Non-Hierarchical Approach to Couple CCIS with M&S

Dr. H.-P. Menzler and M. Sieber
Armed Forces Technical Center for
Communications and Electronics
Kalvarienberg, D-91171 Greding
GERMANY

Email: {hpmenzler, michaelsieber}@bwb.org

ABSTRACT

The use of the term interoperability in certain areas of information technology is also predominant in the military community when talking about multinational Command and Control Information System Environments (CCIS) and Modeling and Simulation (M&S). The Multilateral Interoperability Program (MIP) on the one hand and the Simulation Interoperability Standards Organization (SISO) on the other hand prevail among others.

Either community typically has different meaning of the term interoperability and they run dangerous of getting separated whereas unification is even more desirable. Instead of a bottom-up approach ("interoperability by means of technology") a top-down view may help to better understand the real system, which is the one military combat space.

Information flow initially drives the system, hence the system becomes the response function which to some extent generates additional information flow. This generic interpretation of the system gives reason for a non-hierarchical alignment of CCIS and M&S taking into account their domain specific interoperability technologies, like e.g. MIP or HLA.

The GE and US Simulation and CCIS Connectivity Experiment (SINCE) is to become a proof of concept project in a sense of loose coupling CCIS and M&S environments. The paper describes the top-down approach in correspondence to the SINCE four phase experimentation program. The GE technical architecture is outlined in detail.

INTRODUCTION

The term interoperability is commonly being used in different areas of military information technology. Superficially spoken, it refers to the low level capability of different information systems to exchange information content among each other. The IEEE Glossary [01] gives us a quite short definition of Interoperability:

> *The ability of two or more systems or components to exchange information and to use the information that has been exchanged.*

This indicates one should expect that the systems communicate information contents reasonably based on sensible requirements rather than only handling bits and bytes. Such a sensible requirement is to cooperatively link different Command and Control Information Systems (C2IS) becoming more and more important by the implications of the multinational Warfighter.

Paper presented at the RTO NMSG Conference on "NATO-PfP/Industry/National Modelling and Simulation Partnerships", held in Paris, France, 24-25 October 2002, and published in RTO-MP-094.

Report Documentation Page

Form Approved
OMB No. 0704-0188

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
00 NOV 2003	**N/A**	**-**

4. TITLE AND SUBTITLE	
Non-Hierarchical Approach to Couple CCIS with M&S	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Armed Forces Technical Center for Communications and Electronics Kalvarienberg, D-91171 Greding GERMANY**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM001655., The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**UU**	**20**	

Adequate support of the Command and Control process includes the use of military operations research and analysis and other areas of military simulation of an anticipated synthetic threat environment[1]. Instantly, three different instances of interoperability occur within one single cooperative environment:

- C2IS Interoperability
- Simulation System Interoperability
- C2IS / Simulation Interoperability

These become the essential pillars in interoperability technology as needed in military decision making processes, training and exercise, mission rehearsal and last but not least, simulation based acquisition (SBA). And, as elaborated in the following chapters, this also implies that the mission space concept is the most essential prerequisite at the bottom line. The U.S. formerly have called it the Conceptual Model of Mission Space (CMMS), an underlying conceptual view on the military operations and objects in space and time.

The CMMS idea claims a top-down approach in contrast to the bottom-up trial of practicing interoperability by means of technology (data structures, networks and protocols). The US-GE SINCE[2] program is to establish a new way for doing collaborative planning and mission rehearsal serving the new challenges of multinational military operations [07]. The SINCE environment aims to leverage from off-the-shelf technologies, e.g. NATO STANAGs in the area of interoperable M&S and C2IS.

ASPECTS FROM SYSTEM THEORY

From a simulation point of view the combat space evolves with time t as a system of mutually interacting components, or let's say objects. The entire system's state at a time t is well defined in accordance with each single object's state at time t, where the state of a single object may be defined by the values of its attributes at time t.

A question arises what drives the system initially over time. A tank engine for example, which enables the tank to alter its location, appears to be an indirect driver mechanism unlike the initial decision to force the tank commander to start his engine to move the vehicle. In other words, information content and its flow initially drives the system. Dynamics originate from information flow in combat. From this observation it becomes clear that neither simulation nor information systems exist as independent autonomous subsystems but only sustain in coexistence.

A system theoretical approach based on abstract mathematics could be very helpful to better understand the behavior of a system. But analysis still lacks from a fundamental statistical baseline as a foundation for what physics call invariants (like energy) and generalized system co-ordinates (like location and momentum).

Momentarily, for the sake of simplicity, we seek for a coupled environment which enables us to reflect the stimulus from the C2IS in the simulated (virtual) world and to feedback from there the combat status at a later time-point [5]. This is to control cause and action, i.e. information flow and simulated combat, to better support training and education (CAX), collaborative planning and decision making close to reality.

[1] Remember STRICOM's slogan *All But War Is Simulation.*

[2] Simulation and C2IS Connectivity Experiment.

STANDARD TECHNOLOGIES

In 1996 the U.S. DoD Modeling and Simulation Office (DMSO) has outlined the High Level Architecture (HLA) as a future standard for distributed simulation [02] thus continuing IEEE 1278 (DIS) and the national Aggregate Level Simulation Protocol (ALSP) efforts. The HLA comprises communication services as a baseline for any sustainable simulation application, either legacy or new, to interact with any other simulation application (the so called federates).

The HLA does not incorporate any specific data model but specifies a template form (OMT for Object Model Template) to allow for implementing various data models as needed (so called Simulation/ Federation Object Models SOM/ FOM). As a matter of fact, the OMT requires only the naming of distributed objects and their attributes including publication and subscription properties but not their meaning. However, HLA fully captures know-how and expertise from DIS and ALSP and combines publication of objects with time-managed behavior of their states and interactions. HLA is not a starting point for a CMMS but a kind of smallest denominator to transport the corresponding information contents down to the OMT level.

In April 1998 the Multilateral Interoperability Program (MIP) started with the aim to achieve international interoperability of C2IS at command levels in order to support combined and joint operations, and to benefit from the progress of digitization of the battlefield in the international arena, including NATO.

In 2001 MIP succeeded in two Phases: Phase 1 to achieve interoperability by a Message Exchange Mechanism (MEM) and Phase 2 using a Data Exchange Mechanism (DEM). Both Phases have joined in 2002 based on the common Land C2 Information Exchange Data Model as the so called MIP Common Data Model (MCDM).

To date, MIP has not had any interrelation with distributed simulation technology although several programs demand from simulation to cope with C2IS as the aforementioned SINCE does.

Consequently, two independent architectural approaches for interoperable system design do exist in parallel and the SINCE program is an example for emphasizing the overlapping aspects in a heterogeneous confederation of operational and simulated components.

