Diogenes, a Process for Identifying Unintended Consequences

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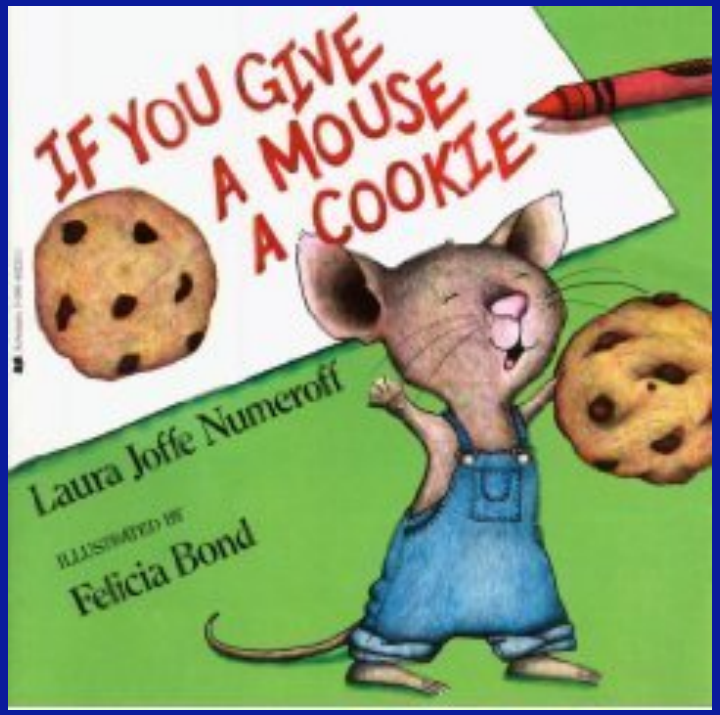
Reference

L. J. Numeroff and F. Bond, *If You Give a Mouse a Cookie*, Harper Collins, 1985.



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.

Compact fluorescence light (CFL) bulbs

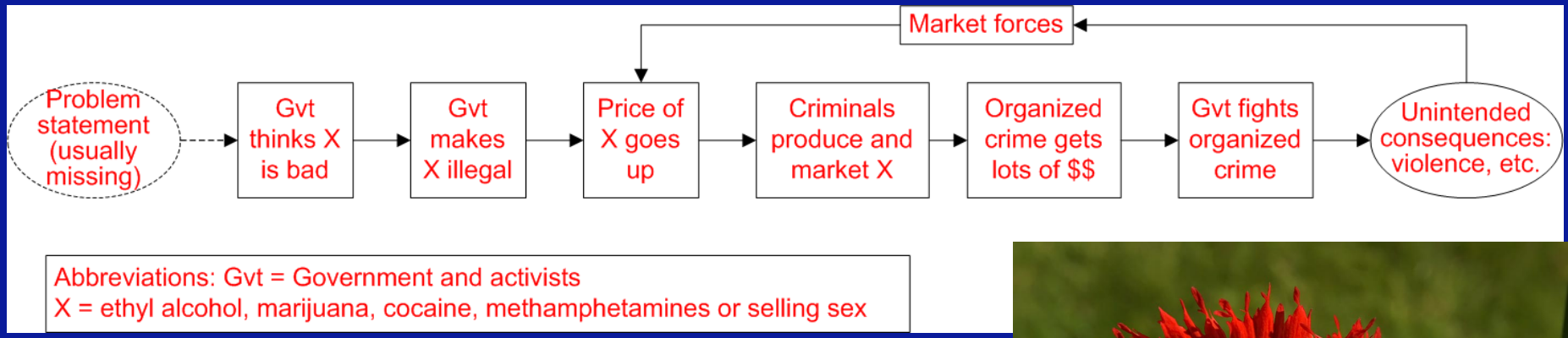
In 2007, Congress tried to force the replacement of incandescent bulbs with more expensive but more energy-efficient CFL bulbs. They said it would

- save consumers money
- increase domestic security
- reduce greenhouse gas emissions
- stop global warming

But they ignored the UiCs

- CFLs use mercury, so if the bulbs are broken people will be exposed to mercury vapor.
- CFLs do not work with dimmer switches.
- CFLs are too big to fit into many light fixtures.
- The lifespan of CFLs diminishes with frequent cycling.
- The manufacturing of light bulbs has now been outsourced to China.

An often repeated government process



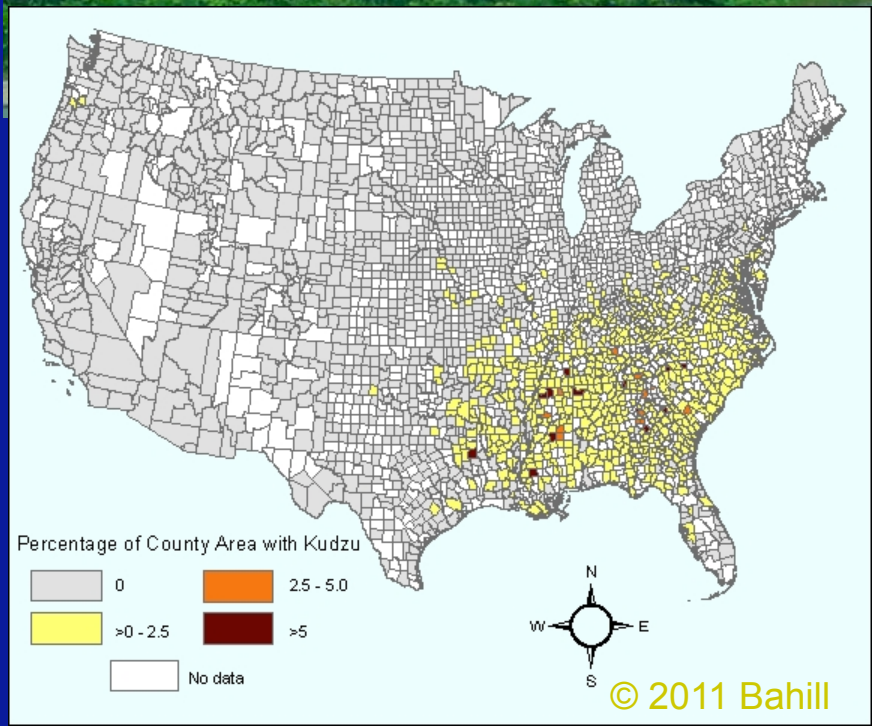
Kudzu

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.

Subsequently they 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.



Asian carp

Asian carp were imported into the United States in the 1970s to remove algae from catfish farms.

They spread rapidly along the Mississippi, Ohio and Illinois rivers crowding out native species.

Conservationists are struggling mightily to prevent them from spreading into the great lakes.

Rabbits

Rabbits were introduced into Australia in 1859 as a game animal for hunting.

This was followed by an explosive growth in the rabbit population; their 200 million rabbits have become a major feral pest.

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.

Rats

In India, a program intended to eliminate rats by paying people a bounty for each rat pelt they turned in, led instead to rat farming.

Ferruginous Pygmy Owl

Ferruginous Pygmy Owl

In 1997, (in order to protect the Cactus Ferruginous Pygmy Owl around Tucson, Arizona) the U. S. Fish and Wildlife Service under the Endangered Species Act of 1973, proposed designating 1.2 million acres of largely undeveloped land as part of the owl's critical habitat.

After the designations were published in December 1998 but before the regulations took effect in August 1999, land identified as likely critical habitat parcels lost 22% of their value. Furthermore critical habitat parcels were developed on average about one year earlier than similar non-critical habitat parcels.

A likely conclusion is that when people saw the value of their land drop, they decided to develop their land quickly, before the new rules could "take" their land. This undoubtedly reduced the number of Pygmy Owls.

Eucalyptus trees are planted in the Oakland-Berkeley hills

In the 1800s San Franciscans used all the redwood trees for railroad ties and lumber.

In 1900 the Oakland-Berkeley hills were predominantly grassland and chaparral with a few conifer trees.

People felt that hills without trees were not productive, so they designed lumber plantations.

Eucalyptus trees grow fast, so they planted millions of eucalyptus seedlings in the Oakland-Berkeley hills.

The trees grew rapidly, but they were unsuitable for lumber, because they were difficult to plane and the wood cracked while drying.

The lumber project was abandoned, but the trees remain.

Eucalyptus trees cover Oakland-Berkeley hills

- Dead leaves and bark accumulate under the trees, when this Eucalyptus trees are a firefighter's nightmare.

the trunks and roots survive and sprout flammable new growth.

- Flames reach the upper branches and form a *crown fire* that jumps from tree to tree.
- Their leaves contain flammable oils
- They explode when they burn
- Pieces of flaming bark can be blown long distances

Eucalyptus trees burn Oakland-Berkeley hills

Eucalyptus trees are responsible for the severity of a dozen

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.

It is not known if the university saved money or

So that a document that is one page in Arial could

Strong passwords

Requiring strong passwords for access to computer systems causes many users to write their passwords

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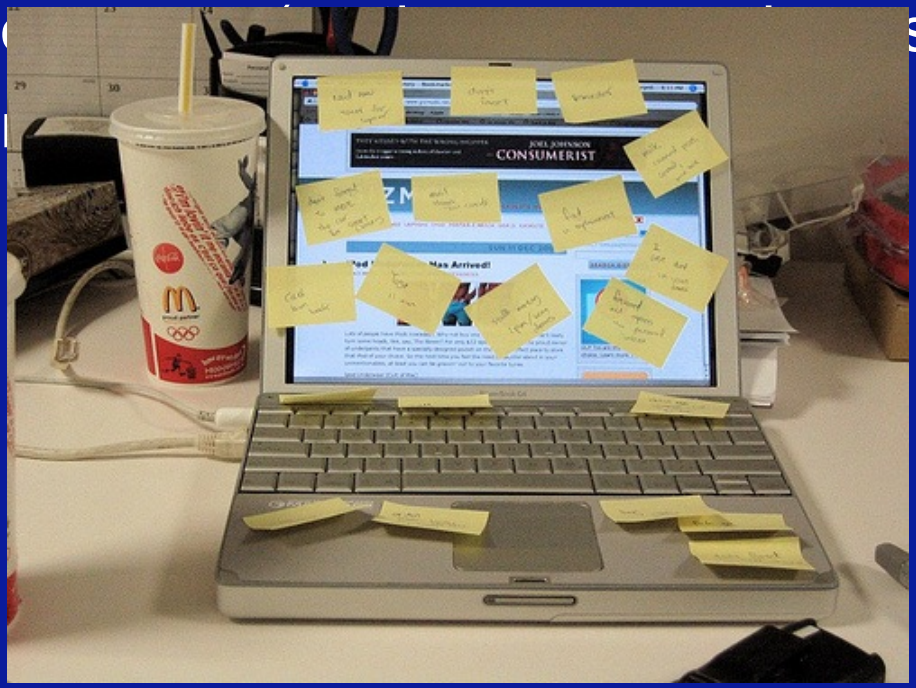

ssible to remember),

of strong passwords.

name as your password?

Get rich by studying UiC

The Dow Jones industrial average dropped 1000

The Dow Jones industrial average dropped 1000

happened, except for the people who studied UiCs points in one hour on May 24, 2010.

