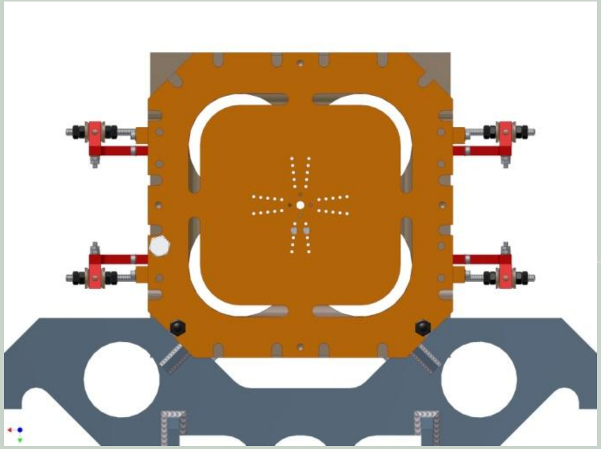
RFQ Assembly Plan #3

August 2011

by P. Savage



Front End Test Stand (FETS) RFQ assembly sequence

We need a step by step plan to follow to enable us to successfully assemble the FETS RFQ so that:

1. The vanes are aligned to the best of our ability.
2. We achieve a vacuum seal.

The assembly sequence can be broadly split into 4 parts:

- Part 1: Vane to vane alignment without O ring in place.
- Part 2: Back to manufacturers for final machining.
- Part 3: Section assembly with O ring in place.
- Part 4: Alignment of completed assembly w.r.t. the FETS.

Note that I have not yet considered where the bead-pull tests come in this sequence.

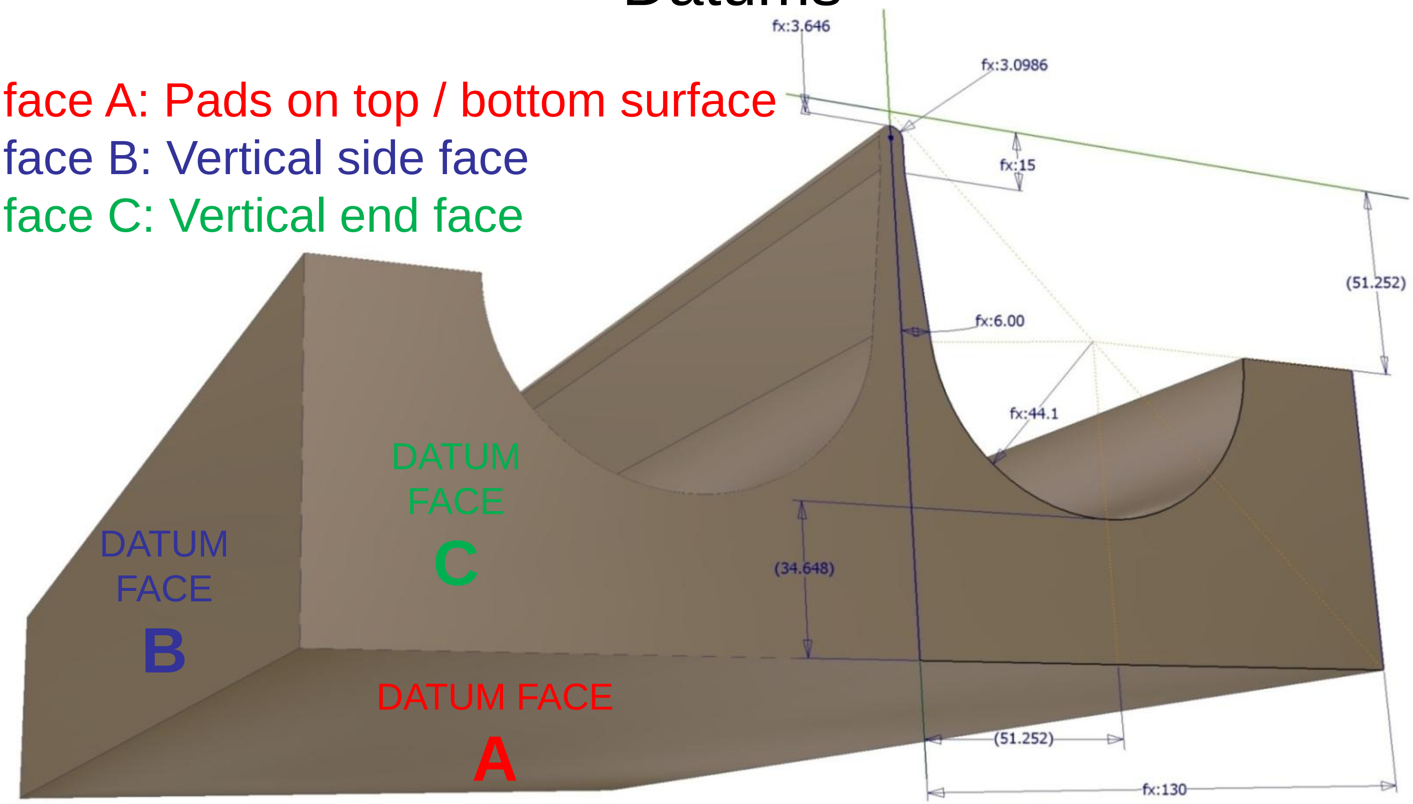
Part 1

Vane to vane alignment without O ring in place.

Datums

NEW

Datum face A: Pads on top / bottom surface
Datum face B: Vertical side face
Datum face C: Vertical end face

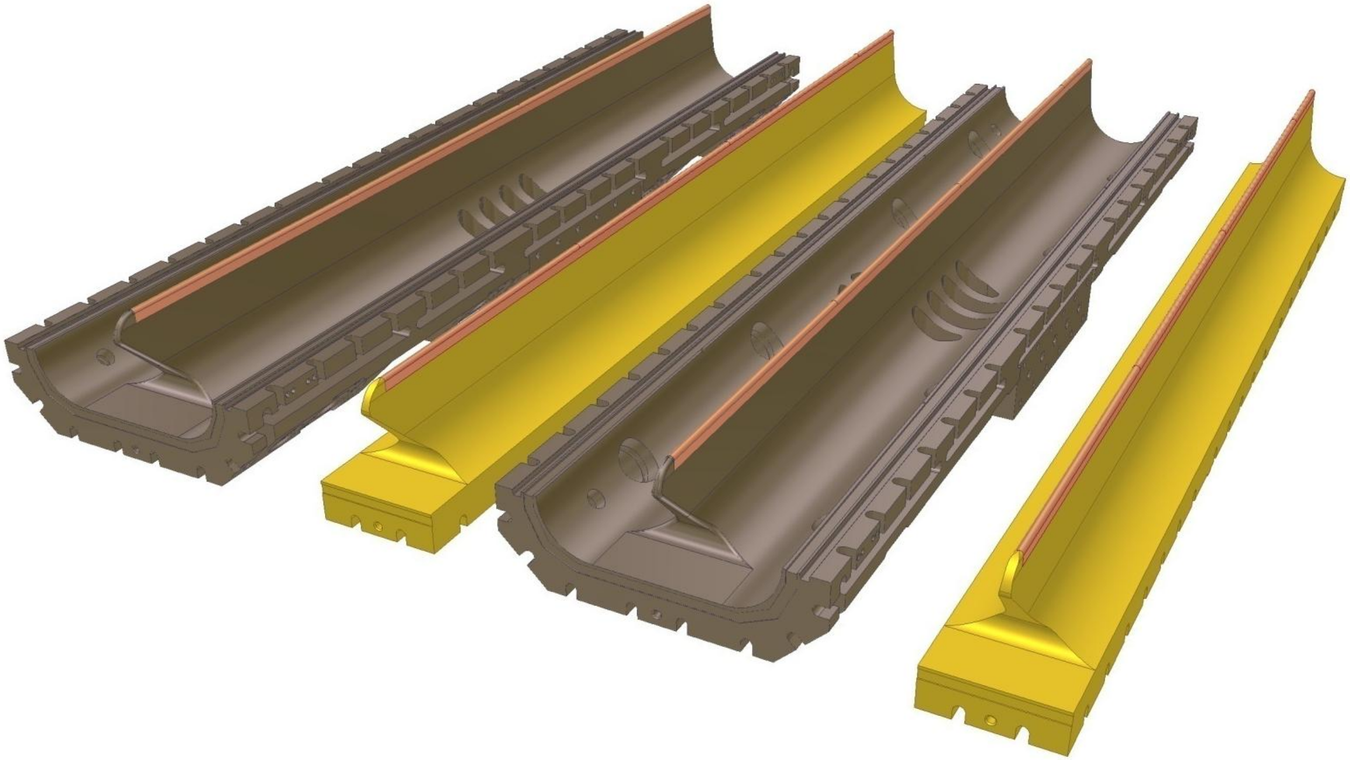


The datums used for the Engineering drawings will be the datums used:

- during manufacture of individual parts.
- during assembly of each one metre section.
- for section to section installation on the FETS.

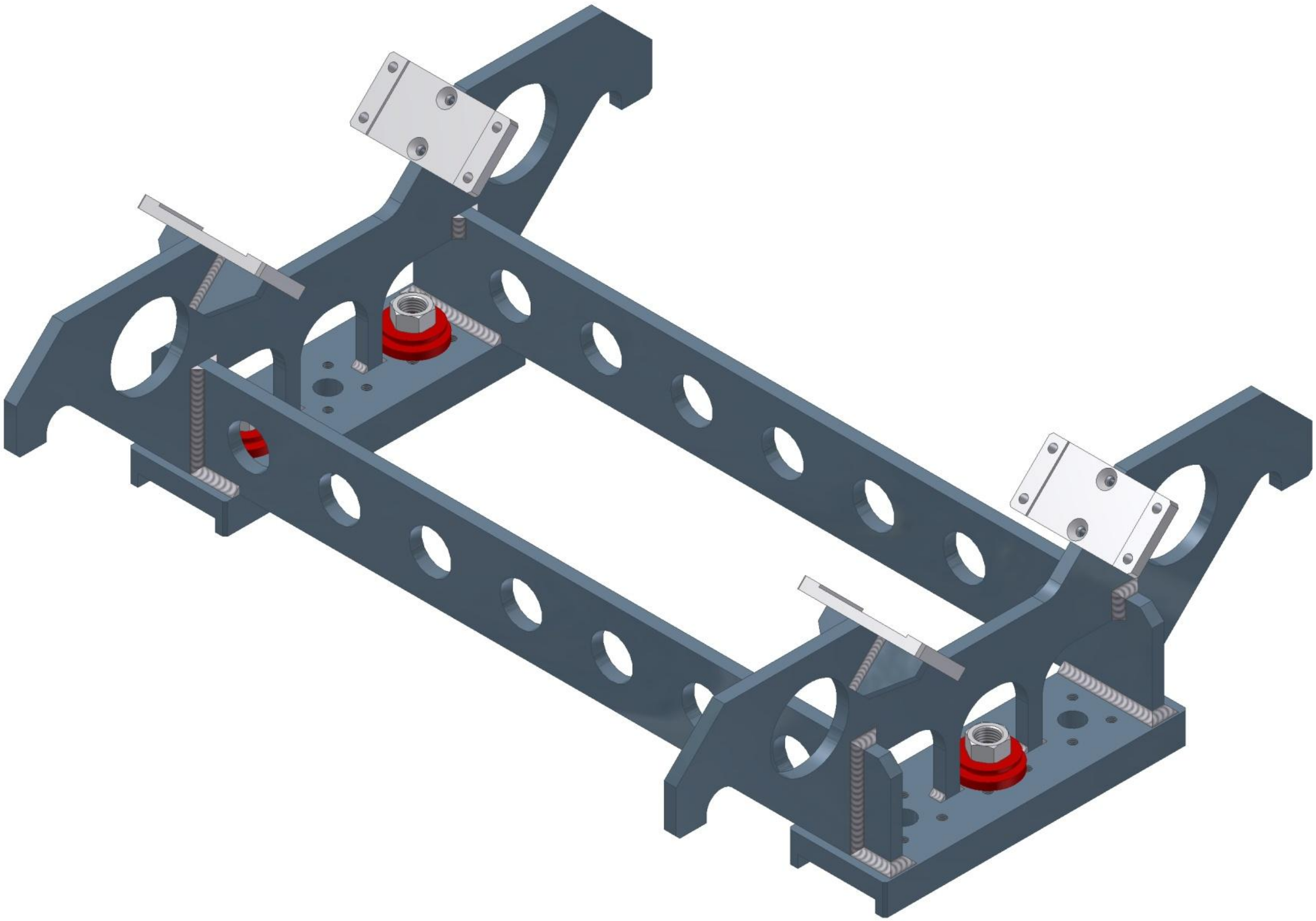
NEW

Assume 2 major and 2 minor vanes are manufactured



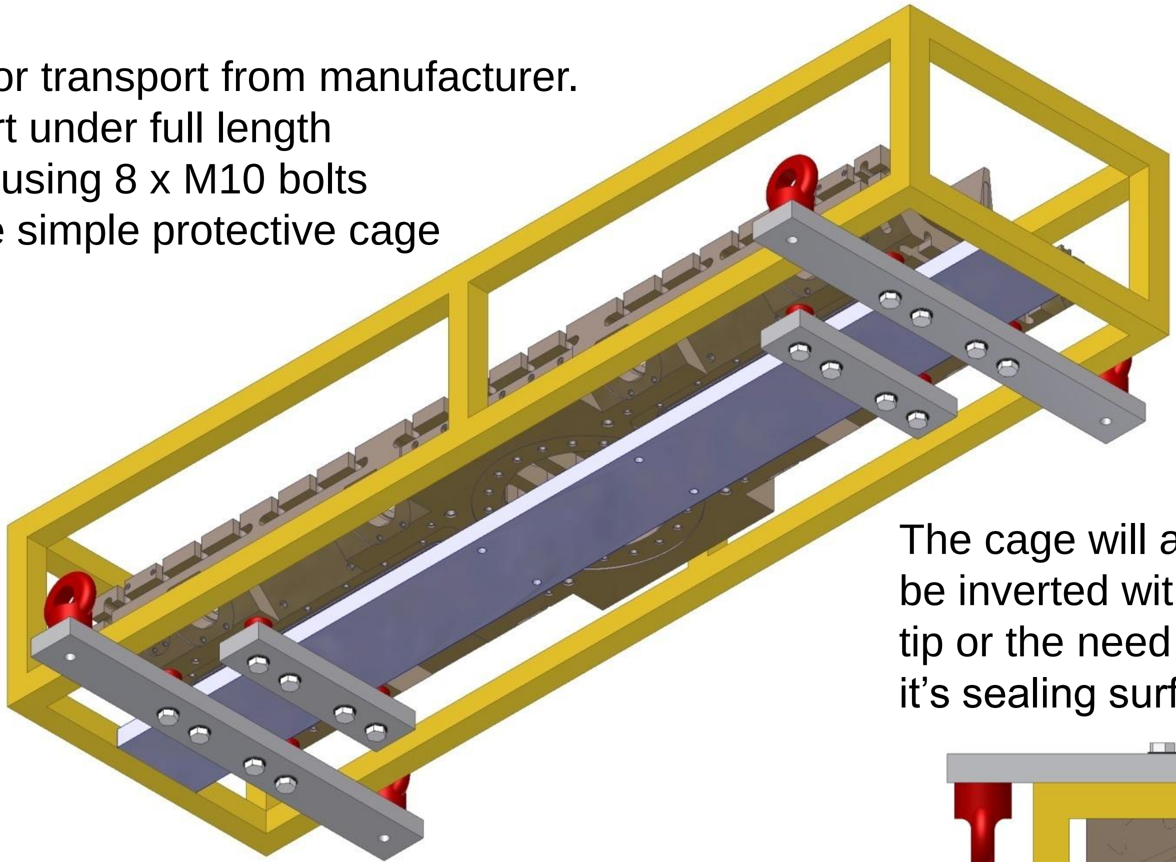
- 2 major vanes and to minor vanes for RFQ section 1 arrive at RAL.
- Moved into R8
- They have been manufactured to tolerance.
- They are complete except are all 2mm over-length, 1mm at each end.

RFQ section will be assembled into the cradle

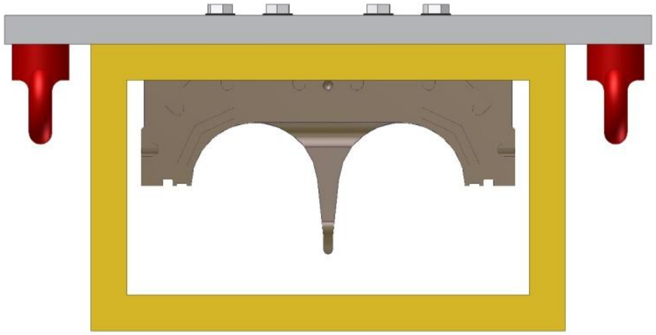


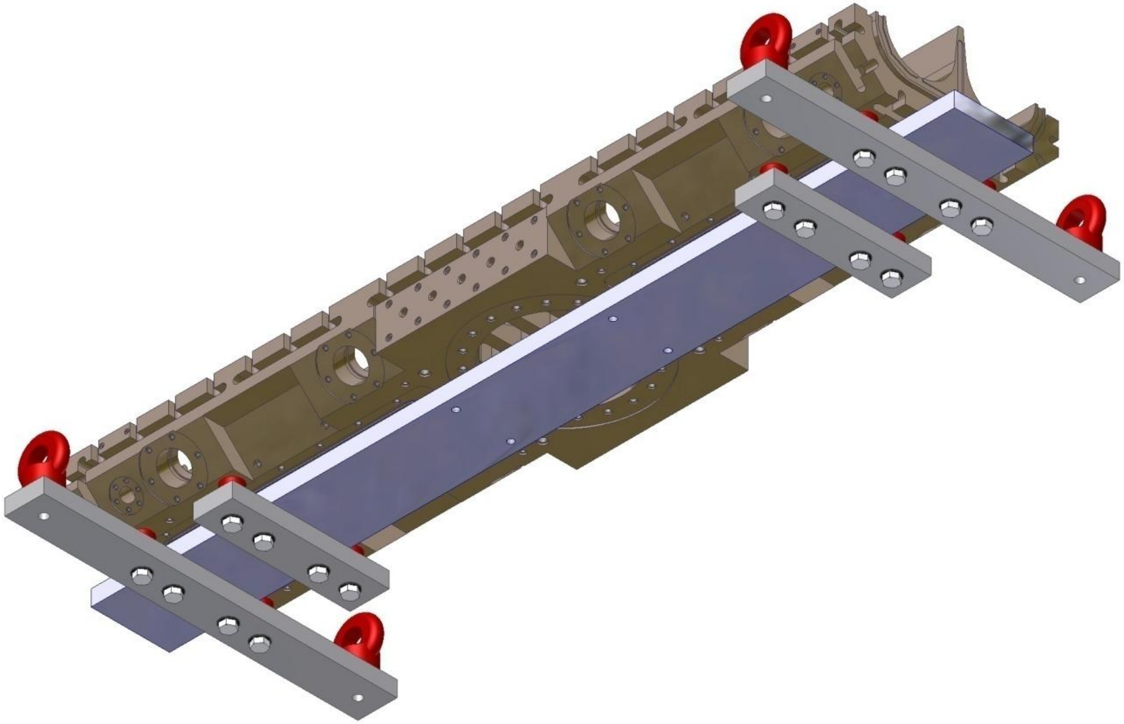
Concept design for Major Vane lifting beam.

- Used for transport from manufacturer.
- Support under full length
- Attach using 8 x M10 bolts
- Include simple protective cage

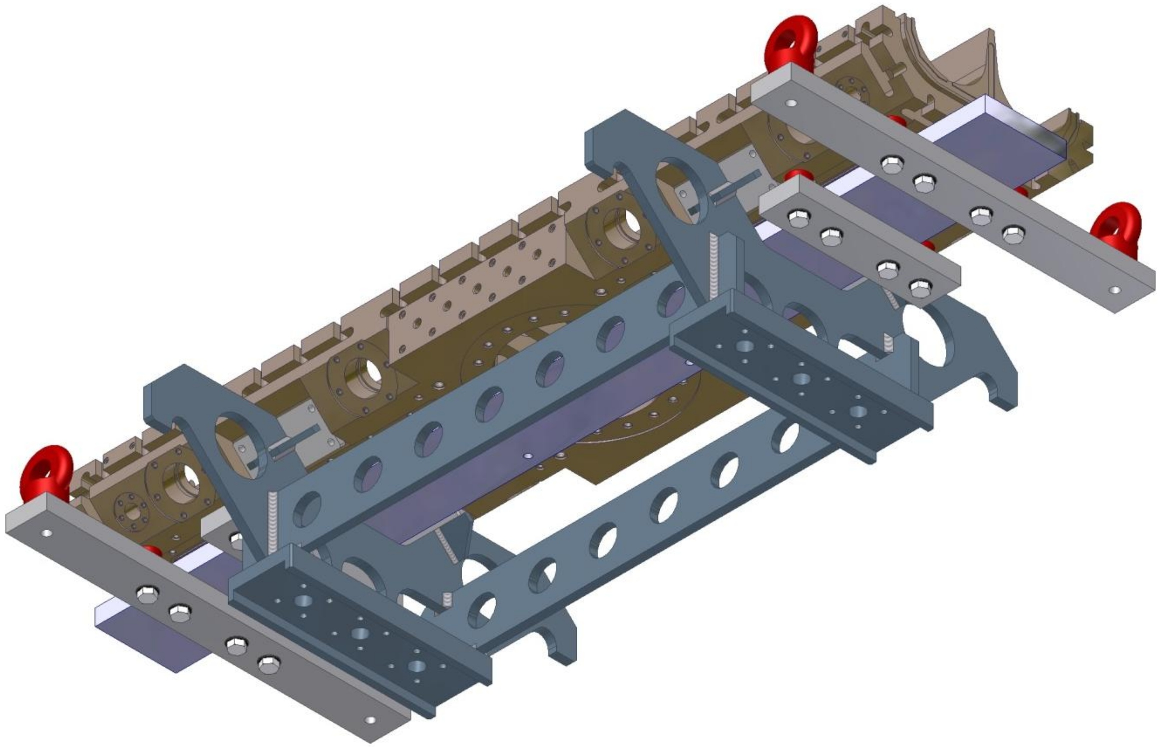


The cage will also enable major vane to be inverted without damage to the vane tip or the need to rest the major vane on it's sealing surfaces.

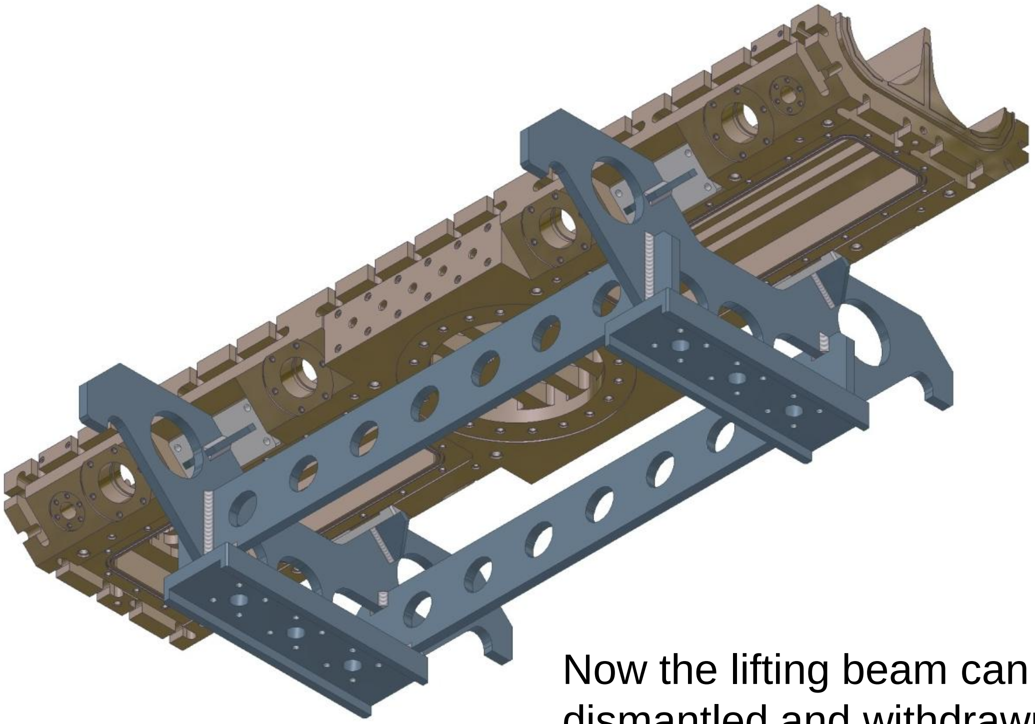


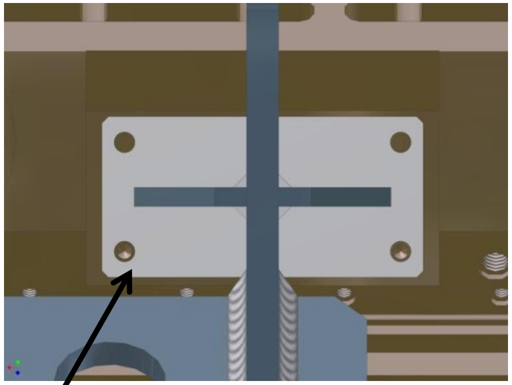


With the protective cage removed the major vane can be lowered into the cradle.



