integrate the future

VDA AK 25 Fügetechnik: χMCF Standardization.

Sources of images: PR / Press areas of web sites of respective OEMs.

Darmstadt, 2016-09-14, Dr. Carsten Franke

Agenda Part 1

- 9:45 Welcome & introduction
- 10:00 Motivation & Overview of χMCF Standard 3.0 (C. Franke, PROSTEP)
- 10:35 Practical use of xMCF at Volkswagen: Demonstration “JointMgr” (Volkswagen)
- 10:45 Handling of joints in CAD systems CATIA and NX (WG 2.6)
  State of the art at major German automotive OEMs
- 11:15 Joining Data Management at Ford (Ford)
- 11:30 Overview of joints in CATIA (Dassault Systèmes)
  Best practices from the perspective of the software vendor.
- 12:00 Overview of joints in NX, Virtual.Lab and Syncrofit (Siemens)
  Best practices from the perspective of the software vendor.
- 12:30 Overview of the implementation of χMCF 3.0 in ANSA (Beta CAE Systems)
- 12:45 Overview of the implementation of χMCF 3.0 in HyperMesh (Altair Engineering)
- 13:00 Lunch

Agenda Part 2

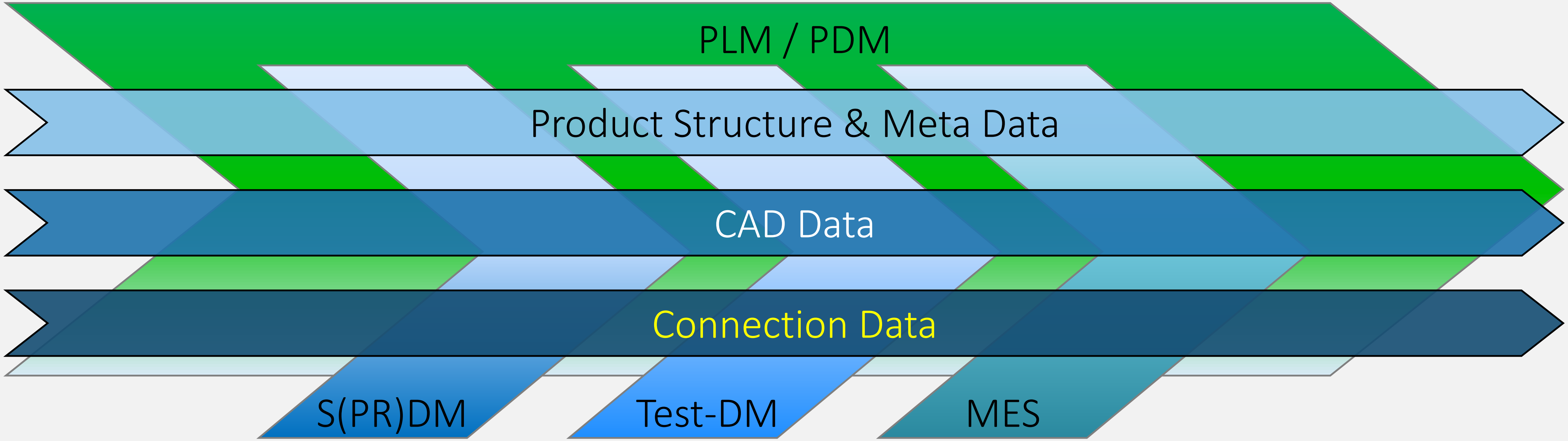
PROSTEP

- 13:00 Lunch
- 13:45 χMCF as a common standard for joint information for PLM (Volkswagen & PROSTEP)
  Most important basic principles.
- 14:15 Continuity of connection data in PLM process chains (C. Franke, PROSTEP).
  Requirements and their level of fulfillment in example software systems. (Excerpts from a white paper)
- 15:00 Next steps regarding software systems (Dassault, Siemens)
- 15:45 Next steps of working group 25
- 16:00 End

Objectives:
- Smooth cooperation between all systems involved.
- No data losses.
- No misunderstandings.

Motivation for χMCF Standard

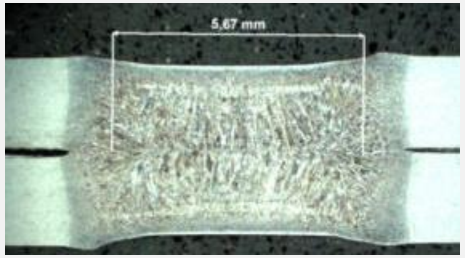
Importance of Connection Information in PLM Process Chain



Connection data forms the ***indispensable 3rd data track*** of PLM!

Challenges wrt Connection Information
Big Variety & Complexity

- > 60 known connection techniques.
- Up to 25 quality criteria per connection technique.



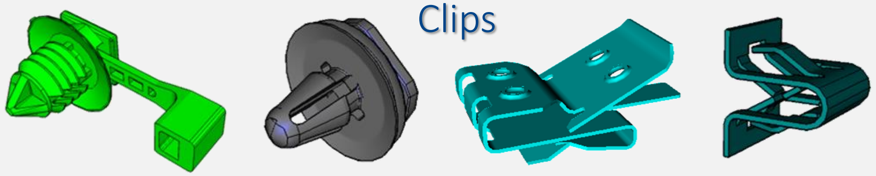
Section of a Spot Weld

Some Screws ...

