PSPO-94-12

VIRTUAL PROTOTYPING FOR THE ARMY

A Preliminary Assessment and Commentary Based in Part Upon

the

2nd Annual Virtual Prototyping Conference
Rosslyn, VA
12-13 May 1994

by
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Systems and Requirements Issue Group

Prepared for
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VIRTUAL PROTOTYPING FOR THE ARMY

INTRODUCTION

This report was prepared at the request of MG Ronald V. Hite, Deputy for Systems Management, Office of the Assistant Secretary of the Army (Research, Development & Acquisition via Chuck Malone, Chairman of the Army Science Board (ASB) Systems and Requirements Issue Group. It is based upon the experience and opinions of the author plus information gathered primarily from briefings, demonstrations and conversations at the TMSA 2nd Annual Conference on Virtual Prototyping (VP), held at the Rosslyn Westpark Hotel on 12-13 May 1994. The attached charts summarize the outline (Chart 1) and objectives of the report and then the definitions, scope, benefits, issues and challenges, conclusions and recommendations, and suggested referrals to particular agencies regarding Virtual Prototyping as it applies to the Army.

This report does not purport to provide a comprehensive response to the draft "Terms of Reference - Issue Group Study" for Virtual Prototyping which has been suggested to the ASB for consideration. Rather it constitutes a preliminary report using information from a relatively small number of sources as interpreted by only one experienced observer, and should be considered accordingly.

It must also be said that the briefings at the 2nd Virtual Prototyping Conference were heavily oriented toward advocacy of the briefers' respective programs. They were general, functional, and qualitative status overviews of certain virtual prototyping and other evaluation activities of the military services and industry. They did ***not*** provide, except in a very few instances, any revelation of either the internal technical integrity, specific structure, robustness or present limitations of virtual prototyping programs or systems.

Management Overview

In summary, the Army is making reasonably good use of VP for training and for ***development of tactics and doctrine***, while there are opportunities for increased use for ***minimizing the cost, schedule and risk in the acquisition life cycle***. Higher priority would appear to be warranted, based upon the limited information available to the author at this time, in the areas of validation and to gathering and processing of the physical data required to support such validation. VP will best be further employed in the Army one affordable step at a time with independent assessment of the proposed approach at each step to avoid invalid or inadequately formulated incremental investments.

Guide to Briefing Charts

Chart 2 provides the authors understanding of his assignment. Chart 3 provides a few key definitions (not all standardized or necessarily widely accepted) pertaining to this subject. Chart 4 indicates that the broad concept of virtual prototyping can involve, and be beneficially used for, a wide variety of purposes and notes several of the implications of choosing a particular scope for using VP. Chart 5 illustrates for one kind of system, how many levels and varieties of models can (and usually must) be involved in any significant VP initiative. Charts 6 and 7 list and illustrate by example why the increasingly complex systems of the Department of Defense (as well as civilian, industry and commerce) create a compelling need for the use of modeling, simulation, virtual prototyping, and, in some cases, virtual reality.

Virtual prototyping is not easy to use, and is easy to use improperly or so as to be of little or no value or even counter-productive. Charts 8 and 9 list some of the issues that should be considered and dealt with by users of VP and their management chain. These issues are translated in Chart 10 into a suggestion as to some of the economic, managerial and technical challenges that an Army PM should work through in considering and planning the use of VP on a program. Chart 11 gives special attention to the challenges of validation of VP models and simulations.

Chart 12 summarizes some general and some specific recommendations for how to use VP in the Army. Finally, some comments are offered in Chart 13 concerning where activities or capabilities seem evident that can be of help to Army management in moving ahead with its use of VP.

The agenda of the Virtual Prototyping Conference is also attached and a copy of the Conference Proceedings is forwarded with this report.

Respectfully submitted,

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CWS:cr

Attachment

CHART 1. REPORT OUTLINE

Report Objective

Definitions

Scope

Benefits

Issues and Challenges

Conclusions and Recommendations

Referral Comments

CHART 2. REPORT OBJECTIVE

To provide a ***summary*** of the background, facts and author's opinions concerning ***how*** and to ***what extent*** the Army should use Virtual Prototyping, based in part upon information obtained at the 2nd Annual Conference on Virtual Prototyping, Washington, DC, 12-13 May 1994.

