

The Cost Effective Development of HLA Federations for Computer-Assisted Exercises (CAX)

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ABSTRACT

The use of Computer Assisted eXercises (CAX) for the training of NATO staff personnel has been exploited successfully for quite a long time. To satisfy the statements of the NATO Modelling and Simulation Masterplan, and thereby to intensify the cost saving effect for simulation systems (a CAX is a kind of a simulation system), NATO decided to conduct the PATHFINDER experiment as the successor of the DiMuNDS 2000 project. One important issue is to establish a generic interconnection to a Command Information System (CIS) that may be re-used in future applications.

This paper suggests – based on a number of lessons noted, limitations, and deficiencies from DiMuNDS 2000 – a bunch of measures, which should be addressed within PATHFINDER (and beyond) and any federated simulation supported CAX. These issues may be divided into the following areas: Technical Management, Administrative Management, Modelling, and Technical Infrastructure.

INTRODUCTION

In 1998 the idea was conceived to conduct a multi-national distributed simulation to prove the concept of the High Level Architecture (HLA) and to demonstrate the cost-effective employment of national models and simulations to support National and NATO Computer Assisted Exercising (CAX). The demonstration of the feasibility and operational viability of this concept was scheduled in two phases: the Distributed Multi-National Defence Simulations programme (DiMuNDS 2000) and a follow-on PATHFINDER programme¹.

The DiMuNDS project was a highly successful precursor experimental system which established the technical viability of combining multi-national simulations using the HLA for the purpose of providing training/ exercises in a Combined-Joint Task Force (CJTF) operational context. This programme demonstrated its military capabilities in the NATO M&S Conference in October 2000. The Pathfinder Programme aims to implement a technological leap-ahead in capability benefits for NATO and PfP. Initially, this capability development will focus on the training of the NATO Combined Joint Tactical Force (CJTF) and component commanders, but the PATHFINDER product has application to a much wider audience.

¹ Note: although the term “distributed simulation” is very commonly used, within this paper “federated simulation” is preferably used to stress the point that the emphasis of PATHFINDER and similar experiments is on coupling simulations that origin from independent sources.

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Essentially, PATHFINDER seeks to develop an integration environment in which national simulation models and decision support tools can be federated to provide a bespoke capability to match the demands of individual Users and the evolving complexity of modern warfare. Where possible, the component simulations will cover the full spectrum of warfighting and offer various degrees of fidelity.

THE NATO M&S MASTER/ACTION PLAN

The overall mandate to conduct DiMuNDS 2000 and PATHFINDER results from the NATO Modelling & Simulation Master Plan (NMSMP) [1] and the derived Action Plan.

The Action Plans identifies 5 main objectives for M&S:

- 1) to establish a Common Technical Framework to foster interoperability and reuse;
- 2) to provide Common Services to increase Cost Effectiveness in NATO M&S activities (including the provision of M&S education to NATO Nations and PfP; the promotion of sharing of M&S resources through a simulation resource library (SRL));
- 3) to develop Simulations;
- 4) to employ Simulations to enhance NATO mission effectiveness;
- 5) to incorporate technological advances: M&S-related technology advances are expected to occur frequently and will provide opportunities to increase functional capabilities, performance and overall M&S effectiveness. To assist M&S users in maintaining awareness of such M&S-related technology developments, NATO should monitor technology developments by others and to conduct its own technology-development activities in key areas not addressed elsewhere.

The recommendations given further below fit very well to the above mentioned objectives.

EXERCISING IN THE REAL ENVIRONMENT

From the operational point of view, conducting a CAX in a real environment is vital for achieving the training purpose and consequently for user acceptance. A real environment in this context simply means interacting with the CIS as it is used during mission. In other words, the simulation systems assisting the exercise should be invisible to the training audience.

This can generally be achieved in three different ways:

- 1) via a swivel chair: the information from/to the CIS is inserted in the configuration files of the simulations (the “old fashioned method”);
- 2) via a proprietary or NATO protocol, i.e. ADat-P3: many CIS rely on ADat-P3 messages for information exchange. Since these are regularly ASCII-files, it is easy to parse the message electronically; this is simply the automation of variant 1 (the “usual way”);
- 3) via a replication mechanisms: this maps the data structure of the CIS to the data model of the federation, enabling an automatic data exchange (the “onthologic way”).

In more detail, the replication is much more than a simple replication of data bases: it includes the mapping of two different data structures in terms of semantics and logics. Unfortunately, the *representation* of the (perceived) truth in a CIS on the one hand and a simulation system on the other is usually very different, thus leading to severe problems in interoperability.

Very recently, a comparison of the U.S. Army Object Model Standards Category (OMSC) for M&S and the Army Integrated Core Data Model (AICDM) for CIS was published [7], concluding that interoperability between these can hardly be achieved unless some modifications are applied.

Thus, for experiments like PATHFINDER it can be concluded that:

- either the coupling is established via proprietary protocols,
- or efforts need to be launched, to establish a generic mapping mechanism.

From a pragmatic point of view it is recommended to undertake both: using the proprietary protocol as used by the CIS in order to meet the timeline of PATHFINDER, but additionally fostering efforts towards a sophisticated technical infrastructure.

THE REQUIREMENT FOR A TECHNICAL INFRASTRUCTURE

The requirement for interconnecting CIS and simulation systems is motivated not only from the perspective of cost-effectiveness for CAXs, but also from the operational view for purposes of decision support and/or operational planning [3-5].

As widely known, CIS and simulation systems exploit various communication mechanisms. Hence, it is desirable to keep the systems separated with respect to their peculiar communication mechanism and to loosen the coupling as far as possible.

From a more abstract point of view upon federated systems – regardless whether we are dealing with linked CIS or linked simulation system – one encounters a striking similarity: as in the case of the Multi-national Interoperability Programme (MIP), where several national CIS based on the ATCCIS model are linked, the distribution within a HLA federation relies on devoting to a common FOM. If we take another step on the ladder of abstraction, then one can introduce a so-called *Data Mediation Functionality* (DMF): exploiting techniques already used for e.g. NC3DM or SEDRIS (therefore denoted as a reference or common data model) allow generally for converting one data base format into another.

However, this approach is based on the assumption that the data models and/or data structures of the underlying data structure reflect states of military relevance. Only then a transformation from CIS to the simulation system and vice versa via a reference data model can succeed: $\psi_{MIP} = \mathbf{O} \psi_{Sim}$ and $\psi_{Sim} = \mathbf{O}^{-1} \psi_{MIP}$, with \mathbf{O} as the operator for the CIS-Sim-Coupling.

It is most important to note that the linkage of CIS and simulation systems is still an issue of R&D efforts and that we are far from having a solution [6]. Up to now, mainly two approaches were taken: the one – motivated by the simulation systems' community – tried to urge the CIS to commit to a FOM. The other – motivated by the CIS community – tried to force a simulation to interact via the CIS peculiar message protocols. Although both approaches have their pros and cons and have demonstrated to be feasible, they are not very universal. With PATHFINDER – still in the domain of a R&D project – it is therefore recommended to investigate the use of a CIS-Sim-Coupling device (the \mathbf{O}) to establish the coupling.

Generally speaking, coupling a simulation systems and a CIS is not a trivial issue. Assuming that the simulation system is HLA compliant, it is represented by its Simulation Object Model (SOM). The CIS, on the other hand, is to be expressed in terms of its internal data base structure: this may be ATCCIS², or more likely any data model. Hence, any generic mapping mechanism must enable mapping of arbitrary data models to FOMs. Clearly, it is necessary to know the data models behind the CIS to be coupled as

² Army Tactical Command and Control Information System.

early as possible in order to “align”³ them. Furthermore, the Run-Time Infrastructure (RTI) is usually not an appropriate software layer interconnecting CIS systems or modules of them.

Concerning the coupling of simulation systems, it is often not realised that interoperability demands for more than mere “*HLA compliance*”: interoperability demands for data standards as well as for a common understanding of modelling. Otherwise the HLA is reduced to the RTI and is then yet another communication medium.