Lifting beam unbolted and removed

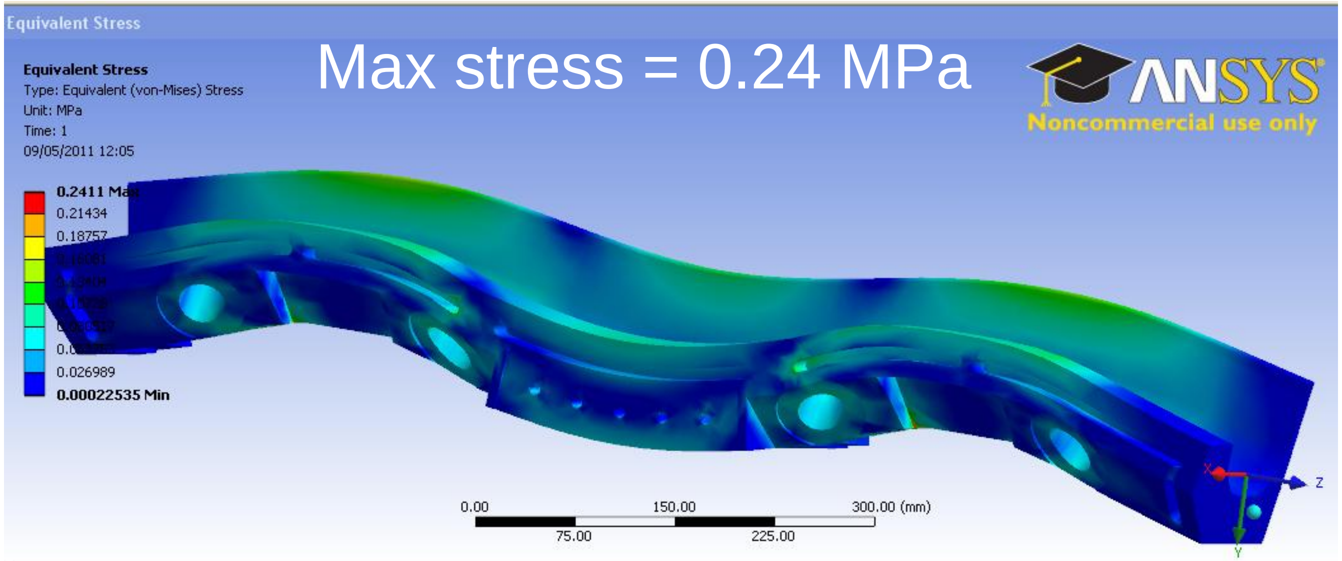


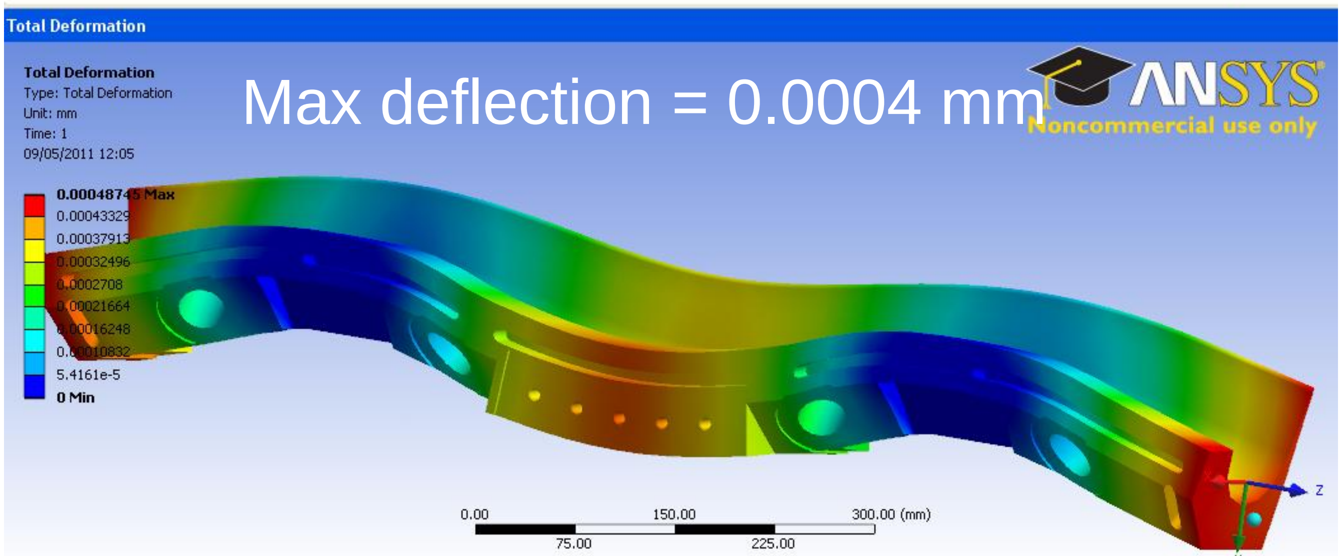


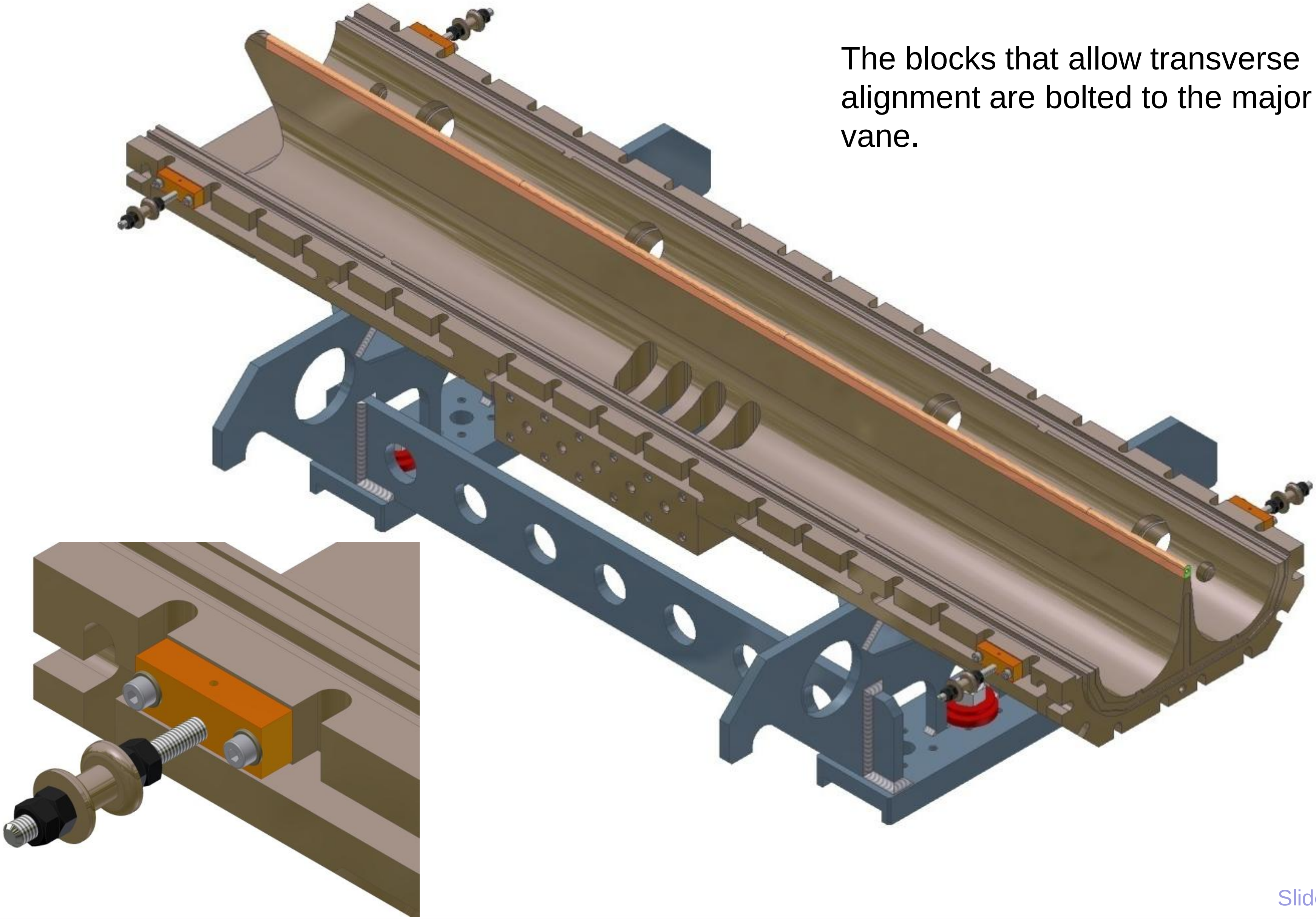
Now the lifting beam can be dismantled and withdrawn from between the vane and the cradle.

The vane can now be bolted to the cradle.

Will the major vane sag when resting in it's cradle?

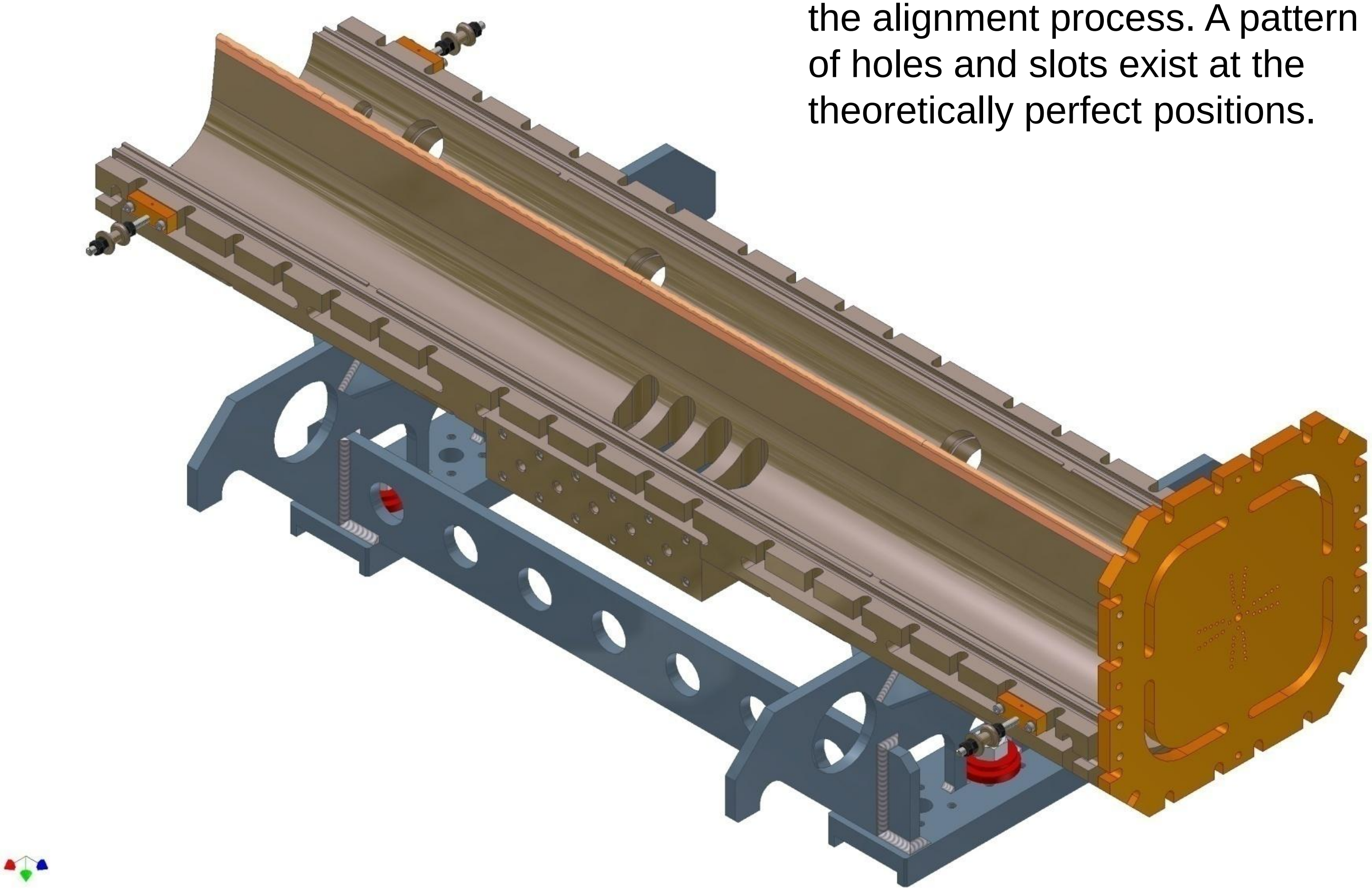






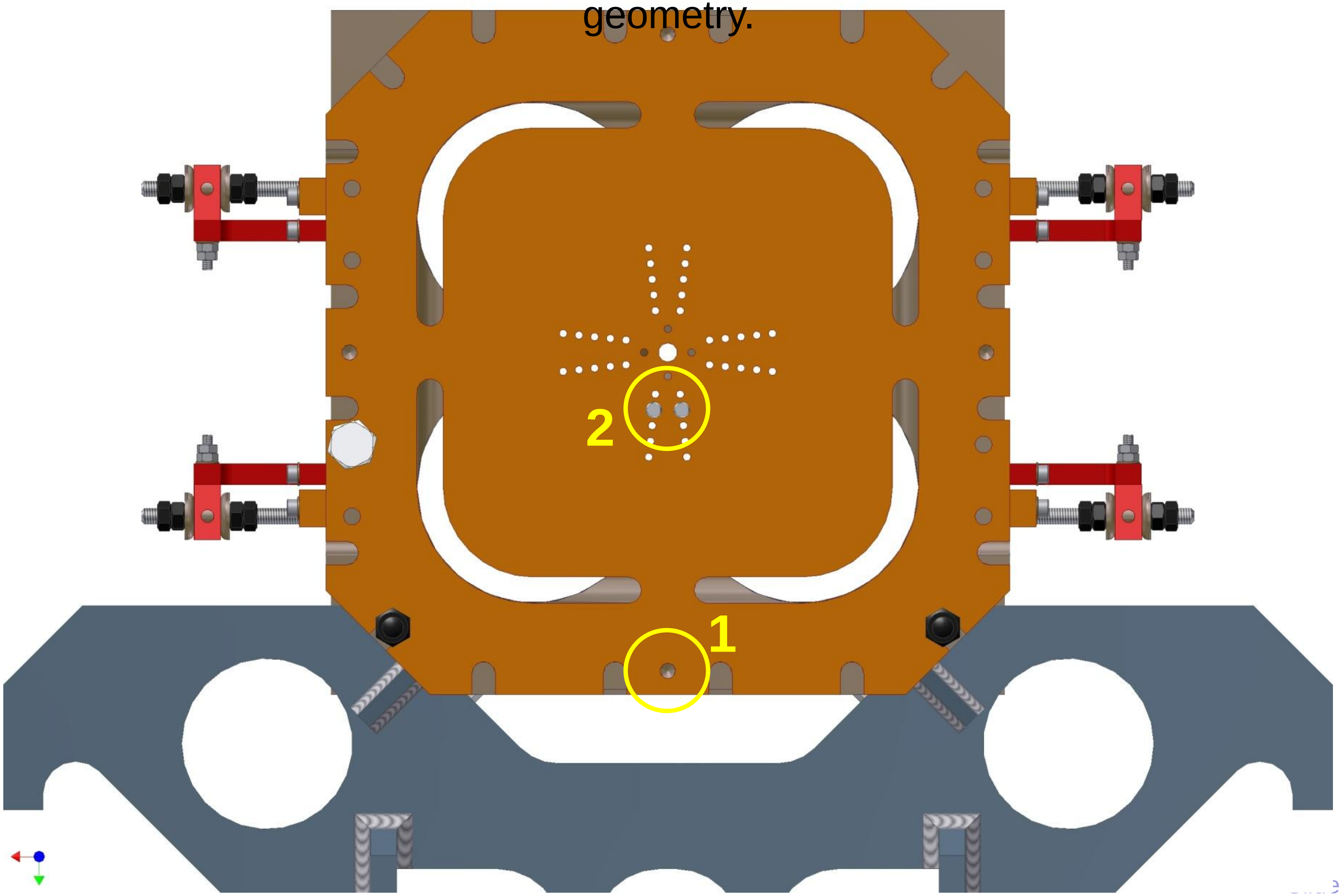
The blocks that allow transverse alignment are bolted to the major vane.

Add alignment end flanges

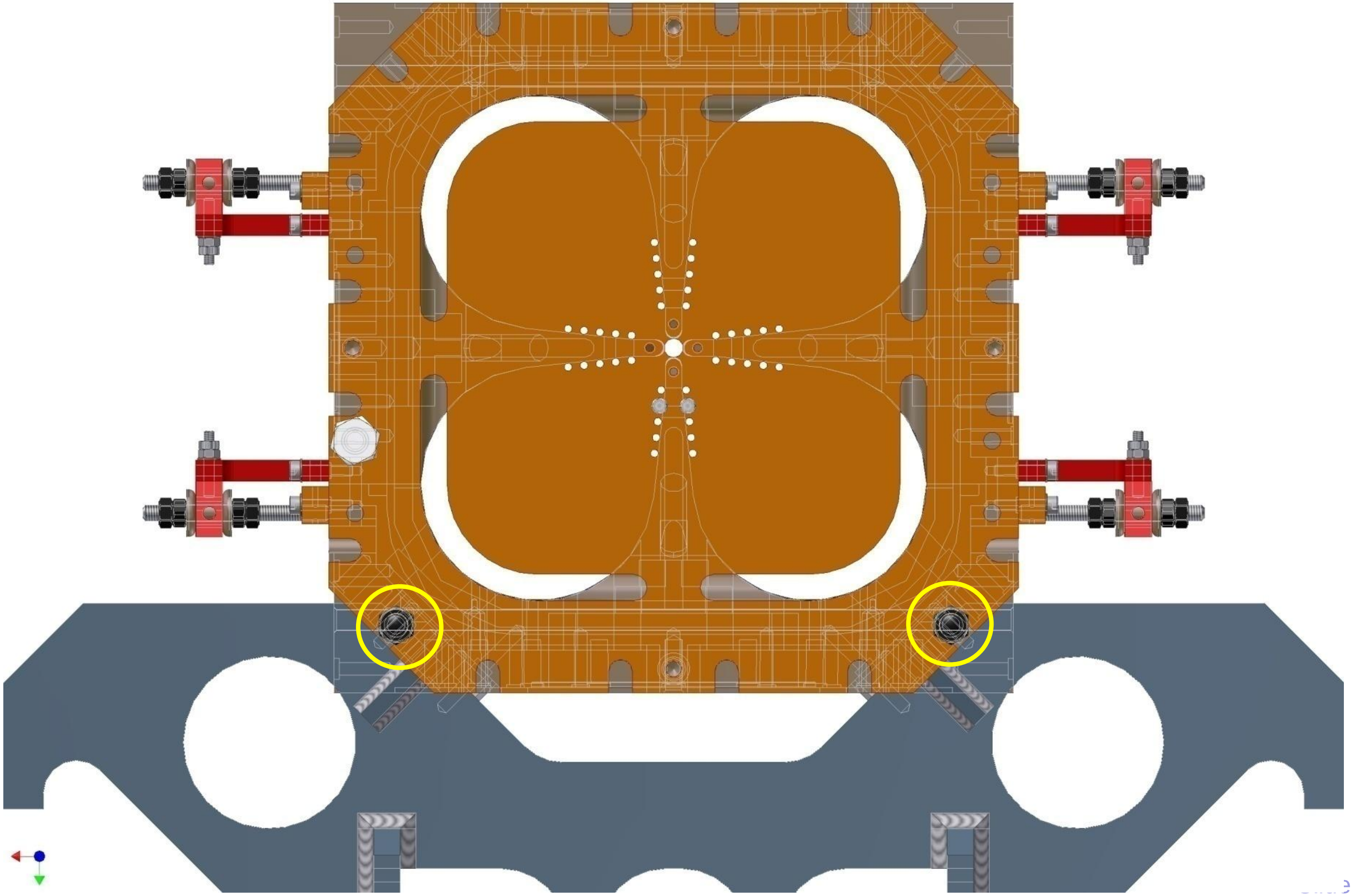


End flanges made specially for the alignment process. A pattern of holes and slots exist at the theoretically perfect positions.

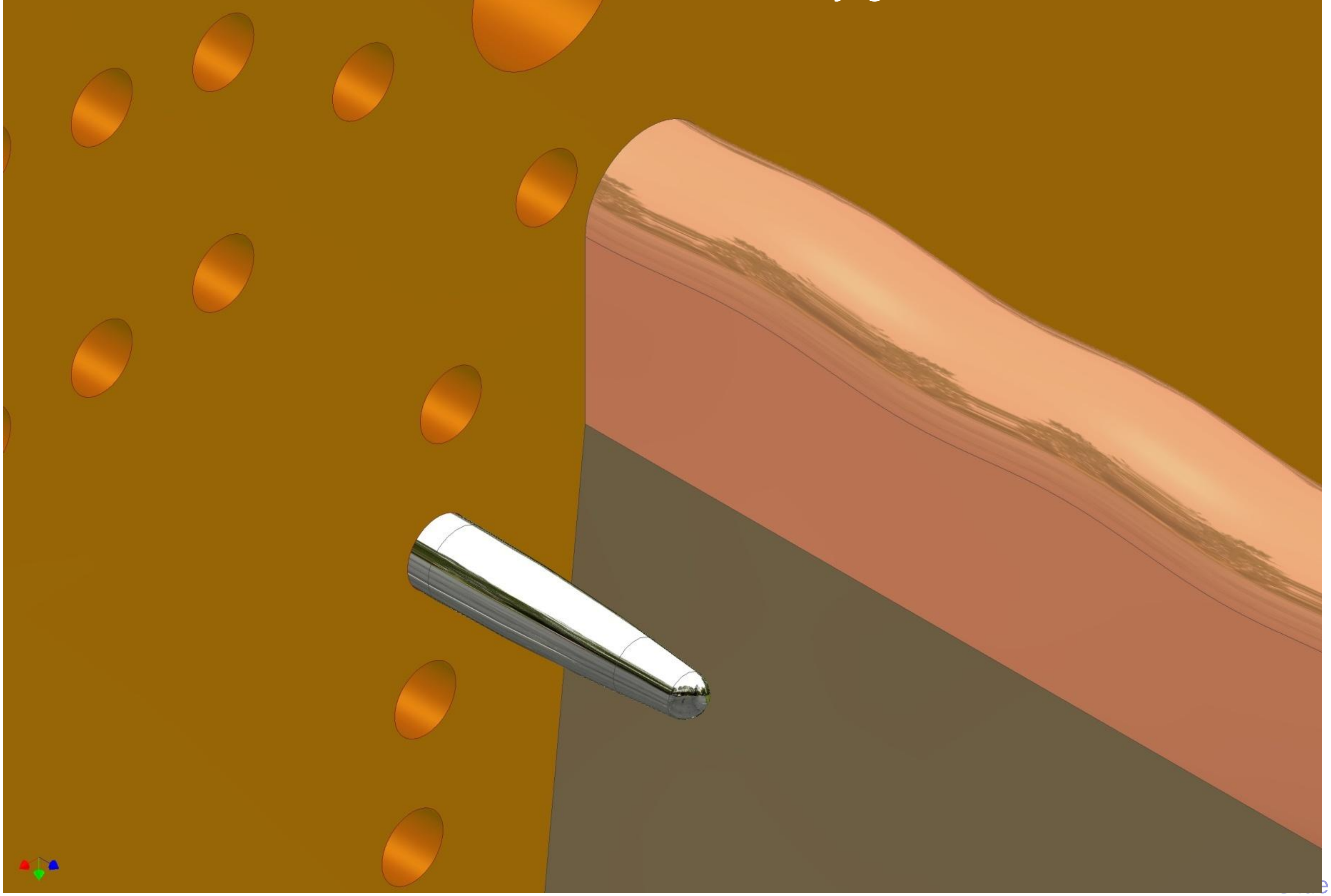
End flange is first doweled to the major vane (1) before being aligned to the vane sides using tapered dowels (2) - close to the beam transport region, in an area of unchanging geometry.



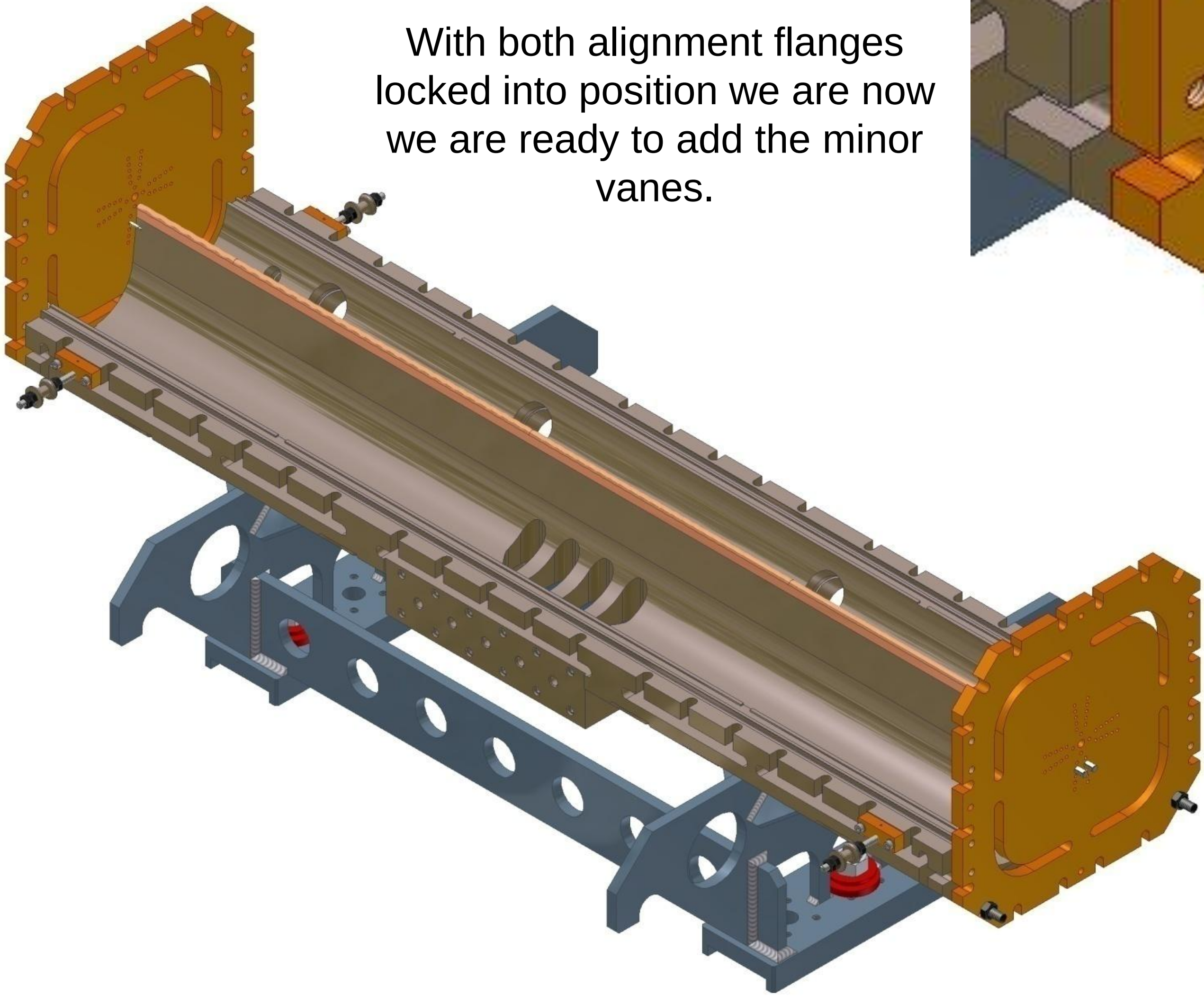
Once the end flange is constrained it can be bolted to the major vane – checking all the time that the tapered dowels are not being forced into the vane sides.

