Grid Reliability/ Grid Dependability

Turning dependability of the grid from “art” into “science”

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University of Cyprus & EKEFE Demokritos
March 28th, 2007

13/3/2005 @ 23:15

Google **Error**

Server Error

The server encountered a temporary error and could not complete your request.

Please try again in 30 seconds.

citeseer 26/2/2007 - 15:26

The connection has timed out

The server at citeseer.nj.nec.com is taking too long to respond.

- The site could be temporarily unavailable or too busy. Try again in a few moments.
- If you are unable to load any pages, check your computer's network connection.
- If your computer or network is protected by a firewall or proxy, make sure that Firefox is permitted to access the Web.

Try Again

arxiv.org 23/3/2007 - 17:56

The connection has timed out

The server at arxiv.org is taking too long to respond.

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- If you are unable to load any pages, check your computer's network connection.
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wikipedia.org 26/2/2007 - 15:52

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The server at en.wikipedia.org is taking too long to respond.

- The site could be temporarily unavailable or too busy. Try again in a few moments.
- If you are unable to load any pages, check your computer's network connection.
- If your computer or network is protected by a firewall or proxy, make sure that Firefox is permitted to access the Web.

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citeseer 25/2/2007 - 13:04

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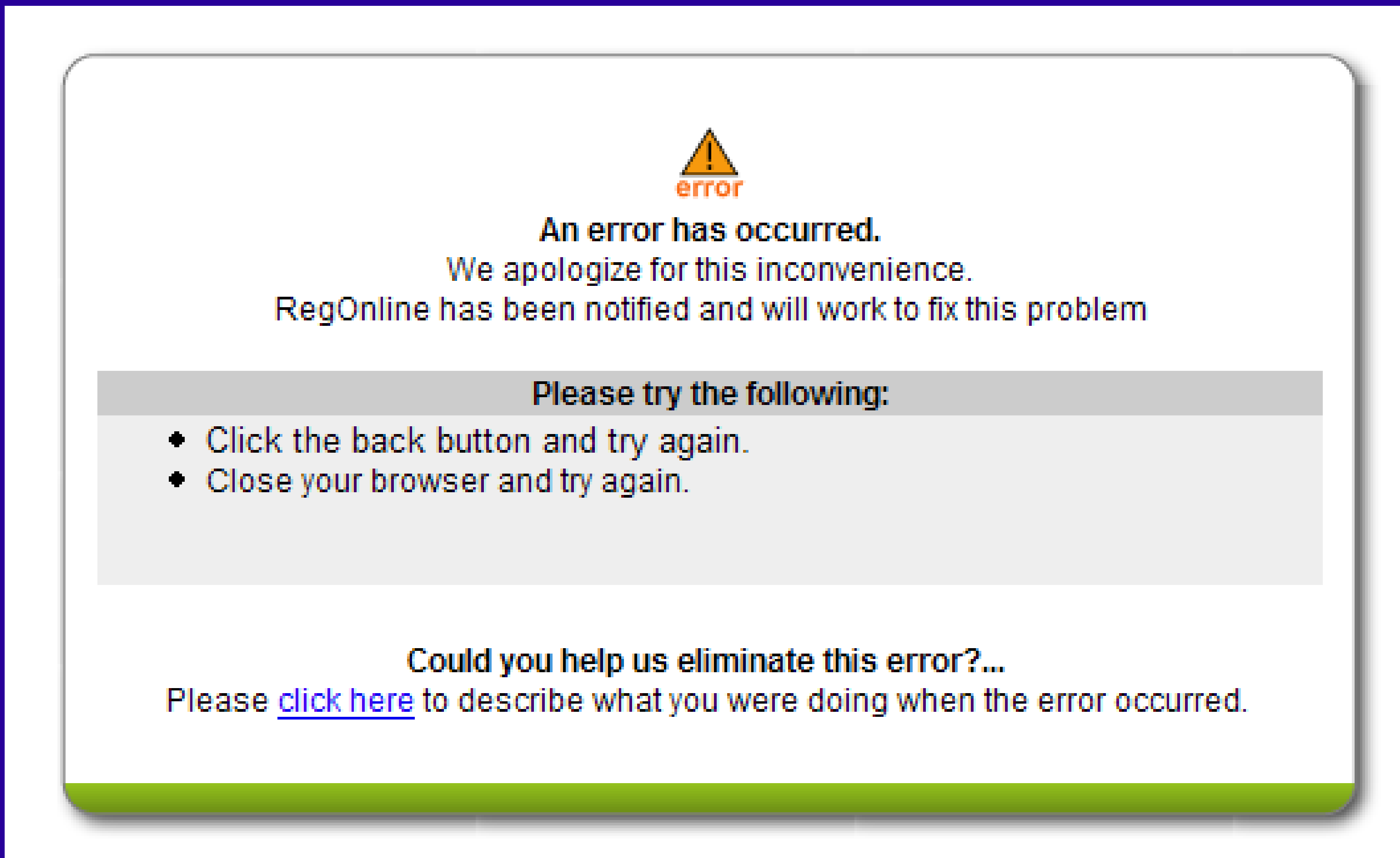

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http://webmail.cs.ucy.ac.cy/horde/imp/message.php?index=302

Getting Started Latest Headlines

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INBOX: Provlimata stin prosvasi stis diadiktiakes efarmog... (302 of 305)

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Date: Mon, 26 Mar 2007 12:14:44 +0300

From: Computer Centre <computer.centre@ucy.ac.cy>

To: UCYALL@ucy.ac.cy

Subject: Provlimata stin prosvasi stis diadiktiakes efarmoges

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Θα θέλαμε να σας ενημερώσουμε ότι τα προβλήματα που παρατηρούνται στην πρόσβαση προς τις Διαδικτυακές Εφαρμογές (π.χ. Σύστημα Βαθμολογιών, Σύστημα Κρατήσεων, Ημερήσιος Τύπος, Υπηρεσίες Καταλόγου) οφείλονται σε τεχνικό πρόβλημα που έχει παρουσιαστεί στον εξυπηρετητή. Καταβάλλονται προσπάθειες για επίλυση του προβλήματος.

Για πληροφορίες μπορείτε να επικοινωνείτε με το γραφείο υποστήριξης (help desk) της Υπηρεσίας Πληροφορικών Συστημάτων στο εσωτερικό τηλέφωνο 4444 ή στο ηλεκτρονικό ταχυδρομείο helpdesk@ucy.ac.cy .

(Σημειώστε ότι το παρόν σημείωμα έχει τοποθετηθεί και στον πίνακα ανακοινώσεων της ΥΠΣ στην διεύθυνση http://noticeboard.ucy.ac.cy/cc/public/sunsrv_memo_26_3_2007.pdf)

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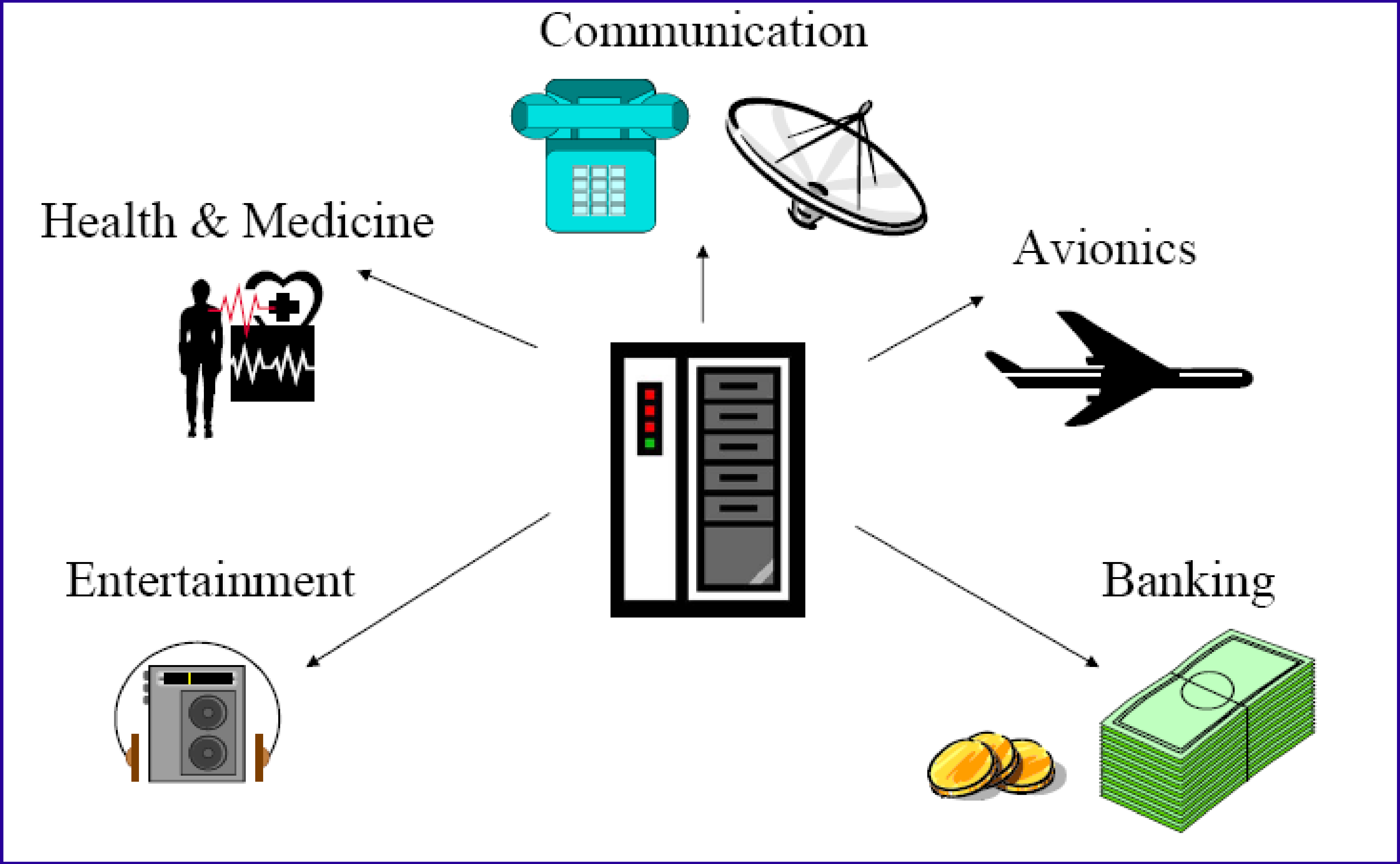
Any Questions?

What is Dependability?

Dependability
is the ability to deliver service
that can justifiably be trusted.

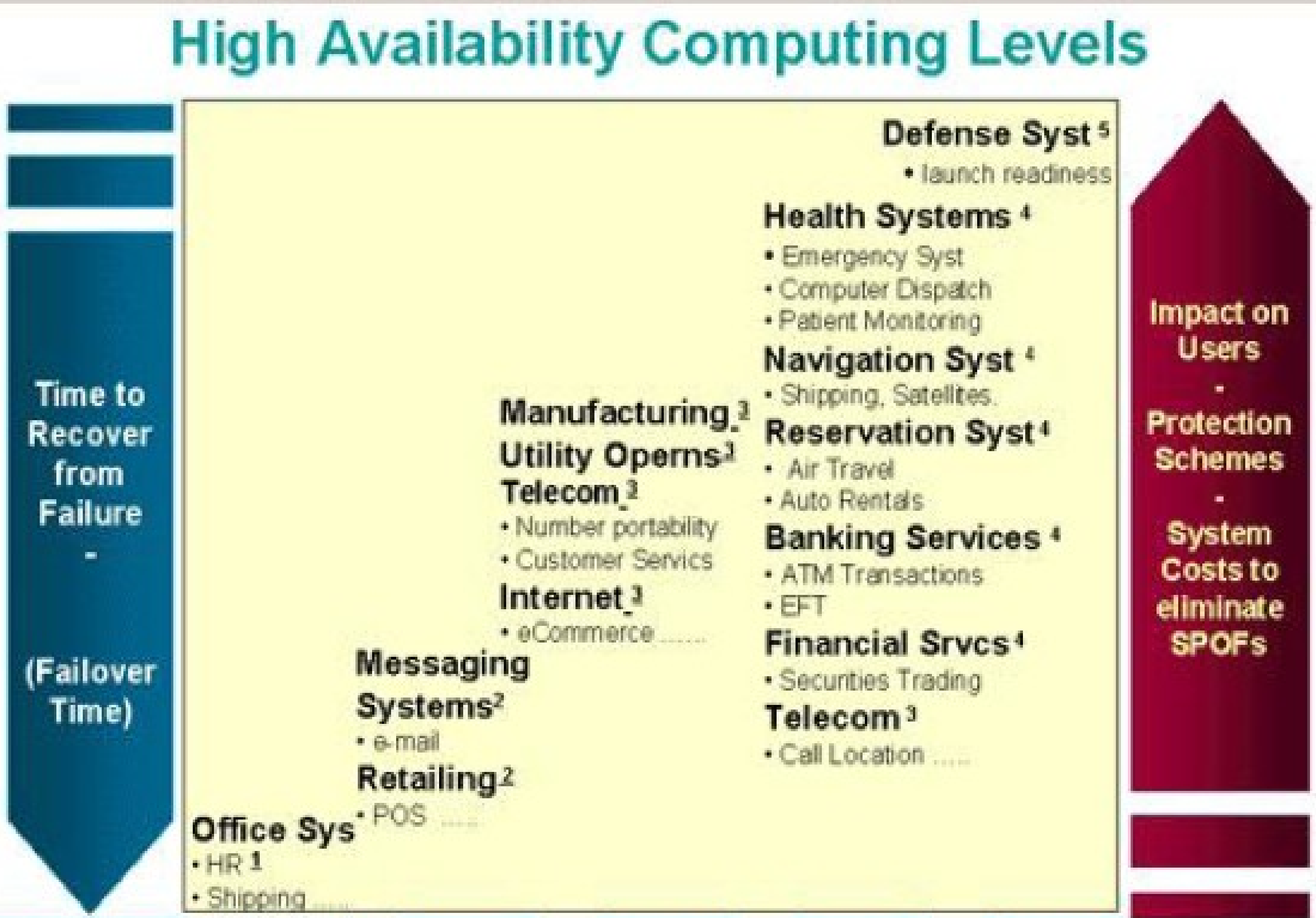
Why Dependability in computing?

