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Diogenes, a Process for Finding Unintended Consequences

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Abstract. Companies, governments and individuals often create products, processes and procedures that solve a particular problem, only to discover that their solution has created a second problem, worse than the first. These secondary problems are often unintended consequences. Finding unintended consequences, as a part of the development process, will likely increase safety, reduce financial risk and improve customer satisfaction. This paper contains the design for a new process, named Diogenes, that will help systems engineers predict unintended, but foreseeable, consequences of a new system that is being designed. This paper contains the use cases, design diagrams, test procedure, validation and verification for Diogenes.

Examples of Unintended Consequences

The US federal spent vast amounts of money to help people grow and ferment corn into alcohol. Federal subsidies for ethanol production were supposed to lower gas prices and reduce greenhouse gases from vehicle emissions. However, if the subsidies lowered the price of gasoline, then they would increase the vehicle miles traveled by consumers. This would produce the unintended consequences of congestion on the roads and increased emissions [Khanna et al., 2008].

The Chinese needed to stop their explosive population growth. So in 1979 they instituted the One Child Policy. While China’s family planning programs successfully reduced the fertility rate, they also had the unintended consequences of increasing abortions and distorting the country’s sex ratio: in 2005, China had 118 boys born for every 100 girls. Some caution that marriage prospects for the next generation of Chinese men are grim [Ebenstein, 2008].

“A cap on drug benefits was associated with lower drug consumption and unfavorable clinical outcomes. In patients with chronic disease, the cap was associated with poorer adherence to drug therapy and poorer control of blood pressure, lipid levels, and glucose levels. The savings in drug costs from the cap were offset by increases in the costs of hospitalization and emergency department care.” [Hsu et al., 2006].

Local habitats and species have suffered from the introduction of exotic animals and plants for food, for decorative purposes, or to control unwanted species, which often leads to more harm than good. For example, Kudzu was introduced into the United States in 1876, as a forage crop and an ornamental plant. Later the US government encouraged farmers in the southeast to plant kudzu to reduce soil erosion. It was subsequently discovered that the southeastern US has near-perfect conditions for kudzu to grow out of control. Kudzu was named a pest weed by the US Department of Agriculture in 1953.

Brazilian researchers imported honeybees from Africa in 1956 in an effort to produce a honeybee better suited to the South American tropics. They were successful. Unfortunately, Africanized honeybees are aggressive. If the bees feel that their colony is threatened, large numbers may sting people, pets and livestock. They have now spread up to the middle of the United States.

The Dow Jones industrial average dropped 1000 points in one hour on May 24, 2010. No one knows exactly how that could have happened, except for the people who studied UiCs and made lots of money on the aberration that they caused.

An event can cause an unintended consequence (UiC). That consequence can cause another UiC, etc. This linked process can continue for a long time and is nicely illustrated by the following 600-year-old poem.

For want of a nail, a shoe was lost
For want of a shoe, a horse was lost
For want of a horse, a rider was lost
For want of a rider, a message was lost
For want of a message, a battle was lost
For want of a battle, a kingdom was lost
All for want of a nail

An article in The New York Times on September 30, 1999 stated, "In a move that could help increase home ownership rates among minorities and low-income customers, the Fannie Mae Corporation is easing the credit requirements on loans that it will purchase from banks and other lenders… Fannie Mae, the nation's biggest underwriter of home mortgages, has been under increasing pressure from the Clinton Administration to expand mortgage loans among low and moderate income people… subprime borrowers [Holmes, 1999]." Later, Wall Street and the bankers found a way to disguise these subprime mortgages by mixing them with good loans. The UiCs of all this was the Great Recession of 2008, where most of the people lost half of their retirement funds, but a few people made a lot of money

Not all UiCs are undesirable

Some UiCs are desirable. For example in the 1960s, scientists at 3M® produced a glue that did not stick very well. The positive UiC was the invention of the ubiquitous Post-it® notes.

In the 1950s, IBM® could have bought the patents for Xerox's photocopy machine very inexpensively. But they did a market research study and concluded that no one would pay thousands of dollars for a machine that would replace carbon paper. The positive UiC of the copy machine was that they could delight their customers with a machine that provided dozens of copies in just minutes.

In 1938, a chemist was attempting to make a new refrigerant. The iron of the pressurized storage container catalyzed the polymerization of perfluorethylene into Teflon®.

Case for Change

The United States of America has problems such as global warming, rising national debt, poverty, illegal immigration, ineffective educational systems, terrorist threats and corruption and greed by officers in our financial institutions. Many of these problems are of our own doing. Quite often, a government organization makes rules or regulations that unknowingly have harmful UiCs (UiCs). However, it is possible to create a process that will help decision makers to find potential negative UiCs of their decisions. Diogenes is such a process. Thwarting negative UiCs will give Americans a safer and more pleasant living environment and it will reduce the national debt. Politicians will be able to scathingly deride negative UiCs of legislation introduced by the opposing party.

In a traditional company, lawyers, ethics committees and shareholders would be most concerned with negative UiCs. A program manager might say, "Why should I care if my system adversely affects another system? That will not affect my bottom line." But Taguchi said that it is not good enough to just be within tolerances: if the product is off its target, then something is wrong and it should be fixed. Taguchi called the penalty of this unknown wrong a Cost to Society. The program manager might say that the harmed system has no power over him and his system. He may be right, but the Customer and the Customer's Customer do have that power, although their effects are not direct. However, as systems become more complex and globally interconnected, the health of the whole ecosystem will affect the program manager's bottom line. Therefore, it *is* in the best interests of the program manger to avoid negative UiCs.

Diogenes can give something for nothing. Most companies already have processes for discovering defects and risks. With Diogenes, while looking for defects and risks, you can also find opportunities for Built-in Self-Test (BiST), positive UiCs and negative UiCs. This process does not generate or need new data, but rather it takes information that is already generated for the purpose of development and reviews it in a way that may anticipate (and thus avoid) future problems.

In any company, this would be a new process. Therefore, to get management support, it will need a powerful sponsor or champion. Perhaps the Vice President for Engineering would be appropriate for this role.

Diogenes Design Model

Product Position Statement. For systems engineers who need to ensure the global success of a system being designed, Diogenes is a process that will help predict unintended, but foreseeable, consequences of the new system. Unlike risk discovery and failure analysis, Diogenes identifies future effects on *other* systems that might be caused by the system being designed.

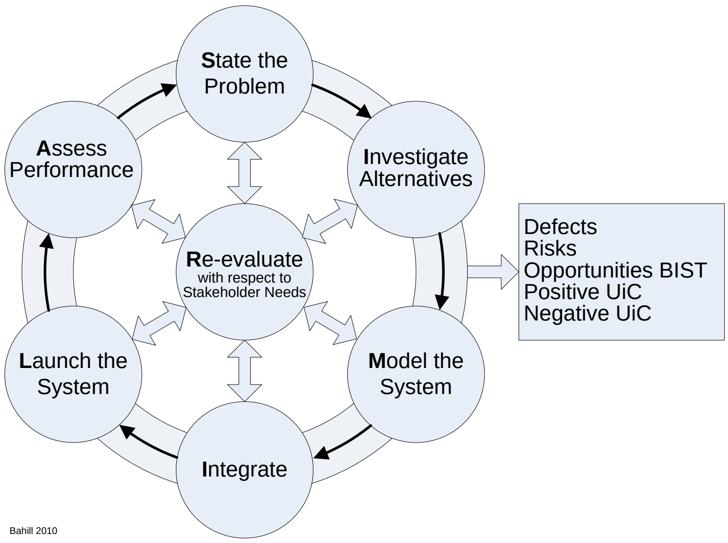


Figure 1. High-level functional block diagram for Diogenes, a process for finding UiCs

Abbreviations that will be used often

SystemZ is the name of a new system being designed that Diogenes will be applied to.
PAL is the Process Assets Library, the place where all of the project's important files are kept.
UiCs is Unintended Consequences.
BiST is Built-in Self-Test.
BICS is Bahill Intelligent Computer Systems

This process for finding UiCs is named after Diogenes of Sinope, a Greek philosopher who lived in the fifth century B. C. Diogenes was a Cynic and disdained conventional thinking and political correctness. He thought that most people were not honest with themselves, because instead of following their conscience, they did what society expected them to do. He carried a lantern in the daytime saying that he was "in search of an honest man."

Philosophy

The purpose of Diogenes is to predict unintended, but foreseeable, consequences of a new system being designed. However, funding for a new process like Diogenes is problematic. Luckily, discovering negative UiCs can be done with a process similar to risk discovery. Therefore, Diogenes might be packaged with risk analysis and would be owned by the Risk Management or the Quality Assurance departments of a company. Fortunately, we have found that defects, positive UiCs and opportunities for BiST could also be discovered at the same time. By searching for all five dropn (defects, risks, opportunities for BiST, positive UiCs and negative UiCs) at the same time, Diogenes can add value, while not adding organizational structure or funding channels.

