Digital Engineering is too important to be left alone to MBSE Practitioners

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Motivation

- Weapon systems becoming more complex and expensive
- Most of the time these are system-of systems.
- Cost overruns of the top 10 weapons systems alone make it the 3rd largest defense budget in the world.
- The cost overruns of all the Major Defense Acquisition Program (MDAP) portfolio programs tops half-a-trillion dollars, making it the undisputed 2nd largest defense budget in the world.
- We are still using some systems developed more than half-a-century ago (like PARCS radar, UWER radar, and B-52
- Maintaining and sustaining these systems - designed with slide rules, pencils and paper - is becoming exceedingly expensive.
- In the case of some systems like PARCS, where the documentation was partially destroyed as per the Anti-Ballistic Missile Treaty the problem is even worse.
- Hence something must be done.

Digital Engineering

- To solve some of these problems, in 2018 Digital Engineering strategy was unveiled
- It has 5 elements/pillars
  1. Formalize the development, integration, and use of models to inform enterprise and program decision making.
  2. Provide an enduring, authoritative source of truth.
  3. Incorporate technological innovation to improve the engineering practice.
  4. Establish a supporting infrastructure and environment to perform activities, collaborate, and communicate across stakeholders.
  5. Transform the culture and workforce to adopt and support digital engineering across the life cycle.

Problems with the vision

- I have two problems with this vision
  - First: the name “Digital Engineering”
  - Second: the concept of Model
- The strategy/vision is laudable in terms of breadth & depth, and it goes much beyond “Engineering”
- However, there is certain poverty of imagination (to borrow a term from AWK programming language which was named with the initial letters of its 3 creators (Aho, Kernighan and Weinberger of Bell Labs) in selecting the name.
- There is no problem with the “Digital” part of it. Now a days everything is Digital and IT is called “Digital Technology”
- It is the “Engineering” part I have trouble with
- However, if we interpret “Engineering” as in “Engineering a political coup” rather than “Engineering in Mechanical/Electronics/Systems/Software Engineering” it will solve the problem (i.e., It is a process of accomplishing some task”
- I derived the inspiration from the creators of the UNIX operating system (Ritchie and Thompson) at Bell Labs.
- In Bell Labs Technical Journal they wrote, “UNIX supports Free Text”. However, the term “Free” is more like “Free” in “Free Speech” rather than “Free” in “Free Beer”

> The term “Free” is more like “Free” in “Free Speech” rather than “Free” in “Free Beer”
>
> -- Ritchie & Thompson

Specialties needed for developing new weapons systems

Defense Acquisition Workforce Improvement Act (DAWIA) offers certification in the following areas:

- Auditing
- Business Cost Estimating
- Business Financial Management
- Contracting
- Facilities Engineering
- Industrial/Contract Property Management
- Information Technology
- Software
- Cybersecurity
- Life Cycle Logistics
- Production, Quality and Manufacturing
- Program Management
- Purchasing
- Small Business
- Systems Planning, Research, Development and Engineering.
- Program Systems Engineering
- Science and Technology Management
- Test and Evaluation

The certifications I need to get when I worked for SPAWAR, US Navy, DOD are highlighted in Yellow

Some of the Models

- Specialty Engineering Models
- Management Models
- Cost Models
- Design Models
- Manufacturing Models
- Verification and Validation Models
- Digital System Models
- Product Support Models
- Acquisition Reference Models
- Government Reference Models
- Performance Models
- Reliability Models
- System Safety Models
- Cybersecurity Models
- Maintainability and Sustainability Models
- Environment Models
- Quality, Safety, and Mission Assurance Models
- Human Performance Requirements Models.

