Model standards interoperability across domains, the life cycle, and the supply chain

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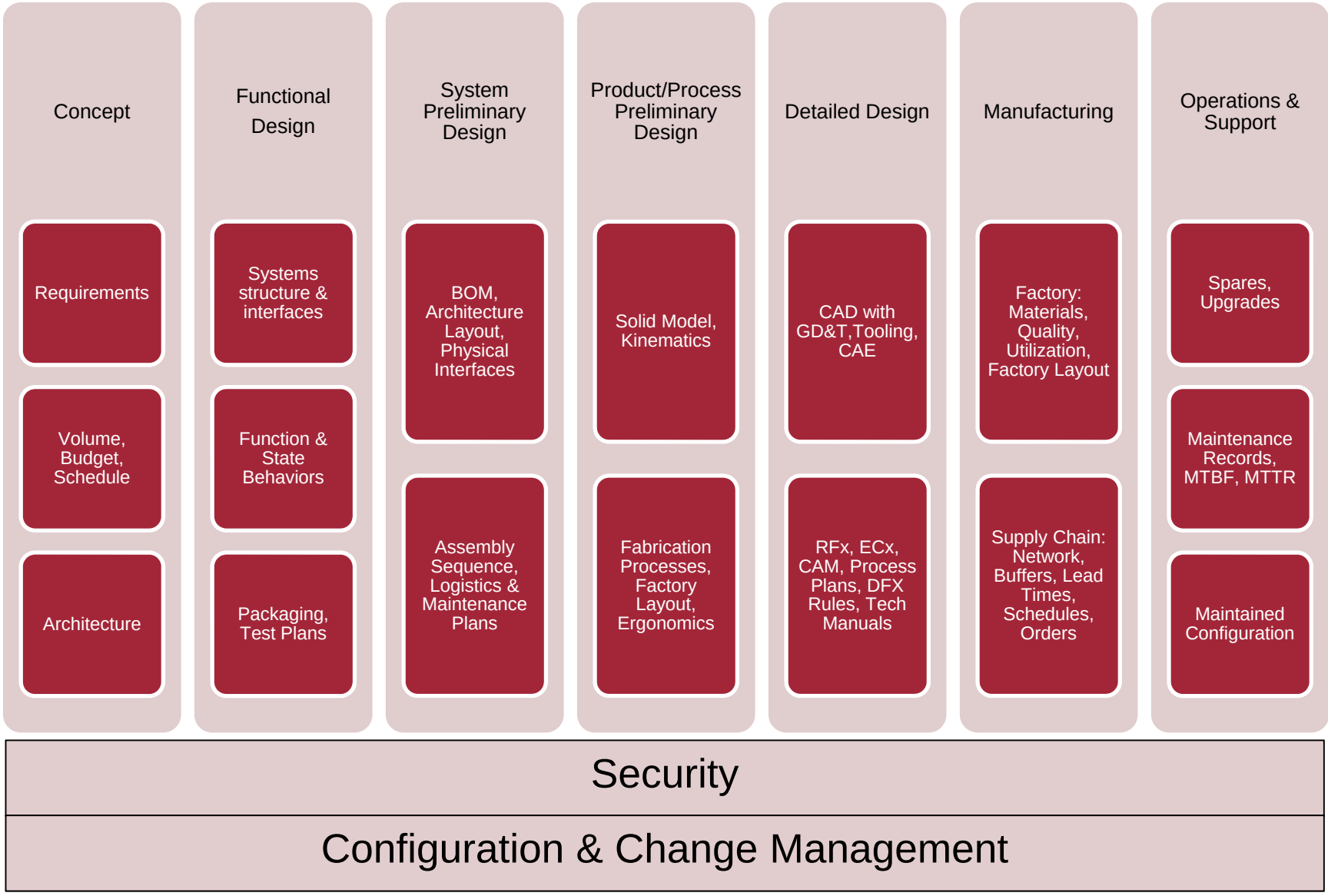
My perspective …

- **Cost models need to interoperate with other models**
  - **Requirements, Arch., Project, CAD, Assembly, Mfg., O&S**
- **Standards Involvement**
  - **PDES Manufacturing & Systems Engineering Teams**
  - **INCOSE MBSE, Tool Integration and Interoperability**
  - **OMG Model Interchange Working Group**
  - **CAX Implementor Forum**
  - **PLCS Implementor Forum**
  - **AIA/ASD Long Term Archiving and Retrieval (LOTAR)**
    - **Product Data Management & Metadata Teams**
  - **AIA/ASD Integrated Logistics Support (ILS S-series)**
    - **Data Modeling and Exchange Working Group**
- **Use of other technologies**
  - **OAGIS, Acrobat/3D PDF, COLLADA, CAD/PLM API's**

Data Across Functional Domains & Life Cycle Stages



STEP Modular Architecture (STEPmod)

- **Modular Application Protocol (AP) Benefits**
  - **STEP Module and Resource Library (HTML on CD) for CHF 352**
    - **Faster revision process (months rather than years)**
  - **Interoperability of implementations through module & code reuse**
    - **requirements, assembly structure, geometry, PMI etc.**

- **Two implementation levels**
  - **ARM domain-specific entities map to MIM entities from integrated resources**

- **Modular STEP AP Domains**
  - **AP209 CAE (FEA and CFD)**
  - **AP210 EDA/MCAD (electrical and mechanical assemblies)**
  - **AP233 Systems Engineering**
  - **AP239 Product Life Cycle Support (PLCS)**
  - **AP242 Mechanical CAD (parts & assemblies)**

Program and Project Management

- **Earned Value Management (EVM)**
  - **UNCEFACT based XML Schemas for Cost and Schedule**
  - **Cost classification by Work Breakdown Structure**
    - **MIL-STD-881 for systems (but hybrid breakdown)**
    - **Operations & Support WBS (functional breakdown)**
  - **DoD requiring on all large programs for EVM baseline and reporting to Central Repository**

- **NATO Guidance on Life Cycle Costing (ALCCP-1)**
  - **Recommends use of PLCS for data collection**
  - **Recommends standard Cost Breakdown Structure**
  - **Recommends standard activity and resource classification**

