

Create your Digital Twin in days, not months.

Using ISO 10303 standards for simulation and structural test data

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KYKLOS 4.0

CHANGE2TWIN

Supported by advanced EU H2020 projects



Introduction to STEP

- The STEP standard
- AP209

Extending AP209 (PhD research)

- The problem
- Structural testing
- Nonlinear analysis

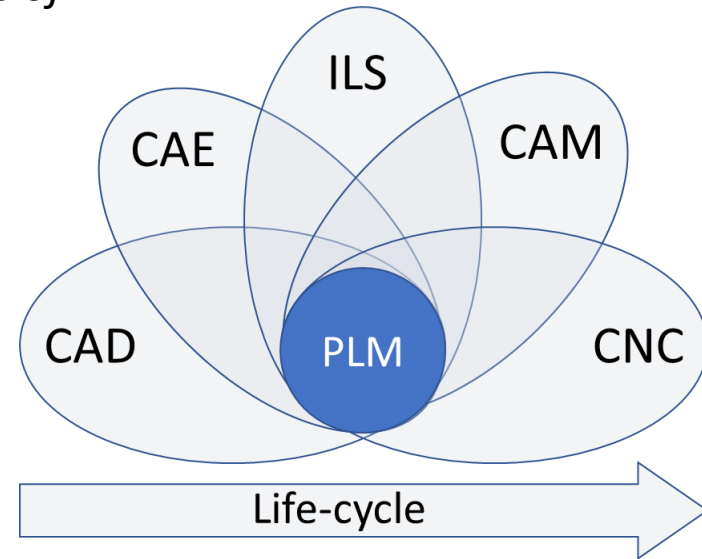
AP209 in project use cases

- Simulation Data Management
- CRYSTAL project (Lockheed Martin)
- DEFINE project (ESA)



STEP ISO 10303

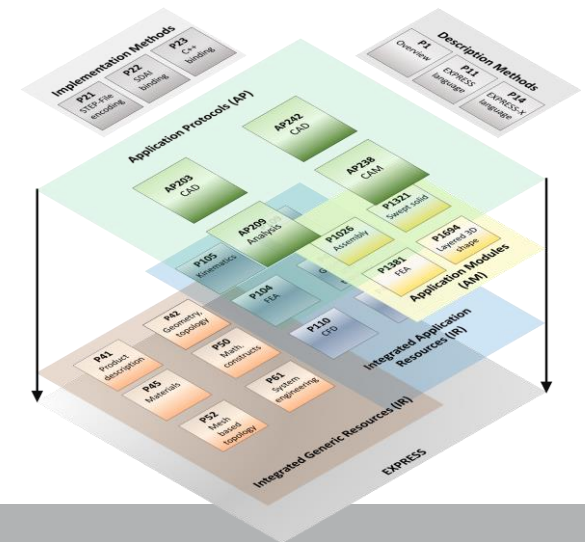
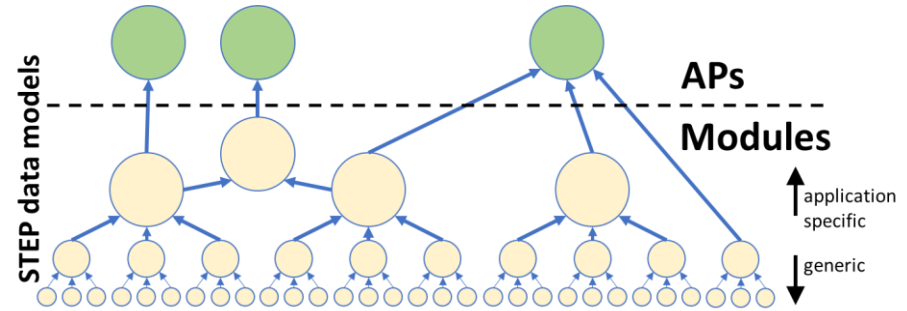
- ISO 10303 (*Industrial automation systems and integration – Product data representation and exchange*)
 - Also know as: **STEP** (*Standard for the Exchange of Product model data*)
- Data model for storing and sharing industrial data with product lifecycle perspective
- The data models are written in the lexical EXPRESS data modeling language





STEP ISO 10303: Architecture

- **Description Methods**
 - EXPRESS language
- **Implementation Methods**
 - The STEP P21 format (ASCII), SDAI, C++ binding,
- **Integrated Generic Resources (IGR)**
 - Core STEP data models; generic (product description, geometry, math, ...)
- **Integrated Application Resources (IAR)**
 - Core STEP data models; application (FEM, CFD, draughting, manufacturing)
- **Application Modules (AM)**
 - Collects multiple IGR, IAR and other AM, data models
- **Application Protocols (AP)**
 - Complete data model, aggregated content from a specific AM
 - *What an application implements to support STEP for a domain*





STEP ISO 10303: Architecture

- **AP203** Configuration controlled 3D design of mechanical parts and assemblies
- **AP214** Core data for automotive mechanical design processes
- **AP242** Managed Model Based 3D Engineering
- **AP209** Multidisciplinary Analysis and Design
- **AP239** Product Life Cycle Support (PLCS)
- **AP238** Integrated CNC Machining (STEP-NC)

- AP 203, *Configuration Controlled 3D Designs of Mechanical Parts and Assemblies*
- AP 214, *Core Data for Automotive Mechanical Design Process*
- AP 242, *Managed model based 3d engineering*
- **AP 209, *Multidisciplinary analysis and design***
- AP 235, *Materials information for the design and verification of products*
- AP 210, *Electronic assembly, interconnect and packaging design.*
- AP 212, *Electrotechnical design and installation.*

- AP 215, *Ship arrangement*
- AP 216, *Ship moulded forms*
- AP 218, *Ship structures*

- AP 224, *Mechanical product definition for process plans using machining features*
- AP 238 - *Application interpreted model for computer numeric controllers*
- AP 240, *Process plans for machined products*

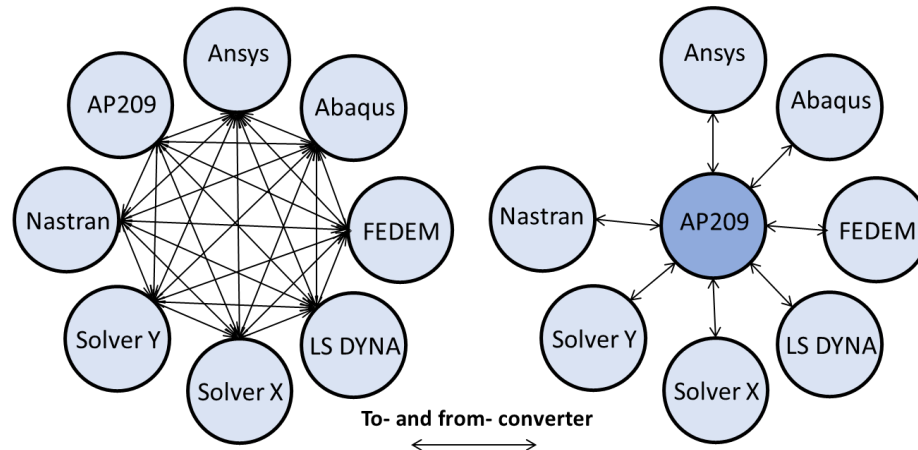
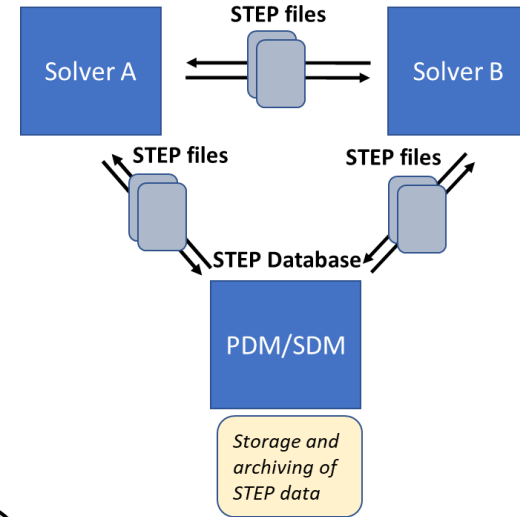
- AP 239, *Product life cycle support*
- AP 221, *Functional data and schematic representation of process plants*