NON-HIERARCHICAL COUPLING

There is no doubt that analytical solutions are best suited for better understanding a system’s behavior. Simulation technology seems to be the most promising tool to cope with complex system behavior, provided that there exists an accepted sophisticated model behind. However, we must notice that the IT community is manifold and tends to increase diversification according to a lot of different requirements in the user community. Consequently, HLA, CMMS and the MIP were launched separately and independent from each other. Although an abstract higher level approach is still missing, a starting point for an analytical effort to balance information flow and combat dynamics would benefit from a conceptual model of mission space being independent of any specific M&S and C2IS representational aspects. This is analogous to a point in space which is relative with reference to a co-ordinate system but absolute in accordance with an object located at this point.

This features the importance of an absolutely defined military mission space and – speaking IT – a corresponding structured data model with the ability to cover both military information flow and combat dynamics with time. Taking into account the above mentioned diversification in IT, overlapping system aspects for a coupled solution (C2IS vs. SimSys) have to be identified carefully in order to merge the simulation’s world with the C2IS world properly and to avoid unexpected intrusive alterations in each system’s interoperability arena.

It seems to be common sense to keep the worlds – M&S and C2IS – loosely coupled if possible. We would call this the *non-hierarchical coupling concept* when based on an independent model to avoid any influence on the interoperability concepts in each respective area. In correspondence to the former mentioned system theory approach a CMMS is to be the generalized co-ordinate system while each specific application area uses its own canonical reference model, best suited for C2IS and M&S purposes, respectively. In fact, the IT community sometimes uses the term *Data Interchange Format (DIF)* which denotes the ability to move from one specific representation to another by intersecting a common reference point (here the DIF) instead of applying proprietary point-to-point transformations. Mathematics calls this *transitivity*: If A relates to C and C relates to B, then A relates to B. Thus, the DIF (the C) makes it possible to size a cardinality of n^2 relationships down to n.

Apparently, the notion of the DIF itself is a problem of international negotiation because of its multinational, joint and combined nature.

From hereon we conceive the existence of such a conceptual reference model (CRM) hypothetically, and furthermore, we assume to have a corresponding object-oriented CRM at hand, so to say a structured implementation, a data model. This can be abstract for almost all aspects of dynamics, but nonetheless, it has to span the military combat space by means of its object definitions; each object definition, or class, denotes a co-ordinate in a multi-dimensional space, filled by an infinite number of the system's states.

Now, the CRM serves as a unique root for any further instance of any other object model with the help of inheritance and dynamics implementation.

E.g., a HLA-federation based on a specific FOM would then have to be derived from the CRM:

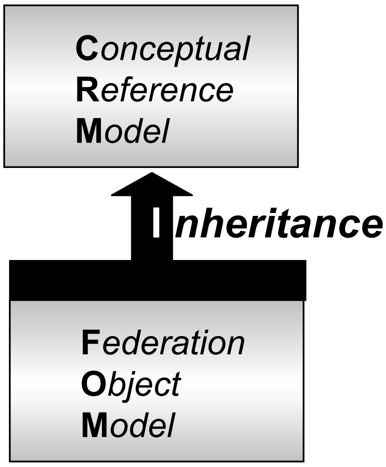


Figure 1: Canonical Data Models (here a FOM) Gained by Inheritance from the CRM.

Each object model derived from the CRM is a specific representation of a specific part of what the CRM represents conceptually. E.g., a simulation federation which deals with battalions and platoons may not address the higher resolution aspects like weapon platforms. In other words, this would be an aggregated view on the CRM's high resolution entities, thus the derived data model typically inherits only fewer parts of the CRM.

With respect to our situation of coupling the C2IS and the simulation space, by theory we have to consider two derivations, either a FOM-like and a MIP-like data model being involved:

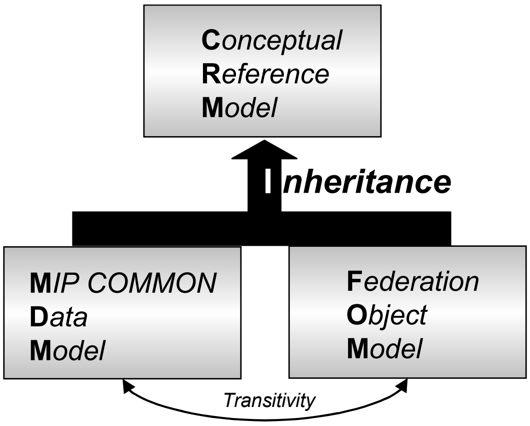


Figure 2: Two Canonical Representations and Concurrent Implementations Based on One CRM.

From the former transitivity argument we conclude that by construction and requirement this ensures a proper relationship between the data model instances underneath the CRM.

IMPLEMENTATION ISSUES

The last figure sketches an approach for a software architecture to couple the spaces under consideration:

The relevant software component is (a kind of) a gateway which mediates among different underlying transport mechanisms for each coupled space. More abstractly spoken, it is a projector mapping one representation of combat space into another and vice versa. We call the appropriate mechanism the *Command and Control to Simulation Proxy* (C2SIM-Proxy). The advantage of the C2SIM-Proxy is that it encapsulates and hides the placeholder for a yet non-existing CRM instance.

Furthermore, Figure 2 degenerates to Figure 1 when setting CRM=MCDM. This is the SINCE project's approach for its first phase. However, it is expected that the collaborative planning process as a central requirement of SINCE cannot be covered without extensions to the MCDM. Therefore, a second phase in SINCE requires iterative refinement of the CRM thus leading us to a more distinctive architecture to catch the situation of multinational planning environments:

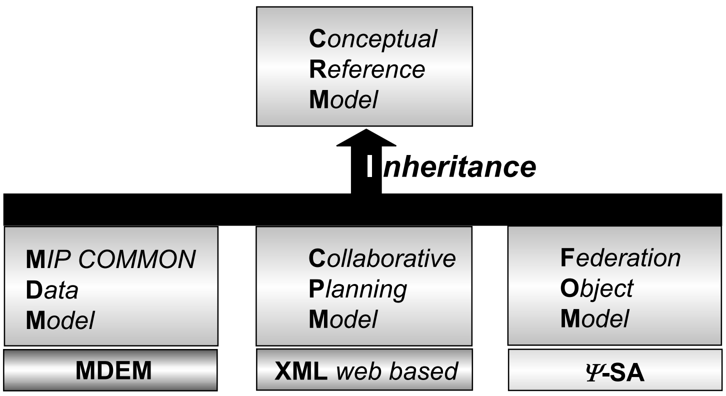


Figure 3: C2SIM-Proxy Architectural Design in Support of Collaborative Planning Beyond the MIP.

