NDIA Conference:

"Physics-Based Modeling in Design & Development for U.S. Defense

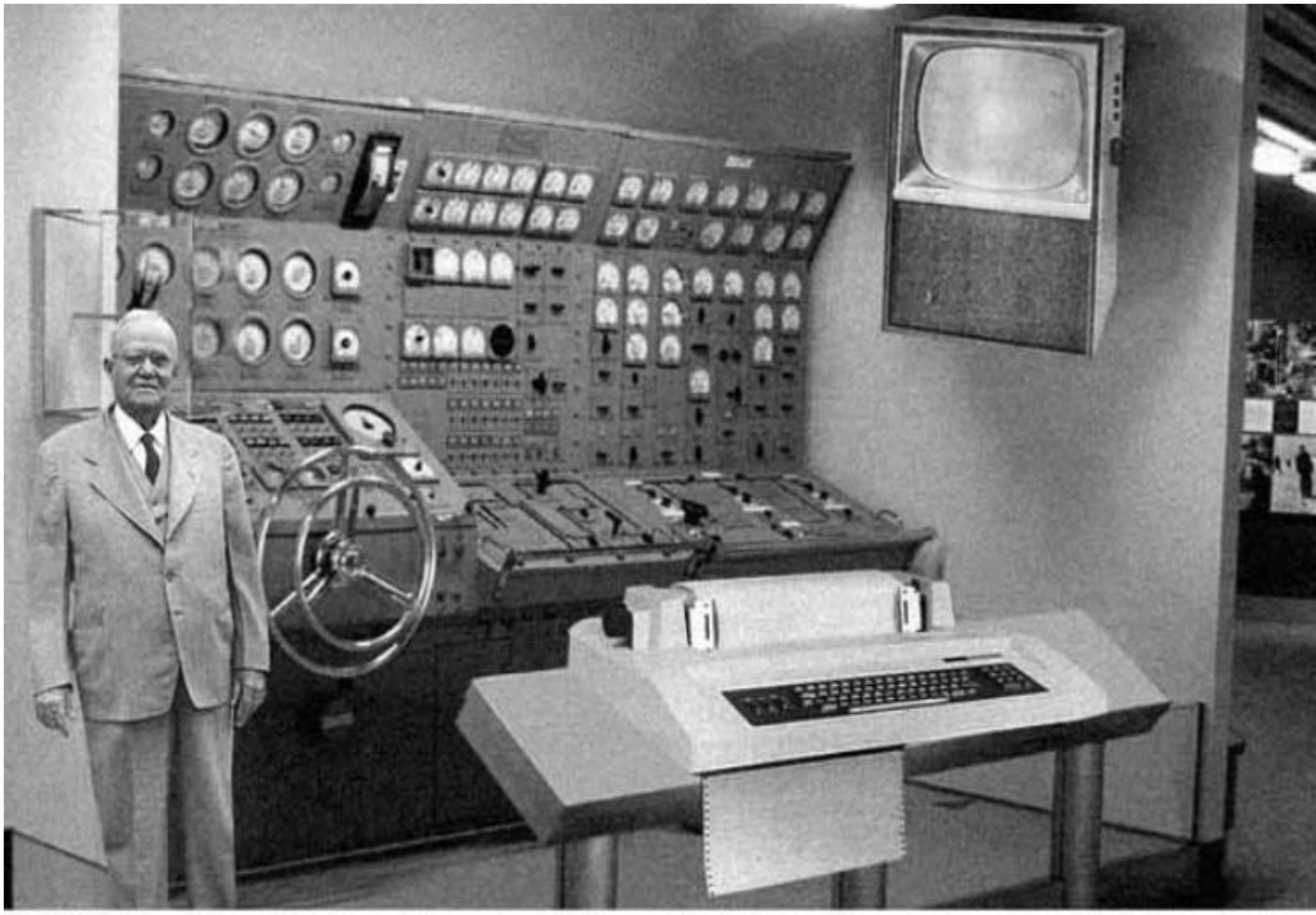
Executive Plenary Session

3:30 – 5:30PM, Tuesday, November 15, 2011

Moderator, James O'Bryon, The O'Bryon Group, MD

- Dr. Ed Kraft, Arnold Engineering Development Center, TN
- Mr. Gary Ross, Raytheon, MA
- MG Paul Nielson, SM/SEI
- Dr. David Womble, Sandia, NM

Yes, M&S Has Come A Long Way, But We Have A Long Way To Go



Scientists from the RAND Corporation have created this model to illustrate how a "home computer" could look like in the year 2004. However the needed technology will not be economically feasible for the average home. Also the scientists readily admit that the computer will require not yet invented technology to actually work, but 50 years from now scientific progress is expected to solve these problems. With teletype interface and the Fortran language, the computer will be easy to use.

Popular Mechanics, 1954

Dr. Edward Teller, (ADPA (NDIA) T&E Conference, January 15, 1997, Livermore, CA

The one great progress we have made over the past ten years has been in computers. Physics has been come a little unpopular. Partly because it has become scary, and more because very essential parts, relativity and particle mechanics have not been understood even by the intellectuals. Physics has slowed down. Computers have speeded up. I think that I might find myself to agree with my grandson, that computers are the things that will produce what we don't expect at all, that what will change the world in a remarkable manner."

Question: Since we cannot predict the future accurately because we don't know enough about the present, do you think we ever will know enough about the present to successfully predict the future.

Dr. Edward Teller, (January 15, 1997, Livermore, CA

"Heisenberg has shown that this is impossible. I can indicate to you why. The simplest things, light, electrons, the things out of which other things like atoms are built, they behave like particles, and they behave like waves, and this is a contradiction. You cannot know everything about the particles, how they will behave like waves when we make measurements on particles, and we make our measurements assuming they are waves, then we don't know how they will behave like particles."

O'BRYON'S OBSERVATION # 02

**" If you don't test,
the model is always right."**

O'BRYON'S OBSERVATION # 03

" If you fit a curve through the data, the data will fit the curve."

O'BRYON'S OBSERVATION # 04

" Realistic looking computer graphics does not equate to physics-based model credibility."

O'BRYON'S OBSERVATION # 05

" Computer models do especially well in predicting after the test is complete."

O'BRYON'S OBSERVATION # 07

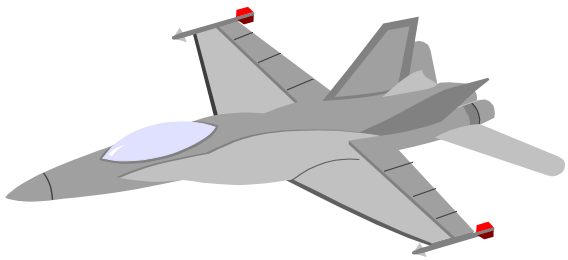
" If it's not in the model, it can't come out of the model."

O'BRYON'S OBSERVATION # 08

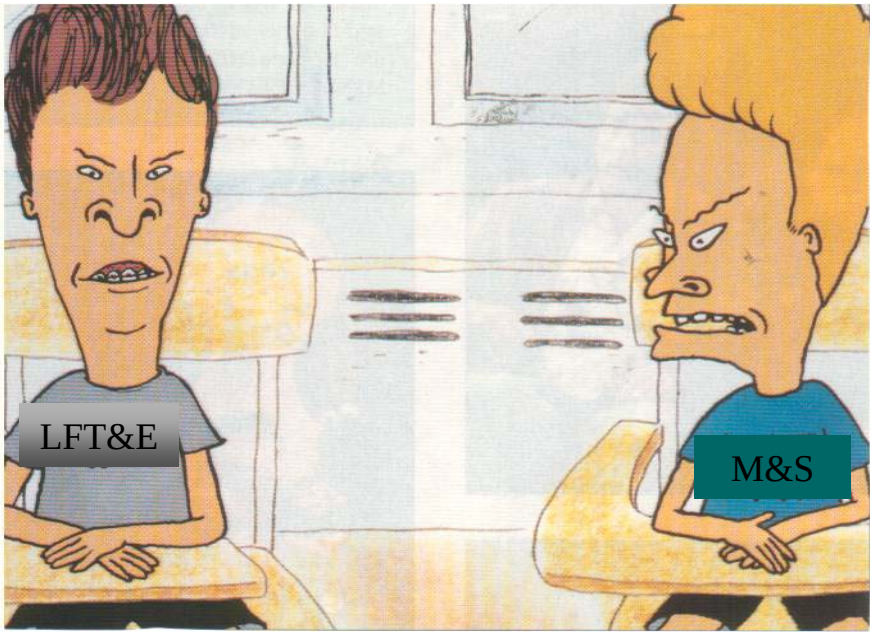
" Computer modeling tells us what we know while testing tells us what we know and some of what we don't."

MODELING AND SIMULATION IN TEST & EVALUATION

Modeling and simulation are an integral part of T&E and not to be looked at as a substitute, nor a means to save money. M&S and testing are mutually supportive and none is complete without the other.



M&S AND T&E ARE PARTNERS, NOT COMPETITORS



This is Not To Say That Modeling & Simulation Has No Role in T&E

"The Bottom Line on M&S and T&E."

"M&S Captures What You Know. "T&E Captures What You Know AND What You Don't Know (The Unknown Unknowns)"

(Jim O'Bryon, May 15, 2001)

"Major Problems Discovered In Testing Would Never Have Been Discovered In M&S. If We Were Smart Enough To Put It In The Model, We Would Have Been Smart Enough To Put It In The System."

(Dr. Marion Williams, (JASPO) JTCG/AS M&S Conference, Reno, NV)

Modeling Today vs. Modeling Tomorrow

TODAY:

- **Empirically-based Models**

TOMORROW:

- **Physics-based Models**

VULNERABILITY/LETHALITY MODELS:

- **Models Which Can Realistically Assess "Multiple Hits"**
- **Models Which Can Assess "Fighting-Hurt"**
- **Models Fully Verified/Validated by Actual Testing and/or Combat Data**
- **Models Which Can Accurately Predict Vulnerability & Lethality Test Outcomes**
- **Model Architecture which Permits Interfaces with Related Modeling Activities**
- **Models Representing Both Ballistic and Non-Ballistic Threats**
- **Models with Measurable Metrics**

What Has LFT&E Done to Improve Modeling & Simulation?