Of course, like all system design processes, Diogenes must be used iteratively. The emphasis of the search will shift in each iteration. In the early phases of the system life cycle, Diogenes will discover mostly defects and risks. In later phases, it will discover more opportunities for BiST, positive UiCs and negative UiCs.

For engineers analyzing design artifacts of a SystemZ, Diogenes will produce five prioritized lists: (1) defects in requirements, programming code, test plans and designs, (2) risks that could adversely affect SystemZ, (3) opportunities for BiST, (4) positive UiCs that could beneficially affect other systems (5) negative UiCs that could adversely affect other systems.

Owner

Diogenes will be owned by the Risk Management or the Quality Assurance departments of a company. It will be a normal part of the risk analysis process. The importance of this paragraph is that it states how the process would be funded.

Work Products

Diogenes will create and maintain five databases: defects, risks, opportunities for BiST, positive UiCs and negative UiCs (dropn). The Moderator and the Systems Engineer will consolidate and edit the five databases to create the following five prioritized lists.

(1) The list of defects in development documents such as requirements, programming code, test plans and designs will be given to the Author/Designer for resolution. Correcting these defects could be managed by the Moderator or they could be submitted to a change control board (CCB).

(2) The list of risks that could adversely affect SystemZ (risks could be divided into risks and opportunities, but this is seldom done in industry) will be given to Risk Management, which assigns likelihood of occurrence and severity of consequences.

(3) The list of opportunities for inexpensive Built-in Self-Test (BiST) will be given to Test Engineering.

(4) The list of positive UiCs, which could beneficially affect other systems, will be given to Marketing, because discovering positive UiCs could provide additional revenue.

And finally our original target,

(5) The list of negative UiCs, which could adversely affect other systems, will be given to Management and the company lawyers.

Diogenes puts these prioritized lists into the project process assets library (PAL).

Victims

Will Diogenes itself have UiCs? If Diogenes reveals that politicians could have, but did not look for UiCs of the laws they passed, the people might vote them out of office. Exposing negative UiCs of Management pet projects could be politically embarrassing to the systems engineer. If Diogenes shows that a company knew about a negative UiC, but did nothing to eliminate it, the company might be sued.

Requirements

Bahill's System Design Process is use case based. The use cases describe the required behavior (functions) of the system. The requirements are derived in the use cases. Later these requirements are elaborated and put in the requirements documents. For Diogenes these requirements documents are eight pages long and cannot be included in this conference paper.

Use Case Model

A *use case* is an abstraction of required functions of a system. A use case produces an observable result of value to the user. Each use case describes a sequence of interactions between one or more actors and the system. Use case 1 is to Sell Diogenes: because of space restrictions, it has been omitted from this paper.

Use Case 2. This is a concrete use case.

Name: Search for Unintended Consequences (Names of use cases are set in the Verdana font.)

Iteration: 2.3

Derived from: Concept of Operations

Brief description: A Systems Engineer uses Diogenes to help find UiCs of SystemZ, where SystemZ is the class name for a new system being designed.

Level: high

Priority: This is of the highest priority.

Scope: The Systems Engineer, the Design Team, the design documents of SystemZ, Diogenes and the portion of the external world that SystemZ could affect. A *typical* product design would not have the external world within its scope.

Added value: The company and society might be able to ameliorate adverse UiCs of SystemZ or capitalize on positive UiCs.

Goal: Find potential UiCs of SystemZ.

Primary actors: Systems Engineer (which could be a single person or a whole department), Design Team (which consists of design engineers, domain experts and managers), Moderator

Supporting actors: Society, Boss, PAL

Frequency: Diogenes will be used in each phase of the design lifecycle.

Precondition: Diogenes has passed all of its Built-in Self-Tests.

Trigger: Conclusion of a design review, which is the start of a new iteration

Main Success Scenario:

1a. A design review has been successfully completed and the next phase of the system life cycle has been authorized to begin.

2. If one does not already exist, the Boss creates a Systems Engineering Team to find UiCs of SystemZ.

3a. If a UiCs Report is in the process assets library (PAL), then Diogenes retrieves it.

4. The Moderator works with the Systems Engineer, uses cause and effect tools and creates UiCs attribute and impact diagrams. These tools are built into Diogenes.

5. <u>Include</u> the Perform Formal Inspection use case.
6. The Systems Engineer shows the prioritized lists of potential negative UiCs to management and assesses the results.
7a. Management authorizes remedial action.
8. <u>Include</u> the Redesign to Avoid UiCs use case.
9. Diogenes puts the UiCs Report in the project PAL [exit use case].

Anchored Alternate Flow:

1b. The system design fails a design review and the project is cancelled or the design team is given another chance [exit use case].
3b. If a UiCs Report is not in the PAL, then the Systems Engineer uses the Problem Statement, writes a UiCs Report and Diogenes puts it in the PAL [return to step 3a].
3b1. If the Problem Statement is not available, then the Systems Engineer writes one [return to step 3b]. The problem statement contains a description of the use cases, risks, design alternatives, most sensitive parameters, test plans and the system design.
7b. Management decides to do nothing about the UiCs
7b1. <u>Include</u> the Ethics Deliberation use case [exit use case].

Postcondition: The project PAL has been updated and the Systems Engineer is ready to start a new iteration.

Specific Requirements (Daniels and Bahill 2004)

Functional Requirements:

FR2-1 Diogenes shall execute Built-in Self-Tests (BiST). (Derived from BICS company policy)

FR2-2 Diogenes shall be capable of reading and writing the project PAL.

FR2-3 Diogenes shall have cause and effect tools that have been modified for making UiCs diagrams.

FR2-4 Diogenes shall have the capability of creating and maintaining five databases: the defects, risks, opportunities for BiST, positive untended consequences and negative UiCs of SystemZ

FR2-5 Diogenes shall have tools for prioritizing lists.

Nonfunctional Requirements:

Author/owner: Terry Bahill

Last changed: September 9, 2010

A use case diagram is the table of contents of a use case model. It shows all of the use cases that have been described so far. Figure 2 is our first use case diagram.

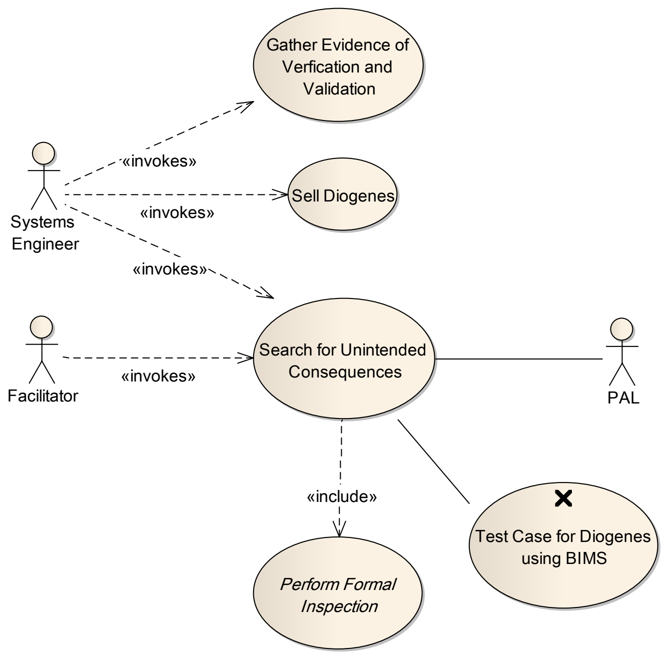


Figure 2. Use case diagram for Diogenes

Use Case 3. This is an abstract included use case.

Name: Perform Formal Inspection

Iteration: 2.3

Derived from: concept exploration document and Fagan [2011]

Brief description: A formal inspection is a structured group review process used to find defects in requirements, programming code, test plans and designs. The flow of this use case is called from the Search for Unintended Consequences use case. When this subflow ends, the use case instance continues where this included use case was called.

Level: medium

Priority: medium

Scope: The Inspection Team, the work products to be inspected and the PAL

Added value: The company will be able to look for defects, risks, opportunities for BiST, positive and negative UiCs all at the same time. This should increase efficiency. Furthermore discovering positive UiCs could provide substantial revenue.

Goal: Find potential defects, risks, opportunities for BiST, positive and negative UiCs of SystemZ.

Primary actors: Inspection Team comprised of Moderator, Author/Designer, Reader, Recorder and additional Inspectors

The **Moderator** leads the inspection, schedules meetings, distributes inspection materials, controls the meetings, reports inspection results and follows up on rework issues. Moderators should be trained in how to conduct inspections. The risk or quality assurance managers often serve in this role.

