Diogenes, a Prognostic Process for Predicting Failure During Design

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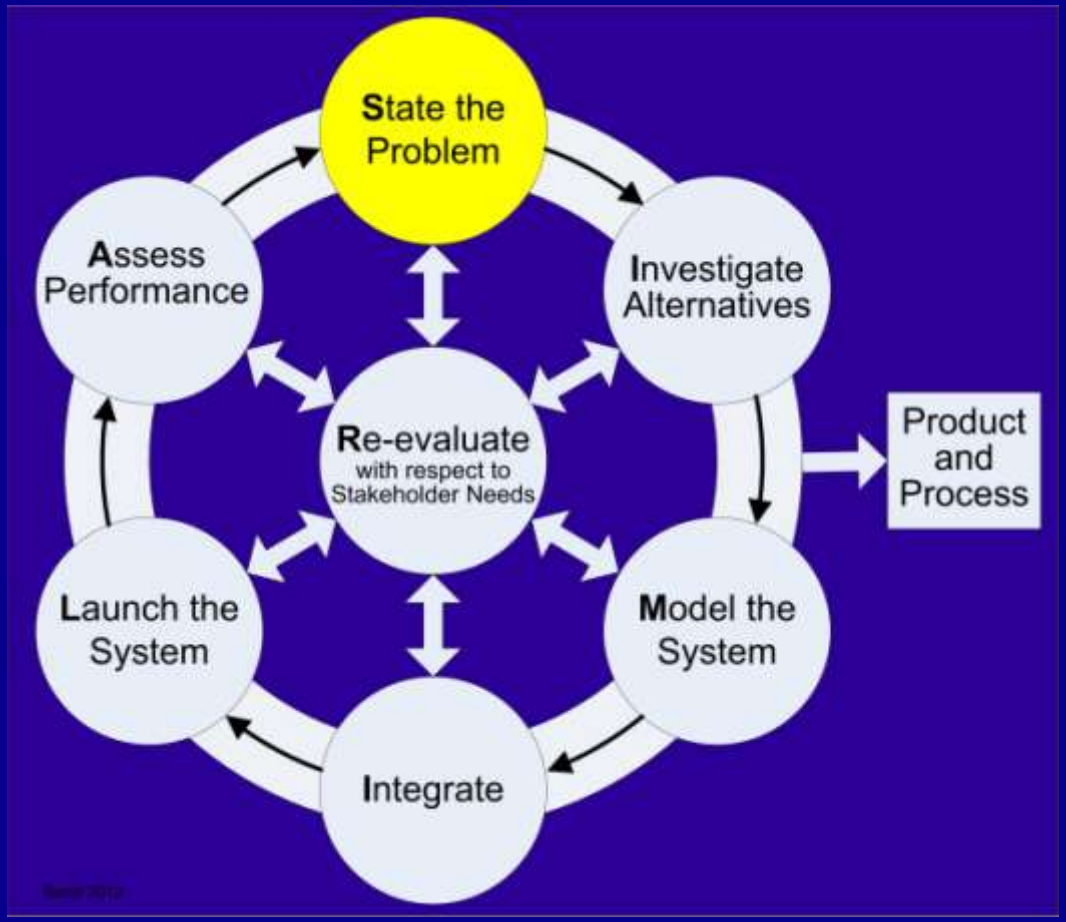
Predicting failure

It is possible to predict some failures during the design phase of the system life cycle.

This paper is about predicting one type of failure, failure due to not anticipating unintended consequences.


State the problem

"Reason must be the beginning of every activity, reflection must come before any undertaking." Ecclesiasticus 37:16



Product Position Statement

For systems engineers, who need to ensure the global success of a new system that they are designing, Diogenes is a process that will help identify unintended, but foreseeable, consequences of the new system. Unlike risk and failure analyses, Diogenes identifies *future* effects on *other* systems that might be caused by the new system being designed.

Examples of unintended consequences (UiCs)

Gasohol versus tortillas

The U. S. government is trying to reduce our dependence on Middle East oil.

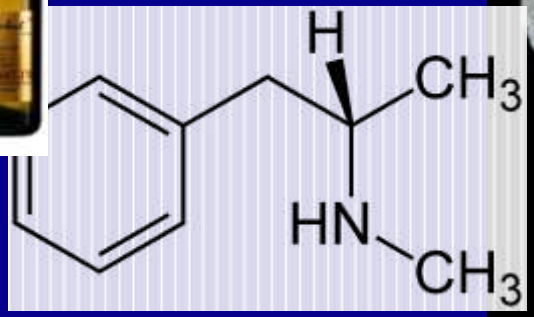
They spent lots of money to grow and ferment corn into alcohol.

With the federal subsidies, this process was economically successful.

However, it drove the price of corn so high that Mexican peasants could no longer afford to buy tortillas, their staple of life.

All of these examples are based on my economic models. Washington politicians might disagree.

An often repeated government process



Africanized bees

Brazilian researchers imported honey bees from Africa in 1956 in an effort to produce a honey bee better suited to the South American tropics.

They were successful. Unfortunately, Africanized honey bees are aggressive.

If the bees feel that their colony is threatened, large numbers may sting people, pets, and livestock.

Century Gothic versus Arial

The University of Wisconsin at Green Bay learned that the Century Gothic font used about 30% less ink than Arial, so in the spring of 2010 they switched their default printer font from Ariel to Century Gothic.

They expected to save $10,000 per year.

However, they later learned that the Century Gothic font is wider.

So that a document that is one page in Arial could extend onto a second page if printed in Century Gothic.

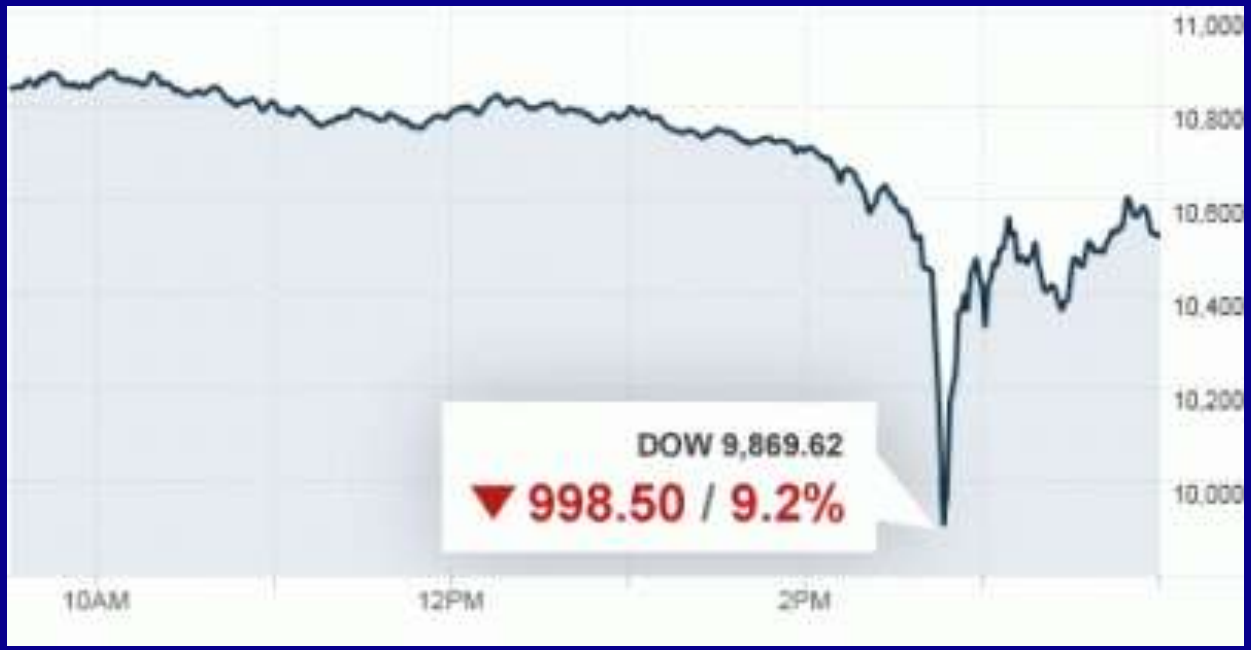
It is not known if the university saved money or saved the environment.

Let's save ink

Get rich by studying UiC

The flash crash of May 6, 2010 caused the Dow Jones Industrial Average to drop 1000 points.

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.



If UiCs caused someone lose money, then someone else made money

On August 1, 2012 Knight Capital Corp updated a software system that helped make trades on the NYSE.

A software mistake caused it to buy $7 billion of stock in the first half hour of trading.

This drove the price of those stocks up by 30%.

Profit takers sold those stocks, driving the price down.

When Knight saw what was happening, they furiously sold stocks: this drove the price down even faster. They settled at a $440 million loss.

Lack of testing or an unintended consequence?

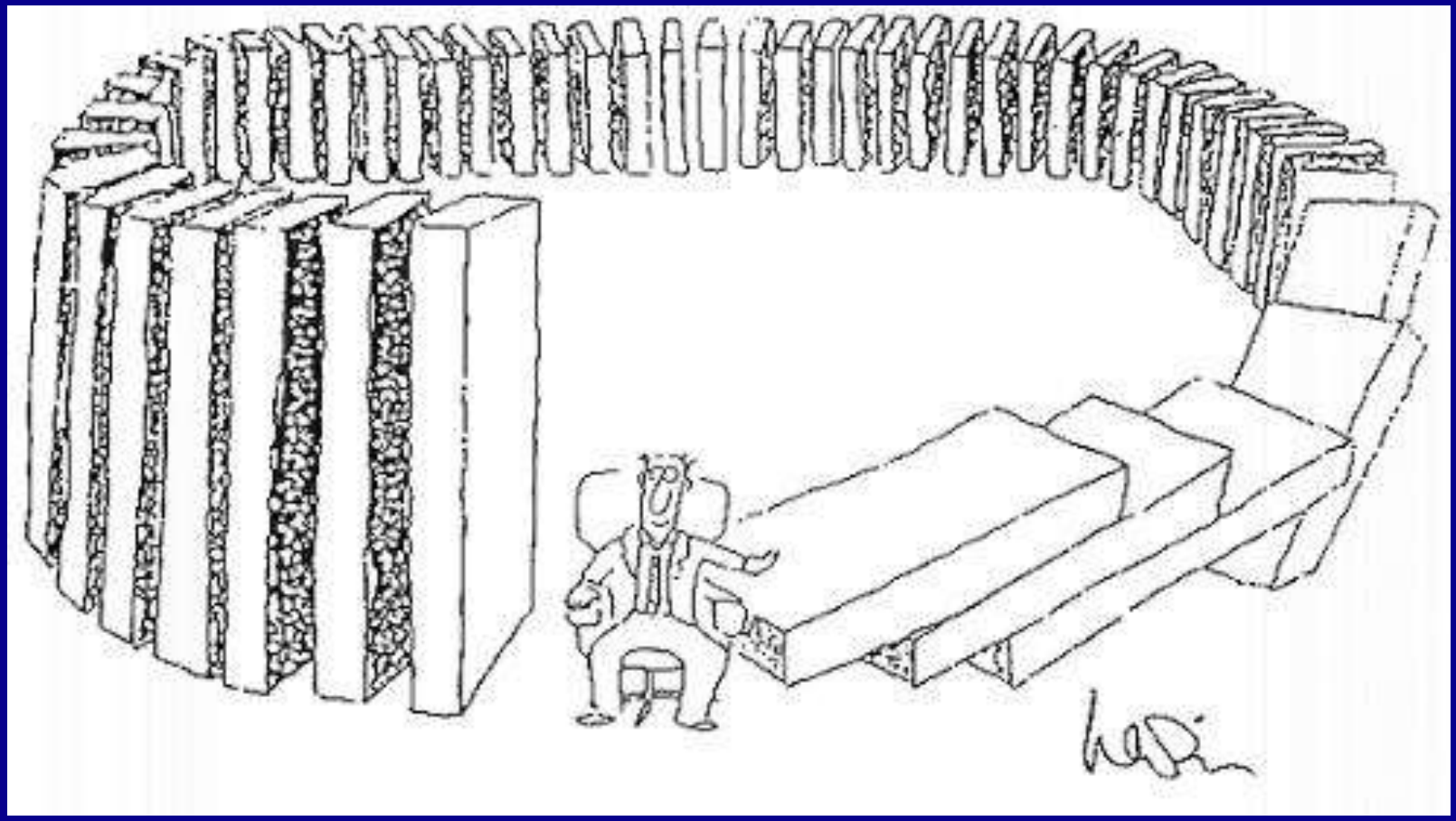
A law prohibiting texting while driving might create this unintended behavior

Argh! That was terrible.