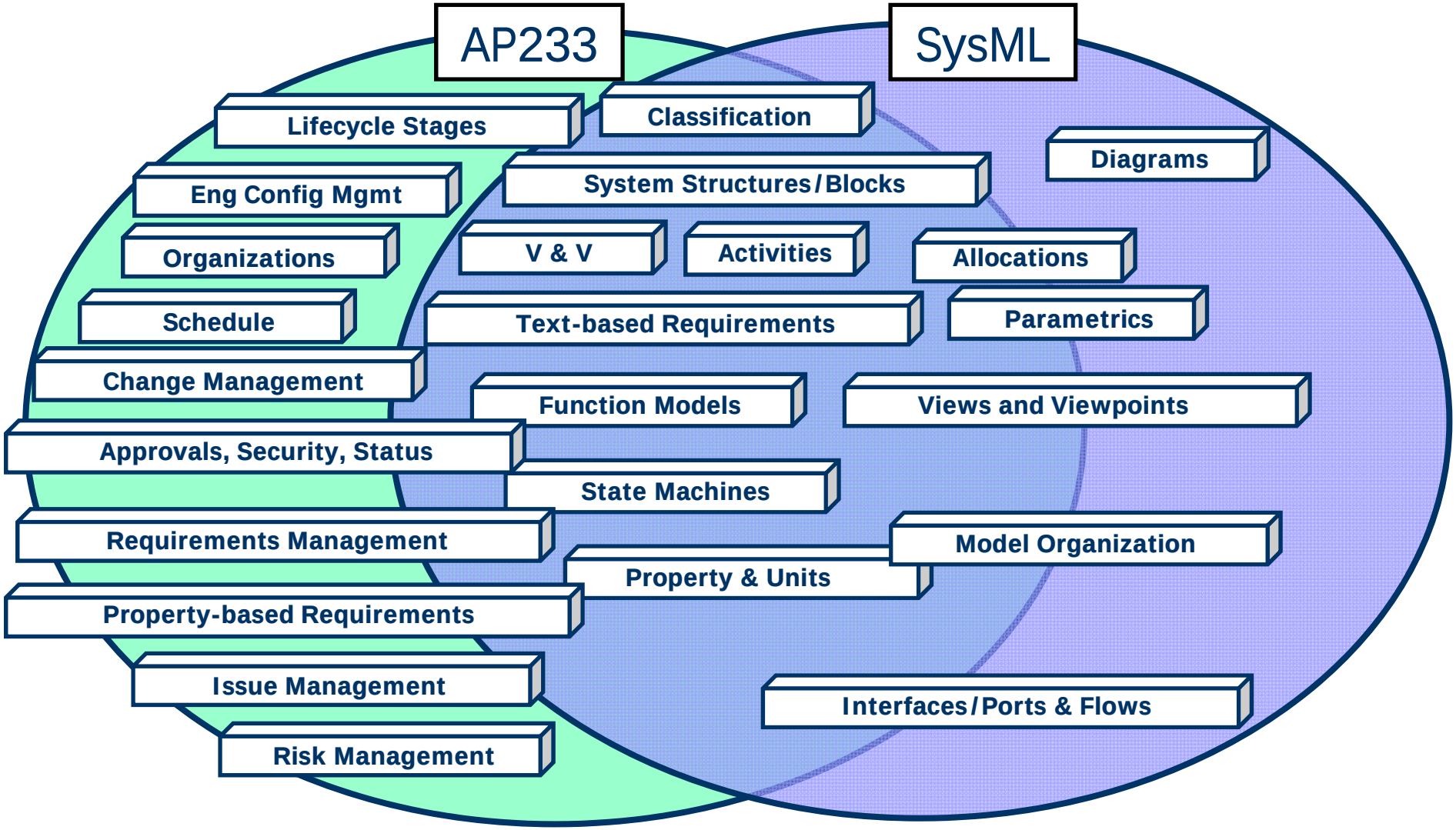
- **Collaborative Project Management (CPM)**
  - **Usage Guide, Data Exchange Model, Implementation Guide**
  - **By ProSTEP iViP with German auto industry**
  - **XML schemas and WSDL transport**

Systems Engineering Model Standards

- **SysML = Systems Modeling Language**
  - **Diagram language based on UML/OMG MOF**
  - **XMI = XML Model Interchange format**
    - **Written specification for OMG MOF (interpreted!)**
    - **Canonical XMI is restricted specification (NIST Validator)**
    - **OMG MIWG testing conformance, but not interchange yet**
    - **Need UID for diagram/data management**
    - **Without diagram exchange, limited to libraries or manual model re-building**
  - **Partial mapping with AP233 needs completion**

- **ReqIF = Requirements Interchange Format**
  - **XML schema for spec hierarchy, data types, attributes**
  - **Several versions in use**
  - **Vendor implementations not interoperable**
  - **ProSTEP iViP setting up an implementers forum**
  - **Early version mapping with AP233 needs updating/validation**

SysML/AP233 Data Overlaps



Model Transformation Technologies

- **XSLT (Extensible Stylesheet Language Transformations)**
  - **Between XML documents, HTML, PDF, relational databases, …**
  - **Many proprietary and open source implementations**
  - **E.g. STEPmod publishing system for STEP AP's**
- **EXPRESS-X (ISO 10303-14)**
  - **Data between EXPRESS schemas**
  - **NIST Expresso open source and commercial tools**
  - **E.g. implement STEP ARM to MIM/AIM mapping**
- **Meta Object Facility (OMG MOF)**
  - **Typically between UML derived languages and models**
  - **Ecore variant in Eclipse Modeling Framework commonly used**
  - **Transformation languages: QVT, ATL, VIATRA**
  - **E.g. ReqIF to SysML Requirements**

Use of AP233/239 in Systems Engineering

- **Early version of AP233 used for**
  - **Data Migration between Slate and TeamCenter SE**
  - **Mapping of CADM 1.5 format for DoDAF**
- **AP233 and AP239 Convergence**
  - **AP239ed2 contains all but 233's Issue and Behavior Models (State Machines and Enhanced Functional Flow Block Diagrams)**
    - **Roll them into modules or reference data**
- **AP239 PLCS used to manage mapped objects**
  - **PLCS supports relationships & configuration management**
    - **Like earlier work with CADM, IFC, SysML**
    - **Add ReqIF, UPDM, EVM, CPM, etc.**
  - **PLCS provides links to other domains (PDM, LSA, provisioning, scheduled maintenance, tech pubs, field data ..**

PDES Systems Engineering Projects

- **Requirements Traceability**
  - **Decomposition from Capabilities to Specifications**
  - **Across supply chain**
  - **Across tools (DOORS, ReqIF, SysML, etc.)**
  - **To verification & validation artifacts**
  - **Engineering change processes**
- **Systems Model Interoperability**
  - **Architecture, Behavior, …**
  - **Across lifecycle (Architecture, Systems, Design, Test, etc.)**
  - **Across languages (UPDM, SysML, UML, AADL, domain specific, …)**
- **Sharing info with ProSTEP iViP Smart Systems Eng.**
  - **Initial focus on Modelica Functional Mockup Interface (FMI)**
  - **Have advantages over Matlab/Simulink S-Functions**

Convergence of AP203 (Aero) and AP214 (Auto)

- **Create single superset standard for MCAD**
  - **203 x 214 = 242 and upwardly compatible**
  - **Modularization for interoperability across domains**
  - **Already harmonized for geometry (translators handle both)**
- **214 adds the following capabilities**
  - **Manufacturing process planning**
    - **Relate plans, operations, tools, raw/in-process/finished, projects, other activities, etc.**
  - **Kinematics**
  - **Machining Features**
  - **OMG PLM Services (web services API) for PDM and Engineering Change**
- **Enable association with 203 unique capabilities**
  - **Catalog, Composites, Construction History, Requirements**

New Functionality for AP242ed1

- **Business Object Model (BOM)**
  - **AP214 ARM was higher level than STEPmod ARMs**
  - **Upward compatibility for AP214 ARM based implementations**
  - **Harmonization ongoing with AP239 for PDM**
  - **Mapping from BOM to ARM**
    - **Enables higher level API**
    - **Composites then PDM and other areas**
    - **Eventually kinematics and mfg. process for visualization**
- **Shape Data Quality**
- **Access Rights Management**
- **Expanded Kinematics Simulation**
- **Improved PMI**
- **External Element Reference (eg. for Assembly PMI)**
- **Tessellated Geometry**