So far, there are some efforts evolving that addresses the issue of CIS to Simulation coupling [2, 4, 5, 7]; they are mainly governed by U.S. initiative, but also some European countries have recently developed some promising ideas.

LESSONS NOTED FROM DIMUNDS 2000

When progressing from DiMuNDS 2000 to PATHFINDER, the scope is not on one single focus, but takes several tasks and restrictions into account:

- the availability of simulation systems provided as national voluntary contributions;
- the support of a particular scenario without limiting the scope of future scenarios;

but still:

- establishing a technical infrastructure and
- proving the PATHFINDER concept as outlined earlier.

These first two circumstances usually endanger to end-up in solutions that are suited only for one specific CAX under consideration and that are hardly re-usable⁴, hence preventing the proof of concept. Therefore, it becomes important to draw attention to some aspects which are regularly neglected:

- Data Exchange Formats;
- the discussion of Federated vs. Monolithic Simulation,
- and the aspects of Modelling and Simulation.

Of course, each federation has at some time to address topics like the big/little endian⁵ problem⁶. Within DiMuNDS 2000 this was solved very effectively by using the XDR standard.

When addressing the topic of data exchange formats the focus is not on distributing the SOM/FOM information in terms of their DIF, i.e. the omd-file in BNF, but on the data to be federated via the RTI. The RTI does not provide a coding scheme for the representation of the byte stream, hence the applications have – as a part of the FEDEP – to agree on the data representation and if a mismatch is encountered they have to write the re-coding code. Within DiMuNDS 2000 the problem was very elegantly solved by adopting the XDR standard.

XDR is a standard for the description and encoding of data. It is useful for transferring data between different computer architectures. It fits into the ISO presentation layer, and uses a language to describe

³ In using the expression “align” the author follows [7].

⁴ Often referred to as proprietary solution.

⁵ The way data is coded into a bit stream.

⁶ At least is the simulation systems are running on different platforms.

data formats⁷. Protocols such as Sun RPC (Remote Procedure Call) and the NFS (Network File System) use XDR to describe the format of their data. Although XDR is still widely used, more modern concepts for federated applications include this problem already: within the CORBA standard, data representation is already standardised and referred to as CDR (Common Data Representation). CDR plays a similar role as XDR, however it is already part of commercially available ORBs.

Summarising:

when setting-up the PATHFINDER federation, the potential participants should recognise that within the DiMuNDS 2000 project a library for data conversion in accordance with the XDR standard was established. Furthermore, if in future extensions of the PATHFINDER project a technical infrastructure after the pattern of the French ESCADRE or the German PSI-SA/GERTICO should come into service, this should be based on a standard in accordance with standards defined by Object Management Group (OMG)⁸ [8], and hence addresses the data exchange problem.

CONSEQUENCES FROM DIMUNDS 2000 TO THE MSG TASK GROUPS

The following areas appear vital to the successful establishment of federated simulations interconnected to CIS and capable to support CAX.

Technical Management:

- Deriving Data Models;

Administrative Management:

- Deriving Authoritative Data Sources;
- Defining clearly a scenario;

Modelling:

- Modelling Technique;
- Use of Modelling Tool-Kits;

Technical Infrastructure.

- Generating rapidly a Scenario;
- Coupling simulation system with CIS;
- Data Marshalling.

Although, different bodies⁹ have already addressed some of those problems/limitations, a short-term guidance document for federated simulation supported CAX experiments has not been produced. The establishment of a CAX using federated simulation (unlike a “conventional” CAX) imposes the above mentioned problems to obtain the benefit of flexibility and re-use of systems.

⁷ Note that the XDR is a description, not a programming language.

⁸ The OMG is a non-profit organisation with more than 1000 members from industry and academia to define standards for the interoperability of distributed object-oriented software applications.

⁹ Defense Modeling and Simulation Office (DMSO), Simulation Interoperability and Standardization Organization (SISO), NATO Modelling and Simulation Group (NMSG), and national authorities (e.g. Daten Management Organisation der Bundeswehr (DMOBw) in Germany).

Presently, NSMG is dedicated to M&S by 14 approved Task Groups. Unfortunately, only 2 of them are explicitly dedicated to the PATHFINDER project: MSG-002 and MSG-005 plus the PATHFINDER Steering Group.

In order to foster PATHFINDER and to avoid some experiences as encountered during DiMuNDS 2000, it appears reasonable, to focus some of the NMSG TAPs in more strength to PATHFINDER. Figure 1 summarises the relationship between different NMSG TAPs and some suggestions given within this paper. Although, many of the NMSG TAPs are devoted to identified problems, only few¹⁰ of the recommended tasks are covered. Some of the important ones are up to now not addressed at all.

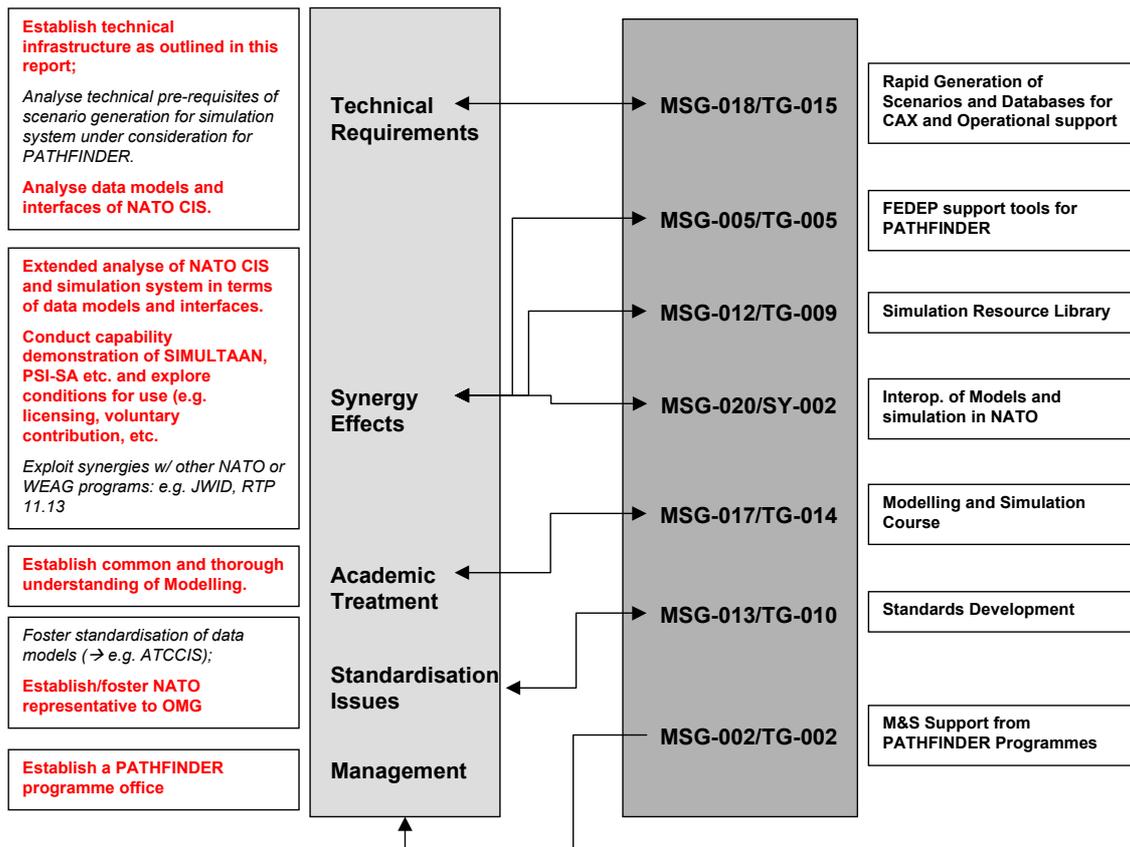


Figure 1: Relationship of NMSG TAPs and Recommendation of this Report.