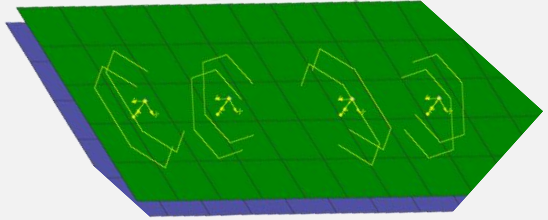

Rivets


Nails

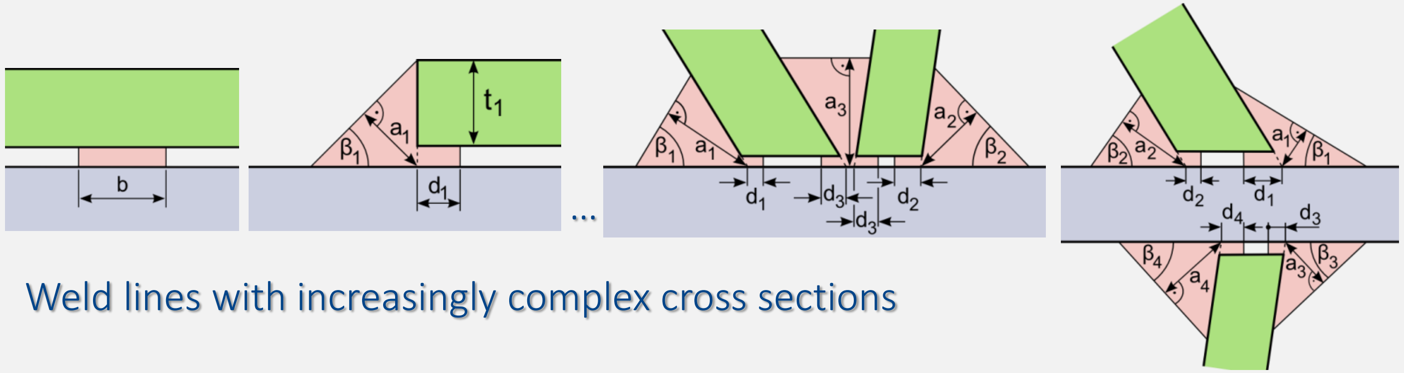
Clips



Robscans @ FE Preprocessor

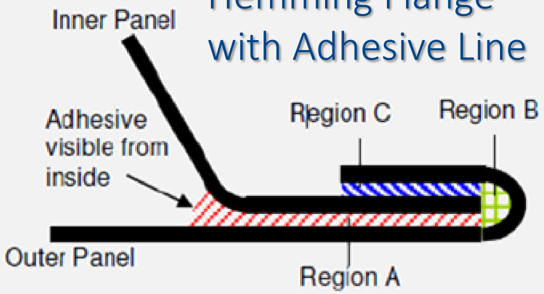


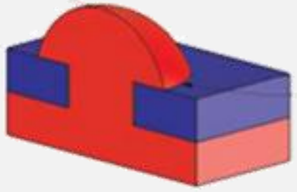
Clinch



Weld lines with increasingly complex cross sections

Hemming Flange with Adhesive Line




Heat Stake

Challenges wrt Connection Information
Structural Differences

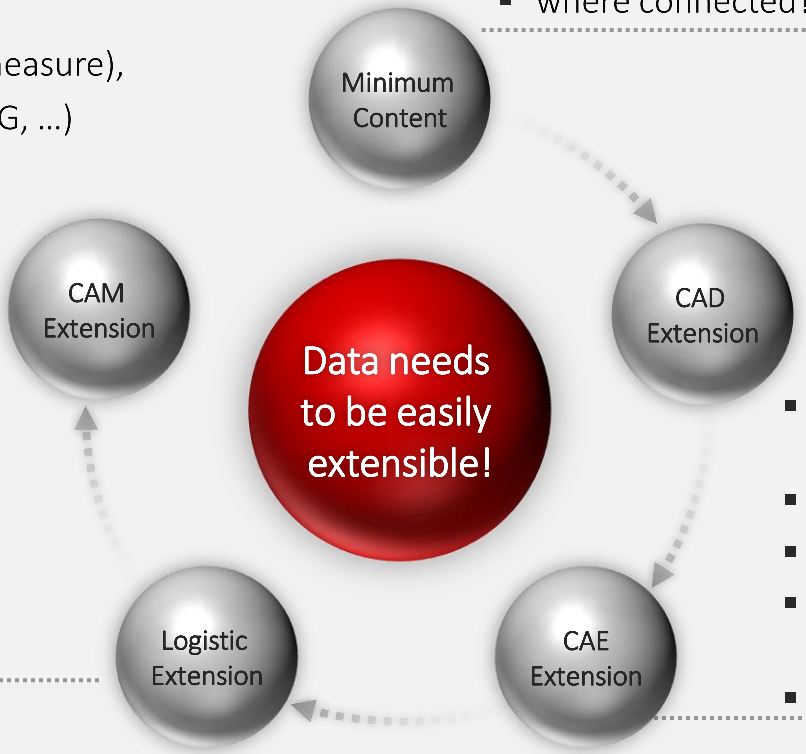
Connections differ from product structure, meta data and CAD data, since e. g.:

- their *function* dominates over their shape,
- they need more *data completion* and hence *PLM upstream data propagation* than CAD,
- they are created / edited / optimized using
  different *tools & plugins*,
  special *process steps* and
  expert *knowledge*,
- they belong to *inner nodes*, not to leaves of product tree(where CAD resides),
- their *size* is much smaller than CAD data,
- they are subject to higher frequency of change.

Challenges wrt Connection Information Data Completion Along Process Chain

- What is (part codes)
- how and
- where connected?

- Production quality (e. g. A-measure),
- Technology (Laser, MIG/MAG, ...)
- Screw torque and angle,
- Die of self piercing rivet,
- ...

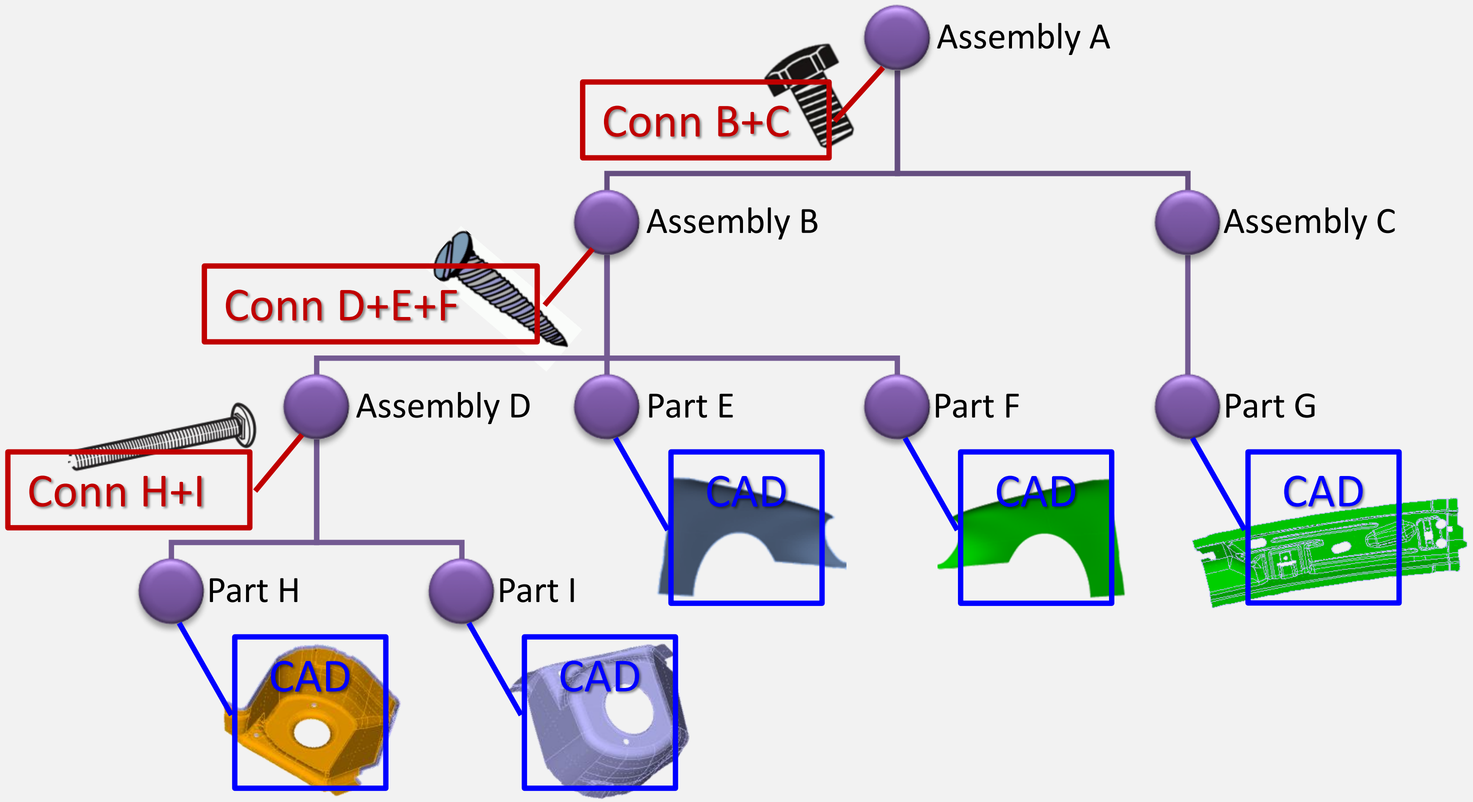


- Part code of screw/rivet,
- Direction of laser or screw,
- ...

