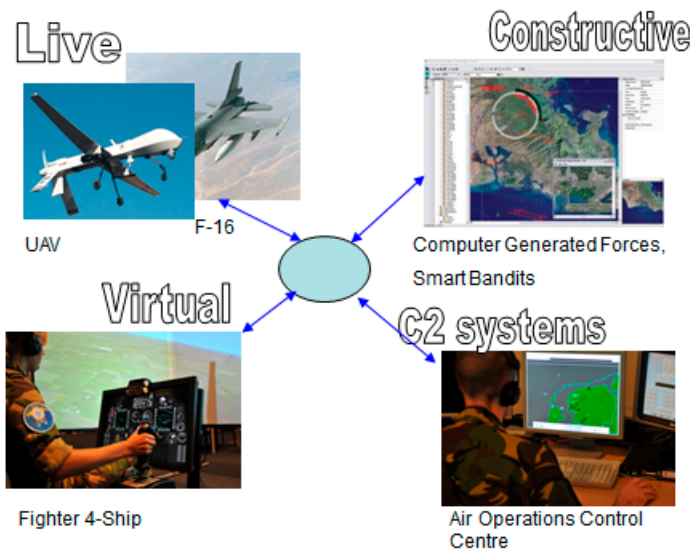




Executive summary

A Comprehensive Perspective on Training: Live, Virtual and Constructive



Problem area

There are growing limitations to live training and availability of training ranges for preparing war fighters for their missions. In recent years, simulation has proved its relevance for tactical training and preparation to large exercises. Initiatives for integration of live assets with virtual and/or constructive assets are growing using embedded simulation as well as via datalink. At the same time training methods are maturing to use the various training media more effectively.

Description of work

NLR has worked the past years in a number of Modeling & Simulation (M&S) activities and training research projects. These activities are leading towards a comprehensive perspective merging developments and experiences in technology and training approaches. The M&S activities include a number of technological innovations that provide the warfighter with unique solutions for operational mission training including for example electronic warfare or virtually inserted scarce military assets. Training research

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activities in The Netherlands have led to a pragmatic competency oriented, whole task training approach in which a set of scenarios or use cases guide the analysis and design phases. This approach ensures the most essential elements will be covered in an optimized training curriculum, using appropriate, economic training media.

Results and conclusions

Assuring good quality of LVC (Live Virtual Constructive) training in a dynamic environment is a challenge. The NLR research activities show an approach where

the LVC technological and the training perspective are matched and applied to new LVC events as a normative model. This model combines soft and hard LVC training services and service elements using the LCIM (Levels of Conceptual Interoperability Model).

Applicability

This paper illustrates how the technical and didactic approaches complement or strengthen each other, and where challenges are seen for further development and research.



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A Comprehensive Perspective on Training: Live, Virtual and Constructive

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Summary

In recent years, simulation has proved its relevance for tactical training and preparation to large exercises, while the limitations of live training and availability of training ranges have not improved. Initiatives for integration of live assets with virtual and/or constructive assets are growing using embedded simulation as well as via datalink. At the same time, training methods are maturing to use the various training media more effectively. This paper presents an overview of NLR's Modeling & Simulation (M&S) activities and training research programs, and works towards a comprehensive perspective merging developments and experiences in technology and training approaches. The M&S activities include a number of technological innovations that provide the warfighter with unique solutions for operational mission training including for example electronic warfare or virtually inserted scarce military assets. Training research activities in The Netherlands have led to a pragmatic competency oriented, whole task training approach in which a set of scenarios or use cases guide the analysis and design phases. This approach ensures the most essential elements will be covered in an optimized training curriculum, using appropriate, economic training media. This paper illustrates how the technical and didactic approaches complement or strengthen each other, and where challenges are seen for further development and research.