Consequently, meeting the above mentioned demands should be performed to the highest possible extend through the existing NMSG TAPs. However, this appears not appropriate, where PATHFINDER and/or similar programmes requires crucially for a technical outcome. For this case, there is the need of a dedicated “Programme Office”, manned by national (as in the case of DiMuNDS 2000) and some NATO technical experts. It is important to note that this “Programme Office” should be responsible for technical decisions and its tasks are:

- to establish a technical infrastructure;
- to run through all the PADEP steps as necessary;
- and, finally, to conduct the concrete experiment, e.g. PATHFINDER.

¹⁰ Printed in italics in Figure 1.

The remainder of the NMGs – if launched at all - is recommended to be re-focused as follows¹¹:

- MSG-018/TG-015: analyse the technical pre-requisites of scenario generation in general, and *demonstrate the feasibility of the results with the ARRCADÉ FUSION 03 scenario*.
- MSG-012/TG-009: Outline a Simulation Resource Library and *include an analysis of NATO CIS interfaces and review capabilities of simulations frameworks (like SIMULATAAN (NL), PSI-SA (GE), ESCADRE (FR) as available for NATO)*.
- MSG-020/TG-014: *Conduct extended analysis of NATO CIS' and simulation systems' data models and interfaces*¹².
- MSG-017/TG-014: *Establish common and thorough understanding of Modelling*¹³ *including review of current commercial developments like the MDA [8]*.
- MSG-013/TG-010: *Establish a NATO representative to OMG*.
- MSG-002/TG-002: *Establish a PATHFINDER "Programme Office"*.

CONCLUSIONS

It is important to note that PATHFINDER and subsequent simulation based CAXs should be able to interconnect an arbitrarily configured federation to an arbitrary CIS. Unfortunately, DiMuNDS 2000 did not address the issue of connectivity to CIS and therefore no conclusions or recommendations can be derived from DiMuNDS 2000 on this subject.

However, the following conclusions can be drawn:

- Technical requirements: For making a CAX based on federated simulation a success, a dedicated infrastructure is needed that enables the mapping of the data models of the simulation system and this CIS, respectively; furthermore, incorporating network specialists into the Federation Management Team at a very early stage is necessary to support scenario generation.
- Synergy Effects: Some of the findings above and recommendations below can be addressed within existing bodies, or establishing relationships between them;
- Academic Treatment: There are many theories of M&S, but very few address CIS. A dedicated theory of the representation of a modern(!) battlefield in terms of data models¹⁴ would yield a benefit for CAX experiments;
- Standardisation Issues: Not only IEEE 1516 (HLA), but also other standardisation efforts, like the MDA of the OMG, should be taken into account for the establishment of distributed and federated applications (simulations as well as databases).

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¹¹ Recommendations in *italics*.

¹² The work may take [B-35] as a pattern.

¹³ Action Item already captured from feedback of the SAS lecture series [A-11].

¹⁴ From the viewpoint of information technology (IT), CIS are commonly organised in data bases; ideally these mirror a data model as the representation of the "real world".

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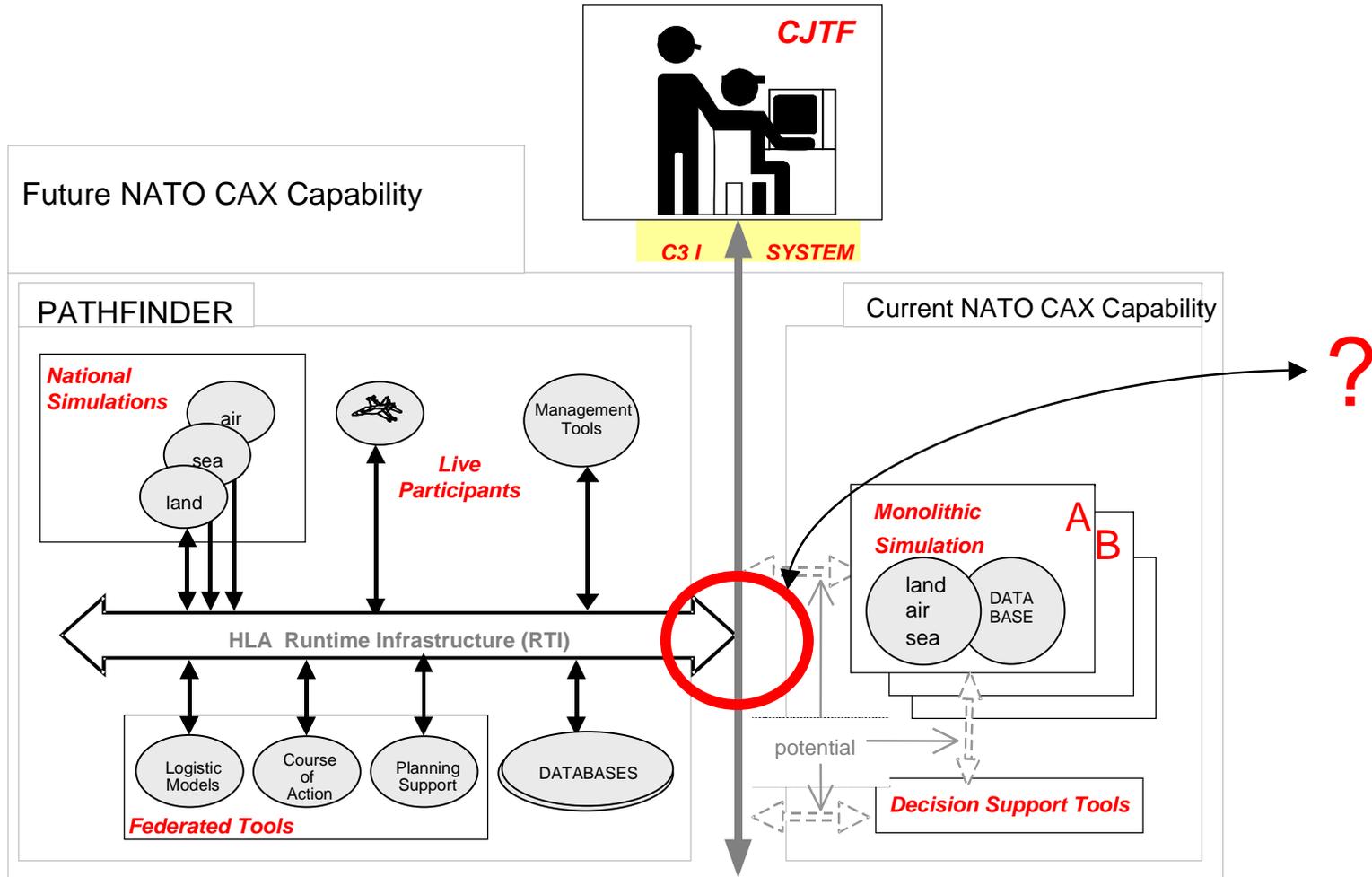
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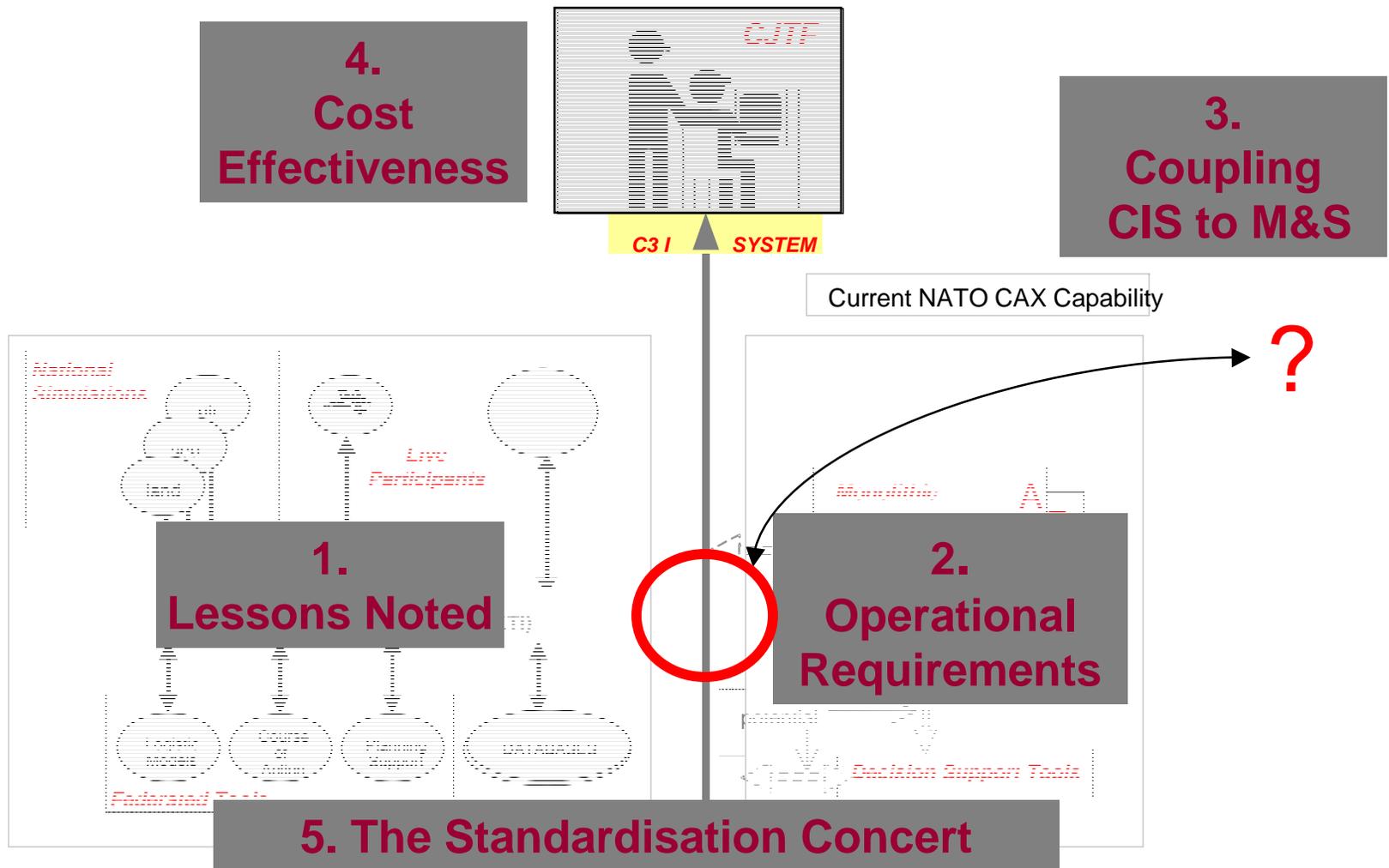