Each single bottom layer denotes a domain-specific communication infrastructure for dedicated information transport:

1) Ψ-SA[3] is a specific German infrastructure technology to encapsulate the HLA OMT in an object oriented manner [3], thus in close neighborhood to any possible object-oriented CRM,
2) the MIP Data Exchange Mechanism (MDEM) is more or less the well known ATCCIS Replication Mechanism (ARM) to synchronize the various C2IS components [4],
3) the SINCE Technical Working Group recently has decided for a XML based exchange of relevant planning data.

According to figure 3 the C2SIM-Proxy consists of three data models each of which represents the corresponding view with respect to each military activity branch. The CRM on top serves as the common root for the C2SIM-Proxy to mediate between those operational data models in support of synchronizing the specific activity branches from C2IS (statics) over collaborative planning (dynamic profile) to simulation (combat dynamics).

The software development process starts with a use-case analysis to identify the different space representations in terms of objects and interactions of mutual interest.

FINAL CONCLUSIONS

The international efforts on interoperable C2IS environments recently resolved in a MIP Common Data Model (MCDM) which helps to follow the path towards a conceptual reference model (CRM) of mission space to be applied for various application areas such as the collaborative planning and decision making process supported by M&S. However, the technical standards in either arena, HLA and MIP, are not based upon modern object oriented approaches to capture the dynamics of the entire system evolving with time. A corresponding CRM plays this central role within a C2SIM-Proxy and paves the way to reasonably couple the disparate representations of the one same combat space.

The C2SIM-Proxy leverages from the recent evolutionary results in the MIP and the M&S communities, and establishes a mechanism to link those representations in a non-intrusive way. SINCE is currently topping this sequel of developments, jointly utilizing each participant's resources and available results of former activities. For Germany the major thrust will be in the practical design and testing of the proxy functionality in a collaborative environment [06]. Beyond that, the basic functionality of the C2SIM-Proxy will also be incorporated in current and future projects in the area of Simulation Based Acquisition as well as Integrated Test and Evaluation, creating a comprehensive Synthetic Environment which is to be expanded beyond national borders by the concepts on so-called Virtual Proving Grounds.

This implies that these efforts continue to be of international relevance. After Experiment 1 of the SINCE project, the results will be leveraged to the NMSG[4] with the option of other nations joining the follow-on experiments by adopting the concept.

REFERENCES

[1] Institute of Electrical and Electronics Engineers. *IEEE Standard Computer Dictionary: A Compilation of IEEE Standard Computer Glossaries*. New York, NY: 1990.

[3] The Greek symbol Ψ points out emphasis on the system's state.

[4] NATO M&S Group.

[2] HLA became IEEE 1516 in 1999. For reference see www.dmso.mil.

[3] H.-P. Menzler: The Ψ-SA Technology in U.S. Simulation Interoperability Workshops, Proceedings 00S-SIW-026, 2000, and 01S-SIW-042, 2001.

[4] NATO Level 4 Interoperability STANAG 5500, within NATO Landgroup 1.

[5] M. Sieber and H.-P. Menzler, Non-Hierarchical Approach to Couple C2IS with M&S, in NATO RCMCIS Conference Proceedings 2002.

[6] Menzler et al.: Command and Control to Simulation Proxy Solution (C2SIM-Proxy) – Loose Coupling of Disparate Worlds, *European SIW, paper 01E-SIW-062, London 2001*.

[7] D. Klose, S. Seth and A. Rodriguez: SINCE – A New Way of Doing Business, NMSG Conference on *Future M&S Challenges – Netherlands – Nov 2001*.

AUTHOR'S BIOGRAPHY

Dr. rer. nat. Hans-Peter Menzler studied physics at the University of Osnabrueck, Germany, and earned his PhD in applied mathematical physics in 1989. He worked for three years as a scientist at the Max-Planck Institute for Plasma-Physics. In 1992 he became a system engineer and project manager at Competence Center Informatik GmbH (CCI) where he primarily focused on object oriented distributed simulation. In April 1999 he became head of the simulation infrastructure section at WTD 81, Greding, where he developed his concept and implementation of Ψ-SA and recently launched the C2SIM-Proxy concept.

Dipl. Ing. Michael Sieber studied Electrical Engineering at the Armed Forces University in Munich and earned his Masters Degree in 1981. After his military career in various technical and staff domains he joined the WTD 81, where he was responsible for research programs in communications including the German military satellite communications program. Other assignments were as a consultant to the OR division of the former SHAPE Technical Centre in The Hague and to the Directorate for Maritime Combat Systems at the Department for National Defence in Hull, Canada. Currently he heads the Information and Communication Systems Simulation Branch at WTD 81.

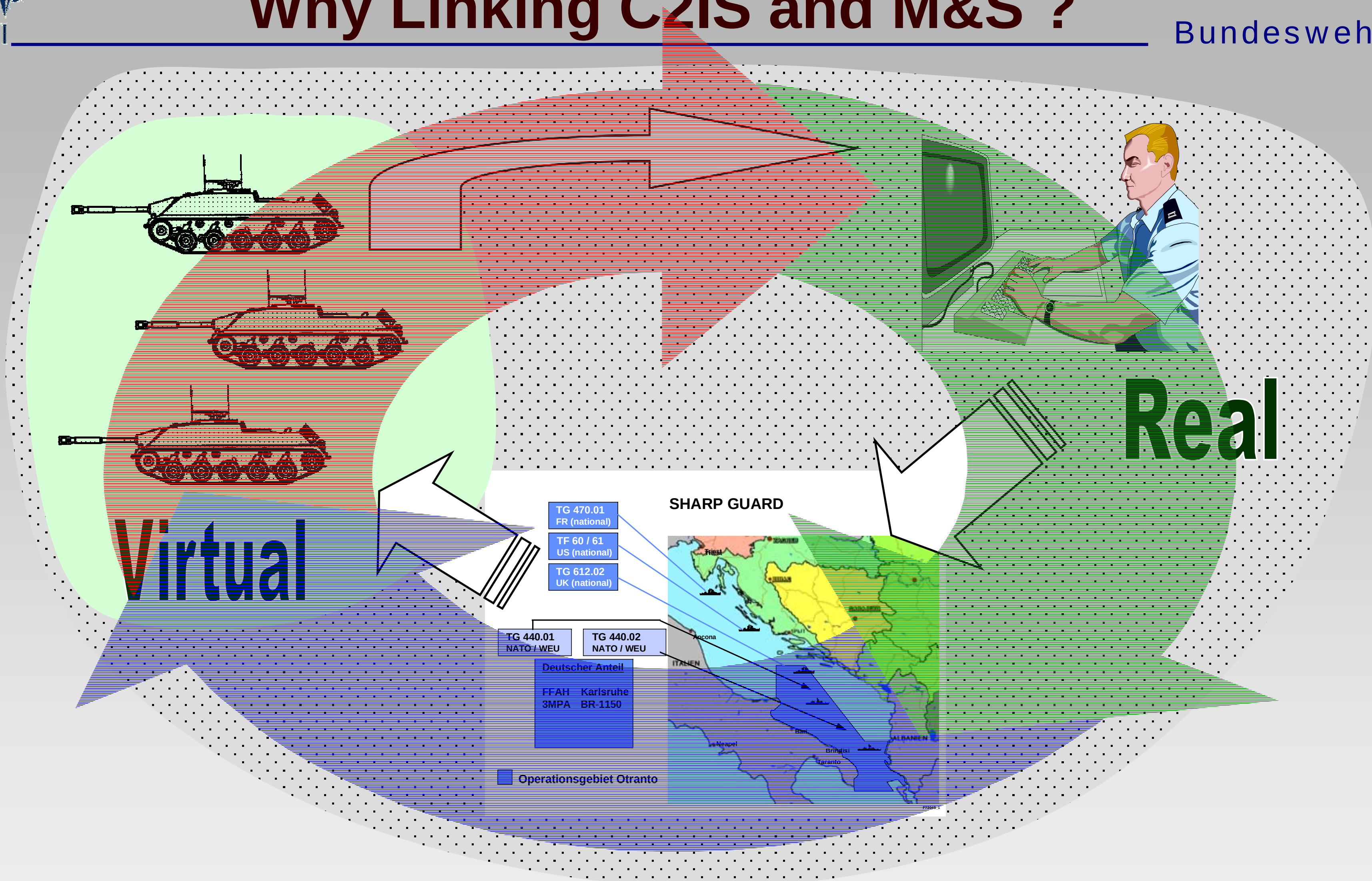
This page has been deliberately left blank