Usually unintended consequences occur during a chain of events

All for want of a nail

Chain of events with unintended consequences



Positive Unintended Consequences

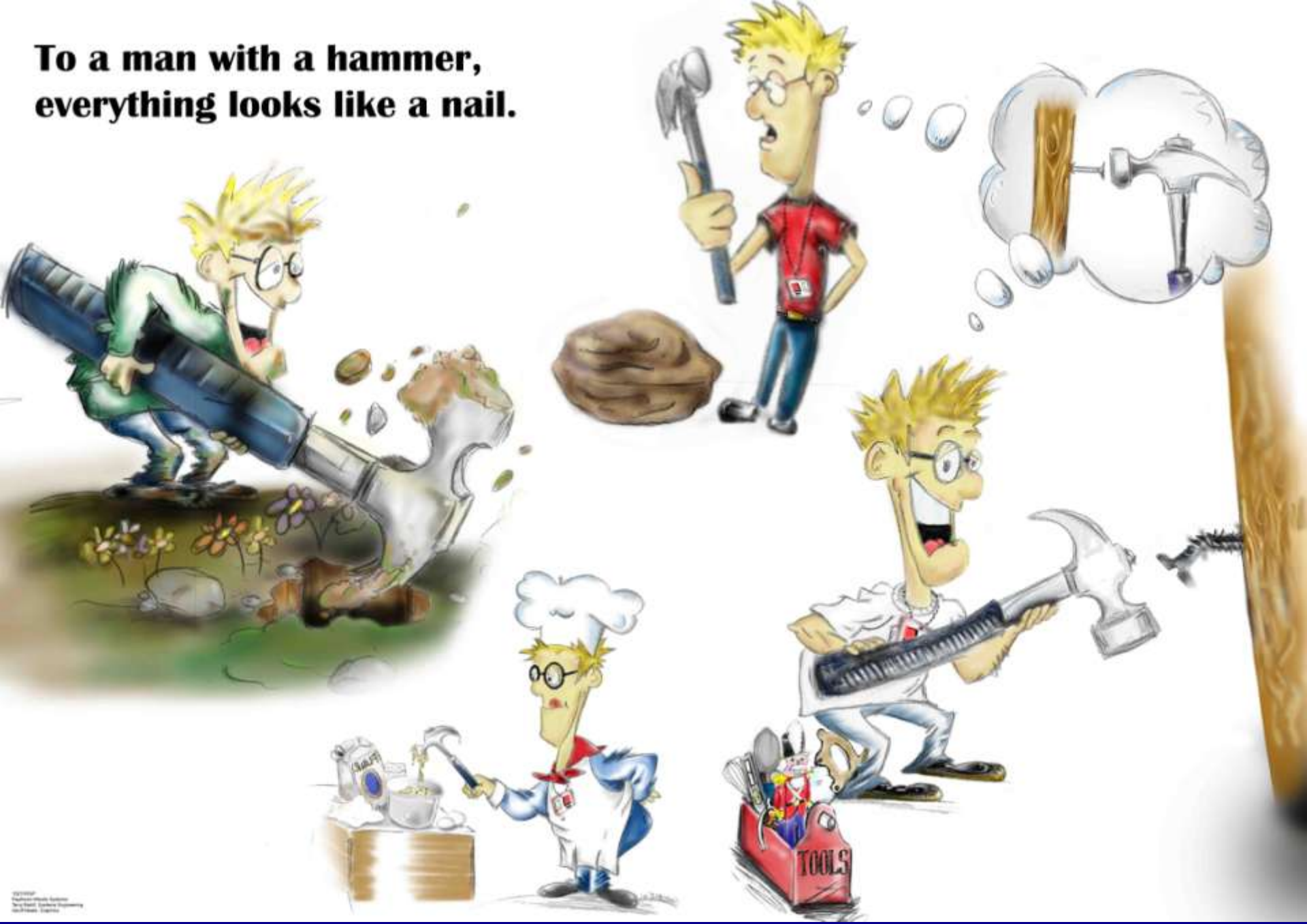
Teflon

In 1938, a DuPont chemist was attempting to use tetrafluoroethylene to make a new refrigerant.

However, as a positive unintended consequence, the iron of the pressurized storage container catalyzed the polymerization of tetrafluoroethylene into polytetrafluoroethylene, Teflon®!

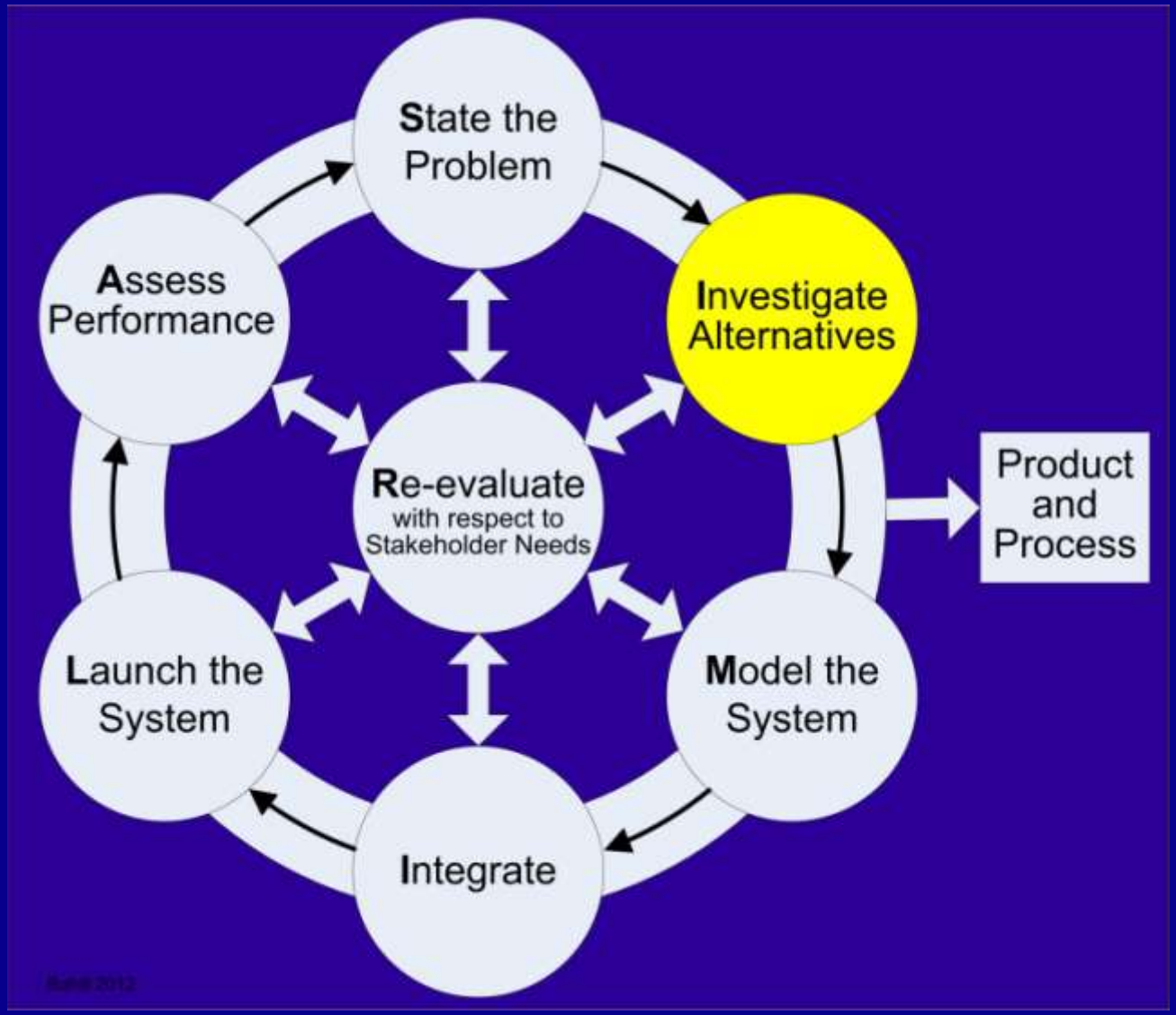
Grass in our backyard

People will not change their behavior
unless there is an emphatic case for change

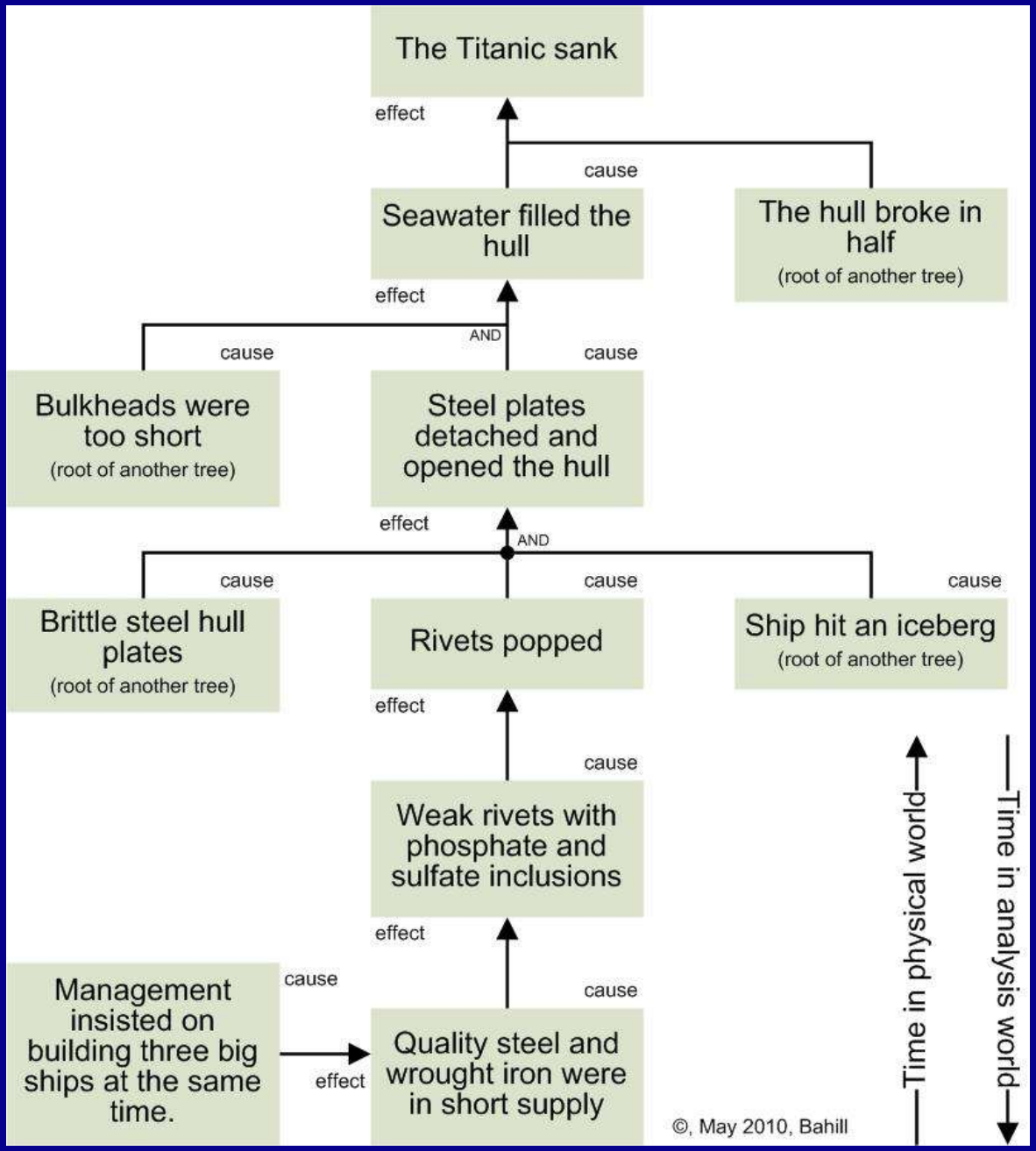


When new problems appear, we should investigate new tools.

Existing tools that might be useful for detecting unintended consequences



Cause and effect diagram for the sinking of the Titanic



Five whys

A very simple cause and effect tool merely asks, Why? Why? Why? Why? Why?

Why did the space shuttle Challenger blow up?

Because a hot flame (6000 ºF) from the side of its right solid fuel rocket booster melted its structure.

Why did the flame spring from the side of solid fuel rocket booster?

Because the O-rings failed to seal in hot gasses from the rocket motor.

Why did the O-rings fail to seal in the hot gasses?

Because the O-rings were brittle.

Why were the O-rings brittle?

Because the temperature was too cold.

Why did management launch the shuttle if it was too cold?

