# AMS-CDR Meeting

*Milano, March 10, 2004*

# *AMS Tracker Thermal Control System Mechanical Design Status*

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& soon in co-operation with Sun Yat Sen University

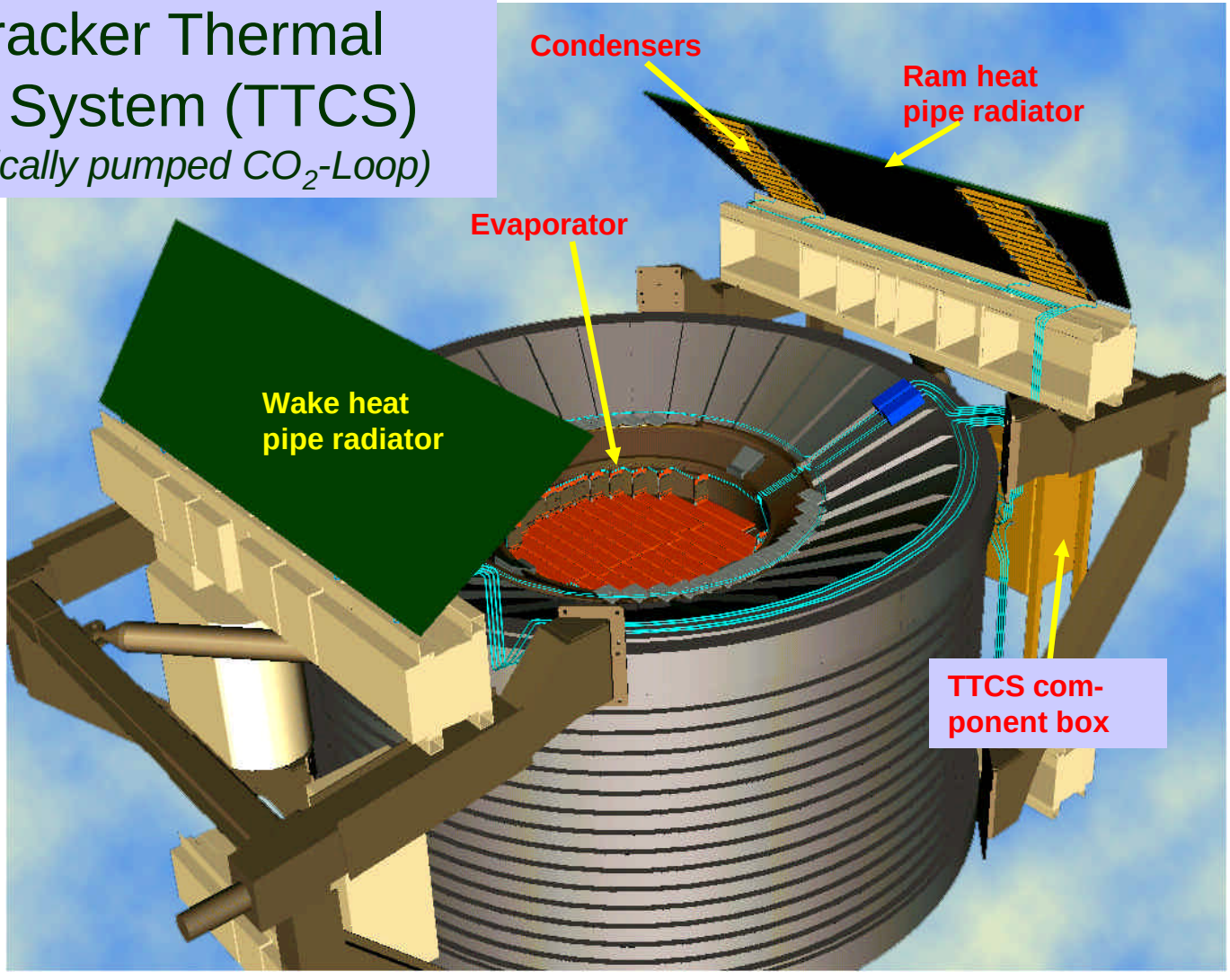
# Contents:

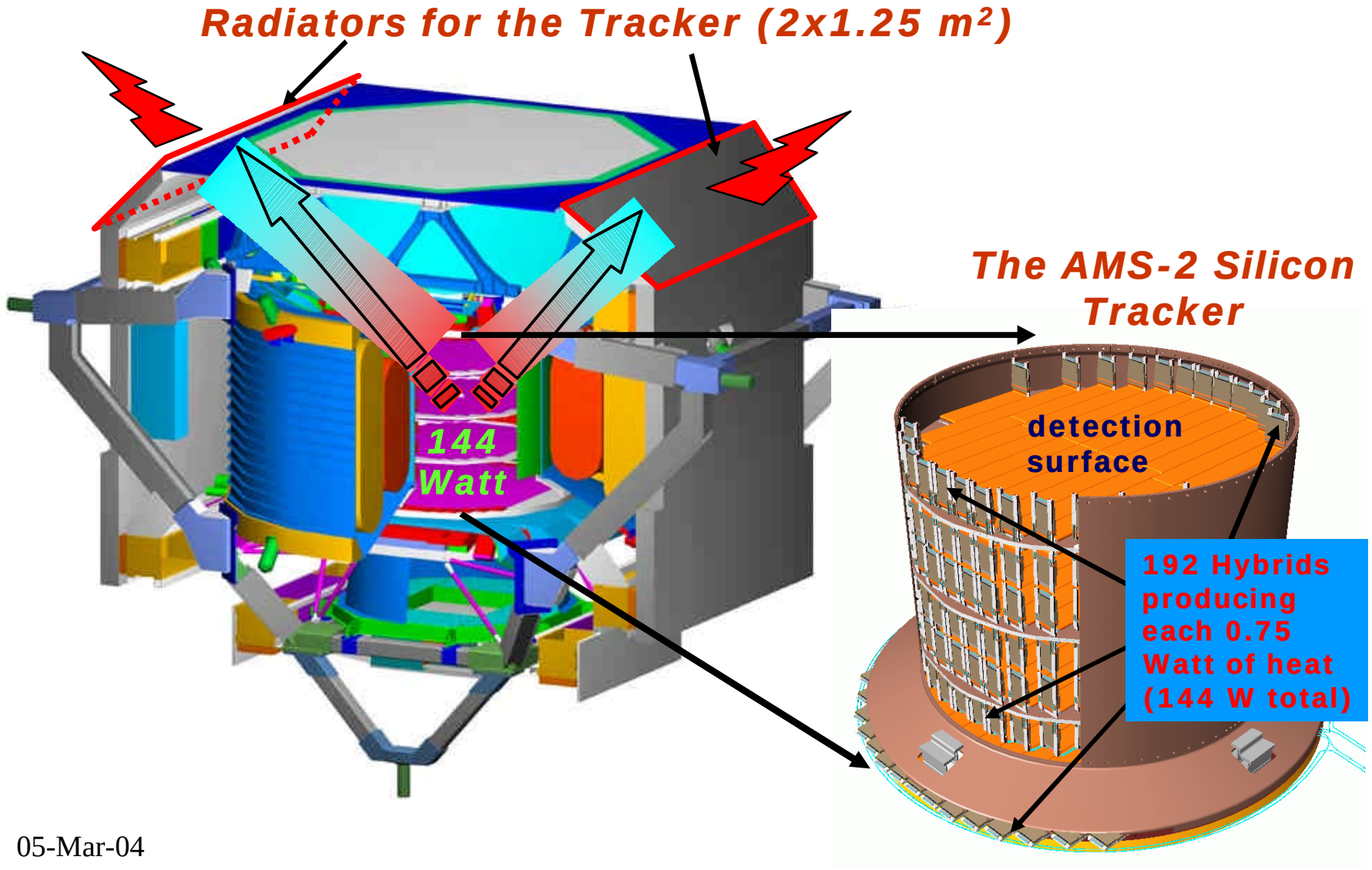
1. TTCS General overview
2. TTCS Evaporator
3. TTCS Radiator and condenser
4. TTCS Electro Mechanics
5. TTCS Component Box
6. TTCS Tube routing

