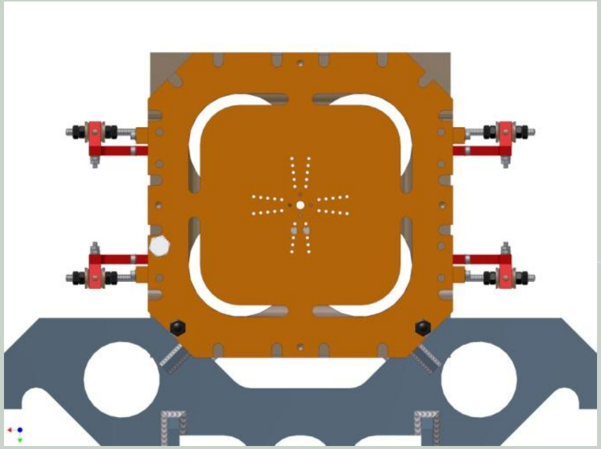
RFQ Assembly Plan #2

1st June 2011

by P. Savage



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 3 parts:

•Part 1: Vane to vane alignment without O ring in place.
•Part 2: Vane to vane alignment with O ring in place.
•Part 3: 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.

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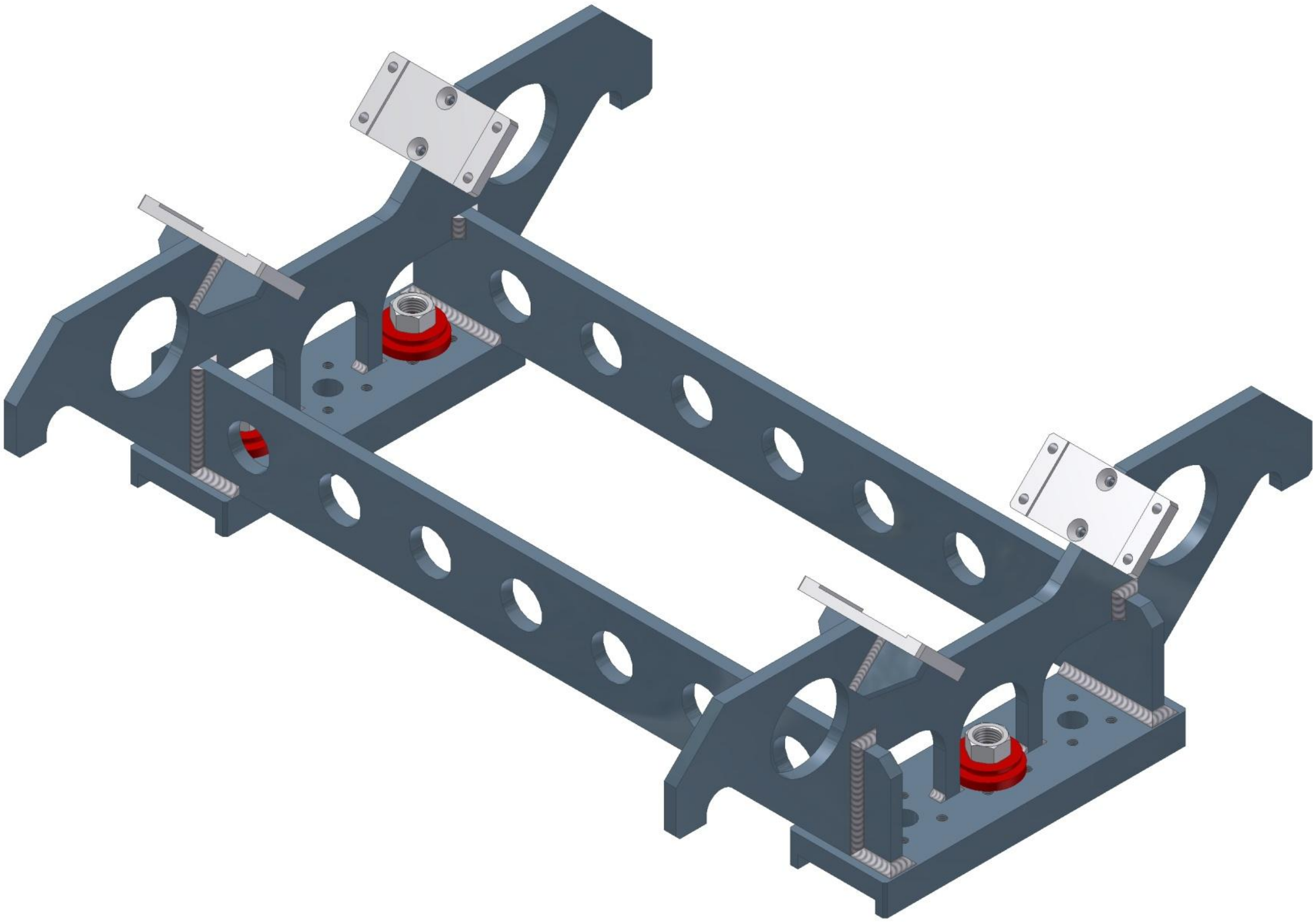
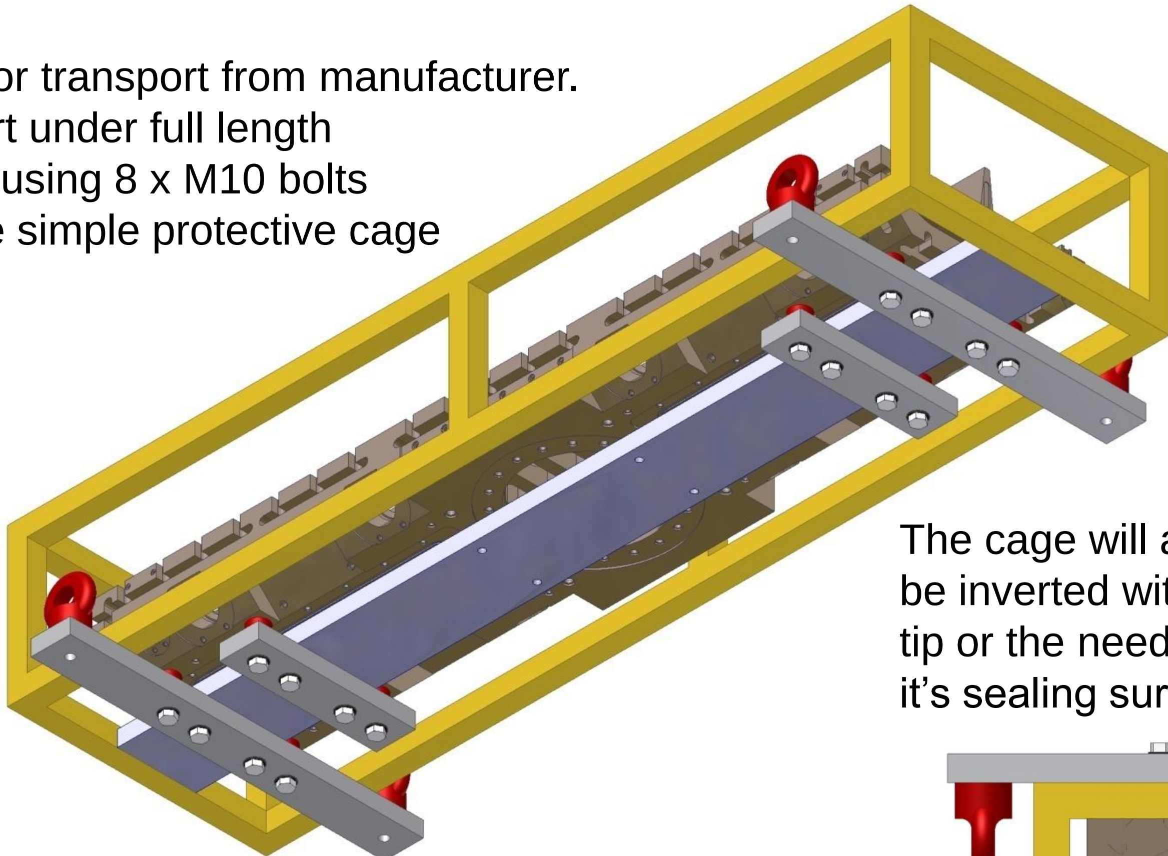
RFQ section will be assembled into the cradle

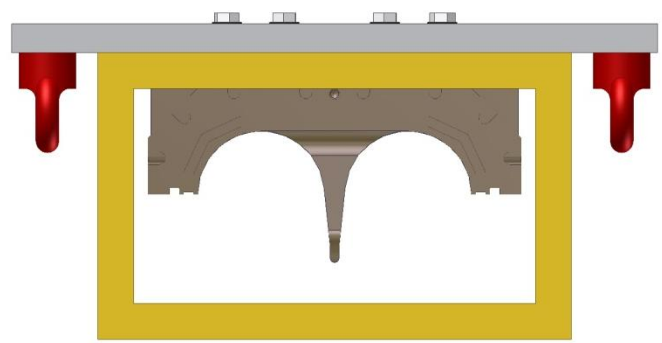


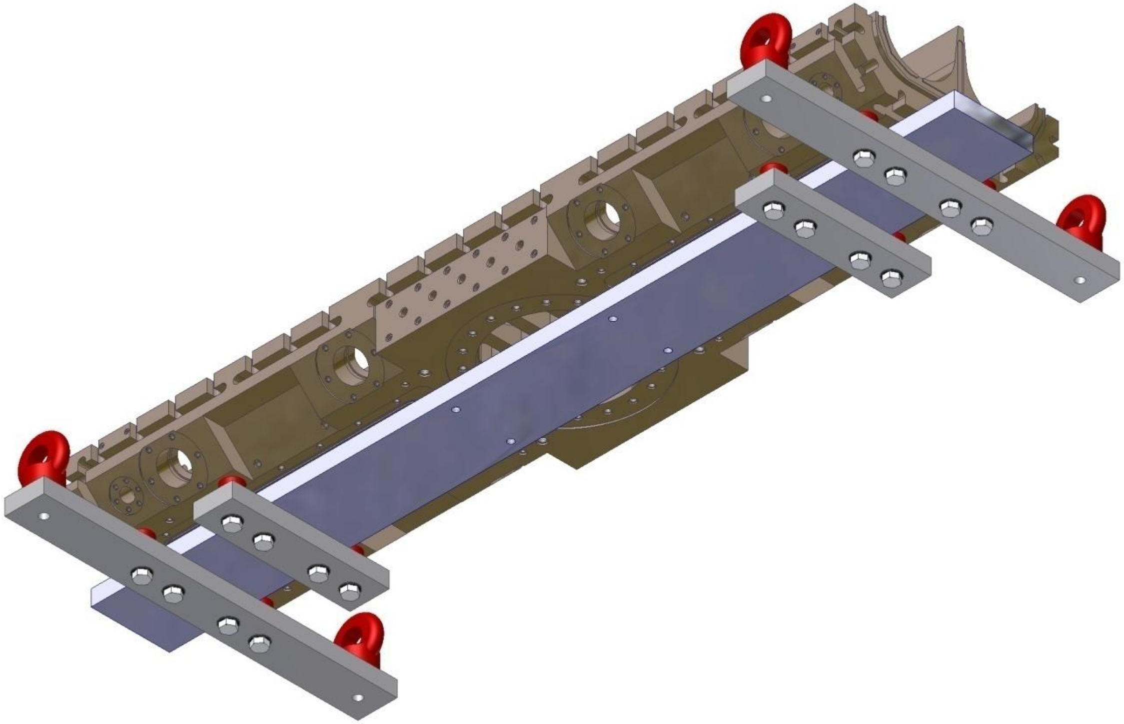
Concept design for Major Vane lifting beam.

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

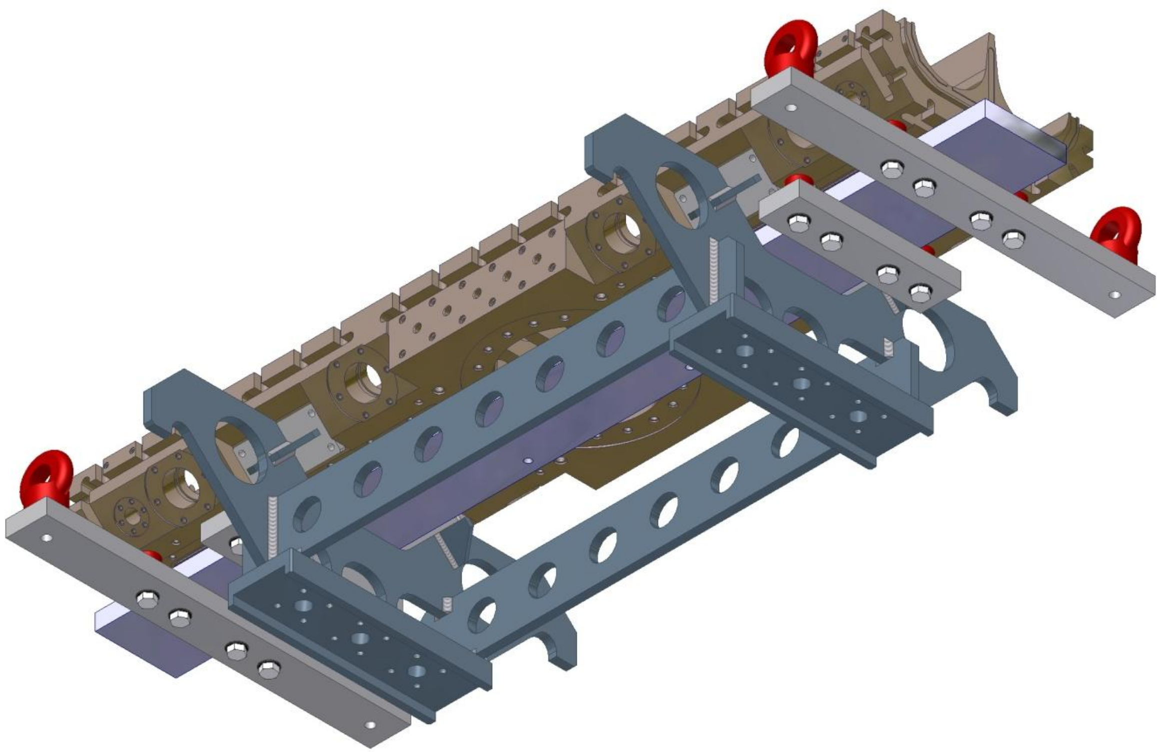


The cage will also enable major vane to be inverted without damage to the vane tip or the need to rest the major vane on it's sealing surfaces.

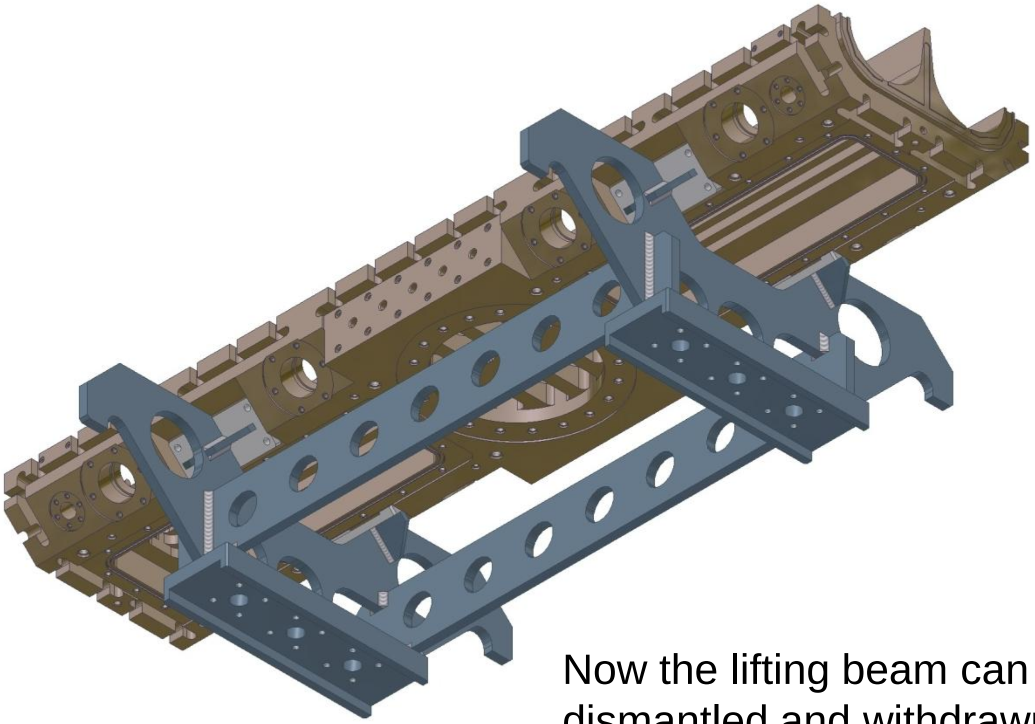


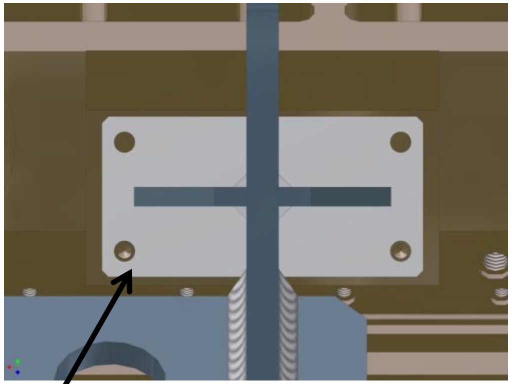


With the protective cage removed the major vane can be lowered into the cradle.



Lifting beam unbolted and removed

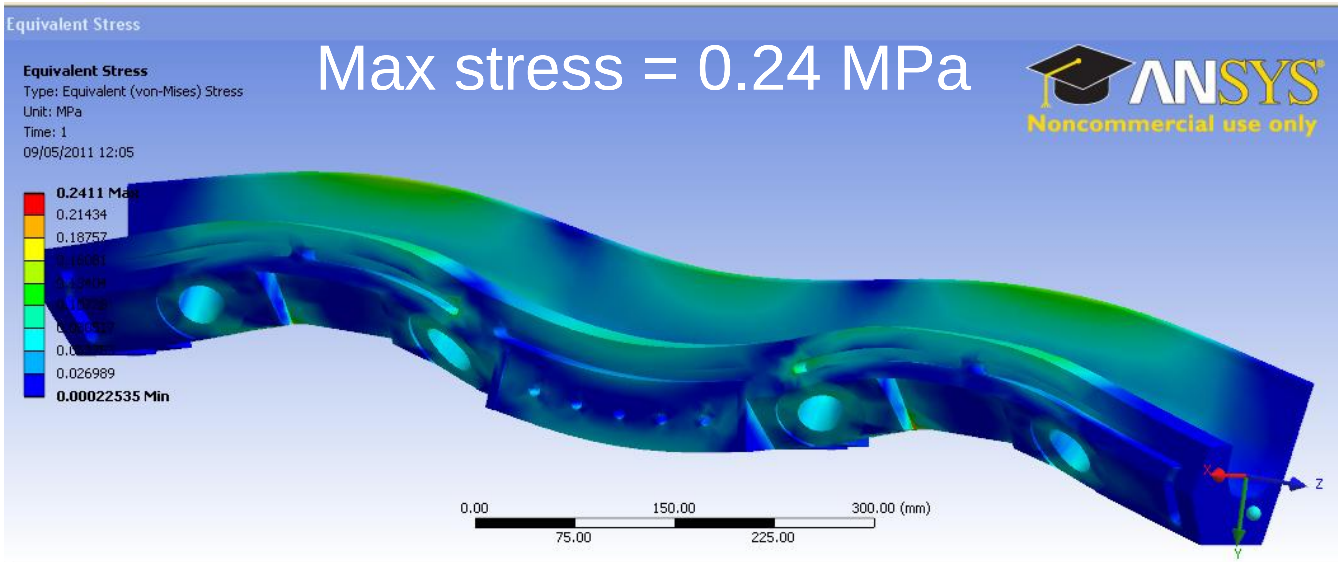


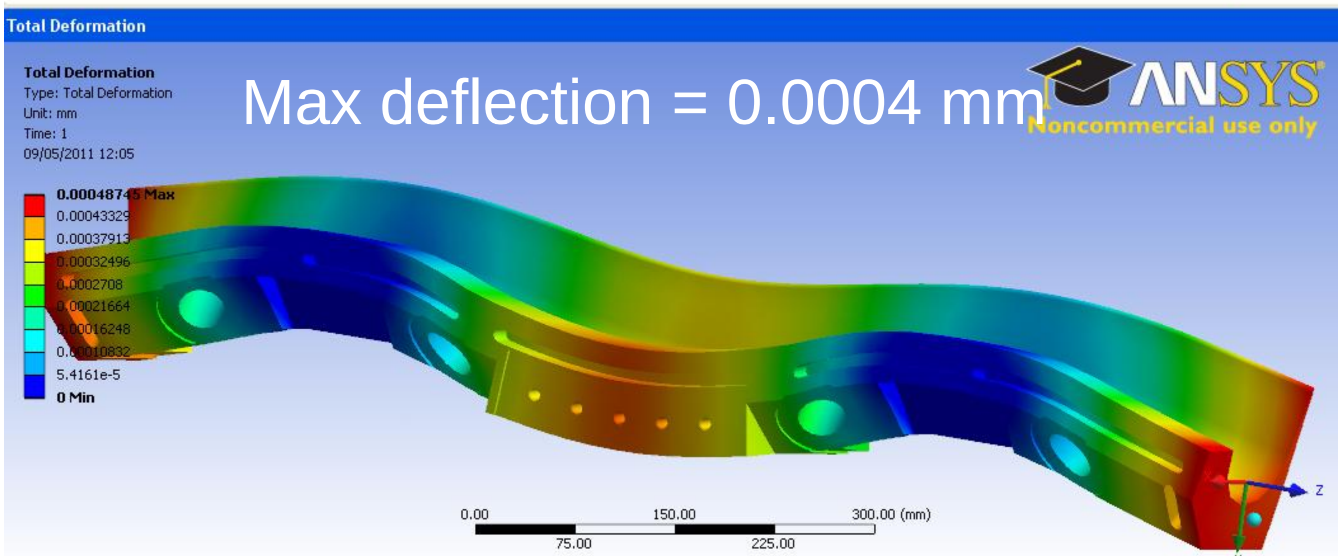


Now the lifting beam can be dismantled and withdrawn from between the vane and the cradle.

