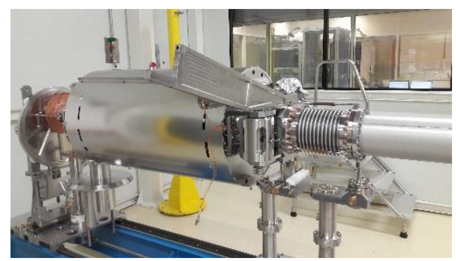
FROM RESEARCH TO INDUSTRY

CDR- MEDIUM B CRYOMODULES

CRYOMODULE ALIGNMENT PROCESS



CDR- Cryomodules medium β | Michel Fontaine

APRIL, 3RD 2017

ALIGNMENT DEFINITION

Mechanical and geometrical components of a module

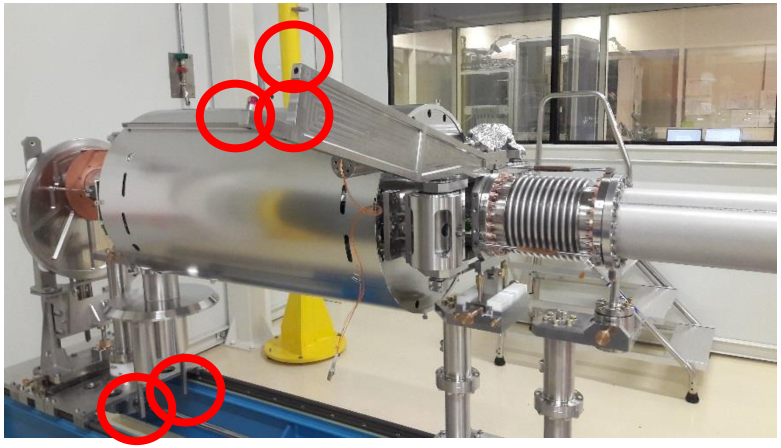
- A module is the result of assembling and aligning various element:
  - cavities, delivered with their geometrical fiducialization .
  - Cavity string : set of 4 cavities assembled and aligned as a string according to nominal positions
  - Space Frame : Frame supporting the cavity string
  - Vacuum vessel : Stainless steel vessel equipped with fiducial points, receiving the “space frame + cavity string” set as the final mechanical assembly set

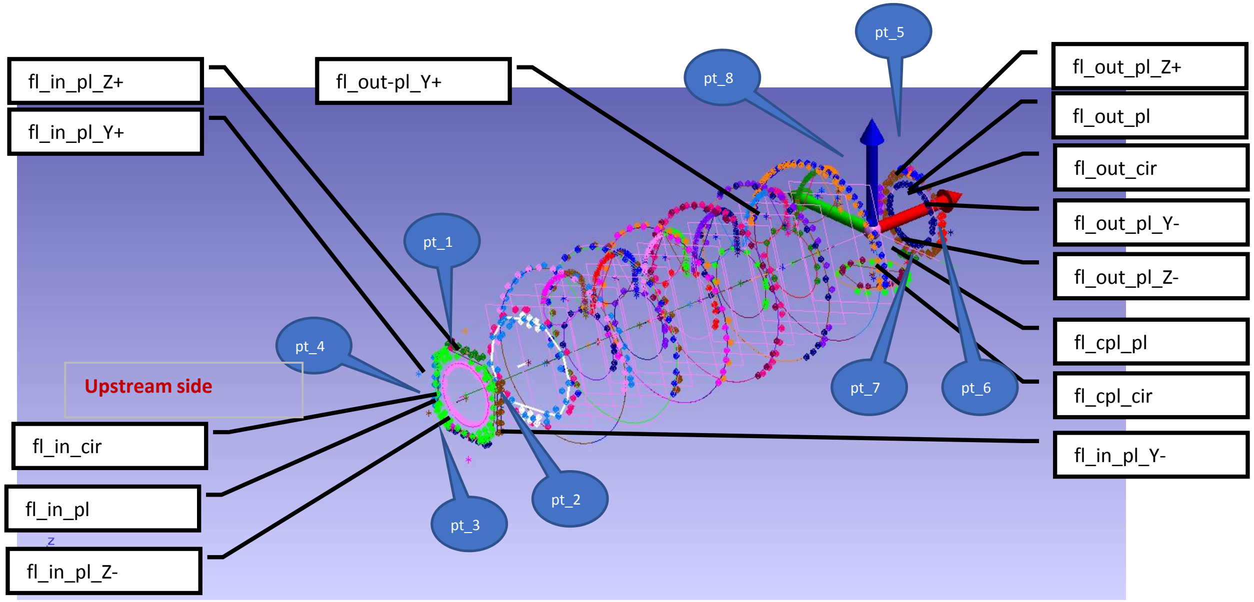
- Each element described in the previous list must be characterized by a coordinate frame based on mechanical axis (see next slide) and fiducial points :
  - Cavity :
    - 8 fiducial points to build 2 definition points (flanges centers upstream and downstream)
    - 5 offset points for cavity alignment on string
  - Cavity string
    - 4 x 13 fiducials to build the nominal set of cavities’ positions
    - 4 x 5 offset fiducials measured points to be compared to 4 x 5 nominal points for alignment in string.

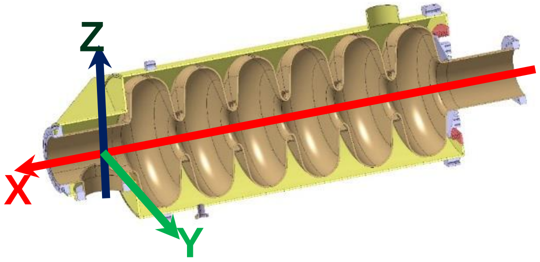
ALIGNMENT DEFINITION

Cavity

- Measured elements (provider's survey) :
  - 8 Points : Pt_1 to Pt_8
  - 11 Planes
- Measured elements (local survey) :
  - 5 offset points on tools



