FE-ME-044
SNS Front-End Systems Technical Note
Category Code: FE3313
30 March 2001

MEBT Raft and Support Structure Final Design Review
March 30, 2001

Daryl Oshatz, Allan DeMello, Peter Luft, John Staples

This technical note is intended exclusively for internal use inside the SNS Front-End Systems Group. The primary purpose of the technical note series is to promote rapid dissemination of results for work in progress. No formal review has taken place to ascertain the accuracy of its contents, or the consistency / compatibility of the information with other SNS work.

Attendees:
Allan DeMello
Richard DiGennaro
Julius Fazekas (ORNL)
Michael Hechler (ORNL)
Ray Low
Peter Luft
Daryl Oshatz
Joseph Rasson
Dulie Reavill
John Staples
Donald Syversrud
Andrew Zachoszcz

MEBT Raft and Support Structure Final Design Review
March 30, 2001

Action Items:

1) Electrical Integration: Confirm that the design provides adequate space and access during installation for cables, wireways, etc.

2) Fiducial mounting points: The fiducial towers could prove cumbersome. Consider other options that would mount the fiducial features closer or directly to the raft surfaces to protect the integrity of the fiducialization.

3) Tighter Hole Tolerances: Consider the adequacy of the positional tolerances on tapped holes and dowel pins on the raft mounting plates. Tighter tolerances might reduce the risk of re-work.

4) Misc. Tapped Holes: Review the tapped holes for optional equipment mounting on the raft z-beams. It may, or may not, be useful to add holes on the top and sides of raft beams, in addition to the bottom.

5) Lifting Points: Add lifting points on rafts.

6) Bellows Damage / Access: Concerns were raised about the accessibility of the flange connection between the bellows on Raft #1 and Raft #2. Look for ways to design this interface so the bellows can be replaced if damaged. Create a well-defined procedure and consider special tools to minimize the risk of vacuum leaks or damage in this and other bellows areas.

7) Scraper Beamox: Add a profile monitor beambox in the scraper location, rather than a beampipe that may have to be later replaced.

8) Chopper Alignment Requirements: Review the alignment requirements for the Chopper Beamboxes.

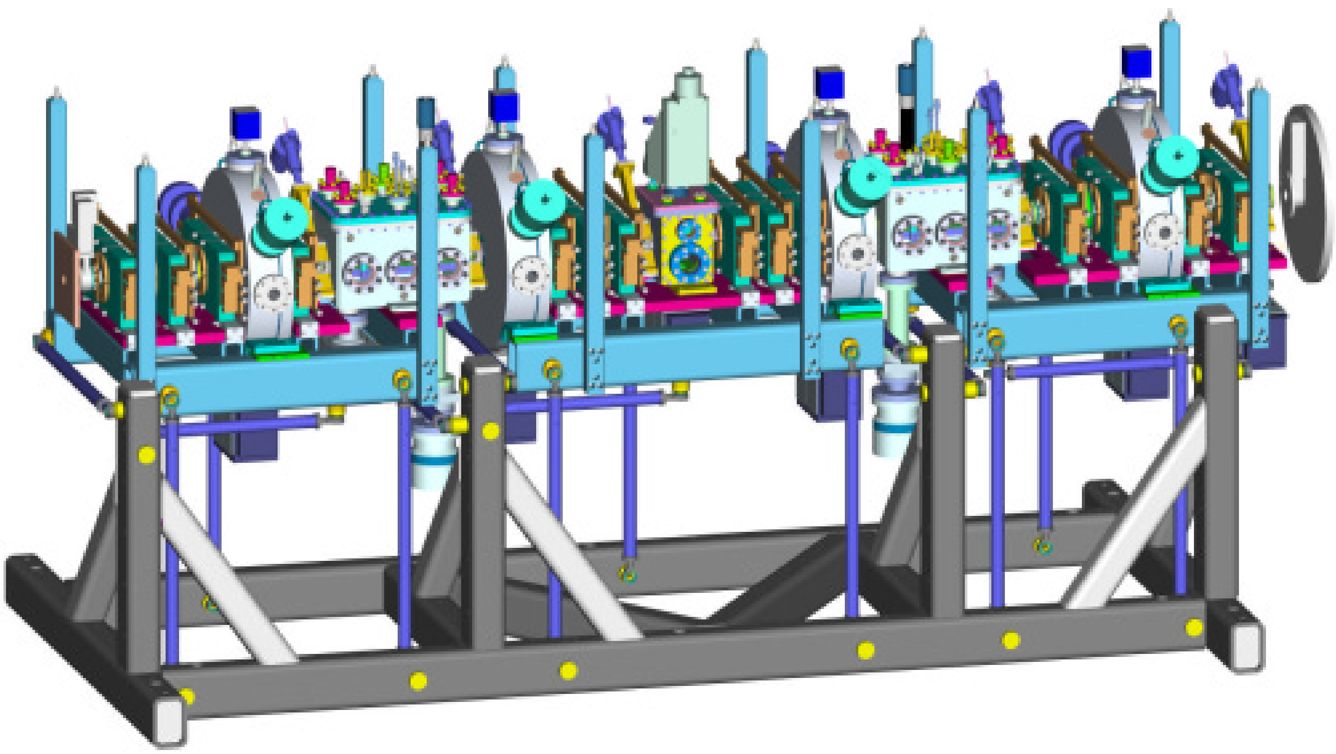
9) Fiducialization of Flanges: Consider referencing the outside diameter of flanges. Fiducialization of the flanges w.r.t. the mounting plane could aid in shim selection.

10) Building 71 Assembly: Develop a plan for setting up space for raft assembly in Building 71.

11) TBD: Perform engineering calculations to determine dynamic loads, deflections, and stresses during operation, handling, and transportation and complete appropriate documentation.

SNS - Front End Systems

MEBT Raft and Support Structure



Final Design Review

March 30, 2001

Accelerator and Fusion Research Division — Berkeley Lab — Ion Beam Technology Program

AGENDA

MEBT Raft and Support Structure Final Design Review

LBNL 71-233 IBT/SNS Conference Room
Friday Morning, March 30, 2001

9:00	Scope of Review	Dick DiGennaro
9:05	Physics Requirements and Design Constraints	John Staples
9:20	MEBT Support and Alignment Overview	Daryl Oshatz
9:50	Raft Mechanical Design	Allan DeMello
10:20	Frame Mechanical Design	Daryl Oshatz
10:40	Discussion / Break (15 minutes)	
10:55	Assembly and Installation Plan	Daryl Oshatz
11:30	Cost Estimate, Schedule, and Procurement Plan	Daryl Oshatz
11:45	Wrap-up and Review of Recommendations	
12:00	Adjourn	

Scope of Review

Richard DiGennaro

March 30, 2001

Physics Requirements
and
Design Constraints

John Staples, LBNL

30 March 2001

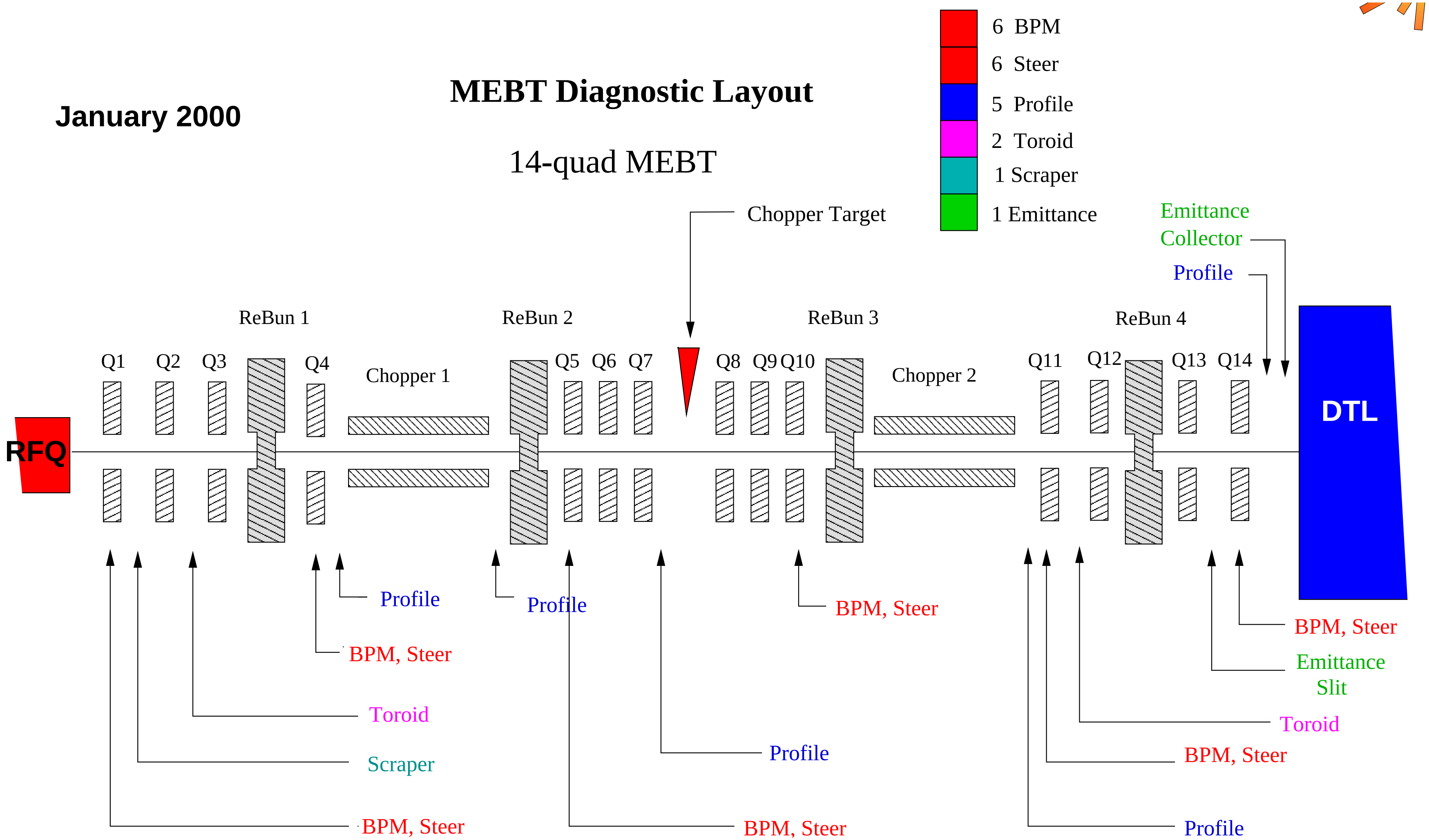
Function of MEBT

- Transport and focus beam to drift-tube linac
- Provide a site for the fast chopper
- Monitor beam performance

MEBT Design Philosophy

- Low emittance growth
  - dense, compact focusing lattice
- Four cavities provide longitudinal focusing
  - Offset beam produces major emittance growth
- Strong focusing requires tight alignment
- High beam power density
  - no intercepting diagnostics

MEBT Layout



6 BPM
6 Steer
5 Profile
2 Toroid
1 Scraper
1 Emittance
January 2000
MEBT Diagnostic Layout
14-quad MEBT
Chopper Target
Emittance Collector
Profile
ReBun 1
ReBun 2
ReBun 3
ReBun 4
Q1
Q2
Q3
Q4
Chopper 1
Q5
Q6
Q7
Q8
Q9
Q10
Chopper 2
Q11
Q12
Q13
Q14
RFQ
DTL
Profile
Profile
BPM, Steer
BPM, Steer
BPM, Steer
Emittance Slit
Toroid
Toroid
Scraper
Profile
BPM, Steer
BPM, Steer
BPM, Steer
Profile

Alignment Accuracy

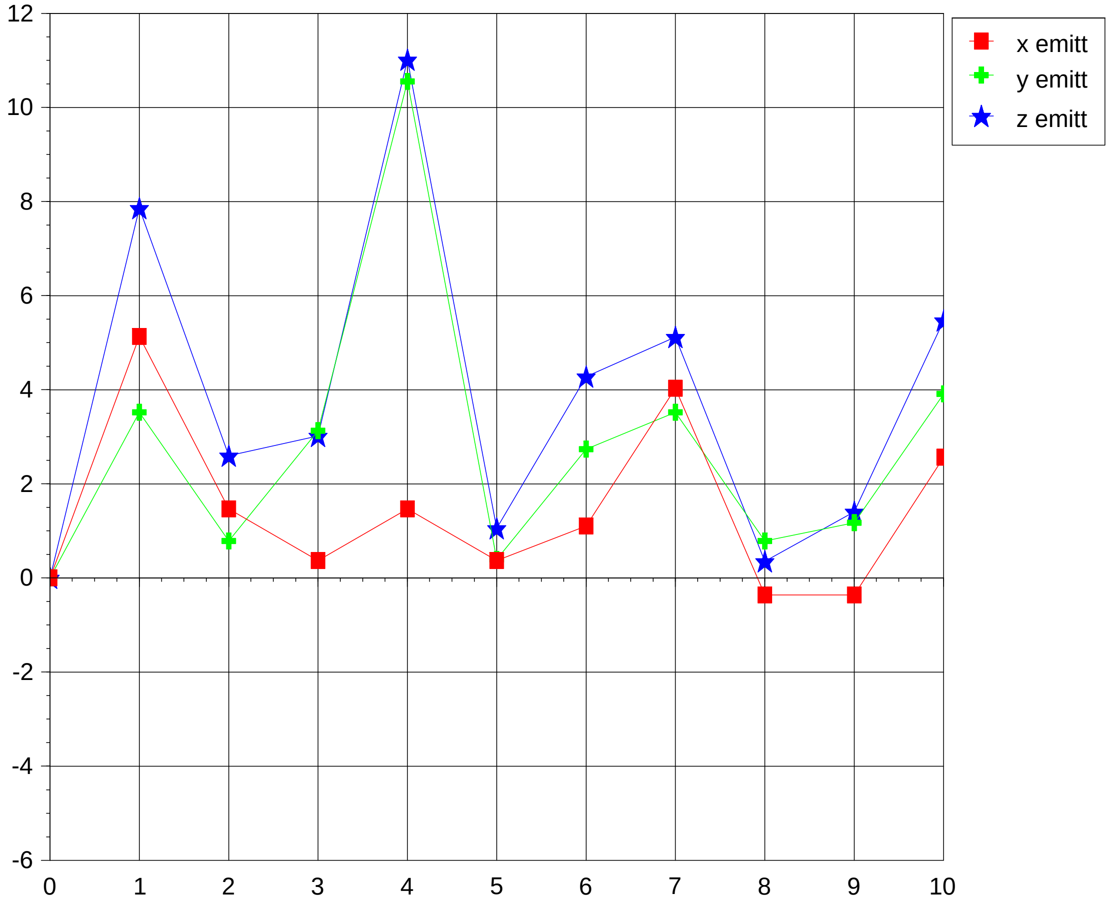
- Transverse quad displacements offsets beam
  - large magnification factor
- Offset beam in cavities generates emittance growth
- Maximum offsets determined with macroparticle simulations with random quad displacements
- Steering helps, but not a cure-all

Error Model

- gaussian quad displacements on rafts
- gaussian raft displacement and tilt
- gaussian cavity field and phase errors