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Abbreviations

4C/ID	Four Component Instructional Design
CD&E	Concept Development & Experimentation
CMS	Collective Mission Simulation
CTIA	Common Training Instrumentation Architecture
DIS	Distributed Interactive Simulation
HLA	High Level Architecture
ECATS	Embedded Combat Aircraft Training System
F4S	Fighter 4-Ship
IEEE	Institute of Electrical and Electronics Engineers
IQT	Initial Qualification Training
ISD	Instructional Systems Design
JCOP	Joint Common Operational Picture
LCIM	Levels of Conceptual Interoperability Model
LVC	Live Virtual Constructive
LVCAR	Live Virtual Constructive Architecture Reference
MoD	Ministry of Defence
MQT	Mission Qualification Training
M&S	Modeling & Simulation
MTDS	Mission Training through Distributed Simulation
NLR	National Aerospace Laboratory
R&D	Research & Development
RNLAF	Royal Netherlands Air Force
ROE	Rules of Engagement
SAT	System Approach to Training
SOA	Service Oriented Architecture
SOD	Service Oriented Design
TENA	Test & Training Enabling Architecture
TNA	Training Needs Analysis
UAS	Unmanned Aerial System
VC	Virtual Constructive
WAVE	Warfighter Alliance in Virtual Environment



1 Introduction

Modern military operation requires a high level of efficiency and effectiveness, both individually and as a team, a result from changed world politics. Military forces all over the world are transforming to adapt to these changes. Examples of operational changes are more expeditionary operations, joint and combined operations, information data management, and distribution of information. This transformation is facilitated by technological advances in many ways from flight control systems to net-centric systems, and from mission training to rehearsal. However, life of the pilot has not really been made easier. The challenge for air crew has changed gradually from psycho-motor flying skills and lower-level cognitive skills to information managing skills and other higher-order cognitive skills. At the same time systems, weapons, theaters, tactics, Rules of Engagement (ROEs), etc., can change rapidly. The need for flexible skills is high. Classic training ranges simply are insufficient to train pilots towards flexibility. Threats will need to be various and realistic. Teams need to cope with a variety of operational conditions like weather, quality of intel, team composition, etc.

Current training technology combines live, virtual and constructive assets in various ways. Fully integrated, scalable, joint/combined application of Live, Virtual and Constructive (LVC) is still under technological development. This is however the most promising and complete perspective available. LVC exercises have not been optimized yet for fitting training perspectives, which are by itself in progress. In this paper it is attempted to combine technological and training perspectives relevant for LVC.

2 LVC Technological Perspective

Developments during the last decade in Modeling & Simulation (M&S) technologies enable, potentially large scale, exercises in combined and joint settings within a mixture of a live and synthetic battle space. Mixing the live and synthetic battle spaces is a new training technology, Live-Virtual-Constructive (LVC), where:

- **Live** = training involving real people operating real systems. For example a pilot operating a real jet.
- **Virtual** = training involving real people operating simulated systems. For example a pilot operating a simulated jet.
- **Constructive** = training involving simulated people operating simulated systems. Real people may stimulate these simulations, but are not directly involved in determining the outcomes. By themselves these simulations are often used to train decision making at higher levels of command. Connected to Virtual or Live training assets, constructive forces form the basis of training scenarios, providing friendly, neutral, and opposing forces.

Actually LVC is not one single new technology, but it is the confluence of several underlying technologies with the goal to further expand the horizon of training enabling capabilities. At the basis of LVC lie technologies from the following domains:

- **Mission Training through Distributed Simulation (MTDS):** standards have matured over the last three decades: experimental in the 1980's, initial standardization through the Distributed Interactive Simulation (DIS) standard in the early 1990's, and the further evolution and standardization with the High Level Architecture (HLA) in the 21st century.



- **Test & Training Range:** a similar interoperability standardization effort as seen for MTDS was performed by the training range community, resulting in the Test & Training Enabling Architecture (TENA). Though designed for a different primary purpose, and thus different in significant ways, TENA shares many properties with HLA and DIS.
- **Embedded Training:** as technology further matured in the 1990's and 21st century, embedding simulations on-board operational platforms became an option. Initially seen on ships and air missile defense systems this technology is now successfully implemented also on fighter aircraft, even with multi-ship synchronized scenarios.