- **EXPRESS schemas and draft recommended practices available for testing**

Proposed Functionality for AP 242ed2

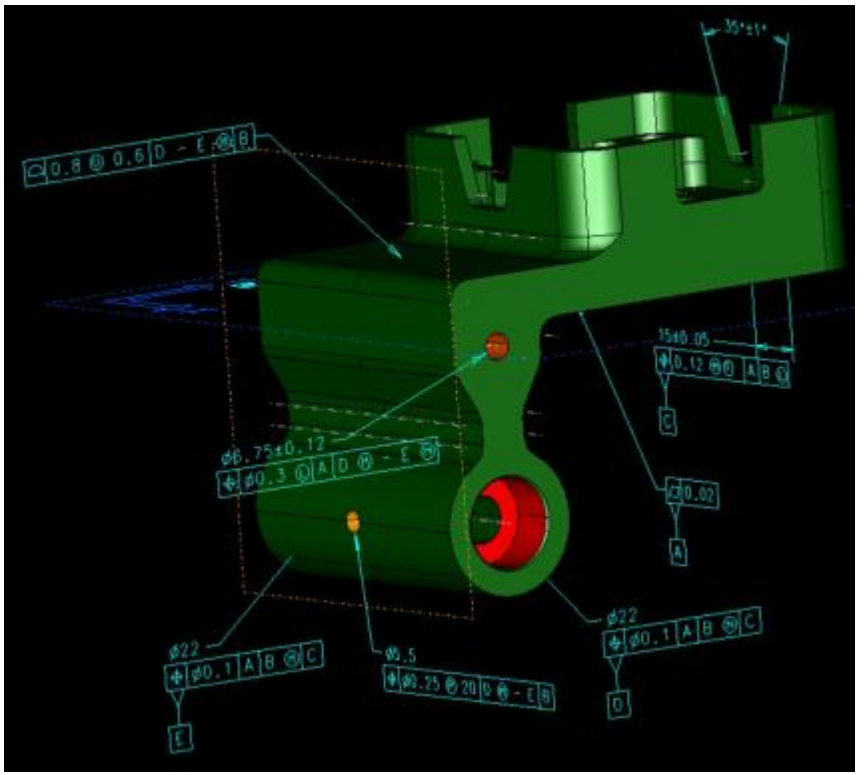
- 3D parametric / geometric constraints design
- 3D kinematics assembly
- 3D GD&T at assembly level
- Sustainability information
- Software / mechatronics
- 3D electrical harness
- 3D piping

AP242 PMI Subgroup work deferred for lack of funding

- **Mapping of screw threads standards to AIC522/AM machining_feature**
- **Welding standards (ISO 2553, AWS A2.4)**
- **PMI for ISO assembly documentation, assembly technology, assembly joint**
- **Support of adhesive standards (ASTM D7447)**
- **ISO 1101 FDAM1 - Tolerances of form, orientation, location and run-out**
- **Surface texture (ISO 1306, etc. and ASME B46.1)**
- **Other items that had been categories as out of scope for PMI-1 e.g. spot-face**
- **Update for new editions of ASME Y14.41 and ISO 16792**

CAx-Implementor Forum

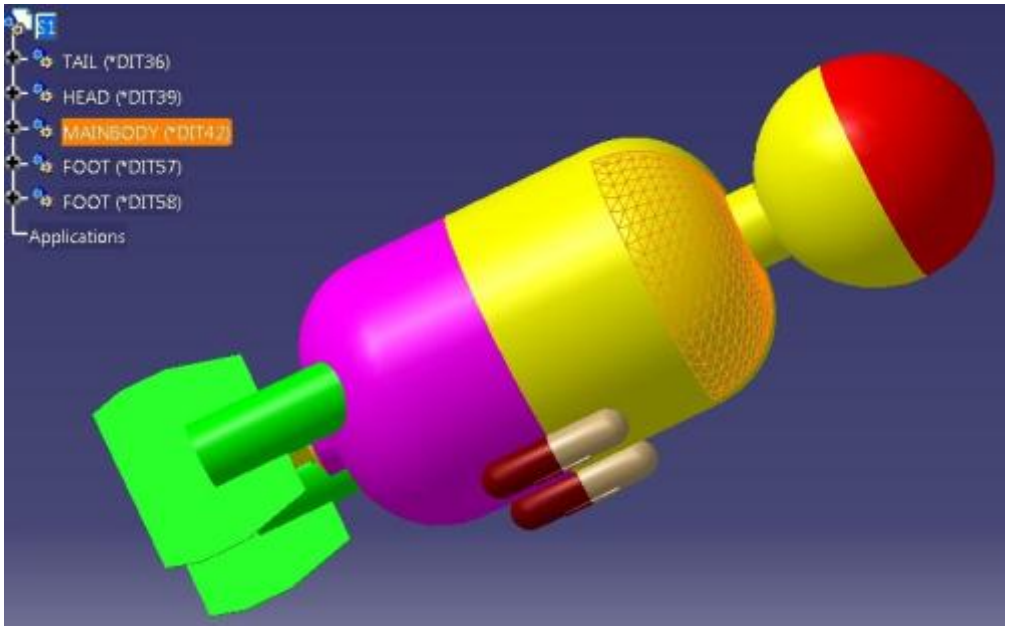
- **Joint testing effort of PDES Inc. & ProSTEP iViP**
- **Participants: AutoDesk, Capvidia, CT Core Technology, Dassault Systemes, DataKit, ITI TranscenData, Kubotek, LKsoft, PTC, Siemens, TechSoft 3D, Theorem Solutions, Vistagy**
- **JT, 3DPDF, 3DXML, CAP-XML sponsors are active members**
- **Bi-annual rounds of testing of CAD data exchange**
  - **Cooperate on implementing STEP**
  - **Feedback to STEP developers**
  - **Accelerate translator development**
  - **Promote interoperability**
  - **Scope is AP203, AP214, AP242**
  - **Capability & Validation**



Semantic PMI Representation Test Model

CAX-IF Benefits

- **Individual results covered by non-disclosure**
  - **Publish only aggregate results**
- **Test Suites**
  - **Instructions on building test models**
  - **Test, production models in file repository (STEP & native)**
- **Draft Recommended Practices**
  - **Model Styling & Organization**
  - **User Defined Attributes**
  - **External References**
  - **PMI**
  - **Tessellation**
  - **STEP File Compression**
- **LOTAR provides requirements and test models**
- **3D PDF Generator**



3D Tessellated Geometry Synthetic Test Model

CAX-IF Implementation Coverage Matrix

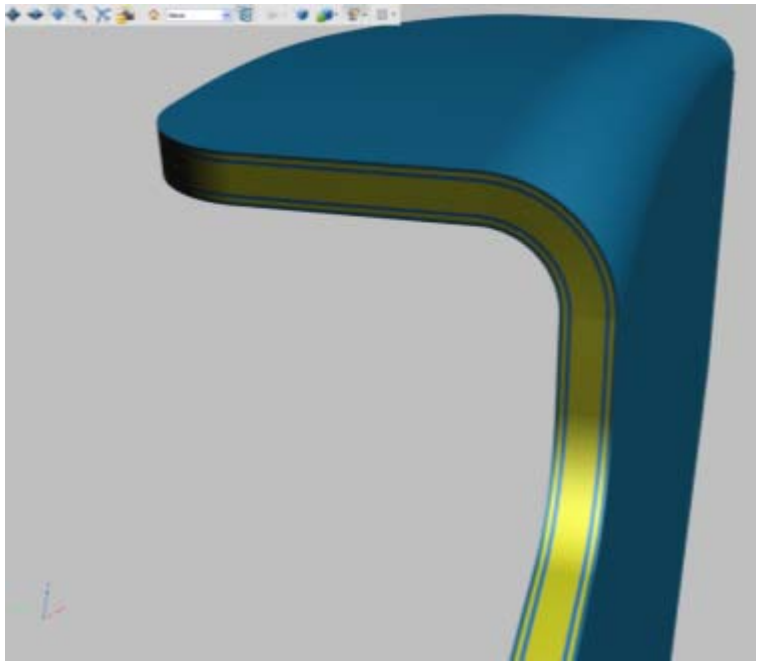
- **Purpose is to coordinate vendor testing**
  - **Organized by major sections of Recommended Practices**
- **Self-reported Vendor Status**
  - **Categories: Production, Customer Tests, Development, Future Plans, Not Supported**
    (Only Production status made public)
  - **Can compare implementations**
- **Total of 6 Vendors testing 242 implementations**
  - **Sufficient to have schema and recommended practices**

Public Implementation Coverage Example (CATIA V6)