Ref. http://www.ee.duke.edu/~kst



Varying levels of Dependability

Ref. http://www.ee.duke.edu/~kst



Avail. Level	HAL-2	HAL-3	HAL-4	HAL-5	HAL-6
Downtime/ yr.	~ 4 day	~ 8 Hrs	~ 1 Hr	~ 5 min	~ 30 sec
Time /Outage	~ 4 hrs	~ 1 Hr	~10 mts	~30 sec	~ 10 sec

Ultra-high-availability domains

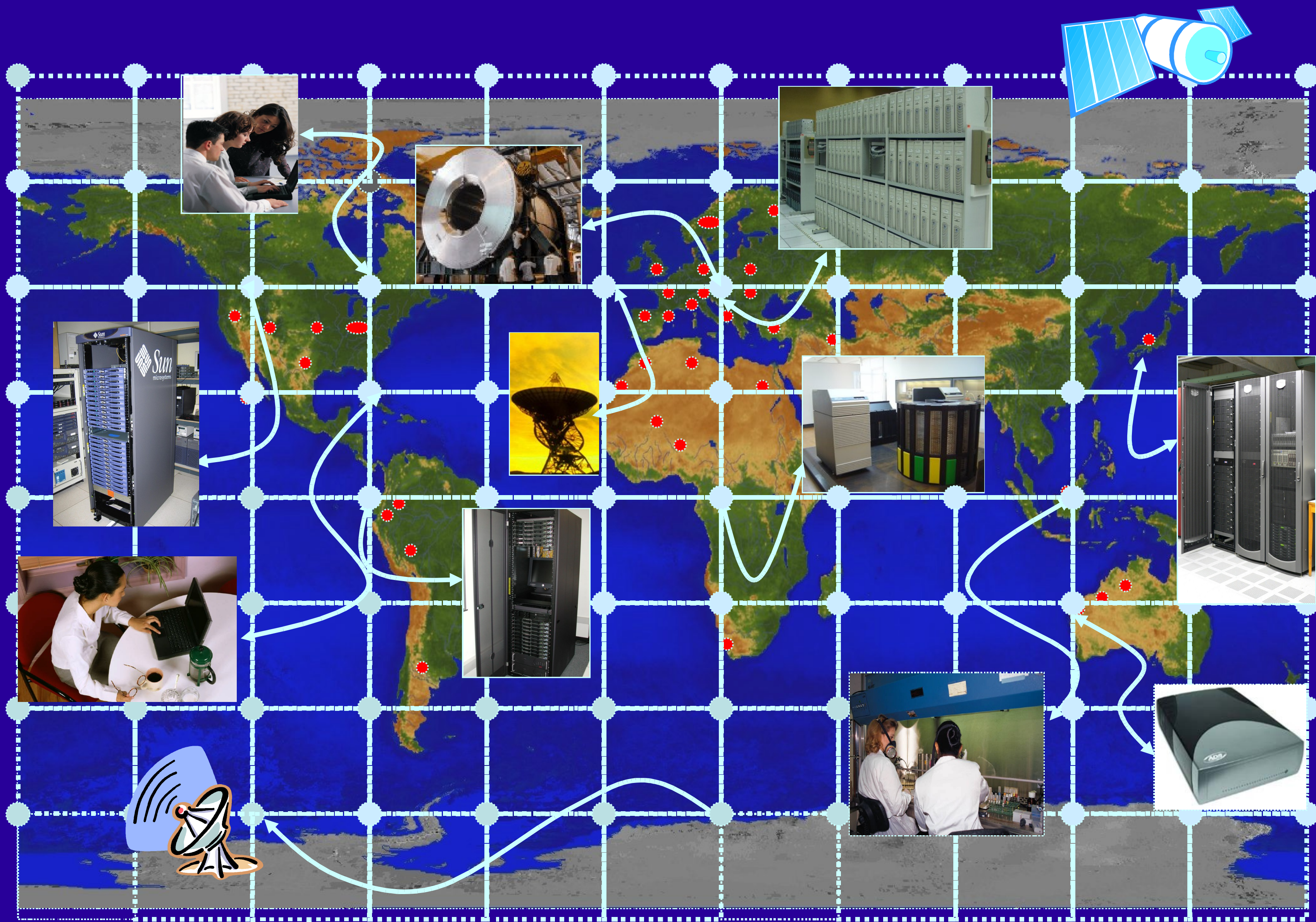
- Critical reliability applications are applications which by virtue of their nature require exceptional reliability standards or, seek zero opportunities for downtime: >"6-nines" availability (less often than 10^{-6})
- Life-critical, long-life, safety critical domains
  - Aviation industry (aircraft control)
  - Space missions
  - Defense systems
  - Nuclear systems
  - Hospital and medical apparatus
  - Telecommunications for previous applications

Grid: New frontiers for e-science

Ref. http://www.gridcafe.org/

Grid: new problems, too!

Because of many chances for service failures



Terminology of Dependability

- Lots of opportunity for learning new words!
  - Dependability, reliability, availability, safety integrity, maintainability, confidentiality, etc. Collectively referred as "-ilities" of a system
  - MTBF, MTTF, MTTR, RBD, FTA, FMEA, FMECA
- In the past, lack of standardization created confusion about exact terms' meaning, esp. frequent, improbable, remote events etc. Even these words are now precisely defined.
- We decided to comply with IFIP WG10.4 terminology and this is the standard we adhere to, during the current material.

Reference: IFIP Working Group 10.4

Terminology of Grid Dependability

MTTF + MTTR = A system cycle of uptime and downtime

- MTTF : Mean Time to Failure
  An estimate of the average, or mean time until a design or component's first failure, or disruption in the operation of the product, process, procedure, or design occurs.

- MTTR : Mean Time to Recover
  The average time that a device will take to recover from a non-terminal failure.
  Useful measure of reliability by itself, in some applications or circumstances

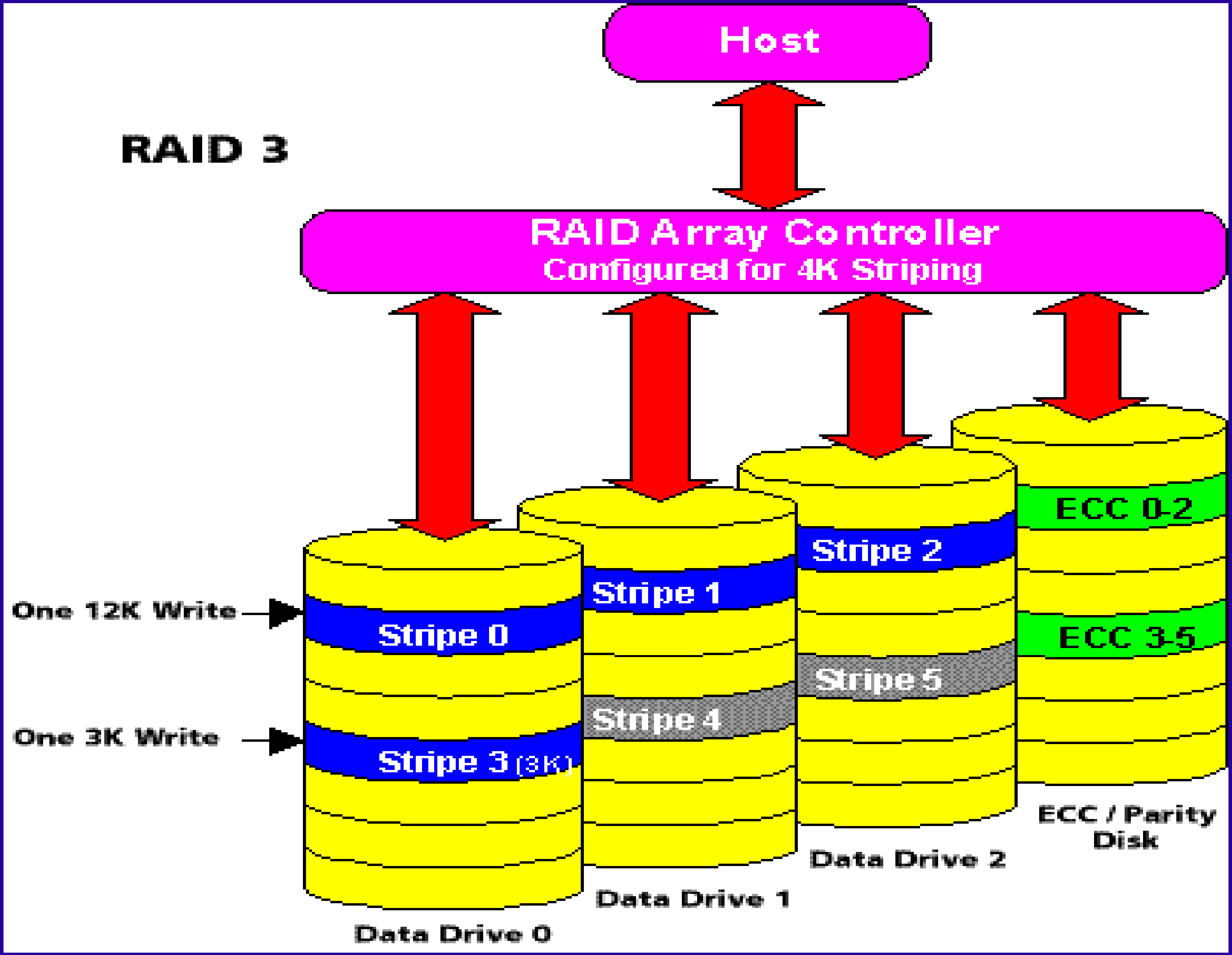
Terminology of Grid Dependability: Availability

$$A = \frac{E[\text{Uptime}]}{E[\text{Uptime}] + E[\text{Downtime}]}$$

- In principle, A=MTTF/(MTTF+MTTR)
- Availability measures can vary:
  - Instantaneous
  - Limiting
  - Average
  - Limiting average
- Theoretical background has been laid by Barlow and Proschan [1975], Lie, Hwang, and Tillman [1977], and Nachlas [1998]

Terminology of Grid Dependability:

Thinking of MTTF/MTTR concepts on a RAID array



Grid Dependability vs Reliability

Enter definitions' war, danger zone

- Reliability has been used, so far, as an umbrella domain term and in a generic sense
- Reliability is also a precisely defined mathematical function (ITU-T Rec. E.800)

- To remove confusion...
  Dependability is the term which has been promoted recently as the domain umbrella term. Reliability is best be used only as the precisely defined mathematical function

Reference: IFIP Working Group 10.4

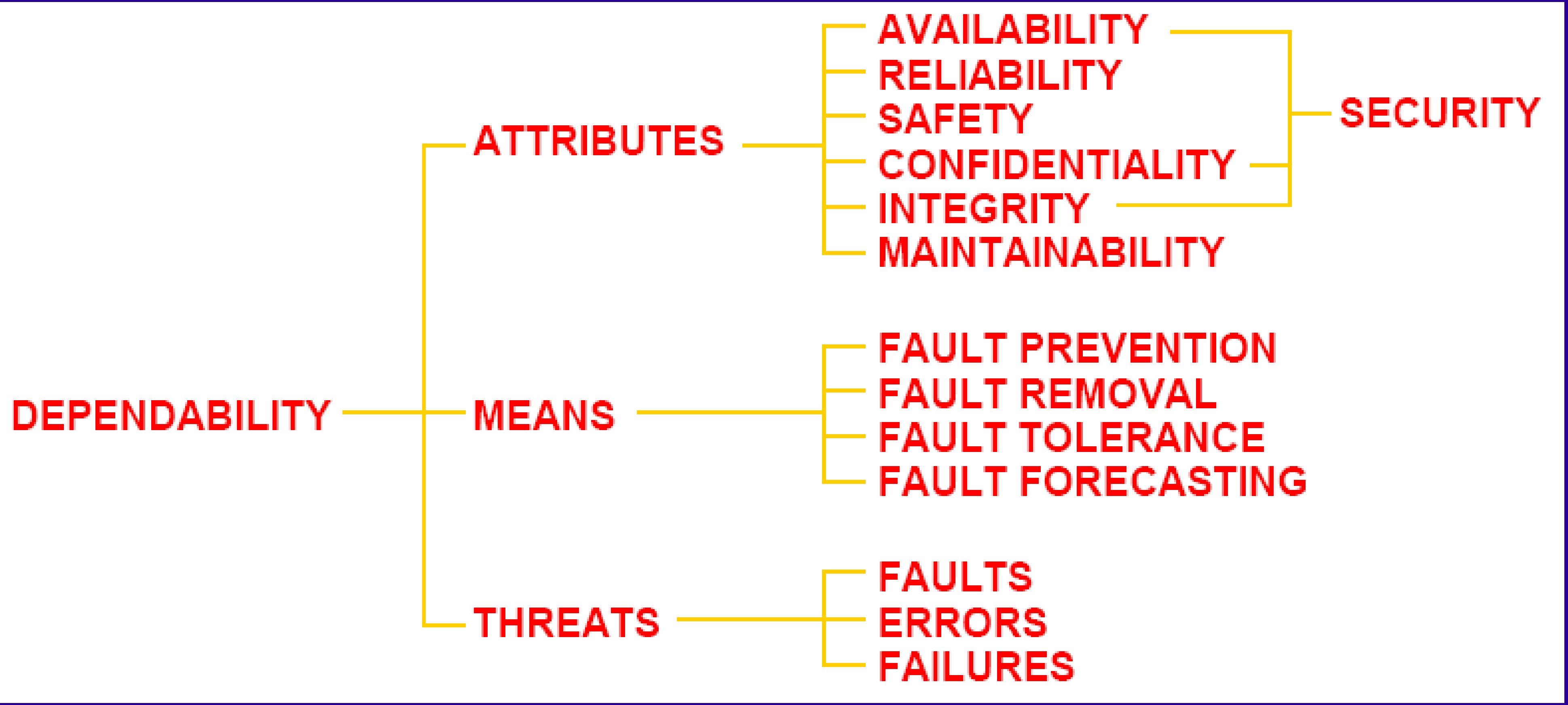
Terminology: Dependability

- *"The collective term used to describe the availability performance and its influencing factors : reliability performance, maintainability performance and maintenance support performance"*
  Quality concepts and terminology, part 1, : Generic Terms and definitions, Document ISO/TC 176/SC 1 N 93, Feb. 1992

- *"The extent to which the system can be relied upon to perform exclusively and correctly the system task(s) under defined operational and environmental conditions over a defined period of time, or at a given instant of time"*
  Industrial-Process Measurement and Control – Evaluation of System Properties for the Purpose of System Assessment, Part 5: Assessment of System Dependability, Draft, Publication 1069-5, Int'l Electrotechnical Commission (IEC) Secretariat, Feb. 1992

IFIP WG10.4 Taxonomy

Ref. Fundamental Concepts of Dependability, Avizienis-Laprie-Randell



Attributes of Dependability

- Availability: Readiness for correct service
- Reliability: Continuity of correct service
- Safety: Absence of catastrophic consequences on the user & the environment
- Confidentiality: the absence of unauthorized disclosure of information (security-oriented)
- Integrity: Absence of improper system alterations
- Maintainability: Ability to undergo modifications and repairs

Reference: "Basic concepts and taxonomy of dependable and secure computing", Avizienis-Laprie-Randell-Landwehr, IEEE Transactions on Dependable and Secure Computing, 2004

Availability versus Reliability

- *"Reliability is the ability of an item to perform a required function under given conditions for a given time interval"*

- *"Availability is the ability of an item to be in a state to perform a required function at a given instant of time or at any instant of time within a given time interval, assuming that the external resources, if required, are provided"*

Reference: ITU-T Recommendation E.800

Means to maintain Dependability

- *Fault prevention:*
  prevent the occurrence or introduction of faults
- *Fault tolerance:*
  avoid service failures in the presence of faults
- *Fault removal:*
  reduce the number and severity of faults
- *Fault forecasting:*
  estimate the present number, the future incidence & the likely consequences of faults