The above list is NOT exhaustive

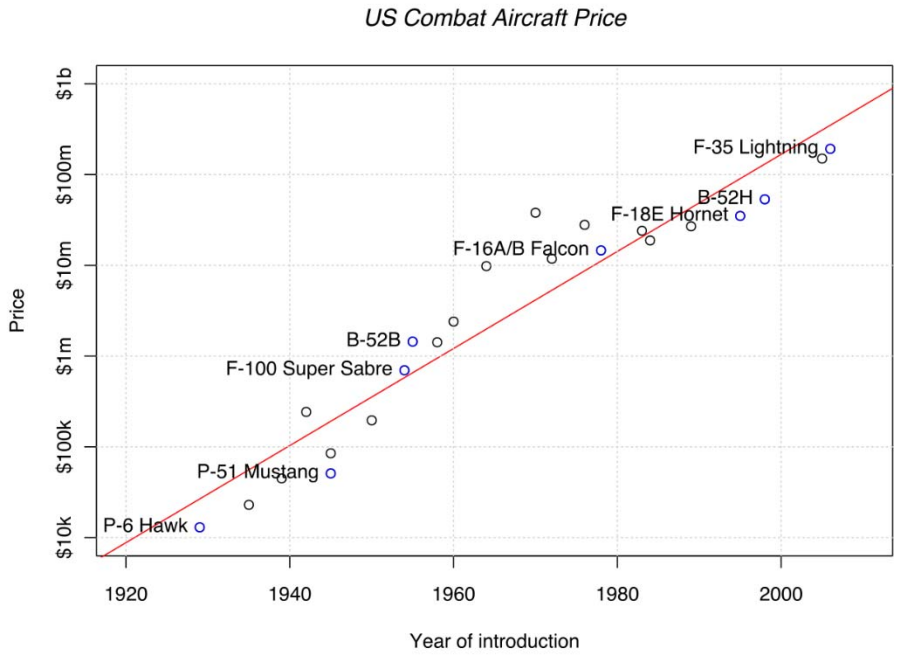
Current state of Digital Engineering

- DOD's Digital Engineering initiative requires all new acquisition programs include the language of Digital Engineering
- Hence each DOD component came up with its own vision of Digital Engineering.
- Some of their requirements are so broad, deep, and ambitious that trying to develop these digital system models for all the systems, including legacy systems, will not only make Norm Augustine's XVI Law a reality but probably will move the target date from the predicted 2054 to 2044.
- Hence most of the Defense and Aerospace companies are in a quandary.
- Moving to wholescale Digital Engineering does not justify the ROI and mostly cannot be funded. But DOD requirements mandate Digital Engineering.

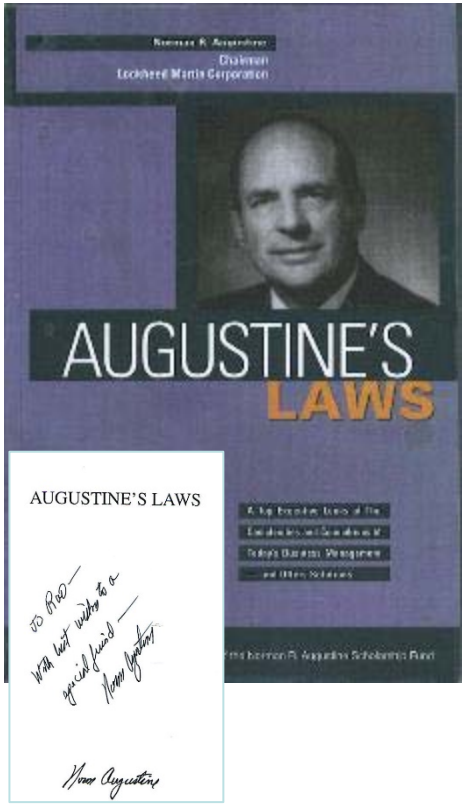
Augustine's Law# XVI

Norm's most cited law is number 16, which shows that defense budgets grow linearly but the unit cost of a new military aircraft grows exponentially:

"In the year 2054, the entire defense budget will purchase just one tactical aircraft. This aircraft will have to be shared by the Air Force and Navy 3½ days each per week except for leap year, when it will be made available to the Marines for the extra day"



Norm Augustine



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October 27, 2015

Mr. Rao Mannepalli
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Dear Rao:

As I write this note I am on the flight home from last night's truly marvelous event in Los Angeles where I was presented the International von Kármán Wings Award. Having so many people there with whom I have shared parts of my life made for an extraordinarily memorable occasion.

But having you so generously devote your time on my behalf added immeasurable luster to the evening. Your thoughtfulness and kindness is appreciated more than you can know, and once again I thank you so very much.

Sincerely,

Norman R. Augustine

Augustine's Law# XVII (Software)

- "Software is like entropy. It is difficult to grasp, weighs nothing, and obeys the Second Law of Thermodynamics; i.e., it always increases"
- **Interesting anecdote:** When Norm was presenting his Law# XVI to the USAF top brass, a general remarked, "Norm it is also true that the cost is increasing exponentially. At the same time the fighter planes are getting smaller every decade. If you extrapolate, soon a fighter plane will cost infinity and weigh nothing. Is it not contrary to the laws of physics?". For this Norm replied, "Software accomplishes that seemingly impossible feat"

Aerospace Industry is in a Quandary

- Hence most of the Defense and Aerospace companies are in a quandary.
- Moving to whole scale Digital Engineering does not justify the ROI and mostly cannot be funded.
- But DOD requirements mandate Digital Engineering.
- The systems engineers found a solution.
- They stretched the definition of MBSE and equated it to Digital Engineering.
- Hence, whenever and wherever the government requests Digital Engineering, MBSE is used as the answer
- However, MBSE is a small part in Systems Engineering which is a small part in Engineering which is a small part in the scope Digital Engineering
- This is similar to the switching from 4G to LTE by AT&T

"AT&T flipped a switch and converted their entire network to LTE. Interestingly the flipped switch was not in their Engineering department but in their marketing department"

Why this undermines the spirit of Digital Engineering?

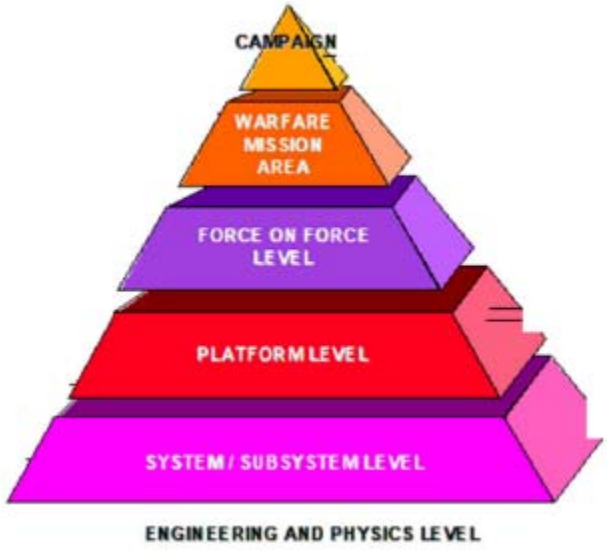
- Most of the output/work products of of MBSE is a collection of mostly static SysML drawings
- This is similar to the Flowchart curse Brooks described in his “Mythical Man Month”.
- During this process, the spirit of Digital Engineering is lost.
- Only systems engineers are concerned with it.
- Even though most major aerospace companies have been using models encompassing all the domains enumerated in the DOD’s vision, there is no coordination among these development efforts and the synergies are not optimized.
- Their efforts are not considered as a part of Digital Engineering.

