Closing the Test & Evaluation Gap
In a Net Centric Future

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Abstract

- **Technology is progressing at an alarming rate - some believe it's at an exponential rate. The funding and research for testing & evaluating new technologies is not keeping pace with the rate of technology change. Machines are becoming more autonomous and are working collaboratively with other machines. The collaborative, highly complex and adaptive nature of the net-centric environment is an example of where current testing methods are totally inadequate. The lack of Test and Evaluation (T&E) research is creating a testing knowledge gap. This T&E knowledge gap will increase and will have major impact if not dealt with soon. This presentation will present a timeline of how this gap is increasing, the impact of inadequate T&E research and a set of recommendations for the industry to close this gap and keep it closed.**

Agenda

- **Exponential Times**
- **Complexity**
- **The Gap**
- **Net-centric Future**
- **Emergent Behavior**
- **Recommendations**
- **Summary**

As technology grows cost goes to zero

EXPONENTIAL TIMES

Exponential Trap

- **Exponential curves start out with very hardly noticeable change until the knee is reached and then change drastically accelerates.**
- **The knee is sometimes referred to as the singularity**
- **Not being prepared for a singularity can have devastating results**
- **Rate of technology change is exponential**
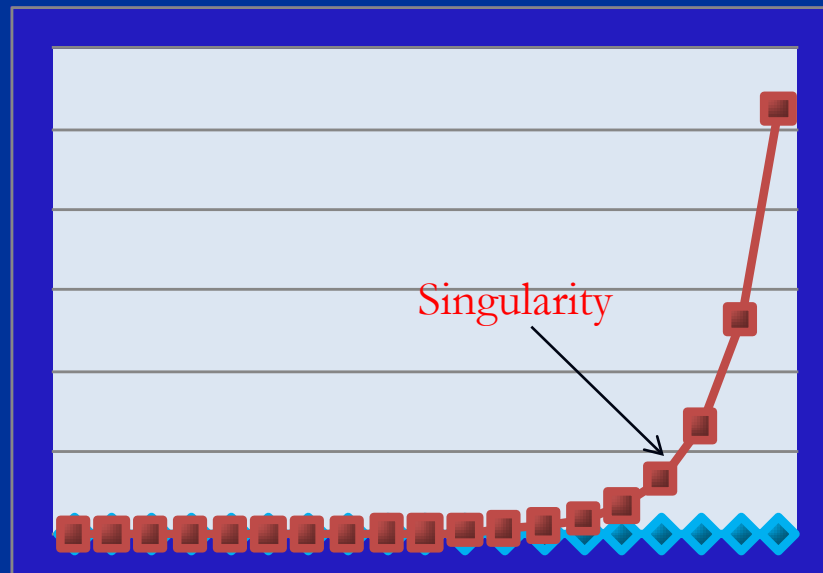
Exponential Times
(From "Did You Know?" website)

Current Rates

- **New technology information doubles every 2 years.**
- **Adoption of technology is accelerating**
  - To Reach 50 million users
    - *Radio 38 years*
    - *TV 13 years*
    - *Internet 4 years*
    - *IPOD 3 years*
    - *Face Book 2 years*

Predictions

- **By 2013, a super computer exceeds capability of human brain**
- **By 2049 $1000 computer exceeds the capability of the entire human species.**

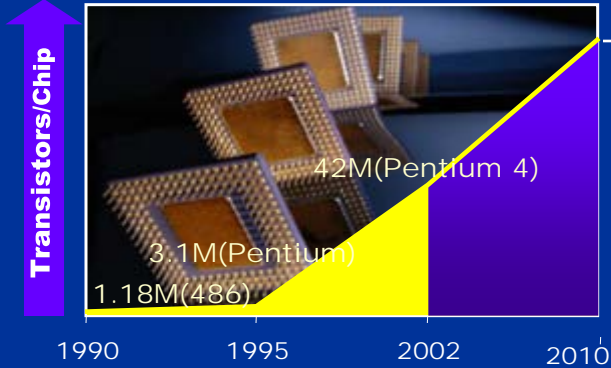# Technologies experiencing exponential changes
(Raymond Kurzweil's "The Singularity is near")

