



**AeroSpace and Defence
Industries Association of Europe**

ASD STRATEGIC STANDARDISATION GROUP

Through Life Cycle Interoperability

A critical strategic lever for competitiveness

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Executive Summary

Vision

The ASD vision of through life-cycle interoperability is that ***‘All players of the global aerospace value network will be able to share digital information securely throughout the life of the products and services’***.

This may be achieved by the establishment and adoption of a coherent set of global information standards which are:

- A critical underpinning factor in enabling joint working between customers and industry through simplification of electronic trading and collaboration.
- A prerequisite to ensure interoperability of product and services information, increasingly based on COTS applications, that have a life cycle not compatible to the aerospace and defence products life cycles (above 50 years).
- The key enabler to respond more quickly to changing requirements, to further optimize processes, improve data quality and drive out unnecessary costs associated with integration and by recommending the most appropriate solution components.

The Business Challenge

The Aerospace and Defence Industry is characterised by a small number of large prime contractors, a global marketplace, a large global supplier network shared among primes and other industries with an average supplier size of 20-50 employees, long product and service life cycles that far exceed the life of software, equipment and people, continuous innovation in products, processes and services for new capabilities and for regular technology upgrade programmes. In many cases this is also subject to rigorous certification requirements. The Industry has also seen the development of new service contract models that include electronic customer services, management of the in-service phase and feedback from service into the design phase. The consequences from all of these business imperatives across the complex lifecycle is the need to manage design, product and service information throughout the product lifecycle, including rigorous configuration management and the long term retention of information, where the data is ‘created once and used many times’.

These interoperability requirements will become more and more critical in the next years, with the move to “Model-Based” engineering practices, where human operators will not be able anymore to interpret directly product representations. A typical example is Product Manufacturing Information, like tolerances, that was previously graphically represented and will become mathematically and semantically represented inside 3D models, with the need to correctly interpret this digital information in downstream processes such as manufacturing, measuring, maintenance.

Moreover the A&D industry has to take into account the national security constraints, export control and intellectual property management related to digital information, in particular related to the supply chain.

Another challenge is to ensure the availability of interoperable IT services for the exchange and sharing of information.

To face this challenge, the **A&D Industries need a coherent standards based approach** that allows the secure sharing of data and models, with partners and suppliers across a global support network, supported by collaborative efforts to ensure and validate the implementation of those standards by vendors.

Benefits

The benefits from a coherent standards based approach to address the business imperatives for through life interoperability apply to all players in the global value chain: prime contractors, collaborators, suppliers and customers. These benefits are delivered through significant reductions in cost and risk and from a faster route to market and to service delivery.

The value will be different for each project or set of projects, for each company and for each step in the lifecycle.

There are many elements to consider when assessing the value of these benefits. These include: increased accuracy of data that can be created once and used throughout the lifecycle, the ability to pass models and exchange information with confidence that all stakeholders use the same data, the ability to re-use models and data for technology enhancements, modifications and for new designs, the simplification of electronic trading where information about products, their condition, their location and quantity can be linked to user needs and to the payment process.

Additional cost and risk benefits also accrue from the ability to provide the right information to the right person at the right time to permit the best decisions to be made for design, supply and support.

ASD SSG answer

The current document begins to build the reference standard architecture needed to drive the Aerospace and Defence industry to successful interoperability, and to provide a sustainable framework for supporting and enhancing the deployment of the necessary standards-based solutions.

This analysis results in the following initial set of recommendations that particularly recognises the value of ISO 10303 STEP Application Protocols, and intends to make these standards the cornerstone of the PLM information interoperability:

1. Strengthen the STEP architecture approach to 1) ensure interoperability between STEP standards and 2) provide unambiguous implementation methods (including for new information technologies, e.g. OSLC).
2. Ensure that 3D visualisation format standards used in the industry are consistent with STEP standards
3. Ensure the common data model for the ILS specifications is consistent with STEP AP239.
4. Promote the ASD-AIA ILS suite of specifications and seek to manage coherence with ATA specifications where needed by the industry.
5. Participate in the development, and interoperability testing of the next generation of PDM/PLM web services.
6. Facilitate data interoperability in the Aerospace and Defence Supply Chain and align business process between Supply Chain stakeholders.
7. Supports the setting-up of implementer forums (e.g. PDM implementer forum) to test and validate the implementation of the standards-based solutions.

Once the proposed recommendations have been refined and shared with partners in the standardisation community (including standardisation associations, IT vendors, solution integrators, as well as AIA and trade associations from other sectors like automotive), the ASD SSG intends to collaborate with these partners and implement a set of actions as part of a global roadmap for convergence to the reference standard architecture.

This will include new and updated standards, with support for implementation through implementer forums. Several of these actions are already identified and/or up and running such as the development of AP 242, JT ed2 and the suite of ILS Specifications, and white papers are being developed to gather support for other actions (e.g. STEP AP242 ed2, STEP AP239 ed3, PDM implementer forum).

To support this, the proposal is to set-up a joint ASD-AIA strategic governance group to expand the existing collaboration between AIA and ASD on digital interoperability.

It is anticipated that the ongoing work of the SSG will further refine the framework and lead to additional recommendations in order to support a growing library of industry use cases.

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1. Introduction

1.1. ASD SSG

This paper on Through Life Cycle Interoperability has been created by the ASD Strategic Standardisation Group (SSG). The SSG was set up in October 2008 by a group of European manufacturers, Aerospace & Defence (A&D) associations and military governmental agencies in order to share efforts towards the identification of a common and coherent set of A&D interoperability standards and associated harmonized European policies to assure interoperability across the industry, its customers and its supply network.

The ASD SSG aims to support effective governance at European level of open interoperability standards and works with the US Aerospace Industries Association (AIA) for global harmonisation. The ASD SSG's missions are to:

1. Identify the business requirements for aerospace and defence digital information interoperability, and analyse gaps with existing standards and practices,
2. Identify a set of coherent standards to use or to develop in order to cover the full spectrum of needs for interoperability,
3. Propose and apply governance tools at strategic and technical level (e.g. radar screen, interoperability framework, assessment process),
4. Develop a network of experts,
5. Develop liaisons with all relevant standardization organizations,
6. Identify and communicate the business benefits,
7. Seek the widest exploitation of these standards to maximise global benefits.

The ASD SSG work is organised in several areas:

- Product Lifecycle Management,
- Integrated Logistics Support,
- Supply Chain,
- Secure Information Sharing,
- Data Quality.

1.2. Objective of the paper

This paper is a transverse study aimed at developing a "big picture" of all the components required to ensure Through-life cycle interoperability to maximise business benefits, including:

- Product breakdown mapping mechanisms (e.g. Design BOM - Support BOM),
- Configuration management (versions, change process) issues,
- Through-life cycle services (managing the service business, feedback to design...),
- Interoperability along Supply Chain procurement process,

- Long Term Archiving and retrieval of product and services information,
- Related security issues.

This consists first in the identification of the relevant standards to be considered in order to constitute a "backbone" of standards enabling through life-cycle interoperability, e.g. STEP AP242, AP239/PLCS. The basis for the identification of this "backbone" is the work that the ASD SSG has been carrying out for each of the areas, and that needs now to be envisaged globally over product life-cycle.

It then seeks to identify the interoperability issues and associated business impacts, and then to propose approaches to resolve these issues.

The approach is based on defining a list of elements to be considered for successful interoperability (PBS exchange, message exchanges, virtual plateau organization, etc.), then on the identification of existing gaps concerning these elements, and finally to propose activities with priorities (e.g. which interface between domains) for closing these gaps. In addition, recommendations will be provided for ensuring interoperability across domains.

1.3. Structure of the paper

Chapter 2 describes the interoperability challenge in the A&D industry, and why model-based engineering will make interoperability a critical enabler for the industry.

Chapter 3 analyses the existing standards for interoperability (using the ASD SSG Radar Chart) from a through life-cycle interoperability perspective.

Chapter 4 drafts a possible architecture of standards in support to this vision and develops an initial list of associated recommendations.

The Executive Summary provided at the beginning of the document provides an overview of the document content and summarises the resulting recommendations.

2. The interoperability challenge

2.1. Paradigm shift: from paper to full model-based engineering

The move of the Aerospace & Defence (A&D) industry to computerised models is not new, as CAD systems deployment started in the early 80s¹, progressively replacing previous drawing boards in Design Offices. However these first "models" used in the industry were organised to support a "paper-based" technical process, e.g. CAD drawings being managed in the same way as paper drawings (in terms of artefact representation and validation process).

Today we see the emergence of full model-based engineering, from early design to in service operations. In this approach, models of the product do not serve a traditional process similar to the paper-based one, but models become the core support for product design, product manufacturing, product certification, product operations, support services, and disposal.

A typical example of this move is the consideration of 3D CAD models as the reference definition for product physical design (3D CAD models including 3D geometric dimensioning and tolerancing semantic representation): human operators will not be able anymore to interpret directly product representation, interoperability will have to be guaranteed all along the data chain from design to manufacturing, measuring, maintenance operations, and data archiving.

Another type of issue relate to process automation. For example forecast-driven automation of procurement process along the Supply Chain is developing (e.g. through Supply Chain hubs), however some disruption of the Supply Chain numerical flow remains due to multiple EDI formats. Moreover, misalignment of business process could create disruptive effects, like larger and larger swings in inventory in response to changes in customer demand.

In addition to the ever-present need to drive out cost and waste, the move of the A&D industry to this full model-based engineering is critical, as the ability to master this new paradigm is fundamental for addressing industry challenges in the 21st century:

- Systems Engineering, including configured requirements management,
- Virtual product validation and verification,
- Services; new support services to customers,
- Novel product architectures,
- Eco-efficiency, energy efficiency,

¹ Actually the first AECMA work on data exchange related to the previous generation of surface geometry systems in the late 1970's

- Preservation and exploitation of digital assets of companies,
- Recycling.

Figure 1 provides an overview of model usage throughout the life-cycle. These models need to be shared and exchanged across all business functions with the corresponding supply chain / extended enterprise. These models also need to be co-ordinated throughout the life-cycle.

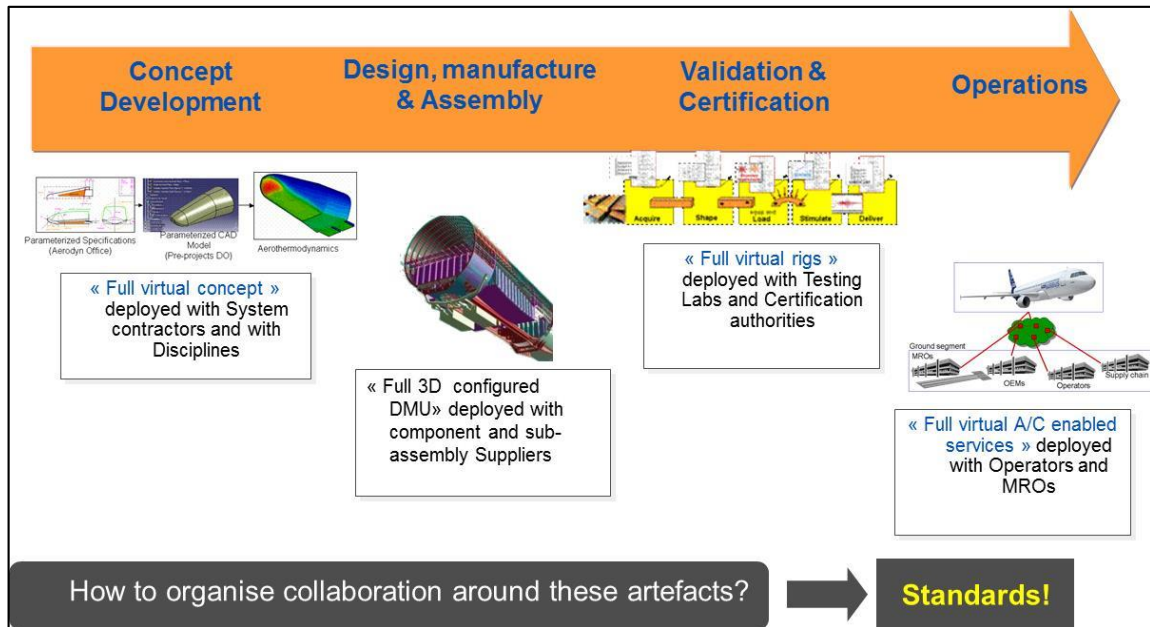


Figure 1: Model-based approach along the life-cycle

The global performance of this new engineering paradigm relies on the quality of the shared information and the effectiveness of information sharing processes which deliver the right information at the right time in the right form, underpinned by standards as key enablers.

2.2. Need for an Enterprise level data consistency

A second major change impacting our business today is the explosion in the volume of data flowing through the life-cycle. As illustrated in Figure 2, data and models are generated and exploited from early requirements identification up to product disposal.

The complexity arises from the combination of the diversity of business activities, applications and data repositories used along the life-cycle, the need to co-ordinate and synchronise heterogeneous product views and from the sheer volume of data such as that required to manage the product in service (including for example Health Monitoring data).

Complexity arises also from the many product views (as-designed, as-manufactured, as-maintained, etc.) which are created and need to be managed from the beginning of the development cycle as they evolve in different ways.

The feedback loops illustrate for example the need of re-design to solve operational issues. These loops highlight also the fact that the "life-cycle" concept itself is misleading, as it is often incorrectly presented and/or understood as a set of sequential phases.

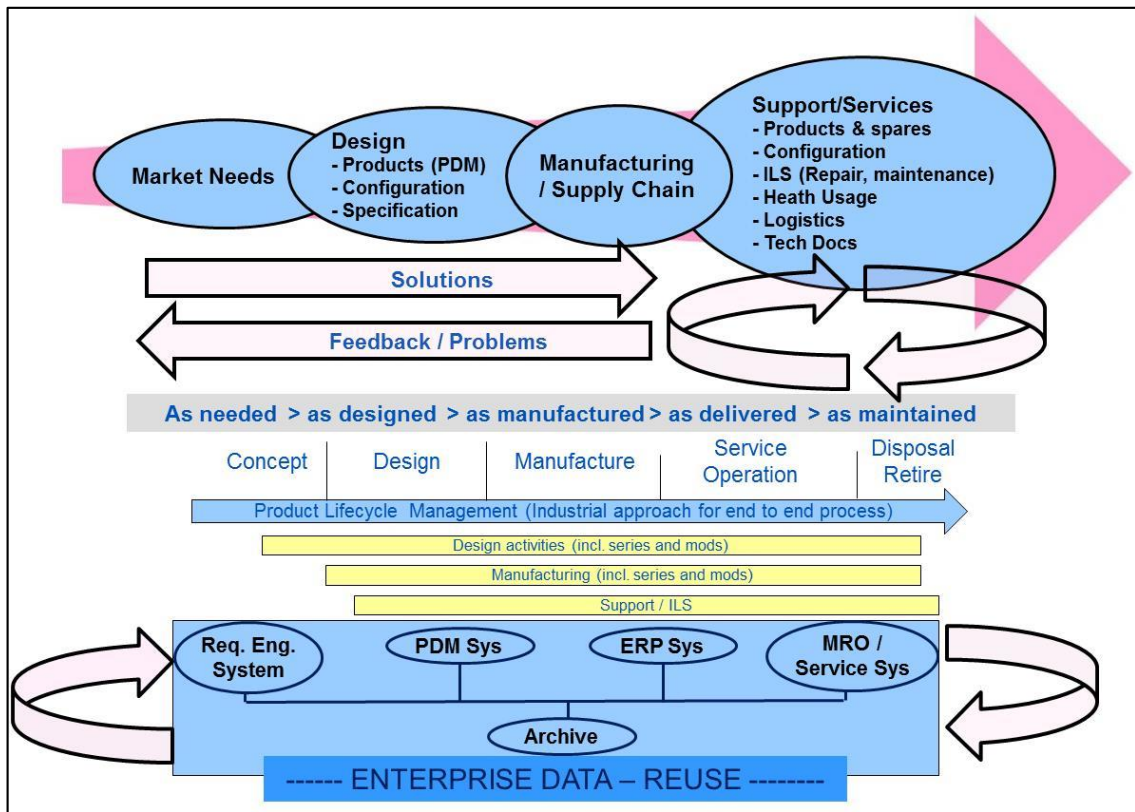


Figure 2: Data explosion through the life-cycle

The Product Life-cycle Management (PLM) approach develops a vision where a set of authoring tools connected to a common data backbone generate and exploit a coherent overall dataset. This vision is not yet in place today, as data is spread in a number of repositories (e.g. PDM systems, MRP systems, MRO / operational services systems) operated by multiple enterprises through the life cycle, that ensure their own local data consistency but fail to ensure through life cycle data consistency.