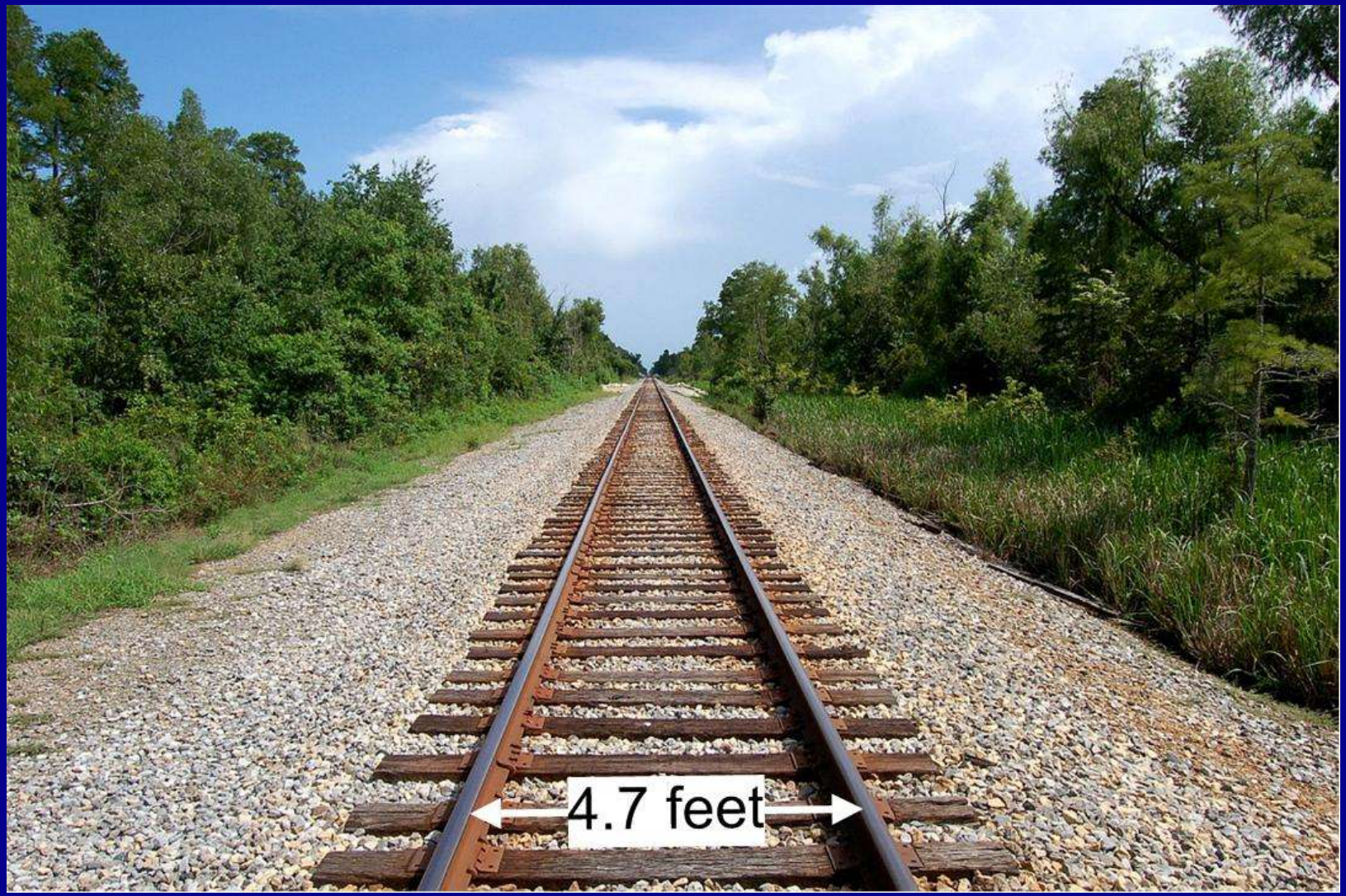
Why was the diameter of a solid-fuel booster 12.2 feet?

To be smaller than the tunnel that it had to pass through

Why?

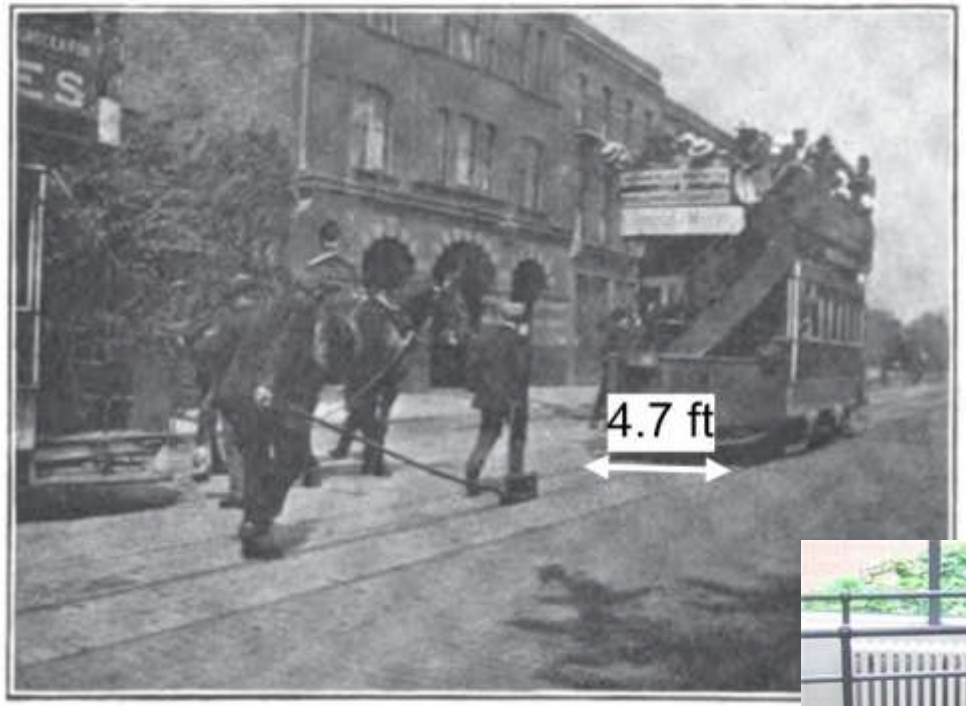
It had to be wider than the train that rides on the tracks

Why?



Because that was the width of the previous tram rails in England

Why?



KENNINGTON CHANGING-PLACE

Because that was the width of the previous wagon wheels


4.7 ft
4.7 ft

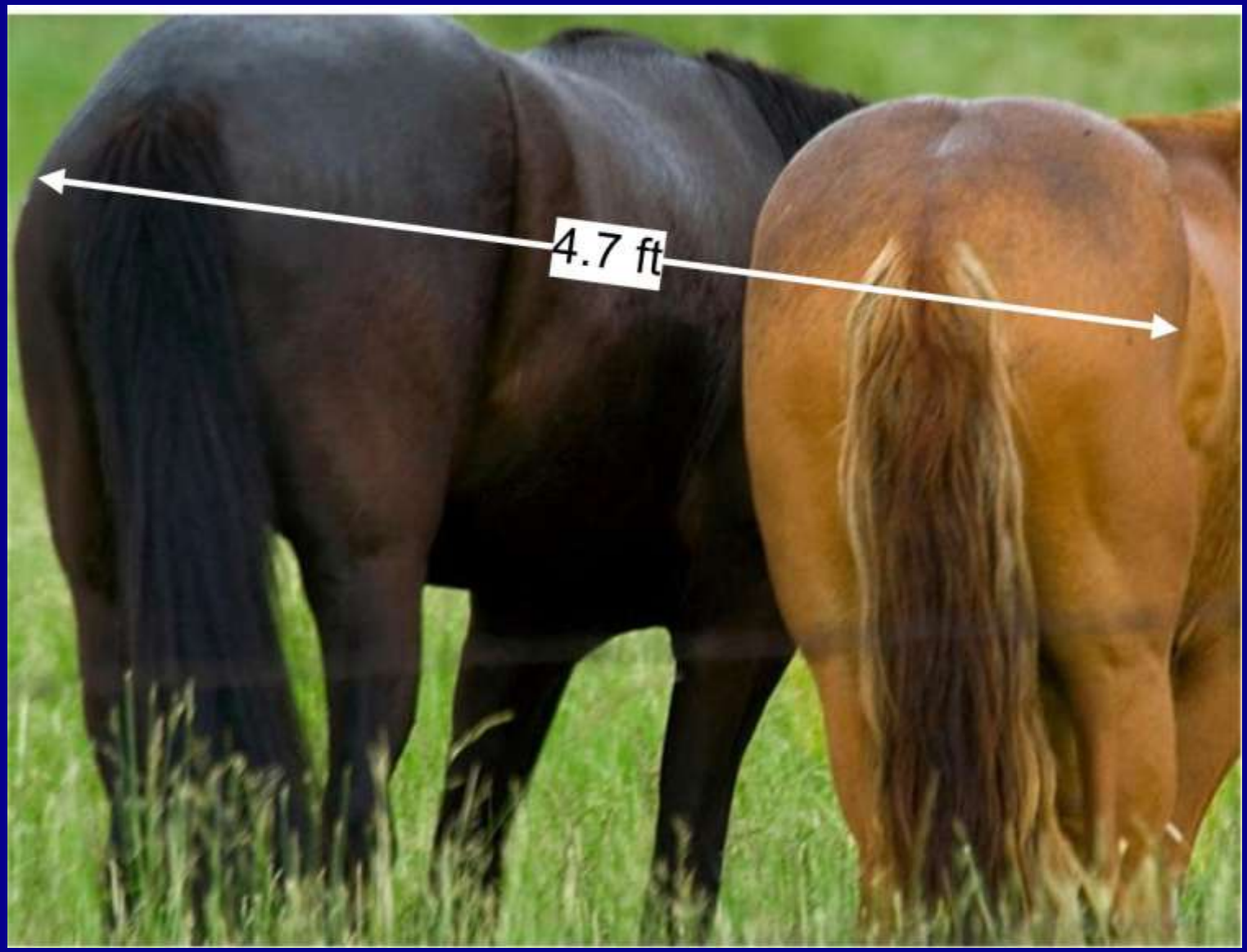
Why?

Because that was the width of the ruts in the old Roman roads caused by the Roman wagons and chariots

Why?

Because the wheels should be broader than the horses

So, specifications for the Space Shuttle were based on the width of a horse's ass



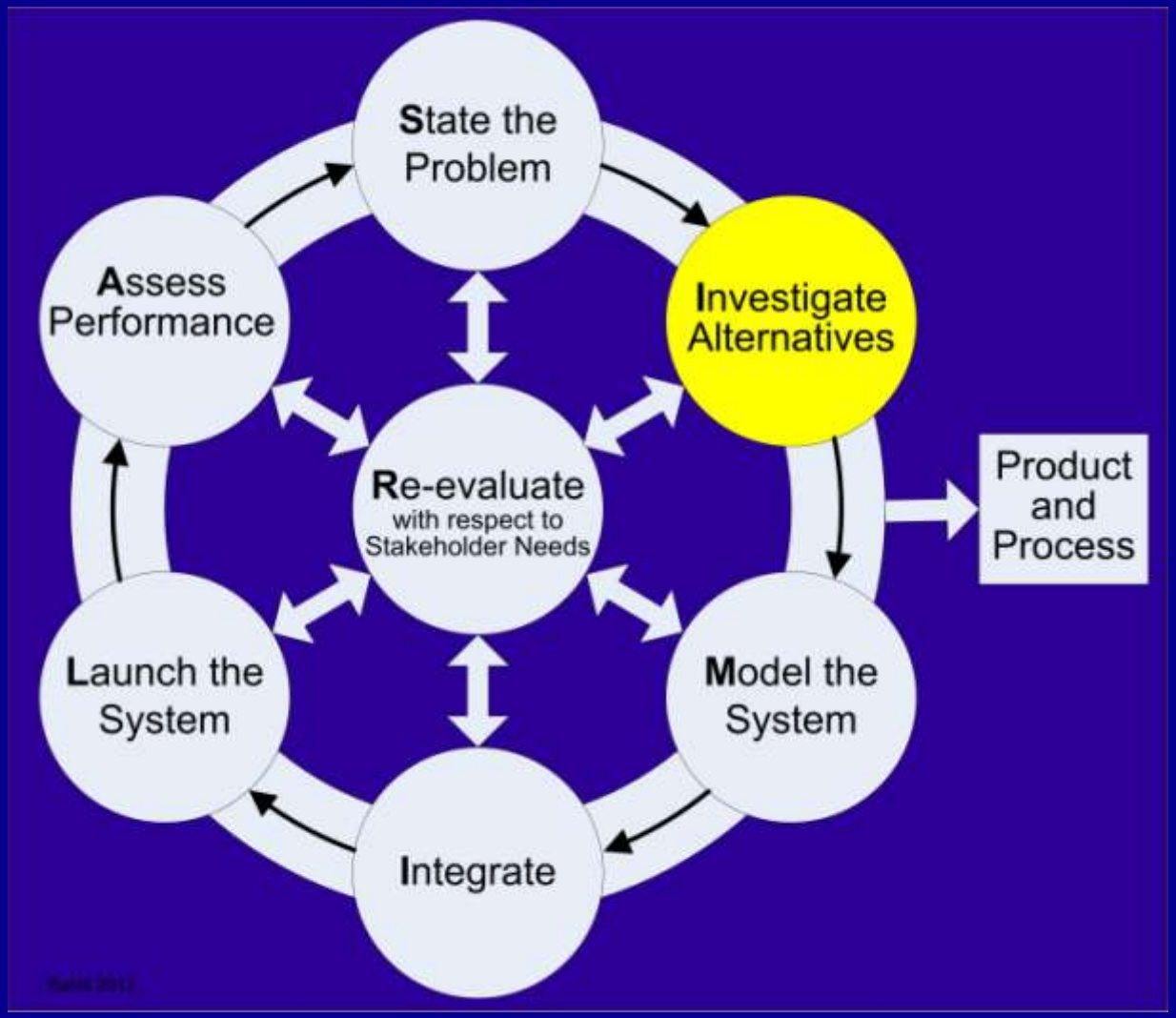
That’s funny

Tradeoff studies

Humans are lousy decision makers.