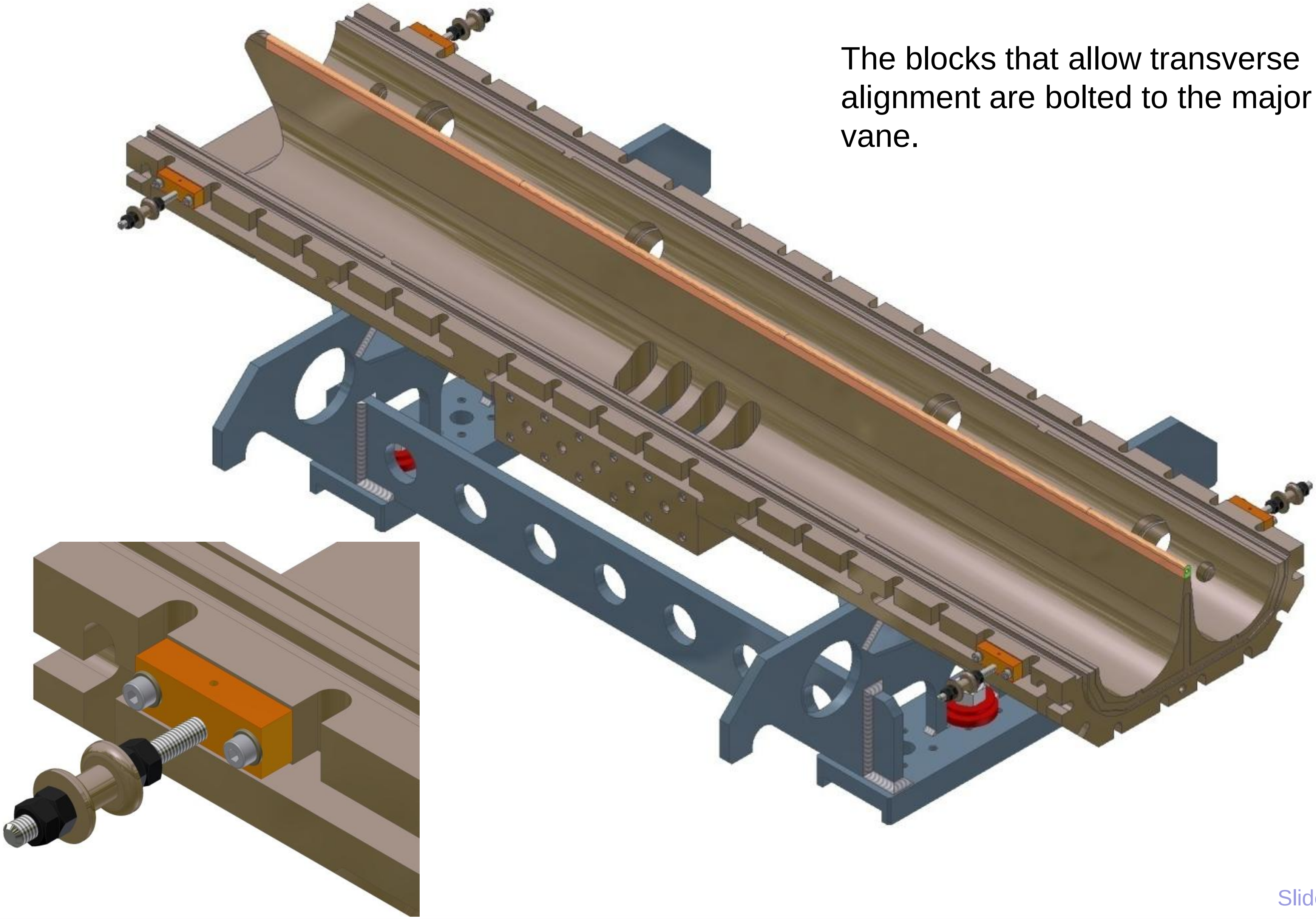
The vane can now be bolted to the cradle.

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

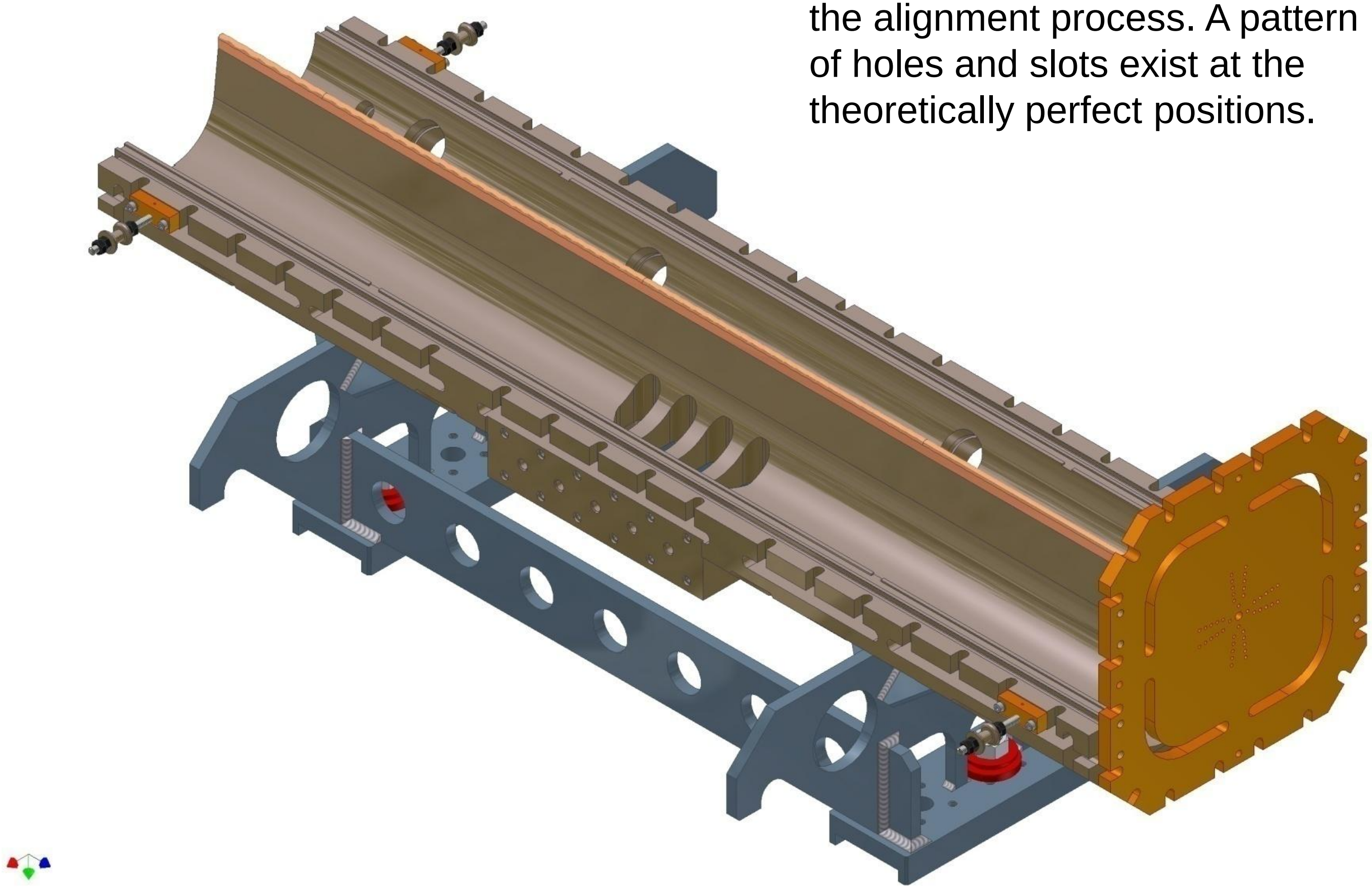




The blocks that allow transverse alignment are bolted to the major vane.

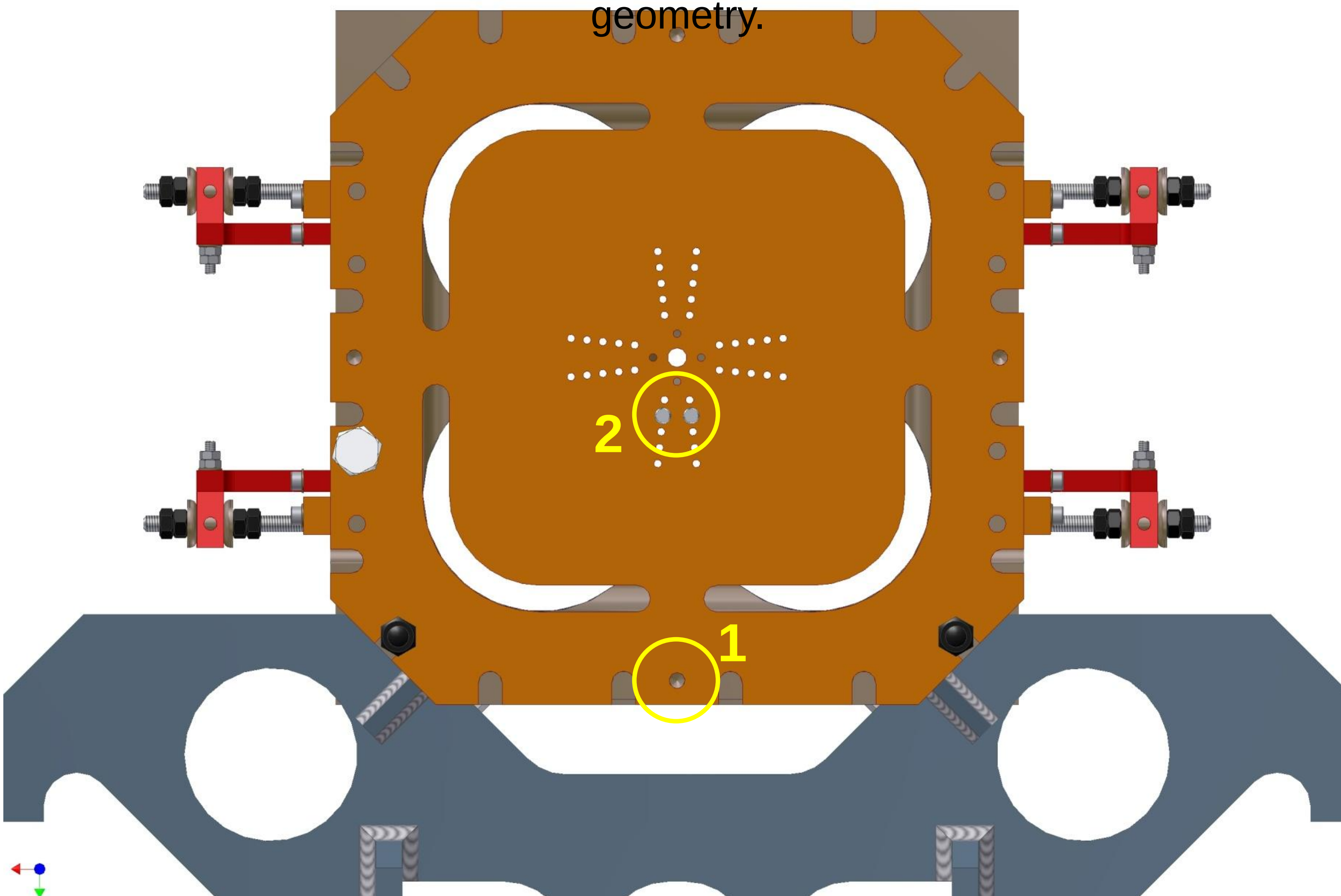


Add alignment end flanges

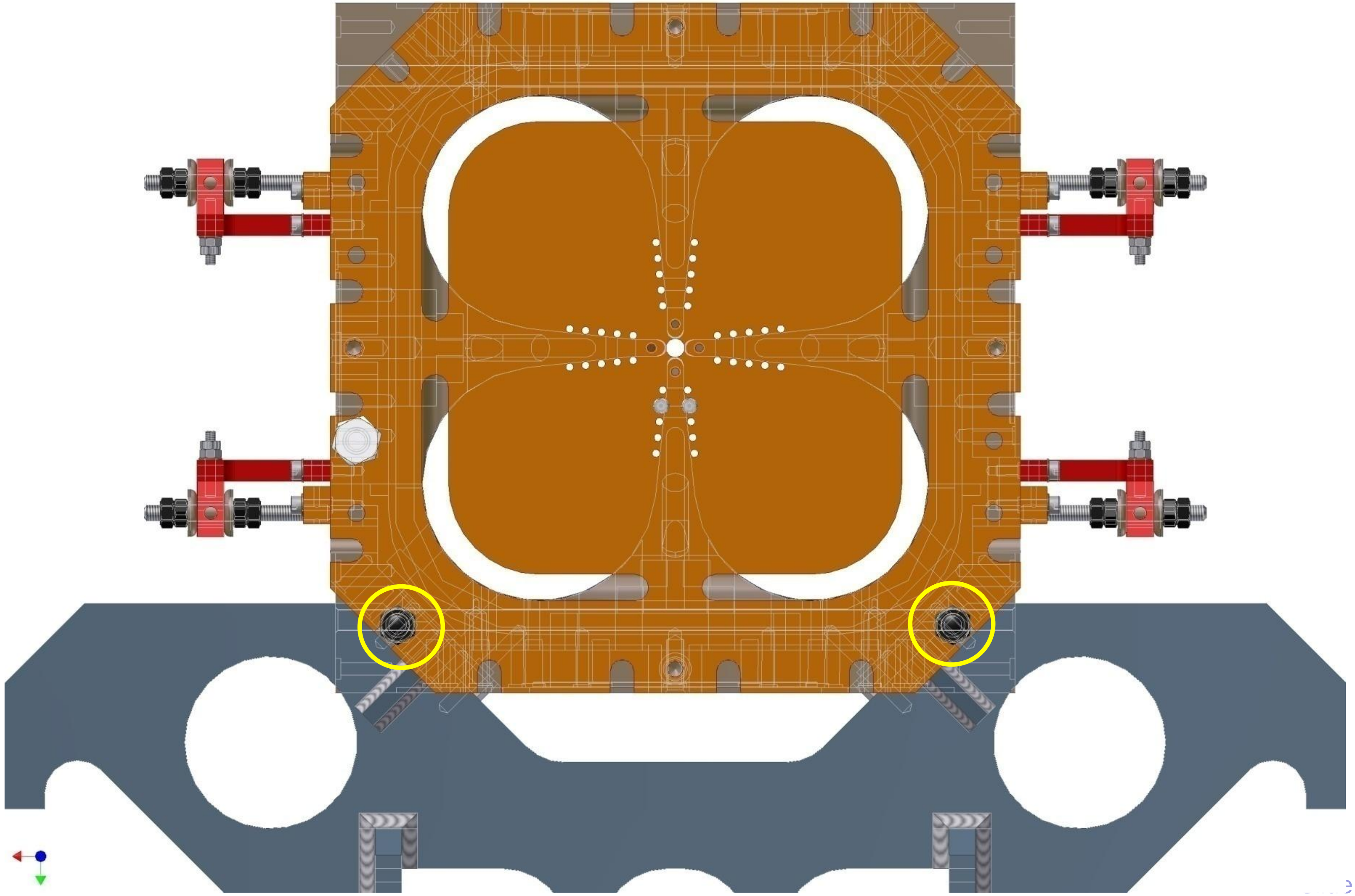


End flanges made specially for the alignment process. A pattern of holes and slots exist at the theoretically perfect positions.

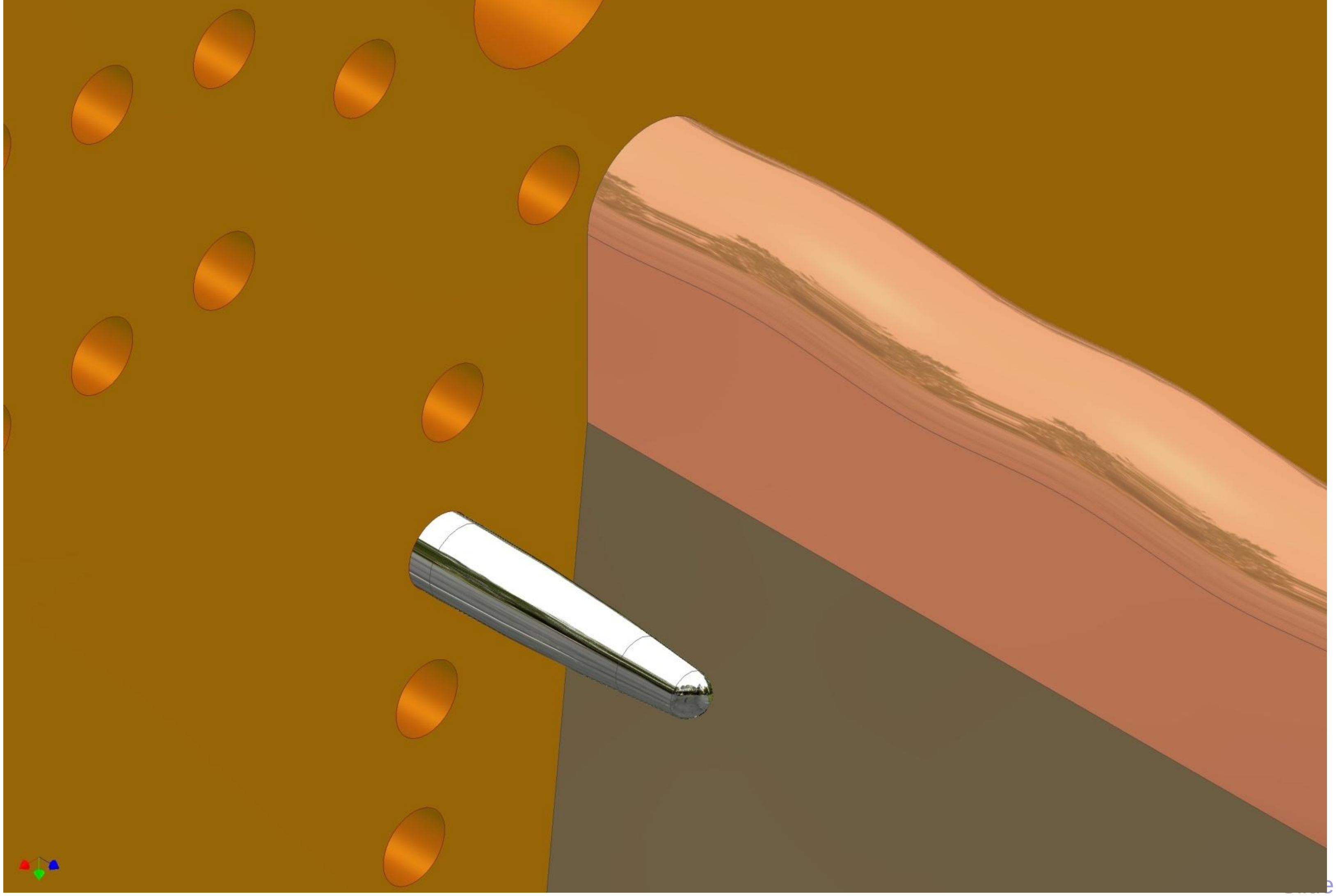
End flange is first doweled to the major vane (1) before being aligned to the vane sides using tapered dowels (2) - close to the beam transport region, in an area of unchanging geometry.

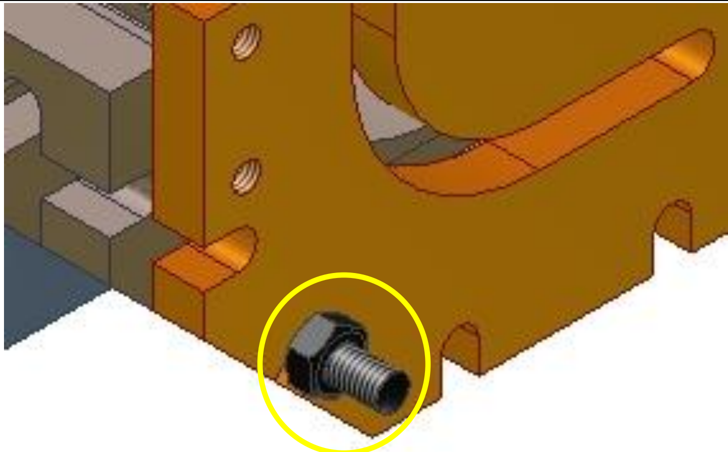


Once the end flange is constrained it can be bolted to the major vane – checking all the time that the tapered dowels are not being forced into the vane sides.