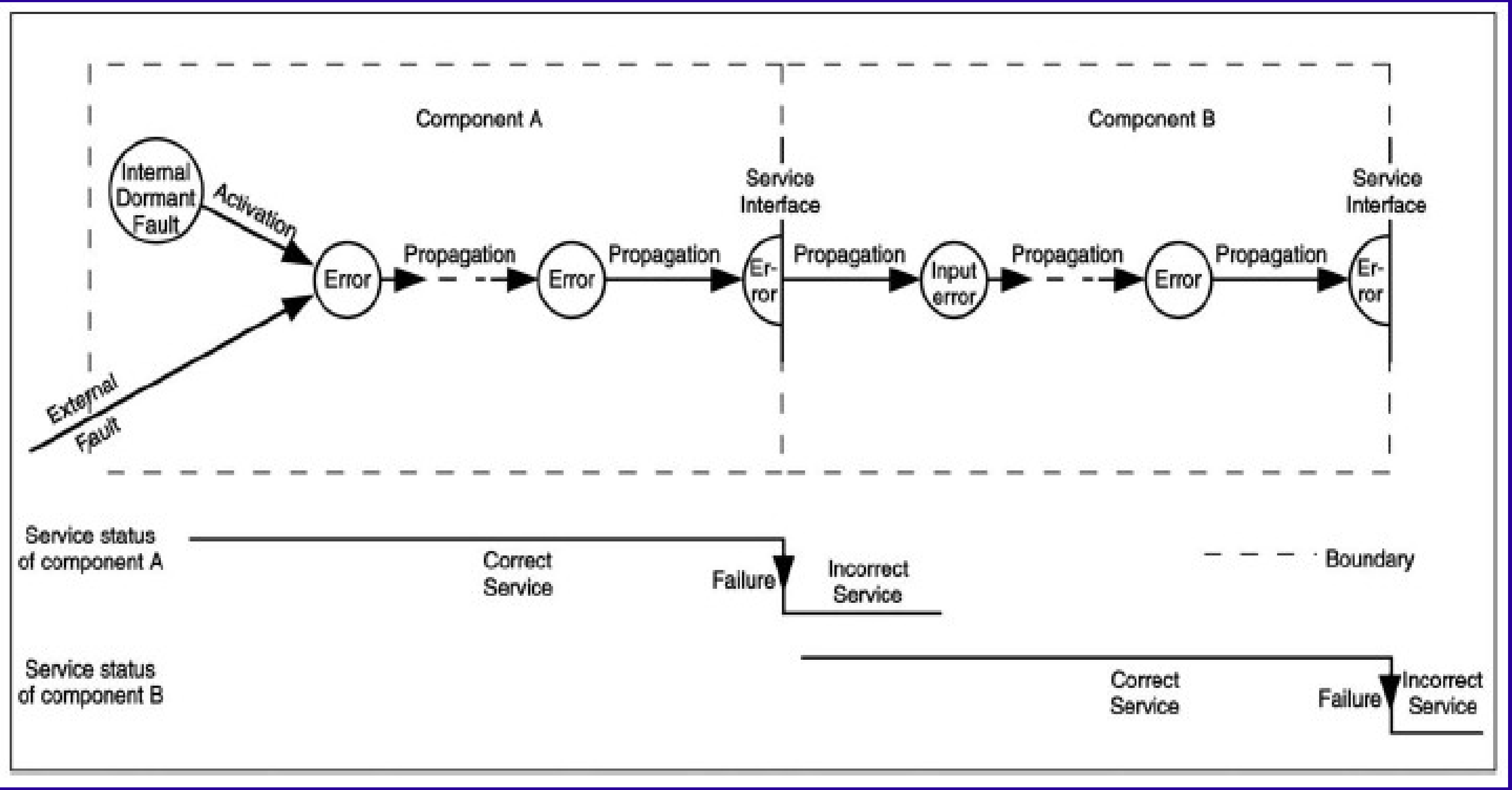
Reference: "Basic concepts and taxonomy of dependable and secure computing", Avizienis-Laprie-Randell-Landwehr, IEEE Transactions on Dependable and Secure Computing, 2004

Faults => Errors => Failures

- *Fault is the adjudged or hypothesized cause of a system malfunction; it can be internal or external, dormant or active.*
- *Error is a deviation from the correct service state for a system or a subsystem.*
- *Failure is the transition event that occurs when the delivered service deviates from the correct service state to an unwanted state.*

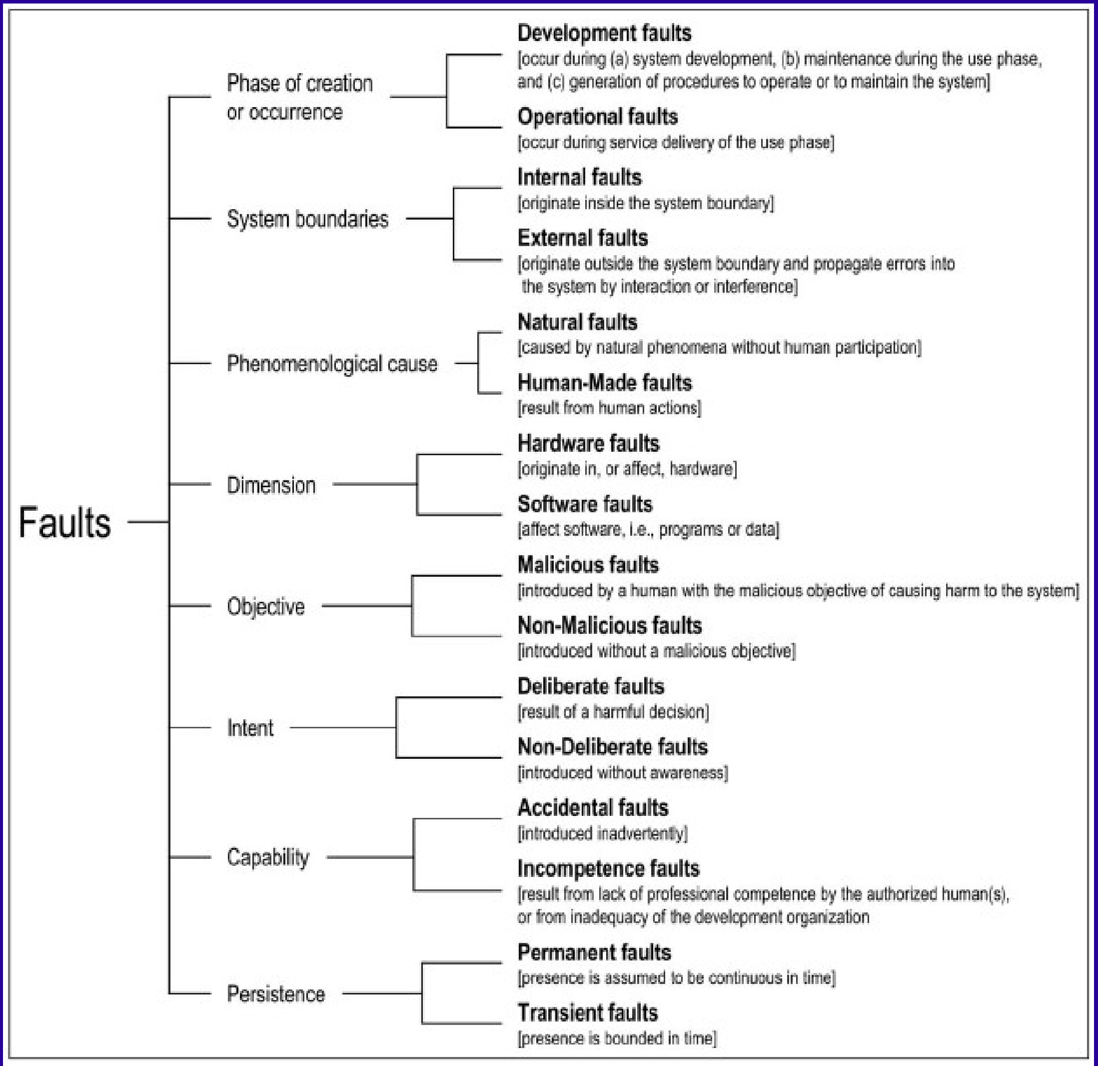
- *A software-system security-vulnerability is an internal dormant fault, that can cause an error during system run-time and result into failure.*

Propagation of faults in a system

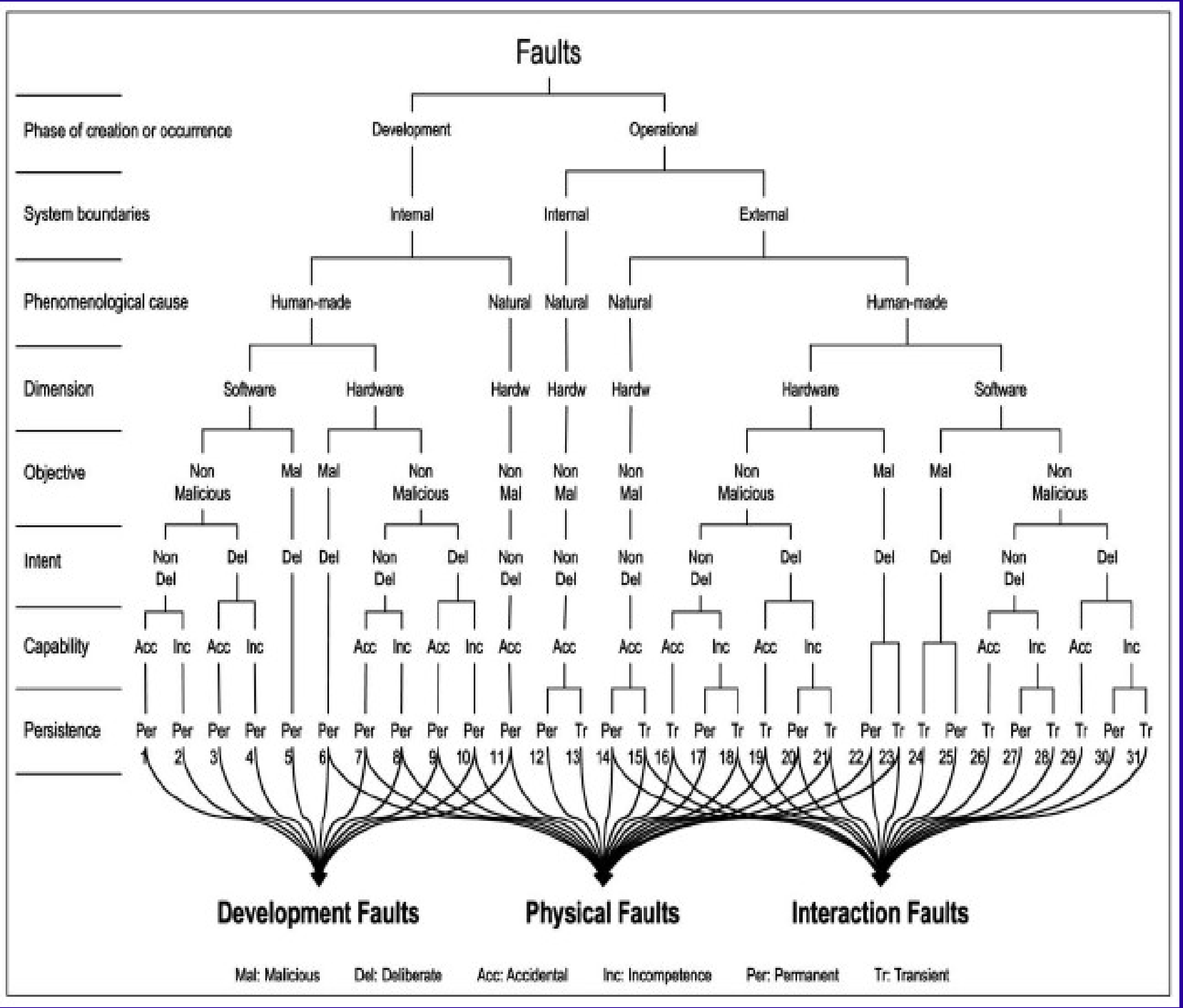


Fault Classes

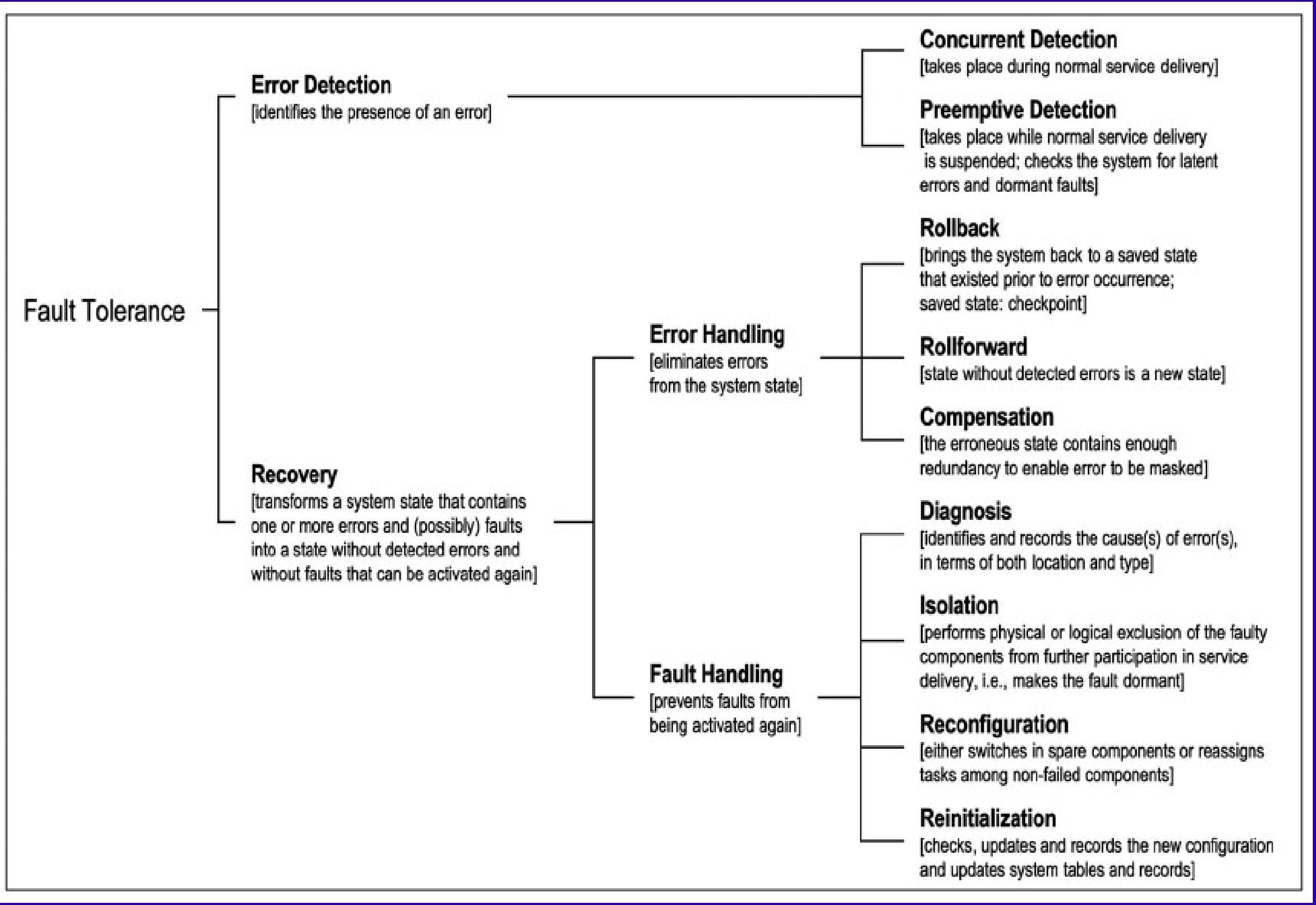
- Occurrence Phase
- System boundaries
- Natural or Human
- Dimension
- Objective
- Intent
- Capability
- Persistence



Tree representation of faults



Fault Tolerance techniques



Probabilistic Risk Assessment tools:

FTA, FMEA, FMECA, PRN, ETA, ESD...

