THE REALITY OF SIMULATION-BASED ACQUISITION — AND AN EXAMPLE OF U.S. MILITARY IMPLEMENTATION

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Information technology is creating more realistic, more capable, and more diversified simulation tools. These tools have been applied to a range of ongoing product development programs with an increasing diversity of applications. Phenomenal reductions in development time, life-cycle costs, and improved system quality are reported from these new opportunities.

In contrast to simply networking more and more computers and software together in ever-increasing capability, entirely new approaches are emerging. One overarching approach within the Department of Defense (DoD) is simulation-based acquisition (SBA). It is the proactive use of simulation and information technologies to rapidly advance all elements of the product development process. It is capturing more elements of industry every day and has the potential to revolutionize product development all over again.

Here we will examine one powerful example of simulation-based acquisition implementation in the American and British Joint Strike Fighter Aircraft Program.

Natural market forces are driving all industries to find better ways to couple information technology and thus improve business processes. Simulation technology is a large part of this revolution. The concept of SBA was begun in DoD in 1996 as an initiative to capitalize on the increasing integration of information and simulation technology throughout business and product development. In conjunction with major participation from industry, DoD has defined SBA as "an acquisition process in which DoD and industry are enabled by robust, collaborative use of simulation technology that is integrated across acquisition phases and programs" (Modeling & Simulation Acquisition Council [MSAC], 2000).

Literally hundreds of enterprises have documented improved performance: shortened development schedules, reduced cost, and improved system quality (Zittel, 1999; Sanders, 1997). Reported improvements include a 3000 percent reduction in unique processes and a 50 percent reduction in overall development time. Such significant improvements have naturally stimulated the increased use of information and simulation technology to further reduce development and market costs.

Development programs in the U.S. military are increasingly implementing the concepts of SBA, but to different degrees, depending on how far along they are in their development, when they started, and how aggressively they are approaching the concept. Many have been trailblazers — leading the greater use of information and simulation technology in new areas. This is one of the difficulties: to implement such technologies when they are mature enough to be helpful, but not so mature as to be obsolete and unsupportable. With information technology, there is very little gap between these two extremes. Older programs are frequently constrained by the need for considerable investment in existing (legacy) processes and supporting tools, and it becomes an issue of how much to change and when. The younger programs can better implement newer technology at lower cost and benefit immediately, with less updating of legacy systems. This applies to all elements of information technology, but its use can be expensive. If not planned properly, it can be far more expensive and time consuming than the more manual process, since the complexity of advanced simulations usually makes them a development project in themselves. As they integrate, are interconnected, or use increases, the investment and applications become more extensive and obviously more complicated. The requirement to treat them as projects supporting the primary development becomes more vast and must be planned and managed even more carefully.

"The SBA vision is to increase opportunities for the Services to benefit from integrated simulation technology."

WHAT IS SBA?

Table 1 shows the principles of SBA summarized from the recent policy statement released by the DoD MSAC, the executive simulation policy-planning group for the four military services (MSAC, 2000).

The SBA vision is to increase opportunities for the Services to benefit from integrated simulation technology. The principles are structured in relatively broad terms, with the application left to the specific opportunities of the project. With simulation technologies, the opportunities to improve dramatically the development (acquisition) process are a strong incentive. Second, specific opportunities of achieving earlier decisions across the systems engineering structure of design, manufacturing, support, and utilization (employment) are expected. Third, the ability to improve system performance with better balance of total life-cycle or ownership costs has been demonstrated, but the need to establish digital standards across the simulations is fundamental.