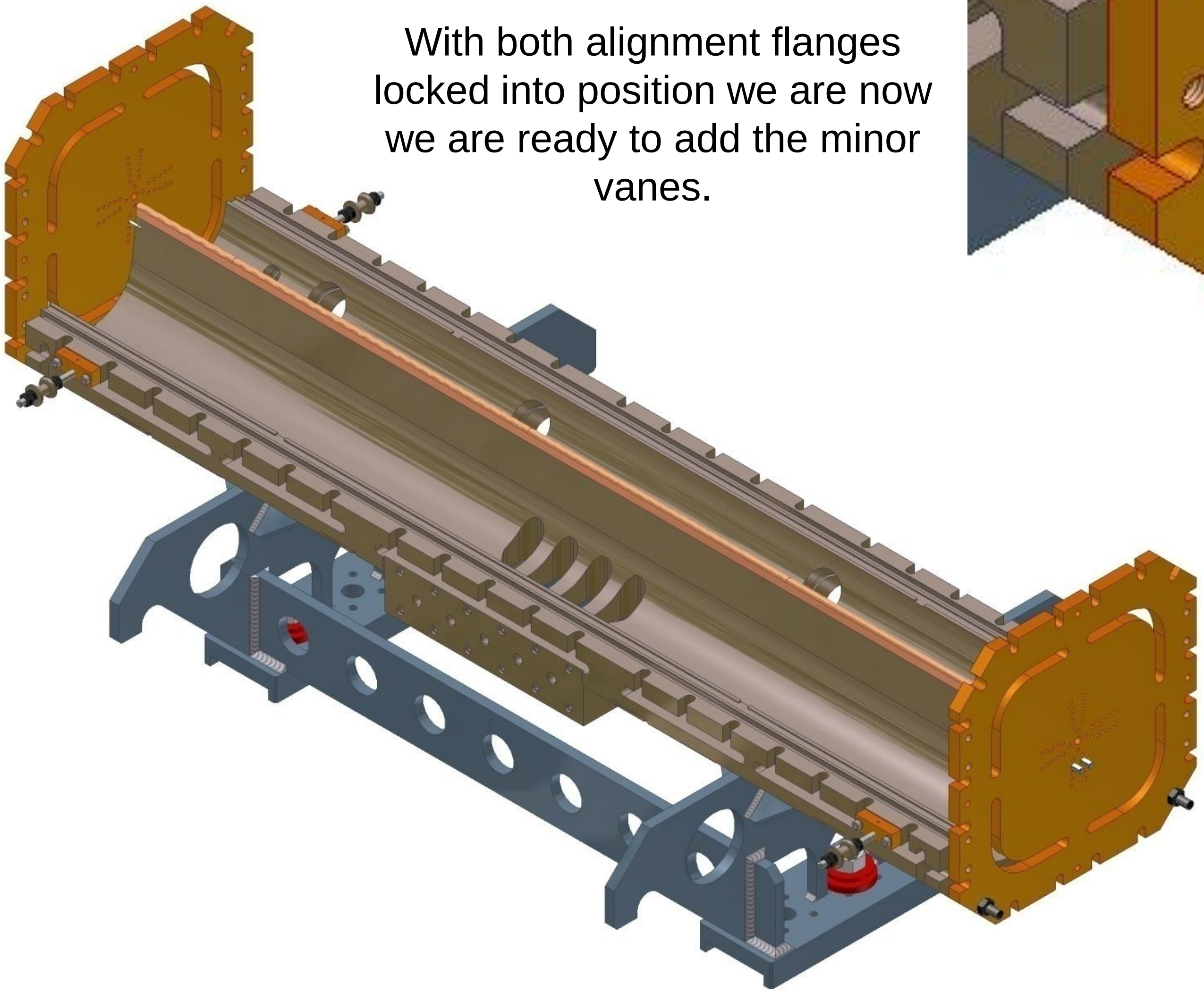


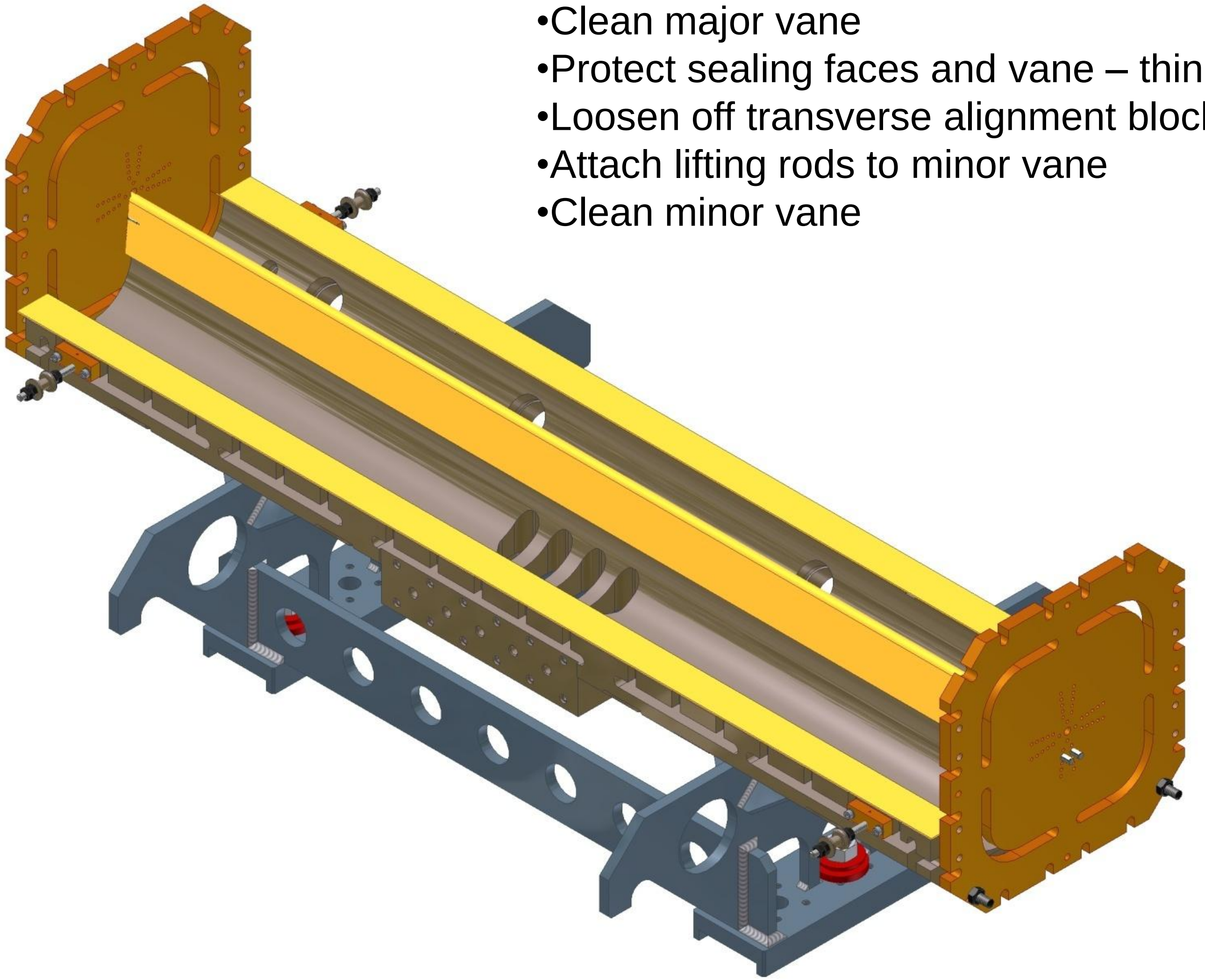
Tapered pins are used to (gently) align end flange to vane – never used as a lever or with any great force



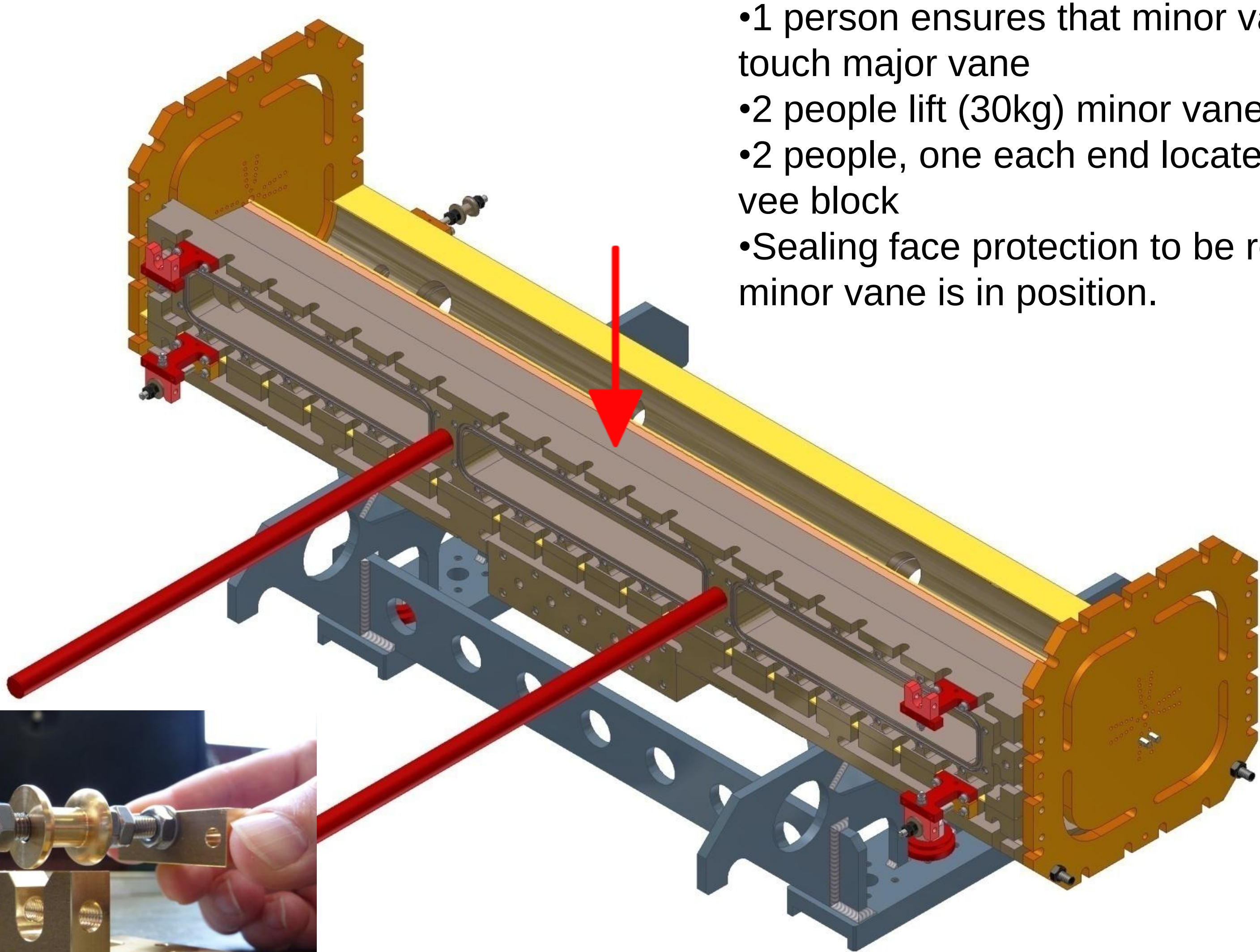


With both alignment flanges locked into position we are now we are ready to add the minor vanes.

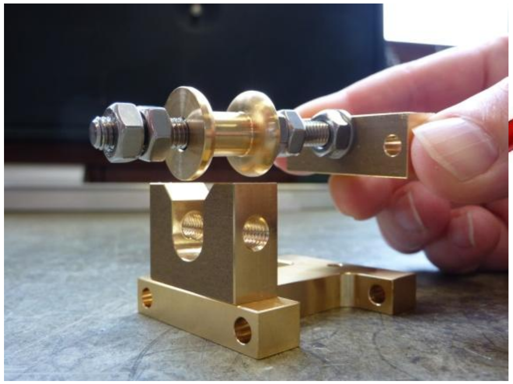




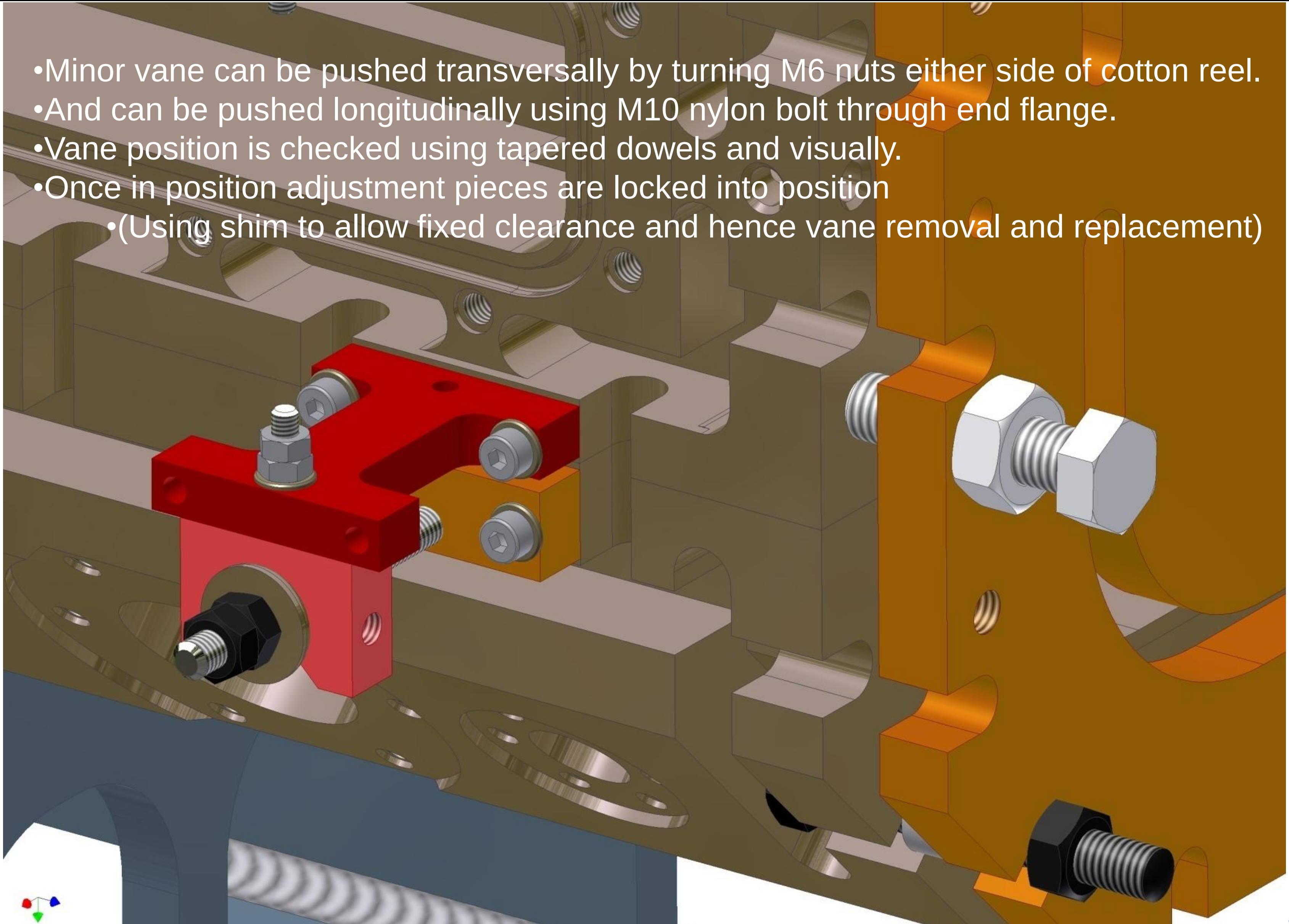
- Clean major vane
- Protect sealing faces and vane – thin Al strips?
- Loosen off transverse alignment blocks
- Attach lifting rods to minor vane
- Clean minor vane



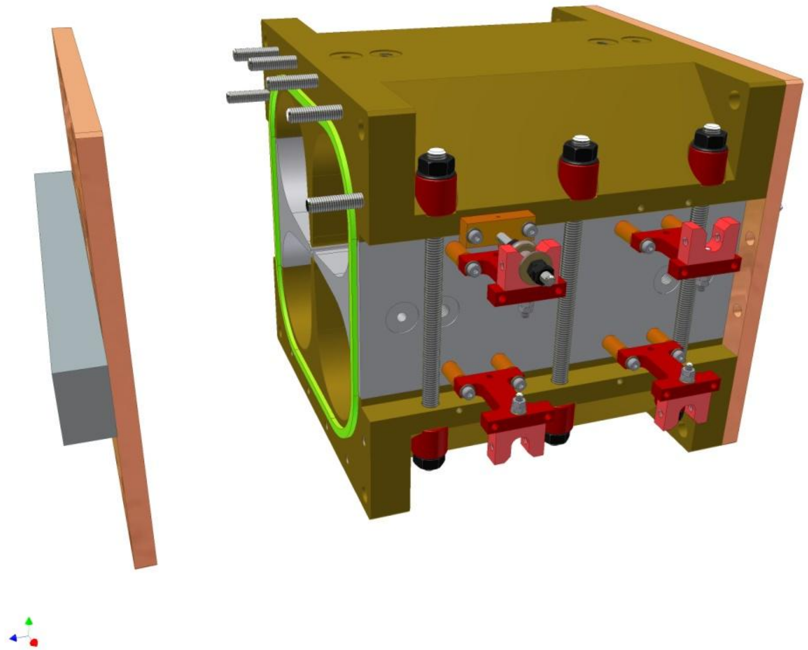
- 1 person ensures that minor vane does not touch major vane
- 2 people lift (30kg) minor vane into position
- 2 people, one each end locate cotton reel into vee block
- Sealing face protection to be removed once minor vane is in position.

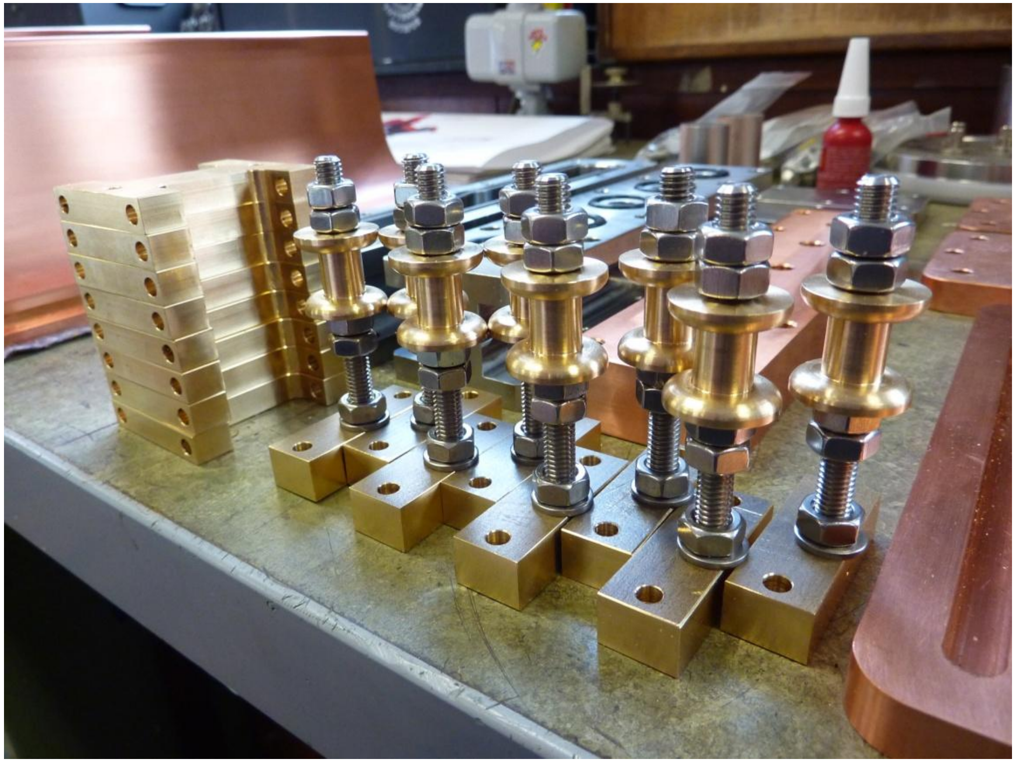


- Minor vane can be pushed transversally by turning M6 nuts either side of cotton reel.
- And can be pushed longitudinally using M10 nylon bolt through end flange.
- Vane position is checked using tapered dowels and visually.
- Once in position adjustment pieces are locked into position
    - (Using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

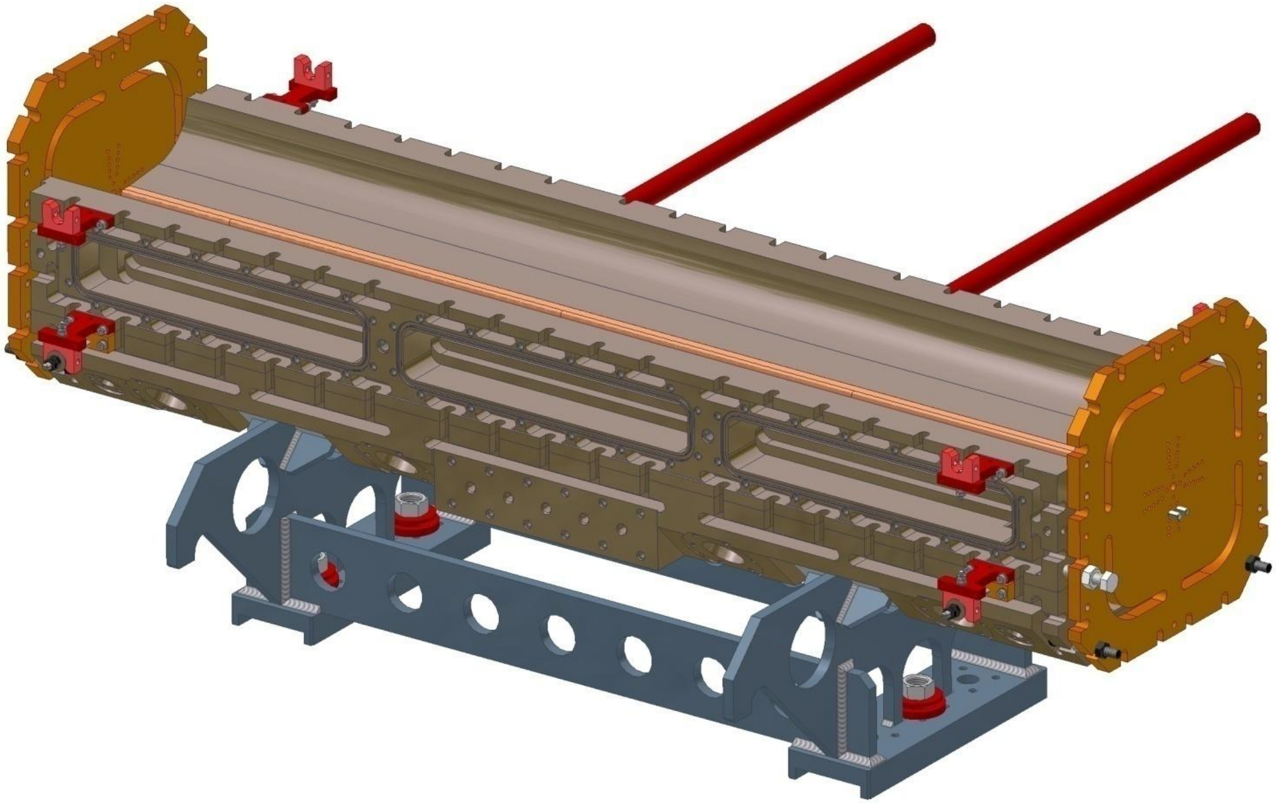


Concept of transverse positioning blocks is about to be trialled on the RFQ scale model.

