U.S. DEPARTMENT OF ENERGY
Office of Science

BERKELEY LAB

ALS-U
ADVANCED LIGHT SOURCE

ALS-U Storage Ring magnet support and alignment

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Mechanical Engineer

ALS-U Supports & Alignment

May 10, 2021

PETRA IV: Mini-workshop on girders and alignment.

May 10-11, 2021

The ALS-U project, creating a world-leading soft x-ray source with highest brightness, coherent soft x-rays

Goals:

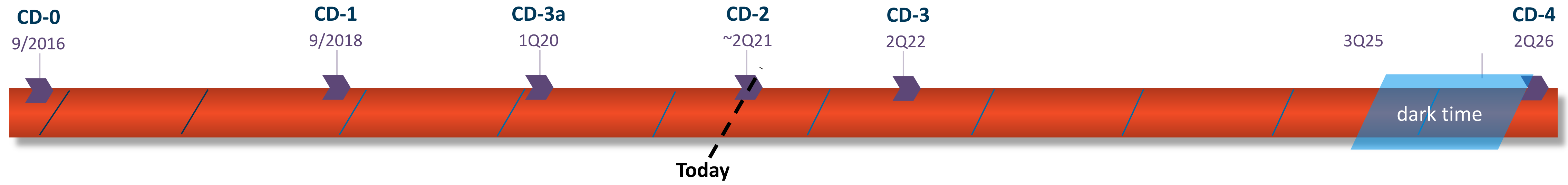
- Increased brightness and coherent flux of soft x-rays (@1 keV) at least 100X today's ALS capabilities
- Experimental capabilities that will enable leadership in soft x-ray science
- Infrared capability across the wavelength range, hard x-ray capability comparable to current ALS
- Rely on existing ALS infrastructure to reduce costs

Scope:

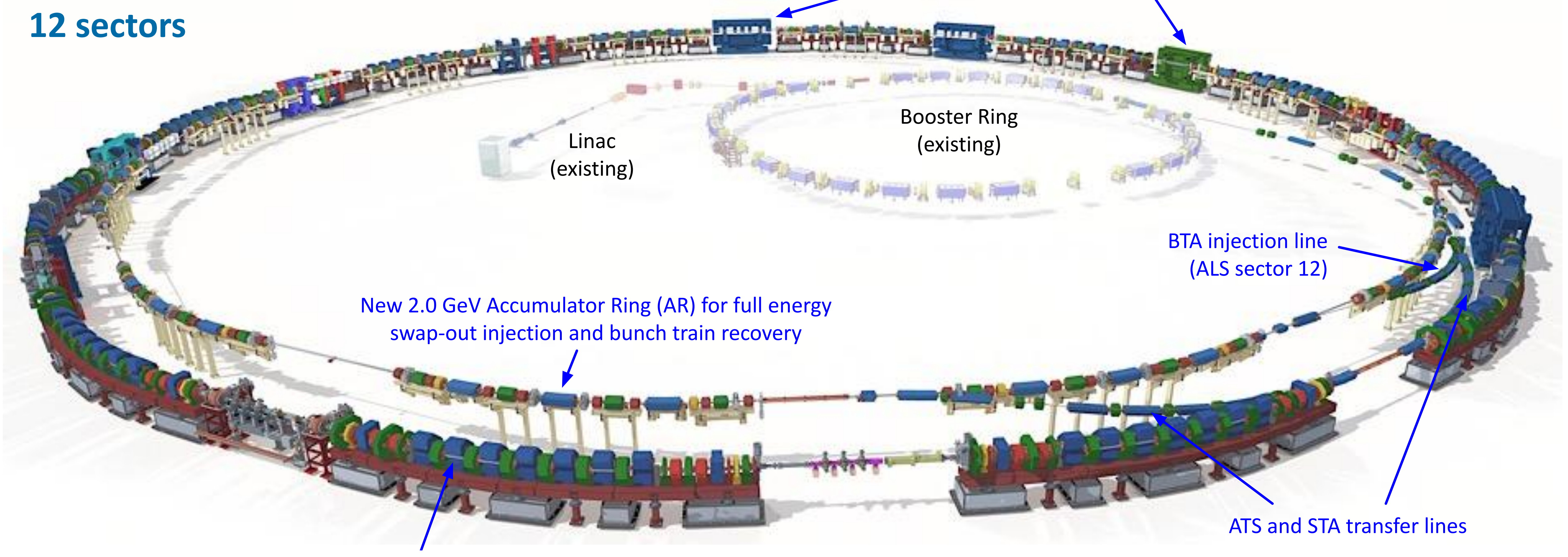
- New 2 GeV high brightness Storage Ring fed by new full energy Accumulator Ring in existing cave
- 2 new full-length undulators & high-field bends
- Realignment of bend-magnet beamlines
- 2 new and 2 upgraded undulator beamlines

Schedule: early finish: 2Q26, formal completion: 2Q28

Cost: current baseline estimate: $563M



197 m diameter
e-beam 1.4 m above floor
12 sectors



Acknowledgements / List of contacts

- **mechanical systems lead**: Steve Virostek spvirostek@lbl.gov
- **supports lead**: Barrie Phillips bphillips@lbl.gov
- **raft design**: Serenity Nguyen serenitynguyen@lbl.gov
- **magnet mounting**: Greg Harris glharris@lbl.gov
- **stability**: Arnaud Allézy apallezy@lbl.gov

Where we are

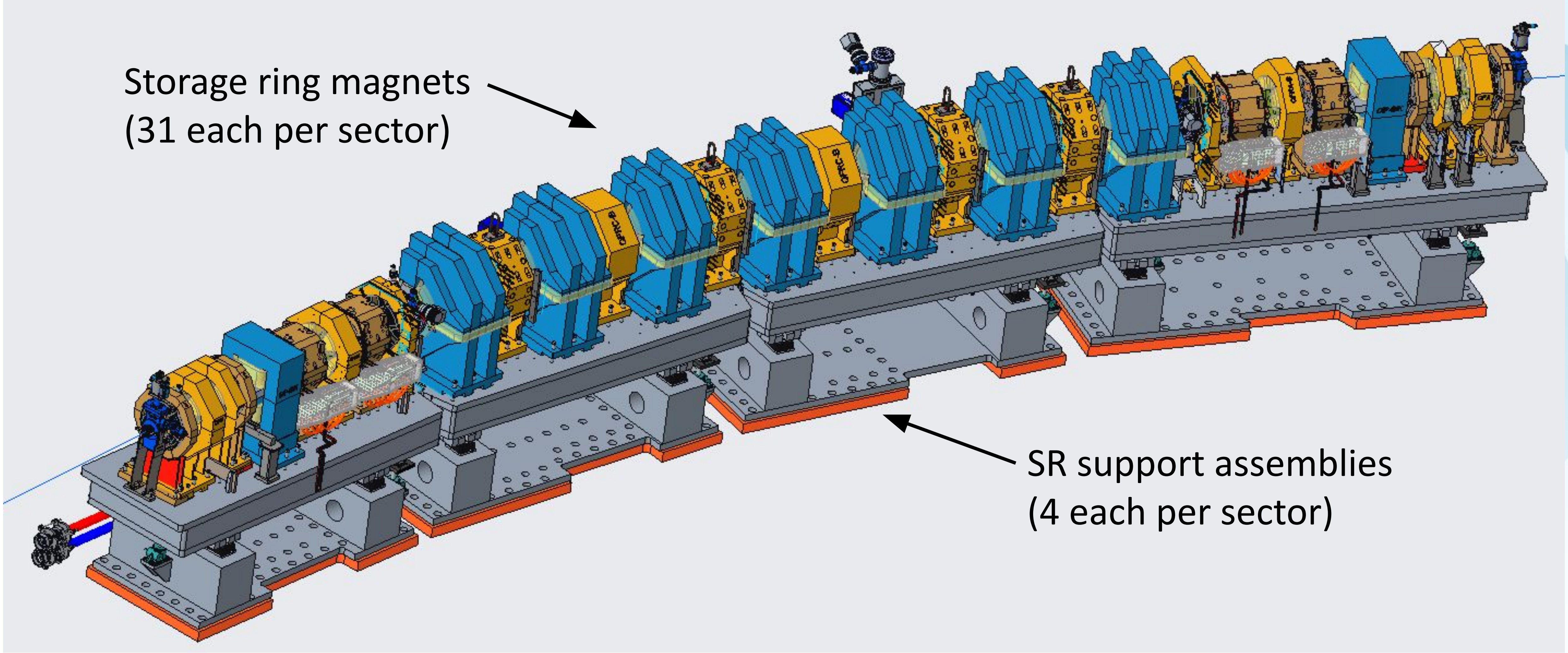
- CD3A authorized (~$50M) for early acquisition and install of the AR
- AR final design is essentially complete
- Planning early installation of the AR to allow commissioning before the dark time
- AR long-lead procurements started in 2QFY20
- Mar 2021: SR PDR
- April 2021: CD-2 approved!
- Currently not funding limited: $62M in FY20, $75M in FY21
- Current focus: initiate SR final design

Outline (extracted from SR PDR Mar 2021)

1. Sector overall design
2. Raft design
3. Magnet & Vacuum mount concept
4. Alignment
5. Stability
6. Conclusions & Next steps

Sector overall design

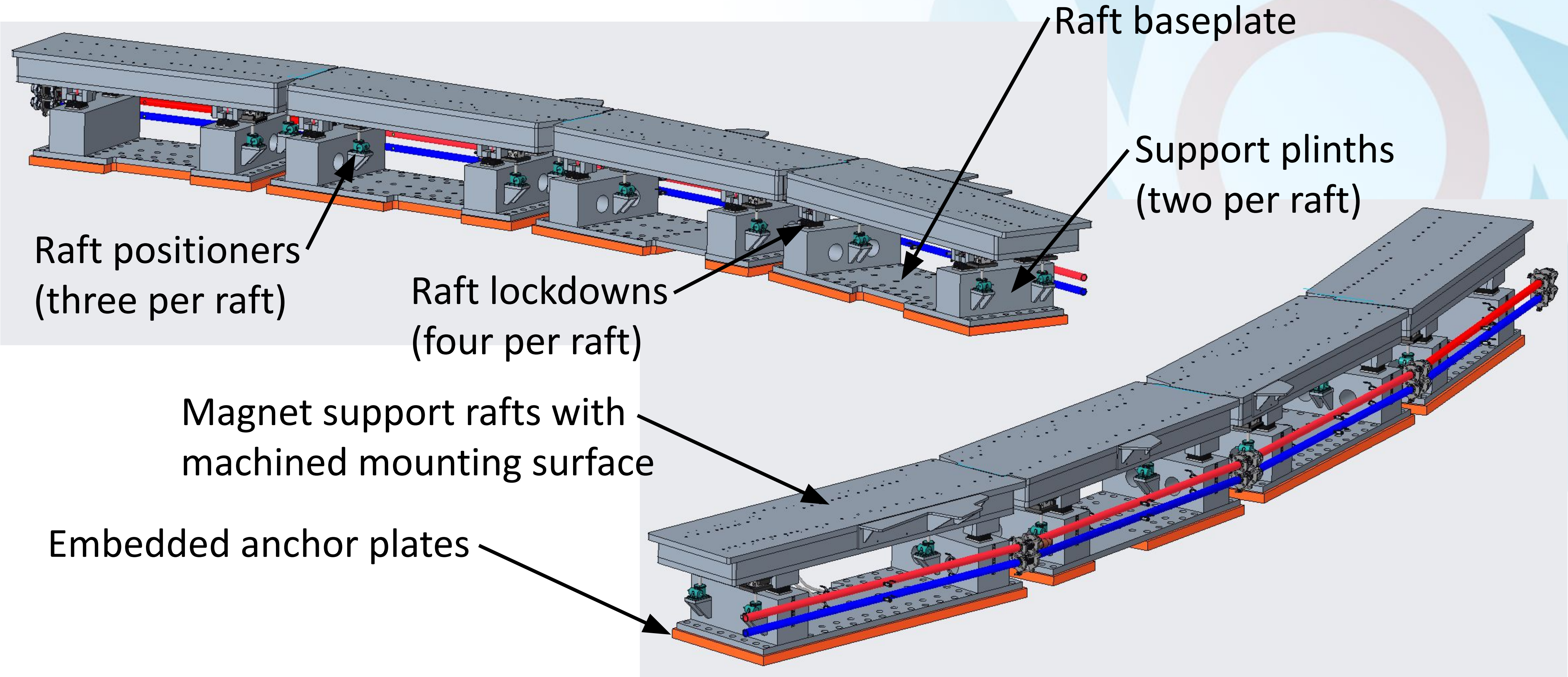
SR representative sector overview



Storage ring magnets
(31 each per sector)

SR support assemblies
(4 each per sector)

SR sector supports hardware



W_m = Magnet mass per raft
W_r = Total raft assy weight

4-raft design

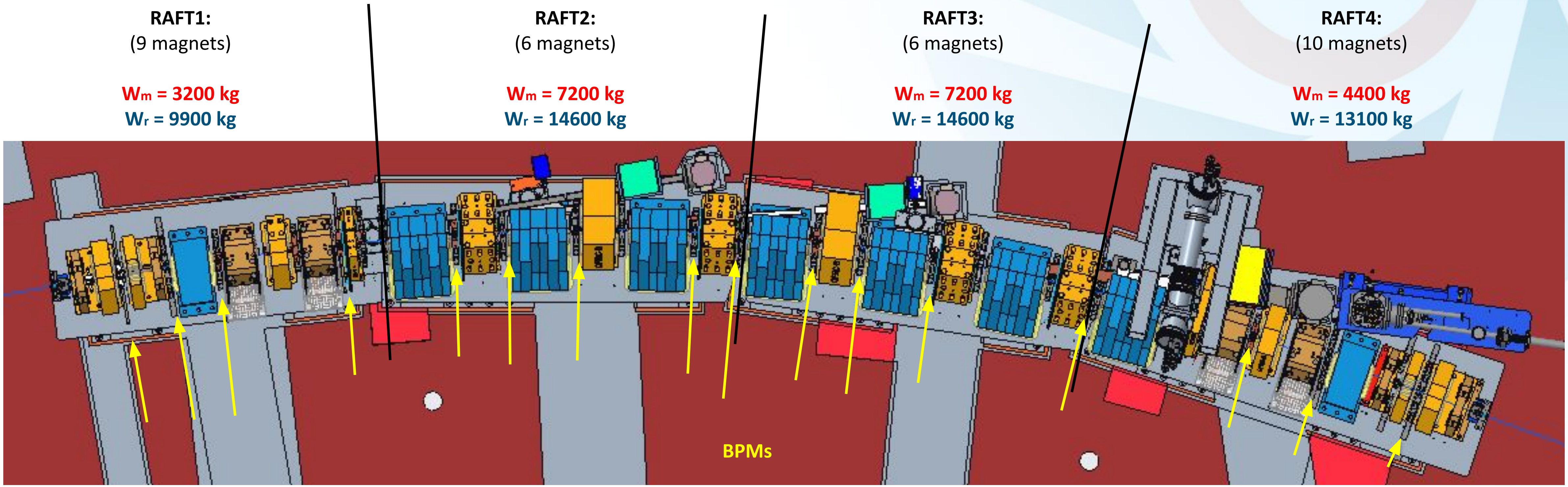
- meets stability requirements
- compatible with vacuum chamber joints
- manages overall weight of individual rafts

RAFT1:
(9 magnets)
W_m = 3200 kg
W_r = 9900 kg

RAFT2:
(6 magnets)
W_m = 7200 kg
W_r = 14600 kg

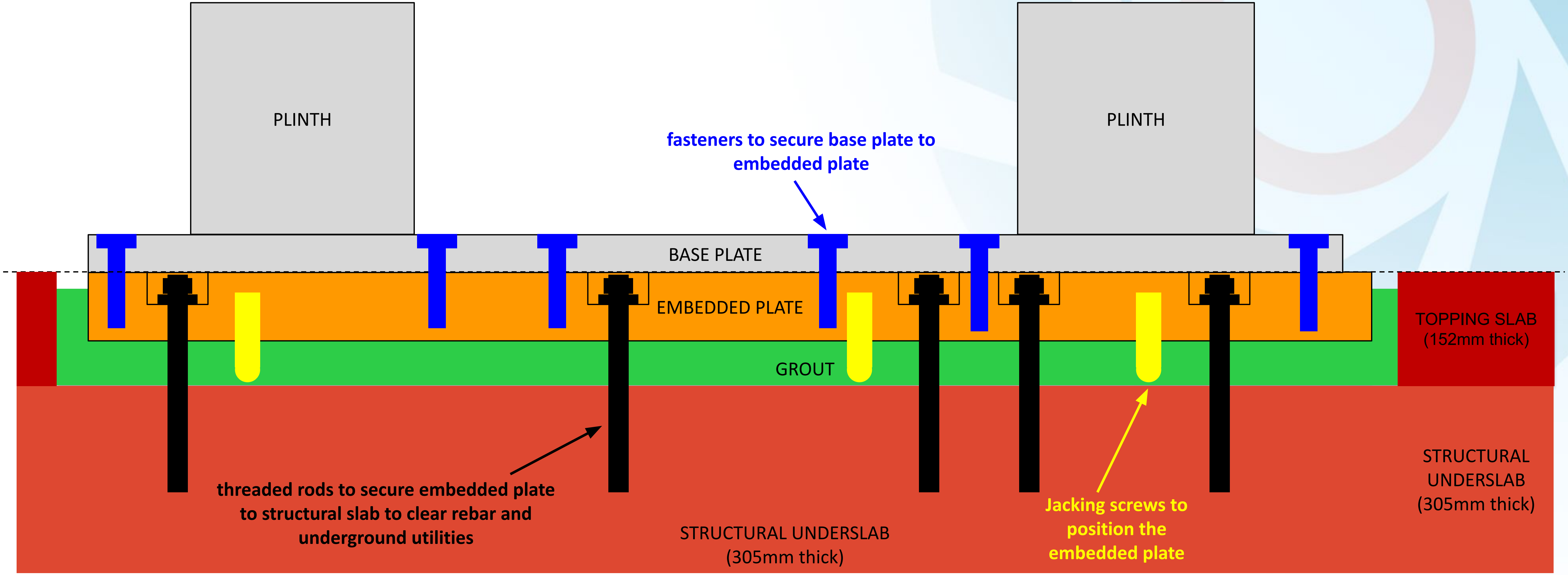
RAFT3:
(6 magnets)
W_m = 7200 kg
W_r = 14600 kg