- PIDs of connected and connecting elements,
- Adjusted coordinates of weld line,
- Heat Affected Zone of weld line,
- Solver specific discretization, e. g. hexahedra size, beam cross section,
- ...

- Weight of screw,
- Shipping time for supplies,
- Unit costs, assembly costs,
- Reusability,
- ...

Challenges wrt Connection Information
Connections Belong to *Inner* Nodes of Product Tree



Otherwise, *reuse* of parts & assemblies
in other products & variants is impossible.

Challenges wrt Connection Information Processes, Tools & Consistency

Connection processes heavily rely on:

- re-use (i. e. finding),
- manual creation,
- modification,
- communication

of connectors, using a *plethora of tools*.

But in the end, it must be guaranteed that

- all CAE simulations converge to the *same physical model*,
- that this model is *documented* in CAD & PDM, *validated* by DMU etc., *tested* on the rig, and *produced* in the factory,
- and that it meets all *legal regulations*.

What is the Problem? – Without any Standard*, Up to Now …

PROSTEP

- In order to handle connections,
  every OEM creates *own CAD* macros/UDFs or buys *proprietary software*.
- Engineering partners must “*have them all*”.
- Data exchange along process chain needs *additional tools*, frequently “home-brewed”.
  ➔ Expensive and error-prone.
- However, in reality only *few techniques* are supported with only a *fraction of their data*.
- Inventing new techniques or adding new parameters
  results in *excessive costs* and *process threats*.
- Changing software vendors implies *high investments*.

➔ Resulting “*vendor lock-in-effect*” impedes competition and hence *hinders progress*.

*) Neither STEP nor JT offer a reliable solution, in themselves.

Overview
of χMCF Standard 3.0

Overview of χMCF Standard 3.0
New Standard with Long History

11 well known names beyond one roof at

FAT Forschungsvereinigung Automobiltechnik AK 25 | Fügetechnik

2001: MCF V 1.0 (Ford)

2011: χMCF V 1.1

2014: χMCF V 2.0

2015: χMCF V 2.1

2016: χMCF V 3.0

to be continued …

Overview of χMCF Standard 3.0 Objectives Achieved

Since χMCF is XML-based, it

- is *easily extensible* regarding new technologies or parameters,
- allows *data completion* along the process chain,
- supports *skipping data* which is contained but yet not needed at a certain process step,
- supports data reduction wrt *intellectual properties*,
- is *easily implementable* at OEM (scripts …),
- is appropriate for *long time archiving*,
- is *human-readable*.

Moreover:

- All automotive relevant connection types & techniques can be represented
- All PLM processes are supported – CAD, CAE, CAT, CAM, including special sub processes, e. g.:
  - Durability simulation,
  - Robot programming,
  - Supplier integration, …
- One file contains either data of *one assembly*, *one car* or *all variants* of a series – meeting any kind of OEM specific process design.
- Data specific to OEM, software or processes can be imbedded.

➔ χMCF replaces existing proprietary formats sustainably.

➔ χMCF becomes „Lingua franca“ for connection data, just like the way JT did for CAD data.

Outlook to χMCF Standard 3.1

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Content:

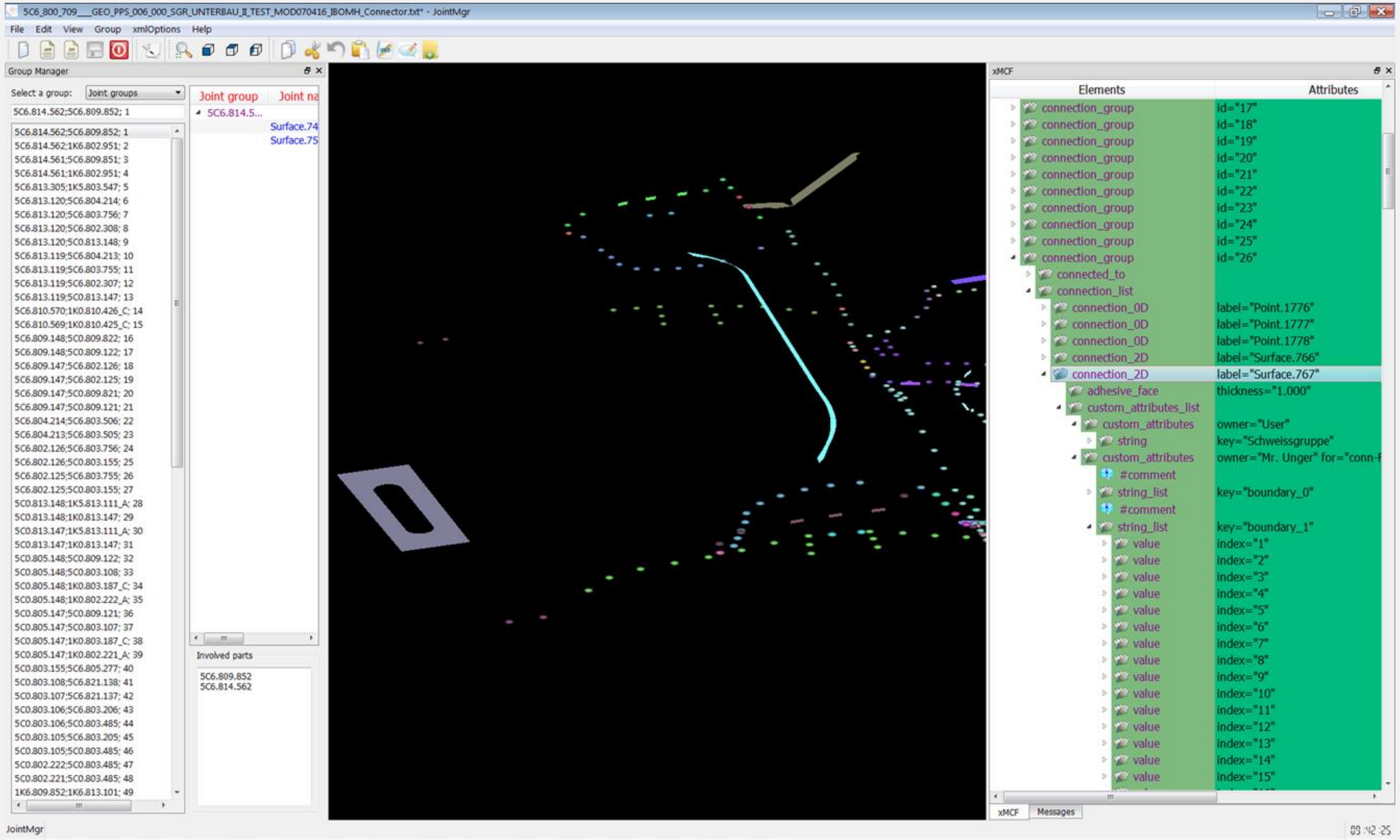
- Catalogs for
  - standard parts (bolts, nuts, washers, rivets, …),
  - standard tools (riveting dies, …) and
  - standard parameters (Robscan pattern, …)
- Step line feature for all connection lines.
- Further improvements according to recent experiences from all-day-use, such as manufacturing tolerances or limits for welding distortion.