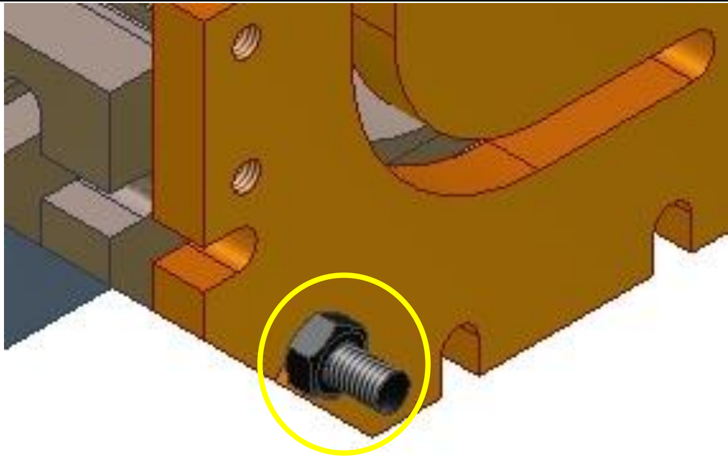


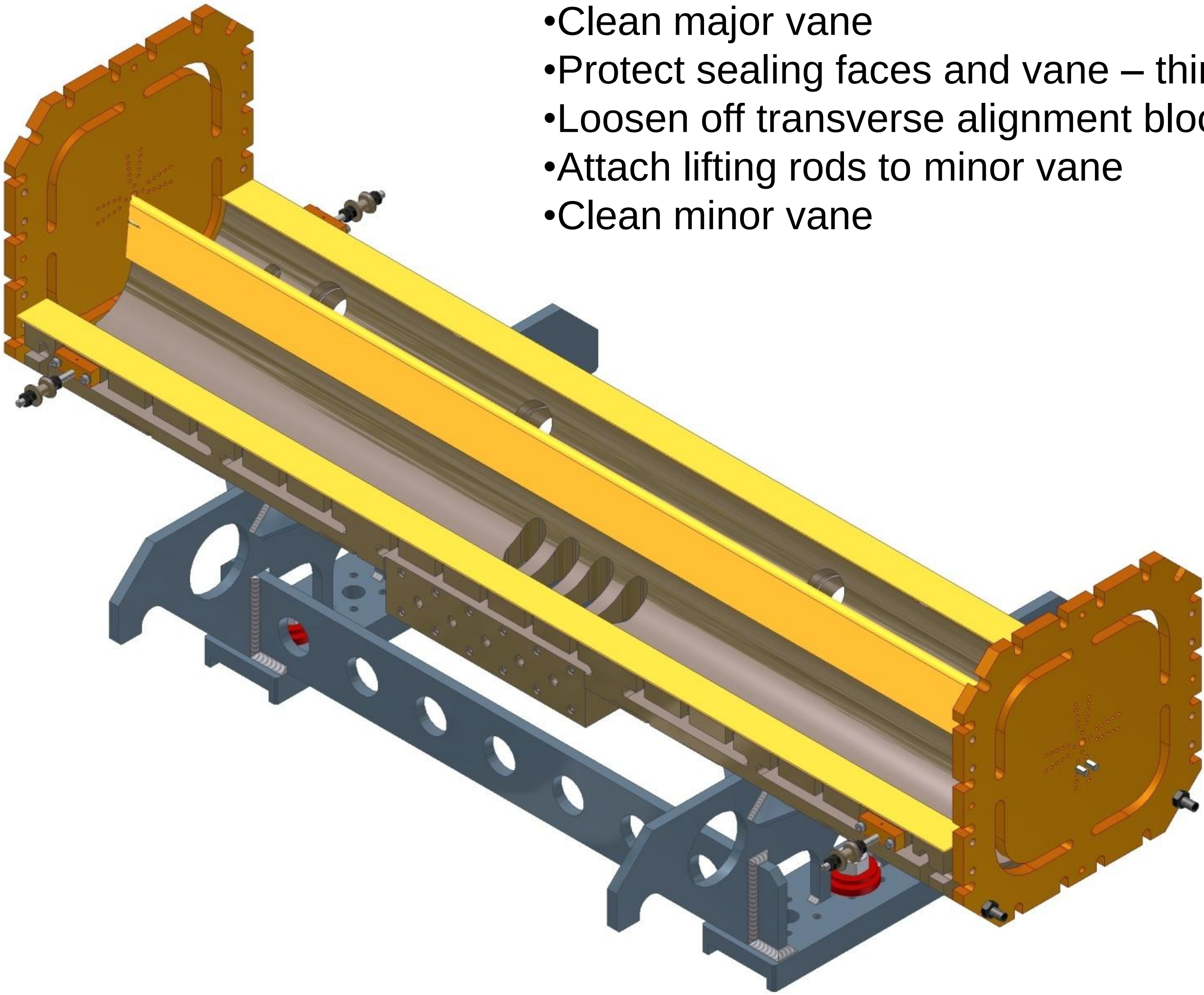
Tapered pins are used to (gently) align end flange to vane –
never used as a lever or with any great force



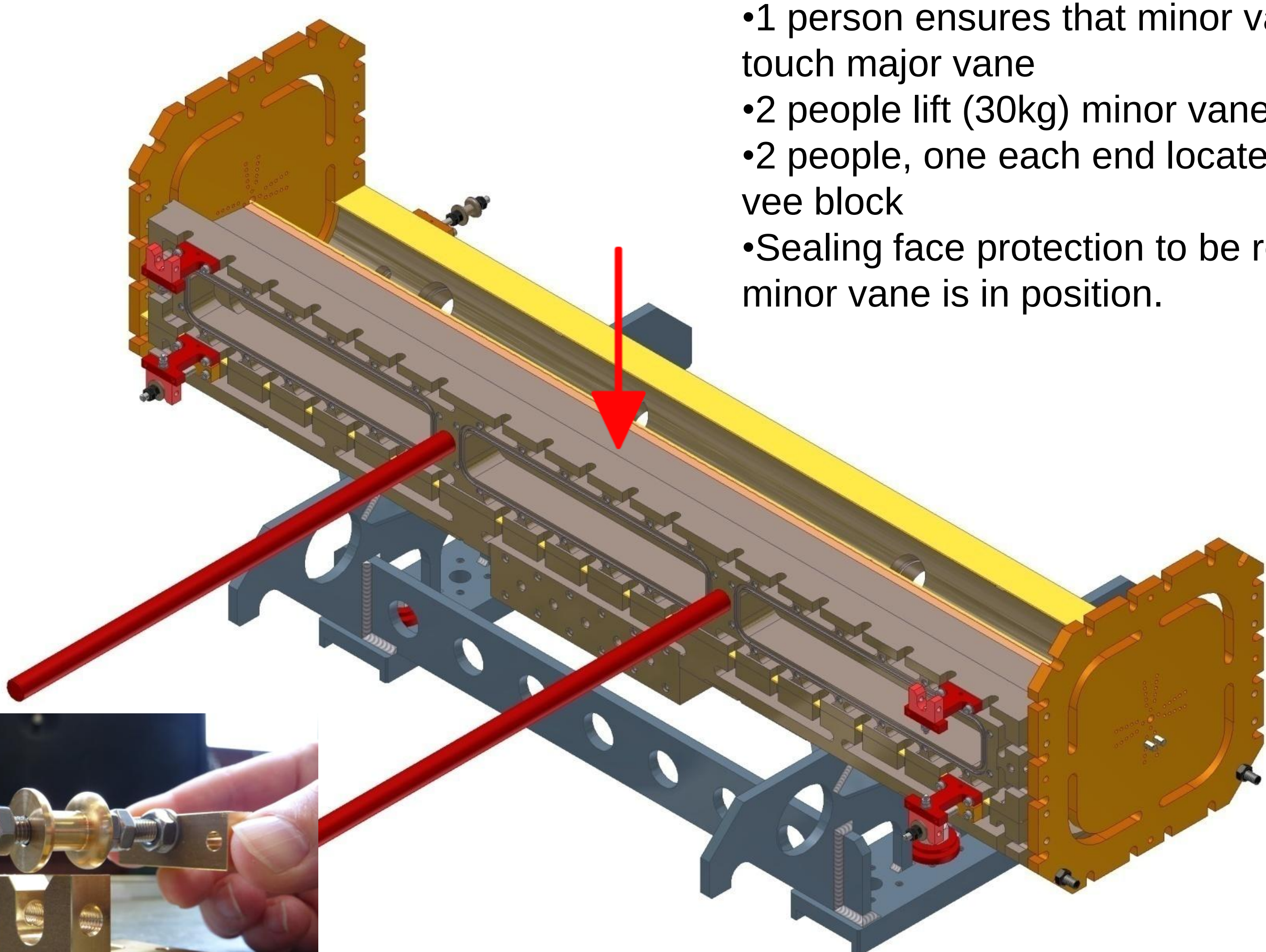
With both alignment flanges locked into position we are now we are ready to add the minor vanes.



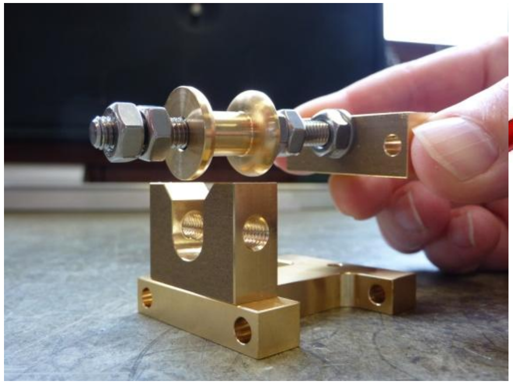




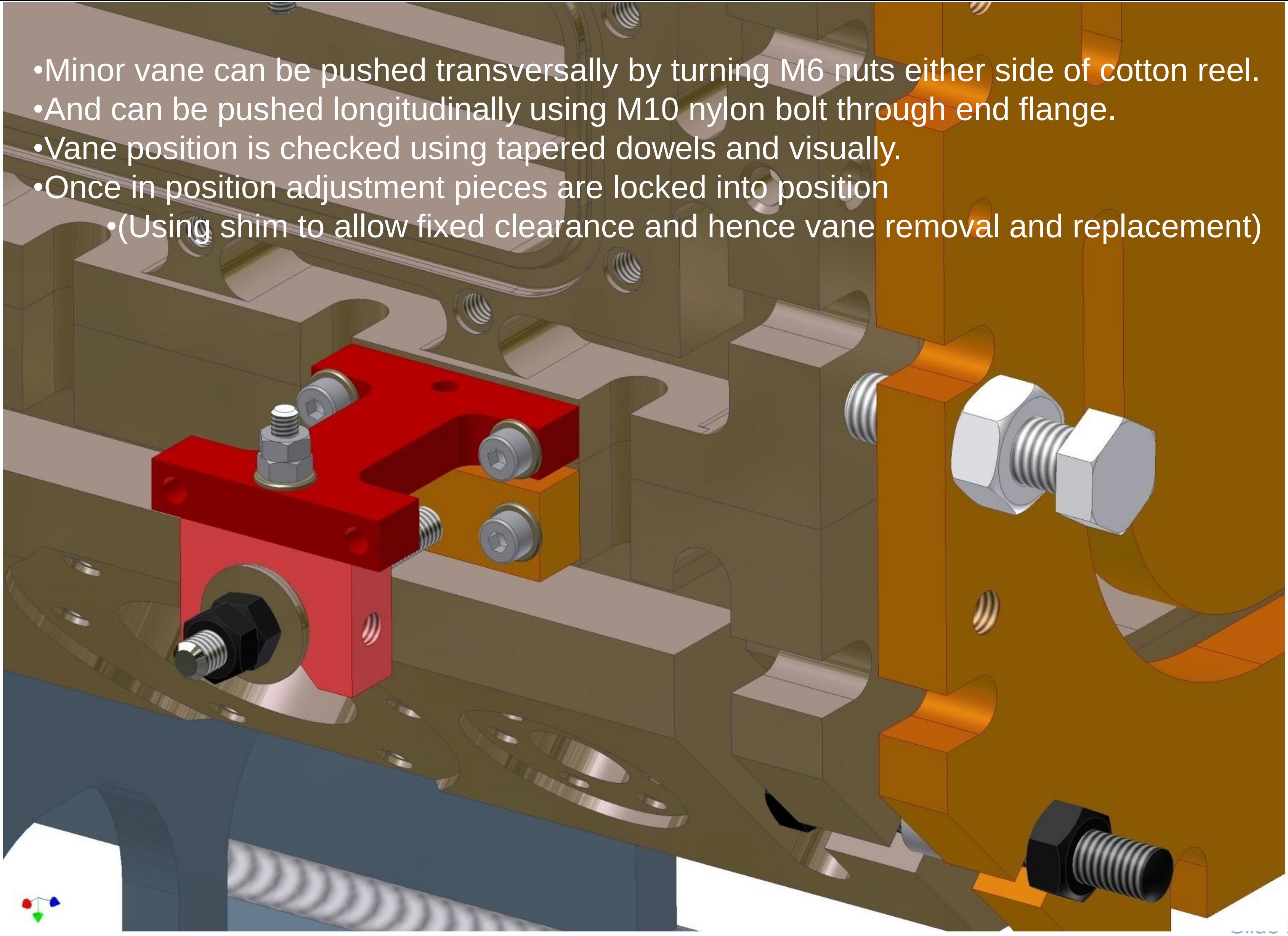
- Clean major vane
- Protect sealing faces and vane – thin Al strips?
- Loosen off transverse alignment blocks
- Attach lifting rods to minor vane
- Clean minor vane



- 1 person ensures that minor vane does not touch major vane
- 2 people lift (30kg) minor vane into position
- 2 people, one each end locate cotton reel into vee block
- Sealing face protection to be removed once minor vane is in position.

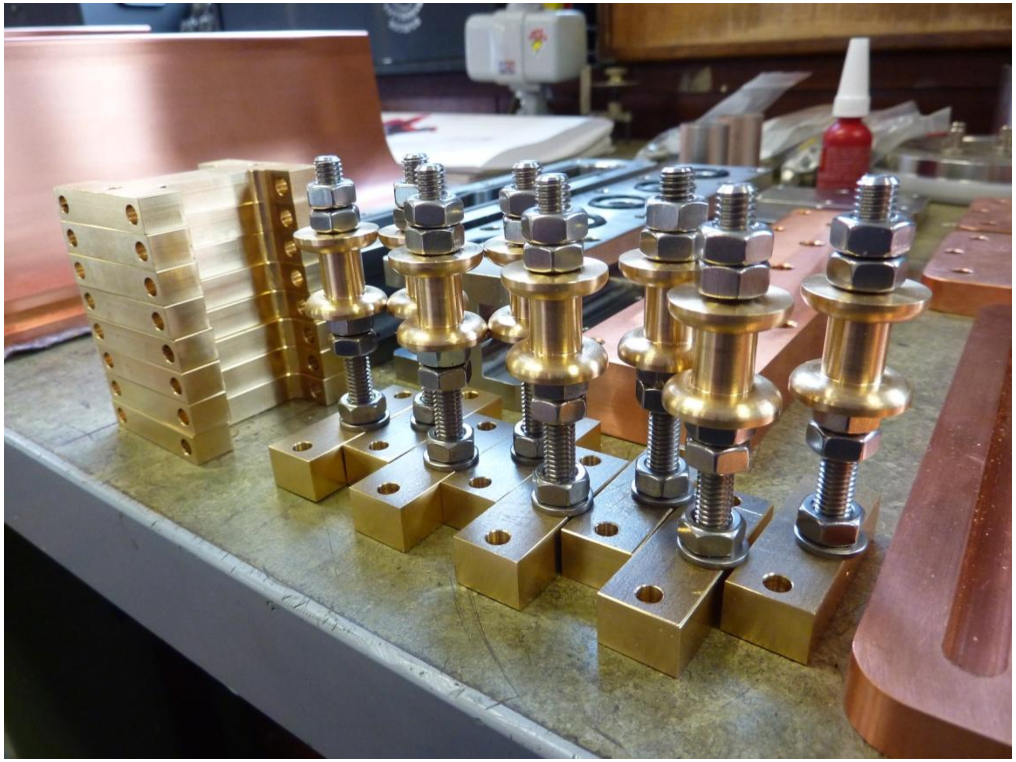


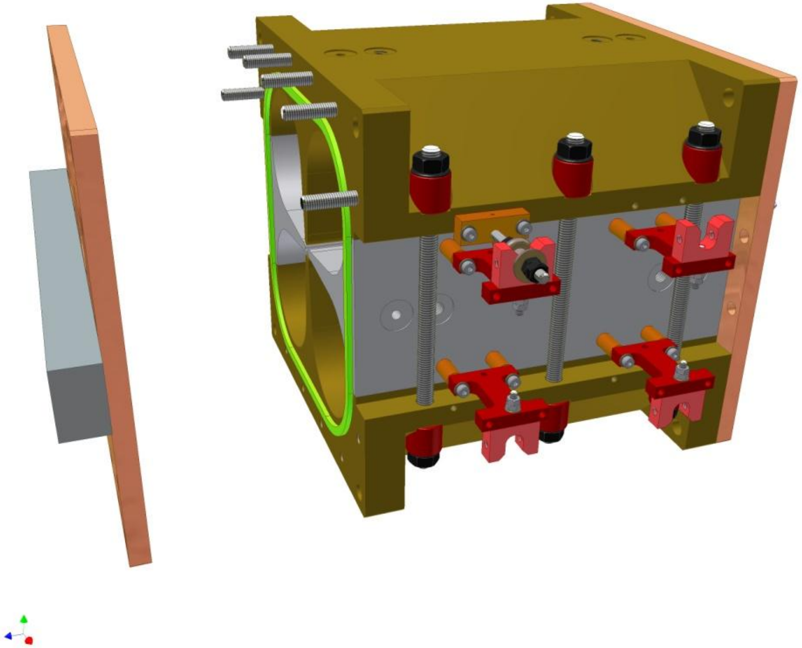
- Minor vane can be pushed transversally by turning M6 nuts either side of cotton reel.
- And can be pushed longitudinally using M10 nylon bolt through end flange.
- Vane position is checked using tapered dowels and visually.
- Once in position adjustment pieces are locked into position
    - (Using shim to allow fixed clearance and hence vane removal and replacement)



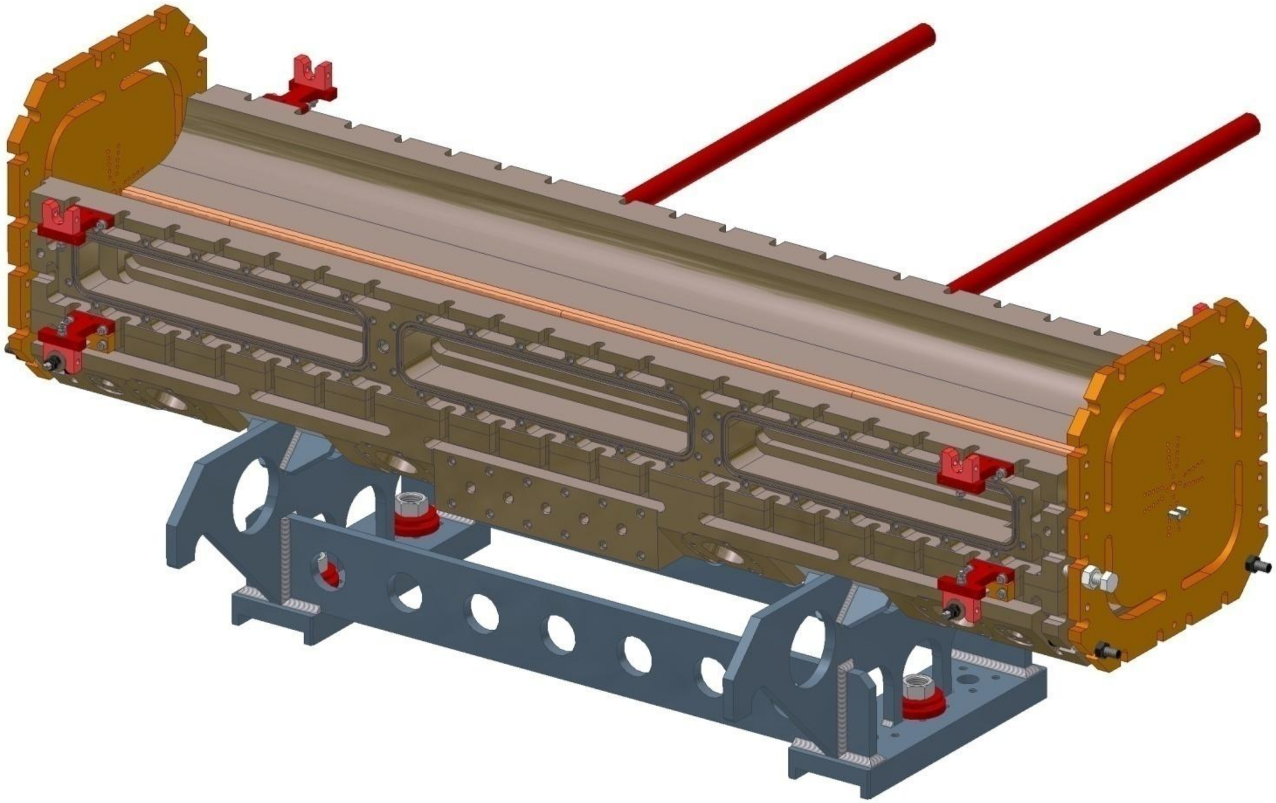
Transverse positioning blocks

Concept of transverse positioning blocks is about to be trialled on the RFQ scale model.