The PATHFINDER Promise



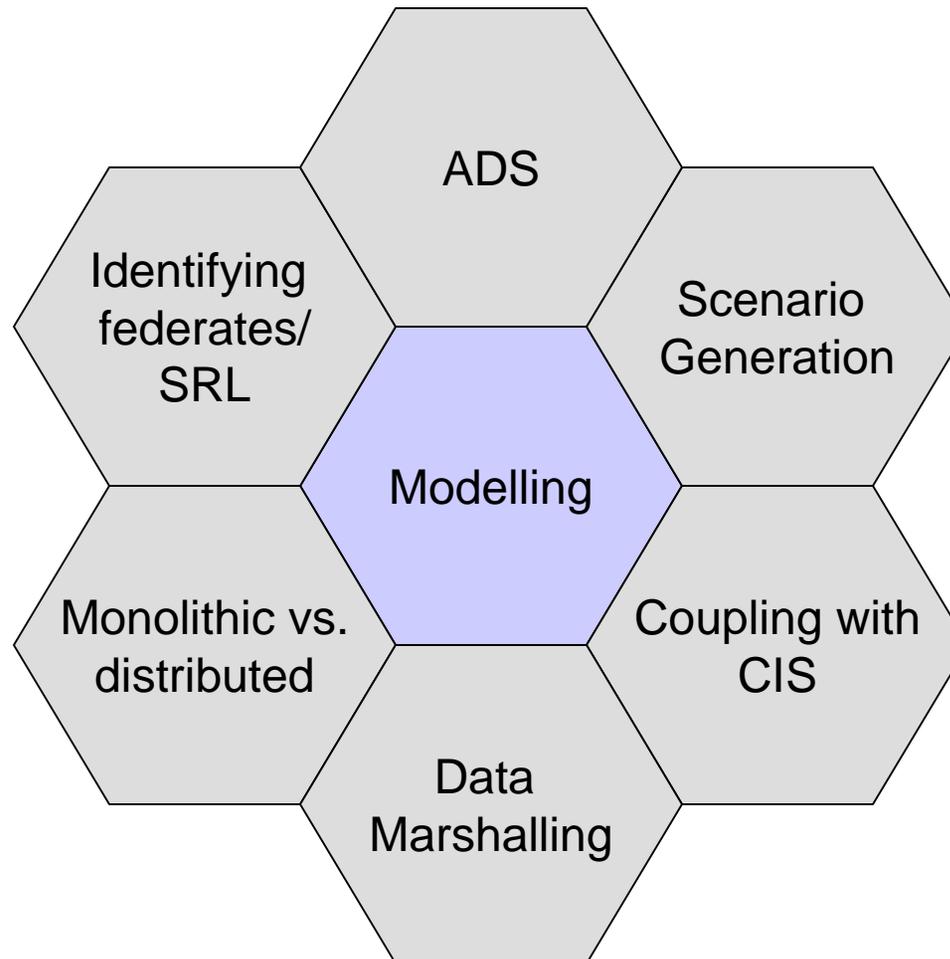


The Approach I



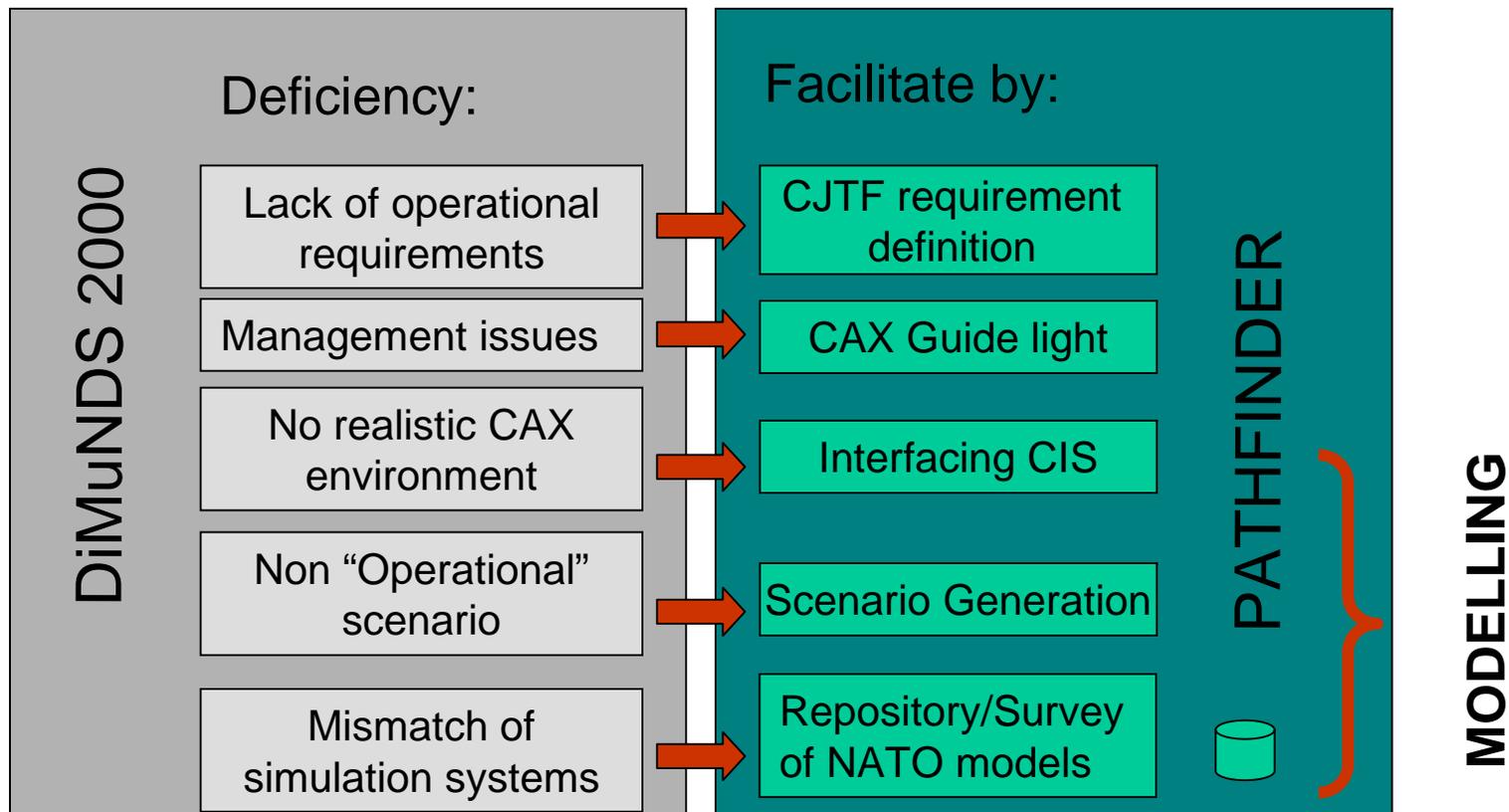


Problem Spaces



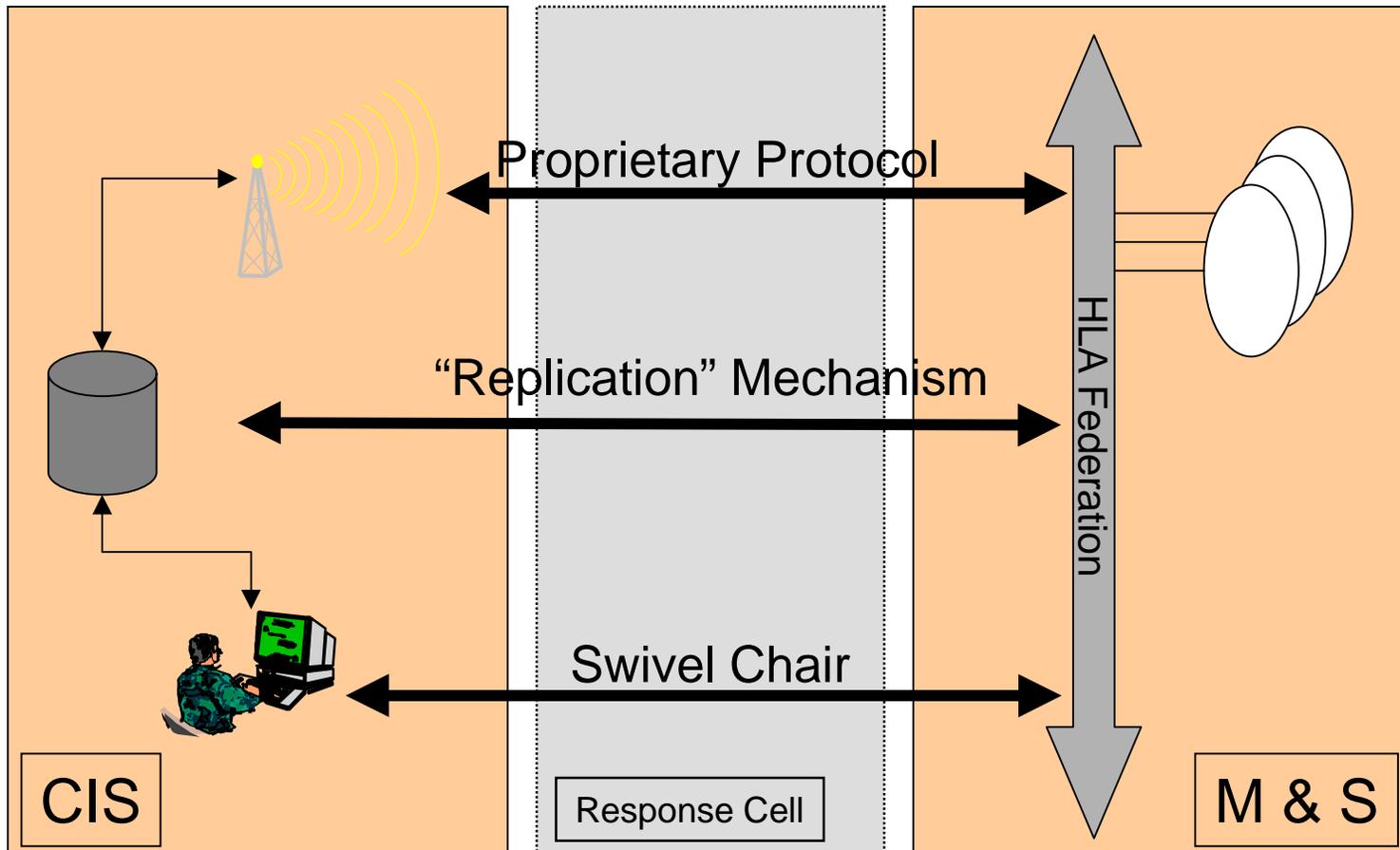


Observations from DiMuNDS 2000