Flow chart curse: “The flow chart is a most thoroughly oversold piece of program documentation. Many programs don't need flow charts at all; few programs need more than a one-page flow chart”

- F. P. Brooks in “Mythical Man Month”

Models an in Modeling & Simulation (M&S)

- Before the dawn of Digital Engineering, (and even MBSE) the most popular use of the models was in the M&S community.
- Models are used to produce real and tangible results that cannot be obtained by modifying and experimenting on an existing system.
- They can also be used to obtain such results at lower cost, in a more repeatable way.
- M&S played a major role in the development and analysis of military systems.
- These models are developed at different levels (commonly known as the M&S pyramid) with varying levels of fidelity and sophistication.
- Highly complex systems-of-systems are analyzed by distributed simulation using independently developed models federated using High Level Architecture (HLA) and Distributed Interactive Simulation (DIS)
- M&S is mostly the domain of designers and operational analysts.



MBSE (from INCOSE)

- MBSE supports the systems engineering activities of requirements, architecture, design, verification, and validation.
- These models have to be connected to the physics-based models used by other engineering disciplines such as mechanical and electrical engineering to be useful.
- One challenge remaining for Digital Engineering is the integration of MBSE with physics-based models.
- Even though the term “MBSE” first appeared in the book “Model-Based Systems Engineering" in 1993 it came into prominence during the early 2000s when it became associated with Systems Modeling Language (SysML) and championed by INCOSE.
- Due to the composition of INCOSE membership (mostly systems engineers) and the prevailing problems with the document-based systems engineering methods used at that time, systems engineers embraced it. Tool vendors pushed it as the “Silver Bullet” for improving engineering efficiency and lowering development costs. Technology, in particular in software and systems domains, is no stranger to Silver Bullets. These are discussed in more detail later.
- Models are not new concepts. Even before the advent of MBSE, there were Model Based Engineering (MBE), Model-Driven Engineering (MDE) and Model-Driven Development (MDD)

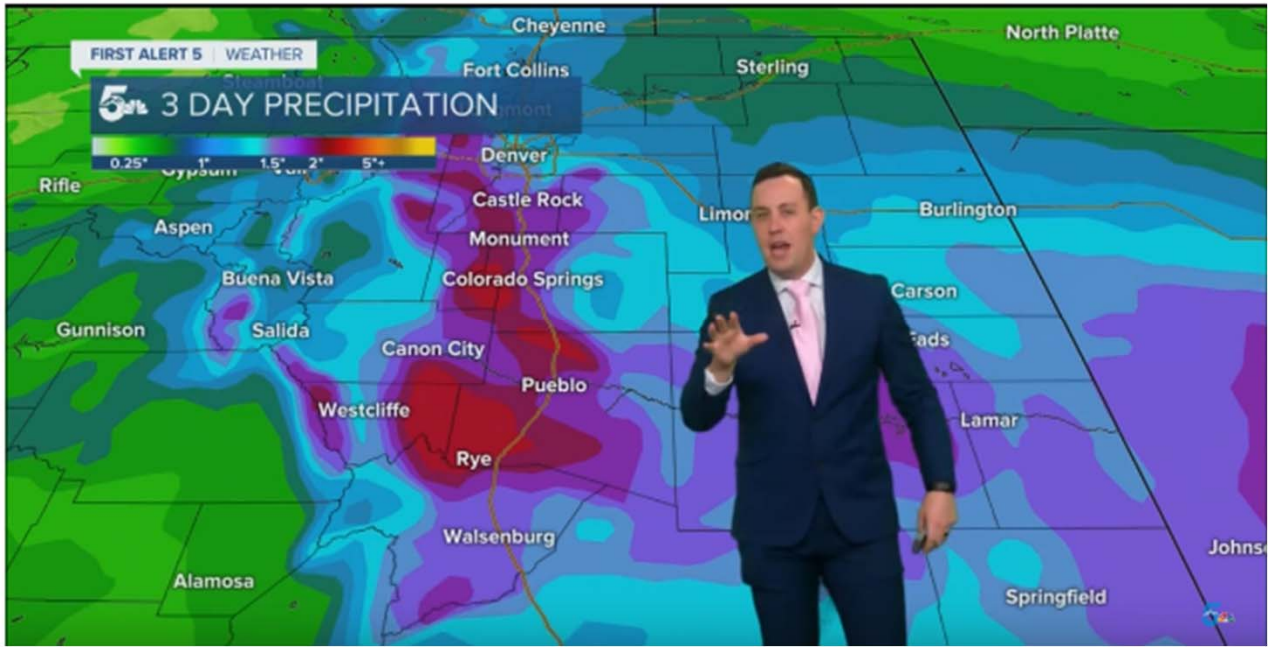
Origin of the word “Model”

- The term originally denoted the plans of a building in late 16th-century English and derived via French and Italian ultimately from Latin modulus, a measure.
- Models can be divided into physical models (e.g., a model plane) and abstract models (e.g., mathematical expressions describing behavioral patterns)

What is a Model in MBSE?

