A Systems Engineering Vision:

Quantifying Future Adaptability and Maintainability, as the basis for Architecture Decisions - something we have not been good enough at engineering into systems.

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Abstract.

- Software system maintenance costs are a substantial part of the life cycle costs.
- They can easily steal all available effort away from new development.

System Lifetime Expectancy: Capers Jones: Think 18-25 Years

Table 30: Estimated Life Expectancy of Applications before Retirement or Replacement

(Note: Data is expressed in terms of calendar years from first deployment until last retirement. Length of service is proportional to size.)

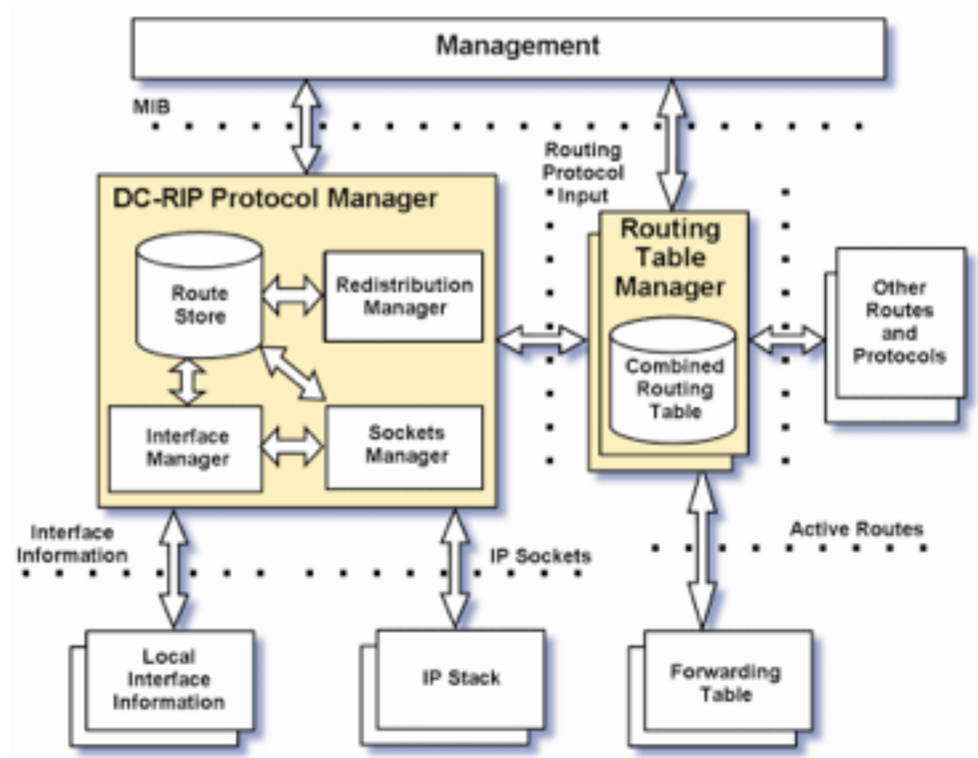
Size in FP	MIS Projects	Web Projects	Domestic Outsource Projects	Systems & Embedded Projects	Commercial Projects	Civilian Government Projects	Military Projects	Average
1	1.40	1.00	1.50	3.00	2.00	2.00	3.00	1.99
10	2.50	2.00	3.00	4.00	3.00	4.00	4.00	3.21
100	4.00	3.00	4.50	4.50	4.00	5.50	5.00	4.36
1,000	5.00	4.00	5.00	6.00	5.00	8.00	9.00	6.00
10,000	18.00	9.00	14.00	13.00	9.00	22.00	23.00	15.43
100,000	20.00	10.00	17.00	15.00	14.00	24.00	24.00	17.71
1,000,000	25.00	12.00	27.00	18.00	20.00	28.00	26.00	22.29
Average	10.84	5.86	10.29	9.07	8.14	13.36	13.43	10.14

Table 5: Major Kinds of Work Performed Under the Generi Term "Maintenance" Capers Jones 2014

1. Major Enhancements (new features of > 20 function points)
2. Minor Enhancements (new features of < 5 function points)
3. Maintenance (repairing defects for good will)
4. Warranty repairs (repairing defects under formal contract)
5. Customer support (responding to client phone calls or problem reports)
6. Error-prone module removal (eliminating very troublesome code segments)
7. Mandatory changes (required or statutory changes)
8. Complexity or structural analysis (charting control flow plus complexity metrics)
9. Code restructuring (reducing cyclomatic and essential complexity)
10. Optimization (increasing performance or throughput)
11. Migration (moving software from one platform to another)
12. Conversion (Changing the interface or file structure)
13. Reverse engineering (extracting latent design information from code)
14. Reengineering (transforming legacy application to modern forms)
15. Dead code removal (removing segments no longer utilized)
16. Dormant application elimination (archiving unused software)
17. Nationalization (modifying software for international use)
18. Mass updates such as Euro or Year 2000 Repairs
19. Refactoring, or reprogramming applications to improve clarity
20. Retirement (withdrawing an application from active service)
21. Field service (sending maintenance members to client locations)
22. Reporting bugs or defects to software vendors
23. Installing updates received from software vendors

Abstract

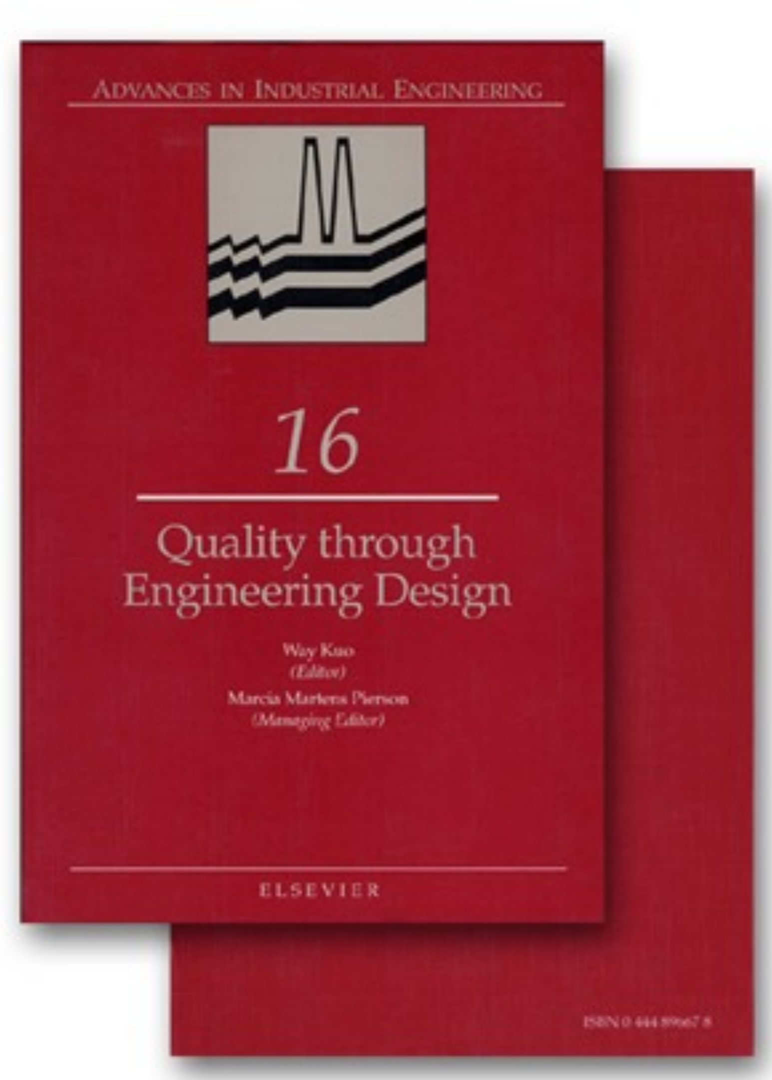
- I believe that this is because
  - **maintainability is, as good as never, systematically engineered into the software.**
- Our so-called software architects bear a primary responsibility for this, but they do not engineer to targets.
- They just throw in customs and habits that seem appropriate.



Did you ever see ideas like performance and quality, for example 'Portability Levels' in a software architecture diagram?

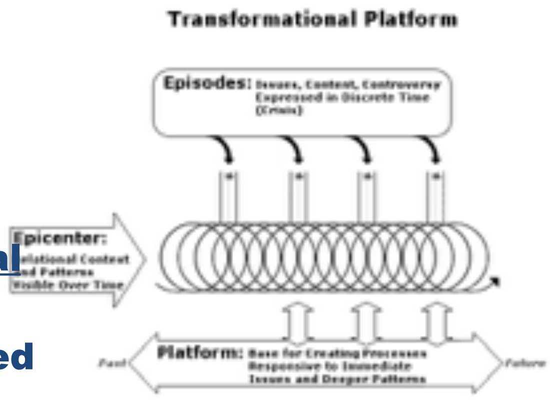
My Main Assertion to Management

- **We need to**
  - **define our maintainability requirements quantitatively,**
  - **Set quality investment targets that will pay off,**
  - **pursue long-term engineered improvement of the systems, and then**
  - **‘architect’ and ‘engineer’ the resulting system.**
- **Traditional disciplines may already in principle understand this discipline,**
  - **some may not understand it,**
  - **some may simply not apply the engineering understanding that is out there**



The Maintainability Problem

- **Software systems are built**
  - **under high pressure to meet deadlines,**
  - **and with initial emphasis on performance, reliability, and usability.**
- **The software attributes relating to later changes in the software – maintainability attributes are:**
  - **never specified quantitatively up front in the software quality requirements**
  - **never architected to meet the non-specified maintainability quality requirements**
  - **never built to the unspecified architecture to meet the unspecified requirements**
  - **never tested before software release**
  - **never measured during the lifetime of the system.**



"A number of people expressed the opinion that code is often not designed for change. Thus, while the code meets its operational specification,

for maintenance purposes it is poorly designed and documented " [Dart 93]

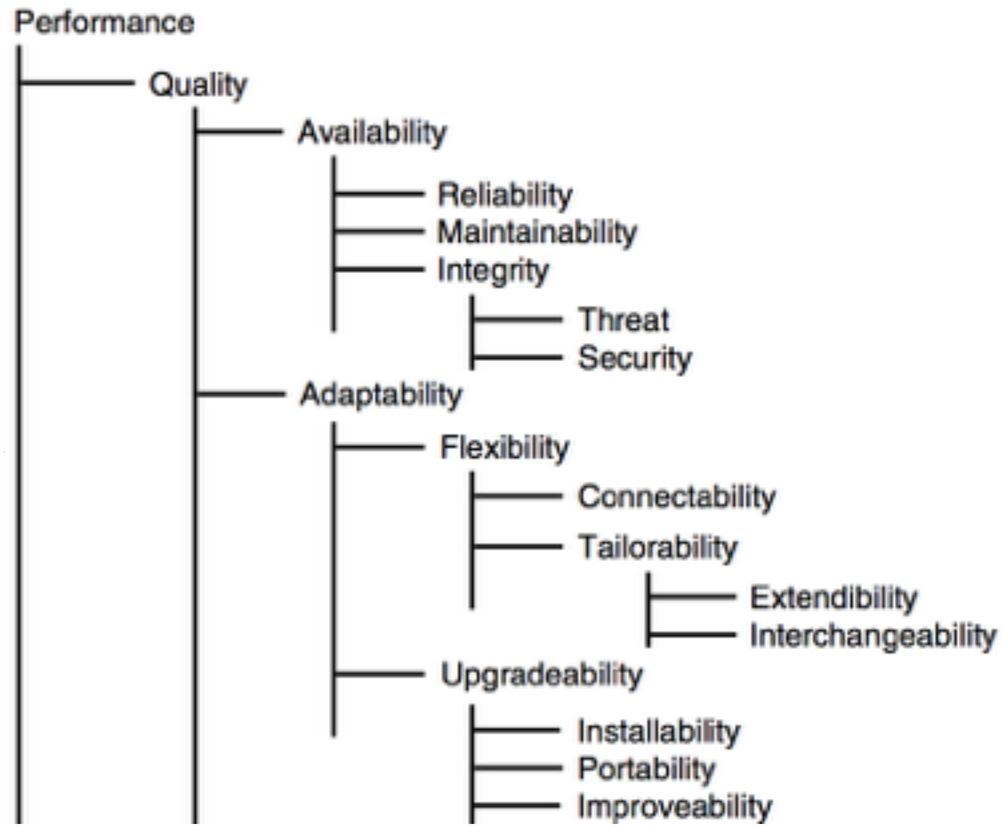
- **In short,**
  - **there is no engineering approach to software maintainability.**

What *do* we do in practice today?

- we might bullet point some high-level objectives
  - ('• Easy to maintain')
  - which are never taken seriously
- we might even decide the technology we will use to reach the vague ideal
  - ("• Easy to maintain through modularization, object orientation and state of the art standard tools")
- larger institutions might have 'software architects' who carry out certain customs, such as
  - decomposition of the software,
  - choice of software platforms and software tools – generally intended to help – hopefully.
  - But with no specific resulting level or type of maintainability in mind.
- we might recommend more and better tools, but totally fail to suggest an engineering approach [Dart 93].
- We could call this a 'craft' approach.
- It is not 'engineering' or 'architecture' in the normal sense.

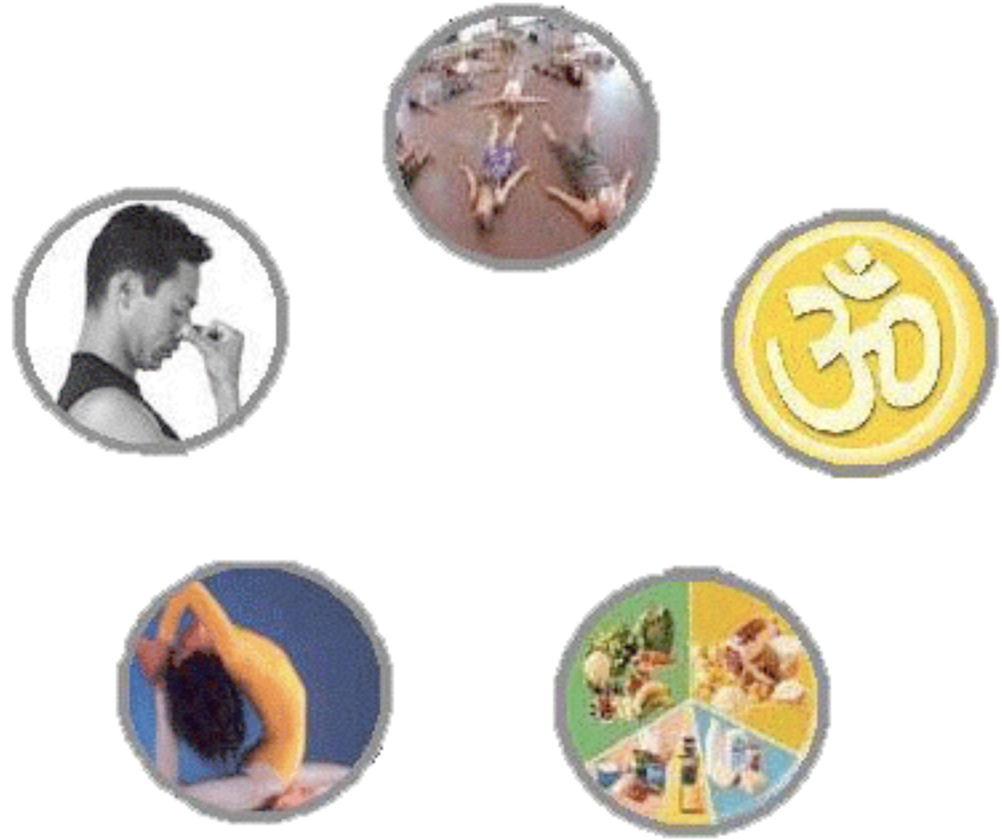
Broader Maintainability Concepts

- Maintainability in the strict engineering sense is usually taken to mean **bug fixing.**
- I have however been using it *thus far* to describe ***any software change activity or process***.
- We could perhaps better call it **'software change ability'.**
- Different classes of change, will have different requirements related to them
  - and consequently **different technical solutions**.
- It is important that we be very clear
  - in setting requirements,
  - and doing corresponding design,
  - exactly what **types of change** we are talking about.
-



Principles of Software Maintainability

- I would like to suggest a set of principles about software maintainability,
  - in order to giv this talk a framework:



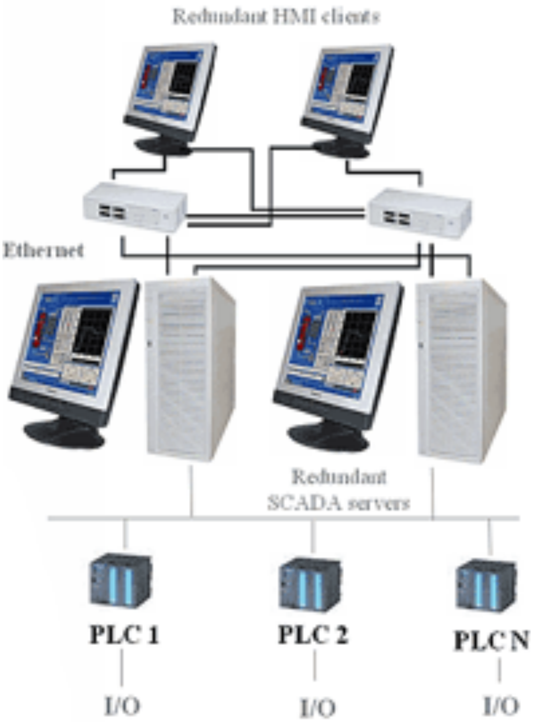
Body Maintenance: {Relax, Exercise, Breathing, Diet, Positive Thinking and Meditation}.