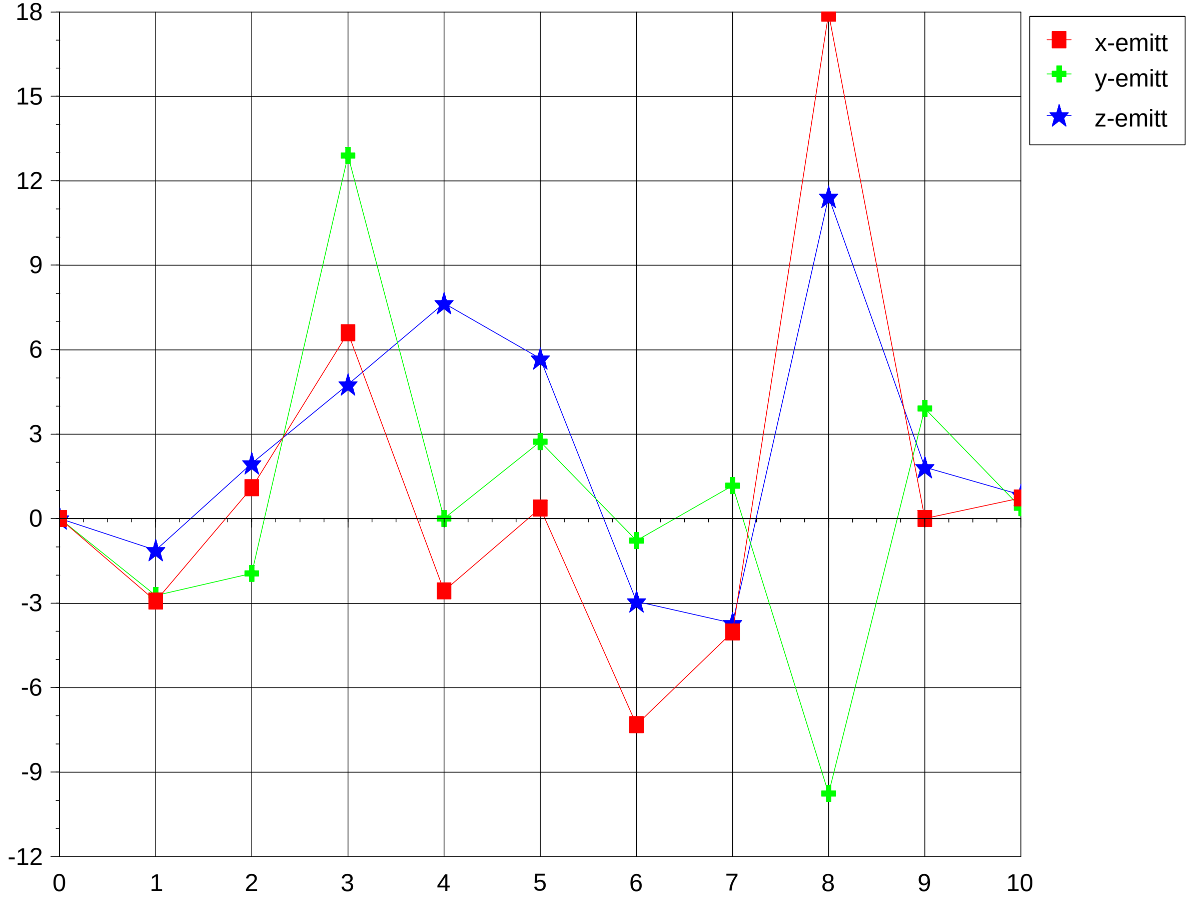
Emittance growth: Geometrics

Geometrics: 1.0 mils quads, 1.5 mils rafts rms



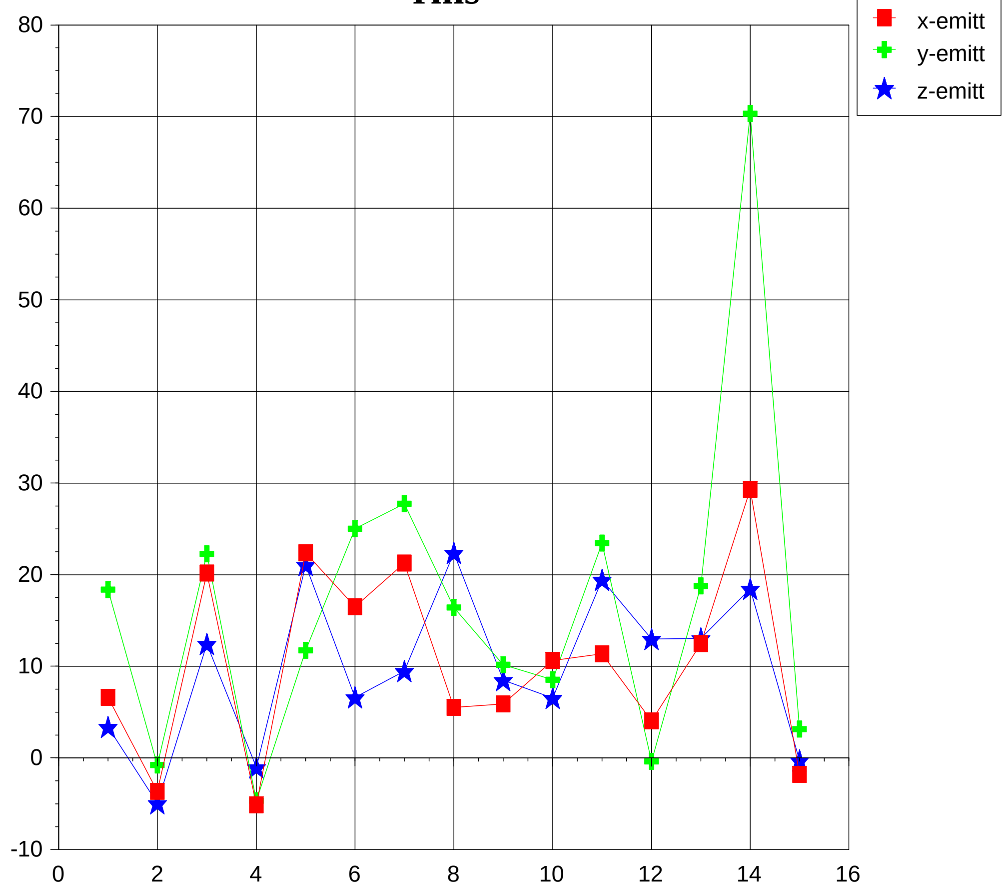
Emittance Growth: Cavities

Electrical: 1 % quad, 2%, 1 degree rebuncher rms



Emittance Growth: Total

1% quad, 2% cav gradient, 1,1.5 mil displ, 1 degree rms



Results

- 1 mil rms quad displacement on rafts
- 1.5 mil rms each end of raft
- This produces a few percent emittance growth
- Emittance growth due to displacement in cavities grows faster than linearly
- Steering itself produces emittance growth due to large sextupole
- Steering limited to ≈±1.5 mrad

Diagnostics

- Will use beam-based scheme to find magnetic centers of quads
- Then validate electrical centers of BPMs
- Wire scanners only provide relative, not absolute beam centroid information.

Summary

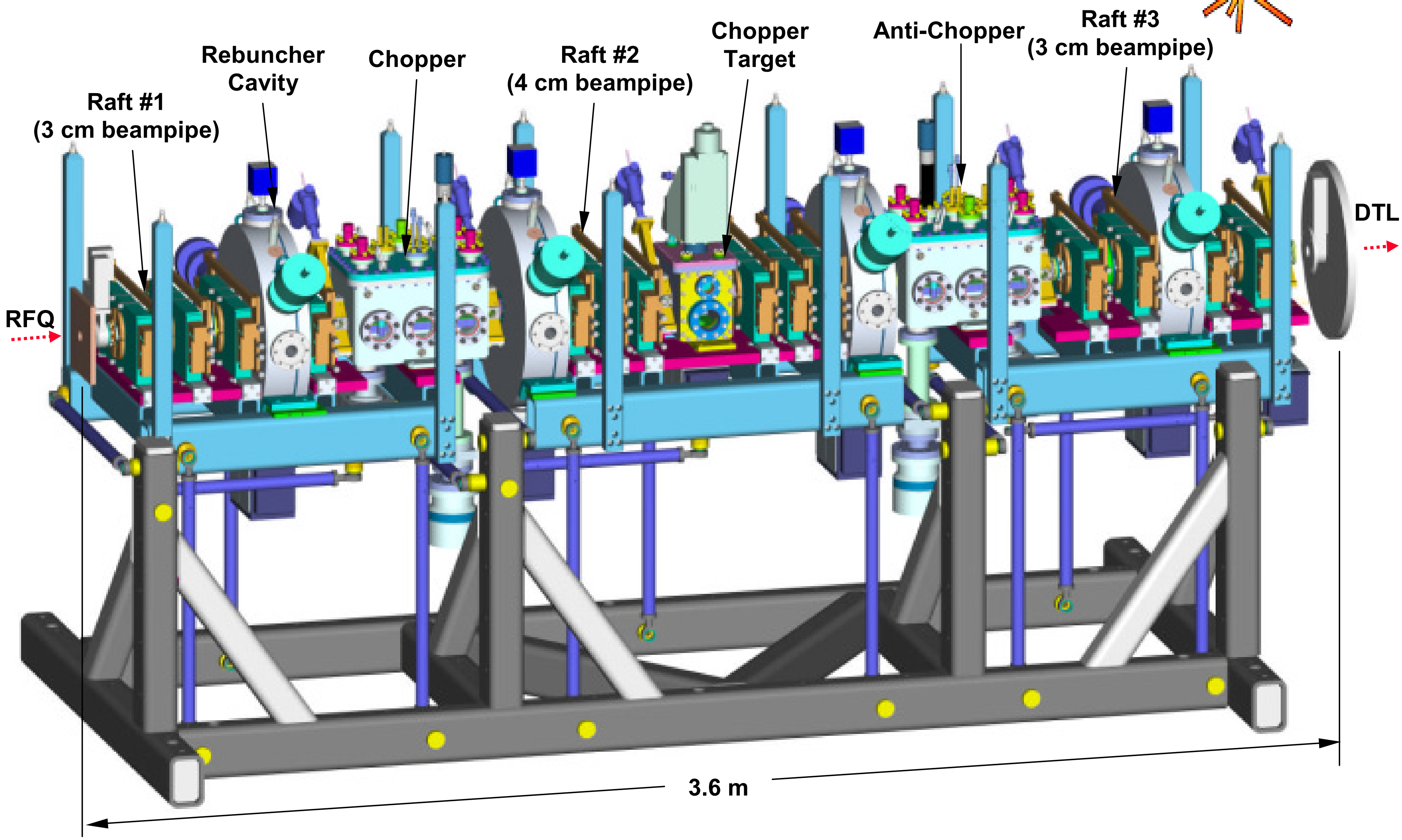
- Tight tolerances, but typical of this type of beam line
- Beam-based analysis will be attempted
- Mechanical implementation looks quite robust and stable.