To help them make better decisions, we use tradeoff studies.

Tradeoff study to help select the best architecture for Diogenes



Components of a tradeoff study

- Alternative architectures
- Evaluation criteria
- Problem statement
- Weights of importance
- Evaluation data
- Scoring functions
- Normalized scores
- Combining functions
- Preferred alternatives
- Sensitivity analysis

Alternative architectures for Diogenes

SIMILAR process

Cause and effect process

Five whys

Brainstorming

Concept mapping (mind mapping)

Risk analyses process

Failure modes and effects analysis

Ishikawa fishbone diagrams

Comprehensive testing process

Sensitivity analysis process

Formal inspection process

Requirements discovery process

Sneak circuit analysis

Tradeoff study process

Evaluation criteria

Ease of Use. The system should be intuitive. The system should hide mathematics from the user.

Has Tools. The system should have tools to help discover pertinent entities.

Inside or Outside. The system must look for effects of your system on other systems, external to your system.

Total Life Cycle Cost

Ease of Implementing Built-in Self-Test

Reusability

Vendor Evaluation

Looks Forward. The system must look forward in time.

Existing cause and effect tools
look toward the past.
A new search for UiCs
process must look to the future.

What is the difference between looking forward and looking backward?

Forward or backward?

- Tools for looking forward
  - Prognostics
  - Diogenes
  - Risk Analysis
- Tools for looking backward
  - Root cause analysis
  - 5 Whys
  - Ishikawa fishbone diagrams

Looking forward

Looking backwards

The medicine man has a 4-ounce bottle and a 9-ounce bottle, but I want exactly 6-ounces of Kickapoo Joy Juice.

How does the medicine man meet my needs?

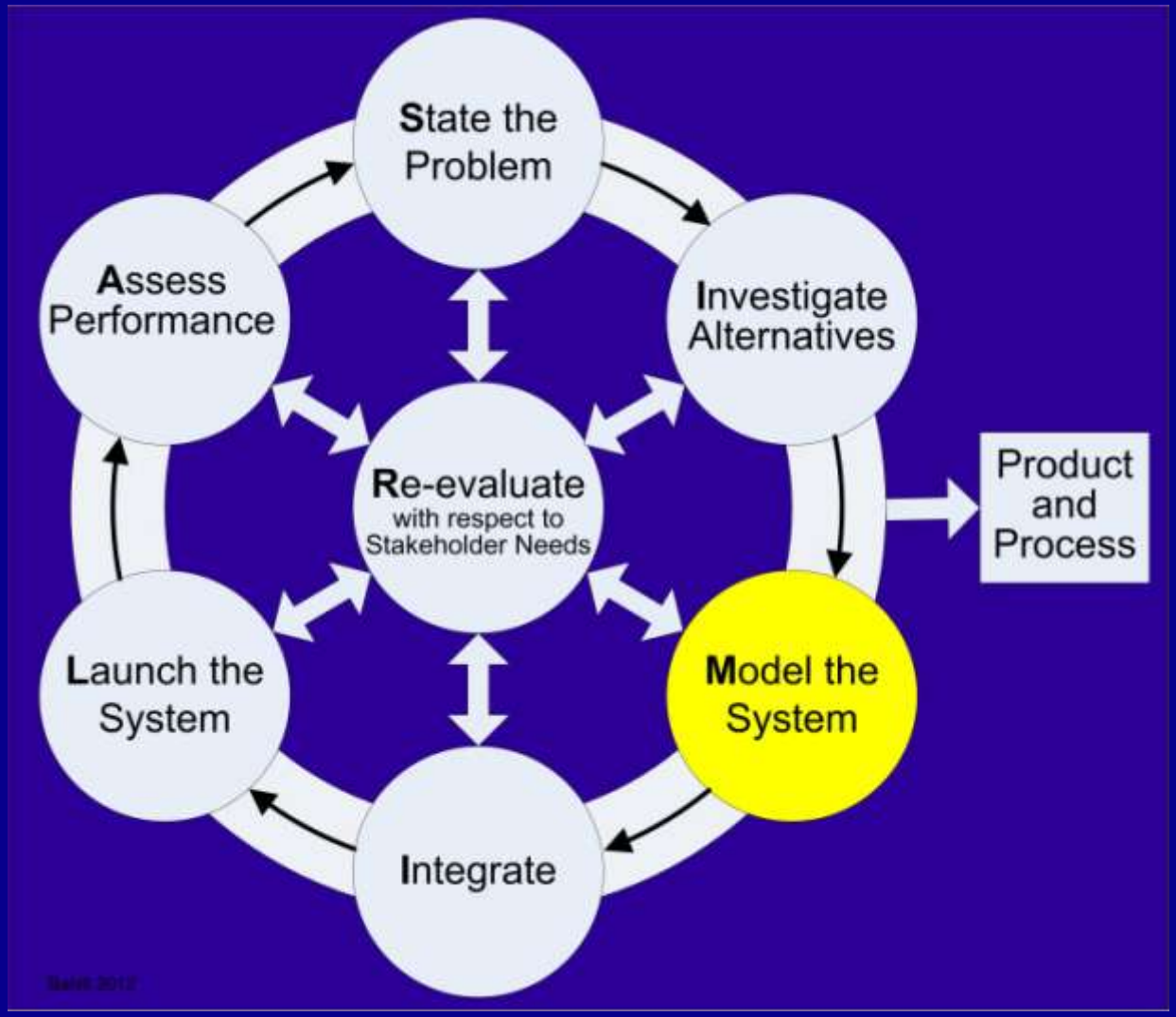
4 ounces

9 ounces

Tradeoff study for Diogenes

Tradeoff Study Matrix for Diogenes using a Sum Combining Function and semirelative sensitivity functions with the number of alternatives,															
Criteria	Wt.	Norm. Criteria Weights	Norm Sub Criteria Weights	Alt 1 Do Nothing, SIMILAR		Alt 2 Risk Analysis		Alt 3 Cause and Effect Analysis		Alt 4 Tradeoff Studies		Alt 5 Test Plan		Alt 6 Sensitivity Analysis	
number of alternatives, m =	6			Sc	Wt×Sc	Sc	Wt×Sc	Sc	Wt×Sc	Sc	Wt×Sc	Sc	Wt×Sc	Sc	Wt×Sc
Performance	8	0.38													
Ease of Use	8		0.27	0.9	**0.24**	0.5	**0.13**	0.6	**0.16**	0.3	**0.08**	0.2	**0.05**	0.1	**0.03**
Looks Forward	10		0.33	0.8	**0.27**	1.0	**0.33**	0.0	**0.00**	0.9	**0.30**	1.0	**0.33**	0.2	**0.07**
Has Tools	4		0.13	0.5	**0.07**	0.9	**0.12**	0.9	**0.12**	0.3	**0.04**	0.1	**0.01**	0.3	**0.04**
Inside or Outside	8		0.27	0.7	**0.19**	0.0	**0.00**	0.4	**0.11**	0.4	**0.11**	0.0	**0.00**	0.0	**0.00**
Cost	4	0.19													
Total Lifecycle Cost	6		0.40	0.6	**0.24**	0.6	**0.24**	0.6	**0.24**	0.4	**0.16**	0.4	**0.16**	0.4	**0.16**
Operating Cost	9		0.60	0.6	**0.36**	0.6	**0.36**	0.6	**0.36**	0.4	**0.24**	0.4	**0.24**	0.4	**0.24**
Company Policy	9	0.43													
BiST	10		0.43	0.6	**0.26**	0.5	**0.22**	0.5	**0.22**	0.4	**0.17**	0.1	**0.04**	0.3	**0.13**
Reusability	6		0.26	0.5	**0.13**	0.5	**0.13**	0.5	**0.13**	0.5	**0.13**	0.0	**0.00**	0.3	**0.08**
Vendor Evaluation	7		0.30	0.5	**0.15**	0.5	**0.15**	0.5	**0.15**	0.5	**0.15**	0.5	**0.15**	0.5	**0.15**
Alternative Rating					**0.64**		**0.55**		**0.48**		**0.47**		**0.31**		**0.28**

Model the system, which is Diogenes, a search for unintended consequences process



Diogenes

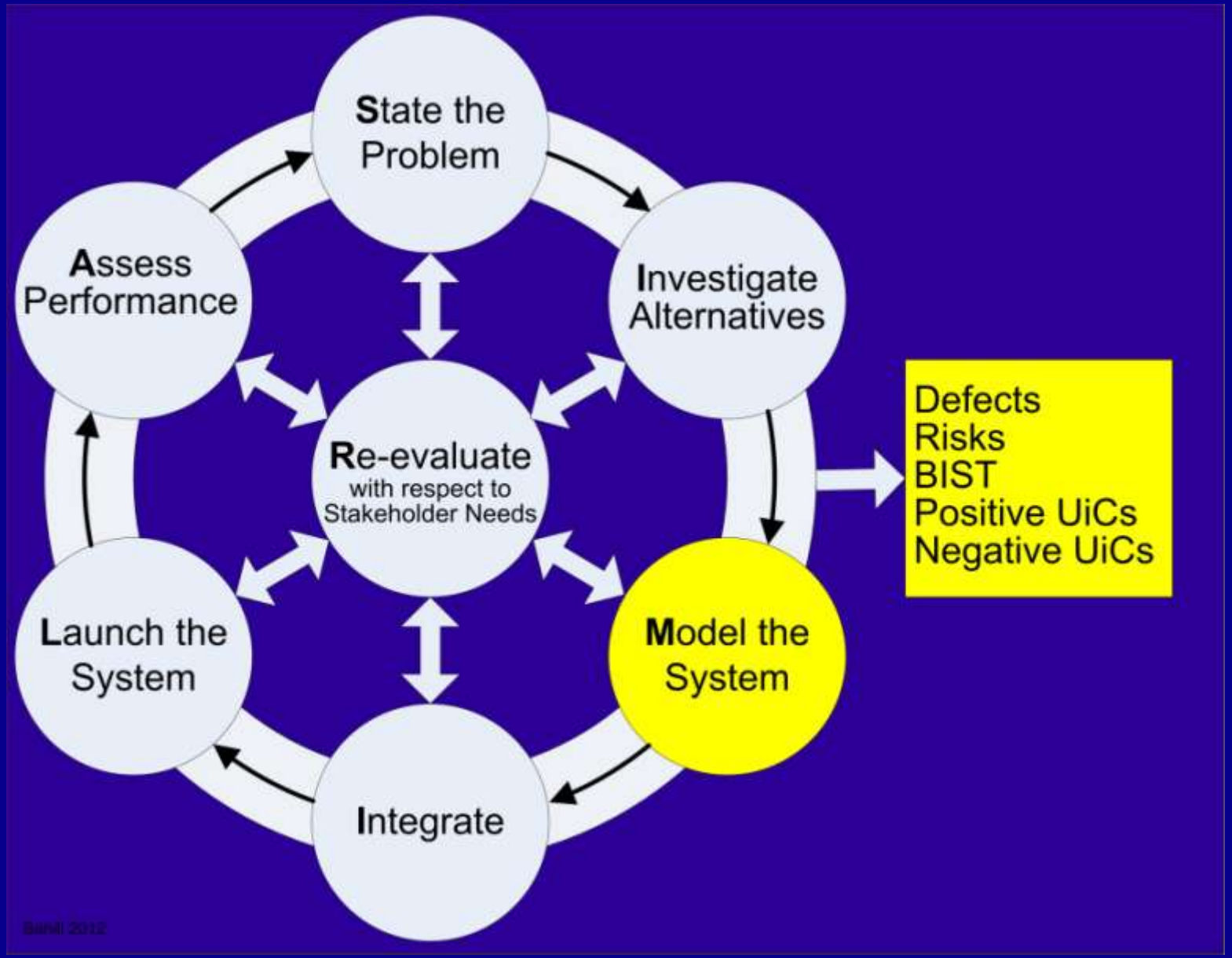
Our process is named after Diogenes of Sinope, a Greek philosopher who lived in the fourth century B. C.

