European Component Oriented Architecture (ECOA®) Collaboration Programme: ECOA White Paper

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4 Abbreviations

AI	Artificial Intelligence
AMS DE-RISC	Advanced Mission System Demonstrations and Experimentation to Realise Integrated System Concepts
API	Application Programming Interface
ARINC	Aeronautical Radio, Incorporated
ASAAC	Allied Standards Avionics Architecture Council
ASC	Application Software Component
AS6	Architecture Specification Issue 6
BAE	British Aerospace
BNAE	Bureau de Normalisation de l'Aeronautique et de l'Espace
DA	Dassault Aviation
DGA	Direction Générale de l'Armement
DSTAN	Defence Standard
DSTL	Defence Science and Technology Laboratory
ECOA	European Component Oriented Architecture. ECOA® is a registered trademark.
FACE	Future Airborne Capability Environment
FCAS	Future Combat Air System
FR	French
GE	General Electric
IAWG	Industrial Avionics Working Group
IMA	Integrated Modular Avionics
IT	Information Technology
LTD	Limited
MALE	Medium Altitude Long Endurance
MoD	Ministry of Defence
OS	Operating System
POSIX	Portable Operating System Interface
RPAS	Remotely Piloted Aircraft System
STD	Standard
TDC	Technology Development Cooperation
UK	United Kingdom
UML®	Unified Modelling Language™
WCET	Worst Case Execution Time
XML	eXtensible Markup Language

5 Introduction

This document is aimed at senior management and provides a high level executive summary of the ECOA collaboration programme.

This white paper highlights:

- The technical and business model findings following the completion of Phase 2 of the ECOA collaboration programme,
- The ECOA open source tools developed during the Technology Development Cooperation study (Phase 4 of the ECOA collaboration programme).

This white paper also presents a roadmap describing the directions taken following the ECOA Phase 4.

6 ECOA White Paper

The European Component-Oriented Architecture (ECOA®)

A joint Anglo-French collaboration programme funded by UK MoD and FR DGA, led by BAE Systems Military Air and Information in the UK and Dassault Aviation in France, involving the following UK and French industry partners: BAE Systems Electronic Systems, Bull SAS, General Dynamics UK, GE Aviation Systems, Leonardo Airborne & Space Systems, Leonardo Helicopters and Thales DMS France SAS.

Introduction and goals

There is a risk that future military air platforms will be unaffordable for the customers if nothing is done to improve lead time and cost by collaborative working and re-use. In addition there is an international movement towards creating and adopting open reference architectures to enable re-use across programmes.

Consequently, future development programmes will require more efficient collaborative software development as cost pressures increase and systems continue to become more complex. Workshare is expected to be an increasingly important factor in future contracts. In addition there is a desire to support an expanded software supplier base, driving further innovation and cost reduction. All this is set in an environment of increasingly complex and connected capability, where it is essential to protect systems from obsolescence and support rapid product upgrade.

Addressing these challenges in a successful way has been considered as part of a vision of how programmes should be developed in the future. In this vision, systems are developed collaboratively and assembled from modular software building blocks that are easy to upgrade and reuse across programmes.
Lessons learnt from the civil world have shown these outcomes are achievable.

To fulfil this vision three objectives must be realized:

1. To create and maintain architectures aimed at providing interoperability, sustainability and portability at a <u>functional level</u>. These architectures facilitate the collaborative design of future Mission Systems Software as assemblies of well decoupled, reusable, service-oriented building blocks (known as Components).
2. For the aerospace industry to adopt an Open Standard for software architecture aimed at providing interoperability and portability at <u>software interface level</u> for real time systems. This would facilitate the collaborative development of systems by assembling software components that are easily integrated onto a variety of computing platforms, and reused across different programmes.
3. To establish a viable comprehensive business model which enables stakeholders (such as customers and industry) to support the vision and actively participate in realizing the preceding objectives.

The software reuse objective also needs to be taken into account from the point of view of safety and security policies.