- The systems engineering community stretched the definition of the Model.
- With the advent of tools like Cameo and Rhapsody, creating static pictures/drawings became very popular.
- They started defining the SysML artifacts as “Models” although they are mostly static pictures, not executable models, and cannot answer difficult questions like the ones shown later (Aegis Ballistic Missile Defense System, Solar power plant and others).
- Some MBSE practitioners started calling anything and everything a “Model”.
- For example, system requirements uploaded to a DOORS database became a “Model”.
- Some even started calling the original text document a “Descriptive Model”.
- Such an informal, permissive and imprecise definitions are like performing surgery with blunt tools. Everyone suffers.
- There are already too many “CAC cards ” and “A2/ADs” in our business and they are helping the cause.
- Even DODAF jumped on the Model bandwagon and started calling almost everything a Model and UAF is not far behind
- The real Digital Engineering effort is greatly harmed by these lax definitions of “Models”.
- When everything is a “Model” there is no need or motivation to develop real Digital Models that are useful.
- Moreover, developing real models that can answer difficult questions (like those shown in the examples later) needs effort, thought, and concentration in addition to resources (experts, time, and money).
- For example, a weather map displayed on the TV during weather bulletins is not a “Model”.
- The real weather model runs on high performance computers. The blueprint of a house is not a Model. The real 3-D model generated using CAD software is the real model.

Climate : Weather Map is NOT a Model

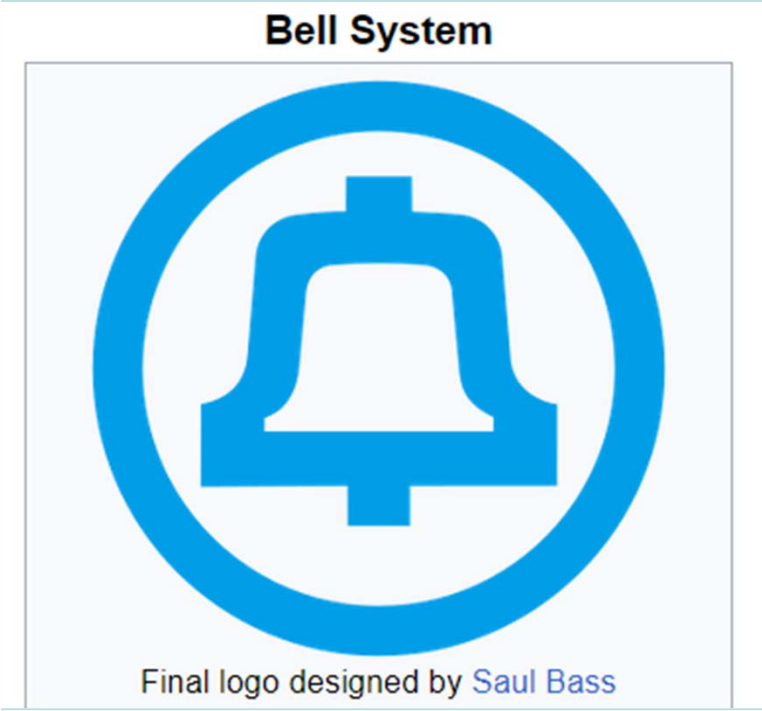


High-impact storm with heavy rain, flooding, and at least a foot of snow above 7,000 feet

Climate Model (Real Model)

- Manipulating the vast datasets and performing the complex calculations necessary to modern numerical weather prediction requires some of the most powerful supercomputers in the world.
- Even with the increasing power of supercomputers, the forecast skill of numerical weather models extends to only about six days.
- Factors affecting the accuracy of numerical predictions include the density and quality of observations used as input to the forecasts, along with deficiencies in the numerical models themselves.

Who is an Original Systems Engineer at Bell System?



- The term “systems engineering” originated at Bell Labs
- It is not the omnipotent role that is being made of now. In those days, the telephone system was called the Bell System.
- The folklore is: There is a charge code for every major technology (e.g., Area-11 (fundamental research), electronics, switching, amplification, transmission, billing, etc.)
- There is one even for IEEE
- There are some people who work on improving the system in general without any specific specialty. Those people are called systems engineers (people who work, in general, on Bell System without an identifiable specialty).

MBSE is no Silver Bullet, and in fact “There is no Silver Bullet”

- Contrary to popular belief ,MBSE is no silver bullet. In fact, there are no Silver Bullets in any discipline
- However, from time immemorial people have always touted silver bullets . Some of them are:
  - Structured Programming
  - GOTO” statement considered harmful
  - Structured programming with GOTO statements
  - Literate Programming
  - ALGOL programming language
  - Simple and systematic programming languages
  - Proving programs to be correct (“I have not tested this program. Only proved. it to be correct”)
  - Beauty is our Business
  - Software Engineering (“Software Engineering: An Idea Whose Time Has Come and Gone, Software engineering should be known as ‘The Doomed Discipline’, and aimed to guide people who can't program”)
  - Object Oriented Programming (OOP) (An exceptionally bad idea which could only have originated in California.”
  - CORBA (Common Object Request Broker Architecture
  - CMM, CMMI, and **CIMM**
  - Agile (“Agile is no silver bullet “)
  - UML (“Death by UML Fever: Self-diagnosis and early treatment are crucial in the fight against UML Fever”)
  - Flowcharts (Flowchart curse)
  - The Waterfall method of software development was an innovation when it was introduced in the 1950s during SAGE development
  - Artificial Intelligence (AI) (“AI had a long and glorious history. It started in 1956 and ended on Oct 24”, Grandmother hack of ChatGPT