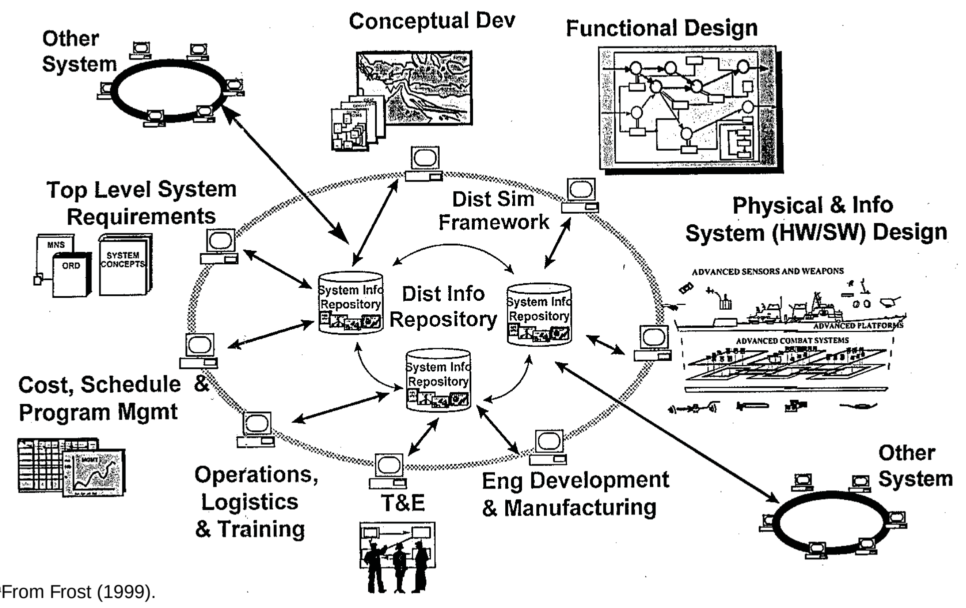
Fourth, simulation technology can now achieve concurrent multiple system evaluations throughout the intended utilization range or mission area. Developing such

Table 1. Principles of SBA

- A dramatically improved acquisition process enabled by the application of advanced information technology (IT).
- Earlier and better informed decisions and reduced risk by more accurate comprehensive assessments of design, manufacturing, support and employment.
- The early optimization of system performance versus total ownership cost (TOC).
- Lower TOC and standards-based reuse of information and software to minimize their cost.
- More optimal program investments enabled by system of systems mission area assessments.
- Enduring collaborative environments, reusable, interoperable tools and supporting resources.
- Automated near real-time sharing of relevant information among all personnel with a need to know (distributed product description, DPD) through a common technical architecture; and open, preferably commercial, data interchange standards.

tools while achieving more diverse and extensive decisions requires better collaboration of the massive and many types of information, and this is achieved through reusability of simulations with greater interoperability and capability. Finally, these technologies have achieved such great advances in computing power that we can now make these better-informed decisions more quickly — that is, in near real time. This sharing of simulation benefits from a foundation of product design information is called a distributed product description. It is well known how capable computer-aided design and manufacturing tools (CAD/CAM) have become (Zittel, 1999). These tools must now be based on a common technical architecture using open data interchange standards. The more they rely on the commercial standards, the more they will be able to use the broader range of tools developed in response to the massive market forces of the digital age. With reduced budgets but increased system complexity, the military can no longer afford their own unique one-of-a-kind tools, so commercial technology is the only option.

Figure 1 graphically shows the SBA process as an integration of information and simulation technologies used throughout the systems engineering development processes. SBA is not a single stand-alone new computer tool, but a tremendous blending of previously stove-piped applications, along with new applications as the technology advances, and where beneficial, is integrated to benefit from a common data



[a]From Frost (1999).

Figure 1. Broad SBA Concept[a]

repository (distributed product descriptions). Although SBA is described by the principles listed earlier, it is very important to note that all such simulation technology need not be integrated only into a total collective. One major Army program is using more than 150 different simulations across its parallel activities and serial development life cycle. Some simulations are mini-projects in themselves, addressing issues of test, design, system employment, etc., across such a wide spectrum that it would be impossible to make all fully interoperable. However, an increasing number of simulations are being integrated to work together. Such a group is called a federation. Furthermore, SBA is not only achieved when *all* principles are fully accomplished, but is evolutionary in its move toward achieving more capabilities, since these are not building blocks. They are massive simulations currently being used in a specific application, which can further benefit from more collective use, but specific increased synergism that can be defined, planned for, and used at the time needed in the development cycle.

Increasing SBA implementation brings increasing benefits — it's not all or none and never static, but dynamically evolving exponentially, with advancing digital technology. An extensive description of SBA, including obstacles and implementation potential, is documented in "A Roadmap for SBA," from which the seven principles were developed (Joint SBA Task Force [JSBATF], 1998).