Diogenes was a Cynic who disdained conventional wisdom and political correctness, which he thought caused most people to be intellectually dishonest. He carried a lantern in the daytime saying that he was "in search of an honest man."

The Product Position Statement:

For systems engineers, who need to ensure the global success of a new system that they are designing, Diogenes is a process that will help identify unintended consequences of the new system. Unlike risk and failure analyses, Diogenes identifies future effects on other systems that might be caused by the new system.

Tailor the process for your project



Abbreviations

SystemZ is the name for the new system being designed.

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.

BIMS is the Bahill Illuminance Management System.

Work products of Diogenes

For engineers analyzing design artifacts of a SystemZ, Diogenes will produce five prioritized lists

(1) defects in development documents for SystemZ, such as requirements, programming code, test plans and designs

(2) risks that could adversely affect SystemZ

(3) opportunities for BiST in SystemZ

(4) positive UiCs that could beneficially affect other systems

(5) negative UiCs that could adversely affect other systems

(6) possible human abuse of SystemZ

Bahill's system design process is use-case based.

This is a use case from Diogenes.

Inspect Documents use case$_1$

Name: Inspect Documents

Iteration: 3.1

Derived from: Concept of operations

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 UiCs use case. When this subflow ends, the use case instance continues where this included use case was called.

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.

Inspect Documents$_2$

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, Inspector

Supporting actors: PAL

Frequency: once a week

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

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

Main Success Scenario:

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.

Inspect Documents$_3$

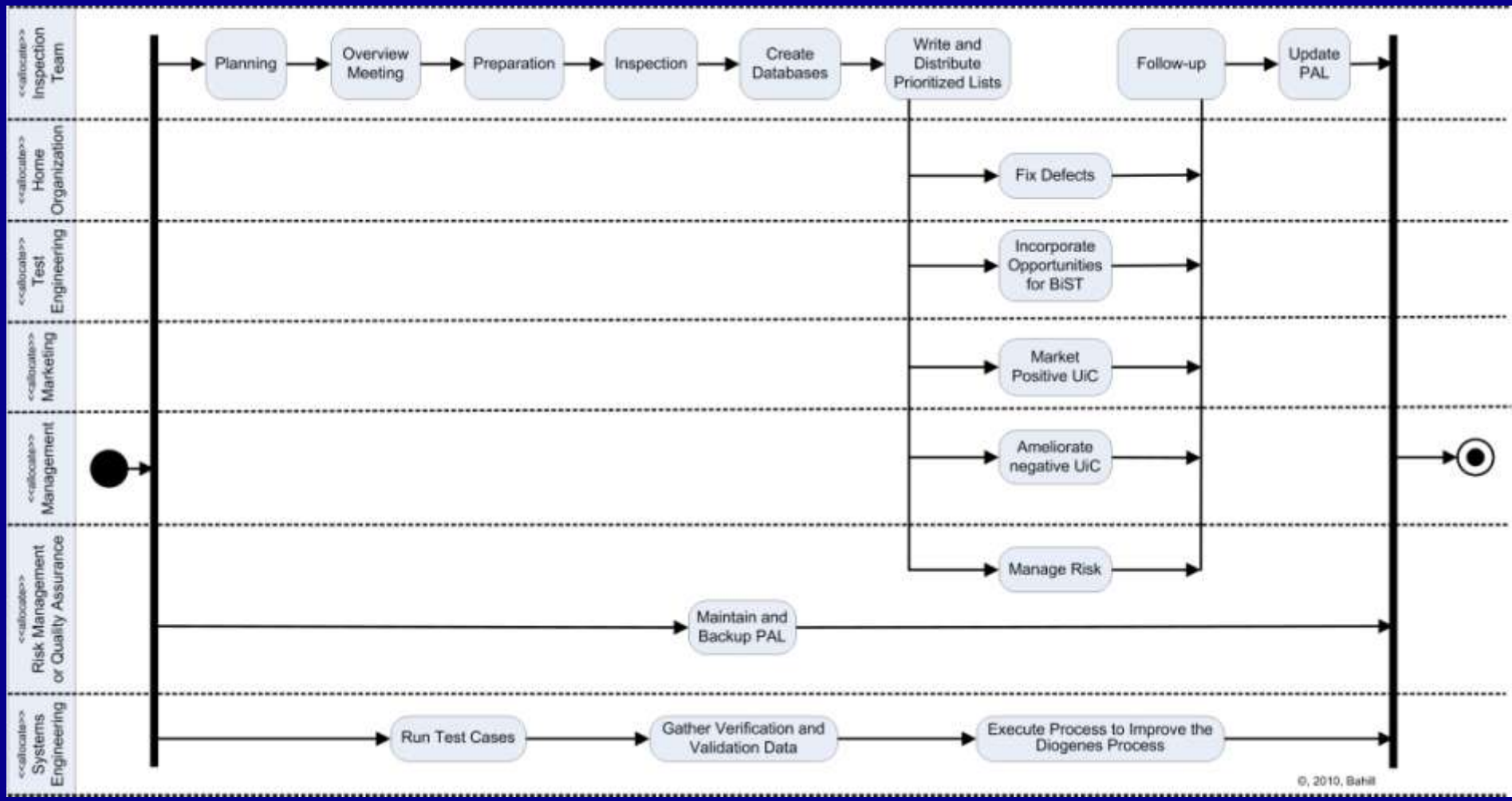
2. **Overview meeting** The Moderator explains the inspection process to the Inspection Team. This will take from ten minutes to three hours depending on the backgrounds of the team members. The Author/Designer may describe the important features of the work products.