Chain of events

For want of a nail, a shoe was lost

For want of a shoe, a horse was lost

For want of a nail, a shoe was lost

For want of a shoe, a horse was lost

For want of a message, a battle was lost

For want of a horse, a rider was lost

For want of a rider, a message was lost

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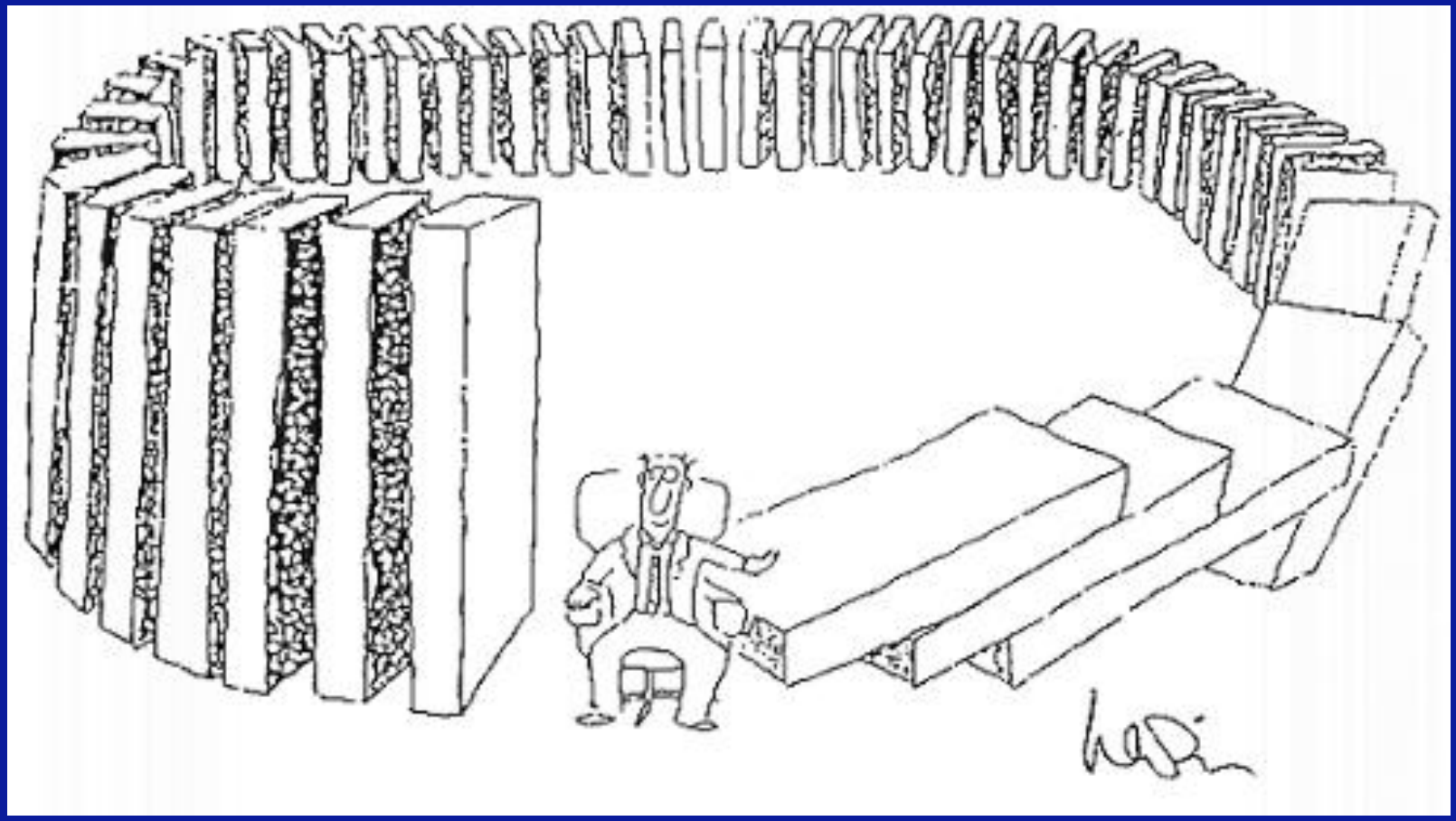
All for want of a nail

Chain of events with unintended consequences

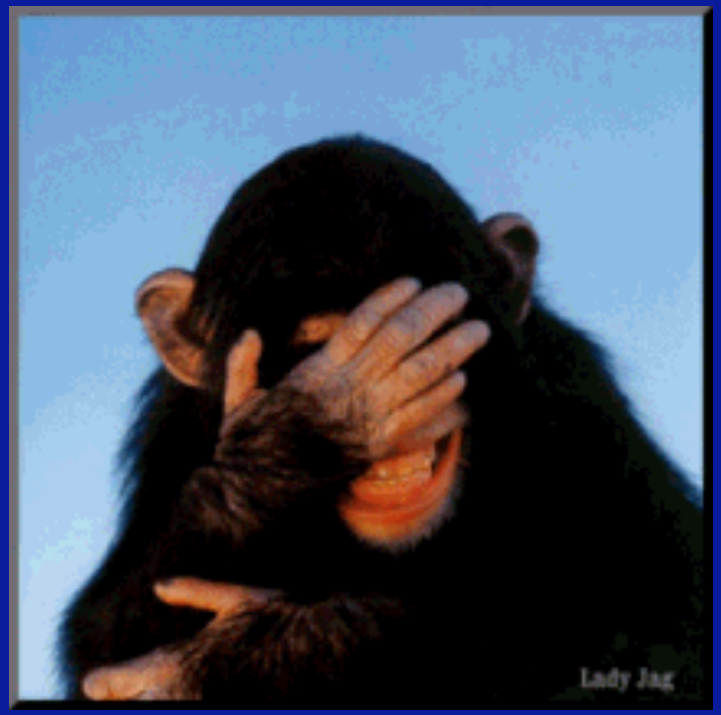


Subprime loans

"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… has been under increasing pressure from the Clinton Administration to expand mortgage loans among low and moderate income people… subprime borrowers." *The New York Times,* September 30, 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.

New law outlaws texting while driving



Argh! That was terrible.

Not all UiCs are bad

- Wolves were reintroduced into Yellowstone Park in the 1990s
- This caused a sequence of UiCs
  - Elk became skittish and stopped eating young aspens, cottonwoods and willows
  - beavers, now feeding on flourishing willow recolonized streams
  - Wolves reduced the coyote population, so pronghorn antelope lost fewer calves to coyotes
  - reestablished vegetation on banks of their which retarded erosion and provided cover fo

Replacing carbon paper

Xerox's photocopy machine at a low price.

In the 1950s, IBM was offered the patents for

Xerox's photocopy machine at a low price.

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 UiCs of the copy machine were that minutes and they could copy the original

owners could delight their customers with a

In the 1960s, scientists at 3M produced glue that did not stick very well.

The positive unintended consequence was the

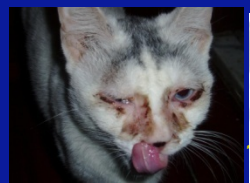
In the 1960s, scientists at 3M produced glue that did

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

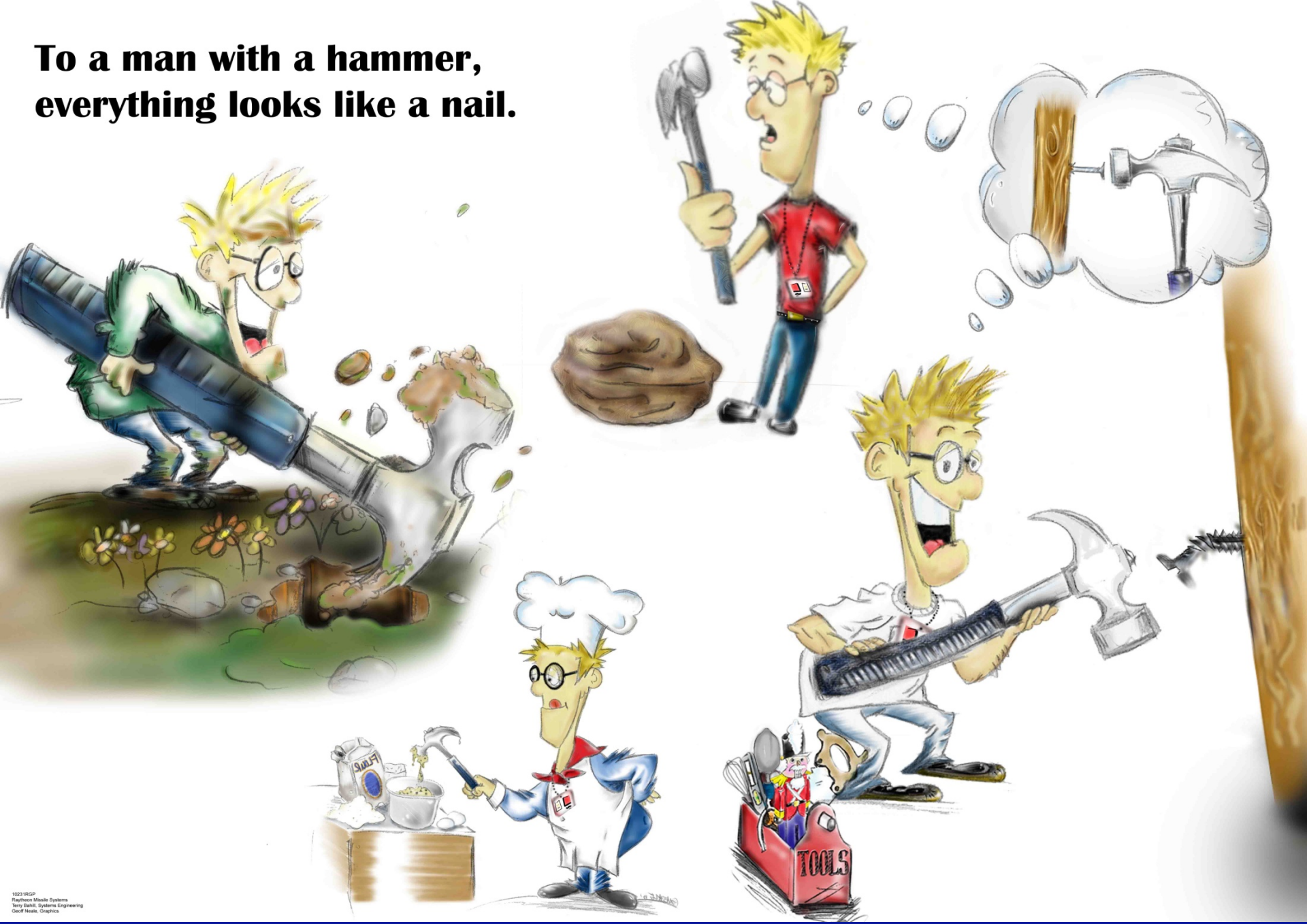
into polytetrafluoroethylene, Teflon®!

Grass in our backyard



Case for change

To a man with a hammer, everything looks like a nail.



10231RGP
Raytheon Missile Systems
Terry Bahill, Systems Engineering
Geoff Neale, Graphics

When new problems appear, we should use a new tool.

Case for change$_1$

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 unintended consequences (UiCs).

Diogenes is a system that will help decision makers to discover negative unintended consequences of their decisions.

Case for change$_2$

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.

Case for change$_3$

- In traditional companies, 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 be within tolerances: the product should be right on target. If the product is off of its target, then something is wrong and it should be fixed.
- Taguchi called the penalty of this unknown wrong “a cost to society.”
- Joel Spira said “Innovate with high quality products.”

Case for change$_4$

The program manager might say that the harmed system has no power over him and the customer has no power over the Customer, but the Customer's Customer do have that power. Their effects are not direct, but if the our environment gets better, then the program manager's bottom line will also get better.

Therefore, it is

in the best interests of the program

Case for change$_5$

Joel Spira's 5 principles

- Take care of the customer.

- Take care of the customer.
- Take care of the company.

- Take care of the people.
- Innovate with high quality products.