AP209

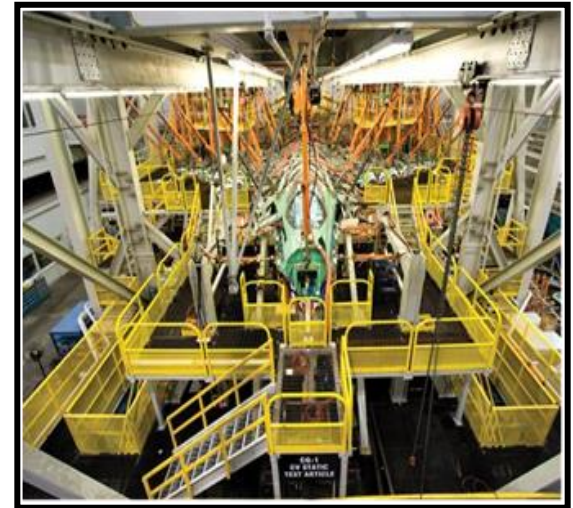
• AP209: *Multidisciplinary analysis and design*

- CAD
- FEM
- CAD & FEM topological relations
- CFD
- Composites
- PLM/PDM
- **Extensions:**
 - **Structural Test Data**
 - **NLFEM**



Simulation and structural testing

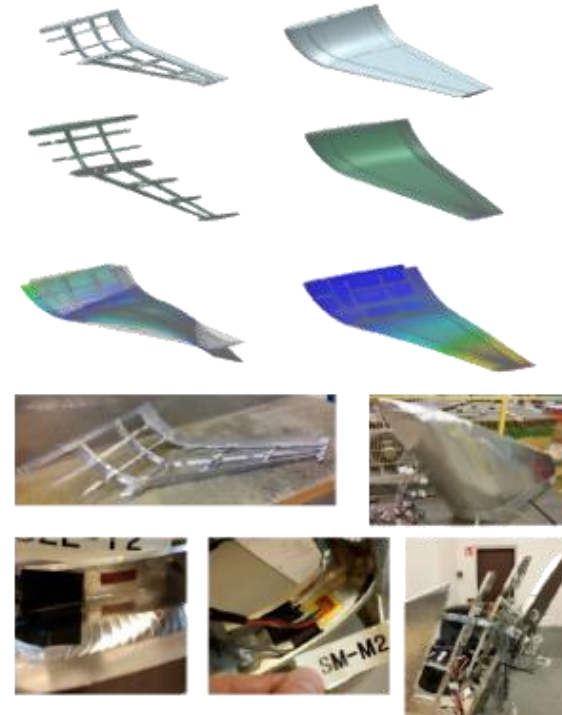
- Structural testing and simulations well integrated in the development processes of complex systems
- During and after projects, finding information is inefficient and time consuming with data spread over many applications, files, formats and locations.
- **Simulations (FEM)**
 - Multiple *analysis* files in different formats
 - Multiple *result* files in different formats
 - Possibly post-processed *result* files (e.g. Excel)
- **Structural Testing:**
 - Large *test result* files (e.g. from CATMAN)
 - These files are usually post-processed (e.g. Excel)
- **Correlation/Validation**