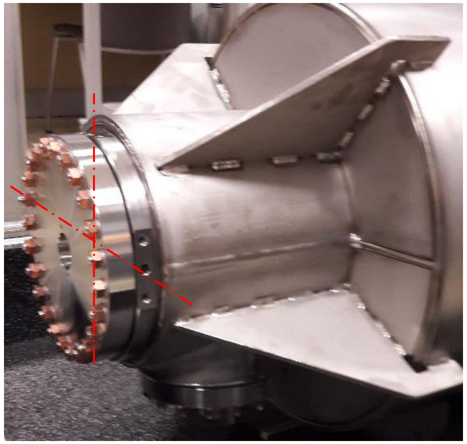


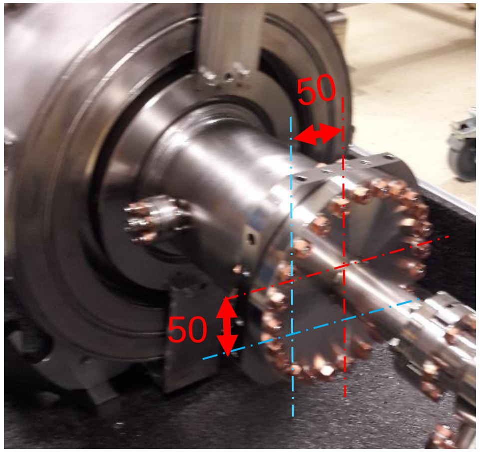


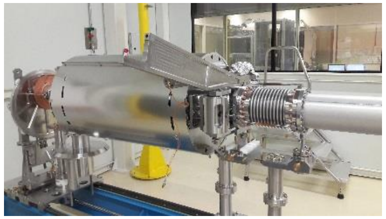
ALIGNMENT DEFINITION

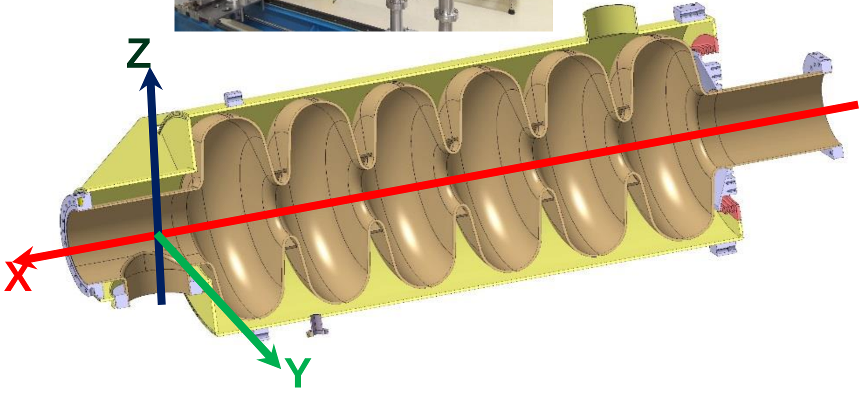
Cavity

- Built elements :
  - 4 projected lines (Pt_1-Pt_3; Pt_2-Pt_4 on upstream flange plane fl_in_pl; Pt_5-Pt_7, Pt_6-Pt_8 on downstream flange plane fl_in_pl)
  - 2 built points :
    - Fl_in_cen as projected intersection of Pt_1-Pt_3 and Pt_2-Pt_4 lines on fl_in_pl plane
    - Fl_out_cen as projected intersection of a parallel to Pt_5-Pt_7 and Pt_6-Pt_8 lines on fl_in_pl plane
  - 5 points on tools for positioning on string







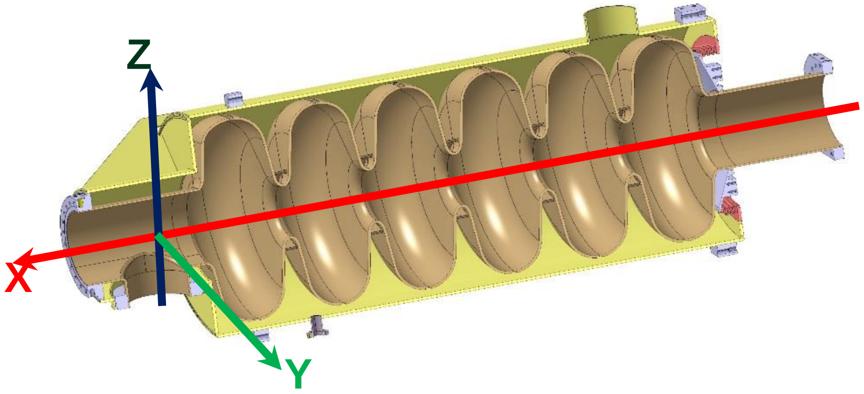


ALIGNMENT DEFINITION

Cavity string

Two definitions are necessary to build the string. A geometrical one called "*Module_name*_cavity string_nominal" and a mechanical one called "*Module_name*_cavity string". The nominal one is a set of nominal fiducial positions to reach in order to consider the cavities as aligned. The second one is a set of real fiducials positions