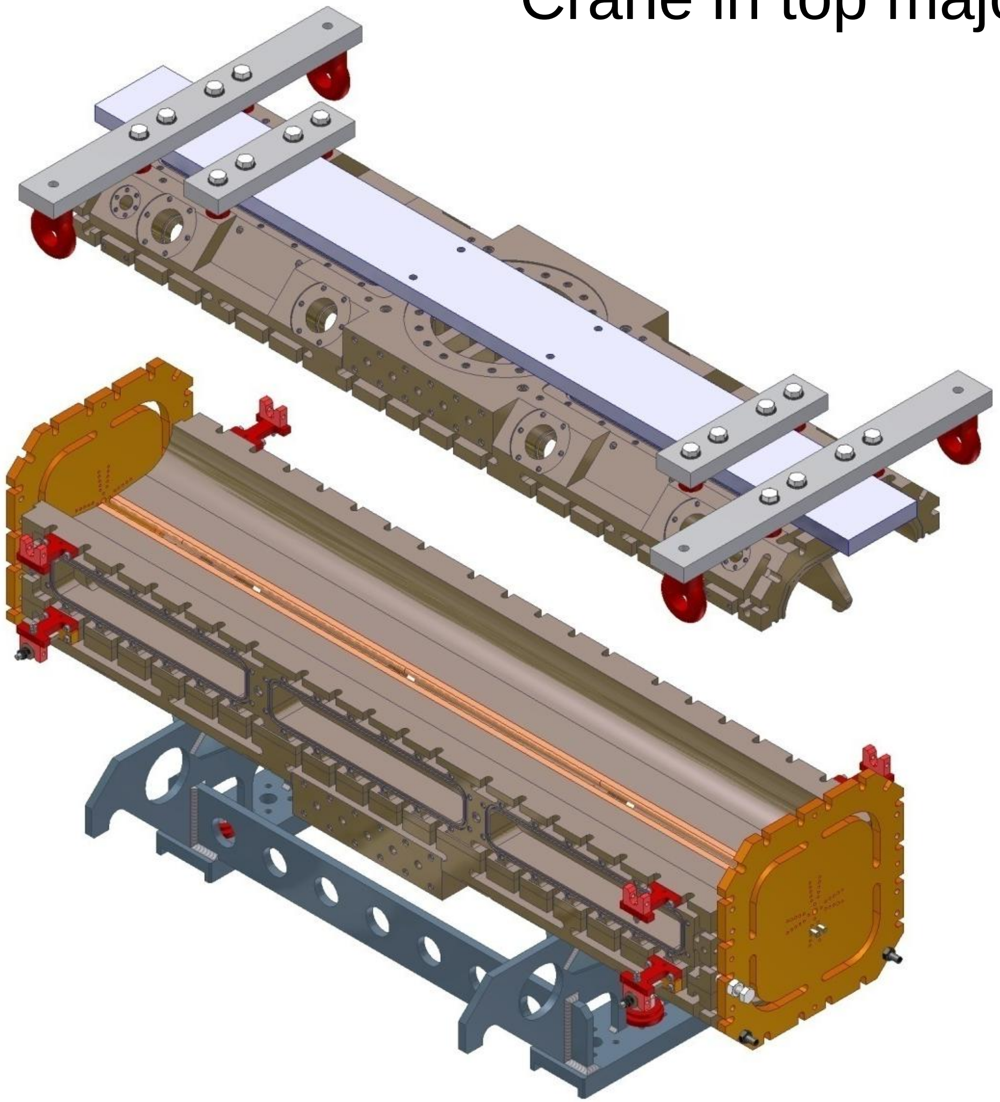




Repeat procedure for second minor vane

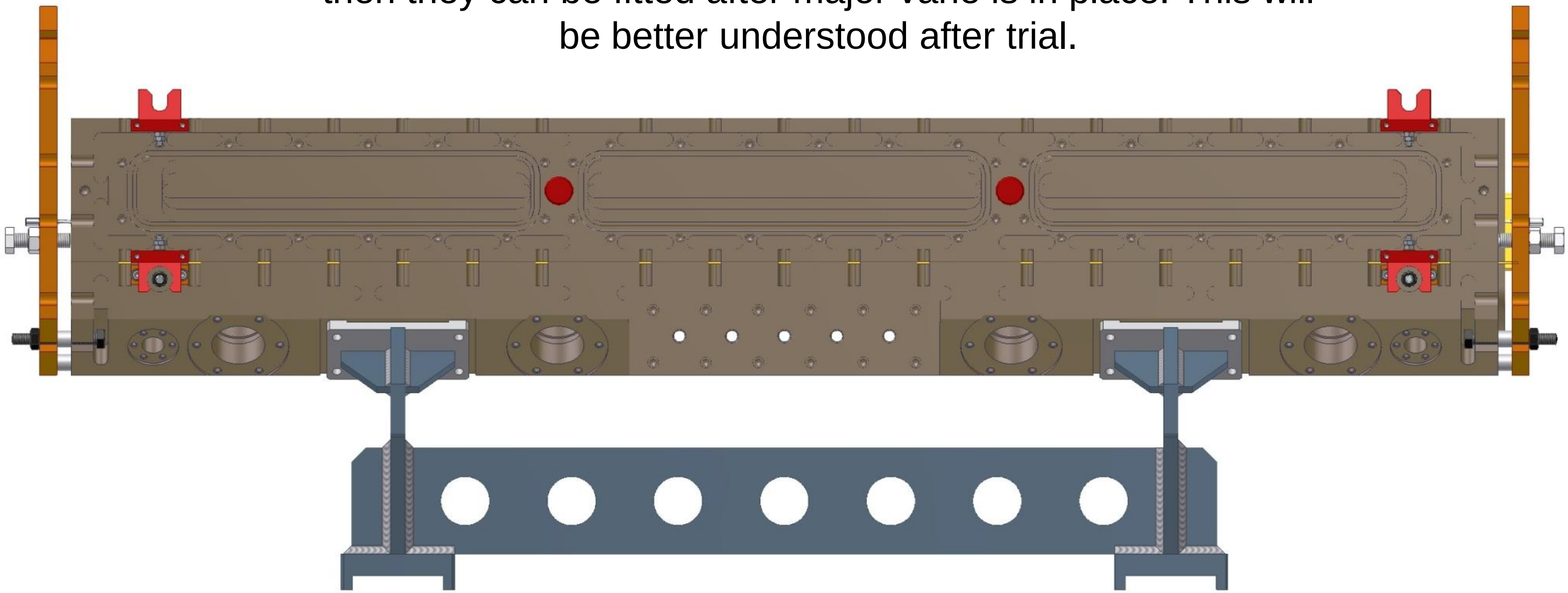


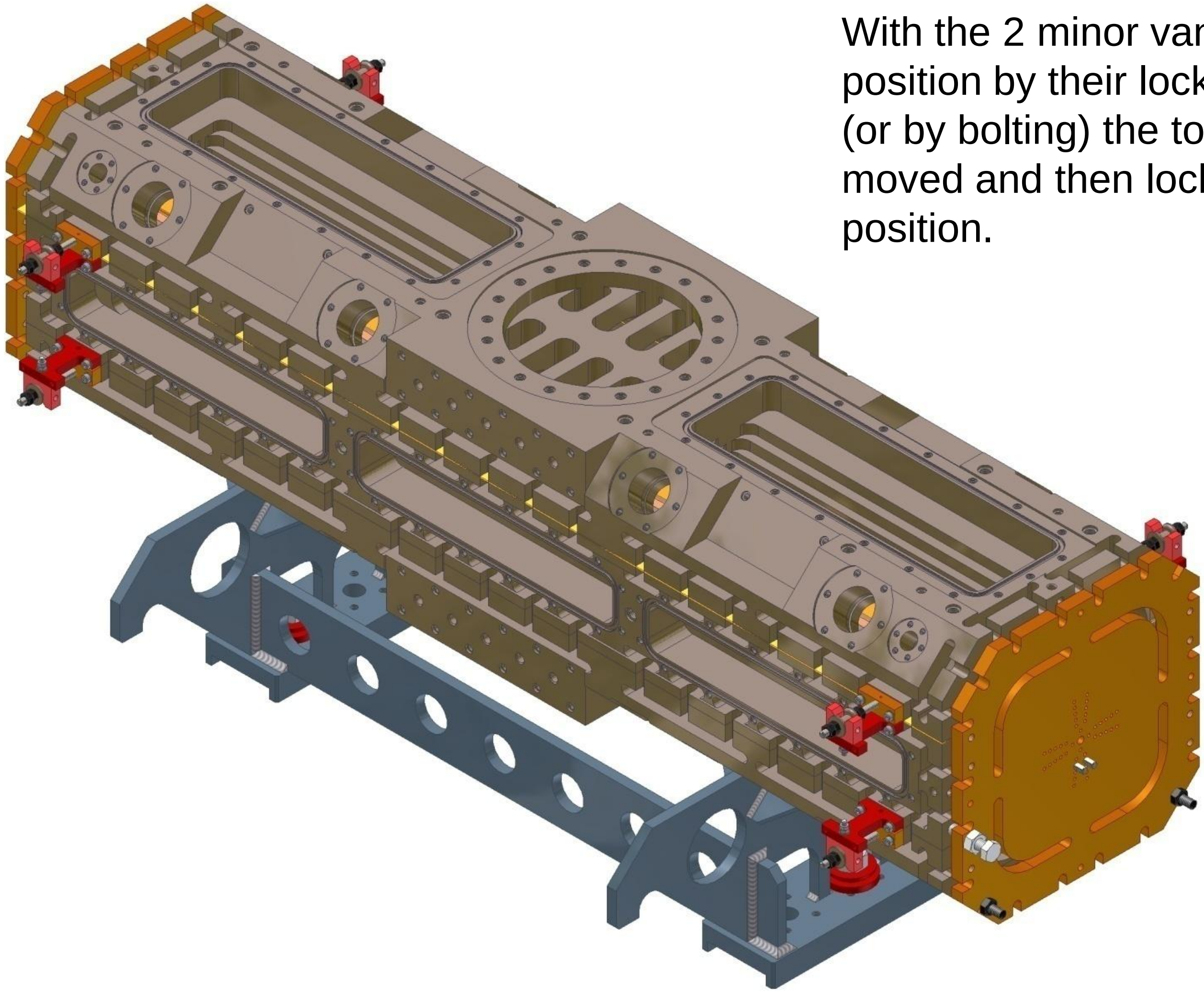
Crane in top major vane



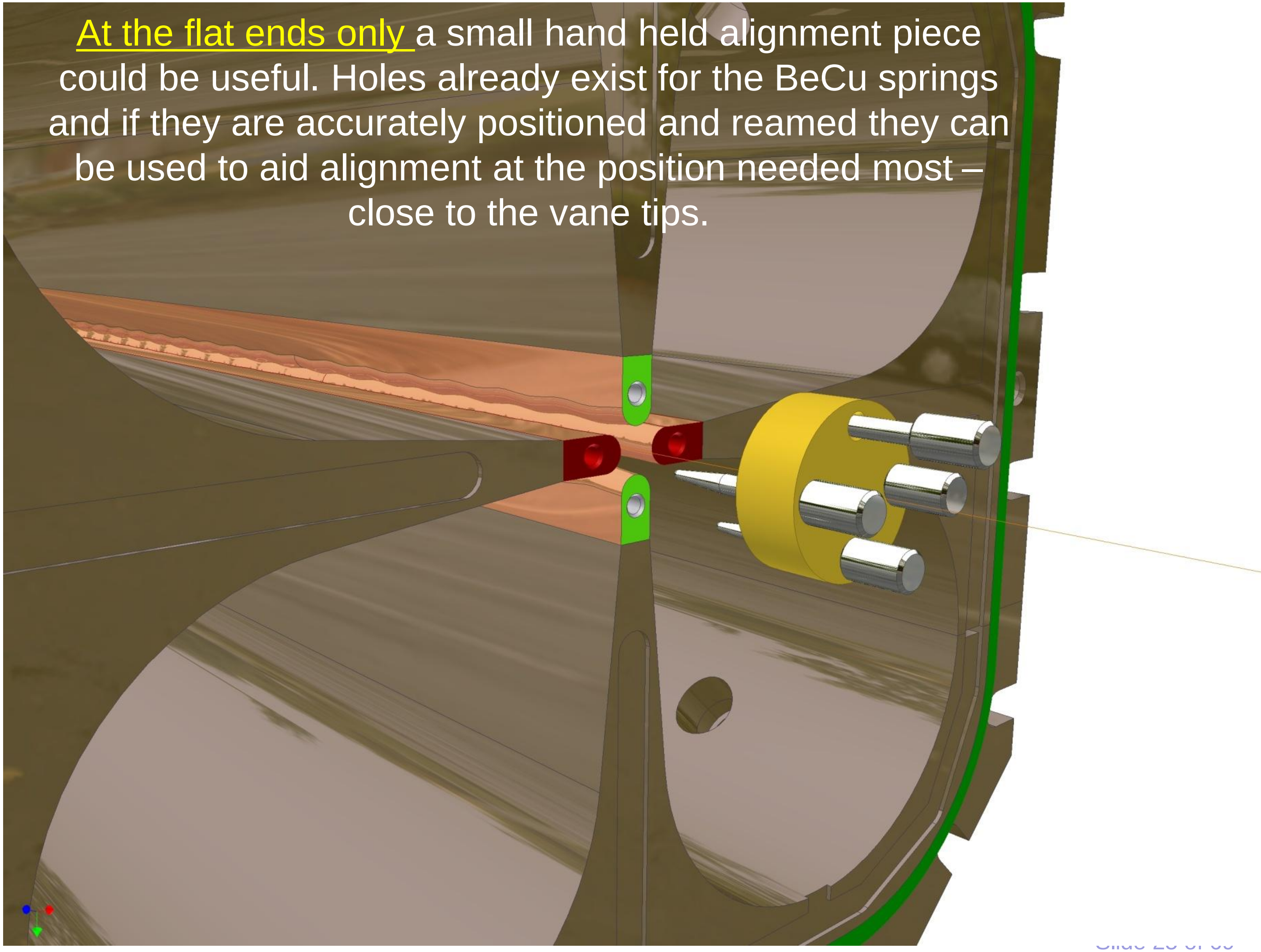
- Clean
- Protection for vanes and sealing faces required.
- Use chain block for sensitivity – NOT the R8 crane
- One person at each corner
- Rest on protective strips before finally lowering into position.

•In case locating into the transverse blocks proves impractical then they can be fitted after major vane is in place. This will be better understood after trial.





With the 2 minor vanes held in position by their locked adjusters (or by bolting) the top vane can be moved and then locked into position.


At the flat ends only a small hand held alignment piece could be useful. Holes already exist for the BeCu springs and if they are accurately positioned and reamed they can be used to aid alignment at the position needed most – close to the vane tips.

RF test required.
Need network analyser and loops for input and output.

If dipole modes are close will need to find out which vanes to move by performing bead pull test.

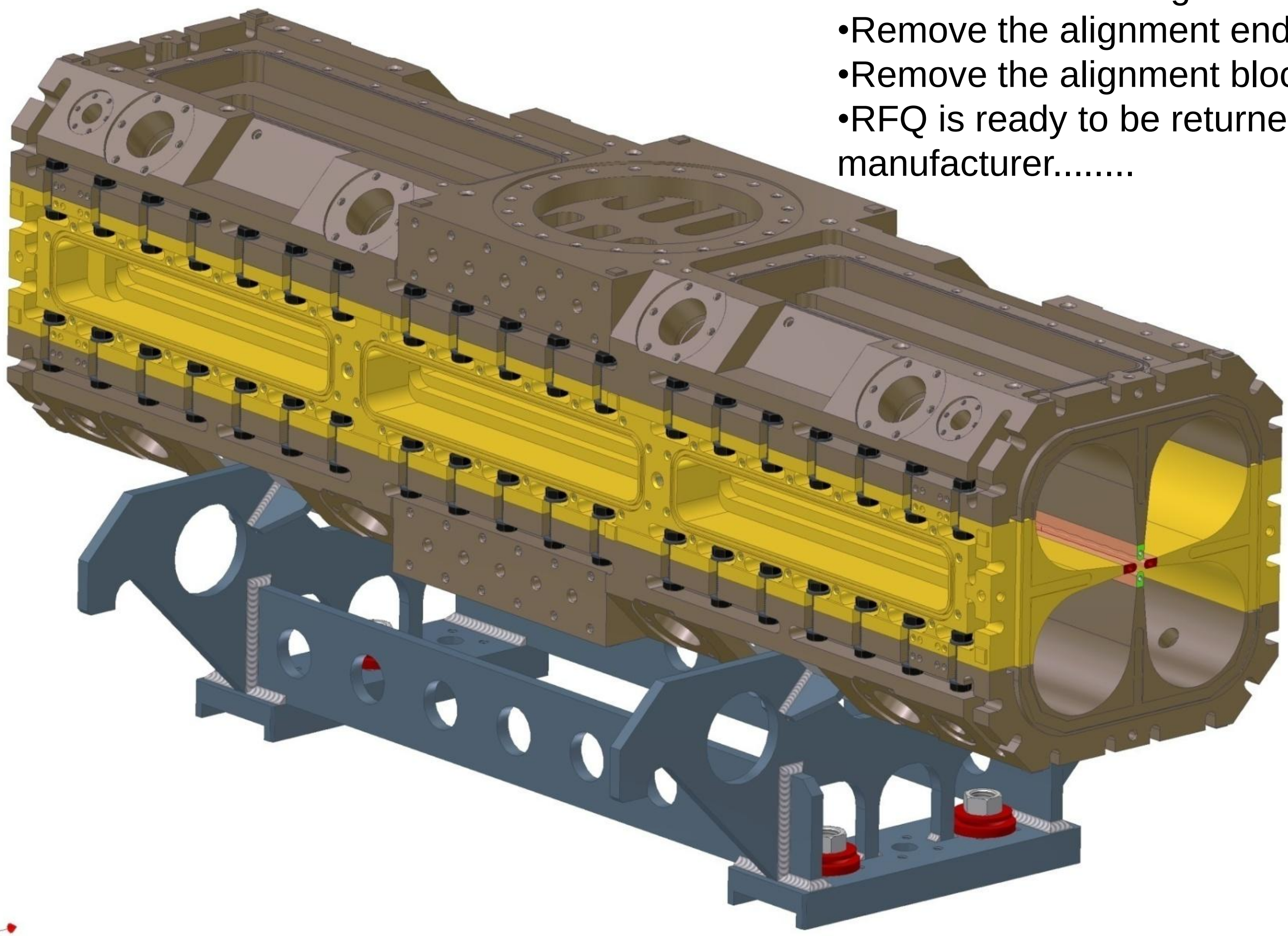
Bead pull test – simple (Imperial) one may suffice?
If vanes must be moved then unbolt and adjust.
Repeat bead pull test.

Blanked off tuner ports will be sufficient. Ideally with tuner plugs in place.

Ready to be returned to manufacturer

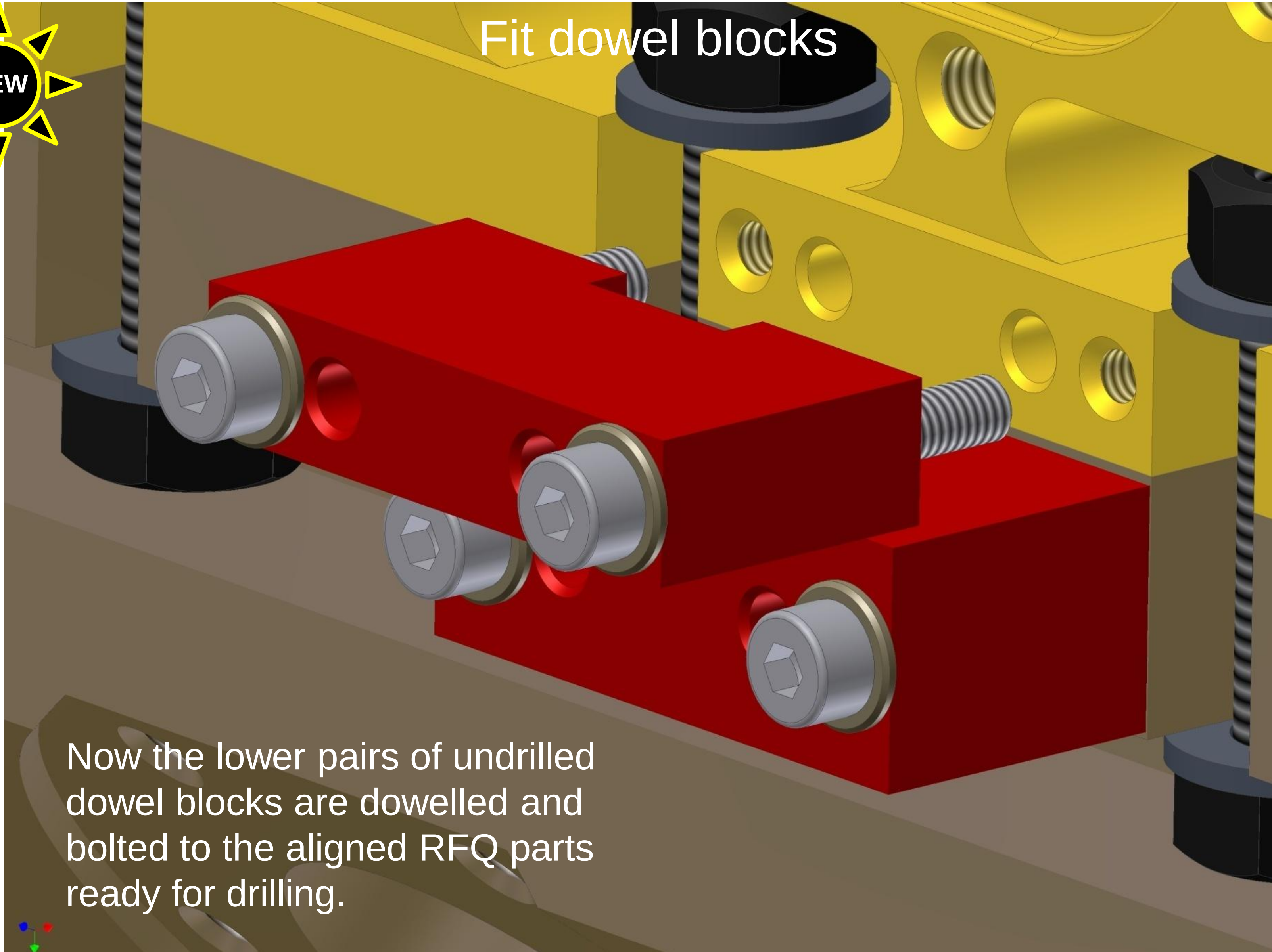
NEW

- Now we have an aligned assembly.
- Remove the alignment end flanges.
- Remove the alignment blocks.
- RFQ is ready to be returned to the manufacturer........



NEW

Fit dowel blocks



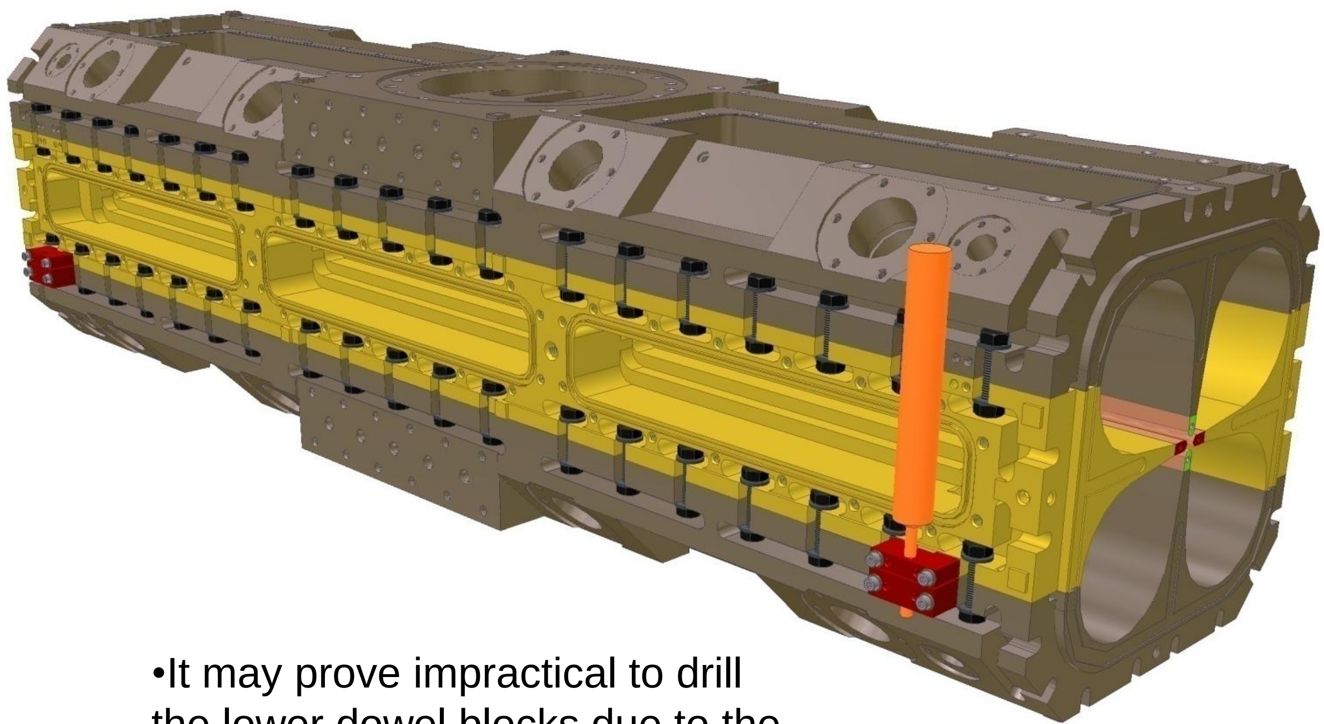
Now the lower pairs of undrilled dowel blocks are dowelled and bolted to the aligned RFQ parts ready for drilling.

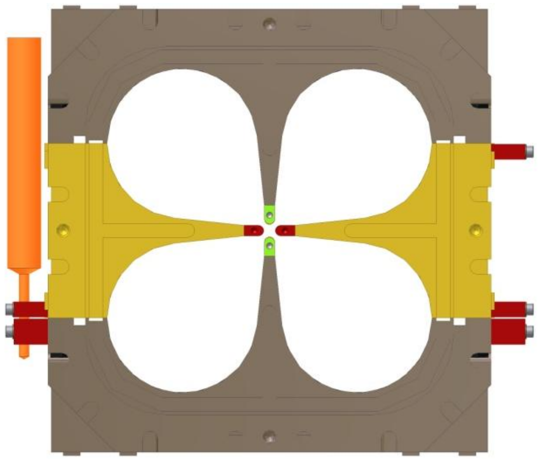
Part 2

Back to the manufacturers for final machining.

NEW

Drilling lower dowel blocks

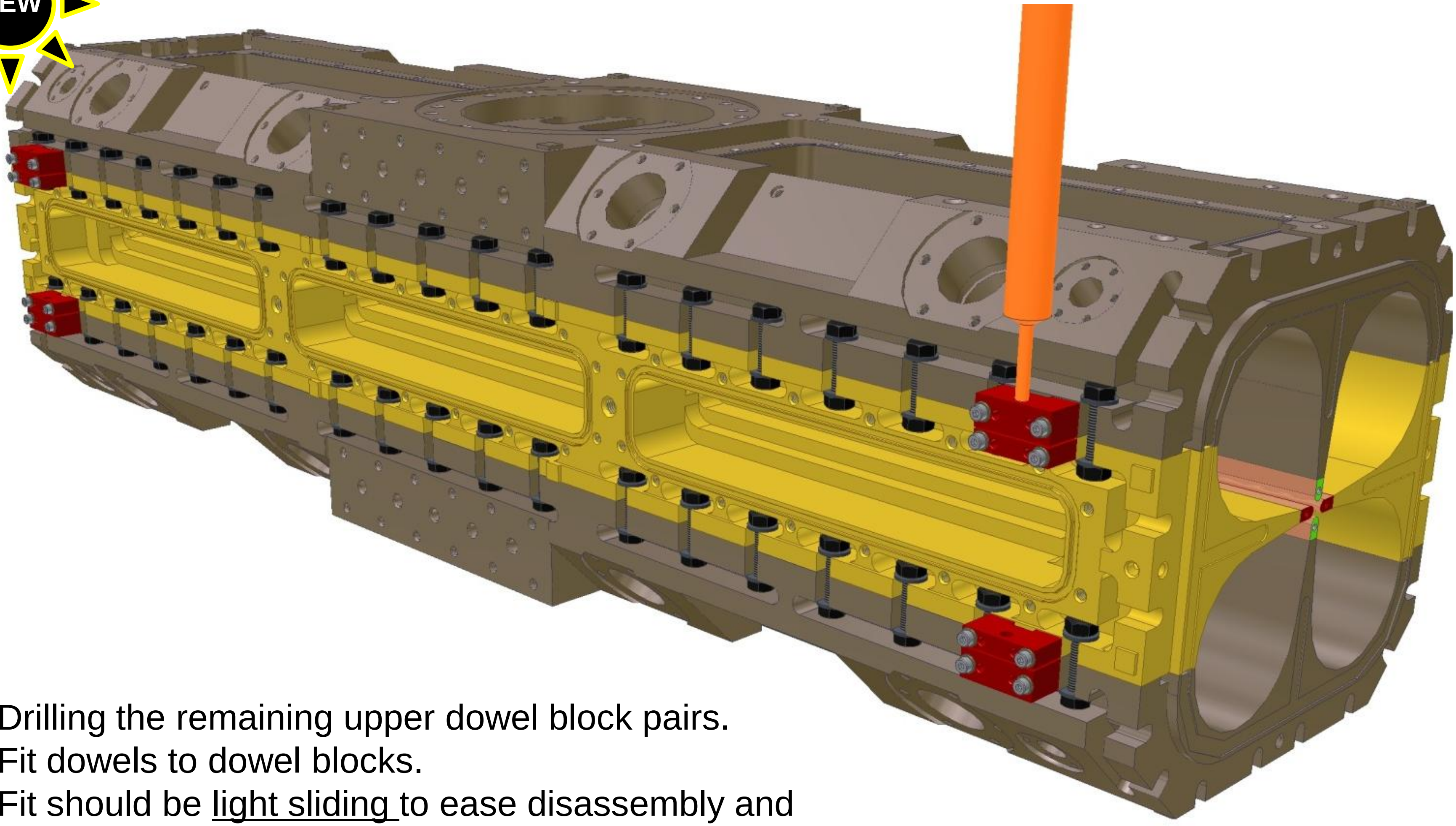




•It may prove impractical to drill the lower dowel blocks due to the proximity of the drill and the RFQ body. If so they can be extended and supported underneath and drilled further away from the RFQ body.

NEW

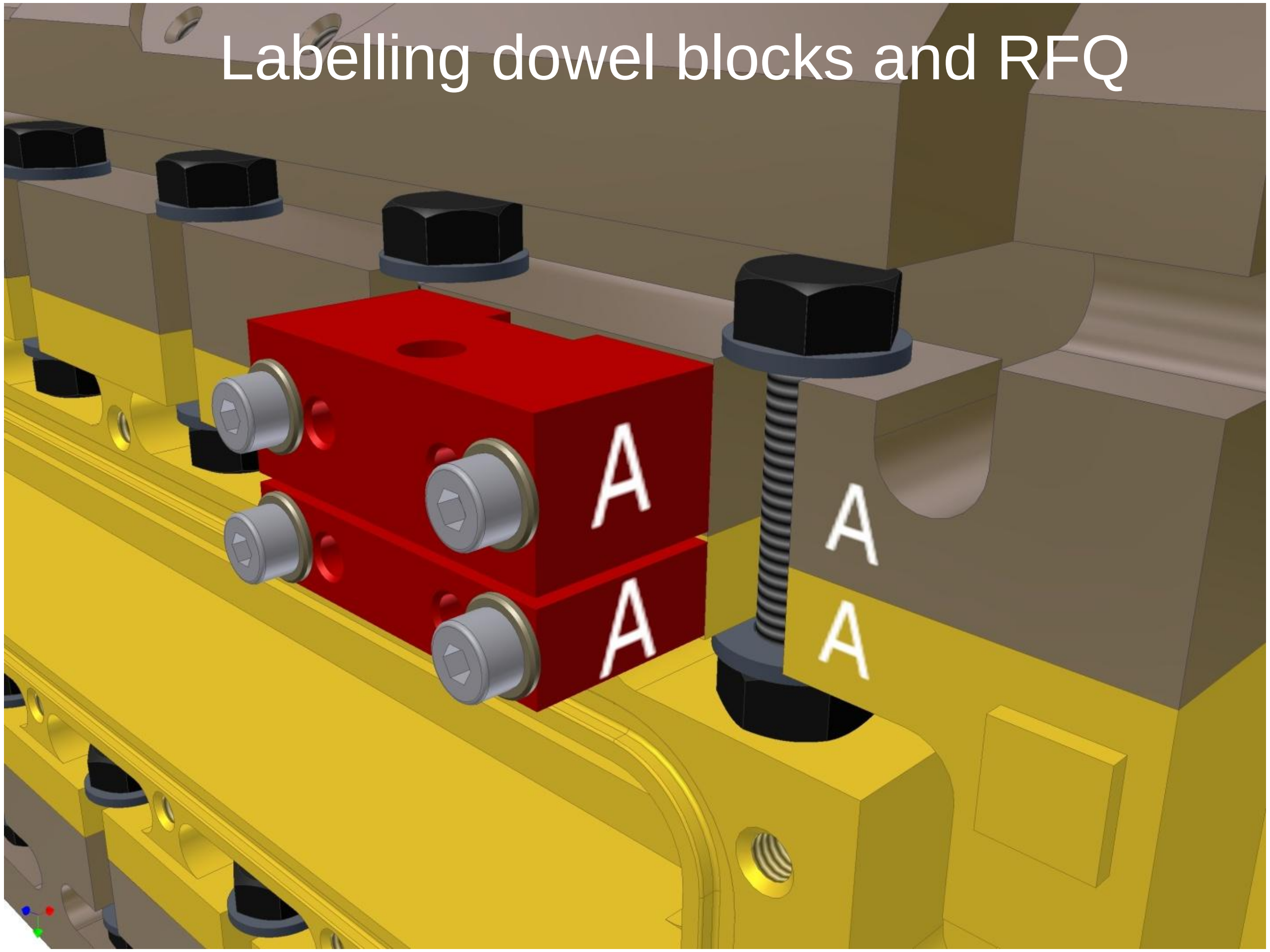
Drilling upper dowel blocks



•Drilling the remaining upper dowel block pairs.
•Fit dowels to dowel blocks.
•Fit should be <u>light sliding </u>to ease disassembly and reassembly.

NEW

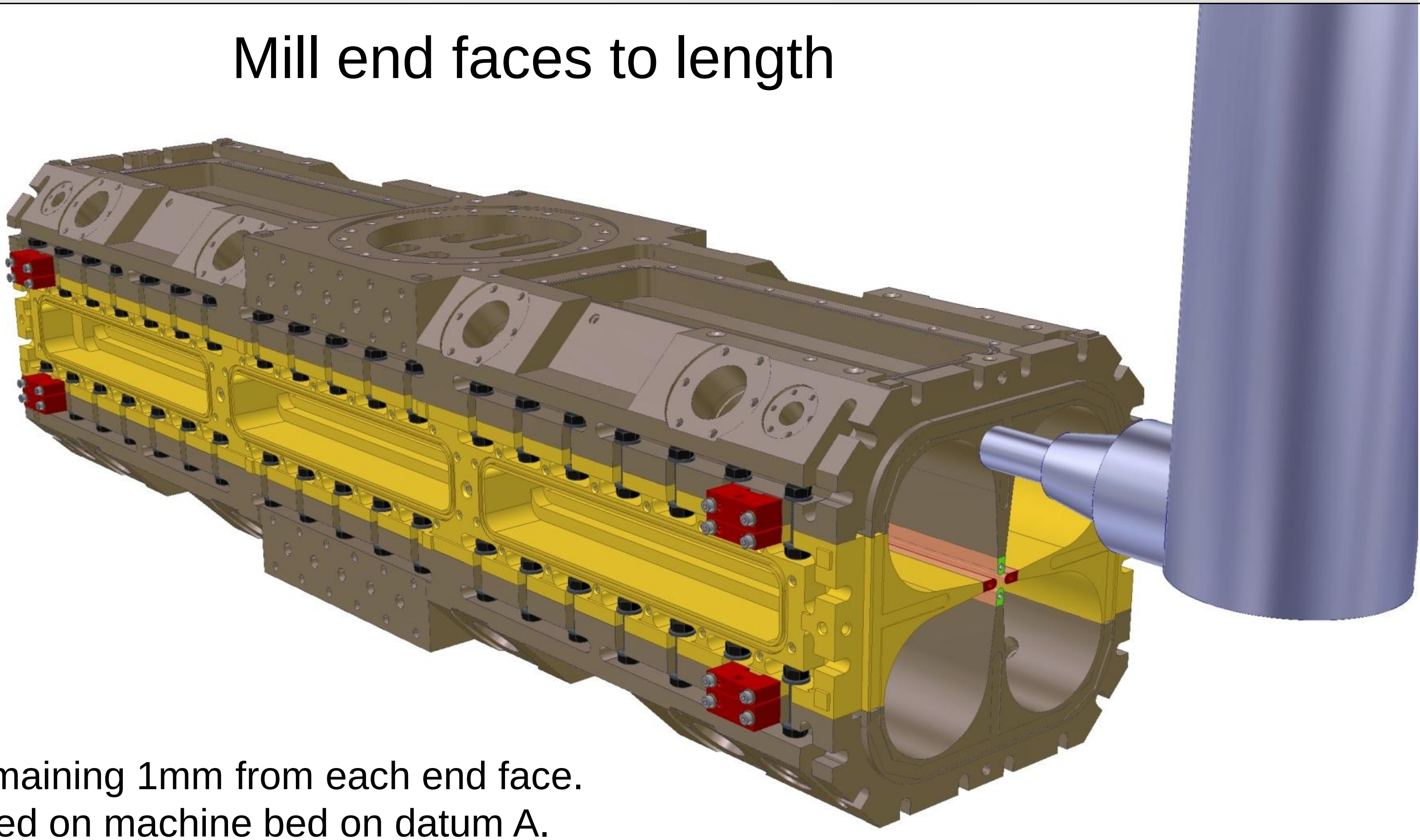
Labelling dowel blocks and RFQ



Each dowel block pair now has a unique orientation and position on the RFQ assembly. They may never need to be removed but in case they need to be replaced by the alignment blocks they must be labelled.