Page intentionnellement blanche

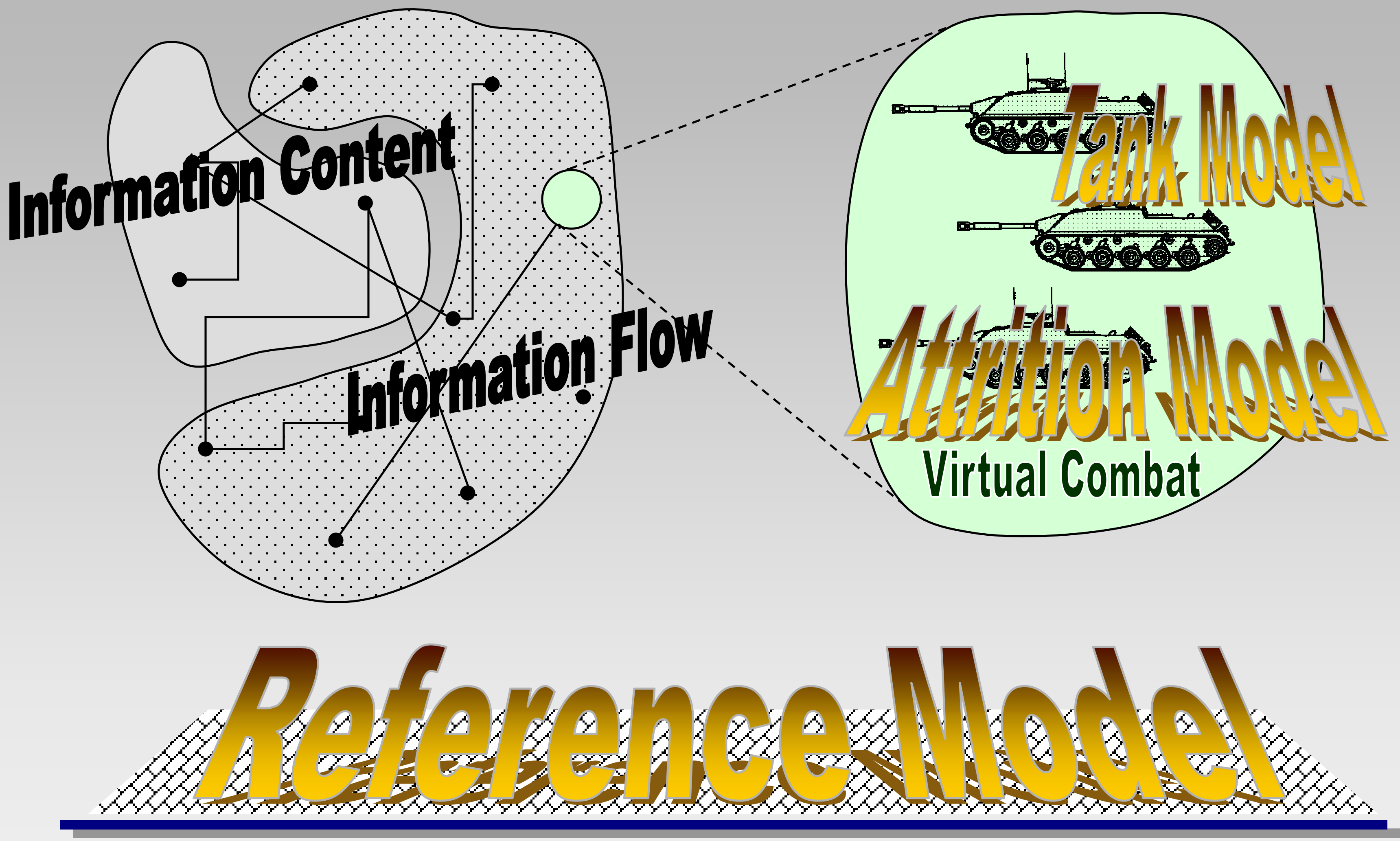
Non-Hierarchical Approach to Couple C2IS with M&S