- Dynamic RAM size (smallest feature sizes decreasing exponentially)
- Dynamic RAM price performance (improving exponentially)
- Average Transistor price (decreasing exponentially)
- Transistor Manufacturing costs (decreasing exponentially)
- Microprocessor clock speeds (increasing exponentially)
- Microprocessor costs (decreasing exponentially)
- Transistors per microprocessor (increasing exponentially)
- Processor performance (increasing exponentially)
- DNA sequencing costs per base pair (decreasing exponentially)

- Random Access Memory bits per dollar (increasing exponentially)
- Magnetic data storage bits per dollar (increasing exponentially)
- Wireless Internet and phone services price performance (increasing exponentially)
- Number of Internet hosts (increasing exponentially)
- Bytes of Internet traffic (increasing exponentially)
- Internet backbone bandwidth (increasing in a very terraced, quasi-exponential manner)
- Mechanical device sizes (decreasing exponentially)
- Number of scientific citations for nanotechnology research (increasing exponentially)
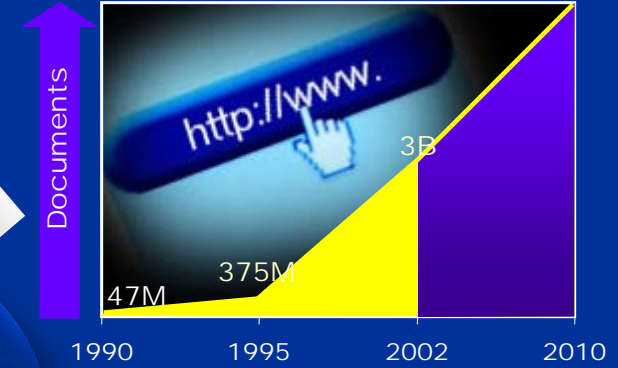- Number of U.S. nanotech patents (increasing exponentially)

Growth is Unabated

Computing Power

Transistors/Chip

→ **Bio Nano**

42M(Pentium 4)

3.1M(Pentium)

1.18M(486)

1990   1995   2002   2010

Internet Data

Documents

http://www.

3B

375M

47M

1990   1995   2002   2010

The Information Revolution

Bandwidth

BPS

900K(DSL)

300K(Satellite)

9.6K(Phone)

1990   1995   2002   2010

Internet Usage

Hosts

150M

160K   20M

1990   1995   2002   2010
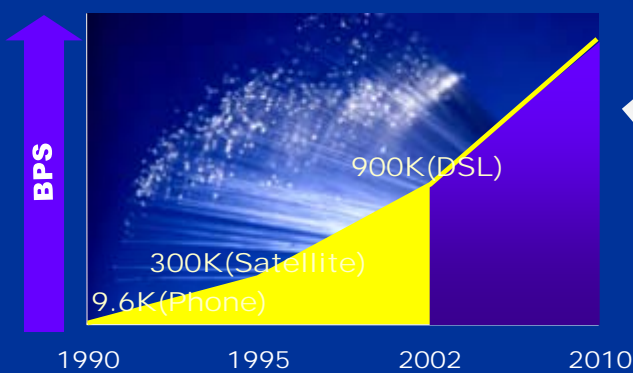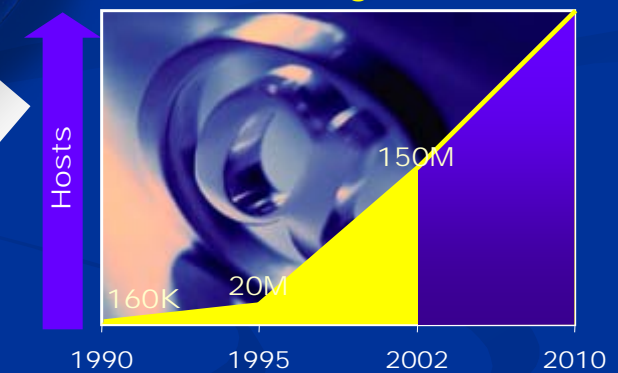
Compute capacity continues to grow
Hardware limitations no longer constrains the software

