is needed to facilitate the moving of the kart to and from the transport vehicle and the raceway as seen below in Figure 1. For solo operations, this is made impossible by the awkward size and weight of a kart.
> Current off the shelf solutions are either expensive and or unstable. The client currently uses a solid stand with wheels which requires a minimum of two people to load and unload the kart from the stand. The current stand also does not facilitate ease of kart transportation because it requires two people to place the kart onto the stand. Thus, there exists a need for a reliable and stable stand which can assist the solo kart racer in transportation and storage of the kart.

Figure 96 highlights the corresponding, relevant questions along with some answers.

FRX	PRX.1	Priority PRX.1	PRX.2	Priority PRX.2
What must it do?	How well does it do it?	How important?	""	""
Lift	Load? 200 lbs/irregular	High	how high? ?????	Med
Move	steer? 360 degrees	High	How fast? ???	Med
Constraints				
Pass/Fail	Criteria			
Geometric dimension	nominal/tolerance			
(Cost)				
(Weight)				
Stability	Lateral load?	Movement surface condition?	Load security?	
Safety	Design Factor?			
Objectives	**Direction**	**Priority**		
Things to optimize		How important?		
(Cost)	Minimize	High		
(Weight)	Minimize	Low		
Reliability	Maximize	Medium		

Figure 96: Towards definition of functional and performance requirements for a kart stand for kart racers.

Appendix H: Support for the ABET Learning Outcomes

Version 1.20 of the Ecosystem for Design Assessment and Verification supports the following ABET learning outcomes:

1. Ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science and mathematics.
2. Ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety and welfare, as well as global, cultural, social, enviromental, and economic factors.
3. Ability to communicate effectively with a range of audiences.
4. Ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.
5. Ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
6. Ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.
7. Ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

For a mapping between the ABET learning outcomes 1 – 7, and the previous A – K, refer to http://www.abet.org/wp-content/uploads/2018/03/C3_C5_mapping_SEC_1-13-2018.pdf

Appendix I: Usage by Formula or BAJA SAE Teams

Configuration

Figure 97 summarizes typical configuration of the Ecosystem 1.20 SW in case of large project teams, such as Formula or BAJA SAE. Here, there are separate e-design notebook files (masters) per sub-team. The users sync their local copies up with the masters using one of the sync applications listed in Appendix B. The users may include individual designers, faculty adviser or sponsor. Even fabricators or machinists may be able to enter data.

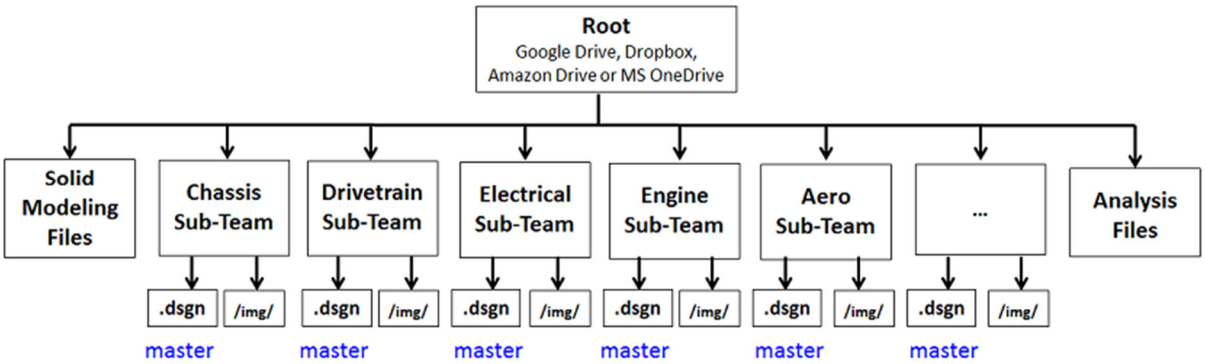


Figure 97: Application of the Ecosystem 1.20 SW in a setting involving a large project team, such as Formula or BAJA SAE. We presently advise each sub-team to keep a separate e-design notebook file. The sync applications from Appendix B can be used to sync up these separate master files with the local copies maintained by each user.

Assumptions

The Ecosystem is primarily intended to capture design projects, specific to a given sub-team. Using the Ecosystem, designers of given a component (e.g., a gear box) for a given sub-assembly can archive their design description, summarize their design selection and provide supporting rational. Although a SolidWorks master assembly for an entire race car can indeed be imported, the Ecosystem – at the present time – is not intended for management of entire race car design projects.