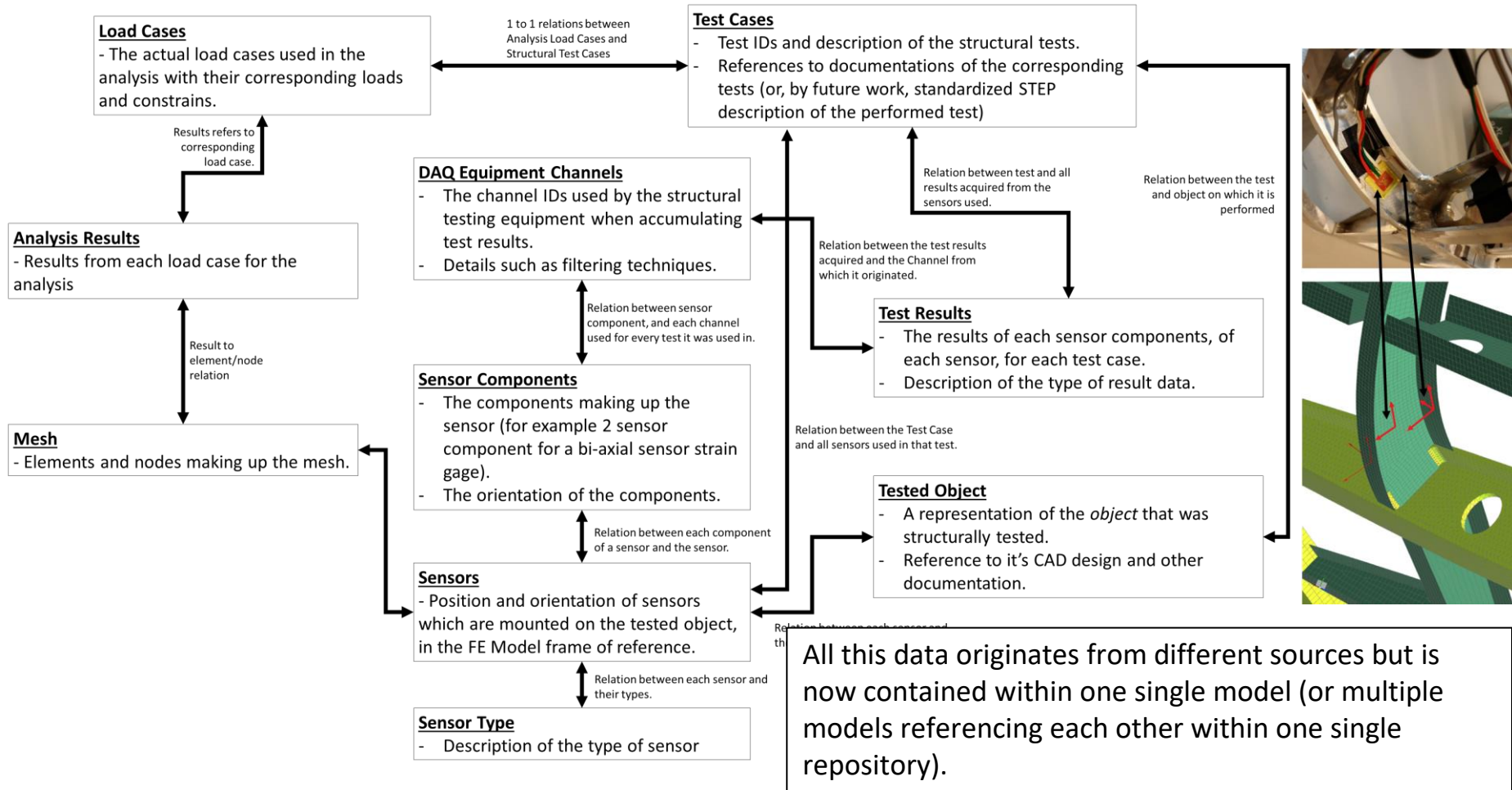


Simulation and structural testing

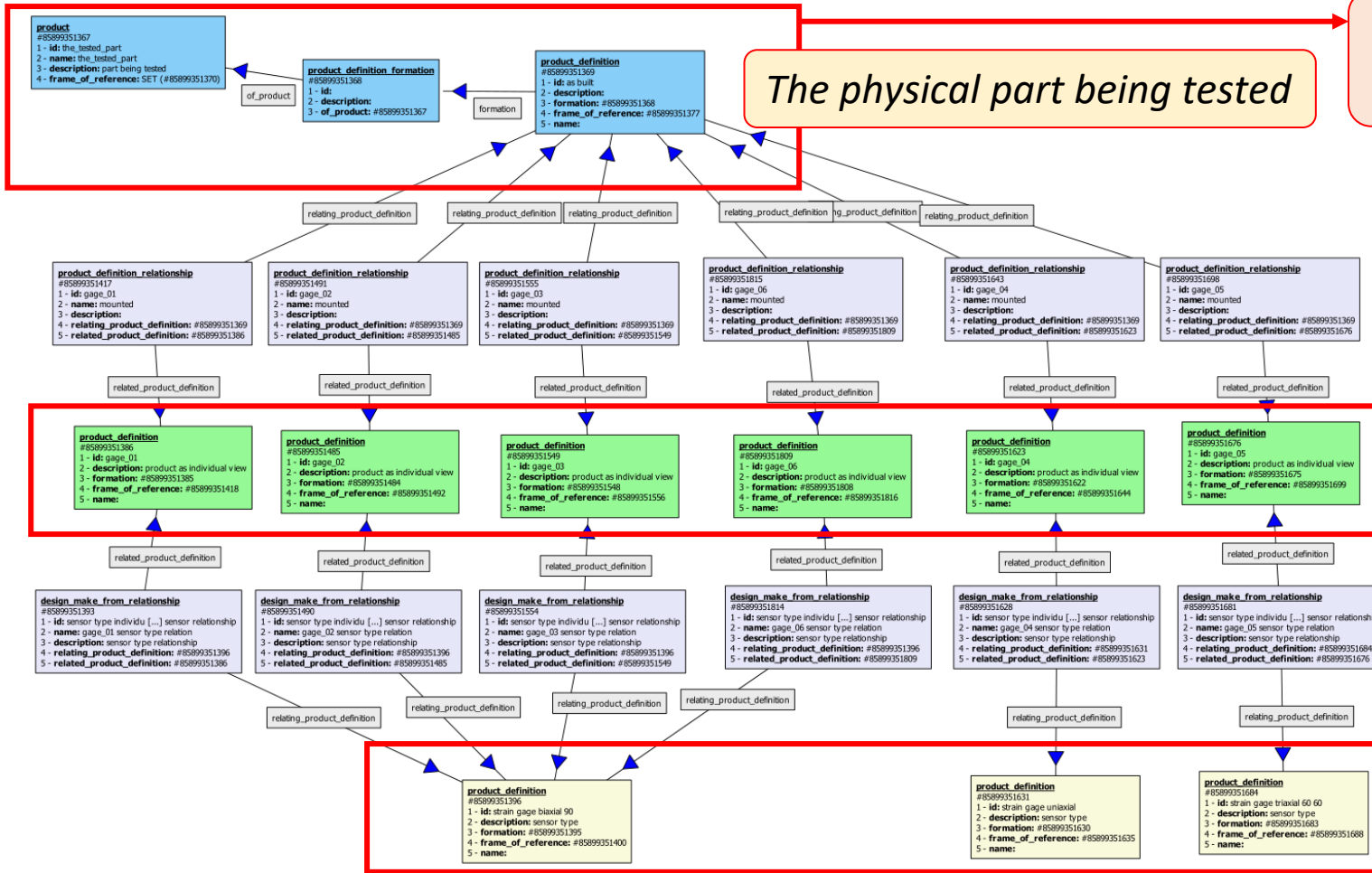
- SDM + PDM are solutions
- However, still locked to proprietary formats of the SDM/PDM provider
- With systems based on open standards
 - Ensure data can be accessed in the future (10, 20, 50 years?)
 - Ensure exchange with other standard based systems