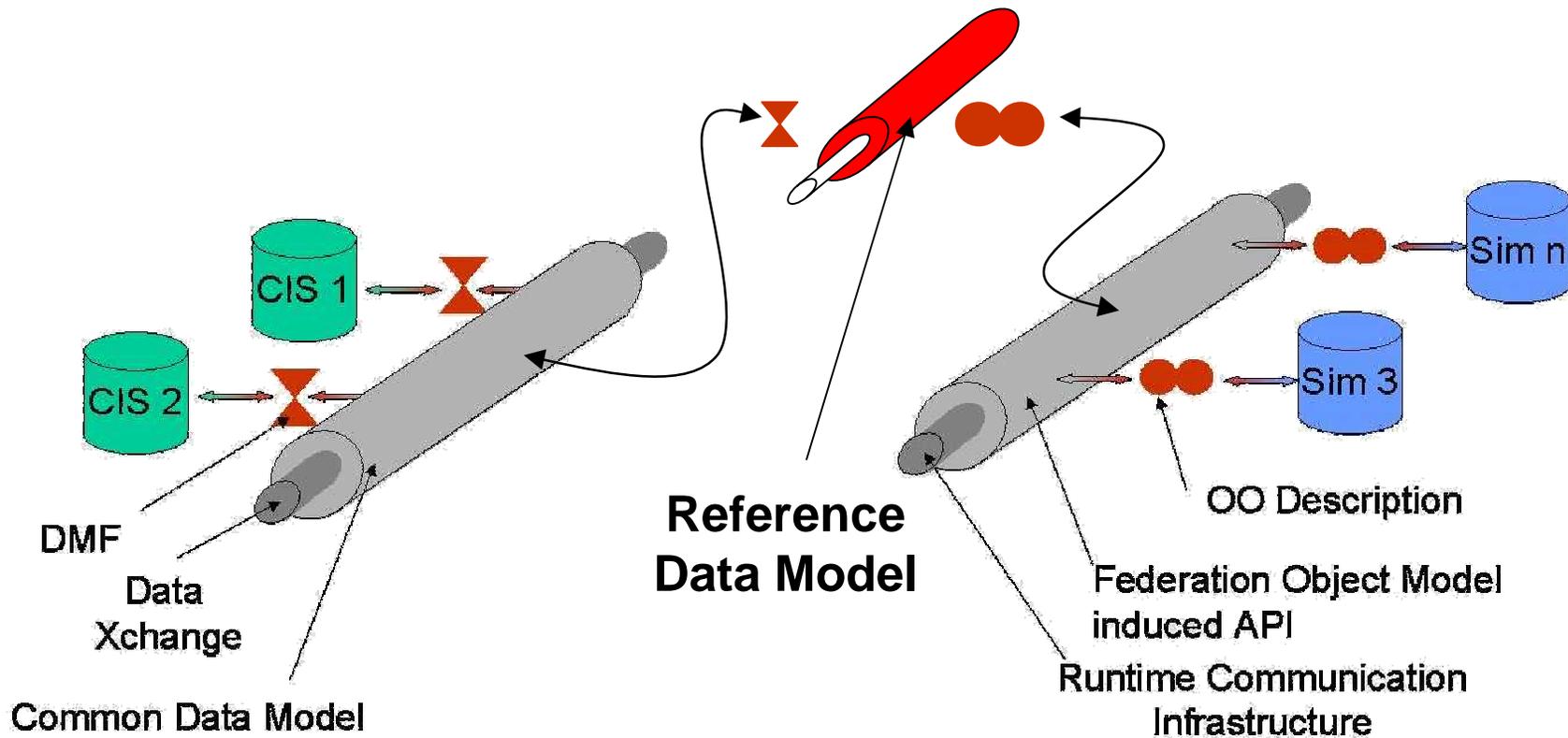


CIS to M&S Coupling





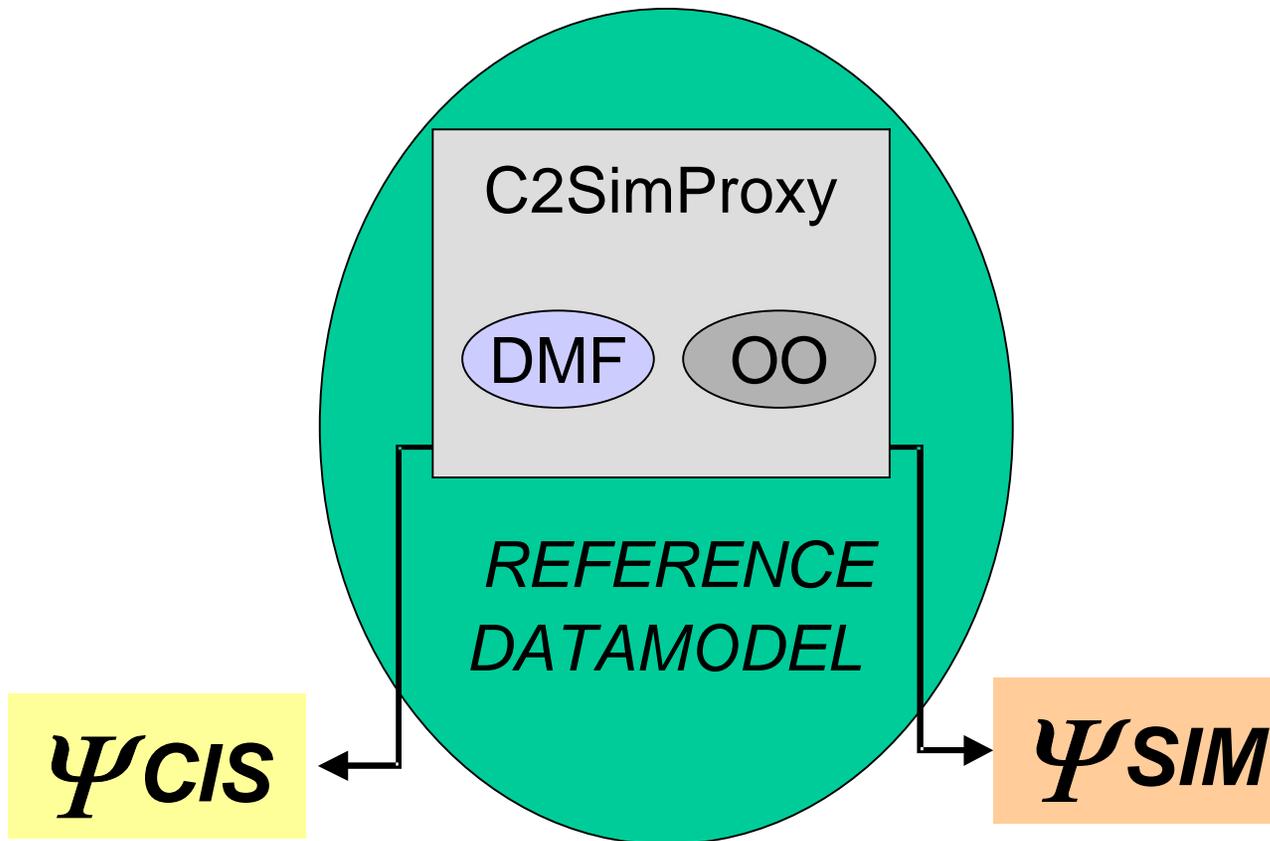
“Loose” Coupling



$$\Psi_{CIS} = \bigcirc \Psi_{SIM}$$

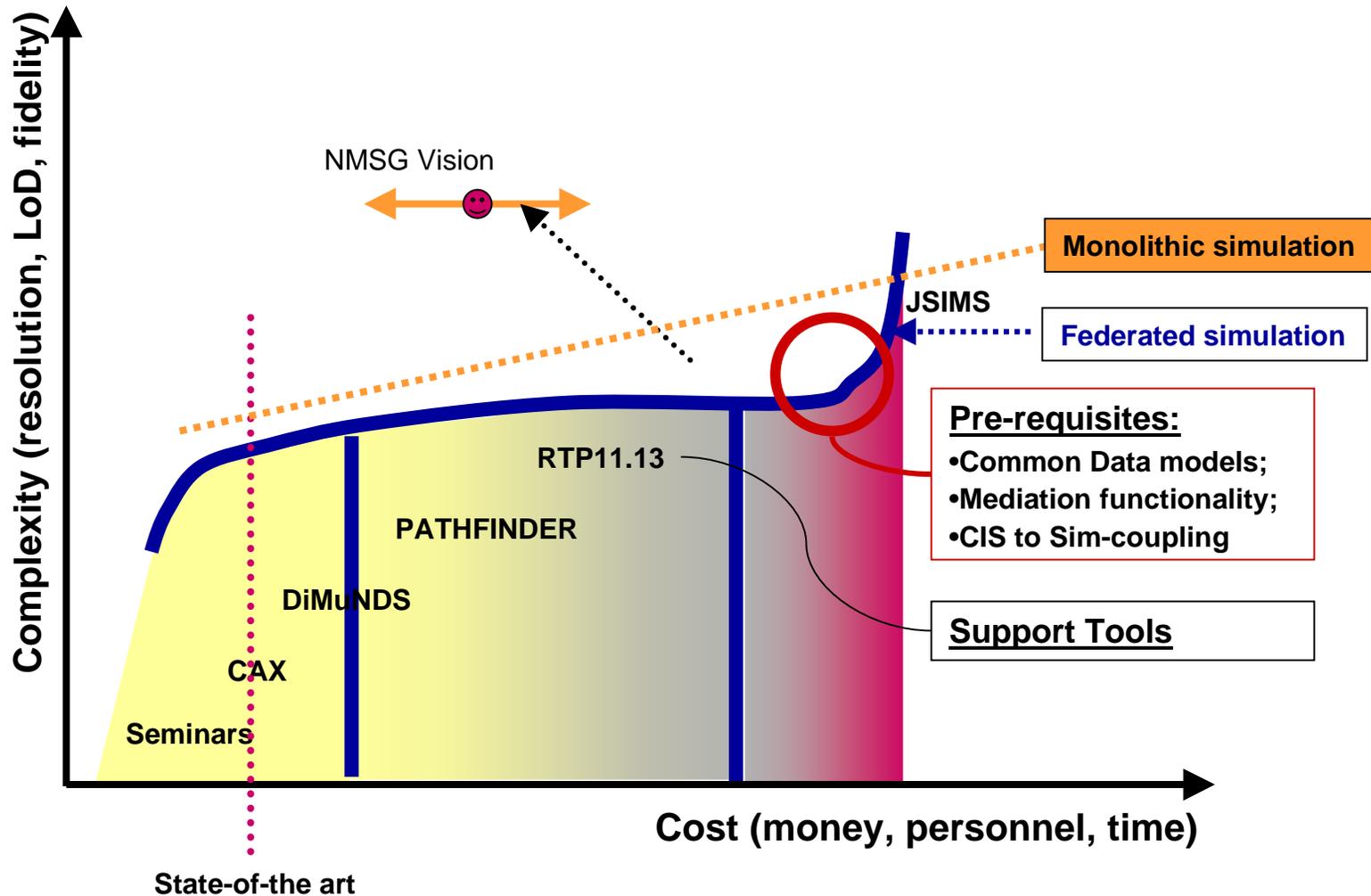


C2Sim-Proxy



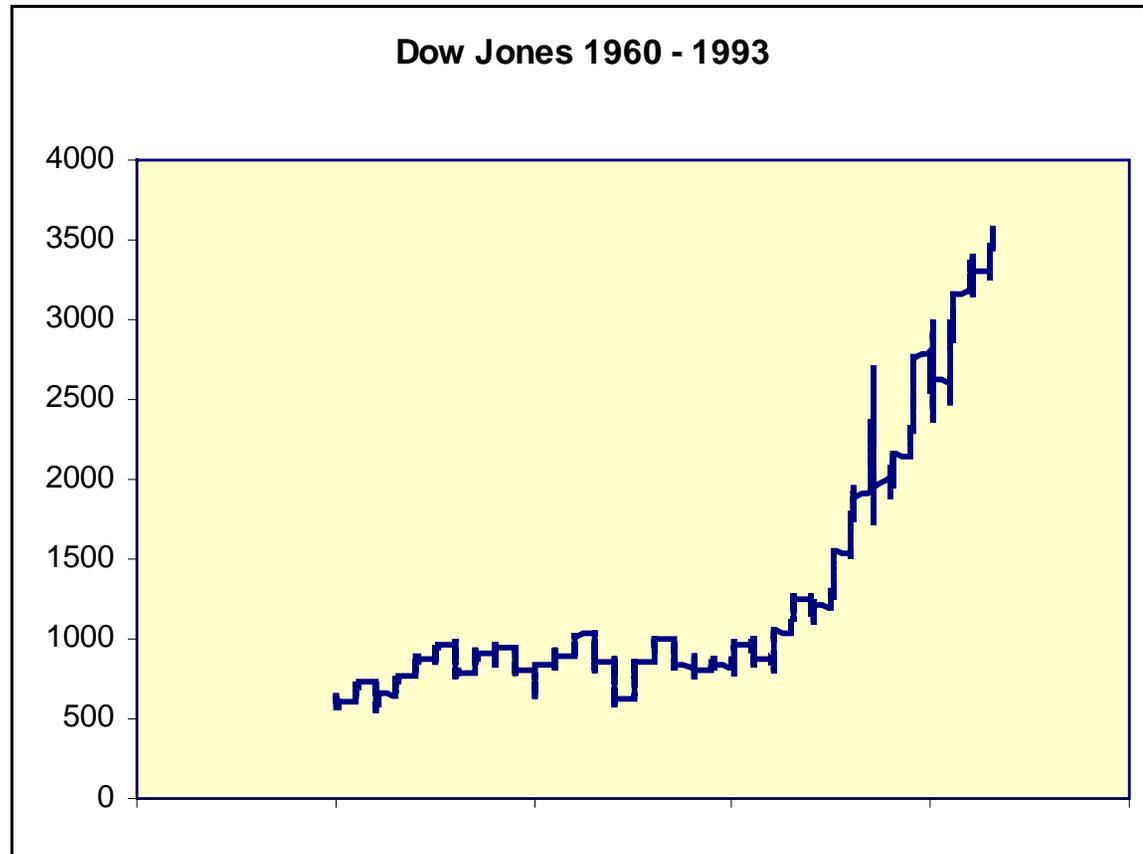