# TTCS General overview

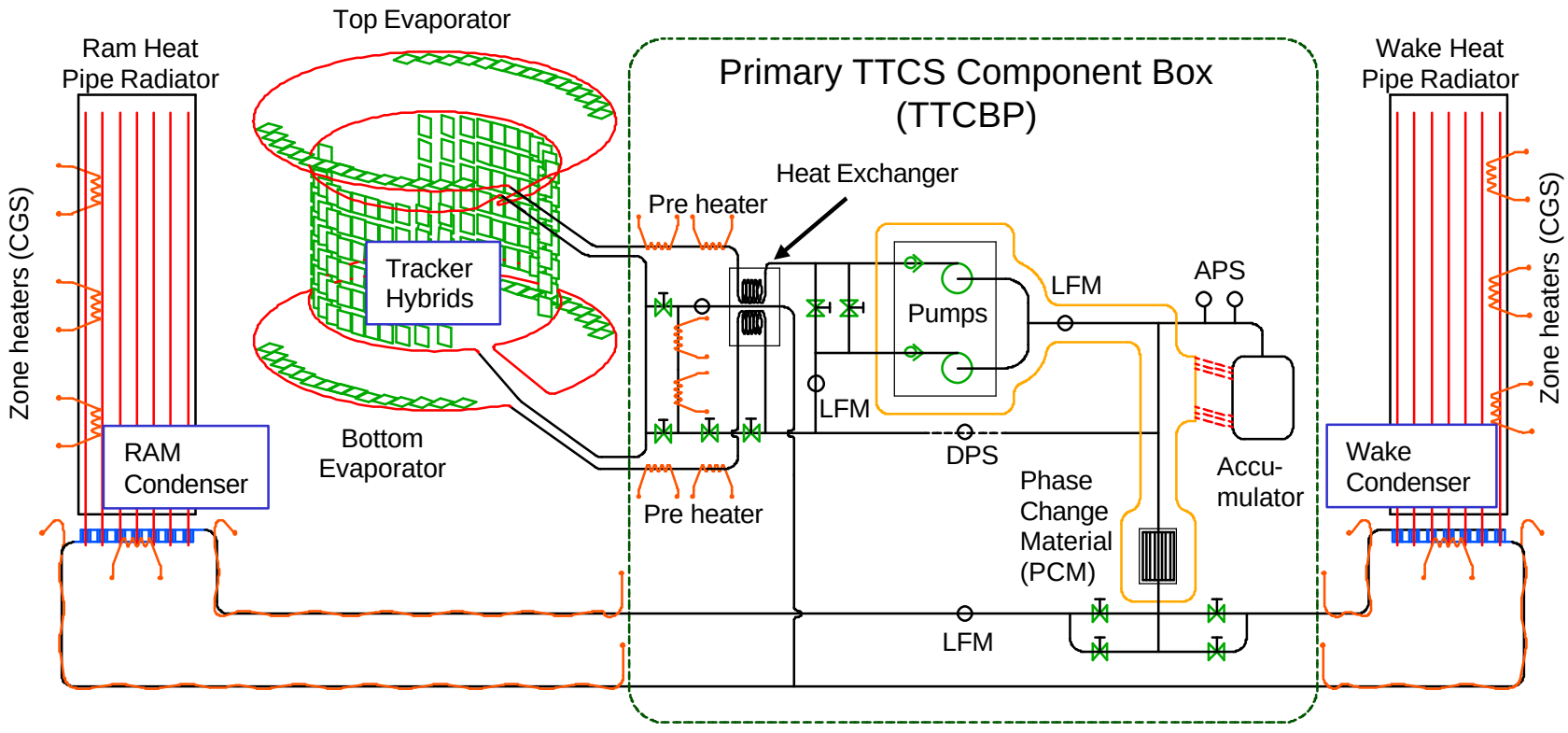
# AMS-Tracker Thermal Control System (TTCS)

(A *mechanically pumped $CO_2$-Loop*)




Radiators for the Tracker (2x1.25 m²)
144 Watt
The AMS-2 Silicon Tracker
detection surface
192 Hybrids producing each 0.75 Watt of heat (144 W total)

# Primary TTCS (TTCSP)




2-Way Valve (VLV)

Centrifugal pump (PMP) with integrated check valve

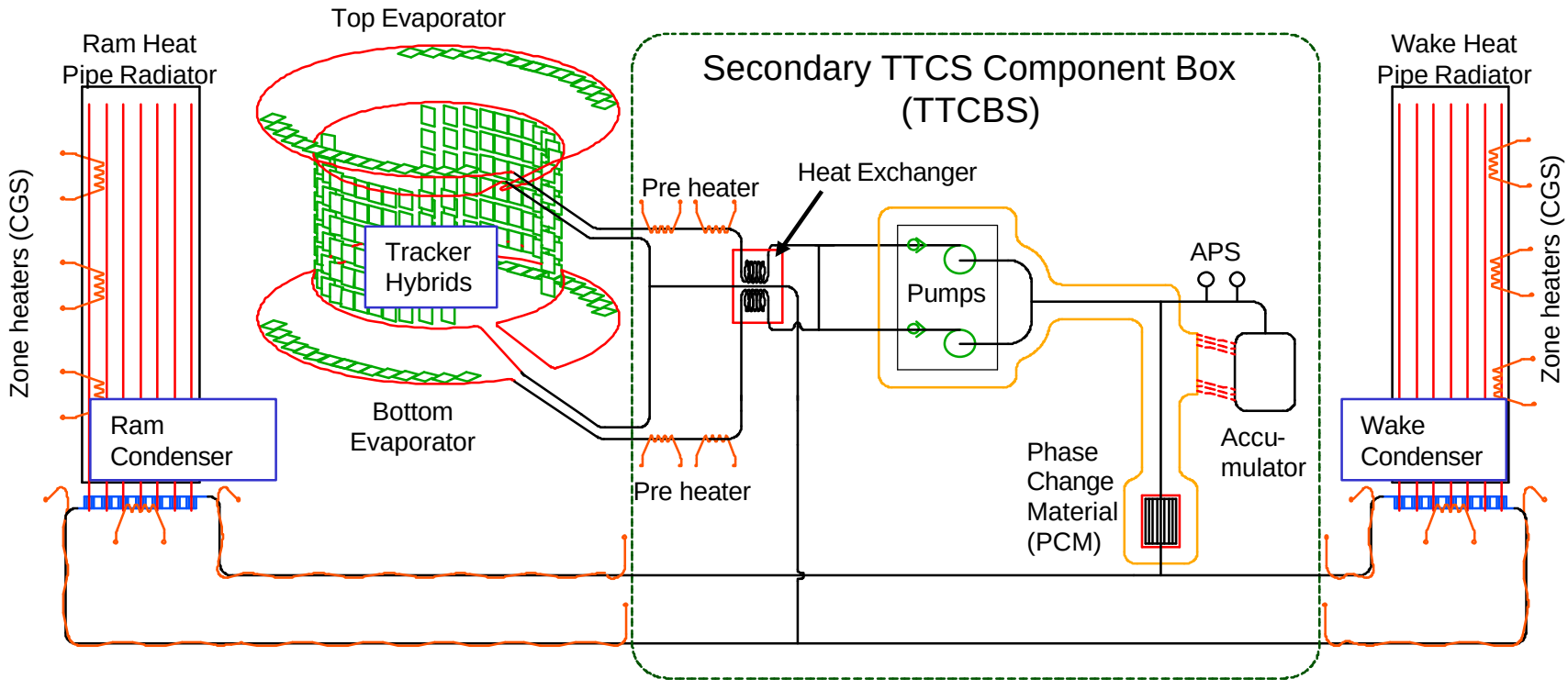
Electrical Heater (HTR)

Sensors:
LFM = Liquid Flow Meter,
DPS = Differential Pressure Sensor
APS = Absolute Pressure Sensor
VQS = Vapor Quality Sensor

Components inside this profile are thermally mounted to the TTCB structure

Thermo Electric Cooler (TEC)

# Secondary TTCS (TTCSS)




2-Way Valve (VLV)

Centrifugal pump (PMP) with integrated check valve

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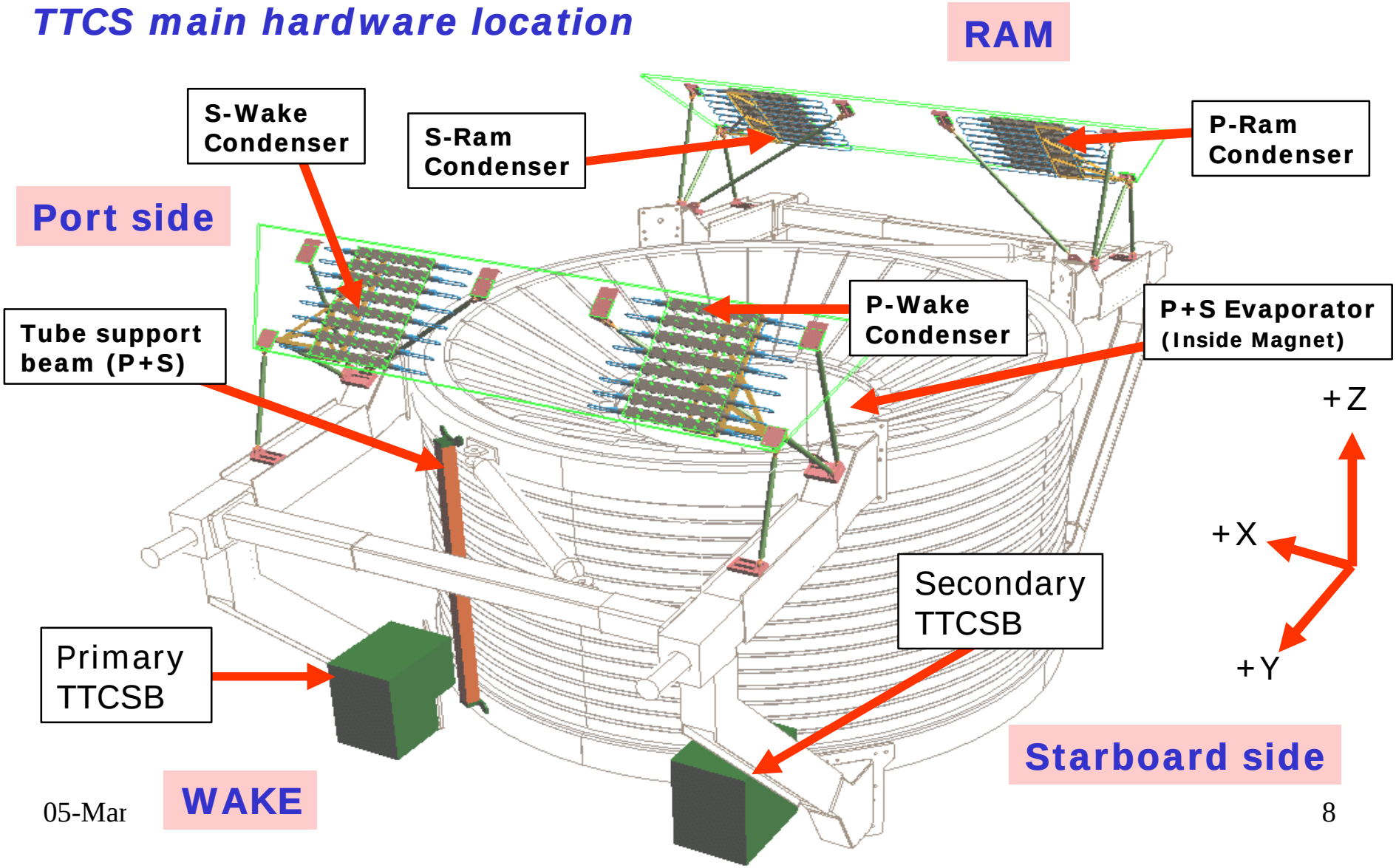
Thermo Electric Cooler (TEC)