Part of first study during PhD and CRYSTAL project with Lockheed Martin





Extending AP209 – Structural testing



The physical part being tested

Ref. to analysis + CAD model

Imported from CAE application files

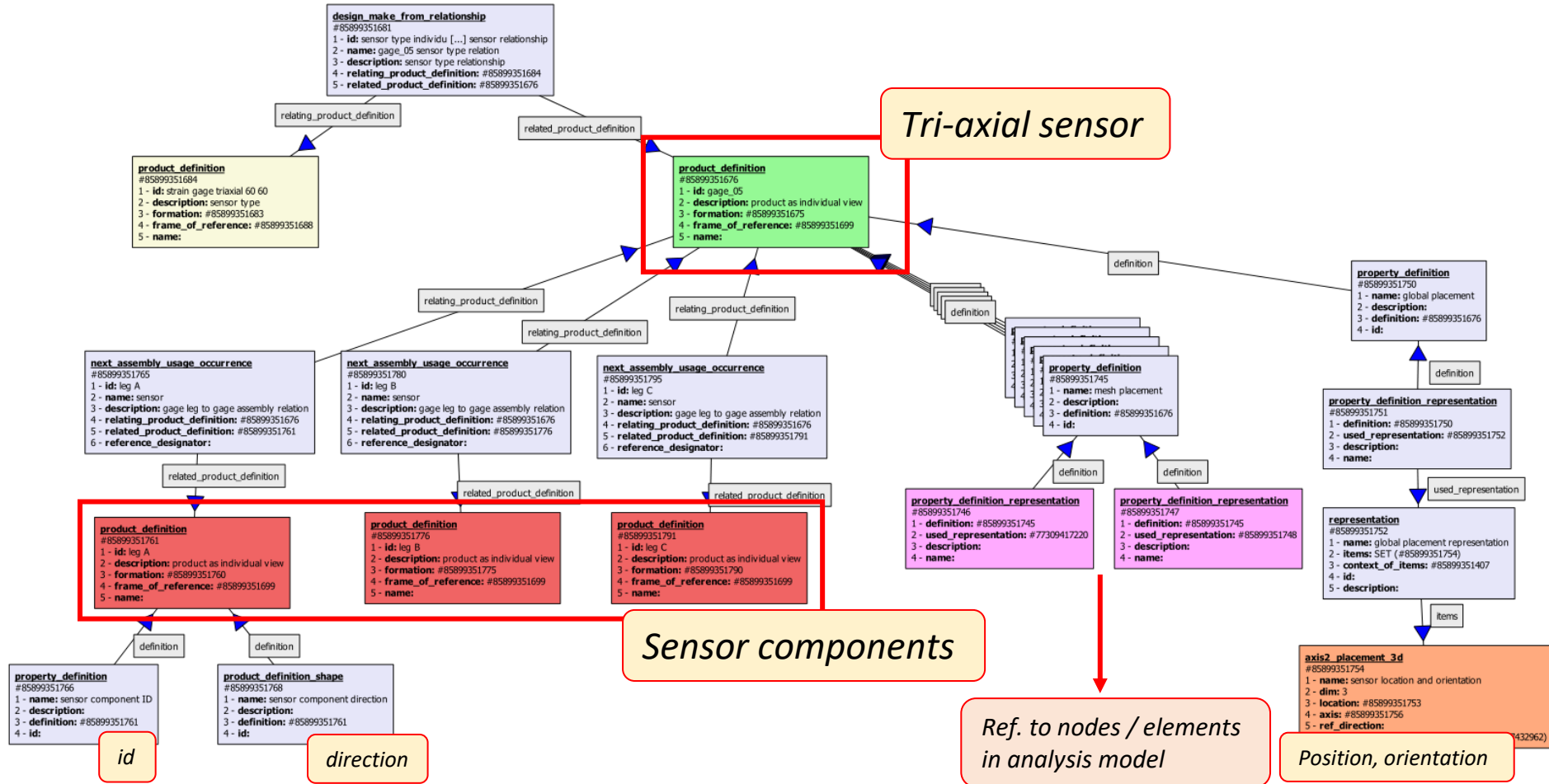
Individual sensors

Imported from sensor definitions files

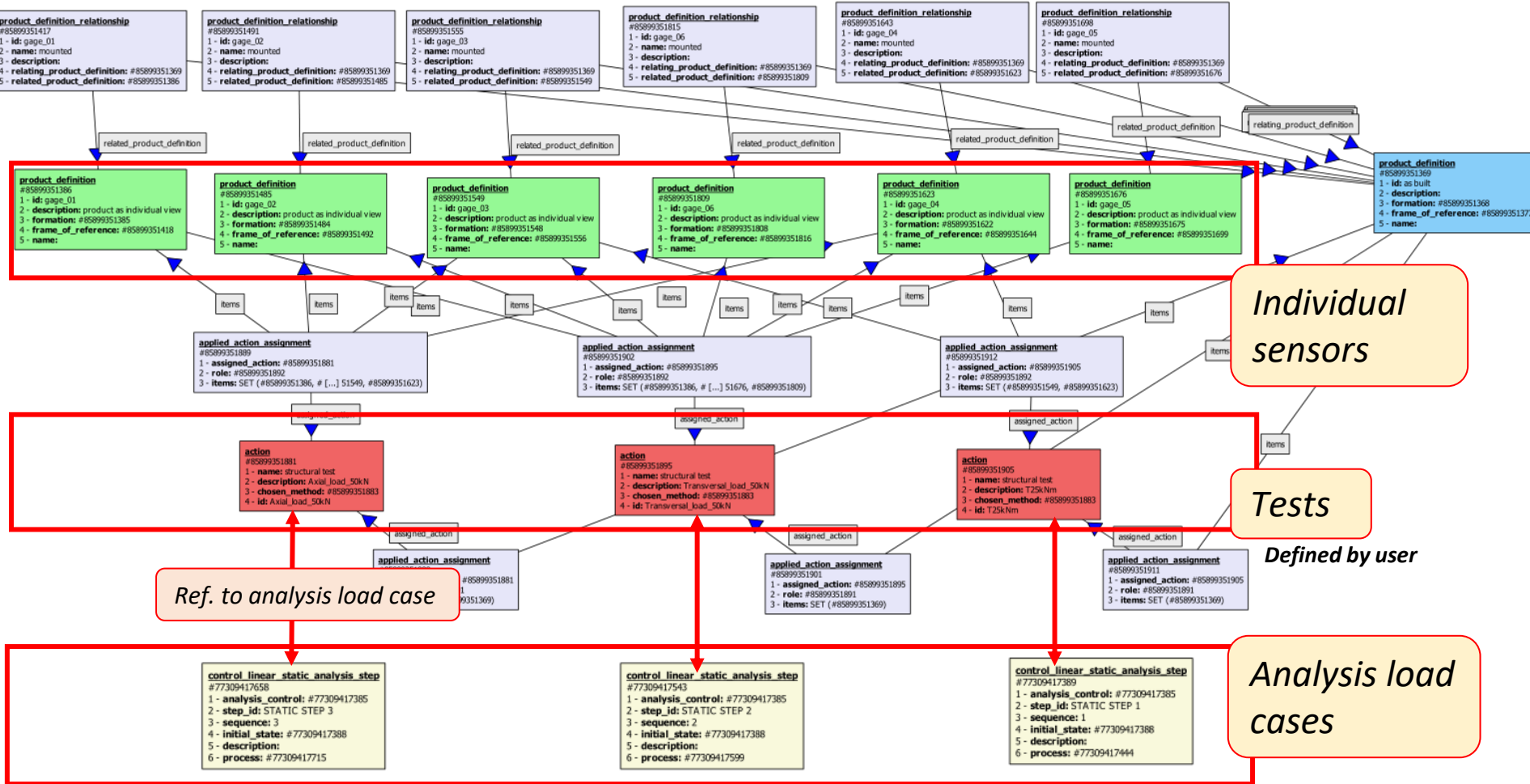
Sensor types

Sensor library

Extending AP209 – Structural testing



Extending AP209 – Structural testing



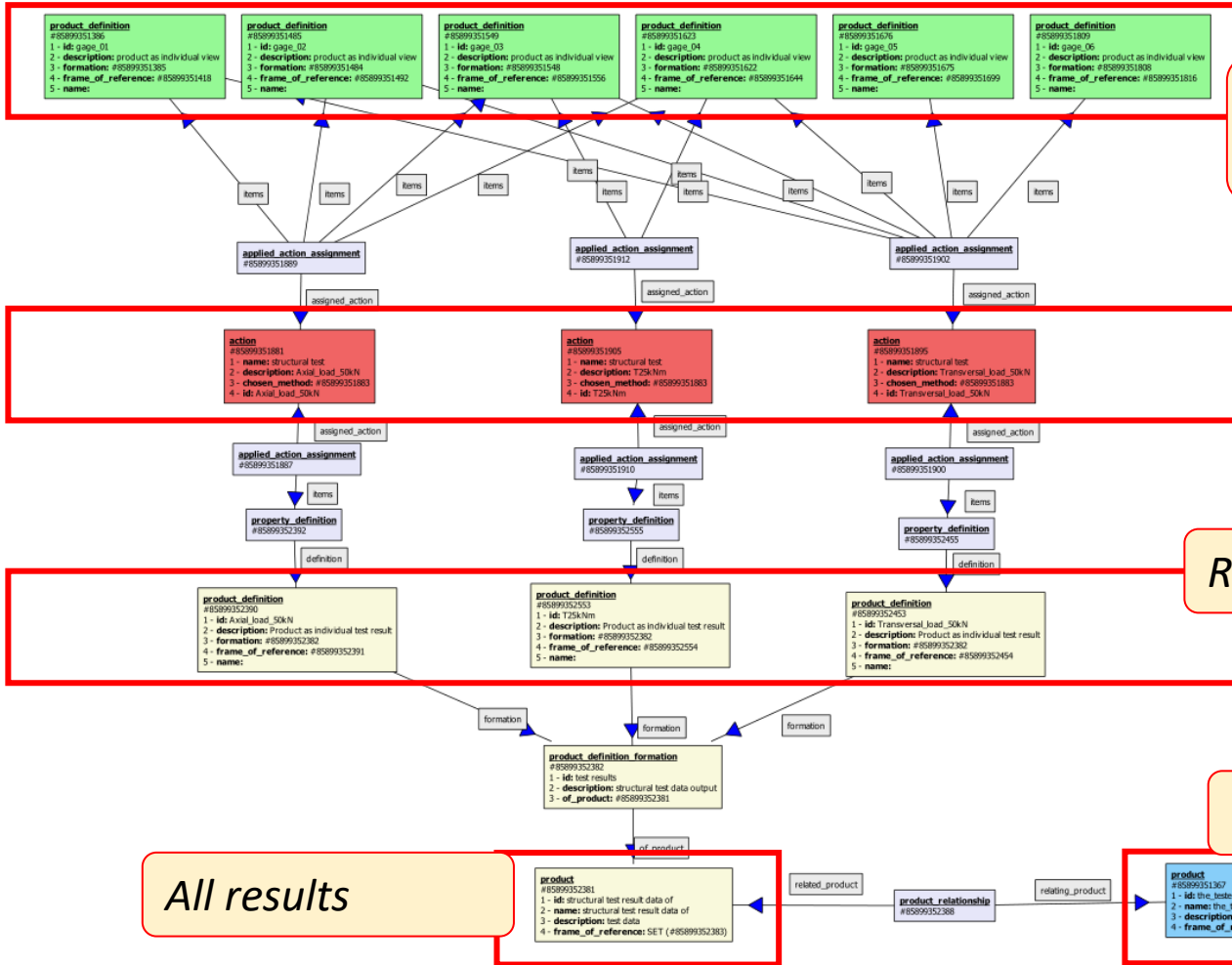
Ref. to analysis load case

Individual sensors

Tests
Defined by user

Analysis load cases

Extending AP209 – Structural testing



Individual sensors

Not shown in figure:
- Results per sensor
- Results per sensor component

Results per test

From .UNV and .CSV files from DAQ software

The physical part being tested

All results

product
#85899352381
1 - id: structural test result data of
2 - name: structural test result data of
3 - description: test data
4 - frame_of_reference: SET (#85899352383)

product
#85899351367
1 - id: the tested part
2 - name: the tested part
3 - description: part being tested
4 - frame_of_reference: SET (#85899351370)