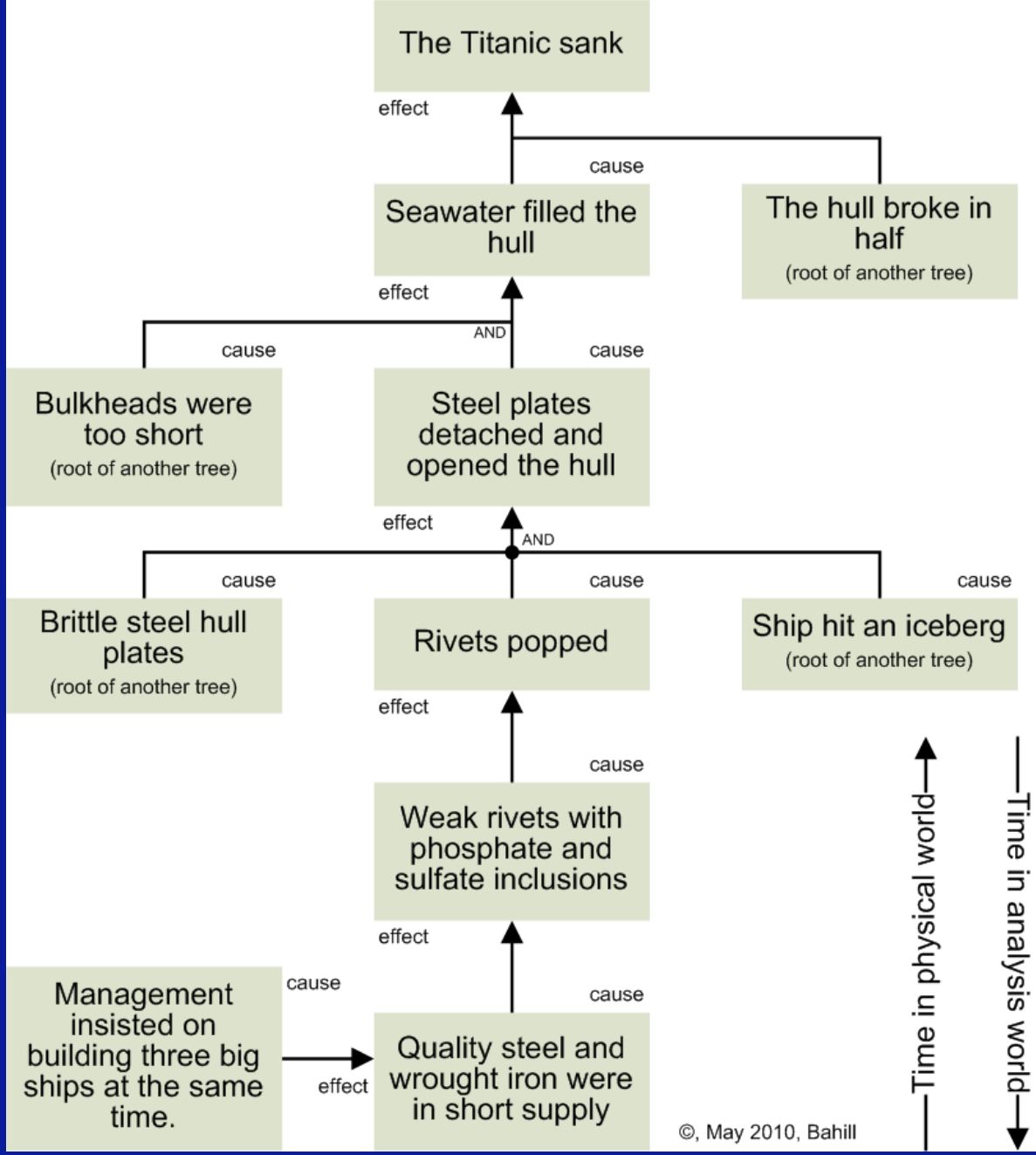
Case for change$_6$

You get something for nothing

- discovering defects and risks -
  - Your company must already have processes for discovering defects and risks .
  - With Diogenes, while you search for defects and risks, you can also find opportunities for Built-in

Existing tools that might be useful

Cause and effect Cause and effect diagram for the sinking of the



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?

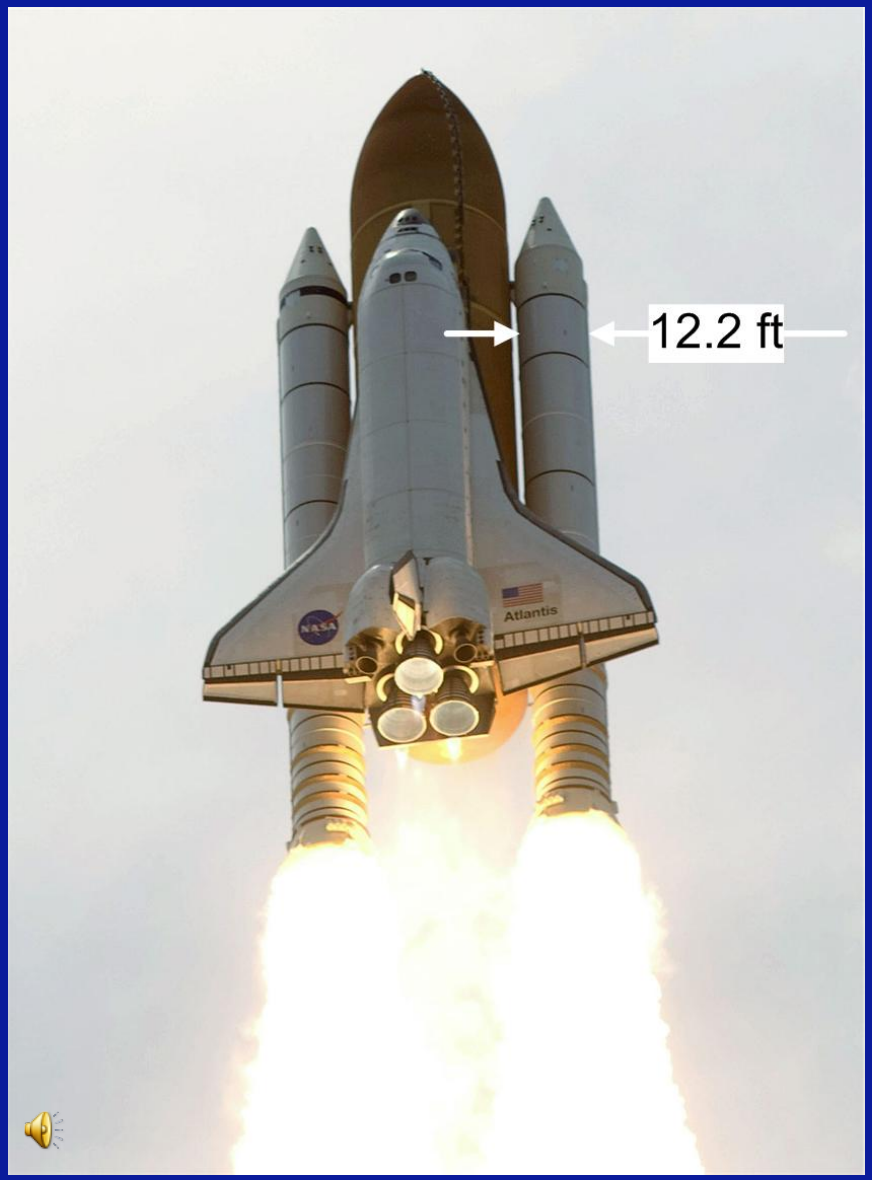
Because the O-rings were brittle.

Why were the O-rings brittle?

Because the temperature was too cold.

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

Why?



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

Why?

To be wider than the train, which rides on rails

Why?

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

Why?

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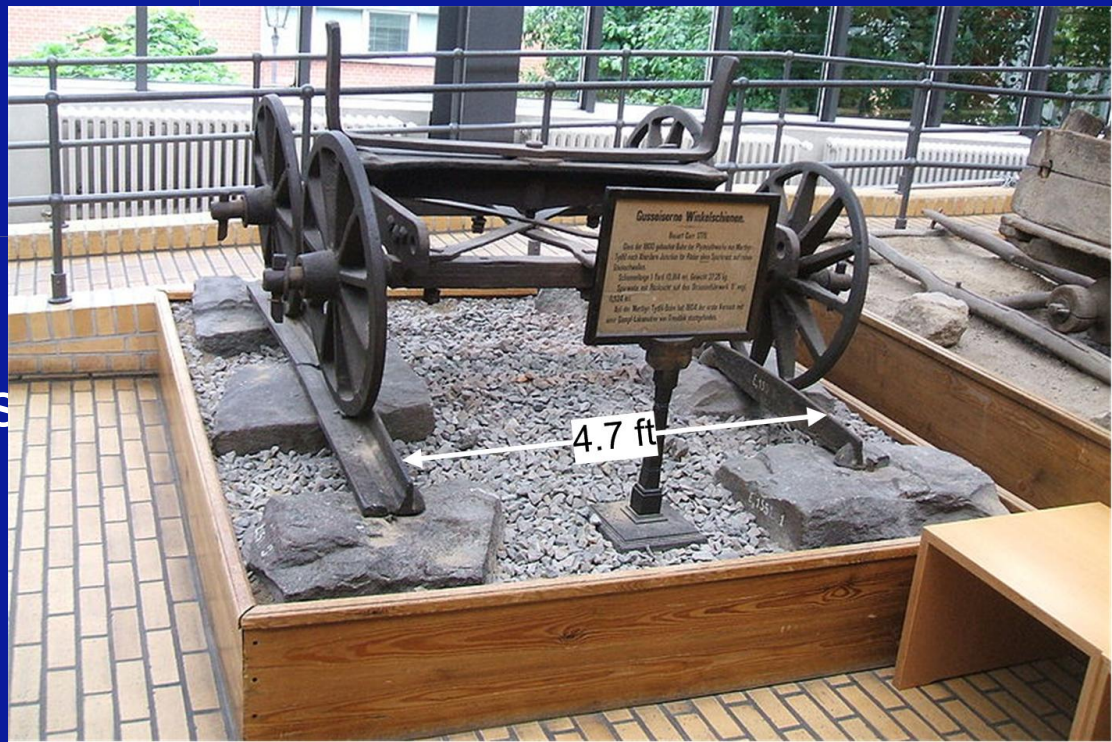
Why?