The Open Standard is expected to be a key enabler for the realization of any type of architecture and for creating a library of truly interoperable product lines (software components and computing platforms) from across the industry.

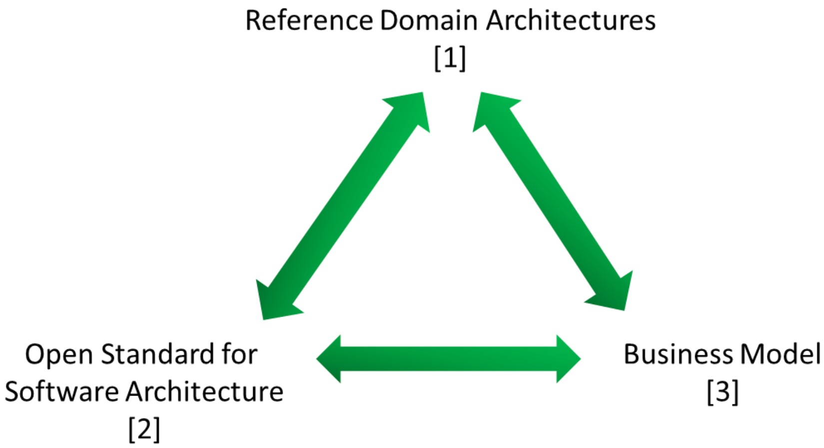


Figure 1: Relationships between Objectives

The overall vision will be achieved through the pursuit of all three objectives which would necessitate the interactions illustrated in Figure 1. The comprehensive business model illustrated in Figure 1 highlights the benefits of design commonality and software reuse in future development programmes, and a market of interoperable, reusable software components and computing platforms will emerge. The ECOA business model is only part of the comprehensive business model illustrated in Figure 1 and does not consider the broader context of open architecture adoption. The ECOA business model supports the comprehensive business model by presenting the essentials for early adoption of the standard onto development programmes.

Initiatives such as the AMS DE-RISC programme in the UK, set out to address the first objective, which is now being considered under the PYRAMID programme. In France, the first objective is being addressed by applying common architecture design drivers on RAFALE, FCAS and RPAS MALE programmes.

The joint UK-FR ECOA collaboration programme was initiated in 2011, following earlier FR ECOS projects started in 2006. The ECOA project set out to create an Open Standard for developing interoperable software components and to establish a staged business model approach. As such the ECOA collaboration programme is aimed at addressing objective two and a subset of objective three.

The ECOA technical approach

The ECOA standard is aimed at anyone involved in the conception and integration of embedded systems, in the development of real-time application software and in the development of embedded computing platforms. The ECOA collaboration programme has developed the ECOA standard in the context of real time embedded Mission Systems.

The ECOA standard enables the construction of a service-oriented architecture using a model based approach, which provides the capability to formally specify an assembly of Application Software Components, as well as their interfaces and deployment onto computing platforms.

Application Software Components are independent of the underlying computing platform thanks to the concept of “ECOA Containers”. These provide all the technical facilities needed by the functional code, using three standardized communication mechanisms (Request Response, Events and Versioned Data).

Figure 2 shows how ECOA Containers and middleware are implemented on top of any computing platform and make use of its Operating System. This provides the potential for any computing platform to host portable Application Software Components.

The key features provided by the ECOA technical approach are:

- Standardized service oriented interface mechanisms, including quality of service.
- High level of functional interactions between Application Software Components.
- Portability of Application Software Components to any ECOA compliant computing platform.
- Interoperability between any ECOA compliant computing platforms.
- Support for many real-time scheduling policies.