Recommended Practices Functionality	AP203 E2 Import	AP203 E2 Export	AP214 IS (2001) Import	AP214 IS (2001) Export	AP214 E3 (2010) Import	AP214 E3 (2010) Export	AP242 Import	AP242 Export
Geometry								
Wireframe	X	X	X	X	X	X	X	X
Geom. Bounded Surface Model	X	X	X	X	X	X	X	X
BREP Solid	X	X	X	X	X	X	X	X
3D Tessellated							X	X
Assembly Structure								
Assembly Structure	X	X	X	X	X	X	X	X
Mapped_Item	X		X		X		X	
Composite Material								
Composite Material							X	X
Model Styling								
Solid Color	X	X	X	X	X	X	X	X
Face Color	X	X	X	X	X	X	X	X
Overriding Face Color	X	X	X	X	X	X	X	X
Edge / Curve Color	X	X	X	X	X	X	X	X
Overriding Edge Color	X	X	X	X	X	X	X	X

Composites

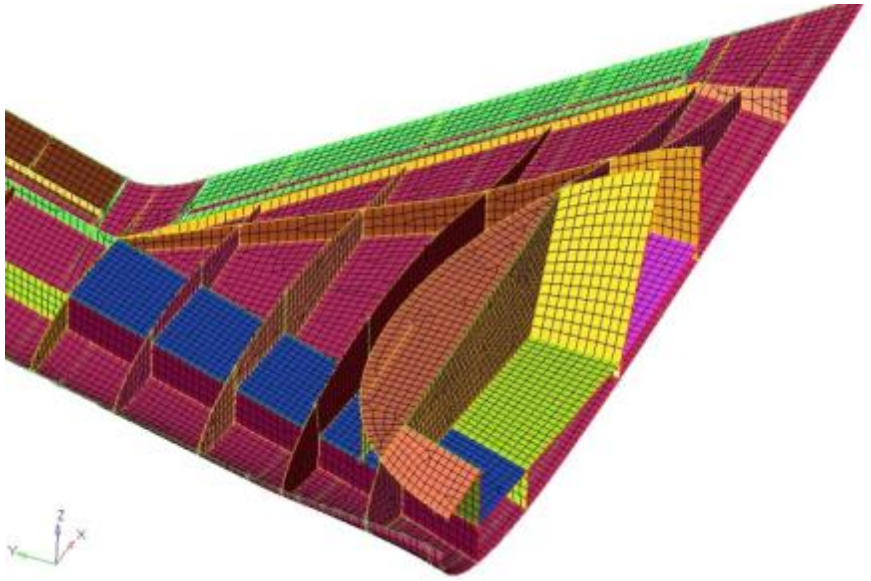
- **Composite meta-data**
  - **Ply orientation angle and thickness**
  - **Material specification**
- **Shape**
  - **2 ½ D wireframe and surfaces**
  - **Explicit solids**
  - **New tessellated geometry**
- **Going forward in AP242 and AP209**



Composite Plies & Core Structure

AP209ed2 Multidisciplinary Analysis and Design

- **Combines CAD, CAE, PDM capabilities**
  - **Superset of AP203ed2**
  - **Finite Element Analysis (FEA)**
  - **Computational Fluid Dynamics (CFD)**
  - **General numerical analysis**
  - **Shares base analysis models with AP233 Systems Engineering**
- **Developing binary format**
  - **Based on open source HDF5 toolkit**
  - **New ISO 10303-26 (part26)**
- **New API specification**
  - **BOM to ARM to AIM mapping**
  - **Web services implementation**



Publicly sharable Finite Element Model for testing

Simulation Data Management (SDM)

- **SimPDM project of ProSTEP iViP**
  - **Business process diagrams**
  - **Business process between SDM, Multi-Body, FEM, CFD, PDM**
  - **Not an interchange data format, it is a metadata model**
- **CAE Services project of ProSTEP iViP**
  - **Successor to Collaborative CAD/CAE Integration (C3I)**
    - **Successor to SimPDM**
    - **XML schemas and WSDL**
    - **Mapping to AP209 entities**
- **SimDM project of PDES Inc.**
  - **Uses AP209ed2 and 242-style Business Object Model**
- **CRESCENDO project of EU**
  - **Based on EU VIVACE, AP233/239 and PLCSlib**
  - **Behavioural Digital Aircraft (BDA) Model …**

Behavioural Digital Aircraft (BDA) Model

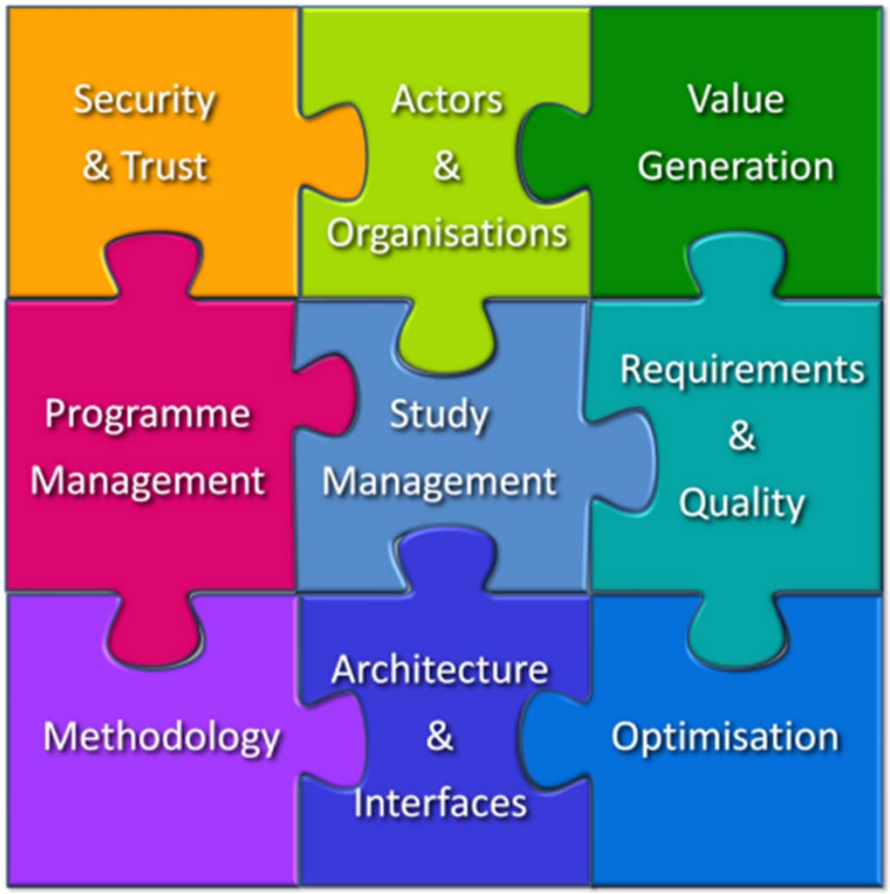
- **BDA Business Object Model defines common language exposed as web services based on 233/239**
- **BDA PLCSlib DEX's to be publicly released soon**
  - **Many base PLCS templates already available as OASIS templates**
  - **Not specific to aircraft, can be used for other types of products**
- **Web services to create, update, read and search data**
  - **WSDL interfaces implemented against**
    - **Share-a-space collaboration hub**
    - **Clients: MSC SimManager/SimXpert, Siemens TeamCenter/NX, Scilab, Proosis, Dassault CATIA/Enovia/iSight/Dymola, Altair/Optistruct**