The report describes the variety of opportunities, as well as the many obstacles inherent in increased simulation interoperability and connectivity. These principles describe the need for careful planning to identify where increased use of simulation is possible, what synergism, common database, and new uses can be sought. So, with many applications already achieved, but in a stove-piped fashion, the dimensions of planning increase to using older simulations with newer applications, some for short-term use, some for longer-term use, and some for multiple uses.

Planning Is Everything

Effective planning has become the greatest requirement in using information and simulation technology, with its continuous upgrades, changing capabilities and quick obsolescence. The whole world is going digital, but suffering under this revolution which violates all of yesterday's business and planning practices. Simulation technology is just information technology applied to replicating the physical world and its physical laws instead of managing business information. (Of course, there are business simulations, such as cost and risk models, which follow economic laws instead of physical laws. And, some are integrated with physical simulations, so as to track cost when materials change.) Information technologies are capable of doing this, but the work culture, business practices, strategic planning procedures, and corporate and government policies are hobbling faster implementation. The digital revolution is moving so fast that people can't understand emerging opportunities fast enough to capture them before new opportunities emerge, preempting the technology just beginning to be understood. The speed with which the Internet is evolving is today's classical example. Only computer experts in narrow fields understand the speed in which their field is changing, but the business advantages are coming from all of these individual computer technologies changing, separately, collectively, and in near chaos.

This speed and our inability to capture it has been described by various digital pioneers who forecast such changes. Such forecasts predict computer processing power is doubling every 18 months; network utility is increasing by the power of two; communications bandwidth for networking and data transfer is tripling; and, finally, new simulation applications are emerging by a power of four, all approximately every 18 months at constant cost. For these reasons, we must have more effective, dynamic, and proactive planning to capture these elements of a widening and more diversified use of information technologies.

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Typical Programs Using SBA

Some development programs that are implementing elements of SBA to different degrees and provide good examples are the American-British Joint Strike Fighter (JSF) aircraft, Crusader advanced self-propelled howitzer, *Comanche* reconnaissance and attack helicopter, *Raptor* F-22 tactical fighter, *Virginia*-class attack submarine, Navy advanced amphibious transport ship (LPD-17), the advanced amphibious assault vehicle, *Apache* attack helicopter, and the next-generation Navy warship (DD-21).

These programs are in different stages of development, and therefore, in different stages of SBA implementation. The F-22 and *Comanche* are well-established programs in final design, having begun in the early 1980s. Their use must consider older simulations more. Younger programs may have fewer legacy systems to consider, but earlier long-term planning is now an opportunity for greater simulation opportunities. But, can they be plan-ned for, to the extent envisioned? Only time will tell, as, young or old, each has been able to capture increasingly more information and simulation technology capability from their respective beginnings.

In the same vein, commercial companies such as Boeing Commercial Aircraft, Daimler-Chrysler Automobiles, IBM, Pfaltzgraff China, and Samsonite Luggage are a few of thousands that have responded to market forces, promoting the increasing development and incorporation of better and better simulation-based tools.

In this article we'll focus on JSF development to demonstrate SBA.

SBA — Not Just Technology

It can be seen from the SBA principles that SBA is not just technology. People, policies, and processes must collectively support this approach. It's effectively coupling those that will bring a greater specific, defined benefit, enabling the designers, users, and supporting staffs to do more — exchanging information faster, easier, and accurately, and with more purpose. This can only be achieved if the following elements change as well:

Culture. There must exist an evolved acquisition culture of people familiar with the advancing tools, new capabilities, and opportunities to do things faster, easier, and in newer ways. This requires continuous education at the pace of the chosen technologies.

Process. An iterative design process with faster electronic data exchange, allowing for rapid evaluation of multiple design options, must be in place. People must be able to do this effectively with the technology provided, while continually changing and evolving.

Environment. An integrated advanced engineering and management enterprise is essential. This requires collaborative distributed engineering and effective seamless integration of the engineering disciplines. It may require an information data repository that achieves user-transparent web-style access (Frost, 1999).

Proven Simulations Are Just the Beginning

As the separate applications improve, so does the understanding, albeit at a slower rate. Forward-thinking managers are moving in this direction to capture more capability faster, and SBA is the encompassing approach to it.