RAFT4:
(10 magnets)
W_m = 4400 kg
W_r = 13100 kg

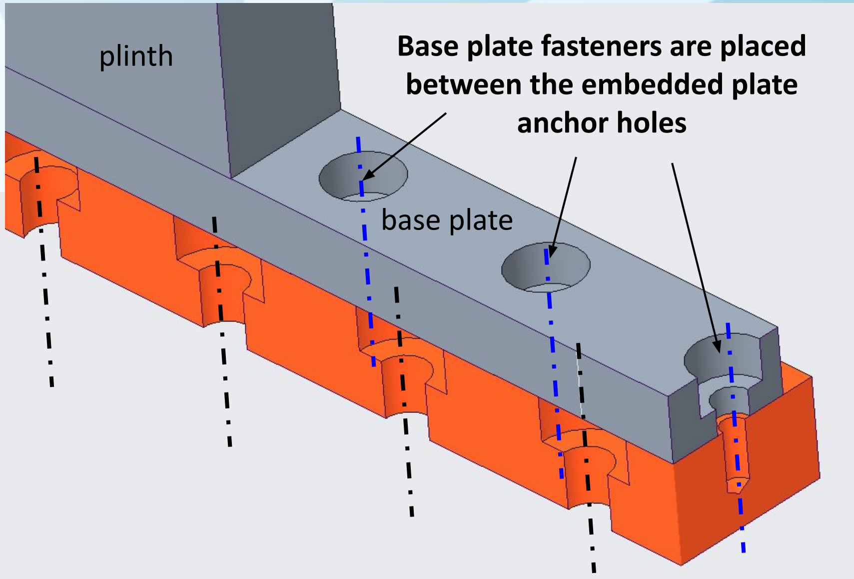


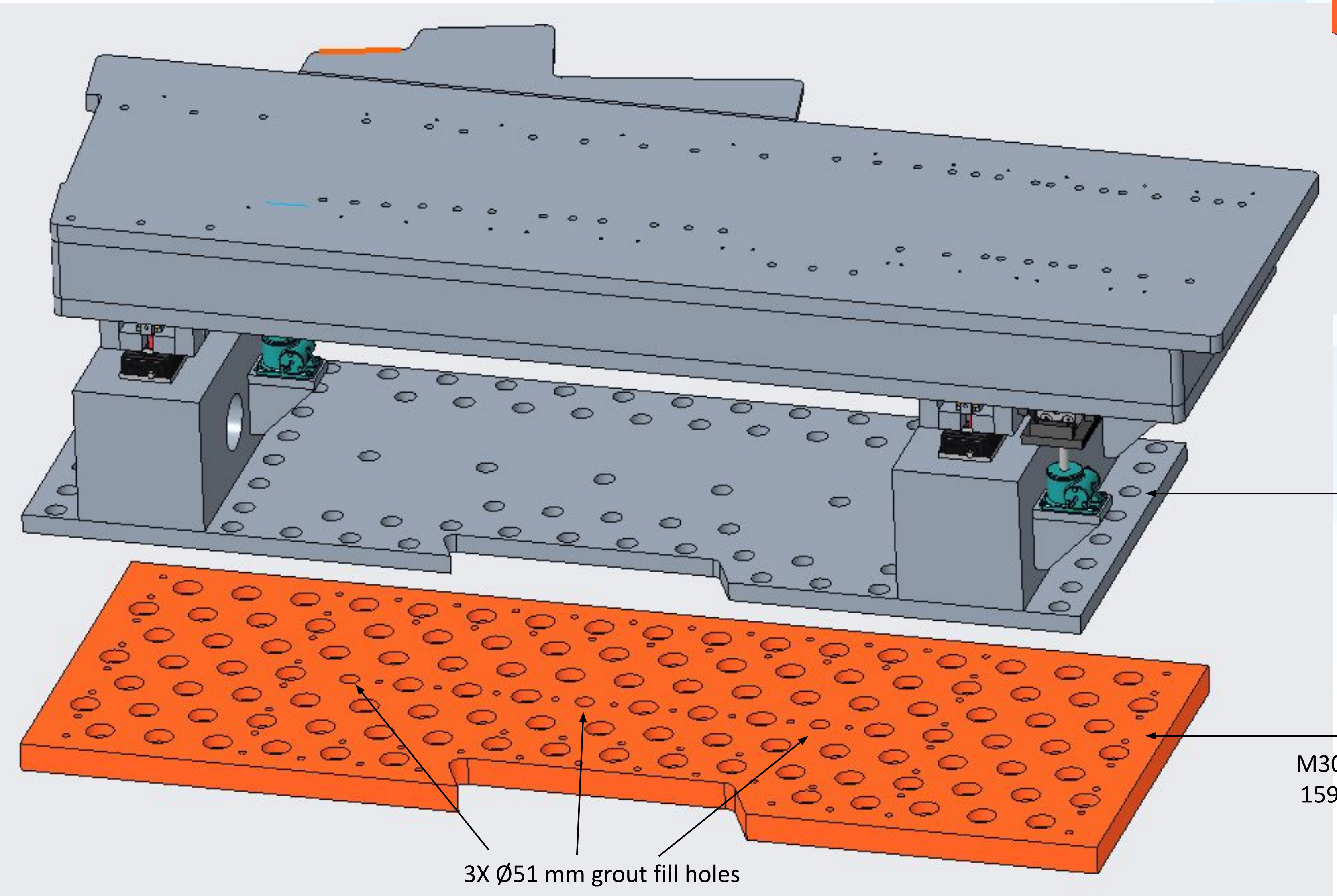
Raft design

Embedded plate concept



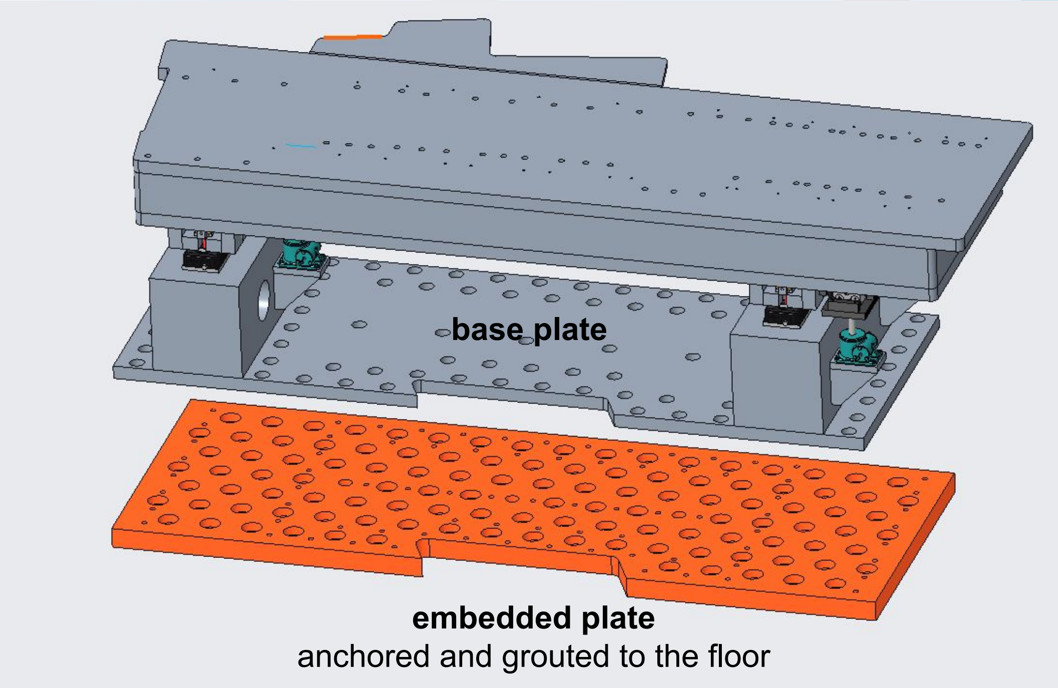
Embedded plate design





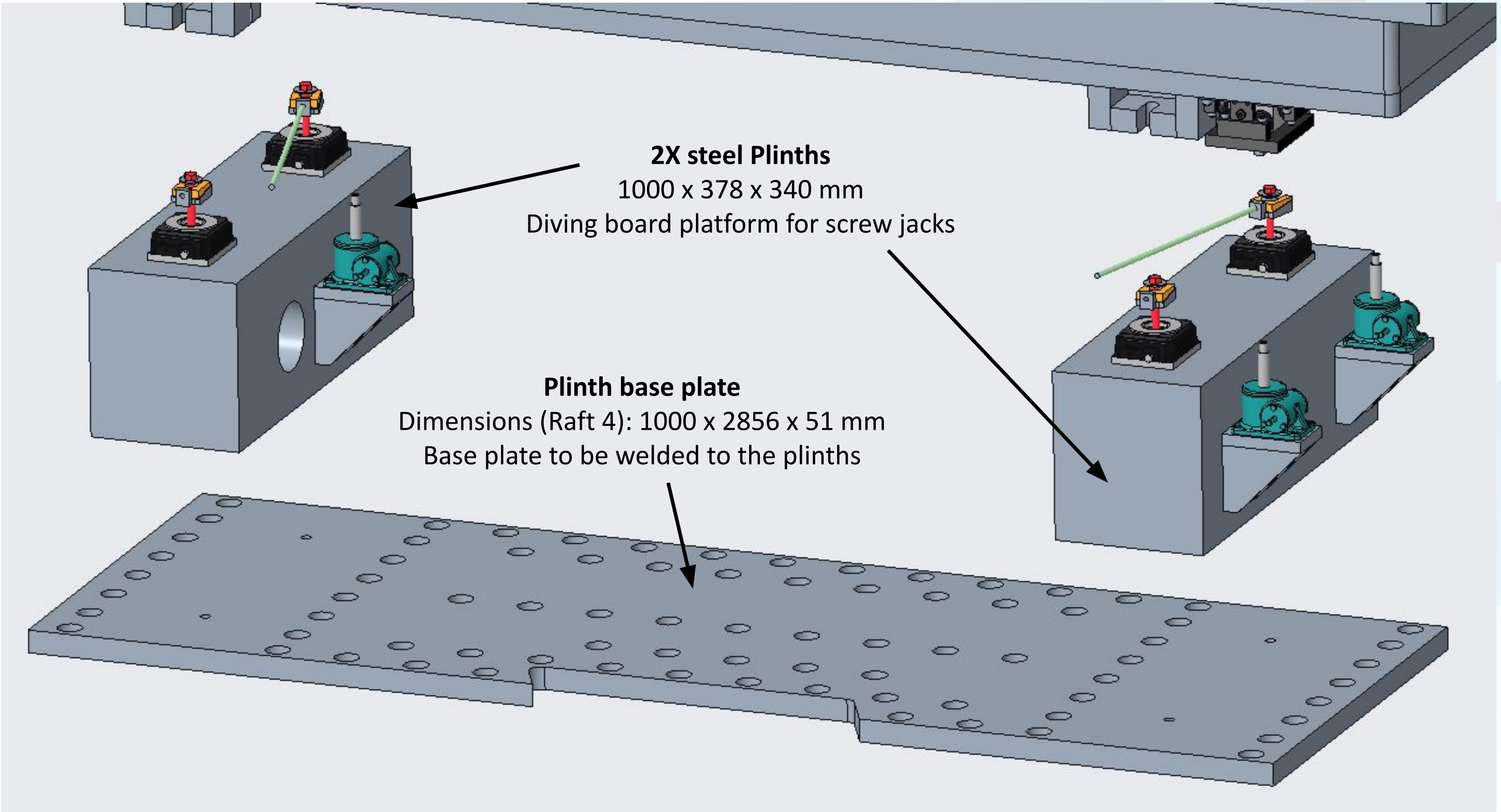
Embedded plate installation

- Procedure:
  - Cut out topping slab around embedded plate
  - drill structural underslab for embedded plate threaded rods.
  - Level and align embedded plate anchor holes over threaded rods.
  - Grout embedded plate & fasten threaded rods.
  - Fasten raft-plinth assembly to embedded plate.
- Advantages/Optimizations:
  - provides lots of options for anchoring while clearing rebar and underground utilities
  - provides a sturdier alternative to anchoring in concrete and reduces number of fasteners in the plinth base plate
  - does not require raft assembly be lifted over threaded rods anchors that would protrude above floor. Threaded rods used to secure embedded plate to be cut to length prior to installation.



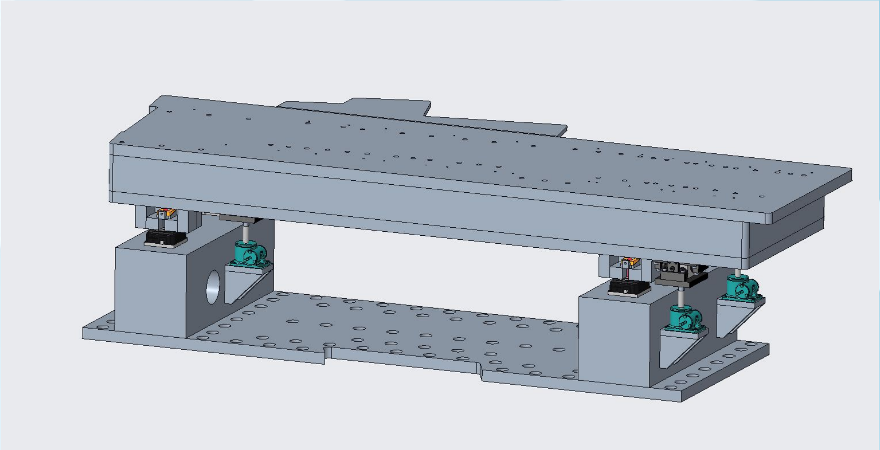
Plinth and base plate design

base plate provides anchoring, supports plinths, room between raft and base plate to pre-stage sub-system components.

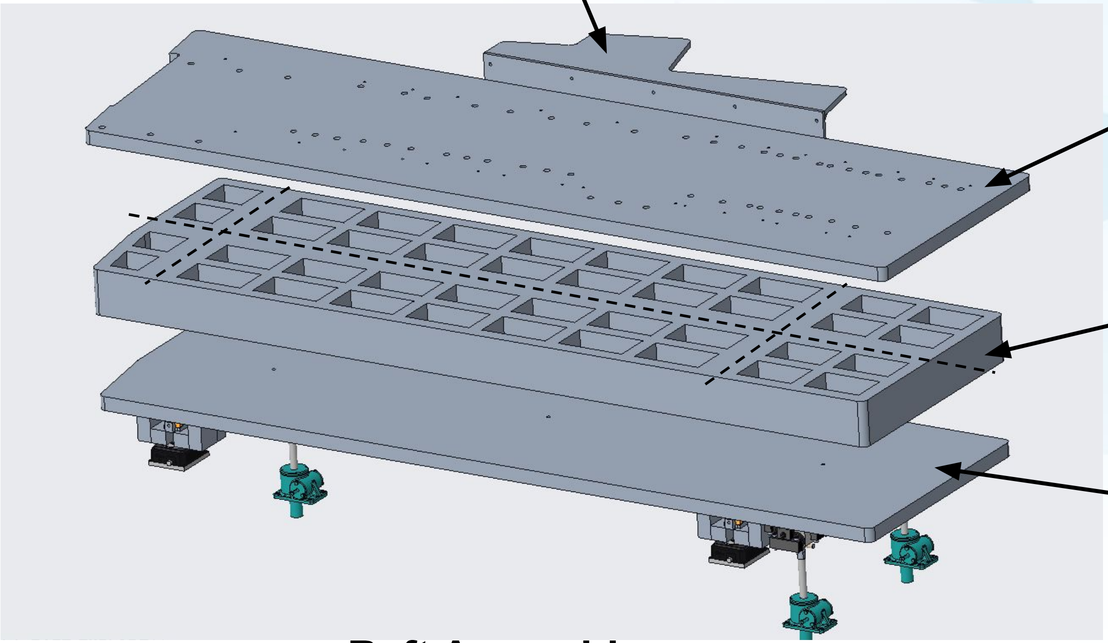


Welded core

- Raft core designed to improve stiffness, thickened spines along centerline (Z) and along the two lockdown positions (X)
- waterjet cutting
- Top plate dimensions and hole pattern machined after welding
- Overhang would replace FE BL stands that interfere with raft plinth base plate



Overhang for FE BL vacuum components, Fastened to raft assembly



Raft Assembly

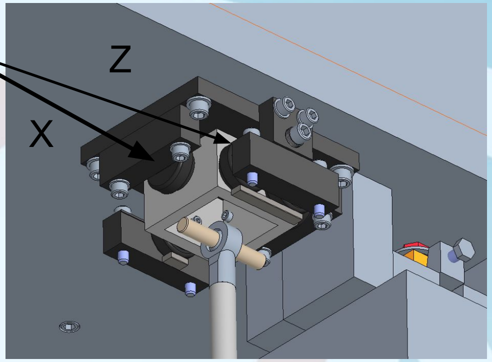
Top Plate: welded to the core, 50.8 mm thk

Raft Core: waterjet cut honeycomb structure, raft core height is 164 mm

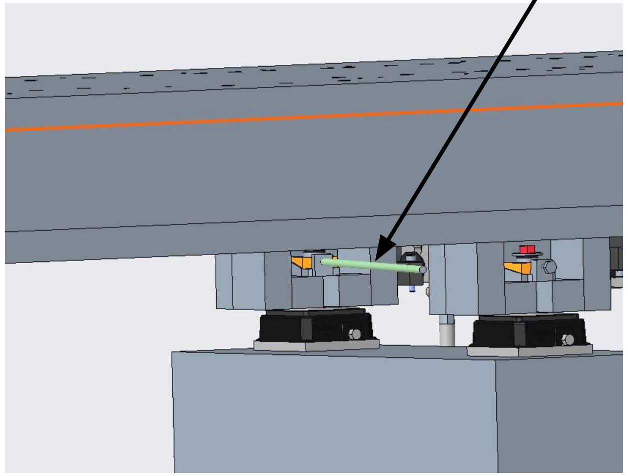
Bottom plate: bolted to the raft core, 50.8 mm thk. Alternative: Welding to the core.

