Real-Time Stimulation for Exercising Complex Systems Employing Adaptive Sensors and Sensor Arrays

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Abstract: Testing military reconnaissance platforms is becoming more difficult and expensive. Future systems will use data fusion from sensors that have greater complexity than previously; coupled with increasing use of unmanned vehicles, on-board testing and carriage of test equipment becomes unattractive even where it is possible. The range of situations that a platform is expected to handle adds a further dimension, making evaluating the full capability a daunting task. Mounting adequate trials is both difficult to define and cost prohibitive, so the buyer isn't sure what is being bought and the seller can't adequately demonstrate what is being sold. This paper presents a preliminary definition of the problem, further work is aimed at defining a method of providing full life-cycle evaluation and testing to cope with these situations.

1 Introduction

Acceptance trials of radar, IR and EO based equipments on aircraft and ships traditionally comprise exposing the equipment to a known set of conditions from which, for example, detection range can be demonstrated. There are a number of real-world variables that are difficult to control; weather conditions and sea-states figure largely amongst these and may conspire for or against a 'successful' trial. Systems that are specified and designed to be adaptive, able to change operating modes according to the number and type of targets detected for example, pose a greater problem: not only for acceptance testing in the real-world, but also for development testing. How can a wide range of complex environments be engineered and controlled so that the results can be predicted from such systems?

This question has exercised minds increasingly over the years, circa 1996 was a watershed period in that the amount of published work increased from that of a few forward thinkers to be a more mainstream activity. From that time more reliance has been put on simulation and computer modelling to define system performance. The feasibility of this is due to improved computer speeds, better structures for system and code design, and growth of modelling tools that span the high-level to low-level abstraction levels. This has fuelled a positive feedback cycle that borders on the euphoric, increasing the reliance on such methods. For it to be effective there must be a link to the performance of the real equipment [1].

There is often a discontinuity in the development lifecycle in terms of practical day-to-day work on projects. Concept modelling, being fully computer based, may use results from previous projects, sometimes even models from previous projects; these issues are highlighted in a report regarding the status in various US procurement processes [2]. The later stages of development however, when prototype final systems are introduced, need a different level of abstraction, formats of data may differ and real time transfer rates become important. It is around this point that the discontinuities in evaluation techniques first appear and traditionally the modelling community's contribution decreases in favour of the 'integration team' contribution.

The way forward would seem to rely on very much improved connectivity between models, data, and real-world equipments, so that the reality is more accurately modelling and simulated. Finding this route is the basis of this thesis, of which this report is an early part.

2 Lifecycle Testing

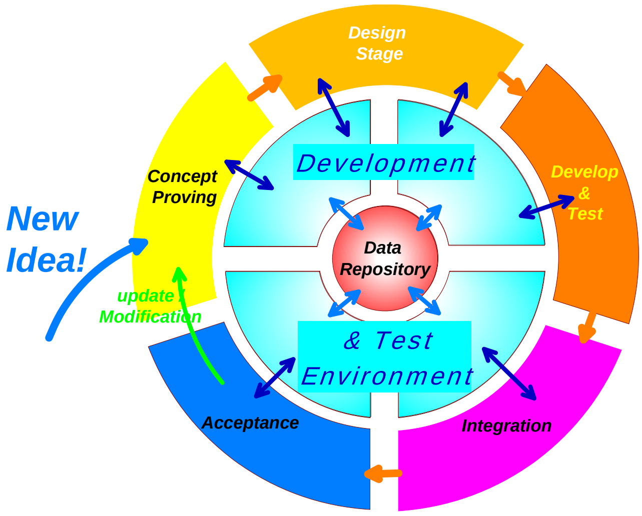

Figure 1 – Design & Development Lifecycle

Figure 1 shows a typical project's design and development lifecycle. Started with a 'New Idea' a concept proving stage is initiated and successful ideas will move to design stage – there may be funding issues associated with flow through these stages that will affect timing, but these are ignored for the purpose of this discussion. A development and test stage follows design, with integration preceding acceptance testing; training and other final issues would take place around this time. In a linear flow (waterfall development) that would be the end of the project, the end of the lifecycle, however further work is often required for one of two reasons. Rather than the waterfall development a 'spiral' model may be preferred, in which the requirements are prioritised and organised into iterations of the loop described above to create a spiral towards equipment with the final specification. This is also consistent with the 'acquisition by simulation' procurement method that runs simulation throughout the life of a project, developing requirements and increased functionality as lessons are learned from earlier iterations. Mid-life updates and similar extensions to the original concept form the second reason to iterate the loop. These are shown in the diagram as re-initiating the loop with a second concept proving stage leading to another full iteration of the lifecycle loop – each iteration will have its own independent timescale.

The centre of the diagram shows a data repository; often this is fragmented and associated with the various stages of the lifecycle. The middle layer of the diagram shows a Development and Test Environment, currently also fragmented; it is the objective to join up the various stages to make a continuous loop with an integrated data repository that is consistent and applicable throughout the lifecycle. This would provide the benefit that test data could be more readily used to modify modelling data, and modelling results could point to key parameters to verify with the real equipment – an integrated development and test environment.