The USA has laid out an LVC Architecture Roadmap (LVCAR) [Henninger 2008], with the goal to define an LVC integrating architecture to provide the foundational structure and framework for integrating live, virtual, constructive systems into an integrated war-fighter's training environment. LVCAR does not select one particular enabling technology, but endorses that these technologies (and others) exist and must be made available to interoperate with each other. Future developments of these technologies should be aligned and ideally converge into one single base technology for LVC. Four major technologies currently in active use are considered by LVCAR:

- **CTIA:** The Common Training Instrumentation Architecture is primarily focused at the live training community. CTIA is not standardized. CTIA is unique in that it is a service oriented architecture.
- **DIS:** The Distributed Interactive Simulation standard primarily focuses on interconnecting virtual and real-time constructive simulations. It is an IEEE standard [IEEE 1998]. DIS uses a simple peer-to-peer broadcast/multicast architecture without central control.
- **HLA:** The High Level Architecture primarily focuses on interconnecting virtual and constructive simulations. It is also an IEEE standard [IEEE 2010]. HLA uses a publish-subscribe peer-to-peer message passing architecture with a central infrastructure that provides coordinating services.
- **TENA:** The Test and Training Enabling Architecture focuses on live training and testing. It is not an international standard like DIS and HLA, but it is controlled by an architecture management team. TENA, like HLA, uses a peer-to-peer message passing architecture.

In The Netherlands, research on networked simulation dates back to the mid 1990's taking up speed in the 21st century. Various national and international research programs have been executed which revealed insight in issues, limitations, and how to tackle them. Most if not all of the challenges encountered in such distributed mission simulations are also encountered in LVC exercises, often even getting more pronounced due to more limiting networking means. Some relevant networking limitations are: bandwidth, latency, reliability, and availability.

Networking is not the only concern for interoperability; security is a general concern applicable to all forms of interoperability especially in international settings. Avoidance of security issues often results in a degradation of 'fair play'. Nations are often not willing or prohibited from sharing performance data of weapons, systems, and platforms. This is often circumvented by either:

- Agreeing on performance data, which has the distinct issue of having impact on tactics and thus the induction of negative training;
- All participants calling 'kills' by their own rules, which obscure any 'fair play' considerations.

Furthermore, adding simulated platforms and systems to live exercises introduce some specific semantic concerns that are not applicable to pure live training. A simulation is by definition an abstraction of a real-world live platform, system, or weapon. As such simulations will never exhibit 100% fidelity and can vary largely in fidelity depending on the intended use of such simulation. Again also security comes into play as fidelity of simulated models is often reduced due to security classification. Variance in fidelity can cause significant 'fair play' issues; this is true for both MTDS as well as LVC.

The Levels of Conceptual Interoperability Model (LCIM) as devised by Tolck et.al. [Tolck 2003] [Tolck 2006], defines a layer model to order interoperability issues at different levels of abstraction. The latest version of the LCIM defines 7 layers of interoperability, from no interoperability (level-0) to conceptual interoperability (level-6). Each of the intermediate levels represents an increasingly complete level of interoperability, with conceptual interoperability being the Holy Grail. This is not say that level-7 is needed for every MTDS or LVC training environment to be effective, but having interoperability at lower levels always will present uncertainties and interoperability concerns. Common protocols like DIS, HLA, and TENA typically focus on ensuring syntactical interoperability, i.e. interoperability at the relatively low level-2. This paper focuses on the intermediate levels of interoperability.

LVC training is nowadays conducted in several places in the world, but in most of these cases the training is set up on an ad hoc basis. In other words, commanders would set up LVC training for a specific exercise at a specific location, then tear it down when the exercise was finished. If a similar exercise were scheduled at a different installation, the same LVC environment would have to be reconstructed from the ground up.

The current state of affairs on LVC activities in The Netherlands is that NLR is actively involved in contributing to a national MoD Concept Development and Experimentation (CD&E) exercise. In this exercise a Joint Common Operation Picture (JCOP) is created using data from simulators as well as live systems. For this purpose one of the NLR research fighter simulators (F4S) is integrated into this exercise through a connection with the fighter command and control systems. Furthermore, also for this exercise the operator station of an experimental Unmanned Aircraft System (UAS) simulator is integrated with NLR's own research aircraft that can as such operate as a UAS player with the safety of having in-aircraft pilots controlling the plane. In a related programme the transition from Collective Mission Simulation (CMS) R&D to implementation in The Netherlands armed forces is performed under the name Orange WAVE (Warfighter Alliance in a Virtual Environment). Furthermore the Embedded Combat Aircraft Training System (ECATS) is a Dutch developed embedded training capability that provides a designed in growth path for easy incorporation of ECATS equipped weapon systems into LVC exercises [Leimomg 2010].