The “Pi”-regime in CAX development



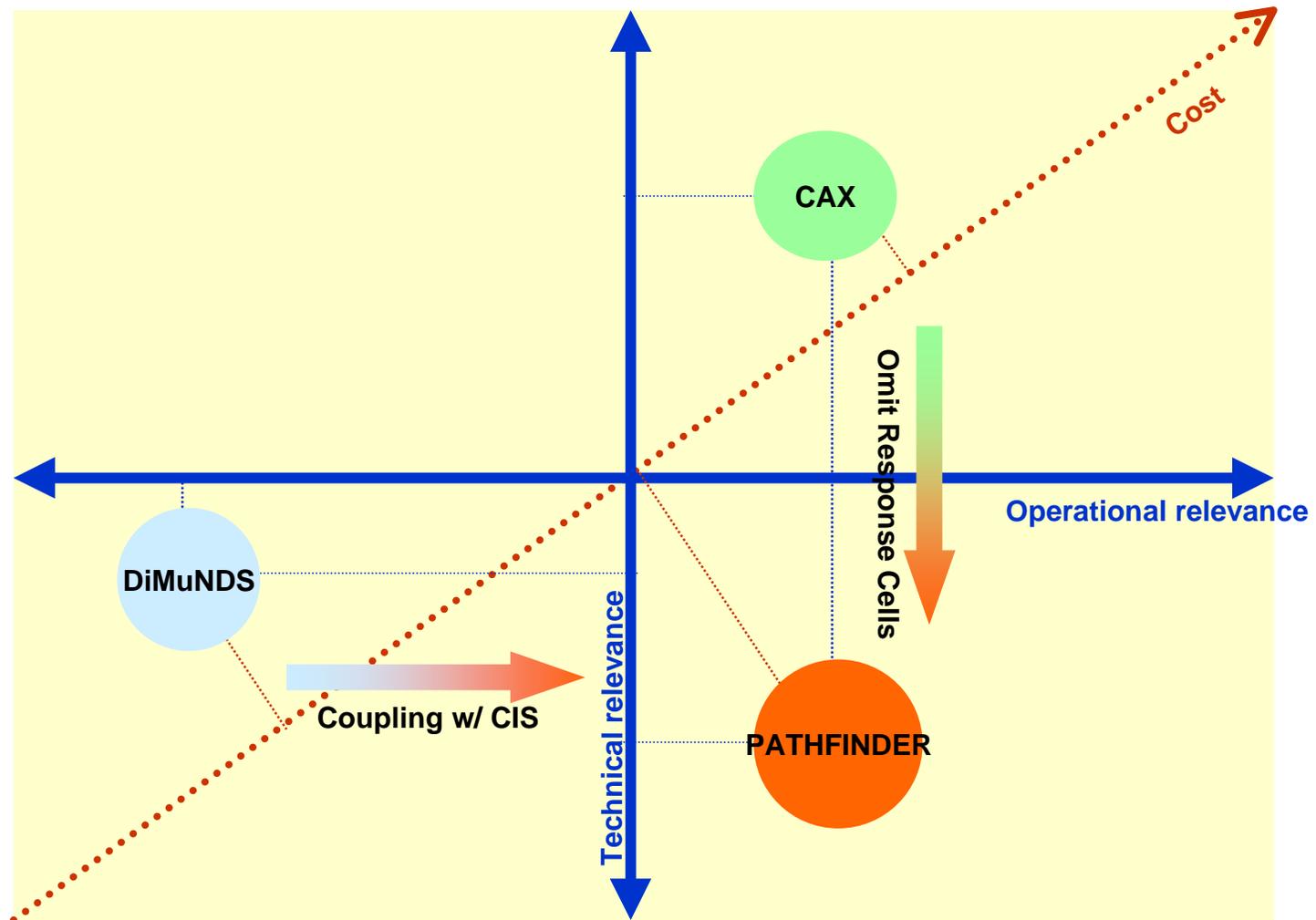


Another “Pi-Regime”





Cost-Effectiveness





Establish technical infrastructure as outlined in this report;

Analyse technical pre-requisites of scenario generation for simulation system under consideration for PATHFINDER.

Analyse data models and interfaces of NATO CIS.

Extended analysis of NATO CIS and simulation system in terms of data models and interfaces.