2.3. Configuration management throughout the life cycle

A global and co-ordinated approach to product data and models requires a rigorous analysis of the various sets of data and their life-cycle.

Despite a generally agreed concept, there is not one "Product life-cycle" that structures product data, but several datasets need to be considered, each having its own consistency and life-cycle.

Figure 3 illustrates several of these datasets, as managed within an Aircraft programme. The upper part of the figure focuses on the "Reference Product" dataset, principally owned by the Original Equipment Manufacturer (OEM). This dataset gathers all product views (as-

designed, as-manufactured, as-maintained). This dataset supports the Type Certificate from the Certification authorities (it must be highlighted that certification doesn't apply to flight test aircraft, but indeed to the reference dataset that flight test aircraft are considered to implement). During the period of up to 60 years after certification, this dataset is exploited to build, operate and support individual products, which may be uniquely identified by for example Manufacturing Serial Numbers (MSNs). In object technology wording, MSNs are instances of the Reference Product.

The "Develop New Aircraft" (DNA) process in Airbus is a typical example of the "Develop Reference Product" arrow in the Figure.

During the "Exploit Reference Product" phase the Reference Product evolves. In civil aviation, these evolutions are mainly linked to Airworthiness Directives (ADs) and Service Bulletins (SBs). Larger evolutions, requiring additional certification, can also happen related to additional models (derived from the same type certificate) or Supplemental Type Certificates (STCs), for example a freighter version derived from a passenger aircraft.

As an aircraft embeds some components (e.g. equipment, standard parts) that are commercial off-the shelf (COTS) products that have their own lifecycles, information related to these COTS products evolve independently of the Reference Product life-cycle and introduce additional complexity such as obsolescence issues.

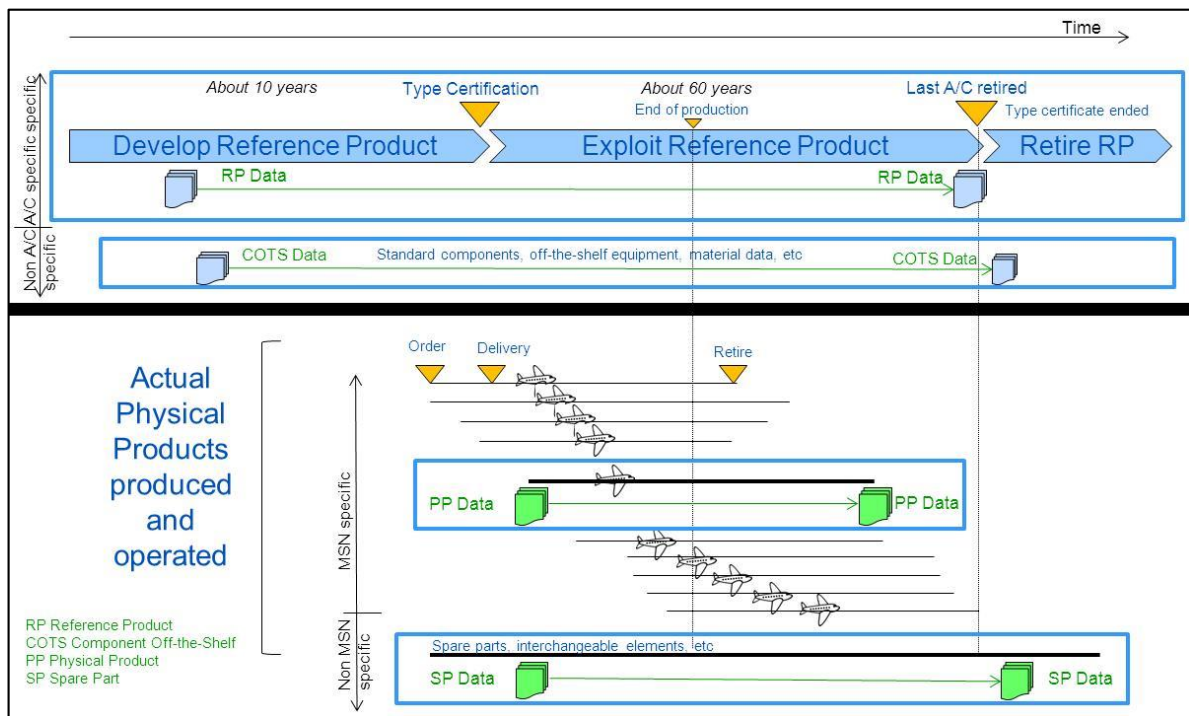


Figure 3 A/C datasets and their life-cycles

The lower part of Figure 3 focuses on Physical Product (PP) data. Each physical product instantiates the Reference Product (RP), and is identified by a Manufacturing Serial

Number (MSN) or equivalent identifier. Additionally, spare parts (SP) information evolves independently of any MSN.

This information typology and related life-cycles are not taken into account in Systems Engineering standards like ISO 15288. However their consideration is key to understanding how the engineering datasets relate to each other and to developing an overall configuration management process.

2.4. Dynamic coordination of Product views and baselines

Clear identification of managed product views and product baselines is essential to structure product datasets. As illustrated in Figure 4, product views are transverse across the entire lifecycle and managed in parallel. A product is defined by all its views. Baselines are used to structure the engineering activities - typically based on product trees with components and/or nodes allocated to the various partners involved in the Extended Enterprise.

At the pre-project phase, all views are coordinated by the pre-project team within the OEM. In the development phase, views are allocated to “engineering domain” teams. During the “Exploit Reference Product” phase the views are spread between the design function (as-design view), the manufacturing and assembly functions (as-built view) and the in-service functions (as-maintained view) which could be spread across multiple organisations (e.g. supply chain and support network).

At a given time, a product baseline crosses all product views. Baselines refer to Configuration Management and are used not only to trace data evolution but also to drive evolutions through change management processes.

The Reference Product (RP) definition matures then from baseline to baseline, up to certification. It is then used to build Manufacturing Serial Numbers, and still evolves during exploitation due to updates/enhancements.

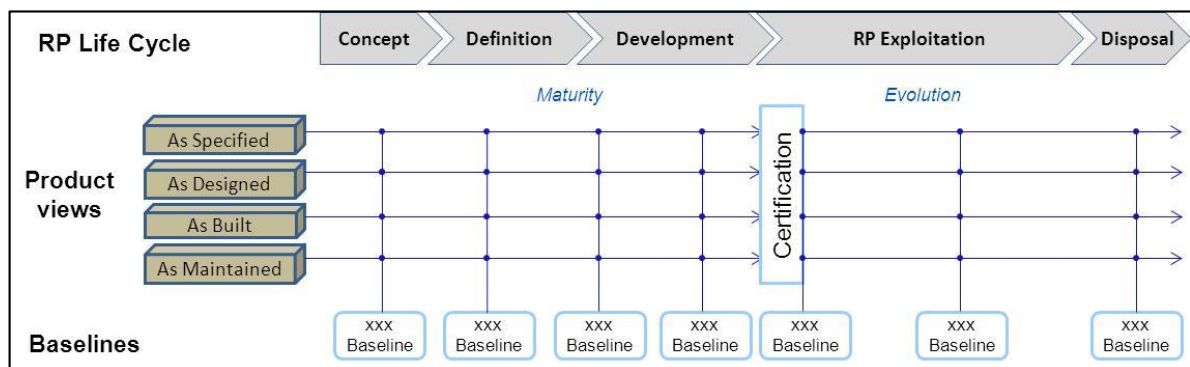


Figure 4: Reference Product (RP) views and baselines

The move to model-based engineering will require the product views to be coordinated dynamically, with the ability to federate models from several views to assess complex behaviours or perform global decisions. This will reinforce the needs for seamless communication and increasingly sharing of information between organisations and disciplines throughout the life-cycle.

2.5. Need for enhanced collaboration processes

As stated in the previous section, a large number of actors and companies is involved to develop and operate the datasets. This includes OEMs (e.g. aircraft architect and integrator) design office(s) and final assembly line(s), engine manufacturers and their supply chain, component/equipment suppliers design offices, simulation centres and testing labs, manufacturing sites, integration sites, flight test site(s), customer support sites, customer offices and operation sites, maintenance sites, etc.

Each of these actors owns a subset of these datasets. This network of actors, or "extended enterprise", is structured by contracts and intellectual property rights apply to the datasets. Each actor manages its own subset in its data management systems, whether a requirement management system, a product definition management (PDM) system, a product manufacturing management system (e.g. ERP), a product operation management system, a product maintenance management system, etc.

The PLM interoperability challenge is to enable these actors to work securely and efficiently on coherent product views.

The move to model-based engineering will significantly reinforce this challenge, as co-simulation for example will require models to be connected seamlessly with short response times.

The current way to ensure consistency between product views and related datasets is through one of the following collaboration processes:

- **Data exchange:** data is exchanged through digital files or Technical Data Packages (TDP). In case of data modification or complement, only the updated part may be exchanged. This collaboration process being asynchronous could require some reconciliation mechanism to maintain product view consistency.
This type of exchange generally requires the partners to formally agree on exchange principles, process, formats, configuration, traceability and quality rules. To protect its Intellectual Property, the sender could choose to reduce the content to be sent, e.g. by removing some part of the data (design rational, parametrics) or by exchanging using a light visualisation format.
- **Data access from a centralised database:** one partner centralises product data and grant access rights and modification rights to part of the database to other partners.

- Data sharing through data hubs: hubs provide a neutral space to share information and to synchronise workflows.
- Direct linkage between data repositories: this solution is in general sought when repositories are hosted inside the same company, to avoid replication of data. This is the case for example when connecting a PDM and an ERP through an Enterprise Service Bus. This collaboration process is quite difficult to develop in an extended enterprise context, due to the diversity of the data management rules (the mapping is not obvious), security, export control and IP protection reasons. Nonetheless some new IT technologies, such as OSLC, propose innovative ways to handle the problem.

These collaboration processes require data exchange contracts between involved actors, to ensure effectiveness and quality of the exchanges.

2.6. Need of compliance of digital model based processes and methods with airworthiness regulations

The Airworthiness authorities have defined rules and applicable means of compliances (AMC) based on aerospace processes and methods relying on paper documents. These regulations for Airworthiness and Continuing Airworthiness have started to evolve in order to take into account the digitization of most of the aerospace processes and information, and the increasing role of the supply chain in the design and manufacturing of new aerospace products.

There are on-going activities between the aerospace industries and the certification authorities to define new rules and applicable means of compliances compatible with digital model-based processes. In most cases, the new regulations will result in new AMCs, referencing open interoperability standards, such as NAS/EN 9300 or the ISO 10303 STEP AP 242 and AP 239 PLCS.

2.7. Case 1: Design-ILS interoperability challenge

Design and support decisions during conceptual / development phase have the greatest impact on performance, lifecycle cost, and Reliability, Availability, Maintainability and Testability (RAMT) when accomplished early in and throughout the system engineering process. Top level requirements are usually given by the Customer. If no Customer requirements are available, e.g. for company financed demonstrators, targets have to be identified by comparative analyses, market surveys etc.

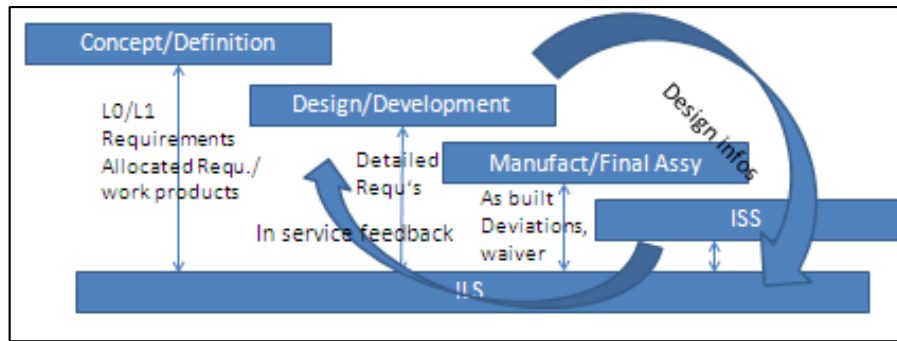


Figure 5: Design-ILS interoperability

The close link between the RAMT and ILS process is fundamental for the support of the product in the In-Service Phase. Therefore it is essential that ILS is included from the beginning of the definition of the RAMT requirements. These RAMT requirements will be further broken down in the following phases. The results from these RAMT requirements (Baselines)/ documents (Specifications) will be released as a RAMT / ILS statement for compliance.

Further detailed requirements are:

- RAMT System requirements,
- RAMT Equipment requirements,
- Structural analysis (e.g. inspection Intervals, preventive maintenance, RCM),
- Zone analysis.

These will be condensed either into models or documents depending on the paradigm of working.

The development/design results have to be verified by RAMT. However to guarantee that development/design results will comply to RAMT requirements and the resulting support resources (ILS), an early and on-going communication will be necessary.

To facilitate this, in many cases, data sharing within a PDM/PLM backbone environment will take place.

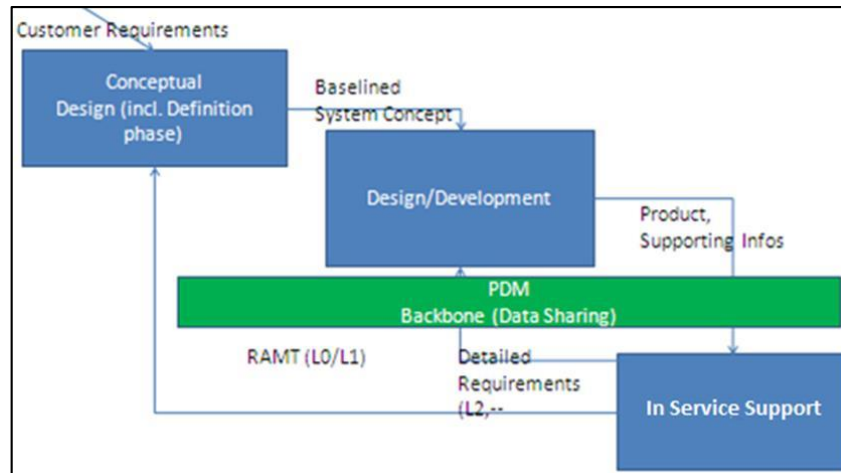


Figure 6: PDM data backbone

For the mechanical and electrical design, a digital mock-up is an important tool to enable this.