Movers and Lockdowns

3x **Horizontal Raft Movers** per raft assembly
3 Roller bearings for X per Raft Mover
3 Roller bearings for Z per Raft Mover

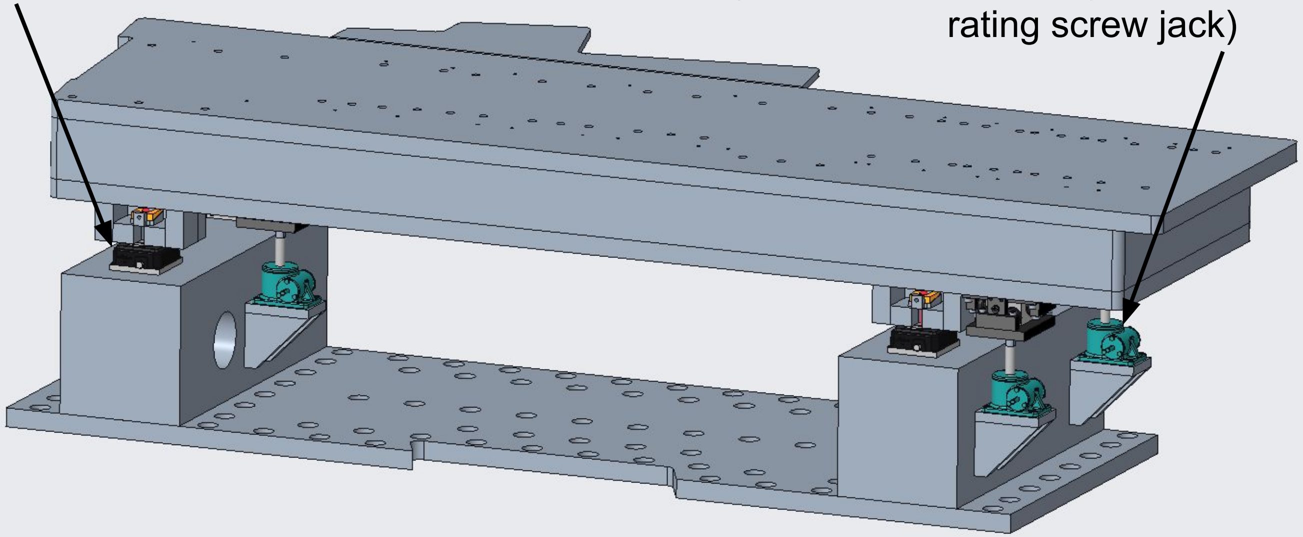


2x **Adjustment Rod**
Allows Lockdown manipulation from aisle side



4x **Lockdown Clamp**
Load Leveler + Wedge Clamp
Post-Alignment Position

3x **Vertical Adjuster**
Y Translation during Alignment
Screw Jacks (to be updated to a higher load rating screw jack)



Raft design take away

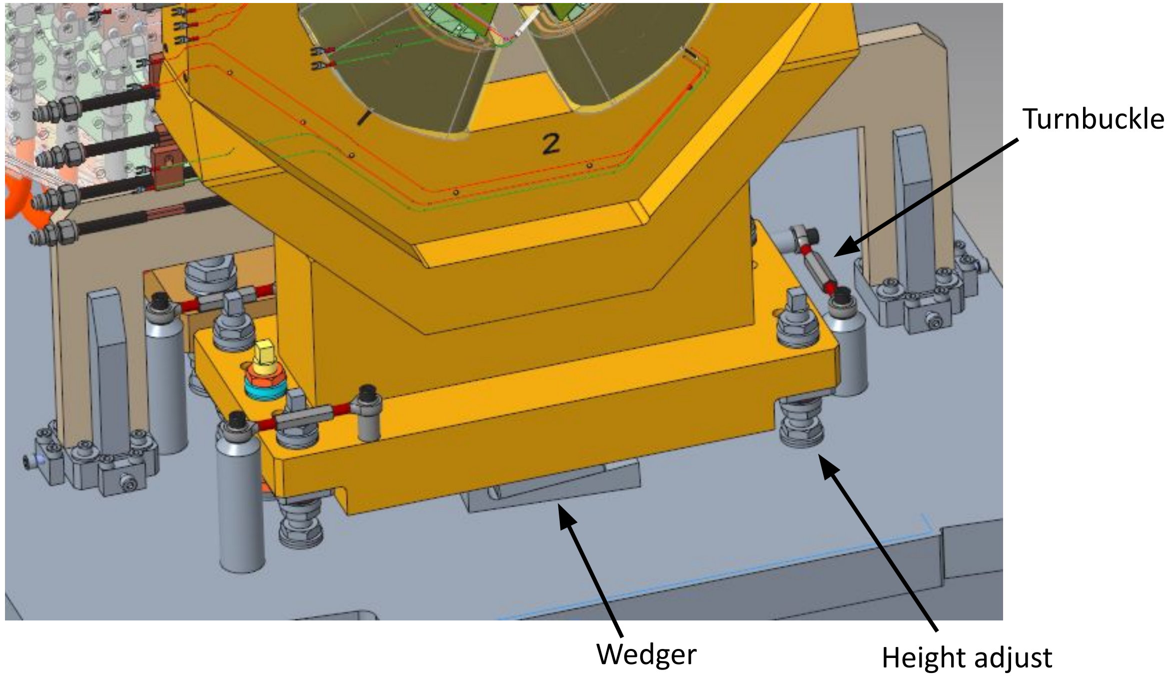
- 4-Raft design has progressed from 7-Raft design to meet stability requirements while decreasing installation time, and designed with compatibility with other subsystems.
  - Plinth and base plate design will mature with FEA verification.
  - Movers and aligners will be re-evaluated as raft loads have increased since 7-Raft design.
- Embedded plate anchoring is in progress with forthcoming input and verification from seismic group.
- Path forward: finalizing subsystem interfaces, structural analysis, and installation procedures.

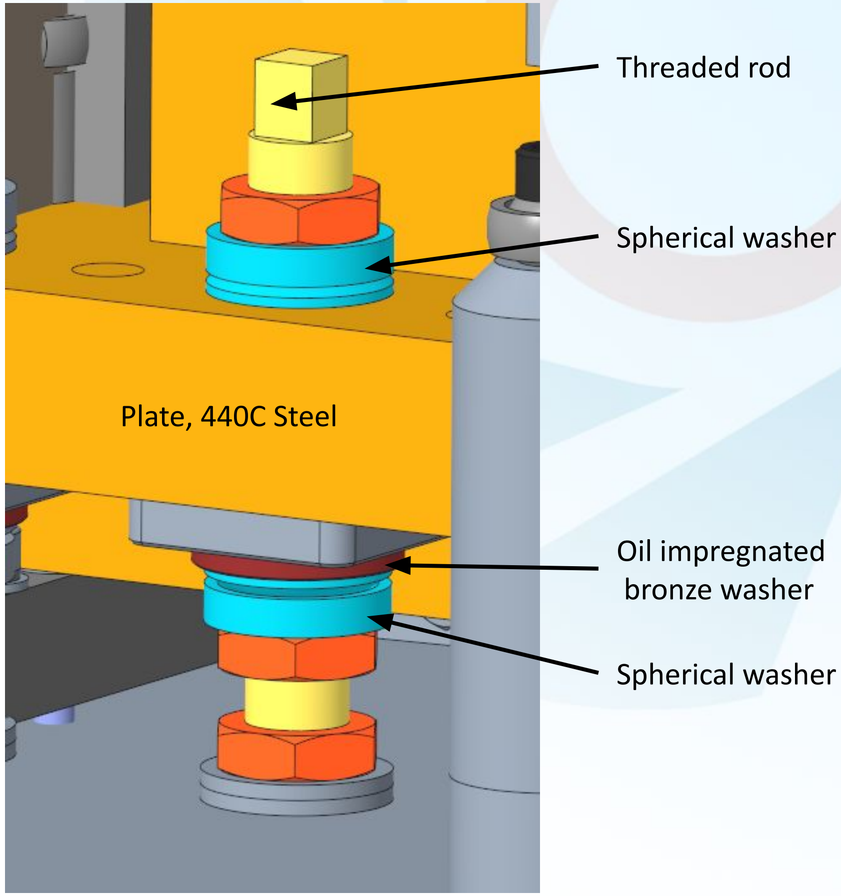
Magnet & Vacuum mount concept

Magnet mount: 3 jacks, 3 struts = 6 DOFs

Magnet alignment:

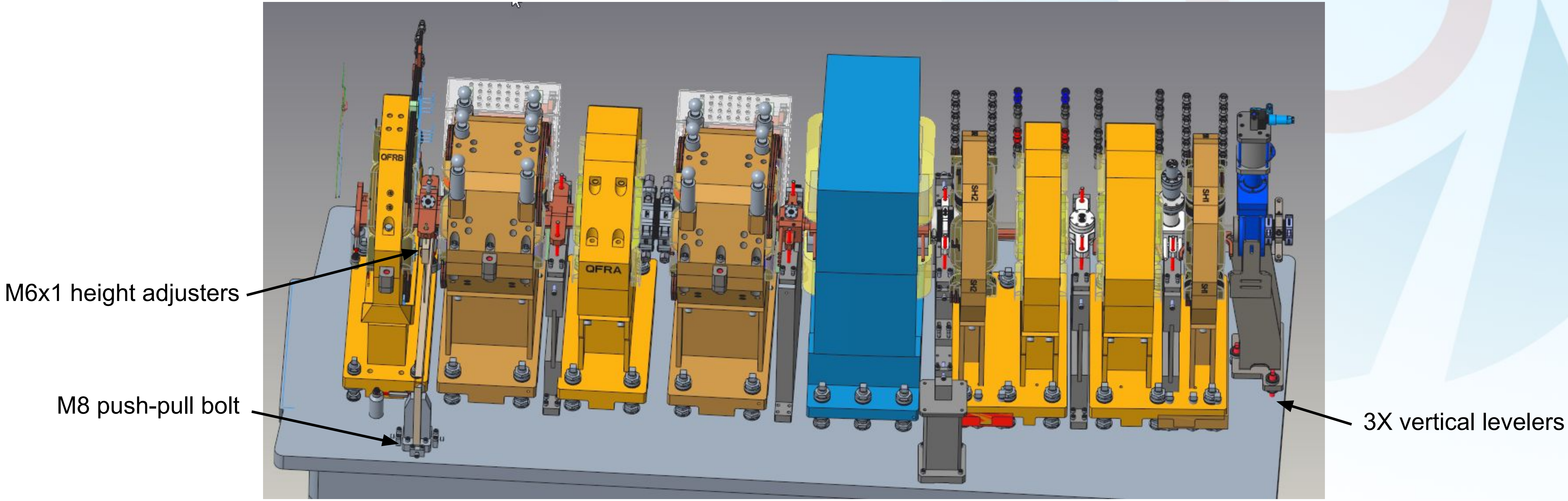
1. 3X M20x2.5 or M24x3 height adjust studs
2. 3X M8x1.25 turnbuckles for lateral adjust
3. Secured magnets with height adjuster nuts
4. Additional 2X studs + 1-2X wedges for stability



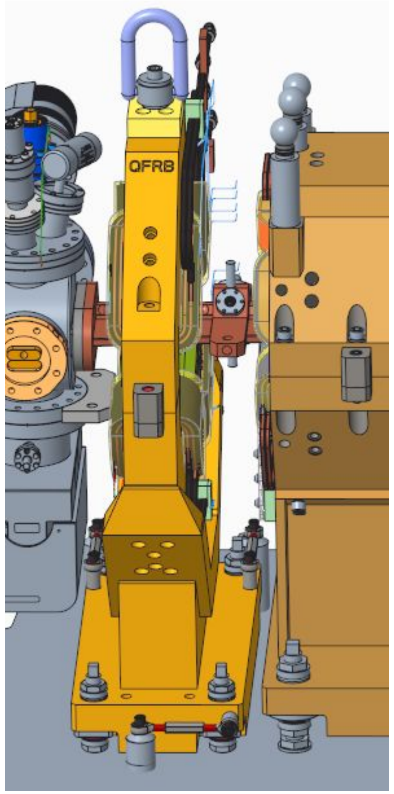


Vacuum mount

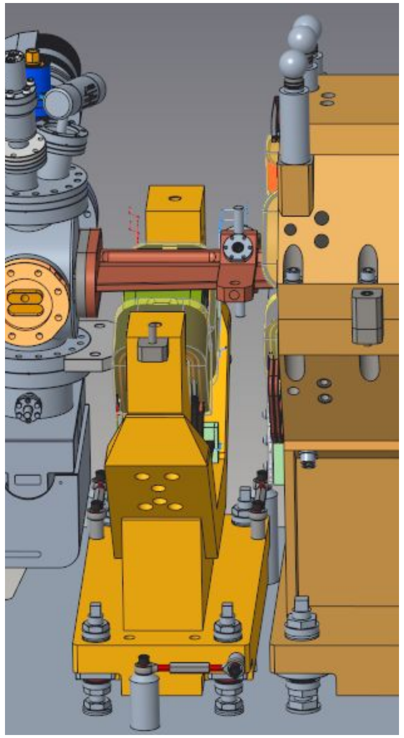
- Inline pump and gate valve have 6 DOFs : 3X M16x1.5 height adjust studs + lateral adjusters
- BPM and chamber flange supports positioned with M8x1.25 hold down bolts + M6x1 alignment rods



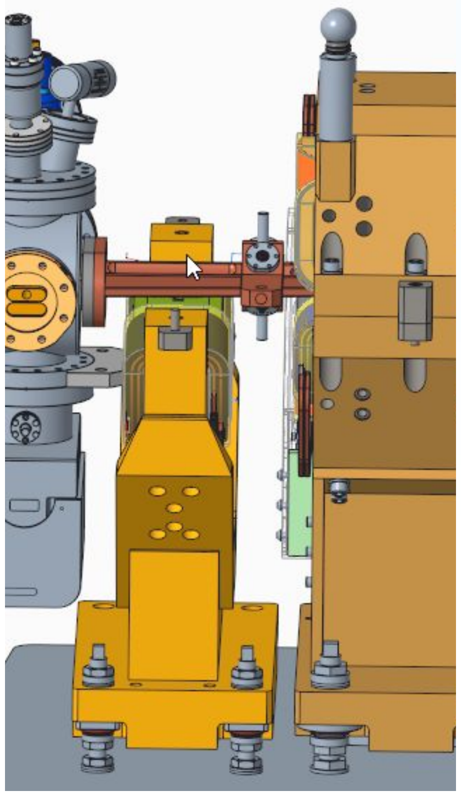
In-situ magnet removal for maintenance (similar to AR raft mounted magnets)