CHART 3. DEFINITIONS

VIRTUAL PROTOTYPING

Use of Virtual Reality to understand and/or evaluate and/or improve systems or operations prior to (or instead of) use of the actual systems or operations.

VIRTUAL REALITY

An environment which is synthetic in that models of components and/or systems are exercised (simulation) as realistic surrogates for the actual components or systems. (Sometimes is taken to implicitly assume that "reality" means "reality as perceived by a human immersed in the environment"). To date the term "virtual prototyping" has not been used to refer to creating a synthetic environment into which to immerse and test hardware.

MODEL

"A representation of a system"
(Army Regulation 5-11)
Models may be constructive or live.
With 1990's technology they are often formed of digital computation codes.

SIMULATION

"The operation or exercise of the model of a system"
(Army Regulation 5-11)
<u>Simulation may be:</u>

- Real-time or not
- If real-time, "man-in-the-loop" or not
- If man-in-the-loop, interactive or not
- Distributed or not
- If real-time, hardware-in-the-loop or not

CHART 4. VIRTUAL PROTOTYPING SCOPE

In each case, *could* include determination of:

- **System operational effectiveness and performance (few or many dimensions)**
- **Human proficiency training and assessment**
- **Bounds of system applicability, capacity, etc.**
- **Human-operator-machine compatibility**
- **Inter-operability**
- **Maintainability**
- **Reliability**
- **Vulnerability**
- **Hardware bounds of utility**

Notes

1. **Most often, VP is used for the first four of the above.**

2. **Each of the above aspects implies the incorporation and validation and support of additional models and simulation components into the over-all VP process, and thus additional VP costs.**

3. **Those not included must be dealt with by other means, sooner or later.**

4. **While Virtual Prototyping is emphasized at the top war-fighting level, it can be used at any level of a subsystem, system, or system of systems.**

CHART 5
HYPOTHETICAL (INCOMPLETE) EXAMPLE OF VP HIERARCHICAL LEVELS
(For a Targeting System)