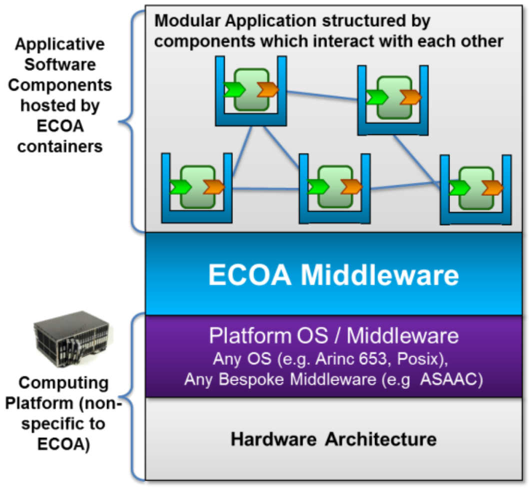


Figure 2: ECOA software architecture

Building an ECOA system consists of formally specifying the interfaces and the internal architecture of Application Software Components, assembling these components together using service links and specifying the deployment of the components over the computing platform nodes.

The details captured in the ECOA design model, formalized by the Open Standard metamodel, support the generation of the technical infrastructure code needed to interface, deploy and integrate the components onto the computing platforms.

The ECOA business model approach

To support modular system design and implementation with reusable components, a variation of the traditional business model is required. Consequently, within the ECOA collaboration programme, attention has been given to establishing a sustainable ECOA business model, which supports and is part of the comprehensive business model illustrated in Figure 1.

The ECOA business model has identified new business actors and their responsibilities, as well as highlighting specific activities related to modular/reusable systems that are being developed collaboratively. These activities integrate well with current business and system development practices, as illustrated in Figure 3.