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

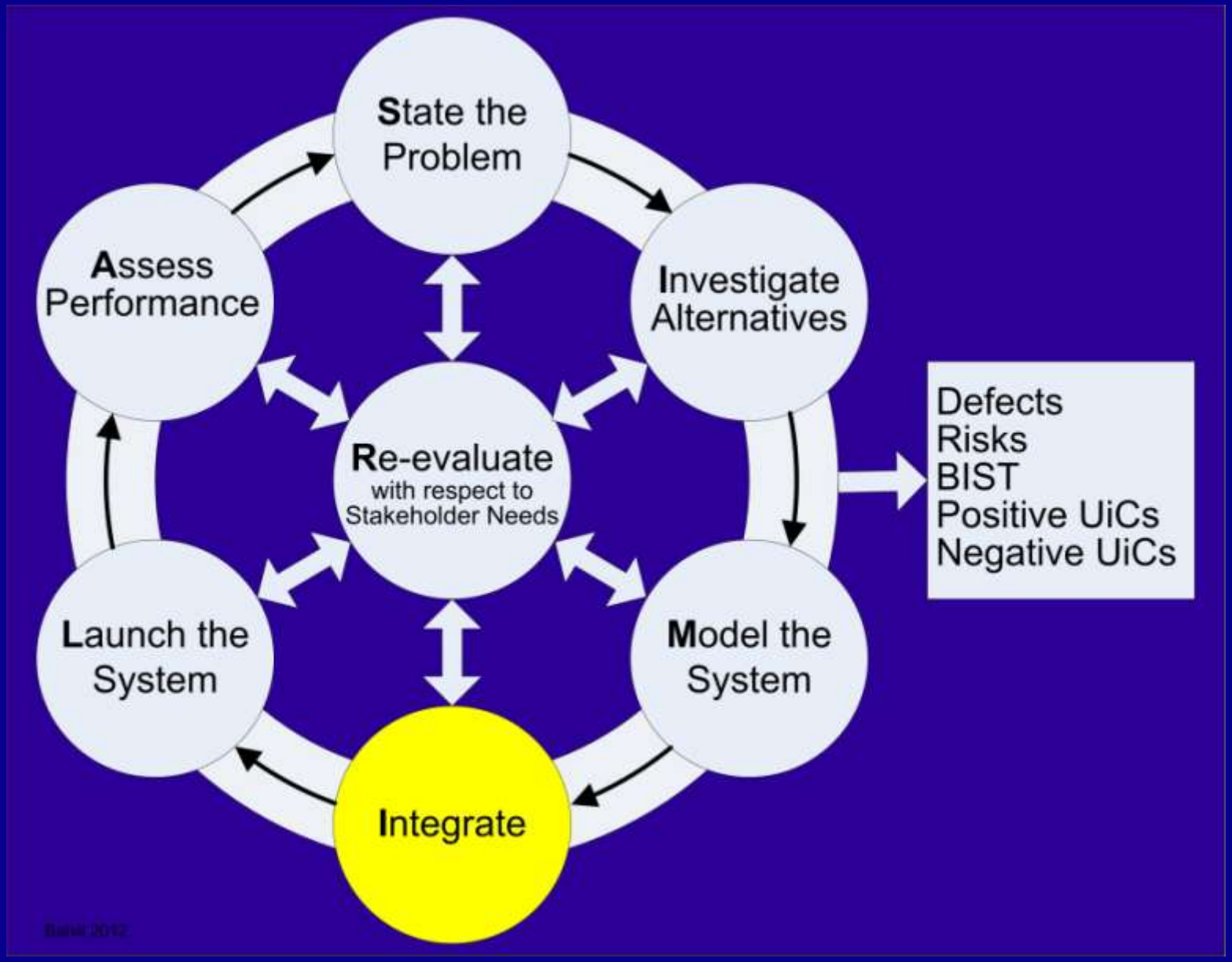
Inspect Documents$_4$

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

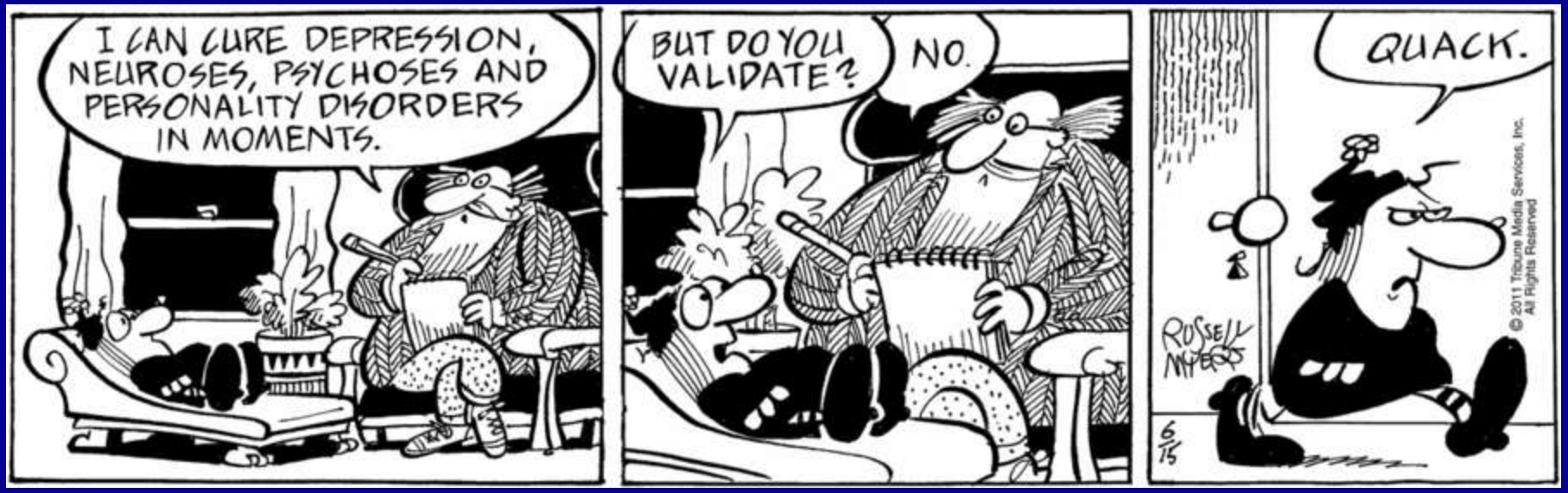
Activity diagram for the use case model



Validation of Diogenes



Validation is important



Broom Hilda © June 15, 2012, Russ Meyers

Apply Diogenes to BIMS

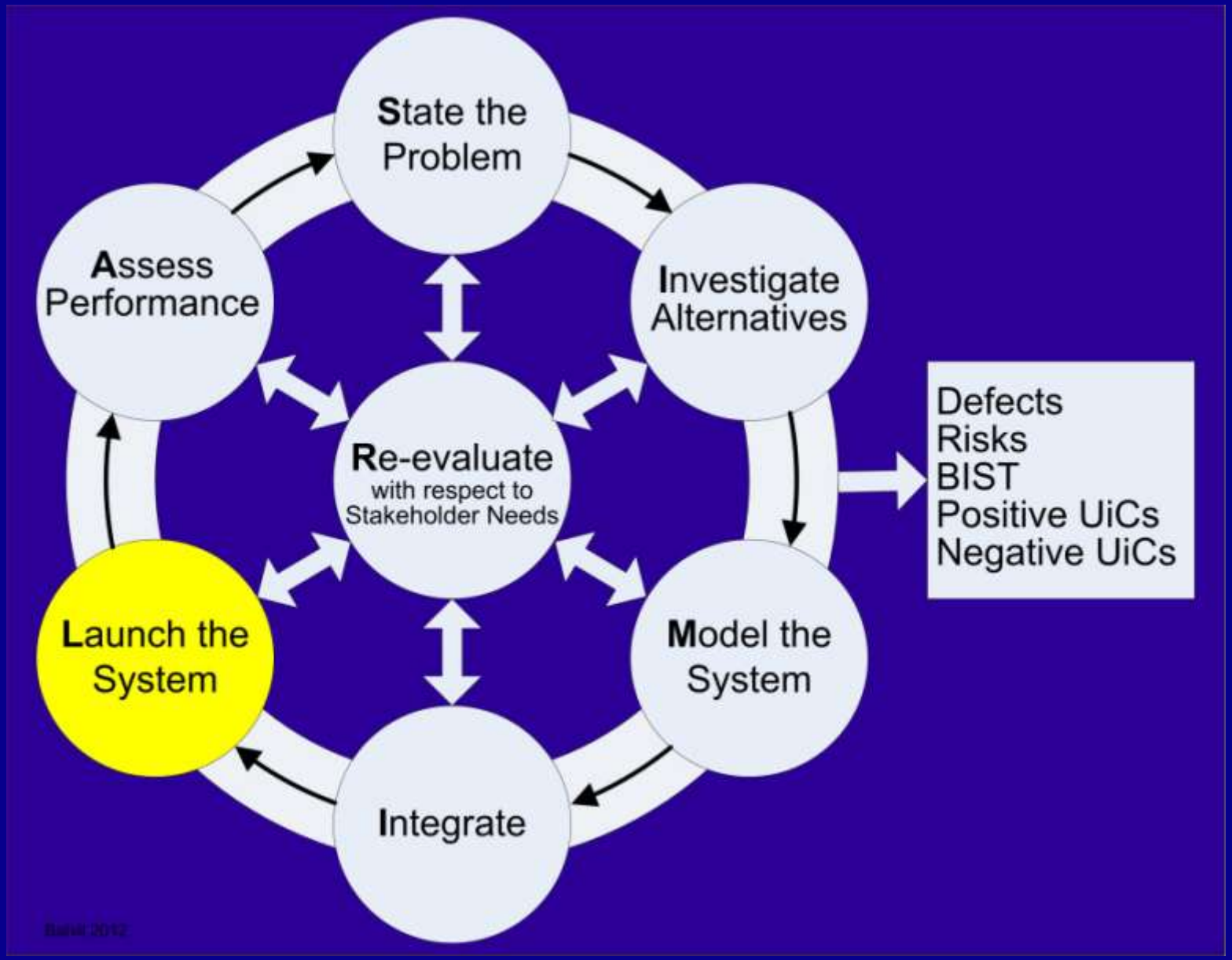
To help validate Diogenes we applied it to an existing, well-documented, system design and observed whether it discovered the defects, risks, opportunities for BiST, positive and negative UiCs of SystemZ.

We applied it to the Bahill Illuminance Management System [Bahill, 2010].

We called this SystemZ.

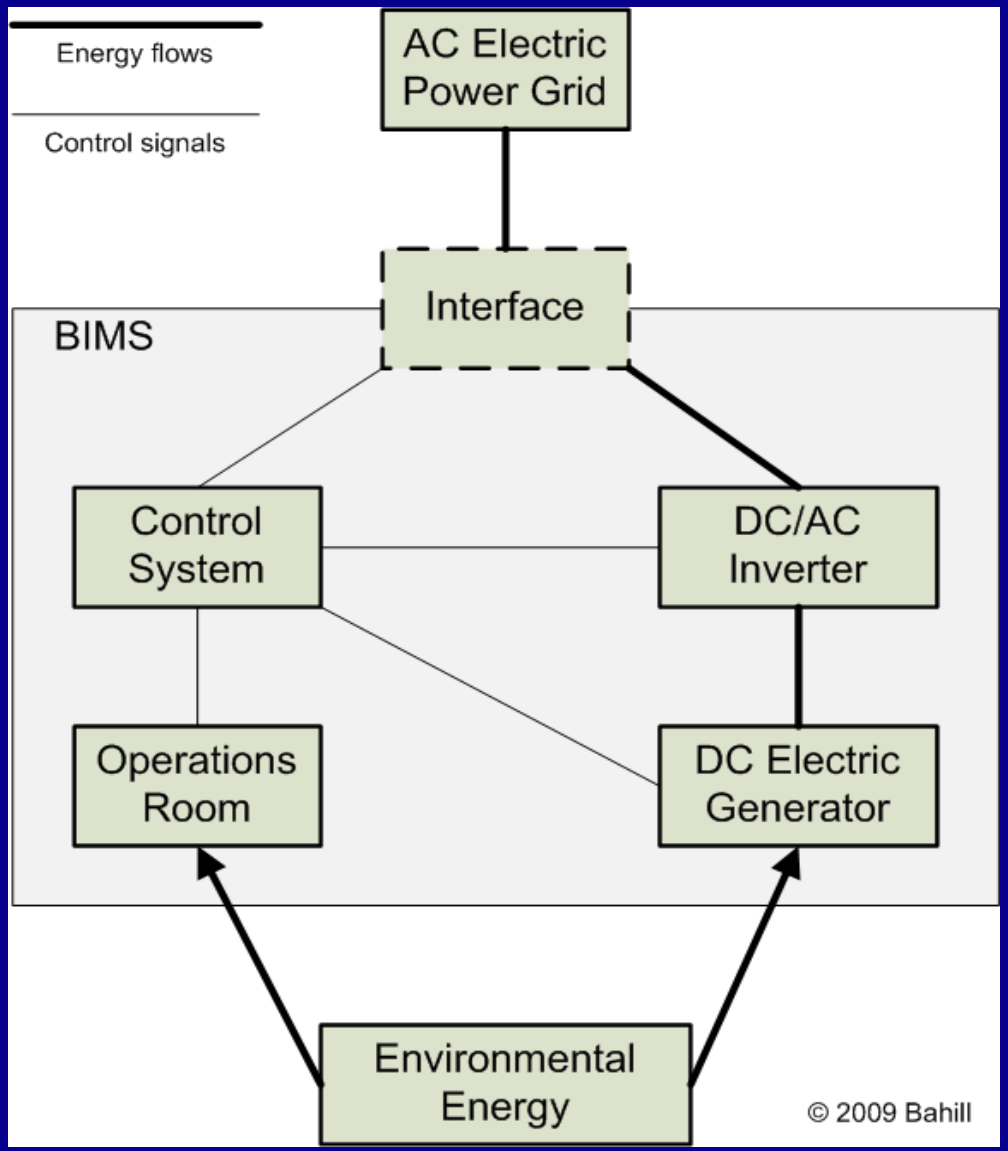
To see if Diogenes does what it is supposed to do, we applied Diogenes to BIMS and observed whether it discovered defects, risks, opportunities for BiST, positive and negative UiCs of SystemZ.

Run the system to see what it does



BIMS Tradeoff study

Scope of BIMS



The absence of energy flows for the Operations Room and the Control System is a documentation defect.

Control Illuminance During the Day use case$_{1a}$

Brief description: The sun rises and sets, but BIMS will keep the illuminance in the operations room constant.

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. What bad things could happen up here?

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

Control Illuminance During the Day use case$_{1c}$

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

Clouds cover the sun unanchored alternate flow

BIMS delivers energy to the AC electric grid. What problem could this cause? 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 between in phase and frequency when a connection is made and indicate failure when either is outside of TBD limits. BiST

Functional requirements

Req1-5 BIMS shall buy electricity from and sell electricity to the AC electric power grid. What could screw this up? 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 efficiency! risk, Reduced efficiency.

Photovoltaic solar panels

What would be the effects of incorporating photovoltaic solar panels into an existing commercial electric power grid?

Unintended consequence

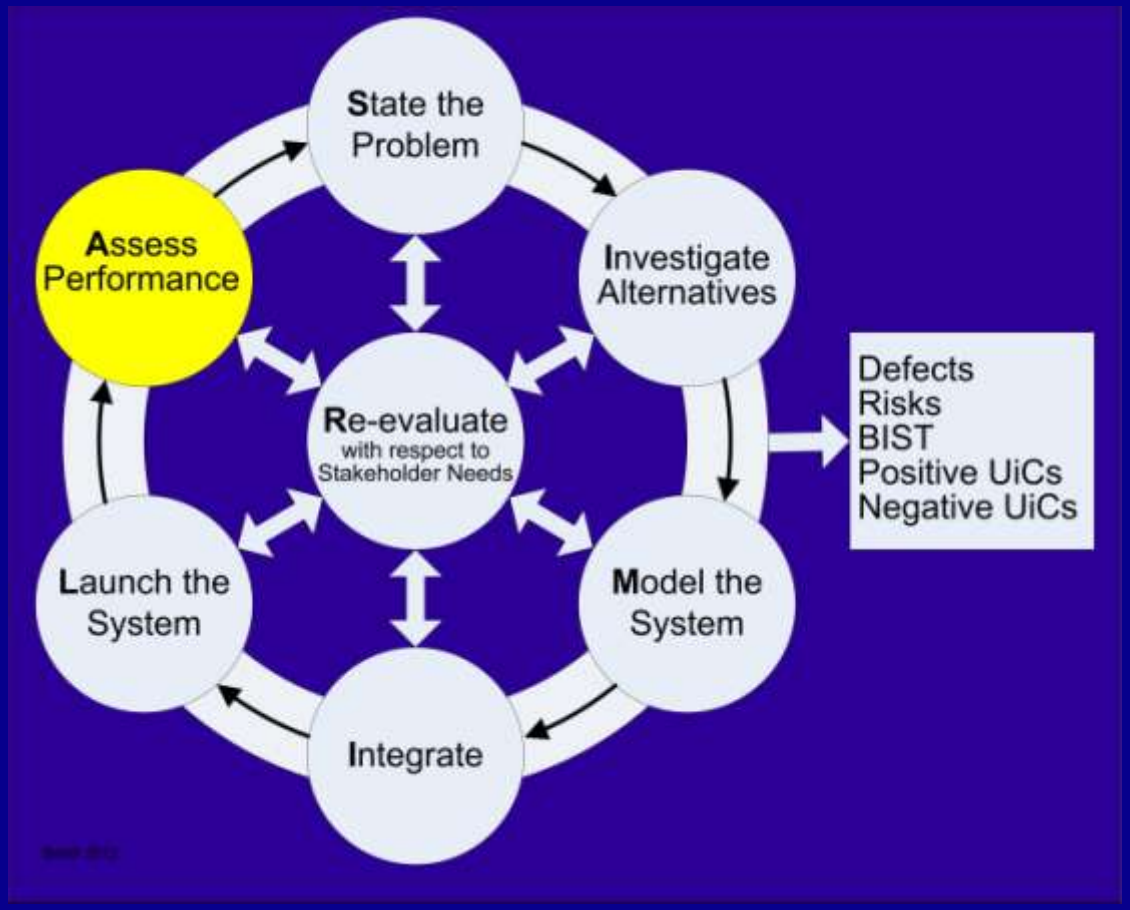
Photovoltaic solar panels

- transform sunlight into electricity
- reflect sunlight back into the atmosphere

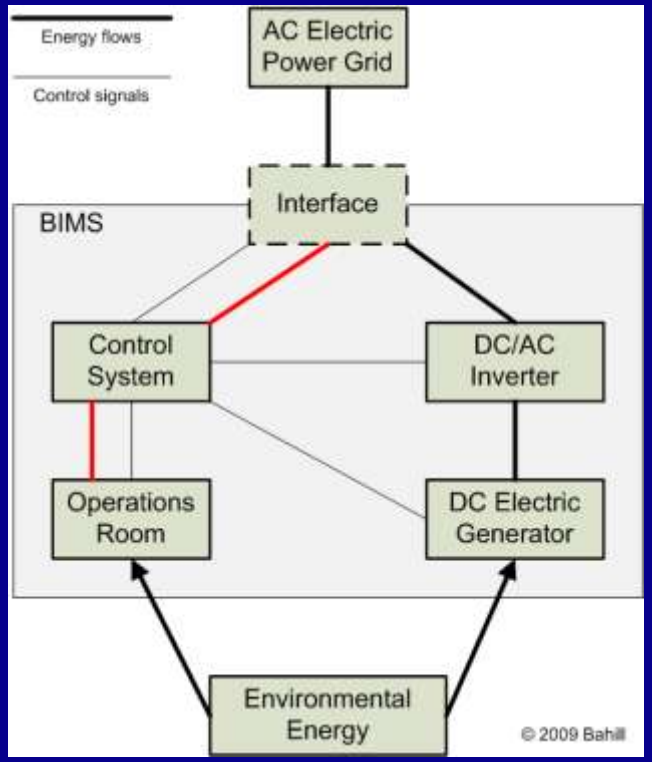
Therefore, photovoltaic solar panels prevent sunlight from hitting the Earth.