Nonlinear analysis

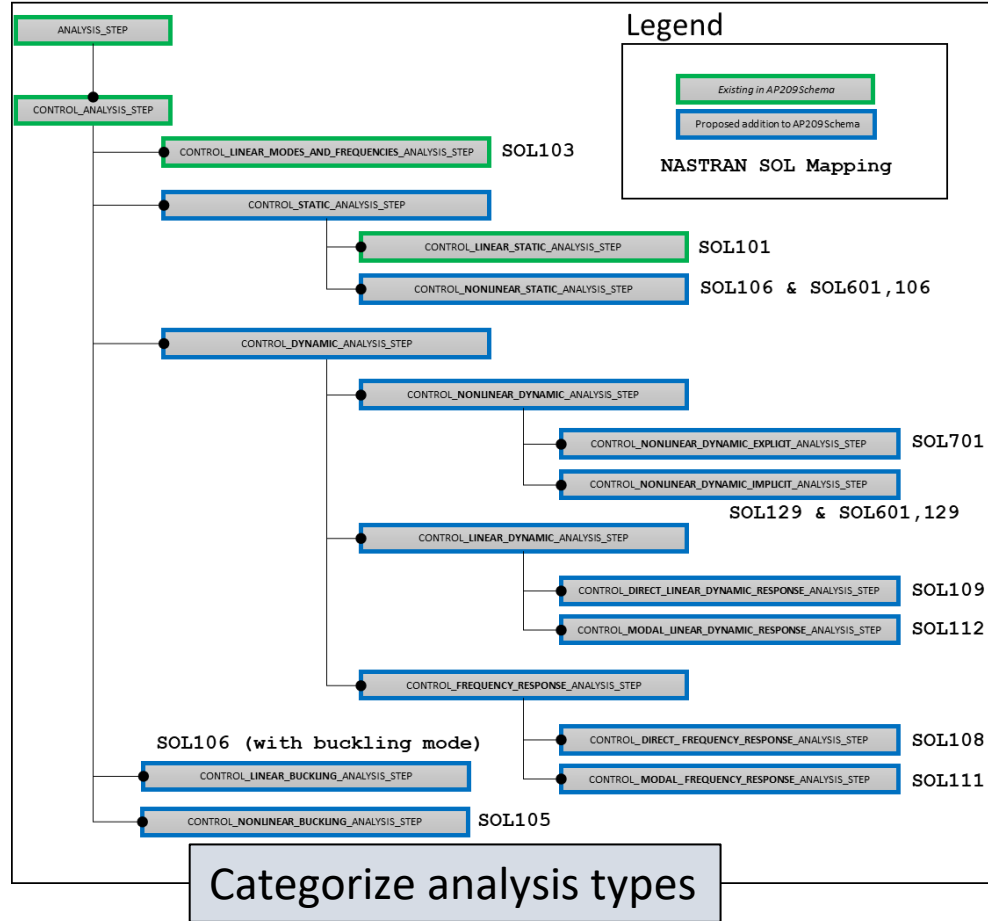
- **Added content in AP209 related to NLFEA**
 - Analysis types
 - Analysis parameters
 - Nonlinear materials
 - Time/variable dependent loads
 - Element contact (and «gluing»)
 - *And more*

NX Nastran 11.0	Abaqus CAE 6.14	Ansys MPADL 19.0
SOL101 - Linear Statics	Static, General	Static Structural
SOL103 - Real Eigen Values	Static, Riks	Transient Structural
SOL103 - Response Dynamics	Dynamic Implicit	Rigid Dynamics
SOL105 - Linear Buckling	Dynamic Explicit	Harmonic Response
SOL106 - Nonlinear Statics	Buckle	Modal
SOL107 - Direct Complex Eigenvalues	Frequency	Explicit Dynamics
SOL108 - Direct Frequency Response	Static, Linear Perturbation	
SOL109 - Direct Transient Response	Steady-state dynamics, Direct	
SOL110 - Modal Complex Eigenvalues	Substructure generation	
SOL111 - Modal Frequency Response		
SOL112 - Modal Transient Response		
SOL129 - Nonlinear Transient Response		
SOL601(106) - Advanced Nonlinear Statics		
SOL601(129) - Advanced Nonlinear Transient		
SOL701 - Explicit Advanced Nonlinear Analysis		

Nonlinear analysis

Define analysis parameters

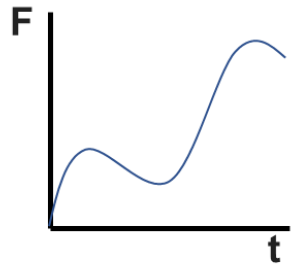
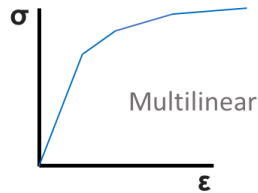
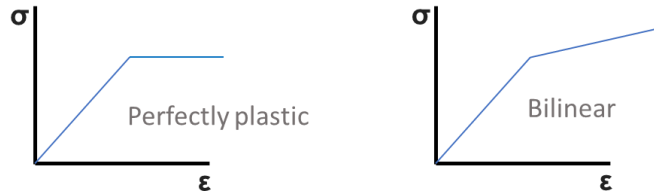
Increment	Iteration parameters
start time Defines the start time of the total analysis. If this value is unset or not existing, the parameters are applicable from the start of the analysis if applied to the control entity, or the beginning of the load cases if applied to one or more control_process entities.	max iterations per increment Defines the maximum number of iterations to use in each increment.
end time Defines the end time of the total analysis. If this value is unset or not existing, the parameters are applicable from the start of the analysis if applied to the control entity, or the beginning of the load cases if applied to one or more control_process entities. <i>Note on start time and end time</i>	iterations before stiffness update Defines after how many iterations in an increment the stiffness matrix is updated. (This value can define if the <i>full</i> or <i>modified</i> Newton method is used.)
<ul style="list-style-type: none"> If a fea_parameter (fppdr) contains the increment parameter specified time frame If a fppdr has a start time and end time are valid from that analysis. If multiple fppdr are used (via fea_parameter but no end time, then each consecutive start time is the next start time specified time frame 	update stiffness at first iteration A boolean that defines if the stiffness matrix is always updated at the first iteration of an increment.
	Convergence parameters
	tolerance variable Defines a convergence variable. Should be implemented as an extendable enumeration, including the following enumerations: DISPLACEMENT_CONVERGANCE , ROTATION_CONVERGANCE , ENERGY_CONVERGANCE , FORCE_CONVERGANCE .
	tolerance value The tolerance value for the specified tolerance variable.
	Large displacement
	use large displacements Boolean that defines if large displacements are accounted for in specific load case or all load cases in an analysis.
	use large strains Boolean that defines if large strains are accounted for in specific load case or all load cases in an analysis.
	Arc Length control parameters
fixed increment size Defines a fixed increment size for the whole load case, or time frame.	min arc length Defines the minimum allowable arc length in the arc length increment process.
initial increment size Defines an initial increment size for the whole load case, or beginning of the analysis.	max arc length Defines the maximum allowable arc length in the arc length increment process.
min increment size Defines a minimum increment size to be used throughout the whole analysis, whole load case, or time frame.	
max increment size	



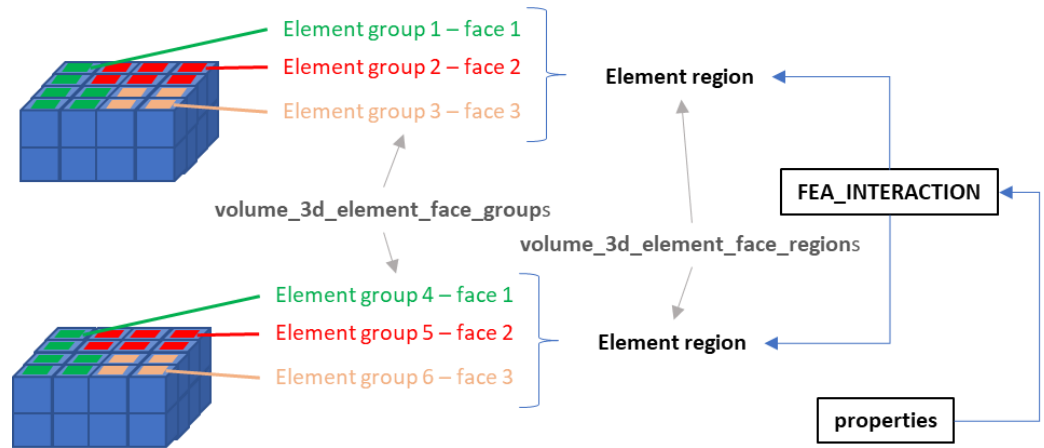
Categorize analysis types

Nonlinear analysis

NL material models



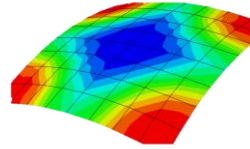
Dynamic loads



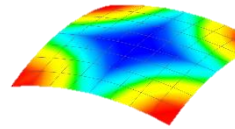
Element surface regions + contact

Test A

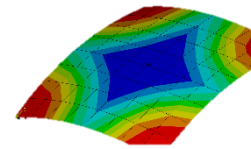
- Shell elements
- NL Static
- Pressure load over surface
- Fixed increment size