Connectivity Complexity

Degree of Information connectivity (vertical axis label)
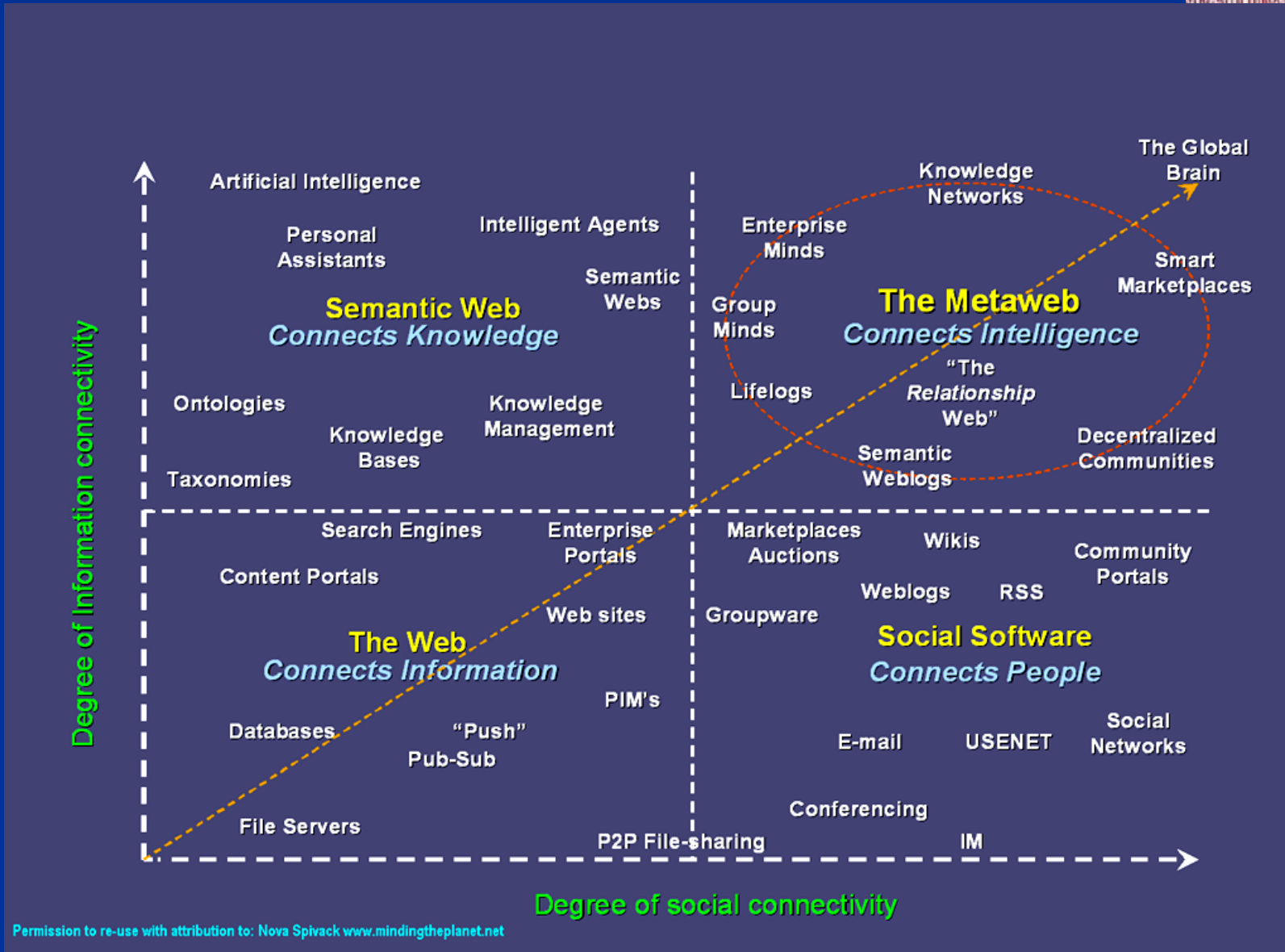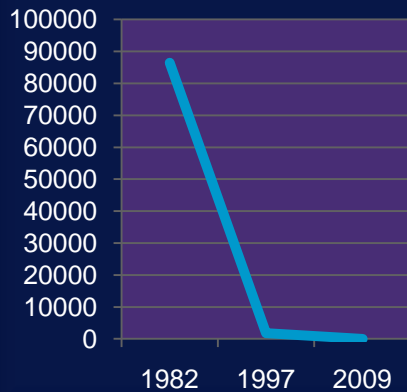
Artificial Intelligence