Organization:

- Providing a set of reference files.
- International standardization of χMCF, e.g. at ISO.

Practical use of xMCF at Volkswagen
Demo “JointMgr”

10:35 – 10:45



Source of image: Volkswagen.

Handling of Joints in CAD Systems CATIA and NX State of the Art at Major German Automotive OEMs

Live from Munich: WG 2.6

10:45 – 11:15

Joining Data Management at Ford

Ford

11:15 – 11:30

Overview of Joints in CATIA
Best Practices from the Perspective of the Software Vendor

Dassault Systèmes

11:30 – 12:00

Overview of Joints in NX, Virtual.Lab and Syncrofit
Best Practices from the Perspective of the Software Vendor

Siemens

12:00 – 12:30

Overview of the Implementation of χMCF 3.0 in ANSA

Beta CAE Systems

12:30 – 12:45

On behalf of Altair Engineering

Status of Implementation of xMCF in HyperMesh

(Cite)

12:45 – 13:00

- We are now able to *import* and *export* xMCF information
  for ALL connection types described in the official document.
- They are treated as connectors in HyperMesh.
- We still have to work on the *FE realization* based on the AppData block information
  we may use in HyperMesh.
  This part of the work is also highly related to customer specific FE realizations.
- But HyperMesh offers already all FE realization capabilities.
  We need to decide on the format of the information to put in the AppData block.
- We are working hard to offer a complete support in one of the up-coming HyperMesh version.

Lunch

13:00 – 13:45

χMCF as Common Standard for Joint Information for PLM

Most Important Basic Principles

Twelve Design Principles*

1) χMCF shall ***completely*** and ***unambiguously*** describe ***all joints*** used in automotive industry.

2) It should be able to address ***all PLM processes***, let it be in CAD, CAE and CAM, on the long run.

3) χMCF contains ***only information relevant to connections***.
Hierarchical product structure, assembly sequence, part variants etc. are *not* subject of χMCF.
However, χMCF ***refers*** to such “external” information, e. g. ***part codes*** and FE ***property IDs***.
This principle grants χMCF’s flexibility for application to any kind of process variants, established at different automotive OEMs.

4) The format has to be ***flexible and easy to extend*** to any future joint types and applications.

5) χMCF is ***built upon XML***.

6) Connection ***data are unique***.
I. e., there are no two different ways of describing the same joint at a given process step.

*) List cited from section 2.1 of χMCF 3.0.

Twelve Design Principles

7) The ***content of χMCF may be incomplete*** to a certain extend.
   This addresses the fact that new data is created and needs to be stored throughout the course of CAx processes, without changing its vessel.

8) χMCF follows the ***max-min principle***.
   It contains as much information as necessary, but as little as possible.

9) At any certain stage of any involved process,
   connectors can be ***reconstructed from χMCF without loss*** of data ***or ambiguities***.

10) The format description is kept compact. ***Elements are reused***, whenever possible.

11) ***Application specific data*** can be stored in χMCF even without standardization.

12) χMCF forms a good candidate for ***long-term archiving*** connector information.

Design Decisions

- All joints between the same set of parts are grouped into one (and only one) *<connection_group/>*.
- Within *<connection_group/>*, χMCF distinguishes between *<connection_0d/>*, *<connection_1d/>*, and *<connection_2d/>*. Hence, geometric details can be interpreted even by a system which does not know a specific joining technique.
- Applications are allowed to store their specific data in *<appdata/>* at appropriate levels of XML tree. Syntax & semantics within *<appdata/>* are not standardized. Applications have full freedom. Hence, users have to expect that this kind of data is lost between different systems.
- Vendor specific data can be stored in *<custom_attributes/>* at connection level. Syntax is standardized. Applications are expected not to loose these information, even if they do not understand their semantics.
- Information about FE solver objects representing a joint are stored in its *<femdata/>*. Its syntax & semantics follow FATXML standard and hence can be used by any χMCF capable system.
- Contacts and their physical properties (e. g. friction) can be described by *<contact/>*s in *<contact_list/>.*

Conclusions from Design Principles & Decisions

- χMCF does *not* contain product structure.
  It just references connected parts and assemblies by their part codes or FE property IDs.
  Hence, these have to be transported by other means, e. g. STEP AP 242, PLM XML or solver decks.

- Similar to FATXML, χMCF data can be embedded into solver decks (via METADATA, CDATA, **XML, …).
  This allows for standard-based "all in one" solver models:
  - Geometry → finite elements in solver syntax
  - Model structure → FATXML
  - Connections → χMCF

Facts & Features

Supported Joining Types of χMCF 3.0
(on high level)

Point (0d):

- Bolt, screw
- Gumdrop
- Rivet
- Robscan
- Spot weld
- Clinch
- Heat Stake
- Clip
- Nail

Line (1d):

- Seam weld
- Adhesive line
- Hemming flange
- sequence connection 0d

Area (2d):

- Adhesive face

Selected Joining Technologies of χMCF 3.0
(on high level)

Welding etc.:

- resistance
- arc (≡ MIG/MAG)
- laser
- projection
- friction
- brazing

Riveting:

- blind
- self piercing
- solid
- swop

Screwing:

- Bolt (≡ Screw with Nut)
- Screw
- Washers
- Studs as “fixed” bolts
- Clipped nuts
- Flow Drilled Screws

Seam Weld Types and Sections

Weld Types:

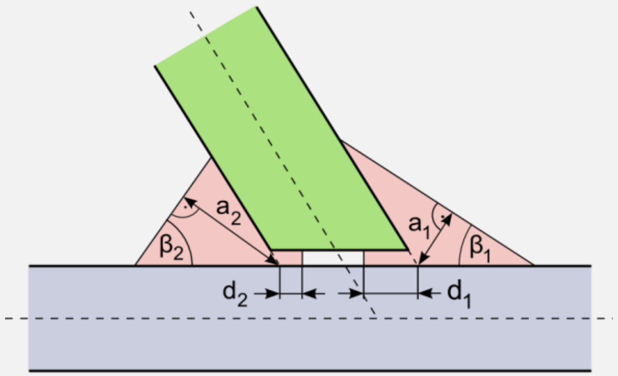
- butt joint
- corner weld
- edge weld
- I-weld
- overlap weld
- Y-joint
- K-joint
- cruciform joint
- flared joint