Because that was the width of the previous wagon




4.7 ft
4.7 ft

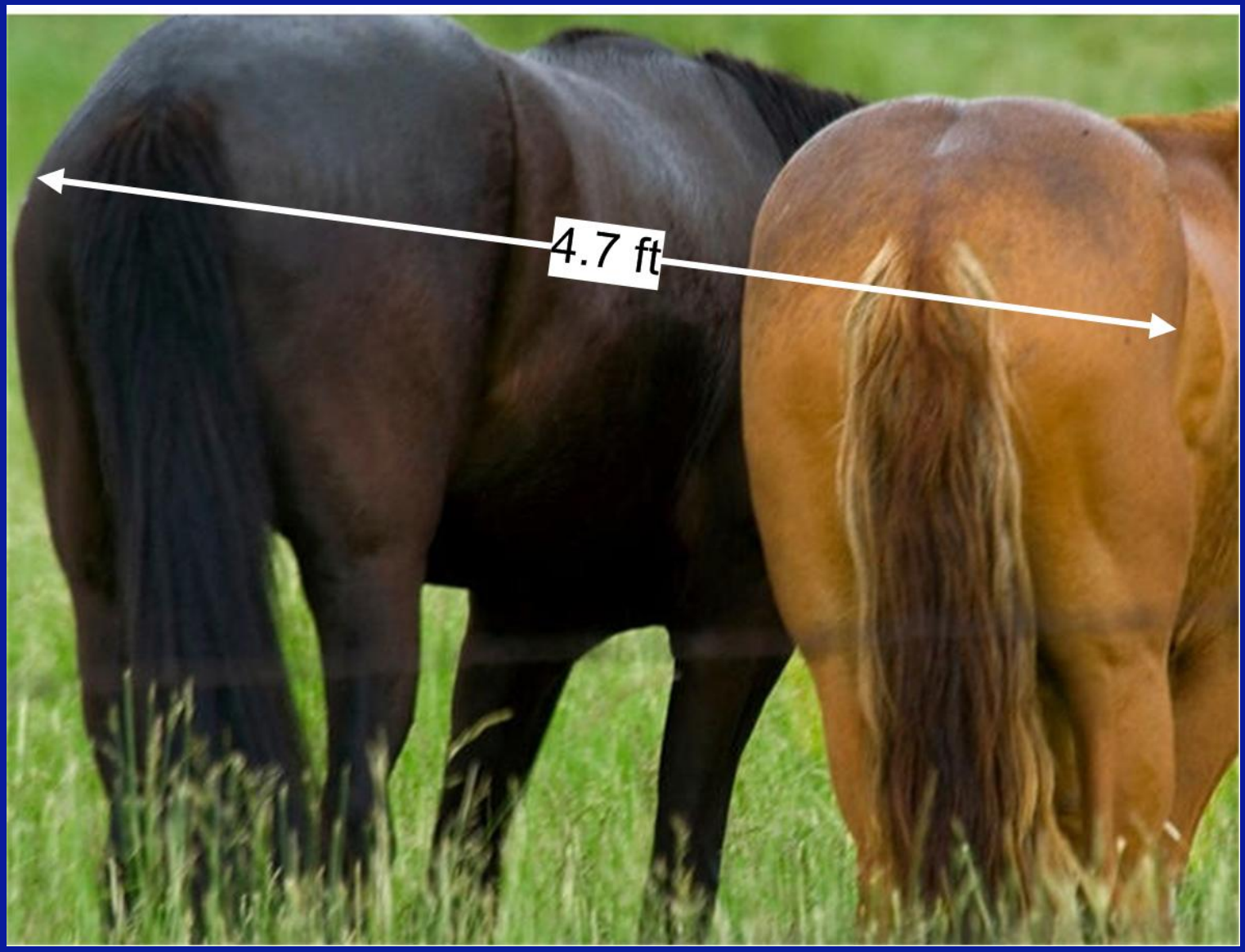
Why?

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



Honda S2000

That’s funny

Ishikawa fishbone diagrams

Write a problem statement (failure). Put its label in a box on the right and draw a horizontal arrow (the backbone) running to it.

Draw four to six main bones. Label these with names of the major categories of probable causes.

Use brainstorming to add bones to the diagram.

Prioritize and identify the most important causes.

Take corrective action.

Verify through testing.

Brainstorming

Your task is to tie two strings together.

On the table are a relay and a three-way switch.

Humans do not abuse the known.

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?

Looking forward

Proper Wine Tasting Technique

See

Smell

Slurp

Looking backwards

I have four dogs. One day I put out a bowl of dog biscuits.
The oldest dog came and ate half the biscuits plus one.

$numberAte_k = ½\ numberInBowl_k + 1$

$numberInBowl_{k+1} = numberInBowl_k - numberAte_k$

$numberInBowl_{k+1} = numberAte_k - 2$

where k is the dog number, 1 in this case.

Then the next dog came and ate half of what she found plus one more.
Then the third dog came and ate half of what he found plus one more.
Finally, the last dog came and ate half of what she found plus one more.
Now the biscuits were all gone.
How many biscuits were originally in the bowl?

One of the interesting facets of the problem is that, unlike most real world problems, there is One unique answer.

You can easily write four equations with five unknowns.
I have four dogs. One day I put out a bowl of dog biscuits.

Looking forward or backward

To further show the difference between a
To further show the difference between a

looking forward, let us look forward from
looking forward, let us look forward from
the Ariane 4 missile to the Ariane 5
the Ariane 4 missile to the Ariane 5
missile.

Ariane 5 missile[1]

The Ariane 5 blew up on its first launch destroying a billion dollars worth of satellites.

A search for UiCs might

A search for UiCs migh

the Ariane 4, and it used the same software.

Ariane 5 missile$_2$

Being bigger, it will accelerate faster.

the attitude where it tilts from vertical to more horizontal flight earlier.

How would that affect us?

In this new state, there would be much more horizontal acceleration than in the Ariane 4.

Ariane 5 missile$_3$

If the horizontal acceleration were still being

If the horizontal acceleration were still being horizontal-velocity storage register would overflow.

integrated into horizontal velocity, then the 32-bit

horizontal velocity storage register would overflow.

If the horizontal velocity were still being used, then the CPU would encounter a fault.

What would that do?

What harm would that do?

If the horizontal velocity were still being used, then the CPU would encounter a fault.

Must Avoid Just Go!

http://dai.ly/bOzNVh

Alternative concepts

Alternative architectures

Five whys

Brainstorming

Concept mapping (mind mapping)

SIMILAR process

Risk analyses process

Failure modes and effects analysis

Cause and effect process

Ishikawa fishbone diagrams

Tradeoff study process

Comprehensive testing process

Sensitivity analysis process

Formal inspection process

Requirements discovery process

Sneak circuit analysis

Evaluation criteria

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

Looks Forward. The system must look forward in time.

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

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

Total Life Cycle Cost

Built-in Self-Test

Reusability

Vendor Evaluation

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**

Diogenes, a search for unintended consequences process

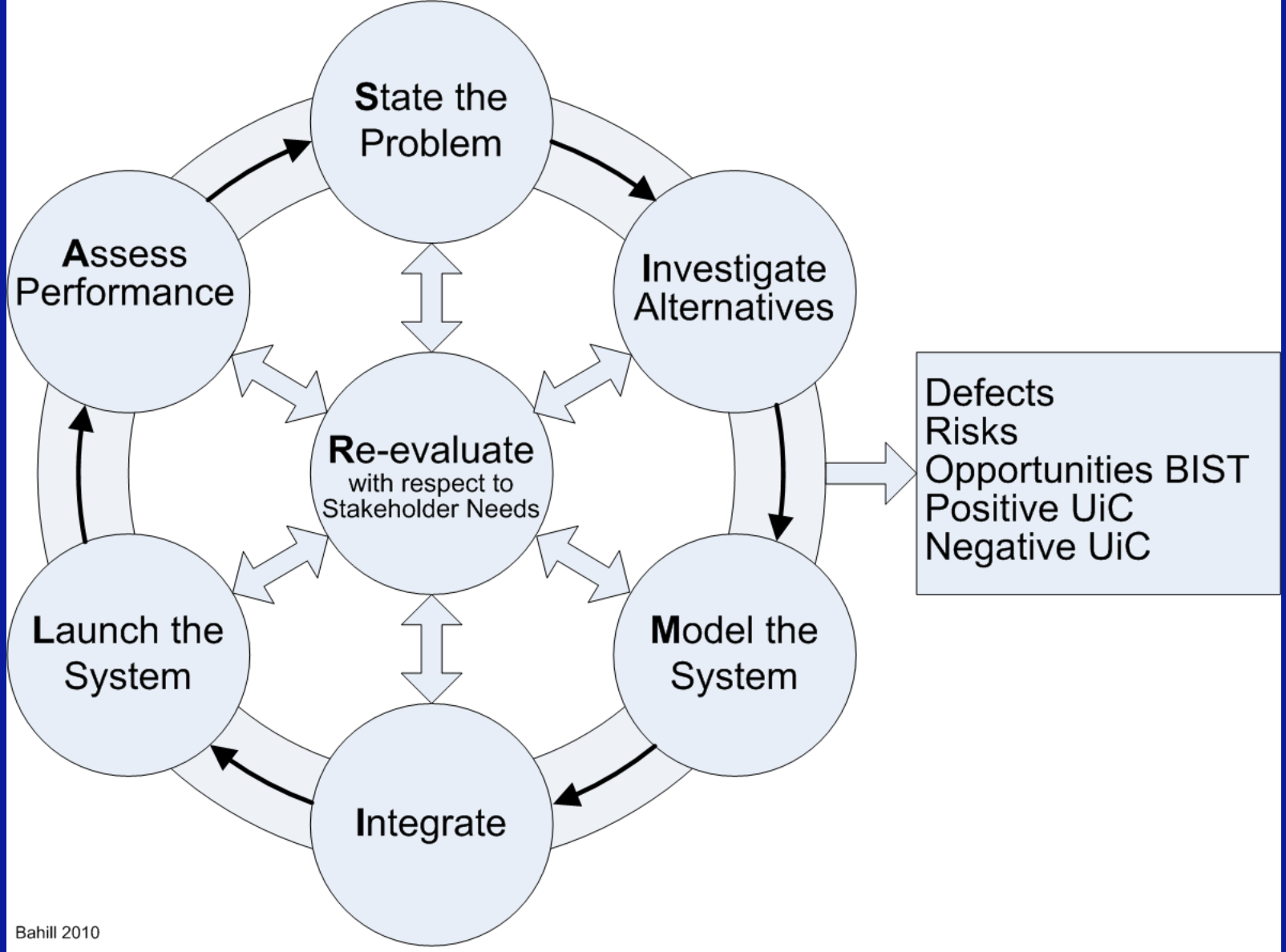
Diogenes

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

- Diogenes was a Cynic and disdained conventional wisdom and political correctness.
- 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.



Diogenes, a search for unintended consequences (UiC) process

Work products of Diogenes

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

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

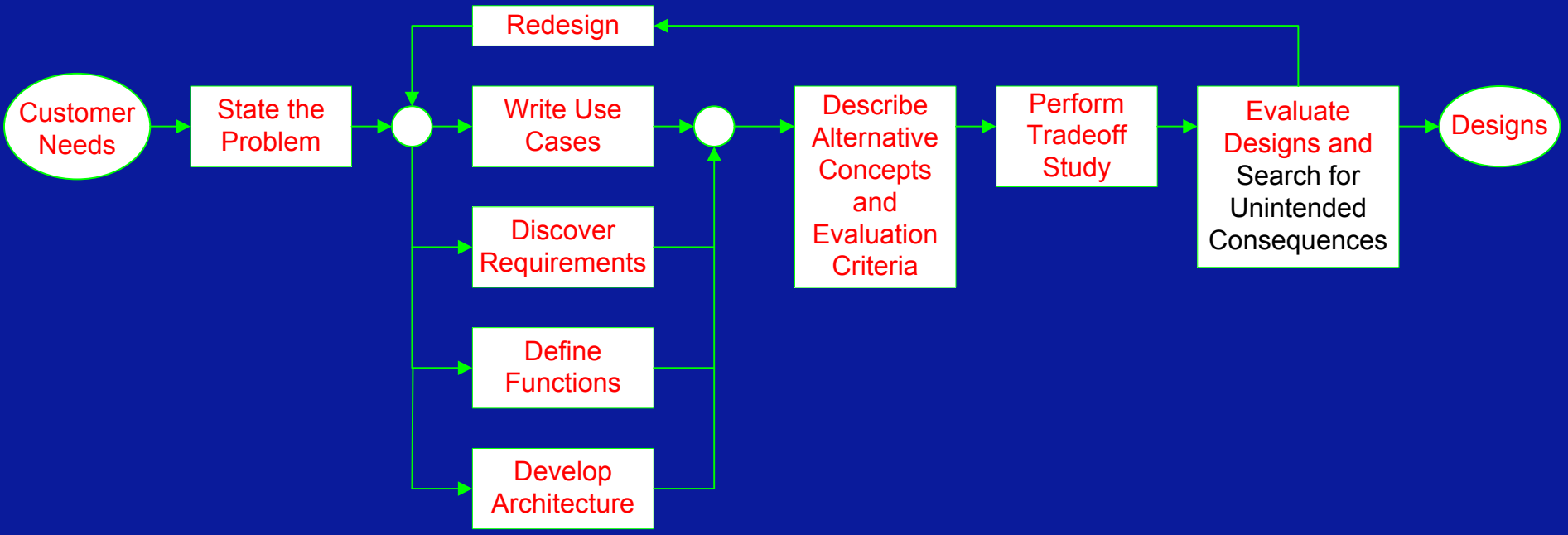
(2) risks that could adversely affect SystemZ,

(3) opportunities for BiST,

(4) positive UiCs that could beneficially affect other systems

(5) negative UiCs that could adversely affect other systems.