Digital Twin

- A Digital Twin is a related yet distinct concept to Digital Engineering.
- The Digital Twin is a high-fidelity model of the system which can be used to emulate the actual system.
- Modeling and Simulation (M&S) is very closely related to Digital Twins
- There is a lot of confusion in what constitutes a Digital Twin.
- The simplest and most practical definition is: It is a computer program which can answer the questions about the real physical system without the need to modify and experiment with the real system.
- More often than not, the real system is either not available, not yet built, cannot be experimented with, and prohibitively expensive in terms of cost, schedule, and complexity.
- The best example is the software model developed by Lawrence Livermore Labs to check the effectiveness of nuclear warhead stockpiles.
- Real testing of them is no longer possible due to the Comprehensive Nuclear-Test-Ban Treaty (CTBT)
- A general rule of thumb: Unless there are equations (often complex equations) it is either not a Digital twin or a useful twin.

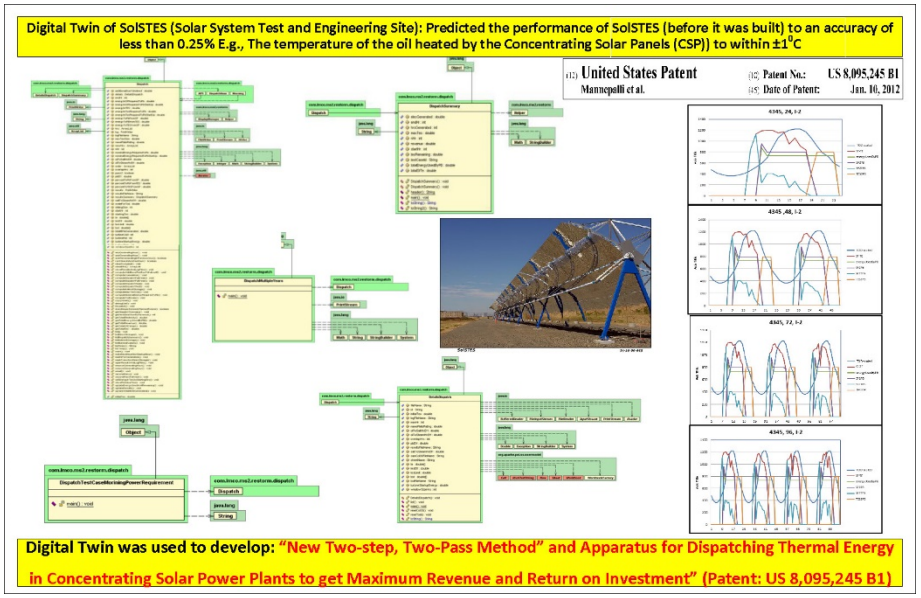
Some examples of Digital Twins

RESTORM (Digital Twin of a Solar Power Plant) has answered:

- How much it will cost to build a 295 MW (or any specified size) Solar power plant in Arizona (or any specified location e.g., Ascension Island in the Atlantic Ocean)?
- What would be the LCOE (Levelized Cost of Energy)
- What would be the LCOE without incentives from Federal Govt?
- Can we improve the ROI of any power plant by at least 8%?
- Can a new Energy Dispatch Algorithm that takes into account the PPA (Power Purchase Agreement) and TOD (Time of the day) pricing?
- Do we really need the NREL (National Renewable Energy Labs) recommended 6 hours of storage (of molten salt) which costs $80 million/hour?
- How can we reduce the capital cost of the 295 MW power plant from $1.8 billion by $200-300 million?

SolSTES


Digital Twin
Solar System Test and Engineering Site (SolSTES)
The Digital Twin of SolSTES predicted its performance to an accuracy of less than 0.25%
E.g., The temperature of the oil heated by the Concentrating Solar Panels (CSP)) to within ±1°C


Digital Twin of SolSTES (Solar System Test and Engineering Site): Predicted the performance of SolSTES (before it was built) to an accuracy of less than 0.25% E.g., The temperature of the oil heated by the Concentrating Solar Panels (CSP)) to within ±1°C
United States Patent
Mannepalli et al.
Patent No.: US 8,095,245 B1
Date of Patent: Jan. 10, 2012
Digital Twin was used to develop: "New Two-step, Two-Pass Method" and Apparatus for Dispatching Thermal Energy in Concentrating Solar Power Plants to get Maximum Revenue and Return on Investment" (Patent: US 8,095,245 B1)

Aegis Shots down an ICBM (FTM-44)

Some of the questions Aegis Digital Twin has answered:

1. Can the Aegis BMD shootdown a satellite instead of regular missile? If not, what changes are needed for Radar, Discrimination, SM-3 missile, Kill Vehicle, and Terminal Guidance?
2. If one ship with an Aegis Ballistic Missile Defense System can handle "n" threats, how many threats 2 ships can handle (2n, <2n, or > 2n)?
3. How the total number of threats handled changes if CEC (Cooperative Engagement Capability) is used?
4. How these numbers change for "Launch on Remote" and "Engage on Remote"?
5. How the numbers change for "shoot", "shoot-look-shoot", shoot-shoot-look-shoot" and "shot-shoot-look-shoot- Shoot"?
6. Sensitivity analysis for QOS (Quality Of Service)
7. How the Probability of Single Shot Kill (P_{SSK}) changes if SPY-1 Radar is replaced by AMDR (Air and Missile Defense Radar)?
8. How the Probability of Raid Annihilation (P_{RA}) changes with (1 ship, 2 ships,…, n-ships)?