Dipl. Phys. Dr. Hans-Peter Menzler
WTD 81-240

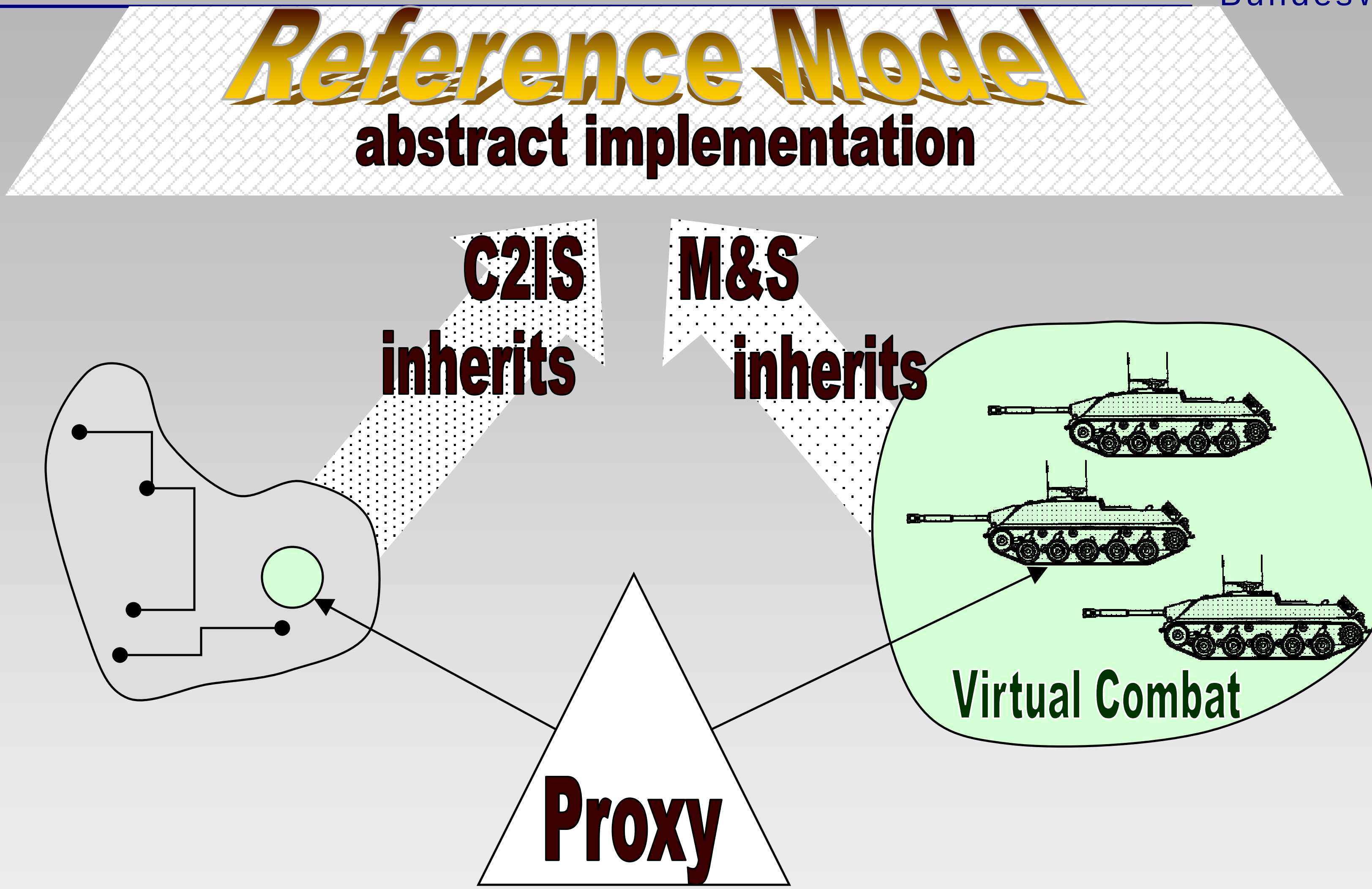
Why Linking C2IS and M&S ?