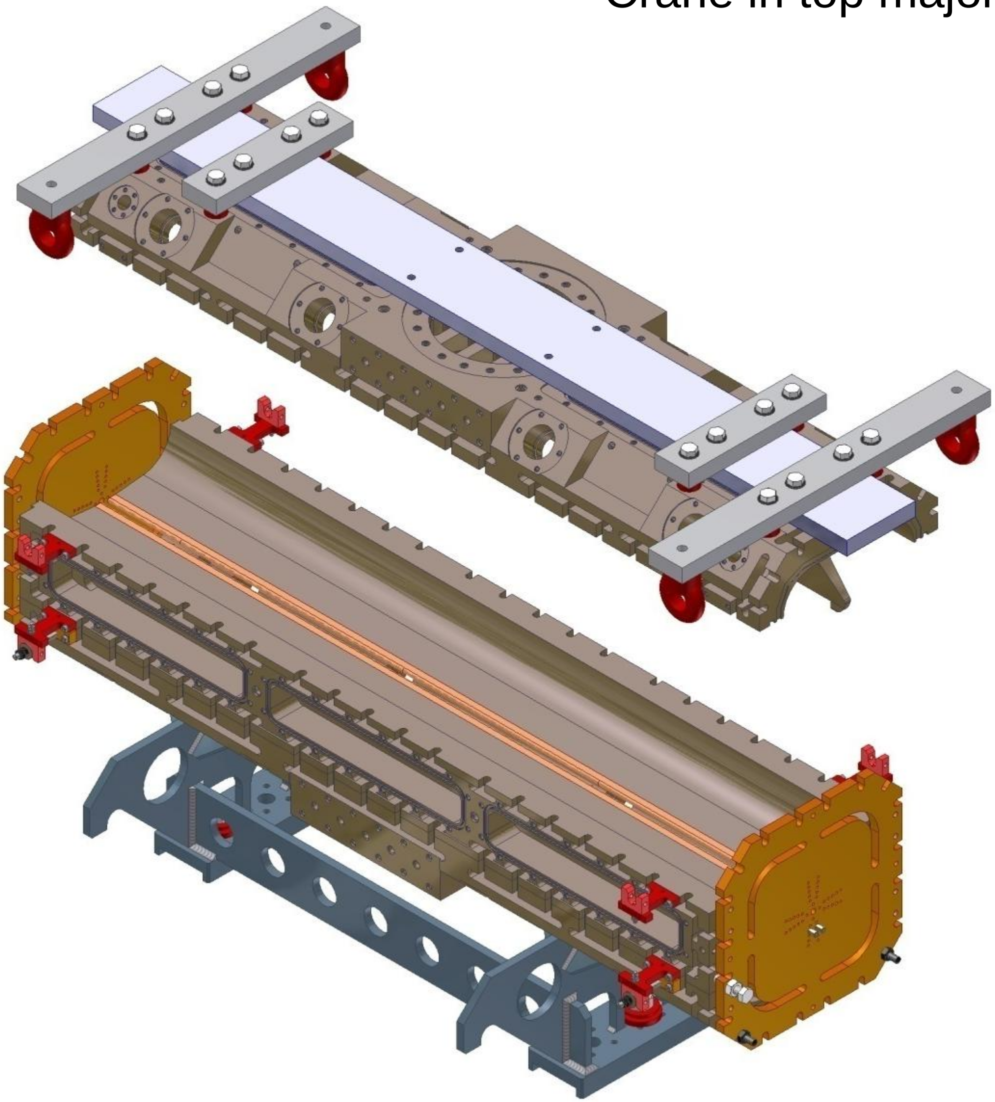




Repeat procedure for second minor vane

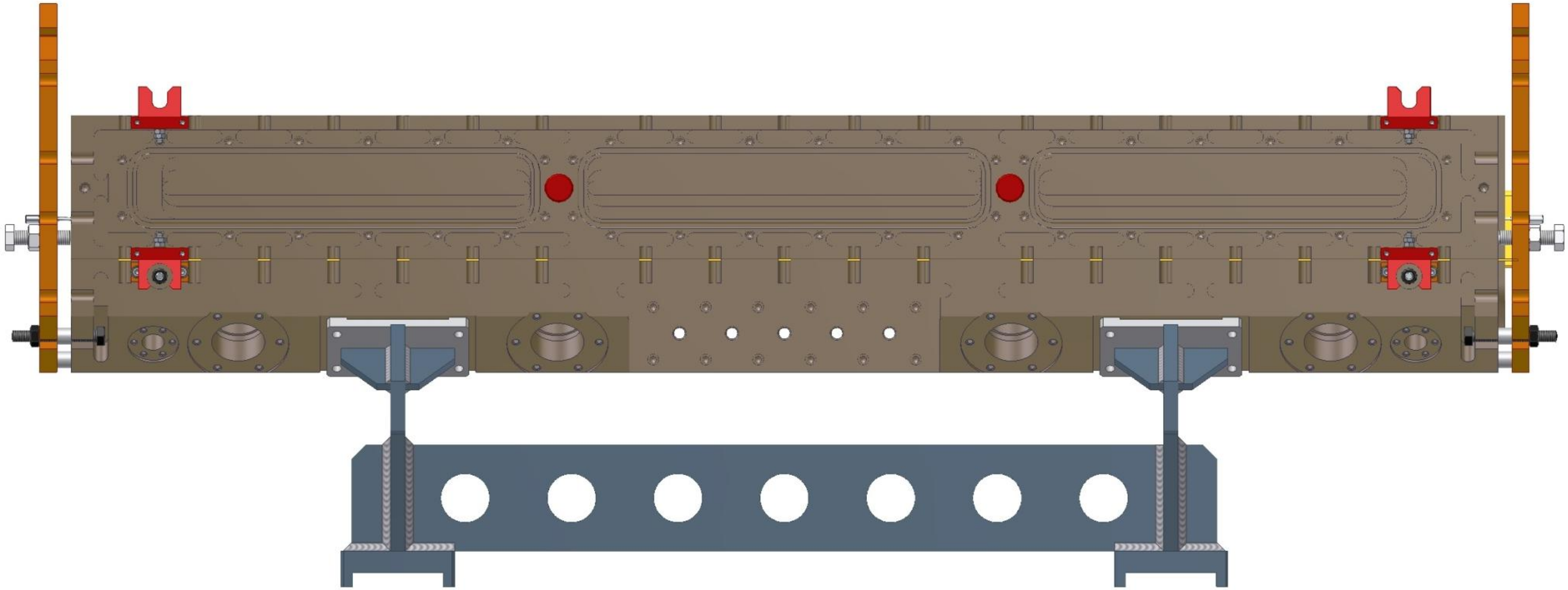


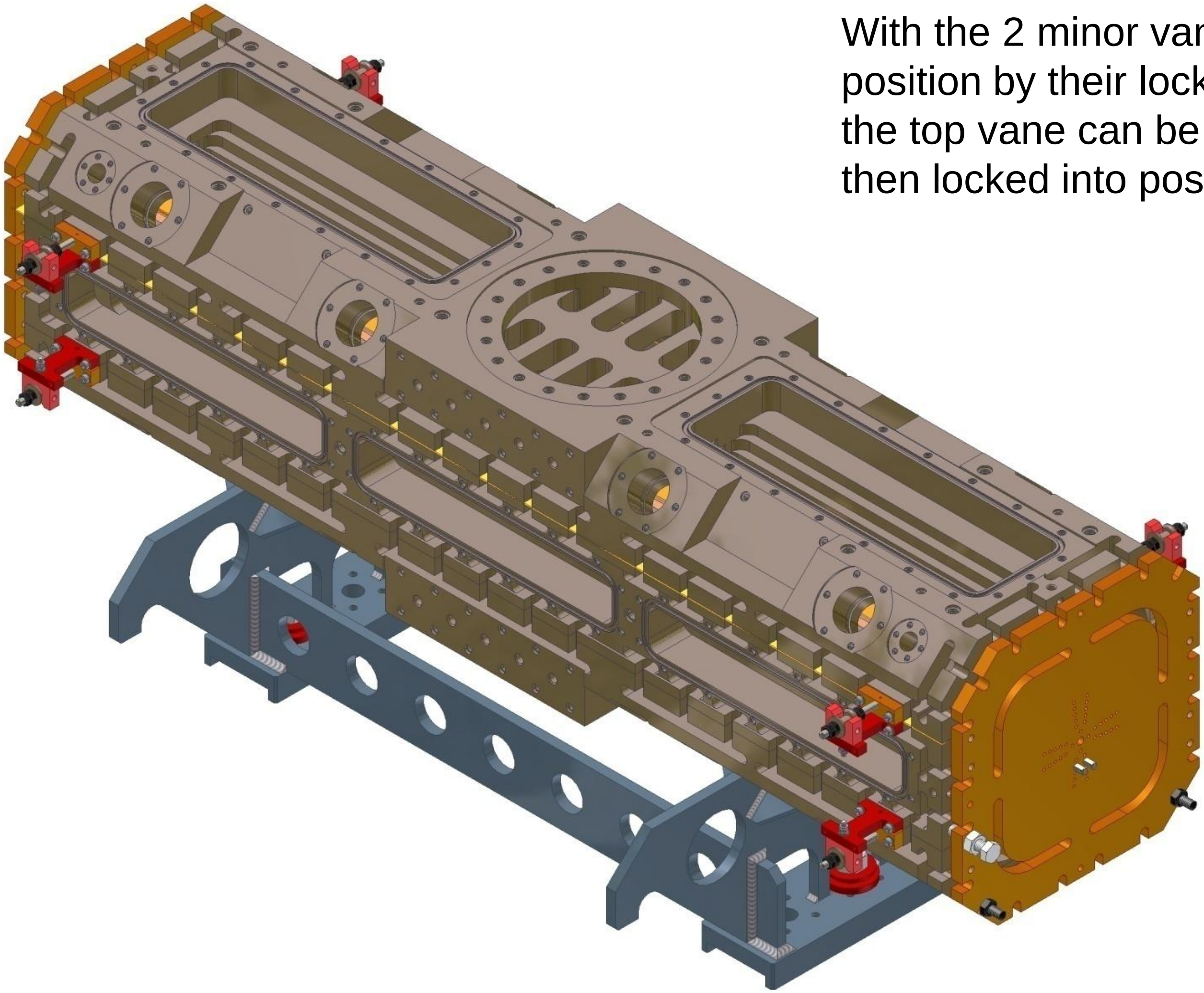
Crane in top major vane



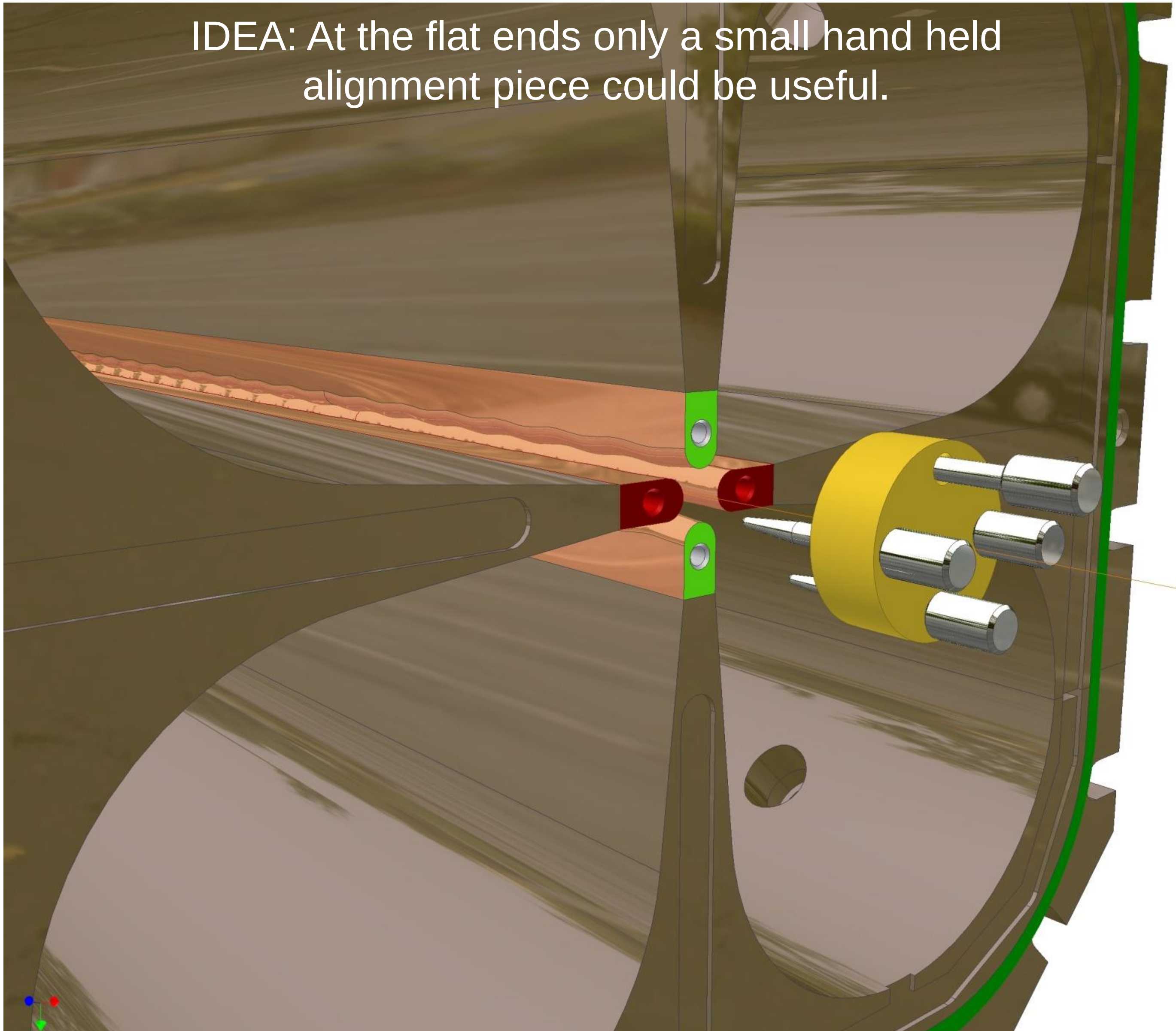
- Clean
- Protection for vanes and sealing faces required.
- Use chain block for sensitivity – NOT the R8 crane
- One person at each corner
- Rest on protective strips before finally lowering into position.

•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.





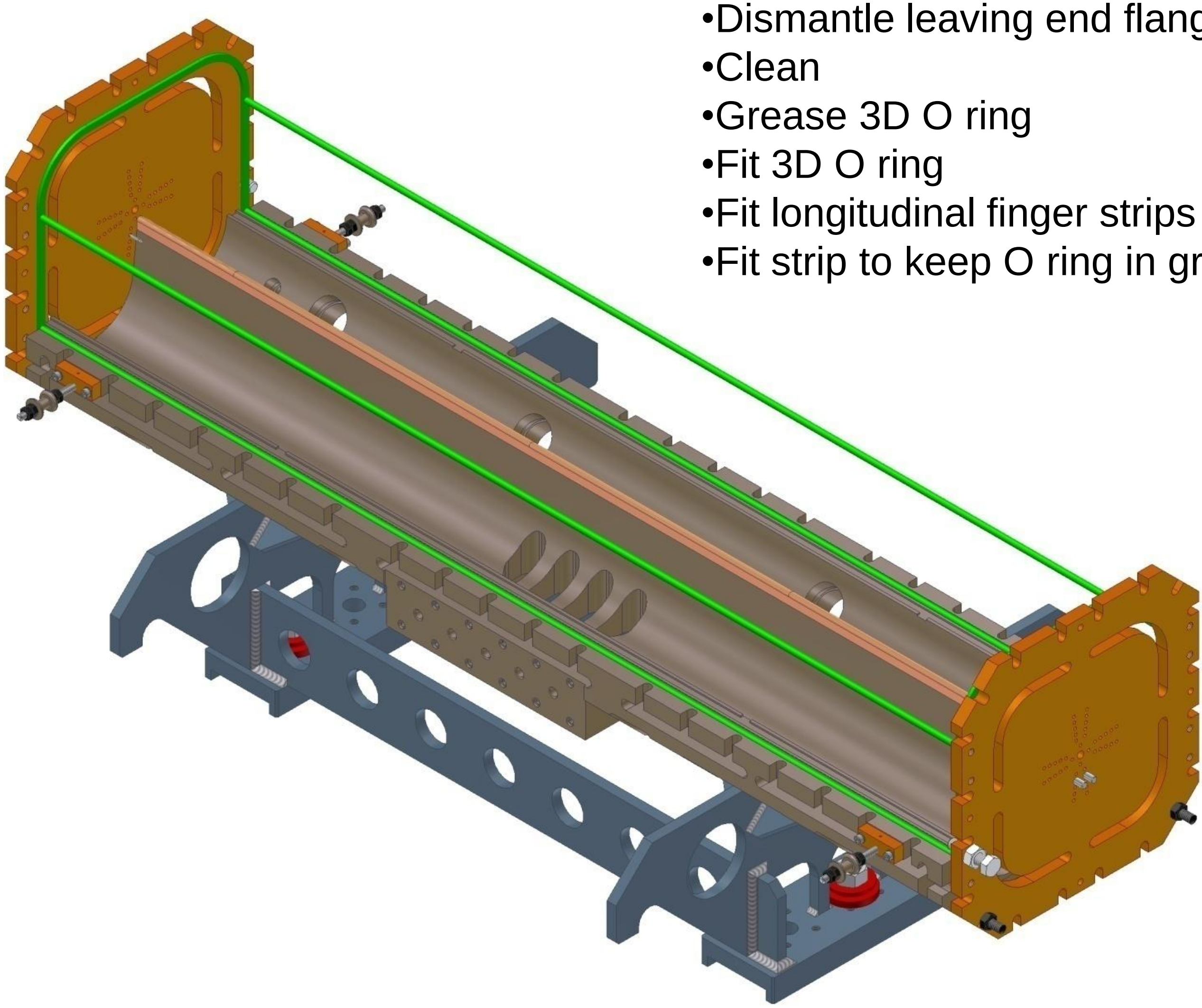
With the 2 minor vanes held in position by their locked adjusters the top vane can be moved and then locked into position.


IDEA: At the flat ends only a small hand held alignment piece could be useful.

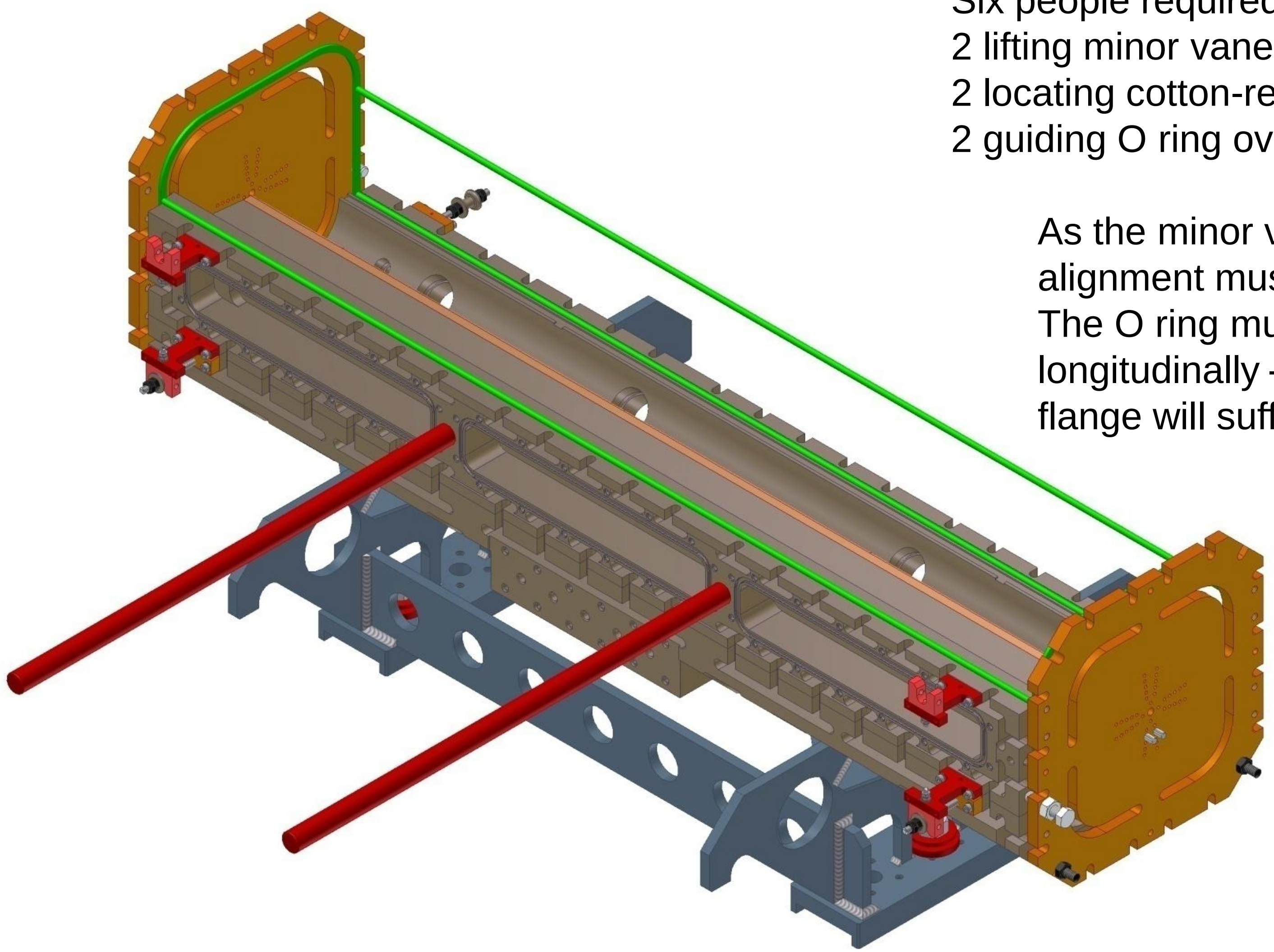
Part 2

Vane to vane alignment with O ring in place.