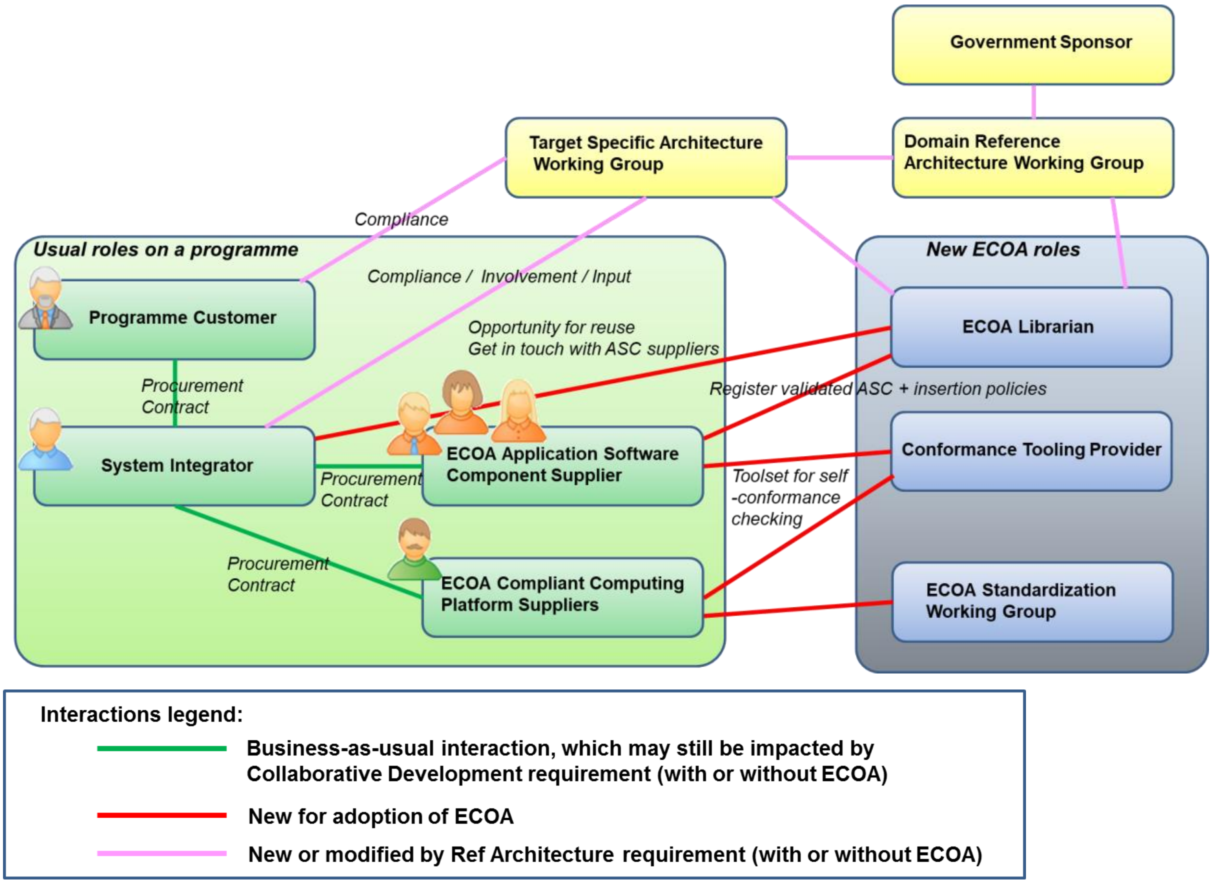


Figure 3: ECOA business model actors

The ECOA business model study found that industry business practices had already begun to adapt and embrace the evolution of open architectures, and establish technical strategies to certify software capability produced from modular software components sourced through the supply chain.

ECOA is a practical and usable approach to further support the collaborative development of complex systems (such as mission systems). It is appropriate for both early adoption onto initial programmes, and for subsequent programmes which could benefit from reuse options.

In any modern development programme, toolset procurement and support is a critical concern. ECOA system development is supported by current development toolchains but ECOA specific tools are required to realize the full benefits of the ECOA approach. These tools encompass design, early verification of models, source code generation and conformance testing for components and platforms. The ECOA business model has set out a staged approach for introducing ECOA specific tools into early adoption programmes.

The advantages of ECOA

ECOA provides a technical solution for implementing software components in a collaborative way.

ECOA focuses on standardizing software interfaces between functional code and containers, but does not restrict any technical solution for implementing the containers. This enables adoption of ECOA by computing platform suppliers who can utilize their existing capabilities (e.g. IMA) to build ECOA compliant products.

ECOA design models provide for the possibility of creating tools to automatically generate container code and the framework for application software. This reduces timescales for the development and integration phases, as well as limiting the occurrence of human errors during development.

The service oriented aspects of ECOA encourage application developers to focus on functional development rather than platform specific details. Consequently, the functional code becomes portable and easier to maintain.

ECOA model based engineering facilitates early validation during the systems engineering stages, thereby detecting errors earlier in the lifecycle and helping to streamline the overall system development and reduce timescales and budgets.

The ECOA technical specification has been published as Open Standards in UK and France by DefStan [1] and BNAE [2] respectively. The use of these Standards will ensure a common consistent adoption of the technology throughout the aerospace industry. The ECOA collaboration programme now aims at supporting a potential European standardization of ECOA.

ECOA is a technology which encourages the development of a market of reusable and portable Components, thus supporting the deployment of capabilities onto multiple programmes.

ECOA is a technology which caters for both new build and legacy upgrades. ECOA is capable of encompassing and interacting with legacy systems.

ECOA positioning with regard to other international initiatives

At present, there is no other technical standard equivalent to ECOA. This was confirmed during the UK-FR joint technical review of ECOA AS6 (TDC study ECOA phase 4).

The Future Airborne Capability Environment (FACE) is a standard being developed by a large consortium of aviation industry partners. It is focused on application portability at OS level as well as on standardizing interfaces between all application layers in an avionics system through a mediation layer. It also aims to provide a “reference domain” data model for a functional interface in military mission systems.

ECOA and FACE are complementary technologies, and since FACE is an interface-oriented standard while ECOA is a component-oriented standard, it would be possible to execute ECOA applications on a FACE implementation.

Variants of IMA, such as ARINC 653 and ASAAC, are largely HW/SW platform architectures that meet some of the goals of the ECOA collaboration programme. There is however, natural alignment between IMA and ECOA. ECOA communications mechanisms can be built on top of a messaging system such as those found in IMA, and this has been demonstrated in a number of implementations throughout the ECOA collaboration programme.