A number of products delivered by design/development will form input to ILS products e.g. for technical publications, maintenance planning and scheduling, material support, training, etc. The downstream ILS processes will be significantly enhanced in terms of efficiency once these data can be shared or re-used without information loss or excessive data mapping.

Once design is complete and the product is in manufacturing/final assembly, additional data will be handed over to ILS including:

- As built configuration per manufacturing serial number (MSN),
- Deviations from the design standard,
- Waivers,
- Limitations.

Information will be fed back from the in-service operations to Design/ Manufacturing to improve both product design and manufacturing processes. Both OEMs and operators will be required to trace and validate any change in configuration in regards to the certified allowable configurations.

ILS delivers a number of Verification and Validation methods and instances which contribute to the qualification/certification of the relevant items.

Out of Design data will be handed over to the material supply systems of customers to enable material management.

An intensive data interchange is ongoing with all RAMT / ILS disciplines to enable pilot and maintenance personal to operate the product effectively and efficiently. This will include design data, S/W, and in great extend configuration and mission /performance data.

3. Status of interoperability standards

3.1. Global landscape

It is essential to have a global view, in order to be able to select the key components (standard processes and methods, standard information models and services) which should be deployed by the industry to ensure the necessary capabilities for through life-cycle interoperability.

The overall strategy adopted by the SSG is to recognize that many interoperability scenarios can be identified, each with their own contexts, applicability and importance to one or more stakeholder groups. These scenarios are likely to be overlapping and may not be consistent.

The need for interoperability can emerge between companies and their business partners across a supply network, between functions in an organization, and even between applications within a function. Many standards and initiatives have the potential to provide components to satisfy part of the overall industry requirements for interoperability, but the key challenges are to reduce overall cost and complexity by identifying the most appropriate solution components, and to provide concrete guidance on how to satisfy specific business requirements using an appropriate selection of those components. In order to get best value from this range of investment by many groups, ASD SSG has defined a clear strategy for adopting the standards that its members need to exploit the full potential of interoperability. In order of preference:

1. SSG adopts existing standards for use in the aerospace industry,
2. SSG influences standards organizations through participation to meet its requirements,
3. SSG develops its own standards or guidelines in coordination with ASD Stan when none exists from standards organizations, although the results may be submitted to the applicable standards organization for international adoption.

In each case, the SSG may supplement existing standards with aerospace industry-specific implementation conventions, constraints, models/examples, or guidelines.

An additional strategy axis is the cooperation with AIA, with the aim to develop a common vision on e-business standards, to reinforce the weight of the Aerospace and defence industry requirements in standardisation bodies, and to develop common guidelines related to the adoption and use of e-Business standards within Aerospace processes.

The ASD SSG have adopted a 'Radar Screen' approach to help to identify the standards that are available for use and to down-select to a coherent set of mature standards that should be used to maximise interoperability and drive down costs. Figure 7 provides a snapshot of the ASD SSG Radar Screen that is maintained by the group and published on ASD SSG website (<http://www.asd-ssg.org/>).

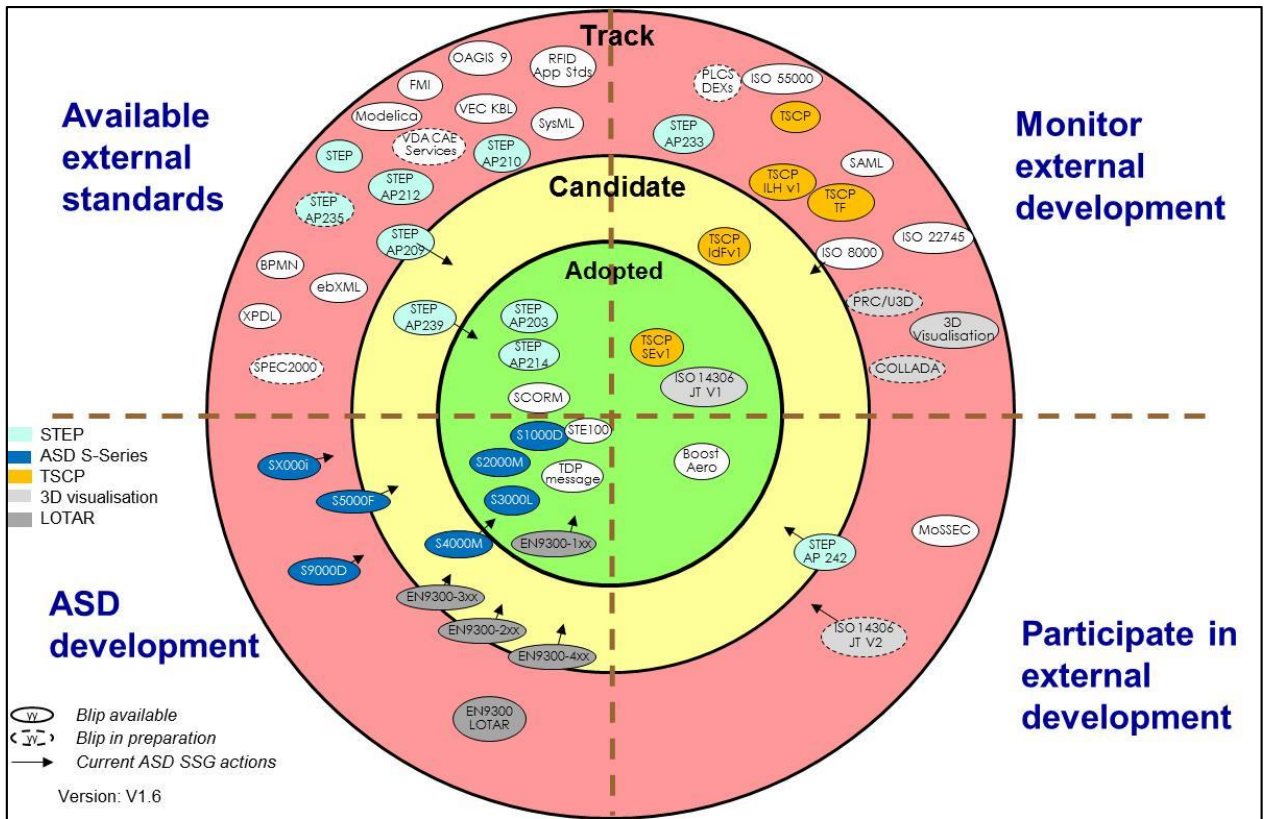


Figure 7: ASD SSG Radar Chart

This Radar Screen provides an overview of all standards potentially contributing to interoperability. This includes:

- ISO 10303 STEP standards (in light blue), mainly used for the "as-design" view.
- PLCS DEXs - managed by OASIS -, mainly used to provide subsets of the overall PLCS models for the "as-maintained" view. DEXs used in the industry are based either on STEP AP239 ED1 and DEXlib or AP239 ED2 and PLCSLib.
- ASD ILS suite of specification (dark blue), help to link from the design phases of the lifecycle to the "as-maintained" view
- LOTAR standards (in dark grey) for the long term archiving of digital data. As an example LOTAR EN9300-110, -115, and -120, based on based on STEP AP242 is currently used for long term archiving of A350 electrical harness installation, with the agreement of EASA.
- 3D light visualisation formats (in grey).
- ATA standards, used for the delivery of maintenance information to airlines in civil aeronautics.
- BoostAero used for the supply chain transactions and implemented in BoostAeroSpace AirSupply.
- MoSSEC proposed as a standard for support of modelling and simulation collaborative studies, based on PLCSLib.
- TSCP standards (orange) for secure information exchange.

- Modelica & FMI for system behaviour modelling, model integration and co-simulation.

3.2. Analysis of standard landscape consistency from a cross-domain perspective

3.2.1. Consistency of STEP standards

Cross-domain rationale: the ISO 10303 STEP suites are pervasive and intervene in many domains (design, manufacturing, support). Interoperability between the several STEP Application Protocols is then seen as a key contributor of cross-domain interoperability

As illustrated in the next figure, the STEP series of standards has been designed to cover the entire life cycle of product data across all functions throughout the supply network.

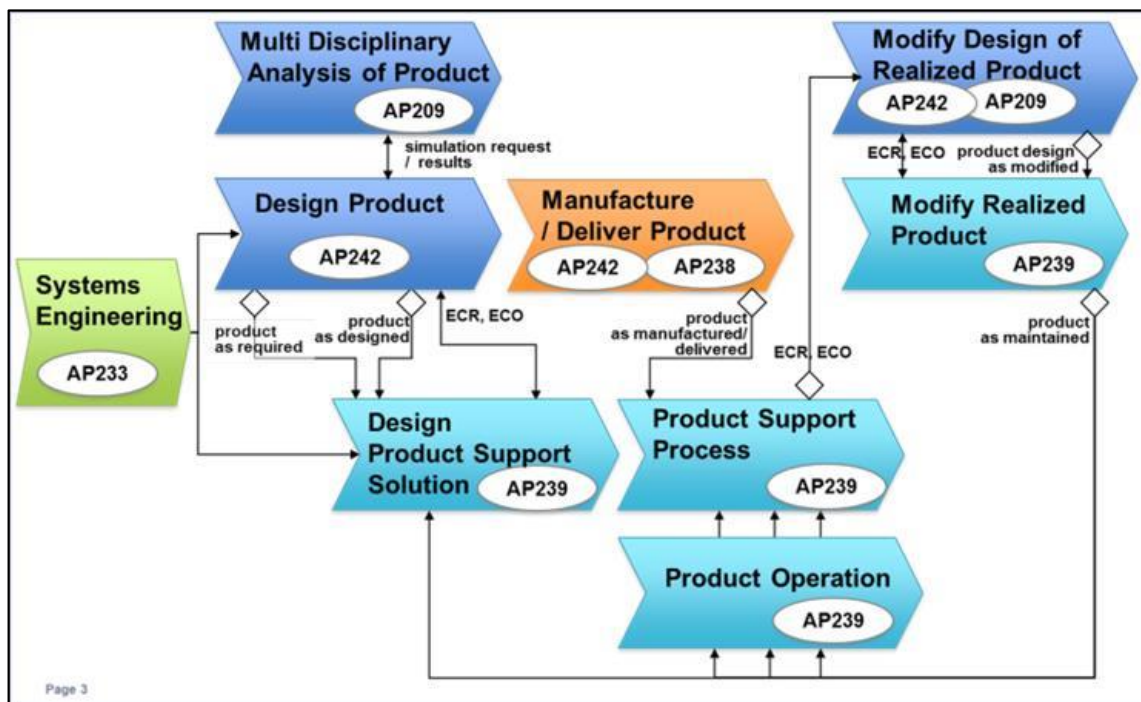


Figure 8: Overall information flow covered by the STEP Application Protocols

A single information model has been proved to be unwieldy for supporting individual business scenarios, which led to the development of Application Protocols, each optimised for a particular function or scenario. Each Application Protocol includes a definition of the scope of the domain of its applicability, often illustrated by an activity model compiled using the terminology of the related domain to illustrate processes and information flows. The corresponding data requirements are again expressed in domain-specific vocabulary as an Application Reference Model (ARM) and mapped to an integrated set of information resources to ensure that common concepts are recognised and reused. The integrated resources are extended as necessary to accommodate new concepts that are required by

an AP, and the extensions are then available for re-use. The mapped model is known as an Application-Interpreted Model (AIM), which is used for implementation. Each AP is typically developed separately as a single monolithic document, but this approach often led to different interpretations of the same concept in a large and complex structure.

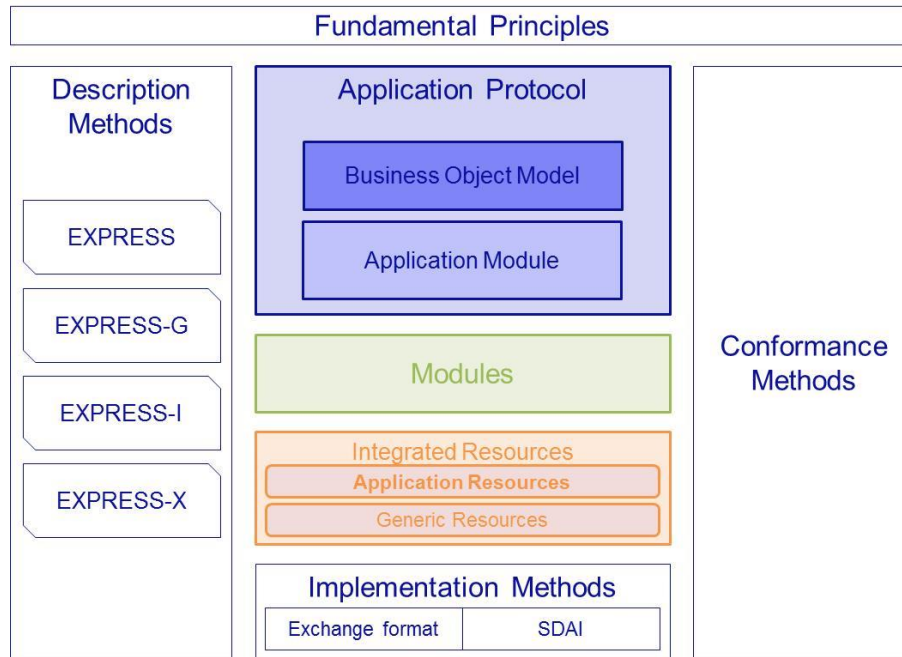


Figure 9: STEP architecture

In order to avoid this proliferation of similar but incompatible models, the STEP community then developed a modular approach to ensure consistency between STEP Application Protocols used in various business domains. All "modularised" Application Protocols (APs) are based on a library of modules which comprise fragments of references models and the mapping to the corresponding integrated resources that can be shared with other APs. This allows software providers to similarly reuse their software implementations. For simplicity of configuration management, all the modules and the underlying resources are managed in a single STEP Module and Resource Library (SMRL) which is controlled and published under an ISO Change Management process.

ISO 10303 defines in its part 11 a formal data specification language, EXPRESS which is used to specify the representation of product information in STEP models. The use of a formal language provides unambiguous and consistent representation and facilitates development of implementations. EXPRESS provides a number of specific capabilities required for product data modelling that are not available in more modern modelling languages. EXPRESS is supported by tools for graphical representation, instancing and mapping.

ISO 10303 separates the techniques of representation of product information from the implementation methods that support the exchange and sharing of product data defined in application protocols. The available implementation methods include file-based exchange/sharing methods, and database access methods.

- Exchanges are based on clear text files, with syntax as defined in Part 21: “STEP-File Clear text encoding of the exchange structure”. Such files reference the schema used, defined in EXPRESS.
- Files may also be encoded in XML, using part 28, with optional configuration files
- Database access is defined through the Standard Data Access Interface (Part 22: SDAI). It defines a low level application programming interface to EXPRESS defined data, such as STEP Application Protocols. STEP defines the set of general SDAI operations in ISO 10303-22. These operations are then implemented in a specific programming language by a language binding. SDAI bindings have been defined for C, C++, and Java.

ISO 10303 also provides conformance testing methodology and framework, although this has not been extensively used due to lack of marketplace demand.

The objective of data exchange cannot be completely achieved unless systems can be tested to determine whether they conform to the relevant product data exchange standards. There is an industrial need to establish conformance testing services for implementations of ISO 10303.

Conformance testing is defined as the testing of a candidate product for the existence of specific characteristics required by a standard in order to determine the extent to which that product is a conforming implementation. It involves testing the capabilities of an implementation against both the conformance requirements in the relevant standard(s) and what the client states the implementation’s capabilities are.