Personal Assistants

Intelligent Agents

Semantic Webs

Semantic Web
Connects Knowledge

Ontologies

Knowledge Bases

Knowledge Management

Taxonomies

Enterprise Minds

Group Minds

Knowledge Networks

The Global Brain

The Metaweb
Connects Intelligence

Smart Marketplaces

Lifelogs

"The Relationship Web"

Semantic Weblogs

Decentralized Communities

Search Engines

Enterprise Portals

Content Portals

Web sites

The Web
Connects Information

Databases

"Push" Pub-Sub

PIM's

File Servers

P2P File-sharing

Marketplaces Auctions

Wikis

Community Portals

Weblogs

RSS

Groupware

Social Software
Connects People

E-mail

USENET

Social Networks

Conferencing

IM

Degree of social connectivity (horizontal axis label)

Cost Going to Zero

10 Mega Byte Digital Image

Transfer Rate

— Transfer Rate

| | 100000 |
| 90000 |
| 80000 |
| 70000 |
| 60000 |
| 50000 |
| 40000 |
| 30000 |
| 20000 |
| 10000 |
| 0 |

1982   1997   2009

Storage Cost

— Storage Cost

2,500.0000

2,000.0000

1,500.0000

1,000.0000

500.0000

0.0000

1982 1997 2009
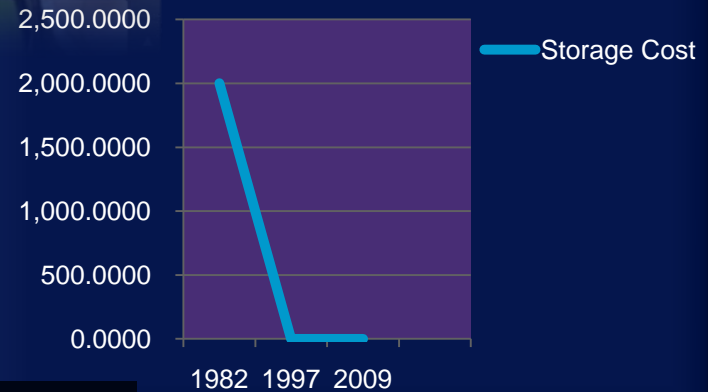
Year	Storage Cost	Transfer Rates
1982	$2,000	1 day
1997	$1.00	30 min
2009	.1 Cent	8 sec

Cost of Failure
Success of IT Projects

LOCKHEED MARTIN

Year	% Succeeded	% Challenged	% Failed
2004	29%	53%	18%
2000	28%	23%	49%
1998	26%	28%	46%
1996	27%	40%	33%
1994	16%	31%	53%