1. The Conscious Design Principle:

- Maintainability must be *consciously* designed into a system:
  - failure to **design** to a set of levels of maintainability
  - means the **resulting maintainability** is both *bad* and *random*.

Conscious Design

- Clarify
  - Robust →
    - 200 Days Between Restarts
- Find Solutions
  - Triple Redundant Systems ?
- Verify Solutions
  - 400 Days average achieved



2. The Many-Splendored Thing Principle.

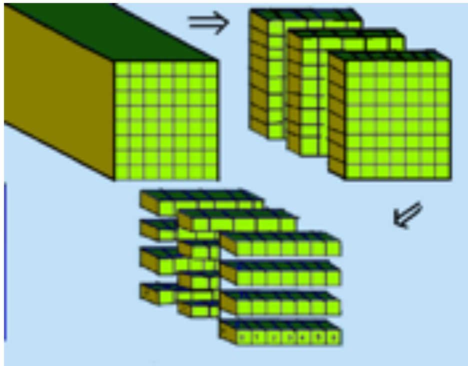
- Maintainability is
  - a **wide set** of change-quality types,
  - under a **wide** variety of **circumstances**:
  - so we must clearly define **what quality type** we are trying to engineer. Like:
    - Portability, scalability, maintainability?

Cazes-Valettes, 2001

http://www.youtube.com/watch?v=X-JiKA1vTRo = Nat King Cole "Love is…"

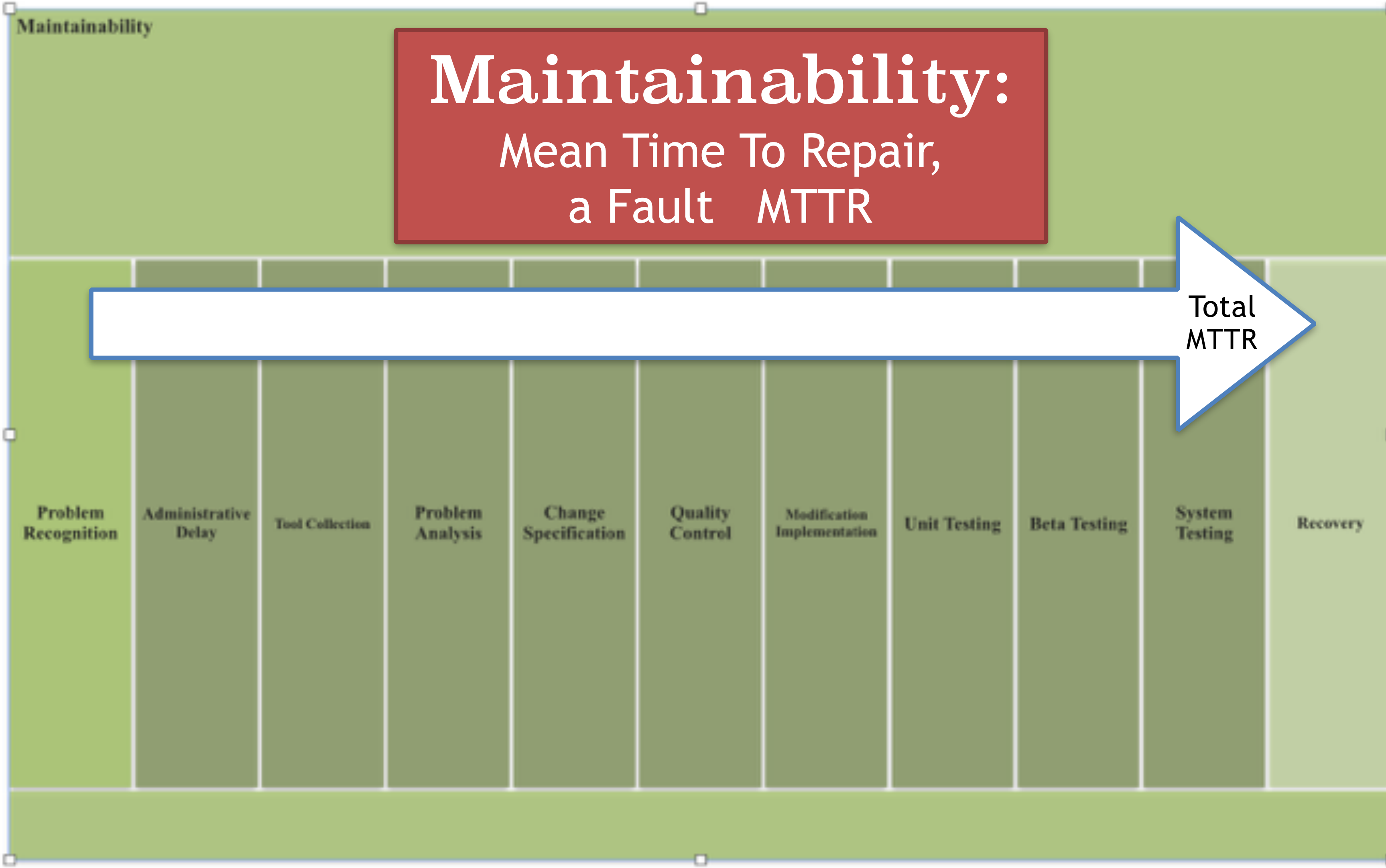
The 'Maintainability' Generic Breakdown into Sub-problems

1. **Problem Recognition Time.**
   How can we reduce the time from bug actually occurs until it is recognized and reported?
2. **Administrative Delay Time:**
   How can we reduce the time from bug reported, until someone begins action on it?
3. **Tool Collection Time.**
   How can we reduce the time delay to collect correct, complete and updated information to analyze the bug: source code, changes, database access, reports, similar reports, test cases, test outputs.
4. **Problem Analysis Time.**
   Etc. for all the following phases defined, and implied, in the Scale scope above.
5. **Correction Hypothesis Time**
6. **Quality Control Time**

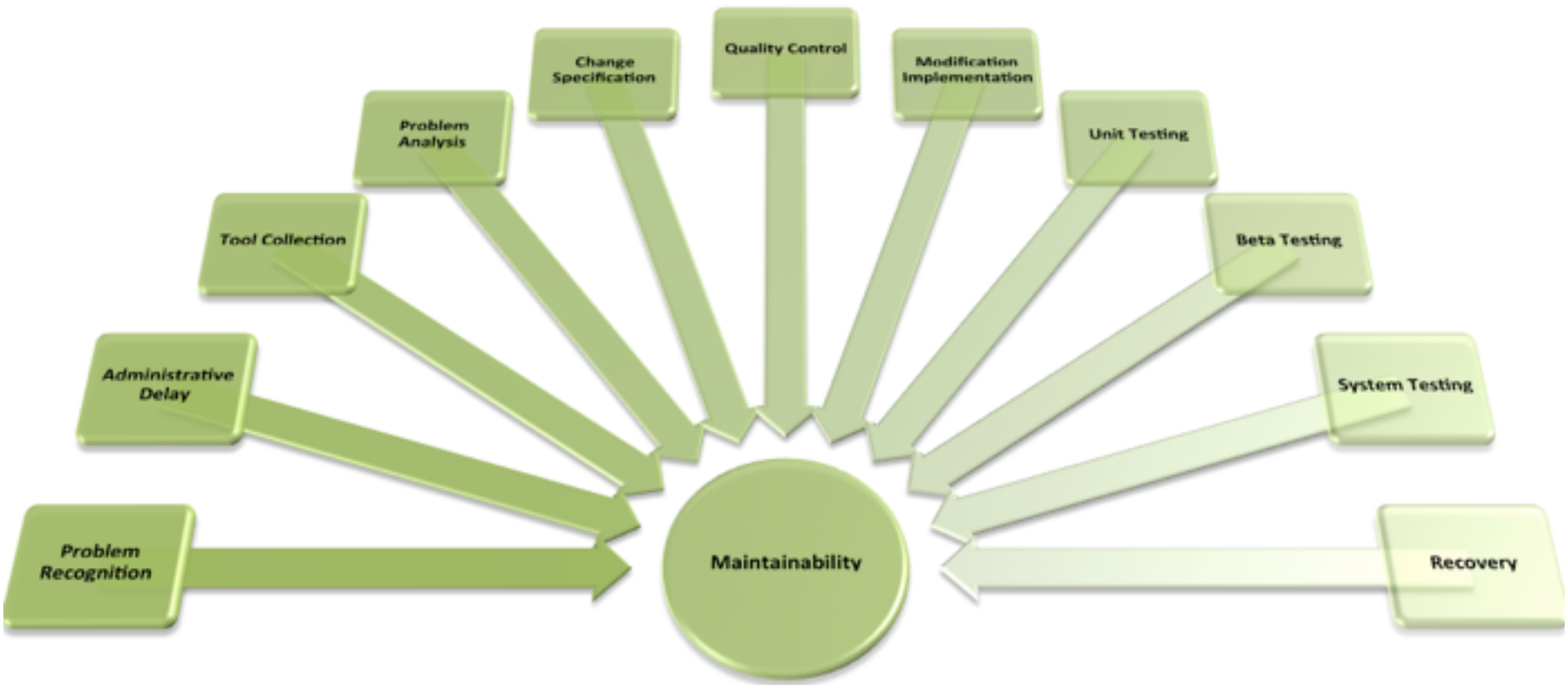


7. **Change Time**
8. **Local Test Time**
9. **Field Pilot Test Time**
10. **Change Distribution Time**
11. **Customer Installation Time**
12. **Customer Damage Analysis Time**
13. **Customer Level Recovery Time**
14. **Customer QC of Recovery Time**

11 Sub-Attributes of Fixing Faults



Aspects of Maintainability



A More Tailored Breakdown

Real Customer Case 2006

Rock Solid Robustness: *many splendored*

- **Type**: *Complex* Product Quality Requirement.
- **Includes:**
  - {*Software Downtime,*
  - *Restore Speed,*
  - *Testability,*
  - *Fault Prevention Capability,*
  - *Fault Isolation Capability,*
  - *Fault Analysis Capability,*
  - *Hardware Debugging Capability*}.

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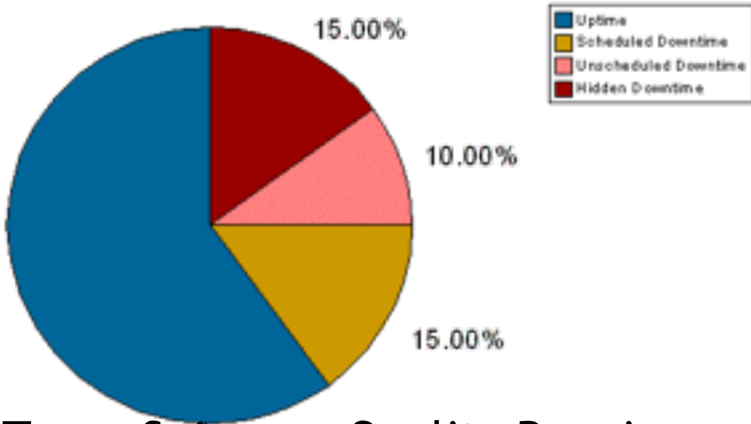


Software Downtime:

Type: Software Quality Requirement. **Version**: 25 October 2007.
Part of: Rock Solid Robustness.
Ambition: to have minimal downtime due to software failures <- HFA 6.1
Issue: does this not imply that there is a system wide downtime requirement?

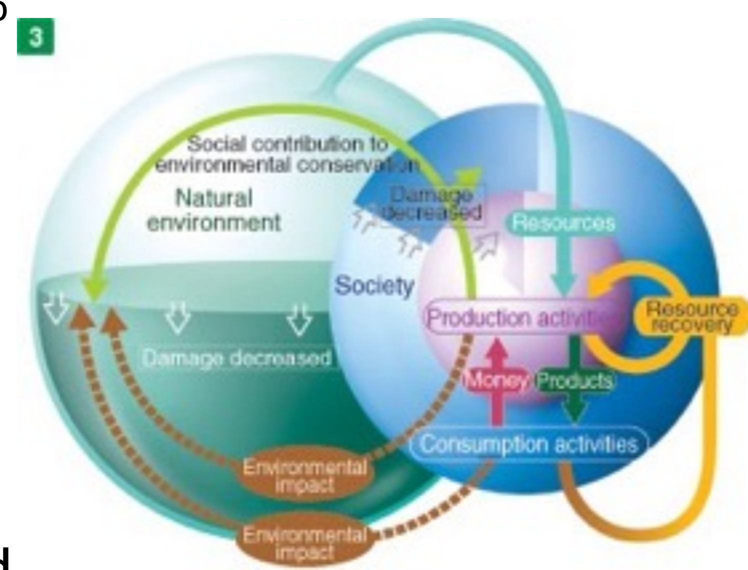
Scale: <mean time between forced restarts for defined [Activity], for a defined [Intensity].>

Fail [Any Release or Evo Step, Activity = Recompute, Intensity = Peak Level] 14 days <- HFA 6.1.1

Goal [By 2008?, Activity = Data Acquisition, Intensity = Lowest level] : 300 days ??
Stretch: 600 days.

Restore Speed:

Type: Software Quality Requirement. **Version**: 25 October 2007.
Part of: Rock Solid Robustness
Ambition: Should an error occur (or the user otherwise desire to do so), the system shall be able to restore the system to a previously saved state in less than 10 minutes. <-6.1.2 HFA.



Scale: Duration from Initiation of Restore to Complete and verified state of a defined [Previous: Default = Immediately Previous]] saved state.

<u>**Initiation**</u>: defined as {Operator Initiation, System Initiation, ?}. Default = Any.

Goal [Initial and all subsequent released and Evo steps] 1 minute?

Fail [Initial and all subsequent released and Evo steps] 10 minutes. <- 6.1.2 HFA

Catastrophe: 100 minutes.

Testability:

Type: Software Quality Requirement.
Part of: Rock Solid Robustness
Initial Version: 20 Oct 2006
Version: 25 October 2007.
Status: Demo draft,
Stakeholder: {Operator, Tester}.
Ambition: Rapid-duration automatic testing of <critical complex tests>, with extreme operator setup and initiation.

Scale: the duration of a defined [Volume] of testing, or a defined [Type], by a defined [Skill Level] of system operator, under defined [Operating Conditions].