The System Design Process



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.

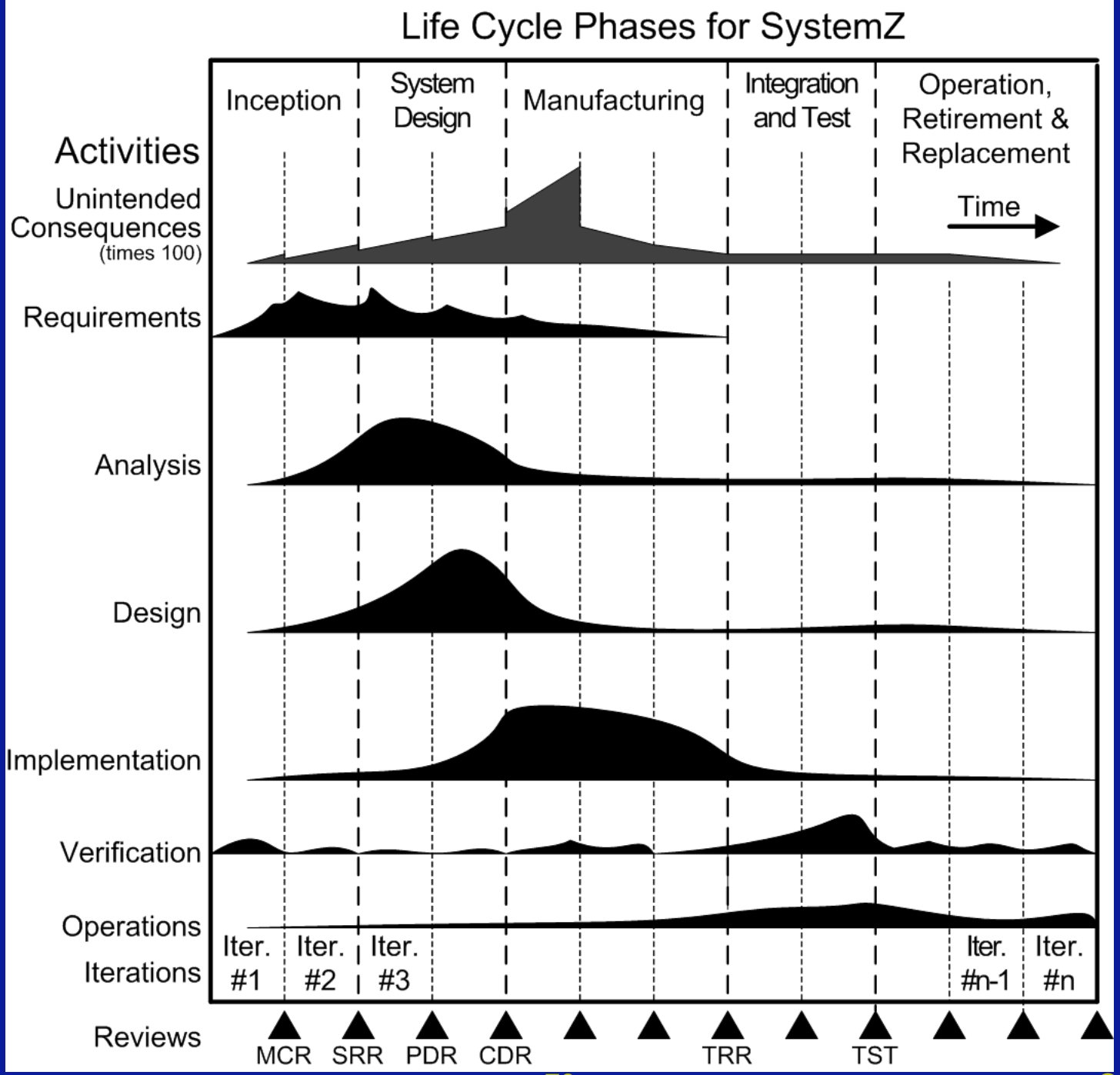
When should Diogenes be used?$_1$

Near the end of each phase of SystemZ's life cycle.

Before each design review

Particularly after CDR

- The designer has already performed the tradeoff studies, risk analysis, sensitivity analysis and comprehensive testing plan.
- Using these studies as input, he can now broaden his scope and start looking outside of the specific problem domain.


Life Cycle Phases for SystemZ
Inception
System Design
Manufacturing
Integration and Test
Operation, Retirement & Replacement
Activities
Unintended Consequences (times 100)
Time
Requirements
Analysis
Design
Implementation
Verification
Operations
Iterations
Iter. #1
Iter. #2
Iter. #3
Iter. #n-1
Iter. #n
Reviews
MCR
SRR
PDR
CDR
TRR
TST

When should Diogenes be used?$_2$

If you cannot afford to run Diogenes in each iteration, then raise the baseline to eliminate the iterations you cannot afford.

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

The use case model

Perform Formal Inspection use case$_1$

Name: Perform Formal Inspection

Iteration: 2.3

Derived from: Alternative Concepts

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.

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.

Perform Formal Inspection$_2$

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.

Perform Formal Inspection$_3$

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

How can we prime our inspectors to look for UiC?$_1$

If they 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?”

How can we prime our inspectors to look for UiC?$_2$

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?"

Perform Formal Inspection$_4$

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.

Perform Formal Inspection$_5$

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 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.

Perform Formal Inspection$_6$

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

Anchored Alternate Flow:

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.

Perform Formal Inspection$_7$

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.

Perform Formal Inspection$_8$

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: November 27, 2010

Verification and Validation of Diogenes

Apply Diogenes to BIMS

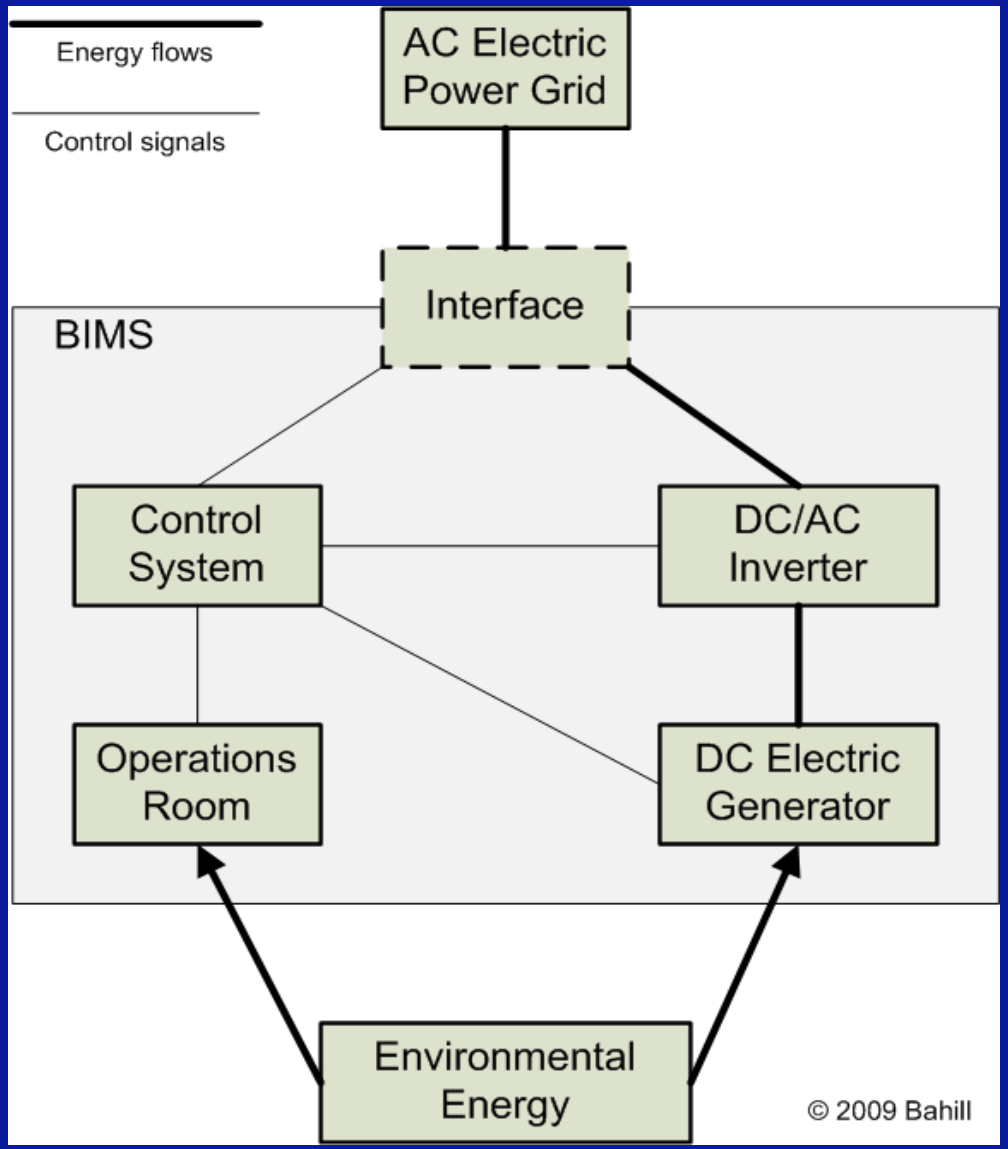
To validate Diogenes we will apply it to an existing, well-documented, system design and see if it discovers the defects, risks, opportunities for BiST, positive and negative UiCs of SystemZ. .

Let us apply it to the Bahill Illuminance Management System [Bahill, 2010].

We will call this SystemZ.

Later we will validate Diogenes by applying it to the Spin Coach.

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$_{1b}$

(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.

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 is more expensive. Electricity is more expensive. Backup electric generators will be necessary. Labor is more expensive! risk, Geographical location causes higher costs.

Control Illuminance During the Day use case$_1$

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! nUiCs, Money is needed for decommissioning.

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.

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.

Functional requirements

Req1-10 BIMS shall generate electricity at a cost competitive with commercial electricity costs at that location, after Federal 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.