MEBT Support and Alignment Overview

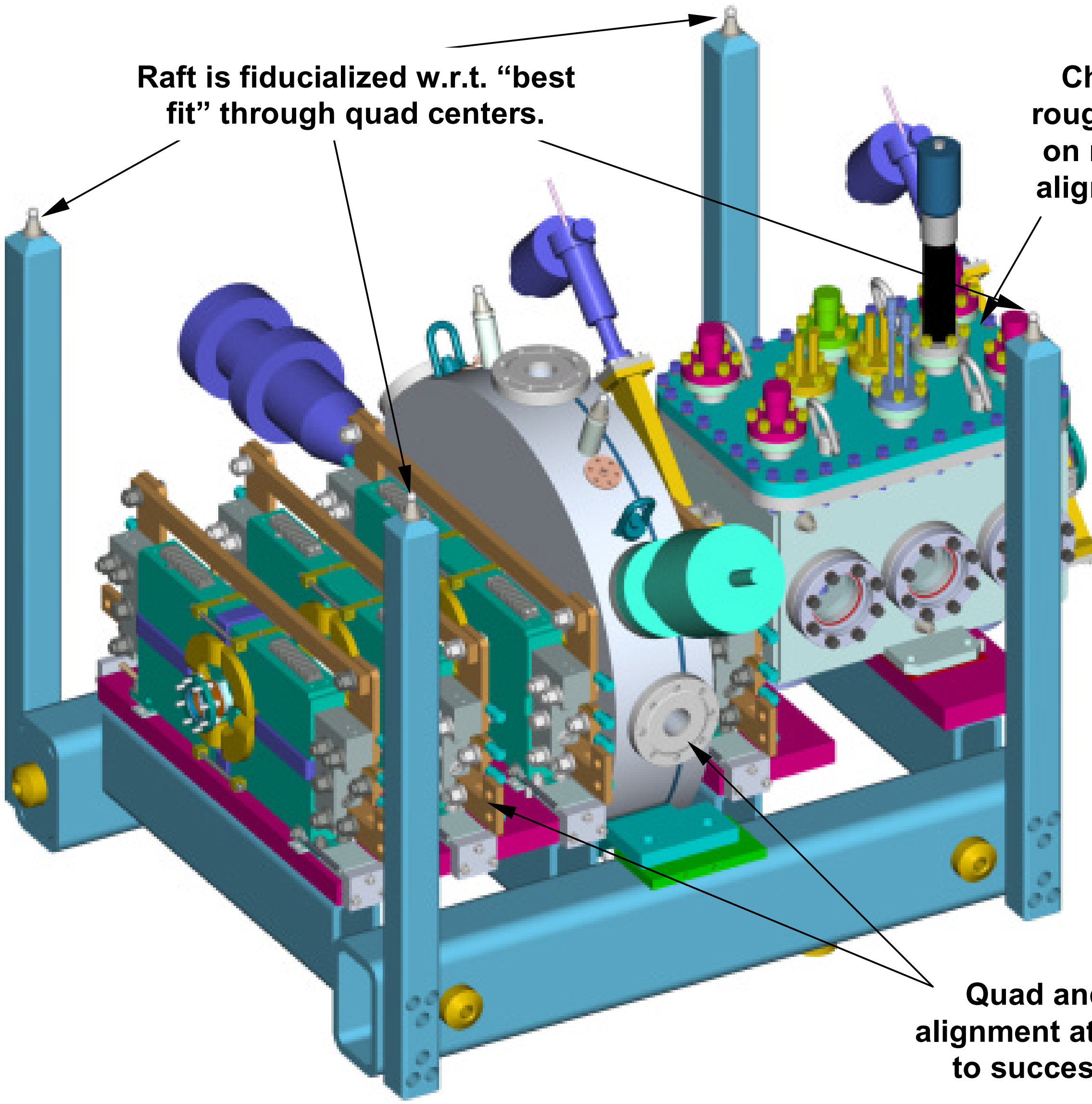
Daryl Oshatz

March 30, 2001

MEBT Components



Assembled Raft #1



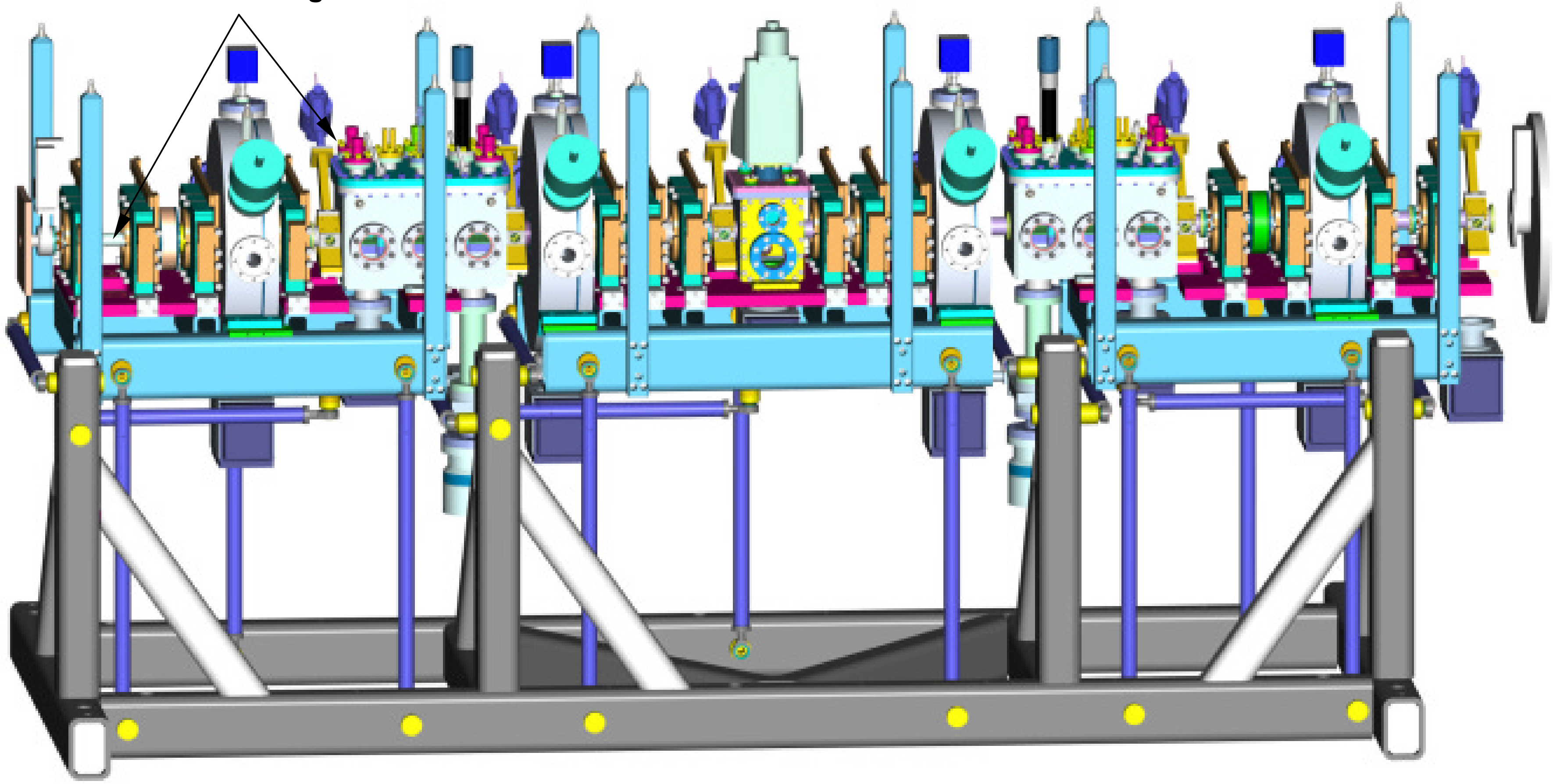
Quad Alignment Requirements

- Positional Tolerance of Quads on Raft
  - Contributing tolerances:
    - Offset of magnetic center w.r.t. mechanical center
    - EDM tolerance
    - CMM precision
    - Assembly tolerances
  - x-direction: ±.003” (.001” RMS)
  - y-direction: ±.003” (.001” RMS)
  - z-direction: ±.015” (.005” RMS)
- Positional Tolerance of Rafts on Beamline
  - Rafts aligned with laser tracker <u>or</u> optical surveying
  - total tolerance: ±.0045” (.0015” RMS)

General Alignment Requirements

Beampipe and beambox alignment requirements are dictated by mechanical fits between flanges.

Quads and Rebuncher Cavities have the same alignment requirements.



Raft Mechanical Design

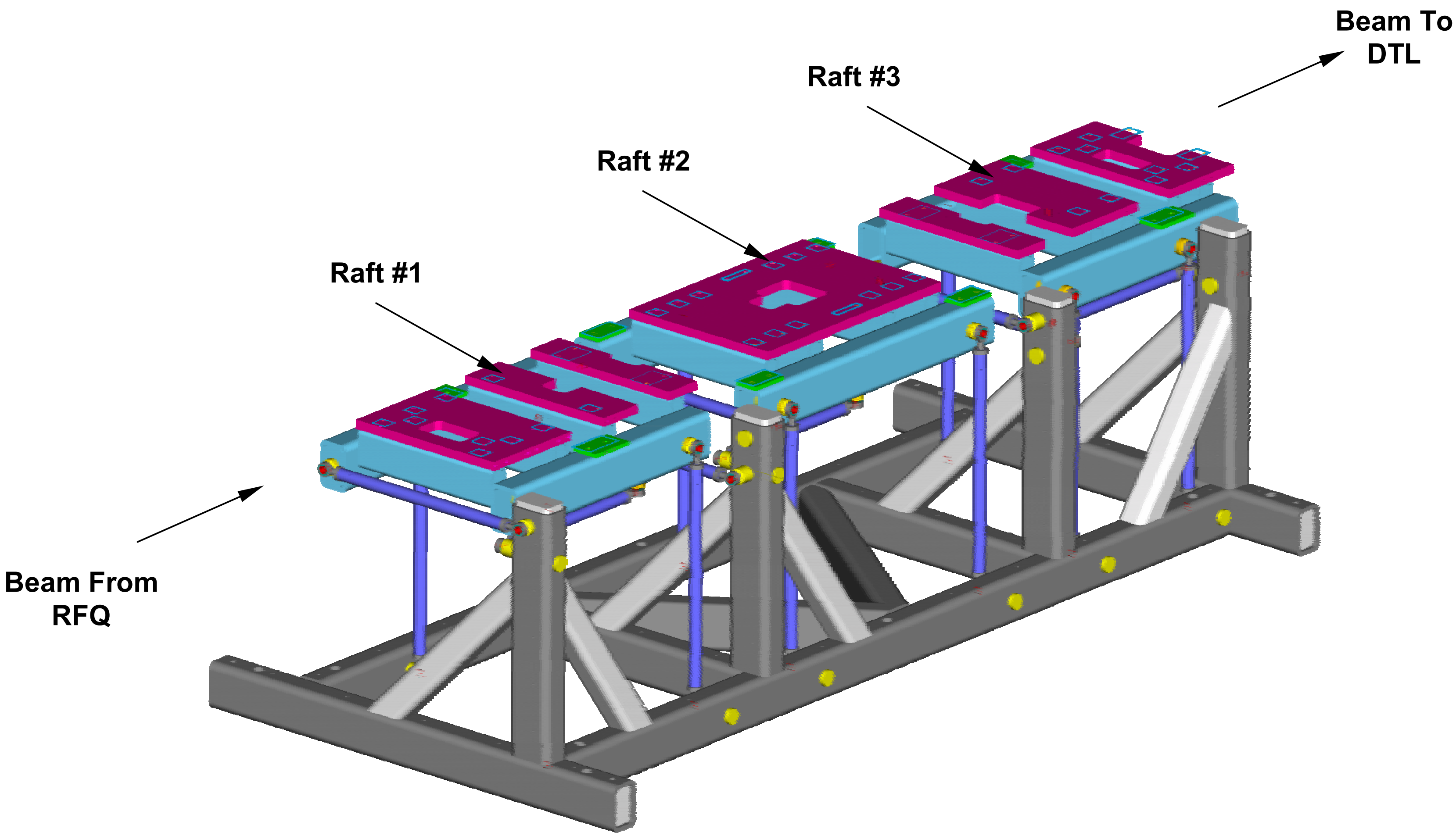
Allan DeMello

March 30, 2001

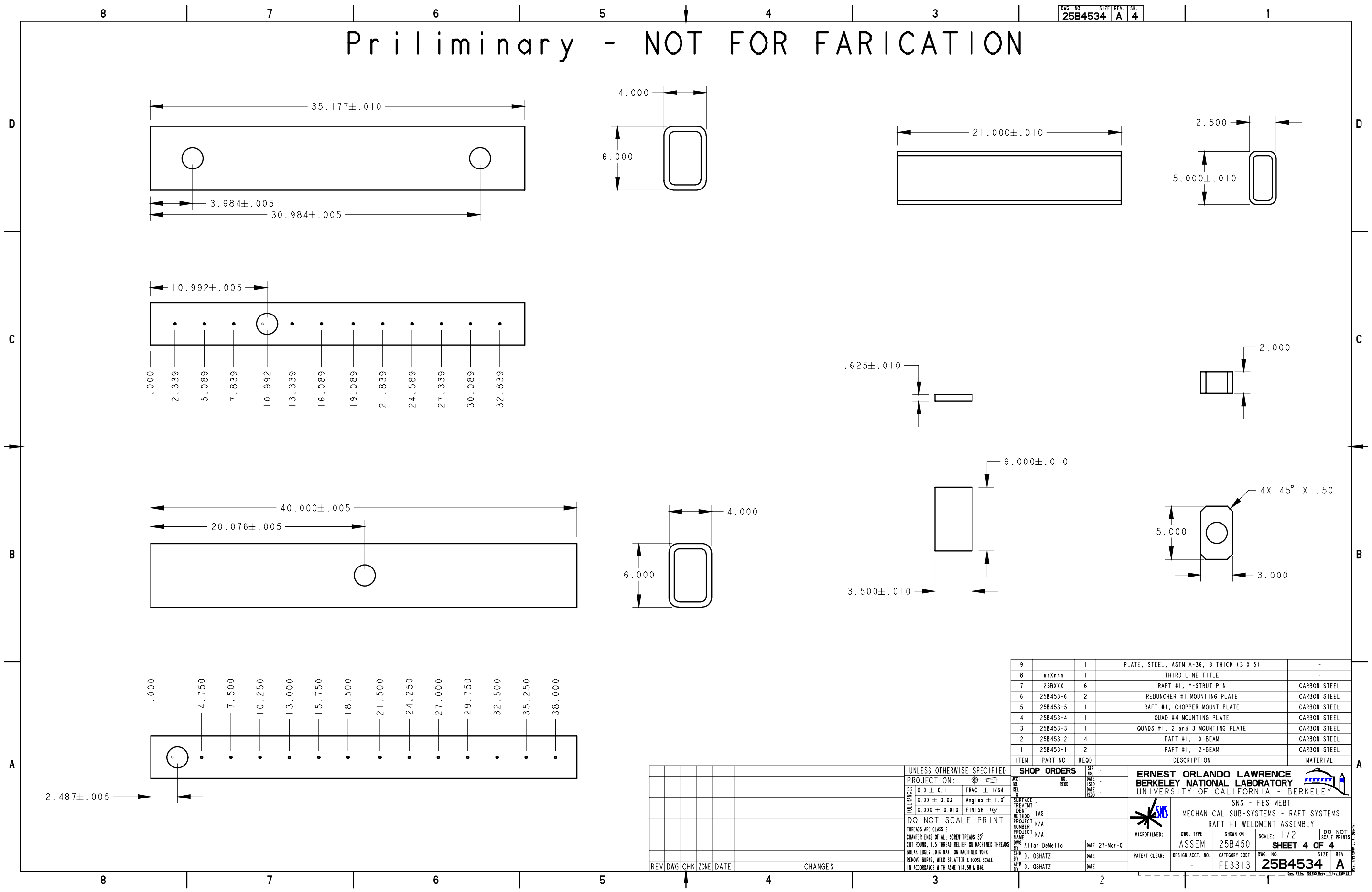
Raft Manufacturing Procedure

1. Cut and Machine Raft Components
2. Weld Frame and Plates into a Single Unit
3. Stress Relieve Entire Raft
4. Bead Blast Entire Raft
4. Grind Critical Mounting Surfaces
5. Precision Machine All Mounting Holes
6. CMM Inspection of All Holes
7. Nickel Plate Entire Raft
8. Paint Entire Raft Except Mounting Surface (depending on the plating appearance)