- Fault Tree Analysis (FTA) consequence-to-causes type of analysis
- Failure Mode and Effect Analysis (FMEA) cause-to-consequences type of analysis
- Failure Mode, Effect and Criticality Analysis (FMECA. As above, accounting for criticality.

- Priority Risk Number,
- Event Tree Analysis,
- Event Sequence Diagrams, there are more...

Existing work in Dependability

Taxonomy of research approaches

as a result of a studying ~60 papers!

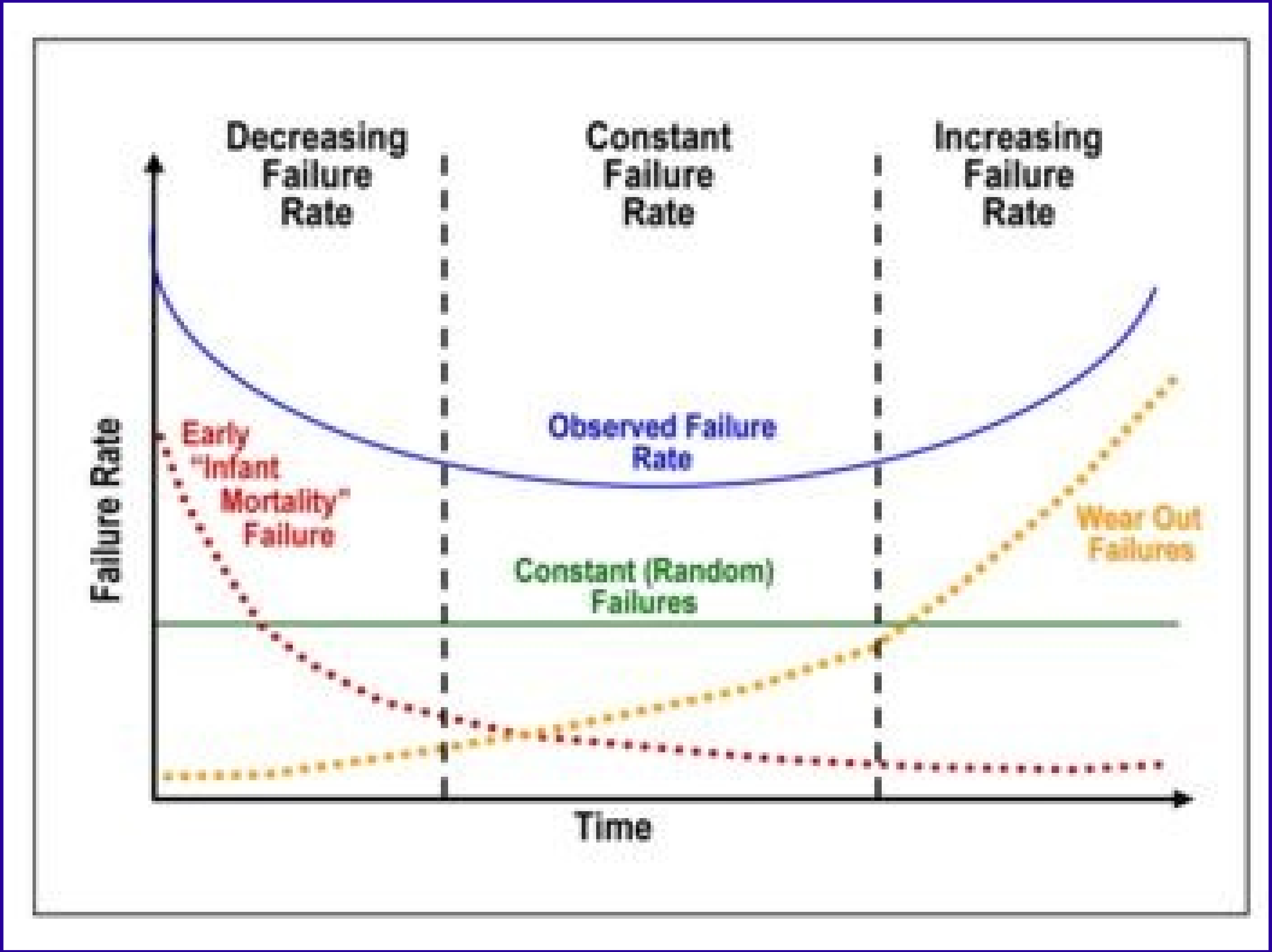
1. Hardware vs Software oriented
2. Design (static) vs Adaptive (dynamic)
3. MTTF (PRA) vs MTTR (ROC)
4. Availability vs Performance oriented
   (or just handled together, as Performability)
5. Tools (Methods, Software, Techniques)
6. Service Level Objectives or Agreements
7. Reports on errors and failure sources
8. Theoretical approaches

- All papers have been systematically classified according to these categories.

Taxonomy of research approaches:
By Scope

- Systems Engineering (generic)
- Computer Systems
- Internet, networked or distributed systems
- Grids

Bathtub curve: a fact to cope with



Tools for PRA and more SHARPE 200x – Trivedi et al

Model Type	Dependability	Performance	Performability
Fault tree (FT)	X		
Multistate fault tree	X		
RBD	X		
Reliability graph (RG)	X		
Markov chain	X	X	X
Semi-Markov chain	X	X	X
MRGP	X	X	X
GSPN	X	X	X
Stochastic reward net	X	X	X
PFQN		X	
MPFQN		X	
Task graph		X	
Phased-Mission systems	X		

Tools for PRA and more
SHARPE 200x – Trivedi et al

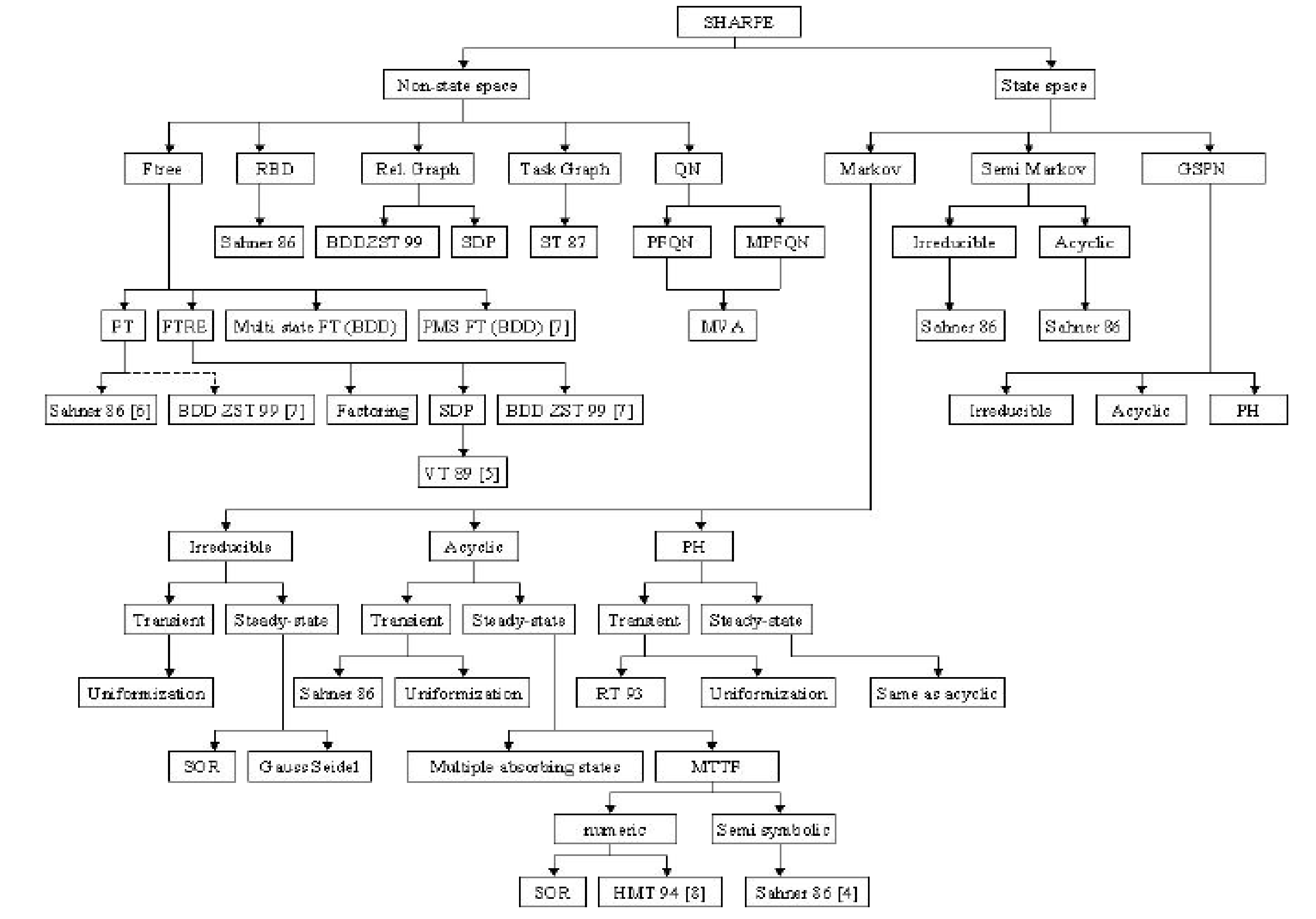
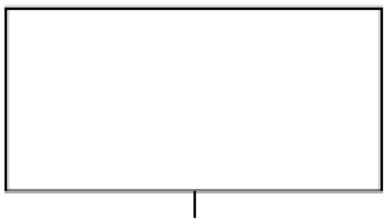


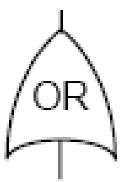
Fig. 1. Description of the SHARPE structure

Probabilistic Risk Assessment: the Fault Tree Analysis tool

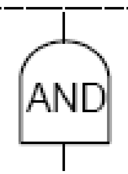
The Logic Symbols



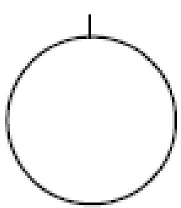
TOP Event – forseeable, undesirable event, toward which all fault tree logic paths flow,or **Intermediate event** – describing a system state produced by antecedent events.



"Or" Gate – produces output if any input exists. Any input, individual, must be (1) necessary and (2) sufficient to cause the output event.



"And" Gate – produces output if all inputs co-exist. All inputs, individually must be (1) necessary and (2) sufficient to cause the output event

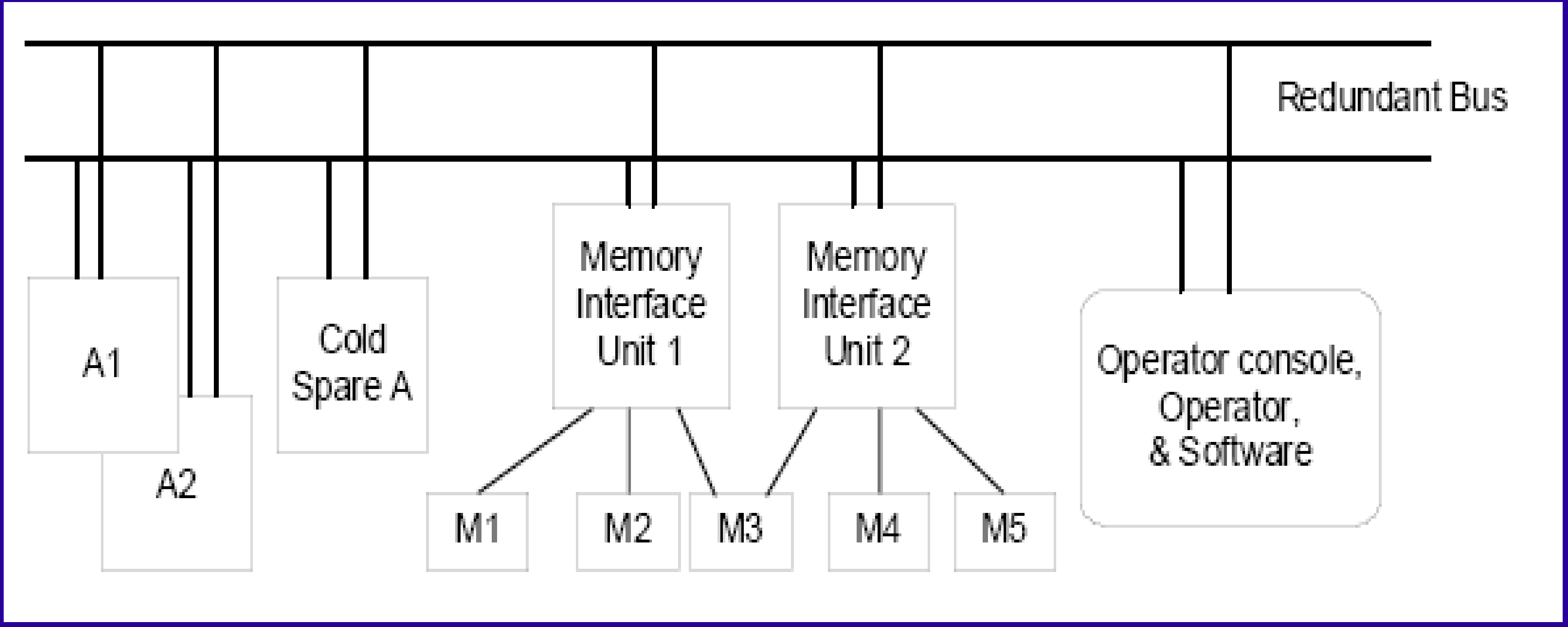


Basic Event – Initiating fault/failure, not developed further. (Called "Leaf," "Initiator," or "Basic.") The Basic Event marks the limit of resolution of the analysis.

Events and **Gates** are **not** component parts of the system being analyzed. They are symbols representing the logic of the analysis. They are bi-modal. They function flawlessly.

> Most Fault Tree Analyses can be carried out using only these four symbols.