SHORT TERM: LFT & JLF are deriving empirical test data to update vulnerability/lethality models

MID-TERM: TILV provided a forum for Services and DSWA to coordinate and prioritize their 6.1-6.3A vulnerability/lethality programs -- meld of empirical and physics based models

LONG TERM: ASCI LFT MOU with DOE to leveraged their ASCI efforts to generate physics-based models to support LFT&E activities

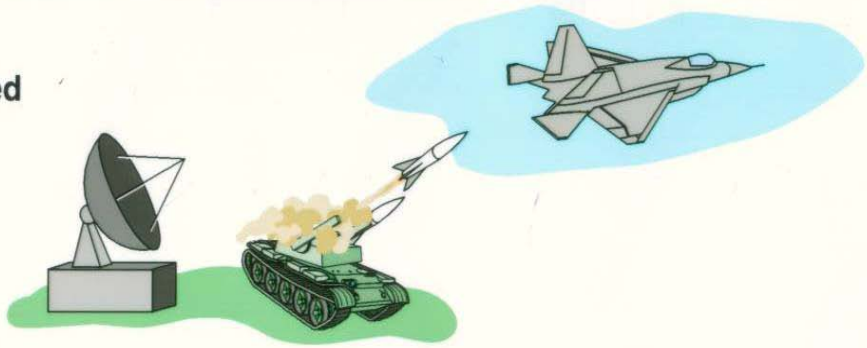
THE F-22 LFT&E PROGRAM: CASE AND POINT

A Case of Current Importance – Live Fire Test of Bullet Impact on F-22 Wing

Integrated Models and Analysis Provide Needed Context for Test Design

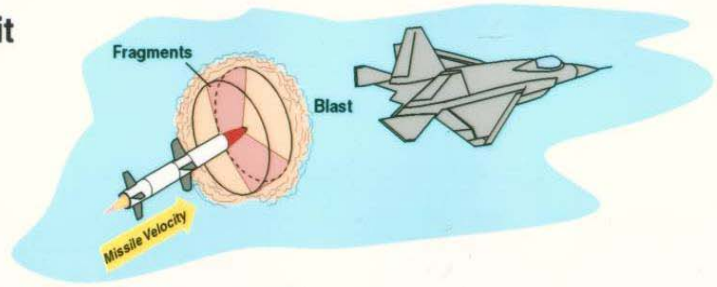
Susceptibility Data

- Interceptor threats expected (SA-7, SA-10, ZSU-23 . . .)



Vulnerability Data

- Probability of intercept hit



T&E Provides Data (metamodels) to Calibrate Integrated Models and Analysis

- Probability of damage/kill given a hit

Los Alamos

HAVEN'T WE LEARNED ENOUGH TO REPLACE TESTING WITH MODELING???

"IF ONE WISHES TO USE THE RDT&E PROGRAM OF THE BOEING 777 AS AN EXAMPLE OF HOW TO DEVELOP A SUCCESSFUL SYSTEM, TAKE NOTE OF THE FACT THAT OVER A PERIOD OF 11 MONTHS, THEY COMPLETED:

751	FLIGHT HOURS IN FLUTTER,
730	GROUND HOURS IN AERO PERFORMANCE,
1,088	FLIGHT HOURS IN PROPULSION DEVELOPMENT & CERTIFICATION,
770	GROUND HOURS IN AERO STABILITY,
830	GROUND HOURS IN AERO DEVELOPMENT,
1,280	FLIGHT HOURS IN ETOPS,
724	GROUND SERVICE READY HOURS,
278	FLIGHT HOURS IN AVIONICS CERTIFIC. &
913	GROUND HOURS IN SYSTEMS IN CERTIFIC.
1,020	OTHER TESTING HOURS

THAT'S 8,384 TEST HOURS, MORE THAN ANY OTHER AIRCRAFT IN HISTORY."

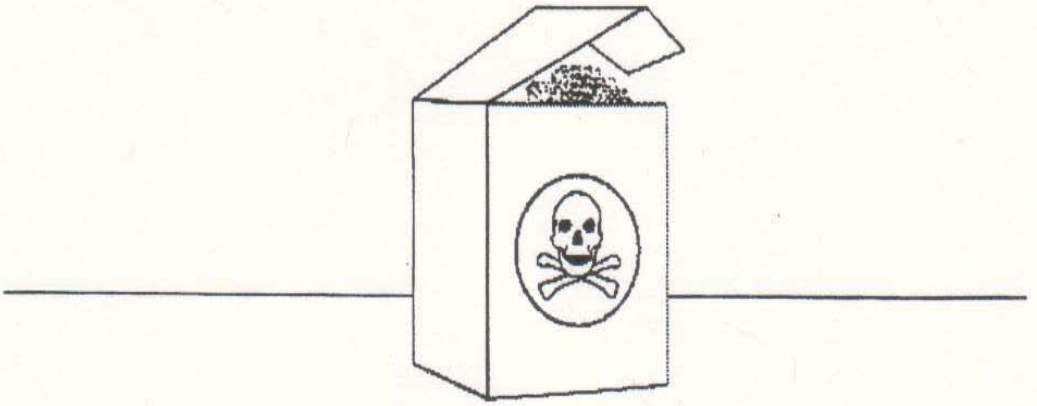
(JERRY ZANATTA, BOEING COMMERCIAL AIRPLANE COMPANY PRESENTATION TO DEFENSE SCIENCE BOARD ON T&E, SEPTEMBER 16, 1998)

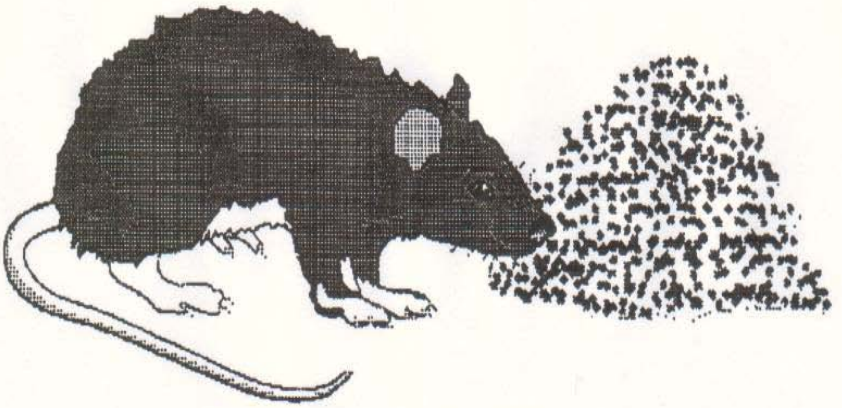
Dangers of Using Modeling and Simulation as "Proof" of Performance

"Modeling and simulation offer the F-22 Program another benefit, Air Force officers said, because the Service would control the inputs into the model, the outcome – proving the aircraft's effectiveness is much easier to shape than the outcome of an open air test with any number of unanticipated variables."

Quote from "Inside the Pentagon", September 1, 1995

M&S Adequacy

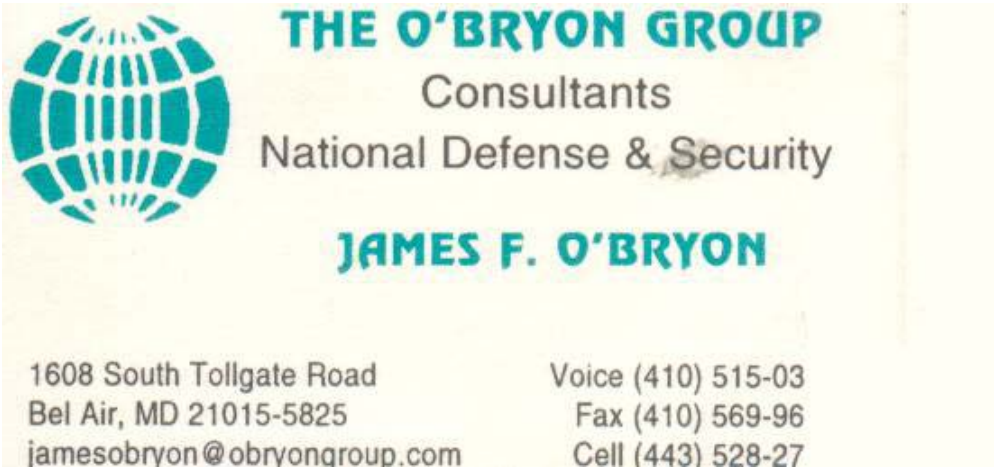




The Devil is in the Detail

Rat Poison: 90% Corn Meal 10% Strychnine

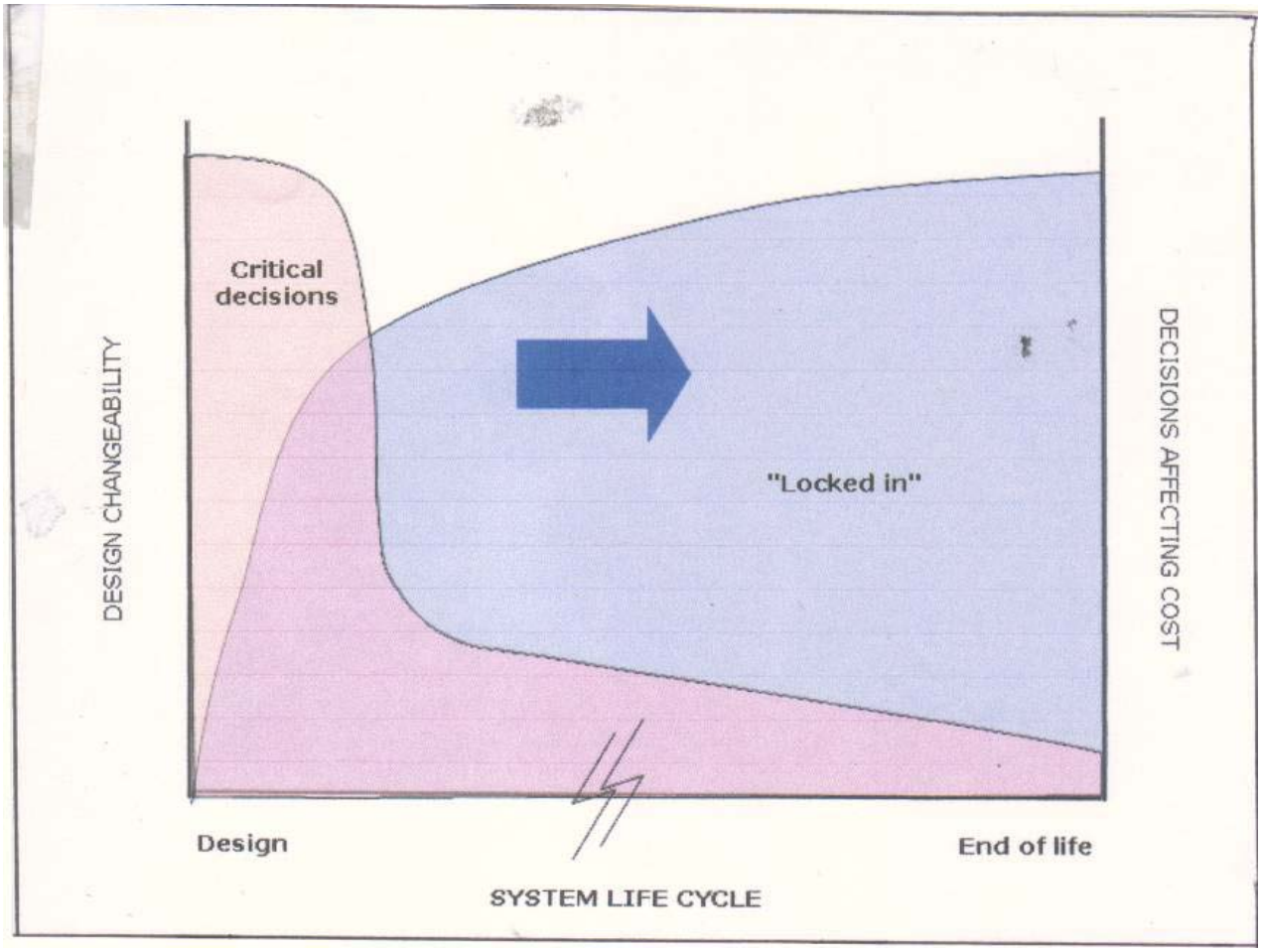
IF YOU HAVE SOME IDEAS YOU'D LIKE TO SHARE OR WOULD LIKE TO CHALLENGE SOME O THESE IDEAS, I WOULD WELCOME YOUR IDEAS.