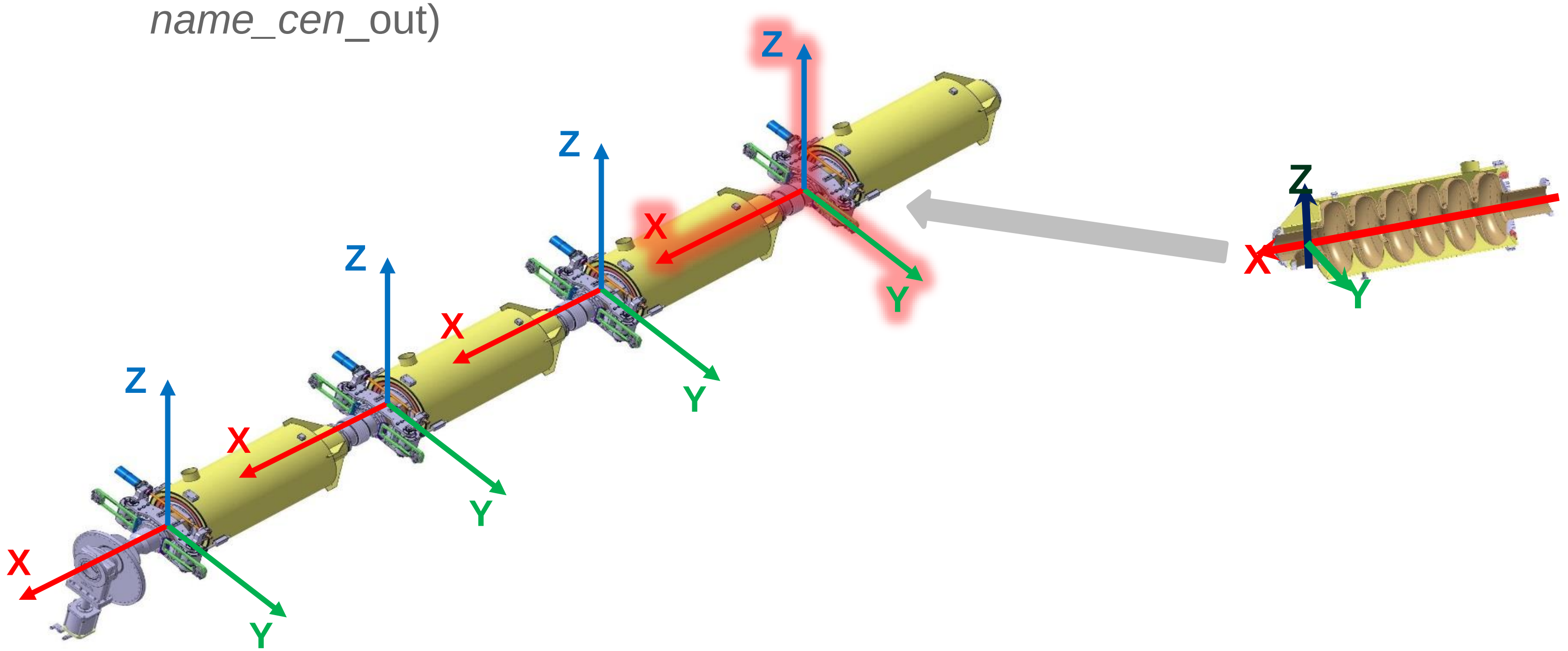
- Nominal set :
  - Frames :
    - X axis on beam axis, Z axis on gravity origin on 1st cavity frame axis position
    - 3 other secondary frames obtained by a 1500mm translation on X
  - Points : imported cavity points according to their position on string



ALIGNMENT DEFINITION

Cavity string

- Positioning set :
  Stored for each step of positioning
  - Same frames as nominal set
  - Set of measured points (laser tracker measurement)
  - Cavities' points records fitted to measured points in order to get the position on string (coordinates board of flanges centers *Cavity name_cen*_in and *Cavity name_cen*_out)

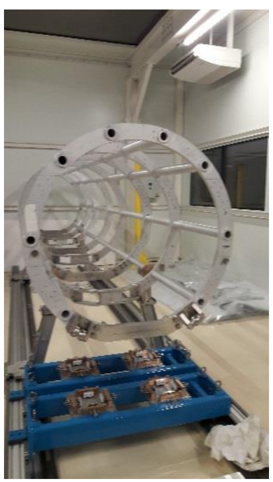


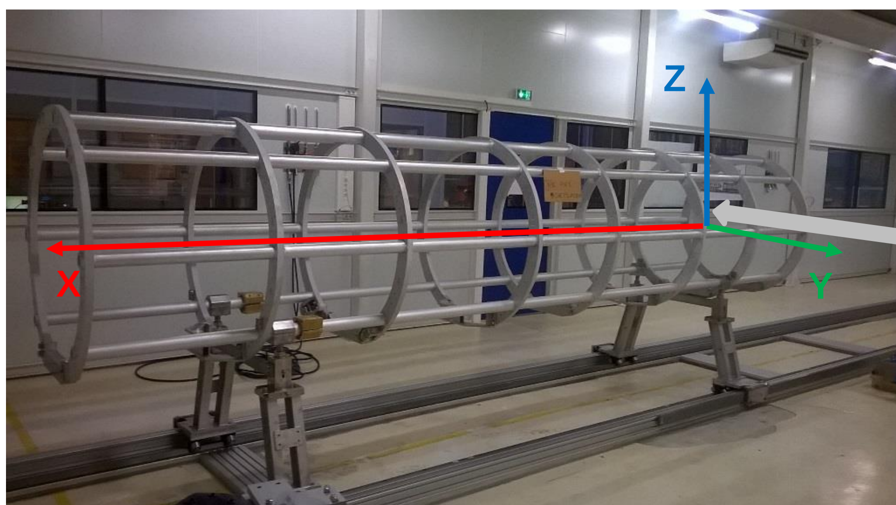
ALIGNMENT DEFINITION

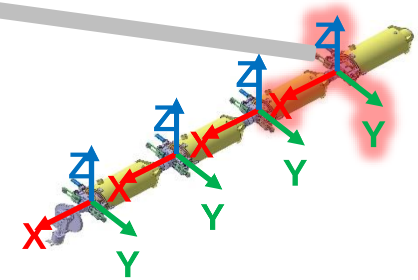
Space frame

Must be defined by a longitudinal axis and a roll angle (see image below). The axis is defined by two circle centers projected on planes and the roll angle is given by M8 threaded holes on structure. Extra glued points are used in prototype phases for positioning. All construction as follows :

- 2 planes : Spf_in_pl, Spf_out_pl
- 2 circles and centers : Spf_in_cir, Spf_out_cir, Spf_in_cen, Spf_out_cen
- 4 points for roll angle : Spf_in_roll_1, Spf_in_roll_2, Spf_out_roll_1 , Spf_out_roll_2 (in 1 and 2 are used to first define the horizontal position)
- At least 3 monitoring position glued points on extremities and mid circle circumference



