10. Conclusion

This chapter provides the lessons learned and possible future work on the framework. The bigger vision of unified system development within the Command and Control environment is also discussed.

10.1 The Framework Implementation

Early versions of the framework have been in use since March 2008 and this has already resulted in four applications that have successfully been applied within the C2 domain (see Chapter 9):

- an air to air tactics evaluation tool for fighter aircraft,
- a protocol gateway that facilitated air force, navy and military system interoperability during preparatory field exercises for the soccer world cup 2010,
- a radar emulator for adding additional information sources to an air force system, and
- a *joint operations operator console* concept demonstrator.

Software requirements can change often and more command and control systems might have to be supported—the success of the applications created with the framework depends on the quality of the framework design and implementation. From the application examples, discussed in Chapter 9, it should be clear that the current implementation of the framework is successful. The test applications created with the framework (see Chapter 9) also show that the framework is flexible enough to allow for discrete time and discrete event based simulation.

The code-base has however not undergone the rigorous testing and validation required to qualify it for use in safety critical systems. Creating operational systems is in fact outside the scope of the framework and this should rather be done by the local defence industry. For now the framework remains part of the support services provided to the defence force.

The framework source code has been included on the DVD accompanying this dissertation. The complete source code for the three test applications, discussed in Chapter 9, is also included. The four C2 applications created with the framework can however not be included on the DVD since the applications contain restricted or sensitive information. The source code for the user interface and visualisation layers used by the C2 applications is not included on the DVD, since it is not directly part of the software framework discussed in this dissertation.

Essentially all the components of the framework can be made open source (i.e. the source code would be publicly available): making the framework open could advance the development of the framework as well as increase the number of applications created with it. Unfortunately, at this stage, contractual complications with the armaments industry prevents this from happening and the source code remains the property of the CSIR.

10.2 Future Work

Distribution of the applications over wide area networks is becoming more important and the current simulation time management and information distribution will have to be updated. The node hub implementation would have to be updated to support nodes entering and leaving the simulation on the fly. This has the added benefit of improving the fault tolerance of the framework by allowing backup nodes to take over when primary nodes fail.

It is worthwhile mentioning that the use of the framework in no way negates the use of something like the High Level Architecture (HLA) for simulation interoperability. The framework can be applied to enhance the capability and quality of HLA federates and could very well be extended to be a federate development environment. The framework also has the potential to parallelise a federate's internal model execution.

10.3 An Open Unified Architecture for System Development

The current framework addresses system virtualisation and system interoperability. The work presented in this dissertation however also contributes to a bigger vision of unified system development within the context of command and control. There is a need for a *unified software architecture for system software development* that enables modular C2 systems with reusable sub-systems. The current framework implementation can be used to create the software for systems within the C2 environment, but falls short when it comes to operational systems since it is not qualified for safety critical applications. An M&S capability is also not necessarily required by operational C2 systems and equipment.

Any system that would function within the C2 environment would have to be compatible with this unified architecture for to be a success. Sub-systems bought from international vendors would also have to be comply with this architecture. This would lead to an open middleware implementation for creating the software for all local C2 systems. One would need buy-in and acceptance of the unified architecture (and the middleware implementation) from the local defence industry. This might seem excessive, but it might also prove to be a *necessary evil* in achieving truly modular systems. A unified architecture will also reduce the required skill set of system developers, potentially extending the operational lifetime of the systems.

10.4 Final Thoughts

This now concludes the final part of this dissertation. This dissertation discussed the design, implementation and evaluation of a *software framework for supporting distributed Command*

and Control applications. The work represents an *unique hybrid approach* that combines M&S and system interoperability to build distributed C2 support software.

The work was put into perspective by an extended literature review and it was shown that the current design and implementation of the framework is of a high quality and is successful. The research outcomes include the framework implementation as well as the key requirements for providing interoperability and M&S support to the C2 enterprise. These research outcomes will contribute to further research in system interoperability, M&S and unified system development within the C2 environment.

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Appendix A: Papers Published Related to Framework

This appendix contains four papers, authored or co-authored by Arno Duvenhage, that discuss research related to the work presented in this dissertation. All four papers were also presented by Arno Duvenhage.

- The Evolution of a C2 protocol gateway, *The Simulation Interoperability Standards Organization (SISO) Euro SIW 2008 Conference, Edinburgh, Scotland, 16-19 June 2008.*
- Effectively Utilizing a 3rd Party 3D Visualization Component in a Discrete Event Simulation Environment for Joint Command and Control (JC2), *Fall Simulation Interoperability Workshop 2009, Orlando, Florida, 21-25 September 2009.*
- Experiences From Constructing Command and Control Simulations Using a Tactical Data Link Standard, *Fall Simulation Interoperability Workshop 2009, Orlando, Florida, 21-25 September 2009.*
- A Layered Distributed Simulation Architecture To Support The C2 Enterprise, *The Simulation Interoperability Standards Organization (SISO) Fall SIW 2009 Conference, Orlando, Florida, 21-25 September 2009.*