HECS: A reference "Hypothetical Example Computer System"



- HECS has a few redundant components; typical of those used in space missions

Reference: NASA Fault Tree Handbook with Aerospace Applications, 2004, pp 167

Probabilistic Risk Assessment: Fault Tree Analysis for HECS

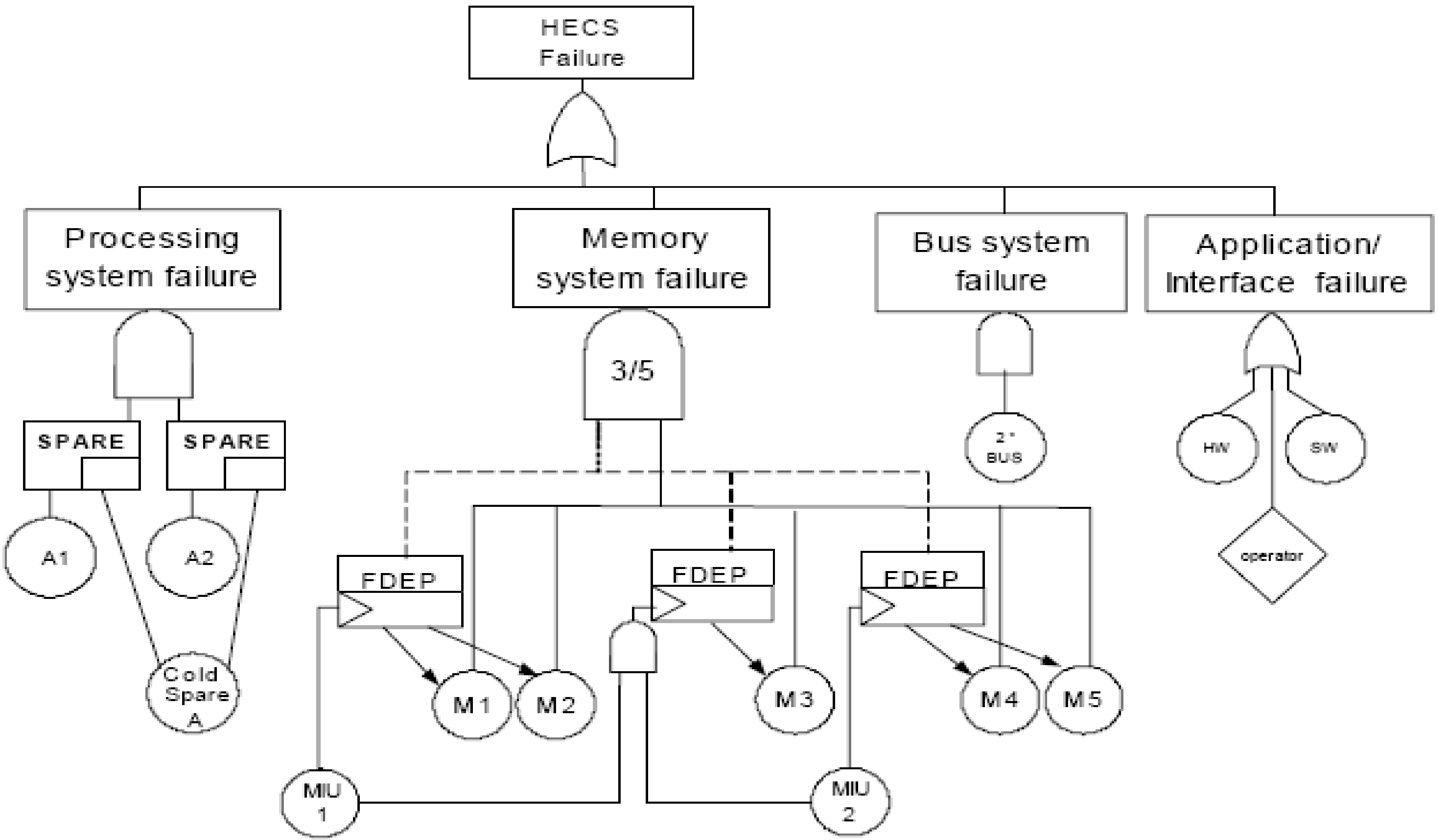
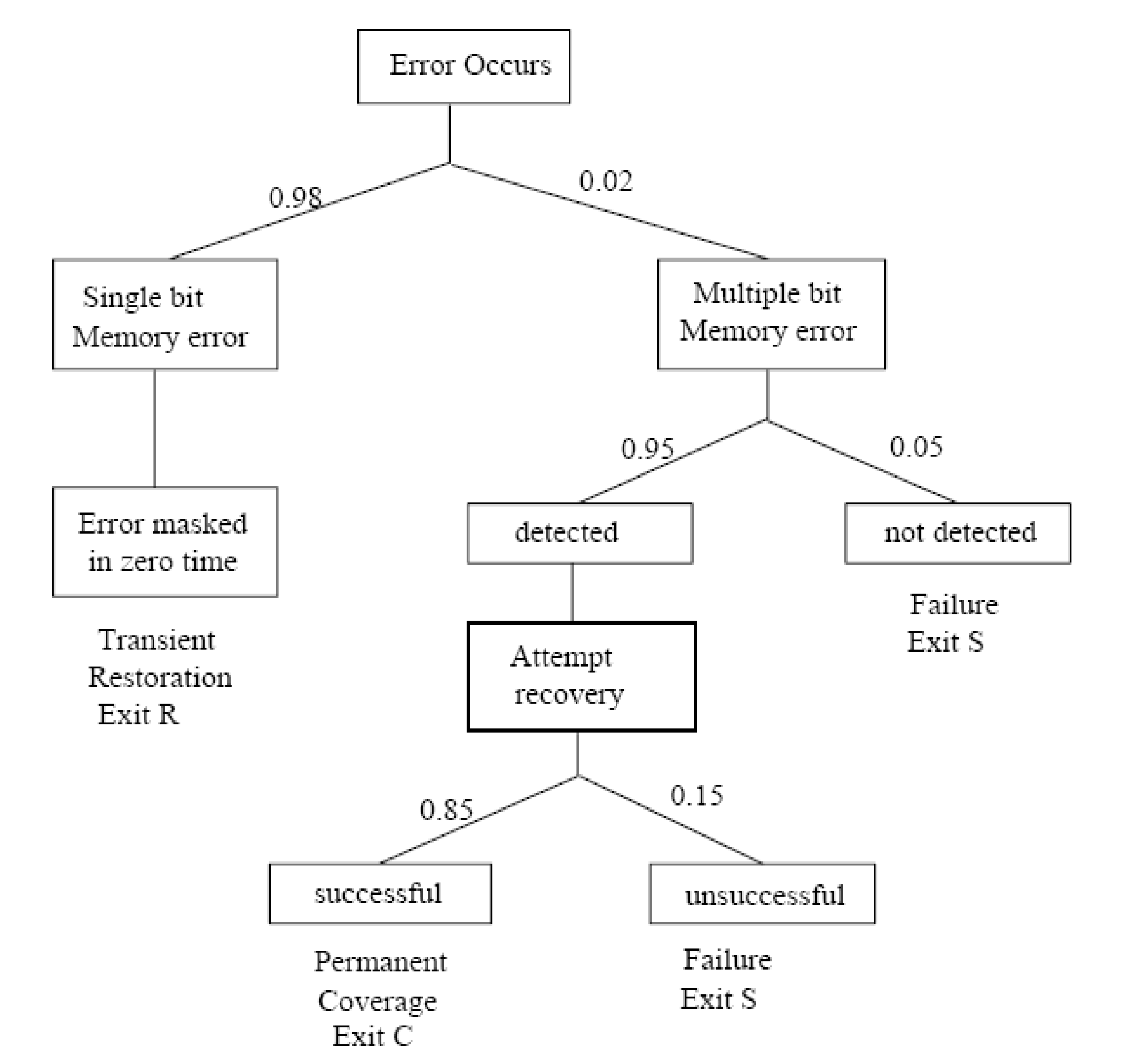


Figure 13-7. Fault Tree for HECS

Probabilistic Risk Assessment: Example from HECS memory



- All digital memory is well known of "missing bits"
- It has been shown that both normal DRAM & ECC-capable commercial chips to have $>10^{-6}$ fault rate, per Gb per hour!

Probabilistic Risk Assessment: Accumulation of HECS Errors

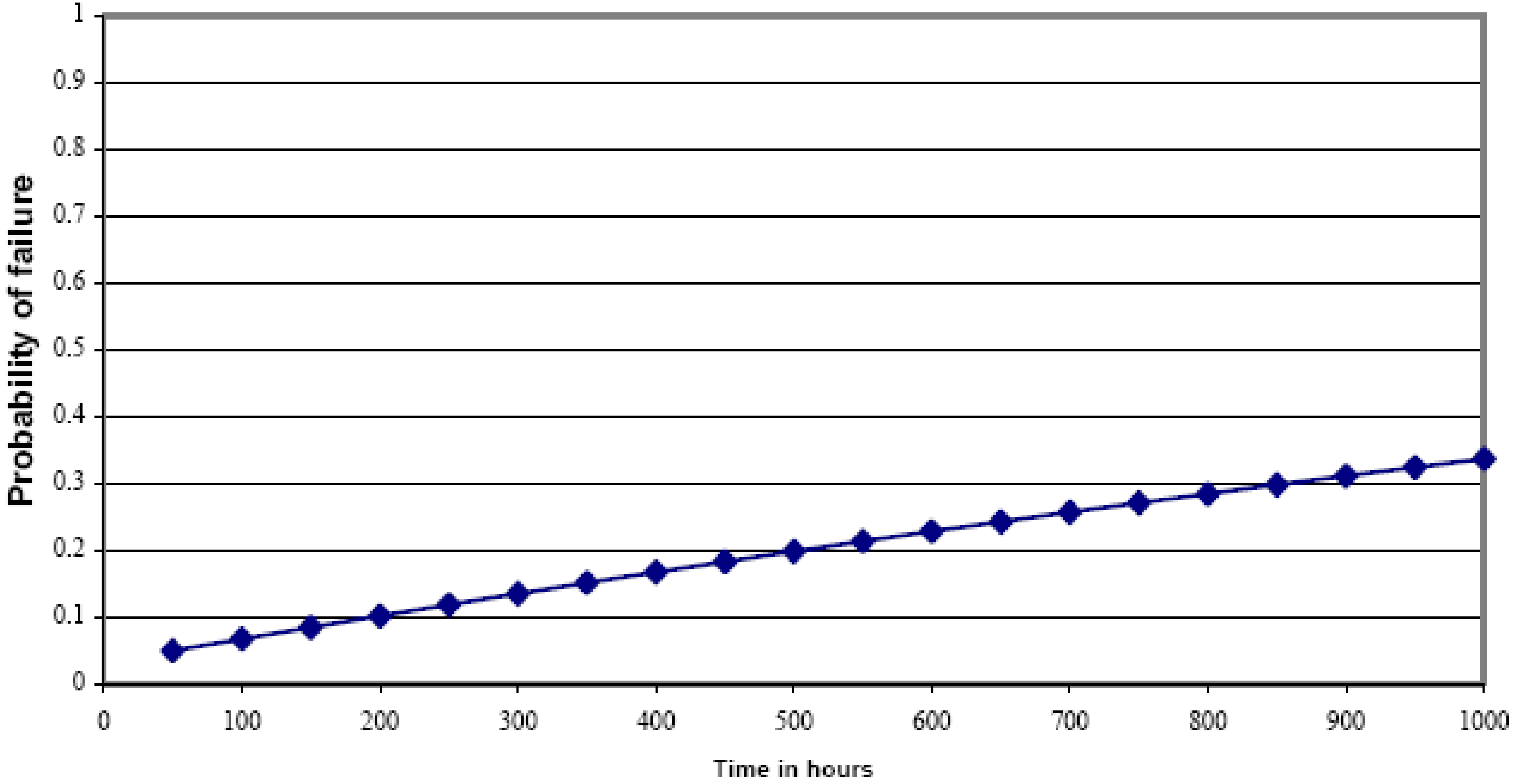


Figure 13-11. Unreliability for HECS

Reliability Block Diagrams (RBD)

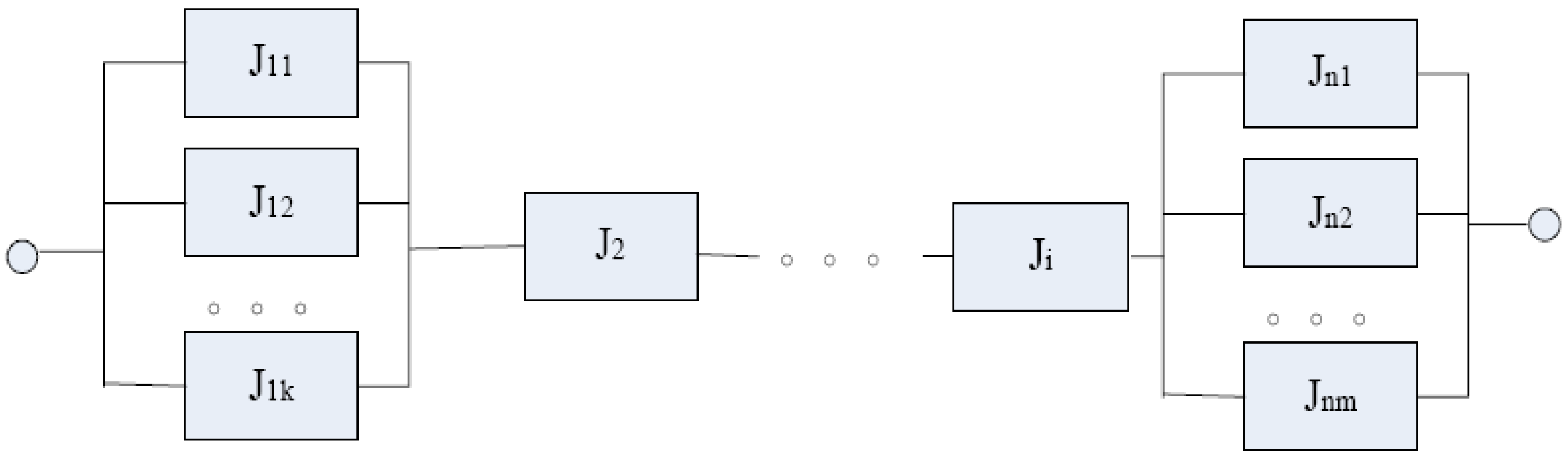


Fig. 2. RBD model for task analysis

$$R(t) = \left[1 - \prod_{l=1}^{k}\left(1 - e^{-\lambda_{1l}P(1l)}\right)\right] e^{-\lambda_2 P(2)} \ldots e^{-\lambda_i P(i)} \left[1 - \prod_{l=1}^{m}\left(1 - e^{-\lambda_{nl}P(nl)}\right)\right] \qquad (3)$$

where λ_{ij} is failure rate of the j-th copy of *i*-th job element.

- Note the parallel and series configuration

Why do Computers Stop and What Can Be Done About It?