This reduces the amount of energy absorbed by the Earth and therefore contributes to *global cooling*!

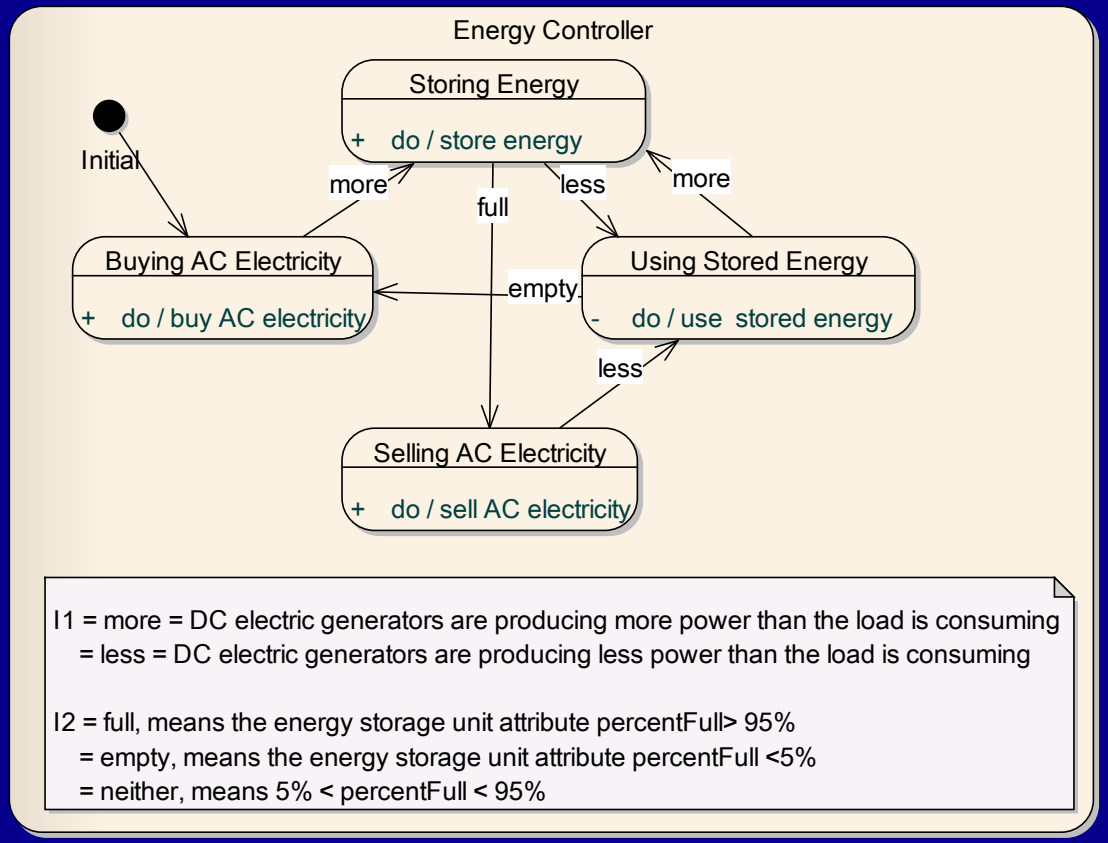
Process: what-if analysis



- This application of Diogenes to BIMS revealed two defects
  - lack of energy flows in the block diagram of the scope of BIMS (figure 4-2)
  - dynamic solution for a static problem in figure 4-7



The energy flows in red were missing in the BIMS documentation.



This is not a dynamic problem, so it does not need a dynamic (state machine) solution.

Prioritized list of potential risks to BIMS

Geographical location increases cost
Sudden drop in generated electricity
Political climate changes
Economic conditions change
Electric company policy changes
High altitude affects humans
Controlled illuminance affects humans
DC to AC inverter failure
Reduced efficiency
Kilauea volcano erupts
Hazards and races
List of TBDs
Diogenes discovered the above 12 risks for BIMS.
The original BIMS risk analysis found more risks.

How did it do?

- This study (applying Diogenes to BIMS) missed
  - a similar system has already been patented
  - the commercial AC electric power grid may fail for hours at a time
  - observatories face heightened community scrutiny because of their prominent siting.
- This study disclosed three risks that the original study did not have
  - controlled illuminance might harm humans
  - hazards and races
  - TBDs

List of potential opportunities for BiST

If the amount of electric energy that is bought from or sold to the Hawaii Electric Light Company differs from predictions, then BiST will send an e-mail to the TestEngineer.

BiST shall record the difference in phase and frequency between the inverter output and the electric grid when a connection is made. These data shall be analyzed statistically.

Every time BIMS changes power to the lights or the positions of the window screens, it will record the measured illuminance in the room. If this is outside the limits, it will report an error.

List of positive UiCs

Contribute to the abatement of global warming

Prioritized list of negative $UiCs_1$

- Destabilizing the electric grid.
  - There is a *positive feedback loop* that could cause BIMS to become unstable.
  - There is a negative *feedback loop* that contains a significant *time delay*. Time delays make systems susceptible to instabilities.
  - Because of these potential stability problems, the project manager should immediately initiate a computer simulation to investigate potential instabilities.
- Increased costs to electric company
- BIMS offends Poliahu
- Destabilizing the solar panel economy

Prioritized list of negative $UiCs_2$

Electromagnetic radiation interfering with telescopes

Improper connection to the grid

Money is needed for decommissioning

Diogenes discovered these seven negative UiCs of BIMS.

The original BIMS documentation had only two, offending Poliahu, which was treated as a risk and increased costs to the electric company for backup generators

Verification and Testing of Diogenes

Use cases can be used to create test plans

Synopsis of Diogenes' use case 3

Name: Inspect Documents

Main Success Scenario:

1. Planning activity
2. Overview meeting
3. Preparation
4. Inspection meeting
5. Databases
6. Prioritized lists
7. PAL
8. Rework
9. Follow-up
10. Update PAL

Fragment of a test plan

1. Planning activity
2. Overview meeting
3. Preparation
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... 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.

Fragment of a test plan$_2$

5. Databases: 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. Prioritized lists: Moderator and SystemsEngineer create five prioritized lists.

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 heads of Risk Management, Test Engineering, 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.

Fragment of a test plan$_3$

7. PAL: 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.

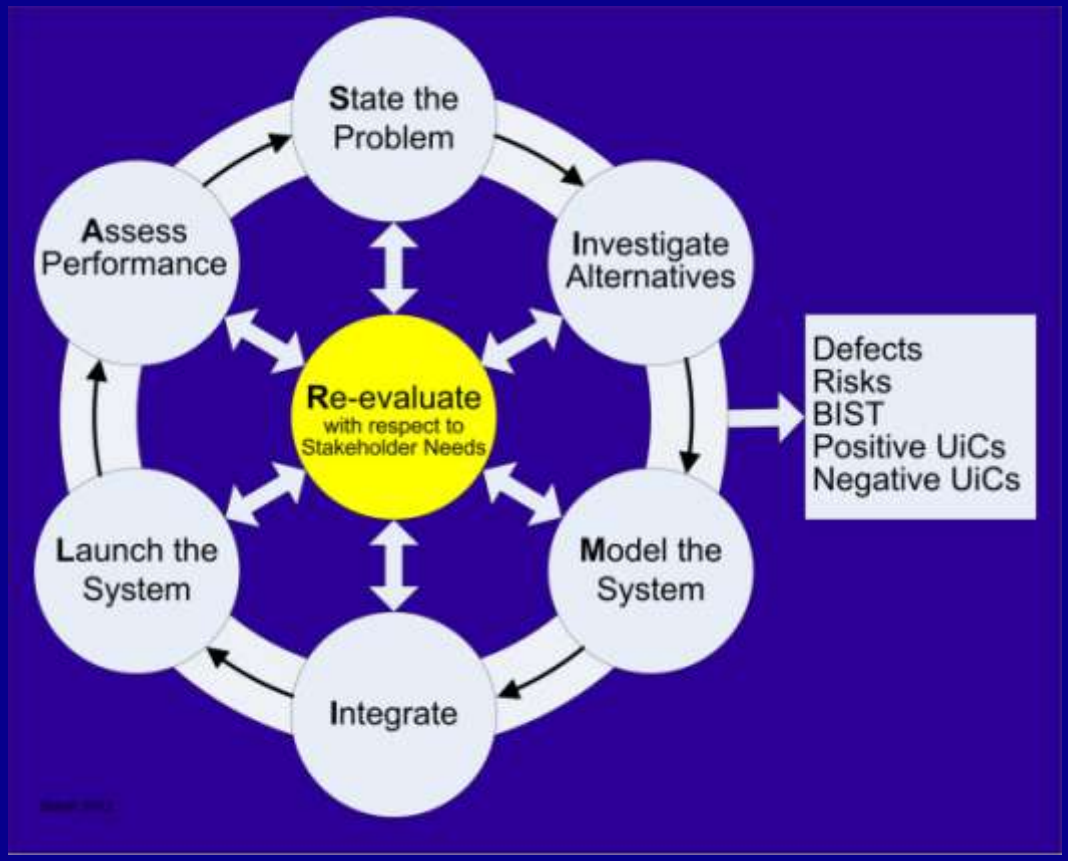
8. Rework

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.

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. Update PAL: Diogenes updates the project PAL [exit use case].

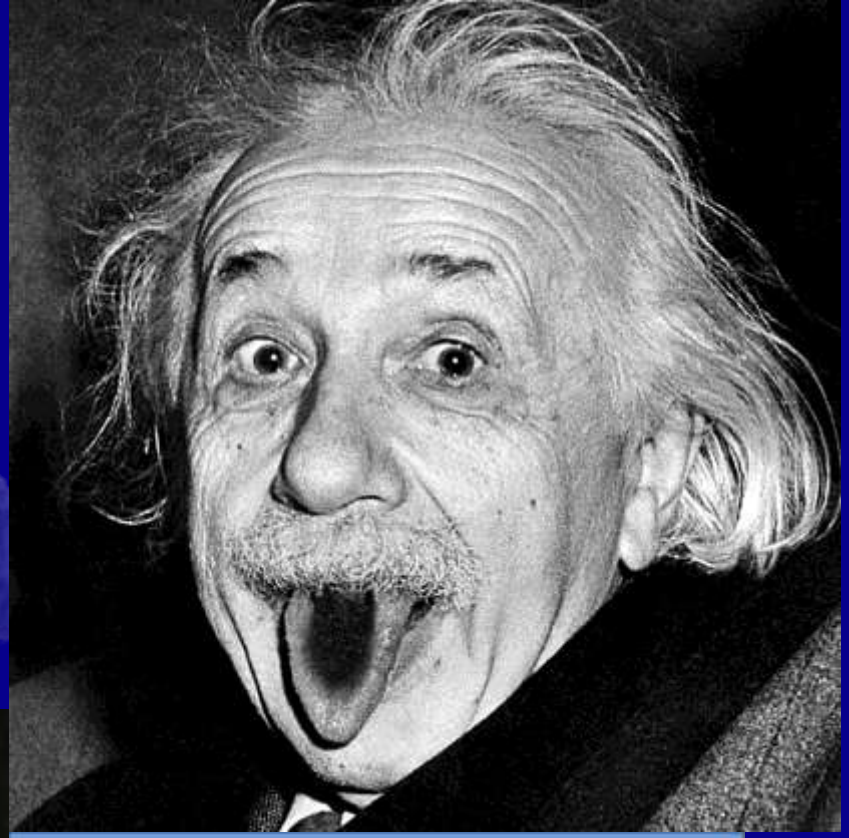
TestEngineer changes the dummy file that he put into the project PAL in step 7 above. This tests FR3-10. TestEngineer records the result.