Call me at 410-515-0345 or email me at jamesobryon@obryon

M & S PLAY A VITAL ROLE EARLY ON IN SYSTEM DESIGN AND VERIFICATION

Source: R. Garrett, "Opportunities in Modeling and simulation to Enable Dramatic Improvements in Ordnance Design, "presented to the Committee on Bridging Design and Manufacturing. National Research Council, Washington, DC., April 29, 2003.



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NAS/NRC M&S Committee Members

Peter Castro, Chair, Eastman Kodak
Erik Antonsson, Cal Tech
James E. Coolahan, JHU APL
Yu-Chi Ho, Syst Engr, Harvard
Mary Ann Horter, Lockheed Martin
Pradeep Khosla. Carnegie Mellon
Jay Lee, U of Wisconsin
John Mitchner, **Sandia NL**
Mikel Petty, Old Dominion
Stuart Starr, **Mitre Corp**
Charles Wu, Ford Research Lab
Bernard Zeigler, U of Arizona

"Modeling and Simulation in Manufacturing and Defense Systems Acquisition; Pathways to Success, p 94, National Research Council, National Academy Press, 2002"

Ten Studies in Ten Years!

Naval Research Advisory Committee Report (1994)

Naval Air Syst Command Study (1995)

North American Tech & Industrial Base Study (1996)

ADPA Study (1996)

Dir. Test Sys Engineering & Eval Study (1996)

NRC Study (1997)

Joint SBA Task Force Study (1998)

DSB Task Force Study (1999)

NRC Study (1999)

MORS Study (2000)

Physics-Based Modeling

"Mathematical models in which the equations that constitute the model are those used in physics to describe or define the physical phenomenon being modeled are referred to as physics-based models.

For example, physics-based flight dynamics models use aerodynamics equations rather than look-up tables to model the flight characteristics of a simulated aircraft.
The physics of failure and assessment of a potential system's durability and operational availability is of special interest. Such assessments would greatly benefit from accurate physical models that support predictions of the modes and times of failure of physical systems.

Several studies have concluded the need for improvements in physics-based modeling (Johnson et al, 1998, Hollis and Patenaude, 1999; Starr, 1998). Physics-based modeling is arguably more important for defense manufacturing and acquisition than for other simulation activities such as training."

"Modeling and Simulation in Manufacturing and Defense Systems Acquisition; Pathways to Success, p 94, National Research Council, National Academy Press, 2002"

Model Correctness

"Model correctness is the fundamental requirement of ensuring that the predictions of a simulation tool can be relied upon (Zeigler, 1998). The vision of defense acquisition contained in SBA requires the development of accurate and reliable models of real-world systems. A prerequisite to this is an understanding of the real-world systems and objects to be modeled, their contextual domains, and the phenomenology of the operations and interactions, all at a level of detail sufficient to justify the model. Once the models have been implemented as simulations, their correctness must be rigorously evaluated."

"Modeling and Simulation in Manufacturing and Defense Systems Acquisition; Pathways to Success, p 93, National Research Council, National Academy Press, 2002"

Modeling Methods

"Lack of adequate methods is one of the most serious shortfalls in using M&S (MORS, 2000). In order to maximize the potential of M&S technologies for commercial manufacturing and defense acquisition, basic research must be undertaken to improve understanding of modeling methods and characteristics including:

Scalability
Multi–Solution Modeling
Agent–Based modeling
Semantic Consistency
Modeling Complexity
Fundamental Limits of Modeling & Computation Uncertainty

"Modeling and Simulation in Manufacturing and Defense Systems Acquisition; Pathways to Success, p 78, National Research Council, National Academy Press, 2002"

Conclusions

Naval Research Advisory Committee Report:

Although no evidence indicates that the DON implemented any of the recommendations made by the panel, the committee believes that the work of this panel had an impact on later reports."

Naval Air Systems Study:

The themes of partnership and sharing, particularly as they pertain to industry involvement earlier in the acquisition process and to the question of proprietary rights are reflected in subsequent studies.

North American Tech and Industrial Base Org. Study;

This study highlighted many more general SBA issues than the NAVAIR study had. Recommended a central government office at the level of OSD to coordinate policy and to act as a source of information.

ADPA (NDIA) Study;

No evidence indicates that specific actions were taken in response to the recommendations of the ADPA study.

"Modeling and Simulation in Manufacturing and Defense Systems Acquisition; Pathways to Success, p 94, National Research Council, National Academy Press, 2002"

Conclusions

Director, Test Systems Engr & Eval Study:
The study reinforced some of the conclusions and recommendations of prior studies.

National Research Council Study:
Infrastructure is needed in the areas of M&S theory, texts, case studies, software engineering methodologies, "Virtual centers", journals and conferences, object repositories and interface standards to enhance reusability and composability, explanation and traceability capability, and tools, such as automated scenario generation and experimental design, &post-processing and data analysis.

Joint Simulation-Based Acquisition Task Force Study;
This study was not formally adopted by the Acquisition Functional Area Council, although it remains a reference document. No DoD action has resulted.

Defense Science Board Task Force Study;
There is no evidence that any progress has been madde toward implementing the process and model improvements recommended by the task force.

"Modeling and Simulation in Manufacturing and Defense Systems Acquisition; Pathways to Success, p 94, National Research Council, National Academy Press, 2002"

Conclusions

National Research Council Study:

It is too early to assess the degree to which the recommendations of the NRC (1999a) report have been implemented by NASA. However, it is important to note that the NASA-sponsored initiative, which had objectives similar to those of DoD's SMA initiative, ceased to exist as a separate NASA program.

Military Operations Research Society Study (MORS);

Up-front investment as the norm to reduce life-cycle costs, making M&S Strategy integral to the total acquisition plan, Making M&S critical to formal acquisition decisions, provide incentives for all stakeholders to participate and DoD policy and guidance on M&S use and sharing M&S technology between government and industry and across programs. There is no evidence yet of substantive, corporate-level DoD action based on these recommendations.

"Modeling and Simulation in Manufacturing and Defense Systems Acquisition; Pathways to Success, p 94, National Research Council, National Academy Press, 2002"

THE RESULT OF THESE STUDIES AND MULTIPLE EFFORTS HAS BEEN TO ORGANIZE, PRIORITIZE, REVITALIZE, FUND, AND PROMOTE THE DEVELOPMENT, VERIFICATION, VALIDATION, ACCREDITATION AND USE AND REUSE OF MODELS ACROSS THE DOD?

Results of LFT&E-Sponsored Survey of Model Usage within the DOD Acquisition Community

H&AI
Hicks & Associates, Inc.

Findings

- Only 25 of 359 M&S surveyed were used by more than one program
  - best of breed?
- Half of the programs had M&S Support Plans
  - these plans were not requirements oriented
- Less than 25% of the programs in the survey had dedicated M&S expertise
- Less than 20% of the programs surveyed were using a collaborative environment
- Only one of the programs incentivized the contractor for M&S performance
- Less than half of the programs addressed M&S activities in the contractor's SOW
- Nearly half of the M&S surveyed were developed by contractors and contractors retained ownership of the majority of these
- Cost data were not available for 72% of the 359 M&S

Results of LFT&E-Sponsored Survey of Model Usage within the DOD Acquisition Community

H&AI
Hicks & Associates, Inc.

Recommendations to USD(A,T&L)

- **Emphasize the important role that acquisition programs must play in the development of M&S**
  - address M&S in the 5000 series
  - incentivize Program Office investment in M&S
- **Foster an improved understanding of the interrelationship of T&E and M&S**
  - Endorse pilot programs with the SAEs that examine and demonstrate the utility of M&S for T&E
- **Review and clarify roles and functions of DoD M&S organizations**
  - "who's doing what" and "who should be doing what"
  - identify and coordinate M&S priorities and funding source
- **Examine payoff from M&S in life cycle cost**
- **Establish a forum to address industry strengths and challenges**
- **Direct the implementation of a process to identify and satisfy M&S requirements for joint, coalition and system of systems development**

Results of LFT&E-Sponsored Survey of Model Usage within the DOD Acquisition Community

H&AI
Hicks & Associates, Inc.

Results to date

- USD(AT&L) directed that language concerning M&S development and management be included in the new DoD 5000.2-R
  - develop M&S plans, co-signed by testing community
  - use M&S to make pre-test predictions and use test results to validate the M&S
  - use M&S to validate interoperability
  - require M&S to be deliverables
  - identify M&S to be used in evaluation proposals
- DOT&E and ASN(R&D) created Pilot Project concept
  - Air Force and Army SAEs agreed to participate
  - USD(AT&L) endorsed DOT&E Pilot Projects with the Services

Brief Summary of Results from LFT-Sponsored Survey of DoD M&S in Support of Defense Acquisition

1. Simulation Based Acquisition is not pursued in any organized manner:
2. It's more myth than reality … a slogan … a bumper sticker.
3. Industry executives either are being disingenuous or are fooling themselves [saying that SBA is here];
4. Program managers have little incentive to do SBA, because of high turnover;
5. PMs often prefer to not have realistic models – since they may make the program look worse;
6. There are no financial rewards for industry to cut costs;
7. On the training side, they [M&S] are more organized than on the acquisition side.