How to head into the future is now the question at hand. LVC has been a mostly technology driven affair. By means of this paper the authors make clear their vision on the evolvement of ways and means of training and the technology to support it. What should be driving LVC technology development is training requirements. The LVC technology should provide appropriate services to deal with the training requirements, which will exhibit a large diversity of demands with a large diversity in complexity and involvement of other operators. As training has many aspects to it over the life-cycle of educating and training any operator, involving training at diverse levels of complexity and interactivity, it is adamant to provide technology that scales with the training requirements.

LVC is a conglomerate of technologies, existing as well as still to be developed technologies. To be able to flexibly adapt to training requirements an LVC architecture should be able to be used not only in its full glory, but also in down-scaled subsets. As a matter of fact MTDS is a subset of LVC, namely Virtual-Constructive simulation. As is an Embedded Training capability, being an implementation of Live-Constructive simulation.

To address the problem of providing LVC technology in line with training requirements a Service Oriented Architecture (SOA) [Erl 2007] perspective is adopted. SOA is a design paradigm that is used to great extend in IT-environments, notably web-based environments. The table below lists the standard SOA principles and presents from the LVC perspective their relevance and applicability:

Table 1: SOA principle versus the LVC perspective

Training SOA principle	LVC perspective
Standardized service contract	Interoperability in LVC is based on commonly agreed communication standards, e.g. HLA, TENA, and DIS. Especially HLA and TENA provide a standardized flexible way to put a communication contract between participants in place.
Service loose coupling	Platforms and systems participating in an LVC exercise are highly independent by nature. Also their location is often very volatile. This makes a loose coupling in LVC environments an essential property.
Service abstraction	When looking at the underpinning technologies of LVC, most particular HLA and TENA, the implementation of a participant is abstracted to a data communication agreement.
Service reusability	Live, virtual and constructive components participating in an LVC exercise should be reusable in other exercises. Due to the nature of the LVC participants this is strongly bounded to the designed usage profile of the operational platforms.
Service autonomy	Each participant in an LVC exercise operates under its own autonomy; this is also one of the principles behind the HLA, TENA, and DIS standards.
Service granularity	In an LVC environment there is less design freedom then in a SOA application designed from scratch. Live platforms and virtual simulations are provided LVC components. The constructive parts of an LVC exercise may allow for more design freedom, depending on the resources in use. As such in an LVC environment there is less room for granularity optimization.
Service statelessness	Here LVC deviates significantly from SOA applications in that for an LVC exercise at least a common exercise state is desired; depending on the design and capabilities of the participants this is enforced using different methods and varying degrees of automation.
Service discoverability	Service discoverability is currently limited in LVC exercises.
Service composability	This is a property that especially HLA and TENA also strive to and is directly related to the reuse of LVC resources in different exercises.



From Table 1 it becomes clear that the principles upon which SOA is based largely map to demands for a successful LVC implementation. This comes as no surprise since SOA is targeting highly flexible distributed applications. Thus much of the SOA architecture and principles can be applied to LVC, although the primary application domain of SOA is very different from LVC.

Besides the obvious leverage that can be taken from SOA experiences, taking a service oriented perspective has a major advantage in designing LVC applications to fulfill specific training requirements. The training requirements can be translated into service contracts, which can then often be implemented using multiple technical solutions. The other way around, existing services provided by LVC applications can be taken by training designers to make the most reuse out of existing LVC services. Service orientation also has merits in that adequate handling of quality of service contracts can facilitate getting to higher levels of interoperability. There are however also some properties of an LVC environment that are very different from normal SOA services. SOA generally assumes the availability of a liberal amount of communication capacity. LVC, especially connecting live-live and live-virtual, has often only very limited communication capacity available by the nature of having to use wireless (medium to long distance) data-links in military operational conditions. This is also one of the main discriminating factors when comparing LVC to MTDS (VC).