Standish Group's Chaos Report
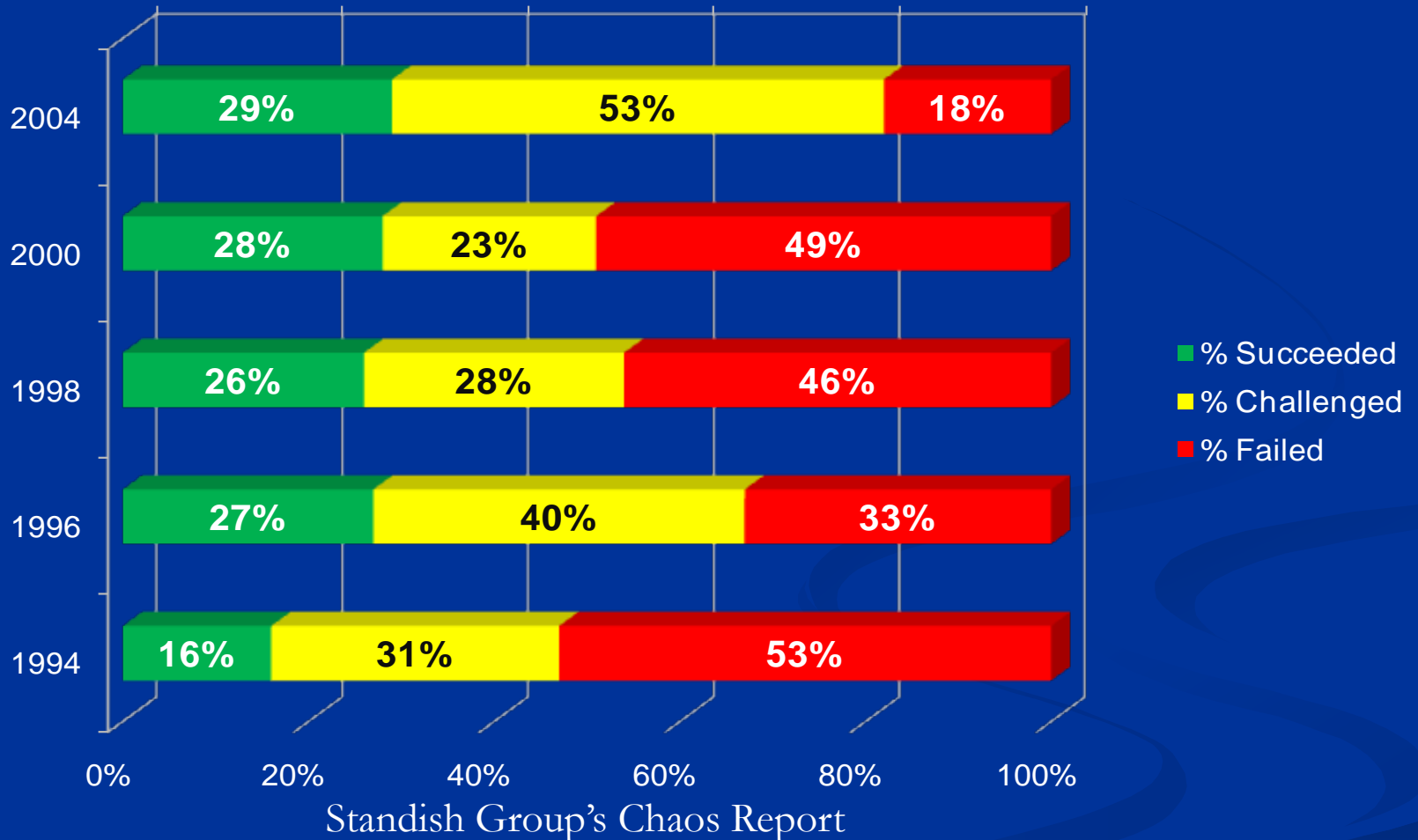
2002 NIST Study indicates poor software testing infrastructure costs the US economy as much as $59 billion a year