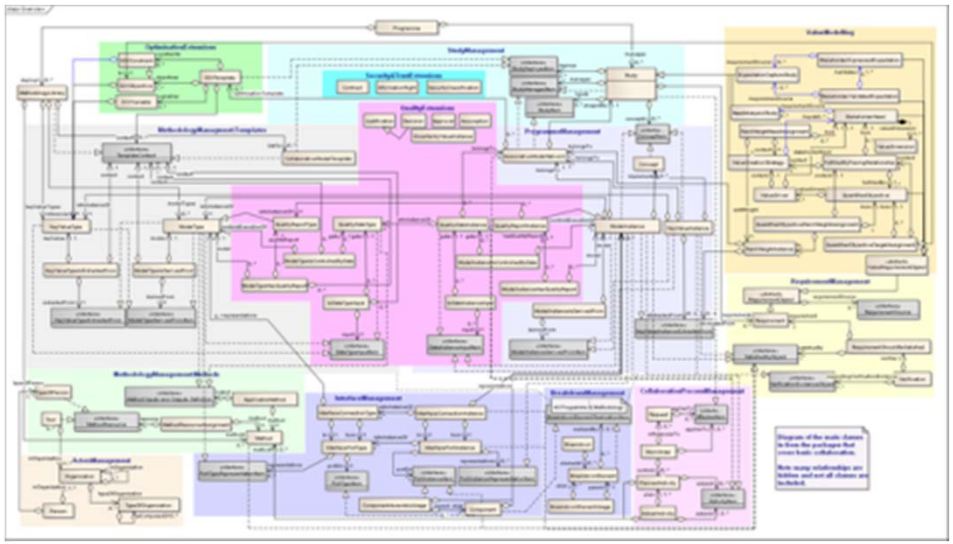
Benefits of PLCSlib

- **New DEX development environment**
  - **Recommended by OASIS PLCS Technical Committee on all new DEX development**
  - **Replaces DEXlib and based on AP239ed2 International Standard (IS)**
  - **Generate DEX XML schema from SysML model**
  - **Reference data in semantic web technology (OWL2 DL)**
  - **Uses new templates (due to AP239ed2 and other lessons learned)**

- **Benefits**
  - **Can transform data for legacy DEX to new DEX's (no DEX transform)**
  - **Re-use DEXlib business information requirements/entity mapping**
  - **Faster DEX development (SysML IDE & encapsulation/abstraction)**
  - **SysML integration to Enterprise Architecture and Systems Engineering**
  - **Smaller file sizes and schemas**
  - **Better re-use and fewer base templates**
  - **Better quality due to built-in object and type checking**
  - **Software code and Web service generation**

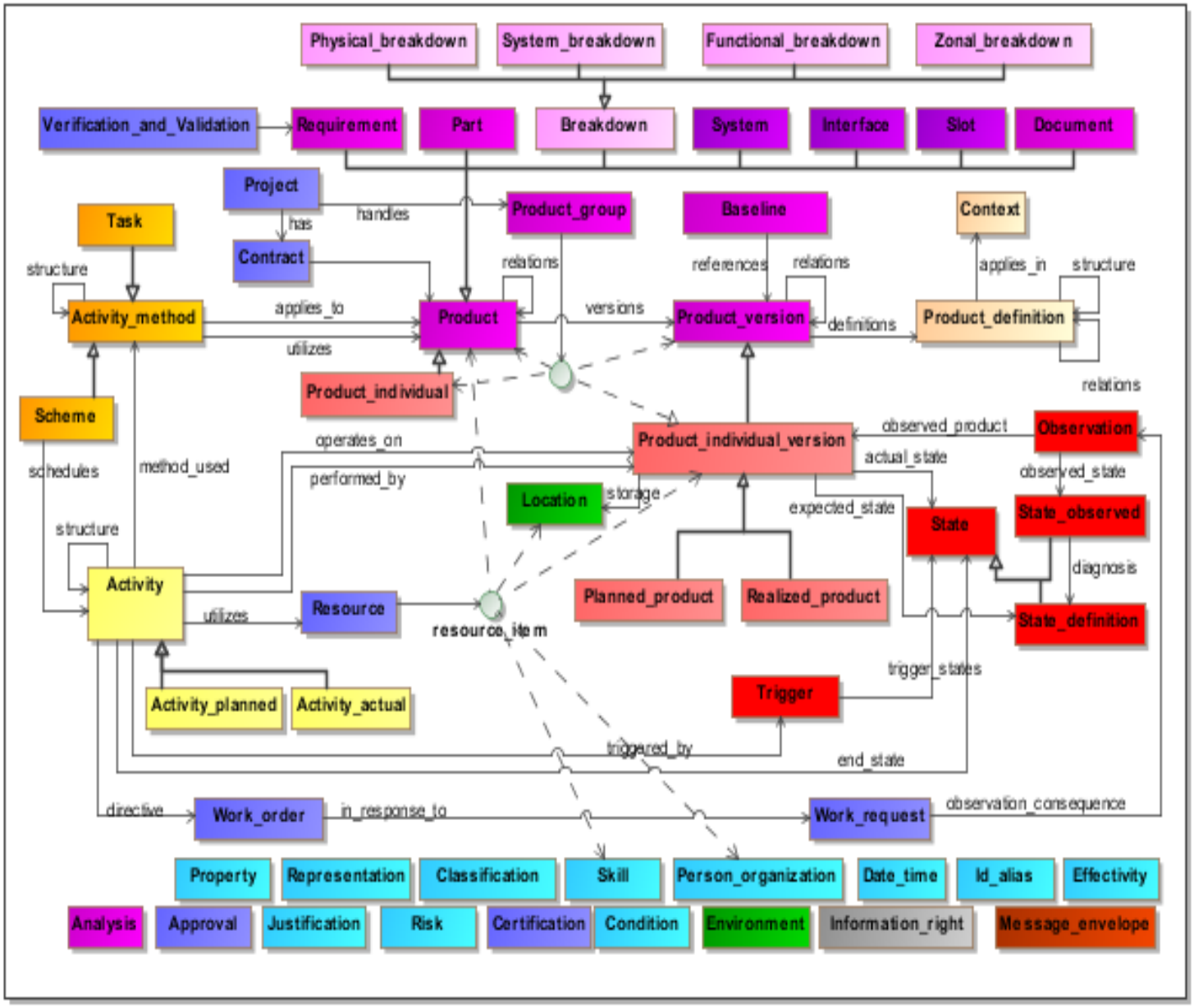
Business Object Model : BDA Dataset coverage





Rich model designed to enable traceability from customer expectations through to certification