ECOA positioning with regard to IT Technologies

ECOA and IT technologies (e.g virtualization technologies such as Docker and Kubernetes) are largely compatible and complementary. Each approach differs in the level of abstraction and precision they instill in the software stack.

ECOA is clearly positioned at component level (inside an application) and can be suitable for applications of different typologies:

- Deterministic Real Time (e.g « traditional » mission system functions: fire control function, sensors management…),
- “Flexible” Real Time (e.g. AI based complex computation with loose WCET).

With regard to IT technologies, they are positioned at binary application level (on an OS that can be on a Virtual Machine) and more suitable for “Flexible” Real Time applications.

ECOA achievements and roadmap

The figure below illustrates the ECOA timeline and highlights the maturity gained by ECOA throughout the different phases of the ECOA collaboration programme.

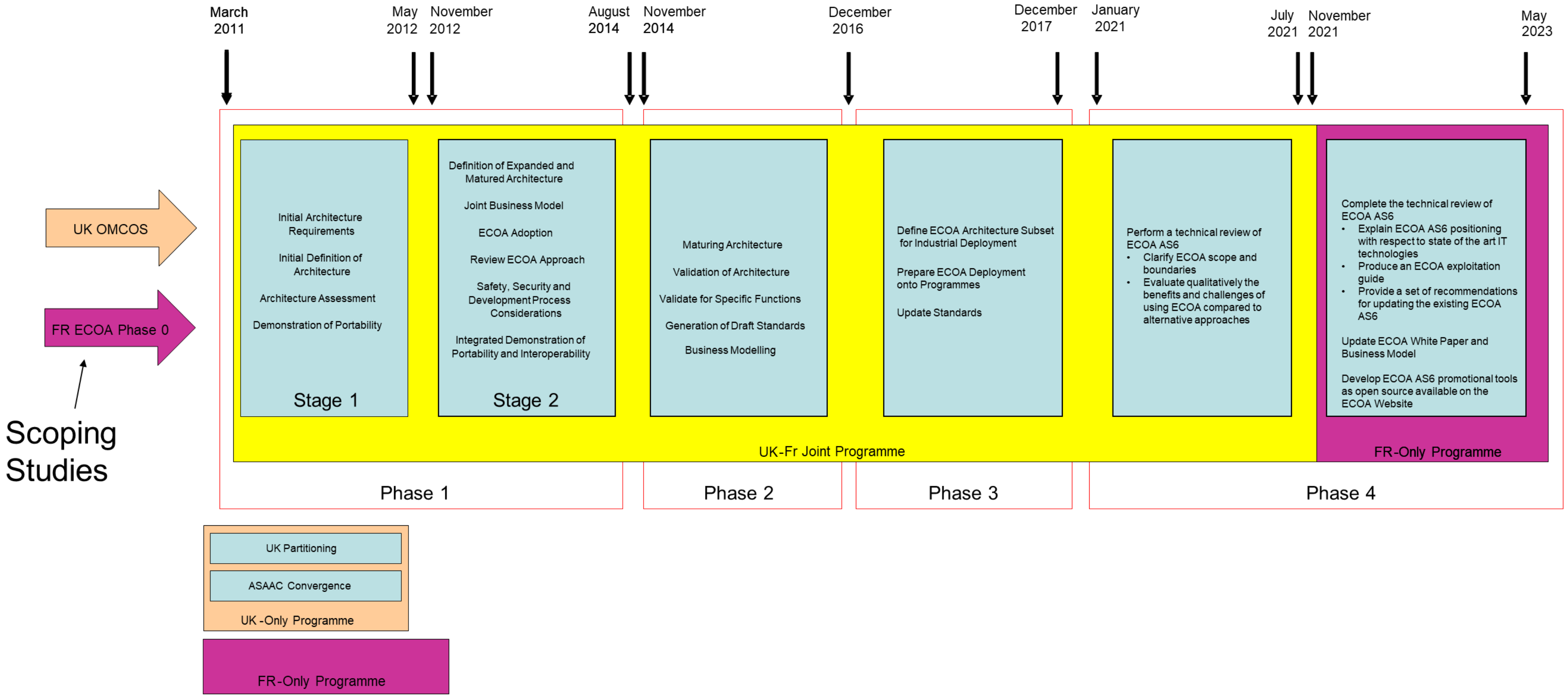


Figure 4: ECOA timeline

The ECOA collaboration programme has met its objectives and has provided a Standard which defines the application software architecture of choice for a number of ongoing and future programmes.

ECOA is used as a key technology for developing real time embedded Mission Systems.

- It has been published as an open standard [1] [2], which enhances its standing within the aerospace industry.
- It has been extensively prototyped and tested in several joint UK and French demonstrations, which focused on demonstrating portability and interoperability, providing confidence in the maturity of the technology.
- It has demonstrated benefits of software collaboration and integration. These benefits have been highlighted during ECOA phase 4 through a case of study of an open source code implementation done with and without ECOA. Thanks to its formal approach based on an XML model, ECOA allows to create lots of tools which significantly enhance the applications development process.
- It has been disseminated through a number of conferences and, in addition, has a number of resources, including guidance documents, promotional tools associated to an exploitation guide and tutorials which are available on the ECOA Technology website (see http://www.ecoa.technology).
- It has been assessed as being compatible with DO178C level C requirements, and hence it is suitable for the majority of Mission Systems applications.
- It has been assessed regarding safety and security aspects without any significant issue being identified.
- It has proposed a business model framework for adopting ECOA, which identified potential ECOA toolsets and priorities.