The **Author/Designer c**reates and/or maintains the work products being inspected. The Author/Designer answers questions asked about the work products during the inspection, looks for defects and fixes defects. The Author/Designer cannot serve as Moderator, Reader or Recorder.

During the meeting, the **Reader** leads the Inspection Team through the work products being inspected, interprets sections of the artifact by paraphrase and highlights important parts**.**

The **Recorder** classifies and records defects and issues raised during the inspection. The Moderator might perform this role in a small Inspection Team.

The **Inspector** attempts to find errors in the work products. This role can be filled by one or several people. However, all participants act as inspectors, in addition to any other responsibilities. The following may make good inspectors: the person who wrote the specification for the work products being inspected; the people responsible for implementing, testing or maintaining the work product; a quality assurance representative; a representative of the user community; and someone who is not involved in the project but has infinite experience and perfect wisdom.

Secondary Actors: the process assets library (PAL)

Frequency: Diogenes will be used at least once in each phase of the design lifecycle.

Precondition: An Author/Designer has requested an inspection of his work product

Trigger: This use case will be included from the Search for Unintended Consequences use case.

Main Success Scenario:

1. **Planning Activity.** The Moderator selects the Inspection Team, obtains work products to be inspected from the Author/Designer and distributes them along with other relevant documents to the Inspection Team.

2. **Overview meeting.** The Moderator explains the inspection process to the Inspection Team. The Author/Designer may describe the important features of the work products.

3. **Preparation.** Each member of the Inspection Team examines the work products prior to the actual inspection meeting. Typically, this will take two hours for each member. The amount of time each person spent will be recorded. Each member should be looking for five things simultaneously: defects, risks, opportunities for BiST, positive and negative UiCs of SystemZ

4. **Inspection meeting.** The Moderator and Reader lead the team through the work products. The issues are brought up one by one and each one is discussed in a round robin fashion where each member comments on each issue. During the discussion, all inspectors can report defects, risks, opportunities for BiST, positive and negative UiCs of SystemZ, all of which are documented by the Recorder. The meeting should last no more than two hours.

   How could a company prime its inspectors to look for UiC?

   If the inspectors are looking at an activity, action, process, procedure, or other verb phrases (an active verb followed by a measureable noun), then tell them to ask, “What problems could this activity create for other systems?” “How could this activity hurt other systems?” “If this activity failed, how could it hurt other systems?”

   If they are looking at an object, component, model or other noun phrases, then tell them to ask, “How could this object hurt other systems?” “How could this object fail?” For each failure event ask, “How could this failure event hurt other systems?”

   If they are looking at a risk, then tell them to ask, “How could this failure event hurt other systems?”

If they are looking at a use case, scenario or other sequences of events, then tell them to ask, "What-if?" For example, "The user does this and the system does that." "What if it doesn't?"

But we really want the mindset of looking for UiCs to become a part of company culture.

5. Diogenes creates and maintains five databases that contain defects, risks, opportunities for BiST, positive and negative UiCs of SystemZ.

6. The Moderator and the Systems Engineer consolidate and edit the five databases to create five prioritized [Botta and Bahill, 2007] lists.

The prioritized list of defects is given to the Author/Designer for rework and resolution.

The prioritized list of risks that could adversely affect SystemZ is given to Risk Management.

The prioritized list of opportunities for Built-in Self-Test (BiST) is given to Test Engineering.

The prioritized list of positive UiCs that could beneficially affect other systems is given to Marketing.

The prioritized list of negative UiCs that could adversely affect other systems is given to Management and the Legal department.

7. Diogenes puts these prioritized lists in the project PAL.

8. **Rework.** The Author/Designer fixes the defects. Each of the other owners will know what to do with his list.

9. **Follow-up:** The Moderator must verify that all fixes are effective and that no additional defects have been created. The Moderator checks the exit criteria for completing of an inspection.

10. Diogenes updates the project PAL [exit use case].

Postcondition. The project PAL has been updated and the Systems Engineer is ready to schedule a new inspection.

Specific Requirements (Daniels and Bahill 2004)

Functional Requirements:

FR3-1 The Moderator shall form the Inspection Team.

FR3-2 The Moderator shall collect the inspection work products and other relevant material and distribute them to the Inspection Team TBD days before the inspection.

FR3-3 The Moderator shall chair the overview meeting.

FR3-4 Each member of the Inspection Team shall examine the work products prior to the actual inspection meeting looking for defects, risks, opportunities for BiST, positive UiCs and negative UiCs of SystemZ.

FR3-5 Each member of the Inspection Team shall record and report the number of hours he or she spent inspecting the materials. Typically, this will be two hours.

FR3-6 The Moderator shall conduct the inspection meeting.

FR3-7 The Recorder shall create and maintain five databases that contain defects, risks, opportunities for BiST, positive untended consequences and negative UiCs of SystemZ.

FR3-8 The Moderator and the Systems Engineer shall consolidate and edit the five databases to create five prioritized lists.

FR3-9 The Systems Engineer shall deliver the five lists to their respective owners.

Stipulation: Each owner will know what to do with his list.

FR3-10 Diogenes shall put these five prioritized lists in the project PAL.

FR3-11 The Moderator shall verify that all fixes are effective and that no additional defects have been created. The Moderator shall check the exit criteria for completing of an inspection.

It has often been said that we can impose requirements on our system, but we cannot impose requirements on operators, pilots and other secondary actors. This is still true. However, here we are imposing requirements on the Moderator and members of the Inspection Team. That is all right, because they are a part of Diogenes.

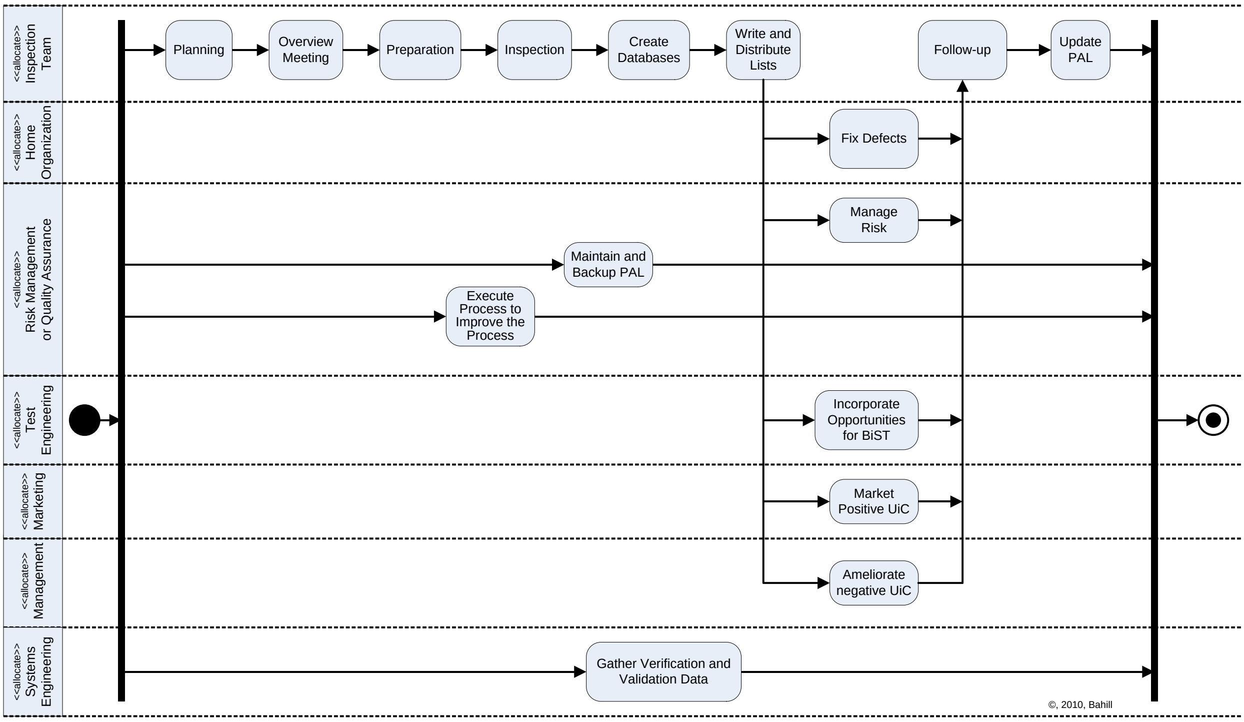
Nonfunctional Requirements:

NFR3-1 The Moderator shall schedule the inspection meeting for two hours. The Moderator shall prepare two dozen pages of documentation for each inspection.

