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THE STATE OF THE ART AND THE STATE OF THE PRACTICE

Architectural Description of the UK Common Core Combat System

Topics – C2 Architecture, C2 Experimentation

Dr Lyn Owen
(Point of Contact)
QinetiQ
Winfrith Technology Centre
Dorchester
DT4 8XJ
Telephone +44 1305 212996
LOwen@QinetiQ.com

Ms Claire Burt
Dstl
Winfrith Technology Centre
Dorchester
DT4 8XJ
Telephone +44 1305 256025
CMBurt@dstl.gov.uk

Dr Andrew Flinn
Defence Science & Technology - Underwater Systems
British Defence Staff
British Embassy
3100 Massachusetts Ave, N.W.
Washington. D.C.
Tel: 202-588-6727
Andrew.Flinn@moduk.org

ABSTRACT

In 2005, the UK embarked on a major new initiative, the Common Core Combat System (CCCS), to deliver a new open architecture and COTS-based combat system for Royal Navy submarines. The initiative is a collaborative programme bringing together DEC (UWE), DPA, DLO, Dstl and UK Industry to drive down cost of underwater platforms and to support reuse and capability insertion.

The CCCS will comprise common platform networks, interfaces and equipment fits to be introduced incrementally to all RN submarines including the new ASTUTE class The approach is radical in that it seeks to put in place an architecture that can evolve over the life of the platforms.

The *CCCS Architectural Description* is being developed incrementally and is widely peer reviewed by a consortium of UK industry under MOD governance.

A CCCS Testbed is under development to validate the architecture and to de-risk the CCCS programme. The Testbed includes innovative components developed via a series of research strands including open architecture sonar and tactical and environmental data servers.

The paper describes the major drivers of the CCCS architecture, the architecture itself and shows, using the example of the Testbed, how instances of the architecture are used to generate specific system designs for individual incremental builds of the CCCS through time.

INTRODUCTION

The UK currently has several unique classes of nuclear powered submarines in service of which no two have the same combat system configuration. Each combat system variant can be defined by the core combat system equipment i.e. Sonar, Command System and Data Highway resulting in around nine unique equipments which have to be supported. Therefore, there is the potential for saving support costs and manpower if the three variants can be reduced to one ‘Common Core’ of equipments.

In 2005, embarked on a major new initiative, the Common Core Combat System (CCCS), to deliver a new open architecture and Commercial Off-The-Shelf (COTS)-based combat system for Royal Navy submarines. The initiative is a collaborative programme bringing together DEC (UWE), DPA, DLO, Dstl and UK Industry to drive down cost of underwater platforms and to support reuse and capability insertion.

The main aim of the CCCS programme is thus to introduce commonality within the combat system design across the Submarine Flotilla. In addition, the CCCS programme must ensure that the architecture is sufficiently flexible and adaptable to allow cost-effective sustainment, upgrade and extension to include other combat system equipments as the opportunity or new requirements arise.

This goal is being achieved by utilising new developments in open system design principles and open system architectures, and by exploiting standards-based computing technologies from the COTS marketplace.

The policy statement from DEC (UWE) states:

> *The Common Core Combat System is to be a co-ordinated programme to achieve reduction in whole life costs. CCCS will deliver the system engineering and software development outputs, necessary to consolidate*

separate Sonar, Command System and Data Highway initiatives into a coherent Common Core Combat System for RN submarines, based on open systems

The CCCS will comprise common platform networks, interfaces and equipment fits to be introduced incrementally to all RN submarines including the new ASTUTE class.

The approach is radical in that it seeks to put in place an architecture that can evolve over the life of the platforms.

Another area of innovation is that a CCCS Architecture Authority Working Group (AAWG) has been set up to produce and control the architectural specification. Chaired by the MoD, this is also attended by representatives from a wide range of UK industry.

MAJOR ARCHITECTURAL DRIVERS

A primary requirement for the architecture is openness, but openness is really an enabler: an umbrella concept that is fed by a number of key architectural design criteria and which yields a range of significant benefits.

It could be said that openness 'makes some things easier'. These include portability, evolvability and so on. The special needs of the CCCS mean that openness is particularly required in three critical areas: evolution, variation and support to procurement.

