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CAD Manual 04-3 Mechanical Design Methodologies

This CAD manual section has been written to define and explain the mechanical design modelling techniques to be used by ITER designers.It is applicable for designers at IO, DA & the suppliers DO using the ITER CAD platform.

Approval Process			
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v2.1	Approved	14 Feb 2014	Figs 4.3-7 & 4.3-8 redrawn.

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4.3 Mechanical Design Methodologies

4.3.1 Purpose

This CAD manual section has been written to define and explain the mechanical design modelling techniques to be used by ITER designers.

4.3.2 Scope

The document is applicable for designers at IO, DA & the suppliers DO using the ITER CAD platform.

Complementary to this CAD manual are the PBS specific CAD Design Handbooks.
Refer to chapter 0

PBS CAD Design Handbook for more information.
The handbooks can be found here:

CAD Design Handbooks (3URXHL)

This manual contains hyperlinks to IDM documents that need to be launched in order to get the full picture of the topics covered.

4.3.3 Definitions

For a complete list of ITER abbreviations see:

ITER Abbreviations (2MU6W5)
DO Abbreviations (24844F)

Abbreviations used in this document:

BT	=	Bake-out Temperature
CAD	=	Computer Aided Design
CCP	=	Copy/Cut/Paste
CSKE	=	Component SKEleton
CV5	=	Catia V5
DA	=	Domestic Agency
DECO	=	DEsign COordinator
EV5	=	Enovia V5
GDC	=	Glow DisCharge
IDM	=	ITER Document Management system
IO	=	ITER Organization
ISKE	=	Interface SKEleton
IVV	=	In-Vessel Viewing
OT	=	Operating Temperature
PBS	=	Plant Breakdown Structure
PSKE	=	Positioning SKEleton
RH	=	Remote Handling
RO	=	Responsible Officer
RSKE	=	Reference Skeleton
RT	=	Room Temperature
SKE	=	SKEleton
VV	=	Vacuum Vessel
WP	=	Work Package

4.3.4 Quick Reference Guide to rules

The following table provides an overview of the rules contained in this section of the CAD Manual.

Categories: M = Mandatory (Shall comply) R = Recommended (Should comply)

Topic	Rule No.	Rule Description	Category	Q-Checker Rule	EV5/FB	CAD Manual Section
General Rules	**RCM01**	Consult the complementary CAD Design Handbooks (3URXHL) for PBS specificities.	M		EV5/FB	**0**
	RCM02	The RT for all modelling at ITER is 20°C (293K).	M		EV5/FB	**4.3.6**
	RCM03	Multi body is the recommended methodology for conceptual design, multi part for manufacturing design.	R		EV5/FB	**4.3.7**
	RCS01	Sketch has to be fully constrained.	M	IO_Ske_201	EV5/FB	**4.2**
	RCM04	Environment or context data must not been copied inside the CATPart of a specific component.	M		EV5/FB	**4.3.7.3**
	RCM05	The CATPart must only contain the geometry of the component itself and the necessary minimum of auxiliary geometry.	M		EV5/FB	**4.3.7.3**
	RCM06	The auxiliary geometry - for example interface geometry - can be linked to another part if this other part is a skeleton.	M		EV5/FB	**4.3.7.3**
Axis system and origin	**RCM07**	Mechanical components which are rotated around the z-axis of the Tokamak shall be designed according to XZ methodology.	M		EV5/FB	**4.3.8**
	RCM08	Other mechanical components can have specific local axis system.	M		EV5/FB	**4.3.8**
	RCM09	Standard parts have a local origin.	M		EV5/FB	**4.3.8**
	REA07	Each part or assembly has to be ISO constrained with 0 degree of freedom **OR** the minimum of constraints has to be "Fix".	M		EV5/FB	**4.2**
Skeletons	**RCM10**	Skeleton methodology shall be used for interface management between mechanical systems and between mechanical and plant systems.	M		EV5/FB	**4.3.9**
	RCM11	CSKE methodology can be used if it is considered as useful for a specific component.	R		EV5/FB	**4.3.9**
	RCM12	After transfer of design data from IO to DA, already existing CAD data based on skeleton methodology shall not be isolated without agreement of the IO DECO.	M		EV5/FB	**4.3.9**
	RCM13	Links between CATPart are only allowed if the reference geometry is inside a SKE part, or between the symmetrical part and the original part.	M		EV5/FB	**4.3.9**