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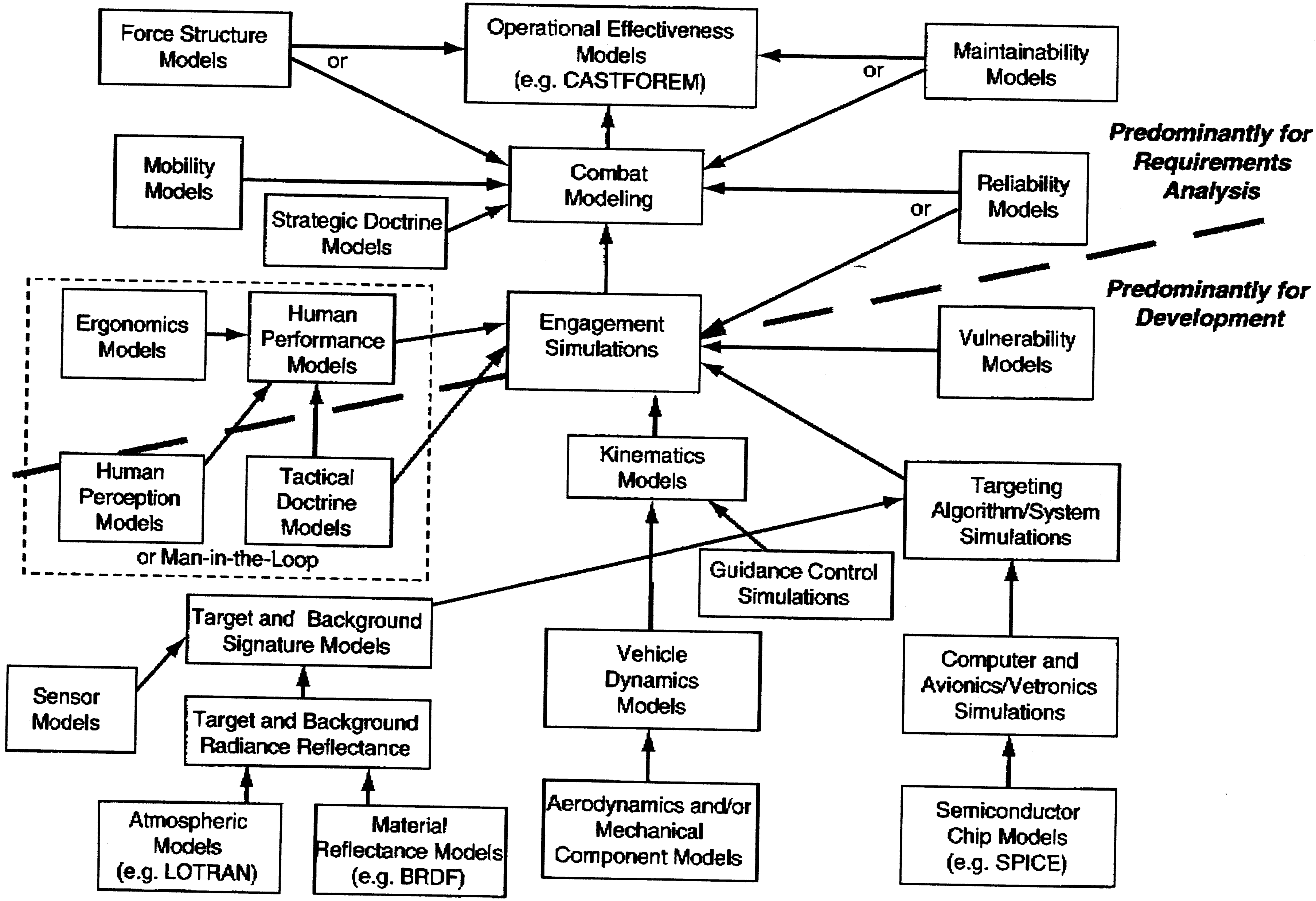

CHART 6. BENEFITS

WHY USE VIRTUAL PROTOTYPING

***Properly executed*, use of virtual prototyping can enable concurrent engineering/manufacturing, which will:**

- reduce development risks (uncertainties, surprises, failures),
- reduce development cost (reduce false starts, re-engineering, over-specification),
- reduce development time (quicker proof, fewer re-development cycles),
- reduce OT&E time and costs (by uncovering deficiencies earlier)
- provide more robust systems (evaluate over more conditions than can be afforded in live tests, and
- provide a basis for more-rapid response to changing requirements/conditions.
- a virtual prototype of a new system (e.g., tank) can be produced by simply copying and then modifying an old system's software

NOTE:

The cost and time for the *Preliminary Phases* of a program may well increase with proper use of VP, but the total cost and time will decrease.

CHART 7. BENEFITS

WHY USE VIRTUAL PROTOTYPING? -- EXAMPLES

- **Typical Military Electronic System in 1994**
  "Exploding Complexity"

- **Logic Gates per "key" chip** — **200,000**
  Chips per module — **50**
  Average modules per subsystem (e.g., computer) — **15**
  Average subsystem per platform — **30**
  Therefore, ≈ $5x10^9$ digital electronic logic gates per platform

- **Without use of virtual prototyping, one chip would take years to design, likely contain many errors and be obsolete by the time it was completed.**

- **Similarly, the Boeing *777* virtual prototyping (replacing a $100M physical mock-up) involves billions of polygons to represent the required 3-D *mechanical* detail of the full aircraft. Results of using it can get to the factory floor in minutes instead of weeks. Developers/maintenance planners, etc., can interact with the simulation to "walk through" and "reach out into" aircraft's compartments.**

- **Complete Navy Ship modeled with billions of component parts (NRL).**

CHART 8. VIRTUAL PROTOTYPING (VP) ISSUES

- The key issue to be addressed in any important use of any level of simulation is how will the validity of the simulation be assured --
  - with respect to all important simulated characteristics
  - under all conditions to be simulated.