Goal [All Customer Use, Volume = 1,000,000 data items, Type = WireXXXX Vs DXX, Skill = First Time Novice, Operating Conditions = Field, {Sea Or Desert}. <10 mins.

Design Hypothesis: *Tool Simulators, Reverse Cracking Tool, Generation of simulated telemetry frames entirely in software, Application specific sophistication, for drilling – recorded mode simulation by playing back the dump file, Application test harness console <-6.2.1 HFA*

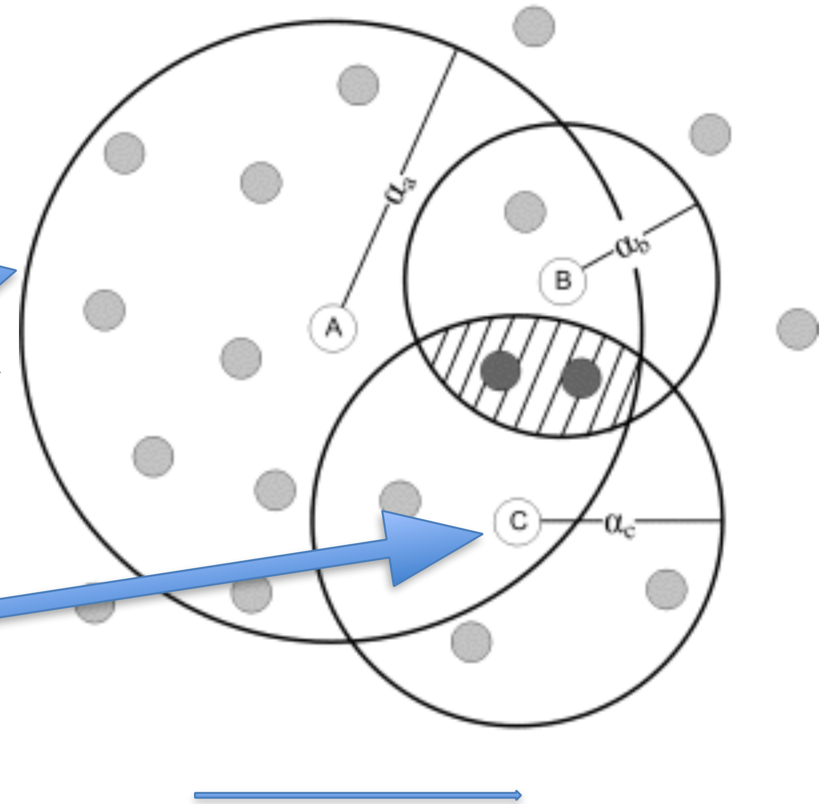
Another Real (Doctored) Example:
Financial Corp. Top Level Project requirements
$60,000,000 in 1 Year Spend ……. but

DO YOU SEE ANYTHING RELATED TO MAINTAINABILITY?

1. Reduce the ***costs*** *associated with managing redundant / regionally* ***disparate*** *systems.*
2. ***Single*** *global portfolio management system.*
3. Reduce overall ***spending*** *with a reduction in redundant initiatives.*
4. Governance structures - system agnostic.
5. All projects in project portfolio system.
6. ***Reduce development*** *project* ***spend*** *on low priority work with better alignment between Technology and business demand.*
7. Project portfolio Framework, Business Value metrics for ***prioritization****.*
8. ***Reduction*** *in* ***cost*** *over runs.*
9. ***Definition*** *criteria for project* ***success****.*
10. Metrics and exception reporting for ***cost*** *management.*
11. Linkage of actual ***costs*** *to forecast.*
12. Increase ***revenue*** *with a faster* ***time to market****.*
13. Knowledge management, project ramp up templates.

3. The Multi-Level Requirement Principle.

- The levels of maintainability we decide to require can be
  - partly ‘**constraints**’,
    - a necessary minimum of ability to avoid failure,
  - and partly desirable ‘**target**’ levels
    - that are determined by what pays off to invest in.



Software Downtime: Multiple Levels

Type: Software Quality Requirement. **Version:** 25 October 2007.
Part of: Rock Solid Robustness.
Ambition: to have minimal downtime due to software failures <- HFA 6.1
Issue: does this not imply that there is a system wide downtime requirement?

Scale: <mean time between forced restarts for defined [Activity], for a defined [Intensity].>

Fail [Any Release or Evo Step, Activity = Recompute, Intensity = Peak Level] 14 days <- HFA 6.1.1

Goal [By 2008?, Activity = Data Acquisition, Intensity = Lowest level] : 300 days ??

Stretch: 600 days.

Restore Speed: Multiple Levels

Type: *Software Quality Requirement.* ***Version***: *25 October 2007.*

Part of: *Rock Solid Robustness*

Ambition: *Should an error occur (or the user otherwise desire to do so), the system shall be able to restore the system to a previously saved state in less than 10 minutes. <-6.1.2 HFA.*

Scale: Duration from Initiation of Restore to Complete and verified state of a defined [Previous: Default = Immediately Previous]] saved state.

Initiation: defined as {Operator Initiation, System Initiation, ?}. Default = Any.

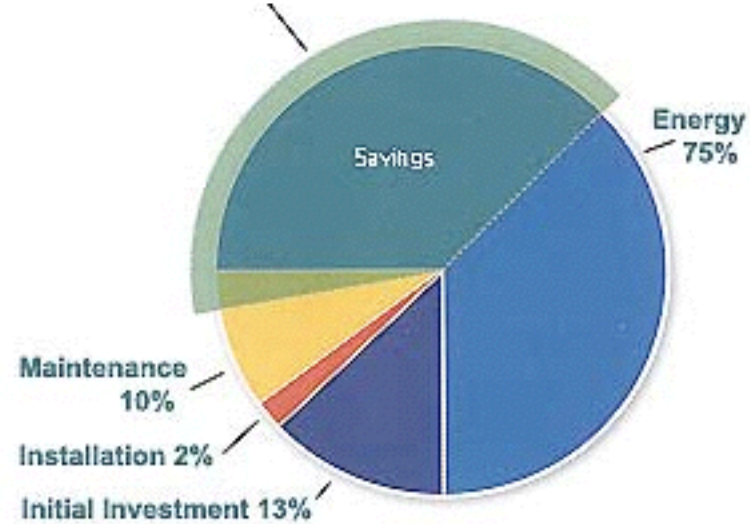
Goal [Initial and all subsequent released and Evo steps] 1 minute?

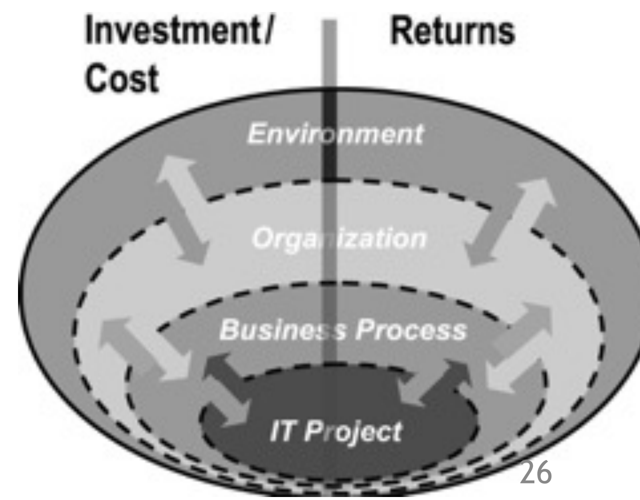
Fail [Initial and all subsequent released and Evo steps] 10 minutes. <- 6.1.2 HFA

Catastrophe: 100 minutes.

4. The Payoff Level Principle.

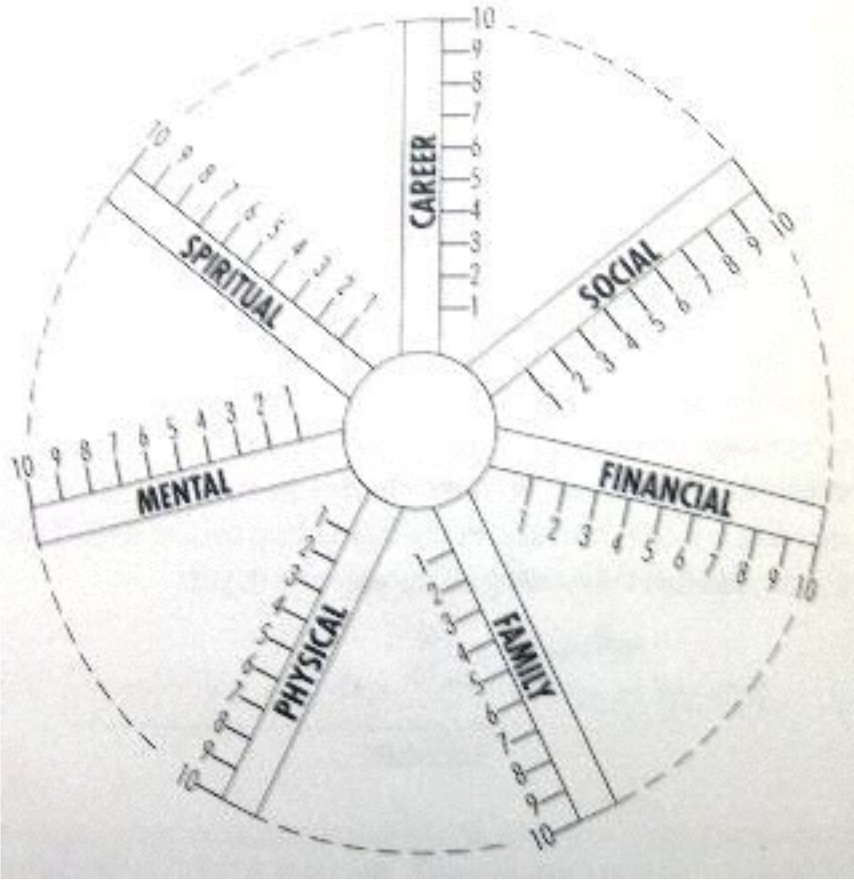
- The *levels of maintainability* it **pays off** to invest in,
  - depend on **many** factors –
  - but certainly on the system **lifetime** expectancy,
  - the **criticality**/illegality/cost of not being able to change correctly or change in time,
  - and the cost and availability of necessary skilled **professionals** to carry out the changes.





5. The Priority Dynamics Principle.

- The **maintainability** requirements must *compete for priority*
  - for **limited** resources
  - with all **other** requirements.
- We **cannot** simply **demand** arbitrary *desired* levels of maintainability.



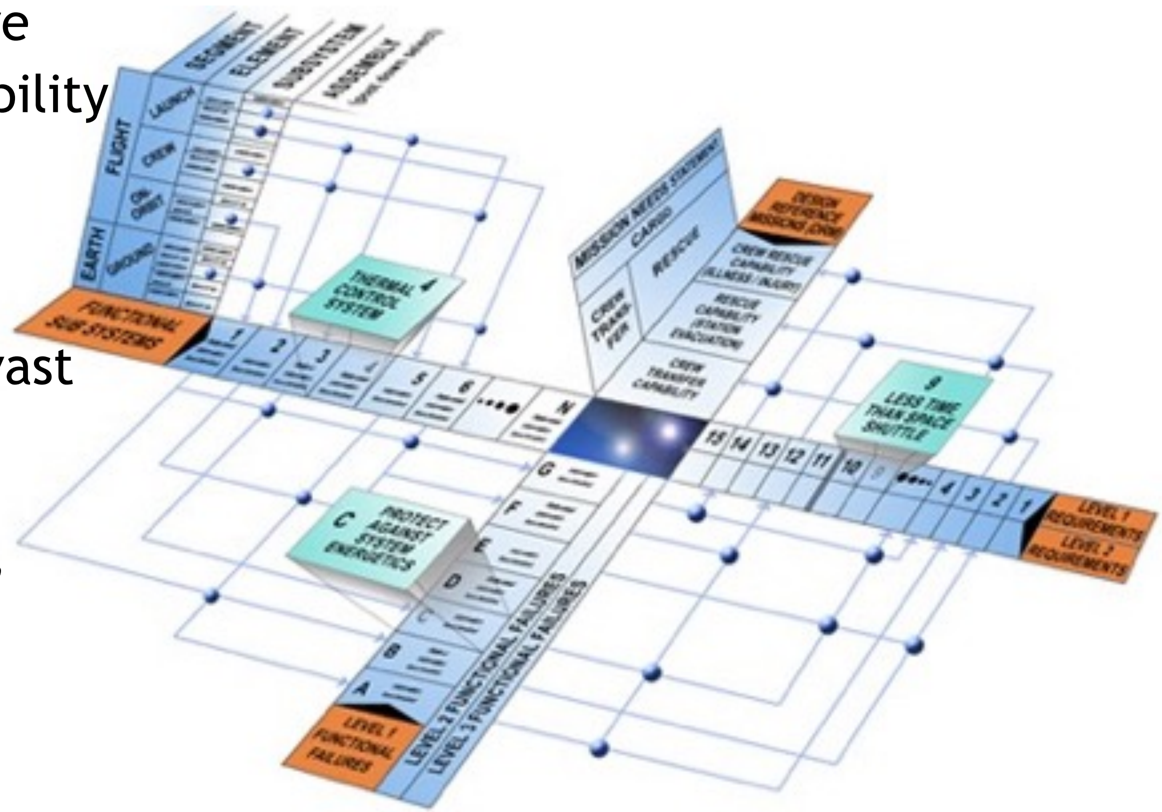
The Engineering Solution

There are many small and less critical software systems where

- engineering the maintainability would **not** be interesting,
- or would **not** pay off.
- **Nobody** cares.

This **talk is addressed** to the vast number of current situations where

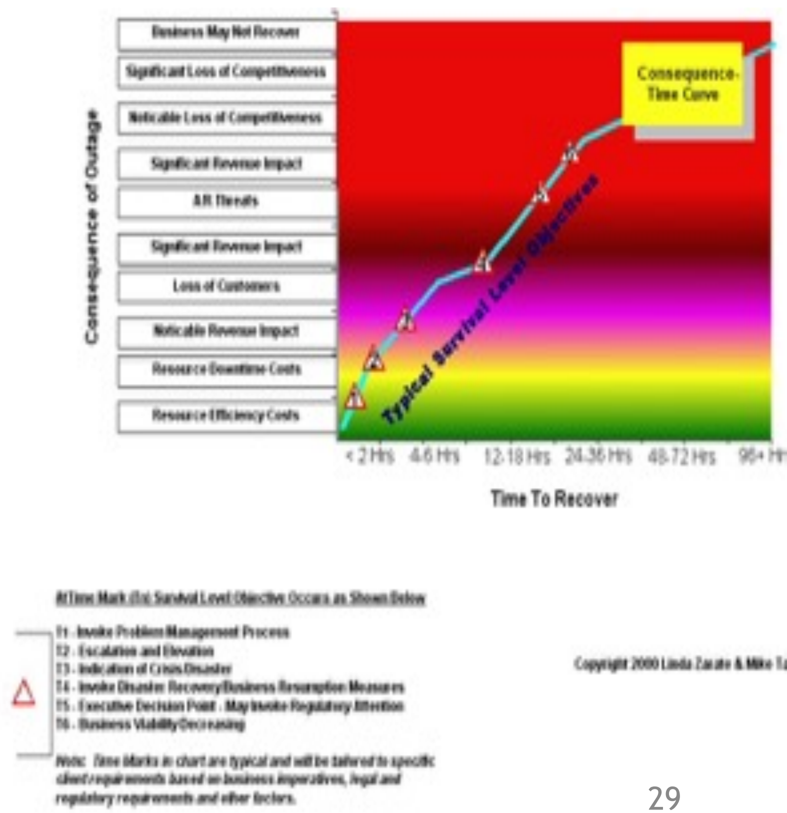
- the total **size** of software,
- the **growth** of software annually,
- the **cost** of maintenance annually – are all causing management to wonder – '
  - **Is there a better way?'**



The method is straightforward, and it is well-understood engineering in ‘real’ engineering disciplines.