NEW

Mill end faces to length

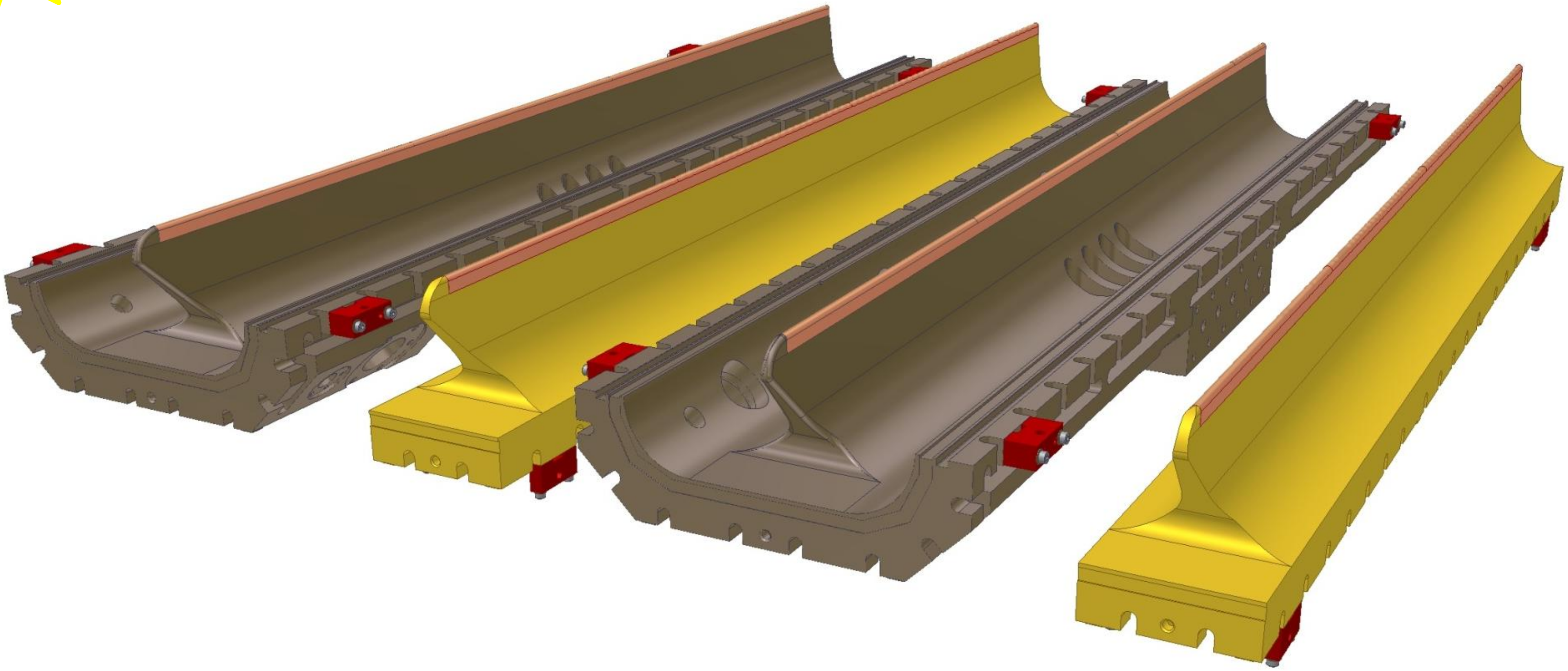


Remove the remaining 1mm from each end face.
Assembly located on machine bed on datum A.
End faces are:

- Perpendicular to datum face A
- Parallel to each other
- To the final length
- Can final operation be done without coolant to minimize contamination?

NEW

Deburring end faces



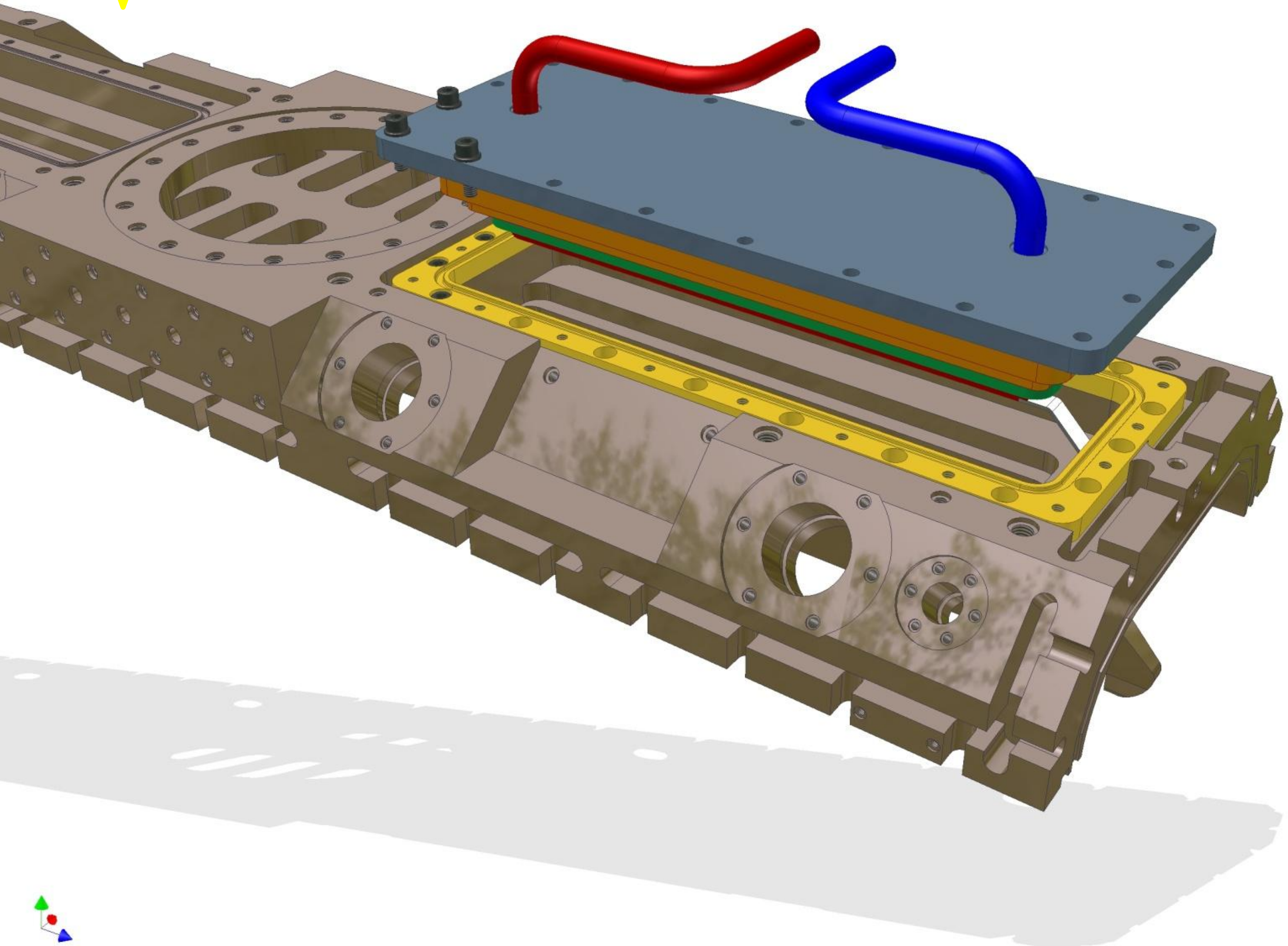
Now the finished pieces of RFQ section 1 can be dismantled leaving the drilled & labelled dowel blocks in position. The new machining of the end faces must now be deburred. This stage can be done either at the manufacturer or at RAL. We are now ready for reassembly with the O ring in place.

Part 3

Section assembly
with O ring in place.

NEW

Fitting lower baffles before assembly

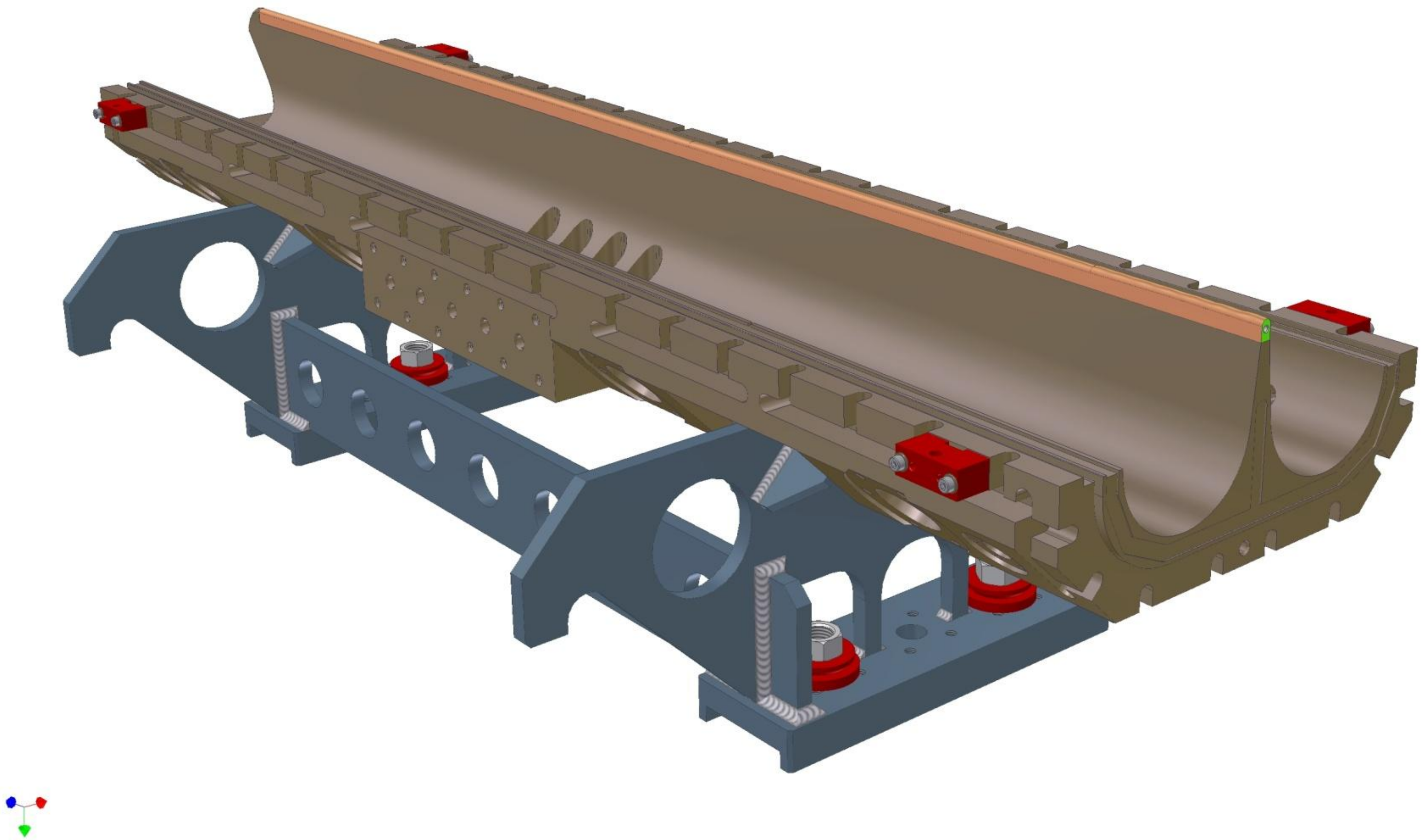


It will be easier to fit the baffles into the lower major vane with it inverted.

NEW

Start assembling RFQ section 1

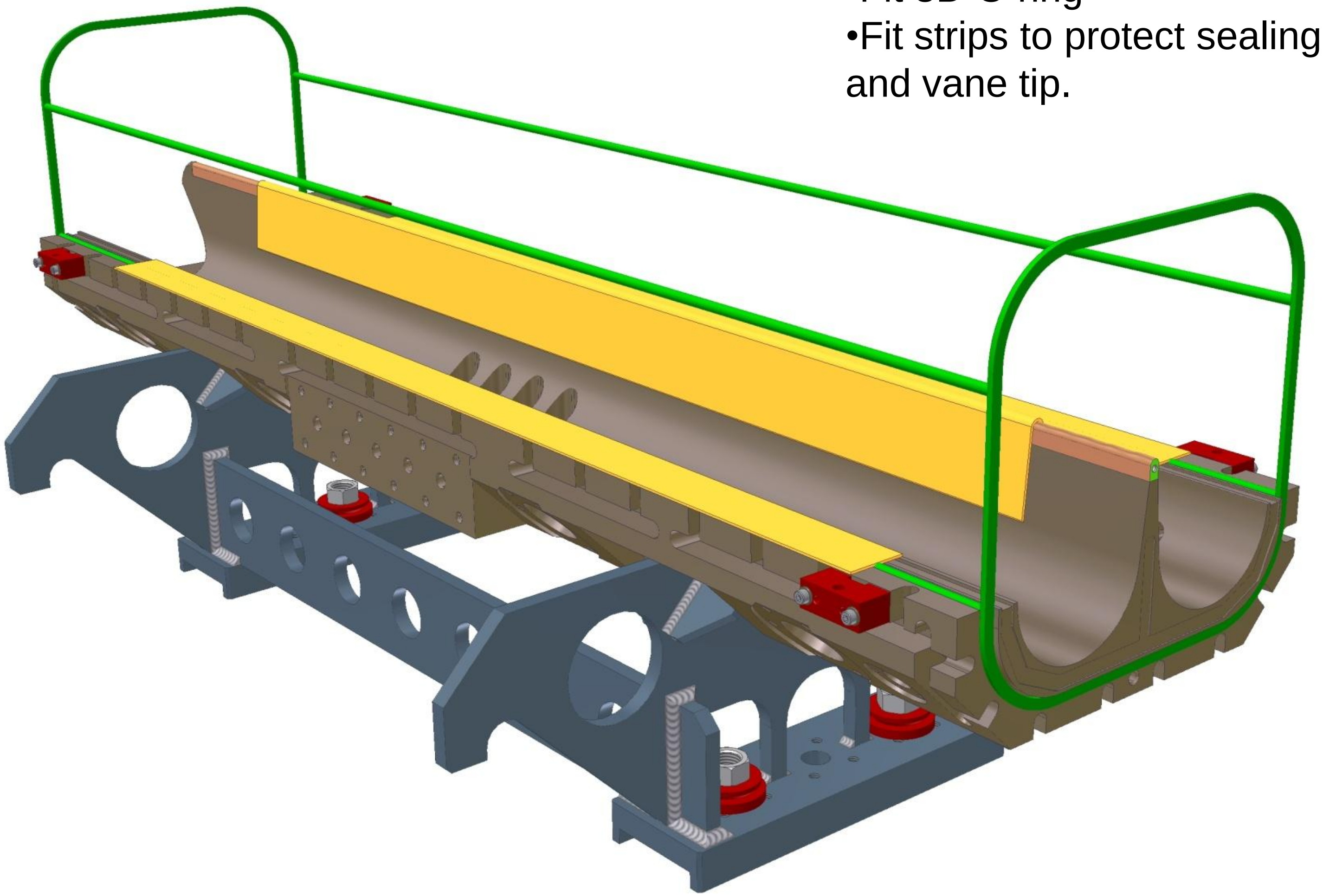
- Lower major vane into cradle
- Clean major vane



NEW

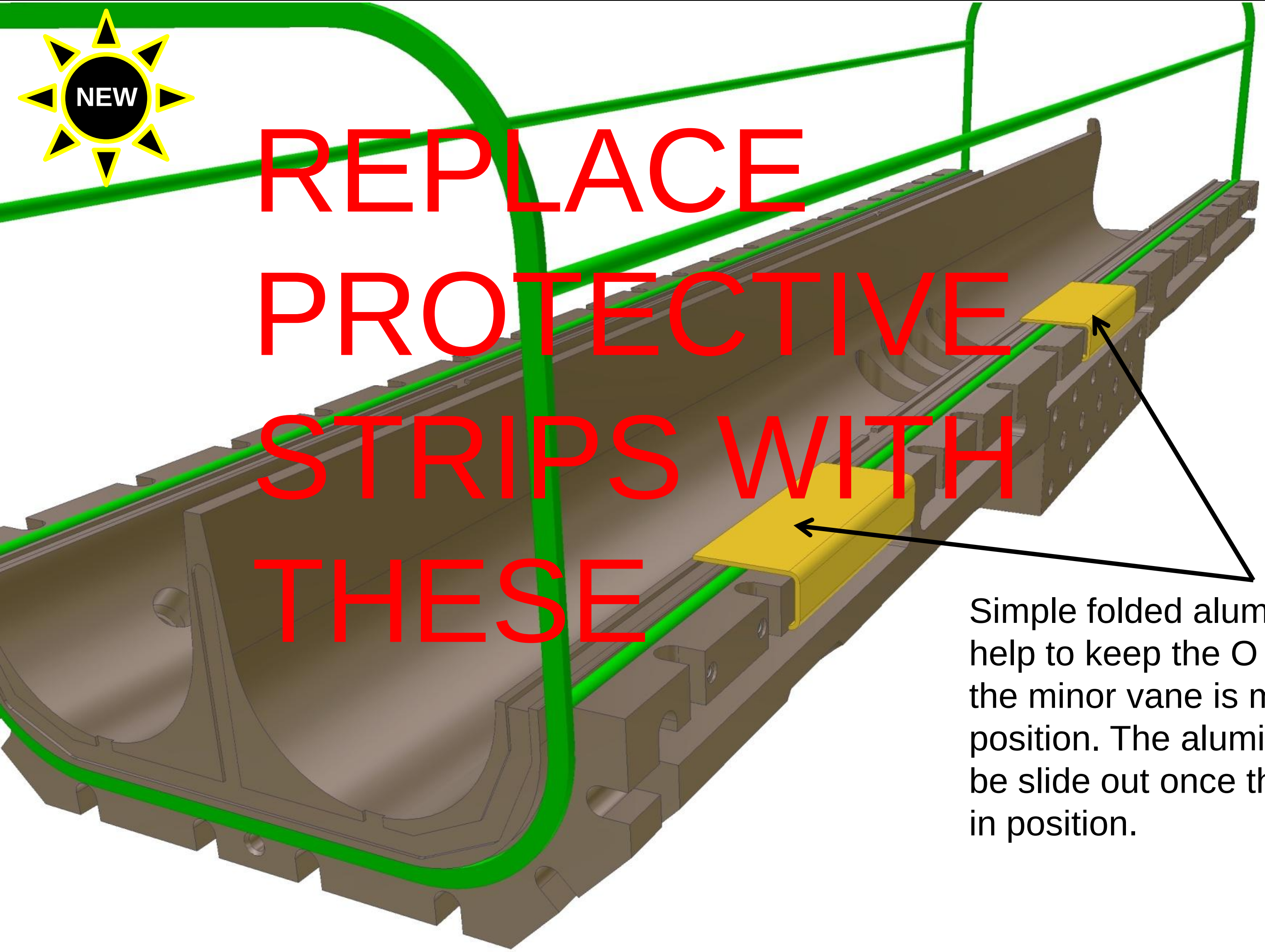
Start assembling RFQ section 1

- Fit 3D O ring
- Fit strips to protect sealing face and vane tip.



NEW

REPLACE PROTECTIVE STRIPS WITH THESE

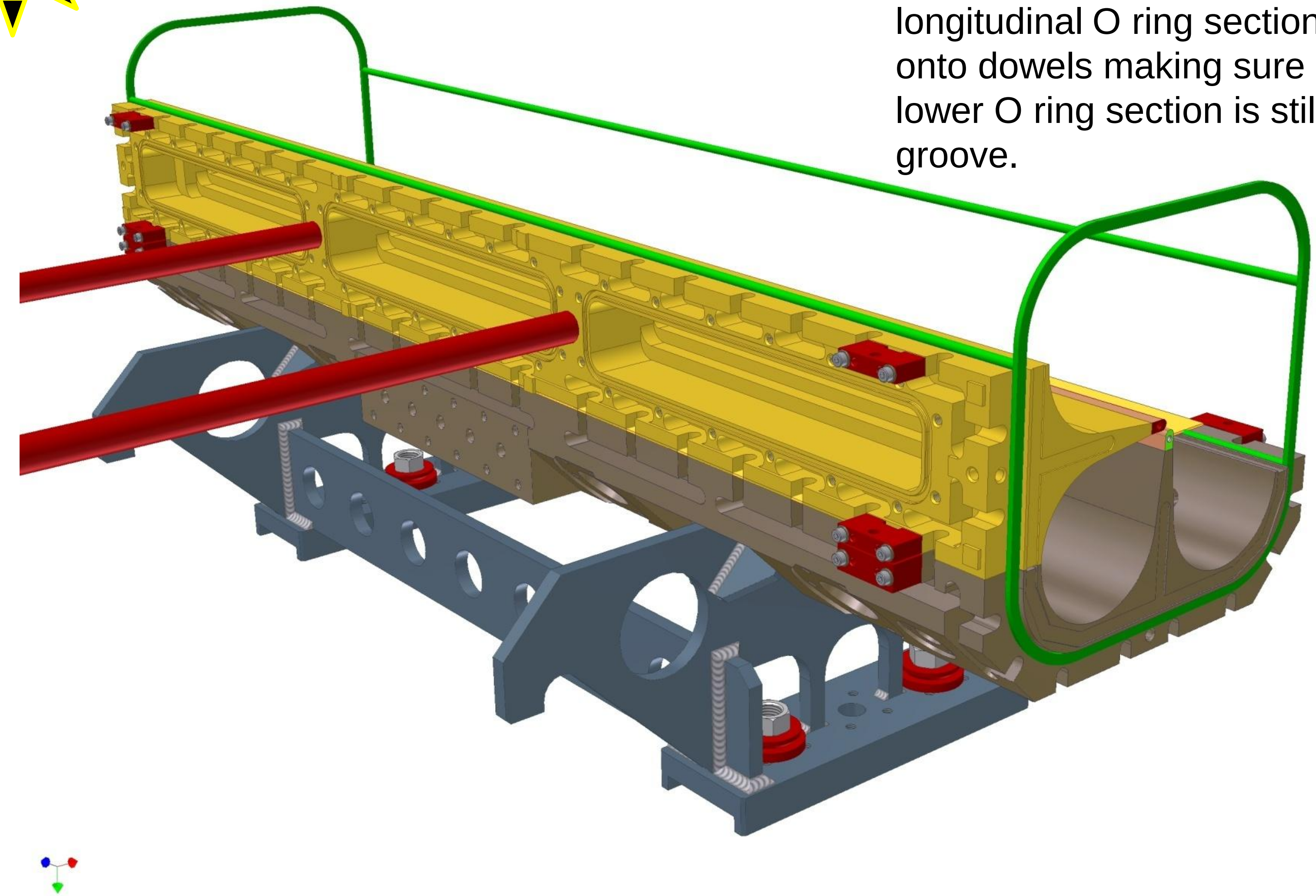


Simple folded aluminium pieces will help to keep the O ring in place as the minor vane is manouevered into position. The aluminium pieces can be slide out once the minor vane is in position.

NEW

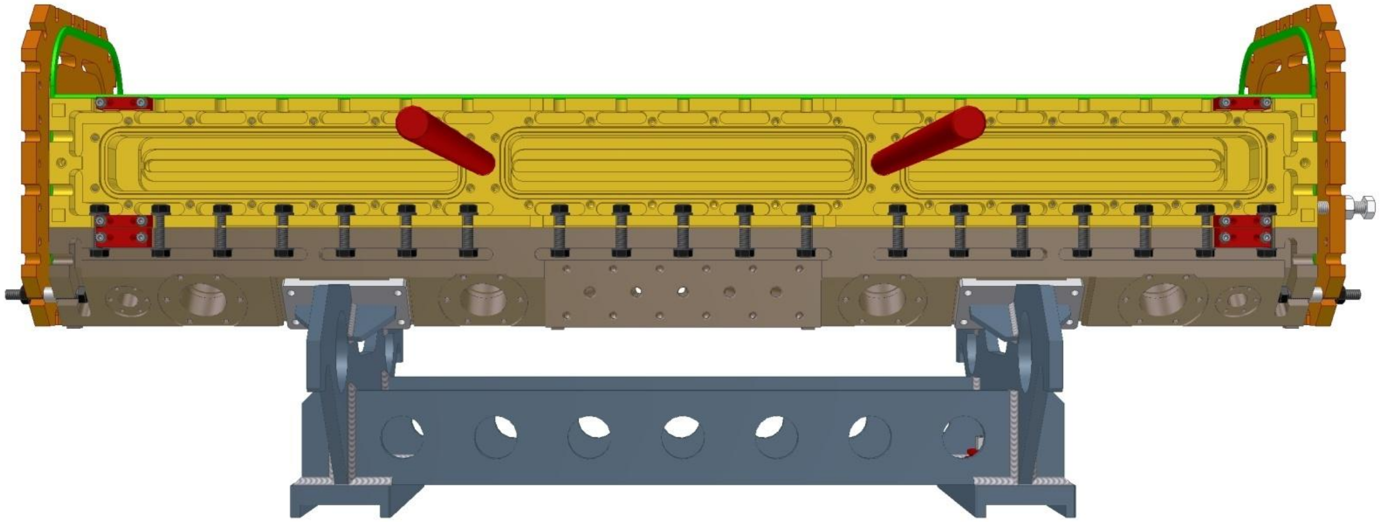
Locate minor vane 1 on dowels

- Locate the minor vane between the longitudinal O ring sections and lower onto dowels making sure that they lower O ring section is still in its groove.