The Business Object Model (BO Model) was introduced recently in AP242 and AP209, in response to a need to have information definitions at a level which was easily understood by business in their own terminology. Introducing the BO Model allows an information model in the language of the business discipline experts. In addition, the BO Model is on a high level of granularity and thus more suited for the communication with and understandable by domains experts (e.g. Aerospace and Defence and Automotive for AP242). An XML schema may be derived from the BO Model, formalised with EXPRESS, in order to support the implementation of data exchange and sharing.

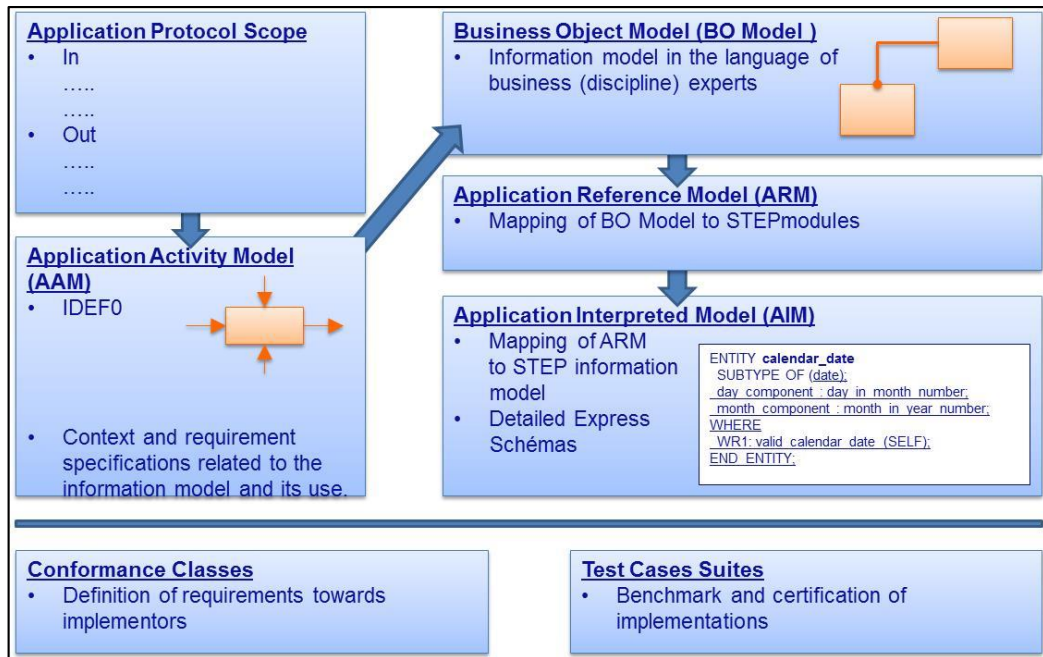


Figure 10: STEP architecture with BOM included

The STEP architecture including the BO Model is shown in Figure 10. A number of challenges to interoperability arises from this architecture.

- The original concept of monolithic STEP APs led to incompatible information models which did not interoperate, leading to a demand for “Recommended Practices” which facilitated common use. This was largely addressed by the introduction of the modular approach, but not all STEP APs have yet been converted to modular form. For example AP238 for STEP-NC and AP235 for material properties remain as monolithic documents, although the modules for the latter already exist within the SMRL in order to support the new AP 242. AP214 for the automotive industry remains monolithic, as it will only have legacy interest after the publication of AP242.
- For modular APs, interoperability issues can arise when the SMRL containing all the component parts is updated to reflect new APs. Changes to modules and their architecture through subdivision and aggregation can demand the regeneration of the AP based on the updated SMRL. If an AP is not updated due to lack of resources, then there is a risk that it will be rendered non-interoperable with those generated from the new SMRL version.
- Interoperability can also be destroyed by selecting different implementation methods with the same application protocol, unless the translators are capable of accommodating all implementation methods.

3.2.2. STEP alternative implementation approaches

Cross-domain rationale: typical cross-domain issue arises from efforts to simplify deployment of STEP by developing alternative implementation approaches.

For example, in an effort to develop a service-oriented approach to deployment of AP214, a series of PLM services were developed in cooperation with the OMG, based on the ARM level definition in order to use the business vocabulary. Such services are not transferable to other APs as they were based on the AP214 terminology rather than the interpreted model.

Similarly, initial deployments of AP239 (PLCS) used the ARM definitions in order to present more familiar terminology to the developers and users. Again these proved to be incompatible with other AP implementations.

A further requirement arose within the PLCS environment where users demanded the capability to define and implement subsets of the overall model to meet specific business scenarios. This led to the concept of Data Exchange Sets (DEX), defined as subsets of the ISO PLCS standard and with standardised reference data defined as part of the model. Users demanded also PLCS to be driven by an organisation that provides direct governance by companies, rather than the perceived overhead of ISO, and OASIS was selected as a suitable vehicle. The resulting DEXs were designed to complement the ISO AP239 PLCS standard, and a liaison relationship was established between OASIS PLCS Technical Committee and ISO /TC 184 /SC4 to ensure transparency.

In order to facilitate the publication of DEX documents, the open source DEXlib publication environment was created on the basis of the first edition of AP239 to allow subsets of PLCS to be integrated into DEXs. Several DEXs and some associated reference data were created using this method and adopted as OASIS Committee Specifications, but the customer experience was that the development and implementation process was complex and unwieldy. The use of non-standard languages and tools was also seen as a barrier. The LOTAR PDM project complained that the XML generated automatically by Part 28 was too complex, and not what a typical XML programmer would expect.

Accordingly, a pilot project was started to provide a simplified view of the PLCS model and suitable templates to facilitate implementation.

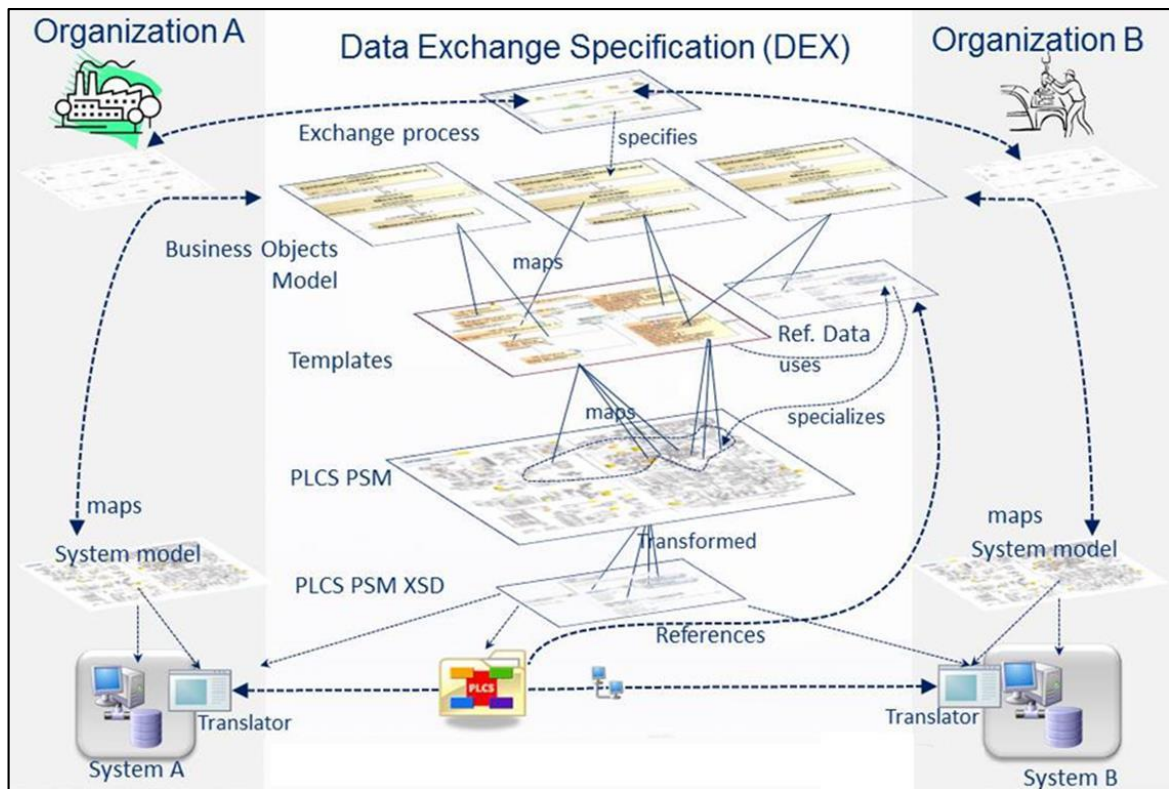


Figure 11: DEX architecture, with OASIS PLCS PSM as a pivot implementation model.

The new approach relies on the use of UML to define the business processes in cooperation with the domain experts, and SysML business objects and templates as the gateway to a PLCS Platform Specific Model (PSM) and the corresponding XSD representation which has been derived from the AP239 ed2 standard with some simplification in order to get a more workable XML representation (see Figure 11). Tools such as Schematron may be used to constrain the population of the resulting models, and to validate content.

All the components are available in a new open-source environment known as PLCSLib, which has been adopted as an OASIS Committee Specification, and formally supersedes DEXlib. The material has been made available to ISO/TC 184/SC 4 as input to its discussions on Business Object Models.

Implementations have been deployed in the French SIMMT, Norwegian NDLO, Swedish FMV, US Marine Corps, and BAE Systems. The faster speed of the approach was validated by a comparative pilot, redeveloping a business DEX created by Rolls-Royce. One further benefit is a much reduced file size for data transfer, resulting from the optimised XML.

The AP242 BO Model and the PLCS PSM both provide improved accessibility for domain experts, and a basis for implementing XML-based PDM exchange. While considerable efforts have been made to ensure the harmonization of the new Business Object Model for AP242 and the PLCS PSM based on AP239e2 there are still some inconsistencies that have not been resolved in the latest documents, for reasons of schedule and complexity.

This leads to coexistence and simultaneous usage of inconsistent implementation frameworks, making it difficult to harmonize the practices and the tests for the different communities relying on STEP.

Figure 12 describes differences between the AP239/PLCS and AP242. A common way for defining recommended practices should be developed, if possible taking the best of model based approach as defined by OASIS PLCS, but having to ensure consistency and full control within ISO.

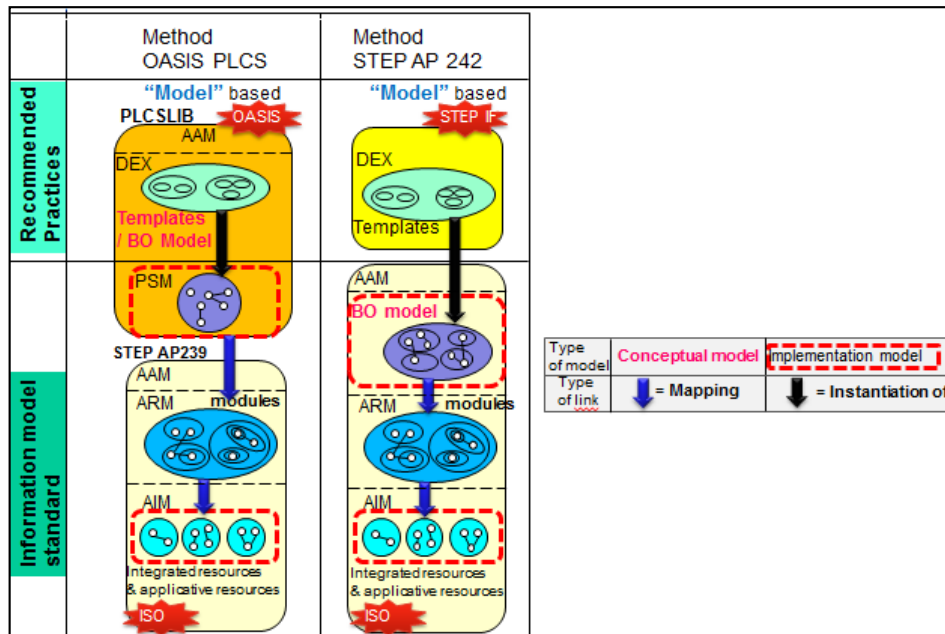


Figure 12: Comparison between OASIS PLCS and AP242 approaches

In order to support the availability of a consistent and configured set of interoperable Application Protocols for supporting the Aerospace & Defence community, there is a clear requirement for a consistent approach to the generation of Business Object Models from the underlying STEP architecture, and to work in a harmonised way on testing and recommended practices.

A further missing component is a consistent definition and implementation of Web services based on the Business Object Models.

3.2.3. NAS / EN 9300 LOTAR standards for LT Archiving and retrieval of digital aerospace product information

The American and European aerospace industries develop the NAS / EN 9300 standards, for long-term archiving (LTA) and retrieval of digital data, such as 3D CAD and PDM data. The LOTAR standards answer to the following business requirements: product liability, certification, reuse, and support in operation.

The development of the technical standards is organized by disciplines: 3D CAD with PMI and mechanical, PDM, Composite, Electrical, 3D visualization, etc. The LOTAR standards do not define ISO information models, but reference the appropriate ISO 10303 STEP standard. As described in Figure 13, ISO STEP (AP 242, AP 239, and AP 209) will be the information model cornerstone for the LOTAR standards.

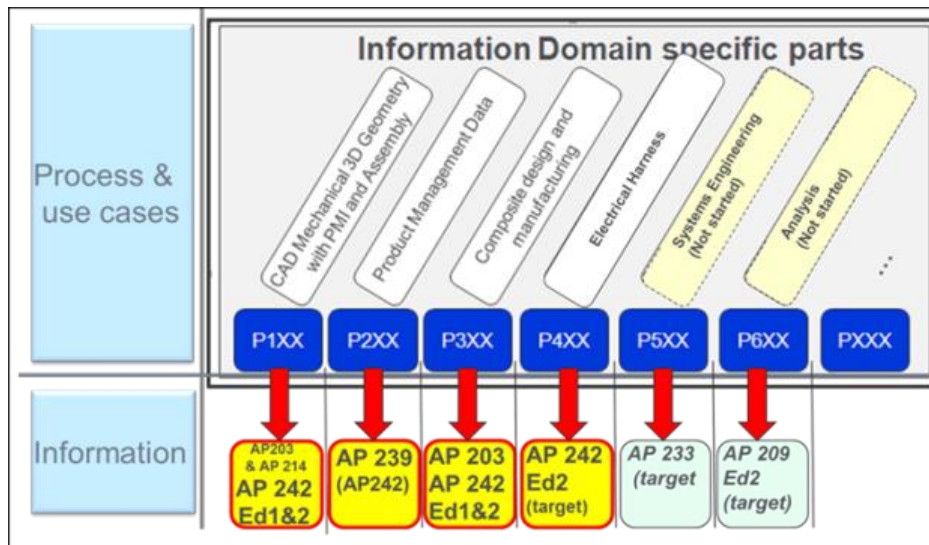


Figure 13: Links between the LOTAR standards and STEP Applications Protocols

Since the LOTAR standards are strongly related with the STEP Application Protocols and their associated implementer forums, regular governance has been set up with the AIA and the ASD SSG to monitor the interdependencies and prevent the risks of inconsistency.

3.2.4. ASD/AIA ILS suites of specifications and ATA standards

Cross-domain rationale: two main cross-domain aspects are considered in this section:

- *Interoperability between aeronautical industry using ILS standards and airlines (operators) using ATA standards.*
- *Interoperability between industry ATA-based processes (e.g. civil fixed-wing) and industry ILS-based processes (e.g. defence products).*

ASD/AIA Suite for ILS is a set of specifications which cover aerospace and defence logistic business needs for airworthiness and continuing airworthiness. The specifications can be applied for land, sea and air vehicles inside the industry on and customer/operator/maintainer sides.