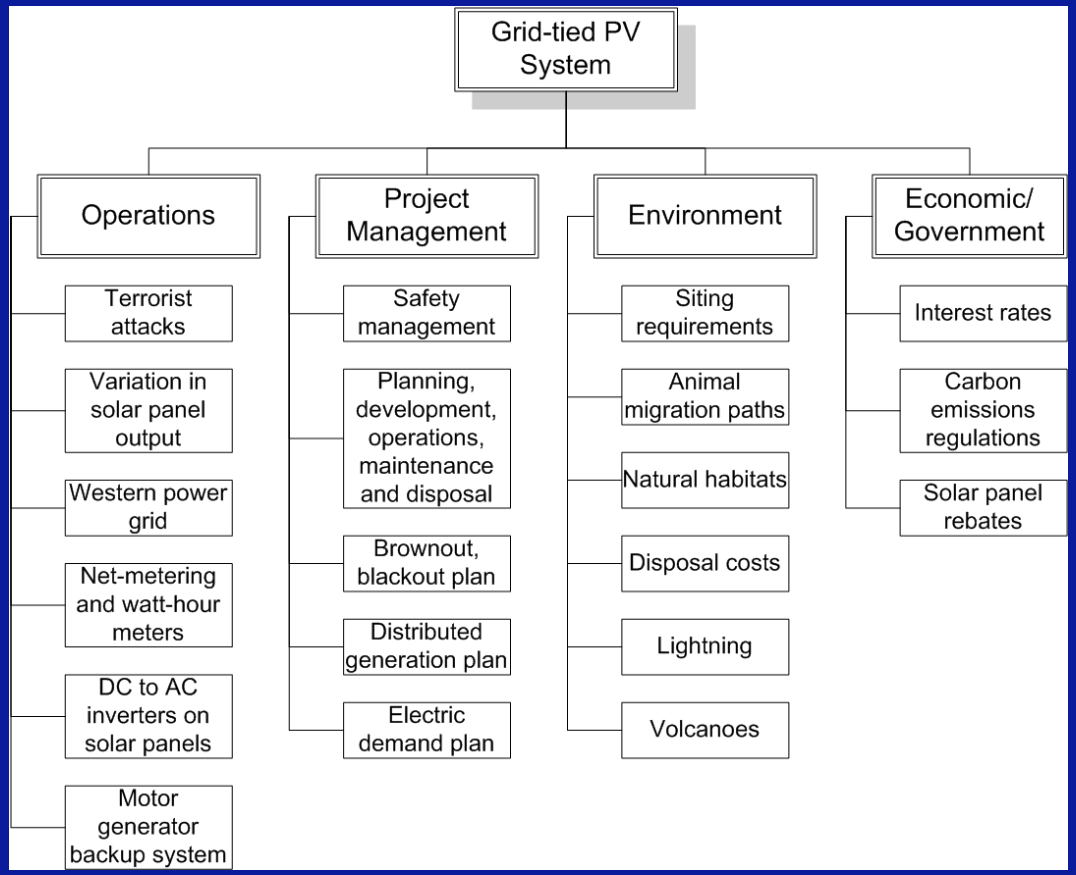
Photovoltaic solar panels

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?

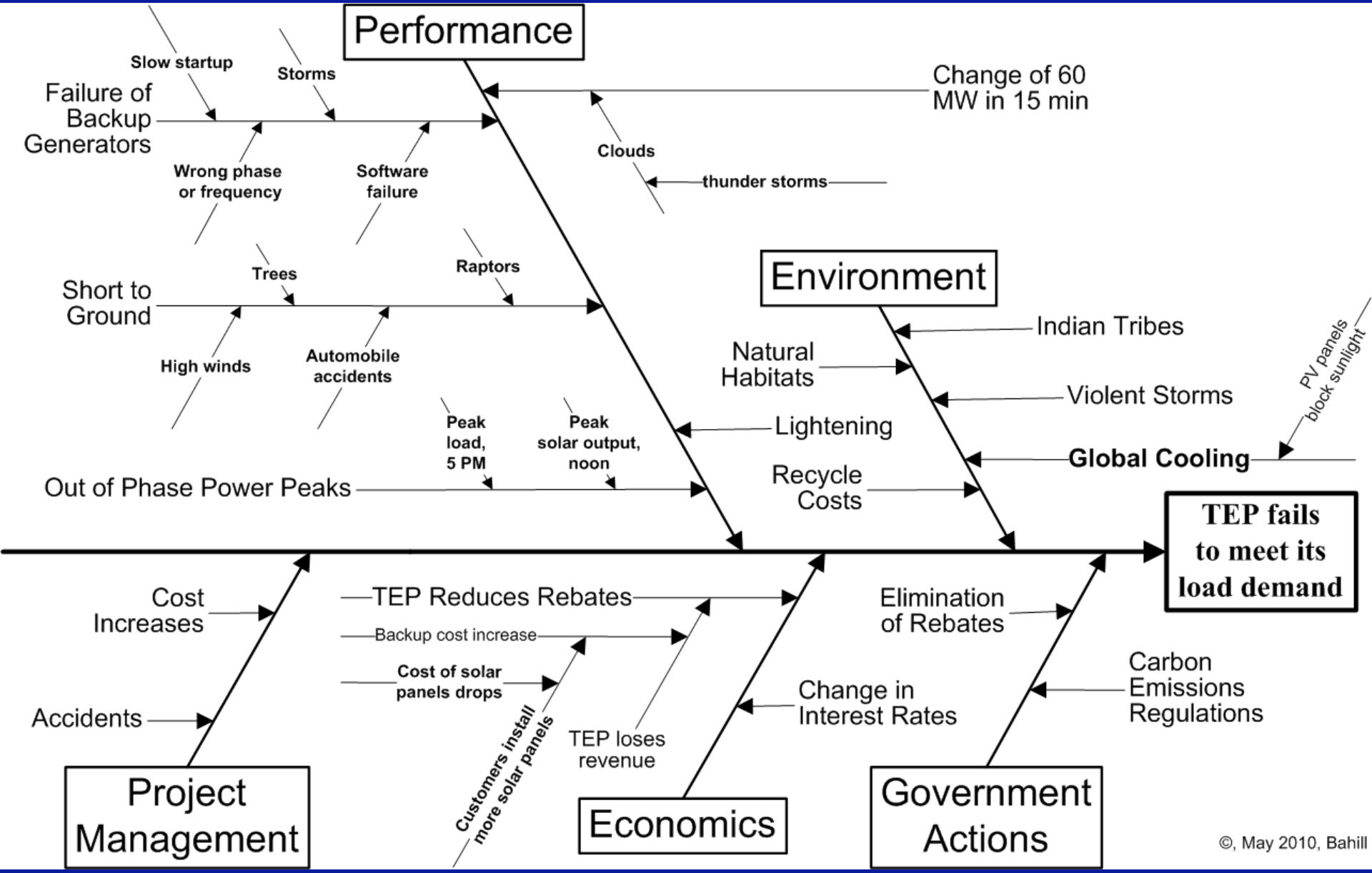
For example, what would be the effects of incorporating photovoltaic solar panels into an existing commercial electric power grid?

HHM



Any one of these blocks could fail constituting a risk to BIMS. The TEP experts have provided numerical data for failure of the DC to AC inverters on solar panels. This risk has been included in the risk analysis of this system [Chaves and Bahill, 2011].

Ishikawa fishbone diagram



Photovoltaic solar panels, price decrease$_1$

What if new technology dramatically drove down the cost of solar panels?

This would increase the number of customers who install solar panels.

TEP 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 TEP and on sunny days, TEP would be required to buy the surplus electricity produced by these customers.

Process: fishbone diagram

Photovoltaic solar panels, price decrease$_2$

This would affect TEP's bottom line: they would lose revenue.

Two things could then happen

- TEP could lose money from decreased revenues and increased net-metering costs or
- TEP 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! nUiCs, Destabilizing the solar panel economy.

Photovoltaic solar panels, clouds block sun

Let us speculate that sporadically TEP cannot meet customer demands.

An explanatory theory could be that variations in sunlight intensity could be changing the amount of electricity that was being delivered by photovoltaic solar panels.

We could collect sun intensity data for a typical 24 hour day and also for yearly variations.

These could be compared to TEP's typical load demands.

These data could confirm that variations in sun intensity would make electric power regulation difficult.

The root cause of the difficulty would be clouds covering the sun! risk, Sudden drop in generated electricity.

Process: Juran's cause and effect analysis

Solar panels block sunlight

Photovoltaic solar panels

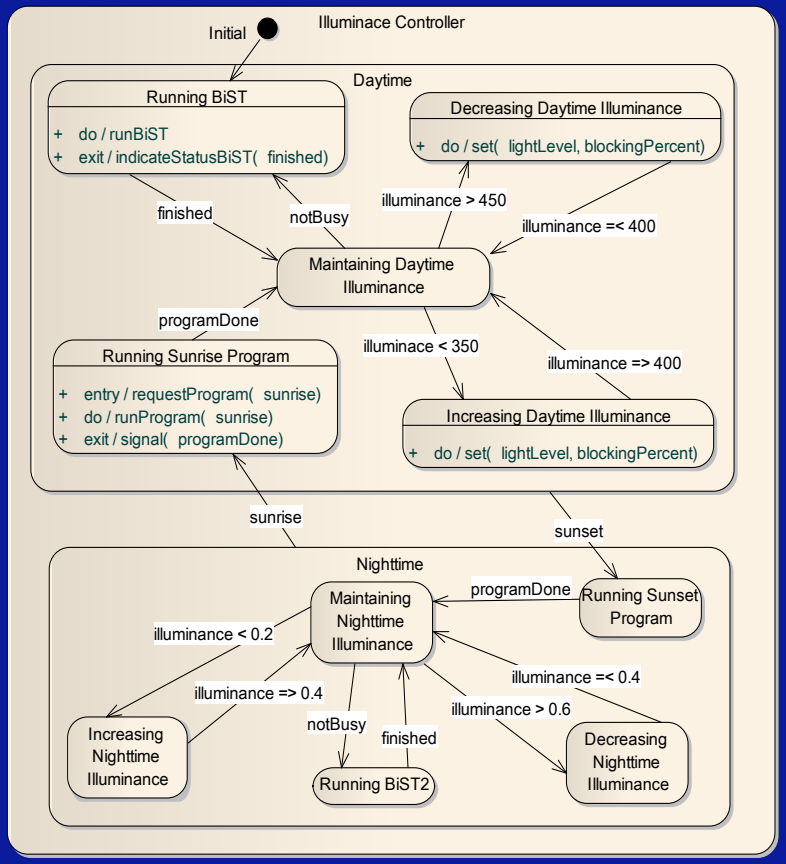
- transform sunlight into electricity
- reflect sunlight back into the atmosphere

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*.