M&S Could Help Avert Program Failures

"The DoD and the Services regularly make high sounding pronouncements that modeling and simulation is going to be the answer and the greatest thing since sliced bread … but it is not easy to find examples in the DoD where M&S has really made a difference," [Philip E.] Coyle says in a February speech to the National Defense Industrial Association T&E Conference.

By comparison, agencies such as Lawrence Livermore National Lab have proved that modeling, simulation and testing can make a "very happy marriage". The lab, it is "literally unthinkable that you would spend millions of dollars on a test without making an equivalent effort first in M&S."

National Defense Magazine, May 2006, p 20

--Dr. Richard Hallion, USAF History and Museums Program, ITEA Journal, September/October, 2000

Cultural Issues with M&S in DoD vs. DOE

“There is a “cultural bias at the Defense Department that views computer models as vehicles to justify programs, rather than as tools to better understand the technology. “The focus in defense acquistion is on buying something and moving on, not on understanding for its own sake.. Detailed scientific and technical understanding is not the first priority.”

“By contrast, the culture in the development of nuclear weapons has been to achieve firs-principles understanding of everything … without those models, the Department of Energy weapons labs would be quite helpless today.”

Honorable Philip E. Coyle, III, National Defense Magazine, May 2006, p 20.

Cultural Issues with M&S in DOE vs. DOD (Continued)

"Another reason why simulations are often shunned by defense PMs is that they don't want to risk delaying production schedules when technical glitches pop up in computer models. The incentives are to get the system into production with as little perturbation as possible.

The goal for modeling and simulation in DOE … is to predict with rather astonishing accuracy what will happen. This means that M&S and the evaluations that come from those models, may produce bad news.

[However] at the DOD, the tendency is to expect that test and evaluation will produce bad news and that M&S will produce good news. Thus M&S is often recommended as the better choice."

Honorable Philip E. Coyle, III, National Defense Magazine, May 2006, p 20.

Dangers of Using Modeling and Simulation as "Proof" of Performance

"Modeling and simulation offer the F-22 Program another benefit, Air Force officers said, because the Service would control the inputs into the model, the outcome – proving the aircraft's effectiveness is much easier to shape than the outcome of an open air test with any number of unanticipated variables."

Quote from "Inside the Pentagon", September 1, 1995

Expressions of Frustration at M&S in DoD Acquisition

"OSD is such a fragmented organization that you can find any opinion you want, maybe you'll even find a good one."

"Working with military instructions is like building a sauna out of ice cubes."

"There's no such thing as validating a model. Validation is just a failed attempt to falsify a model."

It's Vital that Model Extrapolations Are Anchored Solidly on First Principles (cont'd)

Extrapolations based purely on empirical fits to data points are going to leave you hanging…

And combat lives could be at risk!

- Made major strides i
  and addressing M&S
- Brought the testing and
  communities more toge
- Integrated the JTCG communities into the DOT&E mission
- Made major strides in casualty assessment & reduction
- Made industry more of a partner with T&E
- Served as the warfighter's
  "Underwriters Lab

Otherwise, stay with test data and/or small interpolations from known data points.

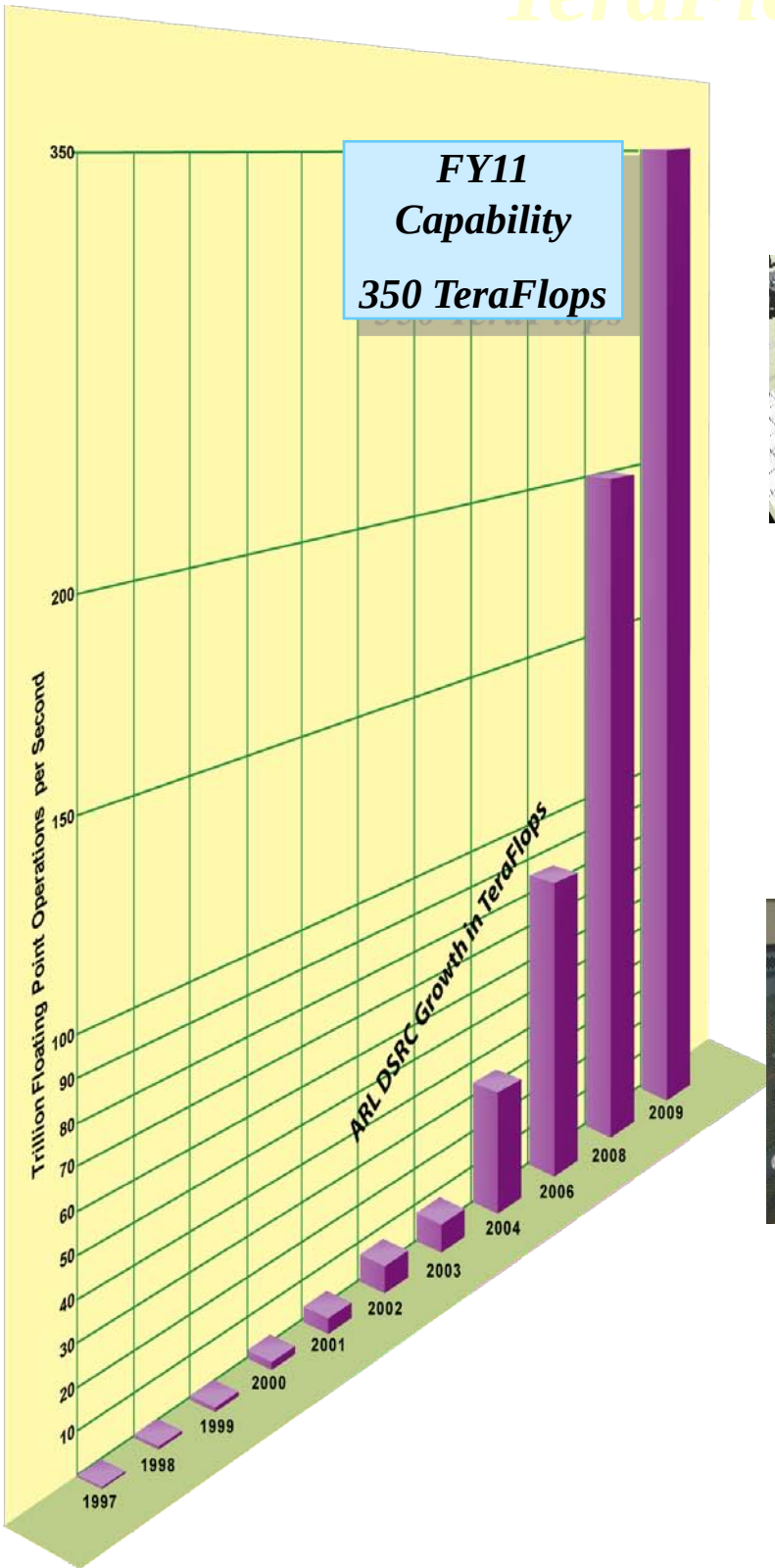
Even M&S of the vortices generated behind large aircraft were inadequate in predicting the collisions of cargo / personnel from C-17 rear ramp

National Labs Can Help

1. Re-energize the DoD/DoE ASCI MOU on LFT&E.
2. Promulgate not only the need to organize M&S but serve as member of the proposed Consortium.
3. Come along side DMSO to help them with M&S Architecture development to enable codes to inter- communicate.
4. Don’t conduct another study on DoD M&S needs until action is taken on the last 10 studies.

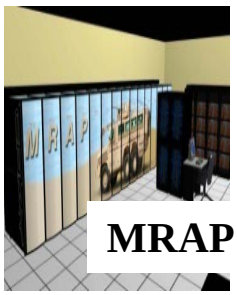
ARL DSRC Processing Speed Has Had Exponential Growth,

TeraFlops



SGI ALTIX ICE
10,752 cores / 32TB

Cray XT5 Cluster
10,400 core / 41.6 TB



SGI ALTIX ICE 8200
6,656 cores / 52.2 TB

Linux NetworX Advanced Technology Cluster
4400 core/8192 GB

Taxonomy of Benefits Attributable to Use of HPCMP Resources

("Determining the Value to the Warfighter; A Three Year Return on Investment (ROI) Study," DoD High Performance Computing Modernization Program, February 2009

Mission Effectiveness

Increase Lethality

Enemy Kills, Enemy Equipment Destroyed, Infrastructure Destruction

Decrease Vulnerability

Friendly Life Savings

Friendly Equipment Savings

Logistics Savings

Fewer Spares

Fewer Types of Equipment

Reduction in Training Cost

Fuel Savings

Better Availability

Longer MTBF

Shorter MTTR

Test/Experimentation Savings

EMAIL FROM MR. HAROLD BREAUX, ARL, APG, MD, TO JIM O'BRYON, OCTOBER 20, 2011

Regarding Physics Based Modeling: Much of the high level efforts on Physics Based Modeling are being done under the auspices or alternatively dependent on the so called HPCMP- hence explanation of my role below and some material on the internet for which I will provide URL's hoping you might find it useful.

I came into my post retirement role as the Army's Supercomputer Allocation Officer through the following:

In the 80's, I served as George Singley's Executive Secretary for the Army Supercomputer Functional Coordinating Group. When the Congress mandated the creation of a Supercomputer Modernization Program [actually called the HPC (High Performance Computing Modernization Program)] HPCMP, I was named as the Army Lead Member on the HPC Working Group that created the program and jump started the structuring, manning, acquisitions and operations. Initially I was the Army member on the HPC Advisory Panel (HPCAP) that oversaw the program.

EMAIL FROM MR. HAROLD BREAUX, ARL, APG, MD, TO JIM O'BRYON, OCTOBER 20, 2011

As you probably know the HPCMP was initially S&T only **and after a year or two T&E was included.** The applications that drive the need for ever-increasing HPC capability are Physics Based Modeling -models **primarily involving partial differential equations.** The models that were commonly used circa 1993 (at the creation of the HPCMP) are now considered routinely easy (I started to say trivial). Let me describe one model that bears on our common history. Dr. J. Sahu, ARL is now the senior member of the ARL staff continuing to do aerodynamic calculations using the Navier Stokes equations-but in a much more advanced multi-physics coupled mode. In a single coupled simulation, Sahu computes all the aerodynamic forces and moments on a projectile,feeds those force moment calculations (real time) to a coupled 6 DOF model, computes the rigid body dynamics (at certain speeds a projectile could bend, melt or break apart) and additionally couples guidance,either through moving fins, thrust adjustment or particle ejection. The model is referred to as the Virtual Aerodynamic Range. In my role I coordinate several aspects of the Army's interface to the HPCMP including the annual competition for Challenge Projects. These projects are inherently physics-based modeling, whose annual computational needs generally are in the millions of hours. The URL's I provide below list the winners in the most recent competition.