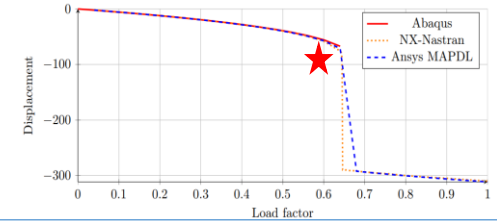
TEST A - ABAQUS



TEST A - NASTRAN

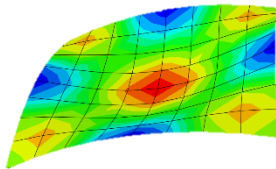


TEST A - ANSYS

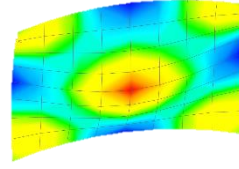


Test B

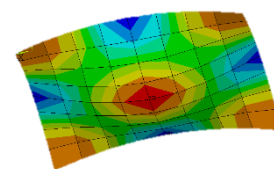
- Shell elements
- NL Static
- Pressure load over surface
- Arclength control



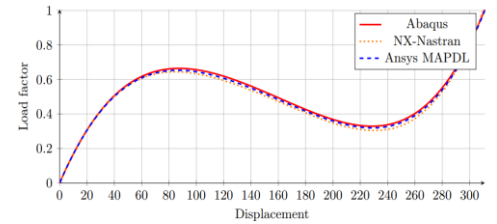
TEST B - ABAQUS



TEST B - NASTRAN

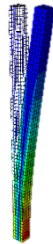


TEST B - ANSYS

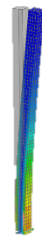


Test C

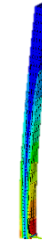
- Volume elements
- NL Dynamic
- Impulse load at beam end
- point defined by table
- Rayleigh damping
- Specified initial / min / max increment sizes



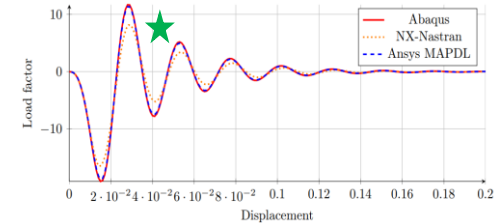
TEST C - ABAQUS



TEST C - NASTRAN



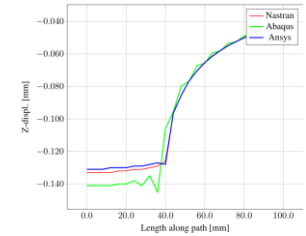
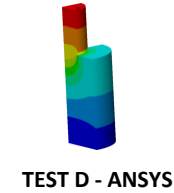
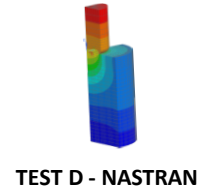
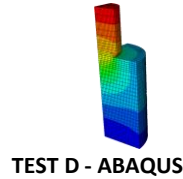
TEST C - ANSYS



Extending AP209 – NLFEA

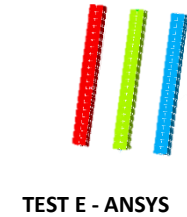
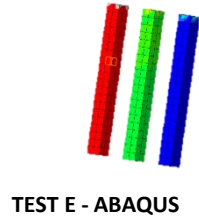
Test D

- Nonlinear static
- Surface to surface contact
- Linear materials



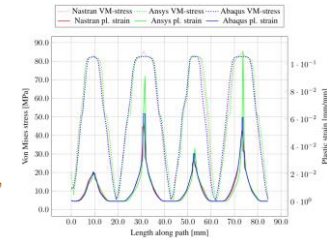
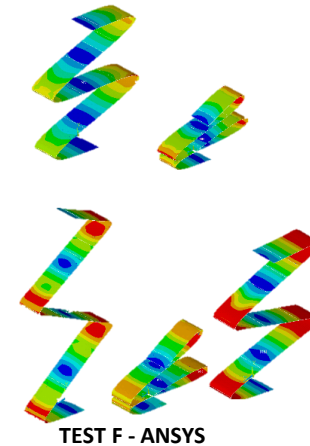
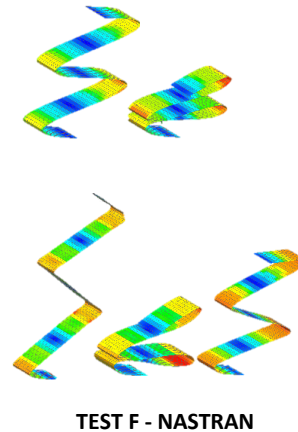
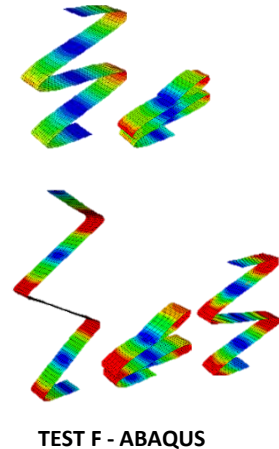
Test E

- Nonlinear static
- NL material (elastic perfectly plastic)
- (MPCs)

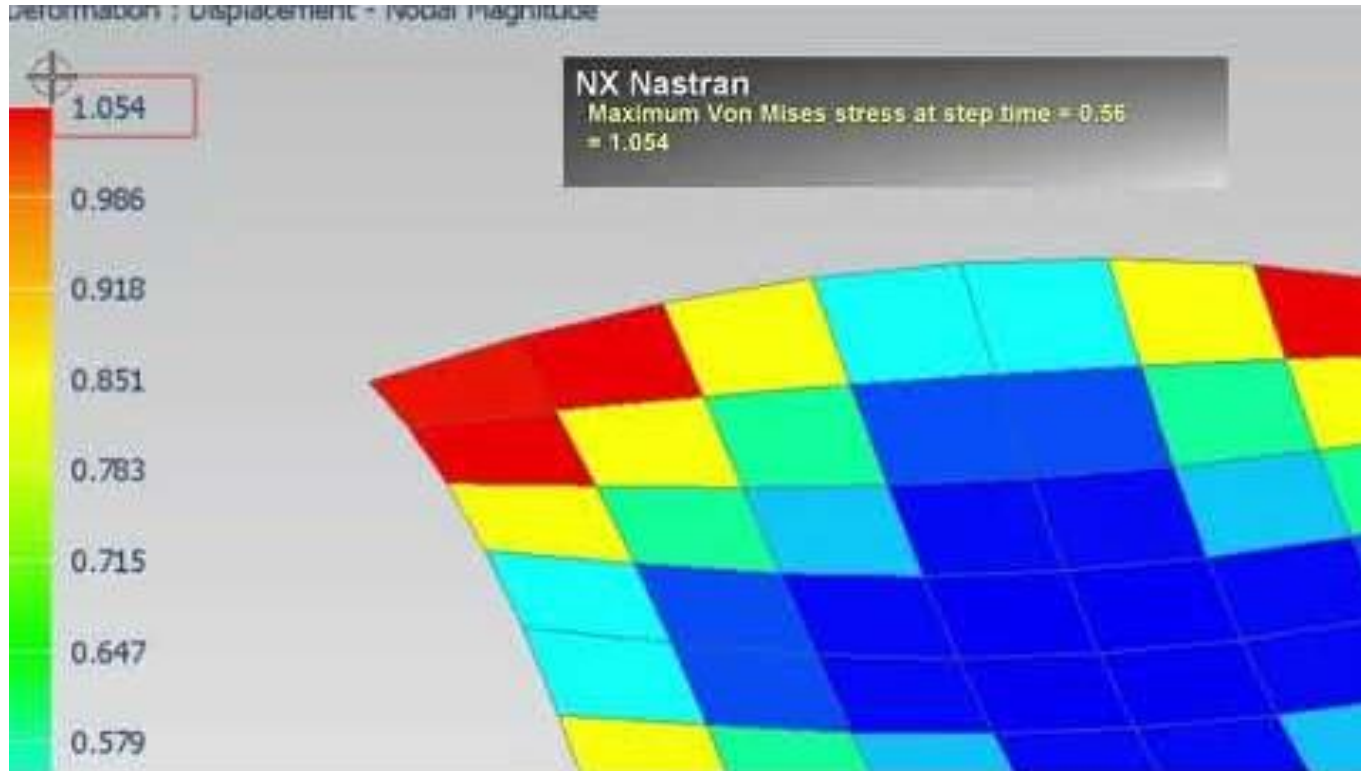


Test F

- Nonlinear static
- NL material (multilinear plasticity)
- (time dependent constraints)



Example: Abaqus → AP209 → Ansys → AP209 → Nastran



https://www.youtube.com/watch?v=nPmlc8ia9dk&t=93s&ab_channel=Remi

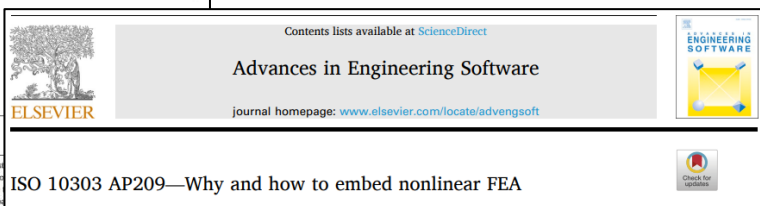


Research paper
Relating structural test and FEA data with STEP AP209

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^bNorwegian University of Science and Technology, Richard Birkelandsvei 2B, Trondheim, Norway

ARTICLE INFO
Keywords:
STEP ISO 10303
FEM Analysis
Structural testing
Data exchange
Simulation data management

ABSTRACT
This paper proposes a method for incorporating FEA data and test data model based on the ISO 10303 STEP Standard [1]. The pre- and elements defined in STEP AP209 Edition 2 [2] to provide information such as sensor and finite elements, test and FEA data also presents an introduction to STEP and AP209e2, and data Management environment.