The Role of Modeling

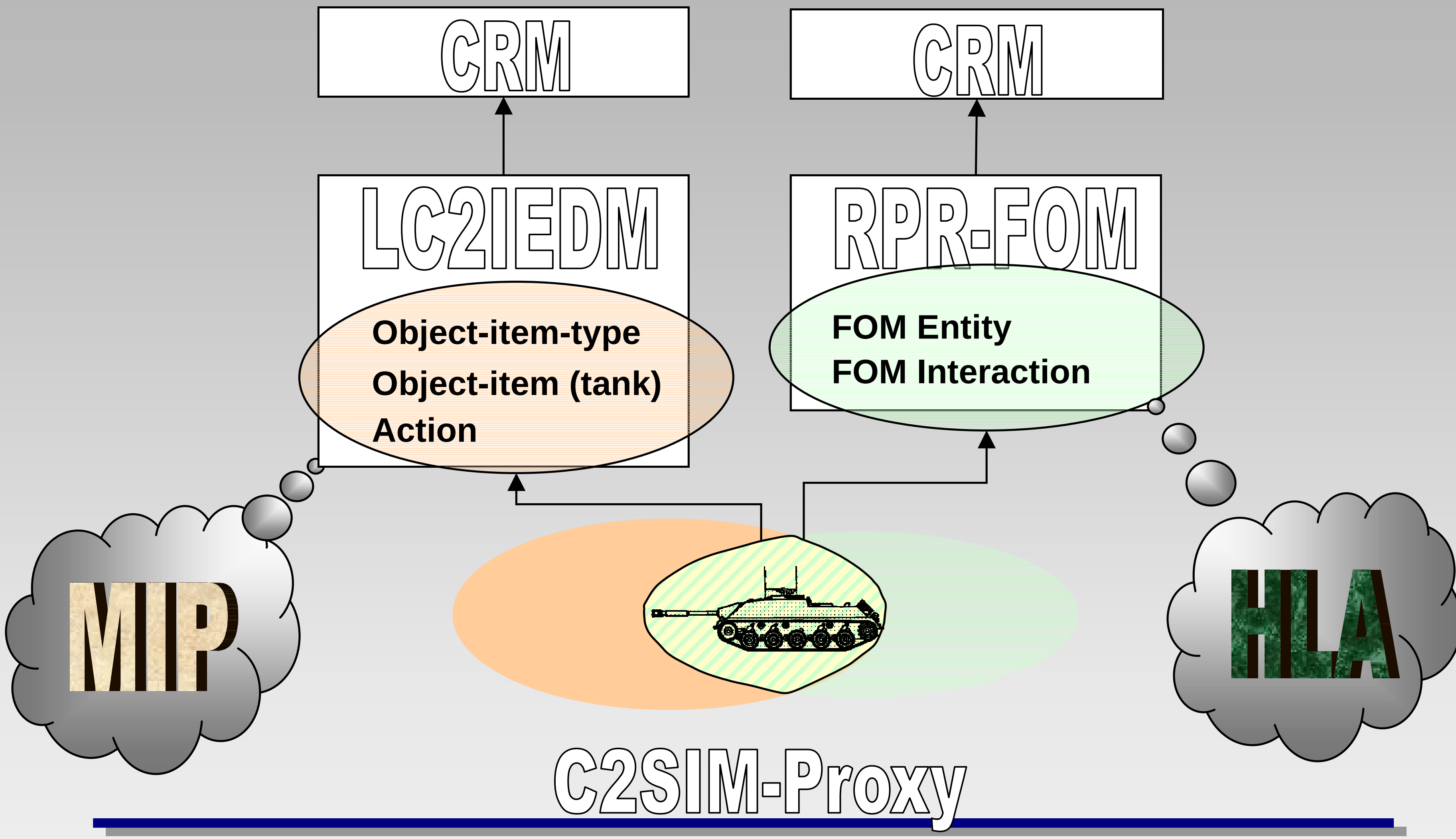


Modeling Technique

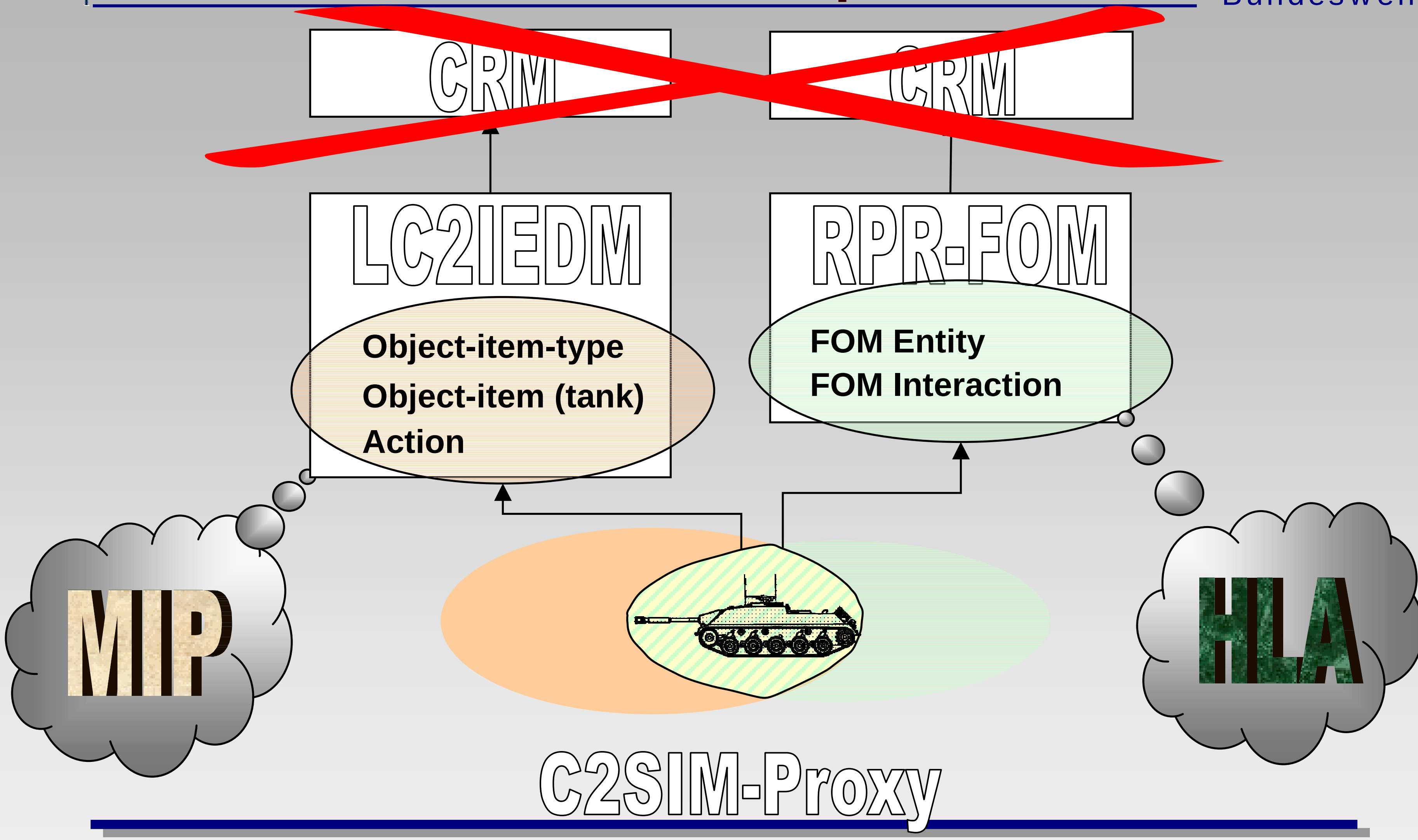


Bundeswehr

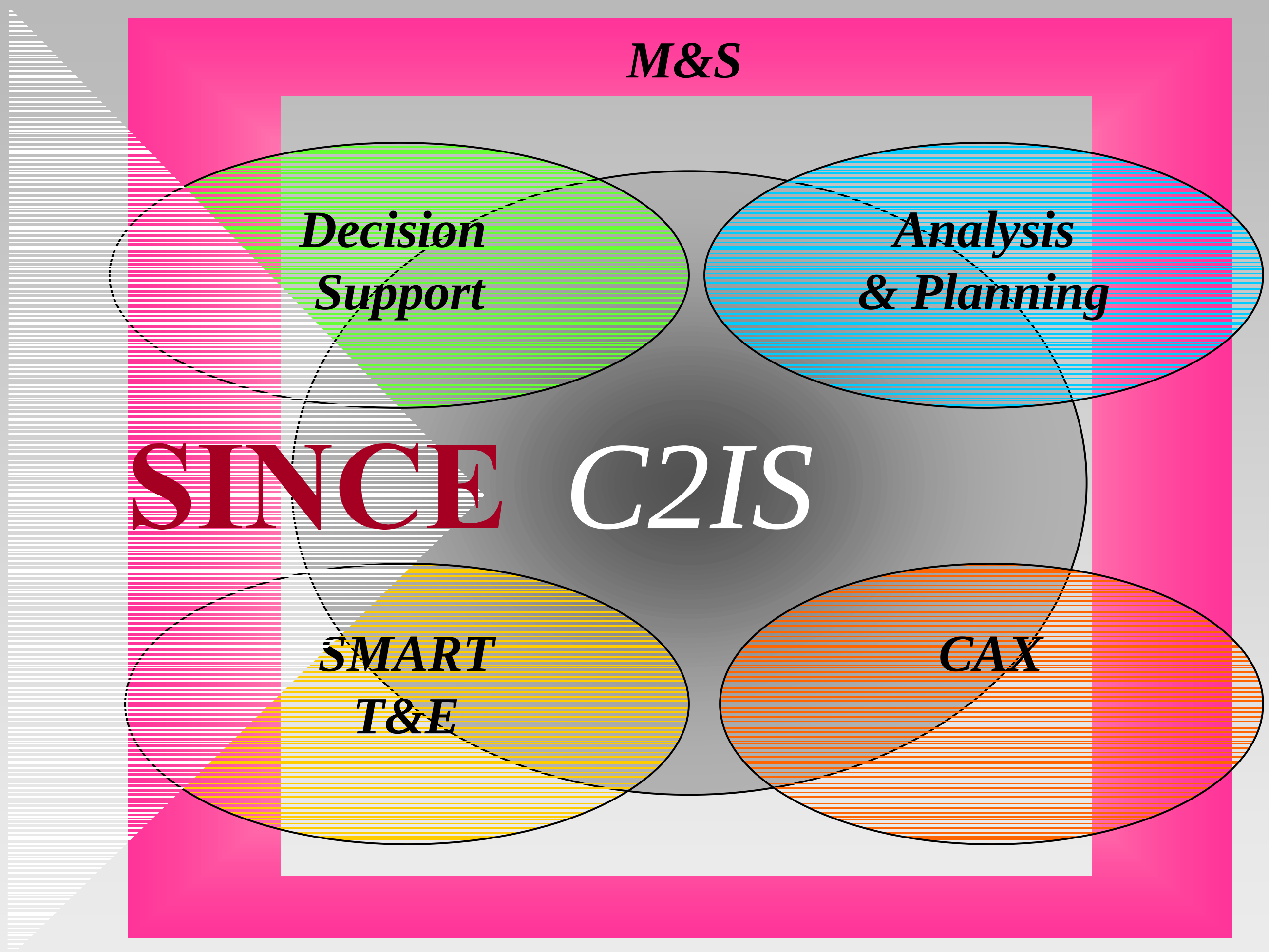