	RCM14	Only CCP (CATIA Copy Paste) type of link shall be used.	M		EV5/FB	**4.3.9**
	RCP09	No inactive features or operations in specifications tree for Skeleton.	R	IO_Ske_203	EV5/FB	**4.2**
	RCM15	All elements in a skeleton used for links must be published on the part level.	M		EV5/FB	**4.3.9**
	RCM16	Publication name must match published element name.	M	IO_PUB_2	EV5/FB	**4.3.9**
	RCM17	Do not use more than 100 publications per skeleton.	R		EV5/FB	**4.3.9**
	RCM18	Publication must be synchronized and resolved (check inside SKE & driven Parts, WP CATProducts).	M	IO_PUB_4	EV5/FB	**4.3.9**
	RCM19	The first level of skeleton is the RSKE which is controlled by IO and driven by physics.	M		EV5/FB	**4.3.9.1**
	RCM20	Lower level of CSKE is controlled by IO designers or DA/supplier designers. CSKE are driven by the 1st level Skeletons.	M		EV5/FB	**4.3.9.1**
	RCM21	If possible limit the hierarchy to 3 (RSKE-CSKE-COMP).	R		EV5/FB	**4.3.9.1**
	RCM22	To allow proper configuration management, the impact of changes of skeleton shall be limited to a minimum.	M		EV5/FB	**4.3.9.1**
	RCM23	Geometry should be used directly from the source skeleton.	M		EV5/FB	**4.3.9.1**
	RCM24	Republication of geometry in lower level skeleton originally defined in higher level skeleton should be avoided.	R		EV5/FB	**4.3.9.1**
	RCM25	Horizontal links, for example between RSKE of different PBS shall not be made.	M		EV5/FB	**4.3.9.1**
	RCM26	Do not make circular references / links between skeletons.	M		EV5/FB	**4.3.9.1**
Skeletons	**RCM27**	For the RSKE-CSKE and the driven component the same modeling approach (XZ or common origin) shall be used. Repositioning of skeleton driven geometry in driven CATParts should be avoided.	R		EV5/FB	**4.3.9.2**
	RCM28	A RSKE contains only wireframe geometry – point, line, sketch…or parameters.	M		EV5/FB	**4.3.9.2**
	RCM29	A CSKE can be built with parameters, wireframe or solid geometry according to the needs.	R		EV5/FB	**4.3.9.2**
	RCM30	Respect writing convention for publications.	M	IO_PUB_1	EV5/FB	**4.3.9.3**
	RCM31	Interfaces between different mechanical PBS are covered by RSKE.	M		EV5/FB	**4.3.9.4**
	RCM32	Interfaces inside a mechanical system can be covered by CSKE.	M		EV5/FB	**4.3.9.4**
	RCM33	Interfaces between mechanical and plant component are handled by an ISKE on the mechanical and interface parts from catalogue.	M		EV5/FB	**4.3.9.4**

	RCM34	The PSKE is used to position at least the main components of the product structure with assembly constraints.	R		EV5/FB	**4.3.9.5**
	RCM35	The PSKE contains only elements like planes and lines to be used for assembly constraints.	M		EV5/FB	**4.3.9.5**
	RCM36	The elements inside a Work package used for positioning of the WP in the next higher structure exposed assembly must be published on the WP level.	M		EV5	**4.3.10**
	RCM37	The flexible PSKE can be used to handle different configurations in position for remote handling and assembly studies.	R		EV5/FB	**4.3.11**

Table 4.3-1 Quick reference guide to rules

4.3.5 PBS CAD Design Handbook

These CAD Design Handbooks contain processes and methodologies specific to a PBS. **RCM01**

They are useful as guidance to new designers and include the following information:

- Global design process, design status, design goal
- Structure PRC, assembly structure, instances
- Organizations involved in the design
- Positioning
- Skeleton
- Interfaces
- ITER methodologies
- Other specific methodologies
- Drawings

Here is the link to the IDM folder for the CAD Design Handbooks:

CAD Design Handbooks (3URXHL)

4.3.6 Modelling at Room Temperature (RT)

The RT for all modelling at ITER is 20°C (293K). **RCM02**

When modelling is carried out at any other temperature, example: Operating Temperature (OT), Bake-out Temperature (BT) etc., it shall be clearly identified in the appropriate ENOVIA attribute.

4.3.7 Choice of Modelling Technique - Multi-Bodies versus Multi-Parts

The choice of modelling technique depends on the scope of the work.

4.3.7.1 Multi-body Parts

Multi-body Parts are preferred in the following cases:

A. A feasibility study – quick investigation of various concepts etc.
B. A detailed study
C. The manufacturing techniques either don't need to be or cannot be defined by the IO (IO is not a manufacturer)

For IO Conceptual Design the multi-body approach is the recommended methodology. **RCM03**

4.3.7.2 Multi Parts

Multi-Parts are preferred in the opposite cases to 4.3.7.1, plus:

A. When the Parts move relative to one another (using CV5 kinematics to simulate assembly sequence, RH operation etc.)
B. When concurrent engineering and/or various Suppliers are required.
C. When only one part needs a new version.
D. For detailed or manufacturing design.

For suppliers the multi-Part approach might be a more appropriate methodology.

A standard part must be a separate CATPart.

4.3.7.3 Environment data

Environment or context data must not been copied inside the CATPart of a specific component. **RCM04**

The CATPart must only contain the geometry of the component itself and the necessary minimum of auxiliary geometry. **RCM05**. The auxiliary geometry - for example interface geometry - can be linked to another part if this other part is a skeleton. **RCM06**

4.3.8 Axis system and origin

For many mechanical components, the ITER methodology is based on the design of the components on the XZ plane as symmetry plane or around the XZ plane in a reference position like sector 1 of the Vacuum Vessel, combined with a positioning (rotation around the Z axis of the machine) inherited from higher assemblies and driven by a positioning skeleton (PSKE). **RCM07**.
The origin of these parts and assemblies is the TOKAMAK Global Coordinate System TGCS but the axis system is rotated around the z-axis.
Other components for example in NB (Neutral Beam) have specific local axis system. **RCM08**
Standard parts have a local origin. **RCM09**
The standard methodology is based on assembly constraints between PSKE (Positioning skeleton) and on an Assembly level, which depends on the specific assembly structure, and a reference part containing simple stable wireframe geometry on the next lower level. Lower level subassemblies inherit then the position from the higher level. As positioning can be defined on higher assembly level the minimum assembly constraint for lower levels are fix constraints.