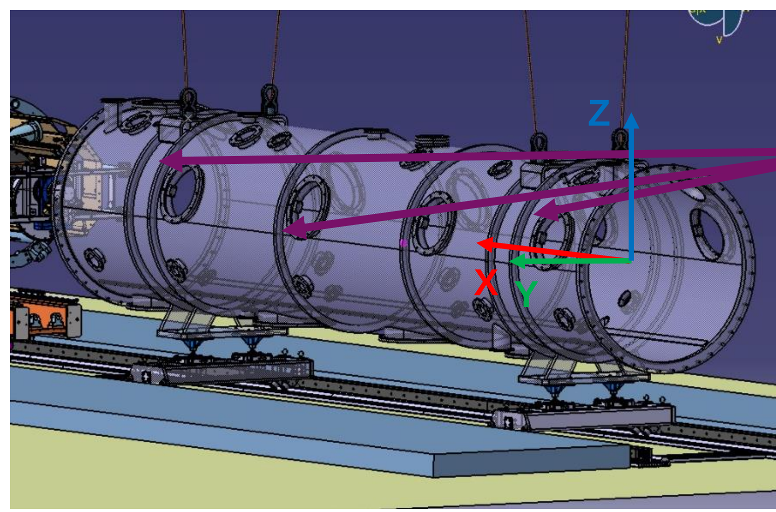




ALIGNMENT DEFINITION

Vacuum Vessel

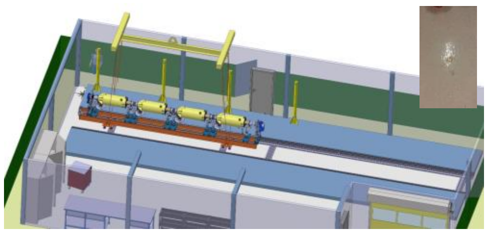
- Must be defined by a longitudinal axis and a roll angle (see image below). The axis is defined by two circle centers projected on planes flanges and the roll angle is given by 4 reference points mounted on two top planes. Extra glued points are used in prototype phases for positioning. All construction as follows :
- 2 planes : VV_fl_in_pl, VV_fl_out_pl
- 2 circles and centers : VV_in_cir, VV_out_cir, VV_in_cen, VV_out_cen
- 4 reference points for roll angle : Module name_rep1,
- At least 3 monitoring position glued points on VV on measurement lateral side



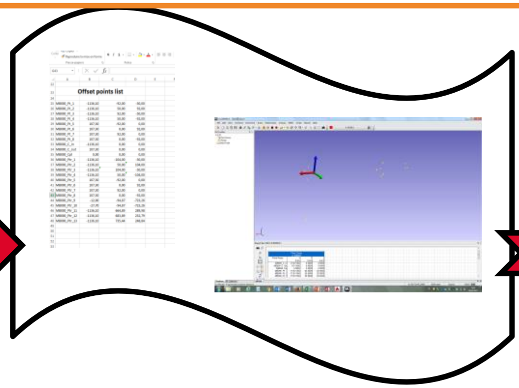
ALIGNMENT PHASES

ALIGNMENT PHASES DESCRIPTION

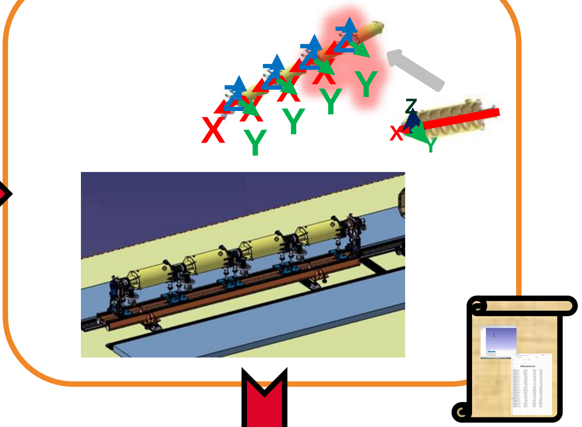
PRELIMINARY SURVEY OF WORKING AREAS

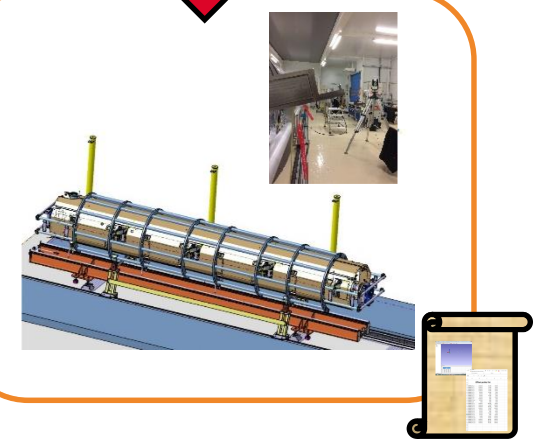


DATA IMPORT AND STORING

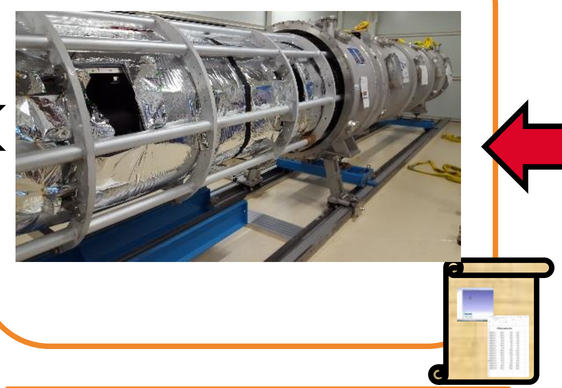


CAVITY STRING ALIGNMENT

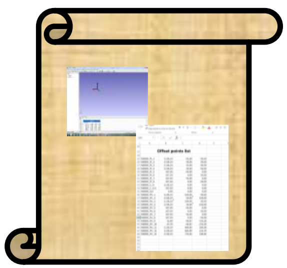




CAVITY STRING ALIGNMENT INTO SPACE FRAME



COLD MASS ALIGNMENT INTO VACUUM VESSEL



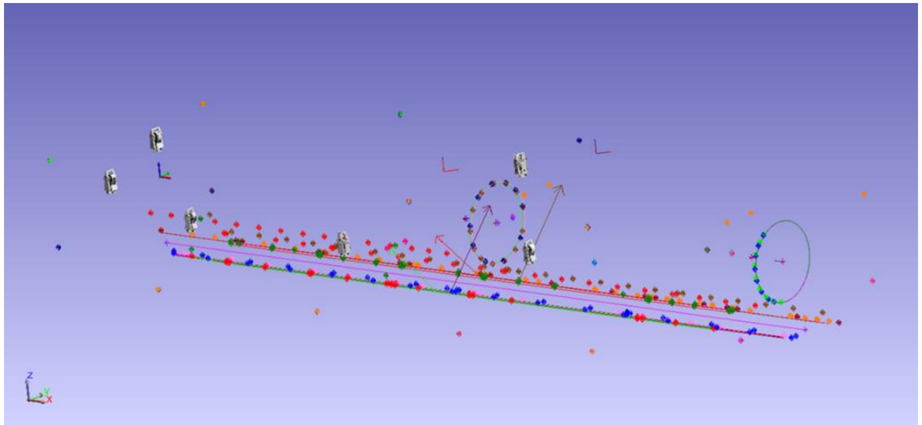
MODULE FINAL SURVEY AND DELIVERY

ALIGNMENT PHASE 0 : PRELIMINARY SURVEY OF WORKING AREAS

Local area network survey

All working areas concerned by survey operations have got a local network made of reference points sealed on floor and wall. For all zone the local frame is built from the local integration bench (see example of the prototype integration bench area). These operation are carried out according to the same planning :

- Mechanical survey of the integration bench to build the local frame : the main axis reference is the beam axis local position and Y,Z orientation is built on gravity.
- Network points coordinates measured into this local frame are stored into a database and into an *Area_name*_network_*survey_date*.xit64. The latest file version will be always set as local reference network.