Jim Gray (1985)

- A example ninety minute outage from a simple fault in 10 days translates to 99.6% availability. Sounds “wonderful”, but not for hospital patients. An 1.5 hour outage every ten days is unacceptable.
- Require systems which virtually never fail => TANDEM NONSTOP systems did this; more than two orders of magnitude better than conventional designs

Ref: Why do computers stop and what can be done about? Jim Gray, 1985

Why do Computers Stop and What Can Be Done About It? Jim Gray (1985)

System Failure Mode	Probability	MTBF in years
Administration	42%	31 years
Maintenance:	25%	
Operations	9% (?)	
Configuration	8%	
Software	25%	50 years
Application	4% (?)	
Vendor	21%	
Hardware	18%	73 years
Central	1%	
Disc	7%	
Tape	2%	
Comm Controllers	6%	
Power supply	2%	
Environment	14%	87 years
Power	9% (?)	
Communications	3%	
Facilities	2%	
Unknown	3%	
Total	103%	11 years

Table 1. Contributors to Tandem System outages reported to the vendor. As explained in the text, infant failures (30%) are subtracted from this sample set. Items marked by "?" are probably under-reported because the customer does not generally complain to the vendor about them. Power outages below 4 hours are tolerated by the NonStop system and hence are under-reported. We estimate 50% total under-reporting.

Recovery Oriented Computing (ROC)

Patterson, Fox, Traupman et al. (2002)

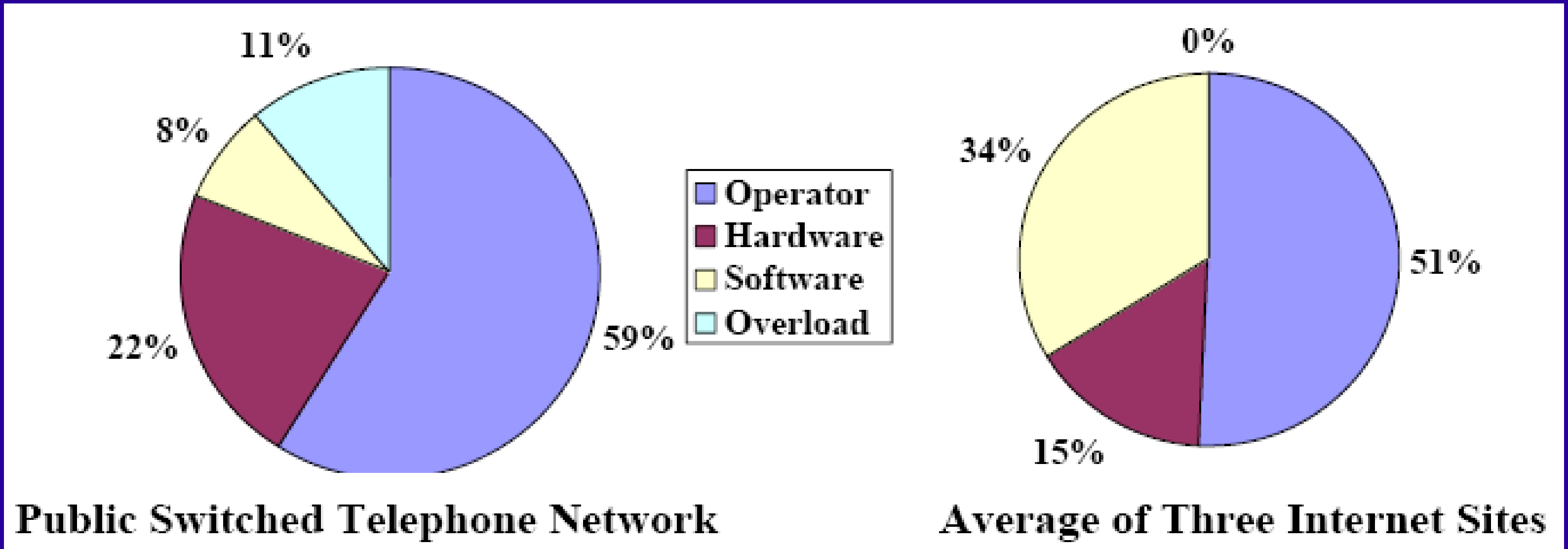
- Patterson et al projected the belief that "hardware faults, software bugs and operator errors are facts to be coped with, not problems to be solved"
- So, they suggest to target services over network: Internet/enterprise services
- Concentrate on MTTR:
  - Reduce recovery time
  - Achieve higher availability

Ref: "ROC: Motivation, Definition, Techniques, and Case Studies", Patterson et al, CSD-02-1175, 2002

Recovery Oriented Computing (ROC)

Patterson, Fox, Traupman et al. (2002)

- Well-managed servers achieve 99%, hours of downtime per year. Each hour is costly:
  - $200,000 per hour for Internet services (Yahoo!)
  - $6,000,000 per hour for a stock brokerage firm
- Causes of Downtime: leader = operator



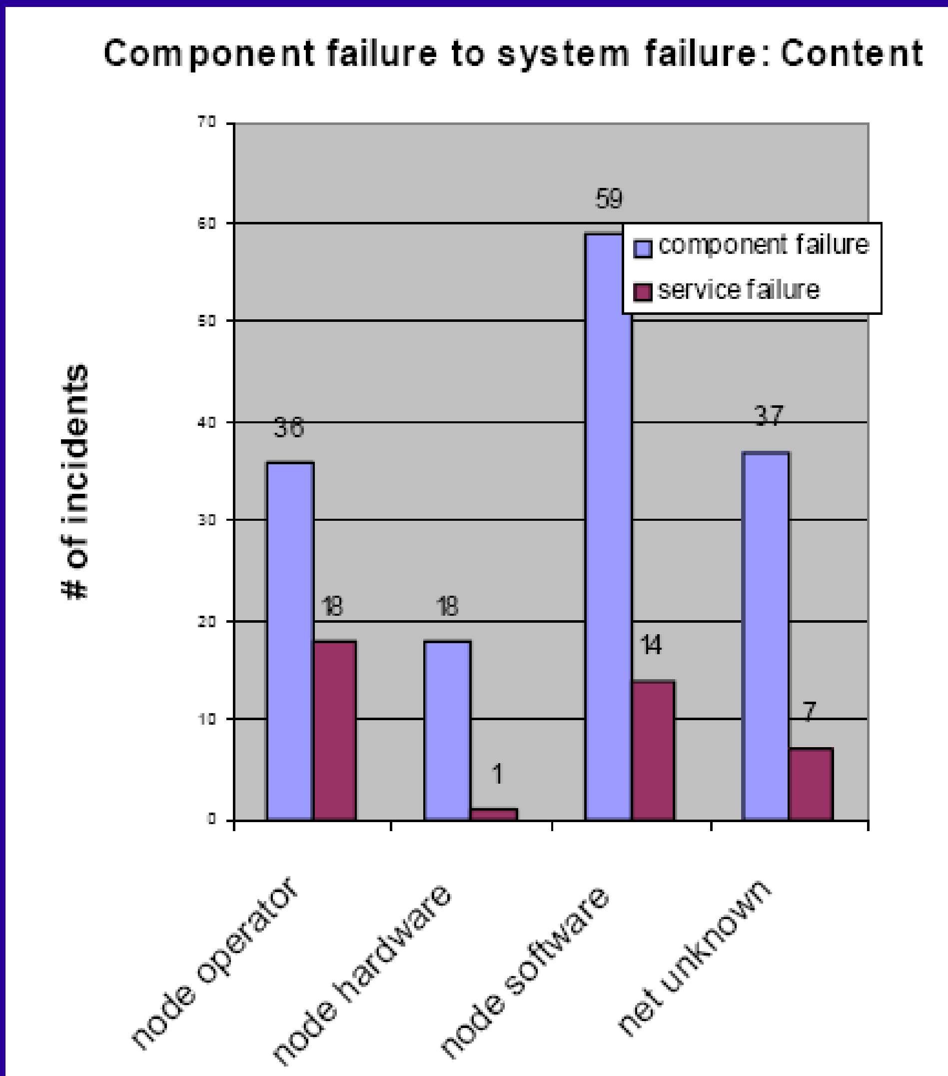
Why do Internet services fail and what can be done about it?

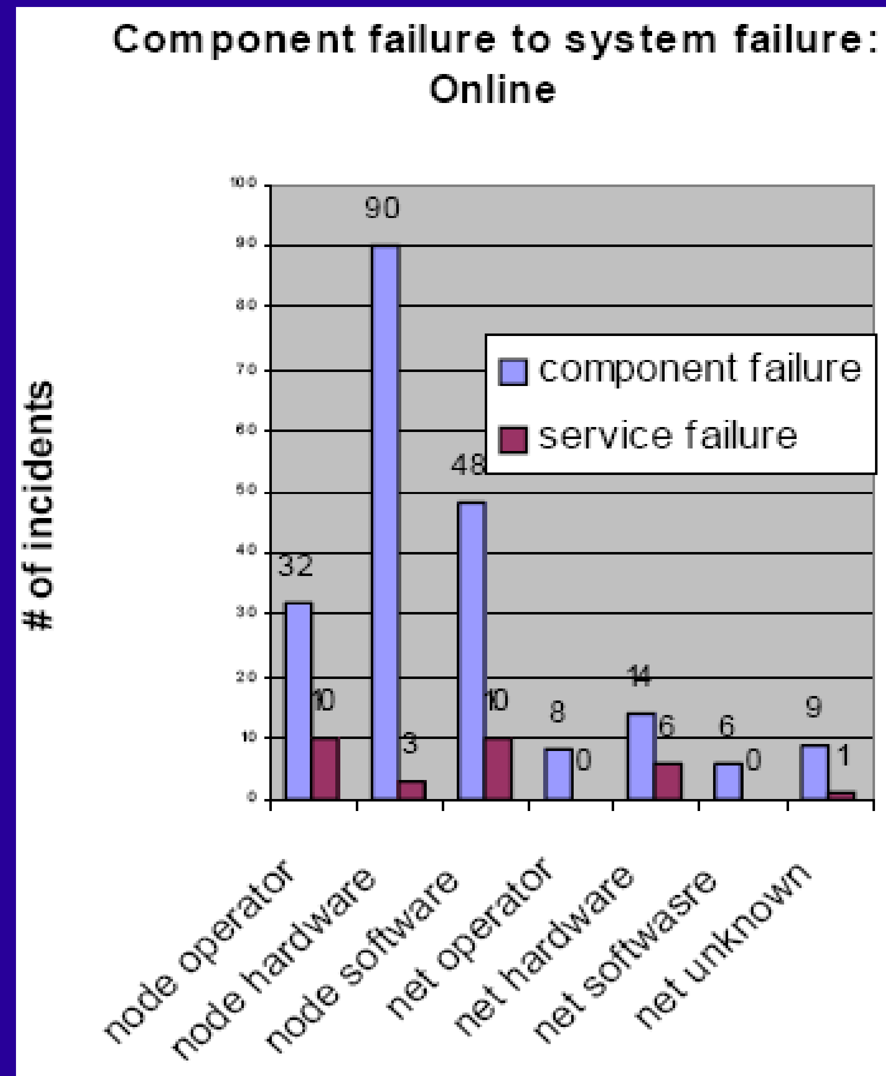
Patterson, Ganapathi, Oppenheimer (2003)

- Operator errors are largest cause of failure
- Operator error is also the largest contributor of time to repair (MTTR)
- Configuration errors are the largest category of operator errors
- Failures in custom-written front-end software are significant
- More extensive on-line testing, more thoroughly exposing and detecting component failures => reduce failure rates

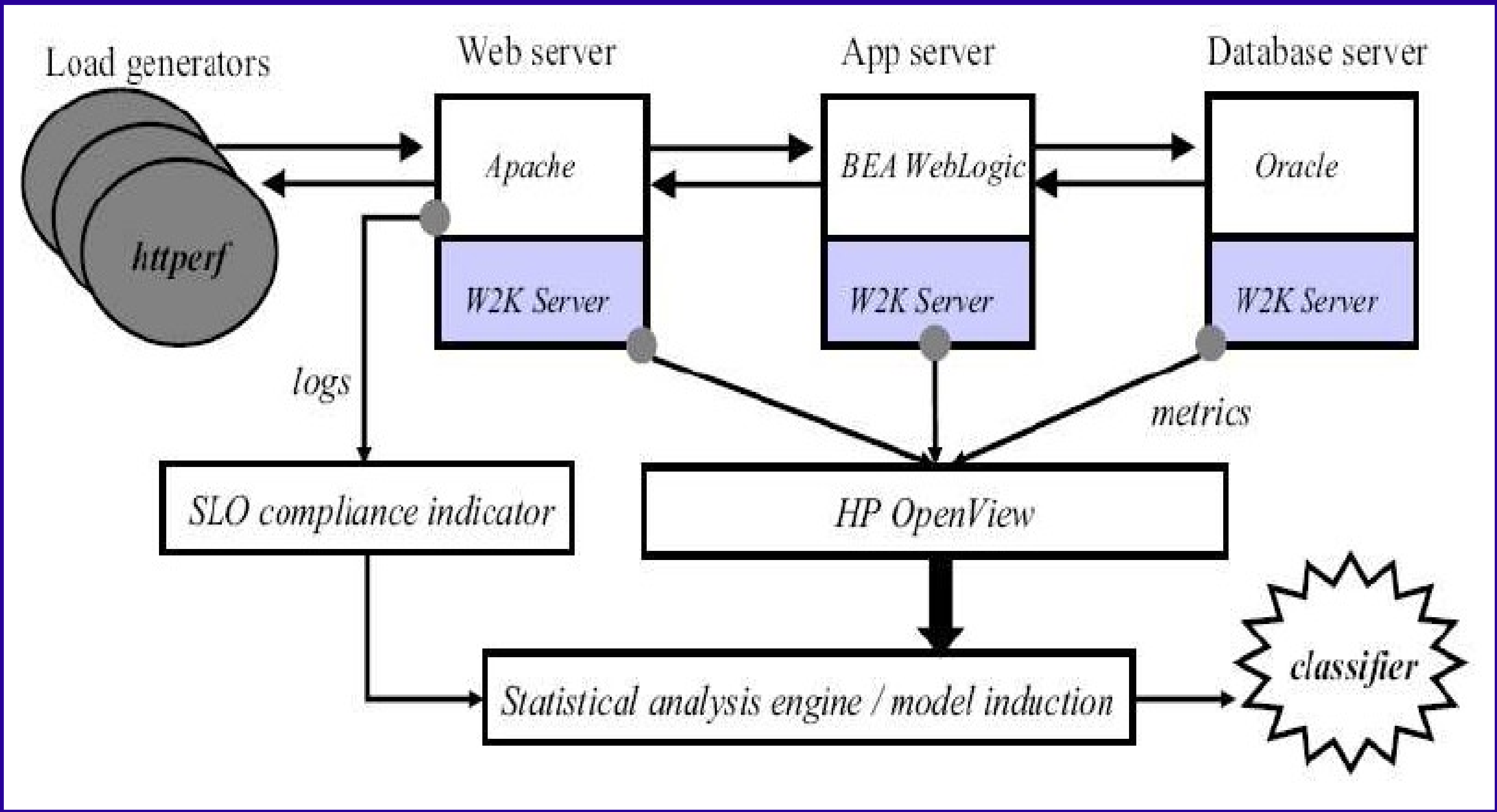
Why do Internet services fail and what can be done about it?