COMPLEXITY

Diminishing Constraints
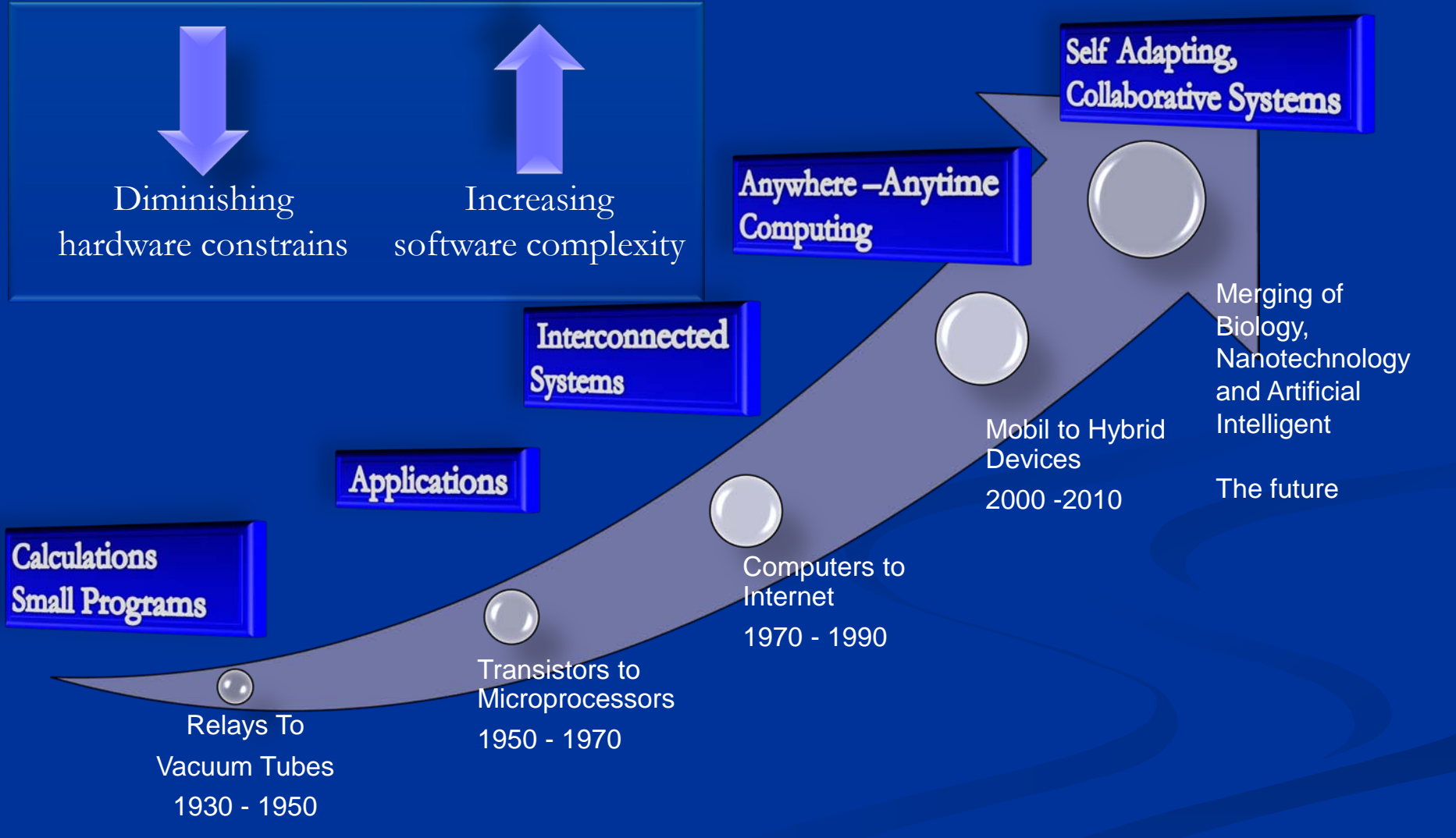
↓ **Diminishing hardware constrains**   ↑ **Increasing software complexity**

Self Adapting, Collaborative Systems

Anywhere – Anytime Computing

Interconnected Systems

Applications

Calculations Small Programs

Merging of Biology, Nanotechnology and Artificial Intelligent

The future

Mobil to Hybrid Devices
2000 - 2010

Computers to Internet
1970 - 1990

Transistors to Microprocessors
1950 - 1970

Relays To
Vacuum Tubes
1930 - 1950

Old paradigm of testing no longer effective

Complexity

- **Today's number one issue facing test is complexity**

- **Increase in software complexity has exceeded the ability of the test industry to adequately test systems.**
  - Test is not on the technology curve
  - Test is not on the state of practice curve

- **Need better tools and processes for dealing with complexity**
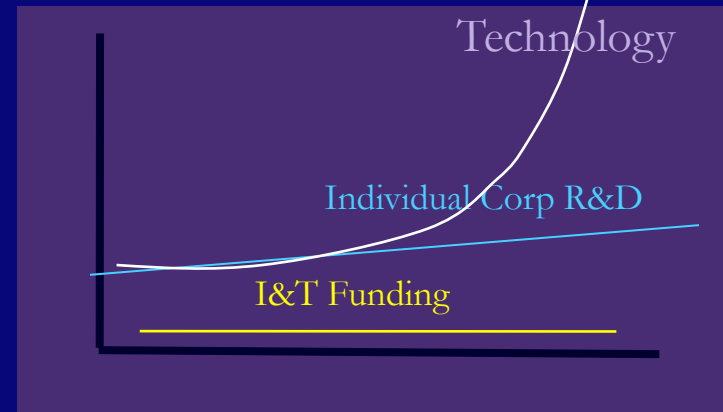 - Get back on the technology curve