EMAIL FROM MR. HAROLD BREAUX, ARL, APG, MD, TO JIM O'BRYON, OCTOBER 20, 2011

"One of the things to note is that while T&E is part of the HPCMP there is very little participation by the Testing Community."

One might ask why! The Sahu Virtual Test Range is one model that the Test community surely could and I hope do use. I can think of two reasons why the testing community has little involvement with Physics-Based Modeling:

Reason 1. A system undergoing tests is influenced by a hierarchy or sequence of physics-based phenomena. The HPCMP divides the world of Physics into ten or so Computational Technology Areas (CTA's)- the Virtual Test Range, e.g., involves CFD (**Computational Fluid Dynamics), Structural Mechanics and Guidance and Control**. As one who has taken graduate courses in Numerical Solution of PDE's I can vouch for the difficulty of solving a system involving only one CTA. Coupling the physics of two or more CTA's into one model becomes a horrendous problem because of fundamental issues of stability and convergence. Additionally the required solution time increases dramatically. Additionally old Fortran skills are grossly insufficient- the programming for parallel systems with up to 10,000 processors or more demands skills way beyond what we had in the early days.

EMAIL FROM MR. HAROLD BREAUX, ARL, APG, MD, TO JIM O'BRYON, OCTOBER 20, 2011

"One of the things to note is that while T&E is part of the HPCMP there is very little participation by the Testing Community."

Reason 2. In the Army we find two agencies that comprise over 90% of the Army's usage of supercomputing, namely **ARL and ERDC** (formerly WES-Vicksberg). Part of this dominance is mission related but I believe a large part is historically due to Bob Eichelberger and Bob Whalin. Both of these Directors (RJE at BRL) and Whalen at WES **created a culture of not only pushing physics based modeling** (even though the computing capacity was grossly inadequate)but **simultaneously** kept **pressing for acquisition of more and more compute power**. The benefit of this legacy is that **staff was created, nurtured and matured** in capability-the fruits of which ARL and ERDC are now benefiting from. Of course that legacy also lead to both ARL and ERDC hosting each a DoD Shared Resource Center (DSRC). The test agencies (aside from AF Arnold Engineering Center and Navy Pax River) simply don't have staff with the requisite skills nor the management support to dedicate years efforts in physics-based model development. In my years as the Army HPC allocation Officer **I have seen (from T&E) one project from Aberdeen Test Center, one from Dugway, one from RTTC at Redstone.**

Web Links to HPCMP

Homepage.

http://www.hpcmo.hpc.mil/cms2/index.php

http://www.hpcmo.hpc.mil/cms2/index.php

Cover Letter announcing this year's Challenge Project Selections

http://www.hpcmo.hpc..mil/community/CHALLENGE/docs/2012/FY2012_Challenge_Project_Selection_Memo.pdf

http://www.hpcmo.hpc.mil/community/CHALLENGE/docs/2012/FY2012_Challenge_Proj

Listing of winners and a sample of what is going on in DoD in Physics Based Modeling.

http://www.hpcmo.hpc.mil/community/CHALLENGE/docs/FY2012_ChallengeSelection.pdf

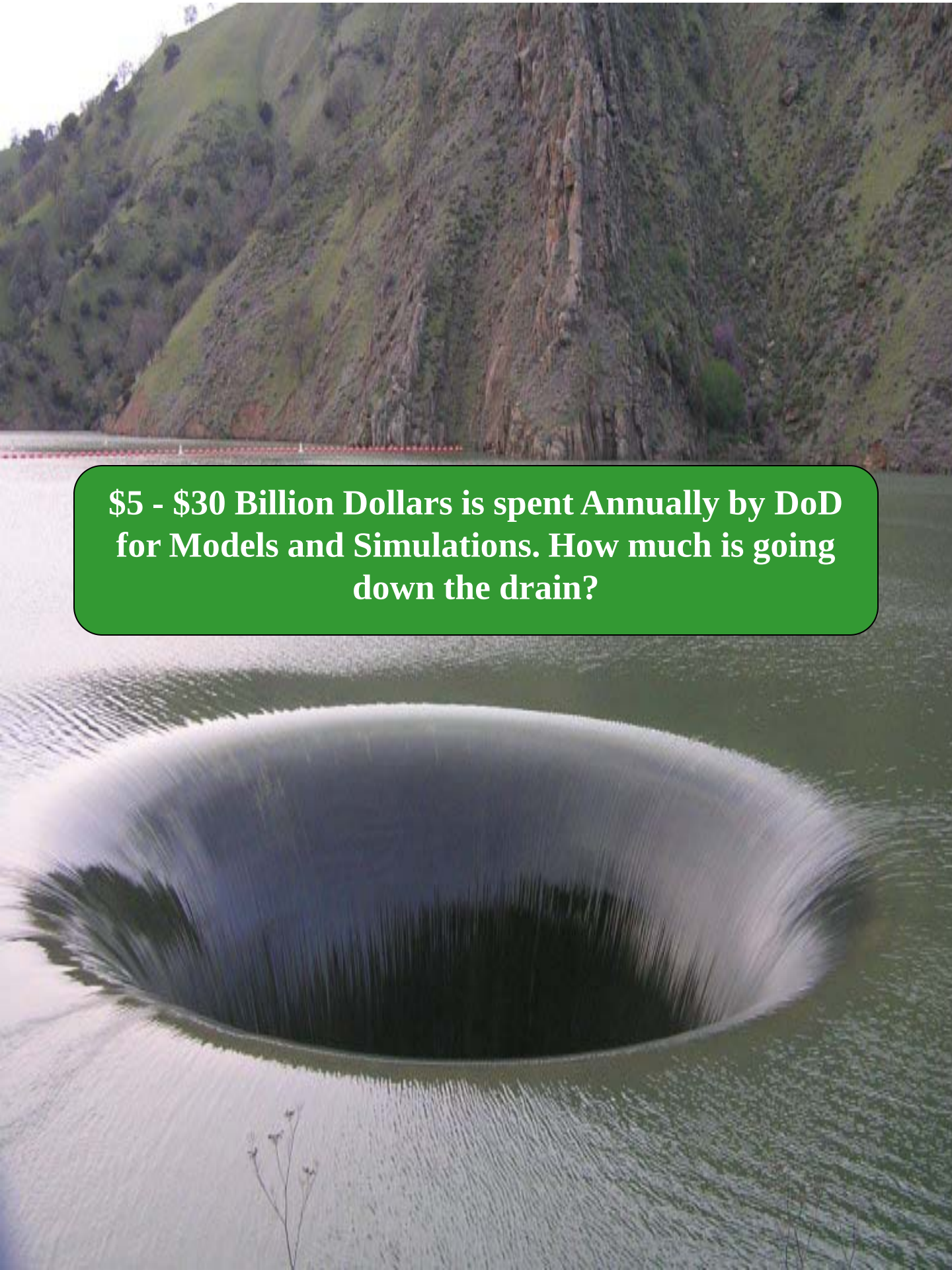
Hhttp://www.hpcmo.hpc.mil/community/CHALLENGE/DOttp://www.hpcmo.hpc.mil/community/CHALLENGE/docs/FY2012_ChallengeSelection.

At Least Three Software Institutes Have Been Set Up

1. Insensitive Munitions, at APG, MD, Brad Forch in Charge

2. Blast Protection and Mitigation, at APG, Scott Kuck in Charge

3. Battlefield Network M&S



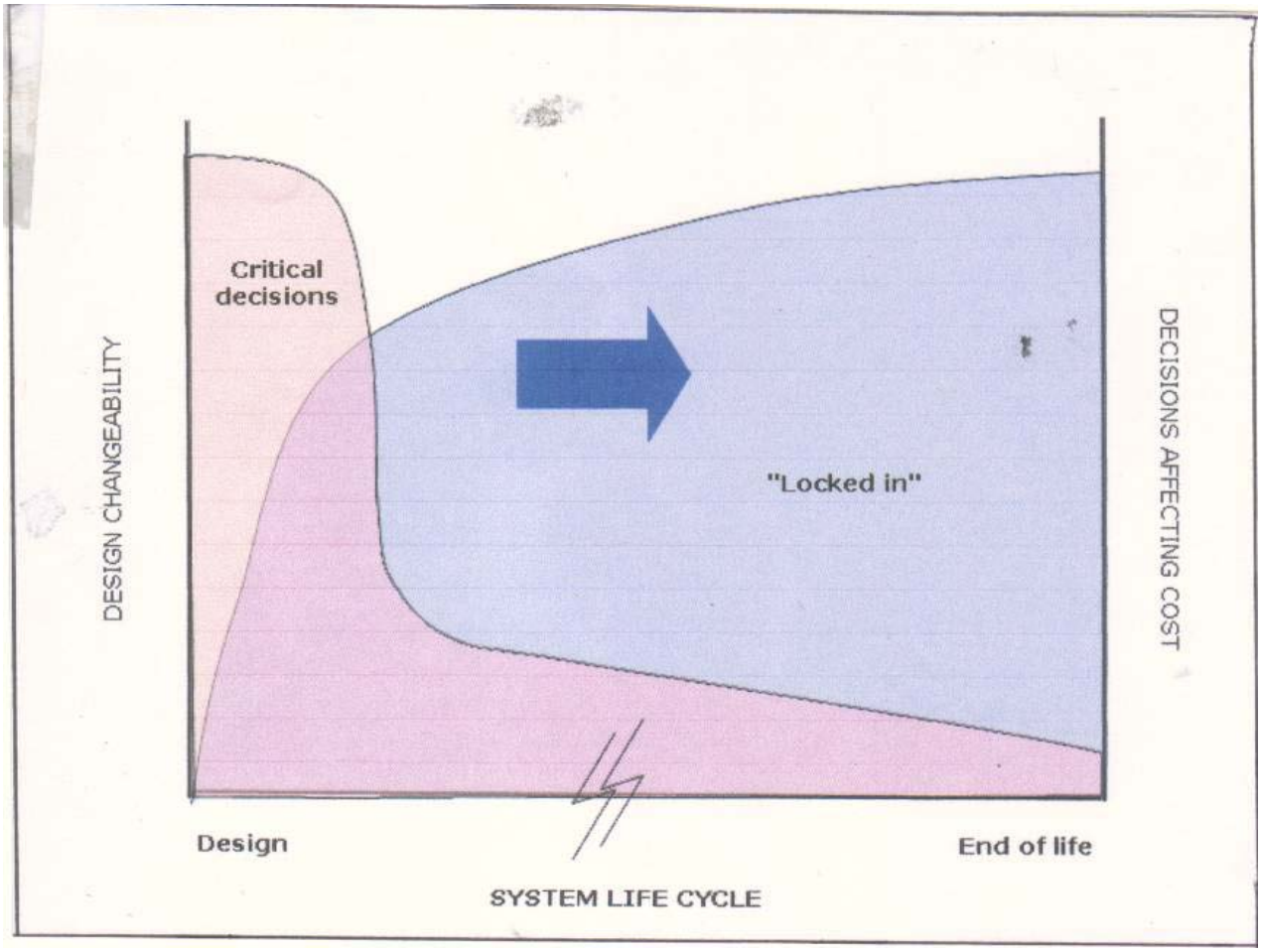
$5 - $30 Billion Dollars is spent Annually by DoD for Models and Simulations. How much is going down the drain?