Weld Sections:

- I
- V
- U
- X
- Y
- HV
- HY
- Fillet
- Radius

Supported Attributes and Sub-Elements of Joints Some Examples

- Base part
- Direction of manufacturing (tool/laser); orientation vector where needed (e. g. Robscans).
- Diameters, widths, thicknesses, gaps, angles, penetration, clearance, ...
- For rivets, screws, bolts, heat stakes, nails etc.:
  shaft diameter, length, head diameter/height/type, sink size, strength property class, hardness,
  labels of head & shaft, part code (of rivet etc.), die label/diameter/depth, insert shape/height, pitch, torque,
  pretension, static & kinetic friction, washer, nut, clipped/fixed to, flow drilled, ...
- For clinches: clinch type, strength class, shear strength, peel strength, button diameter, die type
- For clips: clip/attachment type, hole diameter/length,
  pin diameter/width/length, strap length, clipped to, material, part code
- Robscan pattern
- Filler material
- ...



Weld Throat Thickness: a_1, a_2
Weld Angle: β
Penetration Rate: η

Continuity of Connection Data in PLM Process Chains

Requirements and their Level of Fulfillment in Example Software Systems

Recap: Situation

- Connection data vastly differ from component data.
- Connection data are manifold and highly structured.
- Efficient processing of connection data requires specialized algorithms, data structures and file formats.
- Data structures should follow state-of-the-art design patterns, in order to gain process reliability.
- File formats should be standardized for seamless tool integration.

Unfortunately, other standards such as JT will not do the job.

Example: JT will *not* do the job

Statement of JT Workflow Forum

JT Cockpit / JT-55

Fasteners have to be stored

Comment | Watch Issue | More | Reopen Issue

Details

Type:	Requirement	Status:	Closed
Priority:	Major / Prio 2	Resolution:	Fixed
Affects Version/s:	JT Version 9.5		
Component/s:	Finite Element Analysis (FEA/FEM)		
Requirement Category:	JT Specification		
Proposed Resolution:	Fixed		
Dedicated Format:	JT 9.5, STEP AP242		
Relevant for Content Harmonization:	No		

?

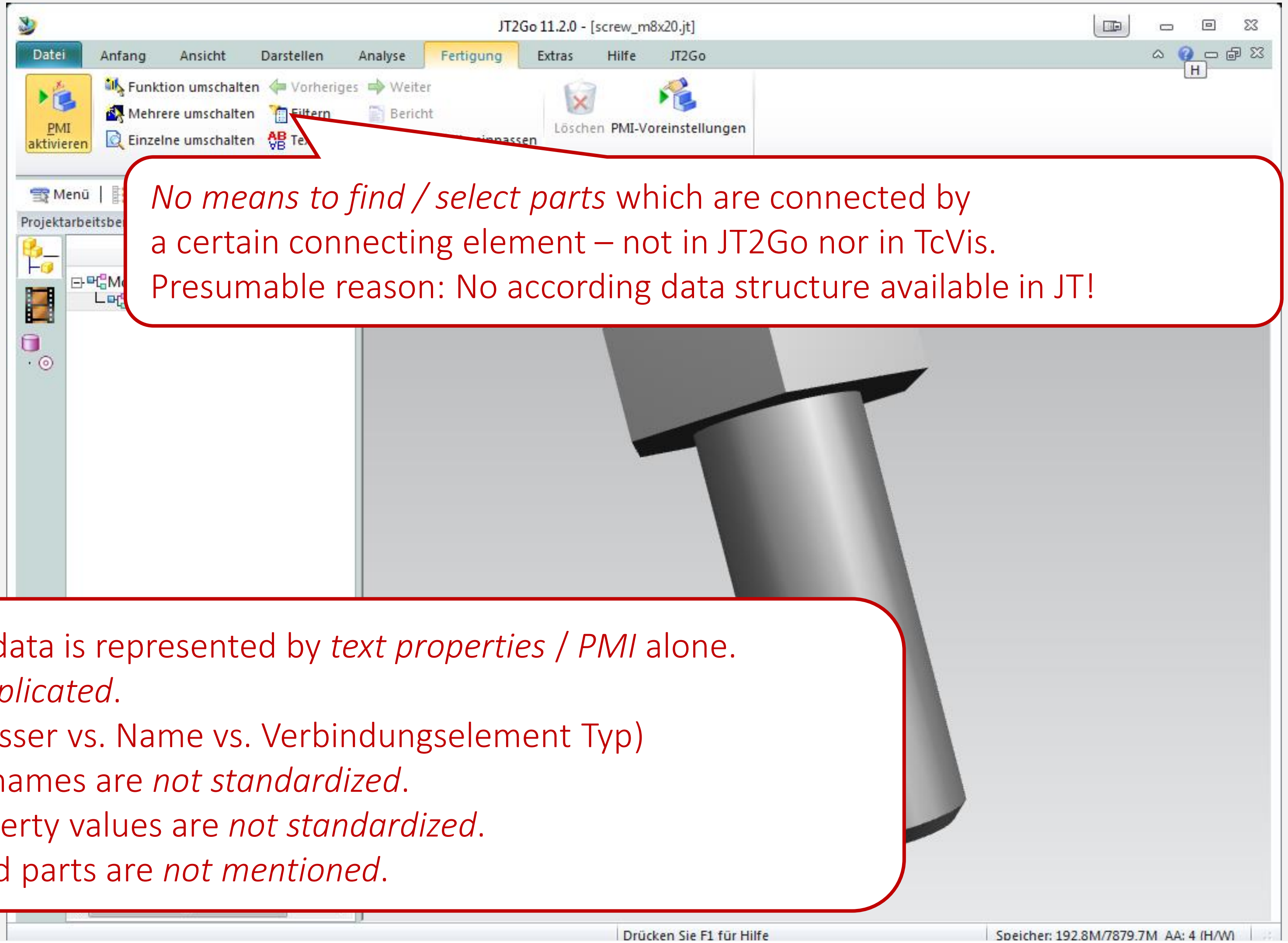
There are good reasons for deviating opinions!