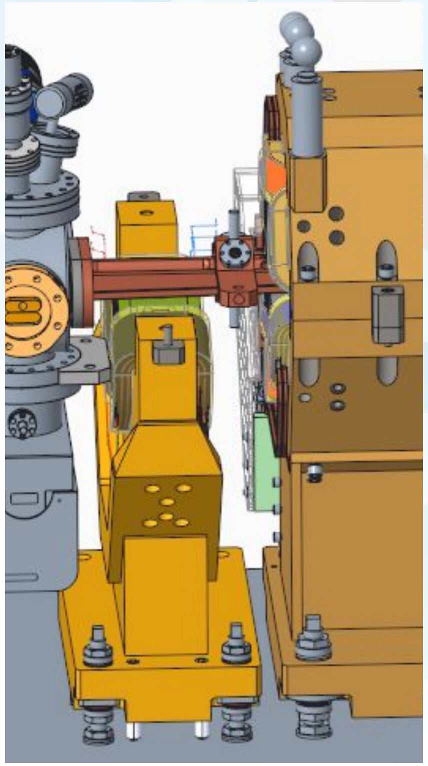
Lifting kit installed



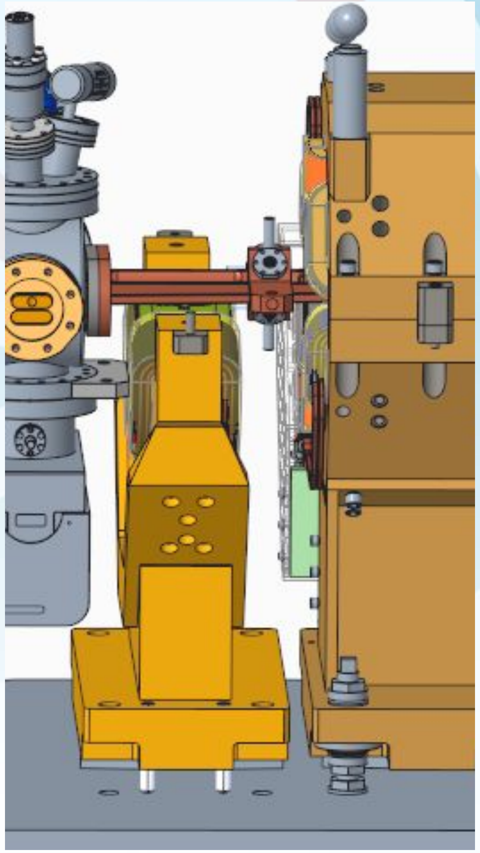
Top half of magnet removed



3X Alignment turnbuckles & 2X Rear stability adjusters removed

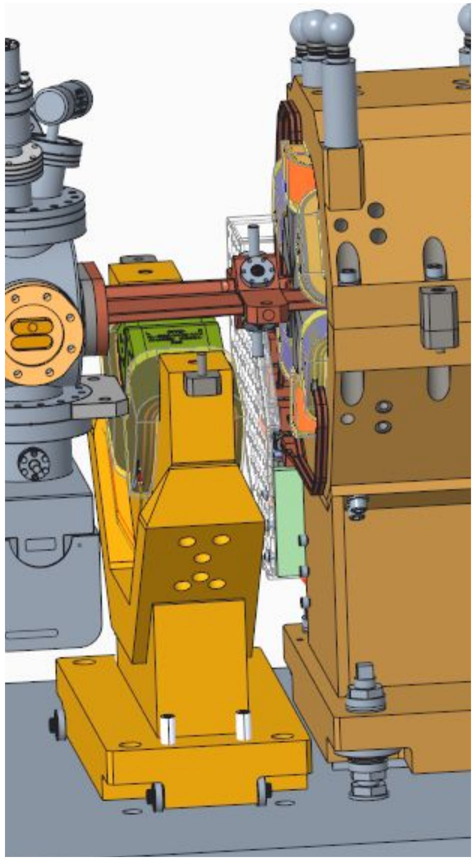


3X lowering bolts inserted (flat faced ball end screw to avoid marring of raft and “walking” of magnet)

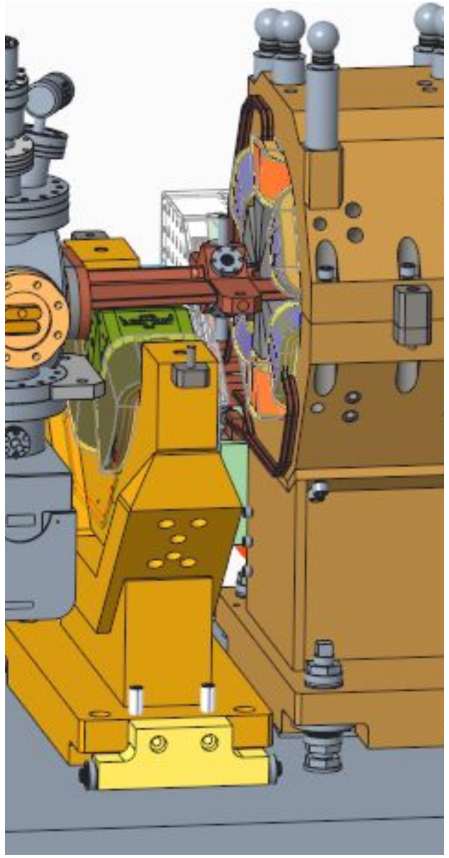


Height adjusters removed

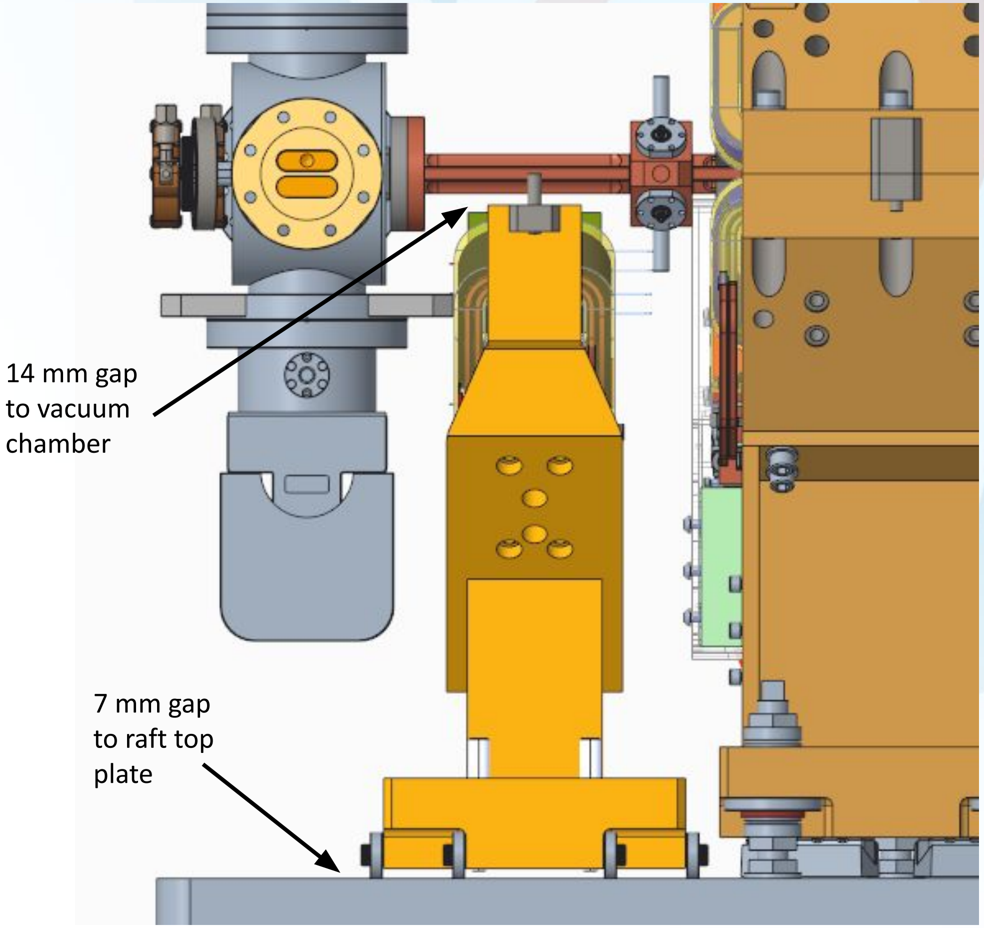
In-situ magnet removal for maintenance (similar to AR raft mounted magnets)



Option #1: lowering bolts bring magnet down onto **roller bearings attached to base plate**



Option #2: lowering bolts bring magnet down onto **magnet service dolly**



Raft alignment

Alignment tolerances developed with beam physics

Magnet-to-raft alignment tolerances

ID NUM (R05-10-)	RQMT DEF	Requirement Description	Value	Unit
006000	Shall	x-direction magnet-to-raft position tolerance	± 60	µm
006005	Shall	y-direction magnet-to-raft position tolerance	± 60	µm
006010	Shall	z-direction magnet-to-raft position tolerance	± 200	µm
006015	Shall	Rotation about x-axis magnet-to-raft angular tolerance	± 400 (TBC)	µrad
006020	Shall	Rotation about y-axis magnet-to-raft angular tolerance	± 400 (TBC)	µrad
006025	Shall	Rotation about z-axis magnet-to-raft angular tolerance	± 400	µrad

Raft-to-Raft within a Sector Alignment Tolerances

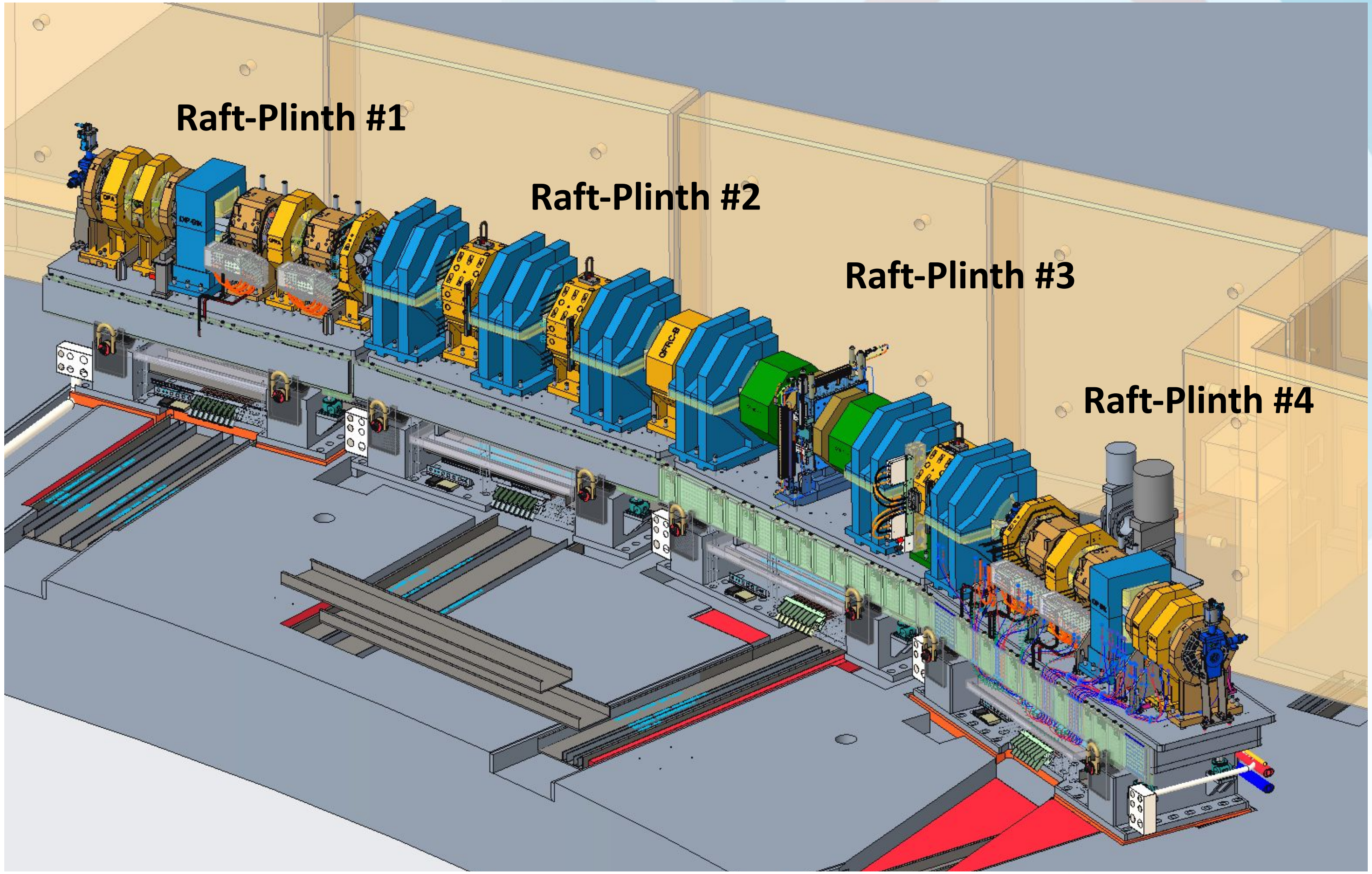
ID NUM (R05-10-)	RQMT DEF	Requirement Description	Value	Unit
006030	Shall	x-direction raft-to-raft position tolerance*	± 60	µm
006035	Shall	y-direction raft-to-raft position tolerance	± 60	µm
006040	Shall	z-direction raft-to-raft position tolerance	± 200 (TBC)	µm
006045	Shall	Rotation about x-axis raft-to-raft angular tolerance	±200 (TBC)	µrad
006050	Shall	Rotation about y-axis raft-to-raft angular tolerance	± 200 (TBC)	µrad
006055	Shall	Rotation about z-axis raft-to-raft angular tolerance	± 200	µrad

Adjacent Sector-to-Sector Alignment Tolerances

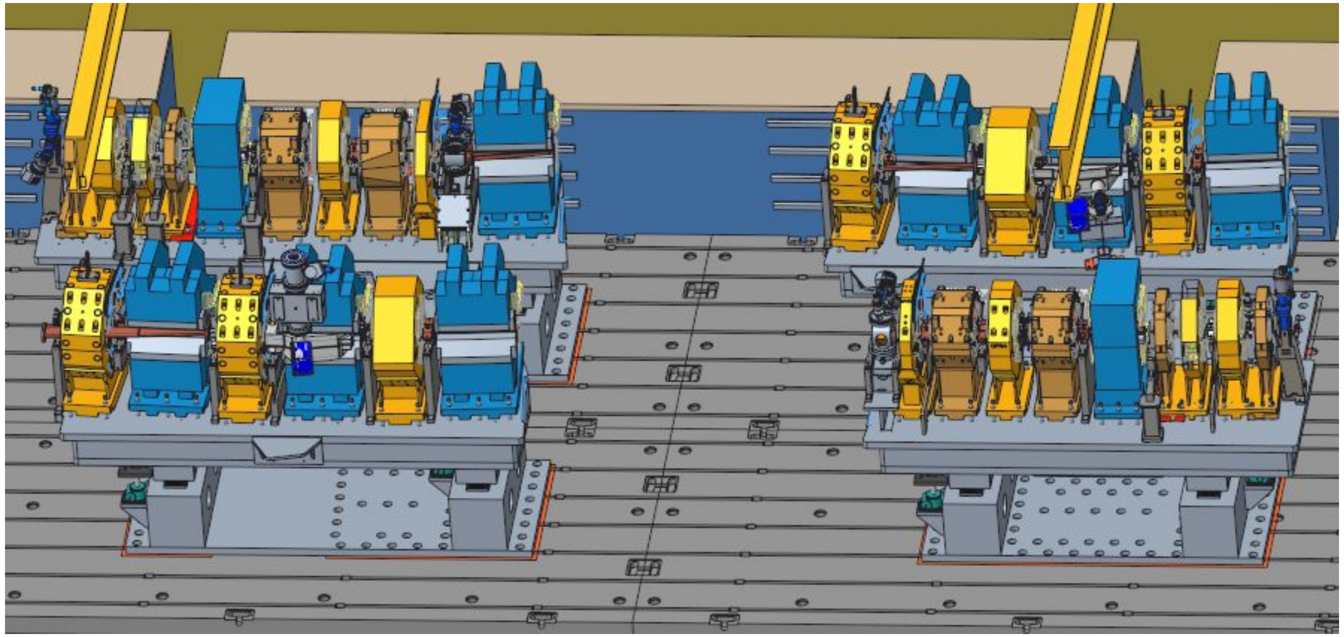
ID NUM (R05-10-)	RQMT DEF	Requirement Description	Value	Unit
006060	Shall	x-direction sector-to-sector position tolerance†	± 200	µm
006065	Shall	y-direction sector-to-sector position tolerance†	± 200	µm

4X Raft-Plinth assemblies per sector

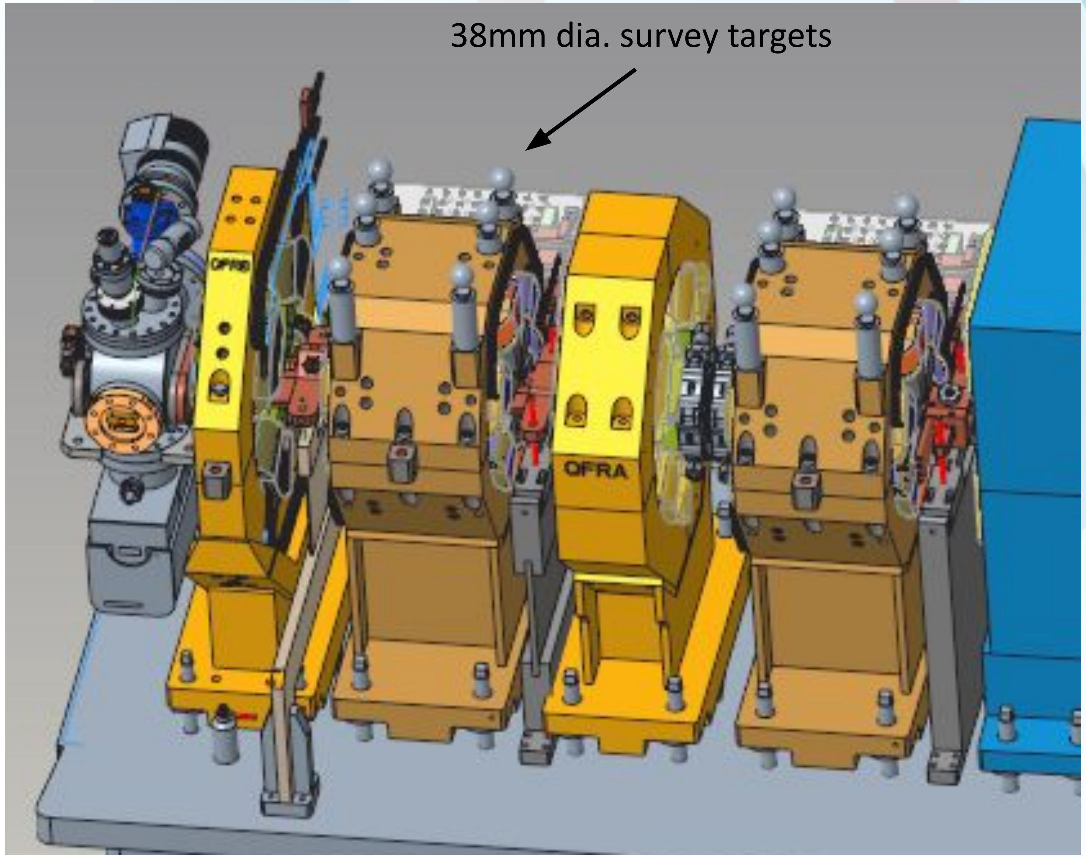
- magnets pre-aligned on rafts (fiducial locations on all magnets)
- In addition to jacks+struts discussed previously for magnet alignment, pins and shims solution is currently being investigated