<u>Evolution</u>

The architecture must allow the specification of an initial procurement of CCCS components but be sufficiently forward-looking as to be applicable to future systems and the incorporation of new capability. The architecture specifies a future increment of the CCCS - in other words a Vision System. This has been done quite deliberately: without being forward-looking from the very start it will be very difficult indeed to break out of the structural mould of current combat system design.

<u>Variation</u>

The architecture, and the systems from which it is built, must be applicable to the complete range of UK submarine platforms with their differing equipment fits.

The architecture is a *generic* architectural vision for the future UK submarine combat system, describing a *common core* of functionality. It is the job of the system integrator and subsystem suppliers to take this specification and use it to generate a system design specification for a particular increment of the combat system on a particular platform.

A significant outcome from this vision system concept is that bridges to legacy and other equipments are currently not included in this specification. They are regarded as temporary interfacing components that are needed to interface from the legacy systems to the evolving common core. Bridges are the province of the system integrator and subsystem suppliers and their system design specifications.

<u>Support to Procurement</u>

As well as guiding the more detailed and lower level design of the system, the architecture must provide input to Invitation To Tender (ITT) documents to ensure that the CCCS subsystems that are to be procured will work together effectively and achieve their aims. In other words the architecture must provide input into contractually-binding specifications that ensure interoperability.

The architecture provides source information which can be used to aid the procurement process. It can be referenced from ITTs or, more appropriately, its content can be used as a basis on which to write requirements, especially openness requirements, and to inform the tender assessment process.

In order to achieve a coherent and open design that ensures interoperability between its parts, the architecture needs to state bold decisions. Some of these architectural decisions must be mandated; others may be regarded as advisory This paves the way for an architectural compliance process in which the submissions of the bidders for the CCCS subsystems and the application components might be assessed against their willingness to adopt the tenets of the CCCS architecture.

THE FORMAT OF THE ARCHITECTURE

The architecture is currently being defined as the *CCCS Architectural Description (AD)* using Standard IEEE 1471 *Recommended Practice for Architectural Description of Software Intensive Systems.* This describes a process for generating a framework for an architectural design based on the definition of a series of viewpoints. The following viewpoints have currently been specified for the CCCS AD and these have been grouped into the six domains shown in Table 1.

Domain	Viewpoint
Overview	VP.O.1 CCCS Architecture Strategy *A high level description of the major CCCS architectural concepts*
Structural	VP.S.1 Context and External Interfaces *Boundary of the CCCS and identification of all external interfaces*
	VP.S 2 Granularity *Definition of the subsystems that make up the CCCS*
	VP.S.3 Physical Data Model *Physical data model covering the major data elements of the whole CCCS*
	VP.S.4 Subsystem Services *For each subsystem, the particular set of services it must provide to other subsystems and the ones it will require to carry out its function*
	VP.S.5 Service Definitions *Detailed definition of every service: its data, protocol, security etc*
	VP.S.6 Subsystem-Centric Service Connectivity *For key subsystems, a service connectivity diagram showing how the particular subsystem interacts with all other subsystems via the services it provides and uses*
Behavioural	VP.B.1 Operational *A set of key UML use cases that describe important aspects of the dynamic behaviour of the CCCS, including the way the system interacts with the external interfaces*
	VP.B.2 Security *How the architecture addresses the security requirements*
	VP.B.3 Safety *How the architecture addresses the safety requirements*
	VP.B.4 Availability, Reliability and Maintainability *How the architecture addresses the ARM requirements*
	VP.B.5 HCI

	The look-and-feel aspects of the HCI
	VP.B.6 System Modes *Describes the various system modes (startup, normal, training, replay, analysis etc)*
Infrastructure and Technical Standards	VP.I.1 Reference *Standards and reference frames*
	VP.I.2 Data Transfer *How information is transferred around the CCCS*
	VP.I.3 Preferred Execution Platform *Hardware and operating system preferences to encourage commonality*
Developmental	VP.D.1 Development Tools *Tool preferences for system development to encourage commonality*
	VP.D.2 Test and Acceptance *Test and acceptance issues and strategy*
	VP.D.3 CCCS Roadmap *For agreed CCCS increments*

Table 1: CCCS AD Viewpoints

The viewpoints have been chosen to capture the major combat system-level design issues that operate between and across the subsystems. The architecture will mandate subsystem interfaces and the use of standards to ensure interoperability.