The concept is not contentious, so what stands in the way of this happening? There are both technical and business issue to resolve.

3 The Business Model

Governments (the buyer) wants more for their money [3], they need a responsive industrial base that can react quickly with equipment that can be rapidly deployed. This means equipments must be validated before deployment with minimal training needs and few failures. The equipment they require must be flexible and cover the functionality that previously may have been covered by several equipments; there must be an improvement in all of the features of the equipments that the new purchase replaces.

The technical community are better trained and more mobile than the previous generation, there are also fewer of them and numbers are possibly still declining [4]. There are more tools available for them to use and, proportionally, more are skilled at a higher level of problem abstraction than previously. So modelling is a natural fit to their skills, and the positive feedback loop referenced earlier gets a further incremental boost.

Companies sit in the middle of this. There are fewer contracts to win, their value is decreasing but the technical specification is rising although required delivery time is reducing. They feel the need to become more efficient. Reducing staff numbers offers this, provided that the tools and techniques they adopt are sufficiently good to provide a net gain. Most large companies have taken this step, as have many small ones, to cite any one of them would be unreasonable.

There is, therefore, another positive feedback loop in place with every stakeholder aiming for the same objective. So it should all come together very readily.

Unfortunately, positive feedback loops can all too easily become unstable. The instability in this one derives from decisions that can not readily be taken. Some of them have already been posed: How do we specify these systems? How do we verify them? Too few engineering staff with inadequate tools can not meet the technical objectives – therefore the financial objectives will also fail; too many with an excess of tools can not meet the financial objectives – maybe not the technical ones either. Inactivity spells disaster – doesn't it? The management dilemma – what to do?

4 Structured Control Initiatives

Government initiatives to help with these issues abound at an increasing pace. The modelling route has gained increasing favour since 1996 when High Level Architecture (HLA) was introduced [5]. This lead to the American Federation Development and Execution Process (FEDEP) that defined 6 stages for the definition of a process that can be used to specify a model of a complex system [6]. During this time the EUCLID program was undertaken in Europe to define **Eu**ropean **C**o-operation for the **L**ong-Term **i**n **D**efence [7]. Both reported around 1999. A year or so later the UK/European version Synthetic Environment Development and Exploitation Process (SEDEP) was generated following a period of Government, Industry and Academic co-operation [8]. Reported in 2002, this is based on the FEDEP model, reflected by the similar name, but adds a definition of requirements stage to the start and extends the test-and-evaluate stage at the end of the sequence. The SEDEP model defines the requirements of a tool-set for each stage of the process. More work would be required to implement these, but it is likely that the individual needs can be met by the myriad of tools that are commercially available; the presentation lists some 40 to 50 of these, getting compatibility between them is another issue.

Also around 2002, a multi-interest task force, chaired by Prof Simon Watts (Thales/UCL), reported on the Specification and Measurement of Radar Performance [9]. This looked at system-level definitions and performance evaluation by modelling as a realistic way to evaluate increasingly complex systems. It also mentioned hardware-in-the-loop testing as an option. The

Experimental Network Integration Facility (ENIF) recommendations in 2002/2003 [10] lead directly to NITEworks, (Network Integration Test and Experimentation works) that is currently active using networked modelling to evaluate the effects of potential responses to military situations. A scenario is run every few months and includes industrial and government resources.

5 Summary

There is a large and growing body of work evaluating the ways to deliver the equipments needed by modern military in a cost-effective and timely way. This is currently focussing on modelling with nodding acknowledgment to the need to include evaluation of real equipment. Recent Government initiatives are designed to promote this important element in the performance evaluation equation thereby allowing the life-cycle evaluation loop to be closed.

This work will look at the technical issues to be resolved, a Development Shell that will provide stimulus and record responses to the current stage of development in a projects lifecycle, from concept to the evaluation of fully operational equipment. This is shown in Figure 2 where the data to and from the current stage of the project's development is shown together with its control links.

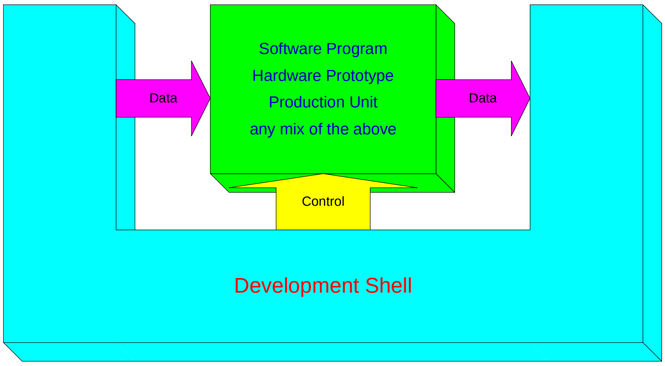

Figure 2 – A Development Shell

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