O'Bryon's 23 Observations

1. A good test is worth a hundred opinions and a thousand computer runs.
2. If you don't test, the model is always right.
3. If you fit a curve through the data, the data will fit the curve.
4. Realistic looking computer graphics does not equate to physics-based model credibility.
5. Computer models do especially well in predicting after the test is complete.
6. Some things scale. Some things don't.
7. If it's not in the model, it can't come out of the model.
8. Computer modeling tells us what we know. Testing tells what we know and some of what we don't.
9. The quantifiable tends to obscure the significant.
10. Statistical significance is not necessary to have a significant test.
11. Sometimes Mother Nature argues with your assumptions and at the worst possible time.
12. Outliers might be the most valuable data you collect.
13. Testing to failure is not necessarily a test failure.
14. If you aim at nothing, you're sure to hit it.
15. If a system is totally survivable, it's probably neither suitable nor effective.
16. If you've tested every system component, you still haven't tested the system.
17. The real world is not a special case.
18. After all is said and done, often more is said than done.
19. Testing does not change anything. Acting on testing does.
20. We never seem to have time to do it right but we always seem to have time to do it over.
21. If it doesn't have to work, we can have it for you tomorrow.
22. If you're not catching some flak, you're probably not over the target.
23. Honest and realistic T&E is the best consumer protection for our fighting forces.

M & S PLAY A VITAL ROLE EARLY ON IN SYSTEM DESIGN AND VERIFICATION

Source: R. Garrett, "Opportunities in Modeling and simulation to Enable Dramatic Improvements in Ordnance Design, "presented to the Committee on Bridging Design and Manufacturing. National Research Council, Washington, DC., April 29, 2003.



VULNERABILITY M&S

How well do we do?

M1/M1a1 LFT&E Included
48 Full-up System Level
Live Fire Shots

Modeled

- Primary Penetrator
- Primary Spall

Not Modeled

- **Fire**
- **Toxic Fumes**
- **Shock**
- **Secondary Debris**
- **Ricochet**
- **Deformation**
- **Cracking**
- **Non-nuclear EMP**
- **Crazing**
- **Other Effects**

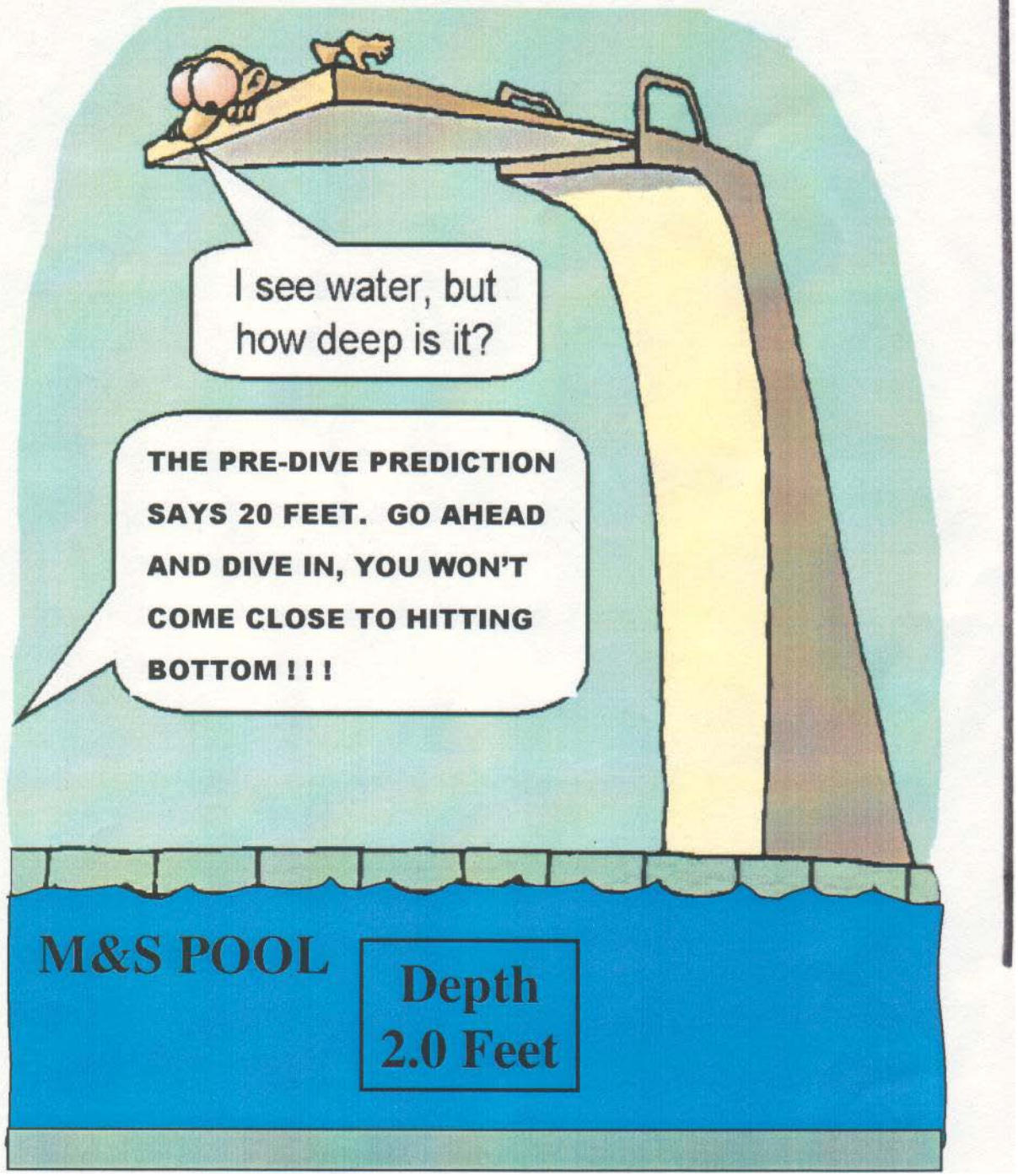
Conclusions

- Even when model claims rigor:

- Less than 1/2 modeled criteria components that were damaged were predicted to be damaged

- This is the best armor vulnerability model currently available!

WELCOME TO THE M&S CREDIBILITY POOL!



What Damage Mechanisms In The Model Were Examined??

- Only Examined Those Damage Mechanisms **Contained in the Model** (Primary Penetrator & Primary Spall)

- Did Not Evaluate Damage Due to Kill Mechanisms Not Included In The Model

If the Model Didn't Predict it, Can I Just Chalk it Up as a "Random Failure?"

"There are no random failures. There are, however, some things we don't understand.

"Testers have to know more about the systems than the engineers that built them."

T.K Mattingly, VP, Lockheed Martin and Former NASA Astronaut, ITEA Conference, Orlando, FL, September 1997

"Modeling cannot replace testing but it can lead to smarter T&E."

Dr. Milton Finger, LLNL, ADPA (NDIA) LFT&E Symposium, January 1997

ARE AIRCRAFT MODEL PREDICTIONS ANY BETTER?

• COVART has been the “workhorse” vulnerability model for aircraft for nearly two decades now in version 4.

• COVART assumes projectiles fly in exactly straight lines after impact (they don’t)

• COVART assumes that projectiles only erode and slow down when impacting (they also break up into multiple smaller projectiles) contains no secondary debris

• COVART has no method of predicting cascading or synergistic damage. (This damage happens on many high-fidelity target shots and must be accounted for)

ARE AIRCRAFT MODEL PREDICTIONS ANY BETTER? (Cont'd)

• COVART does not really predict anything. It is a "book-keeping" operation which spills back out the various component Pk/h's that have been fed into it prior to the vulnerability run.

• COVART does not effectively address multiply redundant components.

• The #1 source of vulnerability, fire, is not adequately modeled.

<u>Example:</u>
TWA#800 / B1 Bomber predictions

• Many other simplifying assumptions.

Modeling & Simulation Wisdom on Empirical Fits

"If you fit a curve through the data, the data will fit the curve. "

Mr. Robert Wojiechowski, APG

Observations on Aircraft Vulnerability Modeling

”Much remains to be done before one could have confidence in the predictive tools for aircraft vulnerability.

We do not have appropriate test data to support many of the relationships which the analytical models use.

Not all things that happen are modeled (e.g. heat transfer at altitude to cause material failure during fires).

Simplifications exist in the models most widely used (e.g. COVART) which prevent their realistic depiction of events)

Although the capabilities to get presented areas is good, the estimation of component damage is poor.

Concepts for vulnerability reduction in initial design are often given up (“sweated out”) when coming down to production designs.
There is next to zero data base on internally stowed missiles.

COVART does not accept many partial damages (e.g. a cracked spindle is assessed as just cracked regardless of the size and depth of the crack.”

The structural effects of an explosion are aircraft unique.