THE GAP

Test Technology, Funding and Adoption Gap
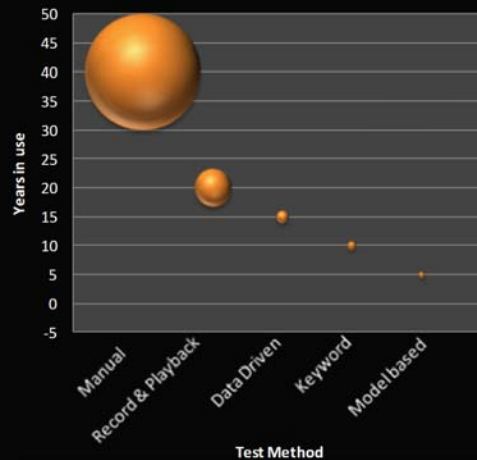## "Based on Personal Experience"

Test **Technology** Gap

Technology Explosion

Test Research

Test Research Gap

Funding Gap

Technology

Individual Corp R&D

I&T Funding

Test Tool Adoption

Years in use

50
45
40
35
30
25
20
15
10
5
0
-5

Manual • Record & Playback • Data Driven • Keyword • Model based

Test Method

Need to reinvent test

NET CENTRIC FUTURE

Micro and Macro level of testing

- **Micro level testing**
  - Testing individual services
  - Issue:
    - *As complexity of service increase our current test techniques and tools will become obsolete*
- **Macro Level testing**
  - Testing the collaboration of system
  - Issues
    - *Inadequate testing techniques and tools to address Emergent Behavior*

EMERGENT BEHAVIOR

Types of Emergence

- **Weak Emergence:**
  - Describes new properties arising in systems as a result of the interactions at an elemental level. Emergence, in this case, is merely part of the language, or model that is needed to describe a system's behavior.
- **Strong Emergence:**
  - But if, on the other hand, systems can have qualities not directly traceable to the system's components, but rather to how those components interact, and one is willing to accept that a system supervenes on its components, then it is difficult to account for an emergent property's cause. These new qualities are irreducible to the system's constituent parts (Laughlin 2005). The whole is greater than the sum of its parts. This view of emergence is called strong emergence.

- **Regarding strong emergence, Mark A. Bedau observes:**
"Although strong emergence is logically possible, it is uncomfortably like magic…"

How does one test magic?

The Future of Test

- **Constraints will continue to diminish**
- **Hybrid systems**
  - Continue to merge more technologies into smaller devices
  - Testing will have to be multidiscipline
    - *Merging of biology, AI, Nanotechnology, communications, computers….*
- **Mission Scenarios will be become increasingly complex**
  - Transforming stove pipes into Systems of Systems
  - Complex, Collaborative, Adaptive systems will create intractable operational scenarios
  - Today's test technologies and methodologies will not support the operational environments of the future
- **Future number one problem facing test is unconstrained mission scenarios**
  - How to identify bad emergent behavior in an intractable set of scenarios

The Government test industry has to change quickly

Progress to DATE

- **Lockheed Martin starting to address the problem**
  - Test and Evaluation Director - changing the way test and evaluation is done across the corporation. Creating a technology roadmap
  - IS&GS Integration and Test Center of excellence advancing the state of practice with IS&GS product lines.
- **Some research at the micro level that addresses weak emergent behavior**

RECOMMENDATIONS

Recommendations

- **Reinvent Test**
  - Need to increase the adoption rate of testing technology
  - Create a roadmap of test research
  - Develop new testing methodologies, deliverables, tools, etc. based on current state and future state of technologies.
  - Increase test research funding
    - *Each new technology needs to have research done to understand how it can be tested.*
    - *Research in testing complex software*
    - *Research in testing emergent behavior in complex systems*
- **Industry needs to have the infrastructure setup to implement and share test research.**
  - Conferences, Training and Experts
- **Need to define boundaries on complex , collaborative, self adaptive systems**
  - Just as society creates laws to bound individuals so should we place rules to bound services on the GIG to limit bad behavior
  - Test then can test to see if rules are violated.
- **Learn from the future**

Summary

- **Test & Evaluation Industry has some tough problems to solve in the Net-centric future**
  - Diminishing constraints lead to ever increasing complexity
  - Current Testing techniques not adequate to test complexity nor is it adequate to detect bad behavior that might emerge from the complex, collaborative, self adapting net-centric environment of the future
- **Need to take action to get back on the technology curve**
- **The DOD test industry needs to increase the rate at which it creates and adopts new test technology and methods**
- **Need to set an industry wide infrastructure to stay on the technology curve**

Q & A