Author/owner: Terry Bahill

Last changed: October 8, 2010

The activity diagram of Figure 3 shows the use case model for Diogenes.



Activity diagram with swimlanes for Diogenes, a search for unintended consequences (UiC) process

Figure 3. Activity diagram for Diogenes

Other Use Case Models

A complete design for Diogenes would probably have dozens of use cases. So far, we have written four use cases. the two above and Sell Diogenes and Gather Evidence of Verification and Validation: Some other proposed use cases include Redesign to Avoid Unintended Consequences and Ethics Deliberation

The Brain Trust

During testing, the Brain Trust served as the Inspection Team. The Brain Trust is comprised of the following retired systems engineering experts: Bruce Gissing, Boeing Commercial Airplanes, Executive Vice President for Operations; Al Chin, Raytheon Fellow, Team lead for CMMI assessment; George Dolan, Raytheon, Engineering Director of Strike Systems, Colonel U. S. Air Force (retired); Bob Sklar, Raytheon Fellow, Project Chief Engineer; Gary Lingle, Raytheon, Director of Systems Engineering, Director Guidance, Navigation & Control; Greg

Shelton, Raytheon, Corporate Vice President for Engineering and Brad Sowers, Raytheon, Technical Director vice Director of Directed Energy Weapons.

Validation of Diogenes using BIMS

To validate Diogenes we applied it to an existing, well-documented, system design (which will be called SystemZ) and showed that Diogenes discovered defects, risks, opportunities for BiST, positive UiCs and negative UiCs of SystemZ. We applied it to the Bahill Illuminance Management System (BIMS) [Bahill, 2010]. Because this system design existed as a document on Bahill's web site, we used MS Word for the implementation. During actual operation, Diogenes looks at all of SystemZ's documentation. But in this validation test, it did not look at the risk analysis documents of BIMS, because we were trying to show that it could find these risks.

Note: the reader of this conference paper should be interested in Diogenes, not BIMS. Therefore, he or she should just skim over the parts of BIMS and concentrate on the outputs of Diogenes, which will be marked in the Gill Sans MT font in red.

BIMS Concept of Operations

Our customer needs a light-management system for the operations rooms of telescope enclosures to be built on Mauna Kea in Hawaii and on Cerro Pachón near **Vicuña** in Chile. However, BIMS must be designed so that it can be adapted for other structures. This system will be named the Bahill Illuminance Management System (BIMS).

Astronomers will use the operations room day and night while observing both the Sun and nighttime targets such as stars and galaxies. In the daytime, the astronomers want a constant illuminance of 400 lux. During the night, the astronomers will be continually going in and out of the operations room. There will be no lights outside, because that would interfere with the telescopes. So they want the light inside the operations room to be dim and constant, so that (1) the astronomers do not have to wait minutes for their eyes to dark-adapt and (2) the light inside does not leak out and interfere with the telescopes. Therefore, they want the inside illuminance at night to be 0.4 lux.

BIMS must conserve energy and provide a natural daylight color spectrum. An efficient way of doing this is to have BIMS use daylight instead of artificial lighting as much as possible. BIMS will be politically correct (environmentally green) because it will use renewable-energy electric-generators. This is a political decision, not an economic or scientific decision. BIMS will probably use solar panels to generate electricity. But other power generating alternatives such as wind turbines and geothermal systems near the Kilauea volcano should be considered. BIMS shall include all equipment needed for connecting to the local AC electric power grid.

BIMS risks, design alternatives, most sensitive parameters, test plans and design are given in Bahill [2010].

Diogenes Applied to BIMS's Use Case

As an example of applying Diogenes, we will use the following use case model. Suggestions of defects, risks, opportunities for BiST, positive UiCs and negative UiCs will be marked in the Gill Sans MT font. This will be followed by a punctuation mark (!), a classifier (defect, risk, BiST, pUiCs or nUiCs) and finally a short name.

Name: Control Illuminance During the Day

Iteration: 3.6

Derived from: Concept of operations

Brief description: The sun rises and sets, but the Bahill Illuminance Management System (BIMS) will keep the illuminance in the operations room constant.

Level: high
Priority: This is of the highest priority.
Scope: The operations room of a telescope facility on a remote mountaintop, a renewable-energy electric-generator and a connection to the local electric power grid. Put your mind in that location and ask what bad things could happen up here?

(1) The Kilauea volcano could erupt or another far away volcano could erupt covering the sky with ash and rendering the solar panels useless! risk, Kilauea volcano erupts.

(2) BIMS could offend Poliahu, the snow goddess of Mauna Kea. It is not known how this could happen. But if the native Hawaiians think that Poliahu is upset, then *we* will have problems. For instance, they have already asked the state of Hawaii change the annual rent from $1 to $50M! nUiCs, BIMS offends Poliahu.

(3) Because Mauna Kea is a remote mountaintop at 13,800 feet, costs will be higher than expected. Transportation is more expensive. Electricity is more expensive. Backup electric generators will be necessary. Labor is more expensive! risk, Geographical location causes higher costs.

Added value: Astronomers are more comfortable and more productive
Goal: Maintain specified illuminance in the daytime.
Primary actors: Astronomer, Engineer, Tester
Supporting actors: Sun, Clouds (and during the night the Moon)
Frequency: It will be used every day. What will happen when it gets old? There must be a plan and a budget for decommissioning each mountaintop structure at the end of its design life. These costs could be quite surprising. For example, in 1959 the UofA purchased and installed a nuclear reactor at a cost of $150k. It is now being decommissioned at a cost of $2M! nUiCs, Money is needed for decommissioning.
Precondition: BIMS has passed all of its Built-in Self-Tests and Tester or the Engineer has started BIMS.
Trigger: The sun rises.
Main Success Scenario:

1. The sun rises in the morning.
2. BIMS turns up the lights and closes the window screens or curtains.
3. BIMS senses the illuminance in the room with light sensors and adjusts the illuminance with light dimmers and window screens or curtains.
4. The sun moves across the sky and the illuminance from the sun starts to increase. (Actually, the earth rotates, but it more intuitive to say that the sun moves.)
5. BIMS decreases illuminance from the lights and partially opens the window screens or curtains. The tradeoff between these two would be determined by sunlight shining on computer monitors, heating and cooling considerations as well as electricity usage.
6. The sun rises to its zenith.
7. If it will not waste heating or cooling energy, BIMS opens the window screens or curtains.
8. BIMS senses the illuminance in the room with light sensors and adjusts the illuminance with light dimmers and window screens or curtains. Every time

BIMS changes the power to the lights or the positions of the window screens or curtains, it should wait one minute and then record the measured illuminance in the room. If this is outside the limits, it should report an error! BiST, Record changes.

9. The sun starts to set.
10. BIMS slowly adjusts the illuminance to its nighttime level. (Due to its complexity, this step will probably become a separate use case in future models.)
11. The sun sets.
12. Include the Control Illuminance During the Night use case.

Clouds Cover the Sun Unanchored Alternate Flow:

1. Electric generation falls due to the wind dropping, waves disappearing or clouds covering the sun.
2. BIMS opens the window screens or curtains.
3. BIMS draws energy from the commercial AC electric grid. What problem could this cause? The Hawaii Electric Light Company will have to buy backup power generators that can provide the total load of BIMS at any time! nUiCs, Increased costs to electric company.
4. Electric generation resumes due to the wind increasing, waves coming back or clouds blowing away.
5. BIMS delivers energy to the AC electric grid. How could this activity hurt another system? Incorrect frequency or phase for the connection to the electric grid could harm equipment or destabilize the grid! nUiCs, Improper connection to the grid.

   It would not be useful for BiST to display the phase and frequency to the human, because the human is not fast enough to make the connection. The connection must be made by the system. BiST shall record the difference in phase and frequency between the inverter output and the electric grid when a connection is made and indicate failure when either is outside of TBD limits. BiST
6. BIMS readjusts the light dimmers and window screens or curtains. [return to the main success scenario.]

Postcondition: BIMS is in the Control Illuminance During the Night use case.

Specific Requirements [Daniels and Bahill 2004]

Functional Requirements:

Req1-1 BIMS shall use an ephemeris, tables, models, firmware or similar methods to anticipate sunrise, sunset, moonrise, moonset and the phase of the moon.

Req1-2 BIMS shall control the illuminance of the lights.

Req1-3 BIMS shall control the opening and closing of window screens or curtains.

Req1-4 BIMS shall sense the illuminance in the operations room.

Req1-5 BIMS shall buy electricity from and sell electricity to the AC electric power grid. What could screw up this activity? The commercial electric distribution company could fail to buy or sell electricity, or they could set unfavorable rates. BIMS cost could exceed the local area rate! risk, Electric company policy.