Patterson, Ganapathi, Oppenheimer (2003)



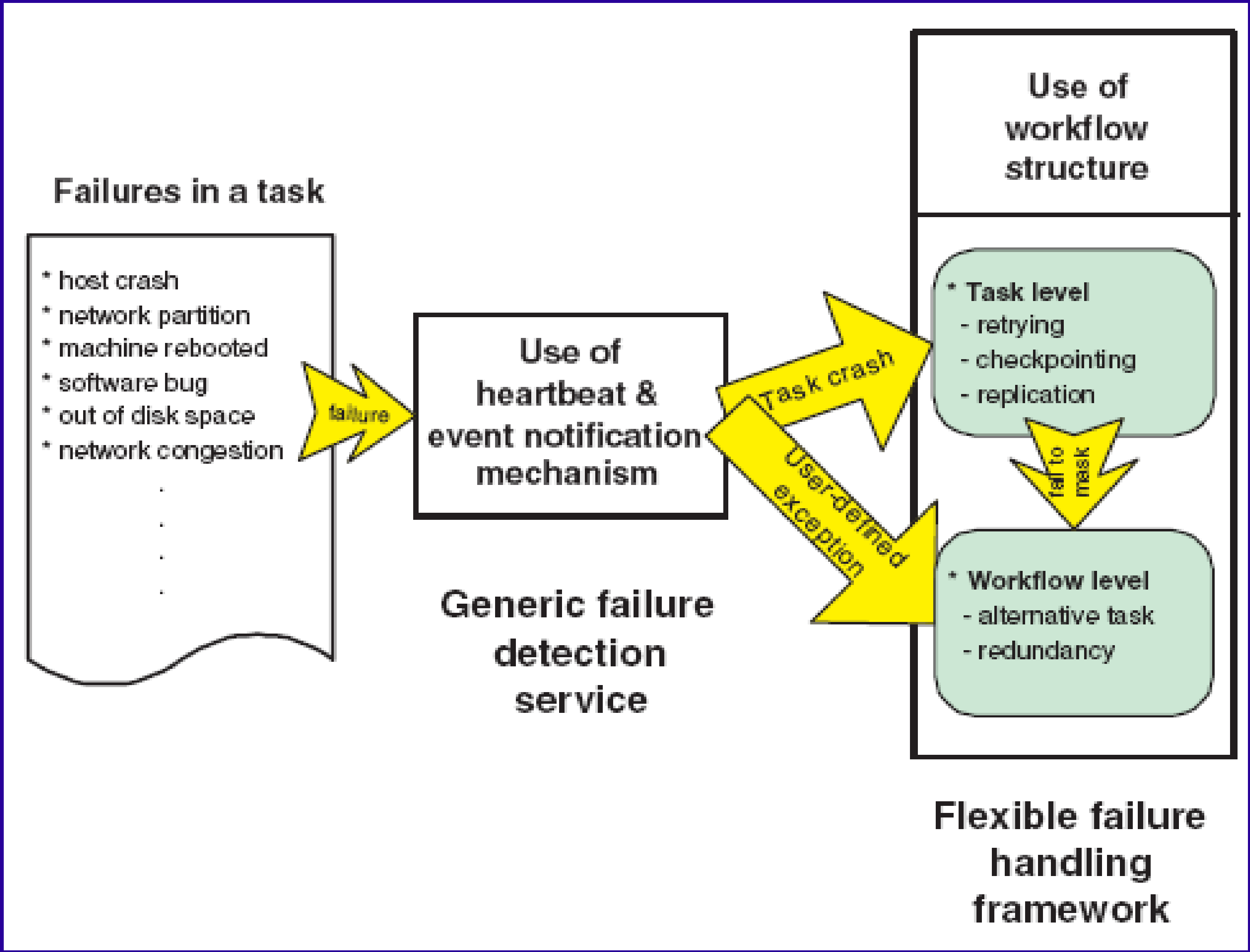


Service Level Objectives, Agreements (SLAs) and more...



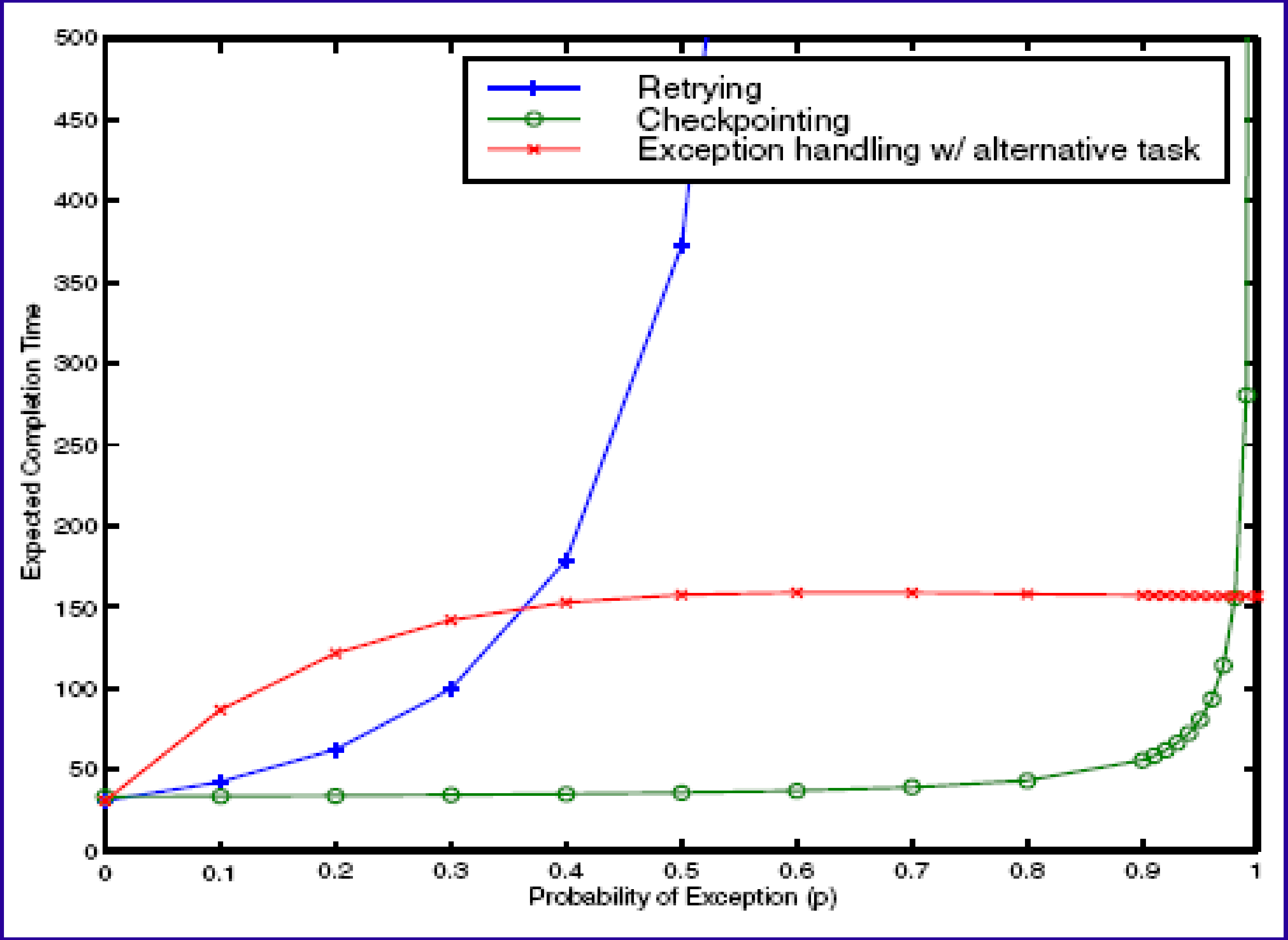
Ref: Ensembles of models for Automated Diagnosis of System Performance Problems, HPLabs, 2005

A Failure Detection & Handling Framework tool: Grid WorkFlow



Ref: Grid Workflow: A Flexible Failure HandlingFramework for the Grid, Hwang and Kesselman, 2003

A Failure Detection & Handling Framework tool: Grid WorkFlow



Ref: Grid Workflow: A Flexible Failure HandlingFramework for the Grid, Hwang and Kesselman, 2003

Failures in a grid instance: EGEE

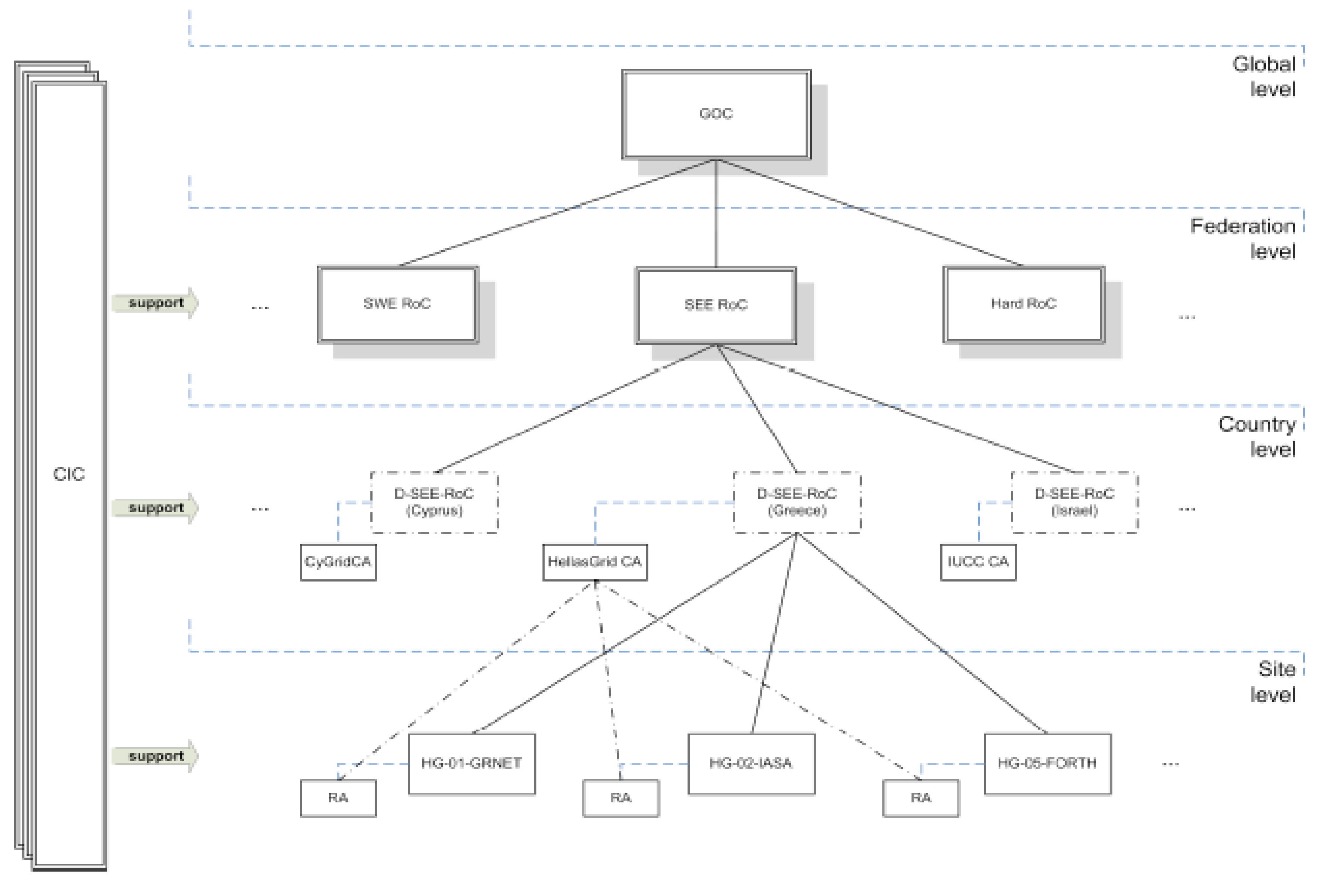
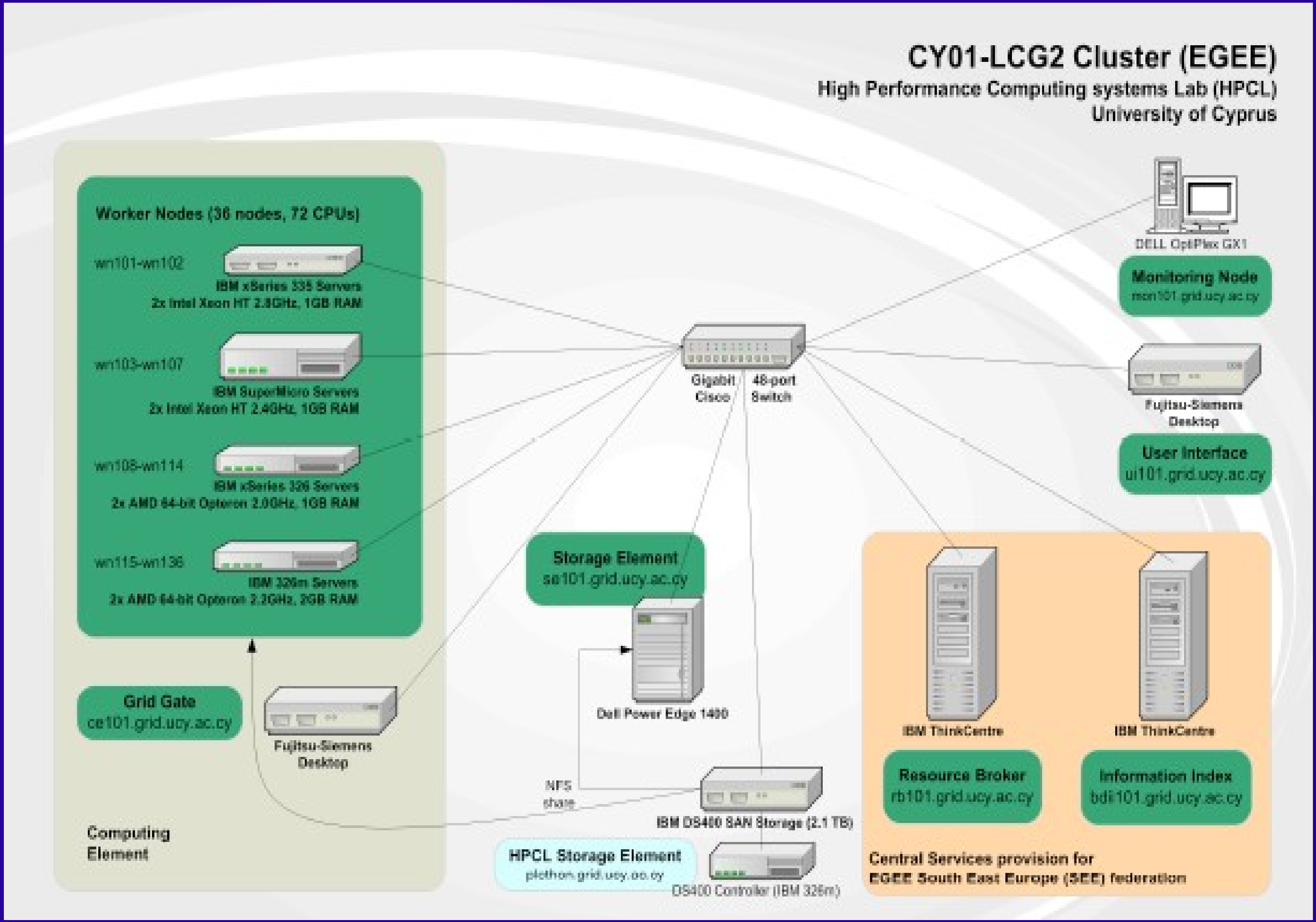