ALIGNMENT PHASE I : NOMINAL DATA HANDLING

Nominal Module dataset construction

When all the module elements are know the nominal dataset is built. Some nominal points have to be measured during alignment phases (mounted tools and glued points for instance). Their coordinates will be implemented all along the integration during alignment phases.

- Nominal cavity string files:
  - Validate cavities' names and location on string
  - Create a Nominal SA file for the module *Module name*_cavity string_nominal.xit64
  - Import cavity points directly into the local position frame and set the first cavity frame as the cavity string frame
- Nominal Space frame file : create a *Module name*_Spf.xit64 SA file to store the characterization dataset. All points will be implemented when the characterization survey is carried out (order in integration process to be determined, it can be done after cavity string alignment or before in another place for serial assembly)
- Nominal Vaccum vessel file : same process as for the space frame creating a *Module_name*_Spf.xit64 SA file, same comment for the chronological order into integration process

Nominal Module dataset storing

All Nominal data can be stored as SA file or as records into a database. Both will be used.

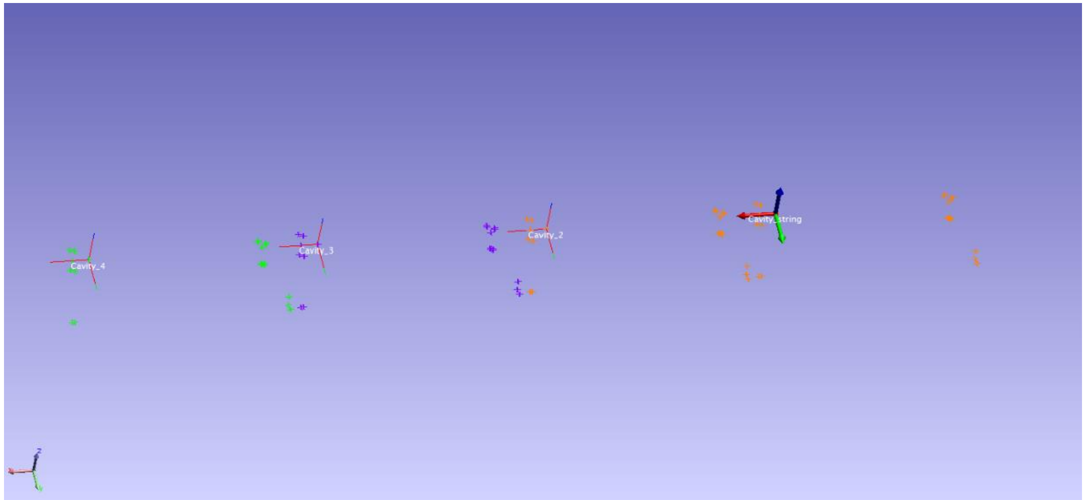
Alignment process : nominal positions

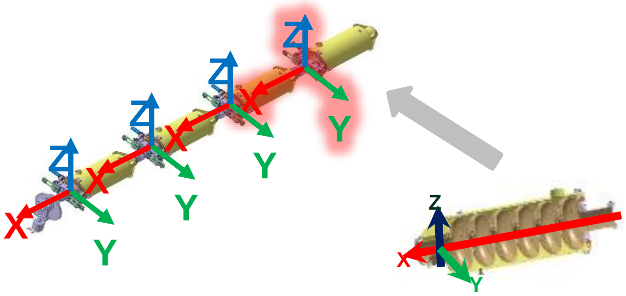
All survey operations are processed with AT401 laser tracker or similar. Measurement files are Spatial analyzer job files (*.xit64, also called SA files in these slides)

- Create and open a measurement file *Module_name*_CS_align_*date*.xit64:
  - Create new file from template file with a nominal network collection inside including network points coordinates
  - Connect and locate the laser tracker into the local network measuring all visible points into precise measurement mode. Reject points with a distance fit over than 0,1mm in X,Y,Z
  - Import nominal cavity string dataset from *Module name*_cavity string_nominal.xit64 file
- Measure all accessible points on cavities creating a measurement group for each cavity. If offset points on tools have been already measured, include them into this measurement and skip the next step.
- Mount the offset tools on cavities and measure the offset points (Ptr_*n* points) into cavities' groups into the *Module name*_cavity string_nominal.xit64. Fit the measured groups onto the nominal points groups. Copy all cavity groups including Pt_*n* and Ptr_*n* points cavity_string nominal_export collection to be imported

Alignment process : positioning cavities on girder

- Verify that the local frame on beam axis is set as active
- Import the nominal cavity string collection from the SA file and rename it CS_nominal
- Open a watch window on CS_nominal and set the cavities' points nearby 0,00 ± 0,3mm using the adjustment screws
- Measure all the offset points for each cavity into a CS_mes_*sequence number*
- Copy the nominal collection renaming it CS_pos_CS_mes_*sequence number* and fit all groups using their measured counterpart as reference
- Collect into a form the centers coordinates to validate the step