## TTCS main hardware location



# Project Objectives: AMS-Silicon Tracker Thermal Requirements

## Silicon wafer thermal requirements:

- **Operating temperature:**
  -10 ºC / +25 ºC
- **Survival temperature:**
  -20 ºC / +40 ºC
- **Temperature stability:**
  3 ºC per orbit
- **Maximum accepted gradient between any silicon:**
  10.0 ºC
- **Dissipated heat:**
  2.0 Watt EOL

## Hybrid circuit thermal requirements:

- **Operating temperature:**
  -10 ºC / +40 ºC
- **Survival temperature:**
  -20 ºC / +60 ºC
- **Dissipated heat:**
  144 W total (±10%),
  0.75 W per hybrid pair
  (S=0.47 W, K=0.28 W)

## Star Tracker thermal requirements:

- **Operating temperature:**
  -30 ºC / 40 ºC
- **Survival temperature:**
  -40 ºC / 100 ºC
- **Dissipated heat:**
  6.8 W total, 3.4 W per ASTS

# TTCS Thermal Requirements

## TTCB (Component box) thermal requirements:

- Operating temperature:
  -50 ºC / +25 ºC
- Survival temperature:
  -50 ºC / +80 ºC
- Allocated power:
  70 Watt

## TTCE (Control electronics) thermal requirements:

- Operating temperature:
  -20 ºC / +55 ºC
- Survival temperature:
  -40 ºC / +80 ºC
- Allocated power:
  3.5 Watt

## Evaporator thermal requirements:

- Operating temperature:
  -20 ºC / +25 ºC
- Survival temperature:
  -40 ºC / +80 ºC

## Condenser thermal requirements:

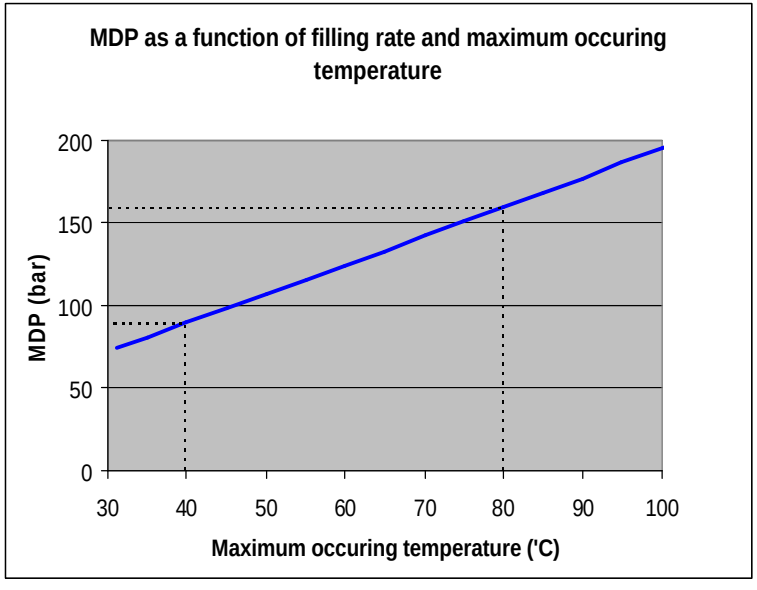
- Operating temperature:
  -50 ºC / +25 ºC
- Survival temperature:
  -100 ºC / +80 ºC

# TTCS Structural Requirements
## (Applicable documents)

- **Pressurized components designed and tested according to:**
  MIL-STD-1522A.
  (Standard General Requirements For Safe Design And Operation Of Pressurized Missile And Space Systems)
- **Pressurized stainless steel welds are manufactured and tested according to:**
  PRC-0010, Rev. A., class B.
  (Process Specification for Automatic and Machine Arc Welding of Steel and Nickel Alloy Flight Hardware)
- **Pressurized aluminium welds (5083) will be manufactured and tested according to:**
  MSFC-SPEC-504C.
- **Non Pressurized hardware is designed according to:**
  JSC-20545 Rev A.
  (Simplified Design Options for STS-Payloads)

# Other TTCS design criteria:

- *Maximum Design Pressure (MDP):* *160 bar (@ 80°C )*
- *Proof Pressure 1.5 X MDP* *240 bar*
- *Burst Pressure 2.5x MDP (comp)* *400 bar*
- *Burst Pressure 4 x MDP (tubing)* *640 bar*
- *TTCS Volume per system:* *1.9 Liter*
- *Accumulator Volume* *1.3 Liter*
- *TTCS $CO_2$ filling per system:* *874 gram*
- *Allowed system leak rate:* *$1*10^{-6}$ mbar*l/s*
- *Mission duration:* *5 Years*