Floor mounted* laser tracker based alignment during pre-staging and tunnel installation (*except for sector 12)

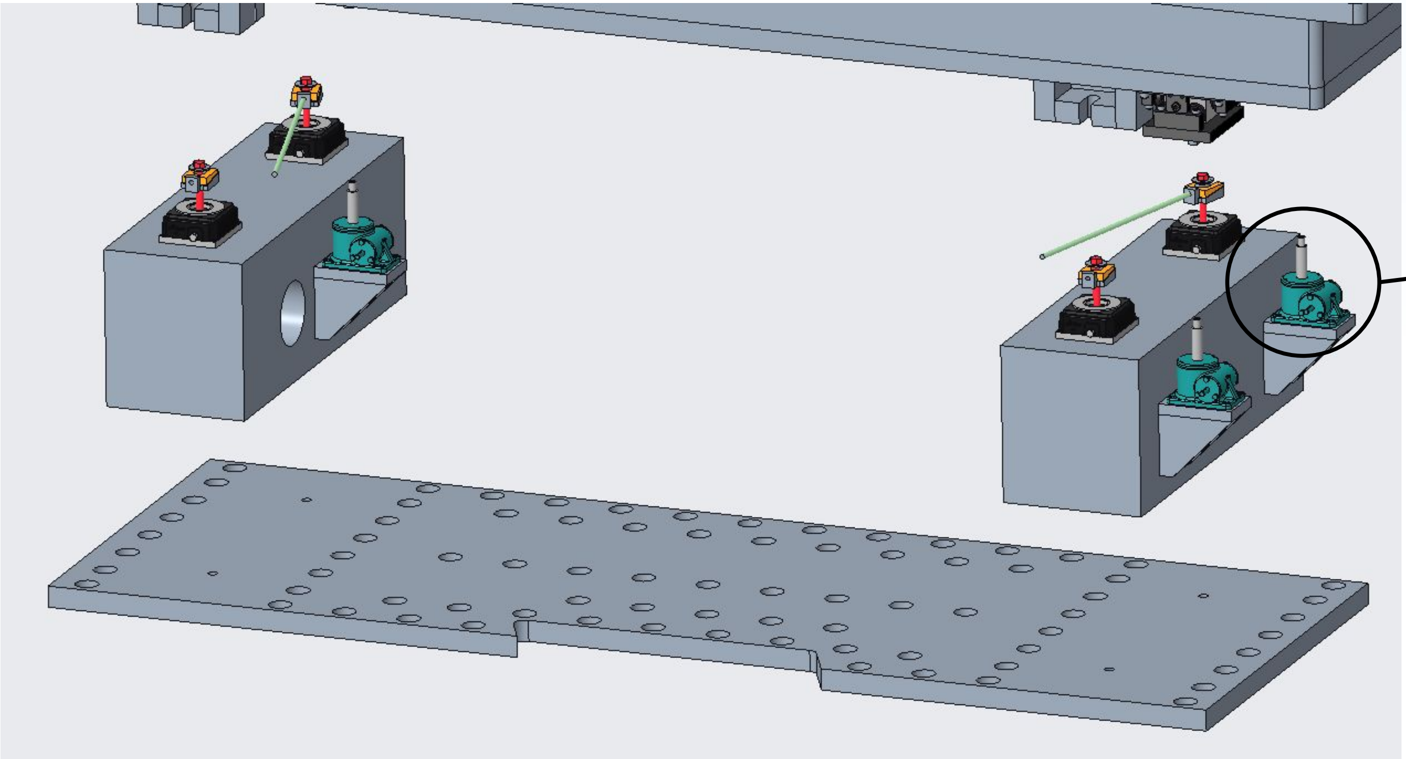


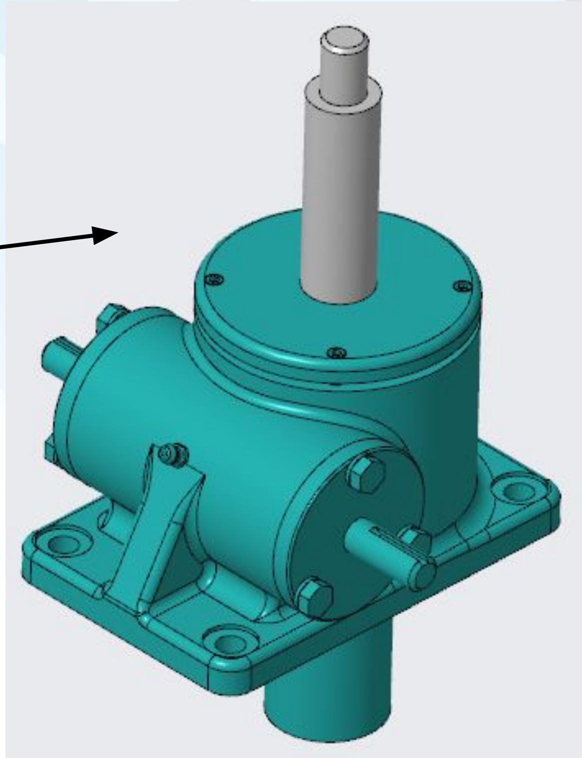
rafts during pre-staging



Raft vertical adjustment

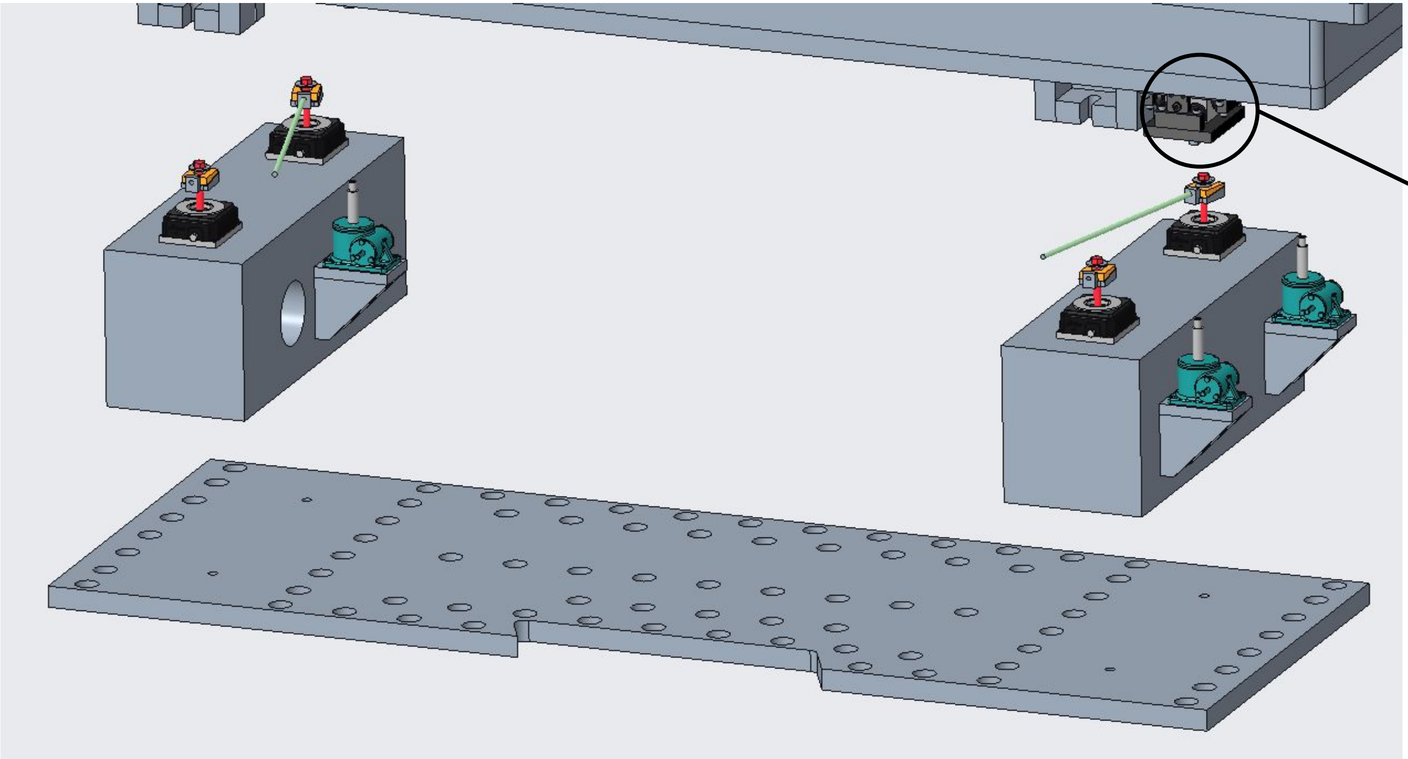
3X vertical jacks – 2X @ 4500 kg & 1X @ 9000 kg

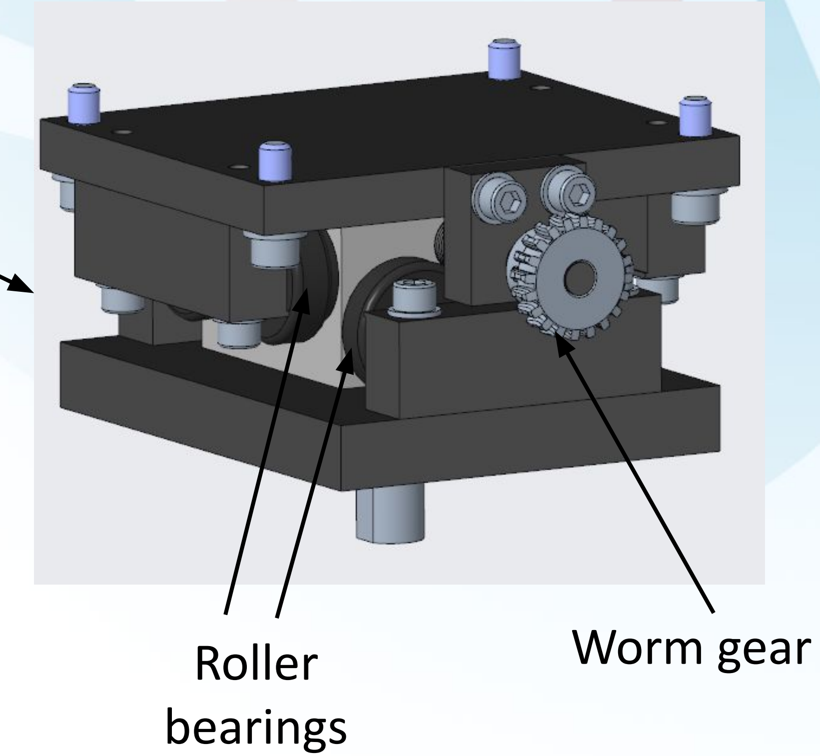




Raft horizontal adjustment

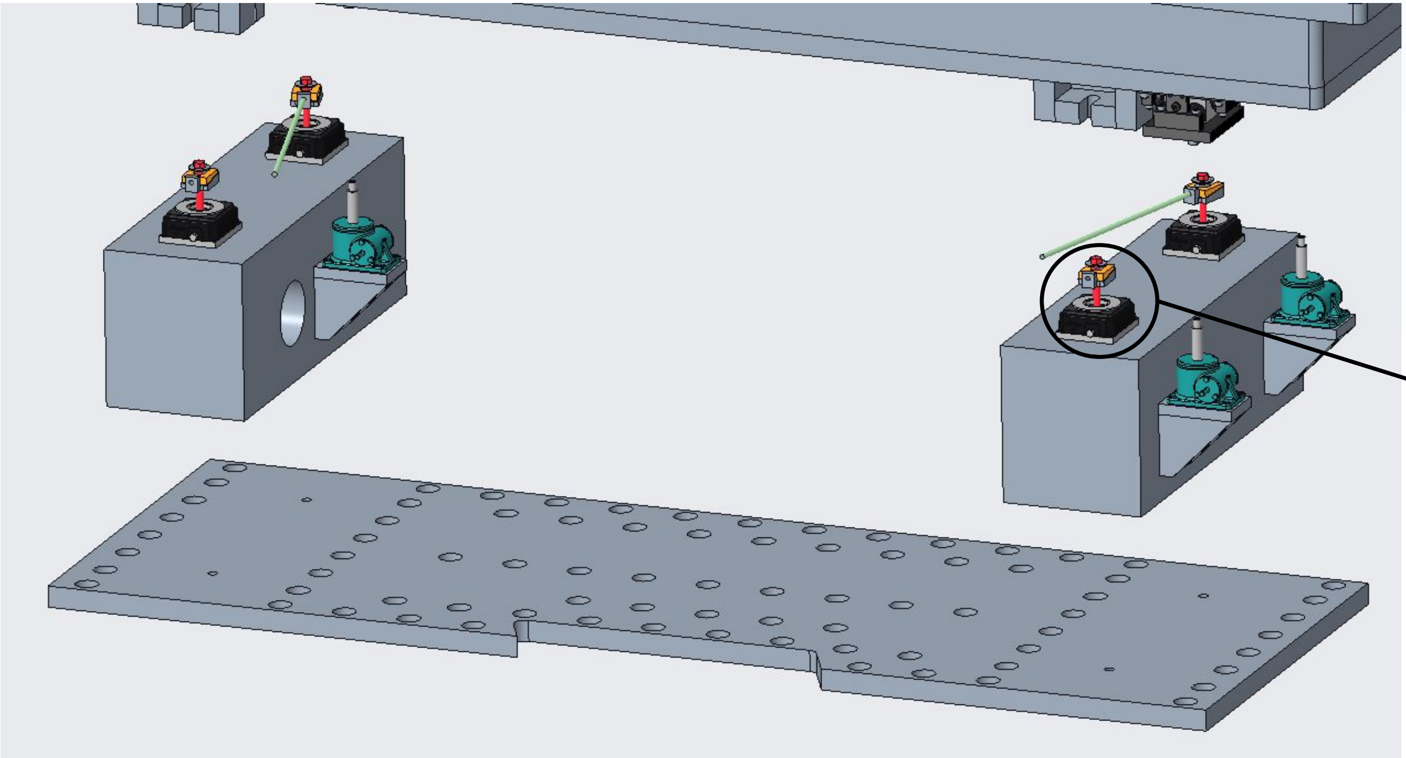
3X adjusters, 3X roller bearings each for both lateral directions

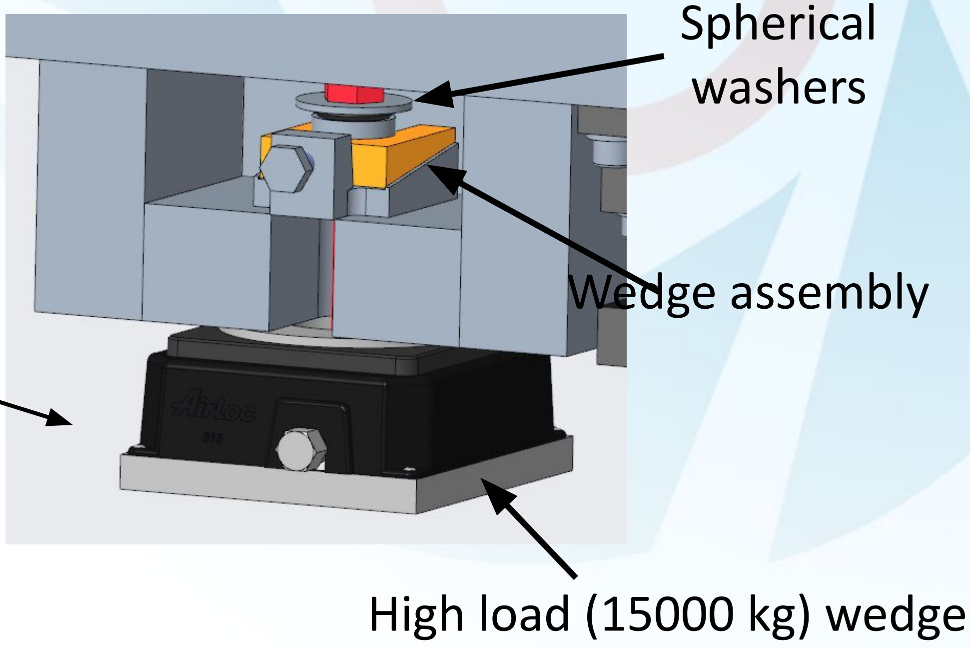




Position Clamping

4X adjustable spherical wedge clamp per raft with wedge adjustable base and clamping under bolt head