Figure 3: EGEE testbed administration hierarchy

Ref: Failure Management in Grids: The Case of EGEE, Neocleous-Dikaiakos-Fragopoulou-Markatos, CoreGRID Technical Report TR-0055, 2006

Failures in a grid instance: EGEE



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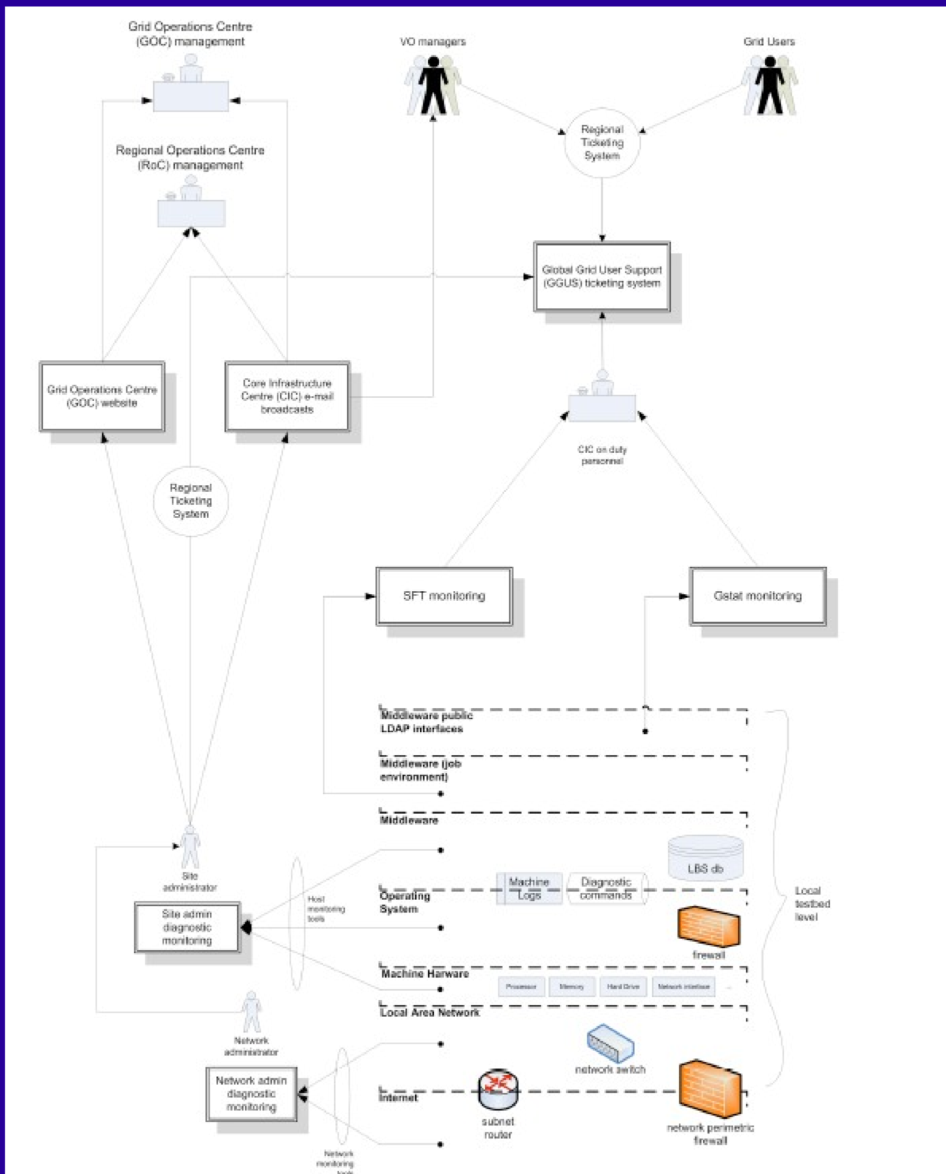
Failures in a grid instance: EGEE



- Current grid monitoring happens at many different levels, with tools that don't communicate well with each other
- Sysadmins & users have to cope with it
- Need for higher-level representation of failures, automation of diagnosis & correction

Ref: Failure Management in Grids: The Case of EGEE, Neocleous-Dikaiakos-Fragopoulou-Markatos, CoreGRID Technical Report TR-0055, 2006

Grid Dependability: Open problems

- Apthorpe (and others) have suggested that PRA tools, Configuration Management and Monitoring are complementary techniques. To what extend should each be applied?
- Deploy PRA tools for security as well !
- Analyze common Internet Protocols in grid implementations (IP, NTP, DNS & LDAP)
- Model process failure in OSs and Networks
- Use PRA and UML, in favor of a Common Risk Assessment Notation or Language

Grid Dependability: More issues

- Solve the optimal allocation of resources problem, in the presence of grid failures
- Understand Grid Information Systems; a lot of relevant work has been done in Distributed Systems; what is applicable?
- Fault masking; in particular, we must avoid the sink-hole effect at the scheduling level

Q & A

Research Methodology:

IDENTIFY DOMAIN KEYWORDS

- grid AND reliability
- grid AND dependability
- grid AND fault-tolerance
- Internet services AND reliability
- Internet services AND dependability
- Internet services AND fault-tolerance
- high-availability
- recovery oriented computing
- autonomic computing
- dependable and secure computing
- self healing systems
- self repairing systems
- computing systems reliability
- fault tolerant computing

Research Methodology:

INFORMATION SOURCES (SEARCH ENGINES)

- University of Cyprus Library - http://library.ucy.ac.cy/
- Collection of Computer Science Bibliographies - http://liinwww.ira.uka.de/bibliography/index.html
- Google scholar - http://scholar.google.com
- Citeseer - http://citeseer.ist.psu.edu/
- Scopus - http://www.scopus.com/scopus/home.url
- Web Of Science - http://access.isiproducts.com/wosnochem
- SpringerLink Books - http://www.springerlink.com/books
- ACM Portal Search - http://portal.acm.org/portal.cfm
- IEEE Xplore - http://ieeexplore.ieee.org/Xplore/dynhome.jsp

Research Methodology:

INFORMATION SOURCES (SEARCH ENGINES)

- Cambridge CSA-Illumina - http://www.csa1.co.uk/htbin/dbrng.cgi?username=cyp&access=cyp845&db=computer-set-c&adv=1
- DBLP.uni-trier.de - http://dblp.uni-trier.de/
- Wiley Interscience - http://www.interscience.wiley.com/
- arxiv.org - http://arxiv.org/
- Web Of Science by EKT - http://wos.ekt.gr/
- ScienceDirect - http://www.sciencedirect.com
- Springer - http://www.springer.com
- Google Books - http://books.google.com/
- Karlsruhe Virtual Catalogue (KVK) - http://www.ubka.uni-karlsruhe.de/hylib/en/kvk.html

Research Results:

RESEARCH GROUPS, WORKING GROUPS & CONSORTIUMS

- @ Berkeley/Stanford Recovery Oriented Computing group, Patterson David, Armando Fox et al - http://roc.cs.berkeley.edu/
- @ IFIP WG 10.4, INTERNATIONAL FEDERATION FOR INFORMATION PROCESSING, DEPENDABLE COMPUTING AND FAULT TOLERANCE, Avizienis, Laprie, Randell, Landwehr, Hiltunen, Lala, Iyer, Schilchting, Trivedi et al - http://www.dependability.org/wg10.4/
- @ Duke University, KS Trivedi et al (S/W TOOL: SHARPE 2002) - http://www.ee.duke.edu/~kst/
- @ OGF, GRID-RL WG: Geoffrey Fox, Christopher Dabrowski et al - https://forge.gridforum.org/sf/projects/gridrel-rg
- @ Sun Labs: Joe Higgins, Robert Sewell - http://research.sun.com/
- @ HP Labs: Armando Fox, M. Goldszmidt, R. Powers, D. Milojicic (OGF::CDDLM-WG) et al - http://www.hpl.hp.com/

Research Results:

RESEARCH GROUPS, WORKING GROUPS & CONSORTIUMS

- @ Microsoft Research: Jim Gray, C .van Ingen et al - http://research.microsoft.com/
- @ Indiana University, Y.S. Dai, R. Raje, L. Xing, M. Xie, K.L. Poh - http://www.cs.iupui.edu/~ydai/Regrid/Improvement.htm
- @ hust.edu.cn: Xuanhua Shi, Hai Jin, Weizhong Qiang and Deqing Zou - http://grid.hust.edu.cn/xhshi/
- @ ReGrid: KS Trivedi, YS Dai, M. Xie, KL Poh, G Fox, G Levitin - http://www.regrid.org
- COREGRID (CONSORTIUM) 2004-2007 - http://www.coregrid.net/
- ASSESSGRID (CONSORTIUM) - http://www.assessgrid.org
- Levitin, G - http://iew3.technion.ac.il/~levitin/ (mostly power-related, but still interesting and relevant due to YS Dai affiliation)
- More Researchers: G Alonso, D. Gannon, Shunji Osaki et al

Research Results:

RELEVANT PROFESSIONAL ORGANIZATIONS

- IFIP - http://www.ifip.org
- IFIP/WG10.4 - http://www.dependability.org/
- OGF/GGF - http://www.ogf.org
- IEEE - http://www.ieee.org
- ACM - http://www.acm.org
- USENIX - http://www.usenix.org
- SAGE - http://www.sage.org
- LOPSA - http://www.lopsa.org

Research Results:

RELEVANT CONFERENCES

- RAMS: Annual Reliability and Maintainability symposium - http://www.rams.org/
- International Symposium on Fault Tolerant Computing Systems (FTCS) - http://www.dependability.org/
- OGF19/GGF16 - http://www.ogf.org/OGF20/events_ogf20.php
- USENIX::LISA 1986-2007 - http://www.usenix.org/events/lisa06/
- USENIX::WORLDS 2004-2005 - http://www.usenix.org/events/worlds04/
- USENIX::HOTDEP 2005-2007 - http://hotdep.org/
- USENIX::OSDI 1994-2006 - http://www.usenix.org/events/bytopic/osdi.html
- IEEE/IFIP::DSN 2000-2007 (+IPDS-2002) - http://www.dsn.org/
- IEEE::IPDPS 1996-2006 - http://www.ipdps.org/
- IEEE::HPDC 1991-2007 - http://www.hpdc.org/

Research Results:

RELEVANT CONFERENCES

- IEEE::CCGRID 2001-2007 - http://ieeexplore.ieee.org/xpl/conhome.jsp?punumber=1000093
- IEEE/ACM GRIDCOMPUTING 2000-2007 - http://www.gridcomputing.org/
- IEEE/ACM::International Conference on Autonomic Computing ICAC - http://www.autonomic-conference.org/
- IEEE::SRDS Reliability in Distributed Software - http://www.informatik.uni-trier.de/~ley/db/conf/srds/index.html
- IEEE::RAMPDS-2005 Reliability and Autonomic Management In PDS - http://www.cs.iupui.edu/~ydai/RAMPDS05/RAMPDS05.htm
- ACM/IFIP/USENIX International Middleware Conference (Middleware)
- COREGRID::Technical Reports - http://www.coregrid.net/mambo/content/view/101/106/
- Grid and Cooperative Computing - http://www.informatik.uni-trier.de/~ley/db/conf/gcc/index.html
- High Dependability Computing Consortium 2000-2001 - http://www.hdcc.cs.cmu.edu/

Research Results:

RELEVANT JOURNALS

- RELIABILITY ENGINEERING & SYSTEM SAFETY - http://www.elsevier.com/locate/ress
- IEEE Transactions on Reliability - http://ieeexplore.ieee.org/xpl/RecentIssue.jsp?punumber=24
- IEEE Transactions on Dependable and Secure Computing - http://www.computer.org/tdsc/
- IBM Systems Journal - http://www.research.ibm.com/journal/sj/
- IBM Research and Development - http://www.research.ibm.com/journal/rd/

Research Results:

RELEVANT JOURNALS

- USENIX Computing Systems - http://www.usenix.org/publications/computing/
- ACM TOCS Vol.1-Vol.24 - http://www.acm.org/tocs/
- Journal of Autonomic and Trusted Computing (JoATC) - http://www.aspbs.com/joatc/
- Wiley Systems Engineering - http://www3.interscience.wiley.com/cgi-bin/jhome/39084
- Wiley Concurrency and Computation: Practice and Experience - http://www3.interscience.wiley.com/cgi-bin/jhome/77004395

- ISSN: 354057767 LNCS: Hardware and Software Architectures for fault tolerance

Research Results:

RELEVANT BOOKS

- ISBN: 9780306484964 M. Xie, KL Poh, YS Dai: Computing System Reliability: Models and Analysis
- ISBN: 0471193666 G Bolch, S. Greiner, H. de Meer, KS Trivedi: Queueing networks and Markov chains: modeling and performance evaluation with computer science applications
- ISBN: 0137722516 Henley-Kumamoto: Reliability Engineering and Risk Assessment
- ISBN: 0471930482 Villemeur: Reliability, Availability, Maintainability and Safety Assessment
- ISBN: 1402004370 Design of Dependable Computing Systems
- ISBN: 0471571733 Handbook of reliability Engineering, Ushakov
- ISBN: 0471035262 Probability Concepts in Engineering Planning and Design

Research Results:

PAPERS : 60 --> 16 representative

- #7. Lessons from Giant-Scale Services
- #16. SHARPE 2002: Symbolic Hierarchical Automated Reliability and Performance Evaluator
- #17. Reliability and Performability Modeling Using SHARPE 2000
- #24. A Flexible Framework for Fault Tolerance in the Grid
- #25. Faults in Grids: Why are they so bad and What can be done about it?
- #27. A Probabilistic Approach to Estimating Computer System Reliability

Research Results:

PAPERS : 60 --> 16 representative

- #31. Approaches to Recovery-Oriented Computing
- #36. Ensembles of Models for Automated Diagnosis of System Performance Problems
- #37. The vision of Autonomic Computing
- #38. Why do Internet Services fail, and what can be done about it?
- #41. Recovery Oriented Computing(ROC), A New Research Agenda for a new Century

Research Results:

PAPERS : 60 --> 16 representative

- #45. Why do Computers stop and What can be done about it?
- #48. Increasing Relevance of Memory Hardware Errors, A case for Recoverable Programming Models
- #52. Managing Failures in a Grid System using FailRank
- #53. Failure Management in Grids: The case of the EGEE Infrastructure
- #55. Basic Concepts and Taxonomy of Dependable and Secure Computing