# TTCS Evaporator

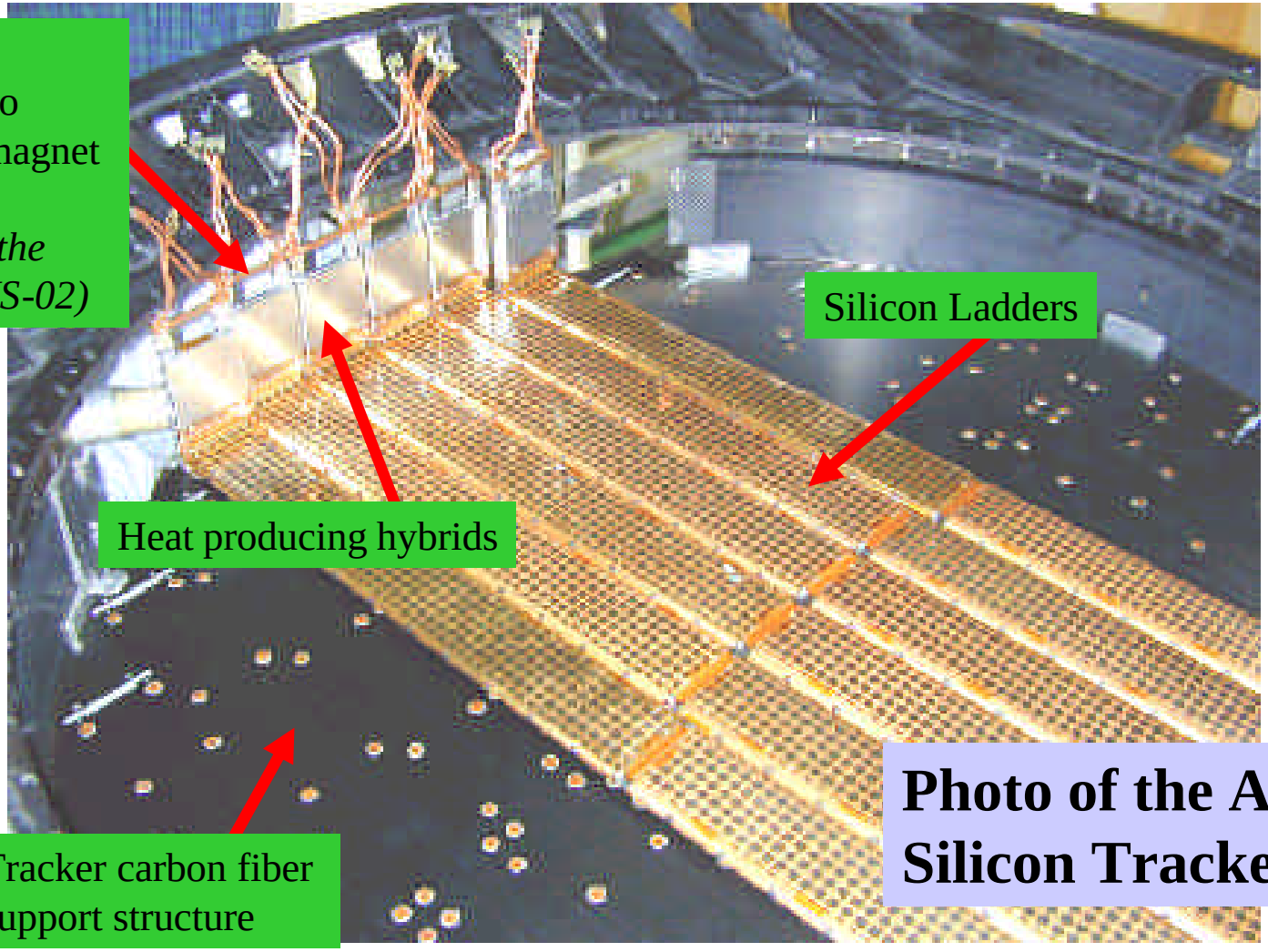
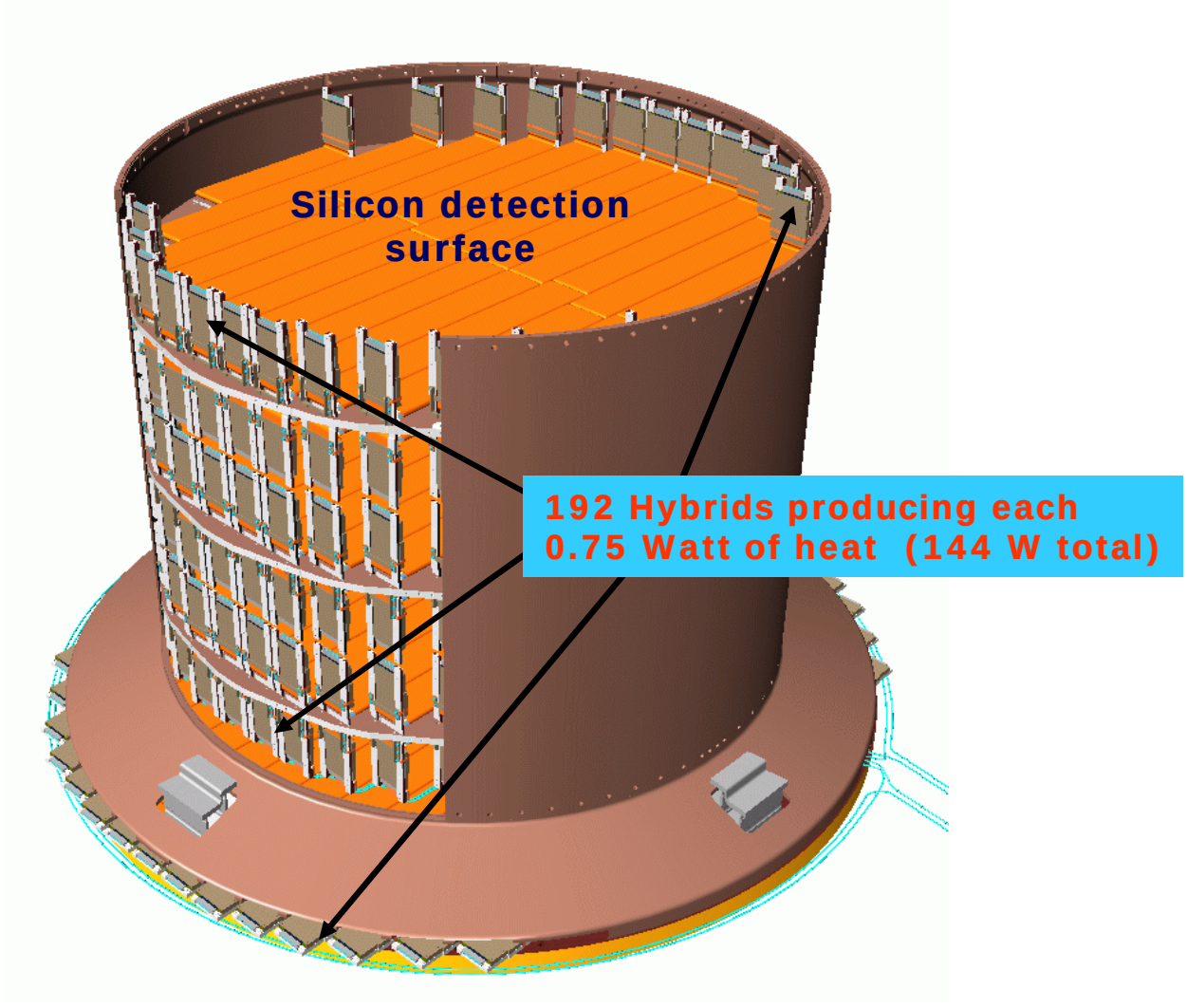
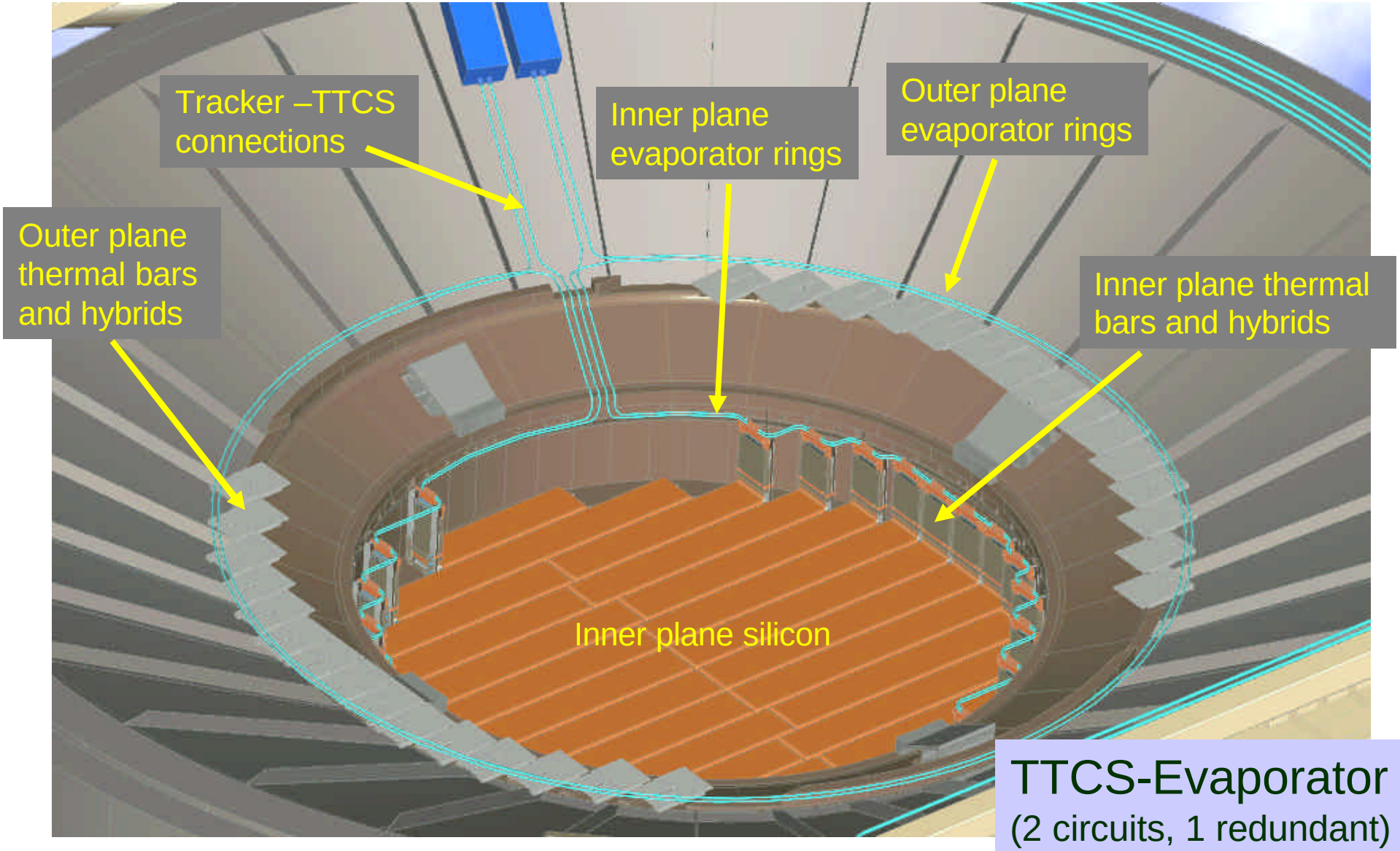