The alignment has been set without the O ring in place because once the O ring becomes compressed the friction makes vane movement very restricted.

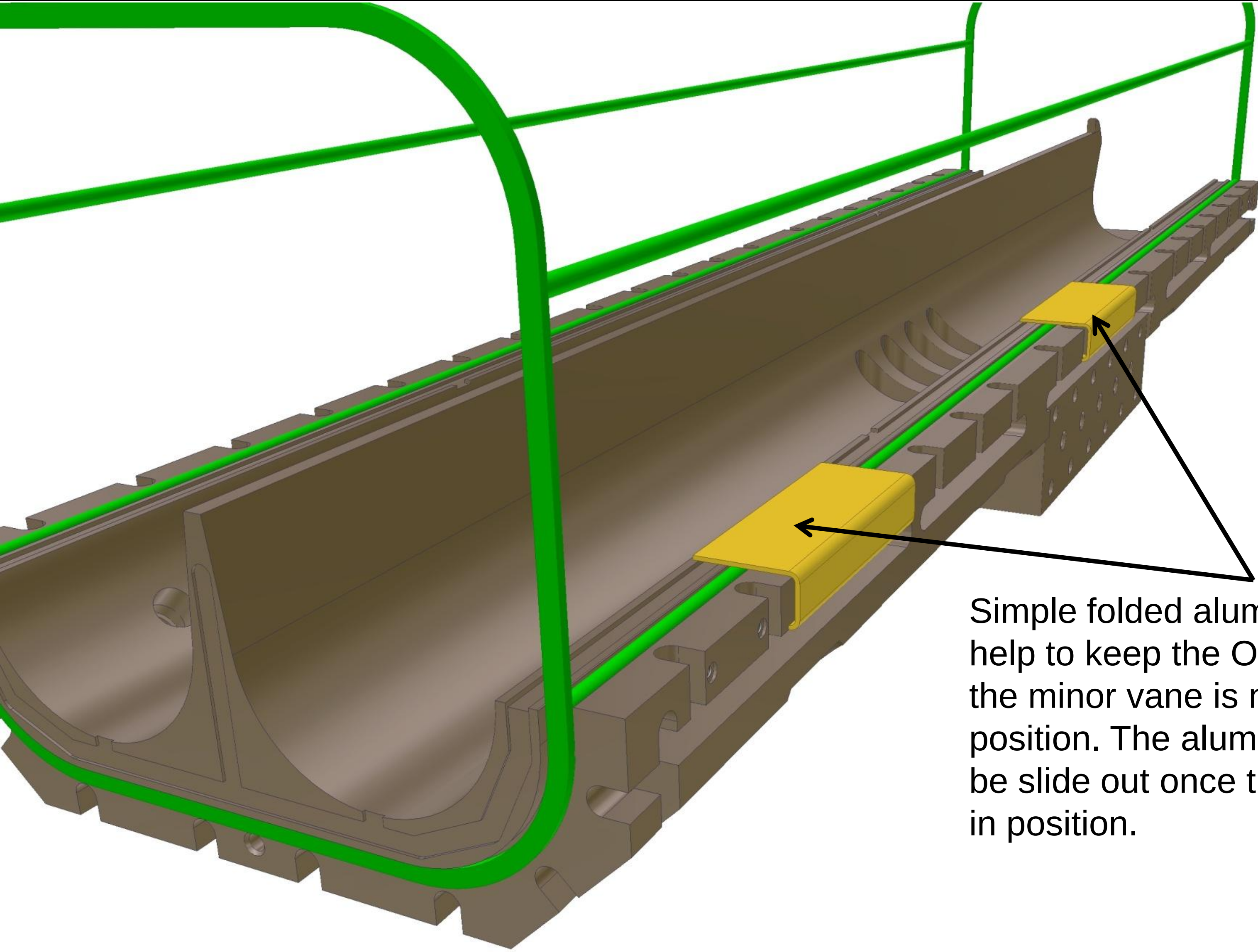


- Dismantle leaving end flanges in position
- Clean
- Grease 3D O ring
- Fit 3D O ring
- Fit longitudinal finger strips
- Fit strip to keep O ring in groove.



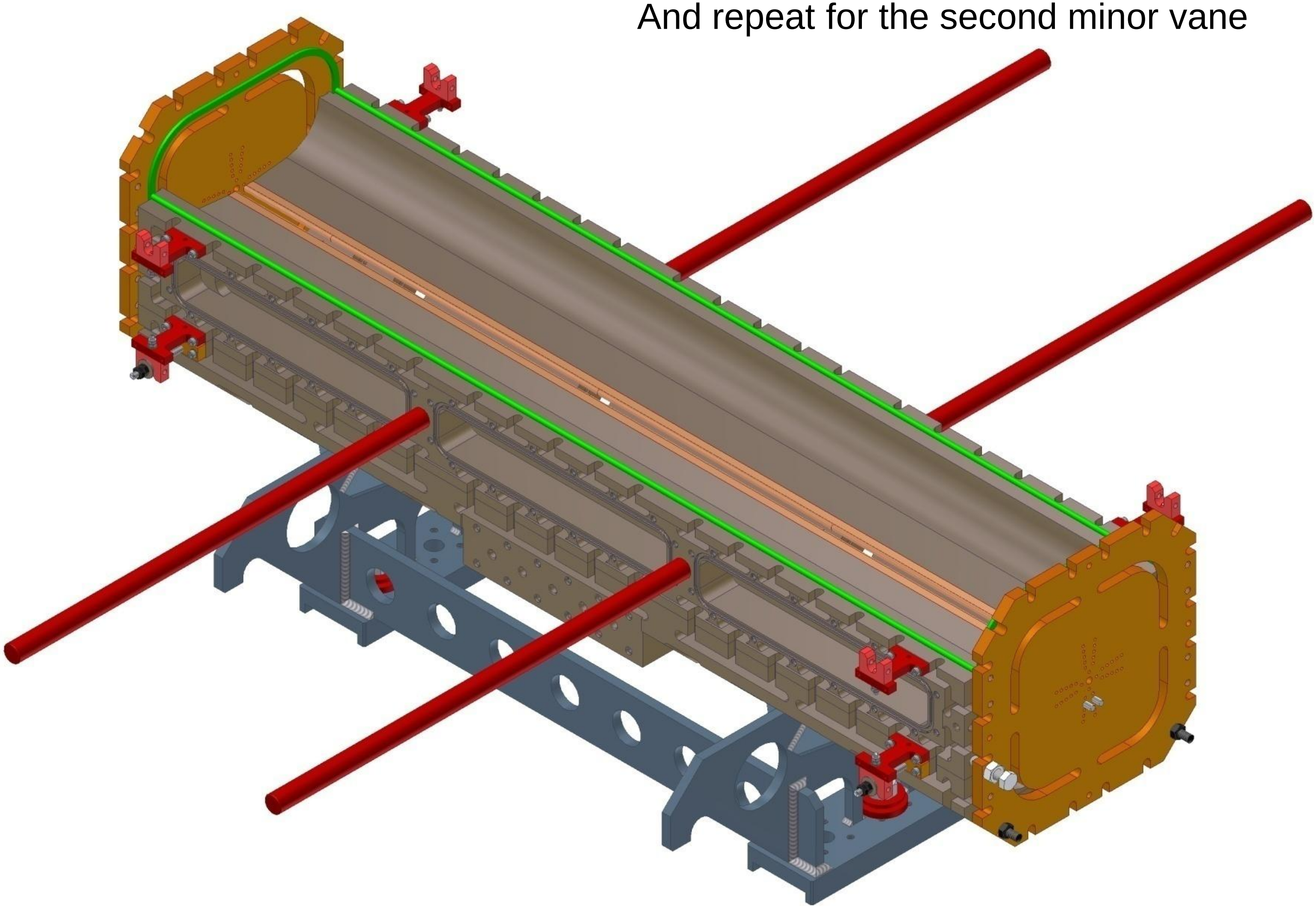
Six people required!
2 lifting minor vane
2 locating cotton-reels in vees
2 guiding O ring over minor vane

As the minor vane is bolted down alignment must be re-checked.
The O ring must be constrained longitudinally – a bolt through the end flange will suffice.

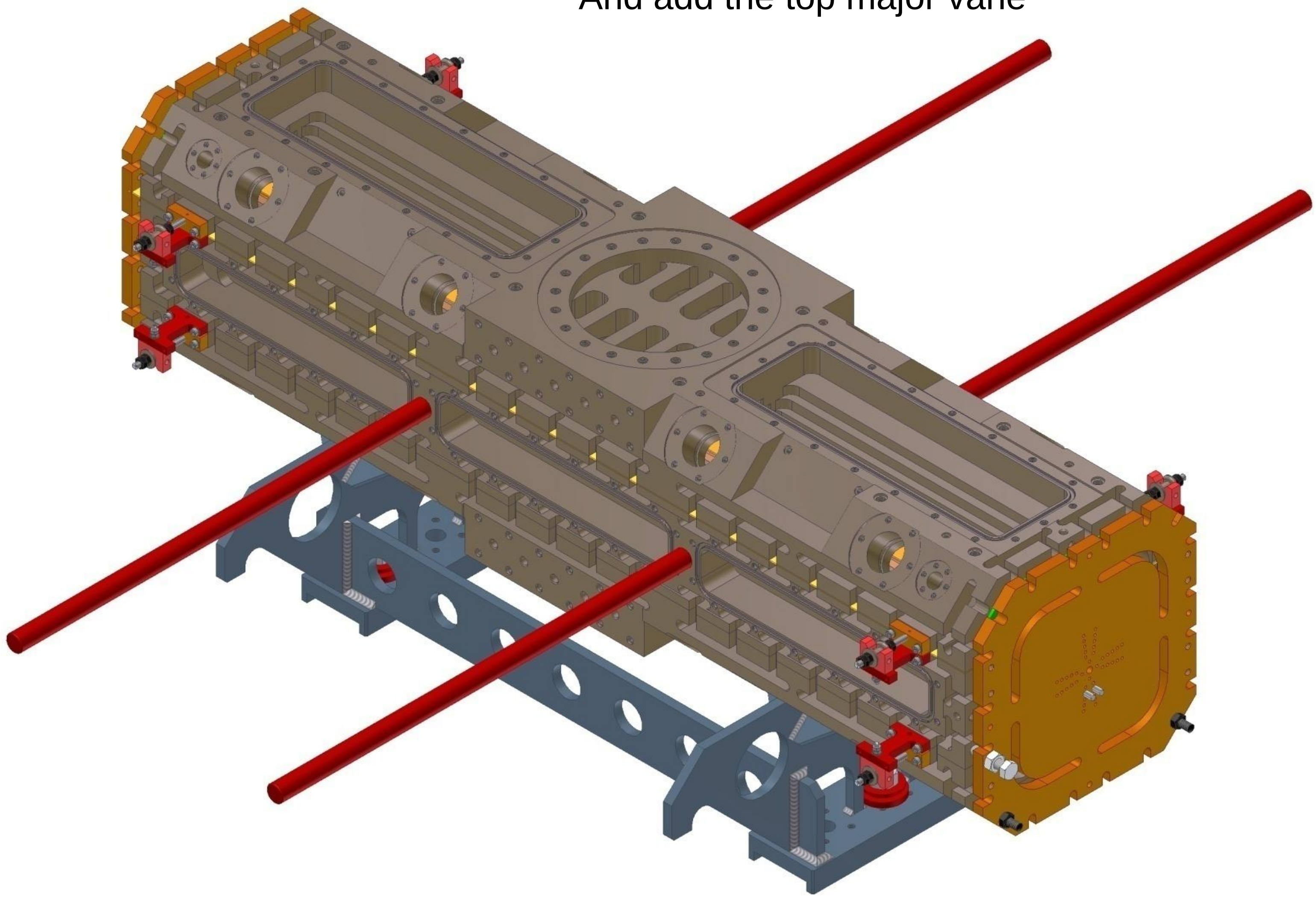


Simple folded aluminium pieces will help to keep the O ring in place as the minor vane is manouevered into position. The aluminium pieces can be slide out once the minor vane is in position.

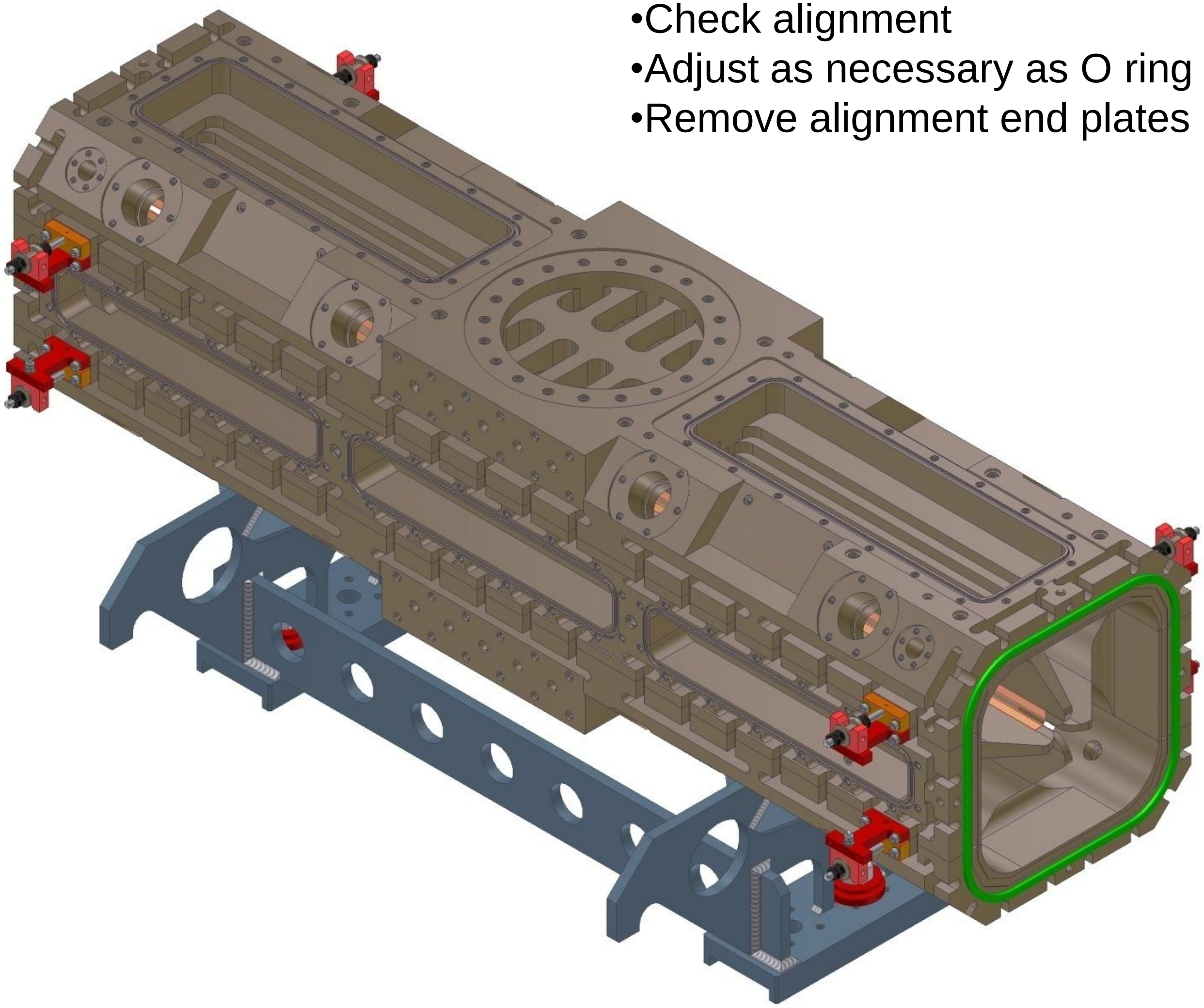
And repeat for the second minor vane

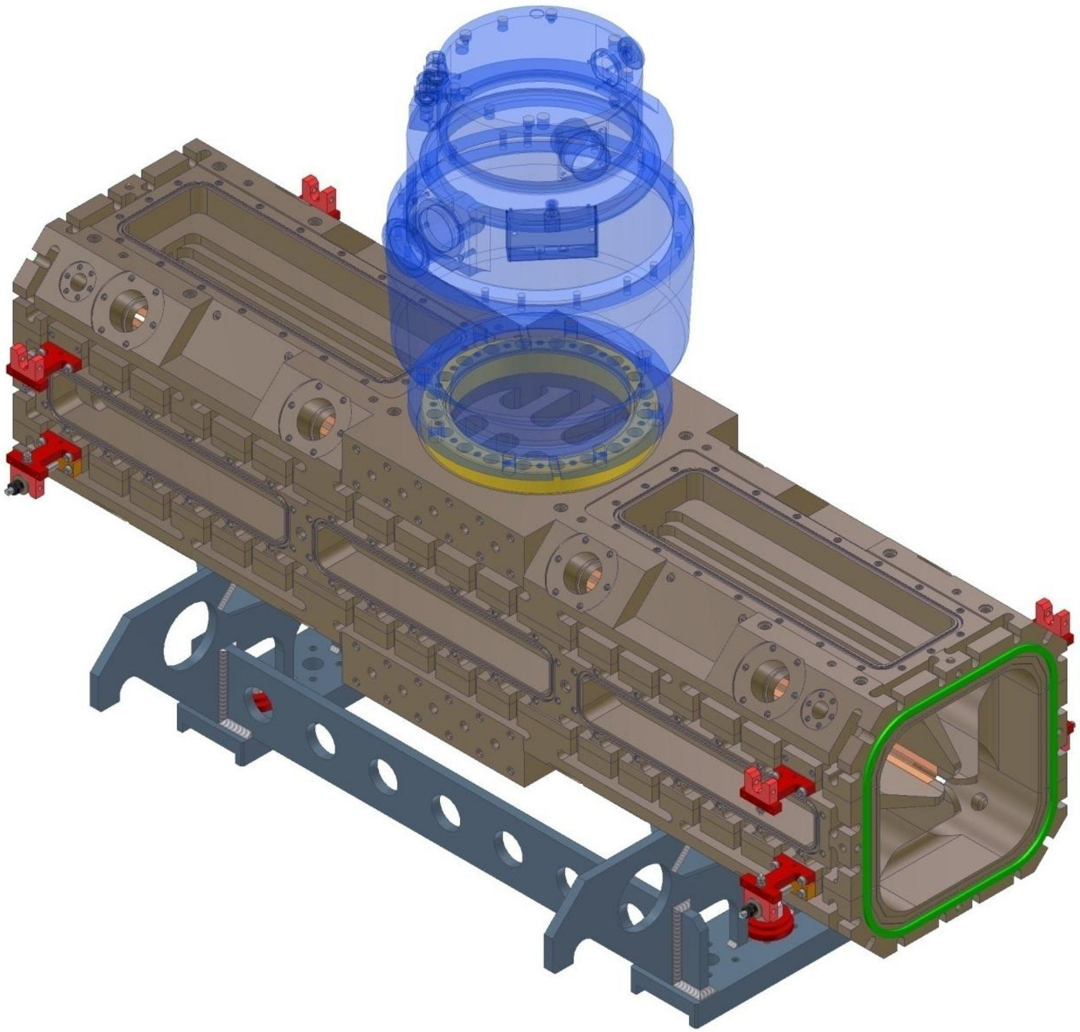


And add the top major vane



- Check alignment
- Adjust as necessary as O ring is compressed
- Remove alignment end plates





- Fit top vacuum pump
- Blank off ends and all ports
- Perform vacuum test.