AP239 ed2 PLCS Concept Model



Product Designs

Information Control

Individual Products

Information Exchange

Product Breakdown

Product Descriptions

States

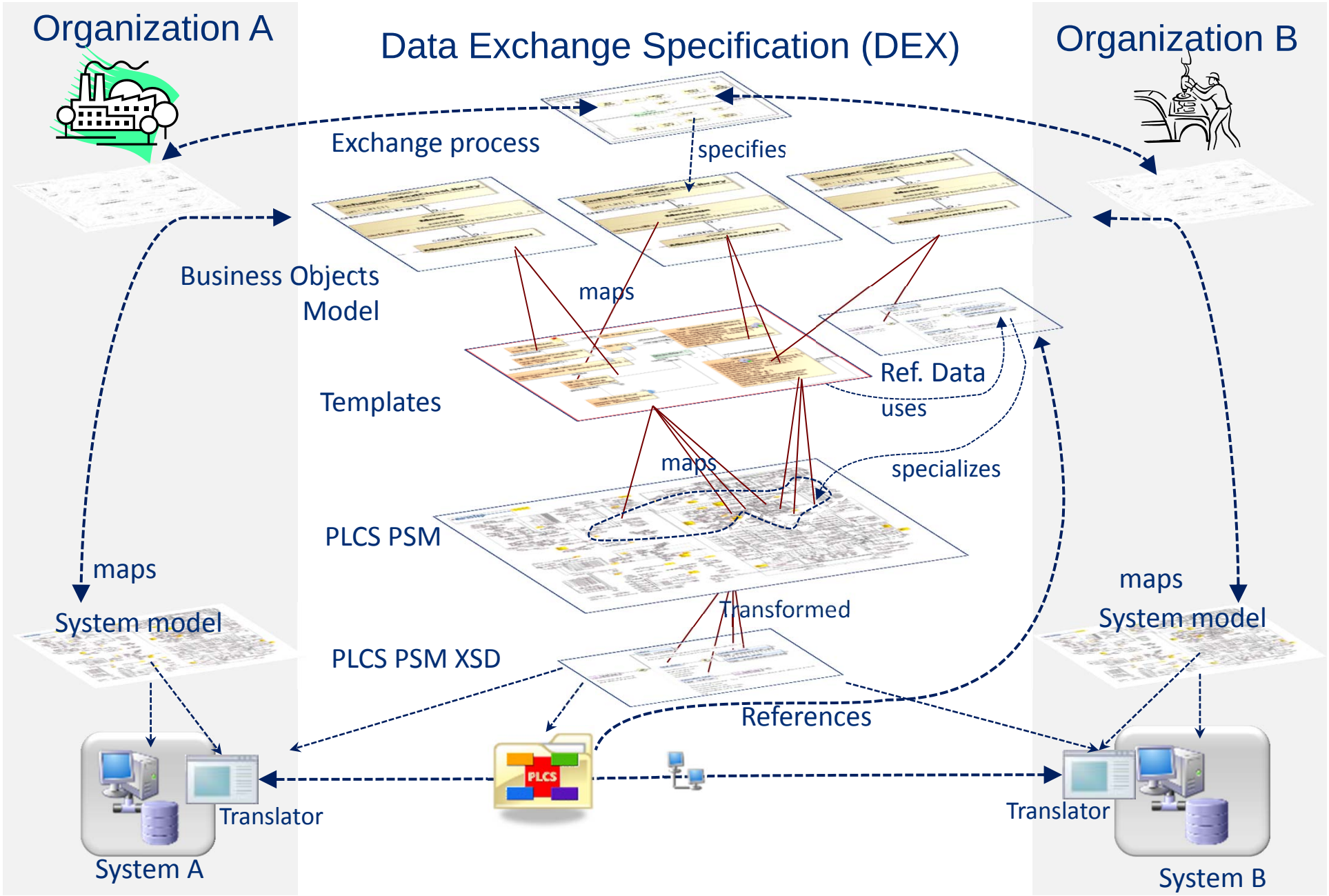
Activity Specifications

Activity History

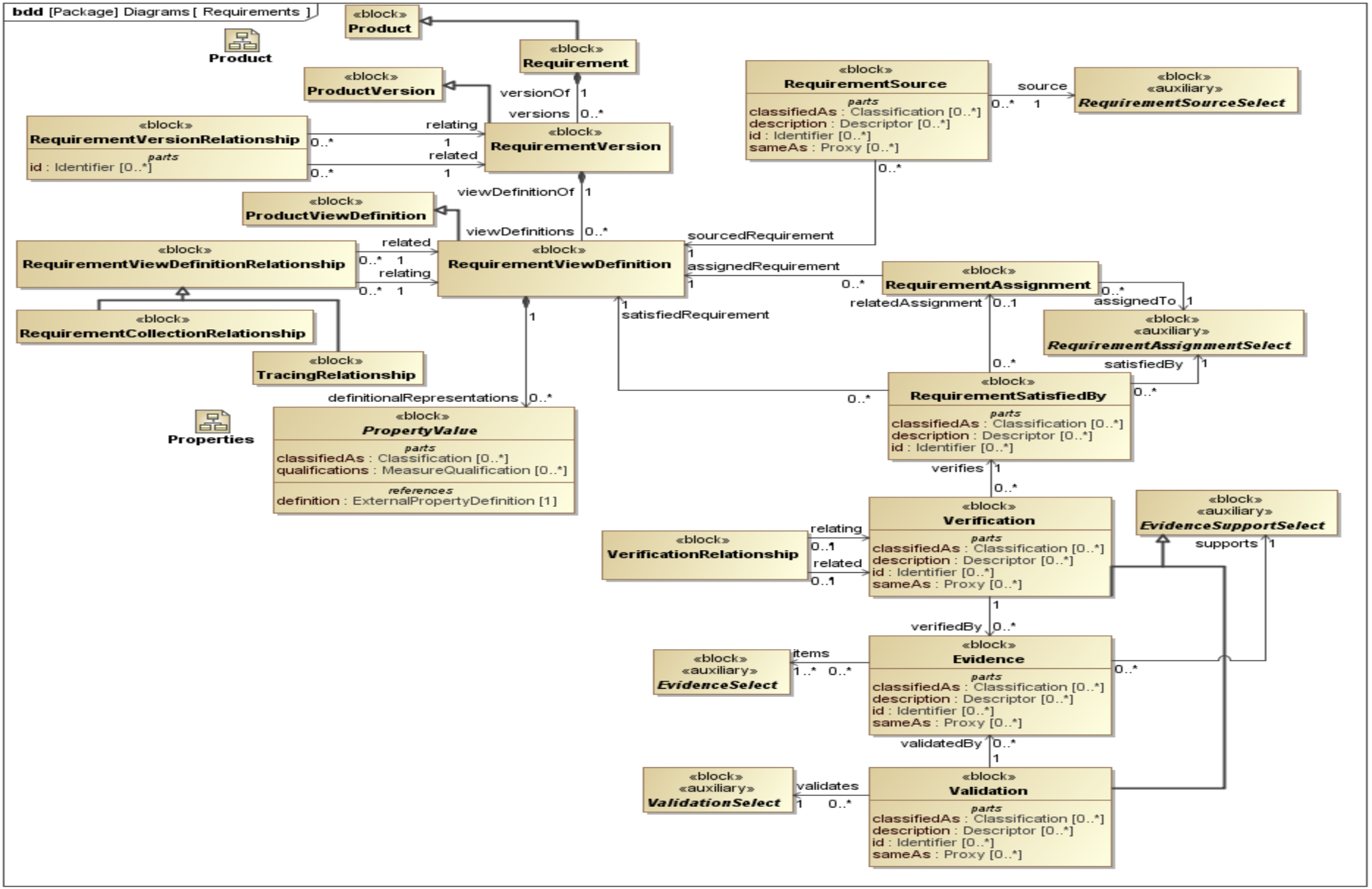
Product Environment

Management Process

Details


Organization A
Data Exchange Specification (DEX)
Organization B
Exchange process
specifies
Business Objects Model
maps
Templates
Ref. Data
uses
specializes
maps
PLCS PSM
maps
System model
Transformed
PLCS PSM XSD
References
maps
System model
PLCS
Translator
Translator
System A
System B