The Joint Strike Fighter

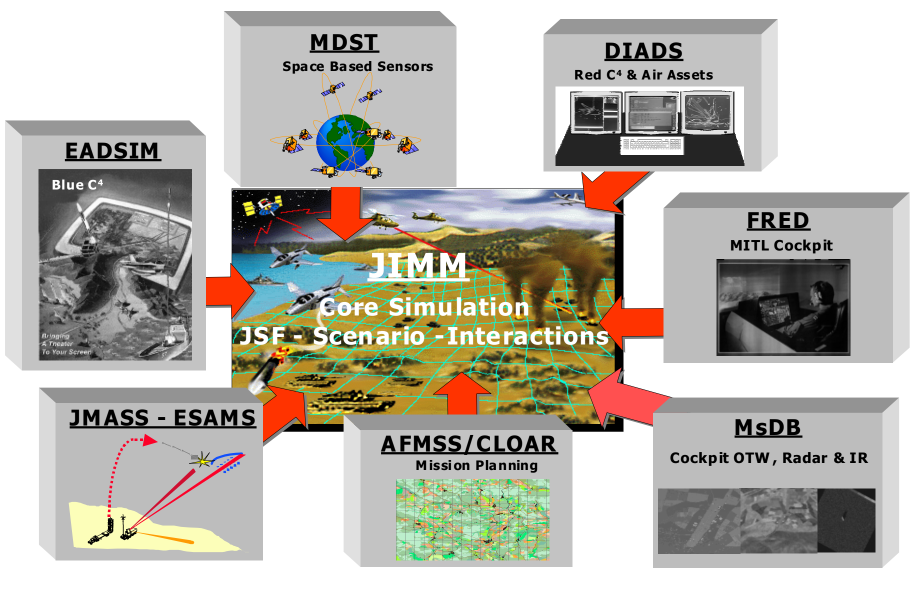
The JSF Aircraft is one of the newest major programs in DoD, and for that reason, it has been designed specifically

The AH-64 Apache Attack Helicopter sits ready to perform a QRF (Quick Reaction Force)

to be an SBA pilot program. Because of the tremendous cost of building a completely new aircraft, this program used many nontraditional approaches. To understand the far-reaching nature of this departure is to understand what the JSF must do. It was intended from the beginning to evaluate cost against user performance constantly and earlier than ever. It is developing a family of aircraft to support five military services, and probably is the last fighter aircraft ever to be built in America. It is to be an immediate replacement for three Navy carrier-capable aircraft, two Marine short-takeoff aircraft, three Air Force aircraft, and is to replace the British Royal Navy *Sea Harrier* aircraft. This extensive list of aircraft capability demands a complex ability to trade off performance and cost in order to provide the most affordable aircraft in world history.

Recognizing the massive set of requirements, a technology development program was conducted beforehand to define and advance special technologies essential for JSF. The entire management process was built around user involvement and the ability to simulate the system, on a campaign level, long before final requirements were locked in. Each of these elements required a tremendous amount of planning and implementation. Just keeping all the traditionalists from finalizing the requirements was a major feat, and some claimed a counter-productive one. But that is what JSF is all about — a dynamic development process that keeps the focus on lifetime affordability while achieving more aircraft capability and battle management information processing than ever before, and by a single pilot, with no second electronics operator to assist.

JSF's "continuum of modeling and simulation (M&S) tools supporting the life cycle of weapon system" operate through a Delphi process, Quality Function Deployment (QFD) analysis, constructive



[b]From Faye (2000).

Figure 2. JSF Virtual Strike Warfare Environment[b]

simulation, interactive digital simulations, and virtual environments, ultimately leading to flight testing, training, and then a repeat of the process (Faye, 2000).

The JSF program carefully structured its design process to use simulation at every step to determine the next step, and in more collective ways than ever before. This required dozens of new ways to use simulations: more interconnected and better understood than before. To understand these far-reaching opportunities, the JSF virtual strike warfare environment (VSWE) beautifully demonstrates the power and complexity of SBA. VSWE is an evolving interoperable collection of simulations to allow for the balancing of different performance requirements in the harshest man-made environment in the world.