The data model of the specifications conforms to ISO 10303 STEP AP239 and allows vendor-independent logistic solutions for data exchange and data sharing.

It covers today:

- Logistic Support Analysis (LSA): S3000L,

- Material Management: S2000M,
- Technical and Operational Publications: S1000D,
- Data Exchange between LSA and Technical Publications: S1003X.

The suite will be completed by specifications for:

- Operational and Maintenance Feedback: S5000F,
- Preventive Maintenance: S4000P,
- Training Needs Analysis: S6000T,
- A common Dictionary: SX001D,
- An ILS Guide: SX000i.

Air Transport Association (ATA) specifications are mainly created, as the name says, for air transport companies like airlines and cargo operators. ATA specifications do not cover the full life-cycle of a product or a service and are developed for civil airplanes only.

The data-model of each specification is ATA-proprietary and even to exchange data between the specifications is difficult to develop.

Material Management and Scheduled Maintenance Analysis for fixed-wing aircrafts are in the focus of ATA:

- Material Management: Spec 2000,
- Scheduled Maintenance Analysis: MSG-3,
- Operators Flight Manual: Spec2300,
- Maintenance Publications: Spec2200 including ATA 100 structure.

A new specification for Operator Flight Manual is under development.

ATA recommends for new projects the use ASD S1000D for Technical Publications instead of ATA Spec2200.

Link between ASD and ATA specifications

On one hand, the OEM of an aircraft is obliged to provide “information” to the certifying authorities for Type Certification (TC). The requirements for this “information” are defined in the Certification Specifications for Airworthiness. Airplane Flight-Manual, Airworthiness limitations and Initial Maintenance and Structure Repair are required for Type Certification.

On the other hand, the OEM provides information to the Customers (Operators, Maintainers, Spares suppliers, Training companies) to cover the requirements for Continuing Airworthiness.

Aircraft Maintenance Manuals, Parts Catalogue or Data, Wiring Diagrams and Component Maintenance Manuals are the most known ones.

Since information for Continuing Airworthiness must be in-line with the certified information (Airworthiness), there is the need to ensure the consistency and traceability.

Historically, operators have used ATA specifications to develop means and tools for Material Management and Technical Publications as stand-alone products. Manufacturers have used Maintenance Steering Group 3 (MSG-3) specification to perform scheduled maintenance analysis and to create maintenance program report for airplanes. Non-scheduled maintenance after events (e.g. bird-strike, hard landing) is not in the scope of the MSG-3 specification, but of course has to be provided to maintainers.

Because of the growing complexity of products and systems (aircraft, embedded software, ground and test equipment, spares and services), demanding requirements from authorities and challenging customer expectations, the logistic information/data and material is also more and more complex, but has to be consistent and compliant to the requirements. As a consequence the involved domains have to work in concert using the same source of underlying information and a common change process (see Figure 14).

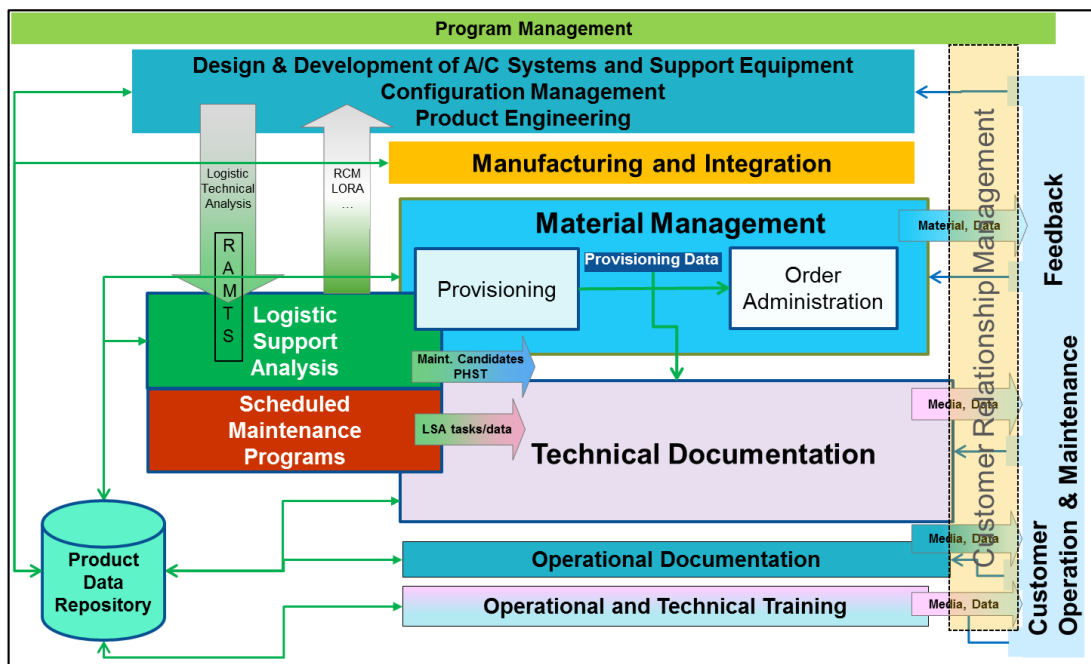


Figure 14: ILS Functional architecture

Taking all these challenges and the scattered standards and specifications landscape into account the link and the interoperability of specifications and standards for the different domains are a must. The interfaces (output, input) have to fit together by a common data-model.

3.2.5. Consistency of ASD/AIA ILS suite of specification

Cross-domain rationale: this section is dedicated to interoperability inside ILS domain. However, it is presented here as a potential contribution - in terms of method - for cross-domain interoperability.

The consistency of the ASD/AIA ILS suite of specifications is established by means of three main drivers:

1. The ILS Council, which is the governing body for the whole ILS Suite of specifications, establishes the policy to be followed by all specifications.
2. The SX000i guide defines the global process framework for the different process specifications, provides guidance on how the specifications should be used in a common program and also defines the governance of the specifications, including a common change process.
3. Finally, the Data Modelling and Exchange Working Group (DMEWG), ensures the consistency among the different data models defined by the different ILS specifications and ensures the interoperability by defining a Common Data Model (CDM), which is defined as all data used by two or more specifications (see Figure 15). This Common Data Model, based on PLCS, will be the core of all specifications, which may extend it to include data that is exclusive to a particular specification. The DMEWG is also responsible to ensure the interoperability of the data exchange between the different specifications. All specification data modellers are members of the DMEWG. The DMEWG is also responsible for the publication of the common dictionary and definitions (SX001D). There is a risk that the CDM may diverge from the existing ISO standard through local interpretation for the ILS specifications.

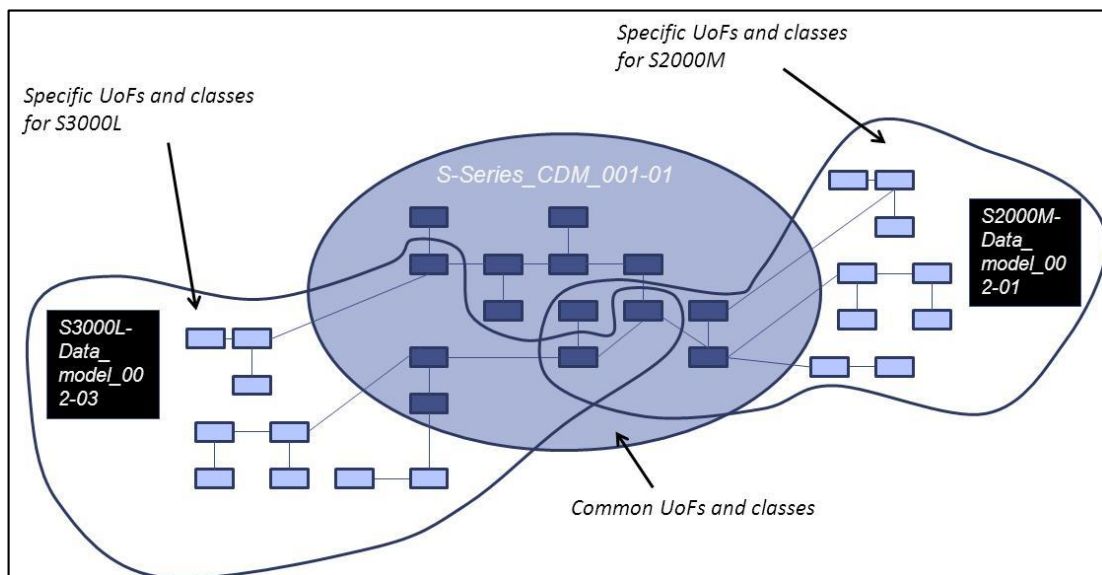


Figure 15: Common core principle illustrated on S2000L and S3000L

3.2.6. Visualisation formats and STEP

Cross-domain rationale: visualisation formats, as well as STEP formats, are required in all domains, and interoperability between visualisation formats and STEP formats is needed to ensure that the exploitation of product information by humans (through visualisation tools) is consistent with STEP definition (that is the reference for archiving, ref. LOTAR).

All along its life-cycle, data is stored in various formats: native format (authoring tool), neutral format (for exchange and archiving purposes), and derived visualisation formats. There are several ISO 3D visualization standards, each of them focused initially on specific needs and specific properties:

- “document based” and/or “model based”,
- 3D exact and/or 3D tessellated geometry,
- Static and/or dynamic scenes visualization.

The next table sums up the main ISO standards dealing with 3D visualization information

	Name	Organisation
ISO 14306 JT	JT file format specification for 3D visualization	ISO/TC 184/SC 4
ISO 10303 AP 242 3D tessellated	“Managed model based 3D engineering”	ISO/TC 184/SC 4
ISO 14739 PRC	“Product Representation Compact”	ISO/TC 171/SC 2
ISO PAS U3D	“Universal 3D”	ISO/TC 184/SC 4
ISO/IEC 19775 X3D	“Extensible 3D”	ISO/IEC JTC 1/SC 24
Collada PAS 17506	“Collaborative Design Activity”	ISO/TC 184/SC 4

In order to ensure a reliable conversion of visualisation data, the ASD SSG recommends to put in place validation mechanisms for the conversion from CAD to visualisation format and between visualisation formats.

For CAD files or PDM metadata, ISO STEP standard is the neutral format and A&D industry has a strong need to ensure that the information displayed by visualisation tools is consistent with the reference STEP product information. This need is growing with the deployment of full 3D definition without 2D drawings archived in STEP (as recommended by NAS/EN 9300 LOTAR).

Current 3D viewers are not fully able to read STEP AP203, AP214, and new AP242 files carrying the following essential information:

- 3D Shape (exact and tessellated BREP representations),
- PMI (graphic presentation),
- Cross-highlight between shape and Product Manufacturing Information (PMI),
- Predefined views,

- Assembly structure.

ASD recommends that vendors include not yet supported capabilities in their 3D viewers, and that they participate to the CAX IF for qualification of their 3D viewer STEP interfaces."

STEP viewers must preserve the quality of the source data. This quality is ensured by several conversions. For example, for a CAD document:

- From the CAD native format to STEP format (validation properties and verification rules as defined in LOTAR are recommended),
- From the STEP format to the viewer with include also a conversion (here the risk is reduced by the consistency with the neutral format).

So a benchmark is required to validate viewers by comparison of results with a set of representative documents in native STEP format. This is very important if approbation of the design and the conformity of manufactured part are done based on the STEP files.

Once 3D viewers include the above capabilities, the archiving processes will become much simpler, as the STEP file will become the reference for both the approbation process of the company and the archiving, and the risk of discrepancy between the several visualisation applications and the reference data will be removed.

3.2.7. Multi-disciplinary models interoperability

Cross-domain rationale: various disciplinary models should be used more and more in the future for various domain simulations (from early concept simulation to operational simulation). Interoperability between these models should then be seen in its cross-domain dimension.

"Multi-disciplinary" here refers to the individual analysis disciplines (aerodynamics, mechanical, electromagnetics, thermal, noise, vibration, etc.) and the links that provide coordination between analysis disciplines. A set of existing standards and emerging standards are identified in the ASD SSG Radar Chart to support this domain.

Interoperability needs to be organised at two levels: 1) system simulation level (0D simulation) and 2) calculation chains level.

At system simulation level, Modelica and FMI appear as potential candidates to organise interoperability between various system-level modelling and simulation languages (e.g. VHDL-AMS, Matlab/Simulink). Interoperability between Modelica and SysML is being developed by OMG in the "SysML-Modelica Transformation Specification".

At calculation chains level, novel co-simulation frameworks should enable the integration and coupling of various physics-based simulation chains. AP209 ed2 appears as a candidate to ensure interoperability between disciplines (e.g. mechanical-aerodynamics). MoSSEC is

also proposed to support the organisation of modelling and simulation studies in an extended enterprise context.

ASD SSG intends to monitor the evolutions of these two levels and to organise A&D use cases to demonstrate the maturity of the approach, with the objective to validate industrial applicability within a 5-year horizon.

3.2.8. Supply Chain Procurement Process Interoperability

Cross-domain rationale: the supply chain intervenes all along the product life-cycle, including design, manufacturing, and support. Main challenges to be considered include alignment of procurement processes, digital continuity and cross-sectorial vision (sub-contractors working for several industrial sectors: aeronautics, space, automotive, etc).

Civil Aerospace and Defence industry EDI Interoperability Map

Figure 16 represents the data flow throughout the Supply Chain, both in defence and civil Aerospace industry, in Europe and in the US.

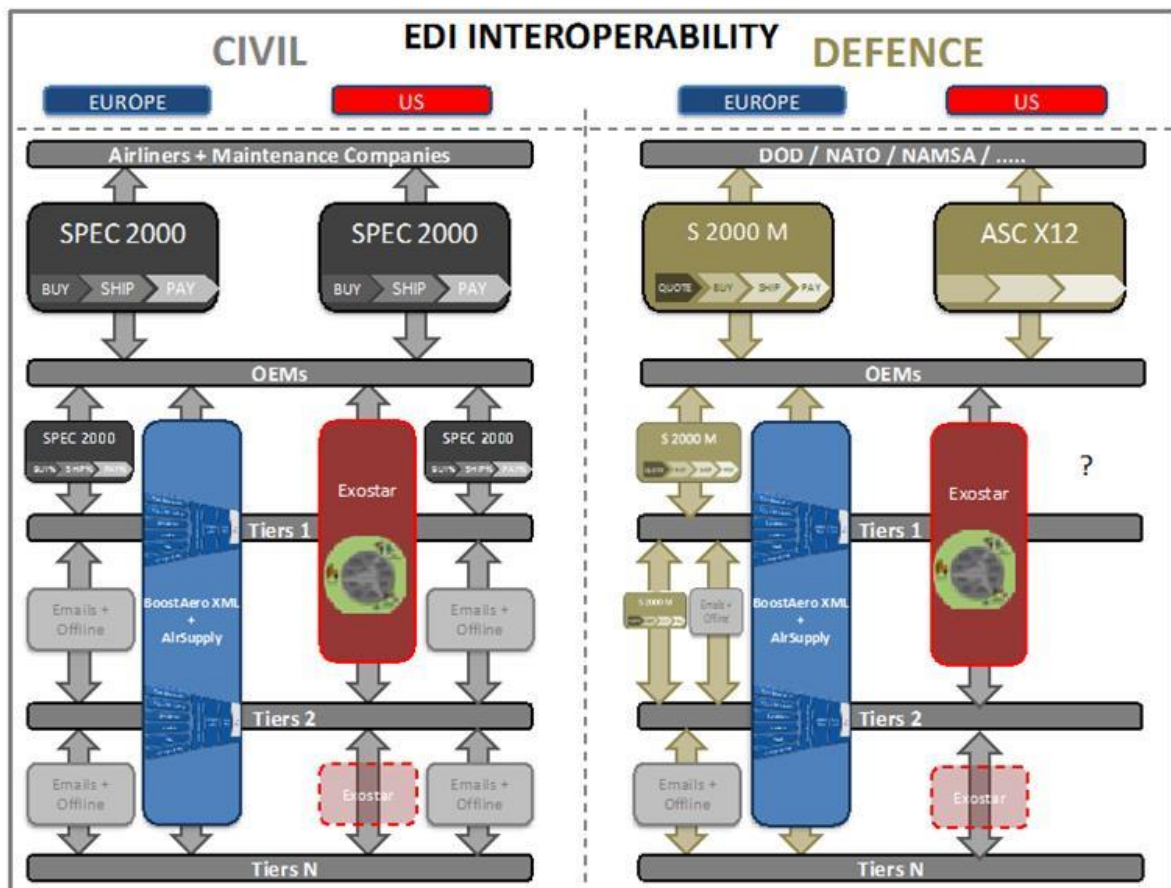


Figure 16: Civil Aerospace and Defence industry EDI Interoperability Map

The upper line represents the airline companies and the principal Defence clients, the second one the Original Equipment Manufacturers (OEMs), the third one the first suppliers of the OEM, the fourth one the suppliers of the first suppliers etc.