To be manufactured (at Imperial):
- 16 x modified tuner DN40CF flanges
- 2 x modified vac port DN160CF flanges
- 2 x end flanges (maybe 4?)
- 8 x modified probe DN16CF flanges

To be bought:
- 16 x DN40CF blank flanges
- 2 x DN160CF blank flanges
- 8 x DN16CF blank flanges

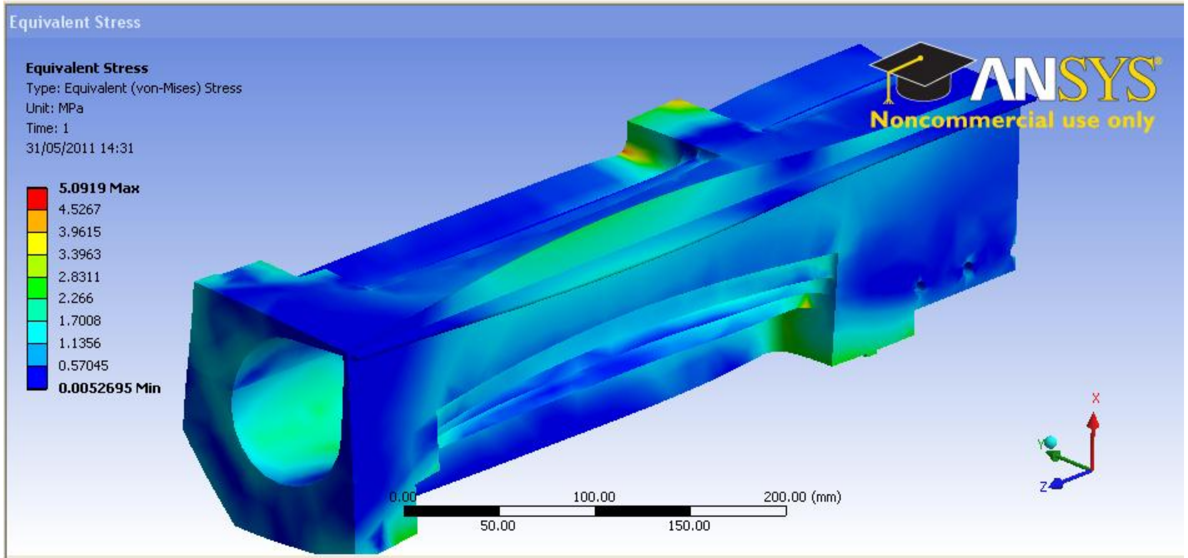
Load due to atmospheric pressure and weight of vacuum pump

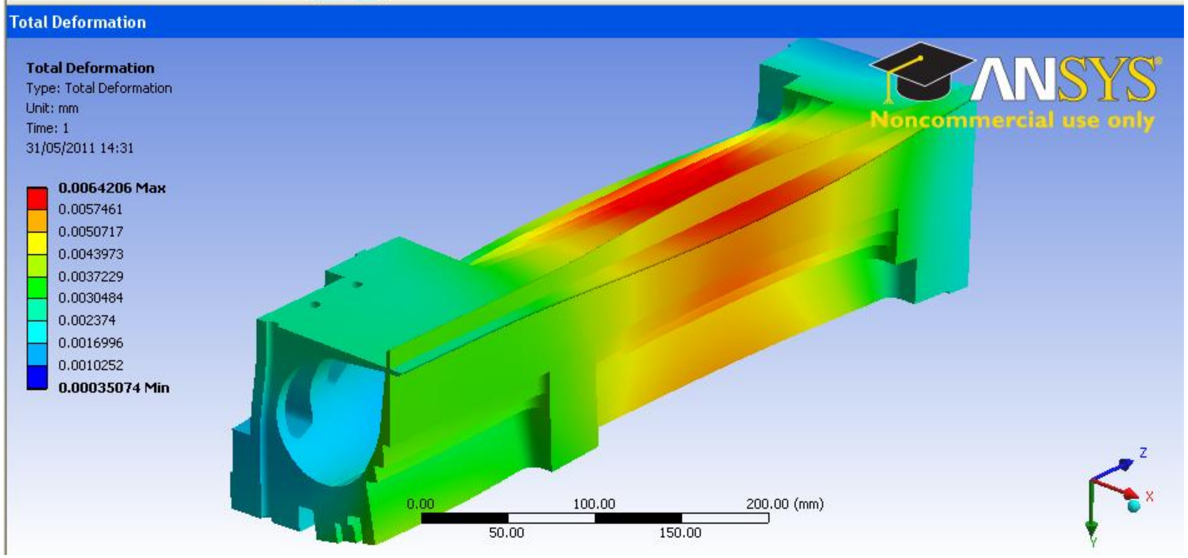
- Quarter de-featured model
- 3 symmetry planes
- Nodes: 24,500

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

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

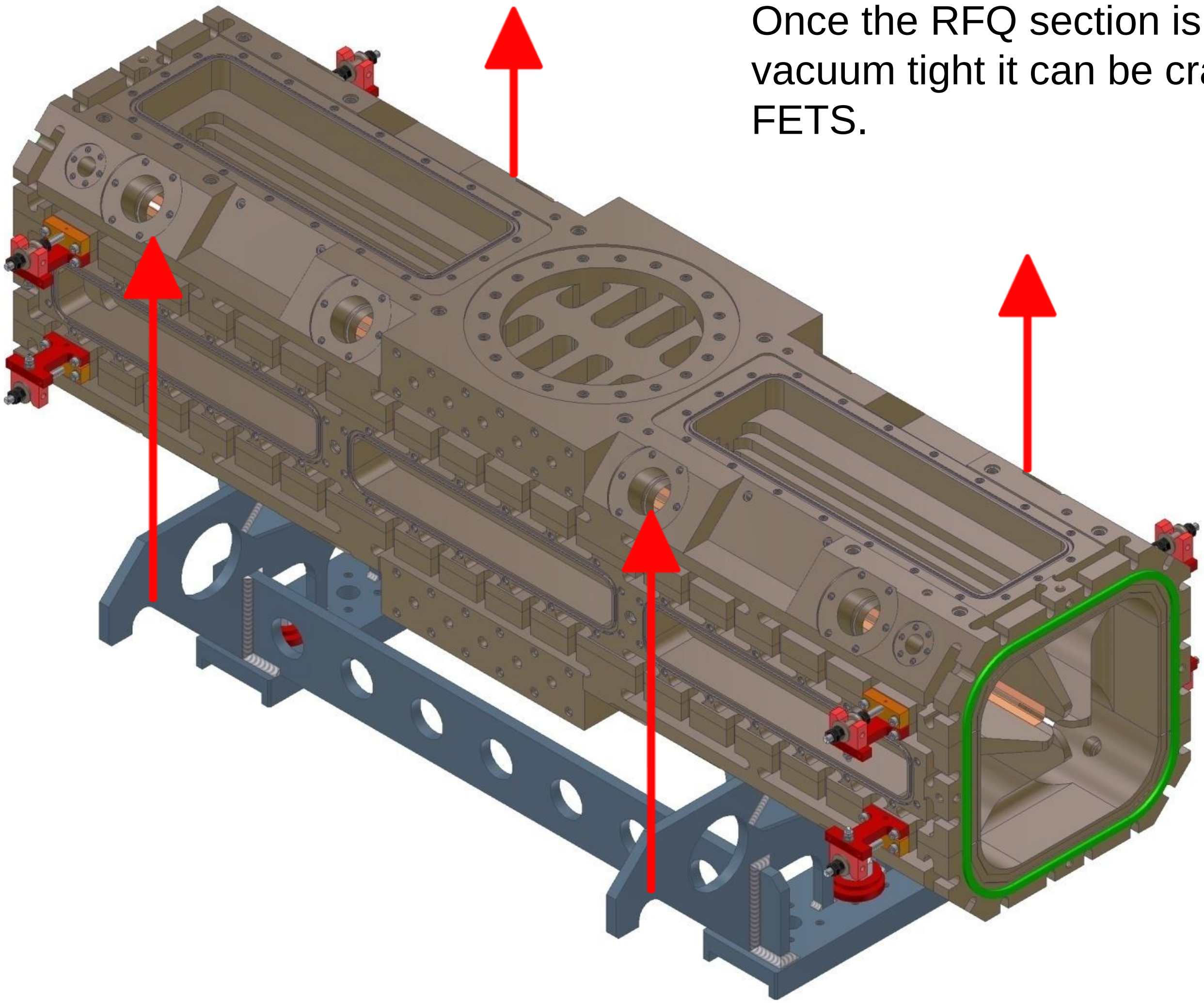
Max. Deformation:
0.0065mm
Vane tips move towards beam axis





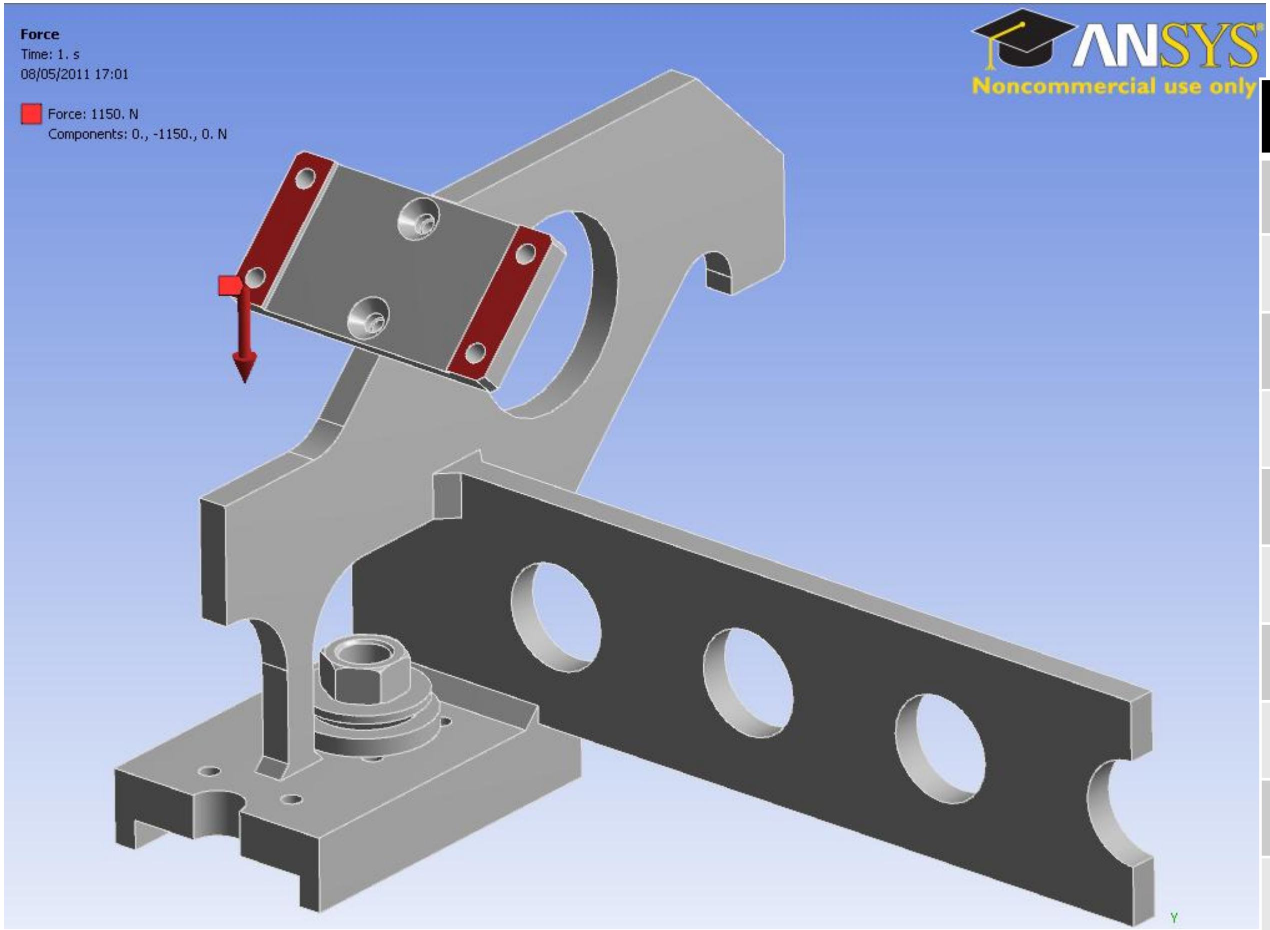
Part 3

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?

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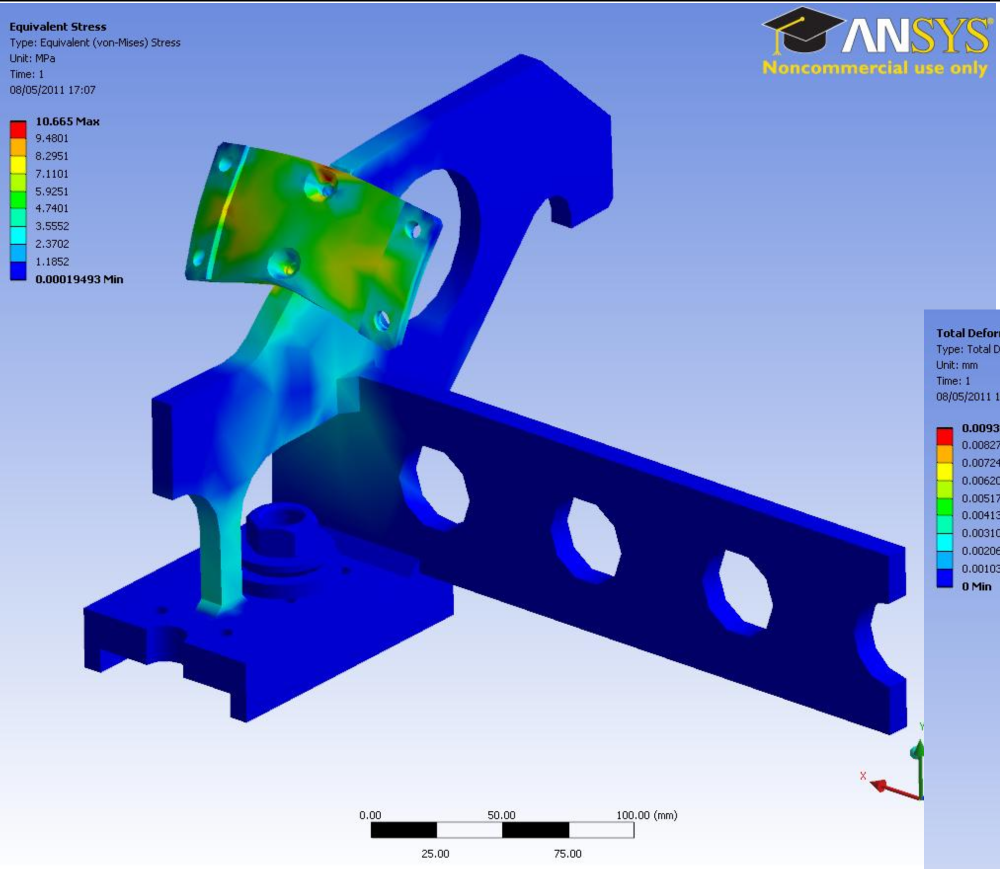
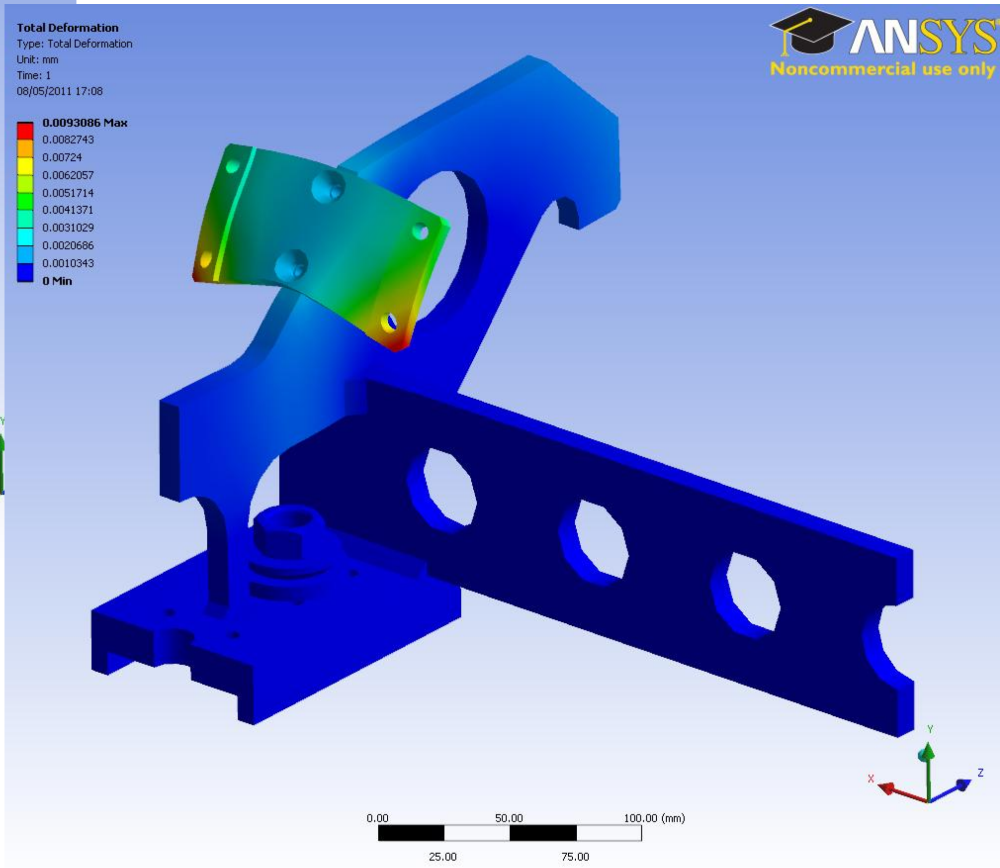
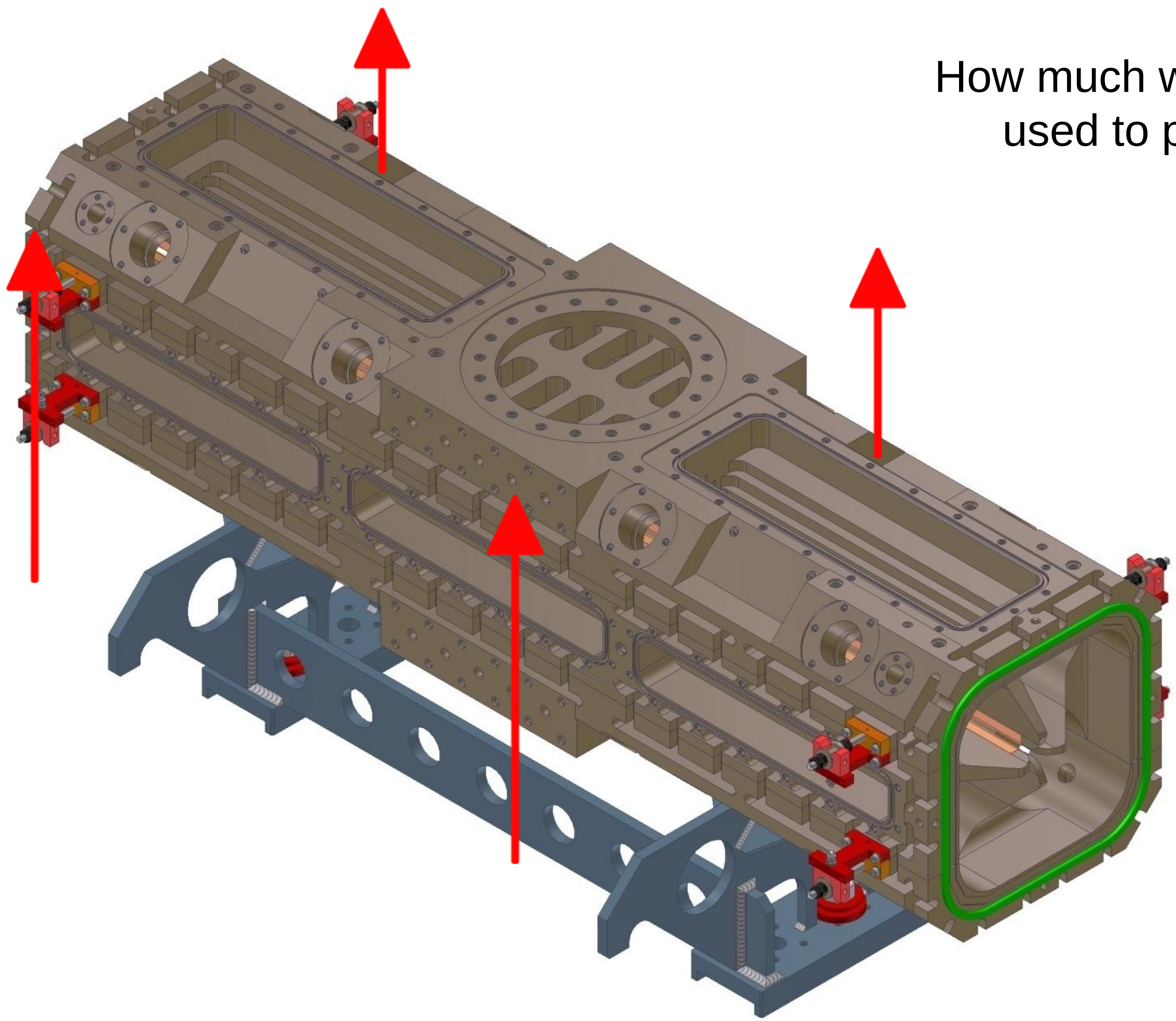