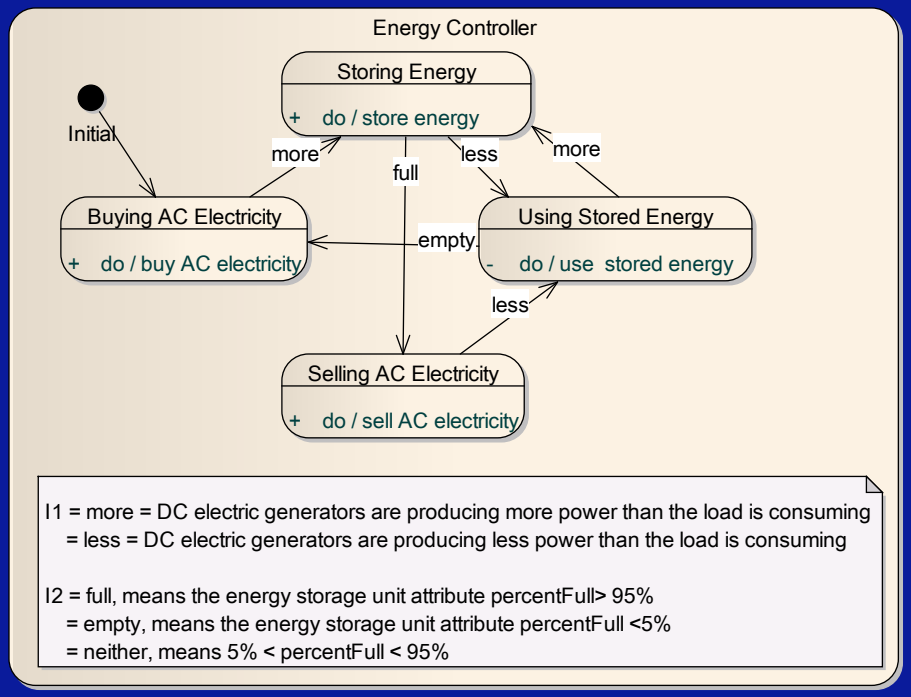
Process: what-if analysis

Control illuminance state machine diagram



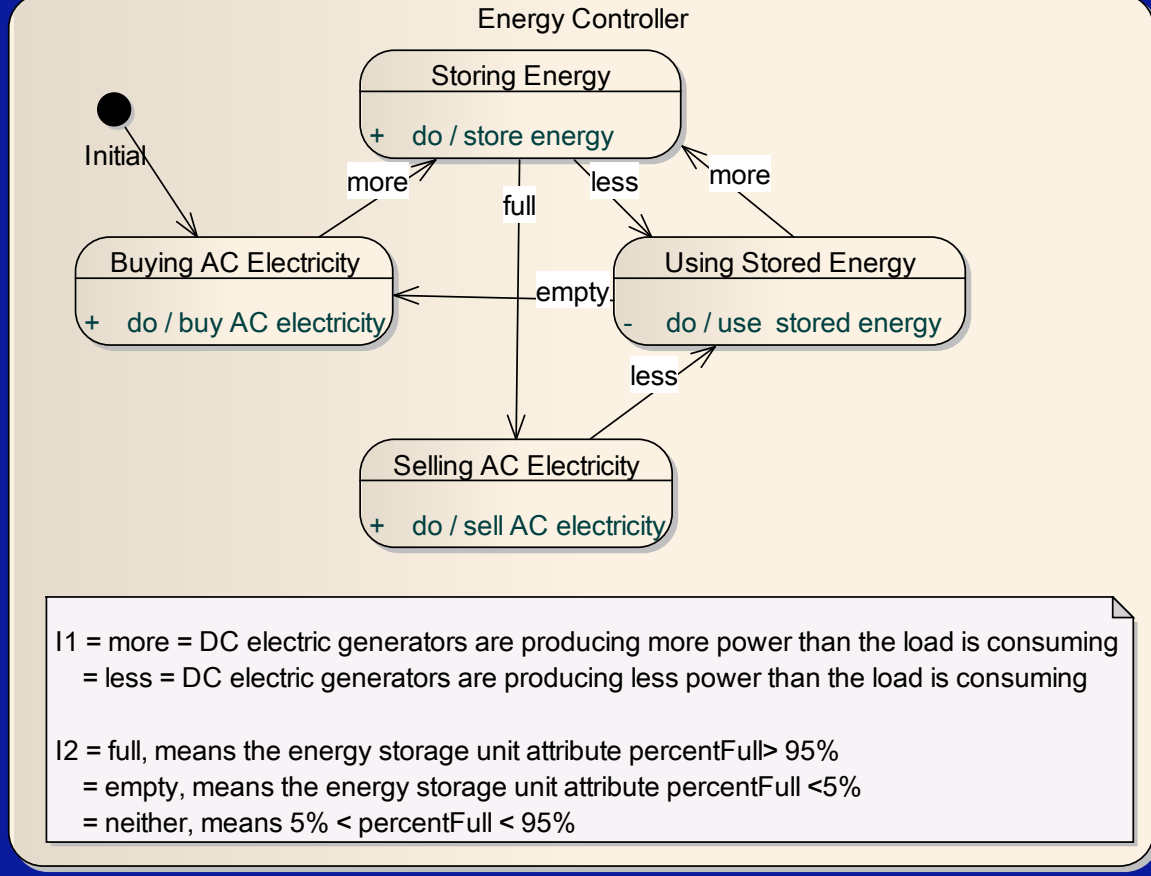
The effects of high altitude on human physiology are well known and they have been managed effectively for decades on Mauna Kea. However, humans are not used to living in a precisely controlled illuminance environment . Studies of the Polaris ballistic missile fleet sailors should be reviewed to see if a regulated environment would cause undesirable entrainment of human circadian rhythms! risk, Controlled illuminance harms humans.

Sell electricity state machine diagram



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 problem, because the logic can be designed to prevent transitions to unwanted states. The topic is called hazards and races. uic r

BIMS



This problem can be modeled with Boolean equations

Buy = less And empty

Sell = Not less And full

Use = less And Not empty

Store = Not less And Not full

Therefore this is not a dynamic problem, so it does not need a dynamic (state machine) solution. Replacing it with Boolean equations would also remove hazards and races. design defect

Interactions may cause problems

BIMS will be affected by changes in government regulations, such as carbon emissions policies.

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 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. negative UiC

Interfaces may cause problems$_1$

Presume that BIMS is in the state of Selling AC Electricity when clouds suddenly cover the sun

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.

Interfaces may cause problems$_2$

Furthermore, BIMS will soon deplete its small local energy store and will switch to the Buying AC Electricity state.

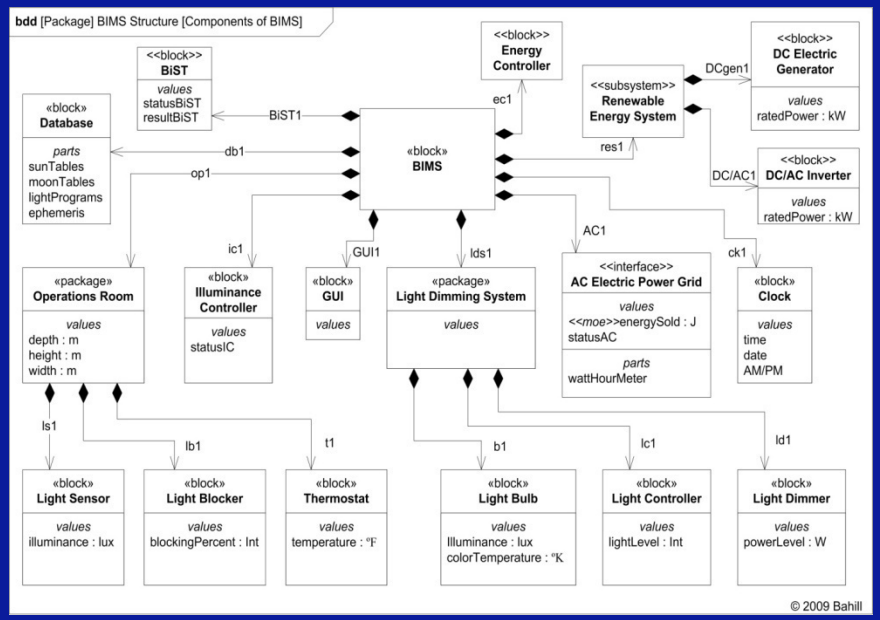
This will increase the operating voltage.

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 simulation of these systems to investigate potential instabilities. uic

Components may interfere with telescopes

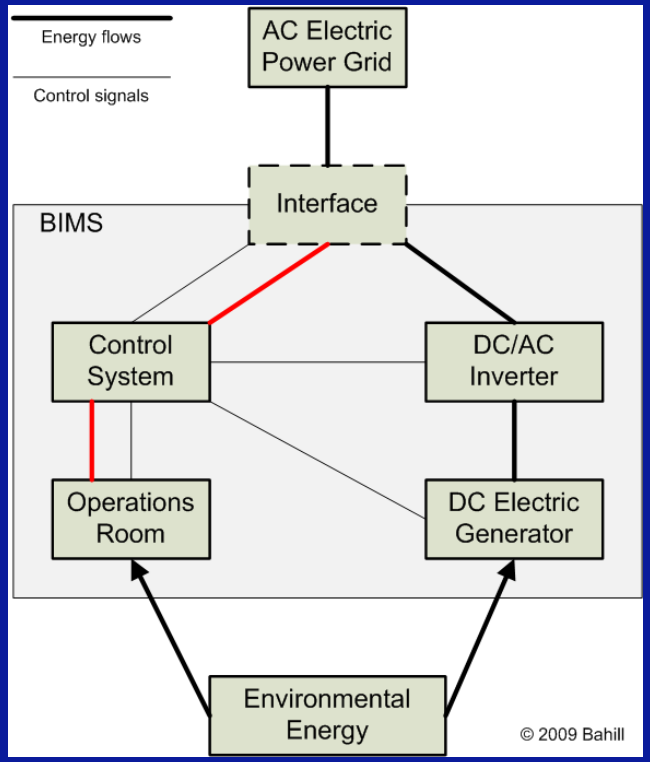


Studying this block diagram suggests that components could emit electromagnetic radiation at nonvisible wavelengths that could interfere with particular telescopes.

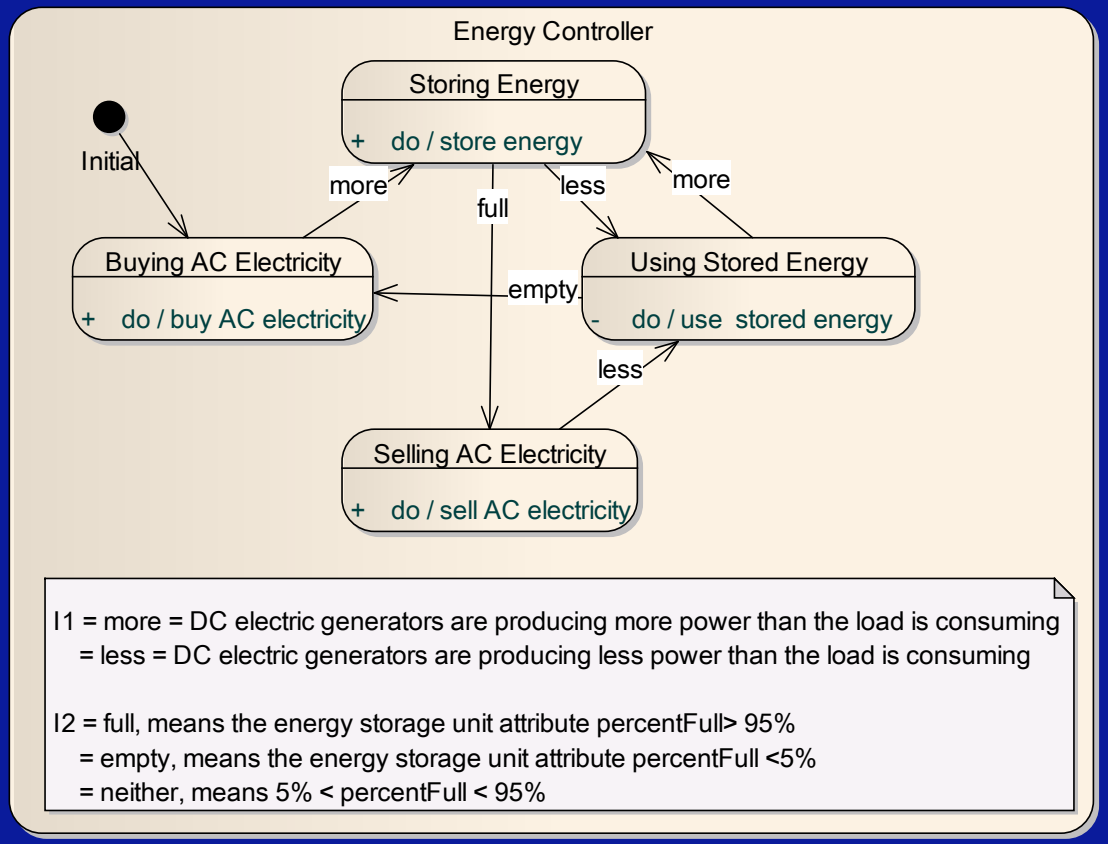
To ameliorate this problem, the spectrum of each telescope must be determined and the noise emissions of each component will have to be computed and measured in each of these bandwidths. uic

List of defects

- This application of Diogenes to BIMS revealed two defects
  - a lack of energy flows in the block diagram of the scope of BIMS (figure 4-2)
  - a 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 $BIMS_1$

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

Diogenes discovered these 11 risks for BIMS.