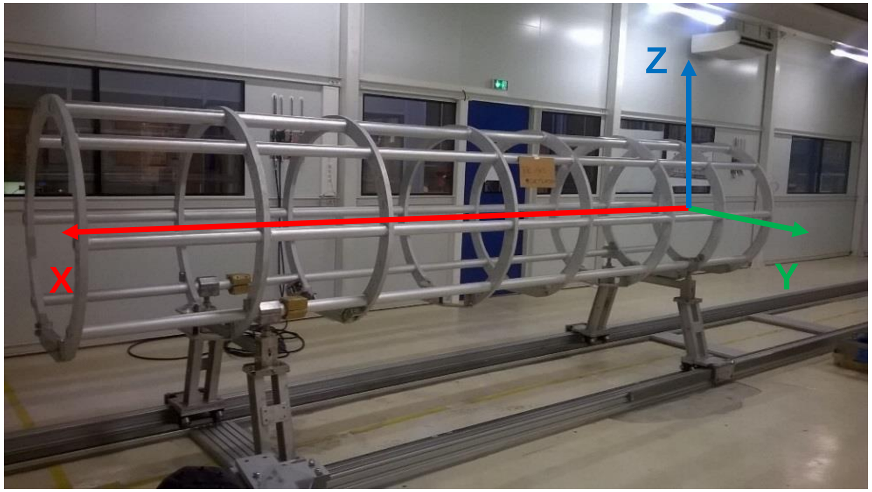




ALIGNMENT PHASE III : CAVITY STRING INSERTION INTO SPACE FRAME

Alignment process : positioning space frame on reference beam axis

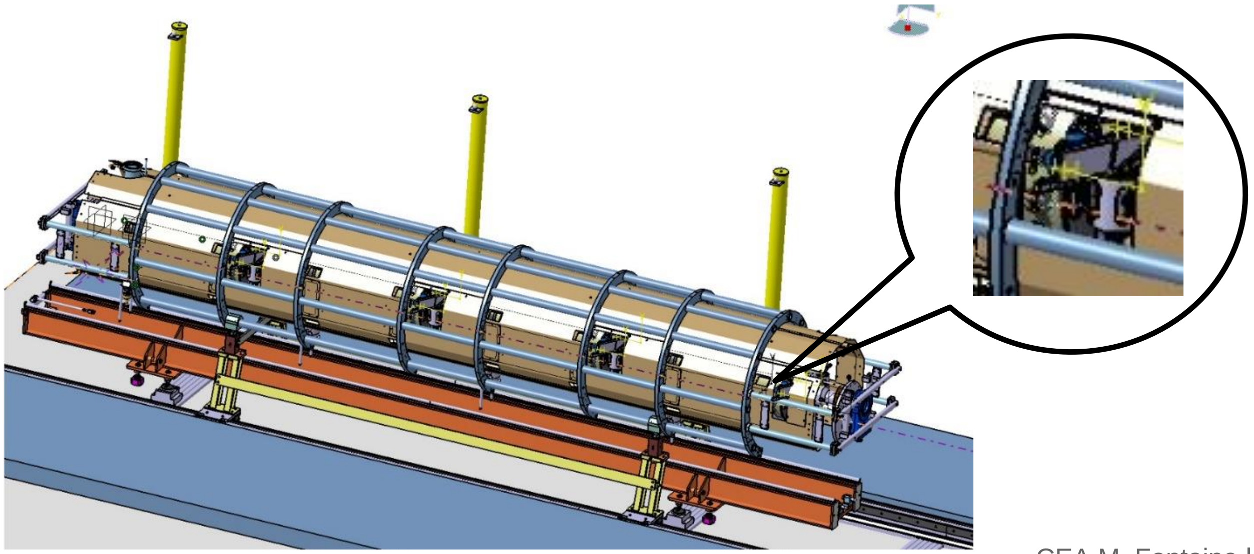
- Create a SA file named *Module_name*_Spf_align_*date*.xit64 based on Local frame
- Import the nominal cavity string position as CS_nominal collection
- Locate the instrument into the local frame, create a collection named Spf_geom and measure planes, circles, roll angle points and glued monitoring points previously described before
- Construct all geometrical elements and the space frame coordinate frame based on them as *Module_name*_Spf_frame, make it active and export the collection into a SA file named *Module_name*_Spf.xit64
- Set the local frame as active and import a new collection *Module_name*_Spf_nominal from the previous file.



ALIGNMENT PHASE III : CAVITY STRING INSERTION INTO SPACE FRAME

Alignment process : positioning the cavity string mounted into space frame on reference beam axis

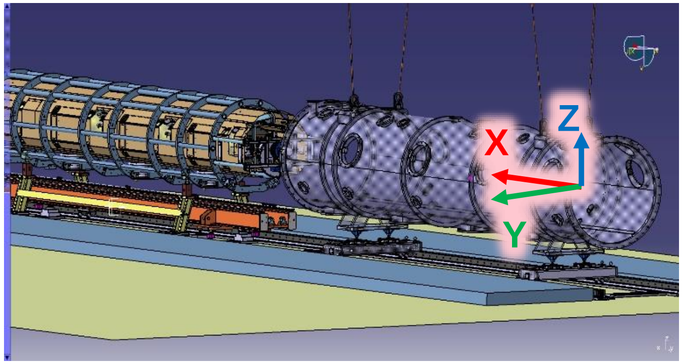
- Open a watch window on the nominal monitoring points group and adjust the space frame position in order to set the monitoring points distance to nominal within 0,3mm
- When the cavity string has been inserted and tightened into the space frame, remove its girder and re measure all cavities. Compare the result to nominal. All coordinates must remain within ±0,3mm from the nominal. Repeat the adjustment procedure until al cavities are aligned
- Measure all space frame and cavity string points and store the result in a collection named CM_*Module_name*_final



ALIGNMENT PHASE IV : COLD MASS INSERTION INTO VACUUM VESSEL

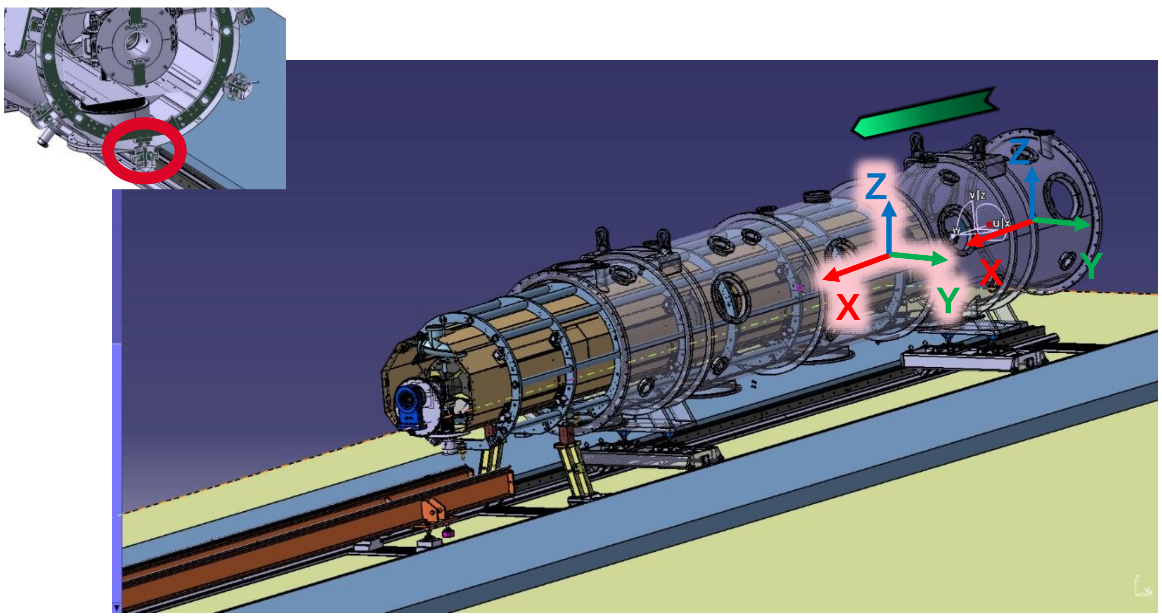
Alignment process : positioning Vacuum Vessel on reference beam axis