This whole-system approach contrasts with the existing situation in which interoperability is achieved through a series of point-to-point interfaces.

It is the intention to migrate the structure to the emerging UK MODAF standard as this matures. MODAF is heavily based on US DODAF framework, augmented with other viewpoints, for example those that support acquisition.

AN INTRODUCTION TO THE ARCHITECTURE

An architecture for a system as complex as a combat system must be viewed in a number of ways in order to gain a full appreciation. One particularly revealing viewpoint is to consider the architecture as a series of layers as shown in Figure 1.

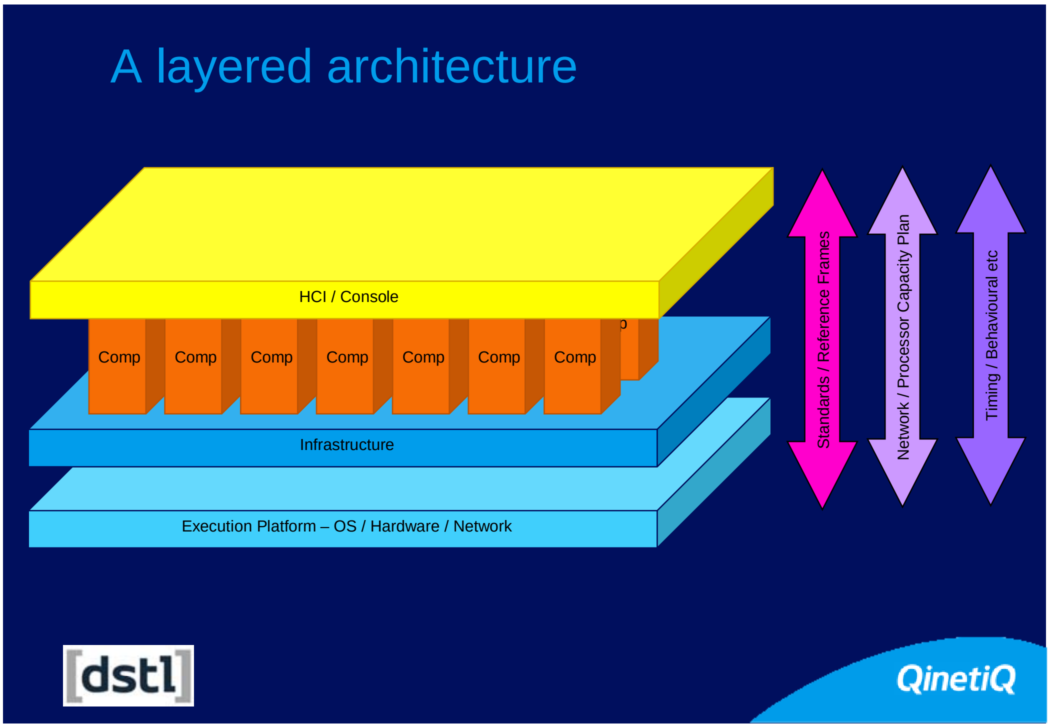

Figure 1: A Layered Architecture

The CCCS AD is not a purely functional and abstract architecture. Rather it takes a pragmatic approach to commercial issues and is based on a series of subsystems that form procurable entities. The subsystems are supported by an infrastructure and communicate via a network. This network is currently being procured and for this reason exists as a distinct entity in the architecture. A Common Console provides the Human Computer Interface for all the subsystems. Finally, a series of mandated and preferred standards ensures that all suppliers adhere to a single set of reference frames, development approaches etc.

The list of subsystems is currently being agreed but includes some innovative subsystems such as open Tactical and Environmental Data Servers, Picture Compilation, a Network Enabled Capability (NEC) Gateway and Rapidly Deployable Sensors (RDS).

Three other properties of the architecture are worthy of note: the adoption of a Service Oriented Approach (SOA) supported by a publish/subscribe paradigm and the definition of a new CCCS infrastructure.