As already noted, the CTIA uses a service oriented architecture. CTIA by itself however has some limitations in that it is not an international standard and is not designed with virtual and constructive simulations as primary participants in a training exercise. The concept of applying service oriented concepts to LVC will need further investigation to evaluate its potential merits and if viable the development of LVC specific service structures and quality of service concepts¹.

3 Training Perspective

In the last decade, leading training concepts in the Dutch armed forces are competency based. Competency based training can be developed in a variety of ways and for a variety of educational levels. The NLR competency model [Abma 2004] includes knowledge, skills, attitudes and the ability to integrate them while performing under operational conditions and standards. The skill, or set of skills, is the core of the competency. In this model an attitude or knowledge does not constitute a competency on its own. This definition links competencies to concrete, task-oriented skills in a direct way. The competency profile for a Chinook pilot for example will include task-oriented competencies, such as 'navigate'. The more abstract competency descriptions often found in competency profiles such as 'flexibility' or 'prioritize' are supportive to more than one task-oriented competencies and are therefore categorized as 'supportive competencies'.

In military pilot training, certain elements from a competency-based training perspective are already covered implicitly. Consider the strong focus on practice and safety critical issues, like Emergency Procedures, in any pilot training program. However, the instructional program does not always fit to the learning capabilities of students. A structural orientation on competencies can benefit the efficiency and effectiveness of the entire pilot education and training program.

¹ Note that modern communication protocols like HLA do provide services. These are however communication and simulation management services, which have a different purpose than the here proposed training services.



Implementing the following three principles to pilot training [Van der Pal 2009] is expected to make the difference:

1. Apply whole task training from the start. This principle forms the core of the competency-based approach. In contrast to a building block principle, which is basically a part task concept, instructor pilots are invited to address, as far as possible, the full set of competencies and related tasks already in the very first training event. Naturally, this will not be possible without minimizing the challenges (operational conditions) and maximizing instructor support (e.g., talk through or demonstrate). Part-task practice will still be required and can be scheduled in support of whole task learning process. Throughout the syllabus, several training events can be scheduled to bring particular skills to a certain level of automaticity.
2. Tailor training to personal needs. Competency-based programs may be expected to reveal a wider variety of strong and weak capabilities of students in an earlier phase of training. This is a result of being subjected to the wider set of tasks that may require more or less support from the instructor. Instructors can use this information to adapt the training to the individual student needs. To use this option successfully, instructors need to acquire enhanced coaching skills, if possible, supported by improved performance assessment and performance logging technology. This principle may also be used to optimize the obligatory training events in recurrency training programs.
3. Mix theory and practice. Theory may be provided in a just-in-time and just-enough manners. Along the training program, theory will be provided in greater detail to support deeper insight. A competency-based program does not support a deliver, check and forget strategy. Theory will require to be repeated and elaborated, in close connection to the flights and sorties scheduled. Therefore, while initially less theory time is consumed than in regular training programs, over the full training program, the same amount of time on theory may be consumed in a competency-based program, but resulting in better retained knowledge and insight.

These principles, further worked out in the RNLAf competency-based pilot training approach [Abma 2009] are based upon the Four Component Instructional Design (4C/ID) [Van Merriënboer 1997] and its pragmatic version ADAPT^{IT} [De Croock 2002], which strongly focus on the optimization of cognitive load during training. Training that successfully implemented these principles is expected to benefit on the following effects:

- Improved skills acquisition;
- A steeper learning curve with smaller integration dips (i.e., natural side effects of integration of skills that are trained in separation of each other);
- Reduction of training sorties.

Applying the principles above will require considerable insight in both the operational tasks and demands. Design of competency-oriented training flights and sorties requires analysis of the operational tasks and missions, analysis of the operational conditions the pilots have to deal with, and identification of the competency profile. During the design of training scenarios, media will be selected (apart from pragmatic options and constraints) on the basis of e.g., the selected competencies to train, particular instructional strategies to apply, particular operational conditions to provide, and the level of proficiency of the student [Abma 2011].