Description

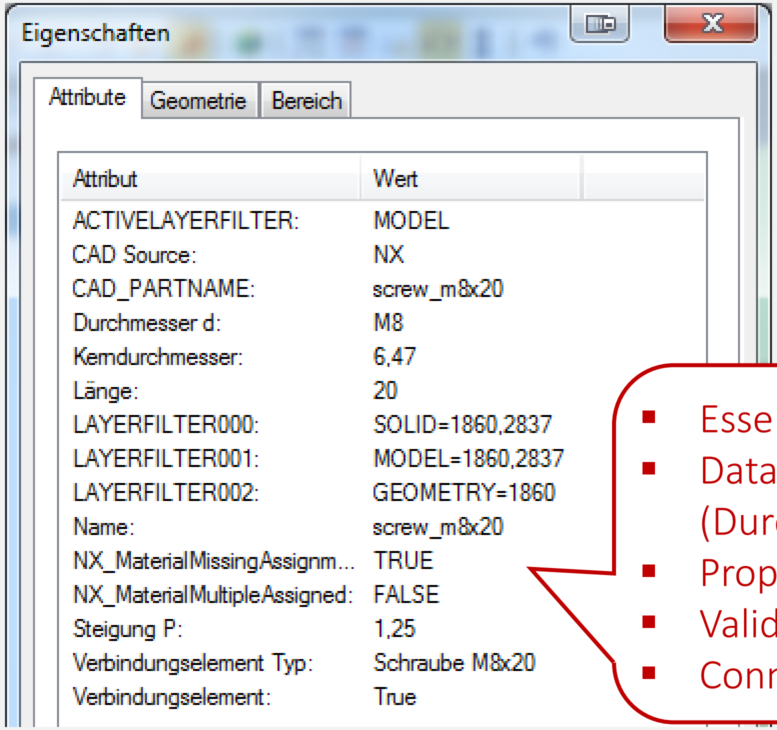
Fasteners are screws, bolts etc. This parts have to be identifiable as fasteners by the FEA meshing tool. The information must be machine readable.

Shortcomings of JT with Respect to Connection Data For Example: Screw

PROSTEP



No means to find / select parts which are connected by a certain connecting element – not in JT2Go nor in TcVis.
Presumable reason: No according data structure available in JT!



Attribut	Wert
ACTIVELAYERFILTER:	MODEL
CAD Source:	NX
CAD_PARTNAME:	screw_m8x20
Durchmesser d:	M8
Kerndurchmesser:	6,47
Länge:	20
LAYERFILTER000:	SOLID=1860,2837
LAYERFILTER001:	MODEL=1860,2837
LAYERFILTER002:	GEOMETRY=1860
Name:	screw_m8x20
NX_MaterialMissingAssignm...	TRUE
NX_MaterialMultipleAssigned:	FALSE
Steigung P:	1,25
Verbindungselement Typ:	Schraube M8x20
Verbindungselement:	True

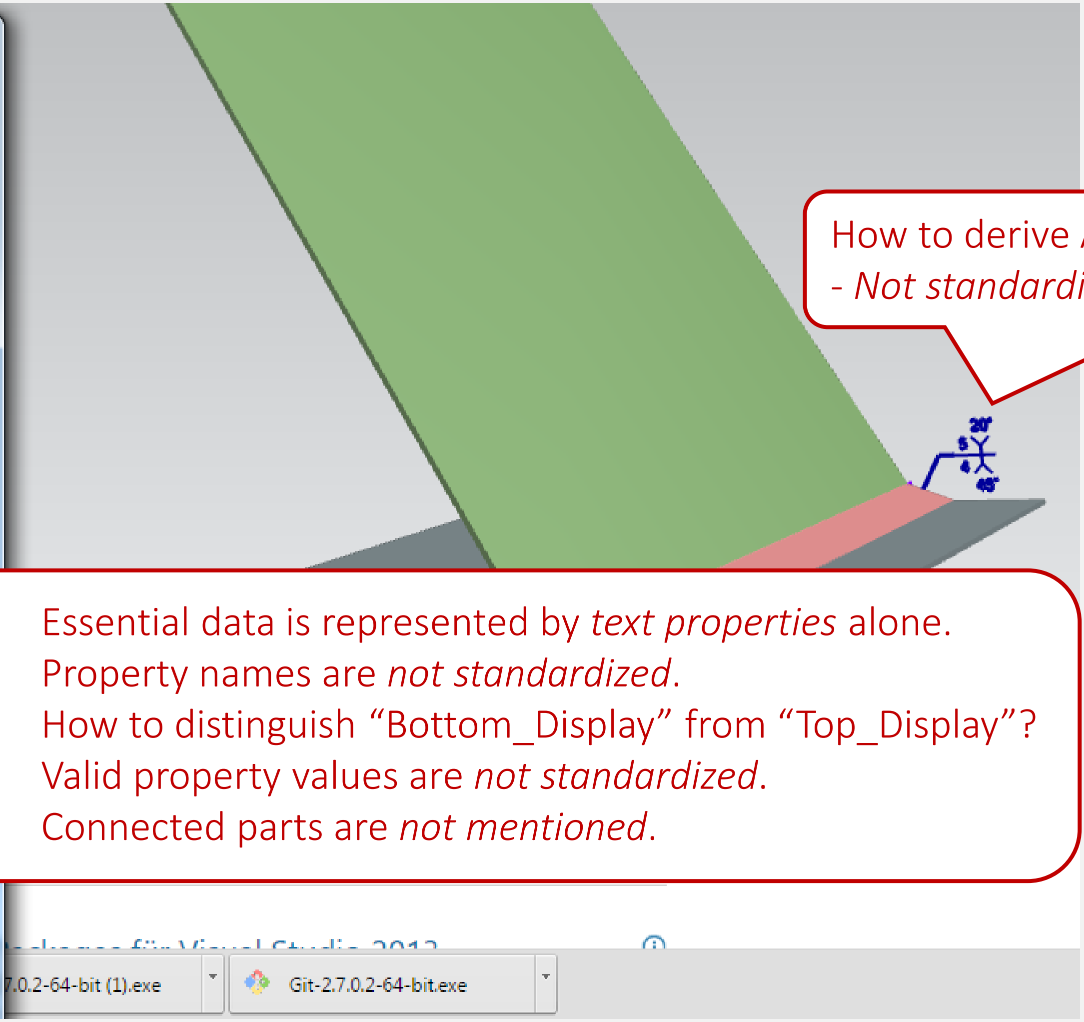
- Essential data is represented by *text properties / PMI* alone.
- Data is *duplicated*.
  (Durchmesser vs. Name vs. Verbindungselement Typ)
- Property names are *not standardized*.
- Valid property values are *not standardized*.
- Connected parts are *not mentioned*.

Shortcomings of JT with Respect to Connection Data
For Example: Weld Line

PROSTEP

Eigenschaften

Attribut	Wert
All Around_Display	No
Angle for Bottom_Display	45
Angle for Top_Display	20
Denominator Part of Symbol Scale_Display	1
Field Flag_Display	No
Horizontal Flip_Display	No
LAYER	1
Number of Welds for Bottom_Display	
Number of Welds for Top_Display	
Numerator Part of Symbol Scale_Display	1
Pitch for Bottom_Display	
Pitch for Top_Display	
Size for Bottom2_Display	
Size for Bottom_Display	4
Size for Top2_Display	
Size for Top_Display	5
Staggered_Display	No
Top Seam Flip_Display	No
Vertical Flip_Display	No
Weld Standard_Display	ISO
Weld Symbol Type for Bottom_Display	V-Groove with Broad Root Face
Weld Symbol Type for Top_Display	V-Groove with Broad Root Face
allAround	0
arrowSideGrooveAngle	45
arrowSideSymbol	29
delta	0
fieldWeld	0
font	Arial Unicode MS
jisArrowSidePartialPenetrationGrooveWeld	0
jisOtherSidePartialPenetrationGrooveWeld	0
jisStaggeredFilletWeld	0
otherSideGrooveAngle	20
otherSideSymbol	29



How to derive AWS symbols from properties?
- *Not standardized*.