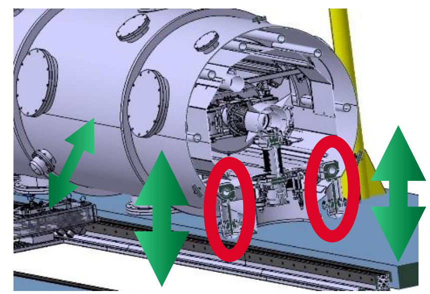
- Create a SA file named *Module_name*_VV_align_*date*.xit64 based on Local frame
- Import the CM position as CM_nominal collection
- Locate the instrument into the local frame, create a collection named VV_geom and measure planes, circles, reference points and glued monitoring points previously described
- Construct all geometrical elements and the Vacuum Vessel coordinate frame based on them as *Module_name*_VV_frame, make it active and export the collection into a SA file named *Module_name*_VV.xit64
- Set the local frame as active and import a new collection *Module_name*_VV_nominal from the previous file.
- Adjust the vacuum vessel position until reference and monitoring points coordinates remain within ±0,3mm from the nominal



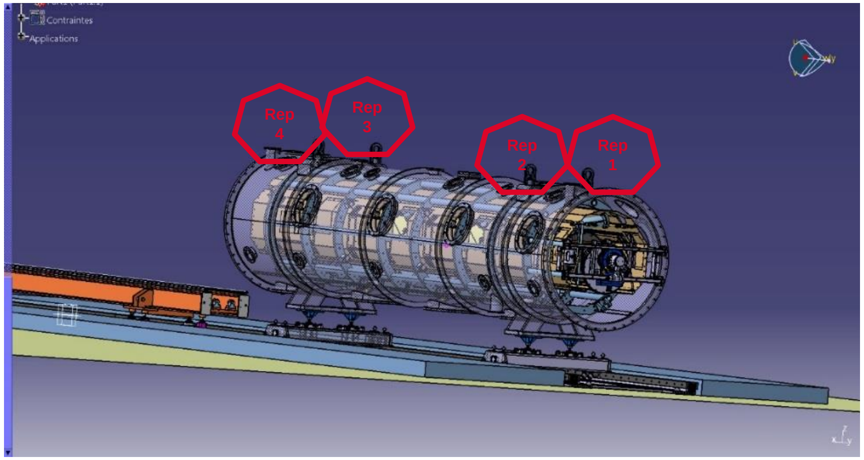
Alignment process : adjusting the cavity string position into its Vacuum Vessel

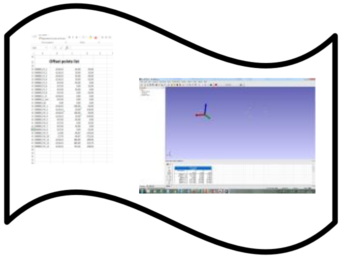
- Insert the cold mass into the vacuum vessel and mount the offset tools on the cavity string.
- Set the vacuum vessel coordinate frame as active
- Import the CM nominal collection as CM_VV_adjust_nominal
- Locate the laser tracker into the local network and measure the offset points of cavity 1 and 4