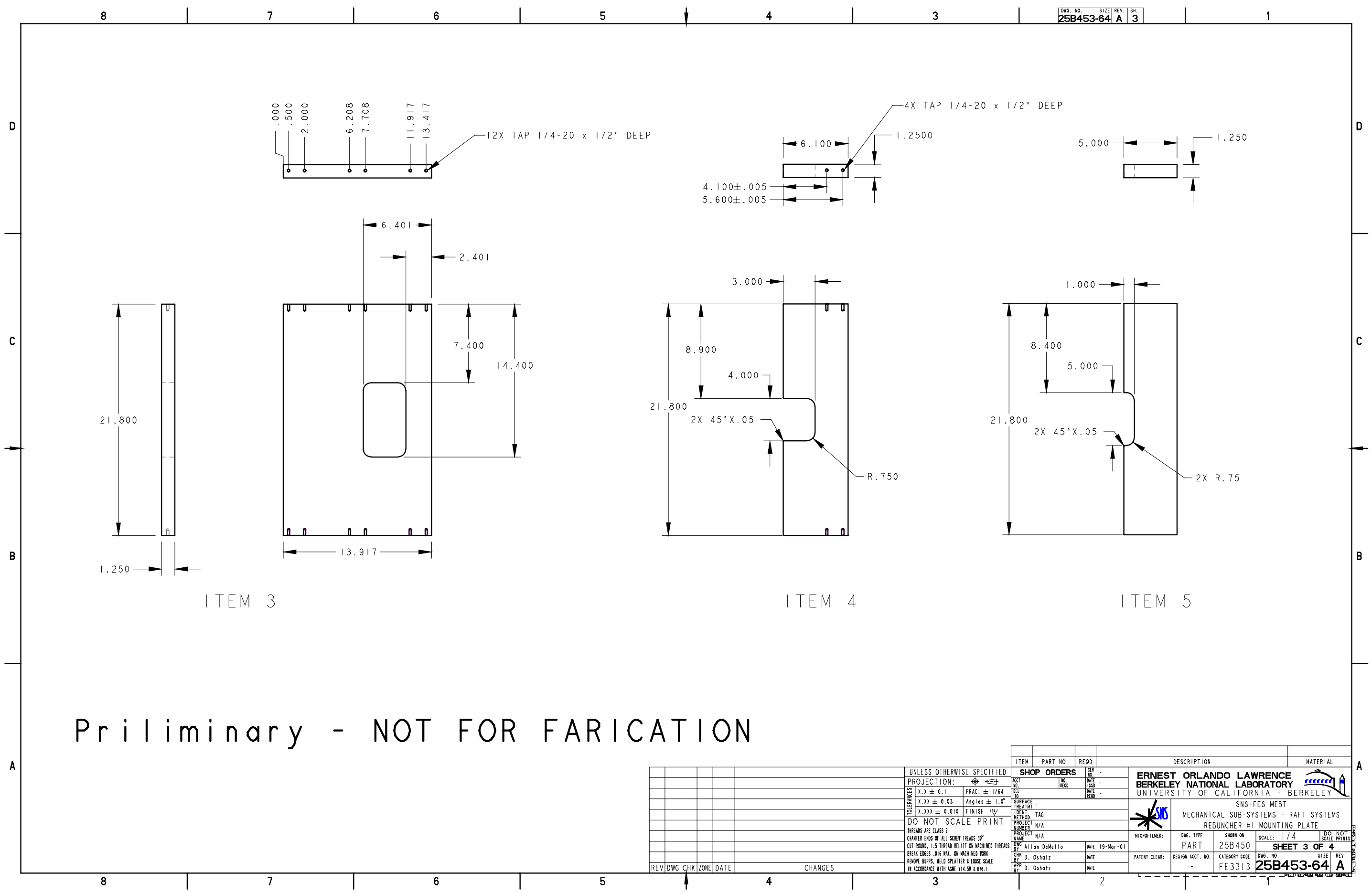
Raft/Frame System Overview



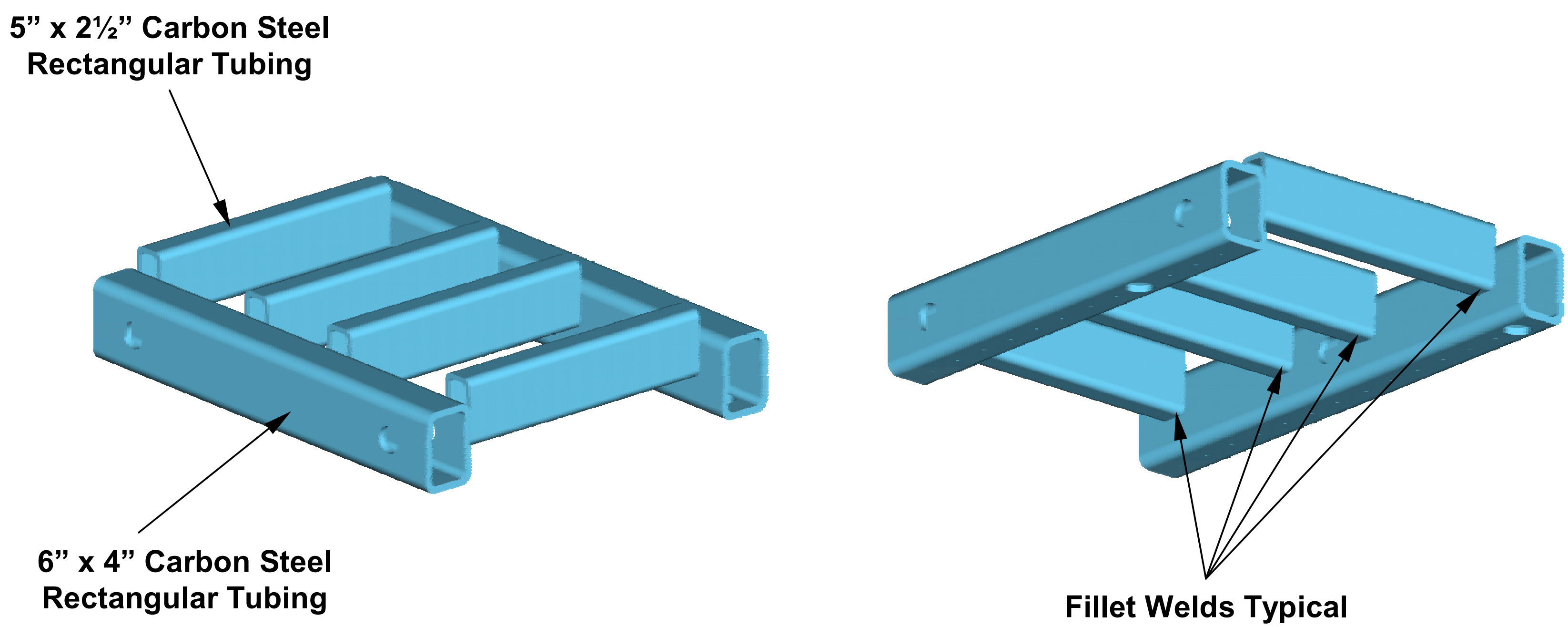
Cut and Machine Raft Components



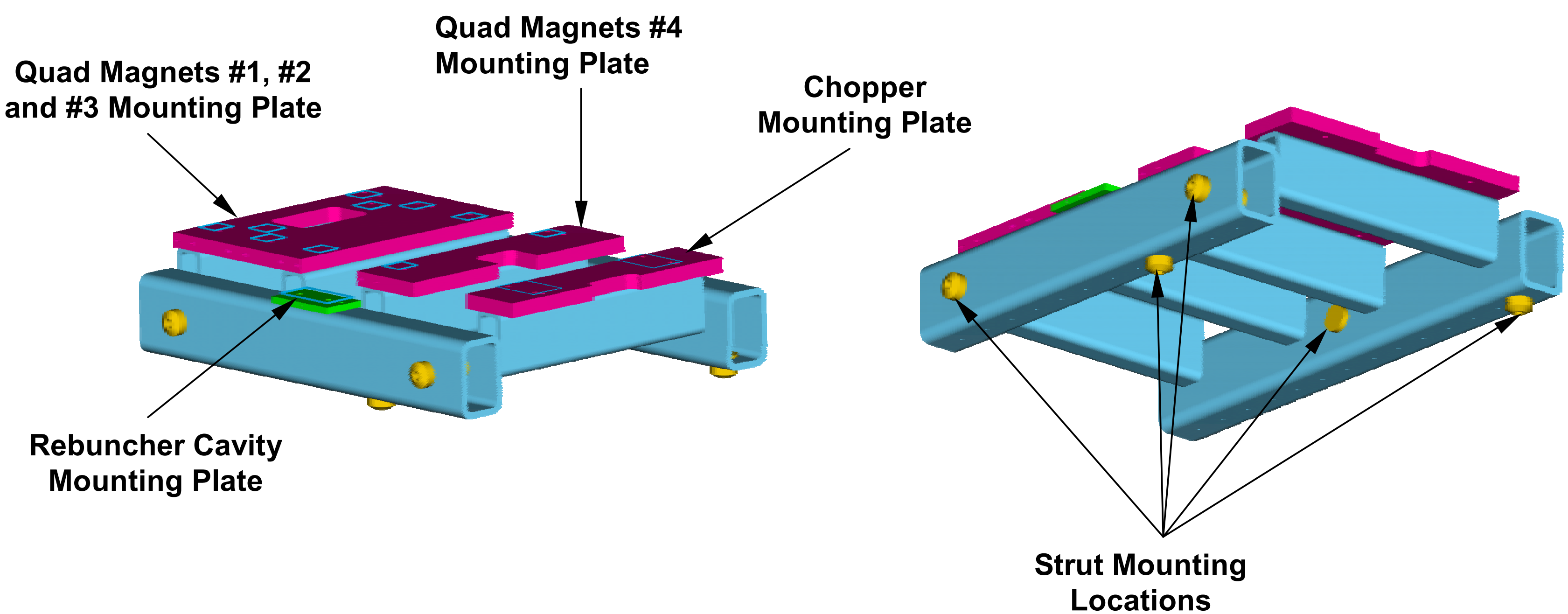
Cut and Machine Raft Components



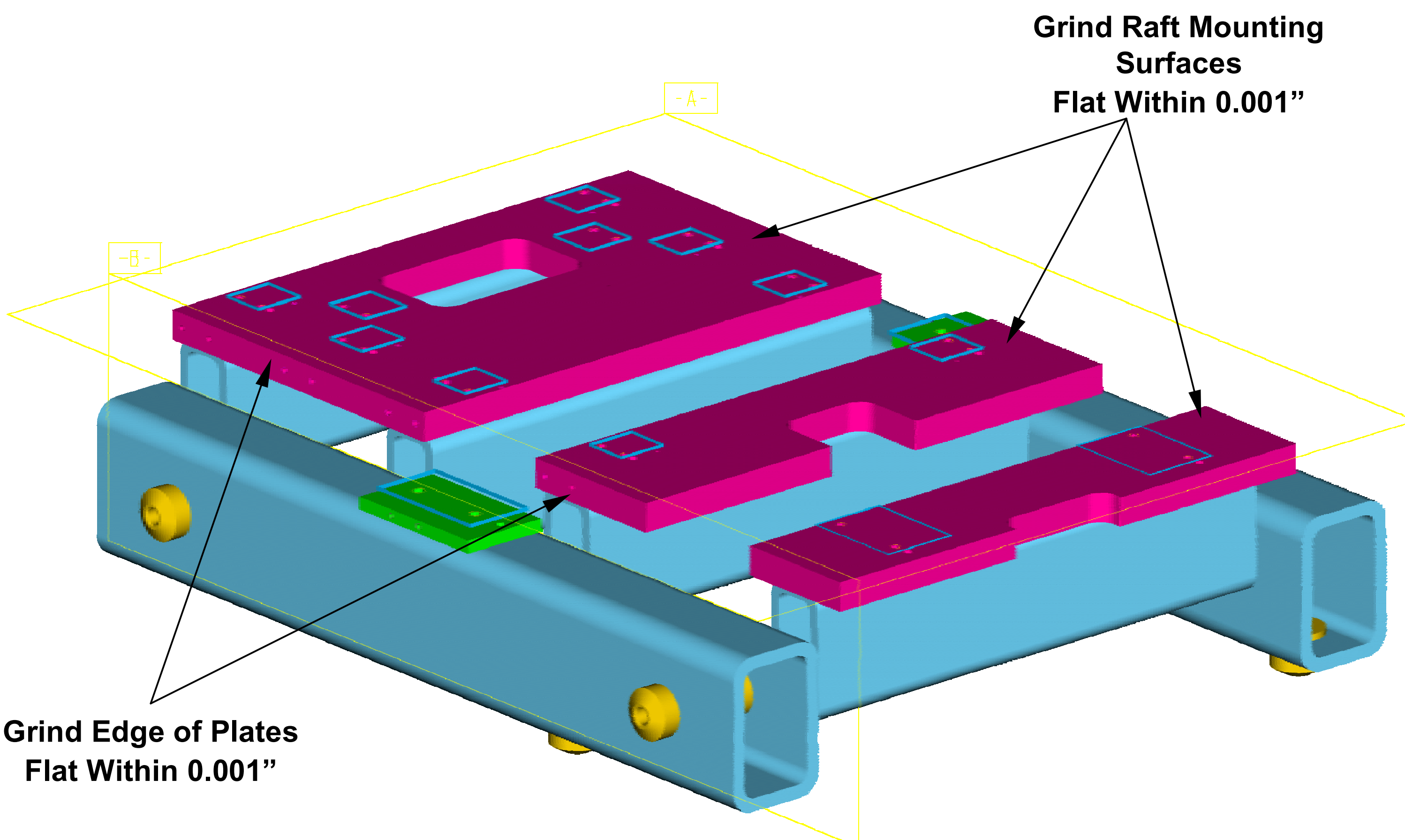
Weld Frame


5" x 2½" Carbon Steel
Rectangular Tubing
6" x 4" Carbon Steel
Rectangular Tubing
Fillet Welds Typical