Req1-6 BIMS shall generate electricity. Here are some common examples of renewable-energy generating sources: photovoltaic panels, wind turbines, ocean waves, ocean tides and geothermal systems. What could cause these sources to fail to provide enough energy at the appropriate time? Clouds could cover the sun, the wind could fail, the ocean could come becalmed! risk, Sudden drop in generated electricity.

High elevation and cold temperature might reduce the efficiency of men and equipment! risk, Reduced efficiency.

Req1-7 BIMS shall execute Built-in Self-Tests (BiST) (derived from BICS company policy).

Nonfunctional Requirements:

Req1-8 BIMS shall maintain the daytime illuminance in the operations room at 400 ± 40 lux (≈40 ± 4 fc). Trace to Req1-2, Req1-3 and Req1-4.

Req1-9 BIMS shall maintain the nighttime illuminance in the operations room at 0.4 ± 0.2 lux (≈0.04 ± 0.02 fc). Trace to Req1-2, Req1-3 and Req1-4.

Req1-10 BIMS shall generate electricity at a cost competitive with commercial electricity costs at that location, after Federal, state and electric company subsidies, etc. Trace to Req1-5 and Req1-6. Changes in interest rates, government policies or TEP practices would change the economic analysis! risk, Economic conditions change.

Author/owner: Walt Zaharchuk

Last changed: December 3, 2009

Diogenes Applied to BIMS's Physical Structure

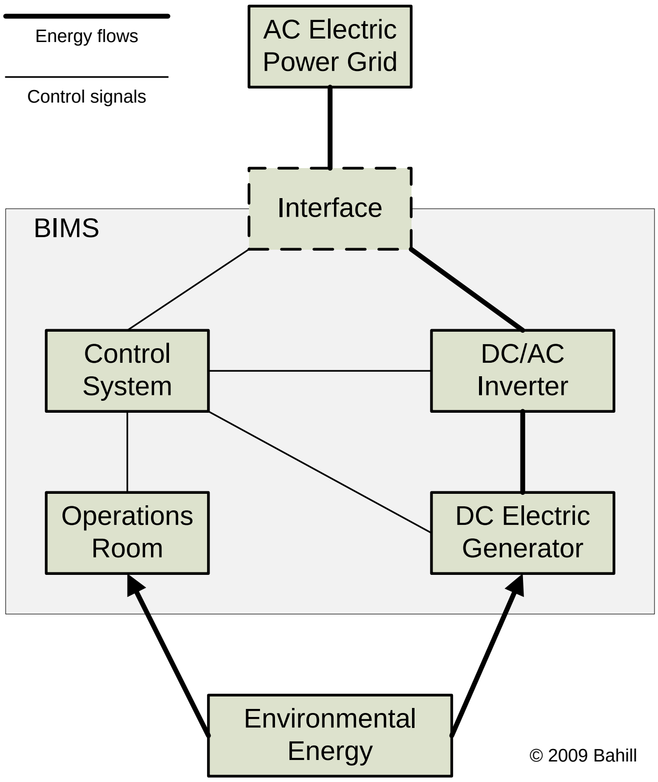


Figure 4. Block diagram showing the scope of BIMS

In figure 4, the absence of energy flow lines to the Control System and the Operations Room is a documentation defect.

Diogenes Applying Cause and Effect Tools

A method for searching for UiCs is the "what-if" analysis. In a "what-if" analysis, speculate on what could go wrong in each state of BIMS. Ask, What if this hypothetical event occurred? What would be the effects on BIMS? For example, what would be the effects of incorporating photovoltaic solar panels into an existing commercial electric power grid? Photovoltaic solar panels transform sunlight it into electricity and reflect sunlight back into the atmosphere. Therefore, photovoltaic solar panels prevent sunlight from hitting the ground and being absorbed. This reduces the amount of energy absorbed by the Earth and therefore contributes to *global cooling!* pUiCs, Global cooling.

We will now look at a SysML block definition diagram. For each block we will ask, "What unexpected events could this entity cause?"

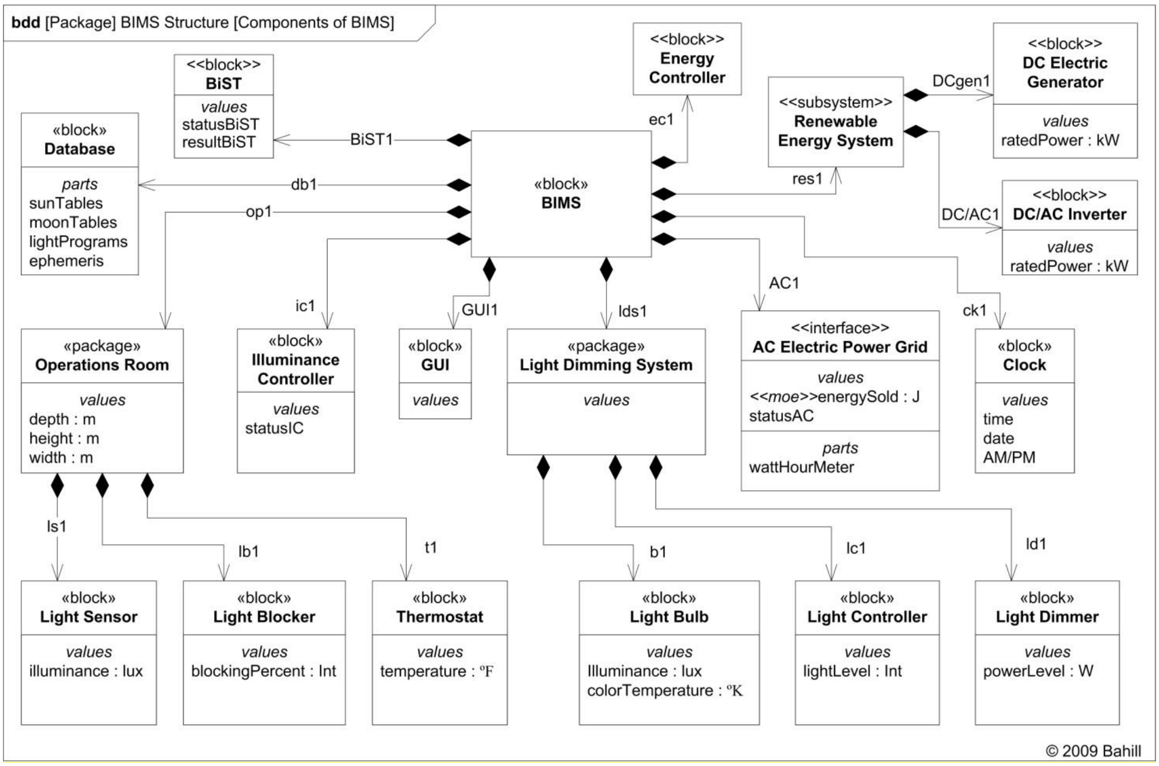


Figure 5. SysML block definition diagram (**bdd**) showing the structure of BIMS

Studying the blocks of Figure 5, prompted the following question. Which of these components could emit nonvisible electromagnetic radiation that could interfere with particular telescopes? To ameliorate this problem, the spectrum of each telescope must be determined and the noise emissions of each component will have to be computed and measured in each of these bandwidths! nUiCs, Electromagnetic radiation interfering with telescopes.

Commercial off the Shelf (COTS) software will be used to predict, on a minute-by-minute basis, the amount of electric energy that should be bought from or sold to the Hawaii Electric Light Company. BIMS will compute the amount of electric energy that is actually bought from or sold to the Hawaii Electric Light Company. These data are stored in the database. If the daily averages differ by more than plus or minus two standard deviation, then BiST will notify the appropriate person! BiST