Benefits

Sample benefits are summarized in

http://www.imagars.com/reasons-for-adoption-oregon-institute-of-technology/

Knowledge Transfer

1. The Ecosystem may provide significant help to future Formula and BAJA SAE teams.
   - The Ecosystem can help new members familiarize themselves with what was done and why.
   - Incoming students can rapidly identify the rationale for given design decisions, as well as the opportunities for improvement identified, and get up to speed.
2. The Ecosystem can provide design teams with access to all the references used in the past.
3. Incoming students, that have been assigned to a given sub-team, can rapidly search the design archives, identify parts or assemblies specific to that sub-team, and quickly locate designs of interest.

Design Report

1. The automatically generated reports produced by the Ecosystem facilitate systematic and effective presentation to the design judges at the Formula or BAJA SAE competitions.
   (a) For any of the sub-systems, the judges are expecting the participating teams to present sound rationale for the design decisions made.
   - The Ecosystem provides facilities for systematically capturing the rationale.

   (b) Student design teams are expected to communicate to the design judges, in the limited time given, all the great aspects about their subsystems.
   - The Ecosystem facilitates sound logical connections and helps identify possible gaps.
   - The Ecosystem allows students to systematically articulate what was done and why.
   - All the relevant results (images) are linked into the tables.
   - If students were to pull the information from many different places, chances are that valuable time may be lost, if students don't immediately locate information of interest.

   (c) The Ecosystem offers user-friendly tools facilitating effective communications with the design judges.
   - Designers can double-click on images of interest and view through pop-up windows.
   - The pop-up window, and corresponding images, can be further scaled at will.
2. The Ecosystem helps design teams capture requirements and meet rules for the sub-systems.
   - Engineering requirements based on customer requirements.

Cost Report

The tabs for the Bill of Material, Manufacturing Options and Cost Summary provide thorough overview of the cost items, and may help design teams prepare the cost report.

Business Presentation

1. The Ecosystem can help capture information provided about the target customer and market profile, provided by the SAE.
2. The Customer Interview tab can help students capture the results of some mock interviews.
   - If students want to utilize surveys or user groups, these results can be captured.
3. The Ecosystem may help students effectively defend their marketing presentation, based on the SAE rule book.

Sample Content for Ecosystem Tabs

Design Overview tab

- The Design Overview tab can be used to comment on integration aspects.
- The front suspension, for example, needs to work with the rear suspension and steering.
- Prior to Detailed Design (CFD or FEA analysis), students might attempt to verify that things actually fit together.
- This may help prevent unwarranted effort down the road (and hence improve productivity).

Model Tab

- Using the Model tab, incoming students, that have been assigned to a given sub-team, can rapidly search the design archives, identify parts or assemblies specific to that sub-team, and rapidly locate designs of interest.
- Designers can compile a short list of designs of interest, and open up in e-Drawings Viewer, SolidWorks or CATIA for closer inspection, ultimate verification or editing.
- Per Table 5, the Ecosystem both provides backward compatibility and assurances for future proofing.

Calculations & Analysis Tab

- The table exported from the Calculations & Analysis tab into the automatically generated report helps with systematic presentation to the design judges.
- The images capturing the FEA results are automatically linked in and included in the exported report.

Gate Review tab

- By entering items from the judges score sheet into the Gate Review tab, students can verify their vehicle design, prior to heading for competition.
- The items in the judges score sheet are made publicly available, prior to competition.
- Systematically checking their designs in advance may help in terms of passing tech inspection.

Meeting Notes Tab

- The Meeting Notes tab can be used to capture lessons learned (to assign dates to important observations).
- The Meeting Notes tab can also be used as a running design log.

Routes towards Adoption

Common Starting Point

The following configuration seems common among Formula and BAJA SAE teams:

1. Google Drive.
- With part and assemblies from at least a few, if not many, of the past years cars archived.
2. SolidWorks.
- SolidWorks seems most popular by far, even though some teams may employ Siemens NX.
3. Design reports from previous years may or may not be archived.