ALIGNMENT PHASE IV : COLD MASS ADJUSTMENT INTO VACUUM VESSEL AND FINAL SURVEY

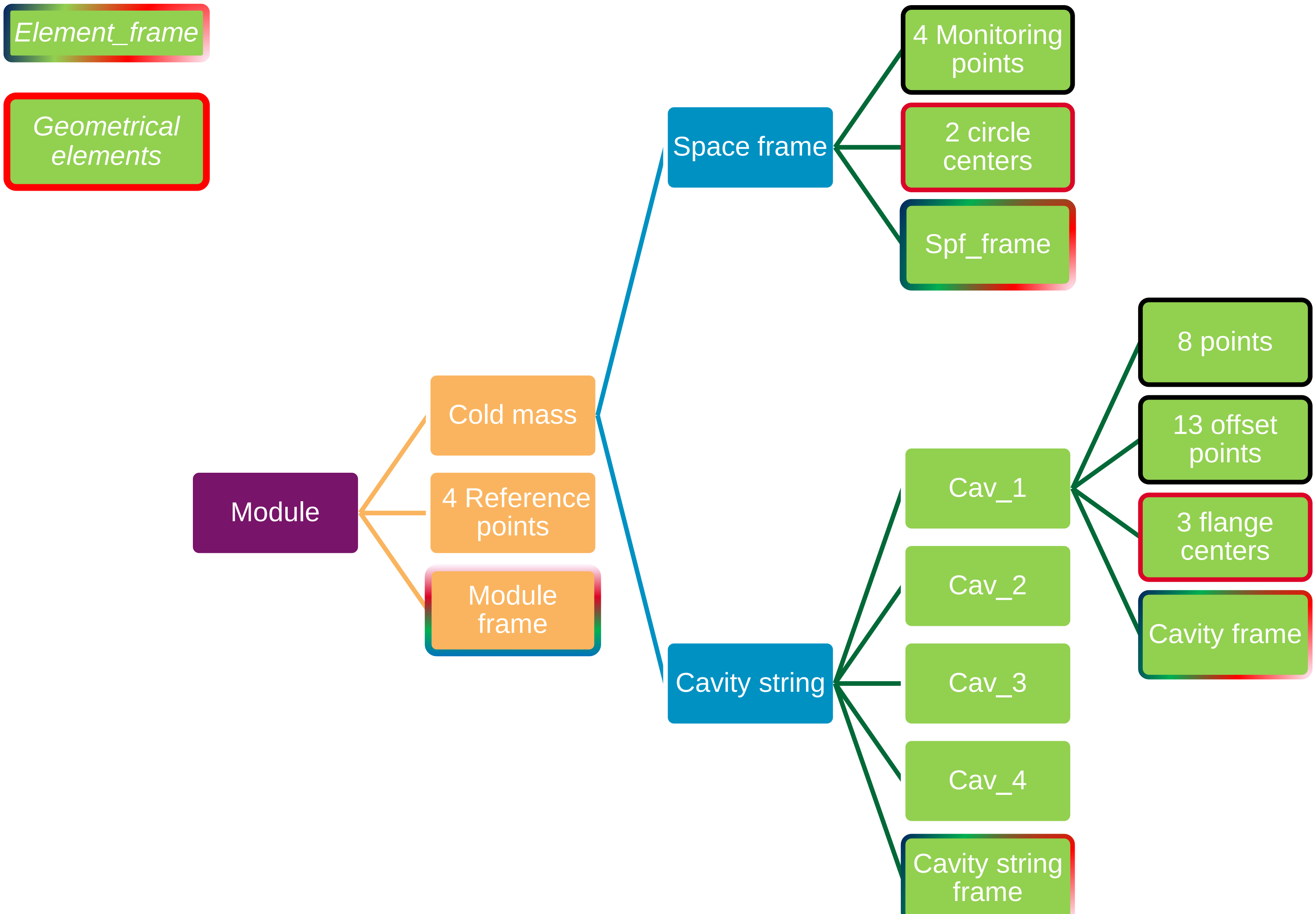




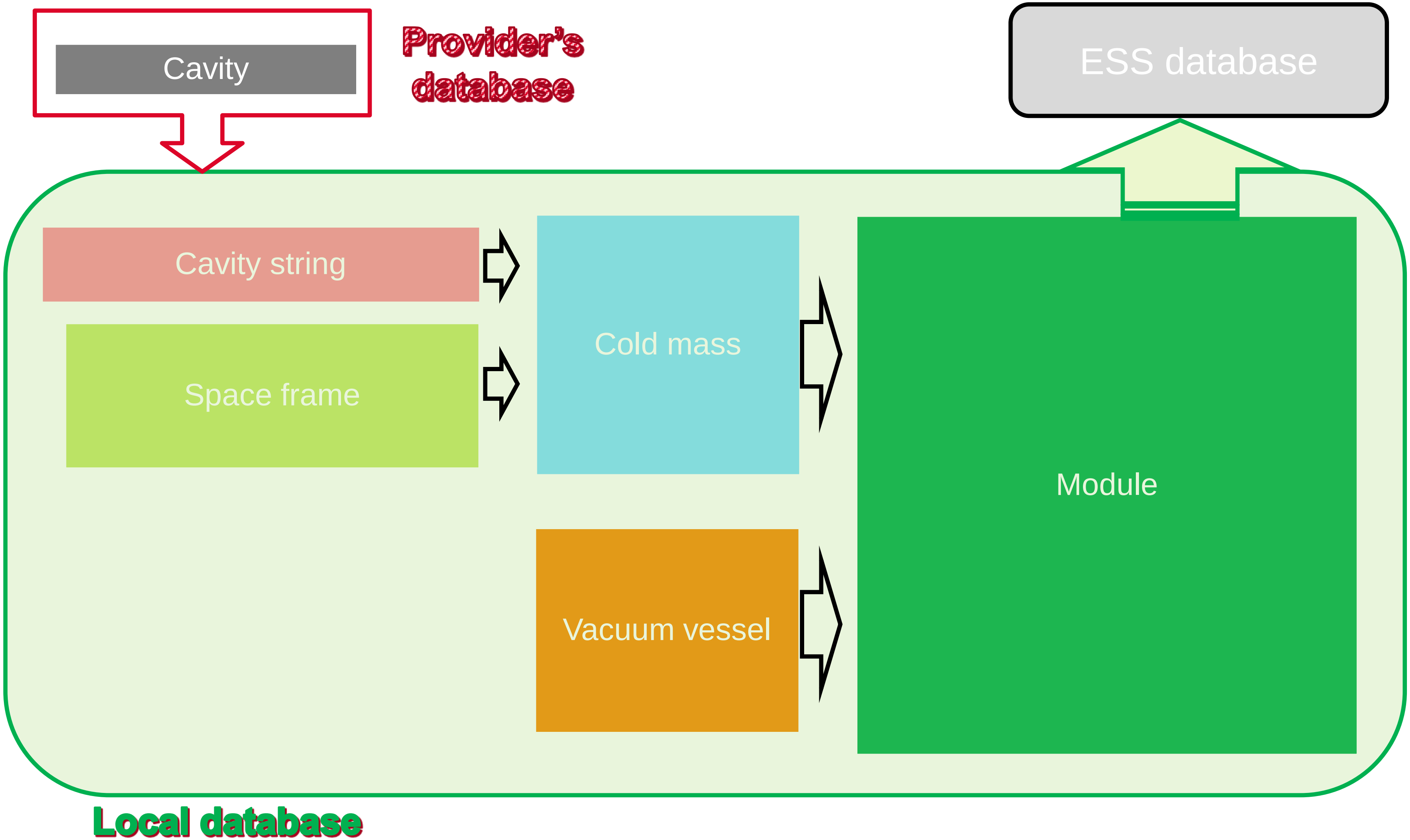
- Open a watch window on and adjust the CM position on CM_VV_adjust_nominal using the supporting jacks until the offset points coordinate remain within 0,5mm from nominal.
- When all the jacks are tightened, measure all the VV points and all the cavity string points into a CM_final_mes collection.
- Import the nominal CM collection as CM_final_pos. The CM frame must be into the collection.
- Adjust CM_final_pos by fitting on the measured CM_final_mes points. Move all the objects of CM_final_pos and set the CM_frame as active.
- Store all the final coordinates into a step report formulary and store the VV reference points into an import file and/or a database

ALIGNMENT DATA HANDLING

DATA STRUCTURE



DATA EXCHANGES BETWEEN DATABASES
(IMPORT – EXPORT FORMATS TO BE DETERMINED)



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