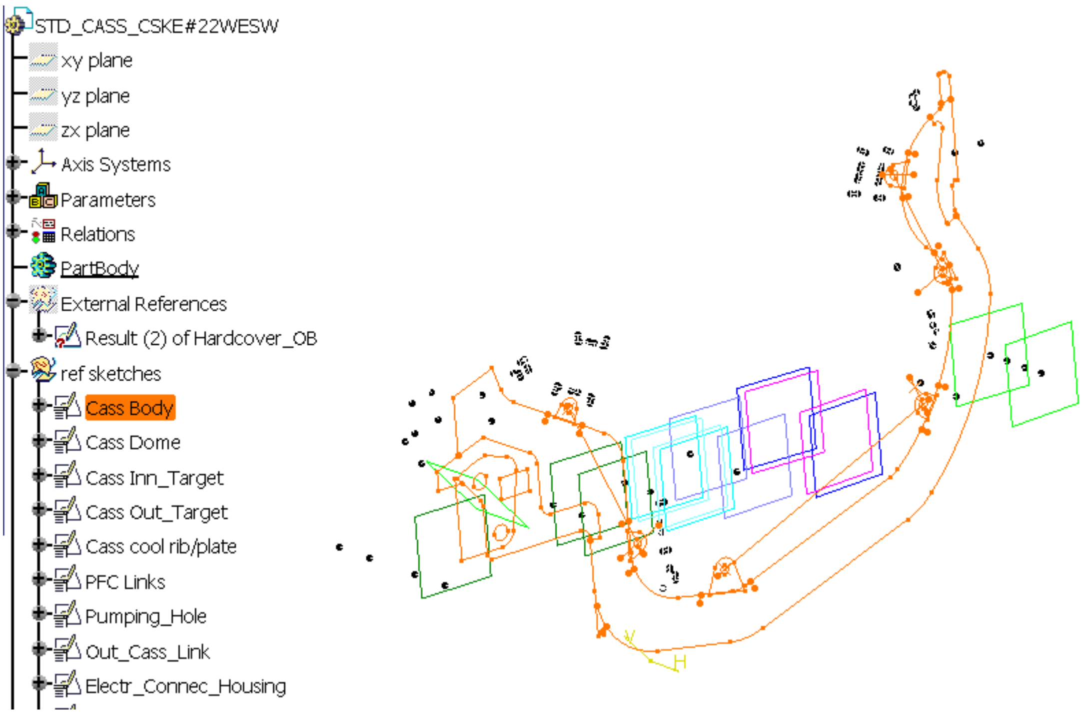

Figure 4.3-1 Design based on XZ method

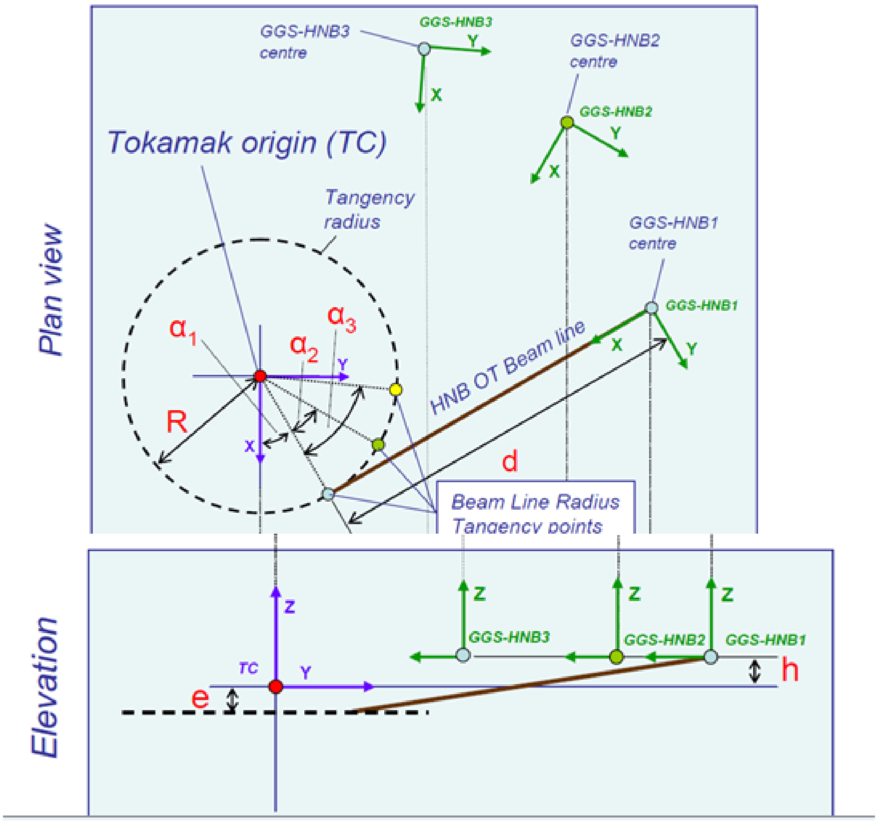

Figure 4.3-2 Positioning of NB components

4.3.9 Skeletons (SKE)

Definition:

A SKE is a CATPart containing geometry, parameters, bodies that are used to drive the geometry and/or positions of other parts.