- **In simple terms it is:**

1. **Define the maintainability requirements <u>quantitatively</u>.**
2. **<u>Design to</u> meet those <u>requirements</u>, if possible and economic.**
3. **Implement the designs and <u>test that they meet</u> the required levels.**
4. **<u>Quality Control</u> that the design <u>continues</u> to meet the required maintainability quality levels, and take action in the case of degradation, to get back to current required levels.**



Let us take a simplified tour of the method.

Requirement specification (using 'Planguage' [Gilb 2005]:

<u>Bug Fixing Speed</u>:

Type: Software Product Quality Requirement.

Scope: Product Confirmit [Version 12.0 and on]

Ambition Level: Fast enough bug fixing so that it is a non-issue with our customers.

Scale of Measure: Average Continuous Hours from Bug occurs and is observed in any user environment, until it is correctly corrected and sufficiently tested for safe release to the field, and the change is in fact installed at, at least, one real customer, and all consequences of the bug have been recovered from at the customer level.

Meter: QA statistics on bug reports and bug fixes.

Past [Release 10.0] 36 hours <- QA Statistics

Fail [Release 12.0, Bug Level = Major] 6 hours <- QA Directors Plan

Goal [Release 12.0, Bug Level = Catastrophic] 2 hours <- QA Directors Plan.

Goal [Release 14.0, Bug Level = Catastrophic] 1 hour <- QA Directors Plan.

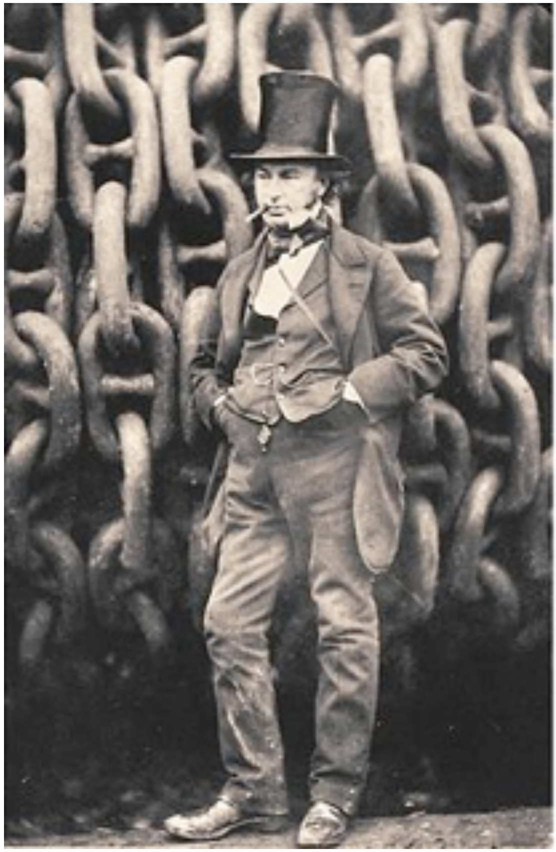
Planguage Intelligibility

- It should be possible to read this specification,
  - slowly,
  - even for those not trained in Planguage,
  - and to be able to explain exactly what the requirement is.
-
- Notice especially the ‘Scale of Measure’.
  - **Scale** of Measure:
    - **Average Continuous Hours from Bug occurs and is observed in any user environment,**
    - **until it is correctly corrected and sufficiently tested for safe release to the field,**
    - **and the change is in fact installed at,**
      - **at least, one real customer,**
    - **and all consequences of the bug have been recovered from at the customer level.**

  - It encompasses the entire maintenance life cycle
    - from first bug effect observation
    - until customer level correction in practice.
  - *That is a great deal more than just some **programmer staring at code** and **seeing the bug** and **patching it**.*
  - The corresponding **design**
    - will have to encompass **many** processes and technologies.

Summary

- **Technical Management must take responsibility for**
  - **Specification**
  - **design engineering**
  - **financing**
  - **Prioritization**
  - **of the long term operational**
    - **adaptability characteristics**
    - **of their systems**
- **It won't happen**
  - **if you leave it to the techies.**
  - **Why should they care?**



Brunel

END OF 30 MINUTE PRESENTATION

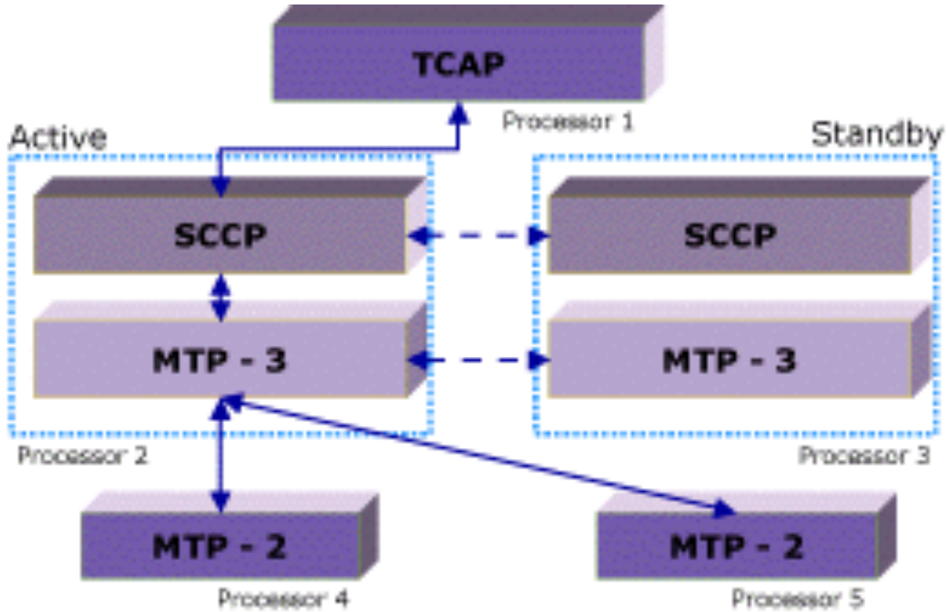
- THE REMAINING SLIDES ARE TO GIVE SOME DETAIL FOR THOSE WHO WOULD LIKE TO KNOW HOW TO QUANTIFY FUTURE ADAPTABILITY FOR SYSTEMS ENGINEERING PURPOSES.
- AND TO GIVE SOME IDEA OF A POSSIBE ARCHITECTURE FOR RECHING SOME SUCH OBJECTIVES.

Let us take a look at a possible first draft of some design ideas:

- Note: I have intentionally suggested so *dramatic* architecture,
  - in an effort to meet the *radically* improve requirement level.
- The reader need not take any design *too* seriously.
- This is an example of trying to solve the problem, using engineering techniques (redundancy)
  - that have a solid scientific history.

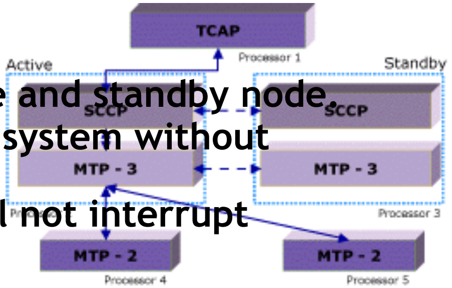
University of Alaska's Museum of the North in Fairbanks

- Design: Automated N-version distinct software comparison [Inacio 1998]
  - at selected critical customer sites,
  - to detect potential bugs automatically.



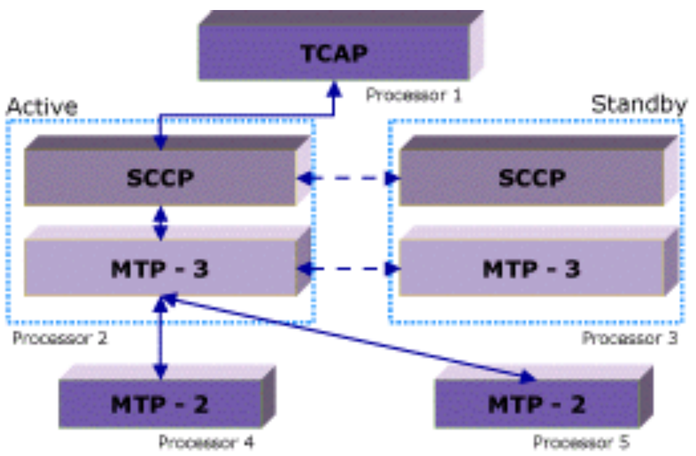
Trillium | Distributed Fault-Tolerant/High-Availability (DFT/HA) Core

- Complete recovery during failure.
  - This feature is available in both pure fault-tolerant and distributed fault-tolerant systems.
  - When a failure occurs, failed protocol layers are able to completely recover stable state information.
  - All protocol resources present in a stable state during the failure are maintained on the standby.
- Application restart on processor loss.
  - This feature is applicable to pure distributed systems. If a processor in a pure distributed system fails, applications on the failed processor may be restarted on available processors to provide service for subsequent user traffic.
- Survive up to n-1 faults.
  - DFT protocol layers may survive up to n-1 faults without loss of service where n is the number of processors over which the protocol layer was distributed.
  - With the lost application restart feature enabled, a distributed protocol layer may continue to provide full service until the last processor in the system fails.
  - User defined system operations. Advanced distributed system operations such as dynamic load balancing may be implemented using basic services provided by the core software.
- Graceful node shutdown.
  - The system manager provides an operation to gracefully shutdown a node and an option to redistribute the protocol load onto remaining processors in the system
  - . The load redistribution is completely transparent to the system users.
- Maintenance operations.
  - The system manager provides an operation to swap the states of an active and standby node.
  - This functionality may be used to perform maintenance operations on the system without shutting it down
  - . These operations are completely transparent to the system users and will not interrupt service provided by the system.



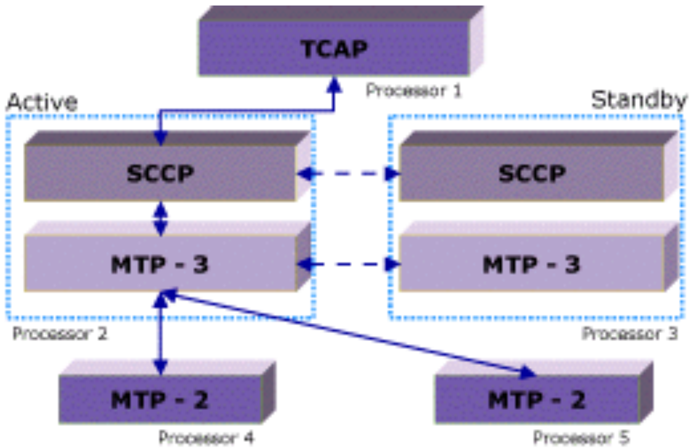
2. Administrative Delay Time:

- Design: Direct digital report
  - from distinct software discrepancies
  - to our global,
    - 3 zone,
    - 24/7
    - bug analysis service.



3. Tool Collection Time.

- **Design: All necessary tools are electronic,**
  - **and collection is based on**
    - **customers installed version and its fixes.**
  - **The distinct software, bug capture**
    - **collects local input sequences.**



4. Problem Analysis Time.

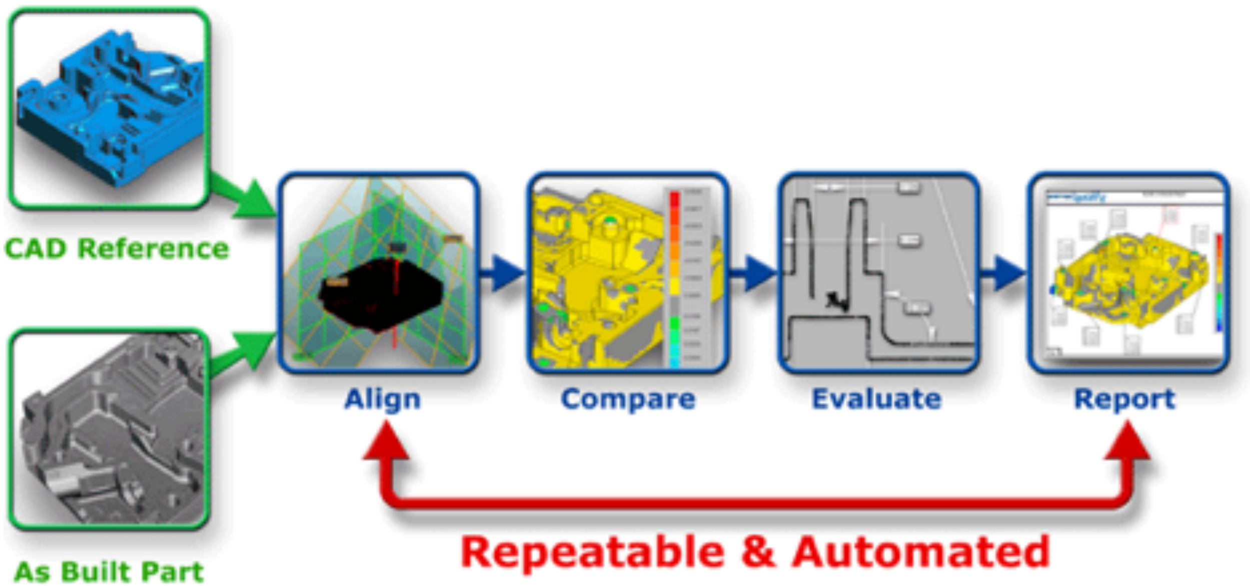
- **<u>Analyst Selection</u>:**
  - **Design: The fastest bug analysts are**
    - **selected based on actual past performance statistics, and**
    - **rewarded in direct relation to their timing**
      - **for analyzing root cause, or correct fix.**

5. Correction Hypothesis Time

- **Design: Same design as Analyst Selection,**
  - **but applies to correct change specification speed statistics.**

6. Quality Control Time

- **Design: Rigorous**
  - **30 minute or less inspection**
  - **of change spec by other bug analysts,**
  - **with reward for finding major defects**
    - **as judged by our defect standards.**



7. Change Time

- **Design: Changes are applied**
  - **in parallel with QC,**
  - **and modified only if change defects found in QC.**

8. Local Test Time

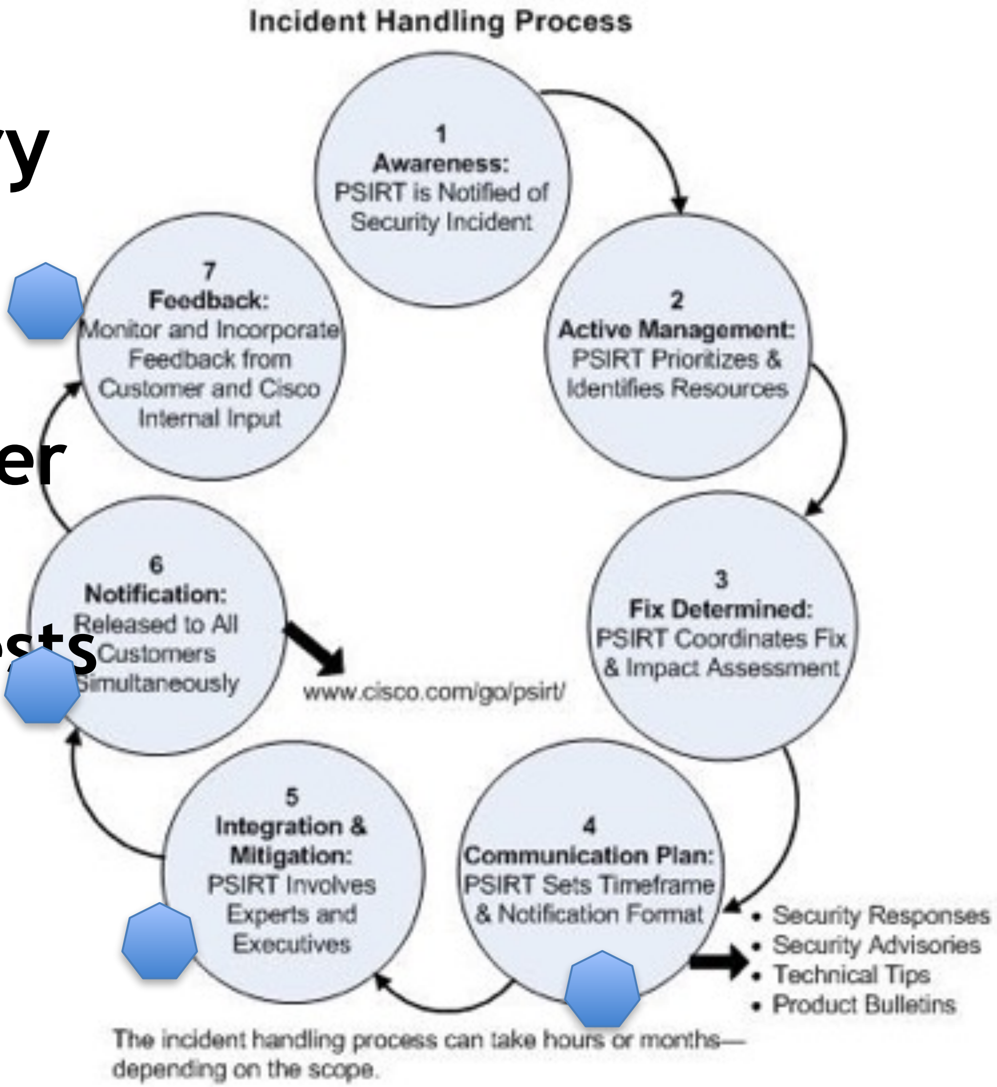
- Design: Automated Test. Based on distinct software (2 independent) changes
  - to distinct modules, and
  - running reasonable test sets,
  - until further notice
  - or failure.