Options Available

Formula and BAJA SAE teams have several options for adopting the Ecosystem:

1. Holistic adoption.
- The Oregon Institute of Technology (OIT) opted for a holistic adoption of the Ecosystem.
- Imagars visited OIT in Klamath Falls OR and offered a full-day training to help the Formula and BAJA SAE teams get started.
- Teams interested in this route are welcome to contact Imagars at marketing@imagars.com.
2. Per subsystem adoption (with data sharing).
- This is our *recommended* approach.
- Teams can elect to start out by capturing the design specific for one of the subsystems in the Ecosystem.
- As opposed to six master e-design notebook files in Figure 84, there only may be one to begin with.
- If Imagars was provided access to the shared repository, e.g., Google Drive, Imagars could
- help teams get started (help populate the initial e-design notebook file).
- Imagars could offer on-site or web-based training, to help teams get started.
- In either case, contact marketing@imagars.com to arrange the specifics.
3. Per subsystem adoption (without data sharing).
- This route is the same as the one before, except here members of the Formula or BAJA team populate the initial e-design notebook file (not an Imagars representative).
- Imagars may recommend a web-based training, in this case.
- Feel free to contact marketing@imagars.com to arrange the specifics.
4. Per project management module.
- The Berkeley Formula Racing (BFR) was planning to capture their design decisions in the Ecosystem, per
  http://www.imagars.com/reasons-for-consideration-berkeley-formula-racing/

- Teams may elect to adopt the Ecosystem to address what they consider a weak (or even the weakest?) link in their project management system.
- The Ecosystem can be adopted in stages, per project management module.
- As before, Imagars could offer on-site or web-based training, to help teams get started.
- Feel free to contact marketing@imagars.com to arrange the specifics.

Appendix J: Usage by Rocket Design Teams

- Configuration of the Ecosystem by rocket design teams, such as the ones participating in the CubeSat or SAE Aero competitions, resembles the one for the Formula and BAJA SAE teams.
- The rocket design teams could maintain a separate e-design notebook (.dsgn) file per sub-team.
- Given the extent of the Ecosystem's alignment with the NASA Product Life-Cycle Model, per Appendix K, we have a reason to believe the Ecosystem can help rocket design teams in terms of project management.
- The example on the Electric Fuel Feed System illustrates an application of the Ecosystem on a rocket design project.

Appendix K: Notes on Textbooks for Engineering Design

Table 9 summarizes the correspondence of the Ecosystem with textbooks in the area of engineering design. Among the textbooks listed in Table 9, the ones by Ulrich & Eppinger and Ullman seem to be the most popular ones for teaching ME capstone design. We are yet to identify a textbook commonly used to teach ME capstone design with which the Ecosystem does not offer a good match.

Table 9: Correspondence of the Ecosystem with textbooks in the area of engineering design.

Textbook	Author	Correspondence
Product Design and Development (11)	K.T. Ulrich & S.D. Eppinger	Very good, as shown in Table 10 (fairly classical design process)
The Mechanical Design Process (12)	D.G. Ullman	Very good, as shown in Table 11 (classical ME design process)
Introduction to Mechanical Engineering Design (13)	Yi, Cho, Byun, Lee and Yoon	Very good (this User Manual appears as an Appendix)
Fundamentals of Product Development (14)	C.A. Mattson & C.D. Sorensen	Pretty good, upon close look (see Table 14)
Shigley's Mechanical Engineering Design (15)	R.G. Budynas and J.K. Nisbett	Shigley's textbook has technical focus (encyclopedic approach)
Design for Electrical and Computer Engineers (16)	Ralph M. Ford & Chris S. Coulston	Apparently good

Alignment with Product Design and Development by Ulrich and Eppinger

Table 10 expands on the alignment between the Ecosystem and Product Design and Development by Ulrich and Eppinger.

Table 10: Alignment of the Ecosystem with Product Design and Development by Ulrich & Eppinger.

Topic	Corresponding Ecosystem Tabs
Product Planning (Ch. 3)	Schedule
Identifying Customer Needs (Ch. 4)	Customer Interviews
Product Specifications (Ch. 5)	Product Design Specification, Engineering Requirements
Concept Generation (Ch. 6)	Design Ideas, Design Description
Concept Selection (Ch. 7)	Design Selection
Concept Testing (Ch. 8)	Customer Interviews or Testing tabs
Product Architecture (Ch. 9)	Risk Identification, Calculations and Analysis, Testing, Bill of Materials, Manufacturing Options
Industrial Design (Ch. 10)	All tabs
Design for Manufacturing (Ch. 11)	Manufacturing Options
Prototyping (Ch. 12)	Model, Testing, Schedule, Bill of Material, Parts and Assembly
Robust Design (Ch. 13)	Risk Identification, Calculations and Analysis

Alignment with Mechanical Design Process by Ullman

Table 11 summarizes the general alignment between the Ecosystem and Product Design and Development by David G. Ullman.