Function:

- The skeleton is used to reduce the time to make changes and/or to make variants – component skeleton.
- The skeleton is used to define an interface between parts.
- Skeleton methodology shall be used for interface management. **RCM10**
  CSKE methodology can be used if it is considered as useful for specific components. **RCM11**
- After transfer of design data from IO to DA, already existing CAD data based on skeleton methodology shall not be isolated without agreement of the IO DECO. **RCM12**

Links between CATPart are only allowed if the reference geometry is inside a SKE part, or between the symmetrical part and the original part. **RCM13**

Links between any CATParts might lead to:

- Difficulty for the designer to understand the link structure and the design intent.
- Cycles of links can lead to unpredictable results.

Only CCP (CATIA Copy Paste) type of link shall be used. **RCM14**

A. There are 3 types of SKE.
   i. Reference Skeleton (RSKE) for interfaces between PBS

ii. A component skeleton (CSKE) for interface inside one PBS and component use
iii. An interface skeleton (ISKE).
iv. A positioning skeleton (PSKE).

B. Publication

All elements in a skeleton used for links must be published on the part level. **RCM15**

The publication name must be identical with the element name. **RCM16**. See Figure 4.3-3.

The publication of geometry allows restricting the access to the correct geometry.
The number of publications should be limited to a reasonable number to be able to manage. The recommendation is to use not more than 100 per skeleton. **RCM17**

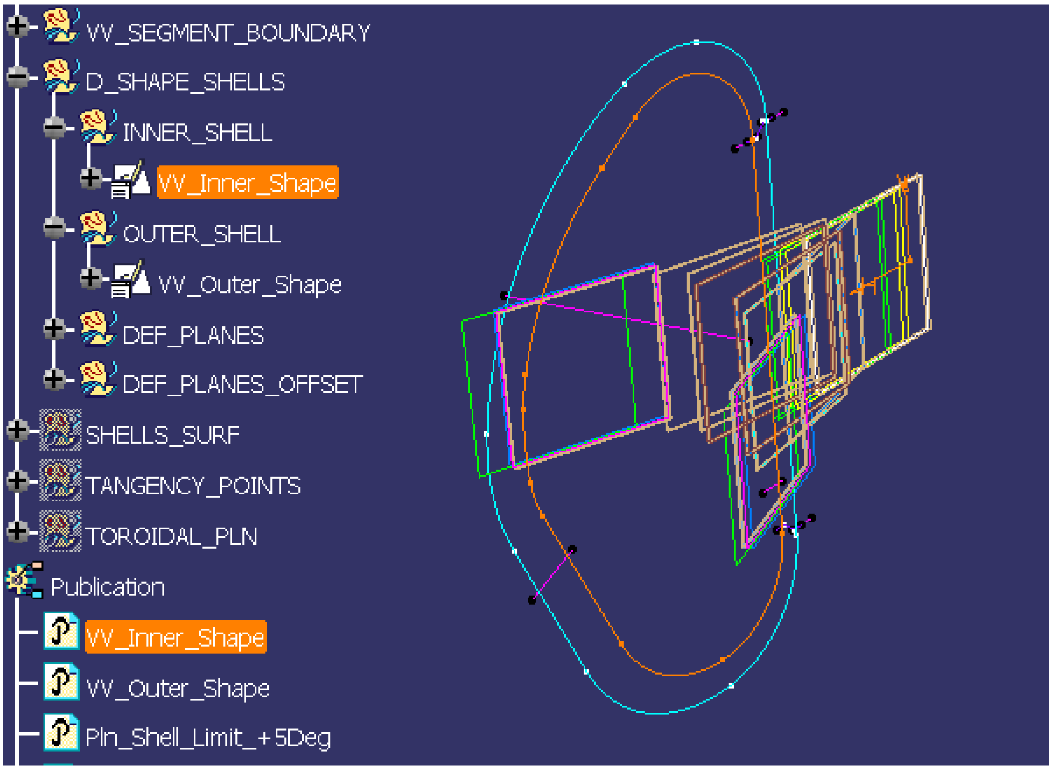

Figure 4.3-3 Publications

Publication must be synchronized and resolved (check inside SKE & driven Parts, WP CATProducts). **RCM18**

Figure 4.3-4 shows an example of unsynchronized publications due to wrong actions (removal of pointed elements, isolate operation, etc. …

<u>Remark:</u> All publications appear with this status when data are loaded in Visualization mode (Cache system enable).