SR supports prototyping

7-raft/sector design prototype:

- original welded box beam design
- smaller raft designed for fewer magnets
- verify performance of the positioning and lockdown mechanisms
- test magnet mounting scheme

4-raft/sector design (to be fabricated prior to SR supports FDR):

- assembly will include raft, plinths and baseplate as well as magnet mounting and positioning hardware
- System will allow integrated testing
- Fabrication sep-dec 2021
- Testing at LBNL dec-feb 2021 (pre-CD3)

Existing prototype SR magnet raft
(7-rafts/sector design)

Stability

Functional Requirements: SR and ATS/STA Transfer Lines

Magnet-to-raft alignment tolerances

Raft-to-Raft within a Sector Alignment Tolerances

Adjacent Sector-to-Sector Alignment Tolerances

Magnet Vibration Limit:

ID NUM (R05-10-)	RQMT DEF	Requirement Description	Value	Unit	Traceability/ Assumption
006070	Shall	x-direction limit†	≤ 20 TBC	nm	Beam Physics
006075	Shall	y-direction limit†	≤ 20 TBC	nm	Beam Physics
006080	Shall	z-direction limit†	≤ 200 TBC	nm	Beam Physics
006085	Shall	Rotation about x-axis limit†	≤ 400 TBC	µrad	Beam Physics
006090	Shall	Rotation about y-axis limit†	≤ 400 TBC	µrad	Beam Physics
006095	Shall	Rotation about z-axis limit†	≤ 40 TBC	µrad	Beam Physics

† RMS value at > 10 Hz

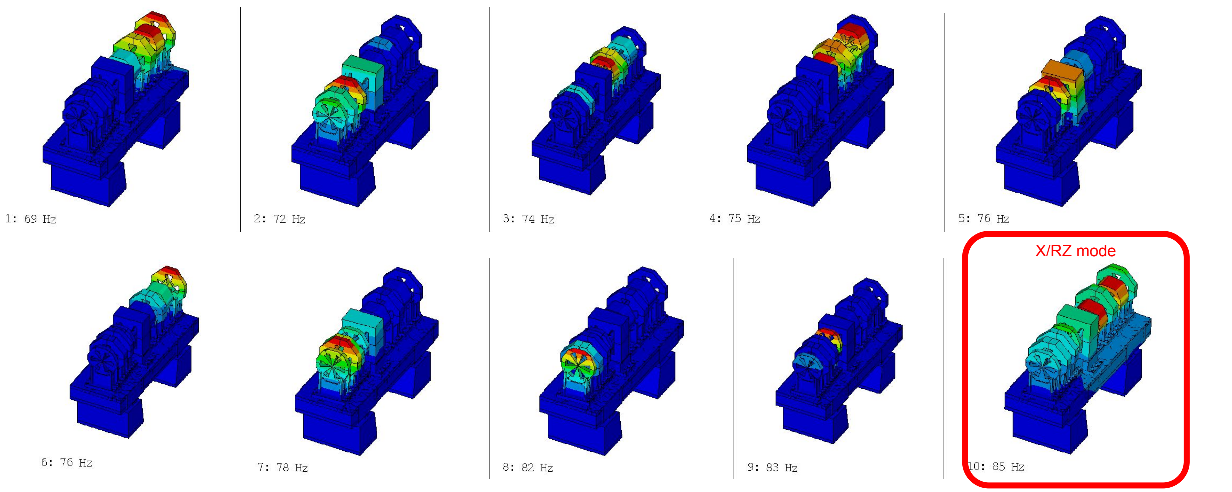
To study feasibility of 4-raft design without mature magnet design, individual magnet mount FNF was quickly increased to > 70 Hz

assuming DIPC=DIPB, SHB=SHA, SDA=SFA, QFRA=QFA

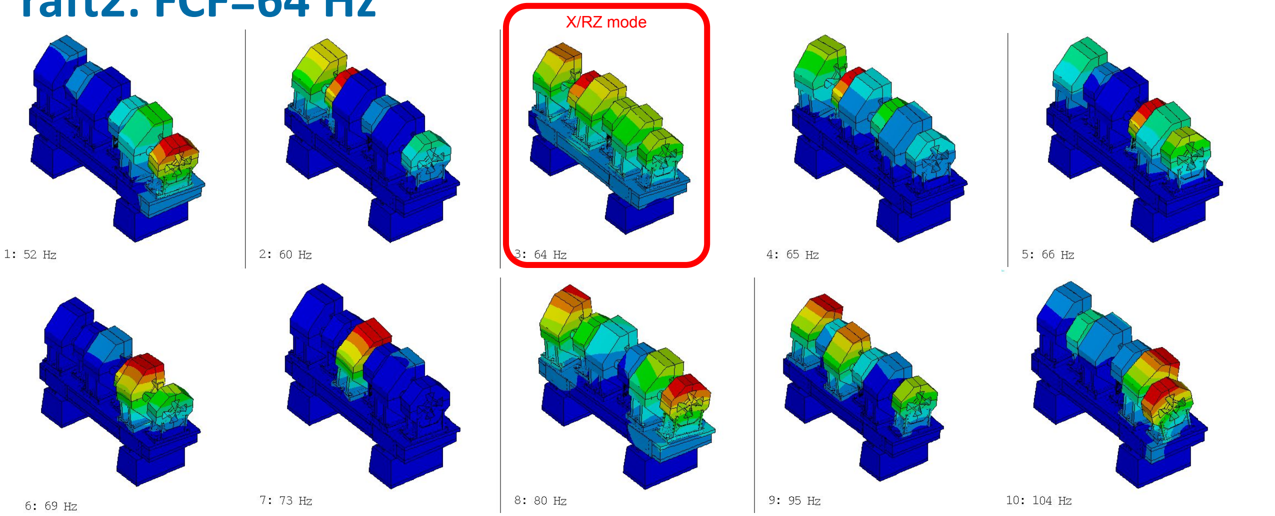
	unique cases	from US to DS	Unique ID	FNF [Hz]
1	SHA	M01	AL-1352-6781	90
2	QFA	M02	AL-1215-7385	73
3	QDA	M03	AL-1218-3142	79
	SHB	M04		
4	DIPA	M05	AL-1249-9121	81
5	SDA	M06	AL-1207-9925	80
	QFRA	M07	AL-1216-3293	
	SFA	M08	AL-1207-9926	80
6	QFRB	M09	AL-1216-7592	77
7	DIPB	M10	AL-1250-3277	93
8	QRFC	M11	AL-1207-9918	75

FNFs are Z modes from magnets, FCFs slightly above 60 Hz

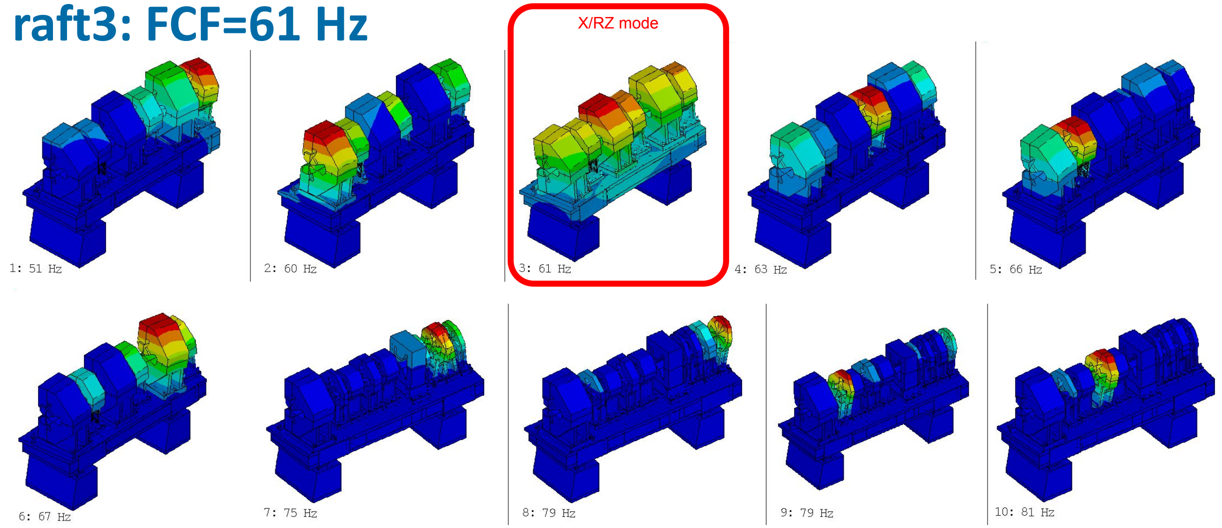
raft1: FCF=85 Hz



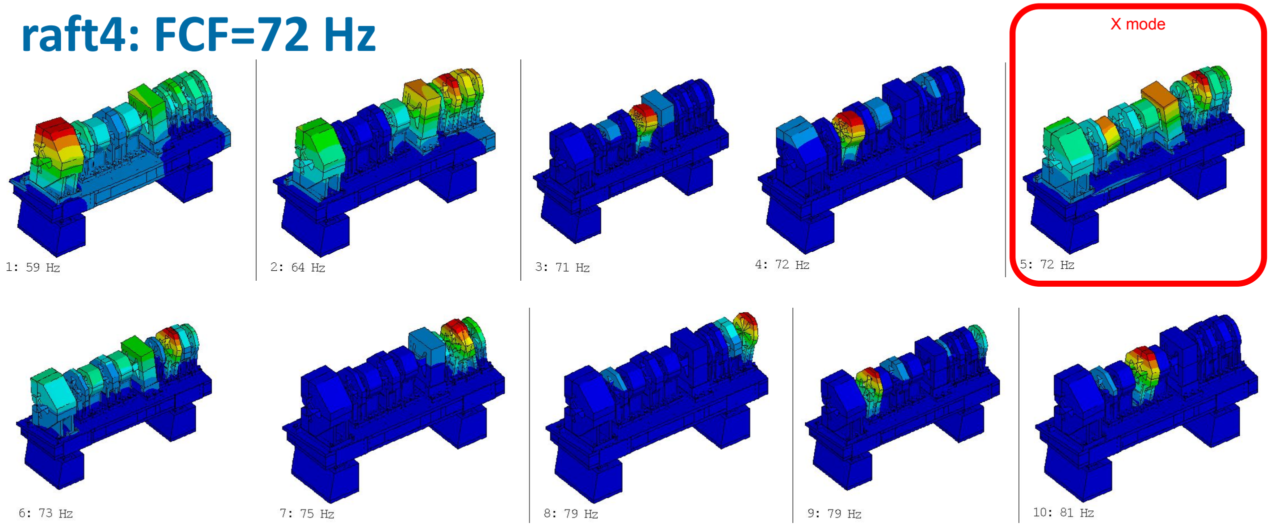
raft2: FCF=64 Hz



raft3: FCF=61 Hz

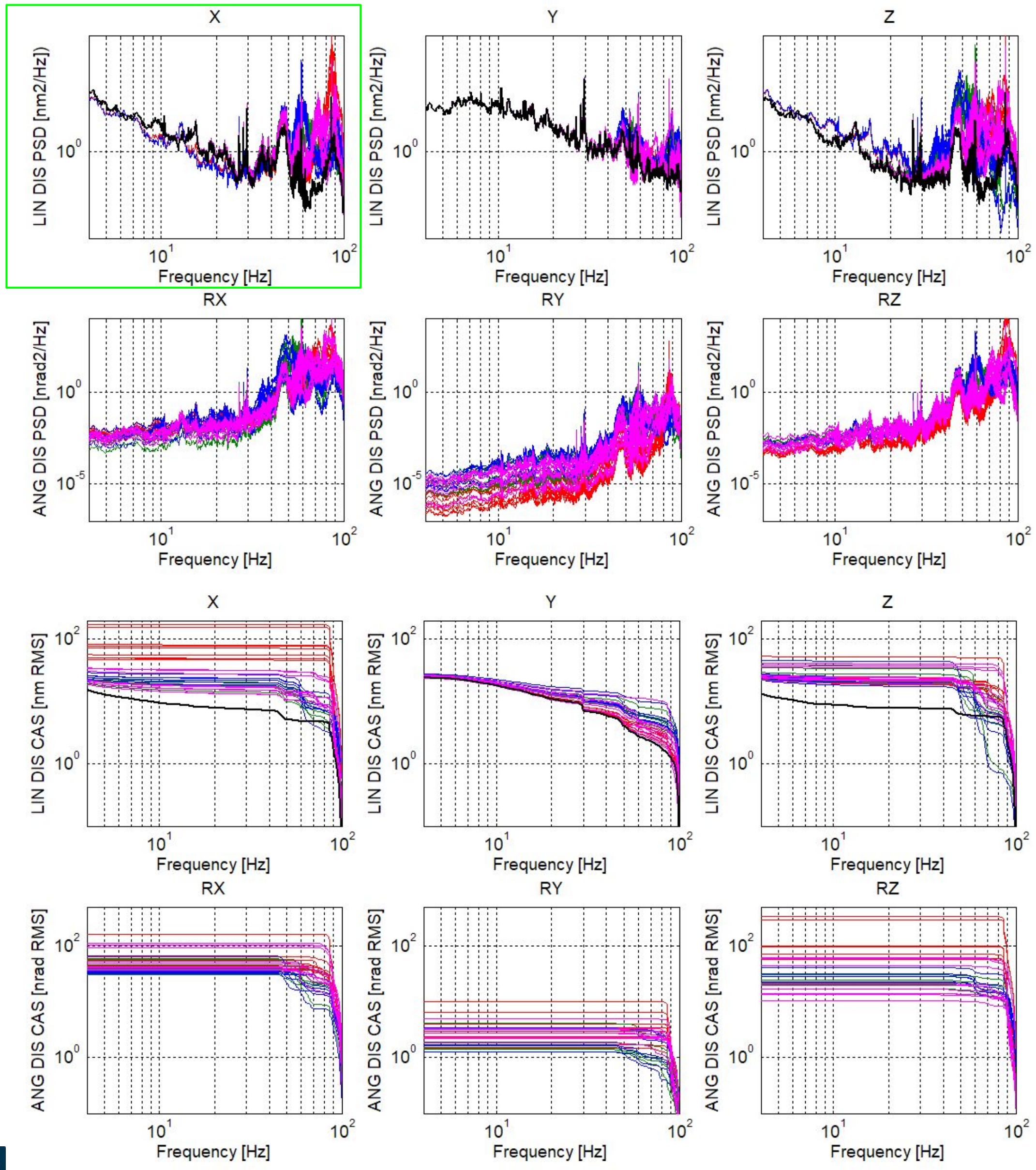


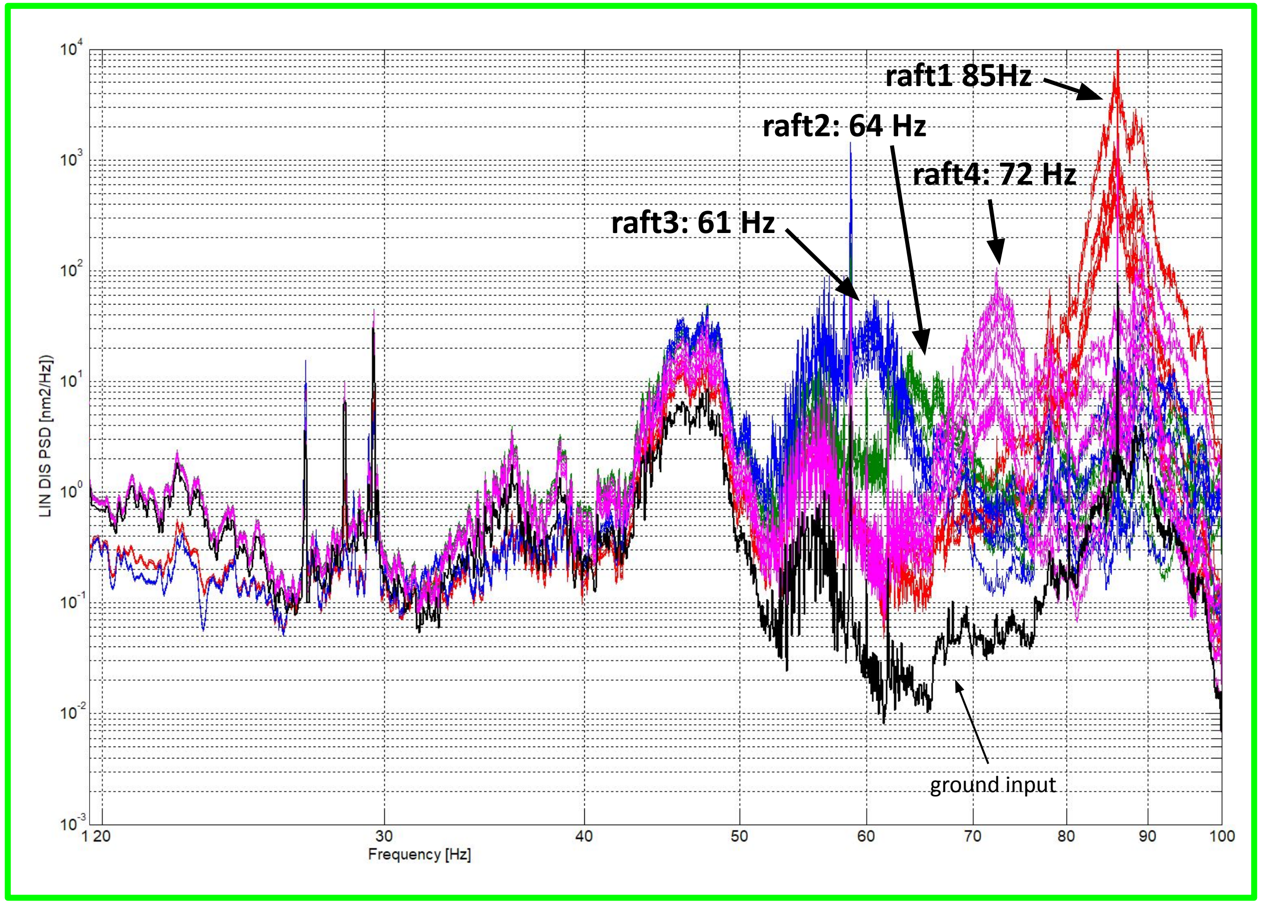
raft4: FCF=72 Hz



Beam jitter at ID meets project goals without FOFB (barely) and with FOFB (5X better)