- It has been successfully deployed on the RAFALE F4 core mission system across multiple applications. This has brought ECOA benefits to the RAFALE programme as a key enabler for deploying application software modularity and by allowing multi-industrial software development without additional integration risks.

To further support the practical adoption of ECOA on programs some of the key aspects of the staged approach proposed by the business model report have been developed:

- ECOA Architecture Specification Issue 6 containing the core ECOA features which are mandatory for being able to develop an ECOA based System in a cost-effective way.
- A set of six AS6 promotional tools described in Table 1 below. These tools have been provided in open source at the end of the ECOA Phase 4 and allow to get a first evolutive ECOA design and development environment. They are available with an ECOA exploitation guide on the ECOA Technology website mentioned above. By providing this set of freely available tools, developers and organizations can more easily adopt and integrate ECOA into their workflows and projects. It is therefore easier to develop case studies that highlight the benefits of ECOA and to demonstrate how ECOA improves interoperability, portability, and reusability for software applications.

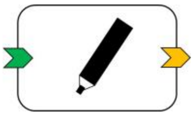
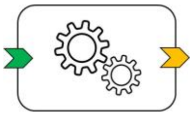
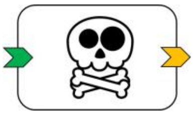
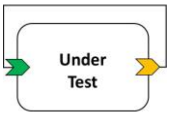
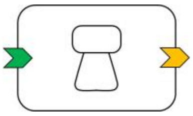
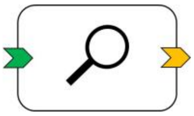
AS6 Promotional Tool Name	Icon	Description
ECOA EDITOR		A graphical editor allowing users to create step-by-step, or to simply update or visualize, an ECOA architecture. It offers an AS6 XML import/export function.
ECOA ENGINE		A tool capable of generating an ECOA middleware that executes components from an ECOA model, following specified deployment rules. This middleware can be used for development, test or demonstration purpose, but is not designed for an embedded use.
ECOA SKELETON GENERATOR		A tool that generates useful artefacts concerning ECOA modules implementation and test.
ECOA TEST GENERATOR		A tool that generates a new ECOA model describing components under test and a new "harness" component to stimulate and control them.
ECOA CORK GENERATOR		A tool that allows a non real-time execution of ECOA components, apart from any ECOA middleware, by generating minimal stubs for each API service call. The main purpose of these stubs is to ensure communication between components.
ECOA CHECKER		A tool that allows to check both the conformity of a set of XML files with ECOA AS6 specifications, and the consistency of described elements with each other. It can be executed on partial ECOA models.