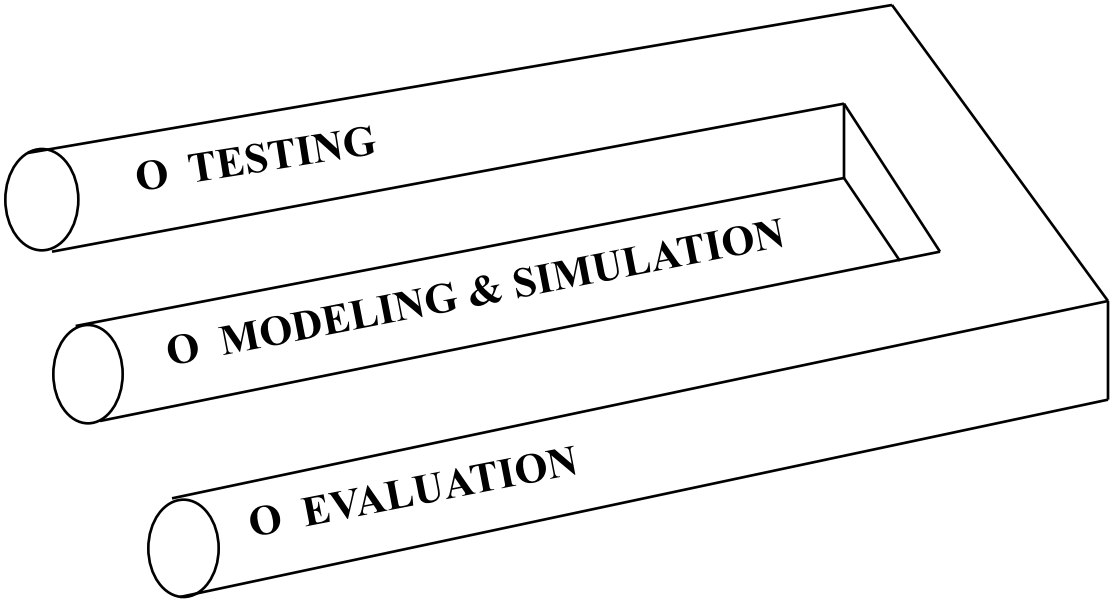
JTCG/AS Component Vulnerability Workshop, WPAFB, OH, March 1991

Commercial Success of M&S

"Let me take this opportunity to firmly state my commitment to the use of M&S in the acquisition of our weapons systems. Over the past decade, the American commercial sector has undergone significant reorganization and restructuring. We have seen many examples in the commercial sector of how application of M&S throughout a program's life cycle can help achieve these goals. Chrysler's Intrepid and Boeing's 777 are just two examples of M&S commercial success."

--Memo from Dr. Jacques Gansler,
USD (A&T), March 16, 1998

Three Pillars of Weapons Assessment: Are they Adequate to Support Weapons Systems Acquisition???



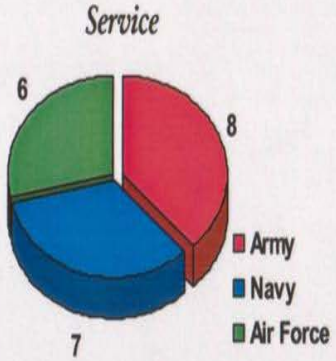
“Is it an illusion?”

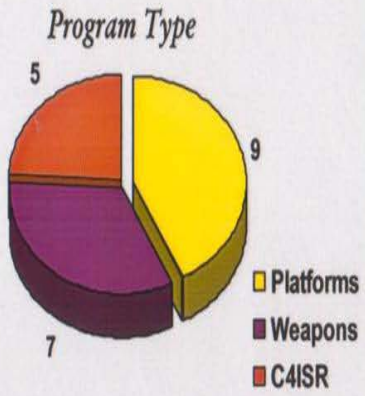
Results of LFT&E-Sponsored Survey of Model Usage within the DOD Acquisition Community

H&AI
Hicks & Associates, Inc.

Summary of Survey Respondents to Date

Program	Component	System Type	Current Status*	FRP Date*
Crusader	Army	Platform	MSII decision 2001	1QFY06
Comanche	Army	Platform	MSII decision FY02	1QFY07
M1A2 Upgrade	Army	Platform	FRP	3QFY94
ATACMS Blk II/BAT	Army	Weapon	LRIP	3QFY00
Javelin	Army	Weapon	FRP	3QFY97
SADARM	Army	Weapon	LRIP	4QFY98
FAAD C2	Army	C4ISR	FRP	3QFY95
C2 Vehicle	Army	C4ISR	LRIP	1QFY00
F/A-18 E/F	Navy	Platform	LRIP	3QFY00
V-22 Osprey	Navy/USMC	Platform	LRIP	2QFY00
LPD-17	Navy/USMC	Platform	EMD	3QFY07
AIM-9X	Navy	Weapon	LRIP	1QFY02
AN/BSY-2 (SSN-21)	Navy	C4ISR	Sea Trials on SSN-22 (USS *CONNECTICUT*)	N/A
UHF Follow-On	Navy	C4ISR	Completing FRP	4QFY88
SLAM-ER	Navy	Weapon	FRP	2QFY99
F-22	USAF	Platform	LRIP	3QFY03
B-2	USAF	Platform	IOC	N/A (did not enter FRP)
EELV	USAF	Platform	MSII Decision FY99	2QFY03 (MSIII decision 1QFY03)
ABL	USAF	Weapon	MSII decision FY03	2QFY05
SBIRS	USAF	C4ISR	MSII decision 1996	First GEO sat deliv. FY02; HEO FY03; LEO FY-04
SFW P3I	USAF	Weapon	FRP	3QFY96





*Source: DOT&E FY98 Annual Report to Congress

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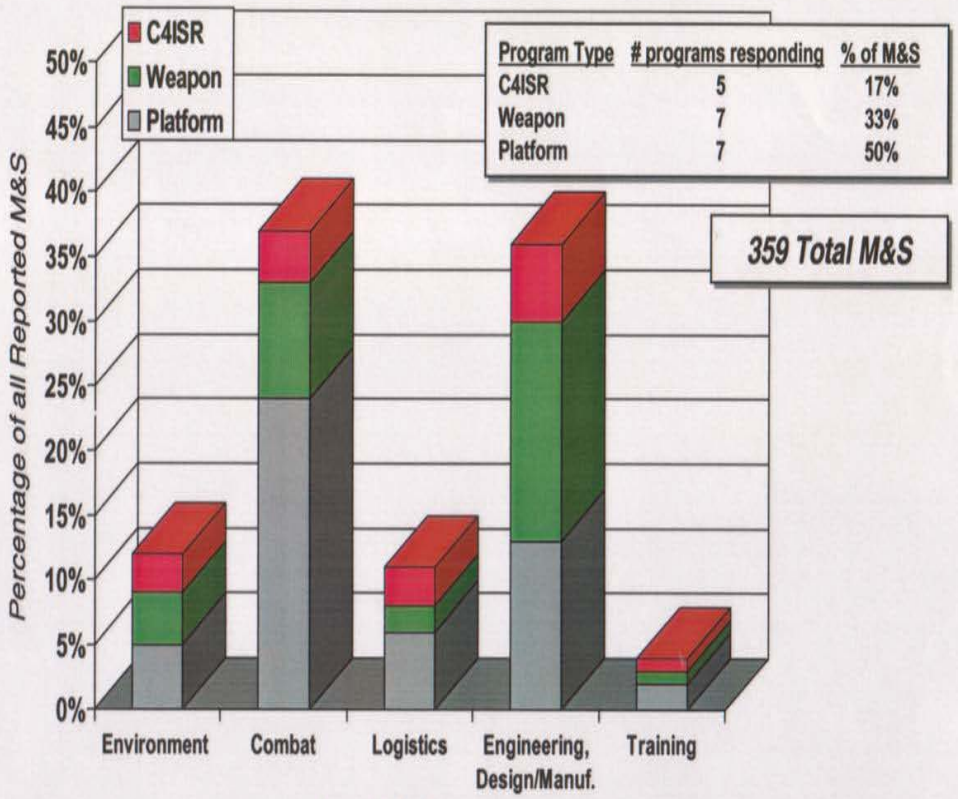
M&S Characterization

By Program Type



Program Type	# programs responding	% of M&S
C4ISR	5	17%
Weapon	7	33%
Platform	7	50%

359 Total M&S

- *Types of M&S used driven partly by program type*
- *"Platform" programs utilized more total M&S assets and comparatively higher percentage of logistics and combat M&S types*
- *"C4ISR" programs utilized comparatively higher percentage of training M&S*

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M&S Characterization

Common M&S

- **Combat Models**
  - ALARM (2)
  - ASAP (2)
  - CASTFOREM (2)
  - SUPPRESSOR (4)
  - TRAP (3)
- **Engineering/Design/ Manufacturing**
  - ANSYS (2)
  - APART (2)
  - CATIA (3)
  - COVART (3)
  - DYNA 2D (2)
  - ESAMS (3)
  - FASTGEN (3)
  - JSEM (2)
  - Pro-E (5)
- **Logistics**
  - COMPASS (2)
  - LCOM (2)
  - RELEX (3)
  - TIGER (2)
- **Environments**
  - EOSAEL (2)
  - LOWTRAN (5)
  - MODTRAN (2)
  - NASTRAN (5)
  - PATRAN (5)
  - SINDA (3)

Exploiting M&S commonality:

- *Best-of-breed?*
- *Strengths/Weaknesses?*
- *Limits on extension/application?*
- *VV&A status?*

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Results of LFT&E-Sponsored Survey of Model Usage within the DOD Acquisition Community