**Photo of the AMS-1 Silicon Tracker**

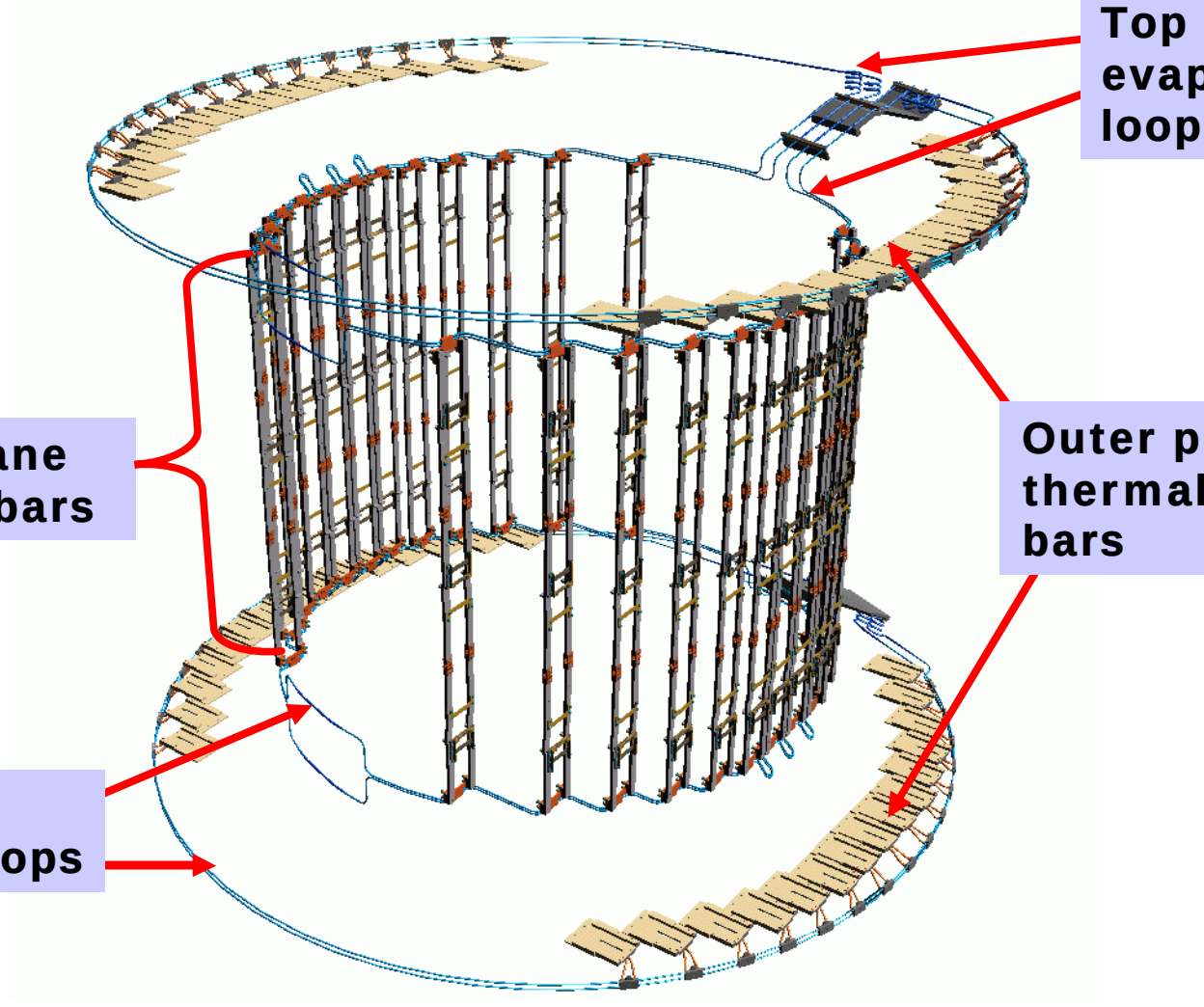
## The AMS-2 Silicon Tracker

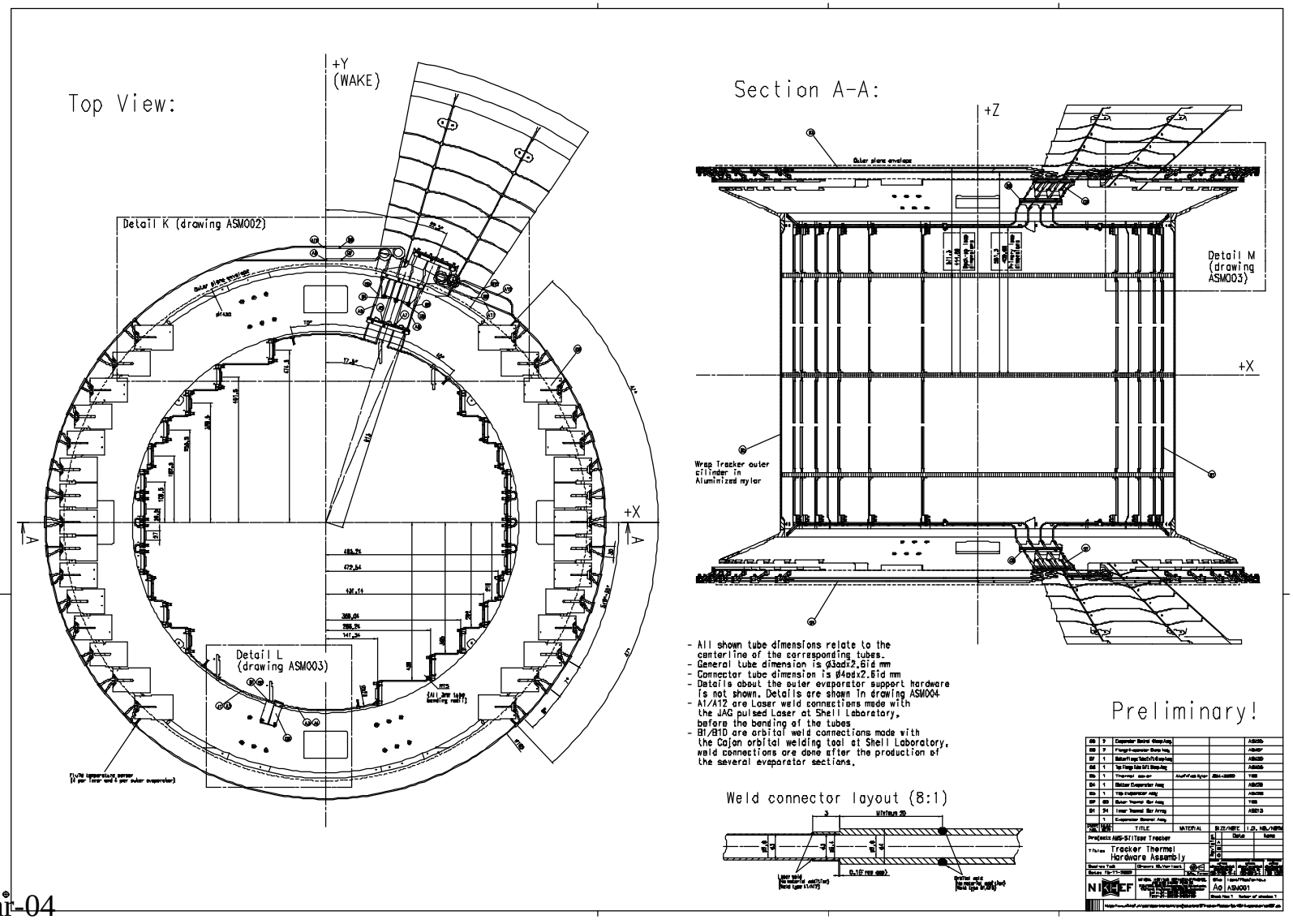




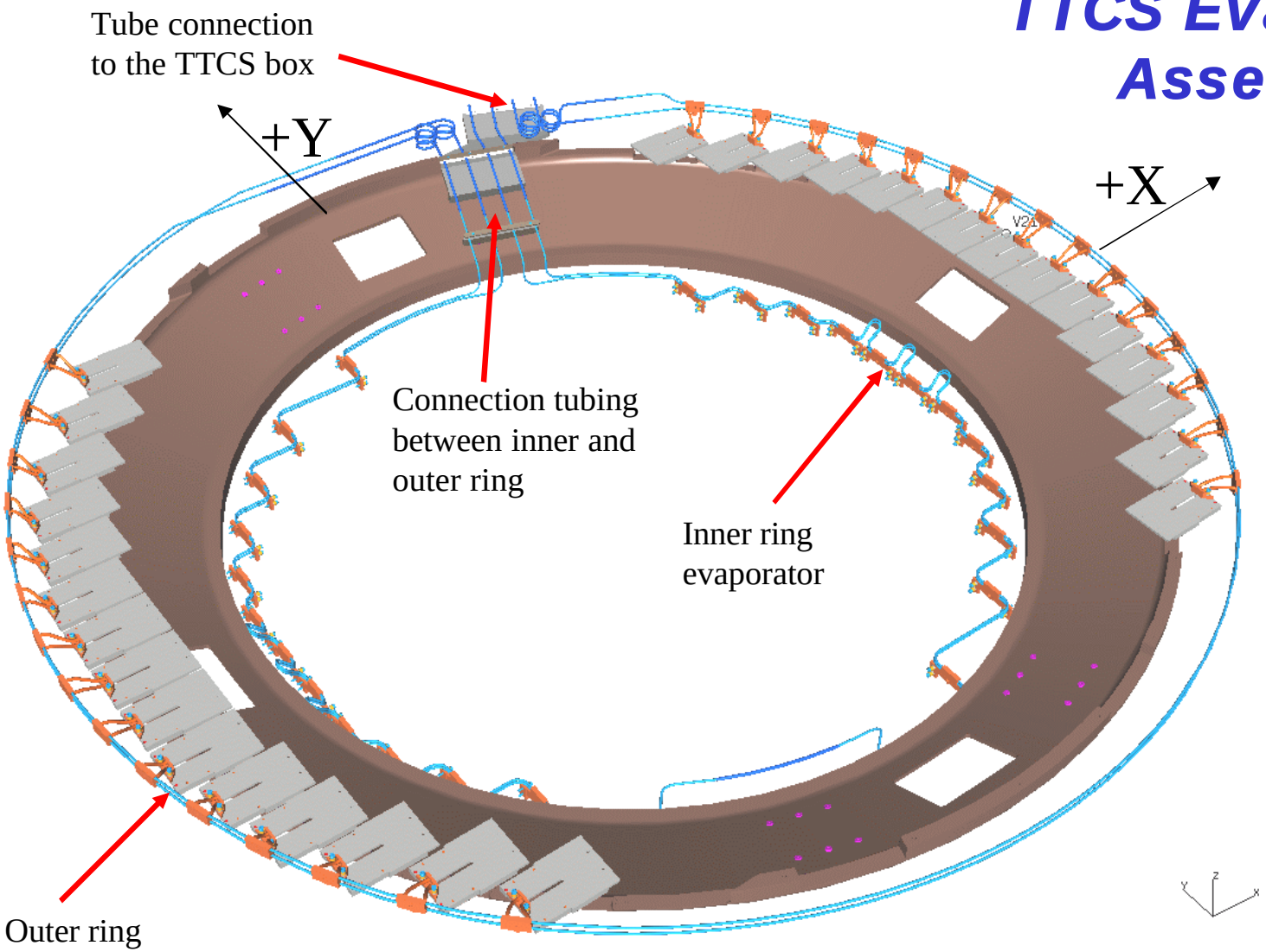

TTCS-Evaporator
(2 circuits, 1 redundant)