Table 11: Generic Alignment of the Ecosystem with the Mechanical Design Process by David G. Ullman.

Topic	Corresponding Ecosystem Tabs
Designers and Design Teams (Ch. 3)	Team Definition
The Design Process and Product Discovery (Ch. 4)	Project Goals
Planning for Design (Ch. 5)	Schedule
Understanding the Problem and the Development of Engineering Specification (Ch. 6)	Customer Definition, Customer Interviews, Product Design Specification, Engineering Requirements
Concept Generation (Ch. 7)	Design Ideas, Design Description
Concept Evaluation and Selection (Ch. 8)	Design Selection
Product Generation (Ch. 9)	Bill of Material
Product Evaluation for Performance and the Effects of Variation (Ch. 10)	Testing
Product Evaluation: Design for Cost, Manufacture, Assembly and Other Measures (Ch. 11)	Cost Summary, Manufacturing Options, Parts & Assembly
Wrapping up the Design Process and Supporting the Product (Ch. 12)	Design Revisions

Table 12 further expands on the alignment of the templates provided by the Ullman's textbook and the Ecosystem. These templates can be accessed through McGraw Hill's website:

http://highered.mheducation.com/sites/0072975741/student_view0/templates.html

Table 12: Alignment of the Ecosystem with specific templates from Ullman's textbook (12).

ID	Template	Correspondence with Ecosystem
1	Product Decomposition	Combines information from the tabs for Bill of Material and Manufacturing Options
2	Team Contract	Not provided in Ver. 1.20 of the Ecosystem SW
3	Meeting Minutes	Aligns reasonably well with the Ecosystem tab for Meeting Notes
4	Team Health Inventory	Not provided in Ver. 1.20 of the Ecosystem SW
6	Plastic Material Identifier	Not provided in Ver. 1.20 of the Ecosystem SW
7	Design Report	Aligns reasonably well with the structure of the automatically generated reports
8	Product Proposal	One should be able to extract the information in the Product Proposal from a fully populated Customer Interview tab. The items listed in the Proposal comprise a subset of the Categories from the Customer Interview tab.
10	Project Planning	Most of the information in the Project Planning template can be extracted from the Ecosystem Schedule tab.
11	Strengths, Weaknesses, Opportunities and Threats (SWOT)	While the Ecosystem does not offer an explicit SWOT tab, much of information in SWOT template can be extracted from a thoroughly prepared Customer Interview tab.
12	Technology Readiness Assessment	Some of the information listed, such as the Failure Modes, appear in the Calculations tab for the Risk Analysis.
13	Plastic part cost calculator	Some of the information listed here can be extracted from the Cost Summary tab in the Final Design phase.
14	Machined part cost calculator	
15	Morphology	Resembles the Decision Matrices from Design Selection tab

Table 13: Alignment of the Ecosystem with specific templates from Ullman's textbook (continued).

ID	Template	Correspondence with Ecosystem
16	Voice of the Customer	The information listed in the Voice of the Customer template is a subset of the information collected in the Customer Interview tab.
17	Reverse Engineering for Function Understanding	While the Ecosystem does not provide a tab for reverse engineering, the information in this template can be obtained by subjecting the product decomposed to the Functional Decomposition in the Design Selection tab.
19	Test Report	The Test Report template resembles the Testing tab in the Ecosystem. It is surprising to see no mention of the requirement to be tested in the Test Report.
20	Vendor Selection or Make/Buy Decisions	Not directly supported in the Ecosystem 1.20 SW, but does resemble content from the Manufacturing Option tab.
21	Design for Assembly	Resonates with content of the Parts & Assembly tab.
19	FMEA	Combines content from Risk Identification and Schedule tabs
23	Bill of Materials	Resonates well with content of the tab for Bill of Materials.
26	Change Order	Align with content of the Design Revision tab.
27	Patent Prospectus	Little support; patents can be listed as an Information Source
28	Personal Problem – Solving Behavior	Not supported in Ver. 1.20 of the Ecosystem SW

Alignment with Fundamentals of Product Development by Mattson and Sorensen

Table 14 expands on the alignment between the Ecosystem and Fundamentals of Product Development by Mattson and Sorensen.