Maximum equivalent stress = 10MPa
Maximum deformation = 0.01 mm

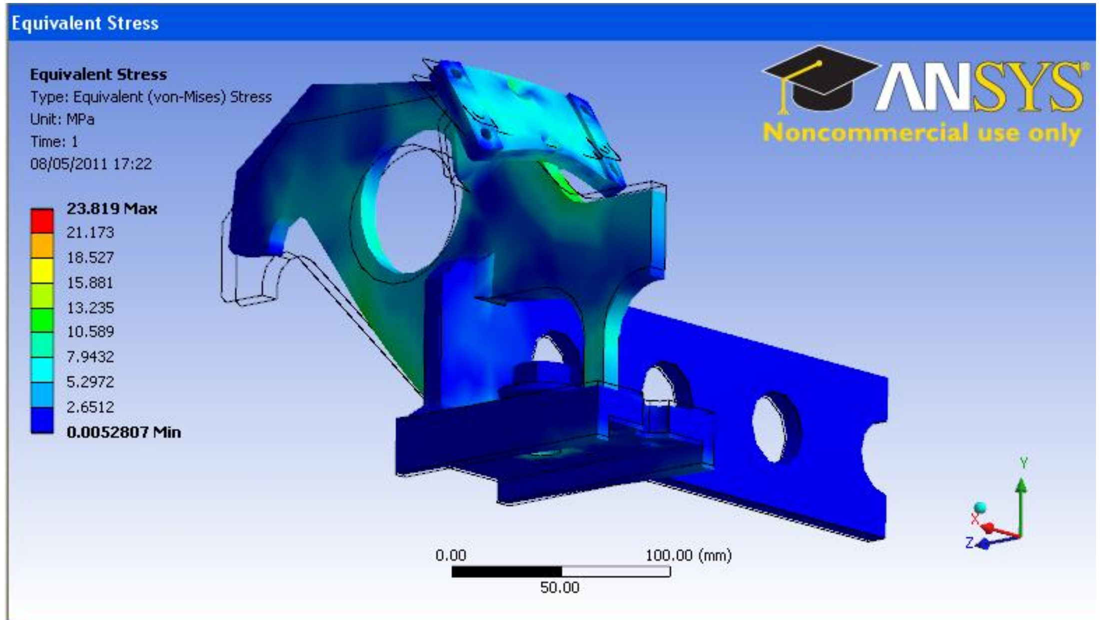


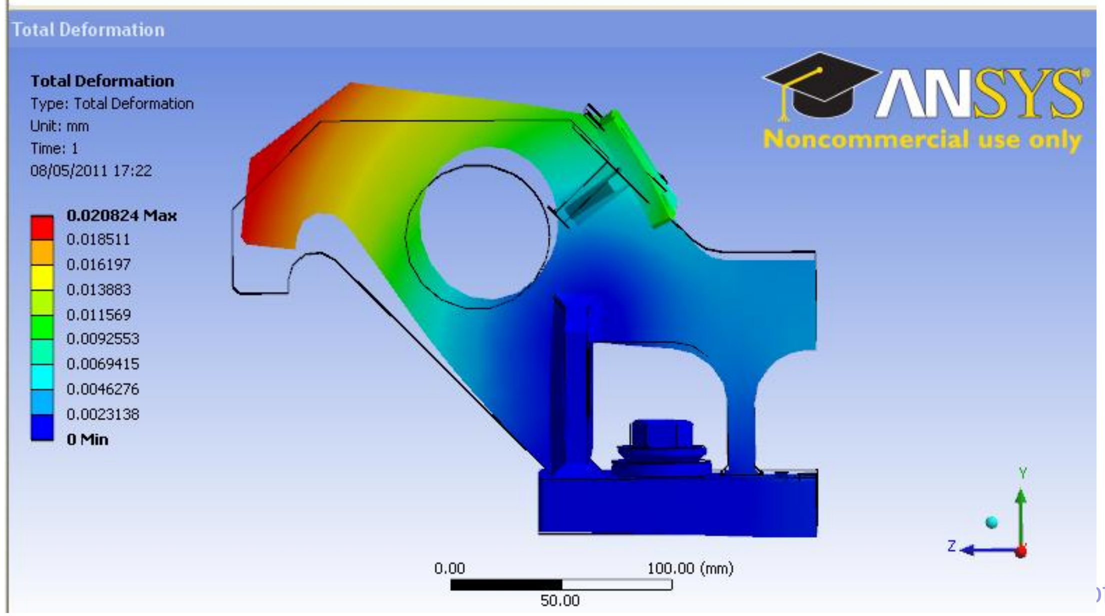


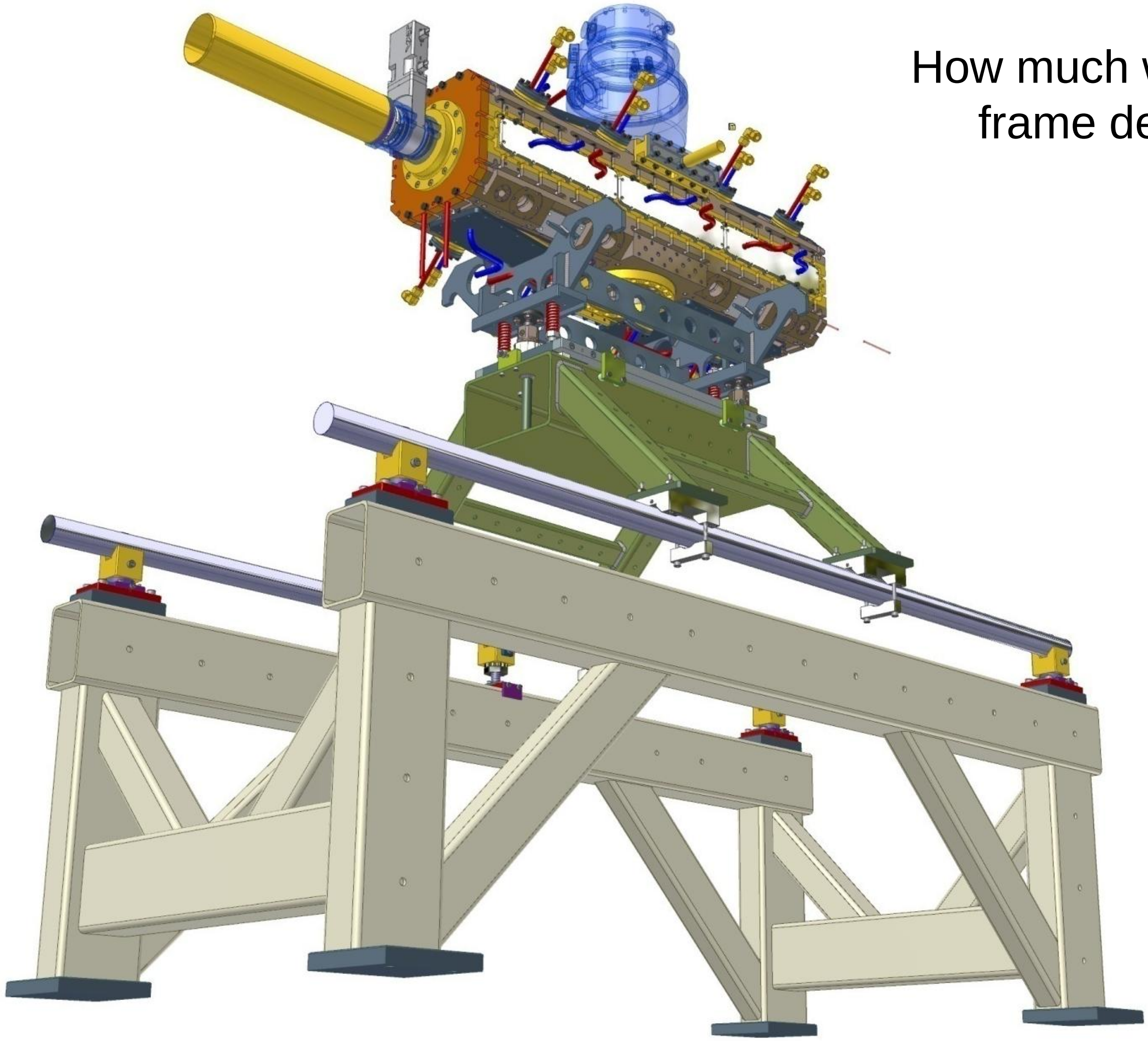
How much will the cradle distort when used to pick up the whole RFQ section?

Max stress = 24 MPa

Max deformation = 0.02mm



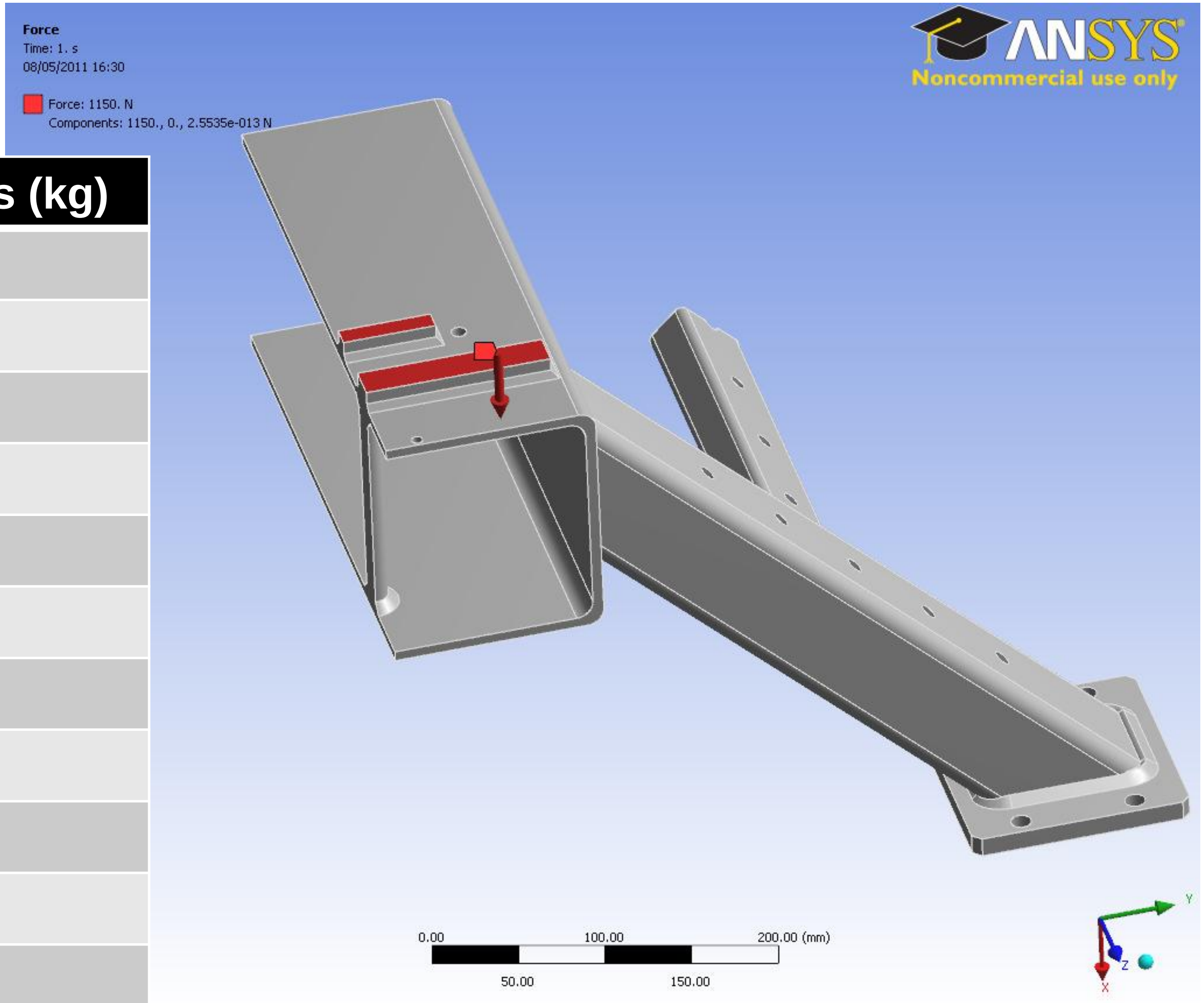


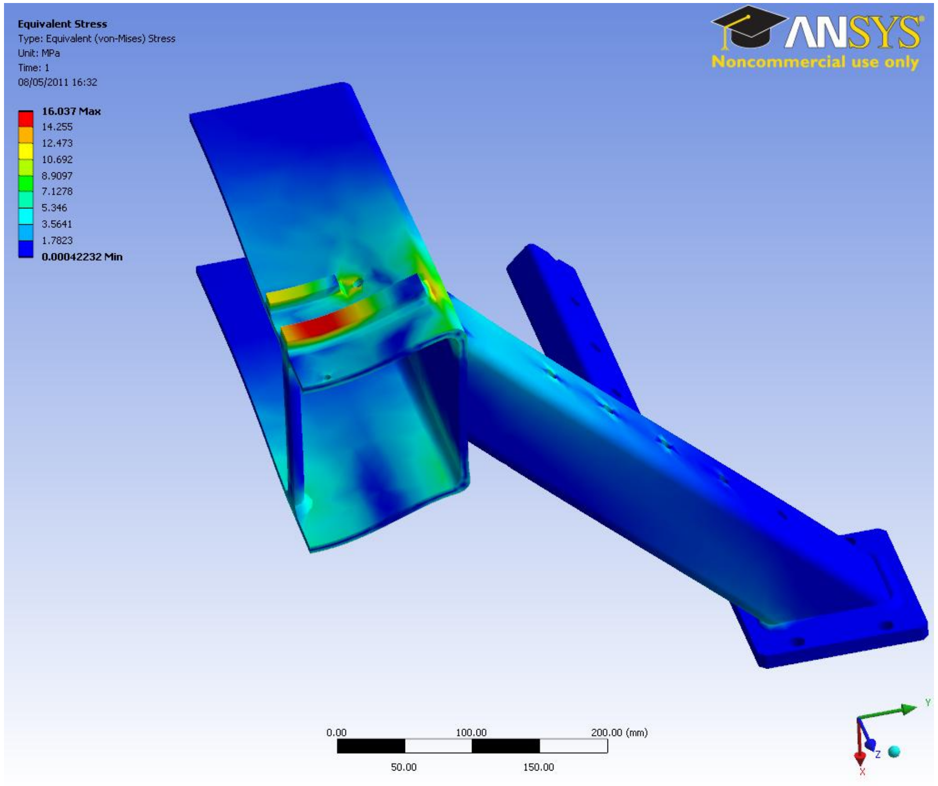


How much will the green RFQ support frame deflect under the weight?

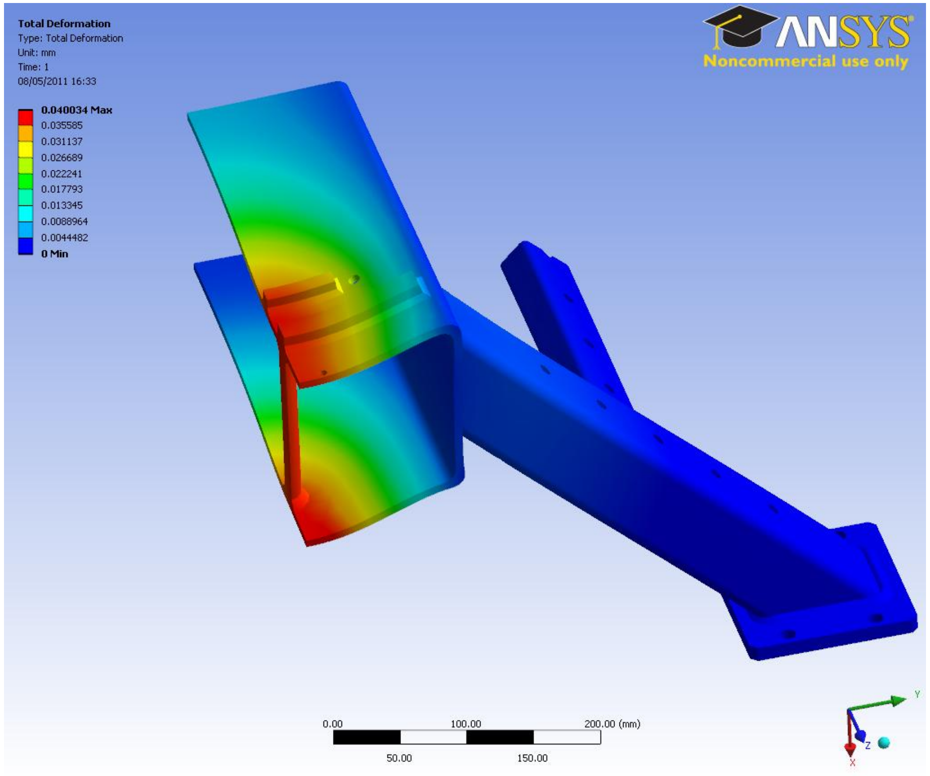
Structural steel, quarter cradle model, 2 symmetry planes, load = 1150 N

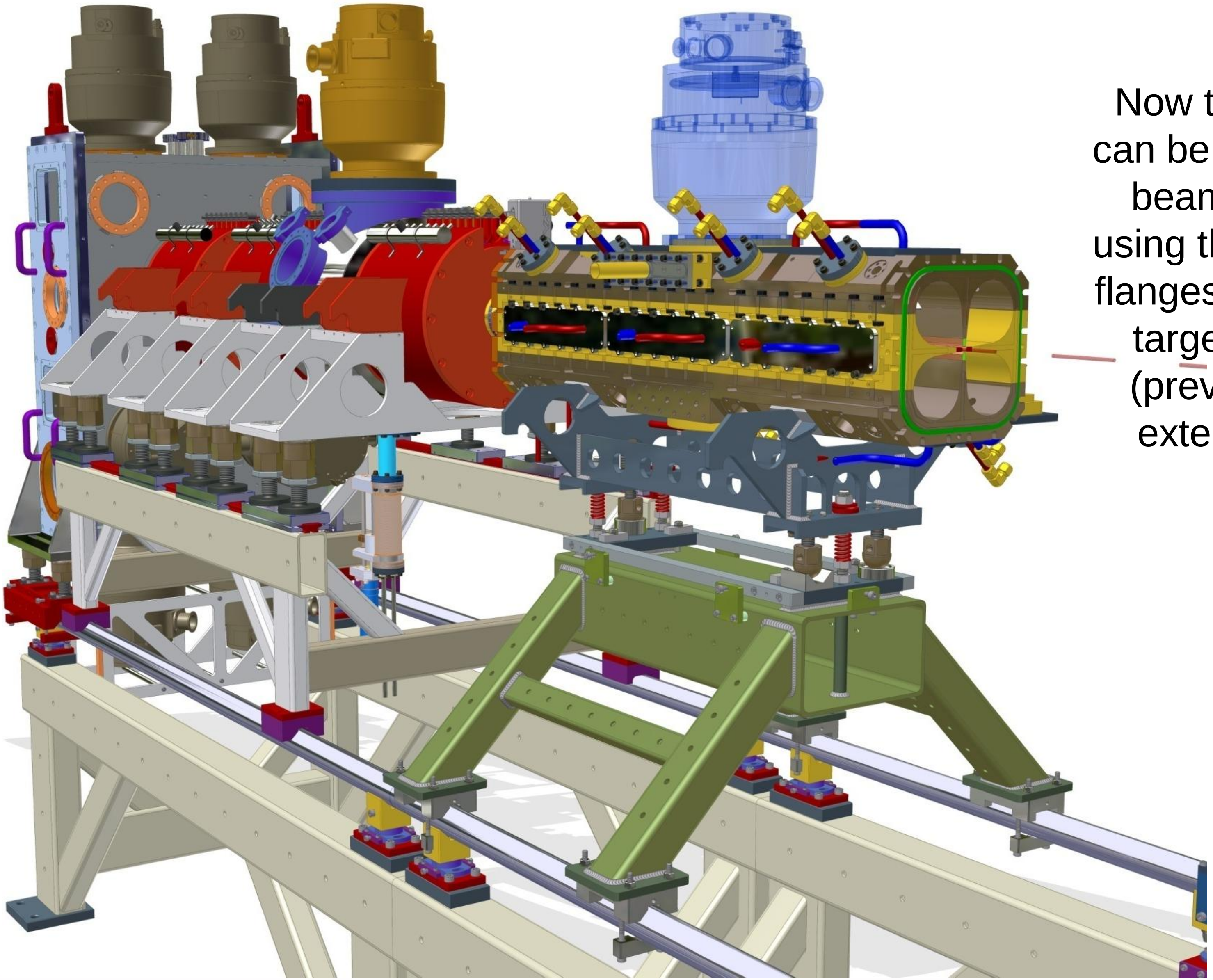
Component	Mass (kg)
Major vane	80
Major vane	80
Minor vane	30
Minor vane	30
Kinematics	10
Cradle	20
Vac pump	30
Tuners x 16	80
Baffles	100
TOTAL	460
Load per ¼	115





Maximum equivalent stress = 16MPa
Maximum deformation = 0.04 mm





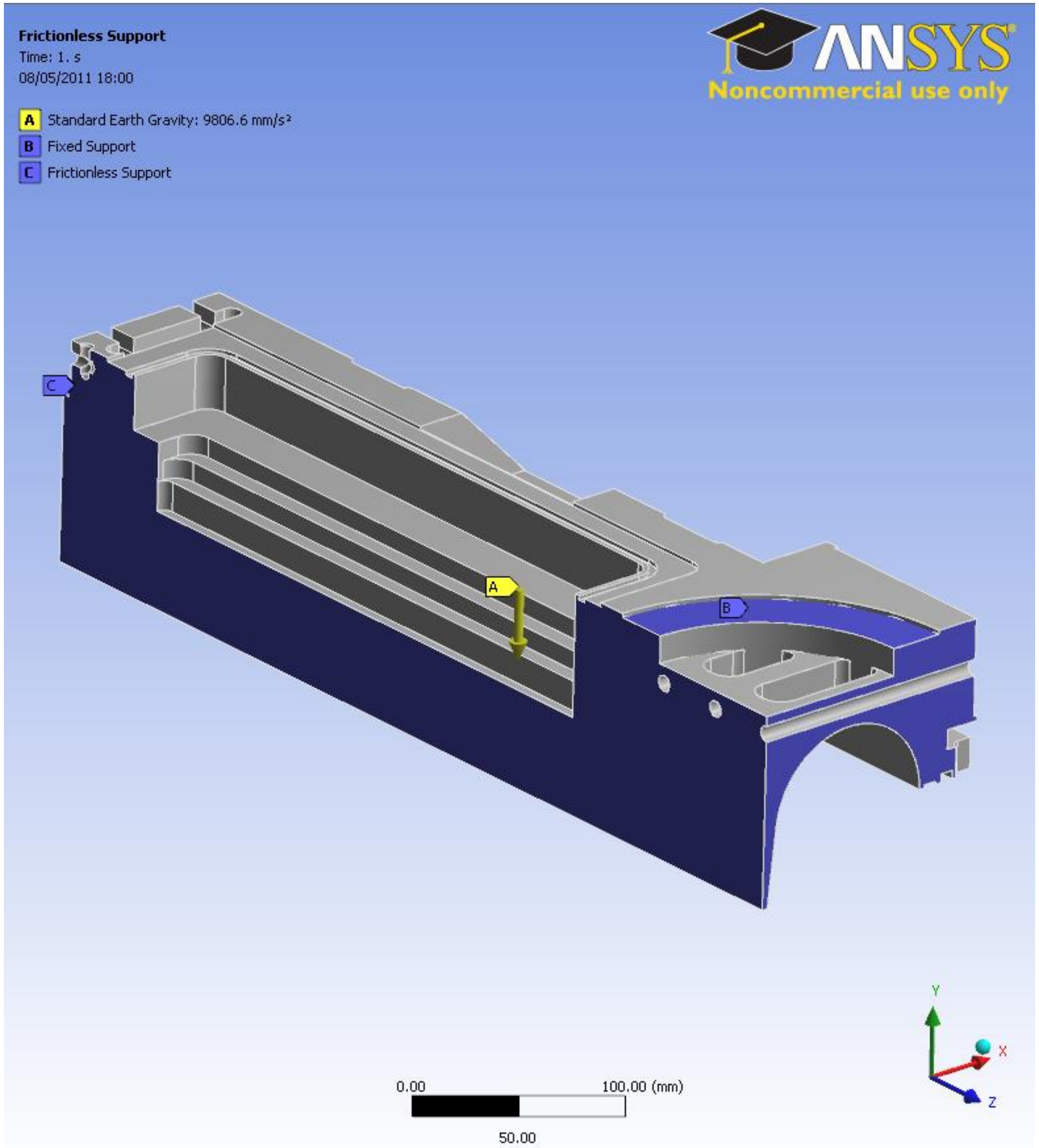
Now the RFQ section can be positioned to the beam axis either by using the alignment end flanges equipped with a target or by using a (previously) defined external reference.