<u>A Service Oriented Approach</u>

In the CCCS AD, the adoption of a SOA does not imply the use of a Web Services implementation. Instead the SOA provides a notational framework that helps to modularise the subsystems by explicitly defining the services that each subsystem provides and requires (Figure 2). These service definitions are being specified in a template that includes the formats of the data being exchanged, the transmission protocol, rate and volume information, quality of service parameters and access protocols.

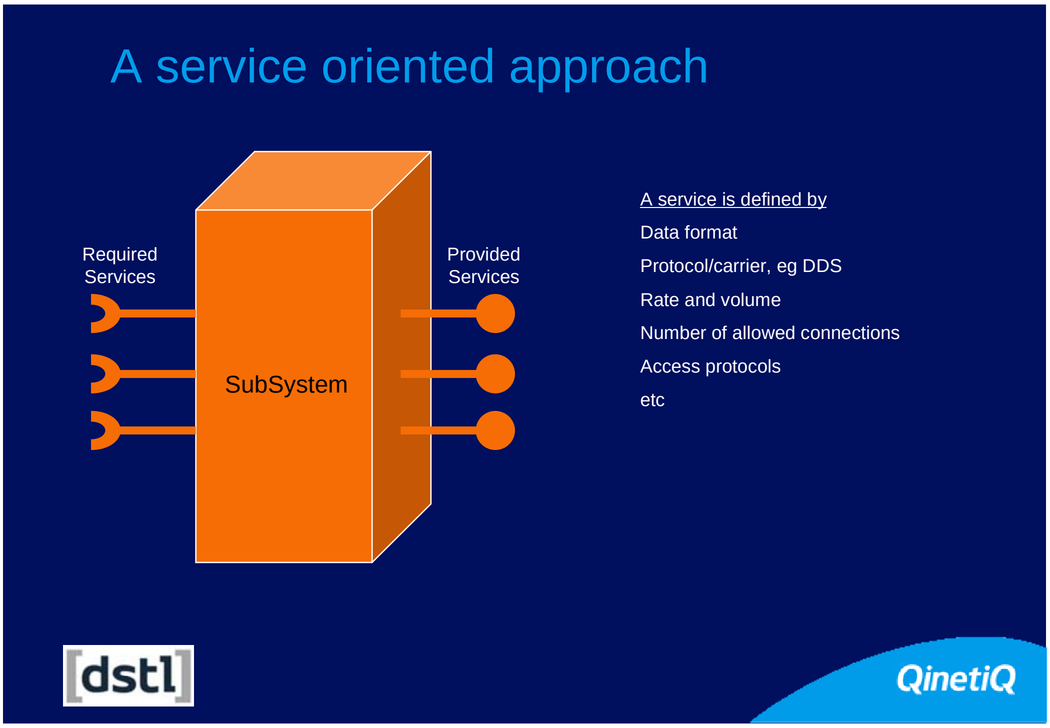

Figure 2: A Service Oriented Approach

The Use of Publish/Subscribe

Many of the key data transfers in the CCCS naturally conform to a publish/subscribe paradigm. One subsystem provides a well defined service and another subsystem (or many subsystems) can connect to and use the service. The use of publish/subscribe provides for a flexible connection mechanism and promotes functional mobility.

The CCCS project is investigating the Data Distribution Service (DDS) as a means of providing publish/subscribe data transfers.

Definition of a New CCCS Infrastructure

A new infrastructure is being defined for the CCCS. This includes the data management protocols plus necessary system management and the handling of coordination information such as system time and control of system modes.

Once proven, the infrastructure will be 'recommended' to potential subsystem suppliers and infrastructural compliance will form a key part of tender assessment.

USING THE CCCS AD

The CCCS AD provides a vision for the future – an aiming point that helps to ensure a product line approach to system development – it is not a concrete design for any particular system.

In order to design a particular increment of the CCCS, the system integrator takes the CCCS AD and tailors it to that particular fit on that particular platform, as shown in Figure 3 below.