The NLR/RNLAf pilot training approach has been applied in several projects:

- Developing syllabi (a prototype F-16 IQT/MQT syllabus, an Instructor Pilot syllabus);



- Identification of competency profiles for current and future air crew (all flying platforms of The Netherlands) and other (foreseen) functions such as a UAS operators, fighter controllers, air traffic controllers;
- Requirements to training media (Eurotraining TNA; Helicopter Multi-ship/Multi-type simulator).

The nature of (soft) training services are quite different from software services as referred to by the SOA design paradigm. However, when applying the paradigm, a useful training development model can be provided, not so much a process model, as many training approaches (ISD, SAT, TNA) suggest, but more a product-oriented model, where each product (service) can be given certain qualities (principles) that support it.

Soft Training Services (content) as opposed to Hard Training Services (media) may include the following:

- Training approach
- Syllabus
 - Training Objectives / Selected competencies
 - Selection of LVC services
 - Scenario events
- Planning
- Briefing content
- Instructor strategies / interventions
- Debrief content
 - Performance Measures / Assessment
- Training Evaluation

Such soft training services for LVC are products that may have a function within the higher level of the Levels of Conceptual Interoperability Model (LCIM). Training content affects level 3 in LCIM (semantics) and training methods and procedures affect level 4 in LCIM (pragmatics).

Soft training services can be described according to what we propose in Table 2 as Service Oriented Design (SOD) principles:

Table 2: SOD principle versus the LVC perspective

Training SOD principle	Competency based training (LVC) perspective
service comprehensibility	Service easiness-of-use level. Can a planning be set up easily? Are syllabus design guides understandable? Is media selection dealt with (How to select Live or Virtual services)? For example, the selection of LVC services need to reflect the need for cueing, operational situation, competencies selected. Guidelines for selection should be provided and easy to use.
service consistency	Consistency of training approach between various soft training services. For example, briefing content should be consistent to the competency based training approach (next to mission specific briefings, specific information or instructions should be provided in relation to the selected competencies).



services correlation	Consistency between soft training service content. For example, selected competencies in a syllabus need to correlate with appropriate performance measures used in the debrief.
service manageability	Making explicit who is responsible for the design, development, usage, and evaluation of each soft training service and how this is coordinated.
service time consumption	Design and development of a service may be fast or very time consuming.
service flexibility	Ability to adjust training (whether a full syllabus or a single scenario event) given new requirements or a pragmatic constraint or possibility.
service explicitness	Service principles can be implicit (experience based, 'same as yesterday') or explicit ('training evaluation according to Kirkpatrick levels').

This set of SOD principles may require revision after first application projects.

4 A Comprehensive Perspective for LVC Training

Assuring good quality of LVC training in a dynamic environment is a challenge. This is a result of the fact that LVC services, operational demands, and training approaches are not stable and they are not consistent between technological components and operational units. While instability may be an inherent quality of LVC environments, inconsistency should be avoided. One way of reaching consistency is to match the LVC technological perspective and the training perspective as described above and to apply this to new LVC events (training event, exercise, R&D activity) as a normative model. Figure 1 provides a draft for such a model.