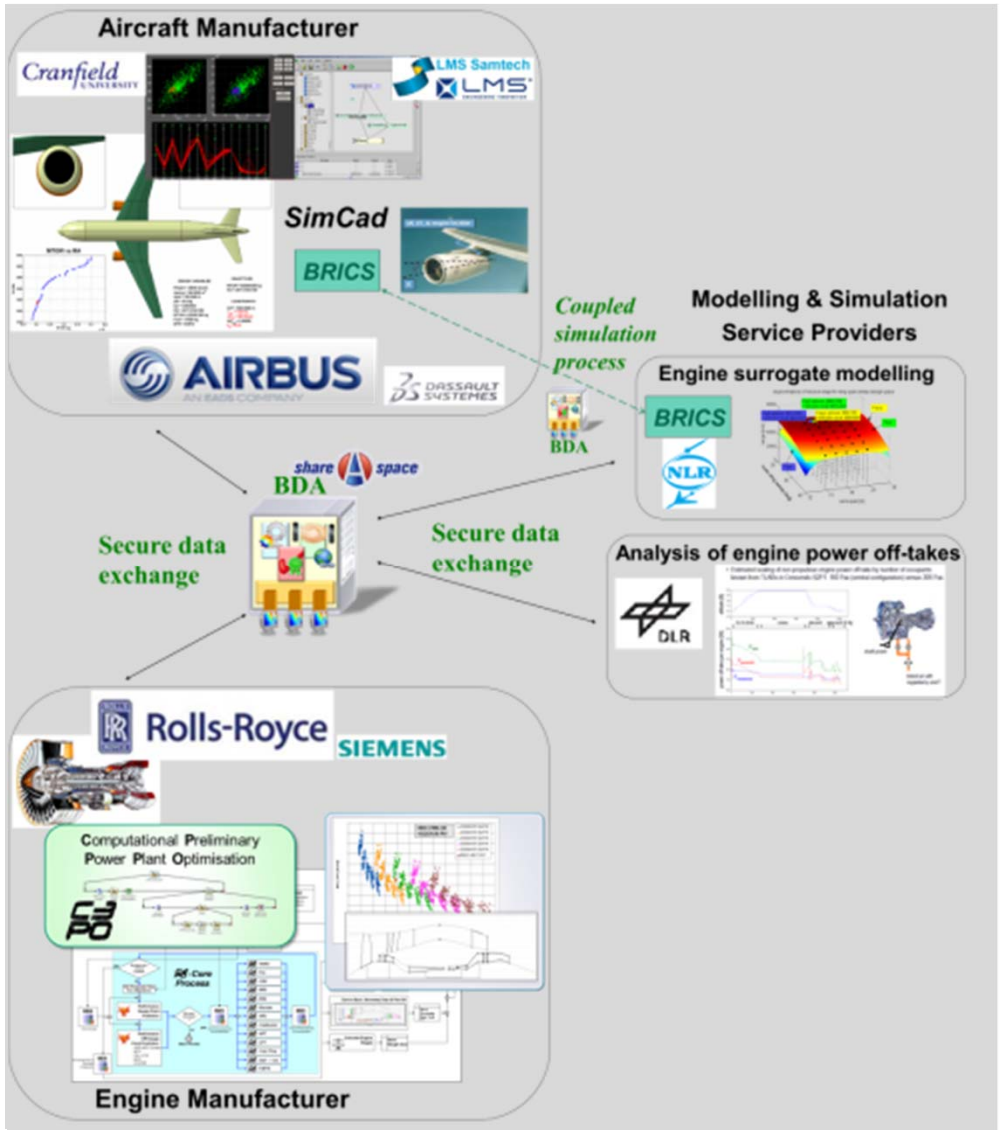
SysML Block Definition Diagram of PLCS Requirements



A CRESCENDO example (simplified)

A typical example case in CRESCENDO:

- **Airbus (France and UK) start to develop a new plane based on an analysis of customer expectations leading to requirements**
- **Cranfield (UK) are asked by Airbus to develop engine properties to match the requirements**
- **DLR analyse power off-takes**
- **The requirements and engine properties are passed by Airbus to Rolls Royce (D and UK) to propose a type of engine with more properties and requirements for which RR then simulate**
- **The results of the simulation are passed to NLR (Netherlands) who produce a "surrogate model" which is passed back to RR and then made available to Airbus**
- **Iterate taking into account thermal, noise, pylon structures,…**



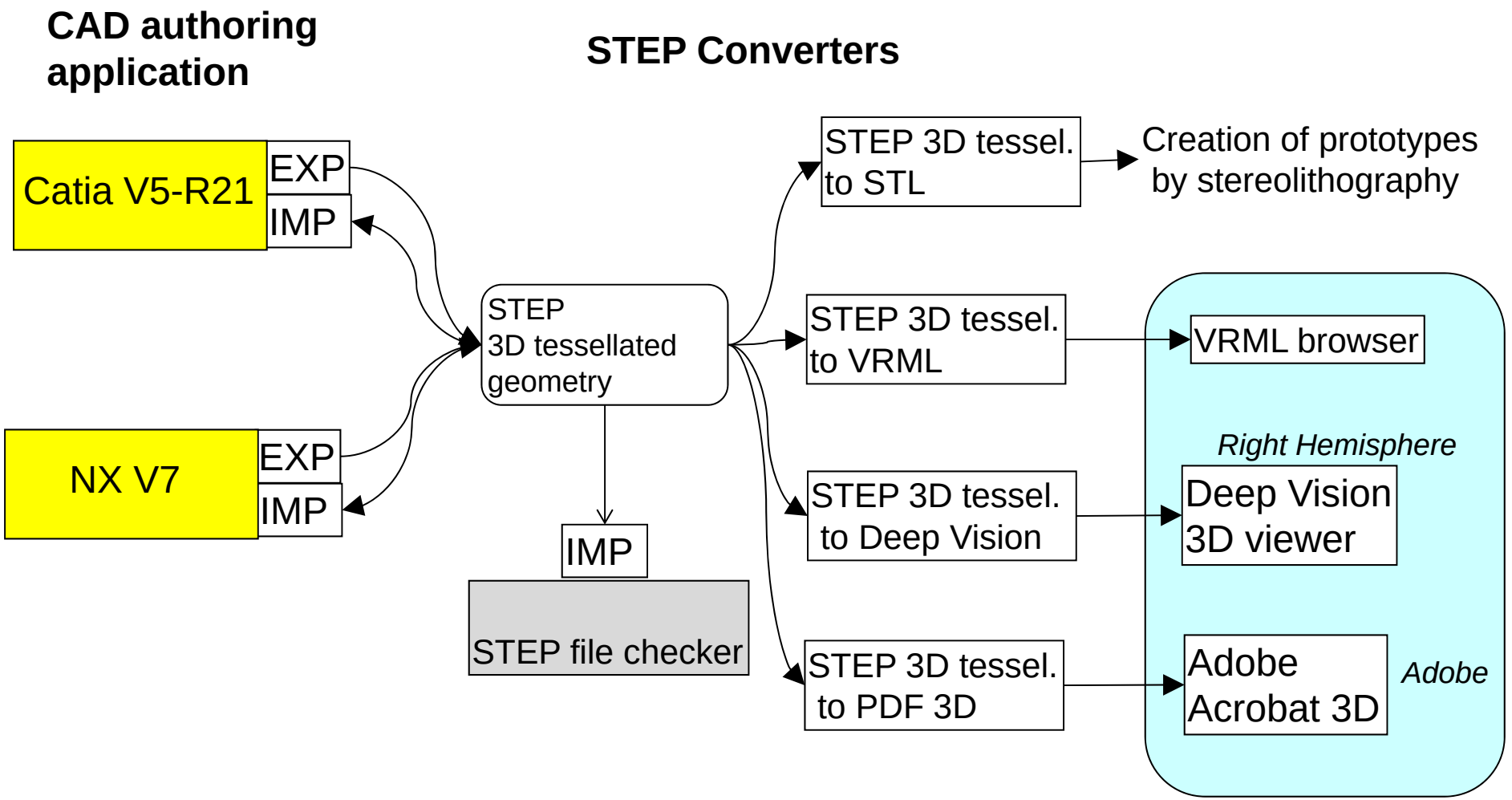
Multiple Visualization Formats

- **New LOTAR visualization team**
  - **Provide requirements to other consortiums**
  - **Interoperability testing with 3D tessellation in STEP**
- **JT and 3D PDF working on PMI**
- **COLLADA from Khronos Group**
  - **Harvesting by ISO TC184/SC4 like JT**
  - **XML schema with an extension method**
  - **Open source toolkits available**
  - **Used in Digital Content Creation industry**
    - **CGI, gaming, training …**
  - **New version includes BREP, kinematics (little support yet)**
  - **Khronos also provides WebGL (3D model in browser)**
  - **Open source for COLLADA to WebGL (three.js, scene.js)**

3D CAD in a Web Browser

- **WebGL in HTML5**
  - **Embedded in most browsers, or plug-in to Internet Explorer**
  - **Runs on desktop and Android, RIM mobile browsers (not iOS)**
  - **Uses GPU for 3D acceleration**
- **Examples using WebGL**
  - **PythonOCC – STEP through OpenCascade to browser**
  - **Sketchfab – publishing system from CAD to web pages**
  - **Tinkercad – parametric 3D CAD in browser and STL interface**
  - **3DTin – modeller with STL, OBJ, DAE (COLLADA) export**
  - **ShapeSmith – parametric NURBS open source**
  - **Sunglass.io – collab. viewer, parts/assemblies, CAD formats and plug-ins**
- **X3D plug-in for browsers**
  - **Collaborating with COLLADA and WebGL teams**