World's First Ever ICBM Intercept & Shoot Down by U.S. Navy Missile

The Digital Twin of a communication Processing system has answered:

1. Given a choice between a single machine with speed *s*, or *n* machines each with speed *s/n*, which should we choose for upgrading the communication subsystem?
2. If both the arrival rate and service rate double, will the mean response time stay the same for the system?
3. Should the Enterprise Database system really aim to balance load, or is this a convenient myth?
4. If a scheduling policy favors one set of jobs , does it necessarily hurt some other jobs or are these "conservation laws" being misinterpreted?
5. Do greedy, shortest-delay, routing strategies make sense in a server farm or is what is good for the individual may be disastrous for the system as a whole?
6. How do high message size variability and heavy-tailed workloads affect the choice of a scheduling policy for the system?
7. How should one trade off energy and delay in designing a computer system for enterprise?
8. If 12 servers are needed to meet delay guarantees when the arrival rate is 9 jobs/s, will we need 12,000 servers when the arrival rate is 9,000 jobs/s?

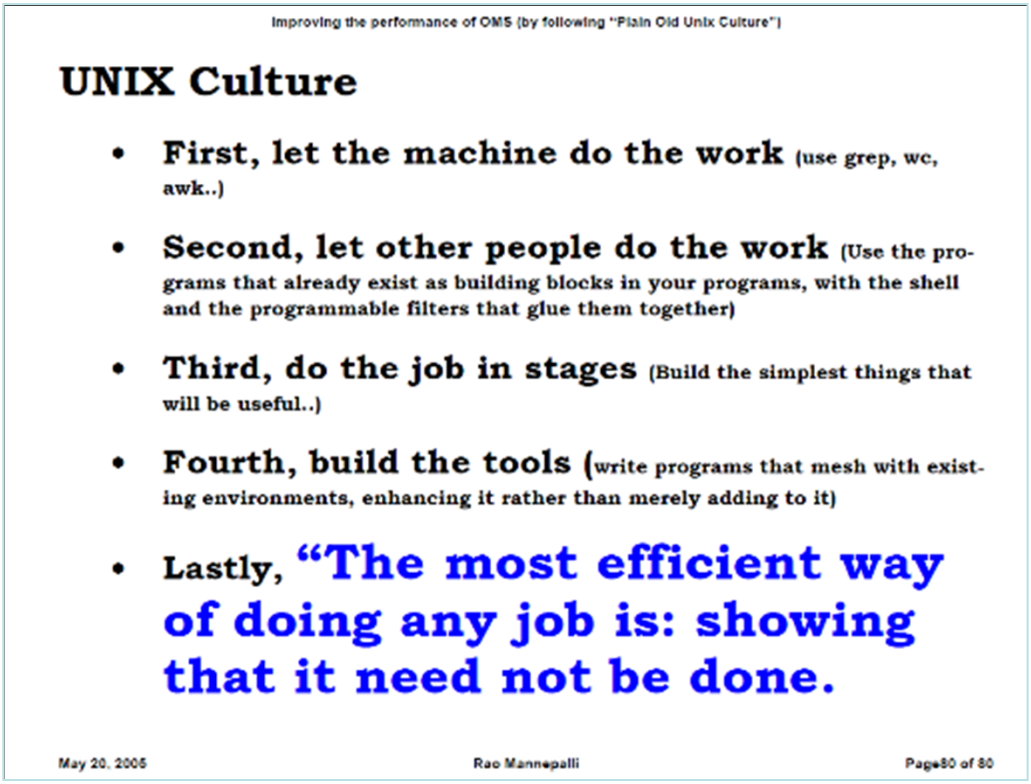
Multi-Mission Analysis Tool (MMAT) for DD(X) developed entirely using only UML

- Throughout my professional life I have seen only one example where the requirements taken from the documents were used to create the UML artifacts using Rational Rose which were then enhanced using Rational Rose Real-time [which are used to generate the executable code.
- The lessons learned are:
  - The effort required is not less. In fact, in some cases, it is much more than the normal methods
  - The code generated is not human readable
  - In spite of recent advantages in compiler optimizations, the efficiency of generated code is suboptimal both in terms of space and time

Best Practices for developing Digital Twins

- Don’t get hung up on the tools (in particular vendor promoted Silver Bullets”
- Do it incrementally, optimum fidelity to answer the questions
- Do not generate dead-end artifacts (e.g., static pictures which cannot be used in the next phase of development (e.g., Automatic code generation, Automatic text script generation)
- Follow Unix culture. The last bullet is most important. If we can eliminate any step by using technological advances (pillar-3 of the Digital Engineering vision) eliminate it. If ChatGPT can generate the code from the documents (or even emails, voice memos) then use it.
- Keep “Model Developer’s Dilemma” in mind

UNIX culture



Preventing the Digital Twins from becoming Evil Twins?