NEW

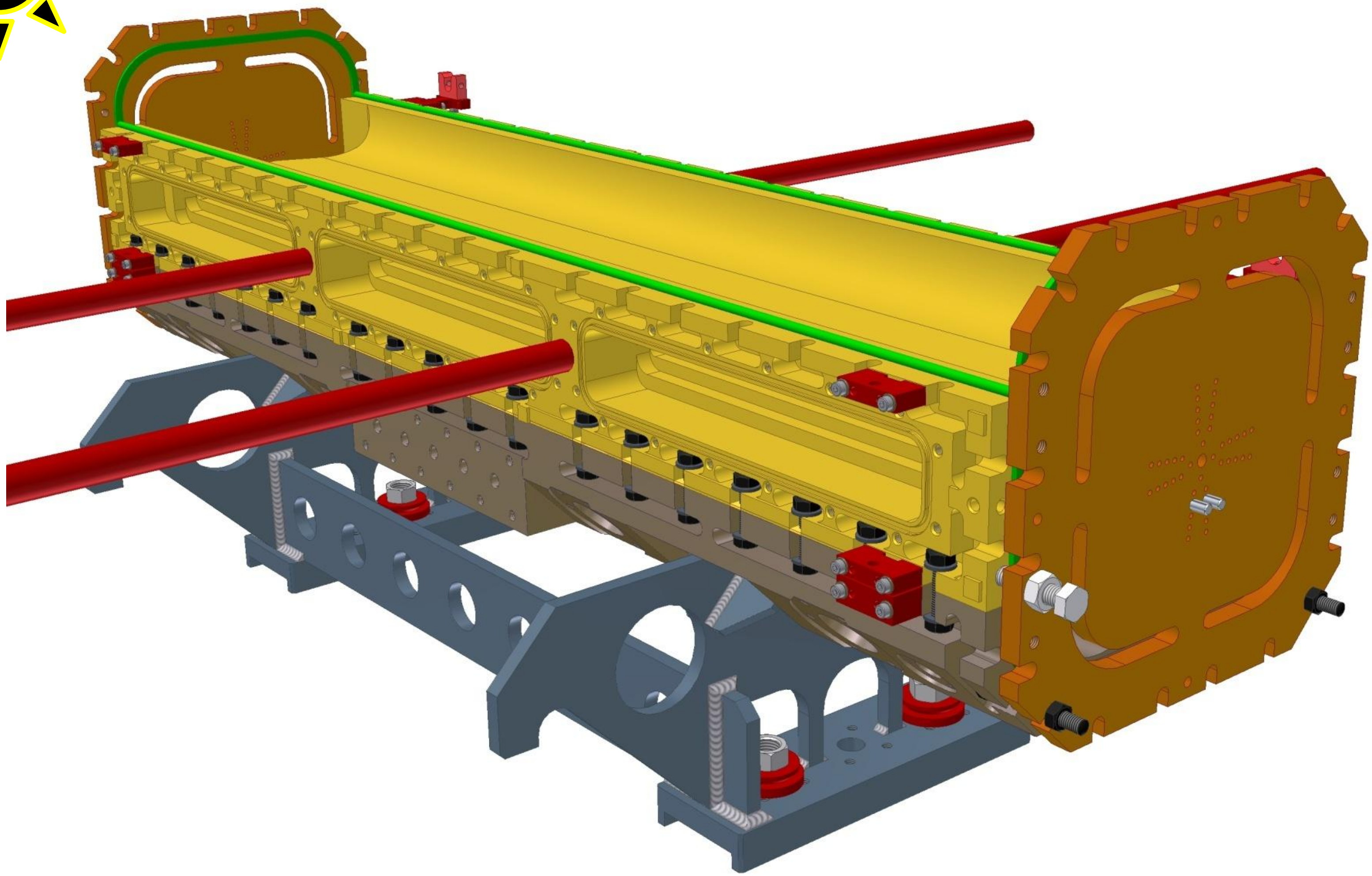
Start to bolt down minor vane 1



•Fit the end alignment flanges – they are there this time just to prevent the O ring from squeezing out during compression as the minor vane is bolted down.

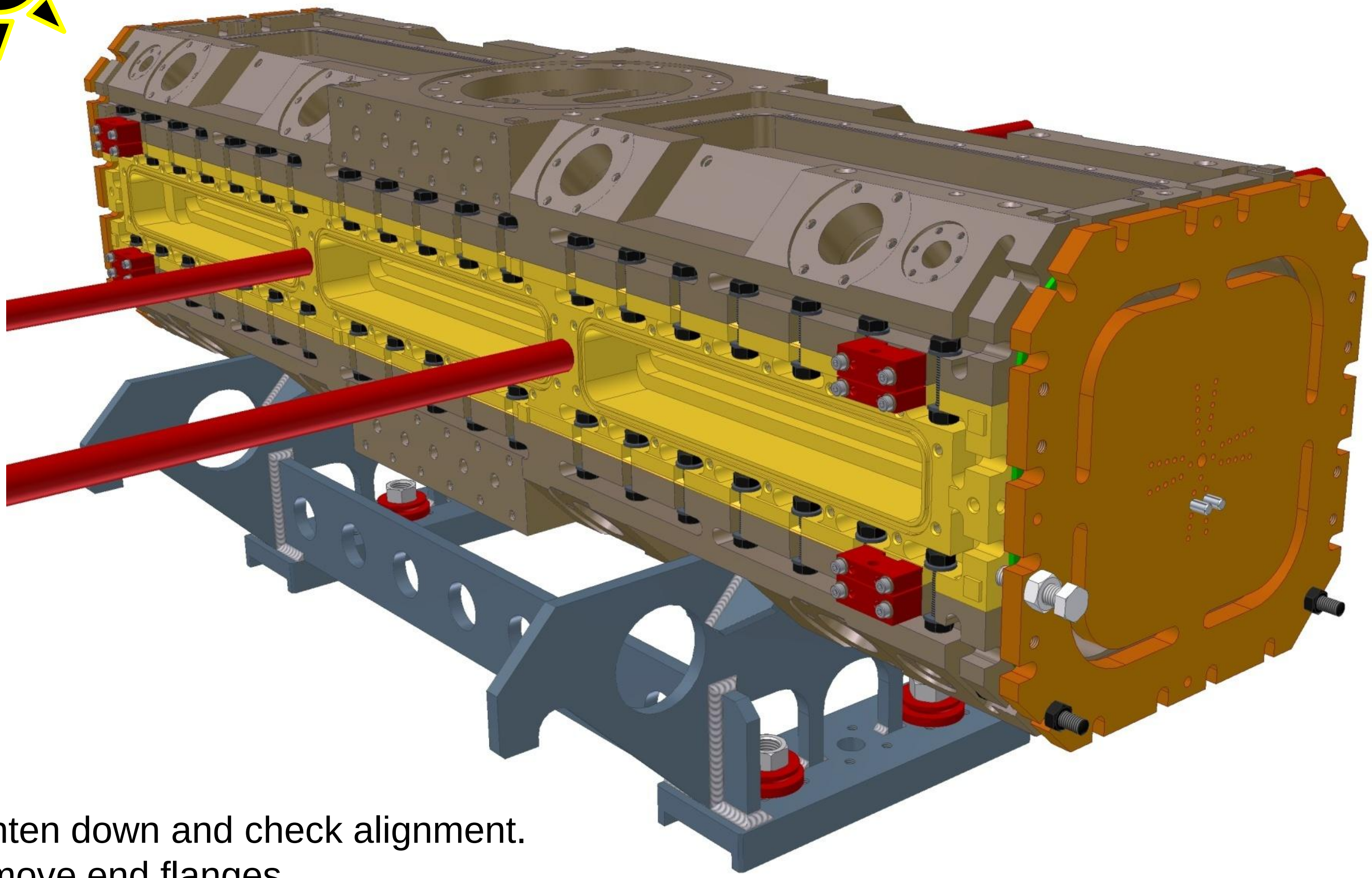
NEW

Locate minor vane 2 on dowels



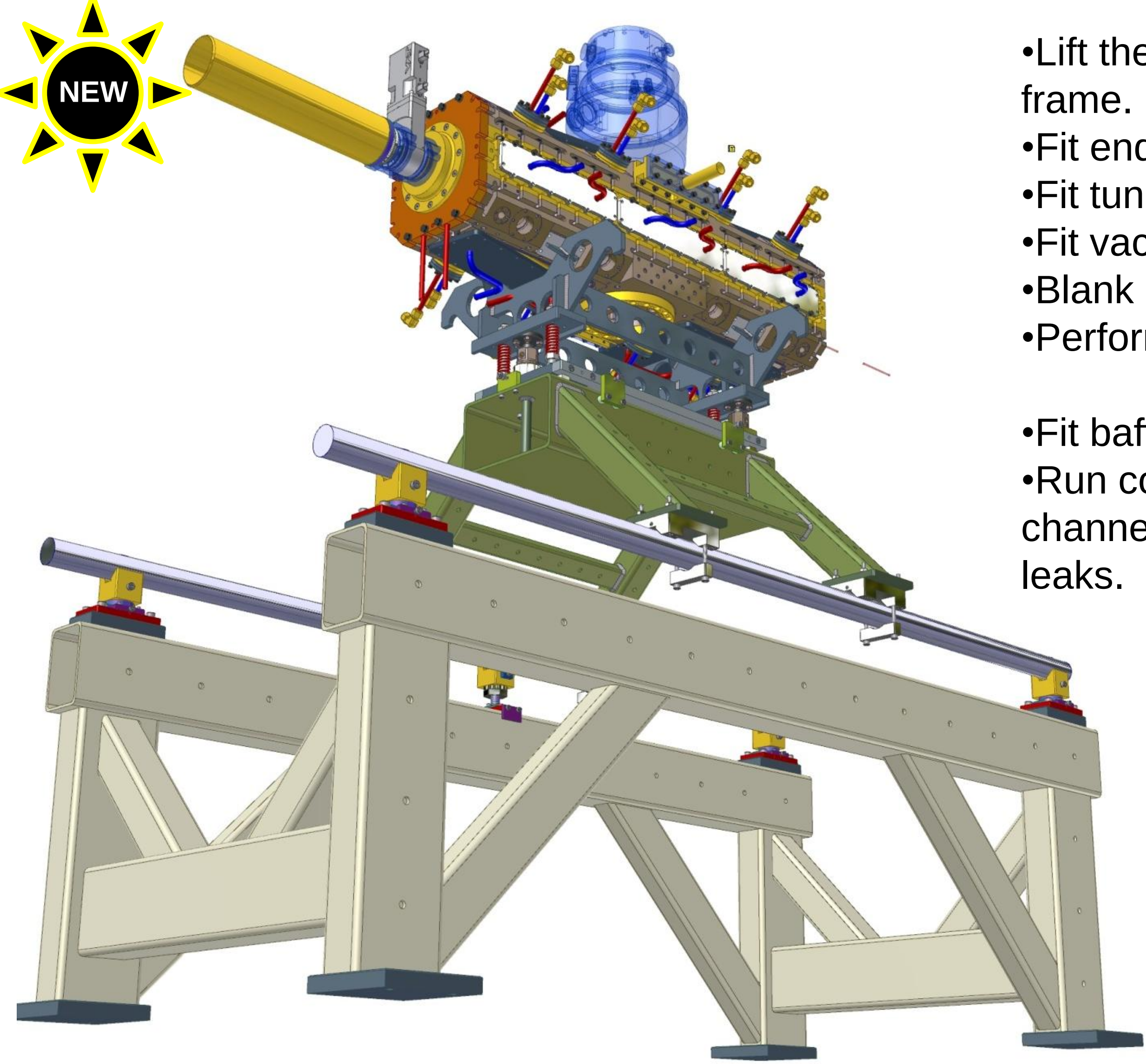
NEW

Fit the top major vane



Tighten down and check alignment.
Remove end flanges.

NEW



- Lift the cradle onto the RFQ support frame.
- Fit end flanges
- Fit tuners or blank off.
- Fit vacuum pump
- Blank off lower vacuum port
- Perform vacuum test

- Fit baffles and lids
- Run cooling water through cooling channels one by one checking for leaks.

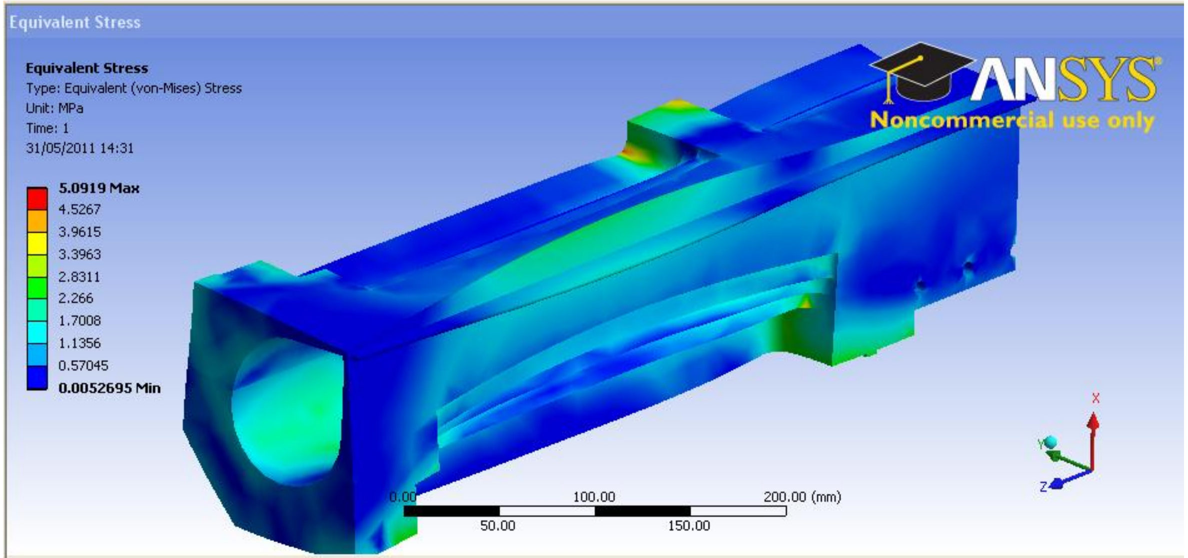
Load due to atmospheric pressure and weight of vacuum pump

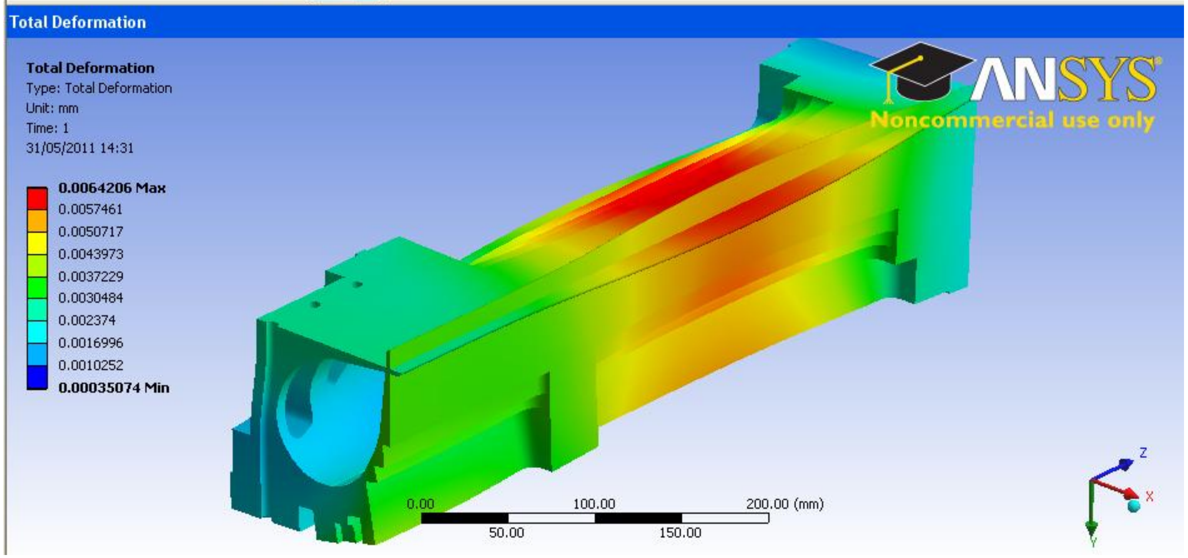
- Quarter de-featured model
- 3 symmetry planes
- Nodes: 24,500

Loads:
- 100,000 Pa atmosphere
- 300N vacuum pump

Results:
Max. Equ stress: 4.6MPa
In region of cooling pocket internal corners.

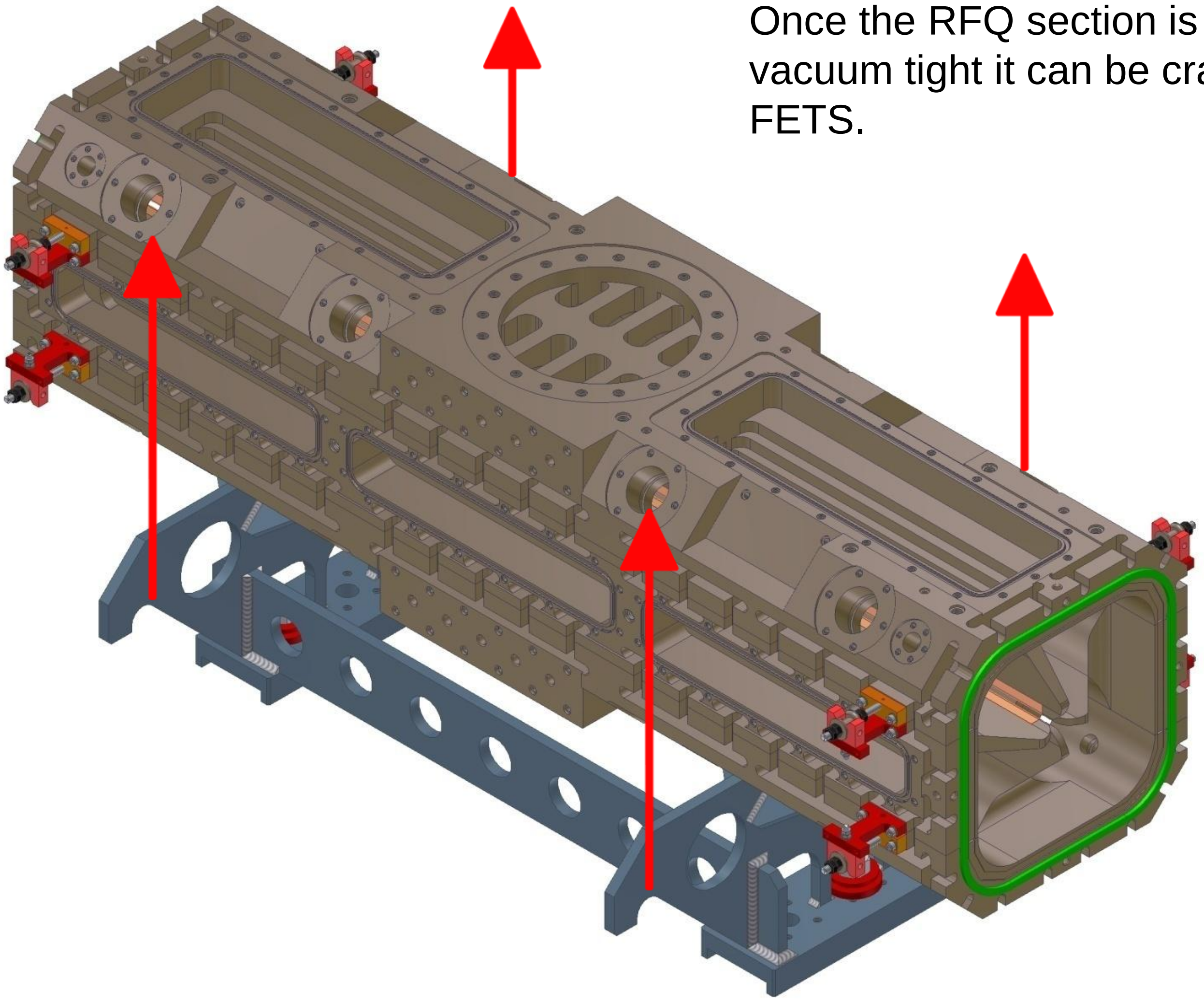
Max. Deformation: 0.0065mm
Vane tips move towards beam axis





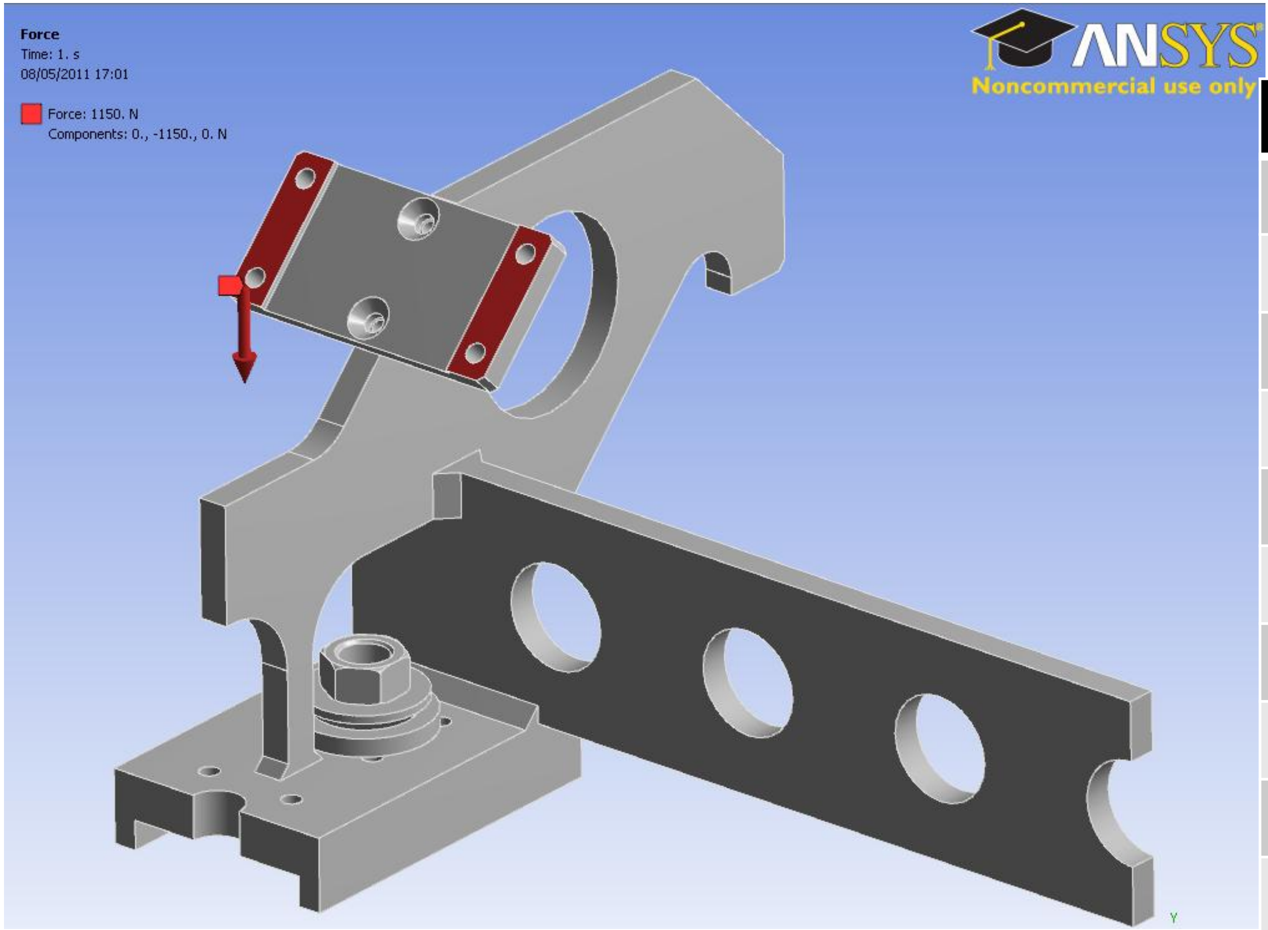
Part 3

Alignment of completed
assembly w.r.t. the FETS.



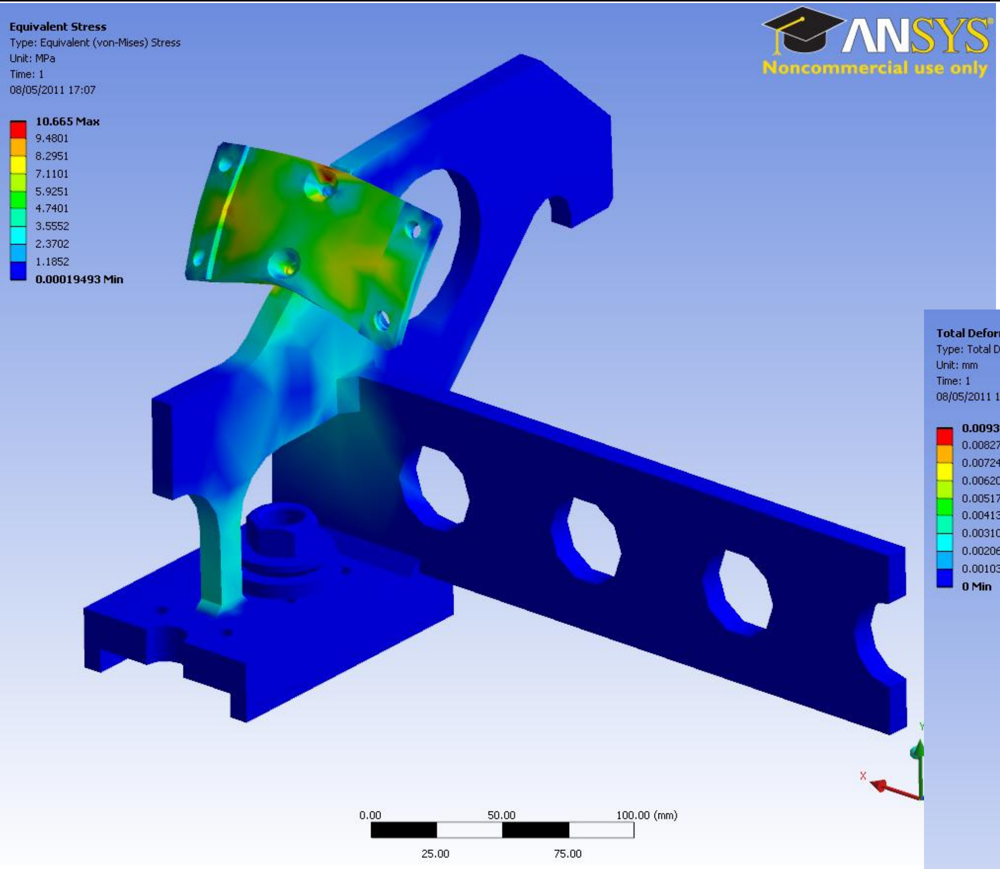
Once the RFQ section is aligned and vacuum tight it can be craned onto the FETS.