Table 14: Alignment of the Ecosystem with Fundamentals of Product Development by Mattson and Sorensen.

Topic	Corresponding Ecosystem Tabs
Concept Development (Ch. 5)	Design Ideas, Design Description, Design Selection
Customizing the Product Development Process (Ch. 8)	Tab Configuration, Schedule, Testing
External search	Customers, Customer Interviews, References
Internal search	
Opportunity Development (Ch. 4)	Customer Interview, Product Design Specification, Engineering Requirements
Product Refinement (Ch. 7)	Design Revisions
Requirement – Measurement matrices	Product Design Specification, House-of-Quality (under Design Selection)
Screening matrices (Appendix)	Scoring Matrix (under Design Selection)
Scoring matrices (Ch. 3 or Appendix)	Decision Matrix (under Design Selection)
Subsystem Engineering (Ch. 6)	Design Overview
Test considerations in early design phases	Engineering Requirements

Appendix L: Mapping to Standard Design Processes from Industry

Table 15 summarizes the correspondence of the Ecosystem with a few common design processes form industry.

Table 15: Correspondence of the Ecosystem with selected design processes from industry.

Process	Correspondence
IDOV Process of Six Sigma	Very good (see Table 16)
V-Model of System Engineering	Good (see Table 17)
Integrated Product Development Systems	Good
NASA Life Cycle Phases	Fairly good (see Table 19)

Alignment with the IDOV Process of Six Sigma

Table 16 expands on the alignment between the Ecosystem and the Identify, Design, Optimize, Verify (IDOV) process of Six Sigma (17).

Table 16: Alignment of the Ecosystem with the IDOV process of Six Sigma.

Process Step	Corresponding Ecosystem Tabs
Identify	Tabs of the Requirement Definition phase
Design	Tabs of the Concept Design phase
Optimize	Tabs of the Detailed Design phase
Validate	Tabs of the Final Design phase

Alignment with the V-Model of System Engineering

Table 17 expands on the alignment between the Ecosystem and the V-Model of System Engineering, shown in Figure 98 (18).

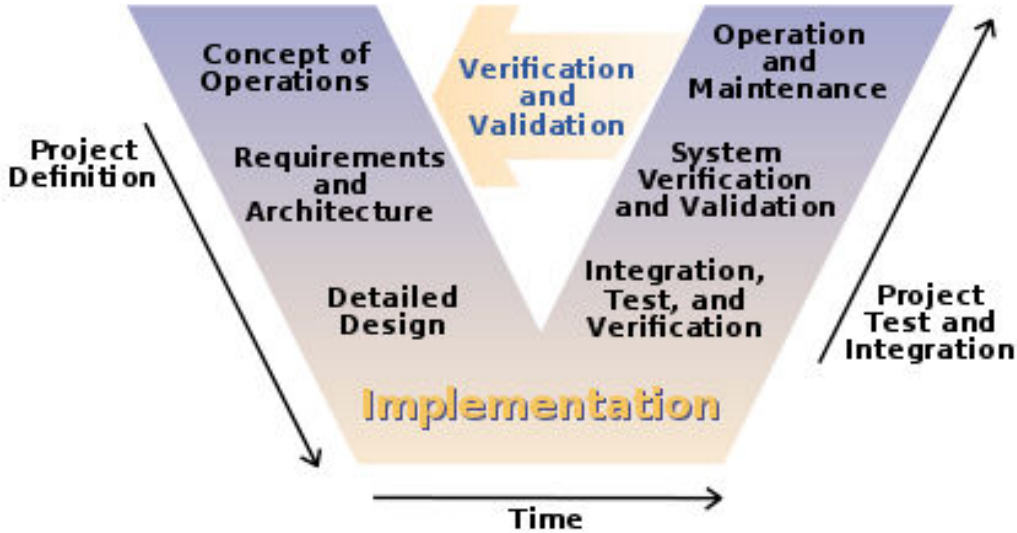


Figure 98: The V-Model of system engineering (18).

Table 17: Alignment of the Ecosystem with the V-Model of system engineering.

Process Step	Corresponding Ecosystem Tabs
Concept of Operations	Tabs of the Requirement Gathering and Concept Design phase
Requirements and Architecture	
Detailed Design	Tabs of the Detailed Design phase
Implementation	
Integration, Test and Verification	Tabs of the Final Design phase
Operation and Maintenance	Tabs of the Design Revisions phase

Military-Standard-498 (MIL-STD-498)

- MIL-STD-498 is a United States military standard whose purpose was to "establish uniform requirements for software development and documentation."
- It was released Nov. 8 1994, but canceled on May 27 1998, and replaced by the essentially identical demilitarized version EIA J-STD-016 as a process example guide for IEEE 12207.
- Table 18 captures the rough correspondence between the Ecosystem and MIL-STD-498.