The original BIMS risk analysis had 14 risks.

Prioritized list of potential risks to $BIMS_2$

- This study missed
  - a similar system has already been patented
  - the commercial AC electric power grid may fail for hours at a time
  - software failures
  - But, BIMS only had one use case.
- This study disclosed two risks that the original study did not have:
  - controlled illuminance might harm humans
  - hazards and races

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 trigger an alarm.

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

Global cooling

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

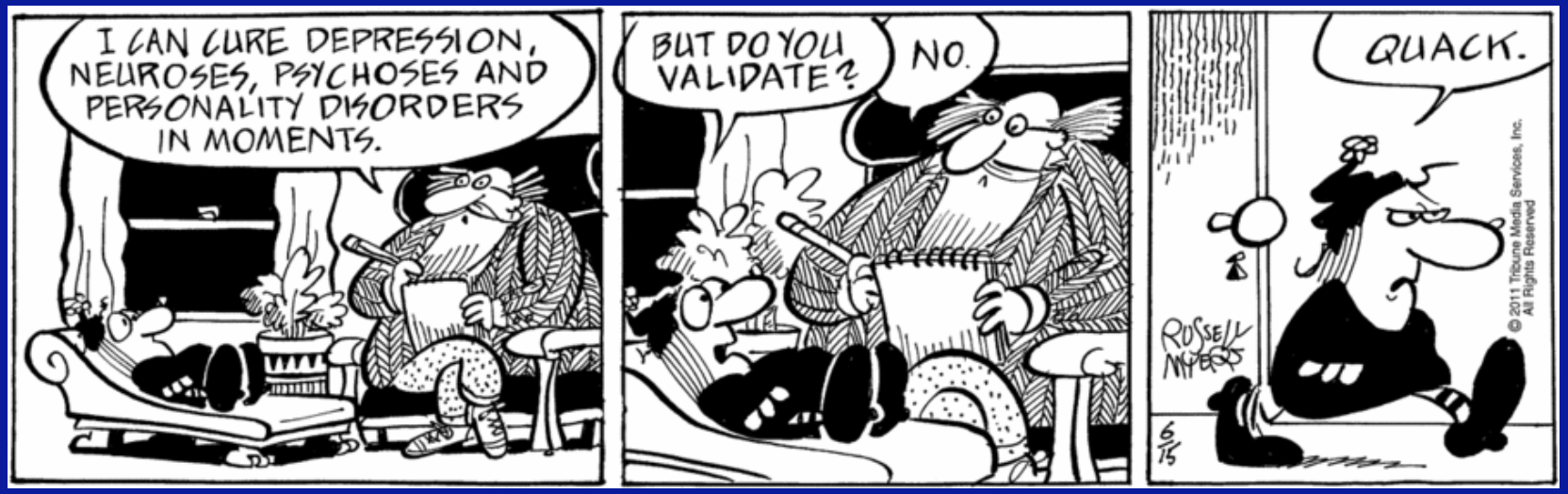
Diogenes discovered these seven negative UiCs of BIMS.

The original BIMS documentation had only one, offending Poliahu, which was treated as a risk.

The next step

The next step in validating Diogenes will be applying it to the Spin Coach.

http://www.sie.arizona.edu/sysengr/sie554/SpinCoach/index.html



This is the end of verification and validation of Diogenes.
We will now show another subsystem of Diogenes.

Re-evaluate$_1$

When designing a process, it is important to include a process to improve the process (PtItP).

Bahill creates a preliminary process.

He distributes it to the Brain Trust and certain INCOSE fellows.

They provide e-mail comments and verbal discussion for a few months.

Bahill then revises the process and applies it to a newly designed system.

The feedback process is used again.

Re-evaluate$_2$

Then this process is given to seniors and graduate students in the *Systems Engineering Process* class.

Their usage of the process and related documents are studied. Eventually the process will be written up in a paper and submitted for review and possible presentation at the INCOSE symposium.

If it is received favorably, then it will be submitted to the journal *Systems Engineering*.

There it will be subjected to rigorous review by a half dozen subject matter experts.

If accepted it will be published in the journal.

Companies will adopt it and put it in their PAL. uic

Risk analysis of Diogenes

Risk Analysis for Diogenes

Failure Event	Consequences	Relative likelihood (events per year)	Severity of consequences	Estimated Risk
Diogenes fails system validation	No one would use Diogenes.	0.6	300	180
Diogenes and the Recorder cannot keep up with the Inspection Team comments in real time	Time of important people would be wasted and chaos would ensue.	0.5	40	20
No Brain Trust member wants to travel and teach companies how to use Diogenes	BICS would have to hire less qualified systems engineers.	0.1	100	10
Software mistakes	Software mistakes are ubiquitous, but hard to diagnose.	10	1	10
Terrorists or industrial spies steal systemZ's designs.	Systems that put SystemZ's designs on the Internet will not be viable.	0.2	50	10
Loss of Dropn data in the PAL	PAL must be restored from backups	0.1	5	0.5
A lawyer or a Wall Street banker thinks that Diogenes has exposed him, so he sues BICS.	BICS is presently a sole proprietorship, we will have to incorporate and buy liability insurance.	0.1	2	0.2
Management refuses to do anything about negative UiCs.	This would put the systems engineer in an ethical dilemma.	0.4	3	0.12
A politician thinks that Diogenes might cost him an election.	Congress taxes profits from Diogenes at 90%.	0.03	2	0.06
A similar system has already been patented	It will cost at least $10,000, but we should apply for a patent.	0.03	1	0.03

Equal ranges

The range of magnitudes for relative likelihood and severity of consequences *must* be the same.

In this table, the relative likelihood covers two and a half orders of magnitude and the severity of consequences also covers two and a half orders of magnitude .

Take home message

It is your responsibility to discover UiCs of your systems.

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.

Dog biscuits

seen – ate = left
seen – (seen/2 +1) = left
seen = 2*left + 2

Dog k	Seen	Ate	Left
4	2	2	0
3	6	4	2
2	14	8	6
1	30	16	14
		Total = 30	

Assignment

Propose some UiCs of installing renewable-energy electric-generators and a total light-management system in the operations rooms of telescope enclosures on Mauna Kea in Hawaii.

Sales success$_1$

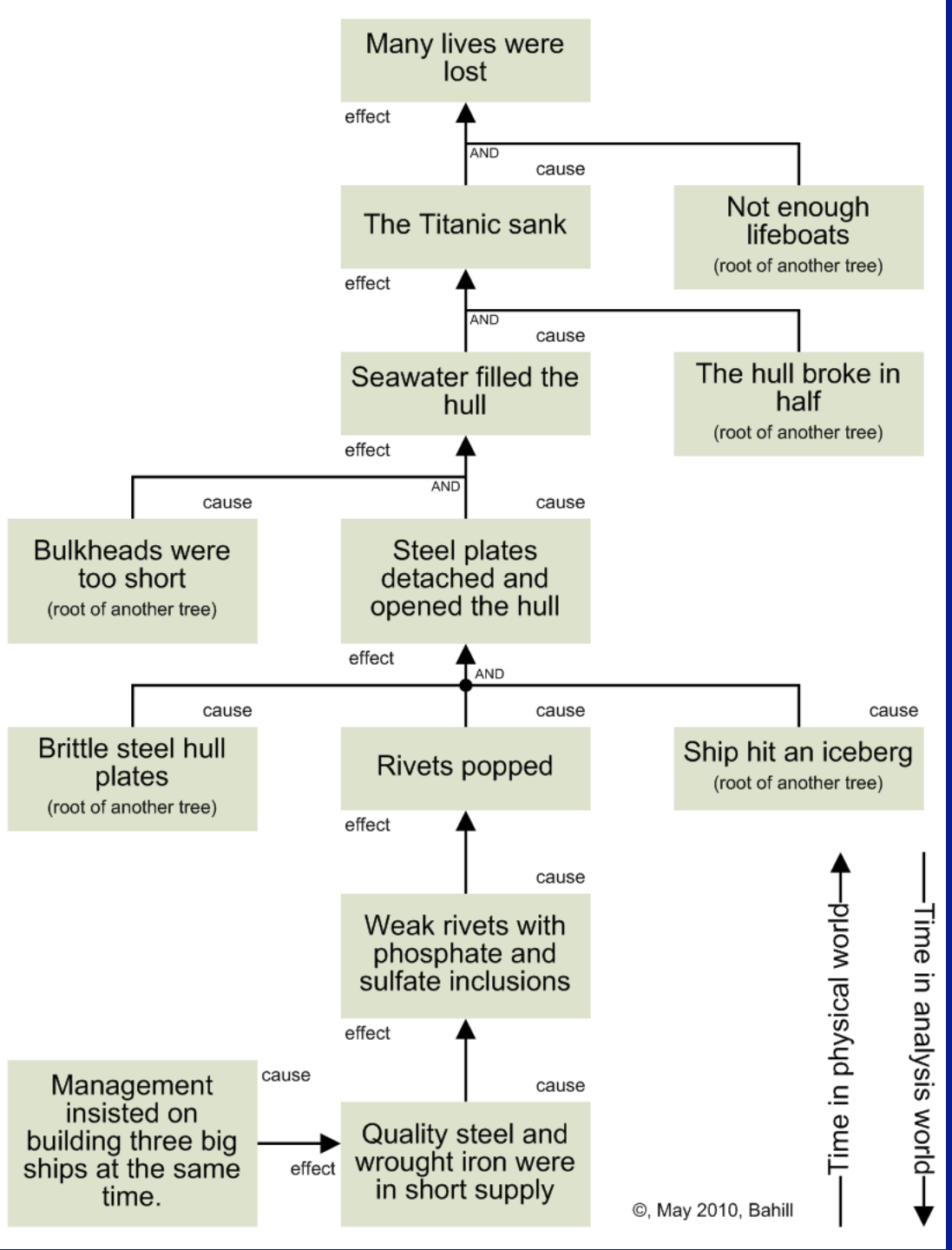
- A sales person can increase success by
  - making eye contact
  - smiling
  - asking questions
  - stating similarities, such as “You live in a nice neighborhood. We tried to buy a house in this neighborhood.”

Sales success$_2$

- A sales person can increase success by mirroring the customers'
  - gestures
  - mannerisms
  - expressions
  - body movements
- When walking, walk in step with your customer.
- Mimicking others can enhance their rapport with you.

Custom colors

- background: H= 172 S=244 L=70, 0% transparency
- text: G=255
- title: H=35, S=255, L=130
- standard yellow, R=255, G=255, B=0
- footer: H=42, S=255, L=100


Many lives were lost
effect
AND
cause
The Titanic sank
Not enough lifeboats
(root of another tree)
effect
AND
cause
Seawater filled the hull
The hull broke in half
(root of another tree)
effect
AND
cause
cause
Bulkheads were too short
(root of another tree)
Steel plates detached and opened the hull
effect
AND
cause
cause
cause
Brittle steel hull plates
(root of another tree)
Rivets popped
Ship hit an iceberg
(root of another tree)
effect
cause
Weak rivets with phosphate and sulfate inclusions
effect
cause
cause
Management insisted on building three big ships at the same time.
effect
Quality steel and wrought iron were in short supply
Time in physical world
Time in analysis world
©, May 2010, Bahill

Materials needed

- Wall switch
- string