Structural steel, quarter cradle model, 2 symmetry planes, load = 1150 N

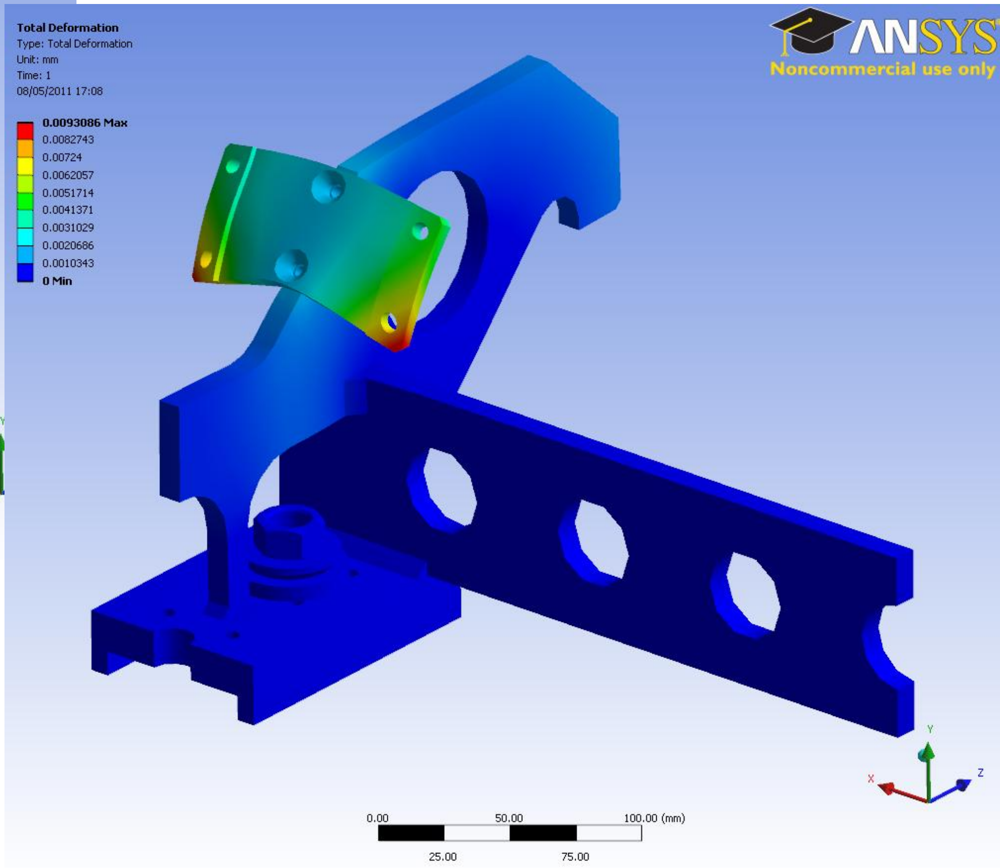


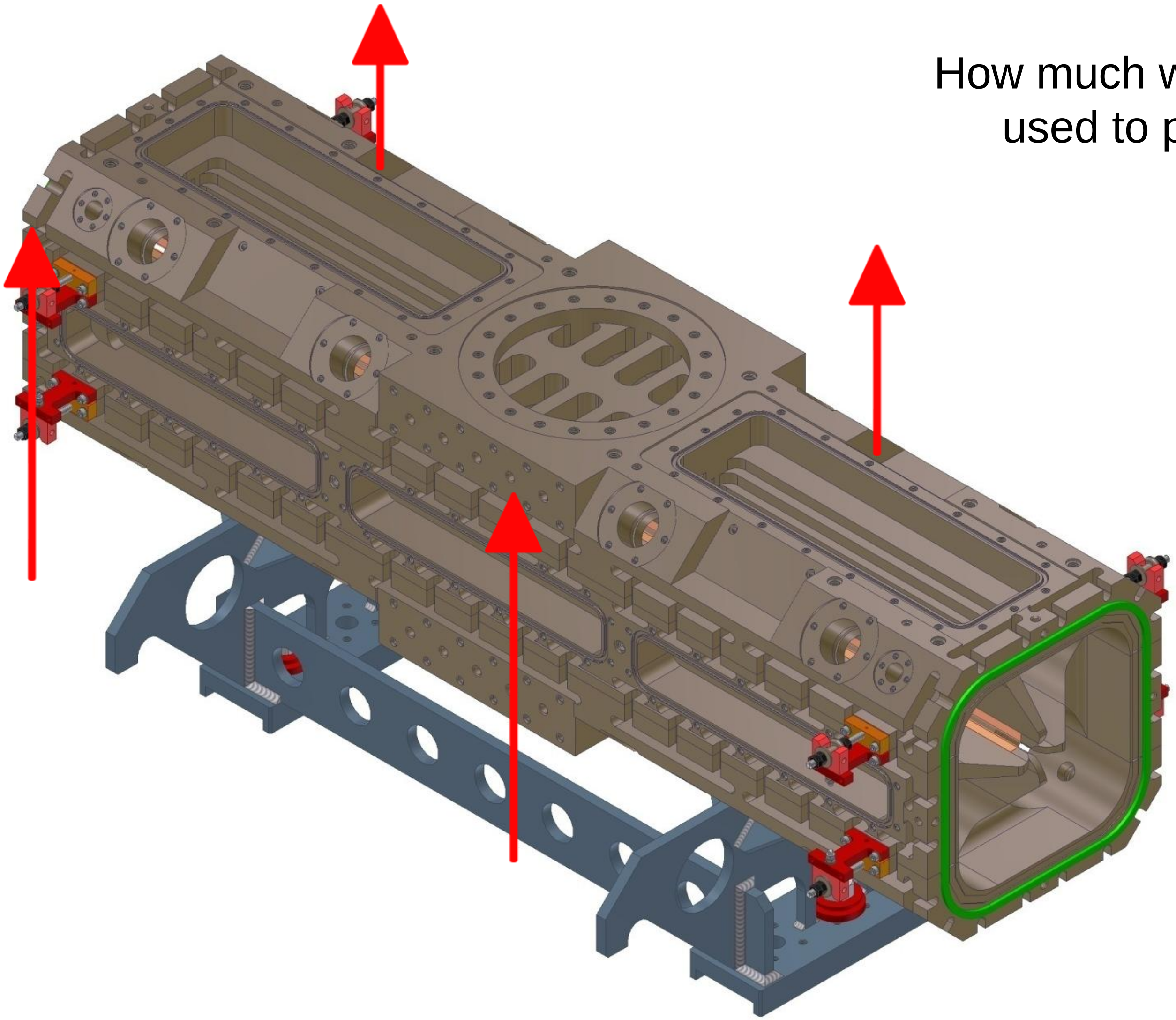
Component	Mass (kg)
Major vane	80
Major vane	80
Minor vane	30
Minor vane	30
Kinematics	10
Cradle	20
Vac pump	30
Tuners x 16	80
Baffles	100
TOTAL	460
Load per ¼	115

QN: What is the stress and deformation in the RFQ support cradle due to the weight of the RFQ and the ancillary components?



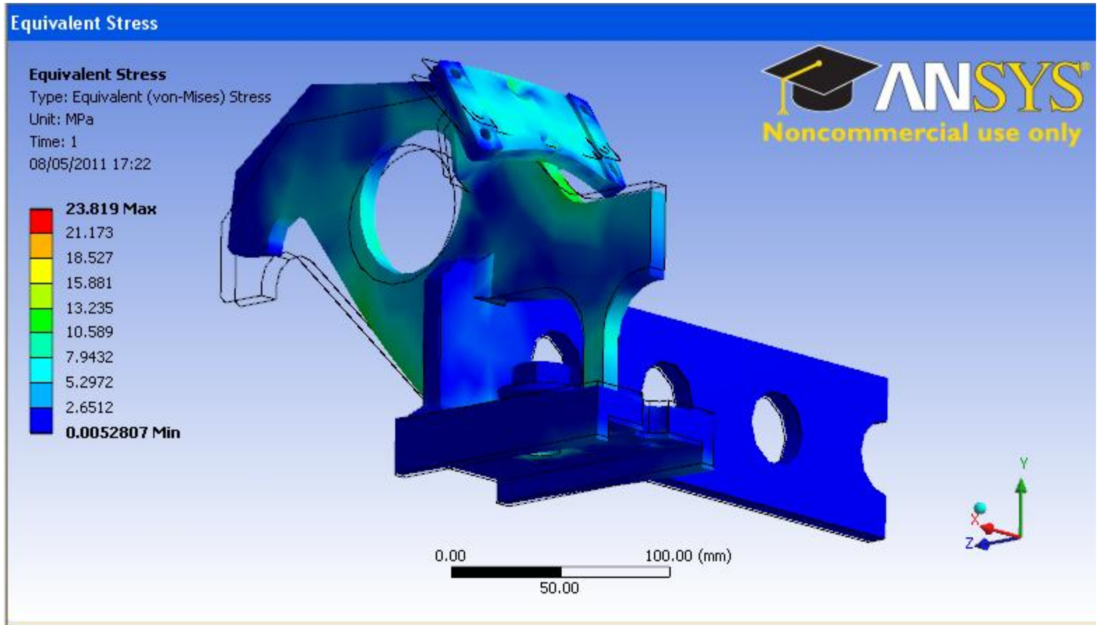
Maximum equivalent stress = 10MPa
Maximum deformation = 0.01 mm



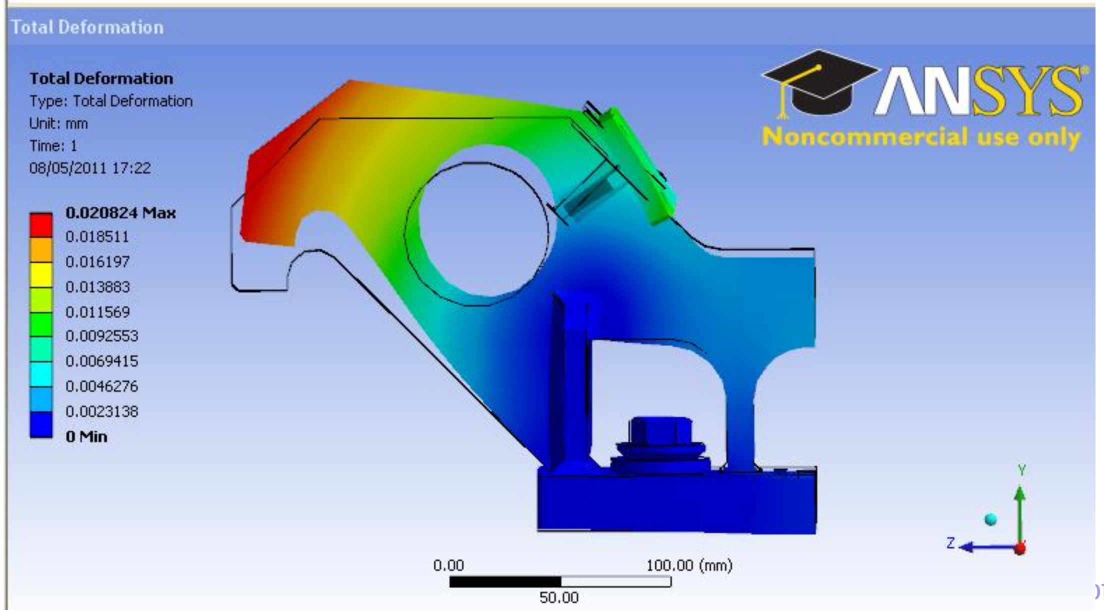


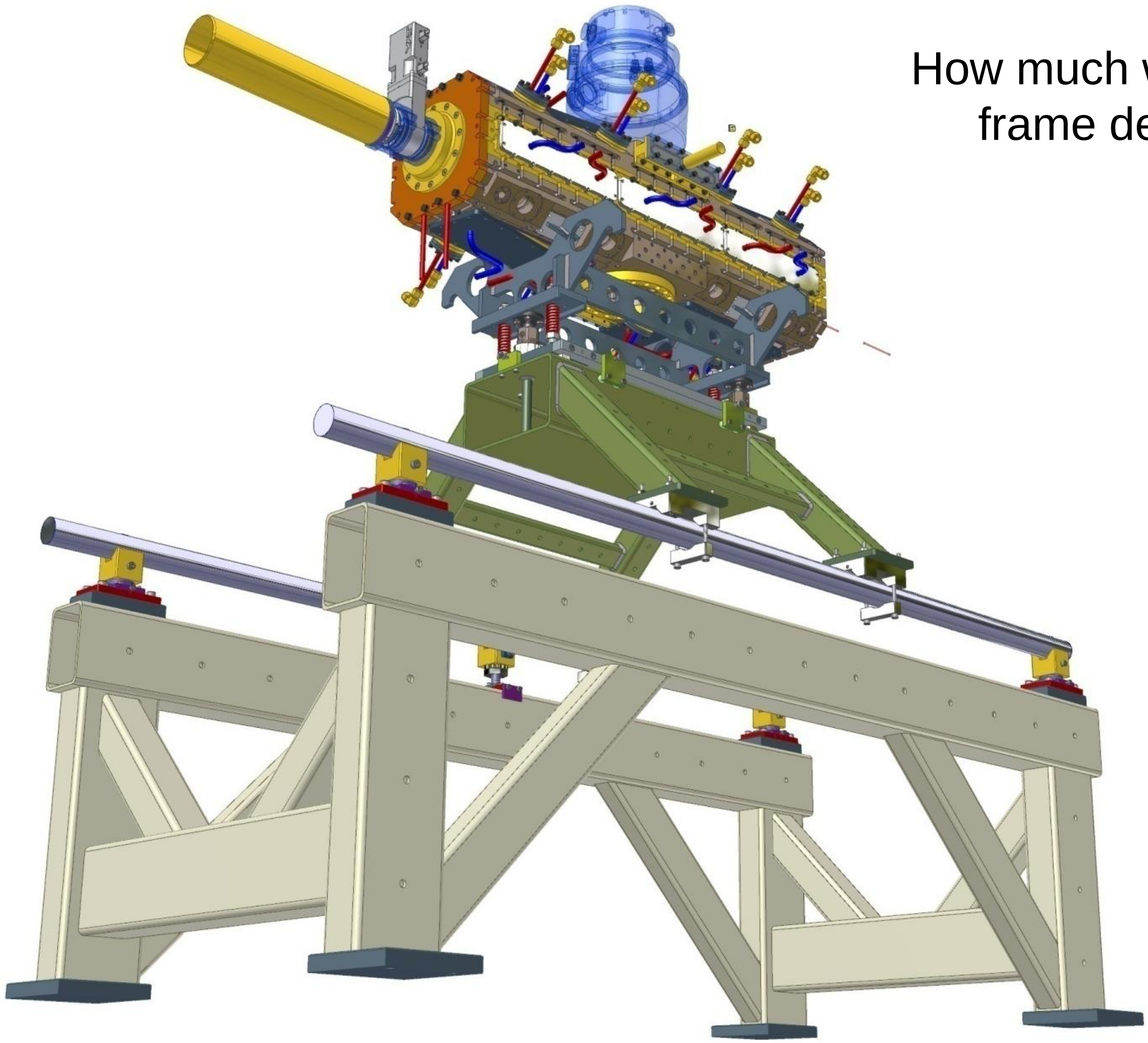
How much will the cradle distort when used to pick up the whole RFQ section?

Max stress = 24 MPa



Max deformation = 0.02mm

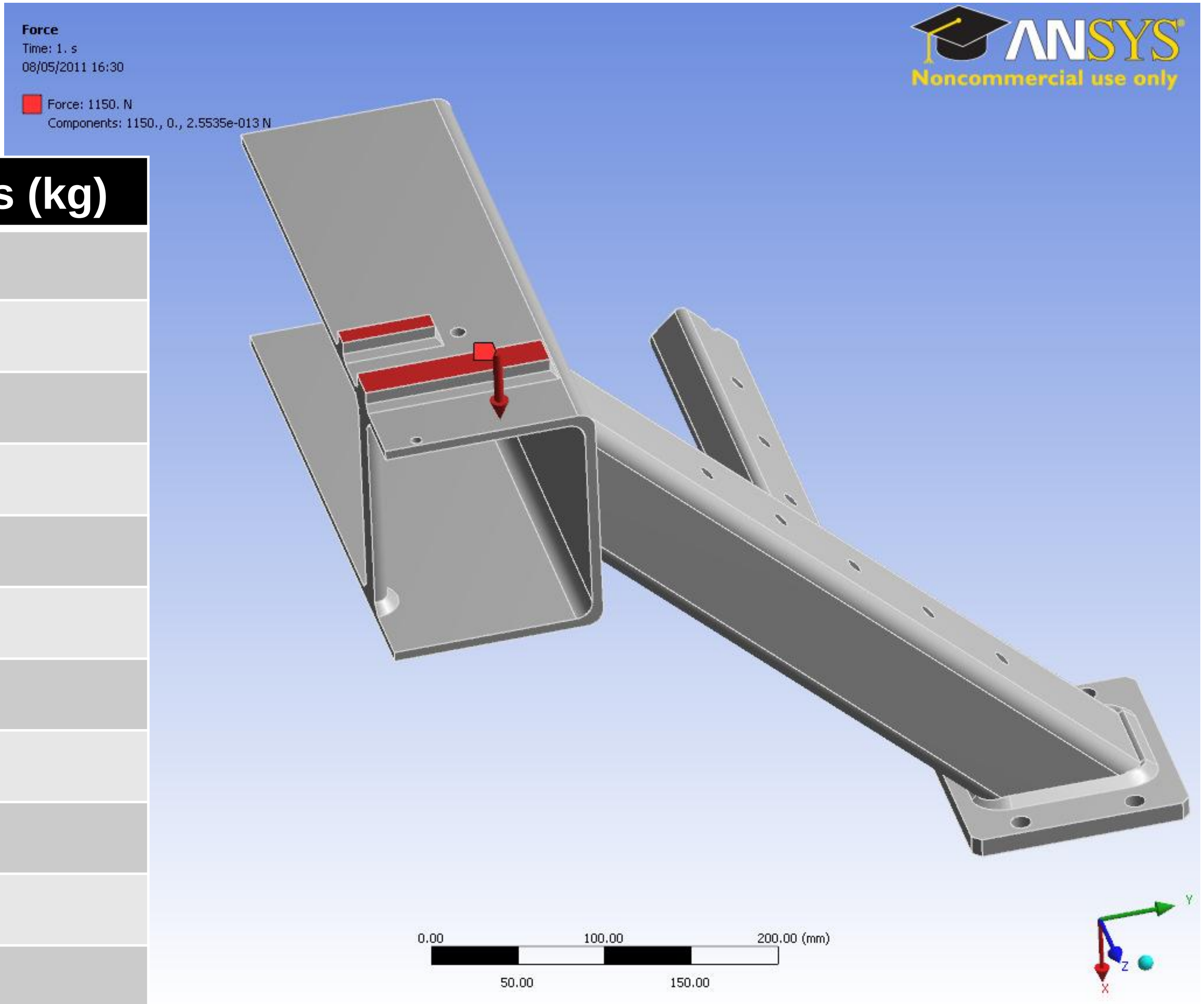




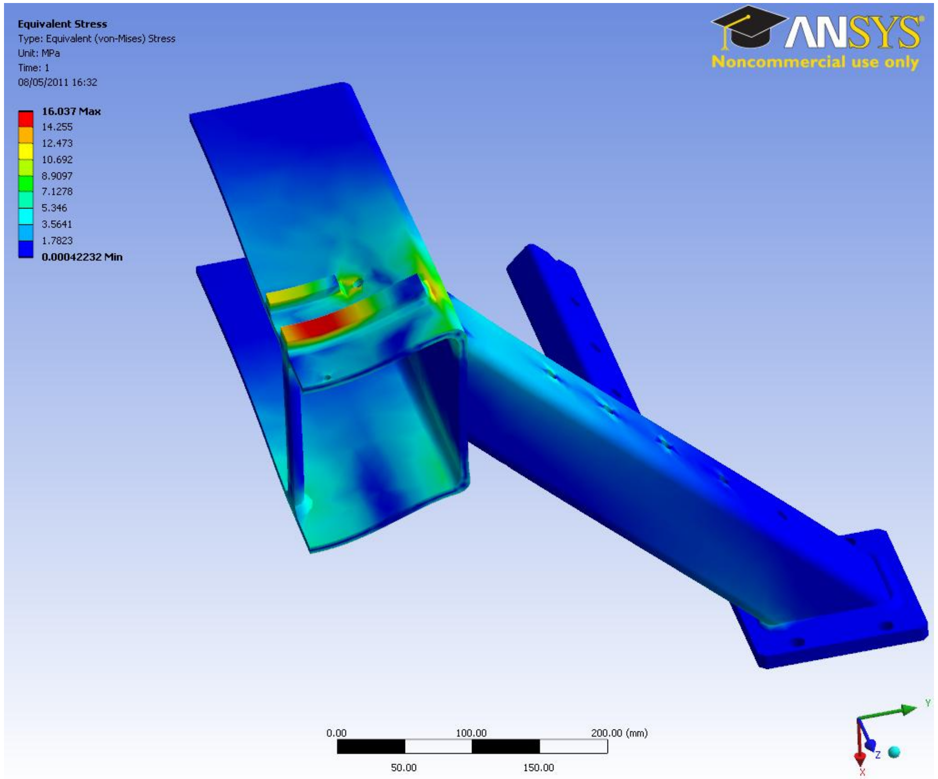
How much will the green RFQ support frame deflect under the weight?

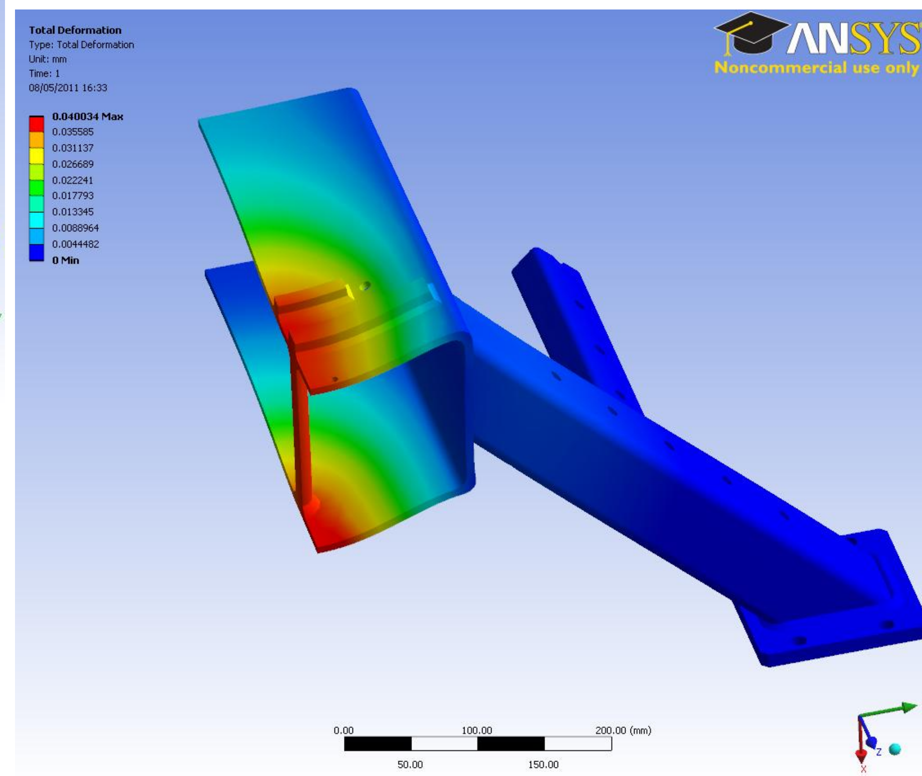
Structural steel, quarter cradle model, 2 symmetry planes, load = 1150 N

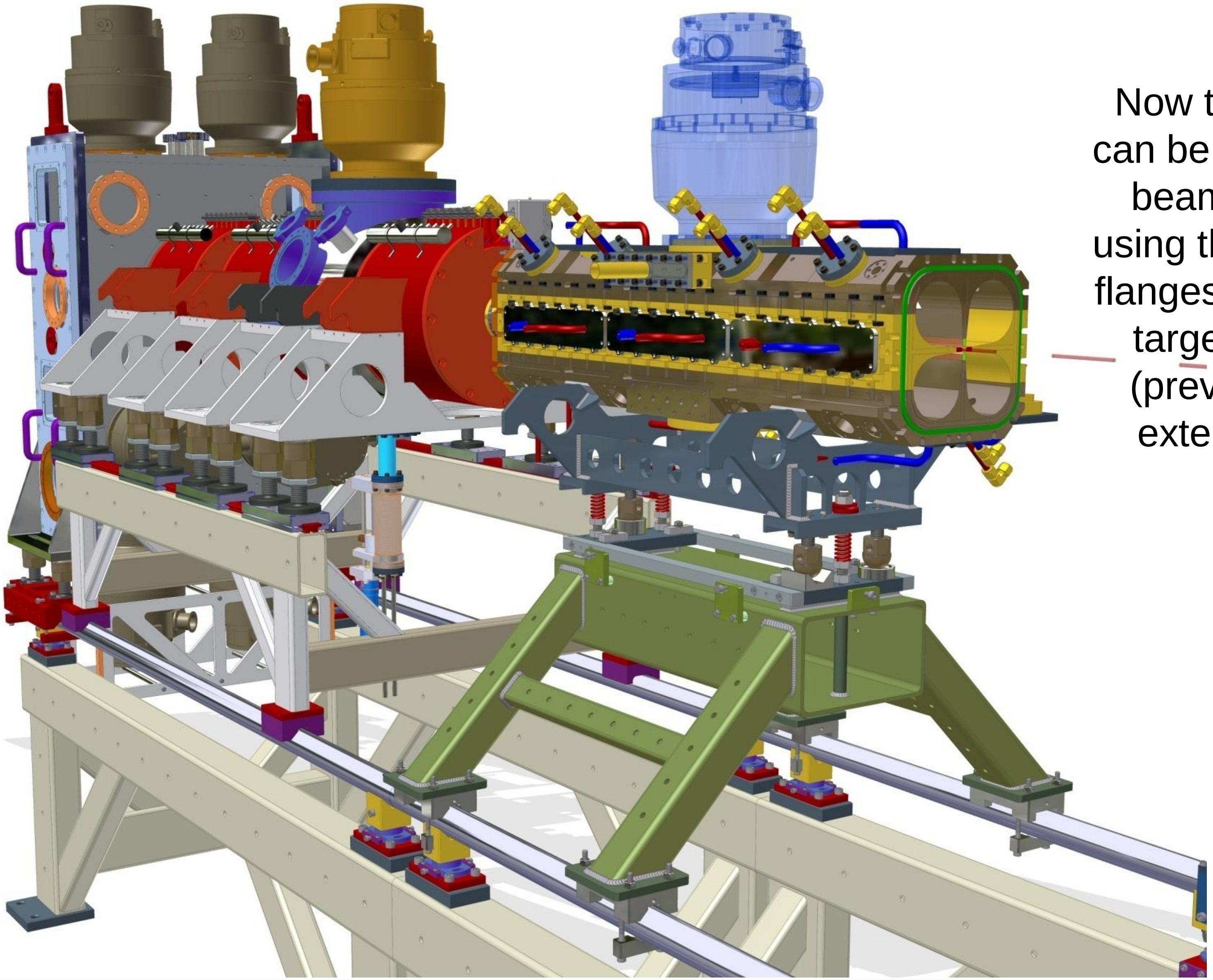
Component	Mass (kg)
Major vane	80
Major vane	80
Minor vane	30
Minor vane	30
Kinematics	10
Cradle	20
Vac pump	30
Tuners x 16	80
Baffles	100
TOTAL	460
Load per ¼	115



Maximum equivalent stress = 16MPa
Maximum deformation = 0.04 mm





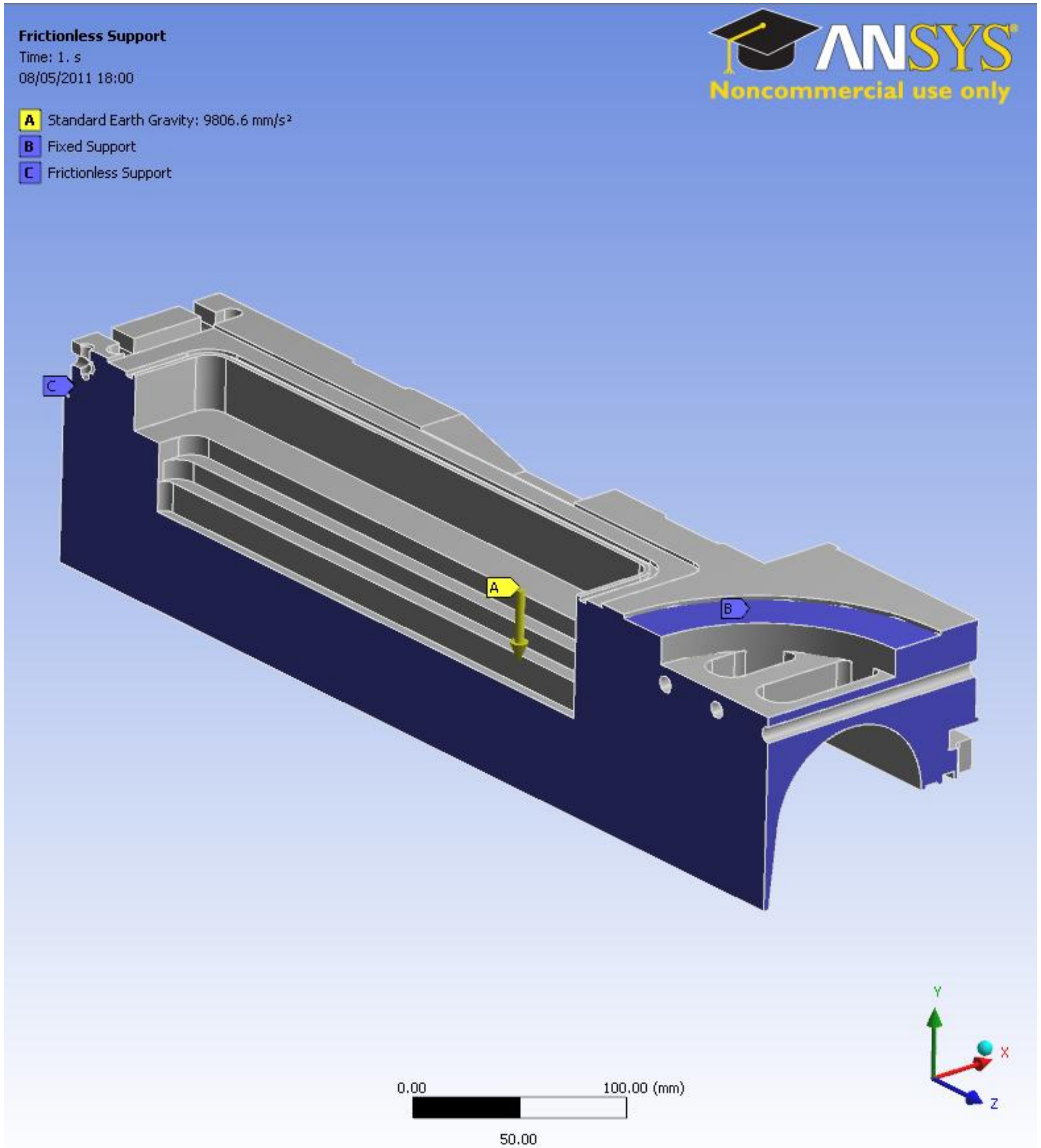


Now the RFQ section can be positioned to the beam axis either by using the alignment end flanges equipped with a target or by using a (previously) defined external reference.