Table 18: Alignment of the Ecosystem with Military-Standard-498.

Activity	Corresponding Ecosystem Phase
5.1 Project planning and oversight	Requirement Gathering
5.2 Establishing a SW development environment	
5.3 System requirements analysis	
5.4 System design	Concept Design
5.5 Software requirements analysis	Requirement Gathering
5.6 Software design	Concept Design
5.7 Software implementation and unit testing	Detailed Design
5.8 Unit integration and testing	
5.9 CSCI qualification testing	
5.10 CSCI / HWCI integration and testing	
5.11 System qualification testing	Final Design
5.12 Preparing for software use	
5.13 Preparing for software transition	
5.14 Software configuration management	
5.15 Software product evaluation	
5.16 Software quality assurance	
5.17 Corrective action	Design Revisions
5.18 Joint technical and management reviews	Management Layer

Alignment with the NASA Life-Cycle Phases

Table 19 and 19 expand on the alignment between the Ecosystem and the NASA Life-Cycle Phases, shown in Figure 99 (19).

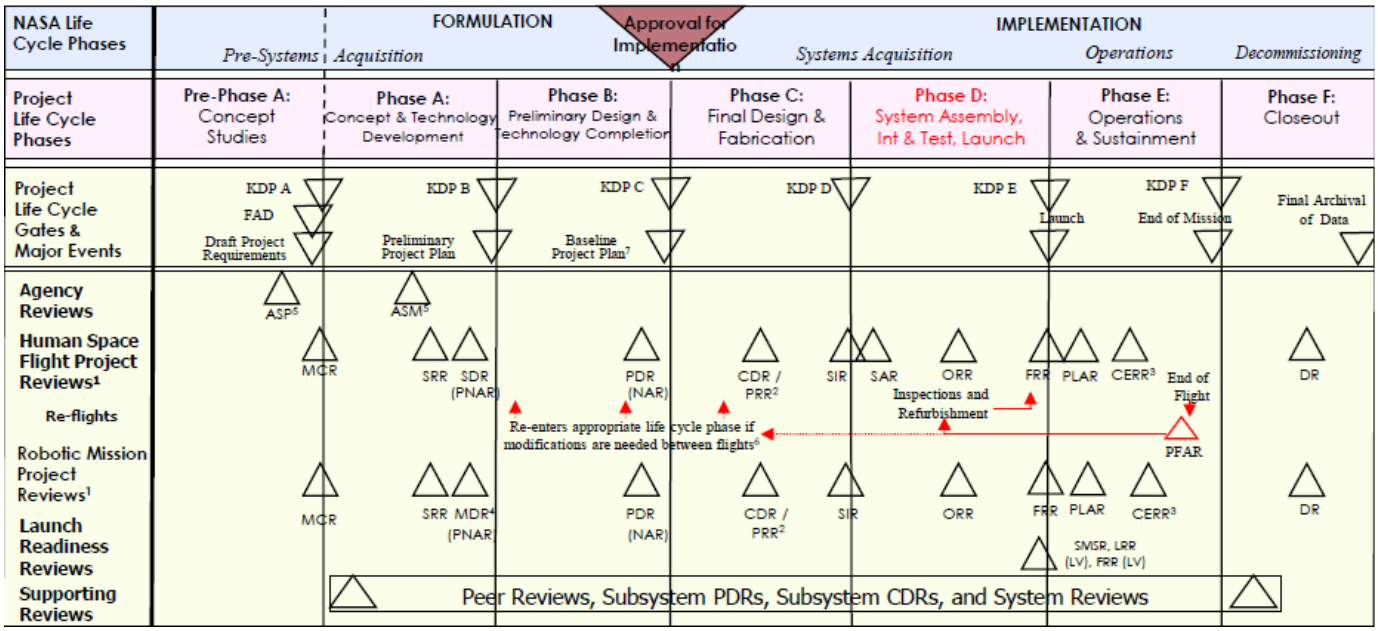


Figure 99: The NASA Life-Cycle Phases (19).

Table 19: Alignment of the Ecosystem with the NASA Life-Cycle Phases.