Tessellated Geometry Interoperability Testing



PLCS and Logistics

- **ASD/AIA Integrated Logistics Support S-series**
  - **SX000i Guide for Use of S-series: writing chapters**
  - **S2000M Material Management: issue 5.0 on May 3**
  - **S3000L Logistics Support Analysis: issue 1.1 Q1 2013**
  - **S4000M Scheduled Maintenance: working on issue 1.0**
  - **S5000F Operational & Maintenance Feedback: early draft handbook, data**
  - **S6000T Training Needs Analysis, TBD**
  - **S9000D Dictionary: issue 1.0 under development**
- **GEIA-0007 Logistics Product Data**
  - **Some DEXlib DEX's developed**
  - **Handbook Rev B Ballot Draft released August 20**
  - **Draft MIL-HDBK-502A Acquisition Logistics on Oct. 1**
- **Other MODs developing PLCSlib DEXs**
  - **France, Norway, Sweden, UK, USMC/NATO**

Convergence on Maintenance Feedback

- **Spec 2000 from Airlines for America (A4A)**
  (A4A formerly known as Air Transport Association (ATA))
  - **E-business Specification for Material Management**
  - **For Maintenance, Repair, Operation (MRO) of civil aircraft**
  - **Strongly recommended by airframers in procurement**
  - **Chapter 11 Reliability Data Collection/Exchange**
    - **Eg. LRU Unscheduled Removal Record**
  - **Chapter 13 Performance Metrics Standards**
    - **Eg. To compute MTBF**

- **ASD Strategic Standarization Group (SSG) Plan**
  - **Analyze Spec 2000 and prepare adjustment proposals to A4A to fit with ASD S5000F requirements**

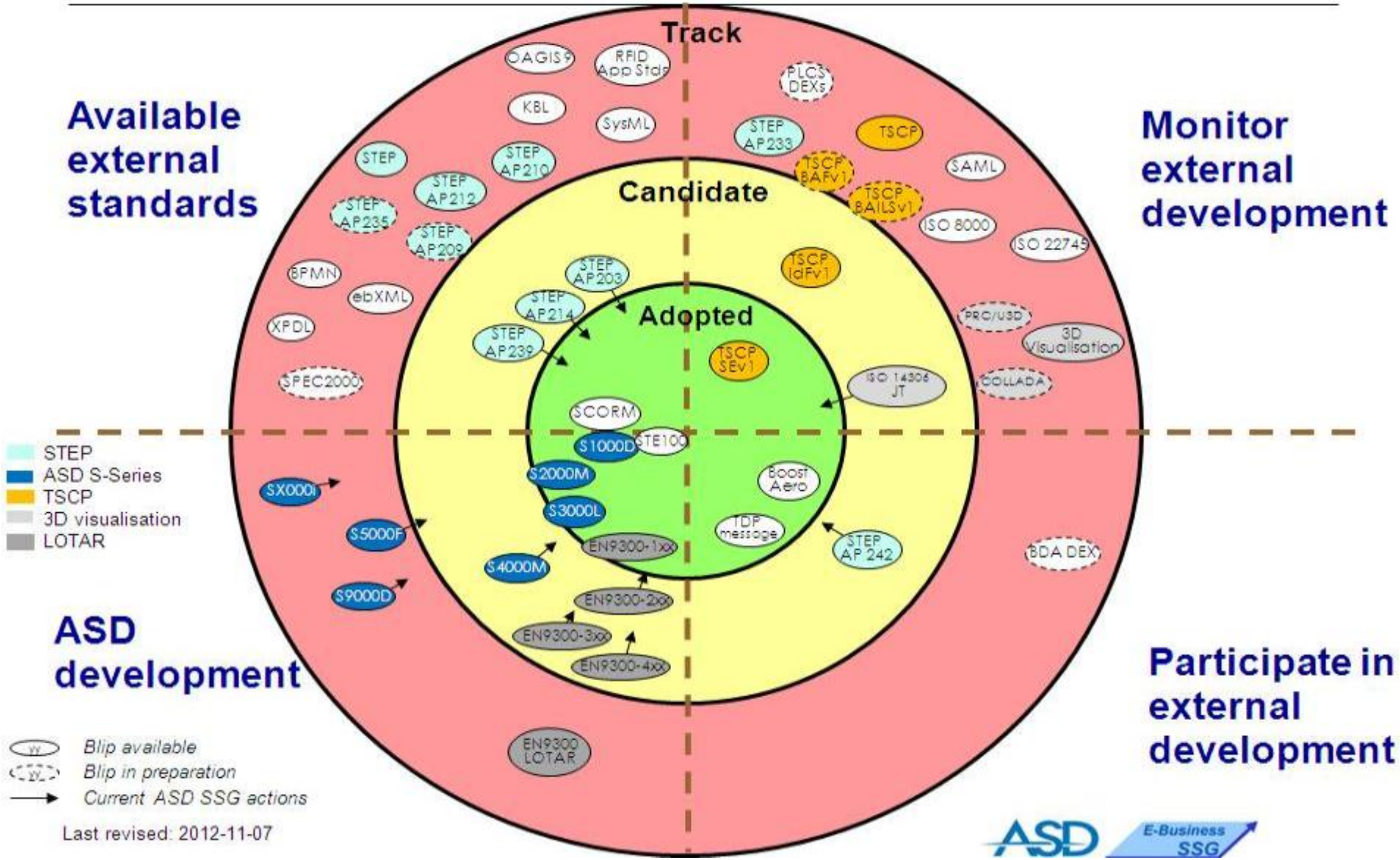
- **Challenge: Input to ASD indicates that A4A is not open to adoption of AIA/ASD S-series standards**

Transglobal Secure Collaboration Program (TSCP)

- **Members: MoD's, DoD, and A&D contractors**
- **Secure E-mail Specification v1 (SE v1)**
  - **Check sender/receiver for EAR and ITAR rules**
  - **PKI certificates for digital signature and encryption**
  - **Certificate Authority and cross-certification**
- **Identity Federation v1 Assertion Profile (IdF v1)**
  - **Security Assertion Mark-up Language (SAML) profile for A&D**
  - **Attributes also passed through WS-Fed Protocol**
- **Communicating with OASIS PLCS TC on Information Rights Management**

Standards Radar Chart by ASD

Radar screen



Available external standards

Monitor external development

ASD development

Participate in external development

Last revised: 2012-11-07

ASD E-Business SSG

STEPcode Open Source

- **Based on legacy NIST STEP Class Library**
  - **BRL-CAD Open Source Reference Implementation**
  - **BRL-CAD used Coverity for static code analysis to find and fix defects and security vulnerabilities**
- **Current STEPcode functions**
  - **Generates p22 SDAI class library in p23 C++ binding**
  - **Compiles p21read/write executable**
  - **Works on major EXPRESS schemas and p21 files**
- **www.stepcode.org**
  - **scl-dev Google group discussions on STEP**
  - **Used by SCView: EXPRESS-G, tree & text viewer**
  - **Github: Notepad++ plug-in for EXPRESS schemas**

Conclusions

- **Many complementary interoperability standards for models across domains and the life cycle**
  - **Need to define interfaces (map overlaps and fill gaps)**
  - **Need to portfolio manage collections (like LOTAR & ASD SSG)**

- **Technology is available, but needs investment**
  - **Standards development infrastructure (eg. STEPmod)**
  - **Share implementer forum resources and best practices**
  - **Tighten implement/test/feedback/modify cycle like CAX-IF**
  - **Need open source reference implementations**
  - **Sharing best practices (Validation, UIDs, Testing …)**