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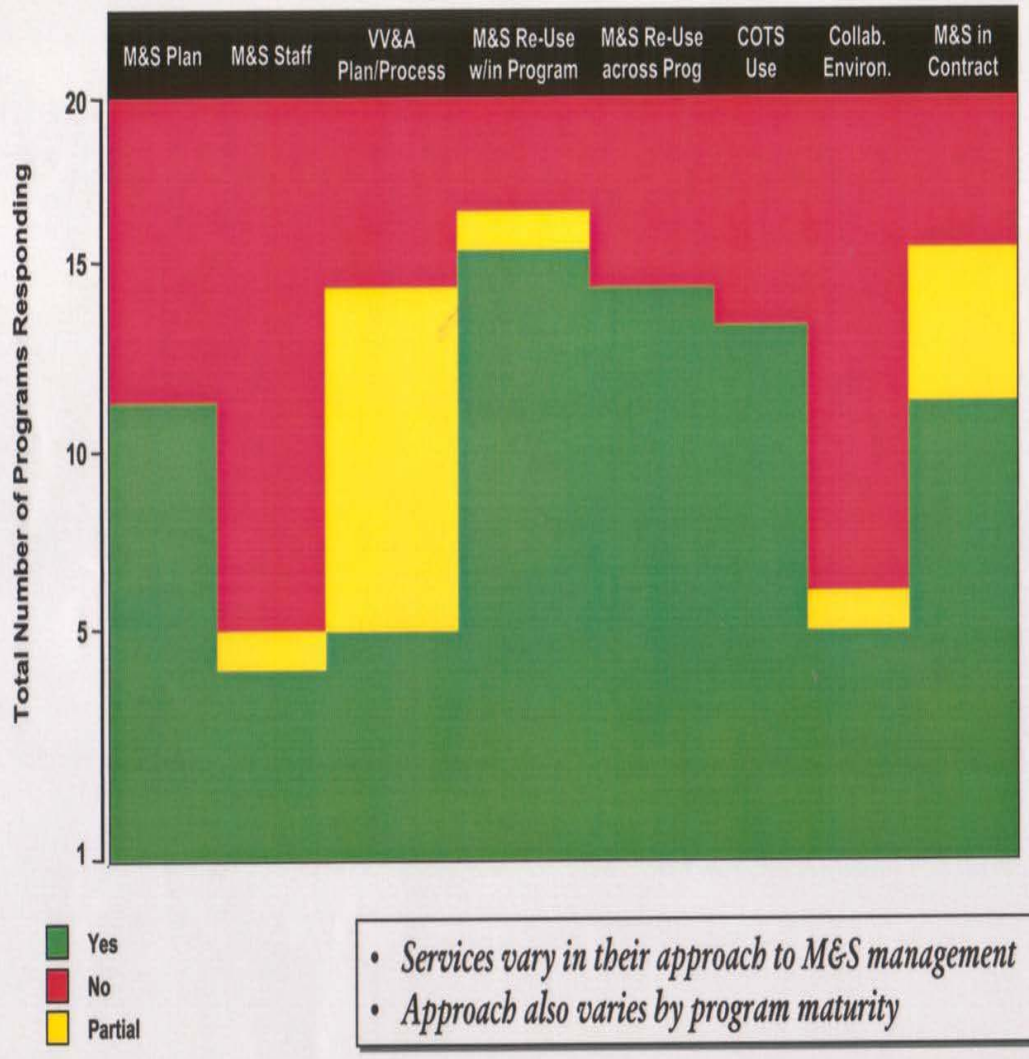
Incorporation of Selected M&S Management Activities



- *Services vary in their approach to M&S management*
- *Approach also varies by program maturity*

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Results of LFT&E-Sponsored Survey of Model Usage within the DOD Acquisition Community

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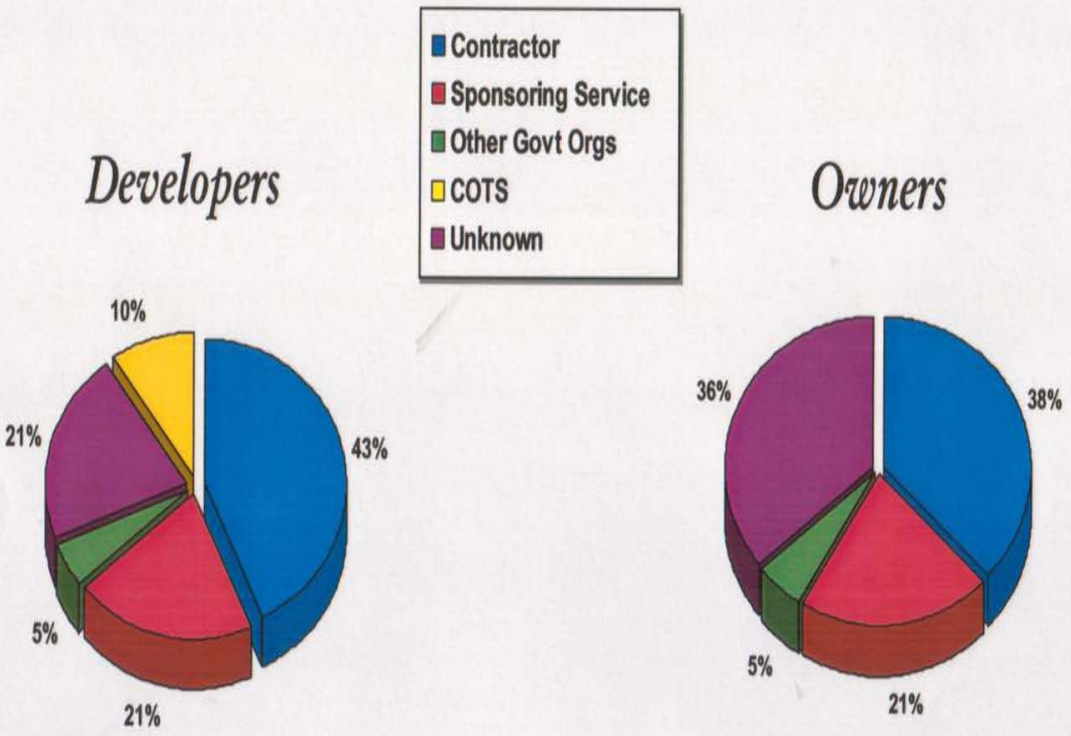
M&S Management



- *219 M&S from 13 programs*
- *Crusader, F/A-18E/F, Javelin, FAADC2, AIM-9X, ATACMS/BAT and Comanche did not provide data on M&S developers*

- *359 M&S*

- *Industry is the predominant developer/owner*
- *Extent of industry involvement in Service/Government-developed M&S (30%) unknown*

Results of LFT&E-Sponsored Survey of Model Usage within the DOD Acquisition Community

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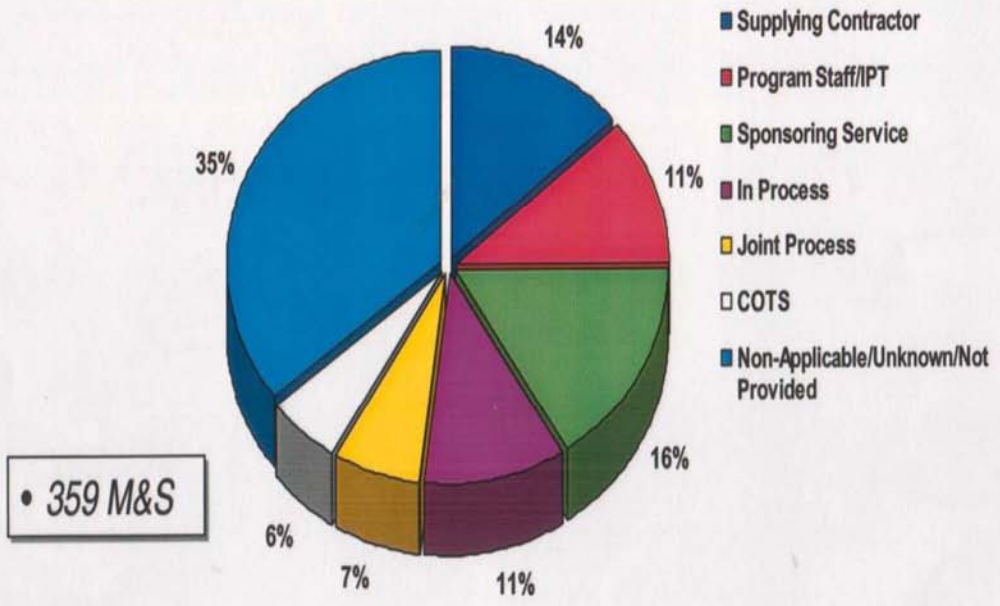
VV&A Overview

Who Does VV&A?



- *359 M&S*

- *Uncertainty about "pedigree" of M&S being used (35%)*
- *Potential conflicts of interest (25%)*
- *VV&A standards for COTS M&S?*
- *Use of joint/independent processes low (7%)*

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Results of LFT&E-Sponsored Survey of Model Usage within the DOD Acquisition Community

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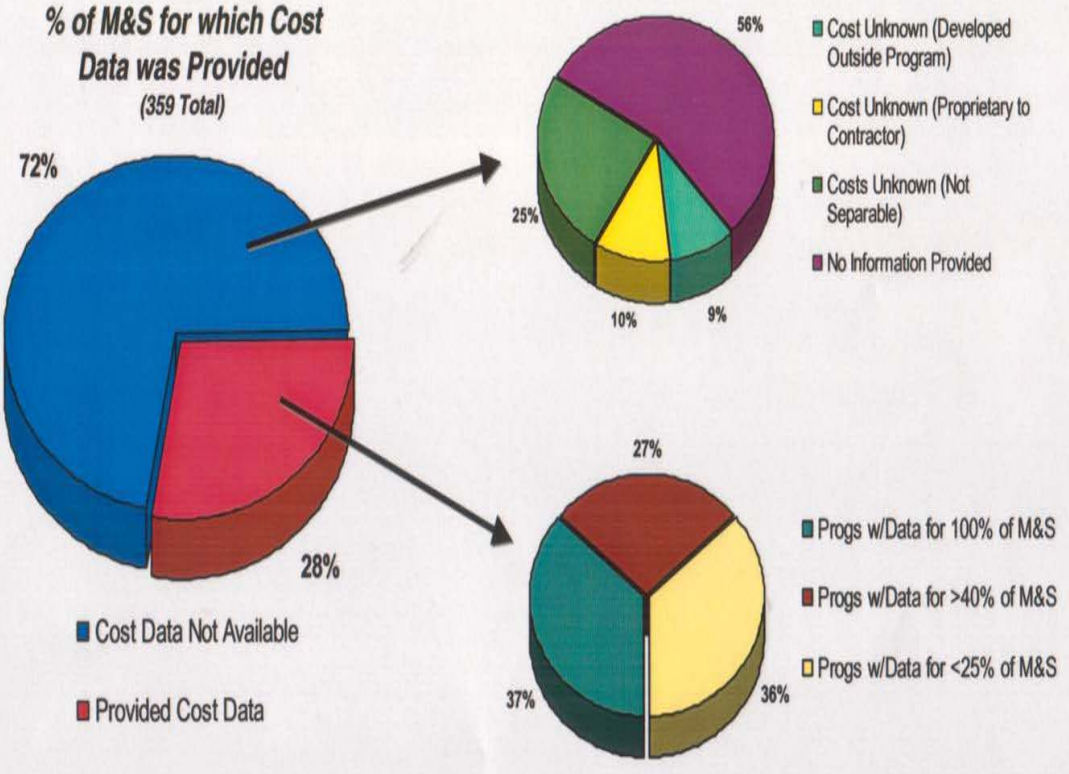
M&S Cost Overview



- *M&S development and application costs data are not readily available within acquisition programs*

Acquisition Reform is Pushing More Reliance on M&S but Is the M&S Train Ready?

MODELING AND SIMULATION IN LIVE FIRE TEST & EVALUATION

Modeling and simulation are an integral part of LFT&E and not to be looked at as a substitute, nor a means to save money. M&S and testing are mutually supportive and none is complete without the other. It's not the pot of gold at the end of the rainbow.