- Essential data is represented by *text properties* alone.
- Property names are *not standardized*.
- How to distinguish “Bottom_Display” from “Top_Display”?
- Valid property values are *not standardized*.
- Connected parts are *not mentioned*.

Conclusions Regarding JT

JT's current approach of using text properties for connection data

- lacks efficient, specialized data structures,
- does not fertilize performant algorithms and APIs,
- makes tool integration hard due to missing standardization of PMI names and values,
- does not provide a strategy for adding new technologies rapidly,
- and hence does not foster process reliability at all.

χMCF does better

Requirements to be Met by a Standard Format – Some High Level Examples

PROSTEP

<u>The standard format …</u>

- must support any *established technology* & any kind of *functional data*,
- must be *easily extensible* regarding new technologies or parameters,
- must support the *complete PLM process chain*,
- must allow *data to be aggregated* along the process chain,
- must support *"skipping" data* which is contained, but yet not needed at a certain process step,
- must support *standard parts* (screws, washers, nuts, rivets, clips, …)
- must support data reduction with respect to *intellectual properties*,
- must be *easily implementable* at OEMs,
- must support *filtering, selecting, grouping* of connection elements,
- must be appropriate for *long time archiving*,
- must allow for different *visualizations*:
  - defining, symbolic, simplified and exact geometry,
  - (non-)deformed shape (rivets, nails, heat stakes, …),
  - textual and graphical annotations, …

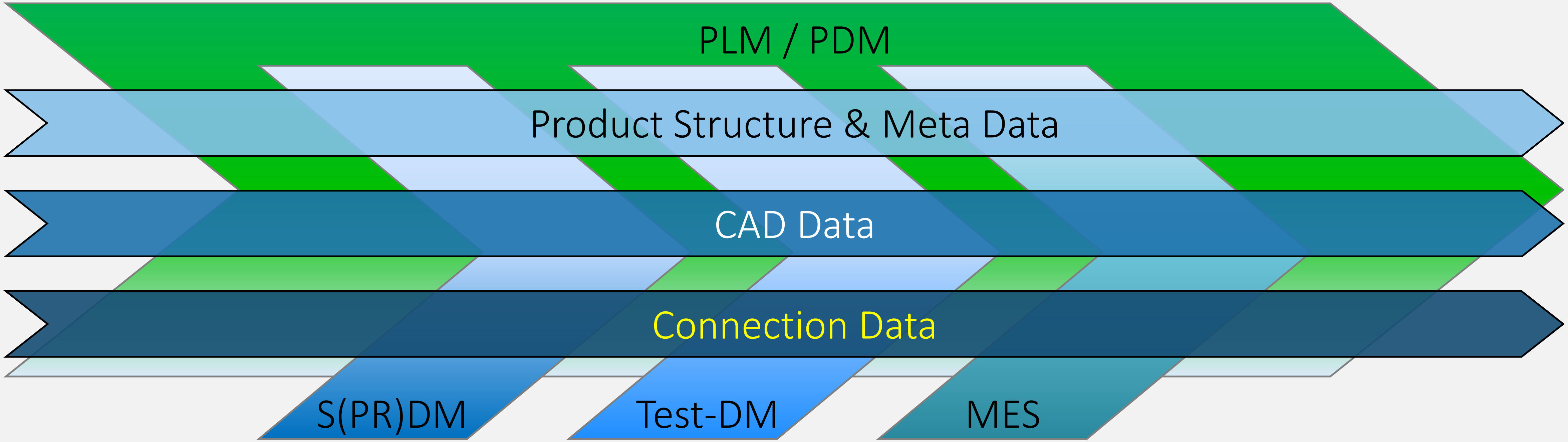
(Achieved in combination with e.g. JT.)

χMCF covers these requirements.

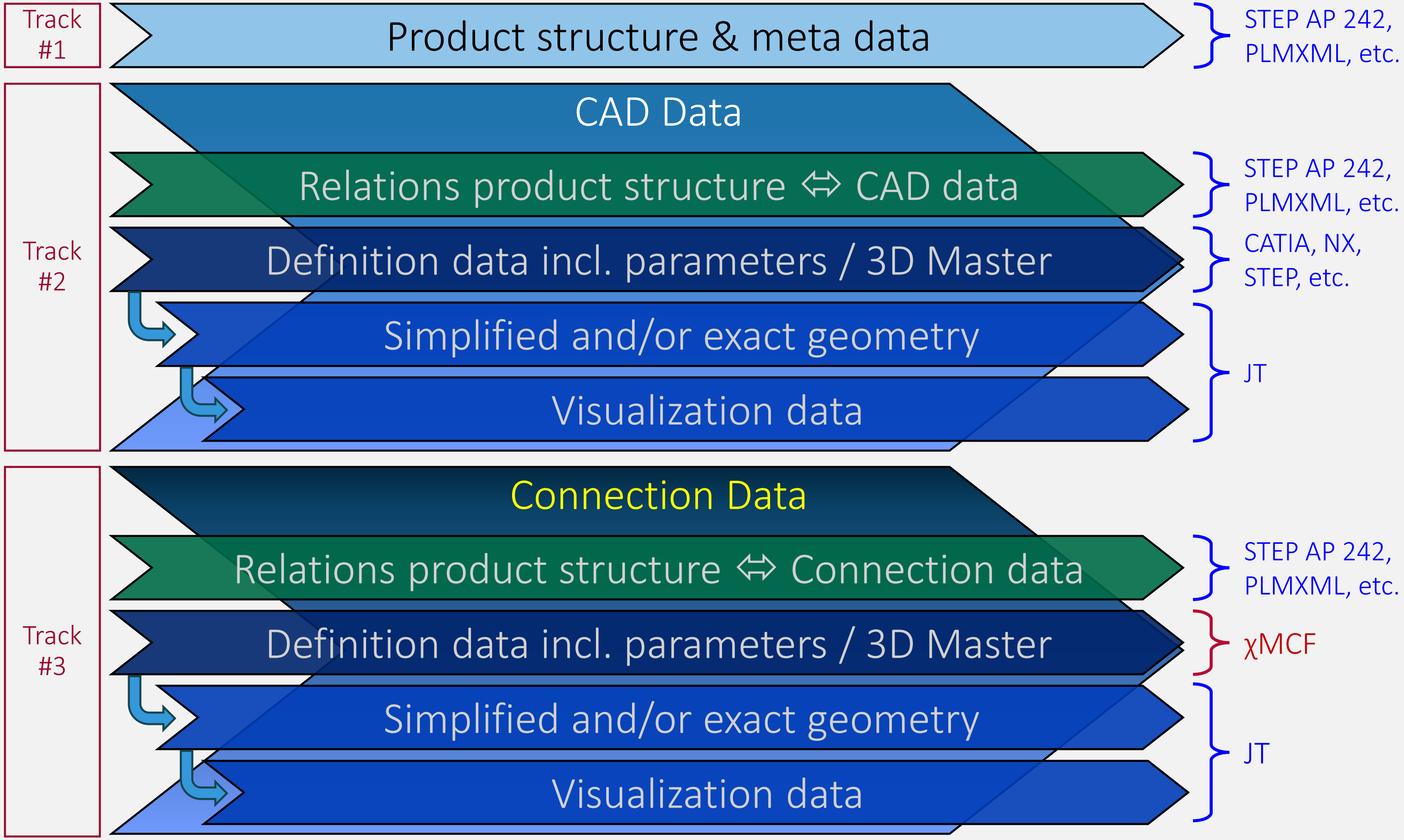
But what about the relations to CAD & product structure?