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.

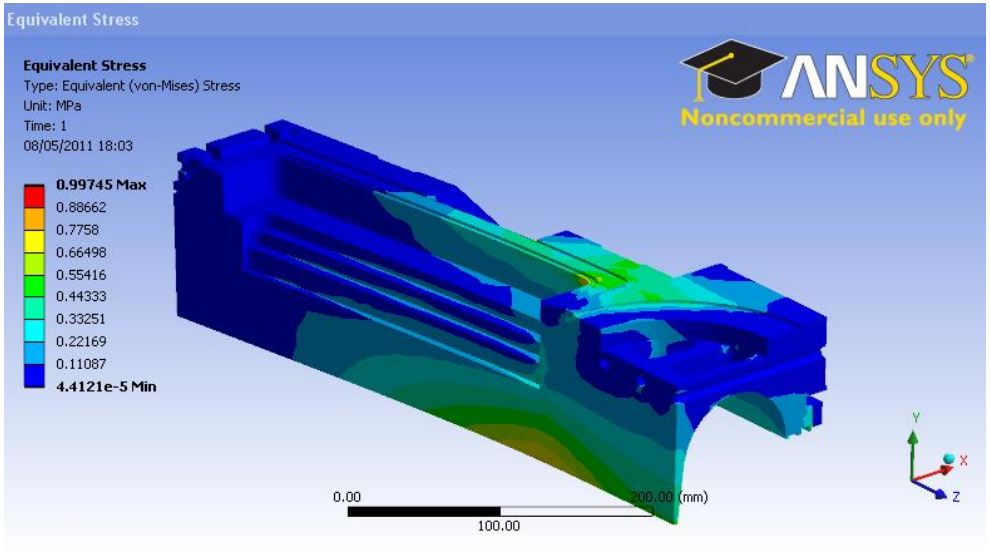
The simulation model



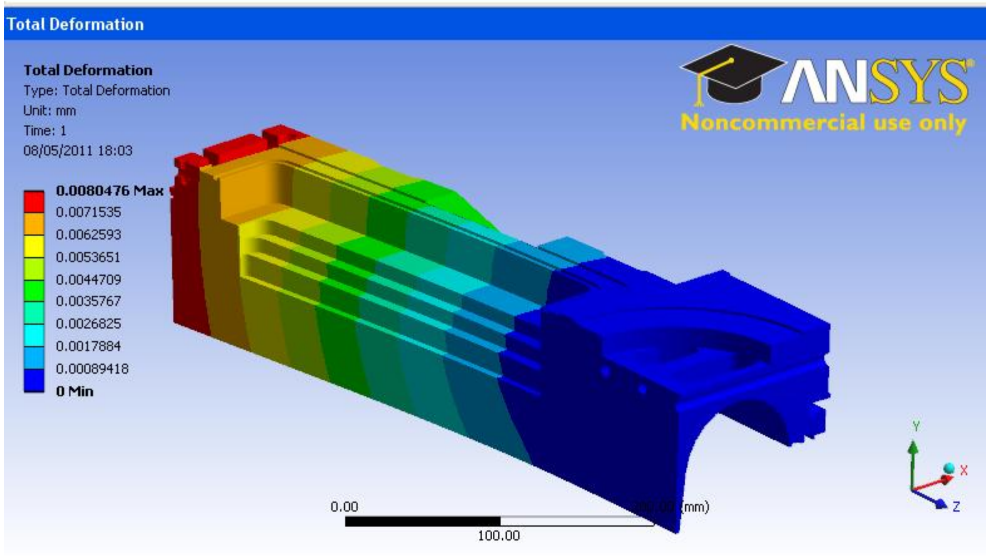
Imagine we supported one RFQ major vane by the vacuum port flange.

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

Max stress = 1 MPa



Max deformation = 0.008mm

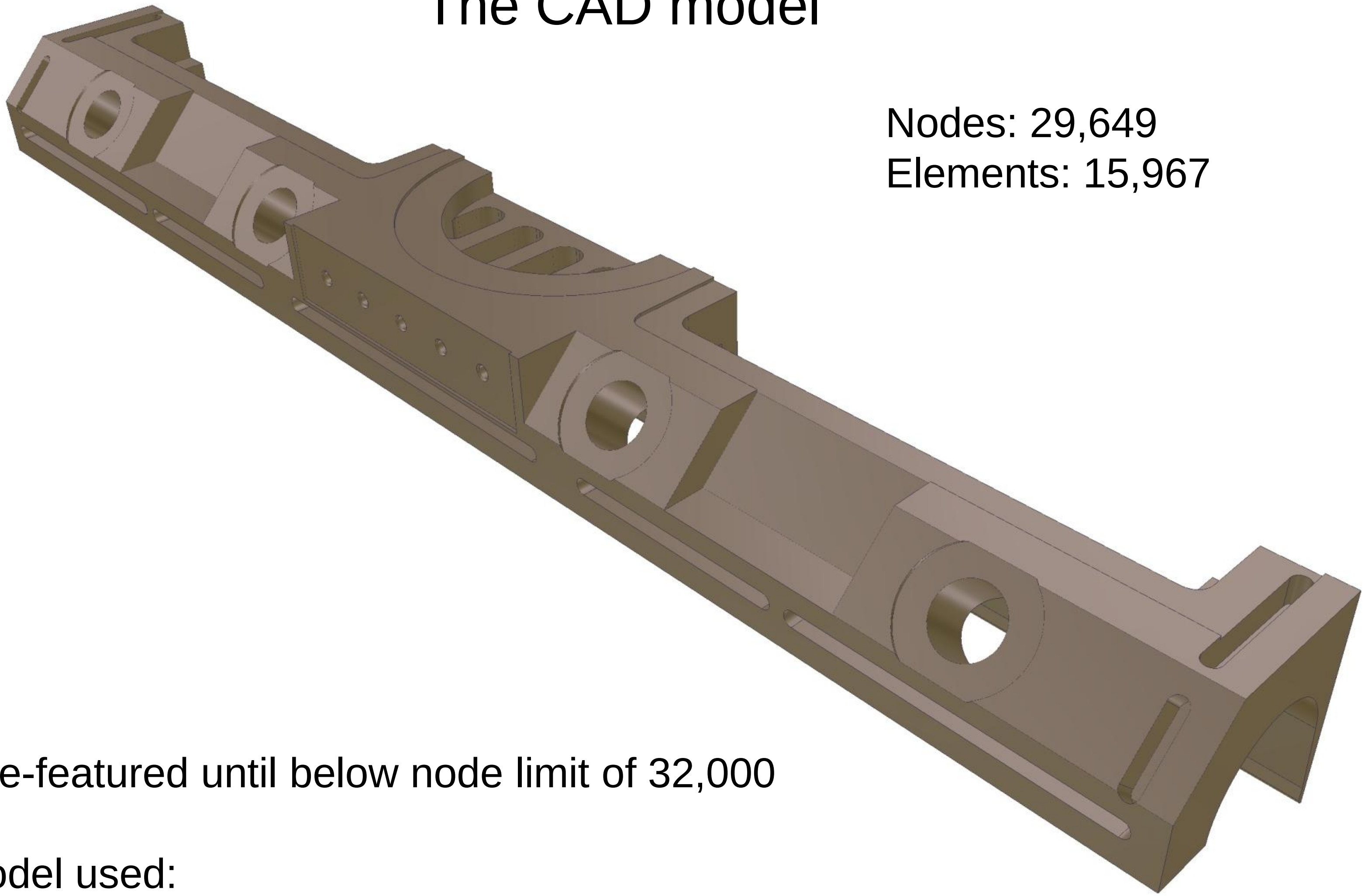


Hypothetical Case 2

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



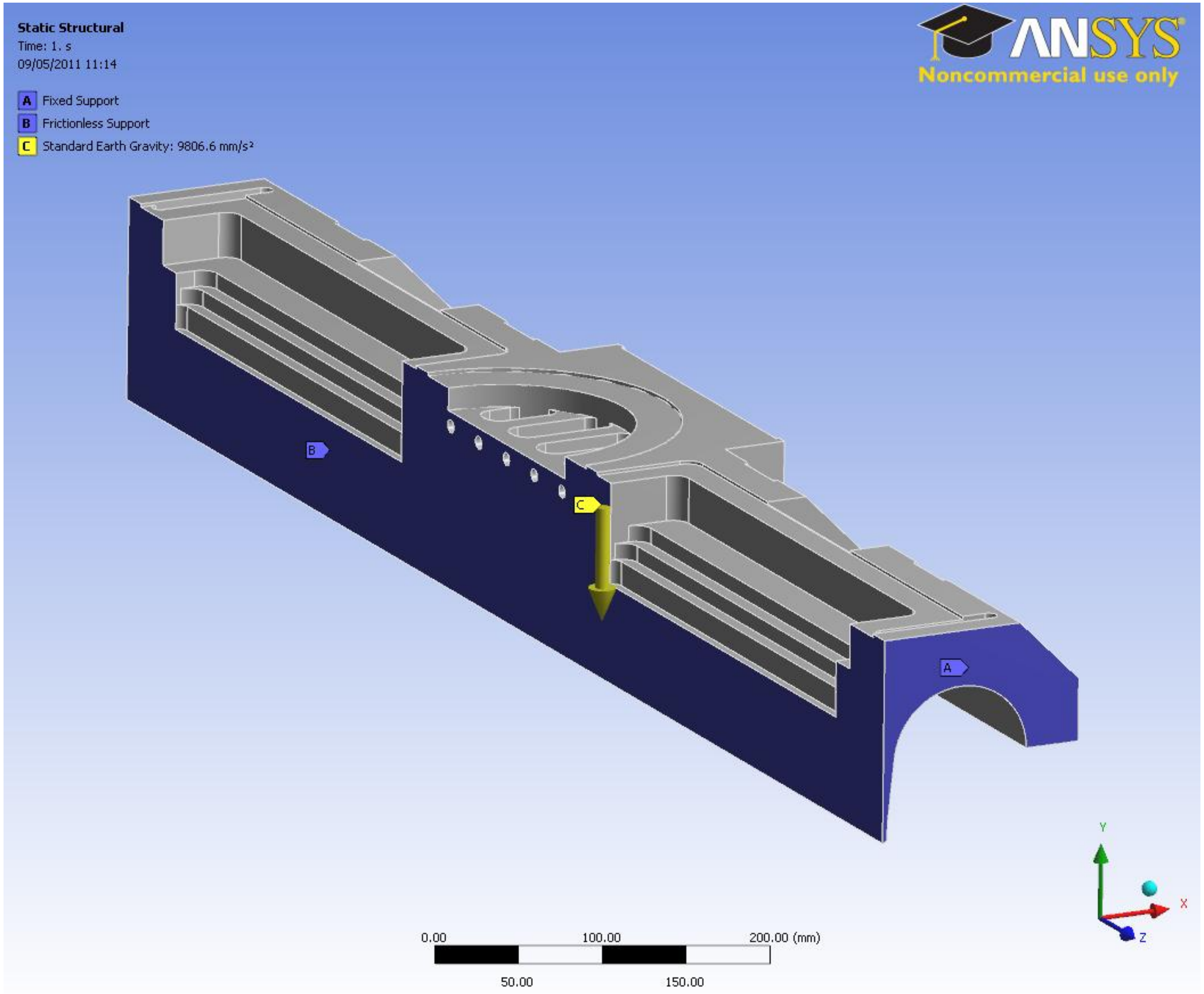
Nodes: 29,649
Elements: 15,967

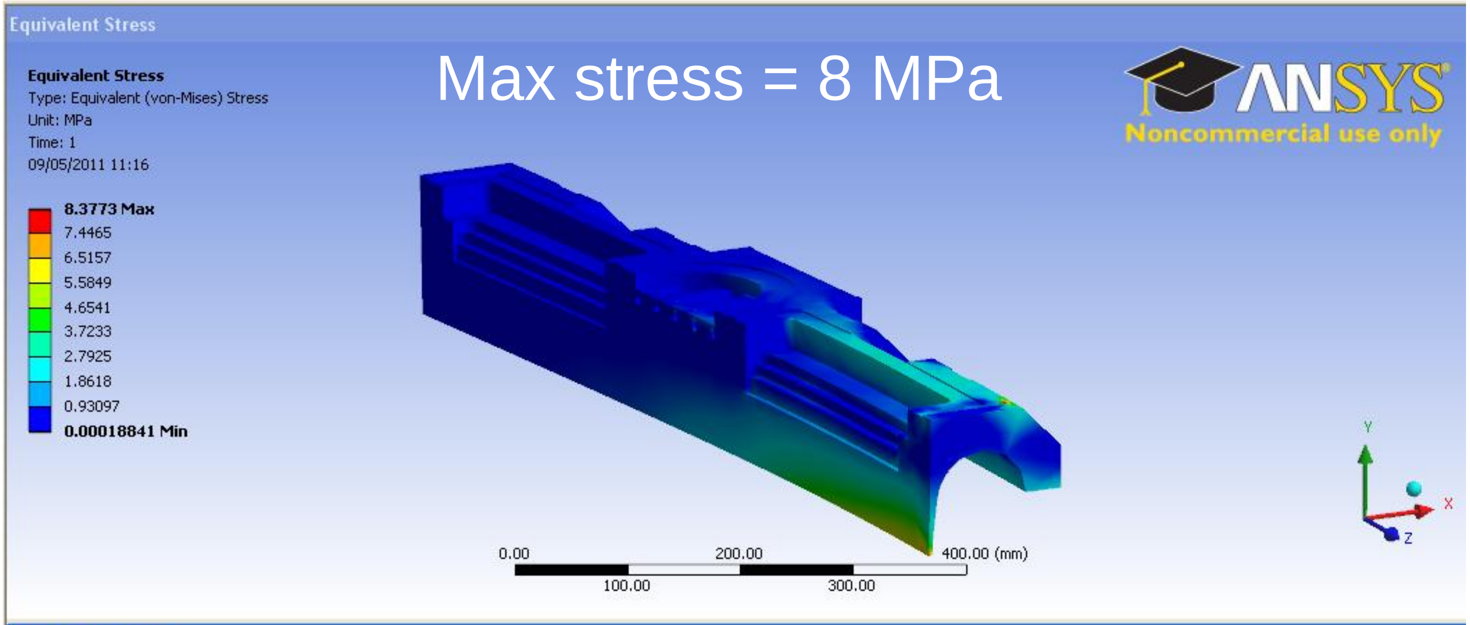
Model de-featured until below node limit of 32,000

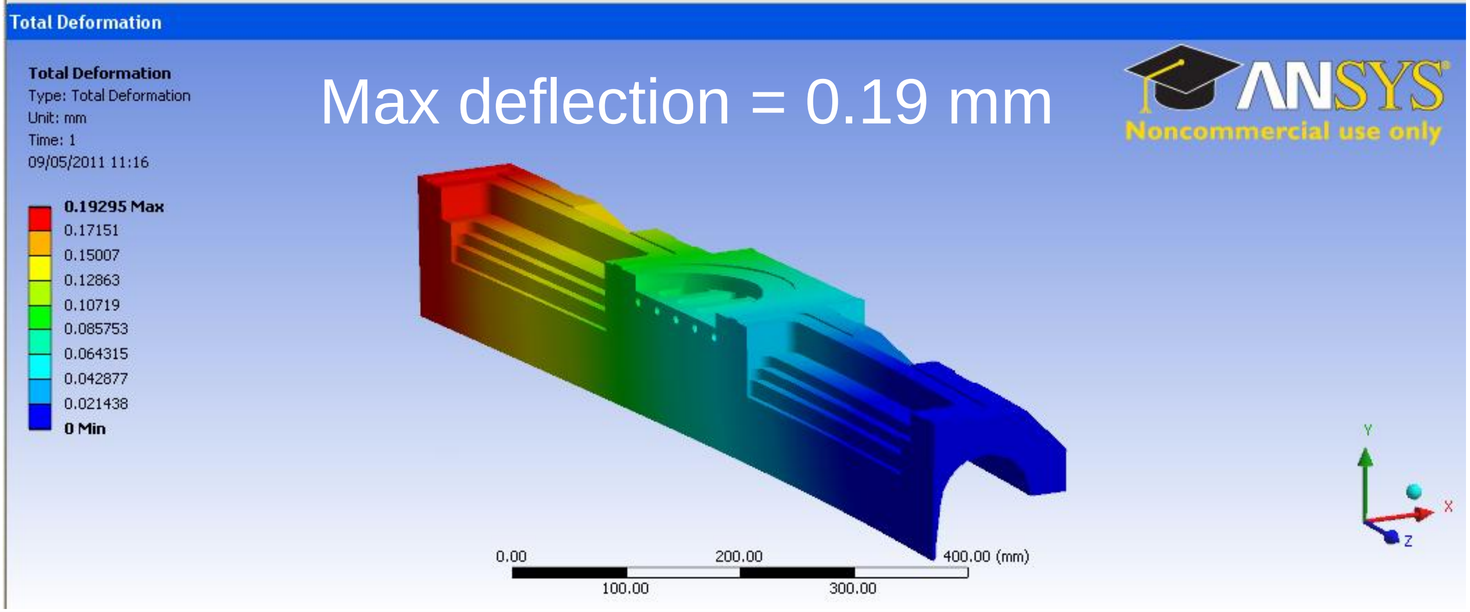
CAD model used:

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
100.00
200.00
300.00
400.00 (mm)
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
100.00
200.00
300.00
400.00 (mm)
Y
X
Z

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.

www.tribology-abc.com

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

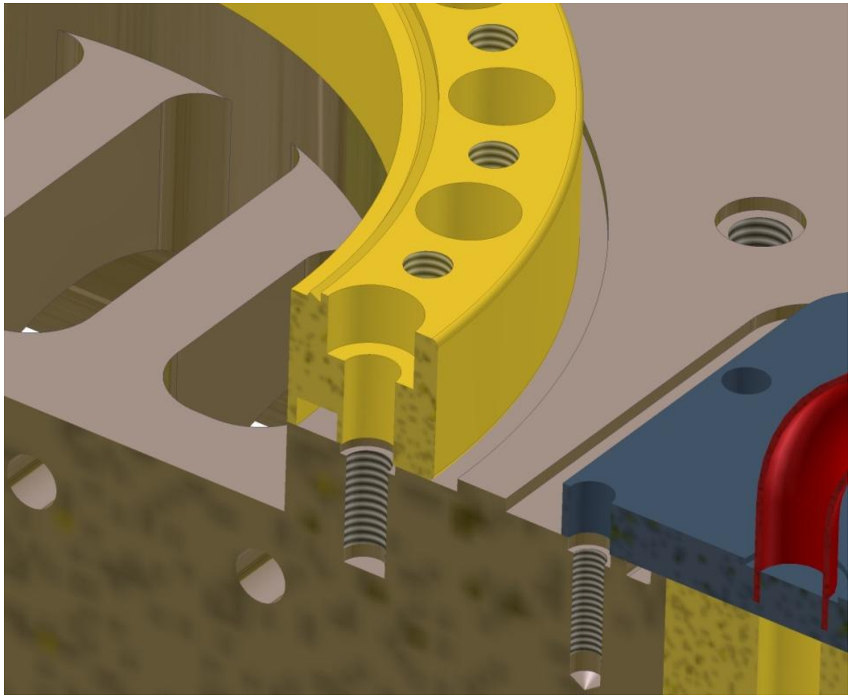
*The minimum value of thread engagement to make the tensile area determinative for the load at which the screw joint fails.

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.

Conclusions

1. Design of lifting beam and protective cage needs finalising
2. Plan needs next level of detail
3. Trial of adjustment blocks – result by end of next week.

Plan

Pete to continue with assembly lifting plan design.

Alberto to start setting out engineering drawings.

Approx. 4 weeks

Meeting with:
Dave Wilsher to show progress of engineering drawings.
Dave Wilsher to show development of assembly plan.
Jim Loughrey for advice regarding RFQ to FETS alignment.