Since the early 1990s, VSWE has evolved into the interoperable series of simulations shown in Figure 2. From a central simulation which generates the joint information virtual scenarios, all other simulations had to provide their virtual representations to it, and respond to its activity. VSWE involves the complete hierarchy of simulations, from engineering to campaign wargame simulations. Virtual and constructive simulations are involved to achieve a broad range of capabilities, including:

- broad wargame activities;
- whether a group of JSF aircraft change the battle as needed; and
- man-in-the-loop applications to determine whether a single pilot can handle all the flying requirements while also managing the battle information from so many C4I (command, control, communication, computers, and intelligence) sources.

Around the central JIMM simulation, Figure 2 shows seven supporting simulations, all necessary to achieve the massive amount of formerly disparate activities now intended to be handled by a single machine.

Joint Interaction Mission Model (JIMM). This is the core simulation — basically all of the interactions from all the other models run through here. It provides the mission scenarios.

Extended Air Defense Simulation (EADSIM). This simulation models the friendly Command and Control (C2), including electronic intelligence aircraft, unmanned aerial vehicles with infrared and Radio Frequency (RF) sensors, and communications networks. It processes that data into the JSF cockpit.

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Missile Defense Space Tool (MDST). This models the space-based infrared satellite system as another source of off-aircraft info. This information is sent to the EADSIM, fused together with the other models' information, and then sent into the JSF aircraft.

Digital Integrated Air Defense System (DIADS). The system models all enemy C2 radars and assigns incoming JSF going through this scenario to particular surface-to-air missile (SAM) sites, as well as the SAM sites; their target tracking radars and the actual fly-out trajectories of those SAM missiles.

Fighter Requirements Evaluation Demonstrator (FRED). Four such actual man-in-the-loop cockpit flight simulators provided actual immersion of real pilots, from the three U.S. aerial services, including test and combat pilots. Cockpits were equipped with heads-down displays, normal flight information, plus moving situational maps, radar images, targeting infrared images and cockpit out-the-window screens of three different test ranges in California.

Multispectral Database (MsDB). This simulator provided the cockpit views out-the-window, as well as the visuals for the terrain, radio frequency and infrared sensors.

Air Force Mission Support System/ Common Low Observable Auto Router (AFMSS/CLOAR). These pre-mission planning simulations actually plan the mission route to achieve the objective.

These separate simulations were physically located around the United States, and networked requiring massive high-speed secure data transfer. Some of the simulations were older legacy models established as the standard for modeling and evaluating warfare activities. Many had to be updated; others were redesigned to a more common architecture and interoperable interfaces.

VSWE has now evolved to an advanced process unto itself. It is operated in three-day sessions of well-scripted activity. Seven sessions have been conducted since its inception, each more complicated than before; the last was in June 2000 with the next is scheduled for this year.

Currently both Lockheed Martin and Boeing are developing competing concepts, which have real prototypes in flight testing. Next year, one will be selected to go into final development for production. Therefore, planning for determining the requirements evaluating the campaign operations of the final design has begun. The VSWE collection of simulations is interoperable within a federation set of rules of a common architecture. Some simulations are legacy Service-proven standards for certain military activities; others are new with the JSF. This all must be planned for. JSF has other activities based on interoperating simulations too numerous to discuss here, but the ability to compare and trade off performance against operator capability and against life-cycle cost is one.

As we move farther from stand-alone information and simulation tools to interoperable cohesive simulation suites and to federations of simulations — all coupled with more aspects of information technology — SBA emerges as more achievable. "We must take bold and innovative strides to encourage increased collaboration and leverage available and developing simulation technologies between DoD and industry...In order to capitalize on our current efforts in this area, I have endorsed a joint DoD/Industry initiative…to define a roadmap for SBA"(Gansler, 1998).

CONCLUSIONS

SBA is not a unique idea, but the natural advancement of information and simulation technology. Global market forces drive corporations and governments toward realizing the very benefits these technologies continue to capture. Those who successfully embrace and manage them or (ideally) master them will benefit over their competitors.

Programs are following the successes to use more integrated simulations. Older programs are adding more integrated capabilities while also upgrading still-valuable legacy systems to work more seamlessly in the new environment.

Effective planning is obviously more crucial than ever before. Understanding the requirements and far-reaching complexities of SBA, such as simulation-integrating architectures, long-range program planning, expert simulation personnel to plan for its development, trained program and industry personnel to use its enabling capabilities, and structured iterative design processes to capture the synergistic benefits are all vital to SBA implementation.

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