Diogenes Applied to BIMS's Behavioral Models

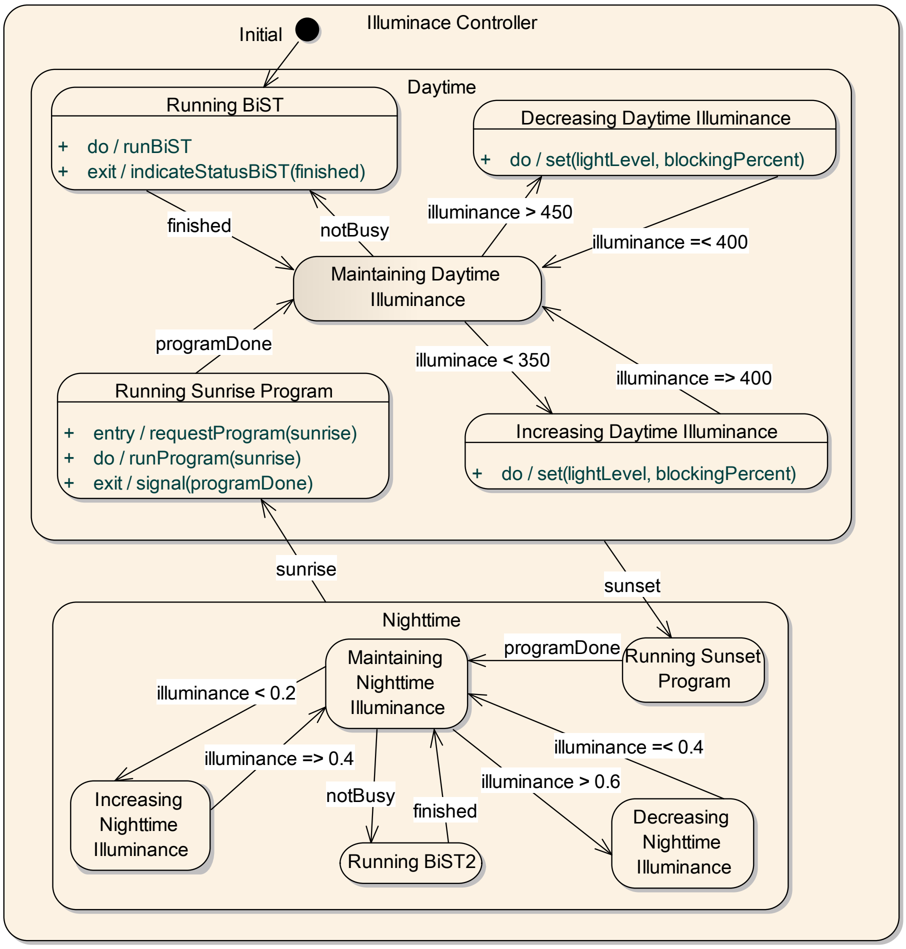


Figure 6. State machine diagram (**stm**) for the BIMS Illuminance Controller. The illuminance limits could be parameters instead of fixed values. The illumination controller increases or decreases the illuminance by commanding a different lightLevel and blockingPercent. Running the sunrise program is accomplished by commanding a sequence of preprogrammed lightLevel and blockingPercent. BIMS will have many built in illumination programs, such as a sunset program, a sunrise program, a program for watching PowerPoint presentations.

How would precisely controlled illuminance over a long period of time affect humans? The effects of high altitude on human physiology are well known and they have been managed effectively for decades on Mauna Kea. However, humans are not used to living in a precisely controlled illuminance environment as described in Figure 6. Therefore, studies of the Polaris ballistic missile fleet sailors should be reviewed to see if such a regulated illuminance environment would cause undesirable entrainment of human circadian rhythms! risk, Controlled illuminance harms humans.

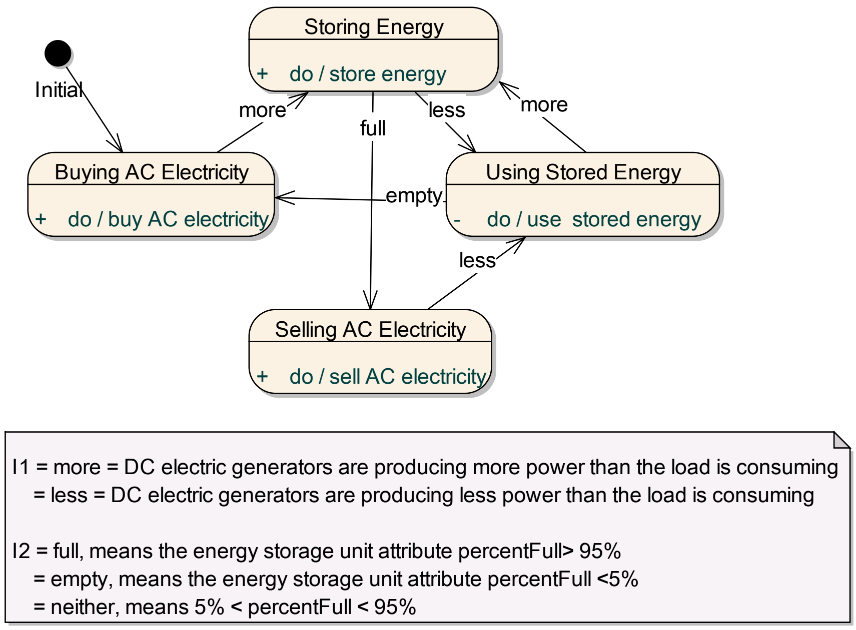


Figure 7. State machine diagram (**stm**) for the BIMS energy management controller

What if BIMS is in the state of Storing Energy when input-port 1 signals *less* and simultaneously input-port 2 signals *full*? Similarly, What if BIMS is in the state of Using Stored Energy when input-port 1 signals *more* and simultaneously input-port 2 signals *empty*? Actually, this is not a serious problem, because the logic can be designed to prevent transitions to unwanted states! risk, Hazards and races.

The initial pseudo state should transition to Using Stored Energy not to Buying AC Electricity. There is an unstated assumption the Hawaii Electric Company is always there for us, that is, it is an infinite source or sink. The equation for neither should be

I2 = neither, means 5% ≤ percentFull ≤ 95%.

The BIMS energy management controller of Figure 7 can be modeled with these Boolean equations

Buy = less And empty

Sell = Not less And full

Use = less And Not empty

Store = Not less And Not full

Therefore, it is a static problem. A static problem does not require a dynamic solution. We can keep the state machine diagram, if we think that is the best way to communicate our design. But we could also represent this behavior more simply with Boolean equations. By the principle of Occam's razor, the simpler model is better, if they model the problem equally well. Although the designer may claim otherwise, this actually was a mistake! defect, State machine not necessary.

Replacing the state machine with Boolean equations eliminates this risk as well as the hazards and races risk.

BiST philosophy. A long time ago, BiST used a single light that indicated go/no-go for the whole system. Now we expect each component to display not only go/no-go but also some intermediate form of system health. For example, for the state machine diagram of figure 7, the system could have binary indicators for the inputs “more” or “less” and “full” or “empty,” and the outputs “storeEnergy” or “useStoredEnergy” and “buyACelectricity” or “sellACelectricity.” But we think it would be just as easy and more meaningful to display the attribute “percentFull” and the state diagram of Figure 7 indicating which state the system is in. Providing state information would also help with developmental testing.

Diogenes Applied to BIMS’s Interfaces and Interconnections

Look for interfaces and interactions when components are integrated together. The biggest potential interface problem is the interconnection between BIMS and the Hawaii Electric Light Company AC electric power grid.

What problems could the interconnection of systems cause? Presume that BIMS is in the state of Selling AC Electricity in the state machine of Figure 7, when clouds suddenly cover the sun (or the wind fails, or the waves disappear, etc.). The voltage generated by the solar panels will drop as will the illumination in the operations room. The sensors will sense this drop in illumination and will command the lights to produce more illuminance. The lights will draw more power from the source. This will produce a bigger voltage drop across the source internal impedance, which will further drop the operating voltage. This is a positive feedback loop that could cause BIMS to become unstable. Furthermore, BIMS will soon deplete its small local energy store and will switch to the Buying AC Electricity state. This will increase the operating voltage. This is a negative feedback loop, but it contains a significant time delay. Time delays make systems susceptible to instabilities. Because of these potential stability problems, we would recommend that the project manager start a detailed simulation of these systems to investigate potential instabilities. The electric industry has many models for the generation, transmission and use of electricity generated from renewable energy sources [GE Energy, 2010]! nUiCs, Destabilizing the electric grid.

How could changes in government regulations affect BIMS? Changes in carbon emissions policies would have an impact on the viability and size of photovoltaic systems. Policy changes would make the electric utility’s renewable energy portfolio plan obsolete and would require re-planning of their strategies. The early elimination of rebates is another government-induced risk. It would affect customer incentives to convert to solar-powered generation. Any reduction in consumer incentives to adopt solar energy would have a significant impact on distributed electric generation! nUiCs, Destabilizing the US energy economy.

Stakeholders

BIMS stakeholders include dealers, architects, contractors, distributors, suppliers, sales people, end users, astronomers, NOAO, university students, a surrogate customer (an in-house person designated to have knowledge of end user needs and expectations), potential victims (such as competing companies, homeowners who get shocked due to faulty wiring, other astronomers on the mountain, construction workers, Hawaii Electric Light Company Inc., the environment and Poliahu the snow goddess of Mauna Kea), environmentalists, the National Science Foundation and the US Congress.

The US Congress and the National Science Foundation could cut off funding for BIMS! risk, Politics change.