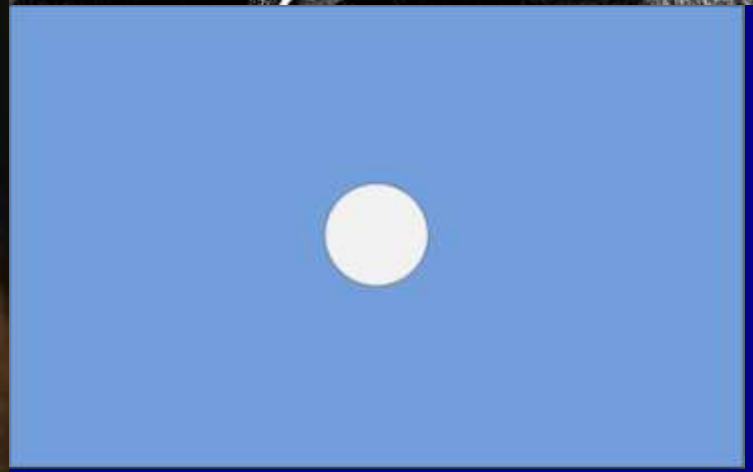


Why do people fail to see potential *unin*tended consequences?
Perhaps because they are too busy looking for *in*tended consequences.

Why do people fail to see UiCs?

- NIH
- My left eye
  - hooks in iris
  - sutures in sclera
- My tongue
- Hubbell telescope
- Invisible gorilla





The invisible gorilla

http://www.theinvisiblegorilla.com/videos.html

Chris Chabris and Dan Simons have a book

The Invisible Gorilla: How Our Intuitions Deceive Us,
about 200 peer reviewed research papers and a web site http://www.theinvisiblegorilla.com/

that develop this concept of inattentional blindness.

This one is especially good.

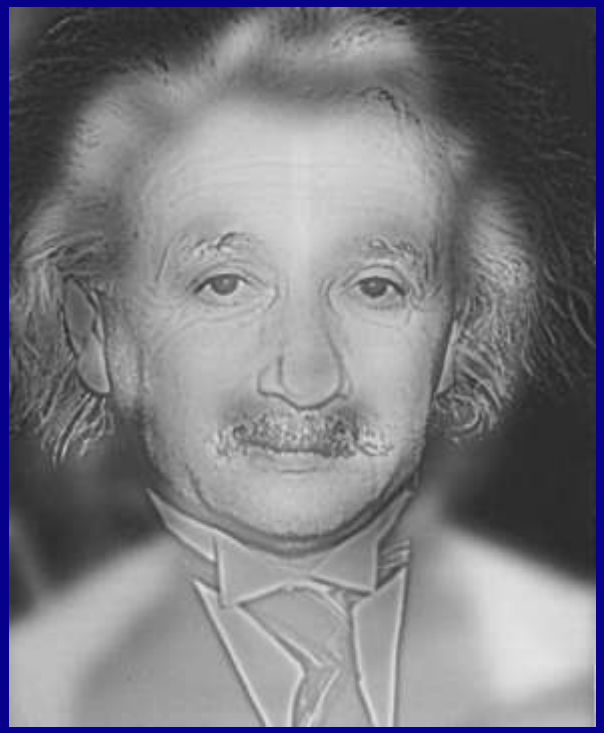
►The Invisible Gorilla And Other Ways Our Intuitions Deceive Us2.flv

The Door Study And Other Ways Our Intuitions Deceive Us.flv

Terry: Hyperlinks work only in “Slide Show” view.

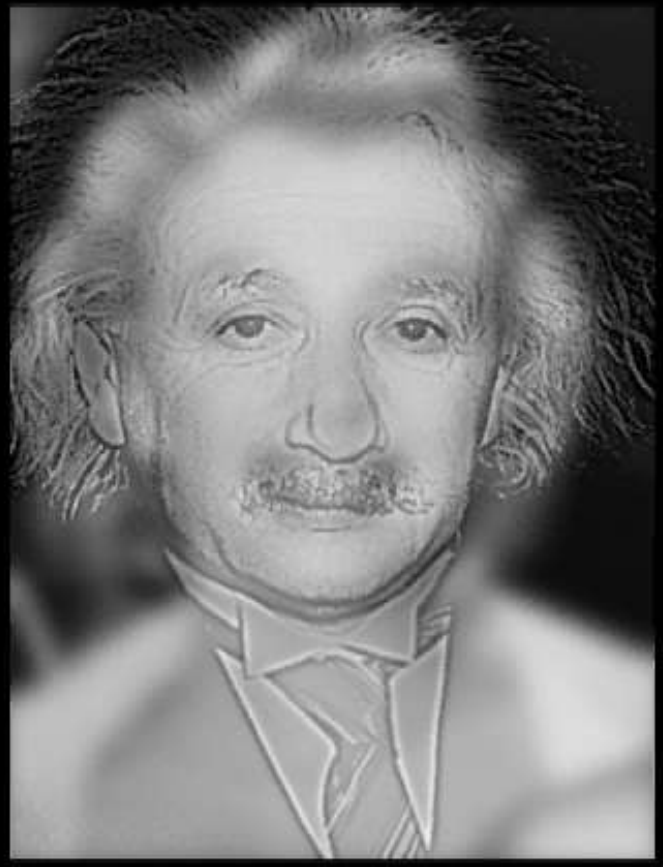
Dan Simons' summary of their work

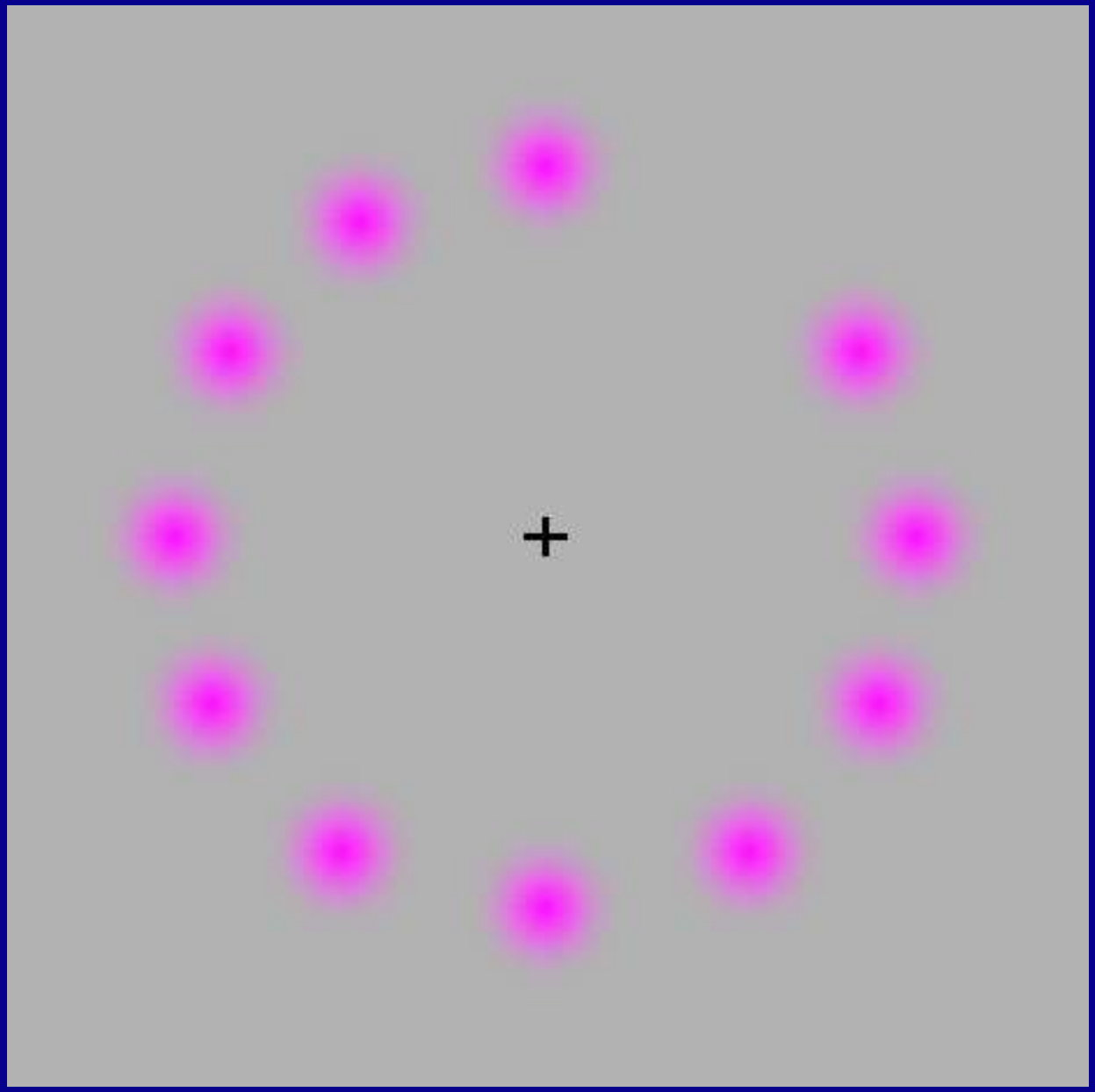
When people focus on a task that demands their attention, they often fail to notice unexpected objects and events that occur in full view. This phenomenon is known as "inattentional blindness" because people typically do not consciously perceive aspects of their world that fall outside of the focus of their attention. These events can be dramatic enough that the vast majority of people are convinced that they would notice. In reality, though, many people do not. In my best-known study of this phenomenon, Christopher Chabris and I asked subjects to watch a brief video of people passing basketballs and to count the total number of times the players wearing white passed the ball. In the middle of the video, a person wearing a gorilla suit unexpectedly walked through the scene. Although 90% of people are convinced they would notice the gorilla, only 50% actually do. The striking disconnect between what we think will grab our attention and what actually does has important theoretical and practical implications. In our general-audience book, *The Invisible Gorilla*, Chris and I explore some of the ramifications of this mistaken intuition about the mind (among many other similar mistaken intuitions).



Aude Oliva, Hybrid Images, *New Scientist,* March 31, 2007, http://cvcl.mit.edu/hybrid_gallery/monroe_einstein.html

Albert Einstein or Marilyn Monroe?





Mental mistakes

People do not see what is there.

People do see what is not there.

Confirmation bias

Confirmation bias means that a person notices and looks for information that confirms his/her beliefs while ignoring or undervaluing information that challenges his/her preconceived notions.

At a murder trial, the mother of the murderer will ignore DNA and eye witness evidence and say, “Oh, He is innocent, because he was always such a good boy.”

During WWII the Japanese were certain that their Purple and JN-25 codes were unbreakable, despite evidence to the contrary.

Confirmation bias

In the High Middle Ages (1000 to 1300 AD), the heavens were thought to be unchanging and eternal, in contrast to life on earth that was tumultuous and fleeting.

Then in the 16th century, the Polish Catholic cleric Nicolaus Copernicus created a heliocentric model where the earth rotated around the sun and the Church went reeling.

In the next century, European astronomers began to *notice* changes in the heavens that they had failed to see before: new stars appeared and others disappeared, sunspots flared and faded out.

In China, where they had different mental models, they had been recording such astronomical phenomena for centuries.

The European astronomers did not *see* evidence that did not confirm their models.

What the astronomers saw in 1054 AD

Crab Nebula Supernova

Chinese

Anasazi

Europeans

But this did not fit the European preconceived model, so they did not see it.

Human knowledge is usually wrong

- Mark Twain said,
  - “It ain’t what you don’t know that gets you into trouble. It’s what you know for sure that just ain’t so.”
- Humans are often very certain of knowledge that is false.
  - What American city is directly north of Santiago Chile?
  - If you travel from San Diego to Reno Nevada, in what direction would you travel?
- Most humans think that there are more words that start with the letter r, than there are with r as the third letter.

Bahill's advice to you

Don't trust your eyes

Don't trust your ears

Don't trust your brain

Don't trust your skin

Ear that hears, eye that sees,

Yahweh has made both of these.

Proverbs 20:12

Summary

Negative unintended consequences (UiCs) can be significant.

UiCs can be anticipated.

Diogenes can help discover

- defects
- risks

and at the same time help identify

- opportunities for BiST
- positive UiCs
- negative UiCs

Therefore, it will not cost extra money to use Diogenes to search for negative UiCs.

Take home message

Uncle Sam wants you to discover UiCs of your systems.

The BICS BrainTrust

If you are interested, we offer a one week short course on implementing this process in your organization.

Terry Bahill, Fellow of the Institute of Electrical and Electronics Engineers (IEEE), of Raytheon Missile Systems, of the International Council on Systems Engineering (INCOSE) and of the American Association for the Advancement of Science (AAAS).

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

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

Brad Sowers, Raytheon, Director of Directed Energy Weapons

Monty Python said,

"Nobody expects the Spanish Inquisition."

Number of slides

- UofA SIE 75 minutes, 160 – 42 = 118
- Intel 60 minutes, 118 slides
- PHM 30 minutes,
  - remove slides 3, 21, 22, 24, 33, 45, 83, 84, 86, 88, 111-114, 117, 144
  - 100 slides
  - I'll cry if I have to remove 35, 137, 140-1