9. Field Pilot Test Time

- **Design:**
  - After 30 minutes successful Local Test
  - the changes are implemented
    - at a customer pilot site
      - for more realistic testing,
        - » in operation,
        - » in distinct software safe mode.

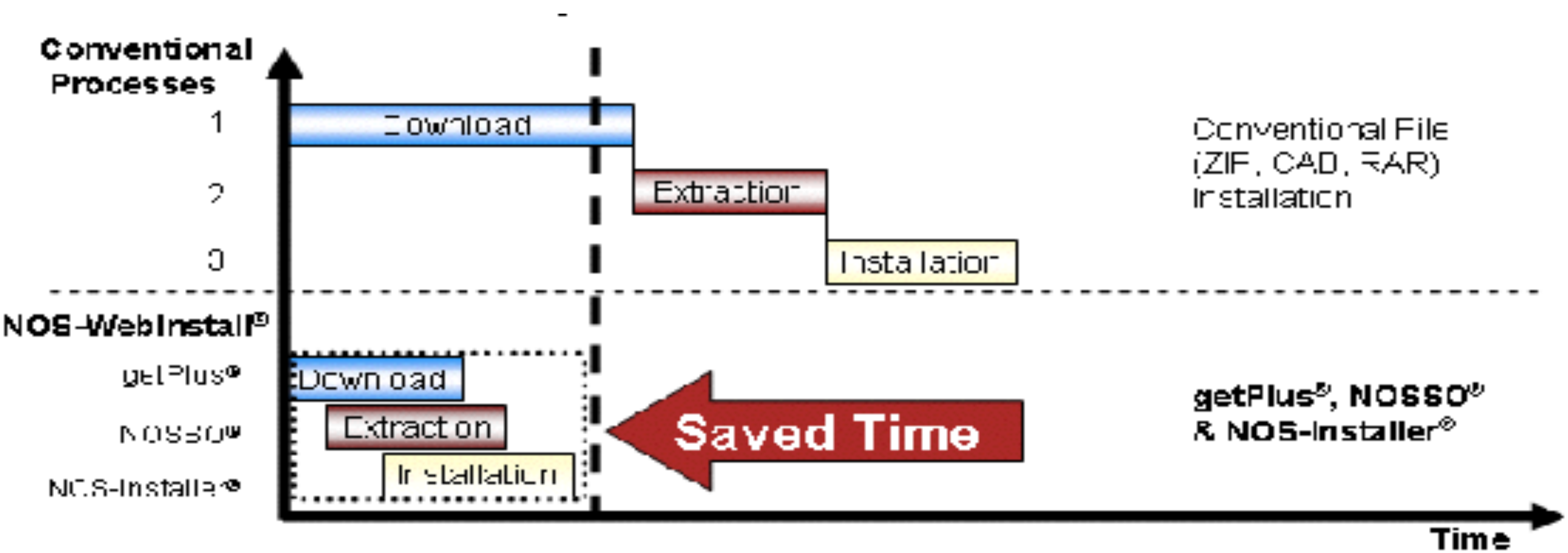
10. Change Distribution Time

- Design: All necessary changes are
  - readied and
  - uploaded for customer download,
  - even before Local Tests Begin,
  - and changed only
    - if tests fail.



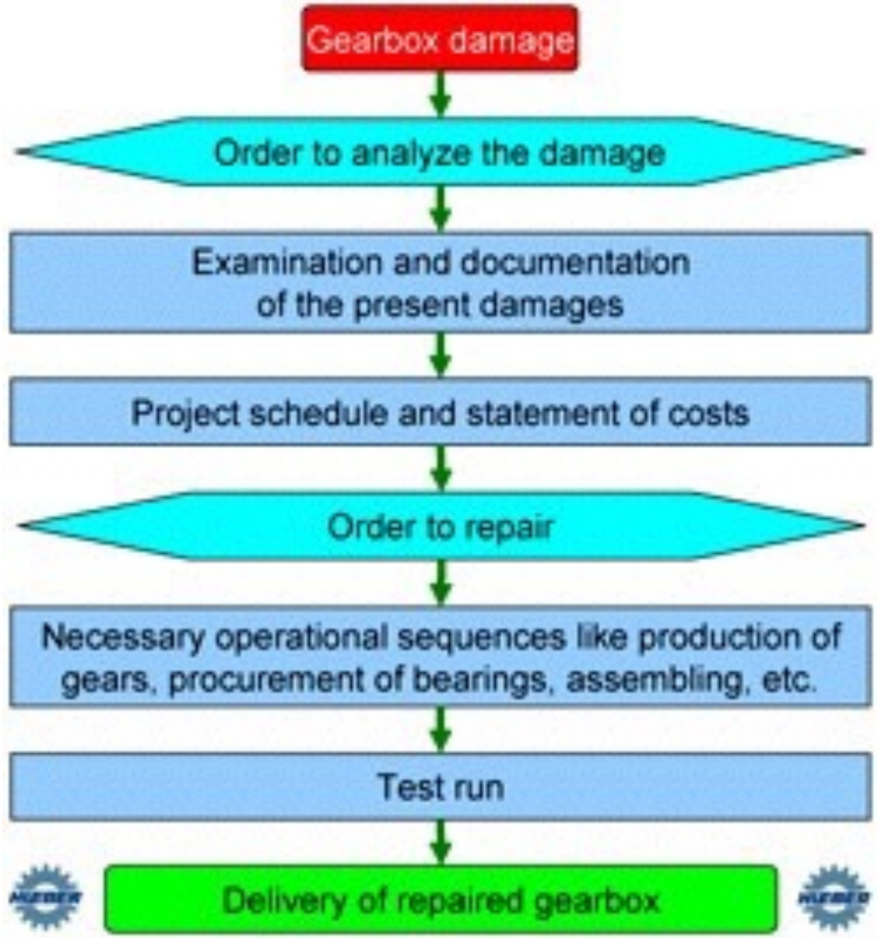
11. Customer Installation Time

- **Design: Customer is given options of**
  - **manual or**
  - **automatic changes,**
  - **under given circumstances**



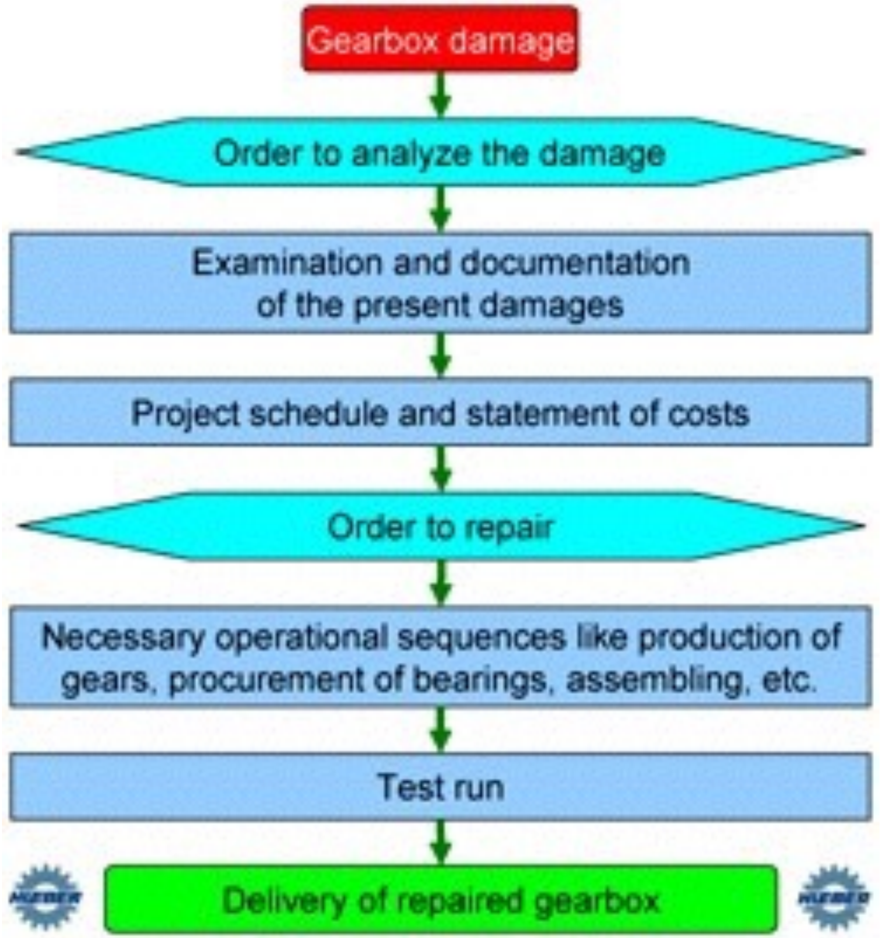
12. Customer Damage Analysis Time

- Design:
- <local customer solution>.
- We don't have good automation here.
- Assume none until proven otherwise.
- We need to be aware of
  – all reports sent
  – and databases updated that may need correction.
-



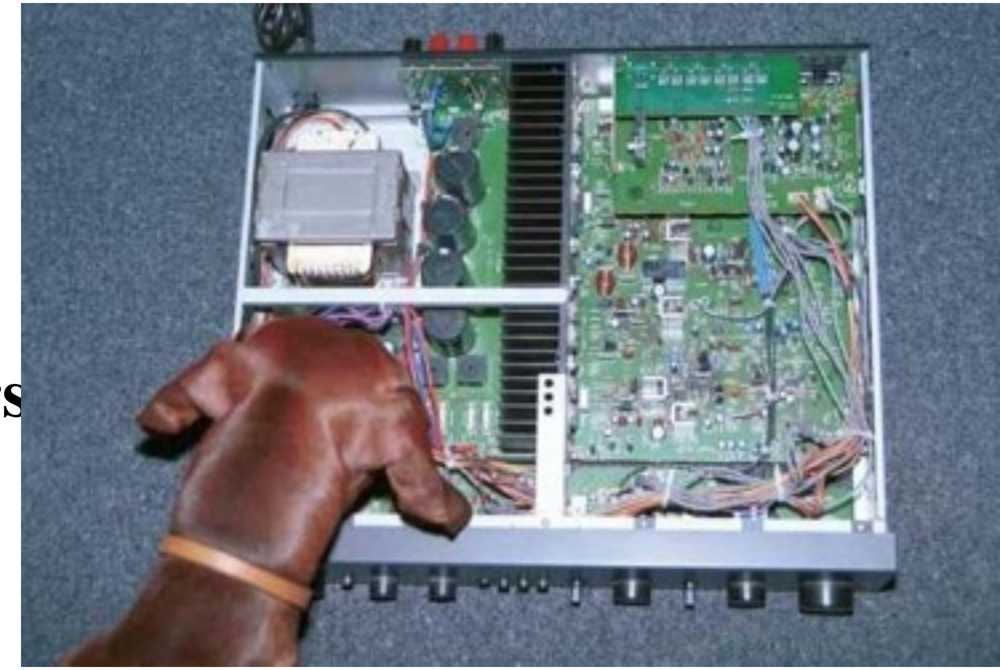
13. Customer-Level-Recovery Time

- **Design:**
- **same problem as Customer Damage Analysis Time**
- **may be highly local and manual.**
- **Is it really out of our control?**



14. Customer QC of Recovery, Time.

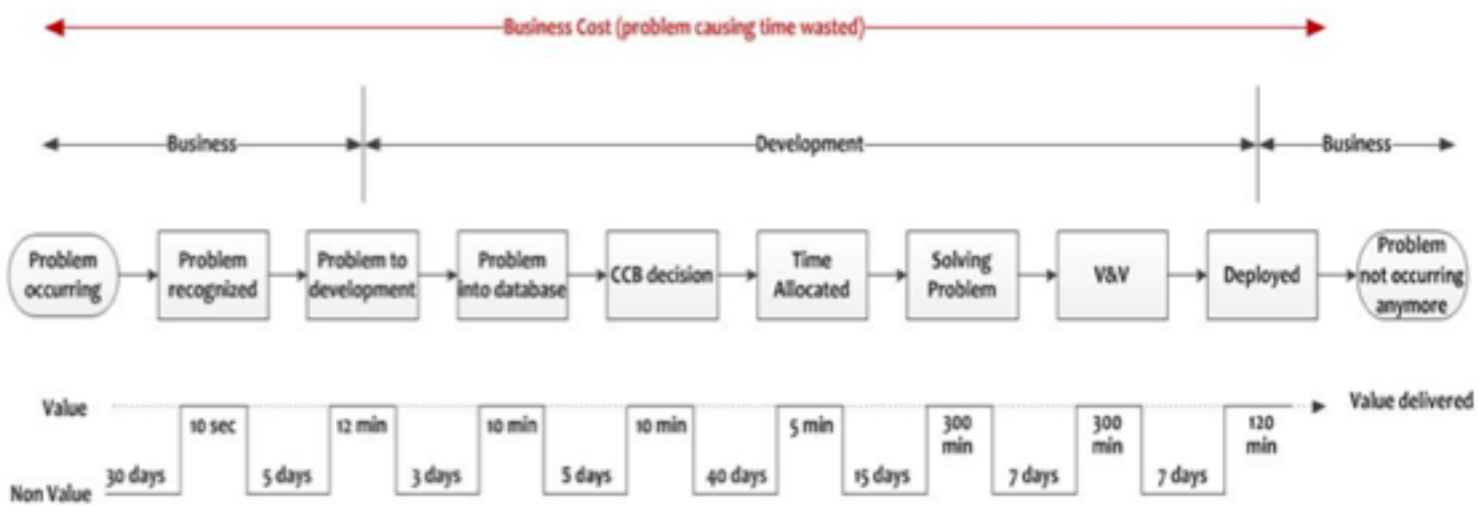
- **Design:**
- **30-minute Quality Control**
  - **of recovery results,**
  - **assisted by our quality standards,**
  - **and for critical customers**
  - **QC By our staff,**
    - **From our office**
    - **or on customer site.**
-



Maintainability from A Value Stream Point of View

You were talking about Maintainability Generic Breakdown.
In Toyota and Lean this is called "Value Stream Mapping", example:

- **Total Business Cost 114 days, Cost of Non Value: 112 days**
- **Occurrence: 2 x per day, delay per occurrence: 10 min**
- **Number of business people affected: 100**
- **Business Cost of Non Value: 2 x 10 min x 112 days x 100 people x 400£/ day = 187 k£**
- **Net Cost of Value: 1.6 days ☺ ~3 people x 1.6 days x 1000£/ day = 5 k£**