Output of "Diogenes Applied to BIMS"

The above concerns have been edited after the initial investigation. They were used to produce the five Diogenes databases. Next, in accordance with the Search for Unintended Consequences use case, these five output databases were edited to produce the following prioritized lists.

List of Defects Detected

This application of Diogenes to BIMS revealed two defects: a lack of energy flows in the block diagram of the scope of BIMS (Figure 4) and a dynamic solution for a static problem in Figure 7.

The BIMS energy management controller is a static problem. Therefore, it does not require a dynamic solution (state machine). We can keep the state machine diagram, if we think that is the best way to communicate our design. But we could also represent this behavior more simply with Boolean equations. Replacing the dynamic solution with a static solution would eliminate the risk of hazards and races. Although the designer may claim otherwise, this actually was a mistake.

Prioritized List of Risks

These are risks to BIMS, BICS and the primary users. The highest priority risks are listed first.

Geographical location increases cost. Because it is a remote mountaintop at 13,800 feet, costs will be higher than expected. Transportation will be more expensive. Electricity will be more expensive. Backup electric generators will be needed. Labor will be more expensive. The supply chain will be more expensive.

Sudden drop in generated electricity. Clouds covering the sun (the wind failing or the ocean becoming becalmed) could cause a sudden drop in generated electricity. This could trip breakers and leave customers without electric power. Voltage and frequency on the grid could drop. The electric company would have to initiate a controlled brownout with load shedding. To ameliorate these risks, the electric company must buy and operate backup generators

Political climate changes. Changes in government regulations will affect BIMS. Changes in carbon emissions policies would have an impact on the viability and size of photovoltaic systems. Policy changes would make the electric utility's renewable energy portfolio plan obsolete and would require re-planning of their strategies. The early elimination of rebates is another government-induced risk. It would affect customer incentives to convert to solar-powered generation. Any reduction in consumer incentives to adopt solar energy would have a significant impact on distributed electric generation. The US Congress or the National Science Foundation could cut off funding for BIMS.

Economic conditions change. Changes in interest rates, government policies or local electric power company rebates would change the economic analysis.

Electric company policy changes. The commercial electric distribution company could fail to buy or sell electricity, or they could set unfavorable rates. BIMS cost could exceed the local area rate. However, federal laws require electric companies to buy electricity from their consumers.

High altitude affects humans. High altitude affects human mental and physical processes. These are known and they have been managed effectively for decades on Mauna Kea.

Controlled illuminance affects humans. Precisely controlled illuminance over a long period of time may affect human mental and physical processes. Humans are not used to living in a precisely controlled illuminance environment. Studies of the Polaris ballistic missile fleet sailors should be reviewed to see if such a regulated environment would cause undesirable entrainment of human circadian rhythms.

Inverter failure. Failure of the DC to AC inverters on present grid-tied photovoltaic solar systems is the most common hardware failure. When an inverter fails, the owner loses a part of the electric generating capacity: but it produces minor harm to the electric company.

Reduced efficiency. The renewable-energy generating systems might have reduced efficiency due to high elevation and cold temperature. Electronic equipment cooling fans are less efficient at high altitudes and may need to be upgraded.

Kilauea volcano erupts. BICS should ensure that BIMS is connected to the USGS Volcano Hazards Program, at the Hawaiian Volcano Observatory in case we have to evacuate the mountaintop. Furthermore, all solar panel installations must consider the effects of a cloud of ash drifting from an erupting volcano, such as the Eyjafjallajökull volcano in Iceland in 2010.

Hazards and races. Concerning the state machine diagram for the BIMS energy management controller, What if BIMS were in the state of Storing Energy when input-port 1 signaled *less* and simultaneously input-port 2 signaled *full*? Similarly, What if BIMS were in the state of Using Stored Energy when input-port 1 signaled *more* and simultaneously input-port 2 signaled *empty*? BICS must take precautions in designing the logic to prevent transitions to unwanted states.

This analysis discovered 11 risks for BIMS. The original BIMS risk analysis had 14 risks. This study missed (1) a similar system has already been patented (2) the commercial AC electric power grid may fail for hours at a time and (3) software failures. This study disclosed two risks that the original study did not have: (1) controlled illuminance might harm humans and (2) hazards and races. The numbers do not add exactly, because some risks were combined in one study or the other, some were eliminated or mitigated, some were treated in other sections and some were at different levels of detail. Furthermore, this example only inspected one of BIMS' use cases.

List of Potential Opportunities for BiST

Commercial off the Shelf (COTS) software will be used to predict, on a minute-by-minute basis, the amount of electric energy that will be bought from or sold to the Hawaii Electric Light Company. BIMS will compute the amount of electric energy that is actually bought from or sold to the Hawaii Electric Light Company. These data will be stored in the database. If the daily averages differ by more than plus or minus two standard deviation, then BiST will send an e-mail to the TestEngineer.

Every time BIMS changes power to the lights or the positions of the window screens or curtains, it should wait one minute and then record the measured illuminance in the room. If this is outside the limits, it should report an error.

A long time ago, BiST had a single light that indicated go/no-go for the whole system: now each component is expected to display its status. However, each component should display not just go/no-go, but rather intermediate values and prognosticators of system health. Furthermore, rather than just system health, BiST could show the status of inputs, outputs, key attributes and system states. The best way to present state information would be to display a state diagram indicating which state the system is in. Providing state information would also help with developmental testing. However, Tester must not be overloaded, so complete BiST information would only be displayed on request or in event of failure.

List of Positive UiCs

This application of Diogenes to BIMS revealed one positive UiC, global cooling.

The whole manufacturing, installing and operating process of a typical solar station has a net negative carbon footprint. Manufacturing the solar panels and other hardware for TEP's Springerville Solar Generating Station consumed 12 MWh AC per kW DC generation capability installed. This facility reduces the carbon footprint by 36.5 tons of CO_2 per kW DC installed. Therefore, the energy payback time would be 2.8 years, which is less than the 30 year expected life of this facility. Thus, this facility reduces global warming [Chaves and Bahill, 2011].

What would be the effects of incorporating photovoltaic solar panels into an existing commercial electric power grid? Photovoltaic solar panels transform sunlight it into electricity and reflect sunlight back into the atmosphere. Therefore, photovoltaic solar panels prevent sunlight from hitting the ground and being absorbed. This reduces the amount of energy absorbed by the Earth and therefore contributes to *global cooling*.

Prioritized List of Negative UiCs

Negative UiCs are bad outcomes that BIMS can create for other entities. The highest priority negative UICs are listed first.

Destabilizing the electric grid. (1) Connecting to the AC commercial AC electric grid will cause problems. Presume that BIMS is in the state of Selling AC Electricity in the state machine of Figure 7, when clouds suddenly cover the sun (or the wind fails, or the waves disappear, etc.). The voltage generated by the solar panels will drop as will the illumination in the operations room. The sensors will sense this drop in illumination and will command the lights to produce more illuminance. The lights will draw more power from the source. This will produce a bigger voltage across the source internal impedance, which will further drop the operating voltage. This is a *positive feedback loop* that could cause BIMS to become unstable. (2) When the sun is blocked by clouds, BIMS will quickly deplete its small local energy store and will switch to the Buying AC Electricity state. This will increase the operating voltage. This is a negative *feedback loop*, but it contains a significant *time delay*. Time delays make systems susceptible to instabilities. Because of these potential stability problems, we recommend that the project manager start a detailed simulation of these systems to investigate potential instabilities.

Increased costs to electric company. BIMS draws energy from the commercial AC electric grid. Therefore, the Hawaii Electric Light Company will have to buy backup power generators that can provide the total load of BIMS at any time.

BIMS offends Poliahu. BIMS could offend Poliahu, the snow goddess of Mauna Kea. It is not known how this could happen. But if the native Hawaiians think that Poliahu is offended, then *we* will have problems. For instance, they have already asked the state of Hawaii change the annual rent from $1 to $50M. Observatories face heightened community scrutiny due to their prominent siting. Proactively seeking accommodation with environmental concerns is one ingredient to a successful project. BIMS must fend off environmental activists who might try to prevent funding and construction of the facility.

Destabilizing the solar panel economy. What if new technology dramatically drove down the cost of solar panels? This would increase the number of customers who install solar panels. The electric company would have to increase their backup capacity in order to handle customer peak load demands during the period around 5 PM in spite of total cloud coverage. During the day, these customers would buy less electric energy from the electric company and on sunny days, the electric company would be required to buy the surplus electricity produced by these customers. This would affect the electric company's bottom line: they would lose revenue. Two things could then happen, the electric company could lose money from decreased revenues and increased net-metering costs or the electric company could substantially reduce net-metering payments and rebates. This would eliminate incentives for residential customers to acquire photovoltaic solar panel systems. This is an unintended negative *feedback loop with a time delay*, which could cause instability.