Hypothetical Case 1

Supporting one major vane by the vacuum port flange.

We would never do this – it's just to get a feel for the stiffness of the vanes.

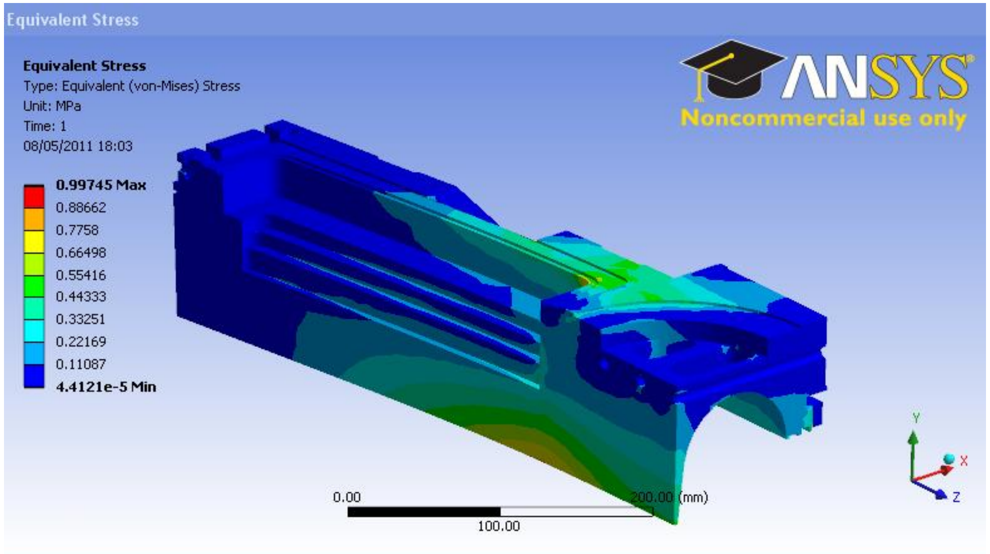


The simulation model

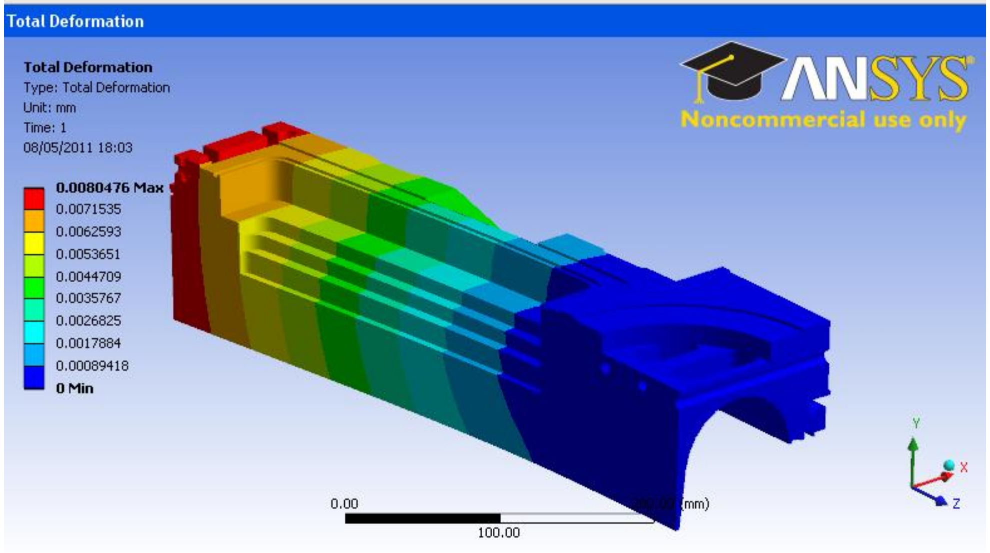
Imagine we supported one RFQ major vane by the vacuum port flange.

QN: How much does the major vane sag under it's own weight?

Max stress =
1 MPa



Max deformation =
0.008mm

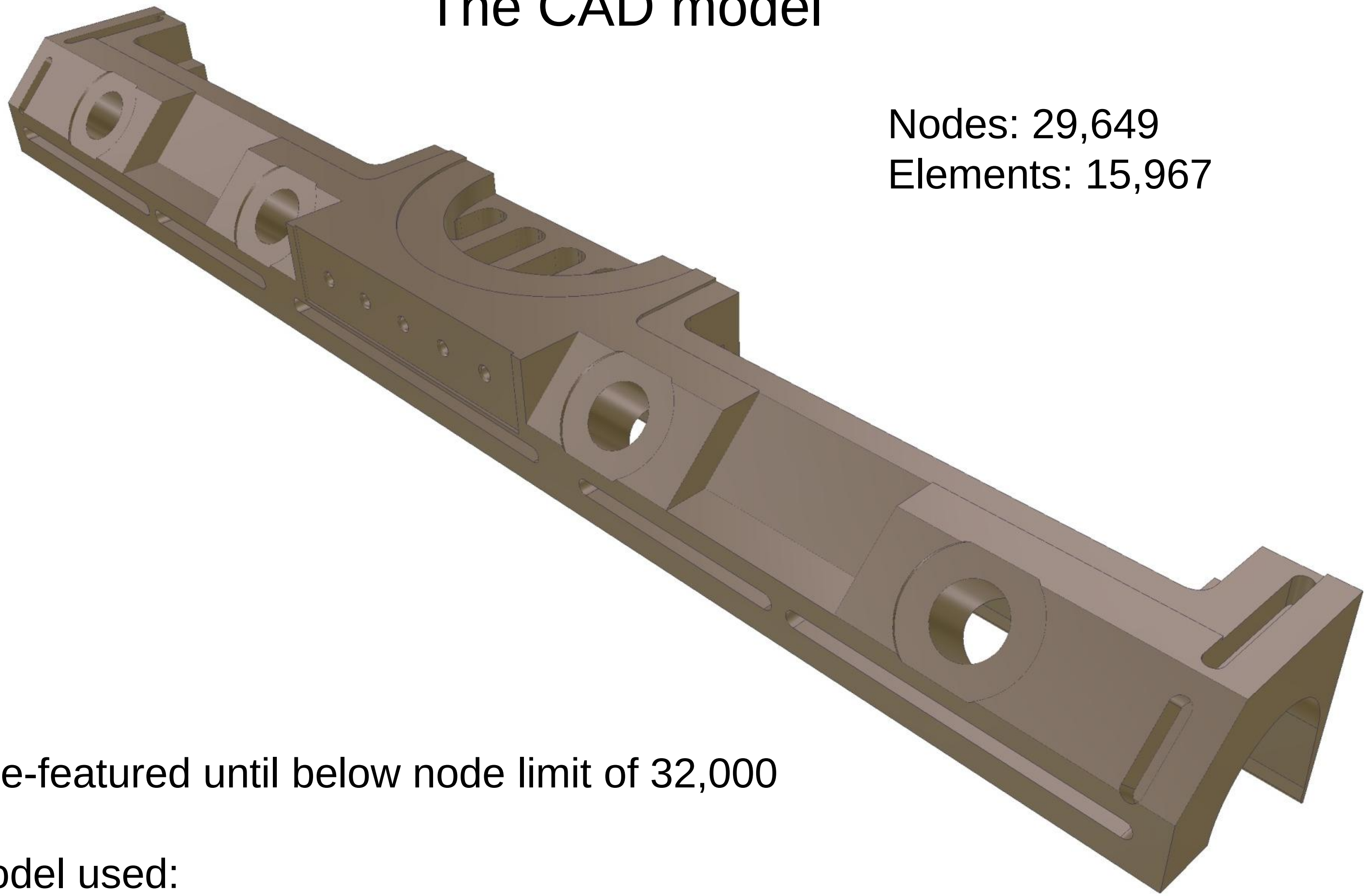


Hypothetical Case 2

Supporting one major vane by the end (cantilevered).

We would never do this – it's just to get a feel for the stiffness of the vanes.

The CAD model



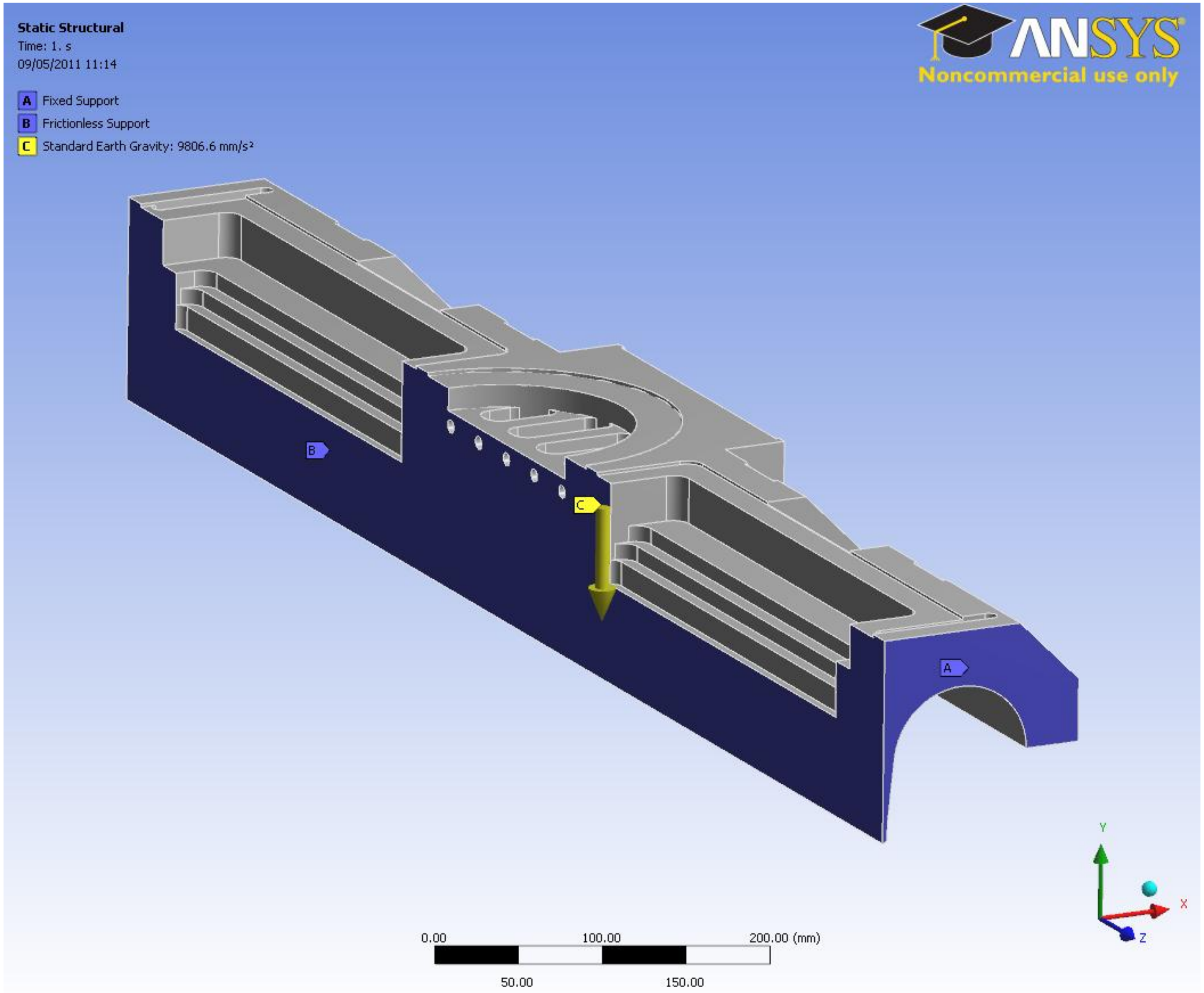
Nodes: 29,649
Elements: 15,967

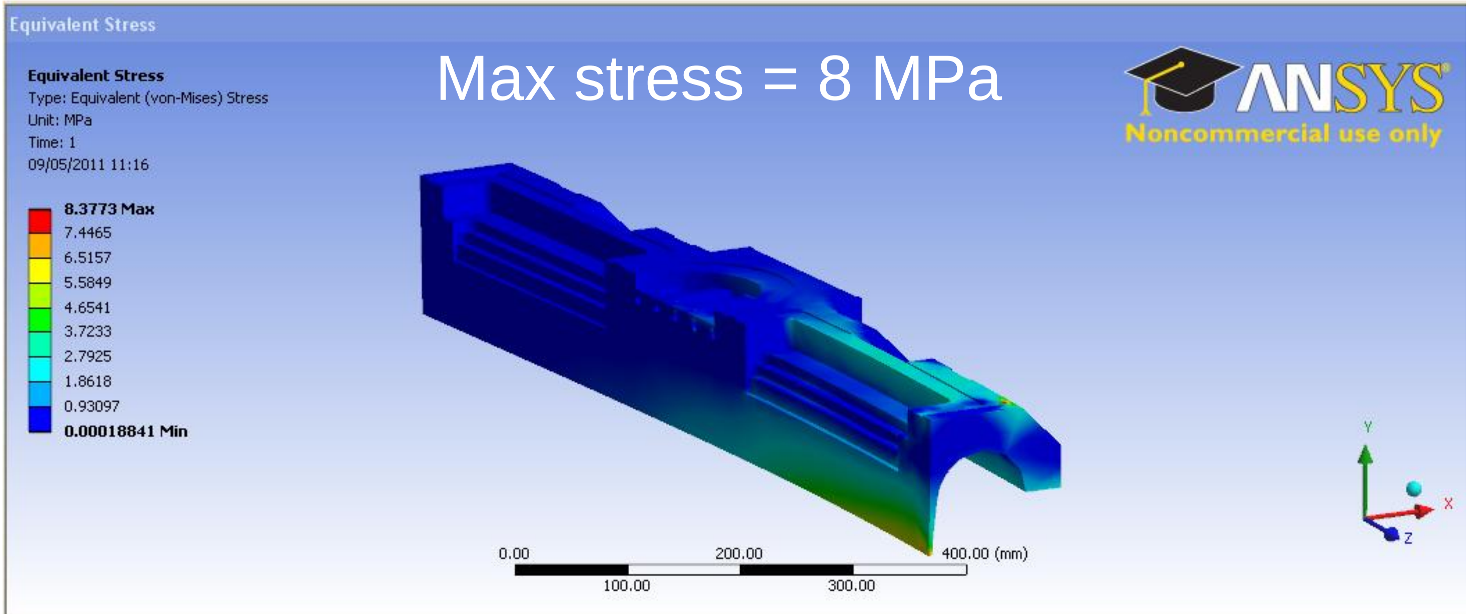
Model de-featured until below node limit of 32,000

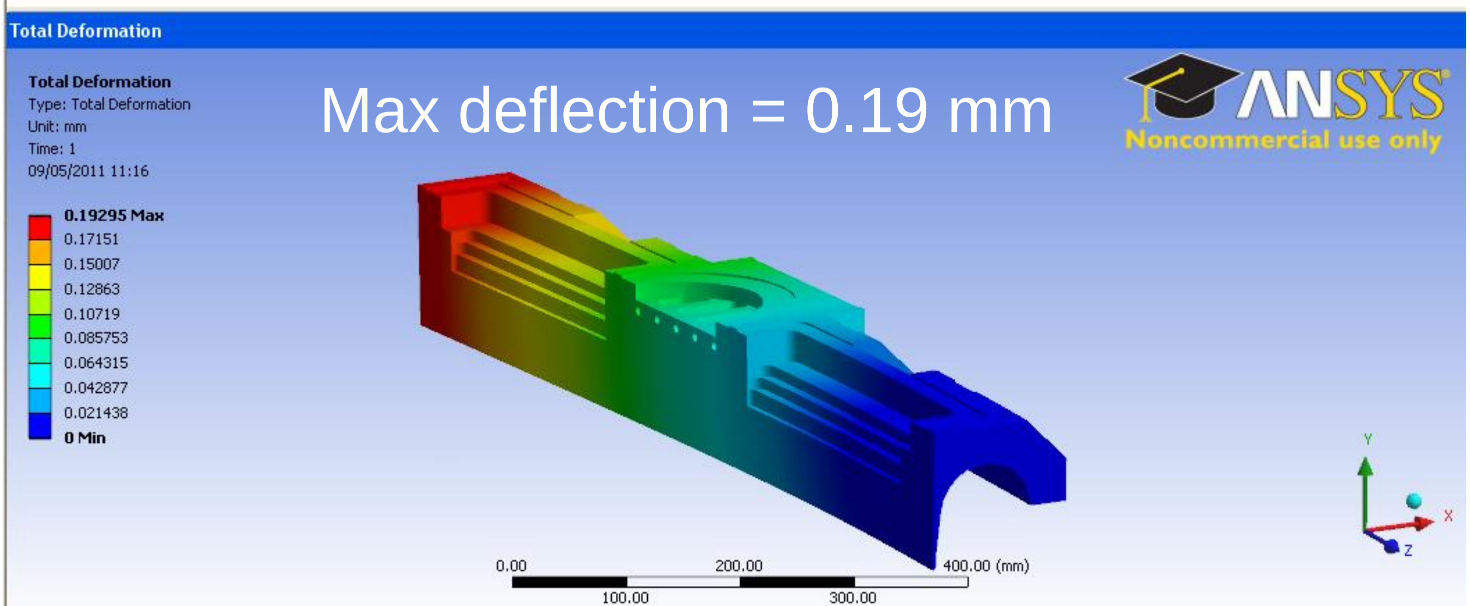
CAD model used:

D:\Pete\CAD_2004-now\FETSProject_B\RFQ_Vane\PhysicsModel13\SIMULATIONS\MODELS\RFQ_v13_MajorVane_1_Half

The simulation model



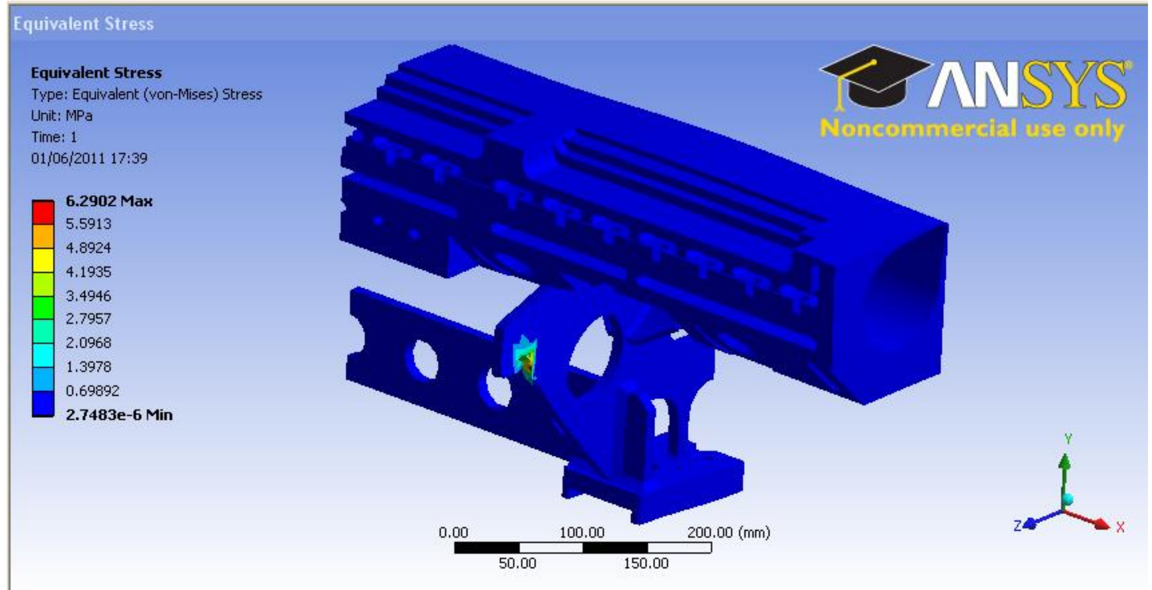

Equivalent Stress
Max stress = 8 MPa
Equivalent Stress
Type: Equivalent (von-Mises) Stress
Unit: MPa
Time: 1
09/05/2011 11:16
8.3773 Max
7.4465
6.5157
5.5849
4.6541
3.7233
2.7925
1.8618
0.93097
0.00018841 Min
ANSYS
Noncommercial use only
0.00
200.00
400.00 (mm)
100.00
300.00
Y
X
Z


Total Deformation
Max deflection = 0.19 mm
Total Deformation
Type: Total Deformation
Unit: mm
Time: 1
09/05/2011 11:16
0.19295 Max
0.17151
0.15007
0.12863
0.10719
0.085753
0.064315
0.042877
0.021438
0 Min
ANSYS
Noncommercial use only
0.00
200.00
400.00 (mm)
100.00
300.00
Y
X
Z

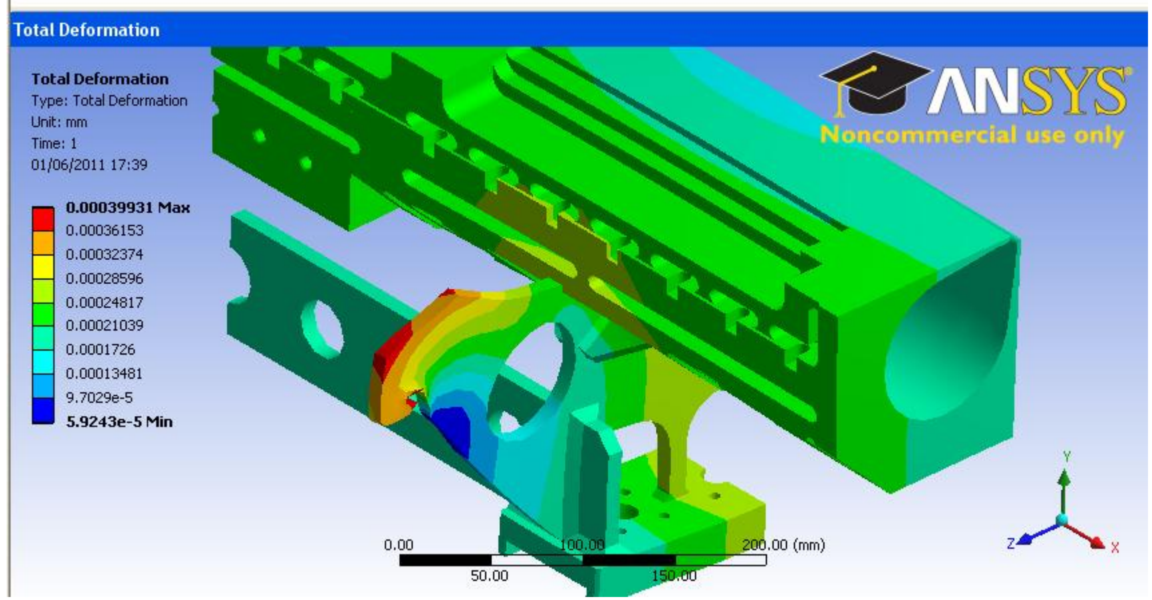
Case 3

Lifting the complete 1m RFQ section in the cradle.

Max stress = 6.2 MPa



Max deformation = 0.0003mm



Use of tapped holes in Copper

Depth of tapped holes in Copper

Effective length of thread engagement

External thread fastener:

Thread - steel grade	M8 - 8.8	
Ratio of shear strength to tensile strength τ/σ	0.580	(steel)

Internal thread tapped hole:

Tensile strength σ	220	MPa
Ratio of shear strength to tensile strength τ/σ	0.65	~~(cast iron)~~

Solve | Reset | Print

tensile stress area $A_t = \pi/4\ d_0^2$; $d_0 = (d_2 + d_3)/2$	36.61	mm^2
ultimate tensile strength R_m	800	MPa
yield strength $R_{p0.2}$	640	MPa
maximum tensile load $F_{0.2} = R_{p0.2} \times A_t$	23.43	kN
ultimate tensile load $F = Rm \times A_t$	29.28	kN
ultimate shear stress T	143	MPa
required shear area external thread $A_{th} = F/T$	204.79	mm^2
Effective length of thread engagement L_e [1)]	20.77	**mm**

[1)] Minimum value of thread engagement length to make the tensile area determinative for the load at which the screw joint fails.

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Thread size	Thread depth
M4	10 mm
M5	13 mm
M6	15 mm
M8	21 mm
M10	26 mm

One M8 bolt can take 23kN (2.3 tonnes) tensile load.

Thread depth in Copper required to match the bolt tensile area = 21 mm.

Tapped holes in FETS RFQ – are they deep enough?

Tapped hole feature	Thread size	Recommend depth *	Actual depth
Tuner Port	M5	13 mm	14 mm +1 mm
Probe port	M4	10 mm	12 mm + 2 mm
Assembly blocks	M4	10 mm	10 mm + 0 mm
Cooling channel covers	M6	15 mm	18 mm + 3 mm
Vacuum port cooling manifold	M6	15 mm	18 mm + 3 mm
Vacuum pump mounting	M8	21 mm	16 mm – 5 mm
Lifting holes	M10	26 mm	26 mm + 0 mm

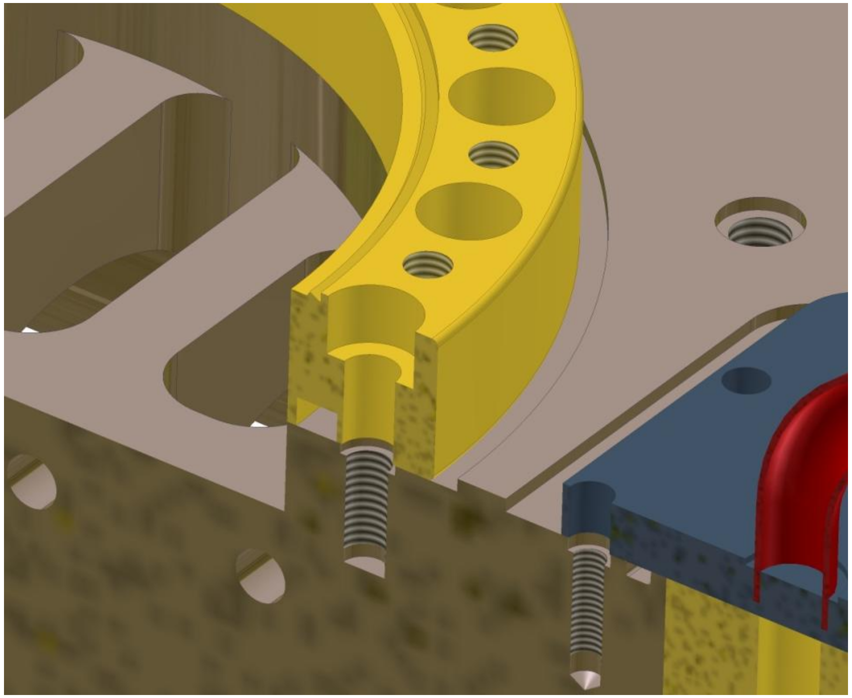
*The minimum value of thread engagement to make the tensile area determinative for the load at which the screw joint fails.

Tapped holes in FETS RFQ – are they deep enough?

One of our features has tapped holes that do not meet the minimum recommended depth.

Why?

Because any deeper and they would break into the cooling holes.



Should we be concerned?

- Each hole is 75% of the recommended minimum depth.
- There are 20 holes.
- Only required to fully compress O ring.
- Withstand pump vibration over time.
- Plus potential pump seizure.
- Use of interim stainless steel flange which will be bolted on once and not removed.

General rules for RFQ assembly

1. By competent person only.
2. Clean parts and tools.
3. Check all threads are free running and bolts can be screwed in to full depth by hand before attempting to attach item.
4. Only small end of allen key required.
5. Threads to be lubricated.
6. Torques to be specified.