Base lining the State of Physics-Based Modeling Use in DoD Acquisition Organizations

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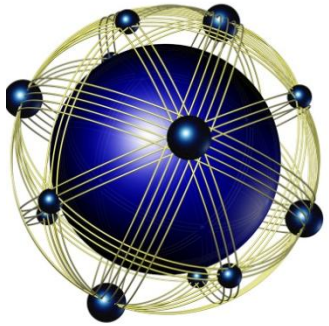

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Outline

- Overview
- Results
- Next Steps
- Open Discussion

Overview

- Assess the current state of Physics Based Modeling.
- Survey conducted Summer 2011.
- Surveyed 800+ NDIA modeling and simulation committee members.
- Assessment includes:
  - how prevalent physics-based modeling tools are
  - how they are being used
  - and what will help these tools gain further acceptance
- Objectives:
  - To analyze the prevalent physics-based modeling tendencies within the DoD acquisition organizations and draw meaningful conclusions that will promote the use of physics-based modeling tools throughout the development lifecycle.
- The result are an information and usage baseline of the current state that can be compared to future states.

Who responded?

- Received 24 Responses and threw out 4.
- Sample size is 20
- 13 Respondents had 20 years experience

Industry (12)	•Government (7)	Academia (1)
•General Dynamics Land Systems •Dynamic Animation Systems •Lockheed Martin •SRC, Inc. •LMI •Advanced Programs •IIS •Raytheon Company •LMS North America •Northrop Grumman (2) •Manufacturing Innovation	•AF Research Laboratory •Naval Air Warfare Center Weapons Division (2) •DASD(SE)/SA •DTRA •ARDEC (2)	•Johns Hopkins APL

Represents an industry and government point of view.

Do you use Physics-Based modeling tools? Specify the names of all of your tools What physics based modeling tools are used?

- 15 responders use Physics Based Modeling Tools
  - I use about 90% of ***my own tools that I write myself*** for high fidelity orbit analysis. But from time to time either by a programs direction or for truth checking I will use tools like Satellite Tool Kit (STK) by AGI or FreeFlyer by A.I. Solutions. I will use licensed tools like MATLAB frequently or for cost savings tools open source tools like Octave (which is a free MATLAB clone).
  - ***We create our own.***
  - Threat Modeling Simulation System Threat Generator
  - Aerosol dispersion ***tool that I developed***
  - Physics Based Model for Aircraft Spares Requirements (PBM Sparing); Reliability Investment Model (RIM)
  - PEP, TAME, ***various missile 6DOF, numerous subsystem models***
  - I specifically don't but people in my company do.
  - LMS Imagine. Lab AMESim LMS Virtual.Lab Matlab/Simulink Nastran
  - STK VRSG GVS JSAF OPNET ***Various in-house simulators*** VSTARS
  - FlightLab AircraftMetrics
  - ***In-house tools*** (all various types) + EADSIM, NSS, etc.
  - ANSYS (2) Fluent, ALE3D (2) Abaqus, Presto, CTH
  - JSAF, a land warfare simulation with some physics based modules, and TEMPER, a physics based model of EM radiation.

To a large extent physics based modeling tools are "home grown" and are unique to a domain.

Are you required to use these tools? Specify what or who mandates their use.

- 5 respondents provided a response.
  - Specific tools are not required but the use of M&S in our program work is expected because it's not possible to do without simulation.
  - GPS requires us to use it.
  - AFRL uses Physics based models in all 10 Tech Directorates. In HQ, I use the output, not the models.
  - Missile Defense Agency requires it.
  - It is part of a program of record software suite, Best-of-breed analysis tools.

From the responses provided physics based modeling isn't typically mandated. When required it is typical that the program or organization mandates the use of PBM.

If you currently use physics-based modeling tools, please classify what platform types these tools are used for.