Electromagnetic radiation interfering with telescopes. Nonvisible electromagnetic radiation could interfere with particular telescopes. To ameliorate this problem, the spectrum of each telescope must be determined and the noise emissions of each component will have to be computed and measured in each of these bandwidths.

Improper connection to the grid. BIMS delivers energy to the AC electric grid. Incorrect frequency or phase while connecting to the electric grid could harm equipment and destabilize the grid.

Money is needed for decommissioning. There must be a plan and a budget for decommissioning each mountaintop structure at the end of its design life.

Although the use of this negative UiCs list is beyond the scope of Diogenes, it is expected that the negative UiCs will eventually become a part of the risk management process.

This analysis discovered seven negative UiCs of BIMS. The original BIMS documentation had only one, offending Poliahu, which was treated as a risk.

To further validate Diogenes we will compare it to the SIMILAR process [Bahill and Gissing, 1998].

Table I. Mapping of Diogenes to the SIMILAR process

SIMILAR process	Diogenes
State the problem	The problem statement is formulated during the Planning activity and disseminated during the Overview Meeting
Investigate alternatives	The Inspectors simultaneously look for ways to Fix Defects, Manage Risk, Incorporate Opportunities for BiST, Market Positive UiC and Ameliorate negative UiC.
Model the system	In the Preparation activity, the inspectors use models of the system and look for defects, risks, opportunities for BIST, positive and negative UiCs.
Integrate	Pull all of the comments together and produce the five databases.

Launch the system	During the Inspection activity, the Inspection Team discusses the work products and possible defects, risks, opportunities for BIST, positive and negative UiCs.
Assess performance	Gather Verification and Validation Data
Re-evaluate	Follow-up is where we re-evaluate SystemZ and Execute Process to Improve the Process is where we re-evaluate Diogenes.

Diogenes maps well to the SIMILAR process. Therefore, it is comparable to other human mental processes. It is not likely that we have missed a crucial activity.

Verification Plan for Diogenes

Now that we have shown that Diogenes does what it is supposed to do, we want to verify the work products of Diogenes. We cannot wait until the system is in use to collect verification data. And it would be too expensive to ask for a dry run, just to get verification data. So for the following test plan, TestEngineer will interview participants. We will ask the Brain Trust to serve as a surrogate Inspection Team.

This is the beginning of the test of the main success scenario of the Perform Formal Inspection use case

1. **Planning.** The Moderator selects the Inspection Team, obtains work products to be inspected from the Author/Designer and distributes them along with other relevant documents to the Inspection Team.

TestEngineer interviews the Moderator to ensure that he or she knows who should be on the team, what type of work products should be chosen, what the entry criteria should be, how long the inspection meeting should last, how long each team member should spend preparing for the inspection and how much material should be in the inspection package. If the Moderator does not know something, then TestEngineer explains it. This tests **FR3-1, FR3-2** and **NFR3-1**. TestEngineer documents this meeting.

2. **Overview meeting.** The Moderator explains the inspection process to the Inspection Team. The Author/Designer may describe the important features of the work products.

TestEngineer interviews the Moderator to ensure that he or she knows the purpose of the overview meeting and the inspection process. If the Moderator does not know something, then TestEngineer explains. This tests **FR3-3**. TestEngineer documents this meeting.

3. **Preparation.** Each participant examines the work products prior to the actual inspection meeting. Typically, this will take two hours for each participant. The amount of time each person spent will be recorded. Each participant should be looking for five things simultaneously: defects, risks, opportunities for BiST, positive UiCs and negative UiCs of SystemZ.

The TestEngineer interviews the members of the inspection team, to ensure that they understand what their responsibilities are, the inspection process that they are supposed to follow, that they must report the hours they spent in preparation, and that they should be looking for five things simultaneously: defects, risks, opportunities for BiST, positive and negative UiCs of SystemZ. If a team member does not know something, then TestEngineer explains it to them. This tests **FR3-4** and **FR3-5**. TestEngineer documents these meetings.

4. **Inspection meeting.** The Moderator and Reader lead the team through the work products. The issues are brought up one by one and each one is discussed in a round robin fashion where each member comments on each issue. During the discussion, all inspectors can report defects, risks, opportunities for BiST, positive UiCs and negative UiCs of SystemZ, all of which are documented by the Recorder. The meeting should last no more than two hours.

TestEngineer interviews the Recorder to find out how the Recorder will capture the data from the inspection (paper forms, laptop computer, desktop computer, Excel, MS Word, Access, etc.). TestEngineer ensures that such material will be available in a typical inspection room. TestEngineer examines the Recorder's access to the PAL. This tests **FR3-6**. TestEngineer documents this meeting.

5. Diogenes creates and maintains five databases that contain defects, risks, opportunities for BiST, positive and negative UiCs of SystemZ.

TestEngineer examines and records the location of the databases. This tests **FR3-7**.

6. The Moderator and the Systems Engineer consolidate and edit the five databases to create five prioritized lists.

The list of defects is given to the Author/Designer for rework and resolution.
The list of risks that could adversely affect SystemZ is given to Risk Management.
The list of opportunities for Built-in Self-Test (BiST) is given to Test Engineering.
The list of positive UiCs that could beneficially affect other systems is given to Marketing.
The list of negative UiCs that could adversely affect other systems is given to Management.

TestEngineer interviews the Moderator to ensure that he or she knows that he or she is responsible for editing the databases into the five prioritized lists. TestEngineer requests contact information for the head of Risk Management, head of Test Engineering, head of Marketing and the Project Manager. This tests **FR3-8**. TestEngineer documents this meeting.

TestEngineer interviews the head of Risk Management, the head of Test Engineering, the head of Marketing and the Project Manager and records what they say that they will do with their lists. This tests **FR3-9**. TestEngineer documents these meetings.

7. Diogenes puts these prioritized lists in the project PAL.

TestEngineer writes a dummy file into the project PAL. This tests **FR3-10**. TestEngineer records the result.

8. **Rework.** The Author/Designer fixes the defects. We assume that the other owners will know what to do with their lists.

TestEngineer interviews the head of Risk Management, the head of Test Engineering, the head of Marketing and the Project Manager and records what they say that they will do with their lists. This tests **FR3-9**. TestEngineer documents these meetings. This is the same activity as in step 6 above.

9. **Follow-up.** The Moderator must verify that all fixes are effective and that no additional defects have been created. The Moderator checks the exit criteria for completion of an inspection.

TestEngineer interviews the Moderator to ensure that he or she knows how to verify that all fixes are effective, that no additional defects have been created and how to write exit criteria. This tests **FR3-11**. TestEngineer documents this meeting.

10. Diogenes updates the project PAL [exit use case].

TestEngineer changes the dummy file that he put into the project PAL in step 7 above. This tests **FR3-10**. TestEngineer records the result.

TestEngineer reviews his report ensures that all functional and nonfunctional requirements of this use case have been tested and submits his report to the head of Test Engineering and the Program Manager. BIMS has not yet written metrics, thresholds or scores for this report that will ordain pass or fail of Diogenes.

This is the end of the test of the Perform Formal Inspection use case.

Summary

The take home message of this paper is that the systems engineer is responsible for discovering UiCs of things that are being designed. This is important because negative UiCs can be significant. However, UiCs can be anticipated. Diogenes can help discover defects and risks and at the same time help identify opportunities for BiST, positive UiCs and negative UiCs. Therefore, it will not cost extra money to use Diogenes to search for negative UiCs.

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Biography

Terry Bahill is a Professor of Systems Engineering and of Biomedical Engineering at the University of Arizona in Tucson. He received his Ph.D. in electrical engineering and computer science from the University of California, Berkeley, in 1975. Bahill has worked with BAE Systems in San Diego, Hughes Missile Systems in Tucson, Sandia Laboratories in Albuquerque, Lockheed Martin Tactical Defense Systems in Eagan MN, Boeing Information, Space and Defense Systems in Kent, WA, Idaho National Engineering and Environmental Laboratory in Idaho Falls and Raytheon Missile Systems in Tucson. For these companies he presented seminars on Systems Engineering, worked on system development teams and helped them describe their Systems Engineering process. He holds a U.S. patent for the Bat Chooser, a system that computes the Ideal Bat Weight for individual baseball and softball batters. He received the Sandia National Laboratories Gold President's Quality Award. He is a Fellow of the Institute of Electrical and Electronics Engineers (IEEE), of Raytheon, and of the International Council on Systems Engineering (INCOSE). He is the Founding Chair Emeritus of the INCOSE Fellows Selection Committee. His picture is in the Baseball Hall of Fame's exhibition "Baseball as America." You can view this picture at http://www.sie.arizona.edu/sysengr/.