## TTCS Evaporator

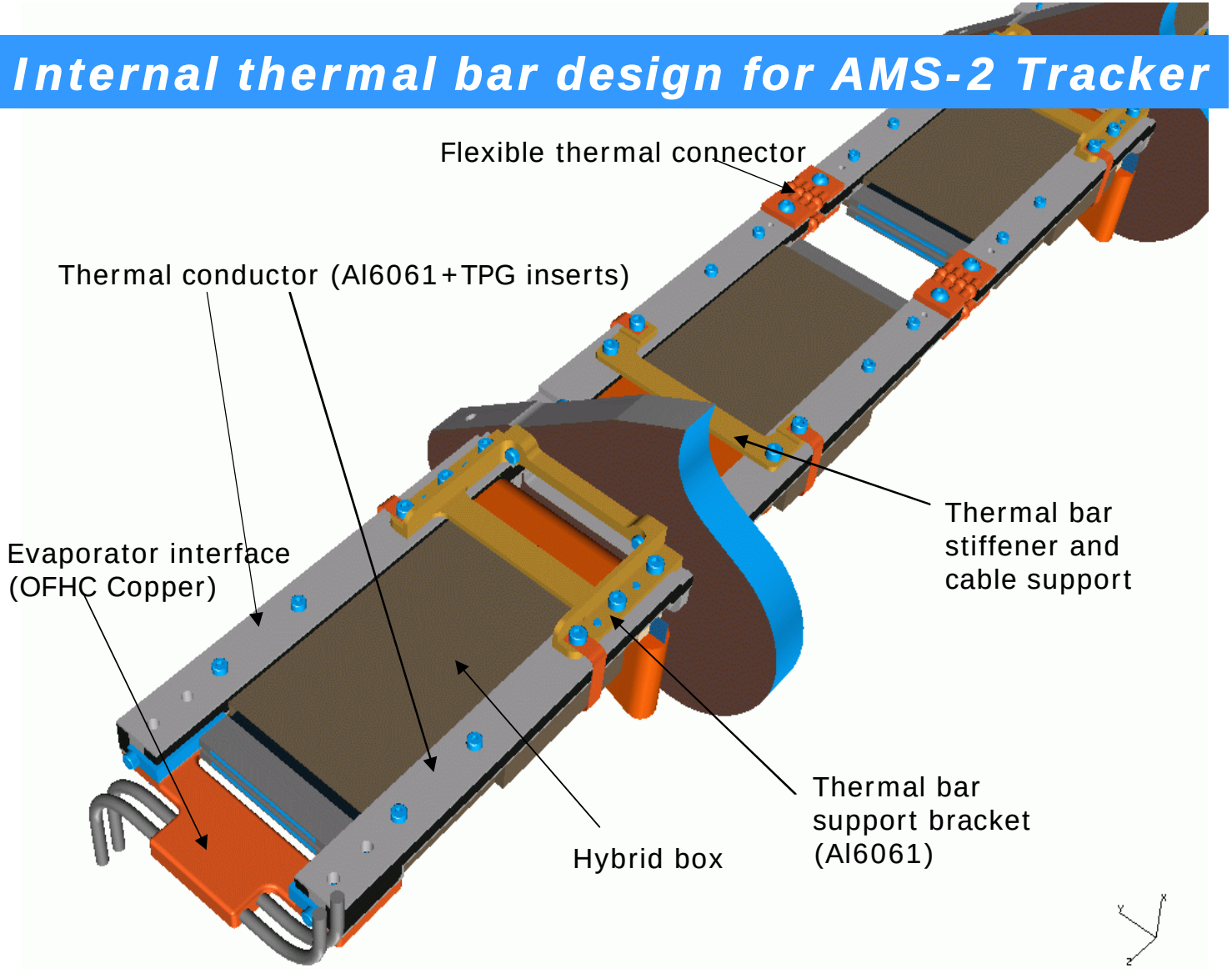



Top View:
+Y
(WAKE)
Detail K (drawing ASM002)
Detail L
(drawing ASM003)
+X
Section A-A:
+Z
Detail M
(drawing
ASM003)
+X
Wrap Tracker outer
cilinder in
Aluminized mylar
- All shown tube dimensions relate to the
centerline of the corresponding tubes.
- General tube dimension is Ø3adx2.6id mm
- Connector tube dimension is Ø4adx2.6id mm
- Details about the outer evaporator support hardware
is not shown. Details are shown in drawing ASM004
- A1/A12 are Laser weld connections made with
the JAG pulsed Laser at Shell Laboratory,
before the bending of the tubes
- B1/B1D are orbital weld connections made with
the Cajon orbital welding tool at Shell Laboratory,
weld connections are done after the production of
the several evaporator sections.
Weld connector layout (8:1)
Preliminary!
Tracker Thermal
Hardware Assembly
ASM001

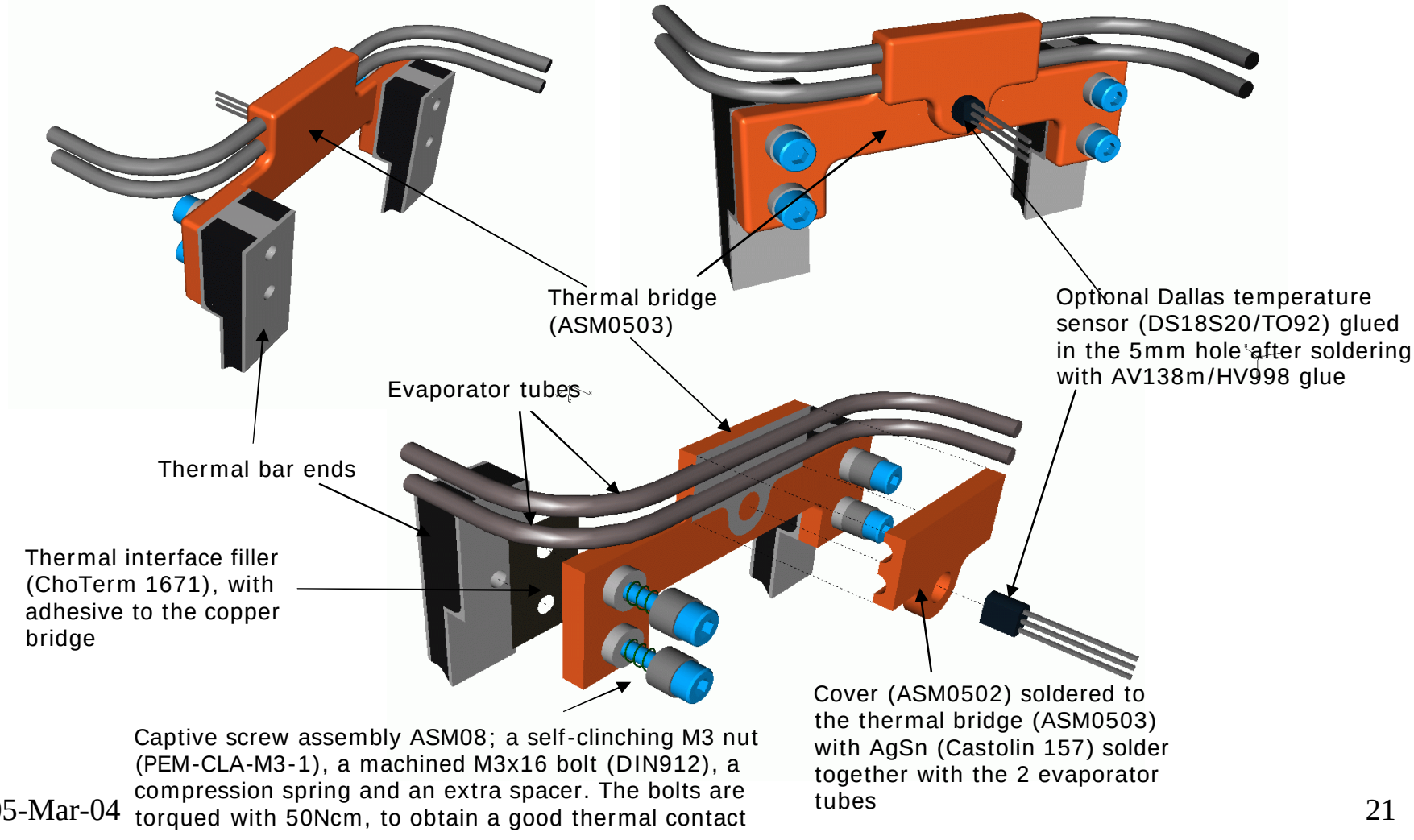
# TTCS Evaporator Assembly



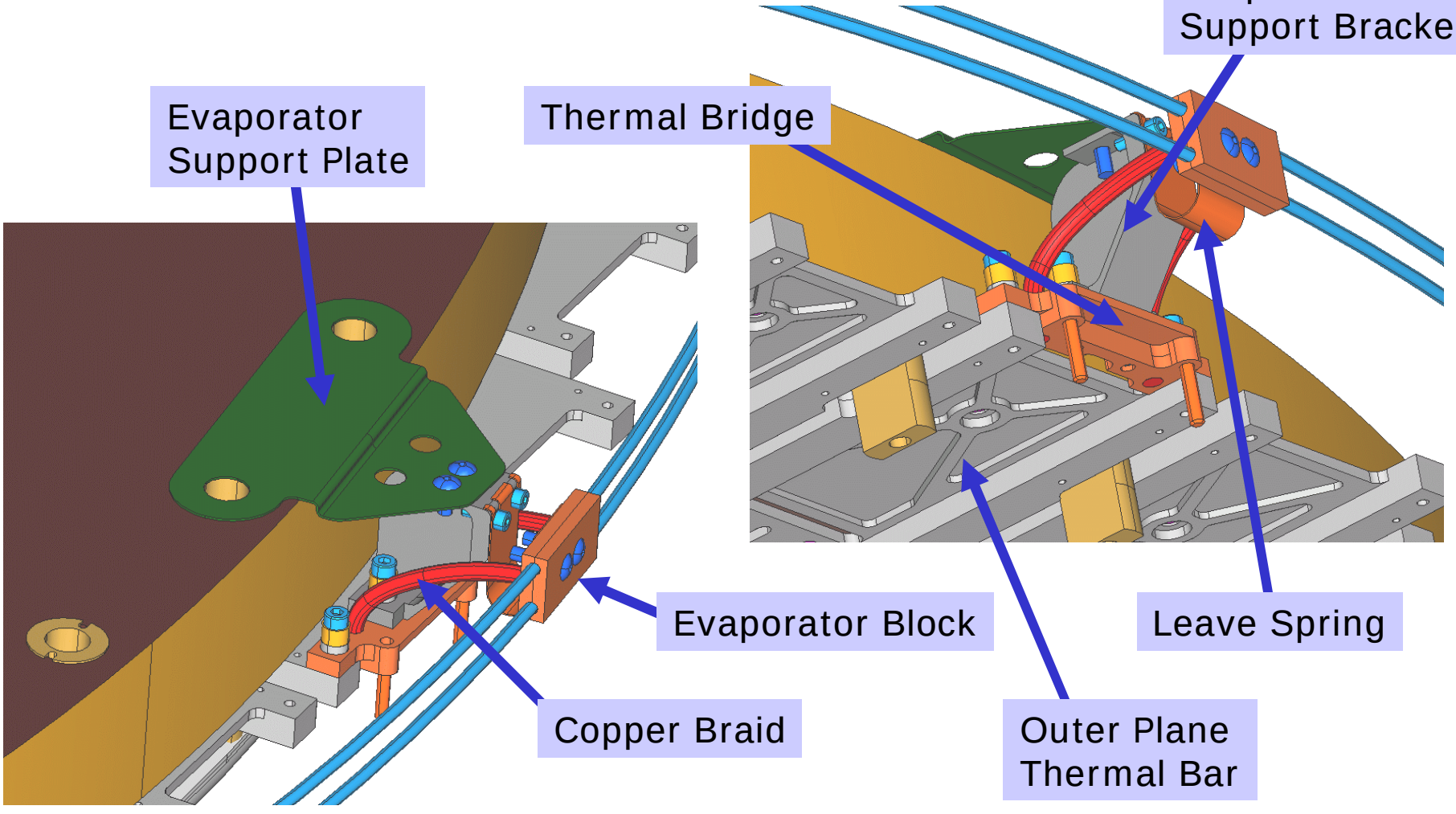
# Internal thermal bar design for AMS-2 Tracker