Weld Frame and Plates into a Single Unit

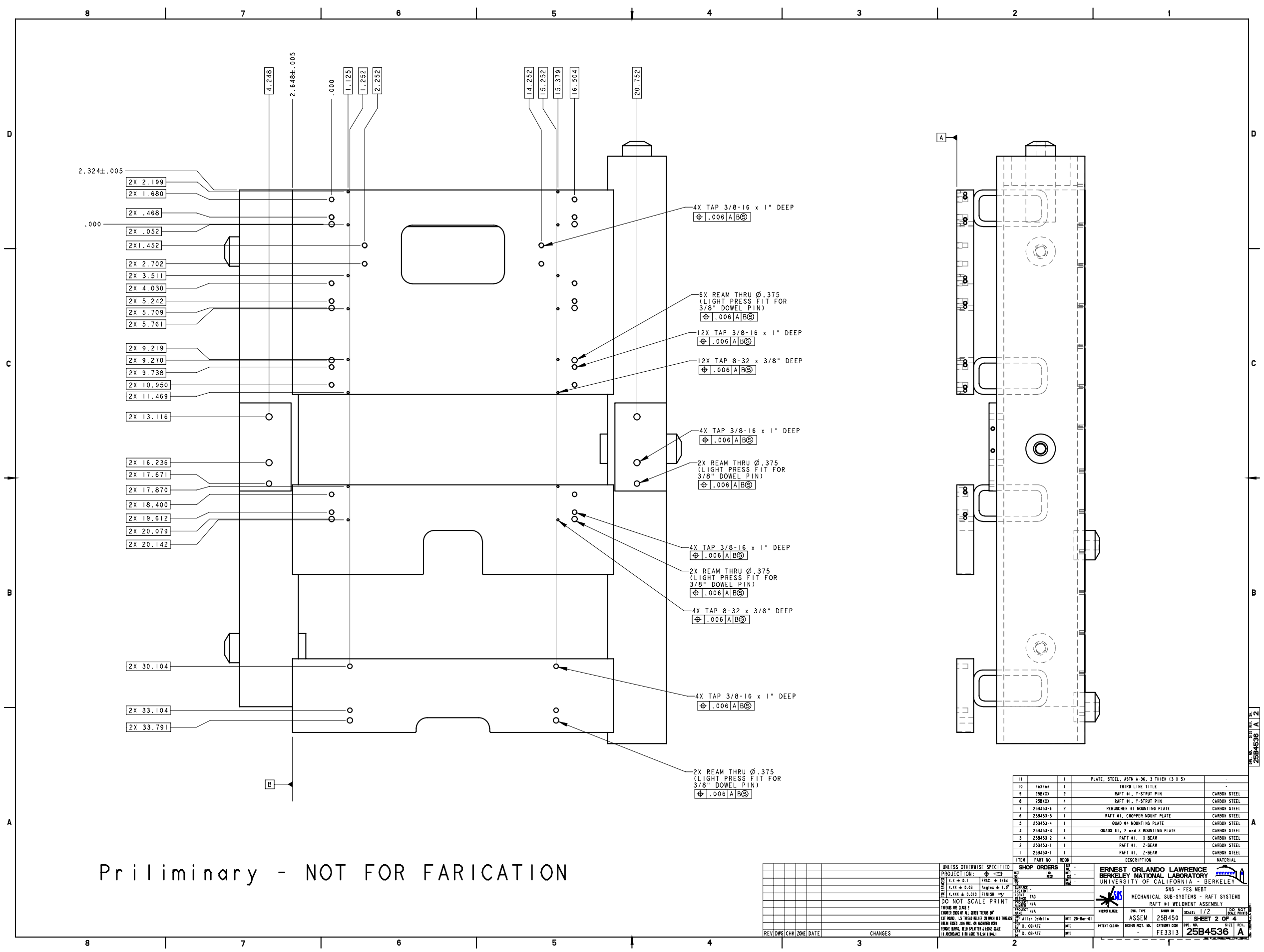


Grind Critical Mounting Surfaces

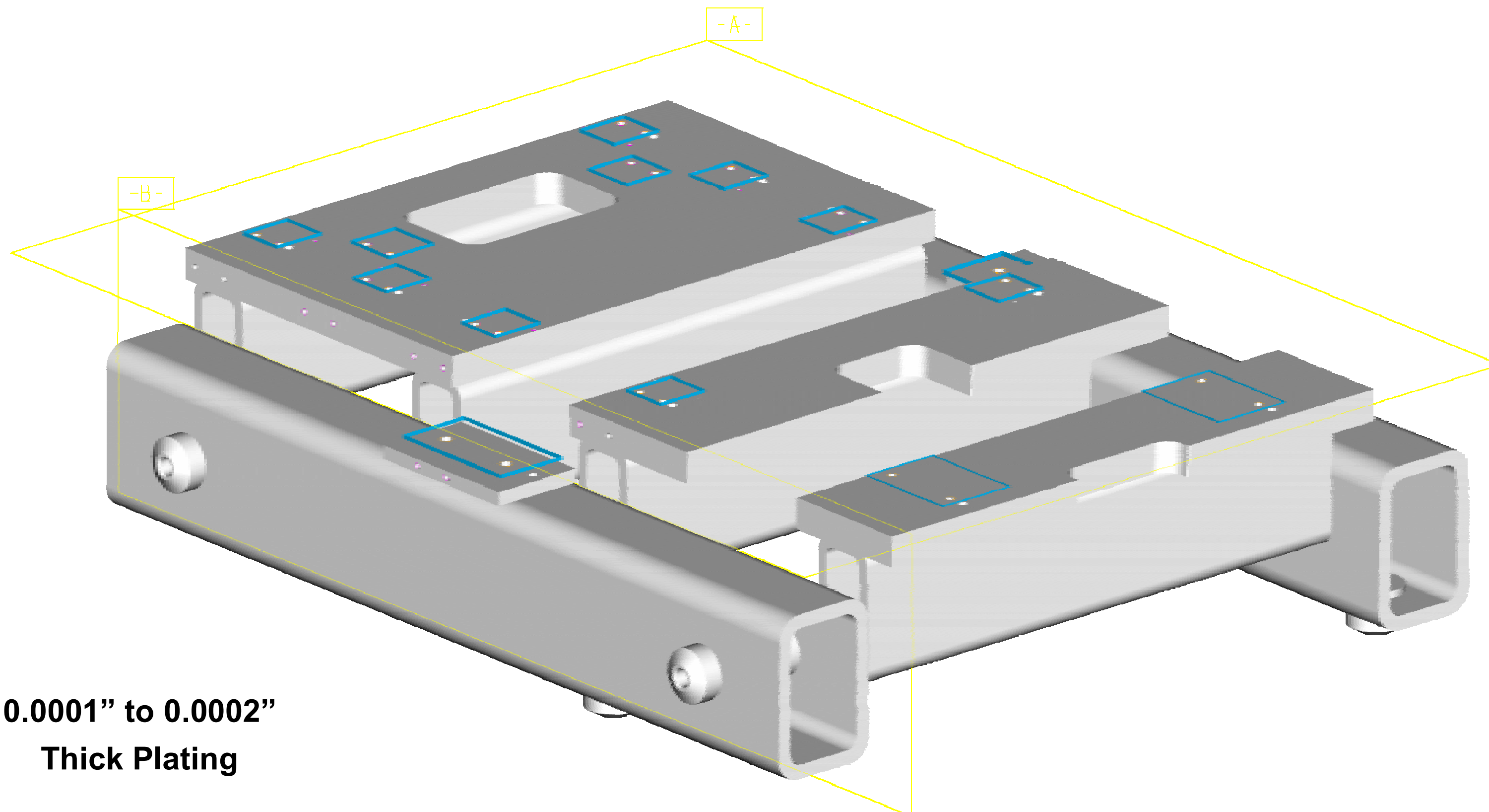


Precision Machine Mounting Holes

- Dowel pin hole true position tolerance of 0.006”
- Tapped hole true position tolerance of 0.015”