ISO 10303 AP209—Why and how to embed nonlinear FEA

Remi Lanza^{a,b}, Jochen Haenisch^a, Kjell Bengtsson^a, Terje Rølvåg^b
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^bNorwegian University of Science and Technology, Richard Birkelandsvei 2B, Trondheim, Norway

ARTICLE INFO
Keywords:
STEP ISO 10303
FEM analysis
Nonlinear FEA
Data exchange
Simulation data management

ABSTRACT
ISO 10303 STEP AP209 edition 2 ISO (1994) exchange and storage of simulation information (Analysis) information, but is missing certain features the STEP AP209 standard and presents project Data exchange
The study then identifies requirements that fully covered by AP209. Each requirements are major solver applications. Without giving data starting points for further research is suggested

NL FEA 1/3
Published

<https://doi.org/10.1016/j.advengsoft.2021.102976>

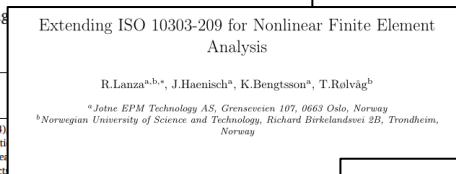
Structural testing
Published

<https://doi.org/10.1016/j.advengsoft.2018.08.005>

Appendix C
Contact and Nonlinear Materials in STEP

NL FEA 3/3
Appendix in PhD thesis

Publications



PhD thesis (NTNU)

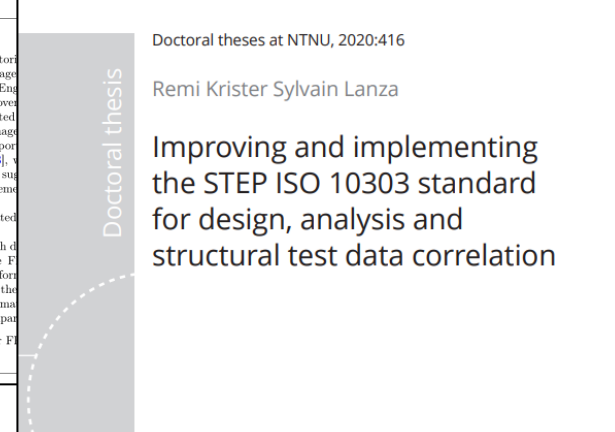
<https://hdl.handle.net/11250/2711837>

Abstract
ISO 10303-209 [1, 2] is a standard for exchanging and storing information along side related PLM (Product Lifecycle Management Aided Design), and other CAE (Computer Aided Engineering AP209 standard, despite being well documented and covered engineering information, has not been widely implemented (Analysis) solver or SDM (Simulation Data Management). This is assumed to mainly be due to AP209 not yet support
The following study takes basis in the findings of [3], where the AP209 standard were suggested. Some of these suggestions nonlinear FEA, are here further investigated and implemented for further standardization.
Analysis test cases using these new features are created between different FEA formats are developed.
The test cases are nonlinear, static and dynamic, with different step control parameters, and loading conditions. The FEA translates data between AP209 and the solver specific format data information from the analyses are preserved during the generated analyses are solved. To confirm that no information the process, simulation results are investigated and compared.
Keywords: STEP ISO 10303, FEM Analysis, Nonlinear FEA Exchange, Simulation Data Management

Doctoral theses at NTNU, 2020:416

Remi Krister Sylvain Lanza

Improving and implementing the STEP ISO 10303 standard for design, analysis and structural test data correlation



NL FEA 2/3
Under review



LOCKHEED MARTIN

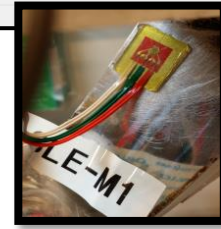
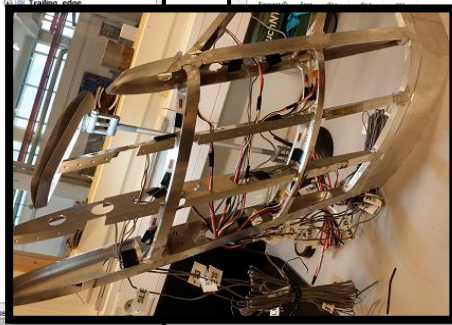
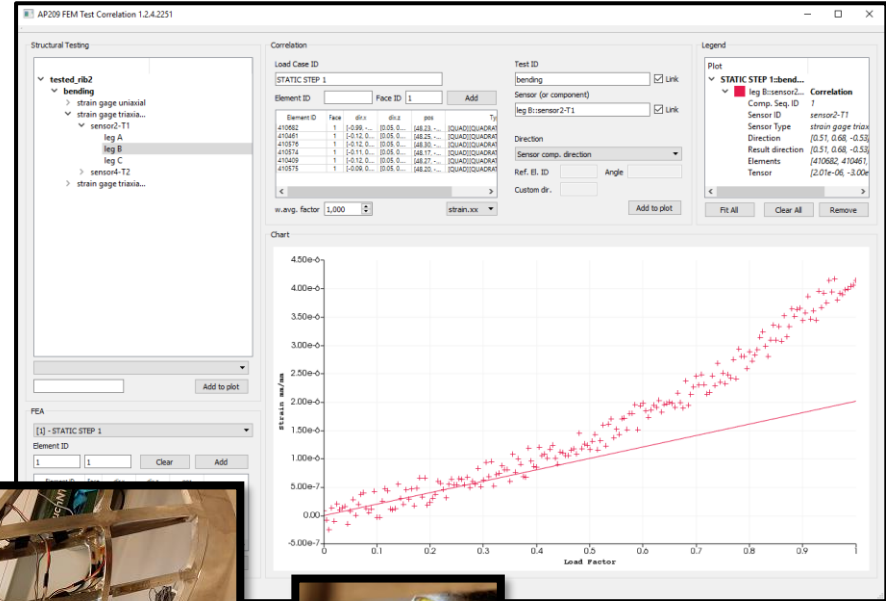
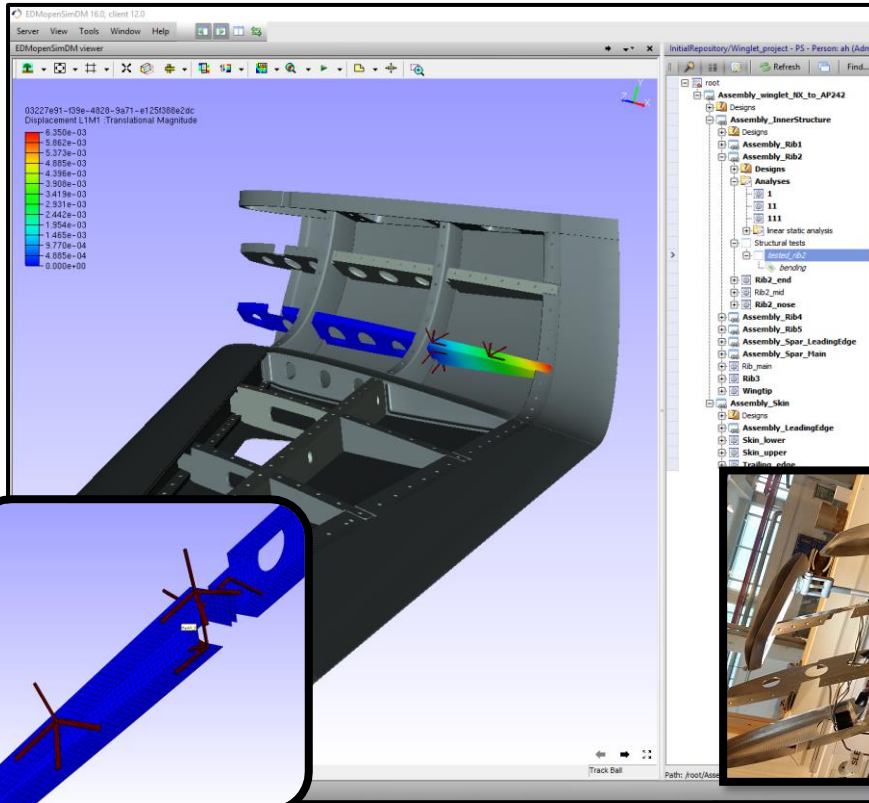
- **CRYSTAL** w/ Lockheed Martin
 - Structural testing + Simulation data in AP209 in ISO 10303 SDM application