2020 data - rev3 - 2% damping



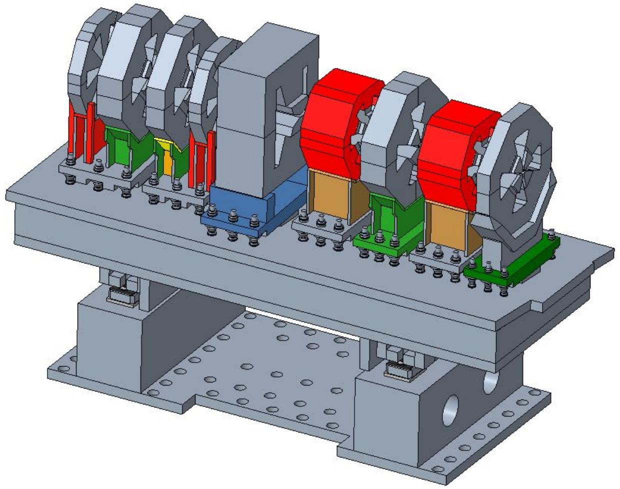


high input from the floor and X/RZ sensitivity => raft1 high levels in X/RZ at 80-90 Hz

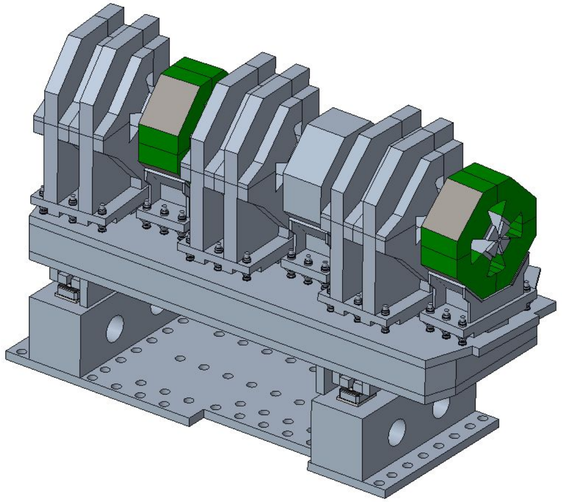
Analysis of the preliminary design geometry

Workflow

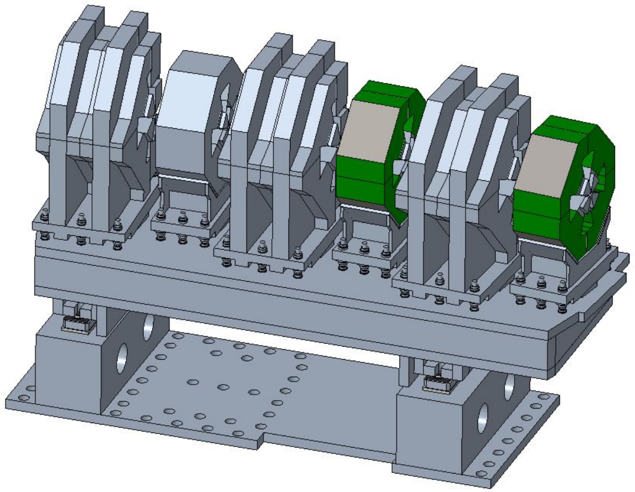
1. De-featuring integrated with CREO+WINDCHILL
2. Model setup, including point mass for defeatured items
3. Modal analysis with participation factors expressed in support coordinate system
4. Random vibration analysis: apply measured ground motion and retrieve predicted motion
5. Gravity deformation + 0.7g seismic loading



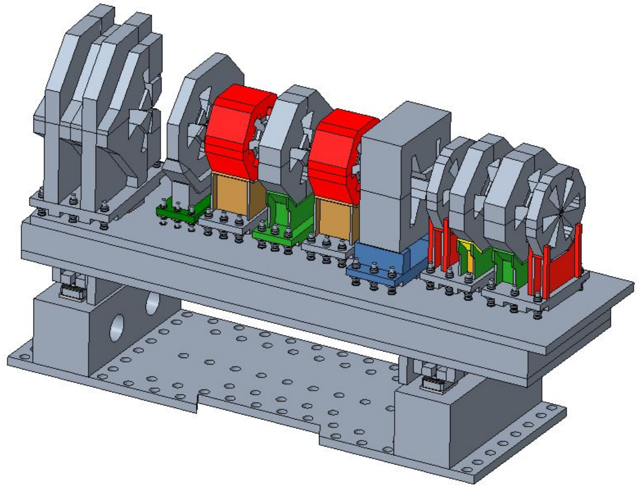
AL-1369-4202
RAFT1
(magnets: 3200 kg)



AL-1344-9144
RAFT2
(magnets: 7200 kg)

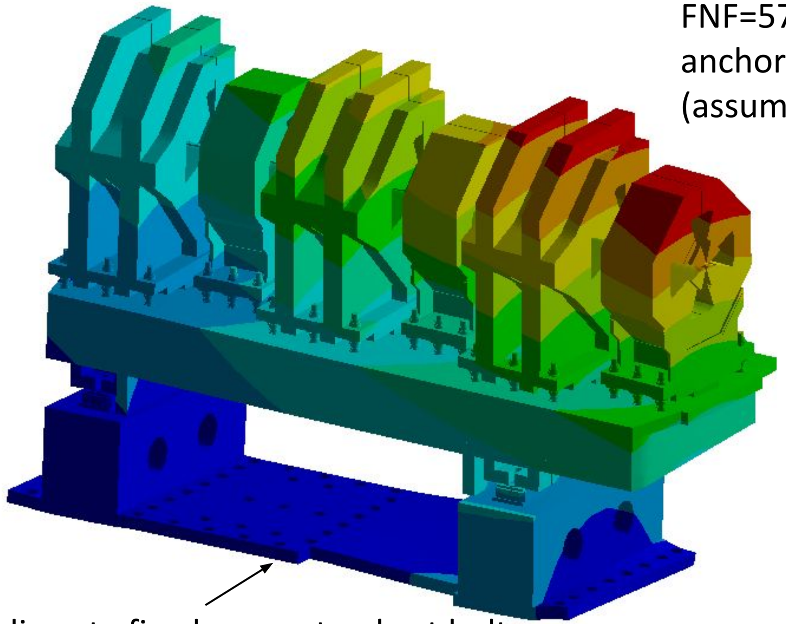


AL-1369-0604
RAFT3
(magnets: 7200 kg)



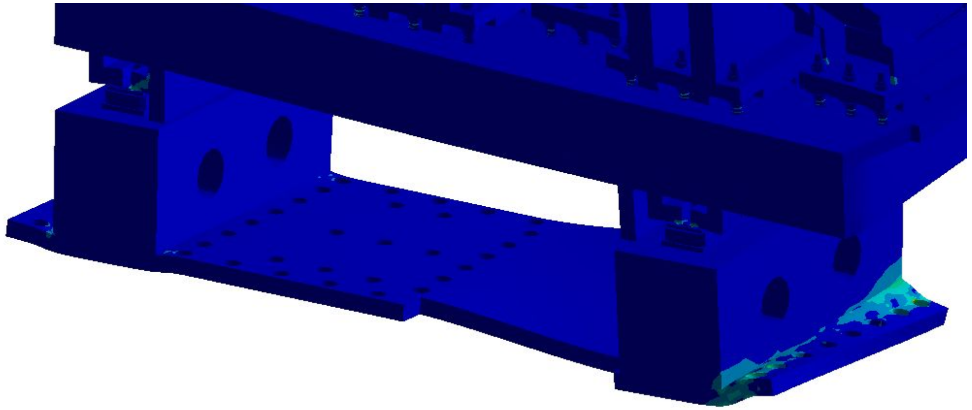
AL-1369-0592
RAFT4
(magnets: 4400 kg)

Worst case is RAFT3 (heaviest and straddling a trench)
76 mm thick base plate is not a sufficient “bridge”

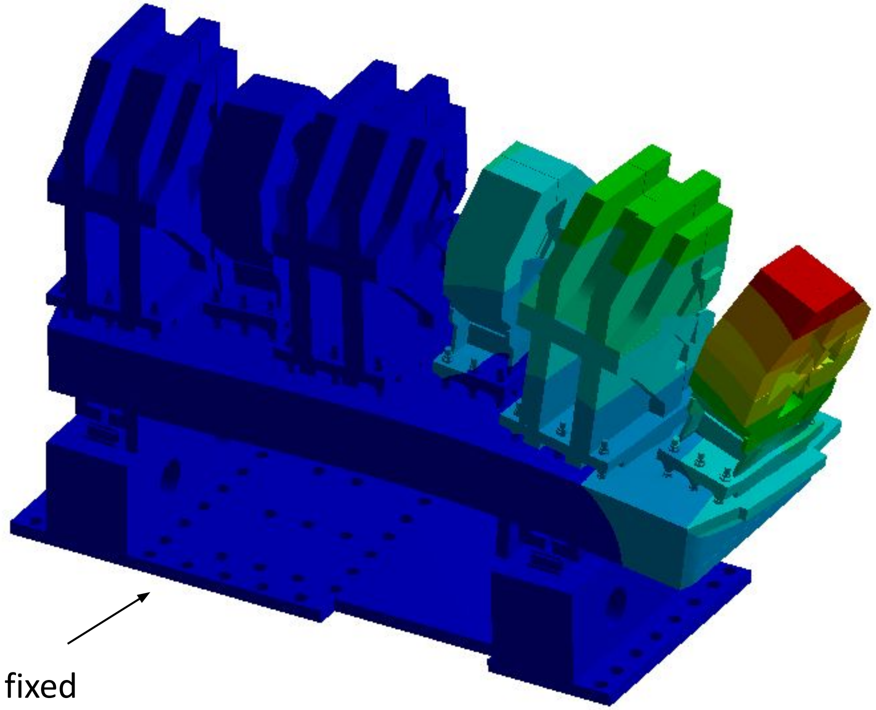


FNF=57.7 Hz with 76 mm floor plate and anchors on each side of each plinth (assuming partially filled trench)

discrete fixed support only at bolts



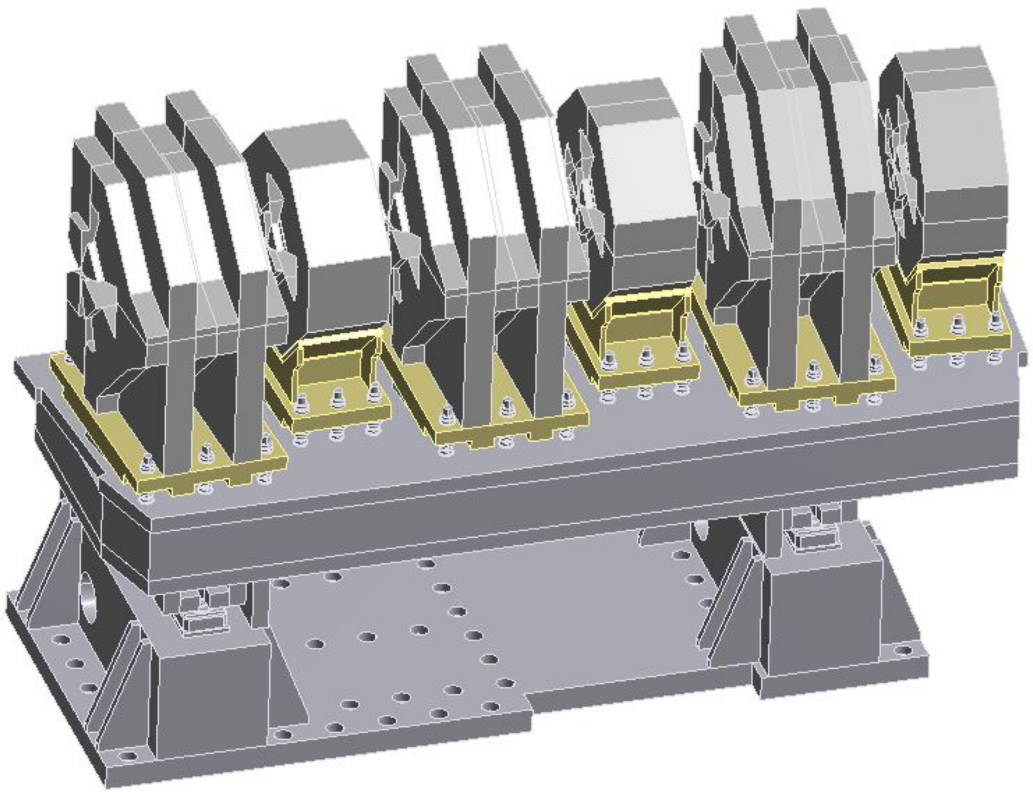
FNF=67.2 Hz
driven by cantilevered magnet. Would likely pass.



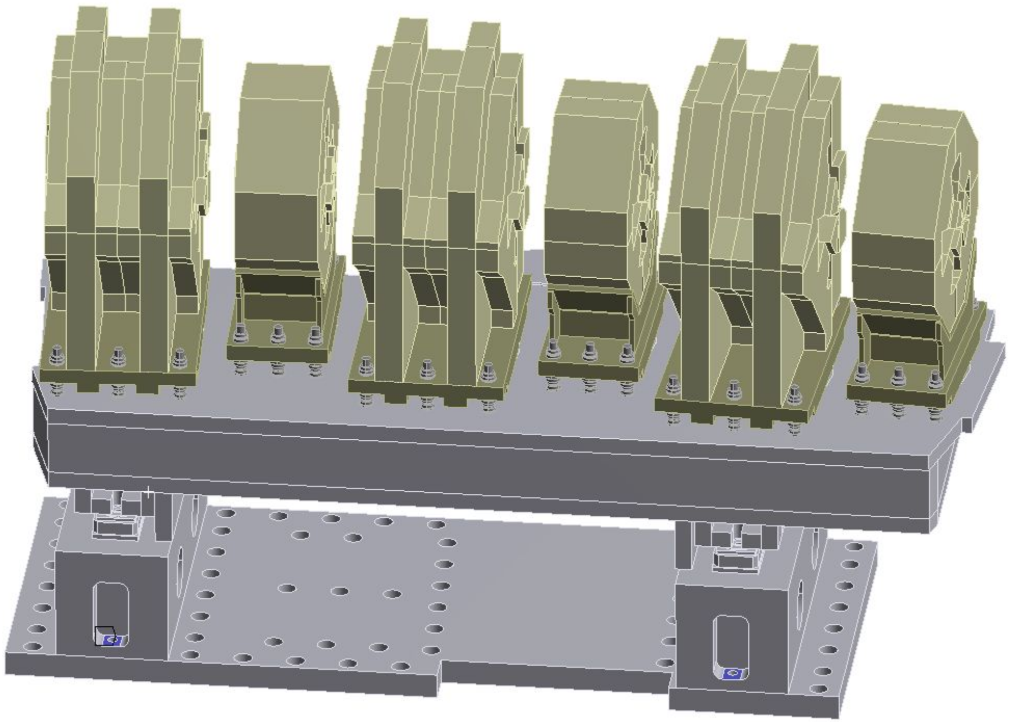
full bottom face fixed

Improving raft3 without resorting to grouting (with 76 mm base plate, anchors on both sides of each plinth, partially filled trench)