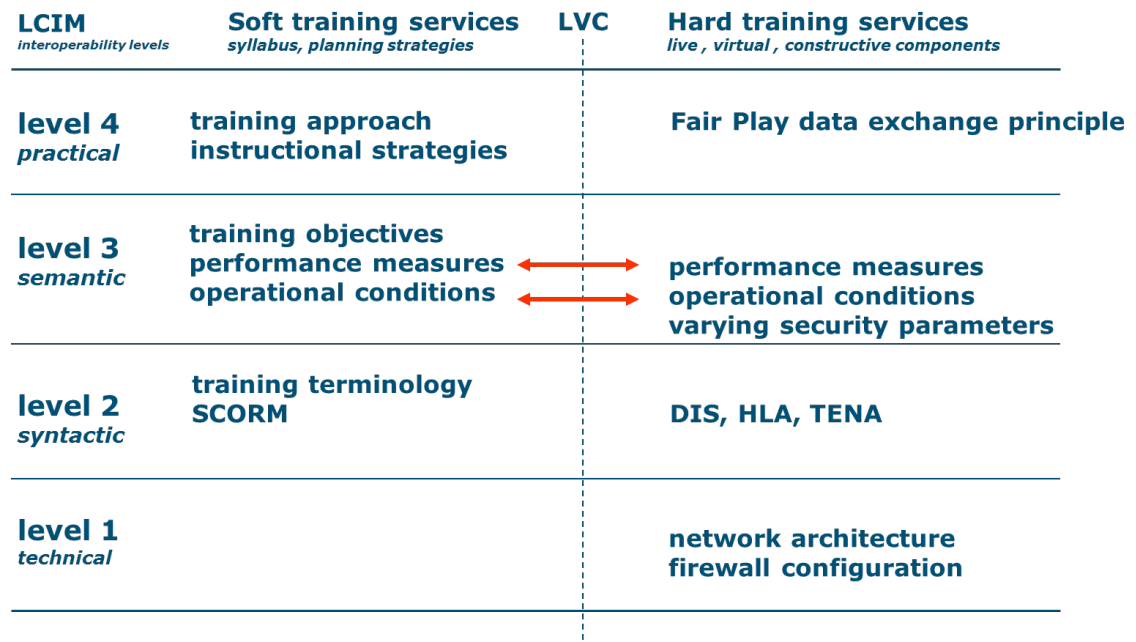


Figure 1: Comprehensive LVC model: Combining Soft and Hard LVC training services and service elements using the LCIM framework

At level 3 in the figure, the link from the soft training perspective to the hard training perspective is likely to be strongest. Instructors setting up training will specify a range of training objectives which need to be interoperable between the students in order to provide training value for as many participants as possible. In order to train for particular objectives (e.g., co-ordination between teams), the environment often needs to provide for certain operational conditions (e.g., change of weather to induce contingency planning), and associated performance criteria are specified (e.g., within a certain time frame). When all such training decisions have been ensured to be consistent over the various participants, the LVC scenario designers need to ensure the operational condition can be provided and the performance can be measured.

For LVC development trajectories, using the comprehensive LVC model could lead to surprising results. For example a training design principle from NLRs training design approach (an LCIM level 4 item) is ‘ensure sufficient variability to foster flexible skills’. This principle enables pilots to be able to deal with new situations during an operation easily, but with new (onboard) simulation technology, it may also be applied to be better prepared for dealing with new weapons, new ROEs, new threats, etc., Such immediate changes are not uncommon when actually deployed to a war-zone. When training has been used to drill the pilot in using his systems (leading to highly routinized skills), it will take considerable time to acquaint to new configurations and settings. In contrast, training that prepares for more flexible skills, may require a syllabus (LCIM level 3 item) in which certain sensor/weapons parameters vary between exercises (or modules). Each time, the pilots need to adapt to the new settings for a number of (simulated sorties) before he can use the systems smoothly, but this familiarization process will be much quicker compared to current training where the tactical and system parameters are almost hard wired into the pilot’s brain (which need to be ‘unlearned’). Such



training concepts can be achieved with LVC technology that supports a varying set of weapon parameters, platform characteristics etc.

As a side effect of this training set up, the comprehensive LVC model has effectuated a new security measure. Using agreed distorted parameters purposefully may reduce the need for very sophisticated multilevel security measures: on level 4 of the LCIM, a data exchange policy is worked out that ensures Fair Play exercises, such that it concurs with the training design principle of ensuring high variability, while on LCIM level 3, the varying system parameters functions both serve training and security purposes.

Such an LVC training and LVC technology co-development requires considerable testing from various perspectives (training effectiveness, safety, security, technology). Along this validation process, the LVC events and resulting lessons learned can be described in terms of (compliance) to the comprehensive LVC model and may guide further development.

More detailed description of the services and service elements need to be provided in the model. It will be attempted to bring the best practices and academic models into the comprehensive LVC model. The input from best practices may be provided from lessons learned of LVC research activities as well as LVC exercises. The LVC community is invited to report on the set up and the evaluation of LVC trials in terms of the model. Applying the model will support the particular LVC event (by making LVC users aware of the decisions they make and of potential inconsistencies) as well as contribute to a more specific version of the comprehensive LVC model.

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