Table 1 - ECOA AS6 Promotional Tools

The very positive return of experience from ECOA AS6 deployment onto RAFALE F4 has demonstrated that ECOA AS6 is a mature technological enabler, which fulfills expectations for supporting complex core mission system implementations.

ECOA phase 4 built up on this return of experience and performed a technical review which identified further opportunities for increasing ECOA interoperability with other standards as well as its backwards compatibility with legacy application components. These opportunities may lead to an update of the ECOA standard in the future according to the following roadmap.

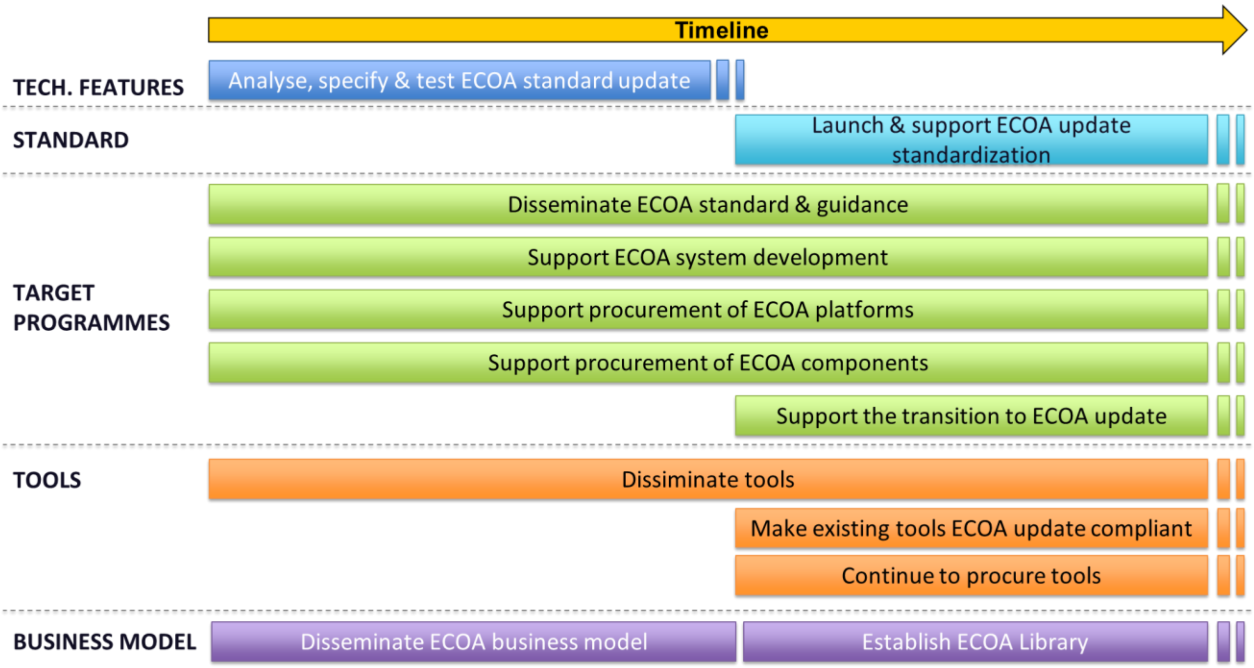


Figure 5: ECOA roadmap

7 References

Ref.	Document Number	Title
1.	DSTAN 00 973	Defence Standard 00-973: European Component Oriented Architecture (ECOA) Collaboration Programme
2.	RG AERO 000 973	General recommendations European Component Oriented Architecture – ECOA

Table 2 - Table of ECOA references