Main Point

- **My main point is**
  - **that each sub-process of the maintenance operation**
  - **tends to require a separate and distinct design (1 or more designs each).**
- **There is nothing simple**
  - **like software people seem to believe,**
  - **that better code structures,**
  - **coding practices, documentation,**
  - **and tools**
  - **will solve the maintenance problem.**

Many Means

Design Ideas ->	Technology Investment	Business Practices	People	Empowerment	Principles of IMA Management	Business Process Re-engineering	Sum Requirements
Customer Service ? <->0 Violation of agreement	50%	10%	5%	5%	5%	60%	185%
Availability 90% <-> 99.5% Up time	50%	5%	5-10%	0%	0%	200%	265%
Usability 200 <-> 60 Requests by Users	50%	5-10%	5-10%	50%	0%	10%	130%
Responsiveness 70% <-> ECP's on time	50%	10%	90%	25%	5%	50%	180%
Productivity [illegible]	45%	60%	10%	[illegible]	[illegible]	53%	303%
[illegible]	50%	5%	75%	[illegible]	[illegible]	61%	251%
Morale 72 <-> [illegible] per month on Sick Leave							
Data Integrity 88% <-> 97% Data Error %	42%	10%	[illegible]	5%	[illegible]	25%	177%
Technology Adaptability [illegible] Technology	5%	30%	[illegible]	[illegible]	[illegible]	60%	160%
Requirement Adaptability ? <-> 2.6% Adapt to Change	80%	20%	60%	75%	20%	5%	260%
Resource Adaptability 2.1M <-> ? Resource Change	10%	80%	5%	50%	50%	75%	270%
Cost Reduction FADS <-> 30% Total Funding	50%	40%	10%	40%	50%	[illegible]	[illegible]
Sum of Performance	*482%*	*280%*	*305%*	*390%*	*315%*	[illegible]	
Money % of total budget	15%	4%	3%	4%	6%	[illegible]	[illegible]
Time % total work months/year	15%	15%	20%	10%	20%	18%	98%
Sum of Costs	*30*	*19*	*23*	*14*	*26*	*22*	
Performance to Cost Ratio	*16:1*	*14:7*	*13:3*	*27:9*	*12:1*	*29:5*	

Many Ends

Many Impacts

Next Slide

DoDef: Persinscom Impact Estimation Table:

Designs

Requirements

R→ D Impacts

Design Ideas ->	*Technology Investment*	*Business Practices*	*People*	*Empowerment*	*Principles of IMA Management*	*Business Process Re-engineering*	*Sum Requirements*
reement	50%	10%	5%	5%	5%	60%	185%
Availability 90% <-> 99.5% Up time	50%	5%	5–10%	0%	0%	200%	265%
Usability 200 <-> 60 Requests by Users	50%	5–10%	5–10%	50%	0%	10%	130%
Responsiveness 70% <-> ECP's on time	50%	10%	90%	25%	5%	50%	180%
Productivity 3:1 Return on Investment	45%				100%	53%	303%
Morale 72 <-> 60 per month on Sick Leave	50%				15%	61%	251%
Data Integrity 88% <-> 97% Data Error %	42%	10%	25%	5%	70%	25%	177%
Technology Adaptability 75% Adapt Technology	5%	30%	5%	60%	0%	60%	160%
Requirement Adaptability ? <-> 2.6% Adapt to Change	80%	20%	60%	75%	20%	5%	260%
Resource Adaptability 2.1M <-> ? Resource Change	10%	80%	5%	50%	50%	75%	270%
Cost Reduction FADS <-> 30% Total Funding	50%	40%	10%	40%	50%	50%	240%
Sum of Performance	*482%*	*280%*	*305%*	*390%*	*315%*	*649%*	
Money % of total budget	15%	4%	3%	4%	6%	4%	36%
Time % total work months/year	15%	15%	20%	10%	20%	18%	98%
Sum of Costs	*30*	*19*	*23*	*14*	*26*	*22*	
Performance to Cost Ratio	*16:1*	*14:7*	*13:3*	*27:9*	*12:1*	*29:5*	

General ‘Change Attribute’ **Tailoring**

- The following slides will give a **general set of patterns** for
  - defining and distinguishing *different* **classes** of ‘maintenance’.
- But in your *real* world, you will want to **tailor** the definitions to *your* domain.
  - You can initially tailor using the ‘**Scale**’ of measure definition.
  - And continued tailoring can be done by defining **[conditions]** in the requirement level qualifier.

Scale:
% of transactions successfully completed by defined [Person**] doing defined [**Task**].**

Goal [Task = Update, Person = New Hire, Deadline = Phase 3]
60%

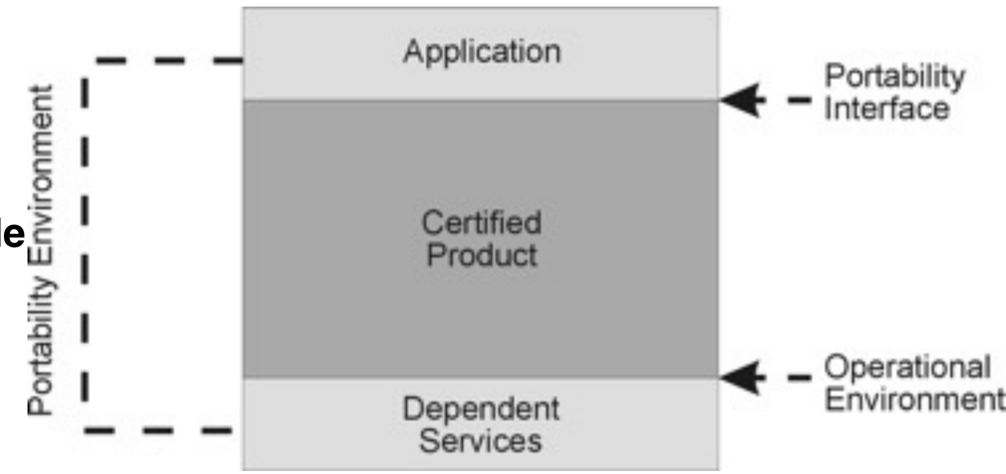
A generic set of performance measures, including several related to change.

For example:

<u>Code Portability:</u>

Scale:

Effort in Hours needed to Port each 1000 Non-Commentary Lines of Code from a defined [Home Environment] to a defined [Target Environment], using defined [Tools] and defined [Personnel].



Goal

[Home Environment = {.net, Oracle,} ,
Target Environment = {Java++, Open Source, Linux},
Tools = Convert Open ,
Personnel = {Experienced Experts, India}] 60 hours.

A Generic Set of Performance measures – including several related to ‘change’

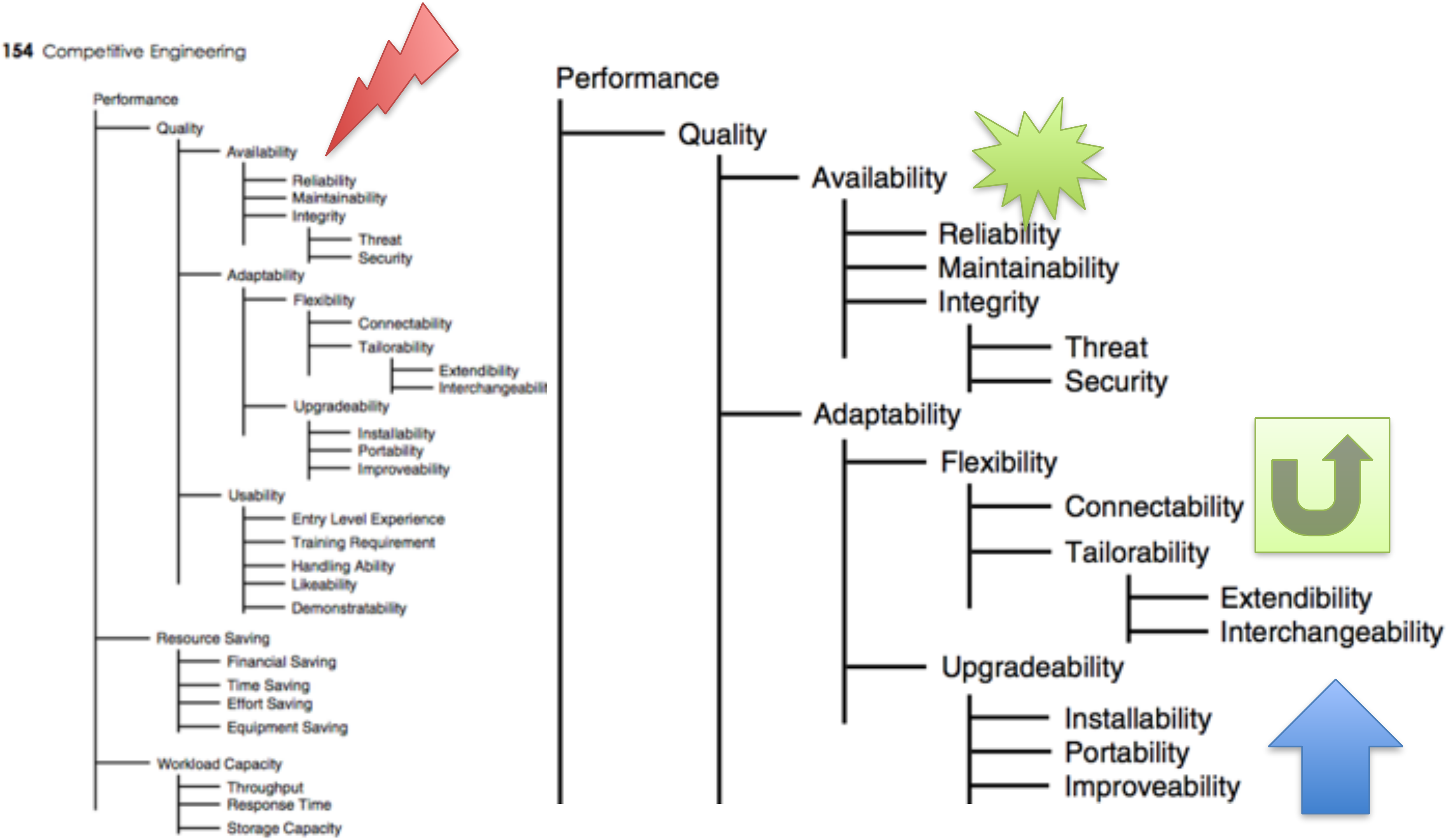
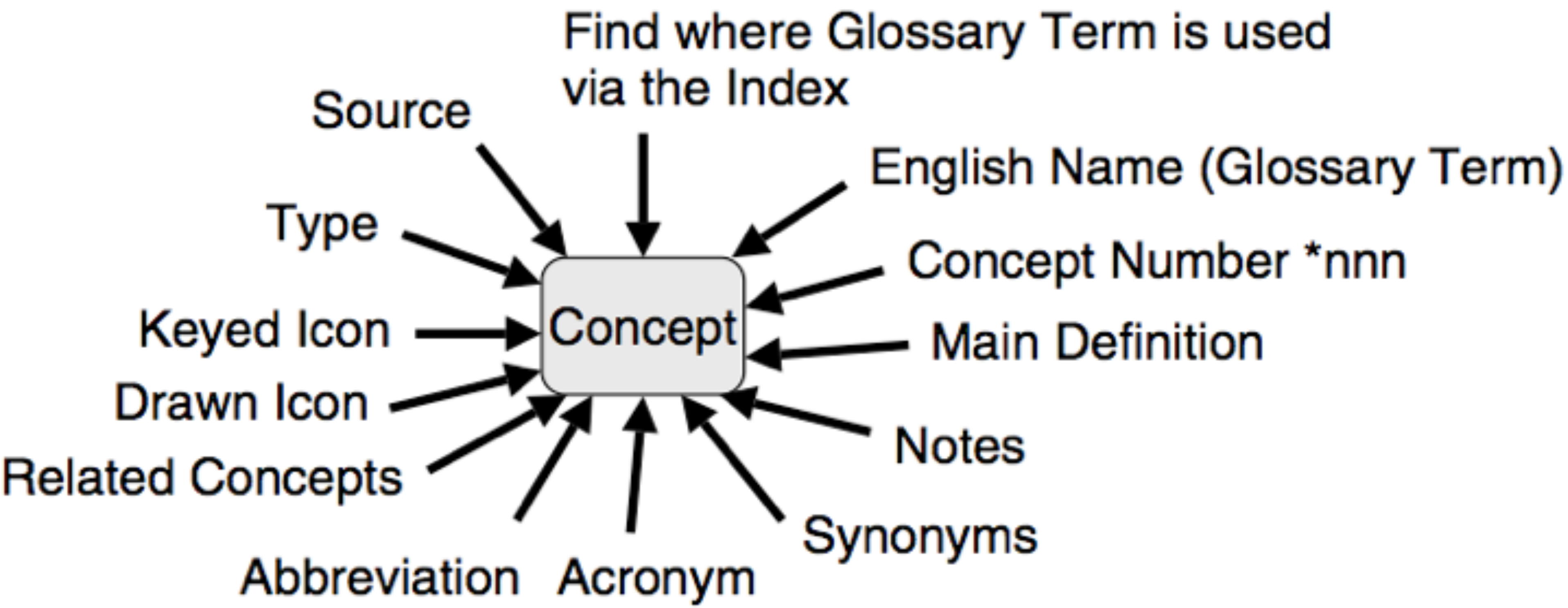


Figure 5.3
One decomposition possibility for performance attributes with emphasis on the detail of the quality attributes.

The *attribute names* used are arbitrary choices by the author.

- **They only start to take on meaning when defined,**
  - **with a Scale of measure.**
- **There are no accepted or acceptable standards here,**
  - **and certainly not for software.**
  - **Even in hardware engineering, there is an accepted <u>pattern</u> – such as "Scale: Mean Time to Repair".**
  - **But it is accepted that we have to further define such concepts locally,**
    - **such as the meaning of 'Repair'.**



Maintainability Measures

- Here are some of the general **patterns** we can use to define and distinguish the different classes of change processes on software.
- First the ‘Bug Fixing’ pattern (from which we derived the example at the beginning of this talk).

Maintainability:
Type: Complex Quality Requirement.
Includes: {Problem Recognition, Administrative Delay, Tool Collection, Problem Analysis, Change Specification, Quality Control, Modification Implementation, Modification Testing {Unit Testing, Integration Testing, Beta Testing, System Testing}, Recovery}.

Problem Recognition:
Scale: Clock hours from defined [Fault Occurrence: Default: Bug occurs in any use or test of system] until fault officially recognized by defined [Recognition Act: Default: Fault is logged electronically].
Administrative Delay:
Scale: Clock hours from defined [Recognition Act] until defined [Correction Action] initiated and assigned to a defined [Maintenance Instance].
Tool Collection:
Scale: Clock hours for defined [Maintenance Instance: Default: Whoever is assigned] to acquire all defined [Tools: Default: all systems and information necessary to analyze, correct and quality control the correction].
Problem Analysis:
Scale: Clock time for the assigned defined [Maintenance Instance] to analyze the fault symptoms and be able to begin to formulate a correction hypothesis.
Change Specification:
Scale: Clock hours needed by defined [Maintenance Instance] to fully and correctly describe the necessary correction actions, according to current applicable standards for this.
Note: This includes any additional time for corrections after quality control and tests.
Quality Control:
Scale: Clock hours for quality control of the correction hypothesis (against relevant standards).
Modification Implementation:
Scale: Clock hours to carry out the correction activity as planned. "Includes any necessary corrections as a result of quality control or testing."
Modification Testing:
Unit Testing:
Scale: Clock hours to carry out defined [Unit Test] for the fault correction.
Integration Testing:
Scale: Clock hours to carry out defined [Integration Test] for the fault correction.
Beta Testing:
Scale: Clock hours to carry out defined [Beta Test] for the fault correction before official release of the correction is permitted.
System Testing:
Scale: Clock hours to carry out defined [System Test] for the fault correction.
Recovery:
Scale: Clock hours for defined [User Type] to return system to the state it was in prior to the fault and, to a state ready to continue with work.