Platform Type	Land Warfare	Fixed Wing	Space	Missile	Missile Defense	Rotary Wing	C2ISR	Communication	Unmanned	Ships/Subs	Don't Use Physics based modeling tools	Business	Training	Biological Defense	Extensions to Ships/Subs	Ground Vehicles (Off-Highway/Agricultural)	Test Planning & Reporting	Commercial Auto	Large Caliber Ammo
Number of Respondents	10	6	6	6	5	5	4	4	4	3	3	2	1	1	1	1	1	1	1

Responses cover a wide range of platform types.

How much money on average does it cost to use a physics-based modeling tool for your organization?

Costs		Sample	Average Costs	High	Low
	Purchase	5	$ 340,400.00	$ 1,000,000.00	$ 2,000.00
	Licensing	6	$ 1,002,250.00	$ 5,000,000.00	$ 3,500.00
	Training	6	$ 54,166.67	$ 200,000.00	$ 1,000.00
	Other	3	$ 3,400,000.00	$ 10,000,000.00	$ 100,000.00

Based on responses organizations spend $840K on average to have a PBM capability. Training costs look low.

Are the physics-based modeling tools used frequently enough to justify all costs? If the tools are not used much, what are the reasons for this?

- Yes (10)
- In the case of MATLAB I use it enough to justify the costs
- Required to stimulate HWIL and digital engagement simulations
- Tools used daily by a workforce of over 3000
- They are used frequently and allow engineering to make decisions that reduce hardware prototyping expense. In addition they allow engineering to achieve performance objectives (hard to put a cost saving on that). The ROI is at least 5X.
- Fluids modeling has become a necessity in cannon development.

- No (2)
- But for other modeling tools like STK and FreeFlyer the answer is no. I can and have written those tools on my own.
- Manpower shortage and lull in business cycle
- They need improvements which are very difficult to make happen.

10 out of 16 responses indicate that PBM tools are used frequently enough to justify costs.

During which phase(s) of the product development lifecycle are your physics-based modeling tools utilized? How do these tools affect these phase(s)? What are the benefits to your organization?

- All Phases (Pre Milestone A, MDD,TD, EMD, O&S, During the Analysis of Alternatives, or trades analyses phase, Proposal, During test planning, testing, and test reporting and post delivery, production & maintenance)
  - Tools are used to inform trades, make decisions, aid integration
  - Concept Analysis and SoS performance assessment
  - Needed for the understanding of fluid flow during the cannon firing helps in the design of several critical components (muzzle brake, tube, breech).
  - To help the customer better understand their problem.
  - Requirements Allocation and verification of requirements; design validation; and test and evaluation.
  - For concept, early development, controls development, verification & validation.
  - Used for sizing, setting component targets in early design, for full system integration & identifying subsystem interaction & dynamics in late design.
  - Used in the detailed design phase where geometry influences are important (stress, fatigue, complex non-linear dynamics)
- They shorten the length of the phase and in some cases the phase couldn't be completed without them

From the 16 responses to this question PBM is used in all phases of the acquisition and product development lifecycle.

Do your physics-based modeling tools show the need for design or other changes, especially early on in product development?

- Reveal limitations of guidance and sensor systems
- Expose whether a solution to a design / development problem is optimal you wouldn't model something you knew absolutely would work.
- Tools are especially useful in exploring the design space, supporting concept trade decisions, identifying risks
- Technology development is adjusted based on test and analysis supported by M&S. S&T aggregated into future concepts also assessed; mil utility assessments can change focus or emphasis or timing of tech program based on utility & robustness against threats and vulnerabilities.
- Used for concept and making architectural trade-off assessment. Once the candidate architectures are chosen it is used for subsystem and component sizing and target setting. Then it is used concurrently for determining boundary conditions and used to update the fidelity of models to analyze system level effects.
- The design is sometimes solely dependant on the tools (i.e. muzzle brake design).
- RIM shows need for more emphasis on reliability in design phase. PBM Sparing shows importance of tracking aircraft operating profiles

15 respondents agreed that PBM shows the need for design or other changes.

How do you find these physics-based modeling tools to be helpful, and how user friendly are they to use?