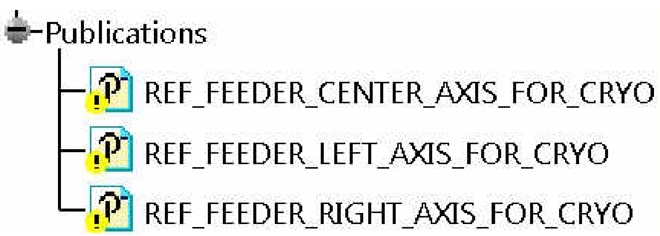

Figure 4.3-4 Example of unsynchronized publications

4.3.9.1 Skeleton hierarchy and complexity

The first level of skeleton is the RSKE which is controlled by IO and driven by physics. **RCM19**.

Lower level of CSKE is controlled by IO designers or DA/supplier designers. CSKE are driven by the 1st level Skeletons. **RCM20**.

If possible limit the hierarchy to 3 (RSKE-CSKE-COMP). **RCM21**

To allow proper configuration management, the impact of changes of skeleton shall be limited to a minimum. **RCM22**

A partial change of skeleton geometry shall not lead to the need of synchronization of other components not affected by the change.

Geometry should be used directly from the source skeleton. **RCM23**

Republication of geometry in lower level skeleton originally defined in higher level skeleton should be avoided. **RCM24**

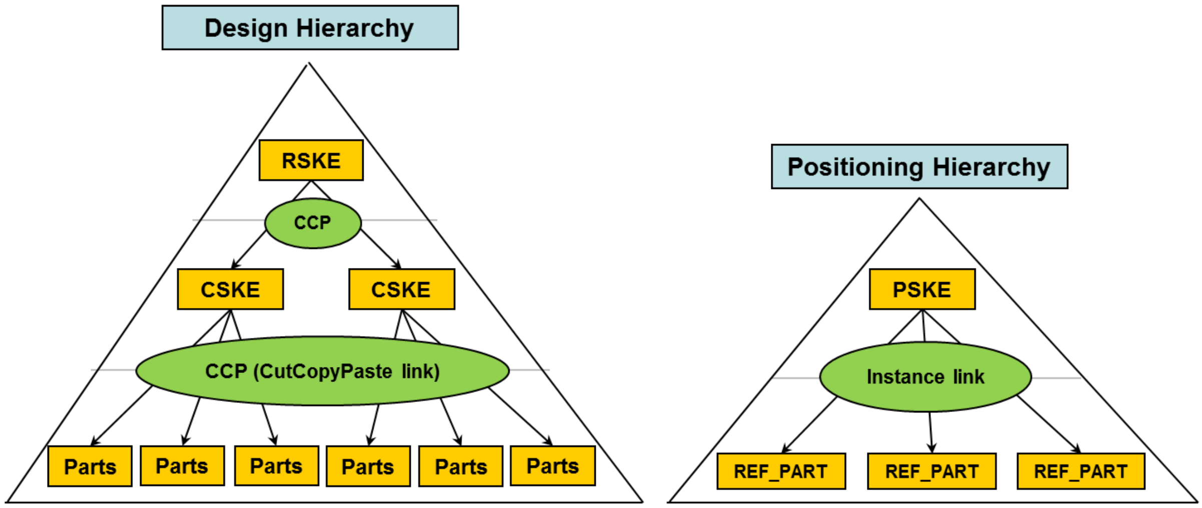

Figure 4.3-5 Skeleton hierarchy

Horizontal links, for example between RSKE of different PBS shall not be made. **RCM25**

Do not make circular references/links between skeletons. **RCM26**

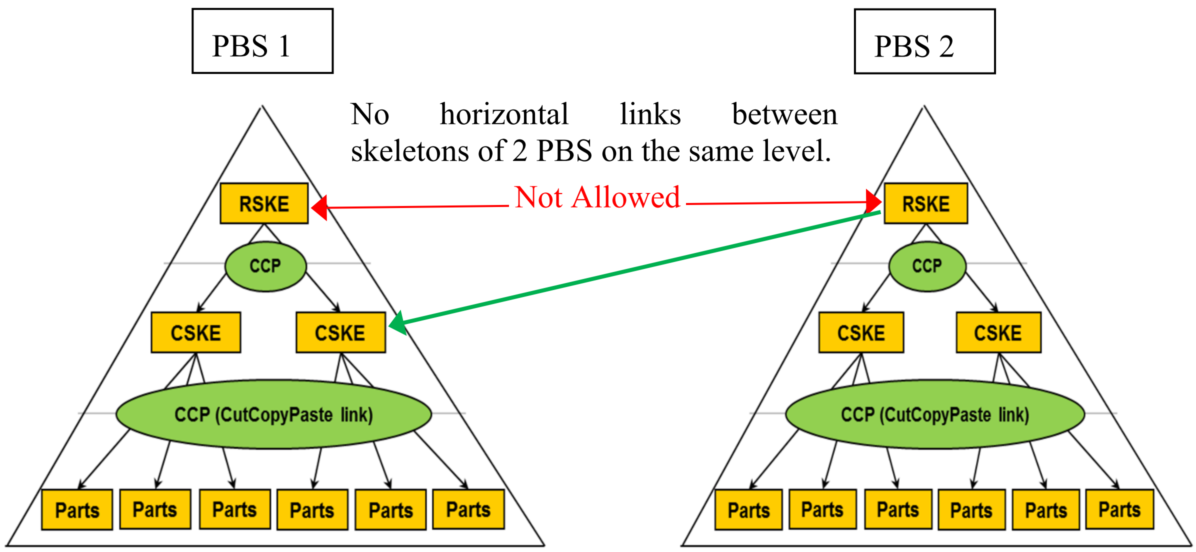

Figure 4.3-6 Horizontal links

4.3.9.2 Reference and component skeleton Principle (RSKE-CSKE)

Definition - The RSKE and CSKE can be used as a link between adjoining parts with a common boundary feature or used for component construction purpose. Therefore the RSKE defines interfaces based on high level reference geometry.
Example: The stub key axis and its bores sketch between the VV and Blanket.