Source: The above is an extension of some basic ideas from Ireson, Editor, Reliability Handbook, *McGraw Hill, 1966* (Ireson 1966).

Maintainability components, derived from a hardware engineering view, adopted for software.

Notice that *Maintainability* in the narrow sense (fix bugs) is quite separate from other 'Adaptability' concepts.

- This is normal engineering,
  - Which places fault repair together with reliability and availability;
  - Those 3 determine the immediate operational characteristics of the system.
- The other forms of adaptability are more about potential future upgrades to the system,
  - change, rather than repair.
- Change and repair, have in common that
  - our system architecture has to make it easy to change, analyze and test.
- The system itself is unaware of
  - whether we are correcting a fault
  - or improving the system.
- The consequence is that
  - much of the maintenance-impacting '<u>design</u>' or 'architecture'
  - benefits
  - most of the types of maintenance (fix and adapt).

Here are a *generic* set of definitions for the '*Adaptability*' concepts.

<u>Adaptability</u>: 'The **efficiency** with which a system can be changed.'

Gist: Adaptability is a measure of a system's ability to change.

Includes: { a set of scalar variables, such as Portability}.

Note: probably not `simple` enough to define with a **single** Scale.

Type: <u>*Complex*</u> Quality Attribute.

Since,

- **if given sufficient resource, a system can be changed in**
  - **almost any way,**
- **the primary concern is with the amount of**
  - **resources**
    - **(such as time, people, tools and finance)**
- **needed to bring about specific changes**
  - **(the change 'cost').**

The Adaptive Cycle

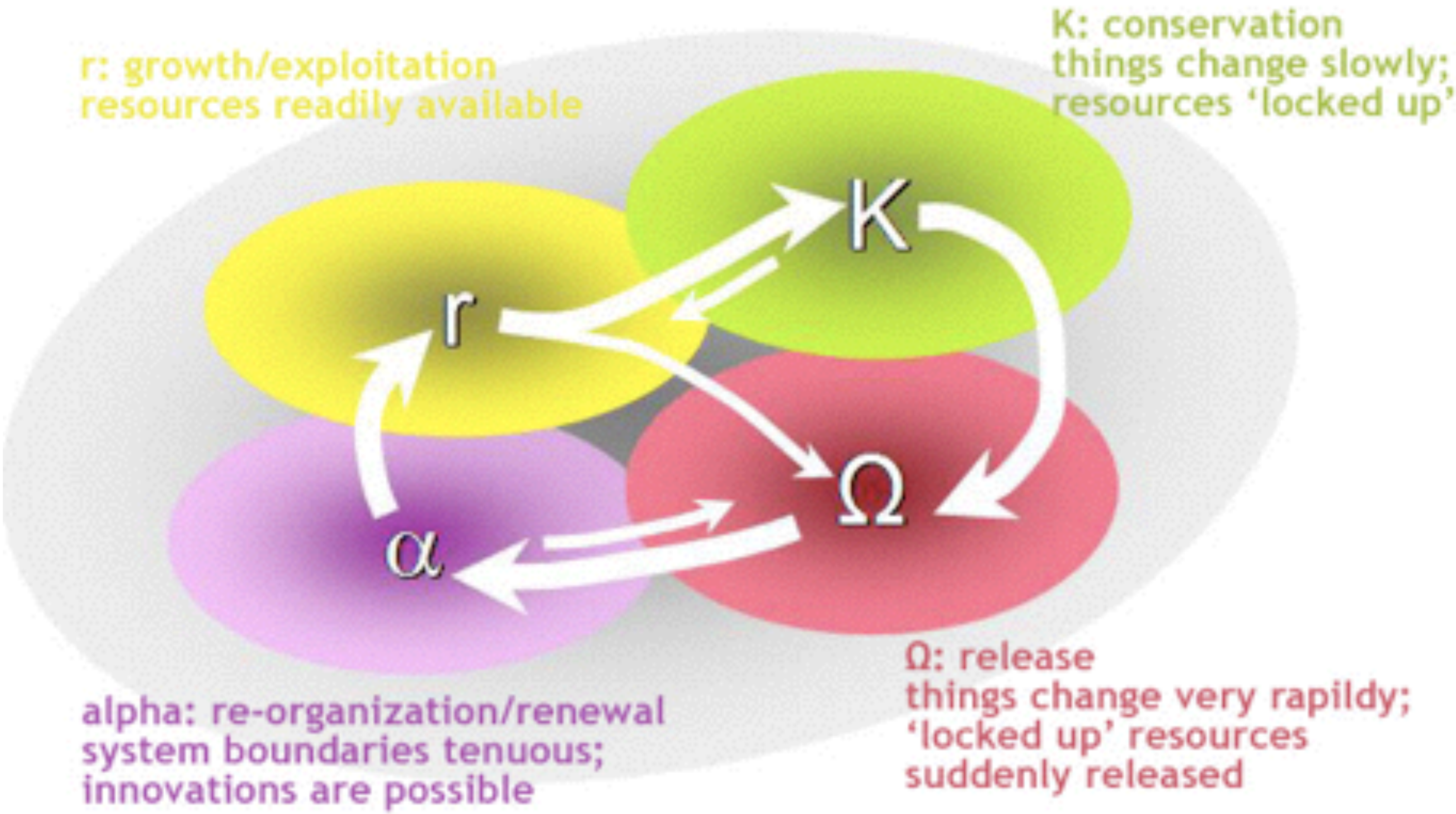


Figure 3. The adaptive cycle, as a simple loop, showing possible changes between phases.

http://www.resalliance.org/564.php

<u>**Adaptability**</u>:
Viewed as
Elementary or ***Complex*** concept..

<u>**Adaptability**</u>:

Type: **Elementary** Quality Requirement.

Scale: Time needed to adapt a defined [System] from a defined [**Initial State**] to another defined [**Final State**] using defined [**Means**].

<u>**Adaptability**</u>:

Type: **Complex** Quality Requiremer

Includes: *{Flexibility, Upgradeabili*

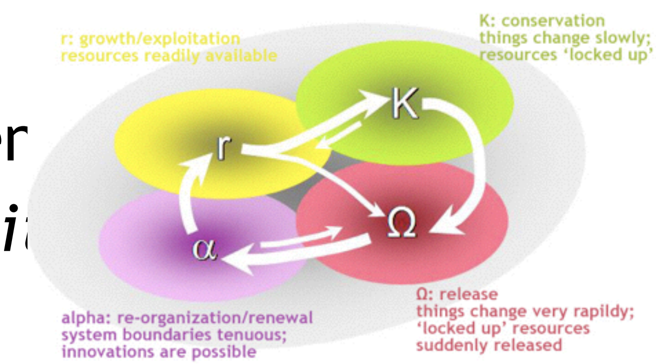


Figure 3. The adaptive cycle, as a simple loop, showing possible changes between phases.

“No system can be understood or managed by focusing on it at a *single* scale.”

Multiple scales and cross-scale effects - "Panarchy"

No system can be understood or managed by focusing on it at a single scale.

- **All systems (and SESs especially) exist and function at multiple scales of space, time and social organization,**
  - **and the interactions across scales are fundamentally important in determining the dynamics of the system at any particular focal scale.**
  - **This interacting set of hierarchically structured scales has been termed a "panarchy" (Gunderson and Holling 2003).**

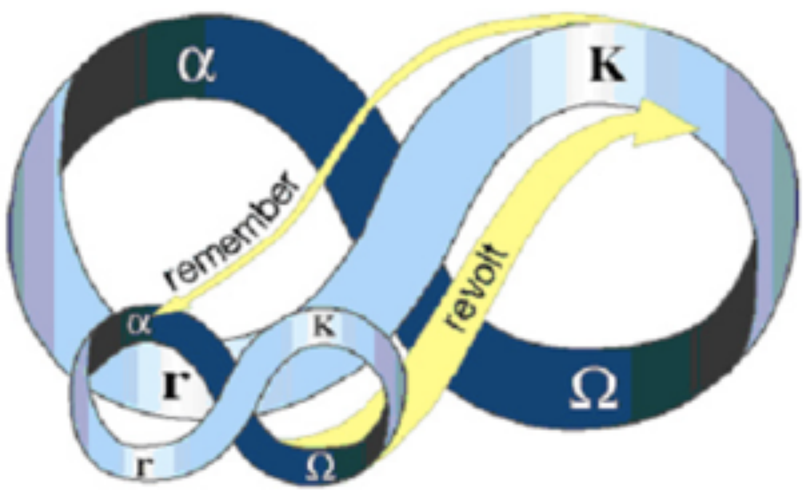


Figure 4. "Panarchy" - nested adaptive cycles, with influences between scales.

http://www.resalliance.org/564.php

Flexibility:

Gist: 'Flexibility' concerns the

'in-built' ability of the system

to adapt,

or to be adapted,

by its users,

to suit conditions

(without any fundamental system modification

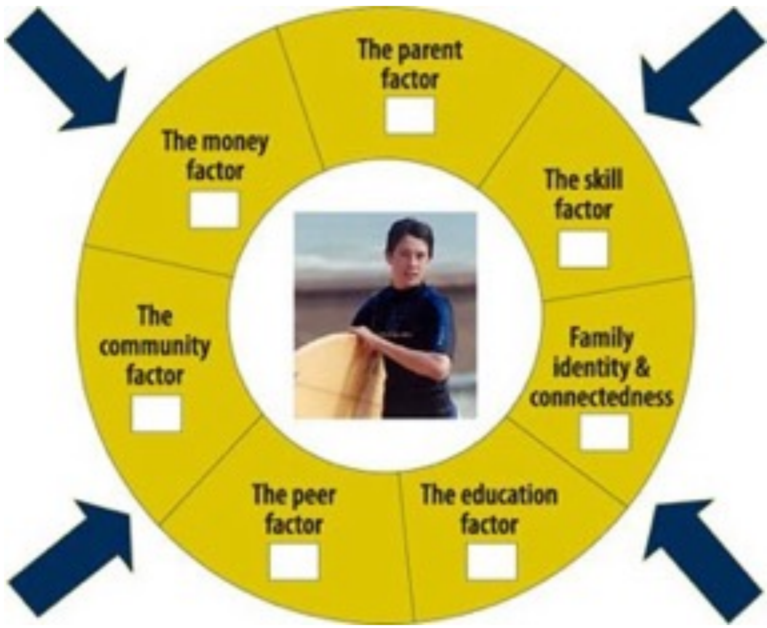
by system development).

Type: Complex Quality Requirement.

Includes: {Connectability, Tailorability}.

See next 2 slides!

Possible Synonyms: Resilience, Robustness



Connectability:

'The cost to interconnect the system to its environment.'

Gist: The cost of connecting **one set of interfaces** to defined **environments** with **other interfaces**

Part Of: Flexibility.

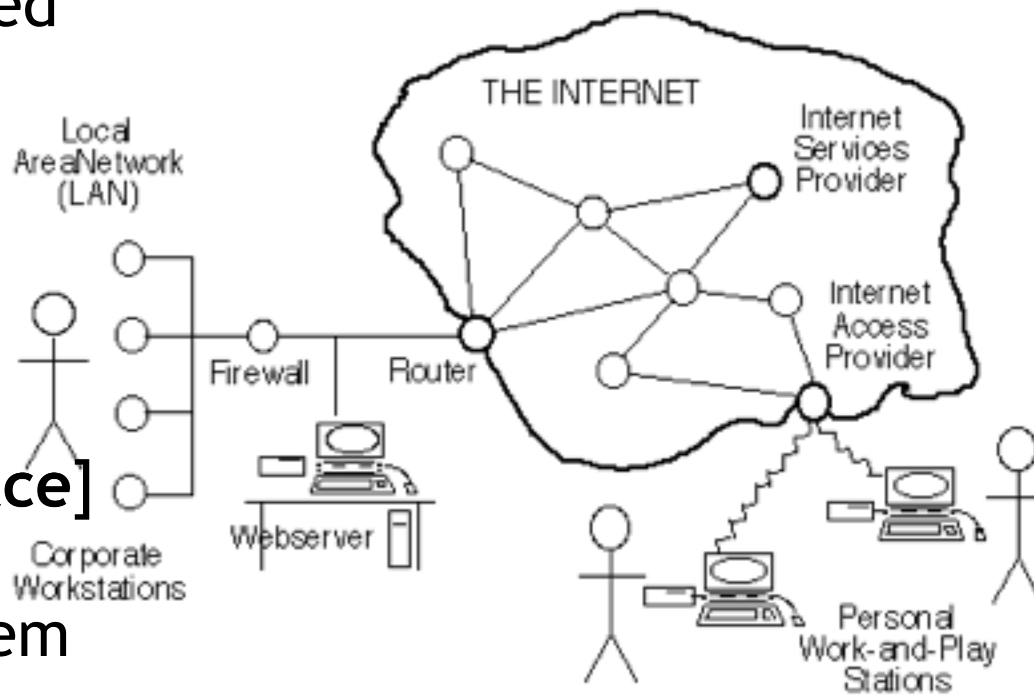
Scale: the **Effort** needed

to connect a defined [**Home Interface**]

to a defined [**Target Interface**]

using defined [**Methods**]

with minimum allowed system [**Degradation**].



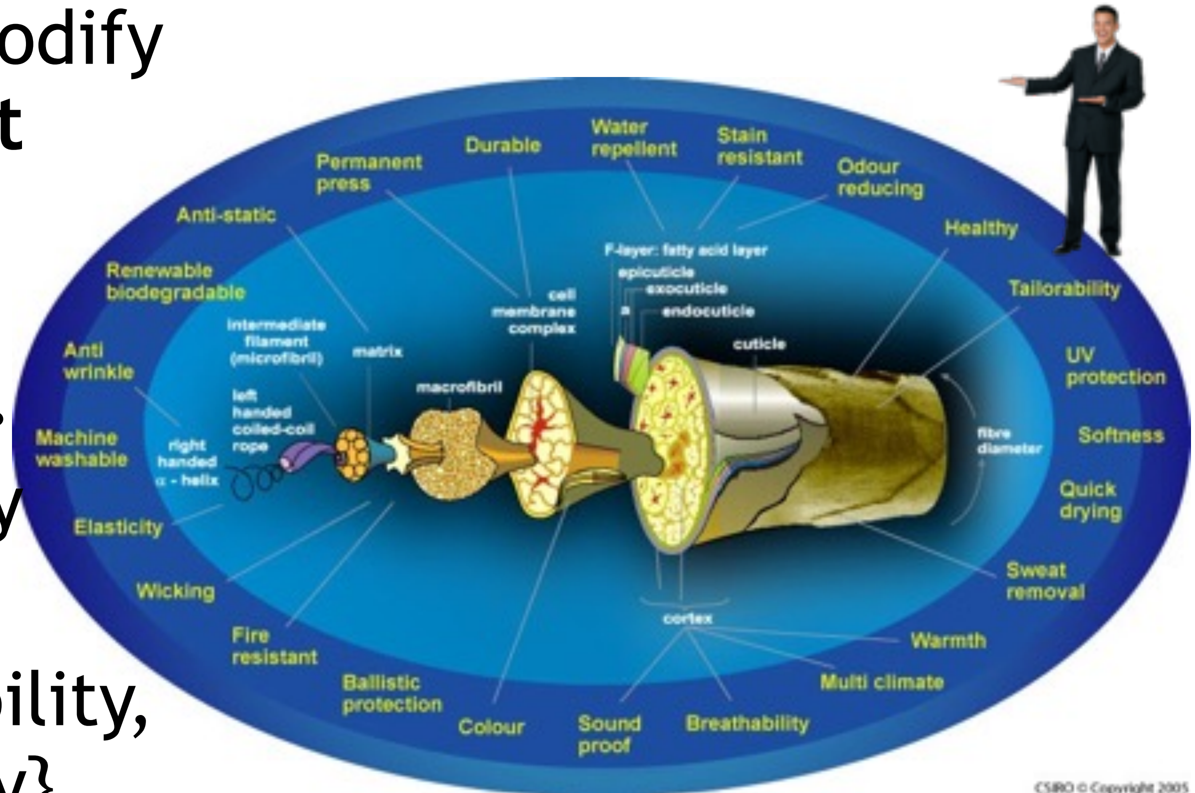
Tailorability:

Gist: The **cost** to modify the system to **suit** defined **future** conditions.