gusseted plinths => FNF=61.7 Hz

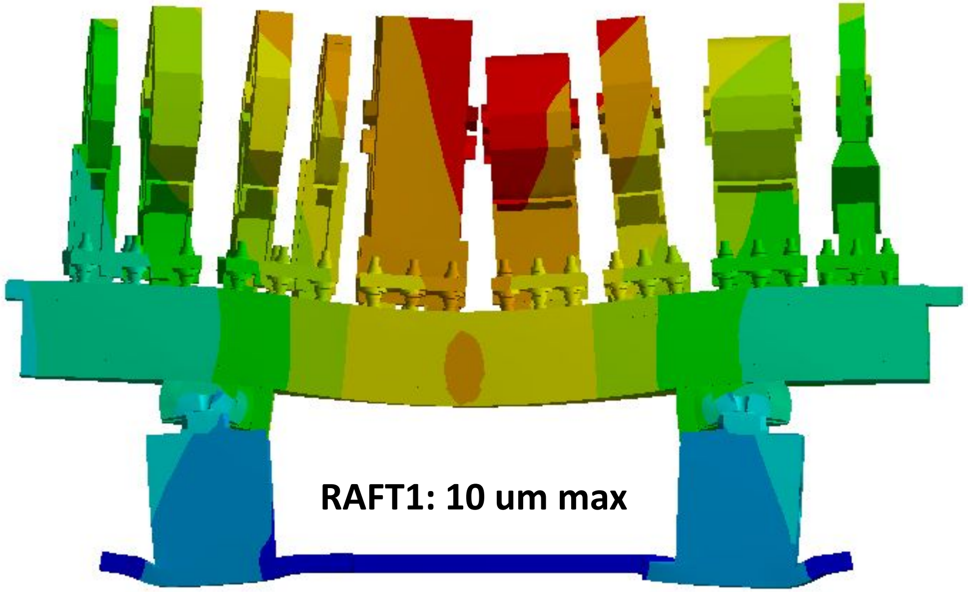


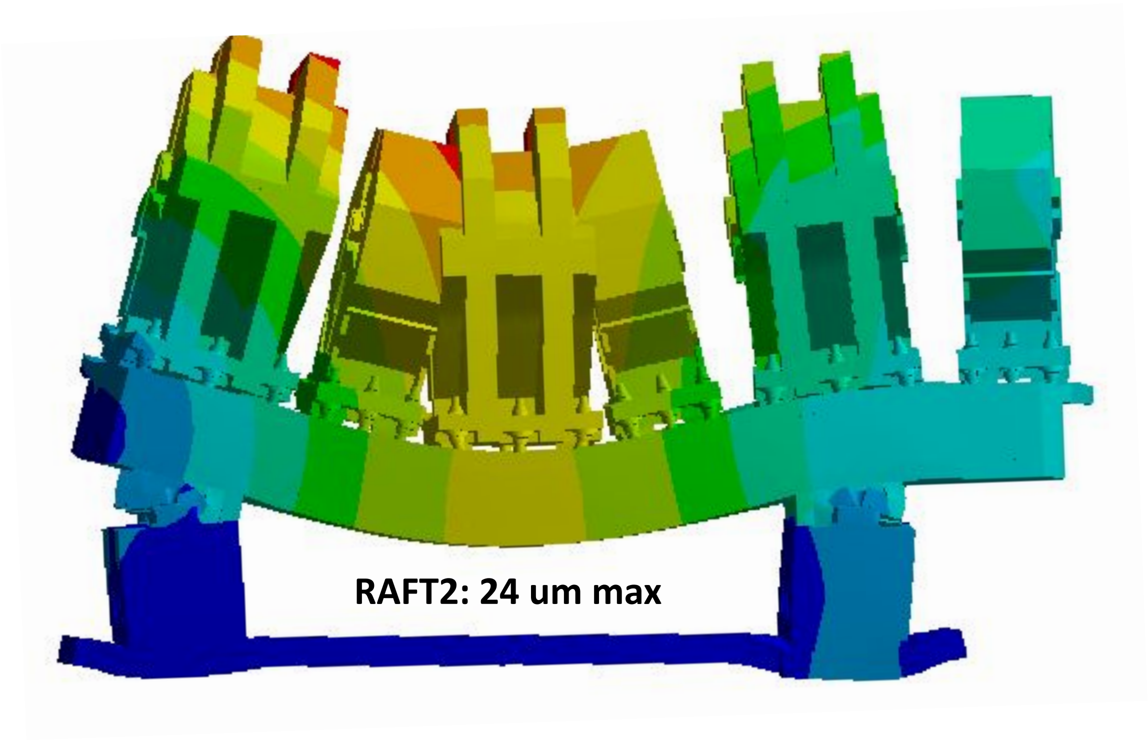
one anchor inboard/outboard of the plinths =>FNF=65.2 Hz



Those design are > 61 Hz and would likely pass.

Gravity sag



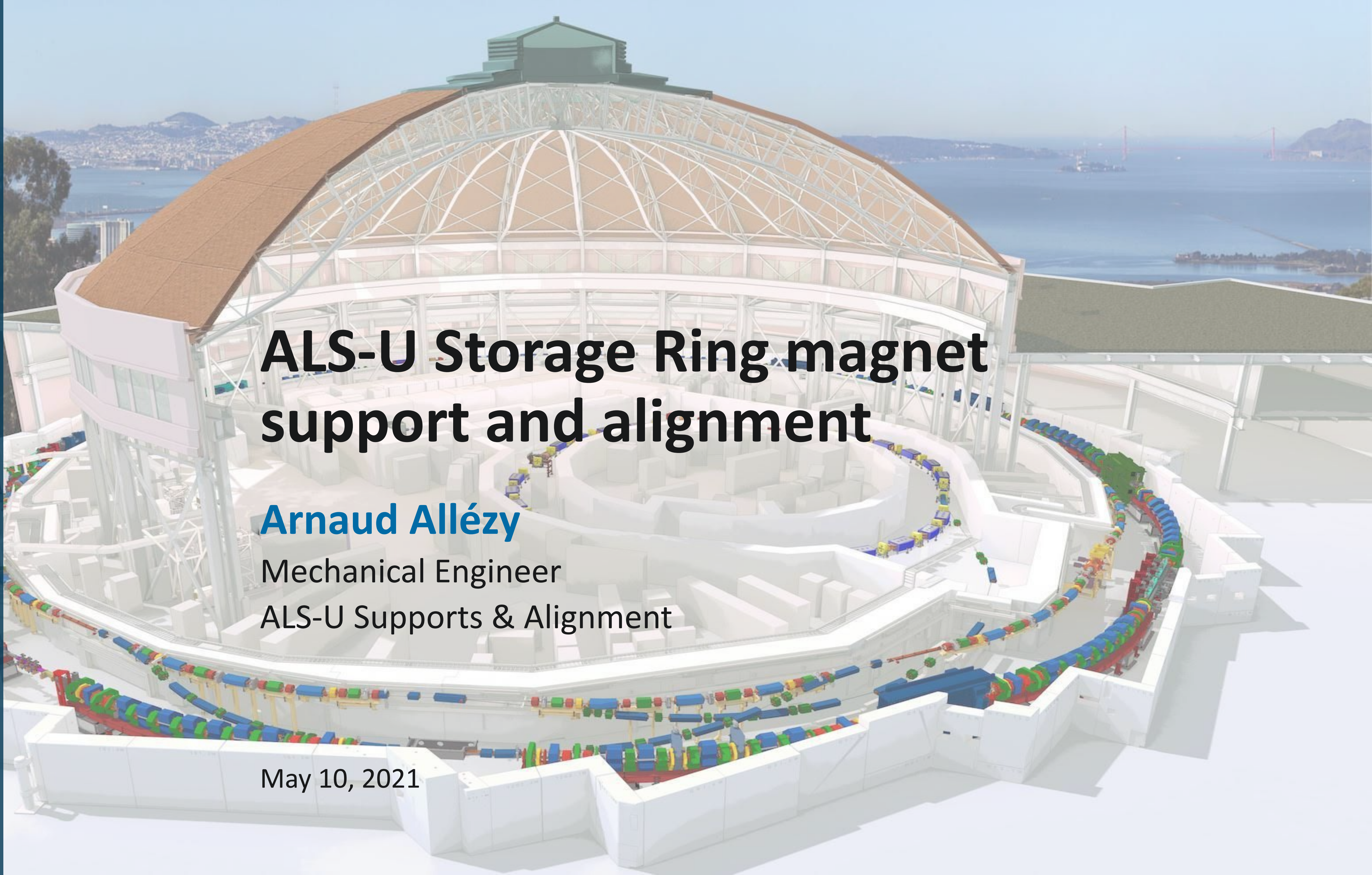


Conclusions and Next steps

- **Sector overall:** design 4 rafts, pre-aligned
- **Raft design:** welded core, 2 plinths on base plate, embedded plate - will mature with FEA/Prototype
- **Alignment:** laser tracker based
  - RAFT: 3 hydraulic jacks= roller bearings / 4 clamps
  - MAGNET: 3 jacks + 3 struts, additional 2 jacks and 1-2 wedges for stability
  - VACUUM: threaded+lock nut for vertical, threaded push/pull for lateral
- **Stability:** 20 nm => 70 Hz FNF
  - Initial 4-raft study indicates performance will be met if FCF raft > 61 Hz and FNF magnets >70 Hz
  - To be conservative, target for is FNF magnet > 100 Hz (magnet group has already achieved this on the two heaviest rafts) and raft FNF > 70 Hz (the support team is working towards this while avoiding having to grout)
  - gravity deformation, seismic integrity should be a formality.
- **Path forward:** finalizing subsystem interfaces, structural analysis, and installation procedures.

Acknowledgements / List of contacts

- **mechanical systems lead**: Steve Virostek spvirostek@lbl.gov
- **supports lead**: Barrie Phillips bphillips@lbl.gov
- **raft design**: Serenity Nguyen serenitynguyen@lbl.gov
- **magnet mounting**: Greg Harris glharris@lbl.gov
- **stability**: Arnaud Allézy apallezy@lbl.gov



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BERKELEY LAB

ALS-U
ADVANCED LIGHT SOURCE

ALS-U Storage Ring magnet support and alignment

Arnaud Allézy

Mechanical Engineer

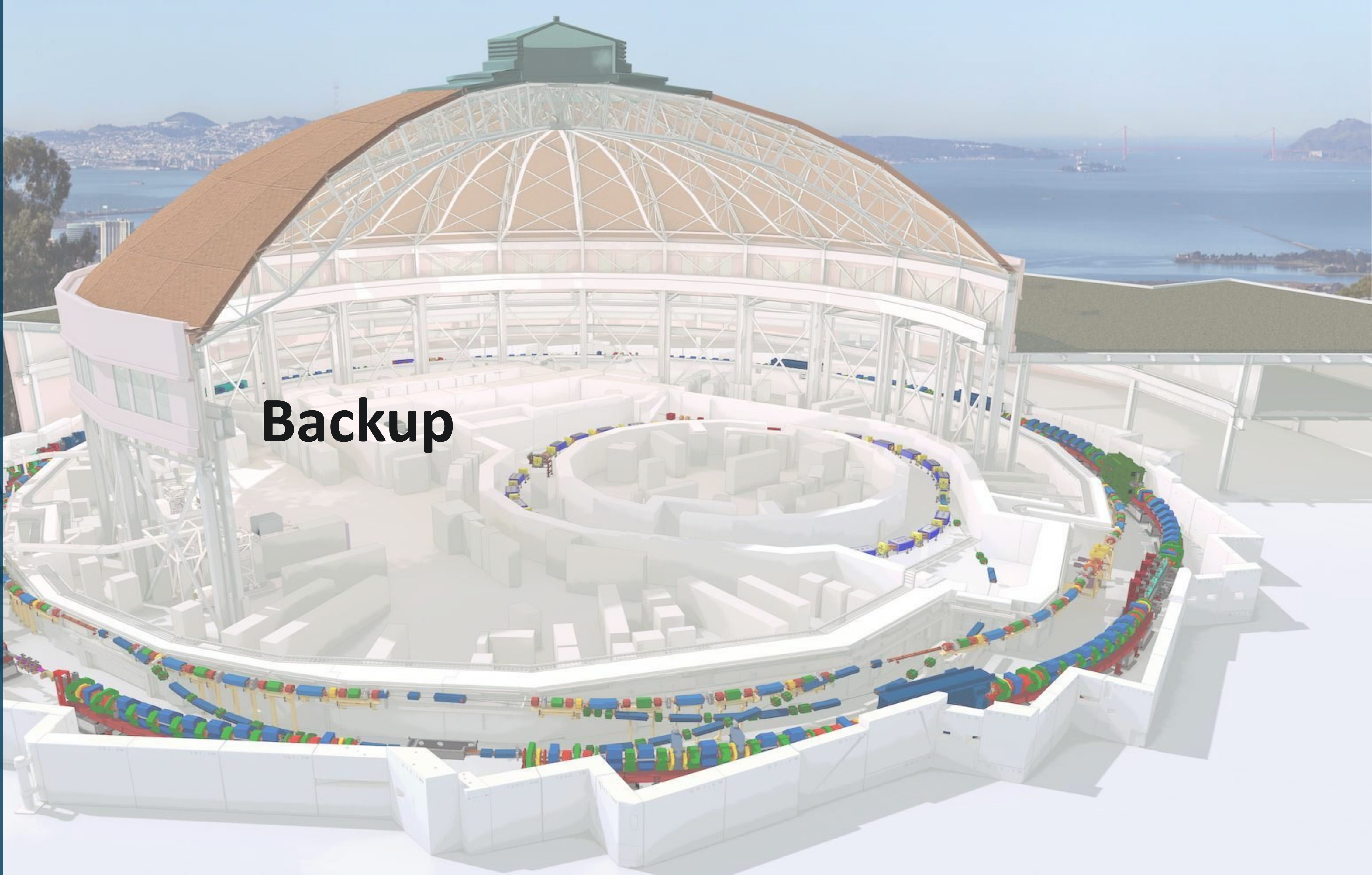
ALS-U Supports & Alignment

May 10, 2021

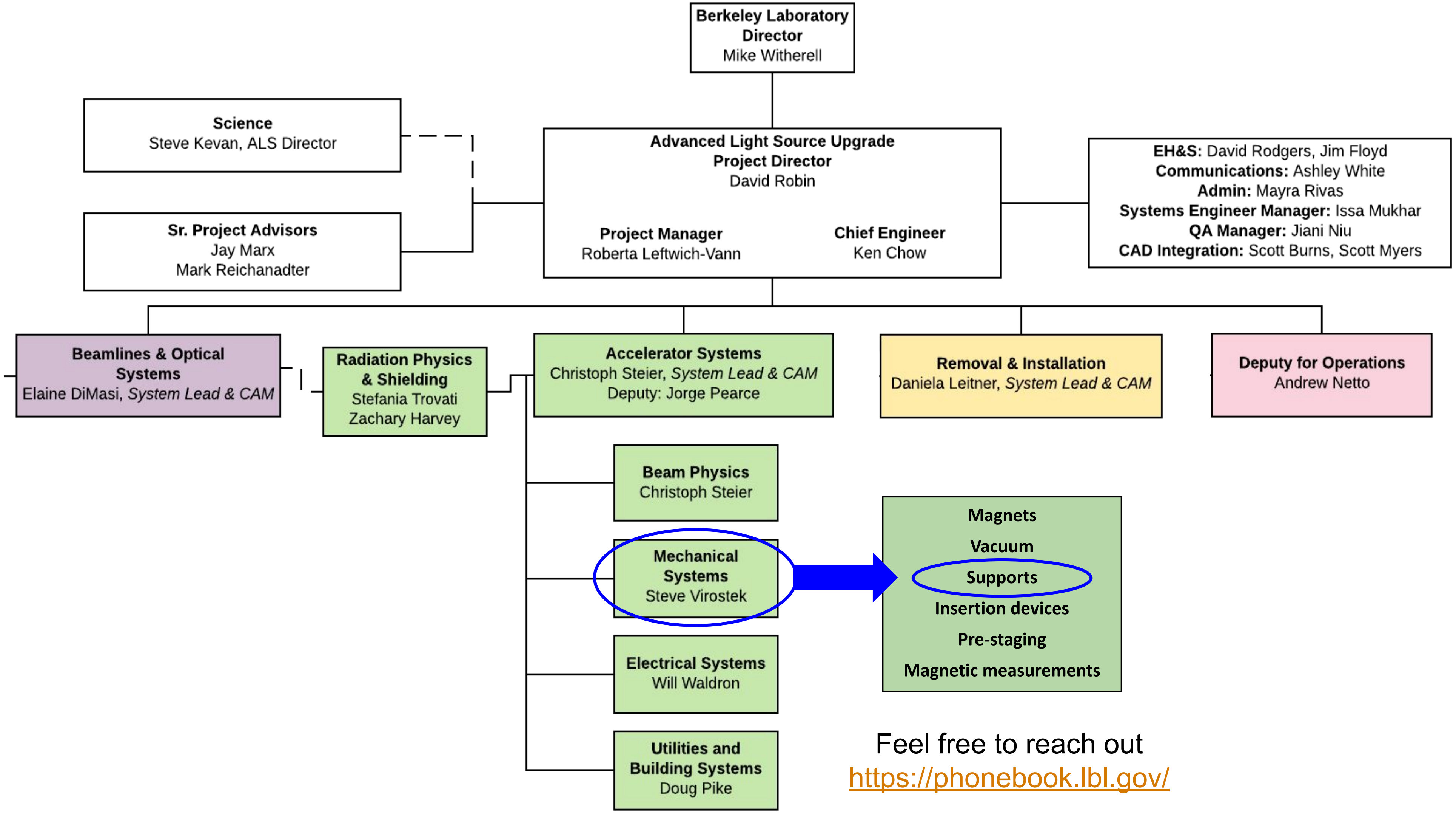
PETRA IV: Mini-workshop on girders and alignment.

May 10-11, 2021

Backup



ALS-U project organization



Feel free to reach out
https://phonebook.lbl.gov/

Storage ring floor > 20 nm above 10Hz