Implementing the C2SIM-Proxy



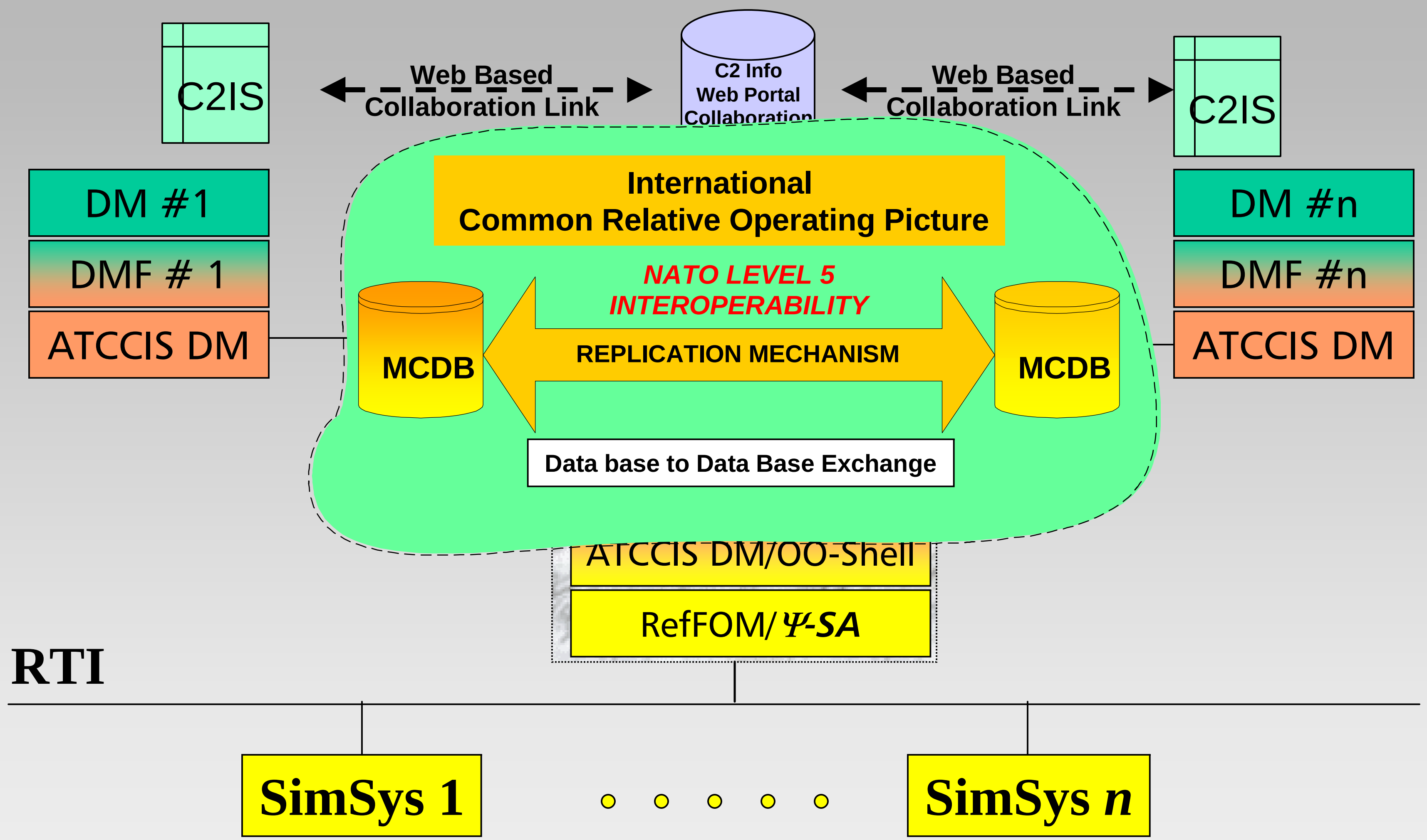
First Step


CRM
CRM
LC2IEDM
RPR-FOM
Object-item-type
Object-item (tank)
Action
FOM Entity
FOM Interaction
MIP
HLA
C2SIM-Proxy