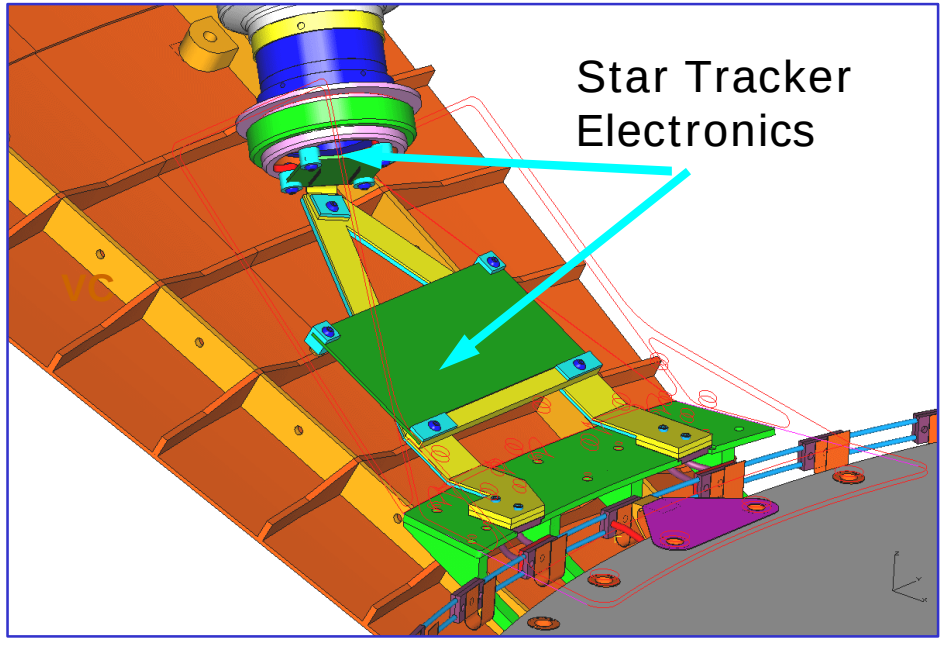
# Internal evaporator interface

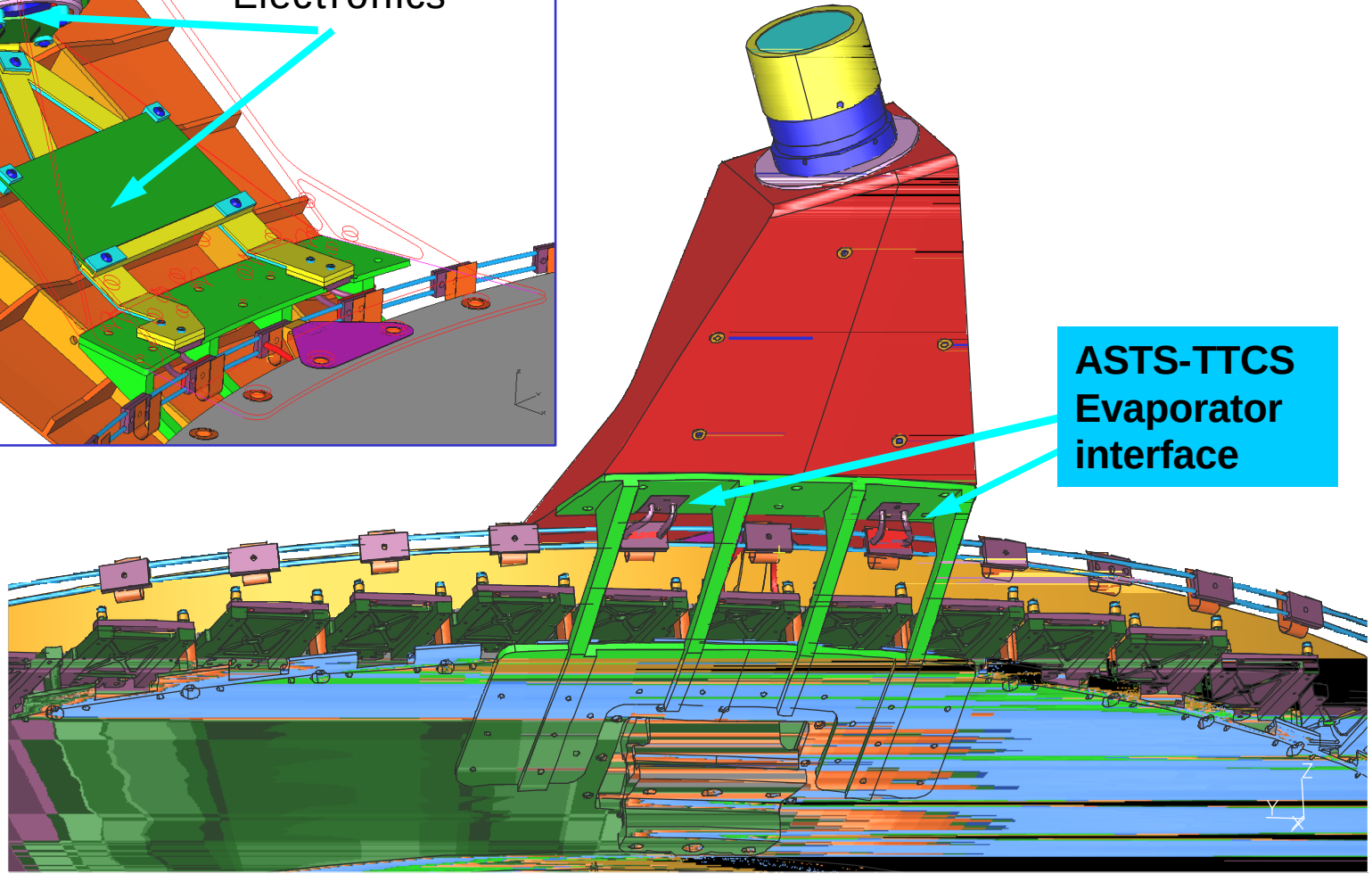


## TTCS Outer Plane Evaporator

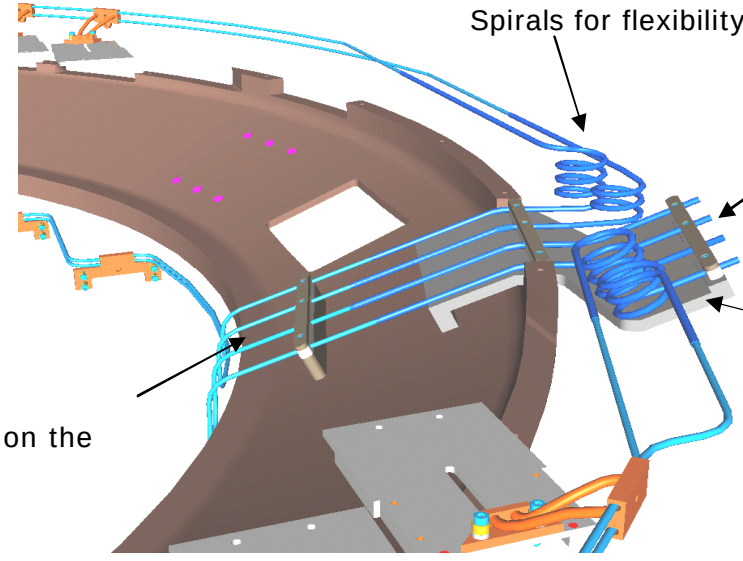


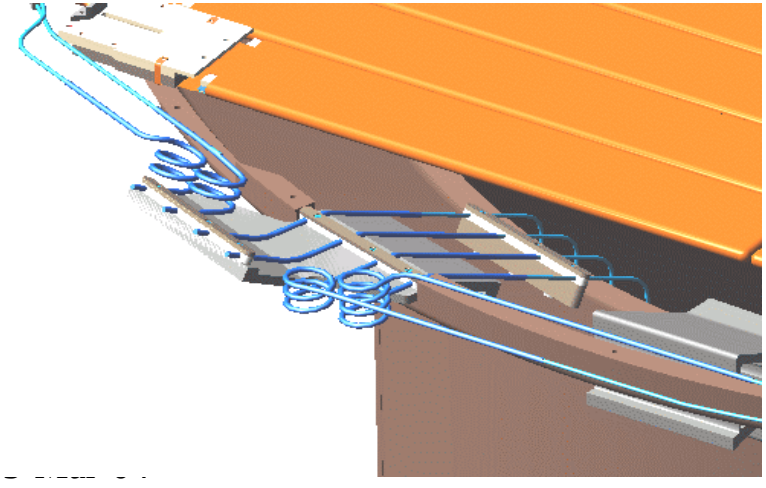