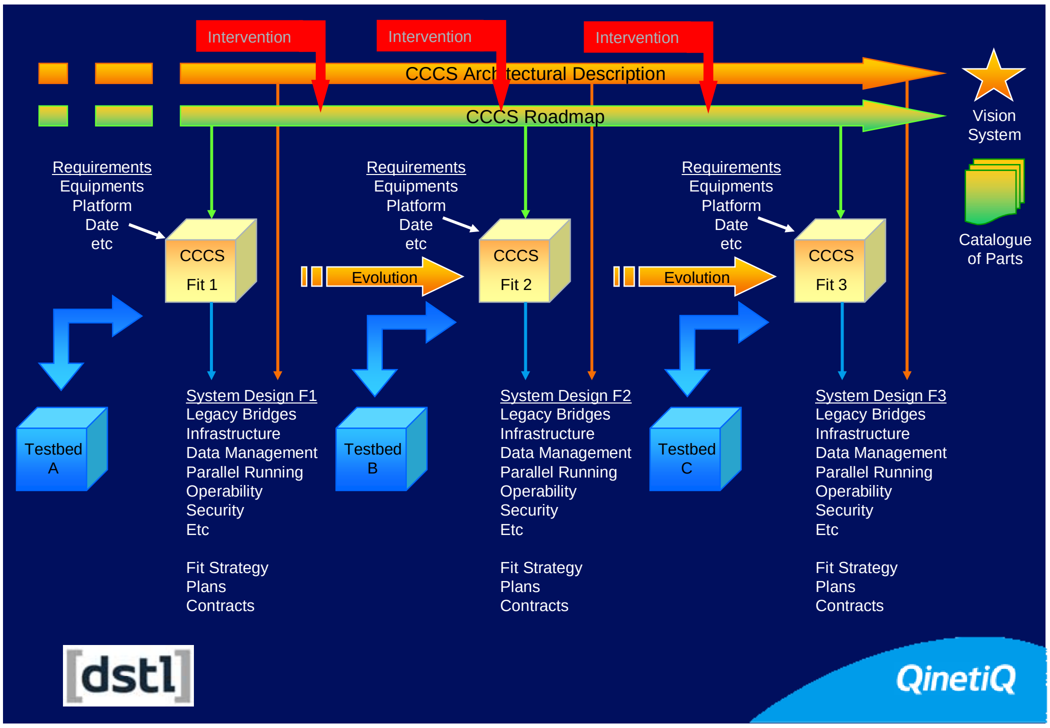

Figure 3: generating Specific Design from the AD

The CCCS AD is shown evolving along the top of the Figure and points at a vision system for the future. It is accompanied by a CCCS Roadmap that covers all the major equipments that currently fitted, being procured or are planned across all submarine combat systems. It lists in-service timescales and upgrade opportunities.

Together, the AD and Roadmap enable a series of evolving CCCS increments to be defined. Formal requirement specifications can then be drawn up for these separate increments and system designs can be generated.

The intention is that the increments are de-risked through prototypes and technology demonstrators that are here called Testbeds.

DEFINING A CCCS TESTBED

The first CCCS Testbed is now being defined and this has a dual purpose: to validate the architecture and to de-risk use of the new infrastructure for the ASTUTE combat system.

The set of Tesbed architectural viewpoints is essentially similar to those specified for the parent CCCS AD but as the Testbed represents a concrete system design rather than a generic architecture some additions have been necessary. These include:

- Additional behavioural viewpoints to capture the dynamic aspects of the design and the various system modes – operational, training, analysis etc
- A Capacity Plan that gathers together network and processing requirements and provides a model that ensures that the software can be executed in a timely manner
- An Openness viewpoint has been found to be highly beneficial to draw out the way that the design achieves the openness requirements. This has been specified as a series of openness scenarios in the form of key openness

questions and corresponding answers taken from the design. An openness viewpoint is likely to be added to the CCCS AD as well

- A Procurement Plan that presents a business model for contracting for the components of the Testbed from the various companies involved

In addition a separate Infrastructure viewpoint has been defined to consolidate more effectively these new data management and system control aspects of the combat system.

A key strategy for the Testbed is that it will address security, safety and availability requirements from the very beginning and this will aid eventual exploitation at full production status.

It is intended that production of the Testbed begins in April 2006 and that demonstration at a shore test facility is carried out a year later. Selected components may then be taken on board a submarine and tested at sea.