Electroless Nickel Plate Entire Raft



0.0001” to 0.0002”
Thick Plating

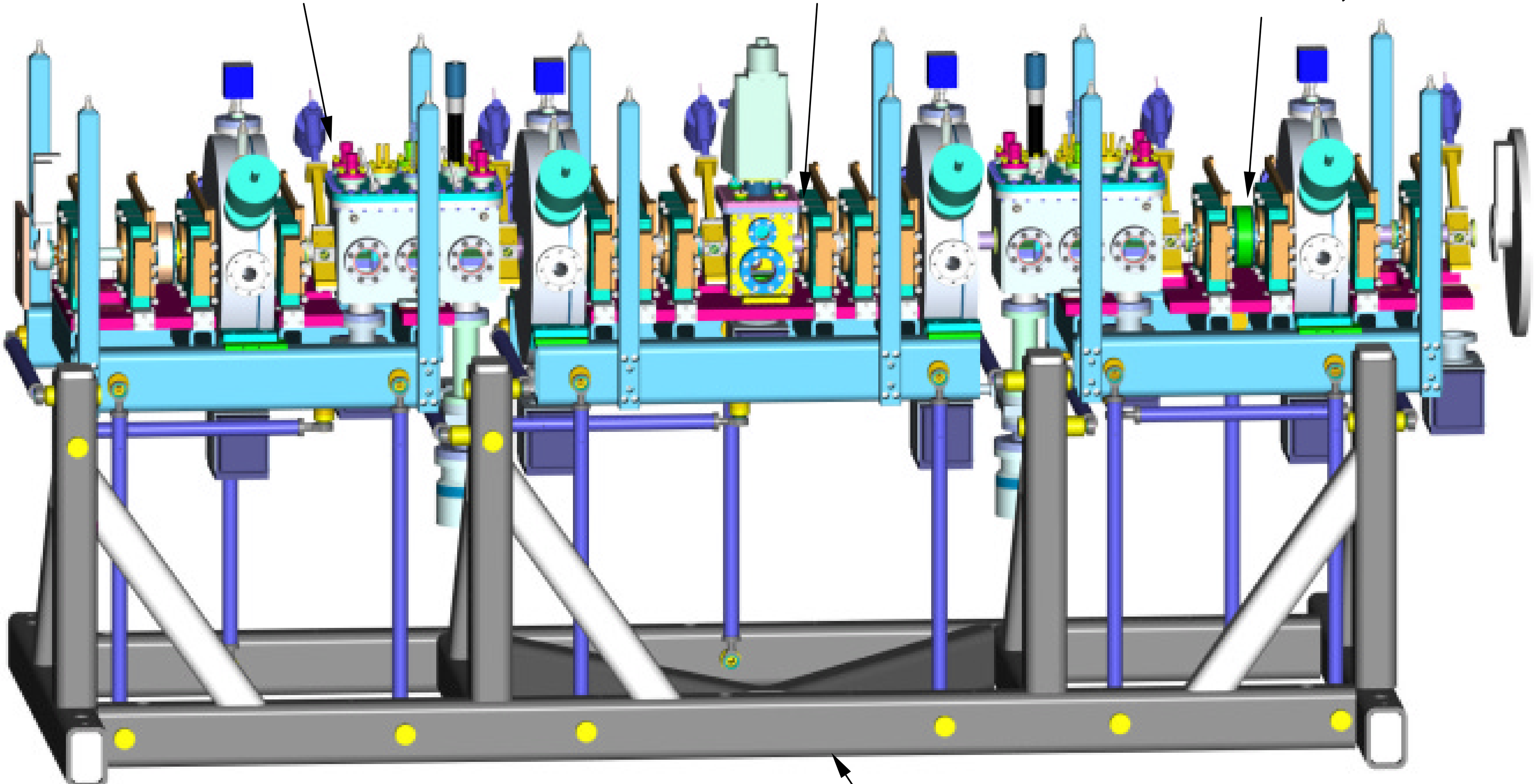
Frame Mechanical Design

Daryl Oshatz

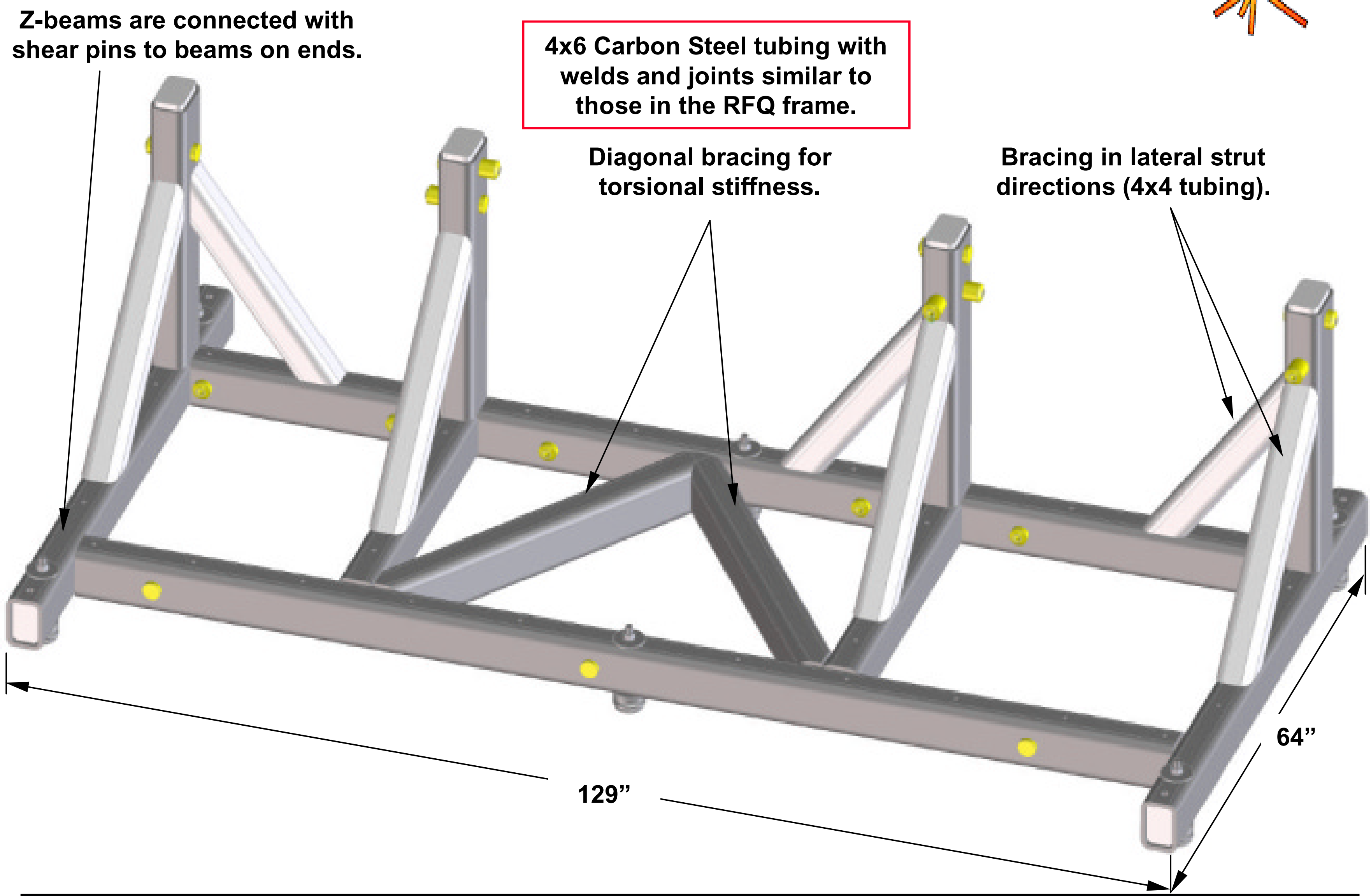
March 30, 2001

MEBT Masses

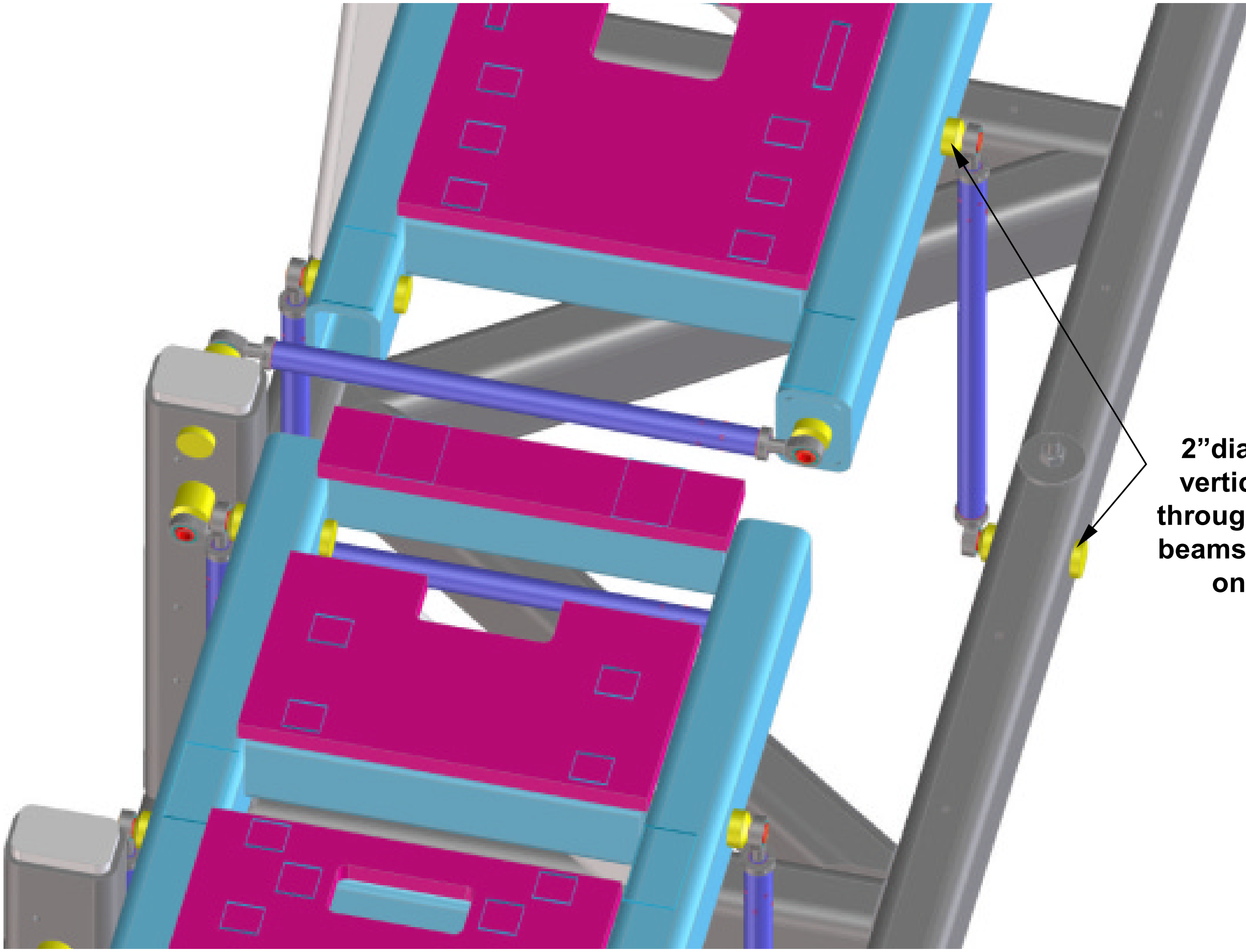
Total MEBT Mass = 7,300 lb



MEBT Frame Weldment



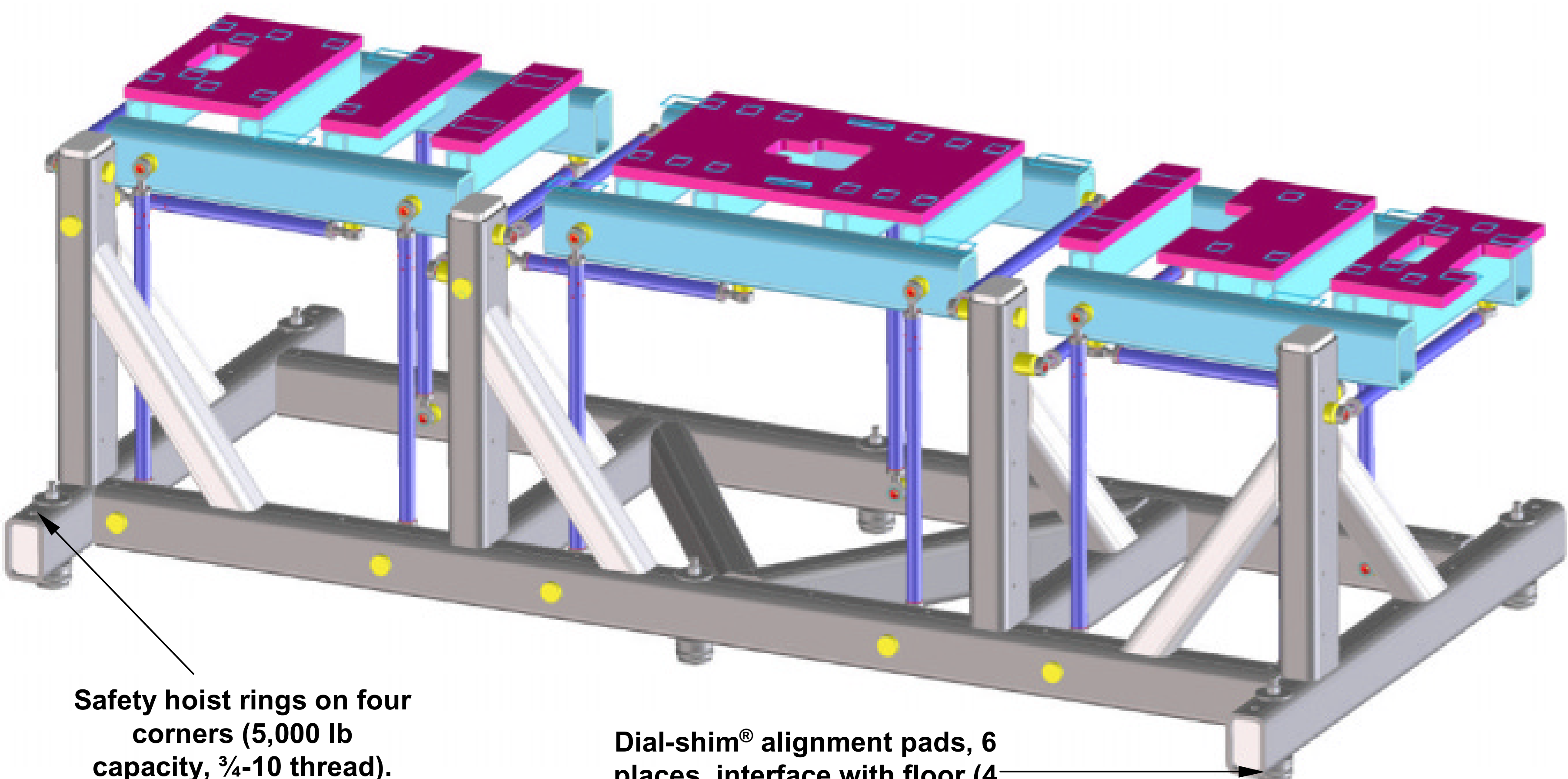
Strut Mounts



2"diam. bosses for vertical struts pass through frame and raft beams and are welded on both sides.

Frame Details

Jacking struts with ¾" rod-ends have a static, radial load capacity of 10,000 lb.



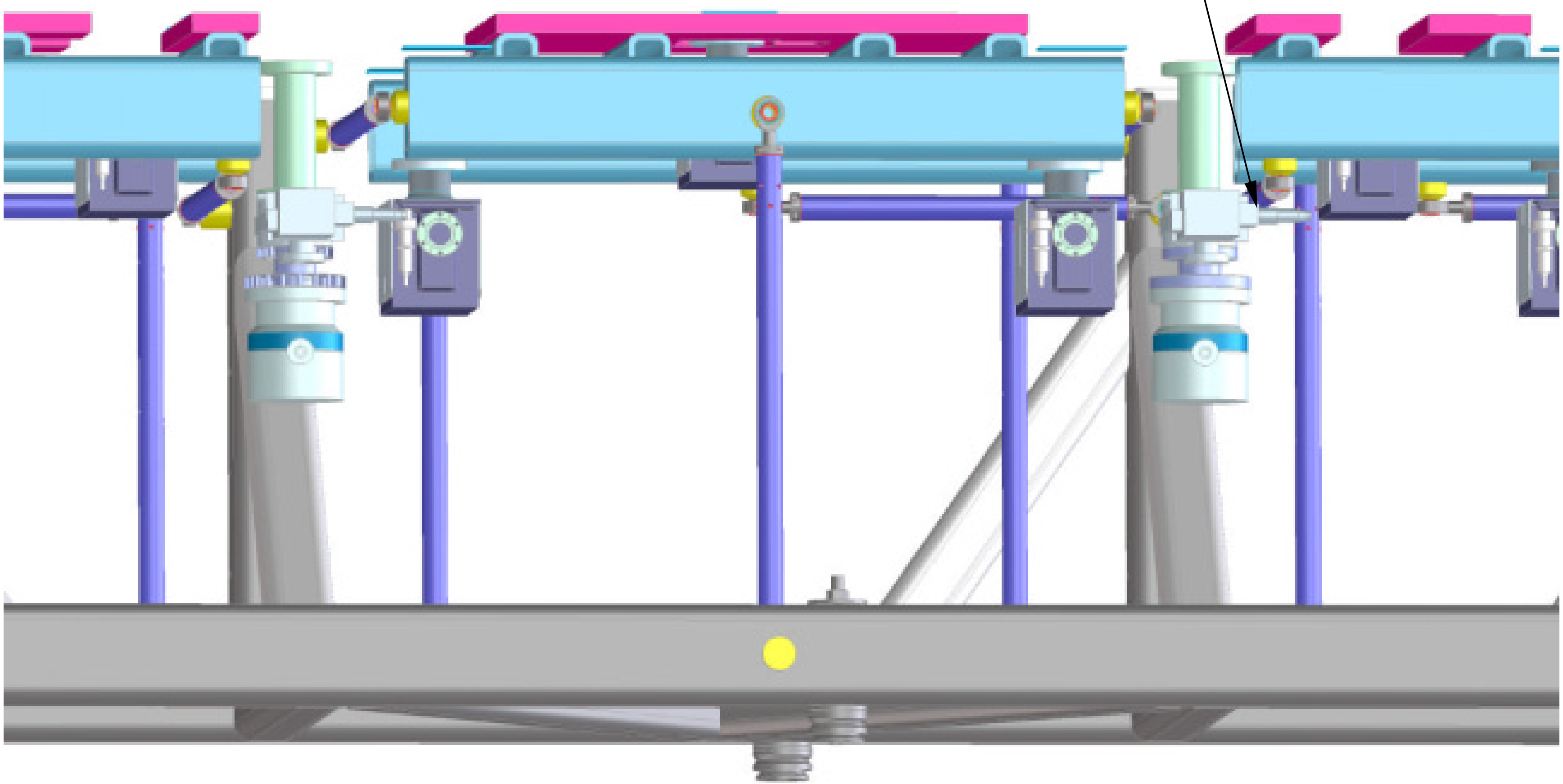
Safety hoist rings on four corners (5,000 lb capacity, ¾-10 thread).

Dial-shim® alignment pads, 6 places, interface with floor (4 inches of clearance to floor).

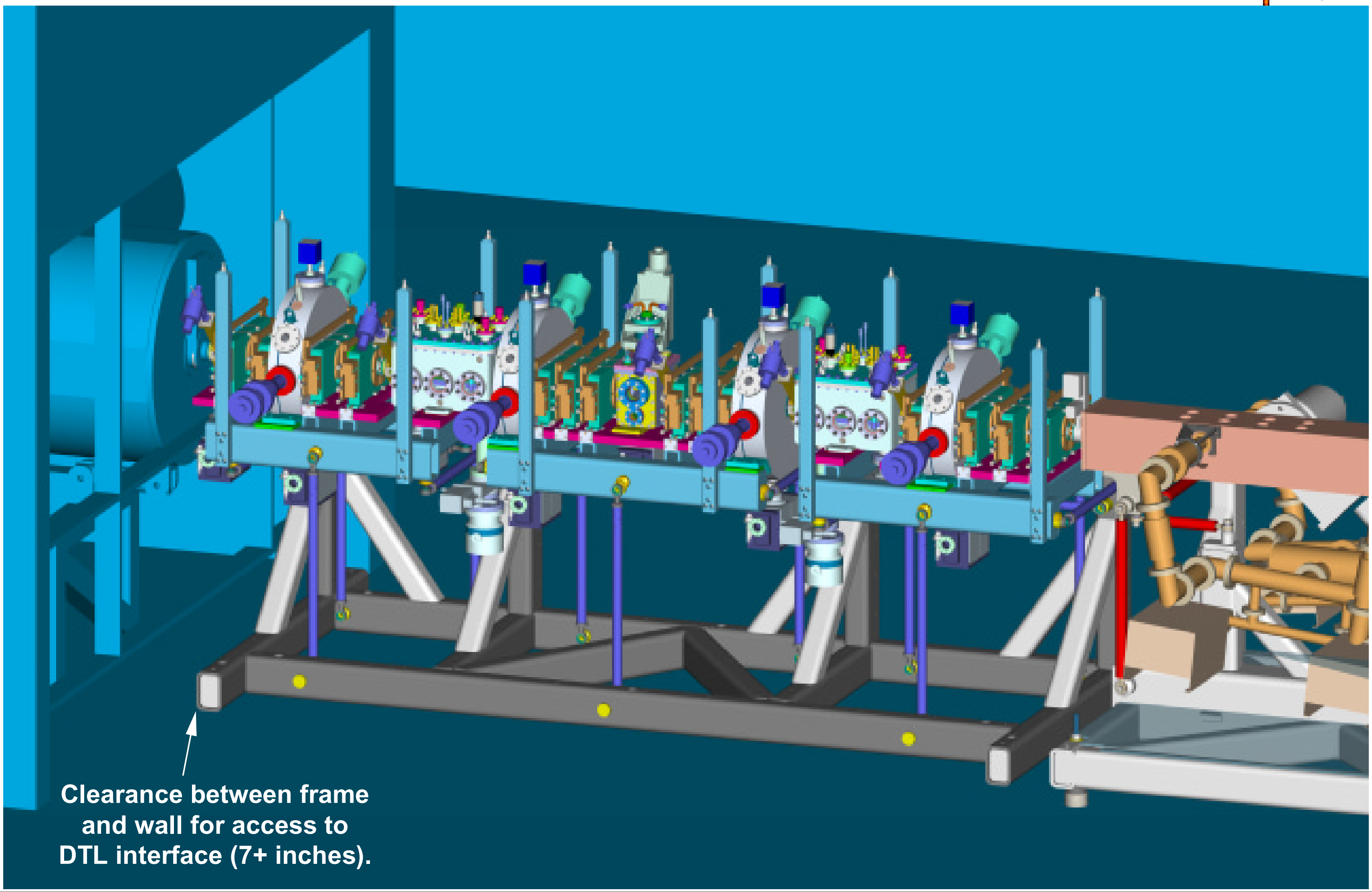
Vacuum System Clearances

Access provided for installation and removal of vacuum pumps and valves.

Small clearance with roughing gate valve connector (0.160”).



MEBT & RFQ Frames

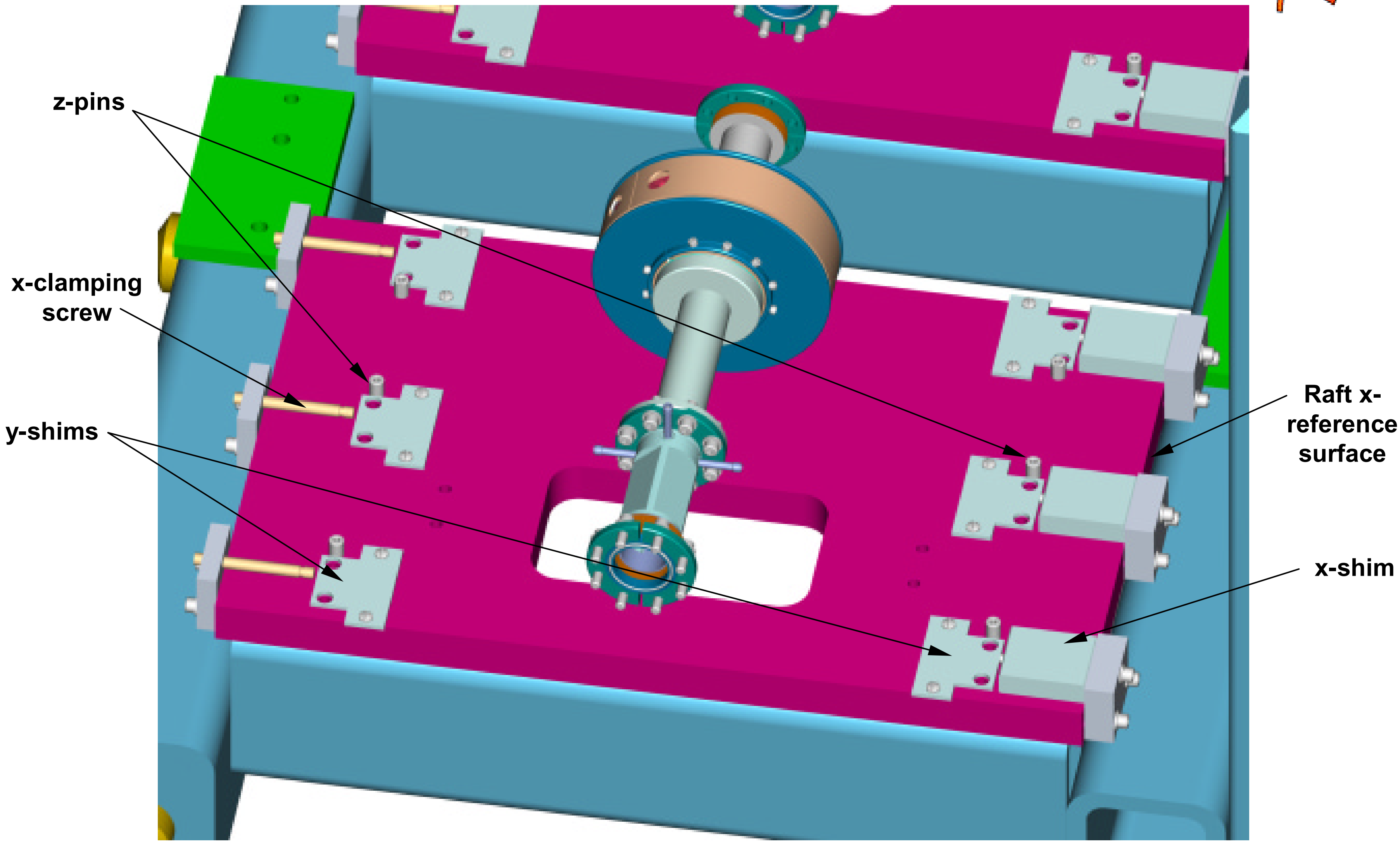


Assembly and Installation Plan

Daryl Oshatz

March 30, 2001

Raft Shim System



Quad y-positional Tolerance

Y-DIMENSION

1) Pole-piece profile to indexed corner of QM: ± .0015
2) Y-shim thickness: ± .0005
3) Raft mounting surface flatness: ± .0005
4) CMM calibration precision: ± .0005
5) Magnetic to mechanical center deviation: ± .0005

$$\delta y = \sqrt{(.0015)^2 + (.0005)^2 + (.0005)^2 + (.0005)^2\ (.0005)^2} = .0018 = 3\sigma$$