- Not user friendly
  - Largely they require specialized skills and each are used by a small group of people.
  - Not user friendly; requires very high skill level
  - The tool I use is not very user friendly as I built it in Excel for my use.
  - you should not need a PhD to run them; they would be more useful if they could be integrated with lower fidelity engineering models
  - You focus the analytics to support the flight test related work you perform, and it may take a few iterations to make the software user friendly.
  - Very helpful, not very user friendly. It takes significant knowledge and judgment to determine what aspects need to be represented in simulation, how to represent them, and what the results actually mean. Good engineering is difficult, there is no automatic formula, that's why it costs so much.
  - ALE3D is not user friendly but more powerful in some instances.
  - Virtual.Lab and Nastran are a little more complex because of the parameters and data needed to build an accurate model. These tools follow a more detail-more complex relationship.

PBM are very useful and require a high level of skill to use. Some would like the tools to be more user friendly.

How do you find these physics-based modeling tools to be helpful, and how user friendly are they to use?

- **User Friendly**
  - They allow insight into why things behave the way they do. If they are not user friendly, they generally don't get used
  - They are very user friendly and have great visualization capabilities. But they fall short when detailed high fidelity modeling is required where custom software needs to be written to help the customer better understand how IIS can help..
  - Good representation of systems and good basis for comparison to real systems during testing; User friendliness is a function of the target systems' complexities
  - Imagine.Lab AMESim is well documented with contextual help links. It comes with an extensive set of demo models & help so that you always have to start from a "clean sheet". Existing model libraries allow a drag-and-drop process to create a system. The layout of the system looks like the physical system. Easy to build, understand it's function, debug and troubleshoot.
  - ANSYS Fluent is a robust code and very user friendly but falls short in matching test results in some simulations.
  - Matlab is powerful and reasonably user friendly.
  - Both RIM & PBM sparing give useful insights into better ways to manage development, and operations & support segments of the life cycle. Both tools are friendly to an experienced reliability person (RIM) or to an experienced logistician (PBM).

User friendly PBM tools are also very useful but may fall short when detailed high fidelity modeling is required

What would you change about your physics based modeling tools?

- Interfaces/standards between applications for data exchange
- Establish a common data/file structure so that models can be shared more easily. Remove the non value add and error prone process of file translation.
- easier means of integrating tech models to build system like concept models for sys of sys assessments etc.
- For RIM: Integrate with Sparing PBM for more detailed insight into costs of new equipments. For Sparing PBM: extend to ground vehicles and ships/subs.
- I would make the tool more modular.
- Make National lab codes more user friendly
- Increase the breadth of physics for each tool's platform.
- Keeping up to date with real system capabilities
- Environmental fidelity could be improved

An easier means of integrating PBM tools seems to be needed.

What physics-based modeling tools do you wish you had that you currently do not?

- Multi-domain, multiple levels of fidelity
- More training
- More realistic models of red and white forces.
- Tools that accurately emulate optical-based biological sensors.
- Is with regards to supporting physics-based modeling tools; data management plugged into Product Life Management (PLM) systems. Ability to manage requirements, functional, logical and physical entities.

Cross domain Integration, greater accuracy, improve data management and traceability to system engineering artifacts.

Do you look for physics based modeling tools that are verified, validated, and/or accredited?

- Rarely are tools VV&A but models may receive V&V. Accreditation is something very rarely performed.
- If the tool hasn't been at least vetted in the field at some point then it is always suspect to errors that haven't been found yet. That's not to say I may not use the tool but I will approach it with a lot of skepticism.
- Yes, V&V essential but rarely possible with real world data
- Yes; absent accreditation, may use tool but must work through all its details independently--an expense.
- in S&T the VV&A is focused on proving that correct pertinent F=Ma is understood and that it is properly coded; all assumptions are correctly documented etc.
- Desirable, but usually not available
- Yes, the air vehicle models need VV&A for each model they represent.
- Yes, one should, but the amount of V&V necessary is unknown. As the modeling is being built Models must be VV&Aed or you don't know what the answers mean. Tools can't be validated independently of the use, the first step of VV&A is identification of its intended use.
- Yes. I also validate results with test every time.