- Digital Twins are very useful in finding the answers which could not be obtained easily using the real systems (Physical Twins).
- However, after some initial successes people tend to trust them blindly and take critical decisions based on their results.
- This is where the Digital Twin becomes an evil twin
- Some of the steps to guard against this are:
  - Be skeptical about the results
  - Remember the worlds of Aristotle
  - Try to cross check the results from a system of lesser fidelity (if available)
  - If possible, use the data obtained from the real system to periodically update the underlying model
  - If the system is really critical (like validating the effectiveness of nuclear weapons) use the method used for Space Shuttle Avionics System

It is the mark of an instructed mind, to remain satisfied with the precision allowed by nature to that subject, and not to ask for exactness when an approximation of truth alone is possible"

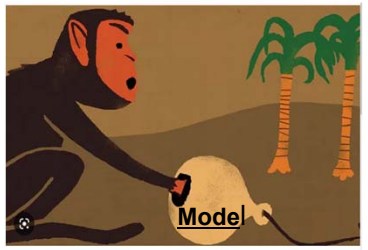
- Aristotle

Incorporating technological innovations

- This is the 3rd and probably most important initiative in the Digital Engineering vision.
- A number of disruptive technological innovations are coming onto the scene.
- They will revolutionize the way systems are designed and developed.
- For example, the field of Computer Science is headed for a major upheaval with the rise of large AI models such as ChatGPT that are capable of performing general-purpose reasoning and problem solving
- We are headed for a future in which it will no longer be necessary to write computer programs.
- These technologies can fuse Unstructured, Uncertain, Incomplete, Imprecise, and even Contradictory (UUIIC) information from all sources (documents, audio, video, web, emails, hidden web etc.) and generate the final systems probably using 3-D printing .
- This will make the current processes obsolete, including the systems engineering

Conclusion

- Digital Engineering is a misnomer and there is certain poverty of imagination in choosing that name.
- It is not specific to Engineering (much less systems engineering) but encompasses all the specialties involved.
- Engineering is a small part of it and System Engineering is a small part of Engineering.
- We need to come up with a new name for it which all disciplines can relate to.
- At present only systems engineers are paying any attention to it and unfortunately, they are equating to MBSE.
- This way we will fail to realize the full potential.
- We should refrain from calling everything a “Model”.
- MBSE should not be equated to Digital Engineering, as currently being done in the Govt, Industry and Academia. The main motivation or justification for MBSE is “Document based process is bad.”.
- However, I am yet to see a program where the original requirements are in any form other than documents.
- If AI can parse those documents and generate the requirements or even final executable software, we don’t need Systems engineering, MBSE or even Software Engineering.
- We must not flip a switch ,like AT&T did in its marketing department, and make MBSE the Digital Engineering.
- There is no Royal Road to Digital Engineering.



Acknowledgments

- I want to acknowledge the inspiration derived from
  - Alex Bell's “Death by UML fever”,
  - Tom Demarco's “Software engineering an idea whose time has come and gone” and
  - Dijkstra’s “Software engineering should be known as ‘The Doomed Discipline’ and should have its charter ‘How to program if you cannot’.".
- I also want to express my sincere thanks to Mr. Norm Augustine and Dr. Paul Kaminski who reviewed the draft and provided valuable comments.

Rao Mannepalli

Rao is currently working as the Chief Scientist of Leidos, USA. He has more than 30 years of international, multi-industry and multi-cultural experience as Division Head, Program Manager, Chief Engineer, Chief Scientist, Chief Architect, and Principal Developer at Leidos, Raytheon, US Navy, Lockheed Martin, Bell Labs, and Indian Space Research Organization (ISRO). He was a member of high-level Senior Executive Service (SES) that needs the approval of the Federal Cabinet of Ministers.

the SES (senior Engineering Service) that He has 24 inventions in the areas of routing in optical networks, capacity and performance improvements, ballistic missile defense, sensors, signal processing, solar power plant design, energy dispatch algorithms, better driving directions, preventing suicide car bombings, prevention of pandemics like H1N1, identity theft prevention, and others. He authored more than 180 papers. Presented keynote lectures at international conferences. Served as the Editor of IEEE's Aerospace Electronics and Systems Magazine (Satellites, Modelling & Simulation, and Energy)

He is a Member of the Defense Acquisition Corps (DAC). "DAC is an elite group of highly qualified DOD acquisition professionals with skills and attributes required to fill Critical Acquisition Positions (CAP) and Key Leadership Positions (KLP) of Major Defense Acquisition Programs (MDAP) like Program Manager of ACAT-ID, Chief Engineer, Chief Scientist, or Science & Technology Manager of ACAT-ID Weapons programs." He was interviewed at Pentagon (finalist) for the job of Chief Systems Engineer of Army, Office of Chief Systems Engineer (OCSE) reporting to Assistant Secretary of Army for Acquisition, Logistics, and Technology (ASN-ALT). He is a DOD certified Systems Engineer, Science and Technology Manager and Program Manager.