The entire graph shows the extended Aerospace and Defence Supply Chain.

The arrows stand for the data flow between the actors. For each arrow, the data type is specified (SPEC 2000, ASC X12, Exostar, BoostAero XML).

The aim of this diagram is to highlight the fact that there is no direct data flow between all the nodes of the entire Supply Chain. Between the different ranks the data type is most of the time transformed by the organizations to allow the transfer.

All stakeholders doing some exchange at a Supply Chain level face the “interoperability challenge”. This can be solved by working on the following layers or dimensions: **Process / Data / Infrastructure**

A Three dimensions Interoperability problematic

Vertical Dimension: Procurement Business process Alignment

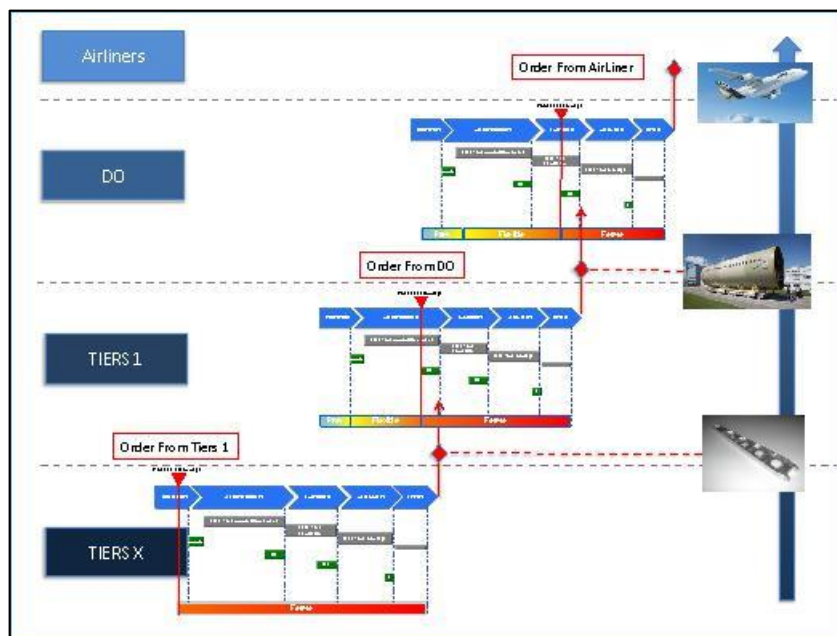


Figure 17: Non Alignment of Procurement Business Process between supply chain stakeholders

One of the problems that the Aerospace industry faces is the misalignment of the Procurement business process across the Supply Chain.

The mechanism of misalignment of business process could create a demand variation across the Supply Chain, from airliner to tiers x (most commonly called Bullwhip effect), an overstock due to a wrong management of this communicated demand, and bad Key Performance Indicators as OTD.

Here is a scenario illustrating the above statement:

- An **OEM** computes and aggregates its needs by supplier using a Delivery Schedule with different Horizons. This procurement mode is called Supply Chain Collaboration Mode. It is composed of a collaborative demand forecast transmitted to the supplier, followed by a Call-up (Supply Instruction).
- Then the **Tier 1** receives this demand forecast from **OEM** and can organise its own production and delivery schedules.
- The Business process alignment or disruption could occur here, as **Tier 1** could not be able, due to technical or business reasons, to transfer its exact need through a Demand Forecast plus Call-up Orders. **Tier 1** will only transmit its need by Simple Order, giving few or no visibility to their suppliers **Tier X** on its need. Of course **Tier 1** will take into account the supplier production lead-time when ordering, but its supplier might be tempted to secure the delivery or has, for scale reason, to work by batch, and will produce more quantities than needed.
- Furthermore, simple orders are not always accepted by supplier **Tier X** in terms of schedule date and quantity, and can generate delays for the whole Supply Chain if this supplier cannot make it on time as expected by **Tier 1**.

Horizontal Dimension: EDI - Data and Semantic Interoperability

Nowadays, companies of a Supply Chain or Supply network, exchange data through machine-to-machine connexion or thanks to file exchange. Because of the number of integration interfaces to manage, some of the stakeholders face the difficulty of handling several exchange formats (Data/Semantic/Syntax) from the other stakeholders.

Then, most of time, there is a disruption of the Supply Chain numerical flow because of interoperability issues.

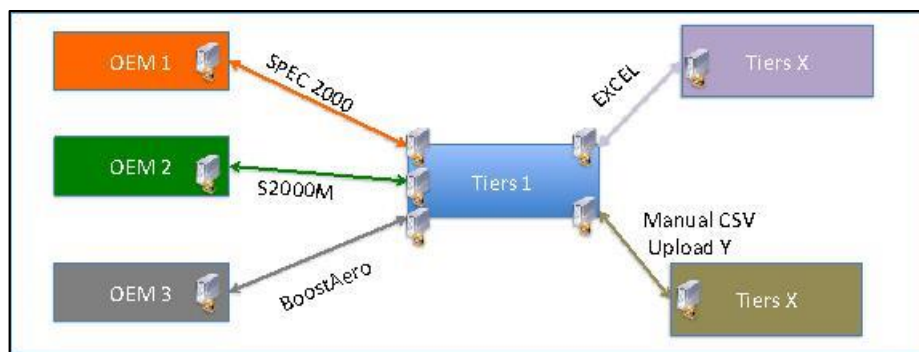


Figure 18: Multiple Interfaces for Multiple EDI Format Map

As Figure 18 shows, Tier 1 could encounter difficulties to handle multiple EDI Format / Standard from its customers, especially if it uses others EDI format / standards with its suppliers. For each standard the Tiers 1 has to develop an integration interface, able to manage Data and Semantics specific to this standard. It is then really difficult to manage in its ERP system different kind of data and different semantics for the same business process, here procurement. There is no interoperability with the different exchange format.

The introduction of a Common Standard EDI format reduces the number of integration interfaces for Tiers 1. The integration of procurement Data is easier thanks to a unique and common semantic/syntax. The integrity of data is complete.

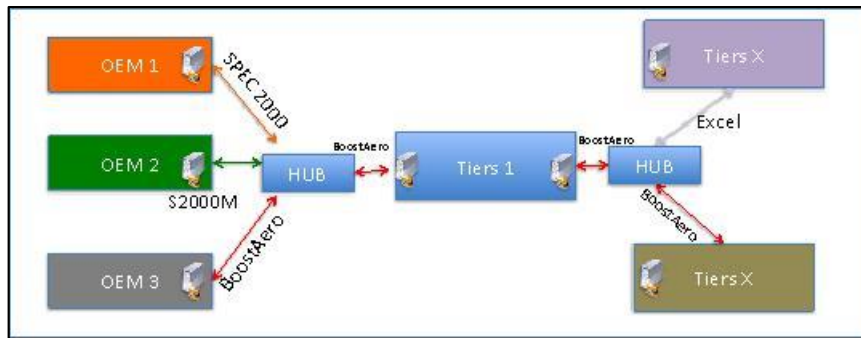


Figure 19: HUB-supported interoperability

In Figure 19, the introduction of « HUB » shows a full interoperability of the different EDI formats all along the Supply Chain. This Hub is able to transform any format to another one and then makes interoperable data exchange.

The exchange of data could be done through a lot of different protocol transfer. The most commonly used nowadays, especially in the industry, is AS/2 protocol, based the HTTPS one. The Supply Chain stakeholders are used to use this kind of protocol and one of the best practices is to be aligned across the Supply Chain on exchange protocol.

3.2.9. Data quality

Cross-domain rationale: Quality is by nature cross-domain, and a Total Quality vision requires a consistency between the quality processes implemented in the several enterprise domains.

Business process integration and automation inside an organization or in an extended enterprise requires a very high level of quality of the data and information. ISO 8000 is a series of standards, which provides a framework for improving information and data quality that can be used independently or in conjunction with quality management systems.

ISO 8000 defines which characteristics of information and data are relevant to information and data quality, specifies requirements applicable to those characteristics, and provides guidelines for improving information and data quality management.

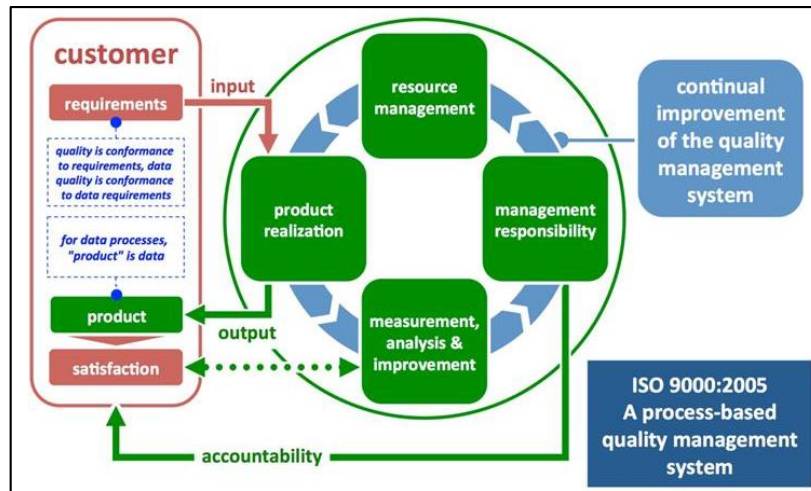


Figure 20: Overall quality landscape

The ISO 8000 standard series are intended to be used in coordination with other existing standards that define the data requirements for specific processes. For example, the product data quality for shape (PDQ-S) model aka STEP part 59 (10303-59) provides a data model to represent geometrical quality requirements, measurement methods and results presentation for quality analysis of 3D CAD models in the context of design and manufacturing. ISO 8000-311 aims at facilitating effective use of ISO 10303-59.

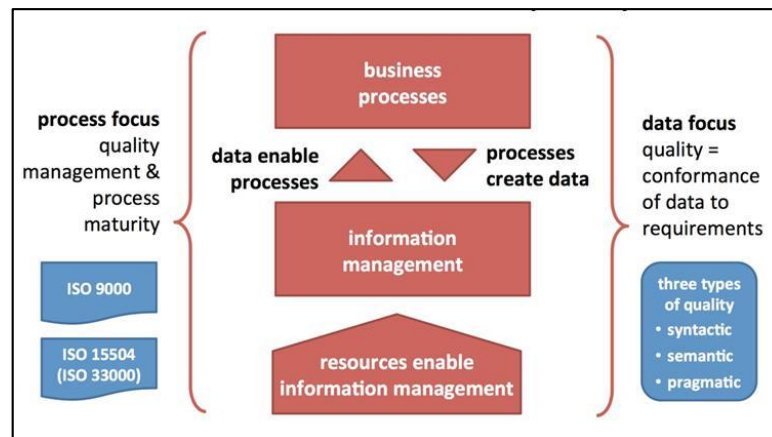


Figure 21: Process quality and data quality

Quality criteria of three-dimensional shape data are classified as either erroneous data or inappropriate data. Each of these classes is further categorized into the following sub-classes: geometry specific issue, topology specific issue, combined geometry and topology issue, geometric model issue.

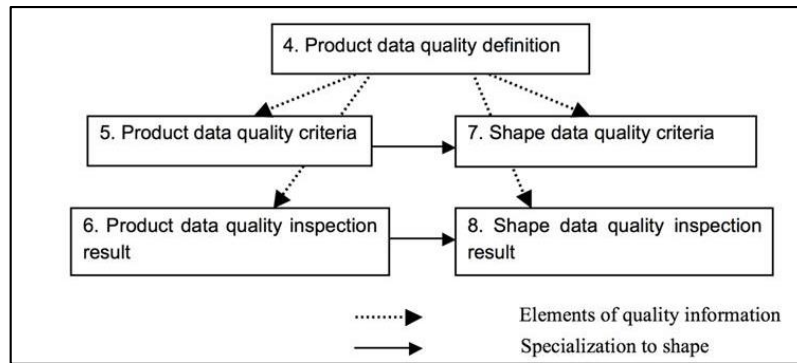


Figure 22: Structure of PDQ-S schemas

In the Design and manufacturing domains, ISO 8000 provides solutions to enhance the data quality of CAD models. In the ILS domain, ISO 8000 provides solutions to enhance the master data quality of parts catalogues and procurement data. For system engineering, ISO 8000 will lead to an improvement of the quality of data and information.

3.2.10. Consistency of IT Services

Lack of standardized PLM web services for Enterprise Services Bus (ESB)

Integration of processes between different PDM applications and downstream systems is a key business priority for the A&D manufacturing industries. Several standards have been proposed since the mid 1990ies, which did not succeed to be implemented to a large scale. The more recent proposals have been the PLCS PLM services, based on STEP AP 239, and the OMG PLM services, developed by ProSTEP iViP, based on STEP AP 214 ARM data model. In addition of business services derived from uses cases, both standards define fine grain services based on the objects of the related STEP Application Protocols, resulting in different web services for the similar functionality.

We may anticipate for the next years a major risk of lack of coordination:

- In the development of the new generation of PLM services standards,
- In the prioritization of implementation of the PLM services by the PLM vendors,
- In the organization of interoperability testing of the PLM vendors and PLM integrators solutions,
- And in the development of the associated recommended practices of implementation.

It may result in different and overlapping sets of services, promoted by different consortiums, resulting at the end in the duplication of efforts and increase of time for qualification and availability for operational use.

Increasing importance of Service Oriented Architecture and interdependencies with product information models and processes.

The Aerospace and Defence companies need to decrease the cost and time of all phases of the product life cycle: development, manufacturing, and support in service. The integration and federation of PLM information through the full A&D product life cycle becomes a challenge and priority N° 1 for a lot of manufacturers.

The solution relies on a close integration of the different processes. It requires a formal modelling of the processes and use cases and on an automation of the interactions between the different PLM applications and associated repositories.

The complexity of PLM services standards is related to the close interdependency between the relevant processes, the appropriate use cases and associated functionalities, the related product information models and the resulting services. It has also to include the security and IPR constraints.