- "Apparent" realism may not be enough.

- Adequate validation requires advanced planning, continuing priority, ***independent*** checks, rigorous thoroughness, and (consequently) significant expense.

- Many redundant or overlapping models are in development/use. there is an economic need to collaborate, choose standard models, and integrate them.

- PM's should be encouraged to resist proliferation of models and join forces to use already developed and validated simulations.

CHART 9. VIRTUAL PROTOTYPING (VP) ISSUES (CONTINUED)

5. Test data which could support validation of simulations is often not ever analyzed and is eventually discarded due to budget constraints and prioritization decisions.

6. Virtual Realty (VR) and VP components (models) developed for engineering and evaluation are NOT significantly integrated with VR and VP components developed for training and doctrine development, limiting the value and validity of both.

7. VP is more than a fad, but it is attracting "every" computer software vendor who senses a hot topic with money behind it. superficially appealing, but ill-founded approaches abound. VP is not well served by video-game levels of design. This suggests the following management methodology:

CHART 10. VP CHALLENGES

EFFECTIVE USE OF VIRTUAL PROTOTYPING

REQUIRES

- **A well-understood and stated purpose and scope of the virtual prototyping: What is it to demonstrate or determine?**

- **A coherent consistent set of available models and simulations that is complete enough for the above scope and purpose to be satisfied**

- **A clear delineation of what "independent" phenomena are to be represented, what cause-effect relationships are to be represented by what means, and what resulting performance or behavioral aspects of the "system" are to be observed or measured**

- **Thorough, continuing validation and control of all VP components.**

CHART 11. VP CHALLENGES

WHAT IS INVOLVED IN VALIDATION?

- **Basic physical measurements to form the basis for component models,**
- **Component model testing transitioning to successively higher-level subsystem testing,**
- **Sound design of adequately rich sets of experiments to validate higher-level tests,**
- **Independent expert oversight of models and simulations,**
- **Bottom-up substantial exercise and review of model behavior and correctness, and**
- **Configuration control and management of validated models to ensure maintenance of their integrity. (A "little" change can invalidate a model).**

The basic management question always should be, "How do we know the model/simulation is right?"

VP cannot be just a video game or a Star Trek movie.

The TRADOC Analysis Center seems to be working on these challenges, but it was not feasible to assess the adequacy at this conference.

CHART 12. RECOMMENDATIONS

- **Crawl, walk, then run with VP. Build its use from the bottom up, but with an architectural framework defined.**

- **Do what can be afforded well, don't skimp to try to build too massive a VP structure.**

- **Insist upon solid, sound validation.**

- **Adequately fund collection and *analysis* of real data to permit sound validation.**

- **Integrate VP component models as they are created and proven.**

- **Don't buy VP proposals just on the basis of the name. First obtain a probing assessment of each proposed approach and its physical underpinnings.**
  - **–In concept development and tradeoff investigations by PM's and support contractors.**
  - **–In full-scale development by prime contractors.**

- **While the Army is the leader in VP for training, tactics and doctrine development and platform development levels, it can and should get more for its RDT&E dollar by using VP at the electronics (sensors, processors, vetronics, avionics) subsystem development levels. Centers of VP excellence should be considered to provide *affordable*, *sharable* VP resources.**

CHART 13. REFERRAL COMMENTS

- NRL, among government presenters at this conference, seems to have the technically soundest perception of how to analyze and implement VP systems.

- Several independent and government labs have contributions to make in adding realistic target signature models to enhance VP.

- U of Iowa and TARDEC are on top of ground vehicle VP for system development and evaluation.

- VP techniques have been successfully employed on a few Army electronics (sensor, processor...) programs and these experiences could be propagated.

- Mr. Jim Fox at TRADOC Operations Analysis Center represented that organization at the conference.

- The Defense Modeling and Simulation Office (DMSO) seems to have the over-all DoD charter for policy and standards regarding modeling and simulation (Lt. Col. David Bartlett).