One of his inventions is termed by Mr. George P. Sutton, Executive Director of Rocketdyne (during Apollo Moon Landing Program), Chief Scientist of DARPA, Professor at MIT and Caltech, and the author of the most respected textbook 'Rocket Propulsion Elements' - which for more than 60 years has been regarded as the single most authoritative source book on rocket propulsion technology - as 'An Original Contribution to Rocket Science'. Rao helped Mr. Sutton in bringing out the 9th edition of his iconic textbook. Two of Rao's inventions (Rao's method and Chord-midpoint method) are references for this book.

He identified an error in the Guinness book of records regarding the highest sound level produced in the world (by NASA during the static firing of Saturn-V Rocket first stage engines during the Apollo Moon landing program) and got it removed from the record book.

Rao Mannepalli (contd.)

At Bell Labs, he studied the software development process, identified the root causes, suggested improvements and documented them in "How can we achieve Level-3 on SEI's CMM with simple process improvements that can save $640 million/year and add $0.32 to Lucent's EPS". It has become a classic ("**Rao's Mythical Man Month**"). F. P. Brooks, the author of the 'Mythical Man Month' and the father of IBM-360, termed them as "Exceedingly valuable to Lucent." ". It starts with "**Improving quality in Bell Labs is like going to Heaven. Everyone is interested. But nobody is in a hurry**" and ends with "**Maturity is the ability to do the right thing at the right time, whether you like it or not".**

He is a quality evangelist and routinely offers $5/bug in the systems developed by him and his team (and never had to pay even once in 8 years). He is a champion of ZDD (Zero-Defect-Delivery) which is not a Rocket Science (even though he is a Rocket Scientist)

He is a Fellow of Royal Aeronautical Society, Royal Astronomical Society, Astronautical Society of India, Institution of Engineering and Technology, Council of Vibration Professionals, Institution of Engineers; Institution of Electronics and Telecommunication Engineers; Distinguished Scientist, ACM ('for significant contributions to almost all the technologies that constitute Ballistic Missile Defense (BMD), including Rao's Method an original contribution to Rocket Science') and Chair of Distinguished Member selection committee; Associate Fellow AIAA, Eminent Engineer, Tau Beta Pi Path Finder, Lucent Technologies; Chartered Engineer (CEng), Professional Engineer (PE); US President Volunteer Service Awards: Gold (2020, 2019, 2011, 2010), Silver (2018, 2009), and Bronze (2017, 2008)

His education includes: M.S (Computer Science: Major Artificial Intelligence), B.E (Electronics), B.S (Physics) and Executive Education at MIT and Wharton Business School. He mentored a large number of engineers, scientists, and managers. Helped 11 team members to become first time inventors and 25, first time authors.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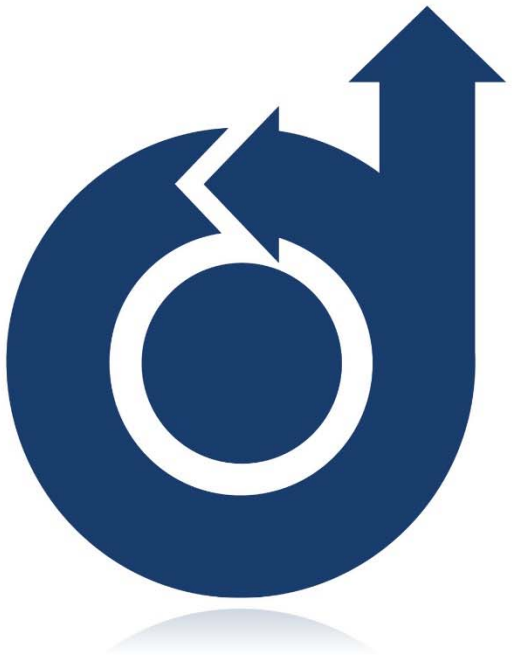
Abstract

Weapon systems critical to national security are increasingly becoming more complex and expensive. The cost overruns alone are estimated to be about half-a-trillion Dollars, making it the second largest defense budget in the world. To address this problem, DOD introduced the Digital Engineering initiative in 2018. Even though its vision and scope are laudable, not all the areas/disciplines involved in realizing these weapon systems are excited. There is a certain poverty of imagination in naming the vision as “Digital Engineering.” Most people misunderstood it to be an engineering initiative (in particular Systems Engineering). This paper redefines the term “Engineering” in Digital Engineering as a process (e.g., engineering a political coup rather than like Mechanical/ Electrical/Systems Engineering), which then addresses all the five pillars of Digital Engineering. Another disturbing trend noticed by the author is that the Systems Engineering community equated Model Based Systems Engineering (MBSE) to Digital Engineering. This prevents new thinking and thereby limits or negates the vision of Digital Engineering. This paper also touches upon the origins of Systems Engineering at Bell Labs, obsession with the term “Model” to mean anything and everything, including a text document or a static picture, and Digital Twins. It gives practical and useful definitions of “Model” and “Digital Twin” and provides examples and some best practices followed in developing them. It also lists some of the disruptive technologies like ChatGPT which could potentially even eliminate the need to write computer programs. These systems can fuse Unstructured, Uncertain, Incomplete, Imprecise, and even Contradictory (UUIIC) information from all sources. This will make the current processes obsolete, including Systems Engineering. Finally, it presents the lessons learned and makes some recommendations for the near-term, including how to prevent Digital Twins from becoming “Evil Twins.”

Thank you



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