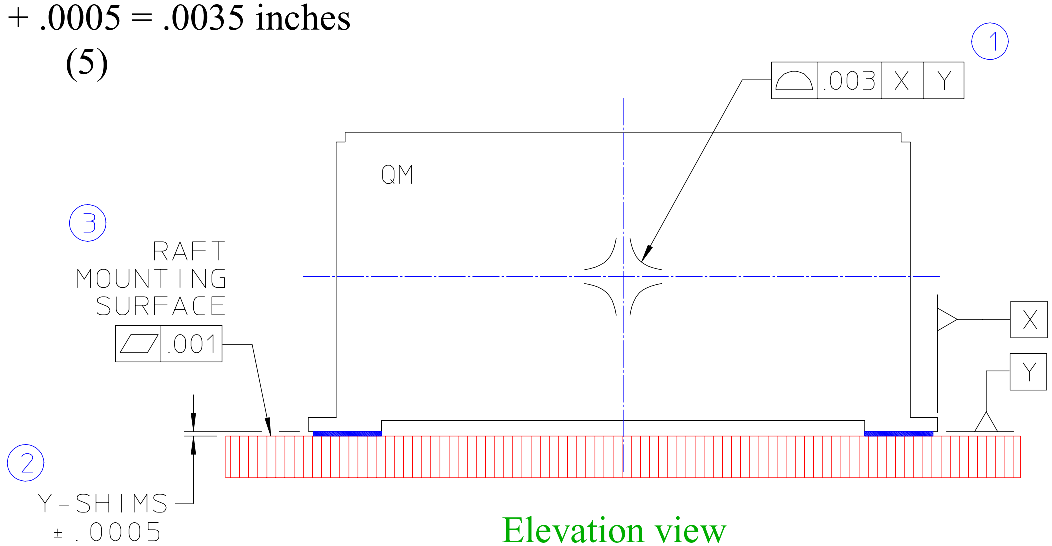
(1) (2) (3) (4) (5)

σ = .0006 inches RMS , requirement is σ = .001 RMS

Worst Case misalignment:

Δy = .0015 + .0005 + .0005 + .0005 + .0005 = .0035 inches

(1) (2) (3) (4) (5)



Quad x-positional tolerance

<u>X-DIMENSION</u>

1) Pole-piece profile to indexed corner of QM: ± .0015
2) X-shim thickness: ± .0005
3) X- shim rail flatness: ± .0005
4) CMM calibration precision: ± .0005
5) Magnetic to mechanical center deviation: ± .0005

$$\delta y = \sqrt{(.0015)^2 + (.0005)^2 + (.0005)^2 + (.0005)^2\ (.0005)^2} = .0018 = 3\sigma$$

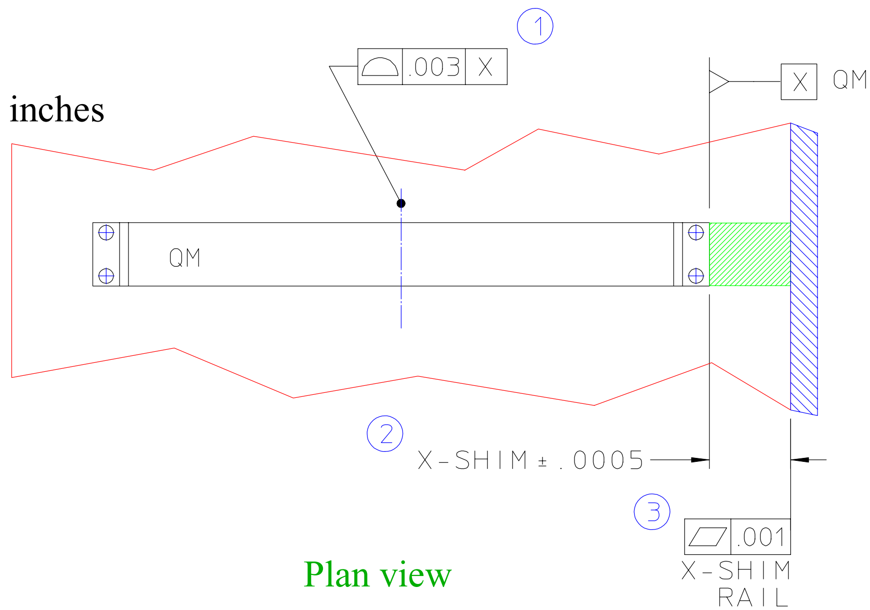
(1) (2) (3) (4) (5)

σ = .0006 inches RMS , requirement is σ = .001 RMS

Worst Case misalignment:

Δx = .0015 + .0005 + .0005 + .0005 + .0005 = .0035 inches

(1) (2) (3) (4) (5)



Plan view

Quad z-positional tolerance

Z-DIMENSION

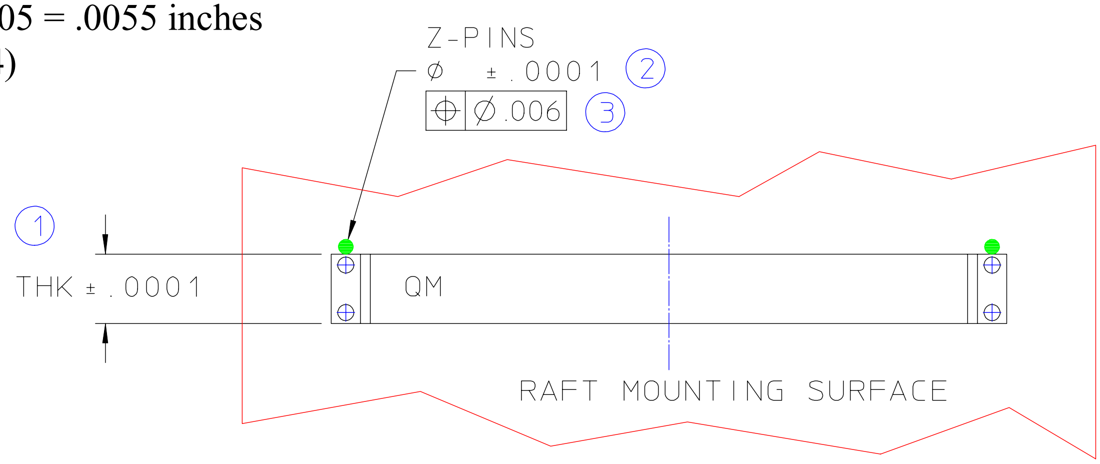
1) QM thickness (post-assy grinding): ± .0001
2) Dowel pin diameter: ± .0001
3) Dowel pin hole positional tolerance: ± .003
4) CMM calibration precision: ± .0005

$$\delta y = \sqrt{\underset{(1)}{(.0001)^2} + \underset{(2)}{(.0001)^2} + \underset{(3)}{(.003)^2} + \underset{(4)}{(.0005)^2}} = .003 = 3\sigma$$

σ= .001inches RMS , requirement is σ = .005 RMS

Worst Case misalignment:

$$\Delta y = \underset{(1)}{.0001} + \underset{(2)}{.0001} + \underset{(3)}{.0003} + \underset{(4)}{.0005} = .0055 \text{ inches}$$



Plan view

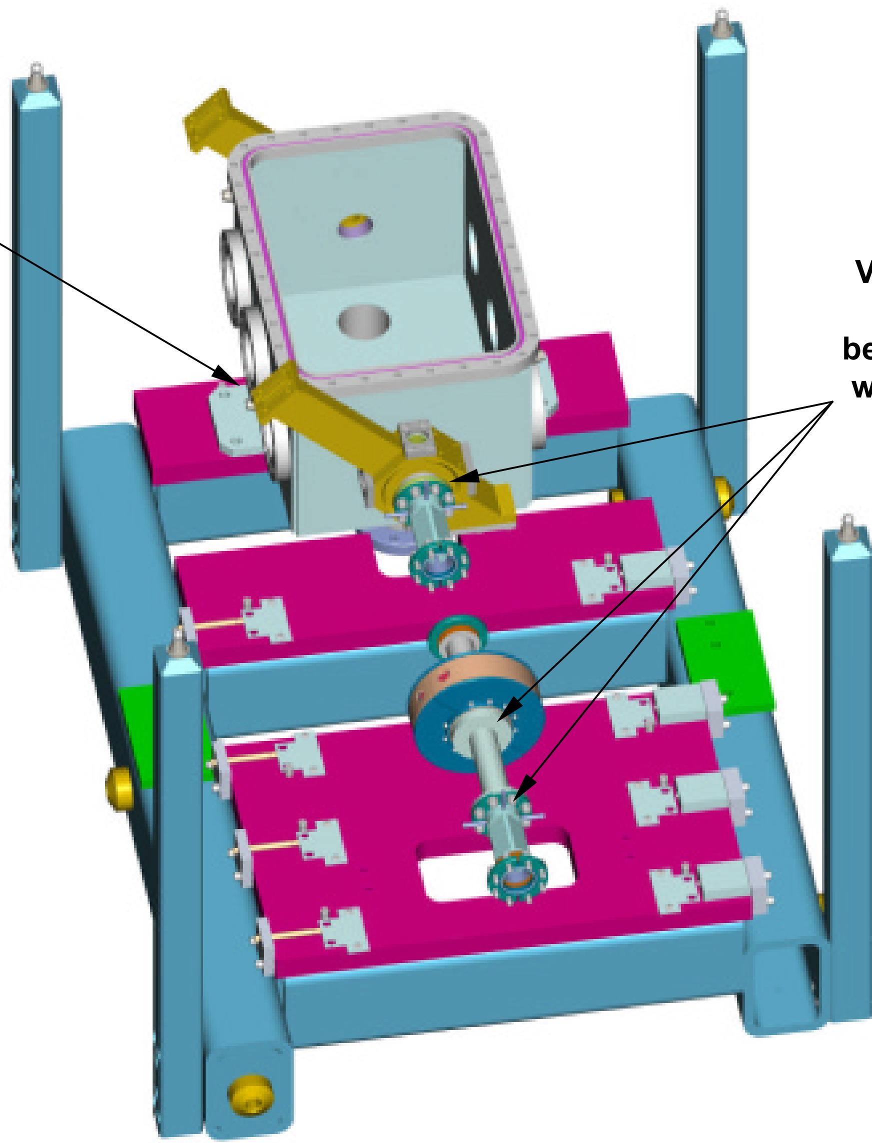
Raft Assembly Procedure Outline

- **Beampipe Assembly**
  - Position beamboxes (+/- 0.020”)
  - Assemble beampipes (rough positioning)
  - Leak check
- **Install quads and rebunchers (if avail.)**
  - Nominal shim dimensions
  - Leak check as required
- **CMM Inspection**
  - Find best fit through quads
  - Fiducialize w.r.t raft targets
- **Adjust shims as required**
- **Final CMM Check and Fiducialization**
- **Assemble remaining raft components**
  - Bus bars, caps and covers, etc.
- **Final Leak check**

Beambox and Beampipe Installation

Beamboxes are bolted and shimmed into position (+/- .020).

Vacuum connections are made between beampipe components which are temporarily supported.