Since the processes and applications change in time, this business requirement implies also to set up a flexible and modular architecture of the information systems. Driven by the business needs for interoperability as detailed above an architecture based on a COTS component approach and using an Enterprise Service Bus (ESB) for communication between the different applications, e.g. relying on a Service Oriented Architecture (SOA), is required.

4. Required standards architecture

4.1. Global requirement

Develop a coherent set of interoperable standards, enabling:

- To minimize project dependency by defining clear guidance and by avoiding inclusion of project and national specific rules and constructs,
- To ensure commonality between related specifications to support the re-use across projects,
- To establish a well-defined data transfer mechanism between the different disciplines,
- To cover all aspects of business interface activities over the entire life cycle of a product,
- To be the contractual baseline for industry and customers,
- To be up to date with the technical development and changes.

This set of standards shall cover several aspects: use cases, methods and application services, considering interoperability between disciplines/organisations.

4.2. Interoperability Framework

Objectives

The framework for interoperability focuses on the necessary and sufficient components to ensure interoperability between a company and its partners, without attempting to control such company-specific decisions as application selection or technical environment. It may also be used to support interoperability within an organization.

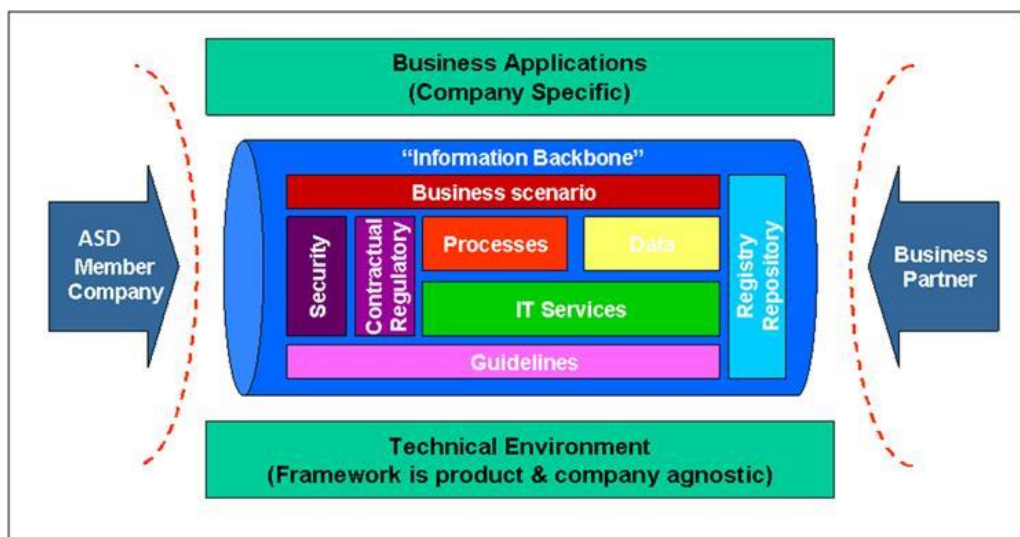


Figure 23: Overview of the Interoperability Framework

The key requirements to be met by the framework include the ability to show the complete landscape for interoperable business processes to the required level of detail as the basis for the assessment of initiatives. The framework must support cross-sectorial coherence, and both IT and business viewpoints. To meet these requirements, the SSG has adopted a framework based on work by the NIST eBusiness Standards Coherence project, and the ISO/IEC/ITU/UNECE MoU Management Group on eBusiness, which in turn build on many other models. The framework has demonstrated the capability to represent any known interoperability initiatives and standards, and the individual boxes can be expanded to any necessary level of detail to illustrate relationships and scopes.

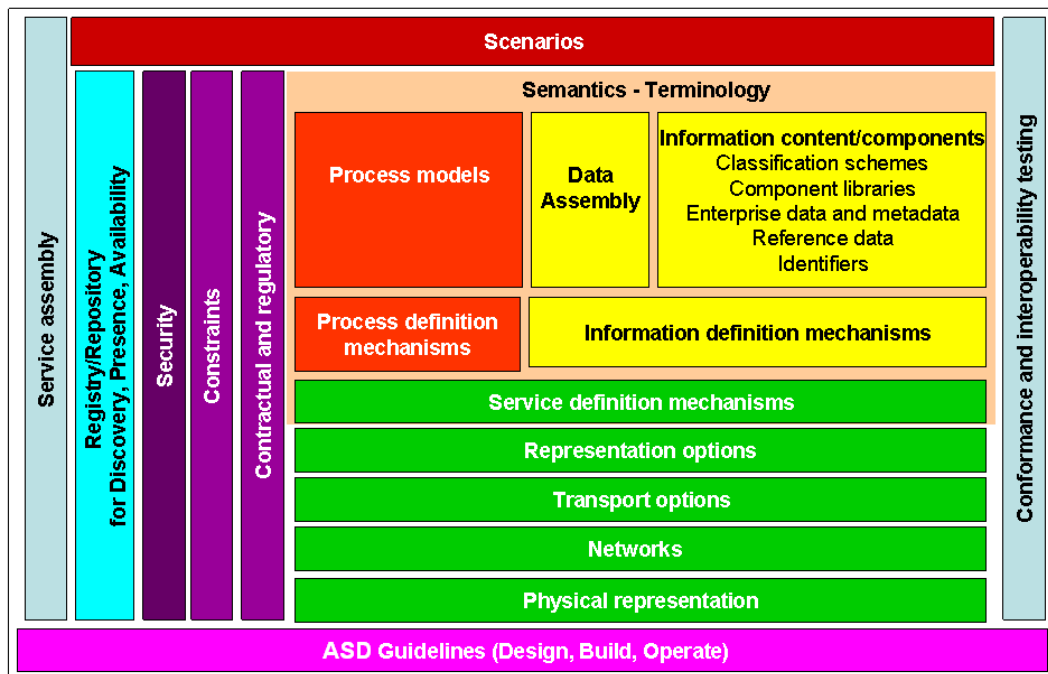


Figure 24: Interoperability Framework components

The Framework contains a number of different classes of components :

Scenario / Use Case

Scenarios define a particular requirement for a business process or interaction, described in sufficient detail to allow agreement by subject matter experts on the validity of the scenario and the identification by the SSG of the necessary interoperability components required to meet the business need. The description may contain business process definitions, trigger states for specific information exchanges, roles of participants and error cases. A scenario should contain the following information:

- Name - meaningful title
- Description of the problem/requirement, and the business justification for action
- Integrated process diagram - business user view containing:
 - o Scenario initiation - what starts it?
 - o Actors - roles of participants

- Sequence of events within activity
- Controls - external influences/constraints
- Internal decision points
- Information flows - using existing components if possible
 - Repositories
 - "Master data"
- Scenario results - range of possible outcomes and output
- Exception handling.

Multiple business scenarios may be satisfied by the same combination of interoperability components, and there is no limit to the number of scenarios that may be identified.

A collection of scenarios may be defined as an integrated set or taxonomy of scenarios, and multiple such taxonomies can exist with overlaps. The range of scenarios is intended to help users to find existing solutions.

Process

A process is a series of steps which can be executed upon specific inputs to achieve a specific output with the application of certain controls and consumption of certain resources. Generally speaking, processes can be decomposed into three major classes:

- General processes, which may be applied to a variety of business environments,
- Specific processes, which are applied under a particular business environment,
- Transactions, covering Individual steps within a process.

These processes may be represented using a range of modeling methodologies using formalized language structures.

Data

The enterprise information required to support the processes in a scenario can be considered in a number of distinct classes:

- Definition of data elements and relationships,
- Patterns for assembling data elements to support specific transaction payloads,
- Master/reference data (including multi-lingual support),
- Structures for data dictionaries and classifications,
- Identifiers for products (or groups of products).

Contractual and regulatory conditions

The business environment for a scenario may be defined by contractual agreements between parties which determine the mode, scope or mechanism for conducting business. Regulatory requirements may be imposed at national, regional or international level. In a given scenario or business relationship, additional constraints may be present due to elements outside the scope of the relationship itself, such as national or regional requirements.

Security

There are a number of aspects of security which need to be considered in any scenario.

- Confidentiality - marking or labelling certain pieces of data or information for restricted availability,
- Authentication - establishing the identities of parties participating in a business scenario,
- Non Repudiation - validating that a specified process has taken place,
- Access Control - restricting access to systems, processes or information,
- Integrity - ensuring that transactions and/or information/data are complete.

IT Services

A range of IT services may need to be assembled to support a scenario.

- Defined formats of representation, storage and transmission,
- Transport, including messaging protocols,
- The physical network required for transmitting data,
- Physical data capture, including methods of rendering and consuming data in machine readable format (i.e. barcode reading),
- Service definition, including tools and language for service implementation & interfaces.

These components generally exist independent from the Aerospace & Defence context and are consumed as commodities. The same collection of services may be used to support multiple scenarios

Service Registry/Repository

In a service-oriented environment, the scenario may require a means of making known to other parties the presence and availability of specific services and their characteristics, and offer the ability to bind to or call a given service.

ASD Guidelines

In order to facilitate the assembly and deployment of standards components in support of particular business scenarios, guidelines may be created for ASD approved and endorsed methods, techniques and recommendations for engaging or deploying one or more components of the framework. Guidelines may address several different aspects of the development of a solution to the business scenario:

- Design of the solution, including key considerations and decisions,
- Implementation of the solution, including key IT considerations,
- Operation of the solution, with any consideration of run time conditions.

4.3. Envisioned standards backbone

The standards backbone is built by mapping the current standards used by the industry onto the interoperability framework developed previous section, and analysis of the interoperability gaps developed in section 3.2 in the context of this framework.

In the resulting standards backbone, illustrated in Figure 25, the STEP standards as well as BoostAero XML ones play a central role, and are complemented by additional standards for services, visualisation and data transactions. In next versions of this document, additional types of standards will be added, like data security services.

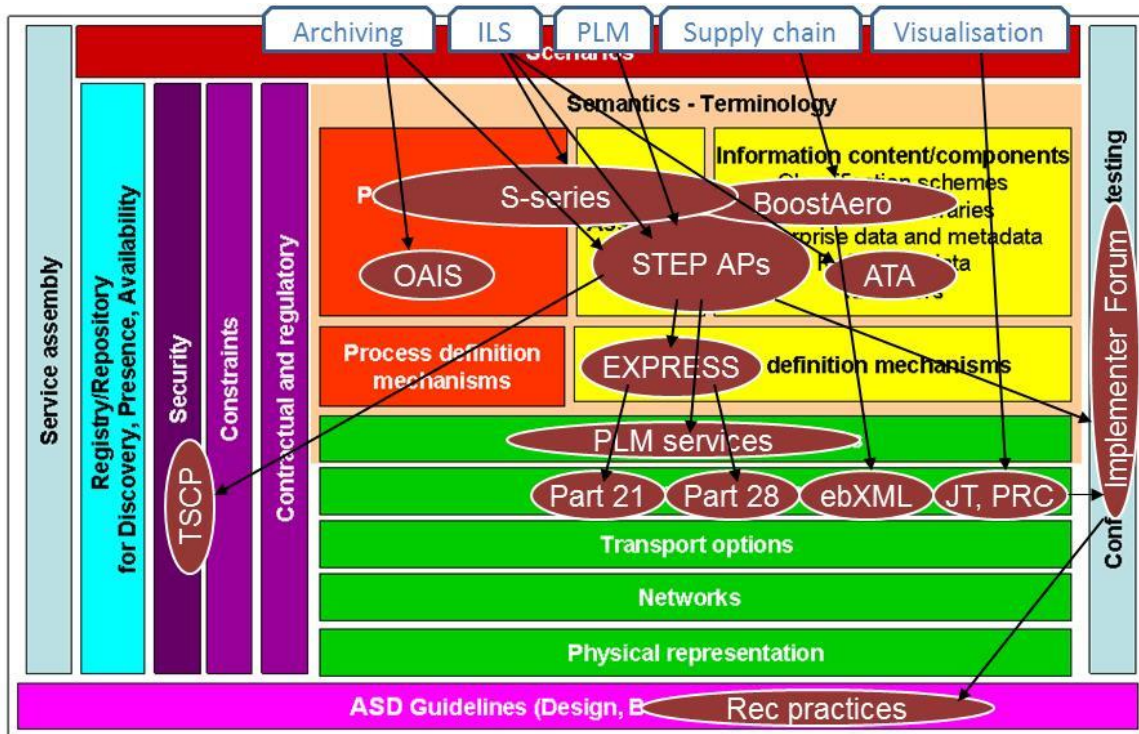


Figure 25: Envisioned standards backbone

The next section provides an initial set of recommendations arising from the interoperability analysis, and seen as mandatory to turn the above envisioned standards backbone to an actual deployed backbone.

4.4. Proposed recommendations

4.4.1. STEP modular Application protocols as the cornerstone for A&D PLM interoperability

The ASD SSG recognises the value of ISO 10303 STEP Application Protocols, and intends to make these standards the cornerstone of the PLM information interoperability. As described in section 3.2.1 and 3.2.2, some risks of divergence or incompatibility are identified, that require clear recommendations and actions to be mitigated.

The next figure summarise the current analysis of STEP Application Protocols coverage and overlaps.

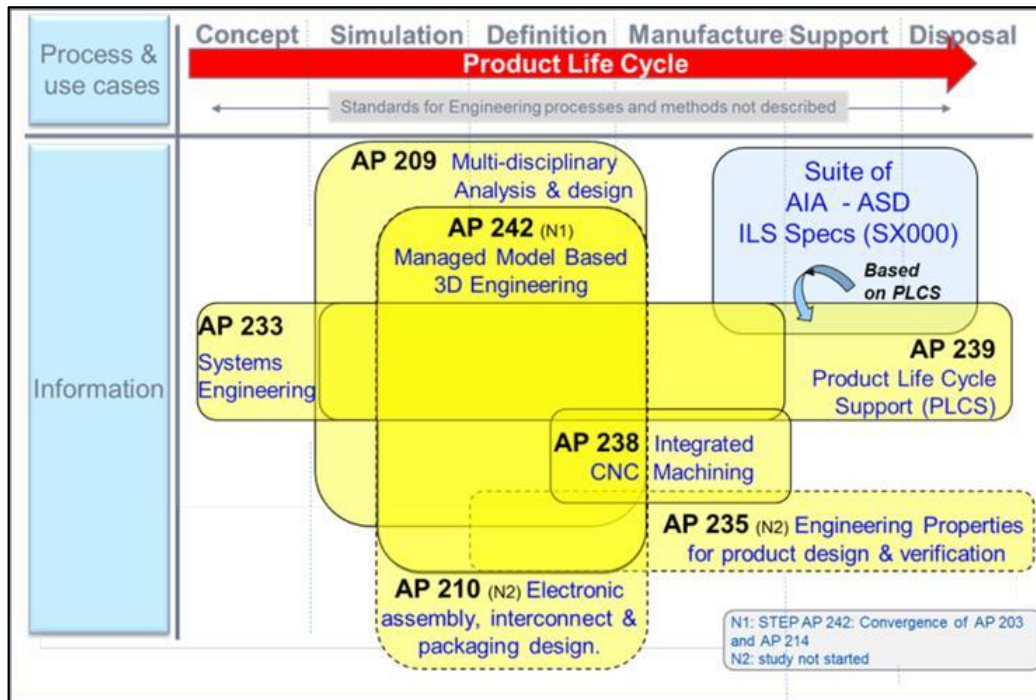


Figure 26: Suite of STEP core standards for PLM interoperability

Recommendation 1: Strengthen the STEP architecture approach to 1) ensure interoperability between STEP standards and 2) provide unambiguous implementation methods (including for new information technologies, e.g. OSLC).