Rationale:
The RSKE and CSKE enable the split of responsibility between IO (interface) and DA (component).
The link between RSKE-CSKE and the driven component allows tracking whether the driven part is based on the current version of the RSKE-CSKE and or is up to date.
The link also allows you to find out what components are affected by a change of the interface geometry.

At the interface between two components, there is a relationship between the components that is defined as 'User' and 'Provider'.
The 'User' component uses the support / alignment / supply / access / handling of the 'Provider' component.
The 'Provider' component provides the support / alignment / supply / access / handling to the 'User' component.
To ease the usage and understanding of the design intent the system or component specific application of the generic methodology shall be explained in the corresponding CAD-Handbook of the system. 03 CAD Design Handbooks (3URXHL)

Interface	USER component	PROVIDER component	Justification
Divertor-Vacuum Vessel	Divertor	Vacuum Vessel	The cassettes need supporting
Divertor-water cooling circuit	Divertor	Water cooling circuit	The cassettes need cooling
Divertor-Remote handling	Divertor	Remote handling	The cassettes need maintenance
Divertor-Machine axis (configuration)	Machine axis (configuration)	Divertor	Absolute position dictated by Machine configuration
Divertor-IVV/GDC	IVV/GDC	Divertor	The IVV/GDC need access (cassette cut-out)
Divertor-Diagnostics	Diagnostics	Divertor	The diagnostics need space / access (cassette cut-out…)

Table 4.3-2 Examples of RSKE-CSKE between parts in a different PBS

The skeleton data is the result of an agreement between the "User" component and the "Provider" component RO with the supervision of Design Integration.
In the case of conflict, DI is in charge of solving the interface issues.

For the RSKE-CSKE the same modeling approach (XZ methodology or other common origin) is used and can only be applied on components using this approach. **RCM27**
Repositioning of skeleton driven geometry in lower level CATParts should be avoided.
A RSKE contains only wireframe geometry – point, line, sketch or parameters. **RCM28**

The responsible DECO oversees all the RSKE (technical content and storage) and the product structure.
A CSKE can be built with parameters, wireframe or solid geometry according to the needs. **RCM29**

CSKE are under the responsibility of the owner organization DECO and can be sent out to the Domestic agencies within the exchange process of data package.

The purpose of a CSKE is mainly related to interface management inside the same PBS but could also contain component related information for the design of variants.

4.3.9.3 Naming convention

The proper naming of the skeleton part itself, the elements and publication in a skeleton is important because the name has to reflect the design intent and it should make clear for the designers which reference geometry shall be used from the skeleton. **RCM30**

Example: the BCC TCC winding pack skeleton, which is containing published solids to be used in several winding variants.

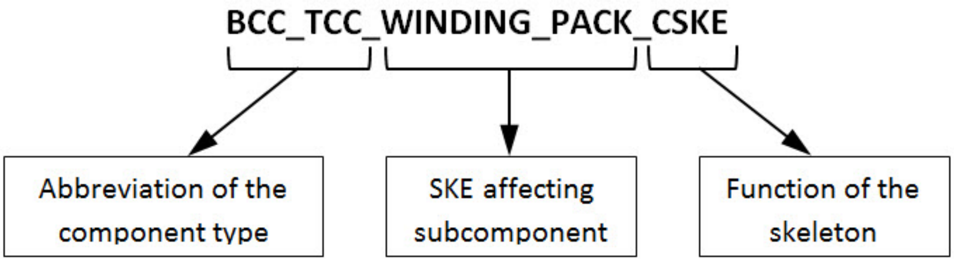

Figure 4.3-7 Naming convention for skeletons

<u>Example:</u> The blanket module is cooled by the manifolds, the related CSKE will be:
Stored in the "Blanket" CSKE Assembly (the blanket being the "User" component).
Named: "Manifold" (being the "Provider" component).
The geometry shall have a speaking name.