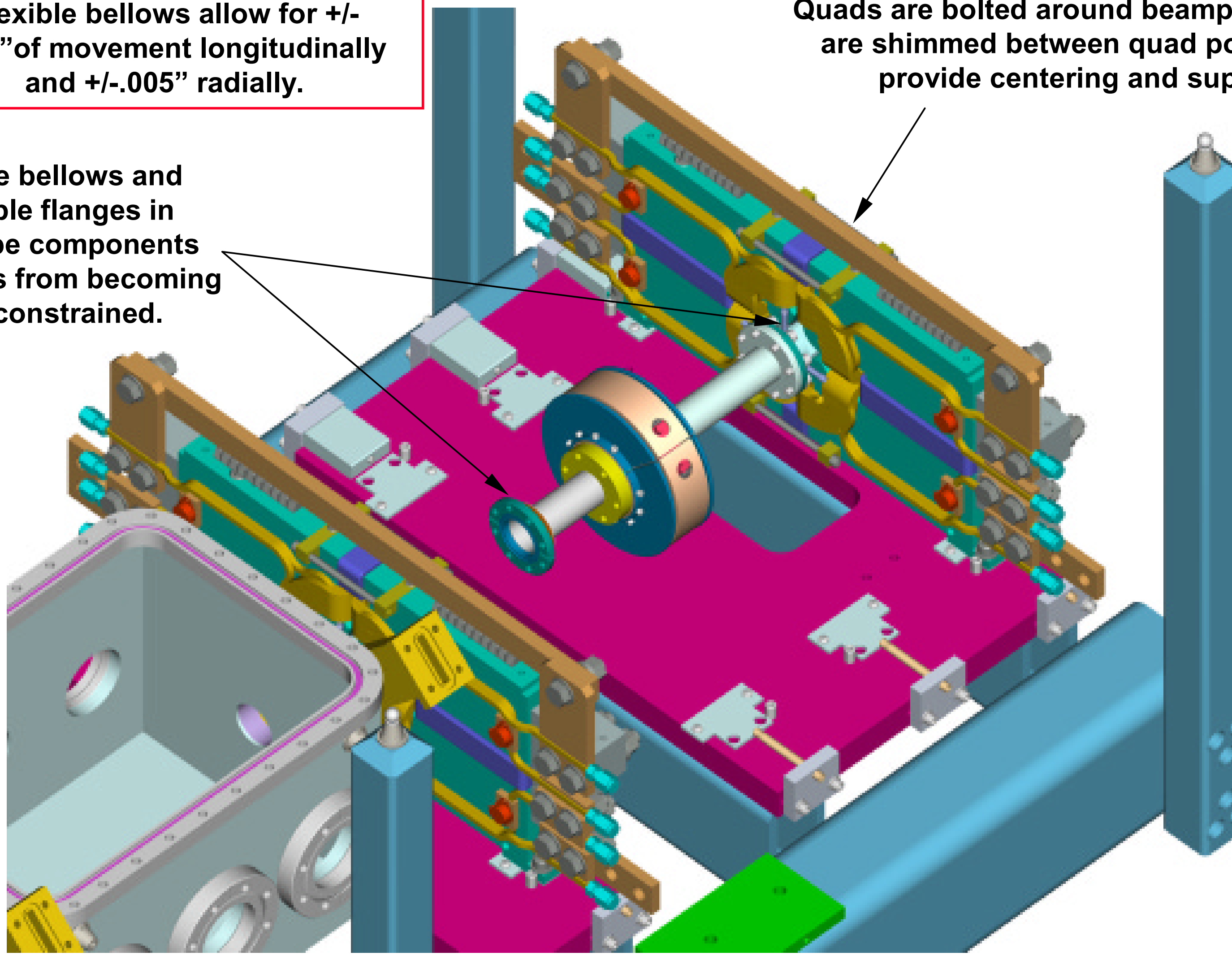


Quad Installation

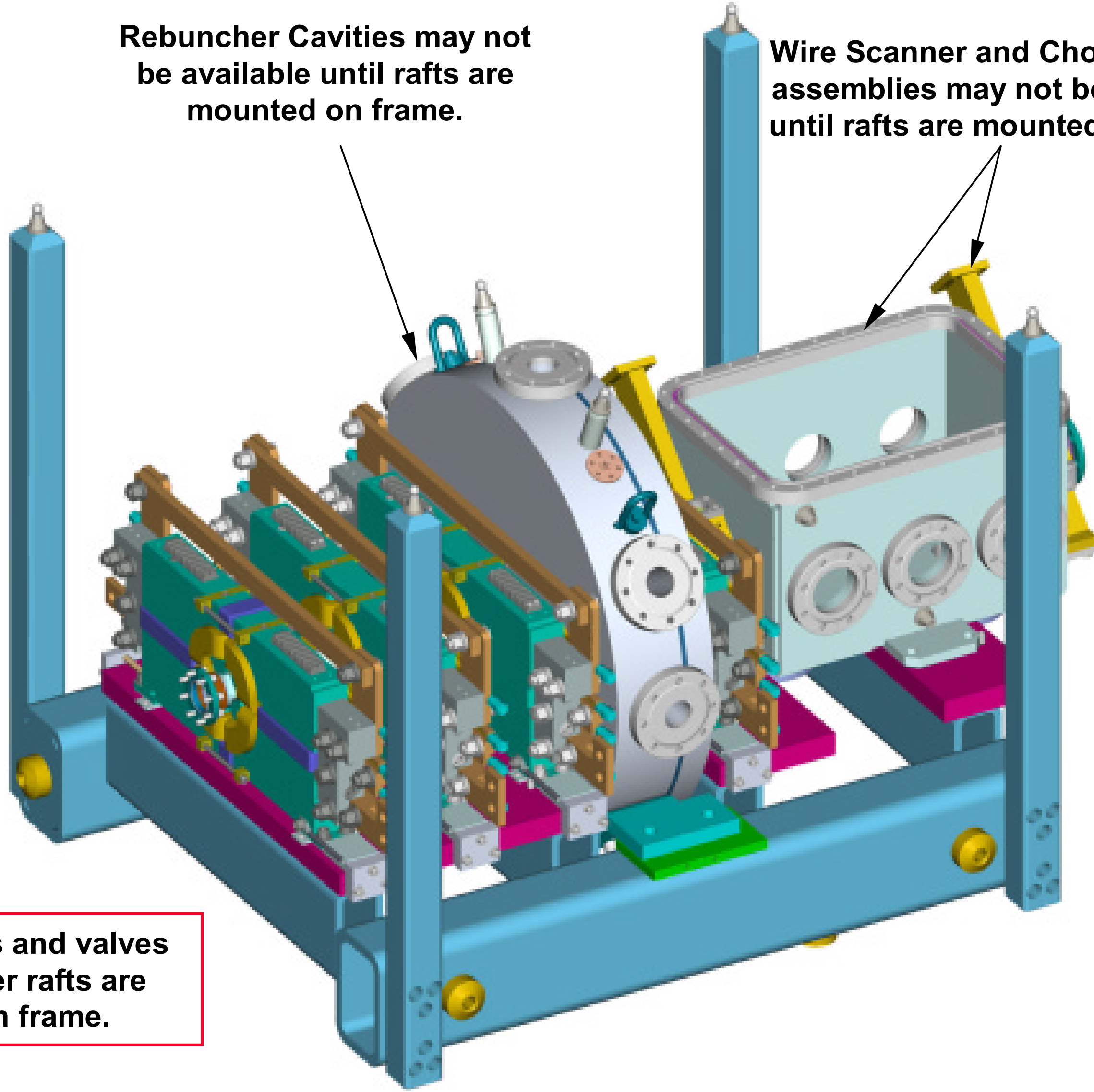
Flexible bellows allow for +/- .125”of movement longitudinally and +/-.005” radially.

Quads are bolted around beampipe. BPM’s are shimmed between quad pole tips to provide centering and support.

Flexible bellows and rotatable flanges in beampipe components keep parts from becoming over-constrained.



Completed Raft Assembly



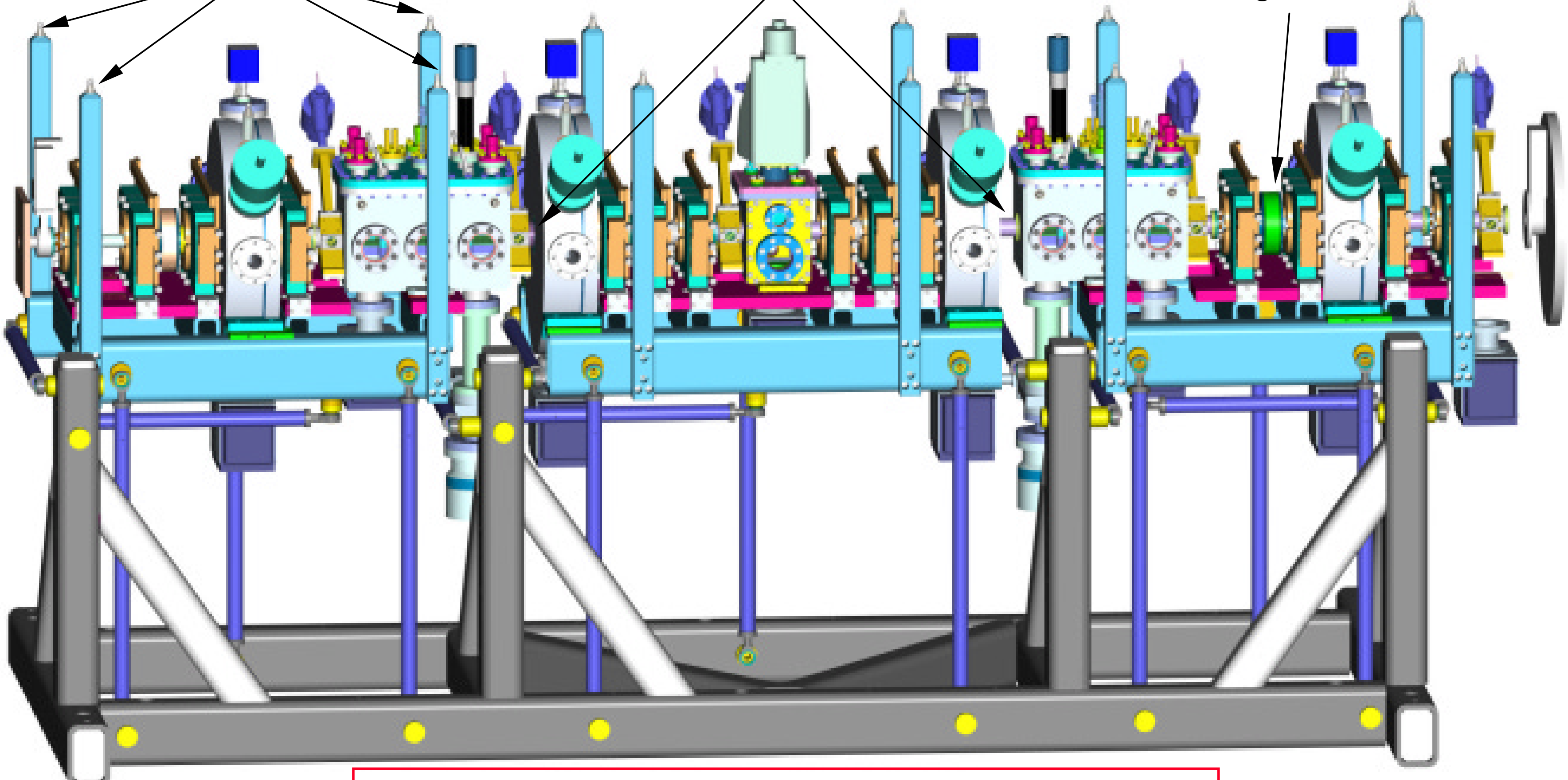
Vacuum pumps and valves are added after rafts are mounted on frame.

Raft Installation on Frame

Raft alignment fiducials are offset so all four are visible from either side of the beamline.

Bellows connections between rafts can be made without removing raft components.

Rafts #2 and #3 are installed first to leave access to the end of the RFQ during beam tests.

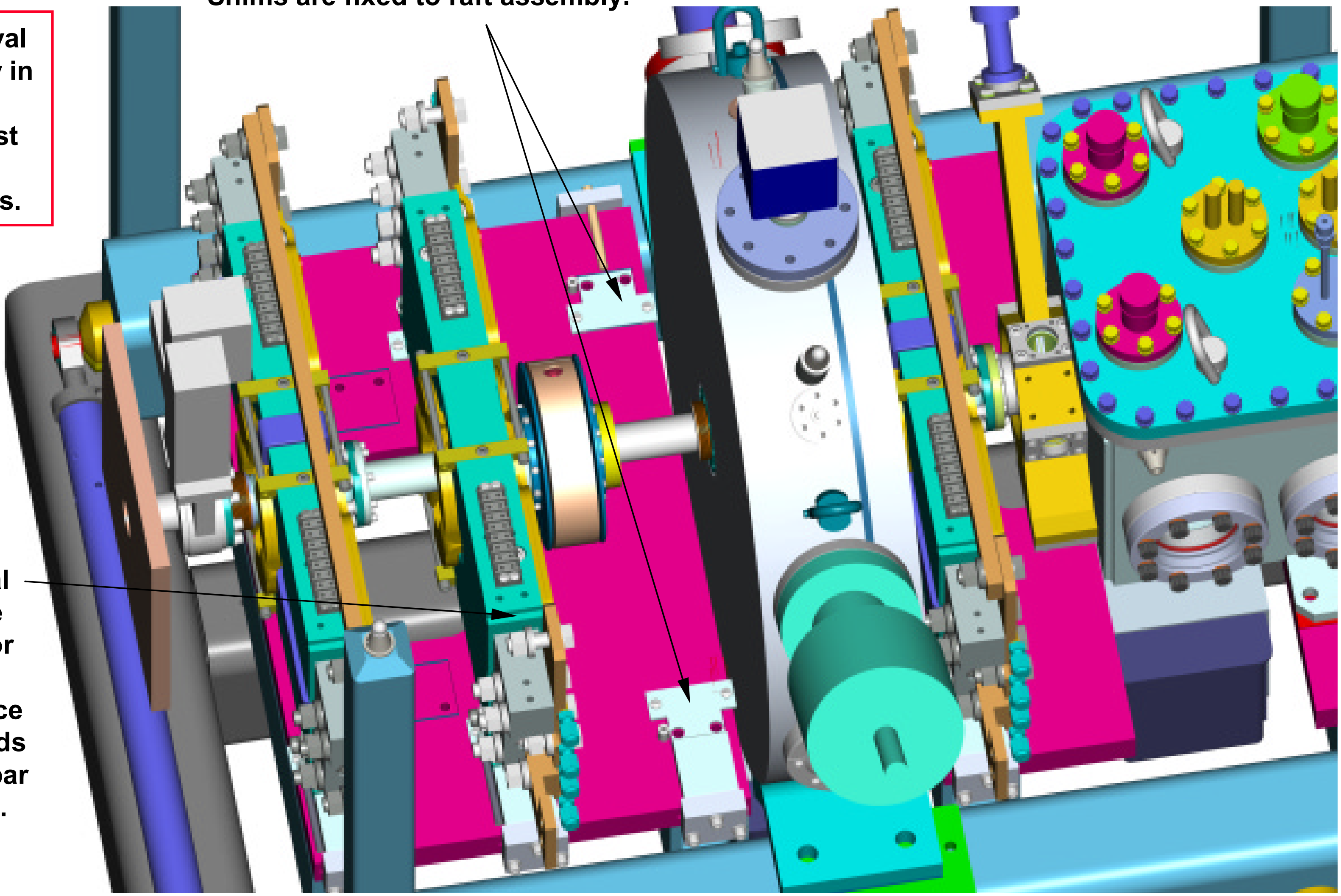


Final alignment is performed with bellows connected to RFQ and between rafts (bellows flexibility = +/- .015”).

Removal / Replacement of Quad

Quad removal is necessary in order to access most beampipe components.

Shims are fixed to raft assembly.



Quad fiducial surfaces are accessible for checking alignment once the power leads and the bus bar are removed.

Cost Estimate, Schedule, and Procurement Plan

Daryl Oshatz

March 30, 2001

Fabrication / Assy Cost Estimates

- **Raft Hardware**
  - **Weldments ($15 k each x 3): $45 k**
  - **Mounting Shims / Hardware: $15 k**
- **Frame Weldment: $15 k**

Total Current Estimate = $75 k

- **Budgeted cost (1/21/00) of fabrication = $60 k**
- **Budgeted cost (1/21/00) raft assembly labor (6 man-months) and materials = $50 k**
- **Budgeted cost of frame assembly is included in the System Integration budget (WBS 1.3.3.3.1)**

Fabrication Schedule

- **Engineering calculations & saftey note**
  - 4/2/01 – 4/27/01 (4 weeks)
- **Rafts – outside procurement**
  - Fab. drawings: 4/2/01 – 4/20/01 (3 weeks)
  - Procurement: 4/16/01 – 4/30/01 (2 weeks)
  - Fabrication: 5/1/01 – 7/06/01 (10 weeks)
- **Frame – LBNL Main Shop**
  - Fab. drawings: 4/2/01 – 4/13/01 (2 weeks)
  - Initiate job order: 4/16/01 – 4/20/01 (1 week)
  - Fabrication: 4/23/01 – 6/15/01 (8 weeks)

Assemlby / Installation Schedule

- **Frame Installation**
  - Begin 7/2/01
- **Rafts Assembly – Building 71**
  - 7/16/01 – 10/15/01 (12 weeks)
- **Raft installation on Frame**
  - Begin 10/1/01