Conduct capability demonstration of SIMULTAAN, PSI-SA etc. and explore conditions for use (e.g. licensing, voluntary contribution, etc.

Exploit synergies w/ other NATO or WEAG programs: e.g. JWID, RTP 11.13

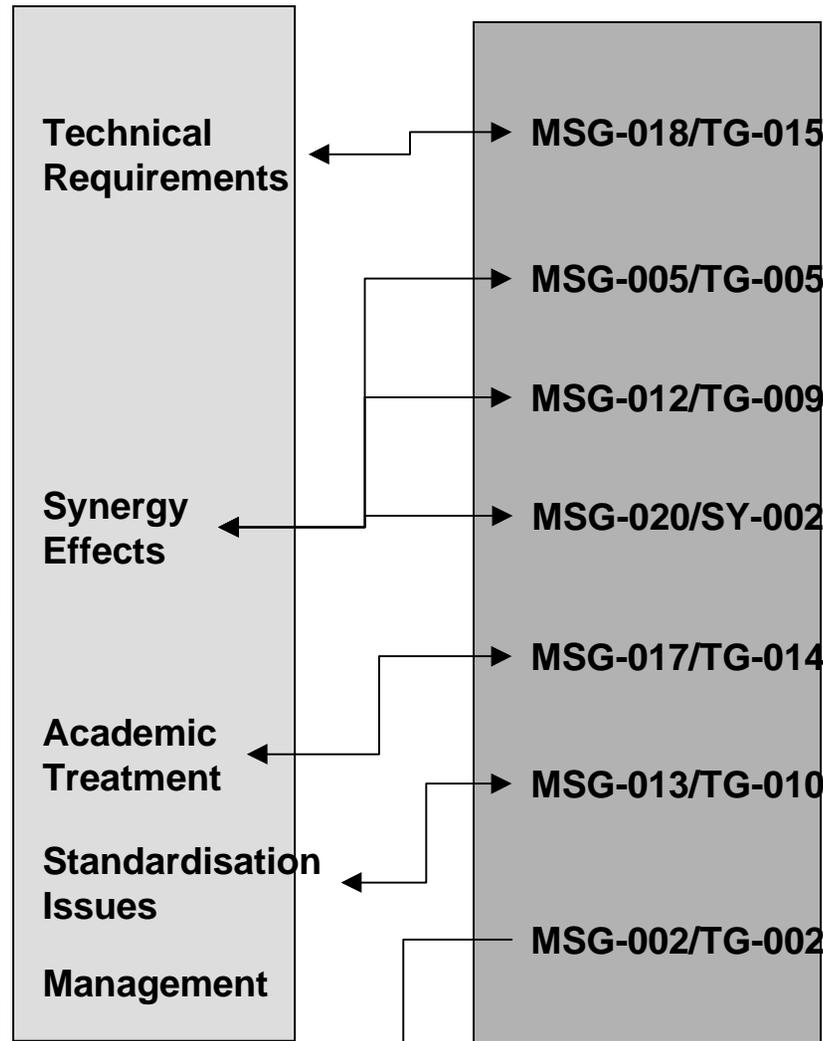
Establish common and thorough understanding of Modelling.

Foster standardisation of data models (→ e.g. ATCCIS);

Establish/foster NATO representative to OMG

Establish a PATHFINDER programme office

Re-Focusing NMSG TAPs



Rapid Generation of Scenarios and Databases for CAX and Operational support

FEDEP support tools for PATHFINDER

Simulation Resource Library

Interop. of Models and simulation in NATO

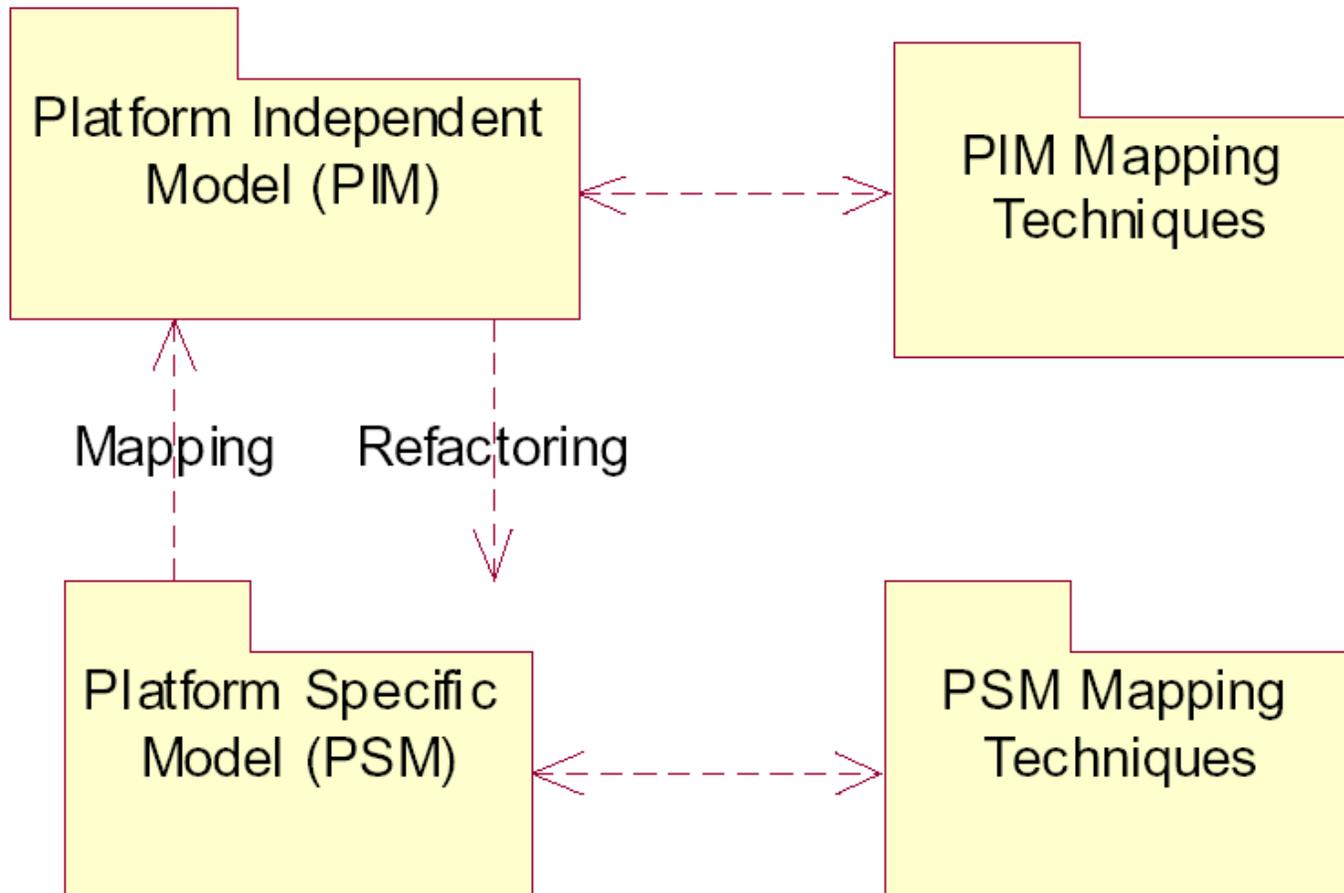
Modelling and Simulation Course

Standards Development

M&S Support from PATHFINDER Programmes



The Model Driven Architecture





Recommendations

The overall recommendation is to establish a dedicated group devoted to the issue of interconnecting CIS and simulation systems, this is to be complemented by the following activities:

Short-term:

1. Re-focus existing MSG TAPs to identified problem spaces, where appropriate;
2. Establish virtual PATHFINDER project office;
3. Launch academic approach to M & S;

Mid-term:

4. Analyse capabilities of existing national simulation **frameworks**;
5. Participate in international, non-military standardisation activities, i.e. NATO to join OMG;
6. Analyse **data models, standards and architectures** as appropriate;

Long-term:

7. Establish **technical infrastructure** to interconnect CIS and simulation systems.