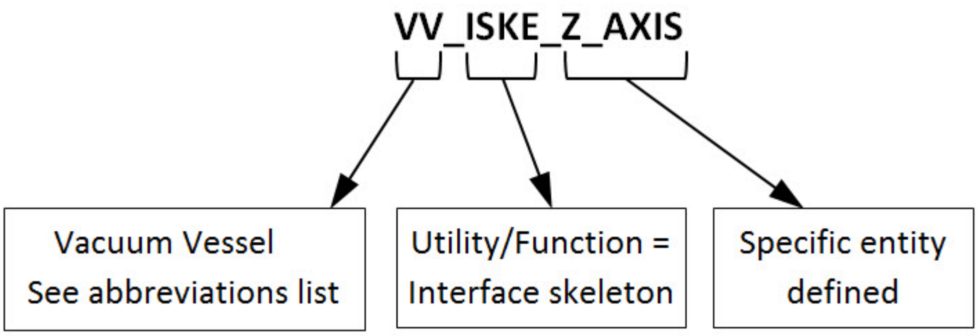

Figure 4.3-8 Naming convention for interface and component geometries

4.3.9.4 Interface skeleton (ISKE)

Interfaces between different mechanical PBS are covered by RSKE. **RCM31**

Interfaces inside a mechanical system can be covered by CSKE. **RCM32**

Interfaces between mechanical and plant component, for example Blanket and Cooling water system, are handled by a ISKE on the mechanical side with wireframe geometry and interface parts from catalogue linked to the ISKE to define their position. **RCM33**

Details are described in:

C14 Interface Mechanical Plant (2F6MSU).

4.3.9.5 Positioning skeleton (PSKE)

Definition:

The standard positioning methodology is based on assembly constraints between PSKE and on an Assembly level, which depends on the specific assembly structure, and a reference part containing simple stable wireframe geometry on the next lower level. **RCM34**

Lower level subassemblies inherit then the position from the higher level. As positioning can be defined on higher assembly level the minimum assembly constraint for lower levels are fix constraints.

Example: the SECTOR_01 inside the SECTORS assembly in the VV PBS. The PSKE contains only elements like planes and lines to be used for assembly constraints. **RCM35**

These elements used for assembly constraints are published.

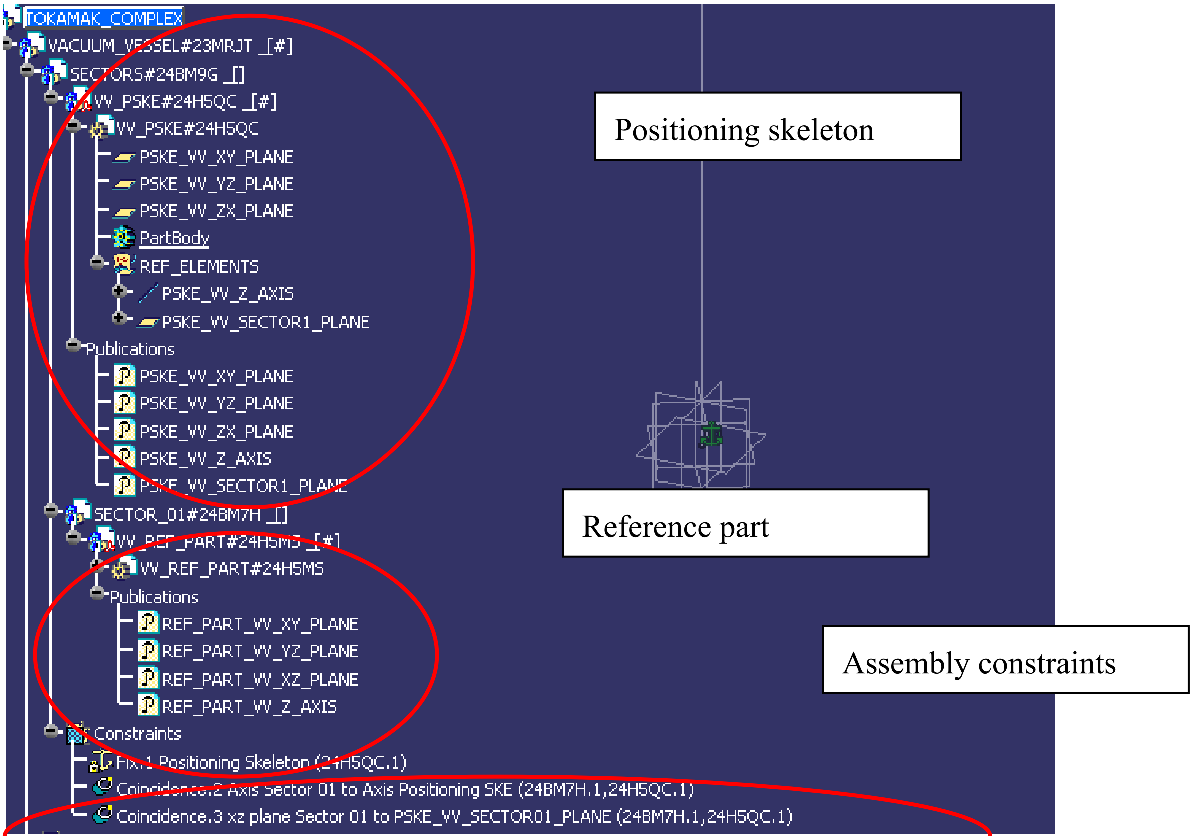

Figure 4.3-9 Positioning Skeletons

4.3.10 Positioning of Work packages (WP)

The elements inside a Work package used for positioning of the WP in the next higher structure exposed assembly must be published on the WP level. **RCM36**

These elements should be inside a reference part. Only use geometry with high stability like lines and planes. See Figure 4.3-10.

The positioning of components inside the WP with assembly constraints can be based on unpublished geometry.