12 out of 14 responses indicate that Physics Based Modeling tool are verified & validated. Accreditation is rarely performed.

Are your tools integrating/coupling multiple physics-based models at once?

- They do. Most of my satellite modeling requires many physical models like gravity potential fields, third body perturbations (sun, moon), atmospheric drag and even solar radiation pressure.
- Yes, contain high-order gravity, space weather, terrestrial weather, sea state, etc
- Yes, either completely in one platform, imbedding a model from platform A into platform B and solving in platform B, or co-simulation between 2 or more platforms.
- I tend to use HLA for integrating models. It's just interoperable data transfer, the representation of gravity or weather is up to the model.
- Yes, but environmental details often emulated internal to each tool - not shared
- Yes, for analytic support for helicopter/ship testing you have to consider the aircraft downwash, the ship airwake, the ship motion, the interference & visibility.
- Sparing PBM explicitly considers physics of failures induced during five flight events: cold starts, warm cycles of propulsion system, landings, cruise flight, and diurnal temperature-humidity cycles. RIM considers physics of failure modes relevant to specific equipments' operations.
- Being fluids codes they can simulate gravity in the simulation and weather can also be simulated.
- There is some of this, but not much. It usually has to be done manually.
- in many cases we do but we have to manually couple them sometimes

Most of the responses indicated that PBM tools are integrated/coupled to some extent.

How would you describe the current state of physics-based modeling tools in both your organization and the community of acquisition organizations as a whole?

- Scattered - many tools, many people, many approaches.
- The use of these tools has been limited. Although they have been used more recently.
- Wrong-headed; too much physics-based modeling in places (esp MDA), too little elsewhere
- Poor , poorly understood
- Becoming mature in our organization; at early stage elsewhere.
- Likely a lot of use but need to confirm
- They have good potential, but they need to be improved.
- Development and fidelity is uneven and non-standard; Interfaces and environmental effect simulation needs to be standardized across platforms
- The demand for multi-physics-based modeling tools is huge and growing, and the commercial providers are responding with increased capability of tools. I think the community has a difficult time to keep up with the latest and greatest capability available in the market.
- They are in broad use, very mature, very numerous very diverse and constantly improving
- The physics based modeling community is robust and well established. It has tools which are robust and proven
- Individual Technology physics modeling is outstanding, well understood, & validated

Scattered, Maturing, Understood, Used broadly, Very Mature, Robust & well established, good potential but need improvement, Uneven and non-standard, Poor, Poorly Understood.

Please provide your own definition (or your organization's) for the term: Physics-Based Modeling? Where did this definition come from?

- Predictive modeling of physical events based on first principles or test.
- Any software modeling tool that uses any physical equations to model the behavior of some naturally occurring phenomenon.
- Modeling that represents the primary science; molecular for Materials, aerodynamics for Air Vehicles, etc.
- A model that describes a physical behavior of a system based on observed or theorized physical principles
- Replicates the physical characteristics to the degree needed; don't use statistics to determine a solution.
- A modeling practice and process that allows the assessment of functional, logical and physical performance factors.
- Representation of the effects of physics phenomena through dynamic representation of first-principles with high resolution and granularity
- Modeling that uses high fidelity physical and behavioral representations to emulate an entity in a synthetic environment.
- Low level of resolution, showing interaction of items at the lowest level possible
- Modeling that can use physics to show the sensitivity of any air vehicle flight test related parameter and permit flight testing to be conducted in a virtual environment using the US Navy Test Pilot techniques.

There is strong alignment in the definitions provided. Definitions often were made up by the respondent.

Next Steps

- Do you agree with the results?
- Should the survey be opened up to the attendees of this conference
- Is there more analysis that should be done on this data set?
  - Do certain platform types rely more heavily on PBM than others?
- Should we do another survey and if so what other questions should we ask?
  - e.g. Describe the environment that is used to perform Physics Based Modeling.
  - How is PBM used to support Systems Engineering?
  - How is CM of PBM done?
  - How could PBM methods be extended to support analysis of complex systems?
  - Is PBM good enough for your needs?
  - …..

Open Discussion