The US-GE SINCE Project

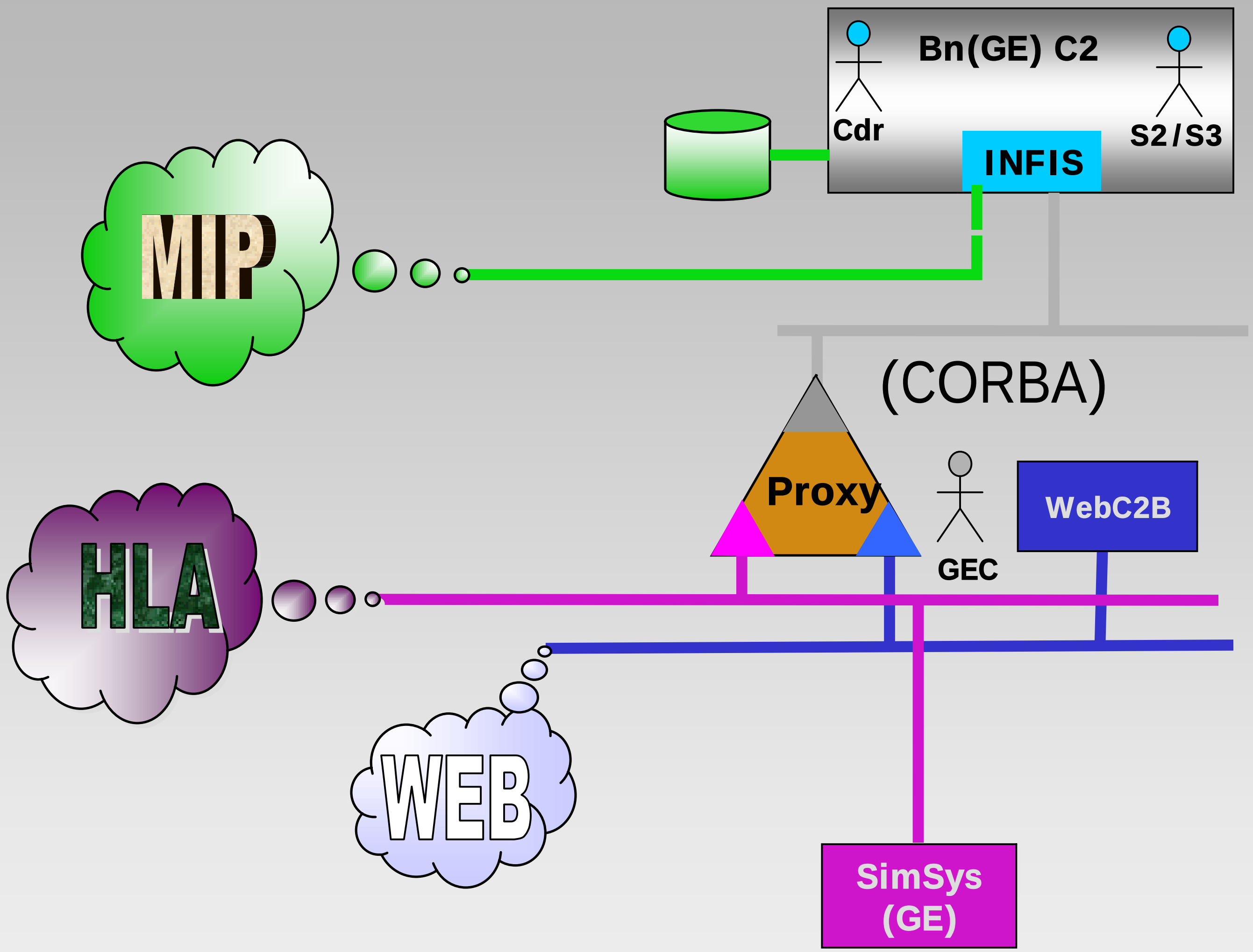


SINCE 1st Phase



GE Environment

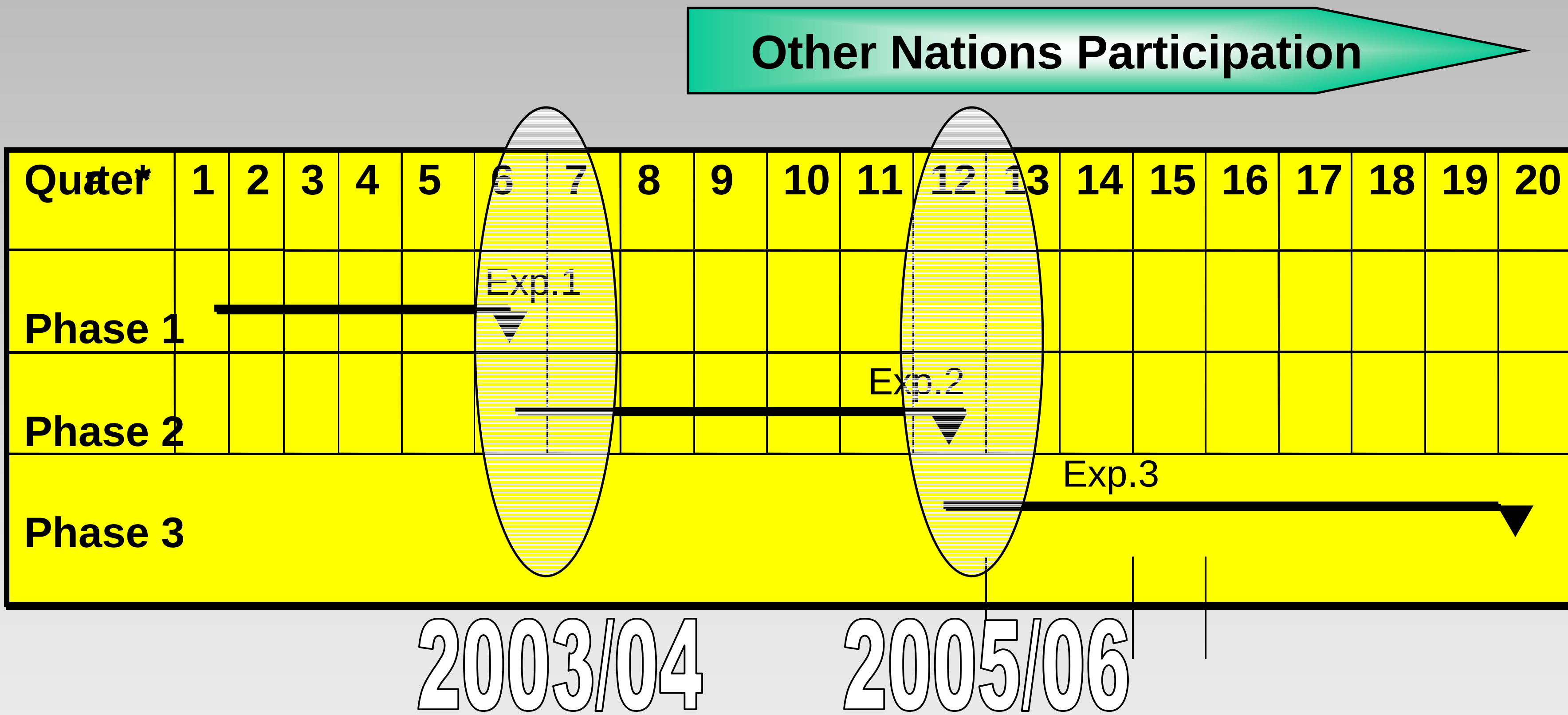
Bundeswehr



GE Infrastructure

- ☞ **MIP compliant C2IS INFIS**
- ☞ **Object Middleware Ψ-SA to Adopt HLA**
- ☞ **German RTI based on CORBA - GERTICO**
- ☞ **C2SIM-Proxy**

SINCE Perspective



Reference

- D.Klose, S.Seth and A.Rodriguez:
  SINCE – A New Way of Doing Business,
  NMSG Conference on
  Future M&S Challenges - *NL* - *Nov 2001*