European Space Agency
Agence spatiale européenne

- **DEFINE** w/ ESA
 - Extended scope of analysis and testing
 - Develop a platform for managing digital models (analysis and design), testing data and associated PLM information.

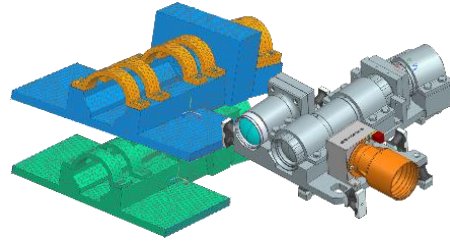
ISO 10303 repository – SDM application



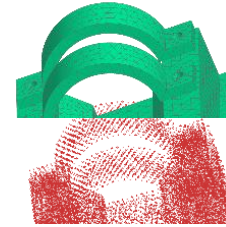
The DEFINE project



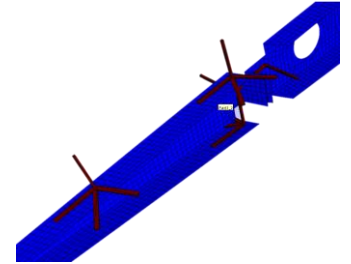
Compare geometric shapes from different applications



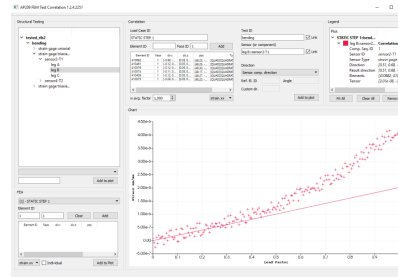
Compare cloud of points with 3D models



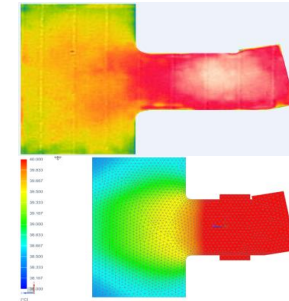
Visualize sensors on 3D models



Correlate/compare sensor results and analysis results



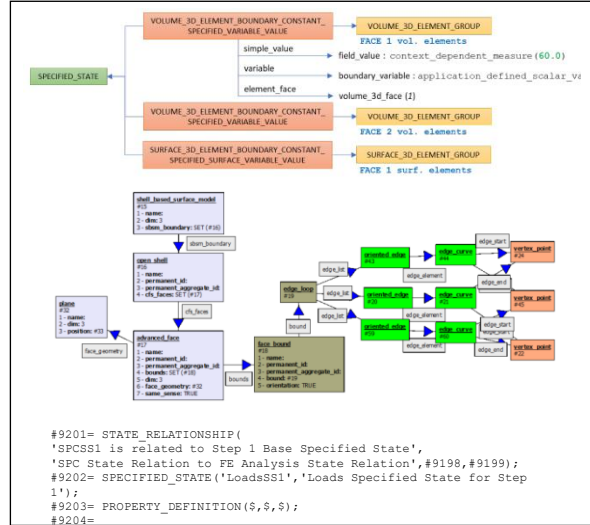
Mapping thermal raster images on meshes and shapes



The DEFINE project, Simulation data



AP209 – Common data model

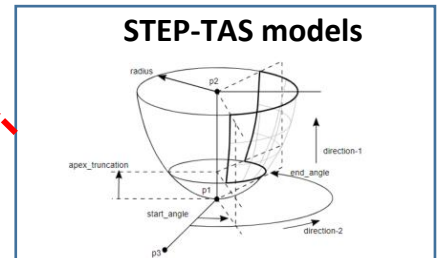
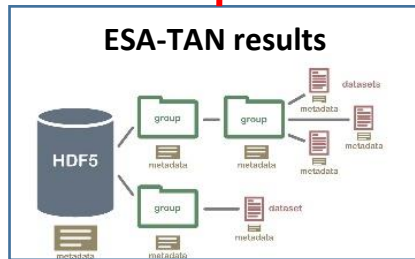


Nastran BDF

	EID	RID2	SIDE	
CHBDVE	54154	45624	2	
CHBDVE	54155	45625	1	
CHBDVE	54156	45626	4	
	EID	PCONV		TA1
CONV	54154	22	0	87126
CONV	54155	22	0	87126
CONV	54156	22	0	87126
	PCONID	MID		
PCONV	22	3		
	MID			H
MAT4	3			60.0

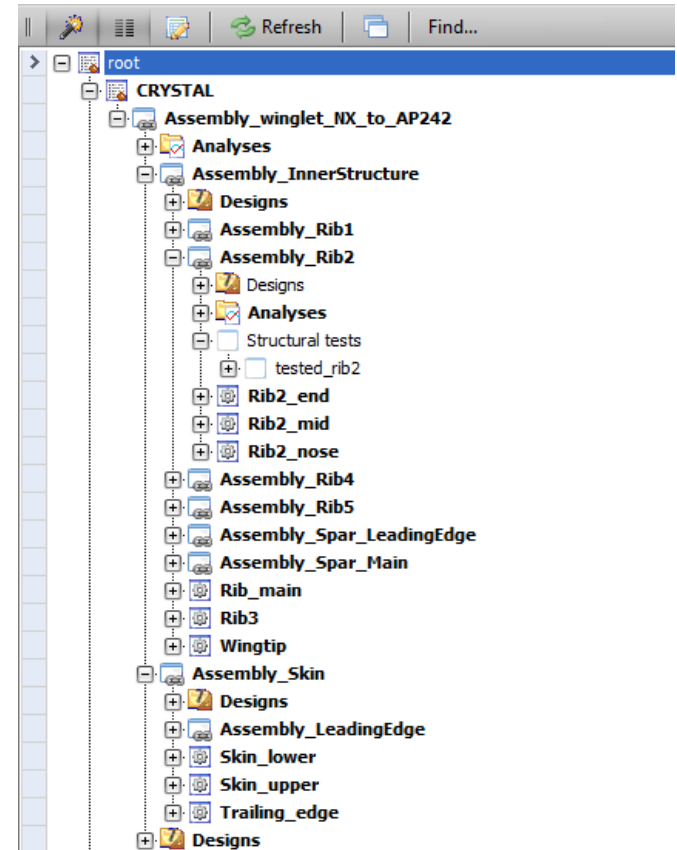
Nastran OP2

Word	Name	Type	Description
4	SUBCASE	I	Subcase or Random identification number
TCODE.1 = 1			
Sort 1			
ACCODE.4 = 01			
Statics			
5	LOADVMN	I	Load set number
6	UNDEF(2)	None	
ACCODE.4 = 02			
Real Eigenvalues			
5	MODE	I	Mode Number
6	EIGN	RS	Eigenvalue
7	MODECYCL	RS	Mode or Cycle



- **Federated model in ISO 10303 repository**

- STEP models imported are treated as sub-models of the overall federated model
- Relations managed between sub-models managed in *link model*
- Models from different domains; CAD, FEA, testing
- High level relations, and low level relations



- Questions?