Part Of: Flexibility.

Type: *Complex* Quality Requirement.

Includes: {Extendibility, Interchangeability}.



Multiple Attributes of Wool Fiber !

Extendibility: Scalability

Extendibility:

Part Of: Tailorability.

Synonym: Scalability.

Scale: The **cost** to add to
a defined [**System**]
a defined [**Extension Class**]
and defined [**Extension Quantity**]
using a defined [**Extension Means**].

*"In other words, add such things as a new user or
a new node."*

Type: *Complex* Quality Attribute.

Includes: {Node Addability,
Connection Addability,
Application Addability,
Subscriber Addability}.

<u>Interchangeability</u>:
‘The cost to modify use of system components.’

<u>**Interchangeability**</u>

Gist: This is concerned with the ability to modify the system, to switch from using a certain set of system components, to using another set.

Part Of: Tailorability.

Type: `Elementary` Quality Attribute.

“For example, this could be a daily occurrence switching system mode from day to night use.”

Scale: the Effort needed to
Successfully,
without Intolerable Side Effects,
replace a defined [Initial Set] of components,
with a defined [Replacement Set] of system components,
using defined [Means].

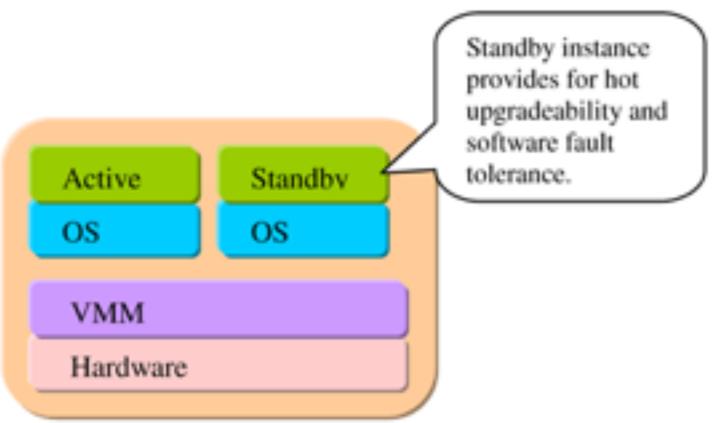
Upgradeability: ‘The cost to modify the system fundamentally; either to install it, or to change out system components.’

Upgradeability:

Gist: This concerns the ability of the system to be modified by the system developers or system support in planned stages (as opposed to unplanned maintenance or tailoring the system).

Type: *Complex* Quality Requirement.

Includes: {Installability, Portability, Improveability}.



Installability: ‘The cost to install in defined conditions.’

Pattern: This concerns installing the system code and also, installing it in new locations to extend the system coverage. Could include conditions such as the installation being carried out by a customer or, by an IT professional on-site.

Portability: ‘The cost to move from location to location.’

Scale: The cost to transport a defined [System] from a defined [Initial Environment] to a defined [Target Environment] using defined [Means].

Type: Complex Quality Requirement.

Includes: {Data Portability,
Logic Portability,
Command Portability,
Media Portability}.

Improveability: ‘The cost to enhance the system.’

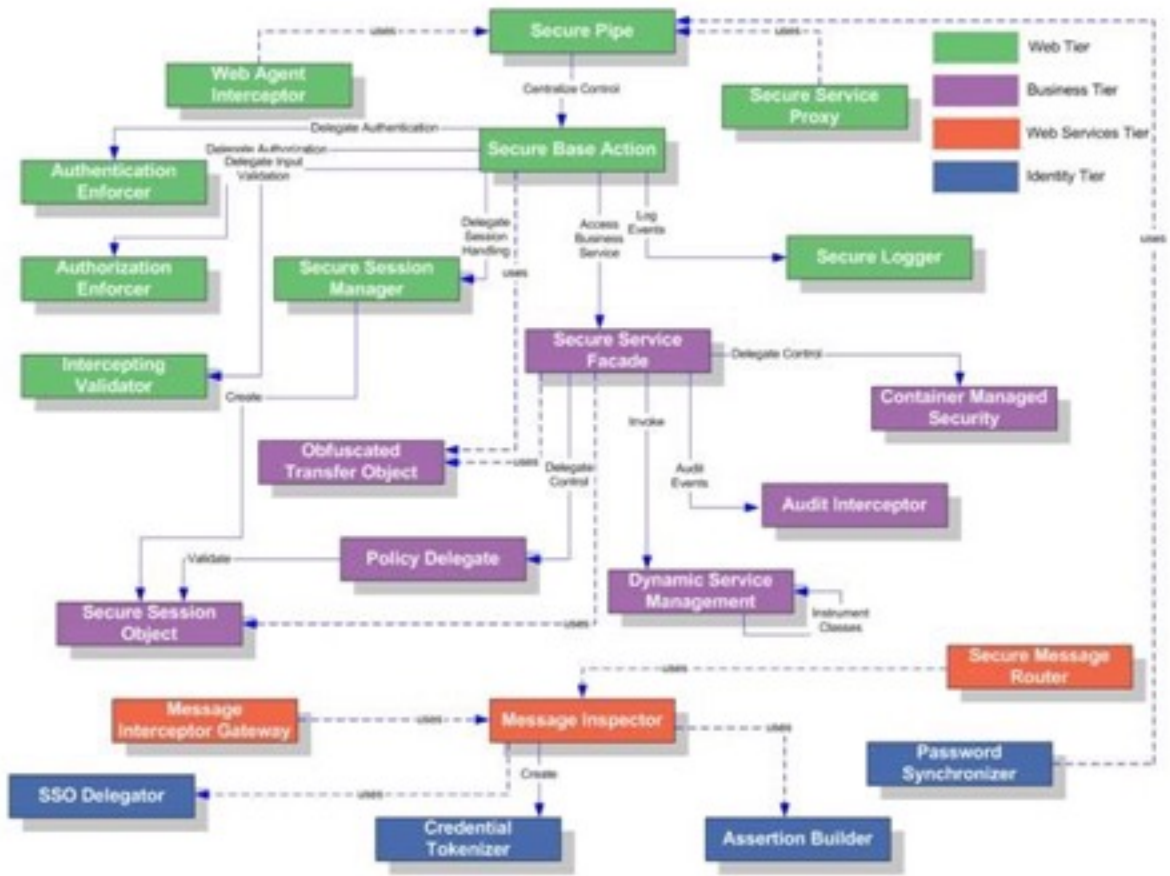
Gist: The ability to replace system components with others, which possesses improved (function, performance, cost and/or design) attributes.

Scale: The cost to add to a defined [System] a defined

This Basic 'Adaptability' Pattern Was Successfully Applied

- Hopefully this set of patterns
  – gives you a departure point
  – for defining those maintenance attributes
  – you might want to control, quantitatively.

- The above adaptability definition
  – was use to co-ordinate the work
    - of 5,000 software engineers,
    - and 5,000 hardware engineers,
    - in UK,
    - in bringing out a new product line at a computer manufacturer.
    - Where 'Adaptability' was the Number One Product Characteristic
  – The Company became profitable for the next 14 years..



Security Patterns

The Software Architect Role in Maintainability

The role of the software architect is:

- to participate in **clarification of the requirements** that will be used as inputs to their architecture process.
- to insist that the requirements are **testably clear**: that means with defined and agreed scales of measure, and defined required levels of performance.
- to then **discover appropriate architecture**,
  - capable of delivering those levels of performance, hopefully within resource constraints, and
- **estimate** the probable **impact** of the architecture,
  - on the requirements (Impact Estimation)
- **define** the architecture in such **detail**
  - that the intent **cannot be misunderstood** by implementers,
  - and the desired **effects** are bound to be **delivered**.
- **monitor** the developing system as the architecture is applied in practice,
- and **make** necessary **adjustments**.
- finally **monitor** the **performance characteristics** throughout the lifetime of the system,
  - and make necessary **adjustments** to requirements
  - and to architecture,
  - in order to **maintain** needed system **performance** characteristics.

Evaluating Maintainability Designs Using Impact Estimation

	A	B	C	D	E	F	G	BX	BY	BZ	CA
1											
2		Current Status	Improvements		Goals			Step9			
3								Recoding			
4								Estimated impact		Actual impact	
5		Units	Units	%	Past	Tolerable	Goal	Units	%	Units	%
6					Usability.Replacability (feature count)						
7		1,00	1,0	50,0	2	1	0				
8					Usability.Speed.NewFeaturesImpact (%)						
9		5,00	5,0	100,0	0	15	5				
10		10,00	10,0	200,0	0	15	5				
11		0,00	0,0	0,0	0	30	10				
12					Usability.Intuitiveness (%)						
13		0,00	0,0	0,0	0	60	80				
14					Usability.Productivity (minutes)						
15		20,00	45,0	112,5	65	35	25	20,00	50,00	38,00	95,00
20					Development resources						
21			101,0	91,8	0		110	4,00	3,64	4,00	3,64

- *See Powerpoint Notes for detailed written comment.*
-

Architecture Level Impact Estimation Table

		……………………………Deliverables						
		Telephony	Modularity	Tools	User Experience	GUI & Graphics	Security	Enterprise
Business Objective								
Time to Market		10%	10%	15%	0%	0%	0%	5%
Product Range		0%	30%	5%	10%	5%	5%	0%
Platform Technology		10%	0%	0%	5%	0%	10%	5%
Units		15%	5%	5%	0%	0%	10%	10%
Operator Preference		10%	5%	5%	10%	10%	20%	10%
Commoditization		10%	-20%	15%	0%	0%	5%	5%
Duplication		10%	0%	0%	0%	0%	5%	5%
Competitiveness		15%	10%	10%	10%	20%	10%	10%
User Experience		0%	20%	0%	30%	10%	0%	0%
Downstream Cost Saving		5%	10%	0%	10%	0%	0%	5%
Other Country		5%	10%	0%	10%	5%	0%	0%
Total Contribution		90%	80%	55%	85%	50%	65%	55%
Cost (£M)		0.49	1.92	0.81	1.21	2.68	0.79	0.60
Contribution to Cost Ratio		**184**	42	68	70	19	82	92

- See PPT Notes

Engineering "Maintainability": Green Week
Weekly 'Refactoring' at Confirmit

Current Status		Improvement	Goals			Step 6 (week 14)		Step 7 (week 15)	
	Units		Past	Tolerable	Goal	Estimated Impact	Actual Impact	Estimated Impact	Actual Impact
	100,0	100,0	0	80	100			100	100
Speed									
	100,0	100,0	0	80	100	100	100		
Maintainability.Doc.Code									
	100,0	100,0	0	80	100	100	100		
InterviewerConsole									
NUnitTests									
	0,0	0,0	0	90	100				
PeerTests									
	100,0	100,0	0	90	100			100	100
FxCop									
	0,0	10,0	10	0	0				
TestDirectorTests									
	100,0	100,0	0	90	100			100	100
Robustness.Correctness									
	2,0	2,0	0	1	2	2	2		
Robustness.BoundaryConditions									
	0,0	0,0	0	80	100				
Speed									
	0,0	0,0	0	80	100				
ResourceUsage.CPU									
	100,0	0,0	100	80	70	70			
Maintainability.Doc.Code									
	100,0	100,0	0	80	100	100	100		
SynchronizationStatus									
NUnitTests									

- Speed
- Maintainability
- Nunit Tests
- PeerTests
- TestDirectorTests
- Robustness.Correctness
- Robustness.Boundary Conditions
- ResourceUsage.CPU
- Maintainability.DocCode
- SynchronizationStatus

POT-SHOTS — Brilliant Thoughts in 17 words or less

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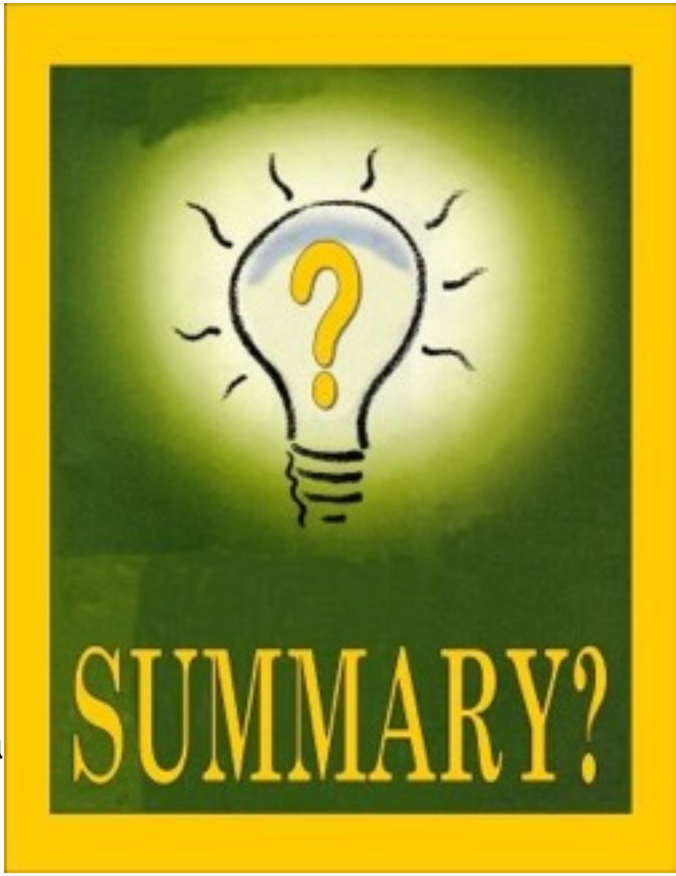
Lecture Summary

- The **many** types of maintainability – ease of change – characteristics needed in large scale or critical software,
  - can be **architected**
  - and **engineered** using **numeric** measurement
  - and sound engineering **principles**,
  - instead of conventional small scale programming culture intuition.
- **Real** systems engineers will move towards this mode of 'real' software engineering.
- We cannot continue to have the craft of programming culture, dominate our systems engineering practices –
  - because software has become too critical a component of every major system.
  - The real engineers have to take **control**.
  - The **programmers will not wake up** without encouragement from real engineers.



References

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Gilb, Tom, Competitive Engineering, A Handbook For Systems Engineering, Requirements Engineering, and Software Engineering Using Planguage, ISBN 0750665076, **2005**, Publisher: Elsevier Butterworth-Heinemann. Sample chapters will be found at Gilb.com.

Chapter 5: Scales of Measure:
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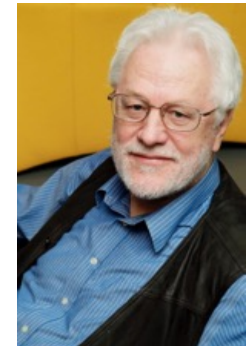
[Dart 93] Susan Dart , Alan M. Christie , Alan W Brown
A Case Study in Software Maintenance, Technical Report CMU/SEI-93-TR-8 , ESC-TR-93-185 , June 1993

Chris Inacio: Software Fault Tolerance, Carnegie Mellon University
18-849b Dependable Embedded Systems, Spring 1998
http://www.ece.cmu.edu/~koopman/des_s99/sw_fault_tolerance/

Google N-Version Software for more information on distinct software and N-version software.

BIOGRAPHY



Tom Gilb is an international consultant, teacher and author.

His 9th book is '**Competitive Engineering**: A Handbook For Systems Engineering, Requirements Engineering, and Software Engineering Using Planguage' (August 2005 Publication, Elsevier) which is a definition of the planning language 'Planguage'.

- He works with major multinationals such as Credit Suisse, Schlumberger, Bosch, Qualcomm, HP, IBM, Nokia, Ericsson, Motorola, US DOD, UK MOD, Symbian, Philips, Intel, Citigroup, United Health, and many smaller and lesser known others. See www.Gilb.com . He can be reached at: Planguage@mac.com

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