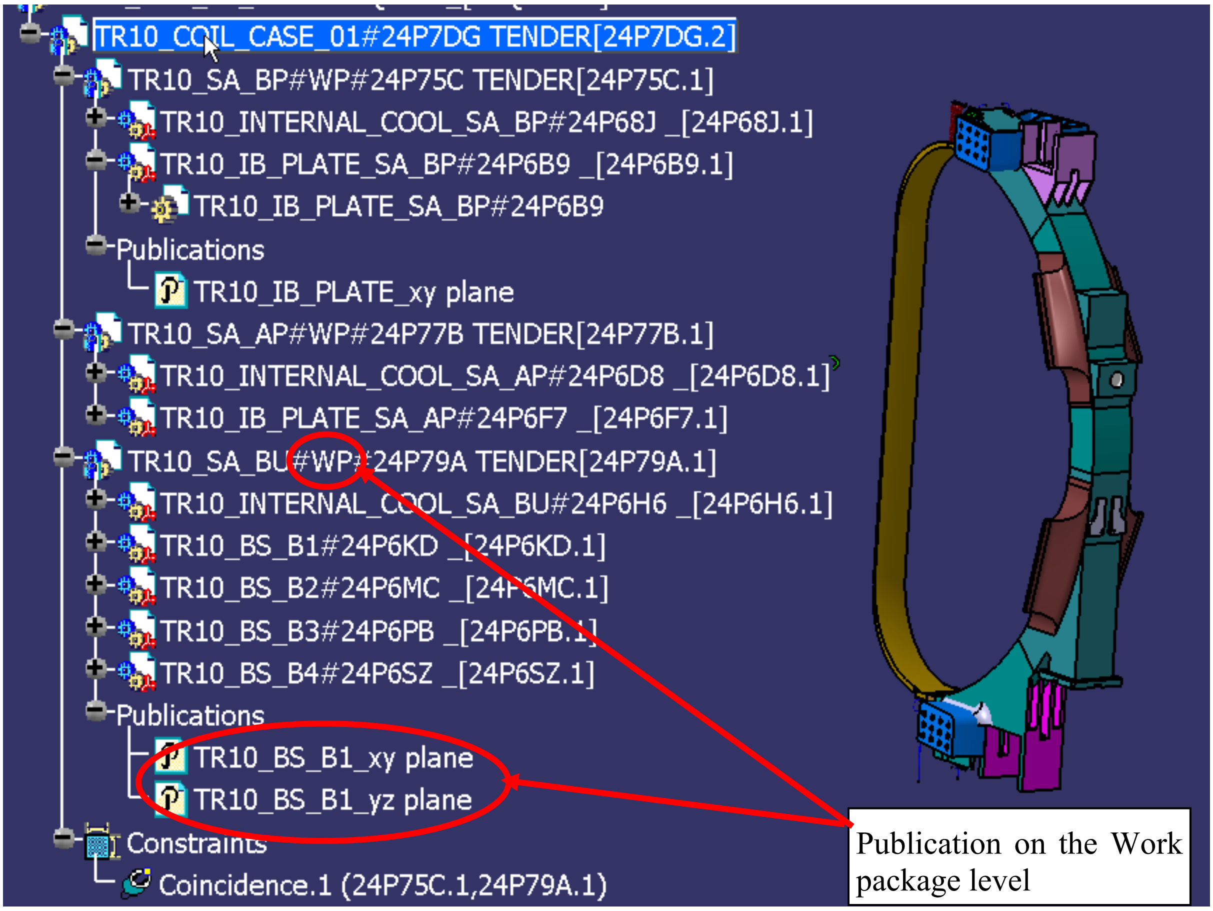

Figure 4.3-10 Publication on WP level

4.3.11 Flexible positioning for different configurations

The tool configuration mechanism for remote handling and assembly studies aims to control the position of the different articulations of a tool in a controlled way.

Bearing in mind the engineering input (actuators' strokes, degrees of freedom, etc.) we can build as many different configurations as needed to study the interfaces. In addition PBS keeps the control on them like in a normal Skeleton.

The flexible positioning method can be applied to **RCM37**:

- All systems which have not a single fixed position (RH and Assembly tooling typically)

- All systems that needs to be moved during maintenance or assembly, in order to represent different maintenance or installation stages. Examples:

> **Tool configurations**: The model WP assembly is modified ➔ Cask docked / undocked, IVT store position, extreme IVT positions within the VV, etc.
>
> **Tool Positions**: In this case the model WP assembly is not modified, only its position (context) ➔ Cask at Hot Cell, at Storage area, at Refurbishment area, etc..
>
> **Combinations of both:** This is possible since the parameters and rules which drive the position or the configuration are independent.

The flexible PSKE contains only parameters. These parameters are published and then used inside the WP to drive assembly constraints.

Details are described in PBS 23 - CAD Design Handbook for Remote Handling (3PTYNJ)

4.3.12 Definition of a welded parts

A complete welded part is the combination of several single Enovia parts included under a Work package. This work package will be filled as the complete part, and its Enovia number represents the final welded assembly.

The complete manufacturing definition of the welded part will be ensured by the drawing (geometry, dimensions, tolerances, welds, etc. …).

Because the “Weld Design” workbench available under CV5 is not mature enough, ITER decided to use this methodology which respects the ISO standard.