Project Life-Cycle Phase	Corresponding Ecosystem Tabs
Phase A: Concept & Technology Development	Tabs of the Concept Design phase
Phase B: Preliminary Design & Technology Completion	Tabs of the Detailed Design phase
Phase C: Final Design & Fabrication	Tabs of the Final Design phase
Phase D: System Assembly, Integration, Test, Launch	
Phase E: Operations & Sustainment	Design Revisions
Phase F: Closeout	Phase and Gate Review tabs of Final Design

Table 20: Alignment of the Ecosystem with the NASA Life-Cycle Phases.

NASA		Corresponding Ecosystem Review Tab
Review	**Title**	
P/SRR	Program Requirement Review	Gate Review tab of Requirement Definition phase
P/SDR	Program Definition Review, or System Definition Review	
MCR	Mission Concept Review	Gate Review tab of Concept Design
SRR	System Requirement Review	Gate Review tab of Requirement Definition phase
MDR	Mission Definition Review	
SDR	System Definition Review	Gate Review tab of Concept Design
PDR	Preliminary Design Review	Gate Review tab of Detailed Design
CDR	Critical Design Review	
PRR	Production Readiness Review	
SIR	System Integration Review	
TRR	Test Readiness Review	Gate Review tab of Final Design
SAR	System Acceptance Review	
ORR	Operational Readiness Review	
FRR	Flight Readiness Review	
PLAR	Post-Launch Assessment Review	
CERR	Critical Event Readiness Review	
PFAR	Post-Flight Assessment Review	
DR	Decommissioning Review	

Other Standards

Table 21 lists five areas that group standards for Model-Based Engineering (MBE) over the product lifecycle.

Table 21: Notes related to other industry standards.

Standard	Notes
1. 3D Data Content and Format	
ISO 10303-242	Content and format data exchange using STEP and PLCS
ISO 14306	Content and format data exchange using JT with Parasolid
ISO 14739-1	Content and format data exchange using 3D PDF with PRC
2. 3D Product Definition	
ASME Y14.41	Digital product definition data practices
ISO 16792	
ASME Y14.100	Engineering drawing practices
3. 3D Technical Data Package	
MIL-STD-31000A	Standard practices for Technical Data Packages How to organize your product data and in what format to deliver it?
4. 3D Model Archival	
NAS 9300-007	Long Term Archiving and Retrieval of digital technical product documentation such as 3D CAD and PDM Data
5. 3D Model Technical Publications	
S1000D	International specification for Technical Publications utilizing a common source database
IPDS	Integrated Product Development Standard (Honeywell and Raytheon)
CM2 Process	Configuration Management

Appendix M: Attaining a Complete Solution for Instructors

- Imagars recommendation to capstone instructors is to deploy the Ecosystem SW along with their Learning Management System of choice (e.g., Blackboard or Canvas), and along with a 3rd party application for team formation and/or peer evaluation.
- If desired, the Ecosystem message board,

  ecosystem.imagars.com

  can be used to keep track of communications within student design teams, or between capstone instructor (or faculty advisor) and the student design teams.
- The Ecosystem can guide students through the design process, help the students learn good design practices, and avoid oversights.
- The reports from the Ecosystem, i.e., the e-design project journal (.dsgn file) and the exported report (.pdf, .html or .odf) can be uploaded into the Learning Management System, and the team formation can be handled using the 3rd party tool.
- The standardized structure of the exported reports is expected to help instructors with evaluation of the students' work, by making it easy to locate content of interest.

Team Formation

While various tools can be used for team formation (even as simple as Excel sheets), it is our understanding that the CATME Team Maker is a popular one:

https://info.catme.org/

Peer Evaluation

Similarly, it is our understanding that CATME Peer Evaluation constitutes one of the tools available for peer evaluation:

https://info.catme.org/

Oversight during the Course of a Term

To oversee students' progress, during the course of a term, instructors have a few options at their disposal, such as:

1. Provide access to the centralized repository (e.g., Google Drive, One Drive, Amazon Drive or Dropbox) storing the master project journal (the e-design notebook file).
2. Ask the students to use the Ecosystem message board for team communication.
   - The instructor can sign up for the message board as well, and gain access to the communication trail.
   - The message board has some nice features for controlling access privileges.
3. Ask the students to submit (e-mail in) interim progress updates.
   - Using the Ecosystem, students can easily export their design work into an interim progress report, at any given time.