How χMCF Combines with other Standards

Recap: PLM Process Chain



Detailed Architecture of PLM Data Tracks



Tracks #2 and #3 are *very similar*, allowing for *re-use* of methods and tools. Unfortunately, only tracks #1 and #2 are well-established.

Advantages of such Combinations of Standards

- Strong similarity of CAD- and connection data tracks allows for *maximum re-use of methods*.
- Each involved format is used *according to its strengths*:
  - Native CAD formats or JT are master for defining 3D shape of components, potentially including parameters.
  - χMCF format is master for 3D shape and functional connection data.
  - JT cares for configurable visualization data.
  - And last but not least, STEP or PLM XML form the “glue” between them all.
- Best practices for *tracks #1 and #2 remain untouched*.
- *“As is”-use* of existing standards.
- *No open gaps*, e. g. no not-standardized attribute names or values.
- *All relevant use cases and requirements* are addressed.

Software Requirements and their Level of Fulfillment in Example Software Systems

Software Requirements and their Level of Fulfillment in Example Software Systems

Use-Case	CATIA V5-6 R2014 (aka V5 R24)	JT2Go 9.1	Teamcenter Visualization 11	NX CAD 10	LMS Virtual.Lab Rev 12	Syncrofit 13	ANSA v16.1.1	MEDINA 8.5	Animator 4
Product Structure									
Import from STEP AP 242 XML	_	_	▄	_	_	n.a.	█	▄	_
Import from JT	█	█	█	█	_	n.a.	█	█	█
Import from PLM XML	█	█	█	█	_	n.a.	█	▄	▄
Export to STEP AP 242 XML	█	_	_	_	_	n.a.	_	_	_
Export to JT	█	█	█	█	_	n.a.	█	_	_
Export to PLM XML	█	█	█	█	_	n.a.	_	▄	_
CAD Geometry									
Import exact geometry (BRep, NURBS) from JT	█	█	█	█	_	n.a.	█	█	_
Import geometry tessellation from JT	█	█	█	█	_	n.a.	█	█	█
Import geometry RGB colors & transparency from JT	▄	█	█	█	_	n.a.	█	█	█
Import CAD properties from JT	█	█	█	█	_	n.a.	▄	█	_
Export exact geometry to JT	█	█	█	█	_	n.a.	_	_	_
Export geometry tessellation to JT	█	█	█	█	_	n.a.	█	_	_
Export geometry RGB colors & transparency to JT	█	█	█	█	_	n.a.	█	_	_
Export CAD properties to JT	█	█	█	█	_	n.a.	_	_	_

Track #1

Track #2

Legend: _ - Use case not supported ▄ - partially supported █ - fully supported

Time of survey: Winter 2015/16

Software Requirements and their Level of Fulfillment in Example Software Systems

PROSTEP

Use-Case	CATIA V5-6 R2014 (aka V5 R24)	JT2Go 9.1	Teamcenter Visualization 11	NX CAD 10	LMS Virtual.Lab Rev 12	Syncrofit 13	ANSA v16.1.1	MEDINA 8.5	Animator 4
<u>Connections</u>									
<u>Defining Geometry</u>									
Creation / modification with level of detail, comparable to χMCF V 2.1.	_	n.a.	n.a.	▪	█	█	█	█	_
Import from STEP AP 242 XML (MatingDefinition)	_	_	_	_	_	_	_	_	_
Import of connection properties from JT and their usage by the application	▪	█	█	▪	_	▪	▪	_	_
Import from χMCF V 2.1	_	_	_	_	▪	▪	█	▪	_
Usage of connection attributes as selection criteria / filter for following steps / program functions	_	_	_	_	█	█	█	█	_
Selection of parts which are connected by a or which are within the search spaces of a certain set of connections for following steps / program functions	_	_	_	_	█	█	█	█	_
Export to STEP AP 242 XML (MatingDefinition)	_	_	_	_	_	_	_	_	_
Export to χMCF V 2.1	_	_	_	_	▪	▪	█	▪	_
Export of connection properties to JT	█	█	█	█	_	▪	_	_	_

Missing functionality of CAD systems!

Track #3

Legend: _ - Use case not supported ▪ - partially supported █ - fully supported

Time of survey: Winter 2015/16

Software Requirements and their Level of Fulfillment in Example Software Systems

PROSTEP

Use-Case	CATIA V5-6 R2014 (aka V5 R24)	JT2Go 9.1	Teamcenter Visualization 11	NX CAD 10	LMS Virtual.Lab Rev 12	Syncrofit 13	ANSA v16.1.1	MEDINA 8.5	Animator 4
<u>Connections</u>									
<u>*Simplified and Exact Geometry*</u>									
Calculation and graphical visualization of details like e.g. weld surface, nuts, screw heads, Robscan patterns etc. as *simplified* geometry (*not* using OEM-specific tool sets)	█	n.a.	n.a.	█	█	█	█	█	_
Export of *simplified* geometry in a non-proprietary 3D format	█	n.a.	n.a.	█	_	█	_	_	_
Calculation and graphical visualization of details like e.g. weld score marks, screw threads, discolorations of heat affected zones etc. as *exact* geometry / photo realistic visualization (*not* using OEM-specific tool sets)	█	n.a.	n.a.	█	_	█	_	_	_
Export of *exact* geometry in a non-proprietary 3D format	█	n.a.	n.a.	█	_	█	_	_	_

Track #3

In our context, exchange of connection data is always combined with defining geometry and/or product structure.
At the moment, there is *no* software known which supports this in combination and maintains references between correlated data.

Legend: _ - Use case not supported ▄ - partially supported █ - fully supported

Time of survey: Winter 2015/16

Conclusions

PROSTEP

The survey shows

- there is *no system*, which supports *all use cases*,
- more systems support PLMXML than STEP AP 242,
- *no system* supports STEP AP 242’s *mating definition*,
- χMCF 2.1 is supported just by CAE systems, not by CAD systems – at least not “out of the box”,
- ***weak support by CAD systems*** of selecting / handling connections, in comparison with CAE systems (o.o.t.b.),
- …

- Standards have evolved to fulfill all requirements, if combined.
- *Software systems should follow, soon.*

Next Steps Regarding Software Systems

Dassault, Siemens

15:00 – 15:45

Next Steps of Working Group 25

15:45 – 16:00