The ASD SSG has already engaged some actions to implement this recommendation, including:

- Preparation of a White paper “state of STEP AP modularity -Requirements for the STEP future architecture”. This action results from the 6-7 March 2014 workshop organized by the AIA, the ASD SSG and PDES Inc. It will improve the consistency of STEP modular architecture taken into account the BO model and the DEXs templates. This action will be closely associated with the ISO/TC 184/SC 4/WG 12 activities for the new STEP architecture.
- Contribution to STEP AP242 ed2 White Paper. Planned enhancements, compared to AP242 ed1 include: PDM (finalization of harmonization with AP 239 ed3 PLCS), 3D PMI (e.g. extension to new entities allowing to support the enhancement of ISO and ASME PMI design standards), 3D geometry (e.g. extension to 3D curved triangles, voxels) CAD composite design (new entities such as Limited Area Application Indicator), Mechanical design (e.g. extension to design information of manufacturing additive parts).

- Initiation of STEP AP239 ed3 White Paper. This action is currently discussed, objective would include:
 - Enhancing the AP 239 ed2 with a BO Model and associated XML Business Implementation model based on the OASIS PLCS,
 - Ensuring the finalization of PDM harmonization between AP 239 ed3 BO model and AP 242 ed2 BO model,
 - Ensuring the full mapping of the BO model with the STEP modules.
- More generally, actions have to be taken to implement the initial objective of the STEP modular architecture to manage all APs in a consistent way, including the ability to regenerate APs from a common library to maintain consistency - under careful configuration management. So other STEP APs are concerned, including AP233.
- Consolidate the coordination with the LOTAR project, for the identification and maintenance of Long Term Archiving payload standards.

4.4.2. Visualisation formats

Recommendation 2: Ensure that 3D visualisation format standards used in the industry are consistent with STEP standards

The ASD SSG has already engaged some actions to implement this recommendation, including:

- STEP viewer action: ASD SSG has developed a statement recommending that 3D viewer vendors include not yet fully supported STEP capabilities in their 3D viewers. In addition, the SSG has launched a STEP Viewer action, in relation with IT vendors, aiming at delivering a common view on tool capabilities in regards to industry needs. Results of this action are available on the ASD SSG website (www.asd-ssg.org/step-viewer-action).
- Support of JT ed2: JT ed1 is an ISO standard only for faceted geometry. Proposal is to complement JT ed1 with exact geometry in STEP format.

4.4.3. ASD-AIA ILS specifications

Recommendation 3: Ensure the common data model for the ILS specifications is consistent with STEP AP239.

The ASD SSG has already engaged actions to implement this recommendation, through AIA - ASD Data Model and Exchange Working Group and governance through SX000i.

4.4.4. ILS suite and ATA

Recommendation 4: Promote the ASD-AIA ILS suite of specifications and seek to manage coherence with ATA specifications where needed by the industry.

This recommendation could be implemented through collaboration with ATA, e.g. MoU to be developed to govern the interactions and interfaces between the 3 organisations: ASD, AIA, and A4A.

4.4.5. Services

Recommendation 5: Participate in the development, and interoperability testing of the next generation of PDM/PLM web services.

The next table sums up a first version of SSG recommendations per groups of standards and associated recommended practise / implementer forums:

	Standards	Rec. Practices	Implementer Forum	ASD SSG comments
Processes				Survey - Contribution
use cases and functionalities		ASD SSG PDM use cases	Future PDM IF	Contribution, coordination
Information model and associated PLM services	STEP AP 214 and OMG PLM services V2.0	ProSTEP iViP implementation guidelines		
	STEP AP 242 and possible new version of OMG PLM services		Future PDM IF	Contribution, coordination
	STEP AP 239 and associated web services	Link to MoSSEC web services (Nota 1)	Future PDM IF?	Contribution, coordination

OMG: Object Management Group.

Nota 1: The MoSSEC project defines a list of business services based on the OASIS PLCS standard.

4.4.6. Supply Chain

Recommendation 6: Facilitate data interoperability in the Aerospace and Defence Supply Chain and align business process between Supply Chain stakeholders.

Two major hubs (AirSupply of BoostAeroSpace, Exostar) have been implemented to allow the uninterrupted data flow. But the multiplication of such hubs can also be an interoperability brake for the suppliers using both hubs.

Having a common hub for the entire industry is not a realistic idea but as the interoperability concept promotes the seamless flow of data, one recommendation is to implement a common format available on the major hubs - for example, having BoostAero XML available on AirSupply and Exostar.

To align business process between Supply Chain stakeholders, the different stakeholders, the customers and the suppliers should agree at least on the following points:

- Identify their own level of Supply Chain Collaboration maturity and agree on a common Procurement Mode.
- When the Supply Chain Collaboration Mode² is used between a Customer and a Supplier, they must both define the length of the Firm, Flexible and Provisional Horizon. The supplier will then define these horizons with its own supplier and so on.
- Collaboration on Demand Forecast Data could be allowed or not. The possibility of commitment by supplier must be defined as well as the ability to collaborate with the firm horizon when requested.

To make Data exchanges interoperable, few solutions could be implemented:

- Create a common EDI Standard: specifying the Data, the Semantic, the Syntax, and the concerned business processes. All stakeholders communicate and exchange using this standard in M2M.
- In case of a multitude of standard already used, launch the action of standard convergence (ex: S2000M and BoostAero, becoming an enhanced version of BoostAero)
- Introduce a common hub, able to integrate several EDI Standard / Exchanged format into another EDI Standard / Exchanged format. This will make fully interoperable the exchanges within a Supply Chain.
- Create workaround solution, but limits are; not standard and duplicable with hardness.

Business process alignment reduces significantly Demand variation and is a source of competitiveness, but is efficient only if the flow of data and its semantic is interoperable all along the Supply Chain.

4.4.7. Implementer forums

Recommendation 7: Supports the setting-up of implementer forums (e.g. PDM implementer forum) to test and validate the implementation of the standards-based solutions.

The definition of standards have to be completed by the setting up of associated implementer forums, to develop recommended practices, accelerating the common

² *Supply Chain Collaboration Mode is composed of a collaborative demand forecast transmitted to the supplier followed by a Call-up (Supply Instruction).

understanding of the standards by the implementers, and to ensure regular interoperability test rounds by vendors. It supports increased quality of standards interfaces and services by COTS vendors and integrators, and is a prerequisite to fully take benefits of the investment in the development of standards. The ASD SSG recommends to strengthen the involvement of its participants in the implementer forums of interest for the aerospace and defence.

As a first priority, the ASD SSG supports the setting up of the PDM Implementer Forum, in charge to:

- Define model based recommended practices completing the PDM interoperability standards,
- Agree on PDM interoperability use cases and associated prioritization of implementation by PDM vendors and integrators,
- Organise and manage PDM interoperability test rounds with the PDM vendors and integrators,
- Present a summary of PDM interoperability functionalities supported by the main PDM vendors and integrators.

The main action for the first year will be focused on STEP AP 242 ed1 XML implementation.

List of Contributors

	Name	Organisation
Deliverable Leader	Yves Baudier	Airbus Group
Contributing Author(s)	Jean Brangé	AFNET
	Jean-Yves Delaunay	Airbus
	Ramón Somoza-Garcia	Airbus Defence & Space
	Bernhard Seidel	Airbus Defence & Space
	Heinrich Byzio	Airbus Defence & Space
	Franz Meier	Airbus Helicopters
	Nicolas Figay	Airbus Group Innovations
	Howard Mason	BAE Systems plc
	Nicolas Bossart	BNAE
	Samy Scemama	Boost
	Franck Ramaroson	HeMe
	Dominique Galpin	SAFRAN
	Bertrand Roche	THALES
	Steve Shepherd	UKCeB
Internal Reviewer(s)	ASD SSG Members	

Document History

Version	Date	Reason of change
0.1	10/09/2013	Document created
0.2	28/11/2013	Document updated following discussions and contributions made during ASD SSG meeting #19.
0.3	20/12/2013	Updates made in chapters 4 and 5 further to SSG call
0.4	19/02/2014	Integration of modification/comments provided by Howard and integration of Supply Chain paragraph (BoostAero)
0.5		
0.6	14/03/2014	Integration of modifications and comments provided by Franck and Heinrich
0.7	24/03/2014	Modifications discussed during the ASD SSG meeting, 19-20 March 2014
0.8	07/04/2014	Modifications discussed during the ASD SSG monthly call, 4 March 2014
0.9	10/04/2014	Final modifications before 1 st draft issue - Distribution to all SSG members plus external partners for review
1.0	2/05/2014	Final modifications before 1 st release, including updates proposed by SSG members and by Everson Moura, Embraer.

Description of Standards

The following table lists the standards identified in ASD SSG Radar Chart. Links allow you to download the related “blip”, including abstract description and ASD related recommendation (if any).

3D Visualisation standards	Modelica
BoostAero (eSupply Chain standard)	MoSSEC Modelling and Simulation in Collaborative Systems Engineering Context
BPMN (Business Process Model and Notation)	OAGIS9 Open Applications Group Integration Specification version 9
COLLADA COLLaborative Design Activity XML file format	PAS 55 BSI Publicly Available Specification Asset Management
ebXML CC (Electronic Business using eXtensible Markup Language Core Components)	PRC/U3D Portable document format (PDF) Universal 3D / Product Representation Compact
EN9300 LOTAR (LOng-Term Archiving and Retrieval of 3D digital aerospace product information, such as CAD and PDM)	RFID Radio Frequency Identification Application Standards
EN9300-1xx (Long-Term Archiving and Retrieval of 3D Geometry, CAD structure and Product Manufacturing Information)	S1000D International specification for technical publications using a common source database
EN9300-2xx (LOng-Term Archiving and Retrieval of Product Management Data & Configured Mechanical Product Structure)	S2000M International specification for materiel management - Integrated data processing
EN9300-3xx (LOng-Term Archiving and Retrieval of Composite information)	S3000L International specification for Logistics Support Analysis - LSA
EN9300-4xx (LOng-Term Archiving and Retrieval of Electrical Harness information)	S4000M International specification for developing scheduled maintenance programs
ISO8000 Data Quality	S5000F International specification for operational maintenance data feedback
FMI Functional Model Interface	SX001D Data Dictionary for the suite of ILS Specifications
ISO22745 Open technical Dictionaries and automated data exchange	SX000i International guide for the use of the S-Series Integrated Logistic Support (ILS) specifications
ISO 14306 v1 JT file format specification for 3D visualisation v1	SAML Security Assertion Markup Language
ISO 14306 v2 JT file format specification for 3D visualisation v2	SCORM Sharable Content Object Reference Model 2004
VEC KBL (VDA 4968 "Vehicle Electric Container Kabelbaumliste")	SPEC2000 ATA Spec 2000 chapters 11 and 13 (Feedback)

SPEC2300 Data Exchange Standard for Flight Operations
STE100 ASD Simplified Technical English
STEP Standard for the Exchange of Product model data (ISO 10303)
STEP AP203 "Configuration controlled 3D design of mechanical parts and assemblies"
STEP AP209 "Multidisciplinary Analysis and Design"
STEP AP210 "Electronic assembly, interconnect and packaging design"
STEP AP212 "Electrotechnical design and installation"
STEP AP214 "Core data for automotive mechanical design processes"
STEP AP233 "Systems engineering data representation"

STEP AP235 "Materials information for the design and verification of products"
STEP AP239 "Product life cycle support"
STEP AP242 "Managed model based 3D engineering"
SysML Systems Modeling Language
TDP Message ASD Technical Data Package Message
TSCP Transglobal Secure Collaboration Program
TSCP IdFv1 Identity Federation v1 Assertion Profile
TSCP ILHv1 Information Labeling and Handling v1
TSCP Sev1 Secure Email v1
TSCP TF Trust Framework for the Supply Chain
XPDL XML Process Description Language

References

1. ASD SSG website, www.asd-ssg.org, including:

- a. [List of ASD SSG members](#)
- b. Working Groups:
 - [PLM interoperability](#)
 - [Integrated Logistics Support](#)
 - [Hub collaboration](#)
 - [Supply Chain interoperability](#)
 - [Data Quality](#)
 - [Through-life cycle interoperability](#)
- c. ASD SSG [STEP Viewer action and results](#)
- d. Projects
 - [BoostAero](#)
 - [ILS suite of specifications](#)
 - [LOTAR](#)
 - [STEP AP242](#)
 - [TDP Message](#)
 - [TSCP](#)
- e. [Radar Chart](#), including description of all standards mentioned in this document.

f. Results:

- [ASD Statements](#), including statements related to STEP Viewers and 3D visualisation formats.
- [ASD Standard recommendations](#)
- [ASD SSG standards](#)

g. [Publications](#)

2. Analysis of Standards for Lifecycle Management of Systems for US Army -a preliminary investigation, NISTIR 7339, August 2006
3. Interoperability Friction in the Aerospace and Defense Industry, Global Product Data and Interoperability Summit (GPDIS) 2013.

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List of acronyms / abbreviations used in this document

Acronym / abbreviation	Definition
A&D	Aerospace and Defence
AD	Airworthiness Directive
AIA	Aerospace Industries Association (USA), see www.aia-aerospace.org
AIM	Application-Interpreted Model
AMC	Applicable Means of Compliance
AP203	Standard for the Exchange of Product model data (STEP - ISO 10303) - Application Protocol 203 “Configuration controlled 3D design of mechanical parts and assemblies”
AP214	Standard for the Exchange of Product model data (STEP - ISO 10303) - Application Protocol 214 “Core data for automotive mechanical design processes”
AP239	Standard for the Exchange of Product model data (STEP - ISO 10303) - Application Protocol 239 - Product Life Cycle Support (PLCS)
AP242	Standard for the Exchange of Product model data (STEP - ISO 10303) - Application Protocol 242 - Managed Model Based 3D Engineering
ARM	Application Reference Model
ASC X.12	Accredited Standards Committee X.12 (ANSI Committee)
ASD	AeroSpace and Defence Industries Association of Europe, see www.asd-europe.org
ATA, A4A	Air Transport Association of America, Inc. (ATA), now named Airlines for America (A4A). ATA remains as name of standards.
BOM	Bill of Material
BO Model	Business Object Model
CAD	Computer Aided Design
DEX	Data Exchange Specification (PLCS terminology)
EDI	Electronic Data Interchange
EASA	European Aviation Safety Agency
ERP	Enterprise Resource Planning
FMI	Functional Mock-up Interface
ILS	Integrated Logistics Support
IPR	Intellectual Property Rights
ISS	In Service Support
LSA	Logistic Support Analysis
MoSSEC	Modelling and Simulation in a Systems Engineering Context

Acronym / abbreviation	Definition
MRO	Maintenance, Repair and Overhaul
MRP	Manufacturing Resource Planning
MSN	Manufacturer Serial Number
OASIS	Organization for the Advancement of Structured Information Standards. See www.oasis-open.org
OEM	Original Equipment Manufacturer
PBS	Product Breakdown Structure
PDM Schema	STEP PDM (Product Data Management) Schema
PLCS	Product Life Cycle Support
PLM	Product Life-cycle Management
RAMT	Reliability, Availability, Maintainability and Testability
SB	Service Bulletin
SDAI	Standard Data Access Interface
SMRL	STEP Module and Resource Library
SPEC 2000	ATA specification
SSG	ASD Strategic Standardisation Group, see www.asd-ssg.org
STC	Supplemental Type Certificate
TDP	Technical Data Package
TSCP	Transglobal Secure Collaboration Program. See www.tscp.org
XML	Extensible Markup Language