# ASTS Thermal Interfaces

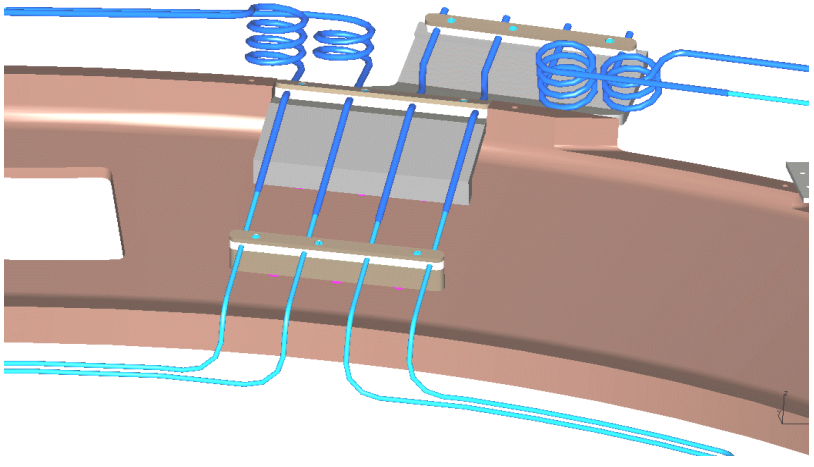


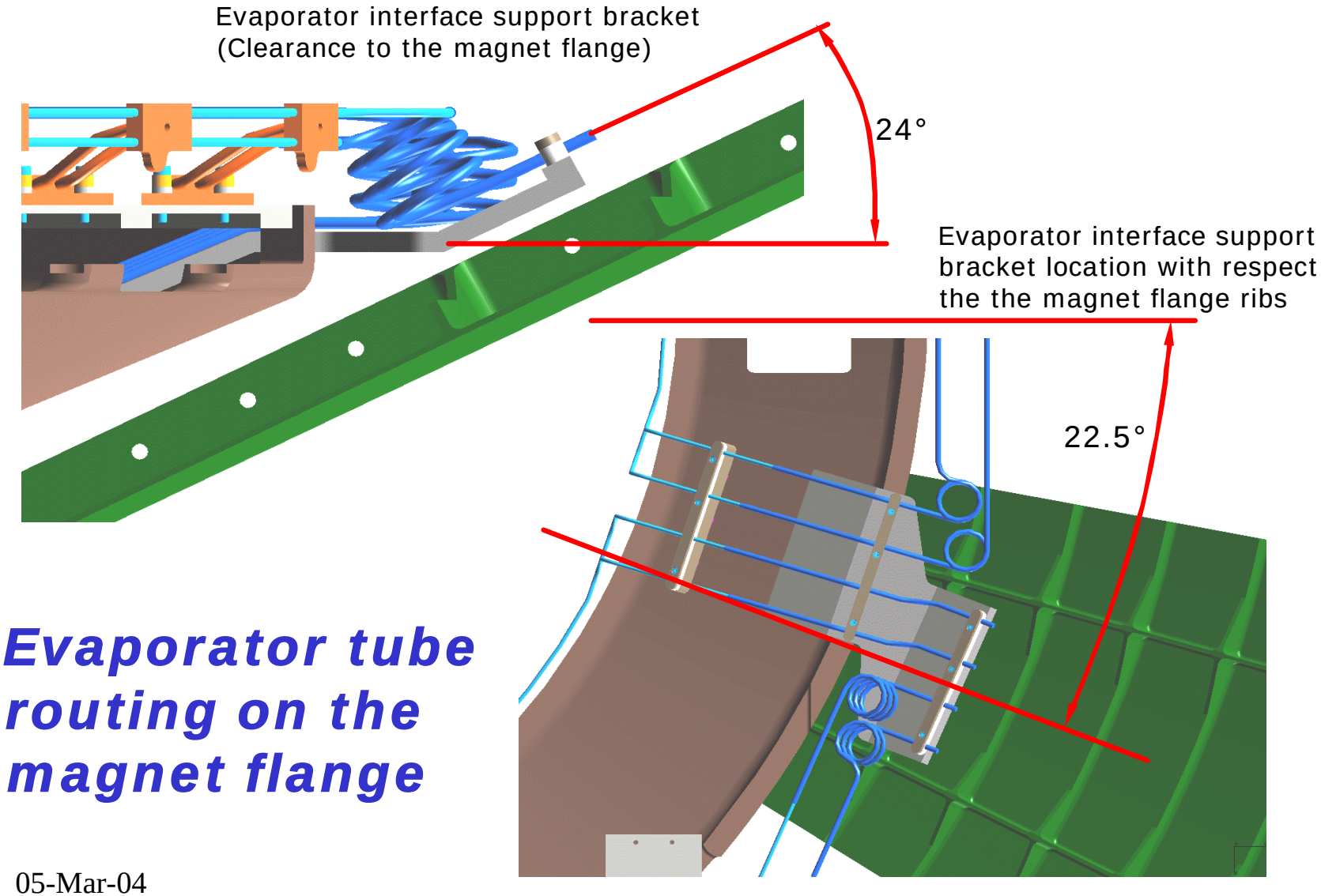



# Evaporator tube routing on the Tracker flange



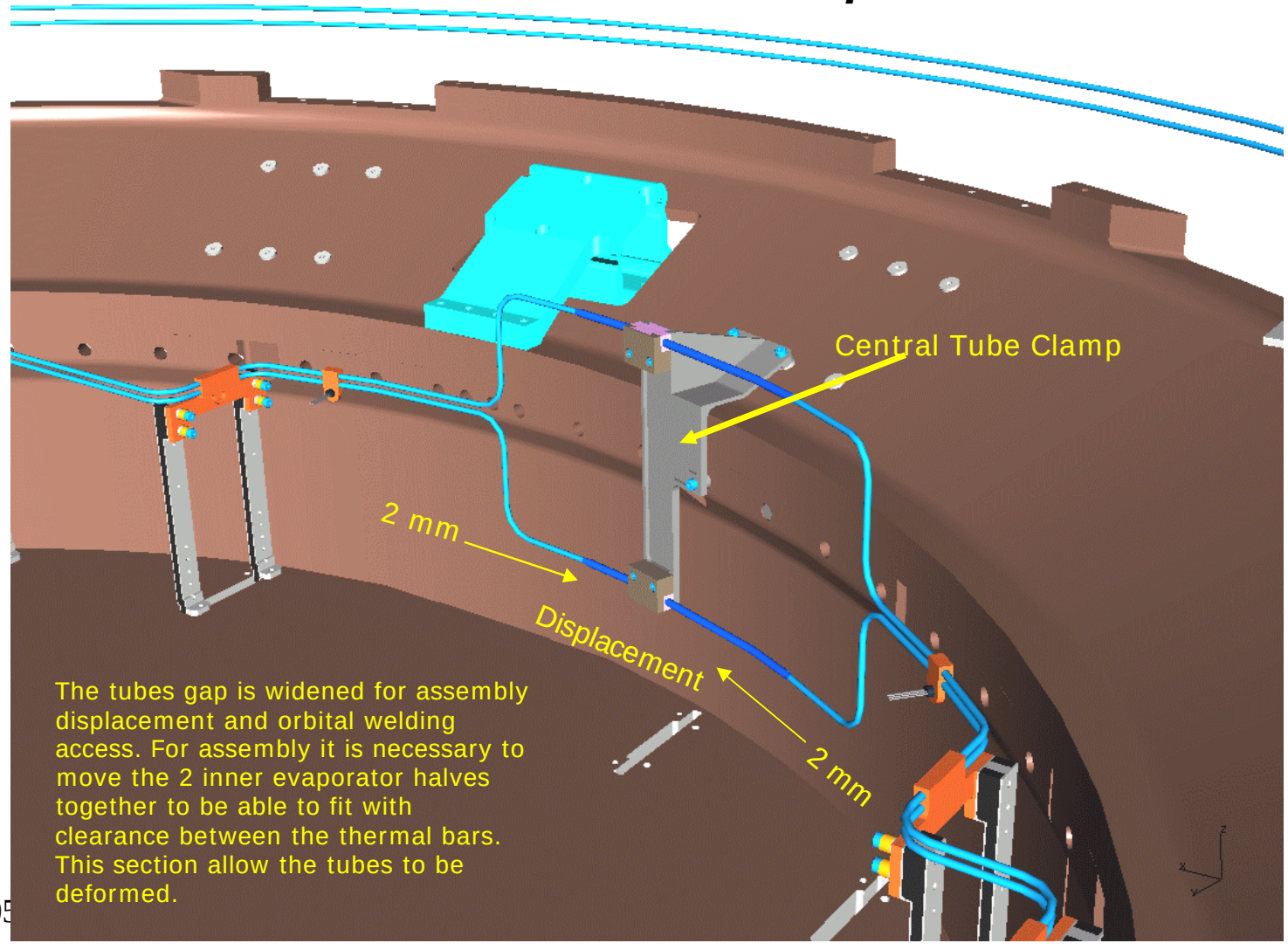





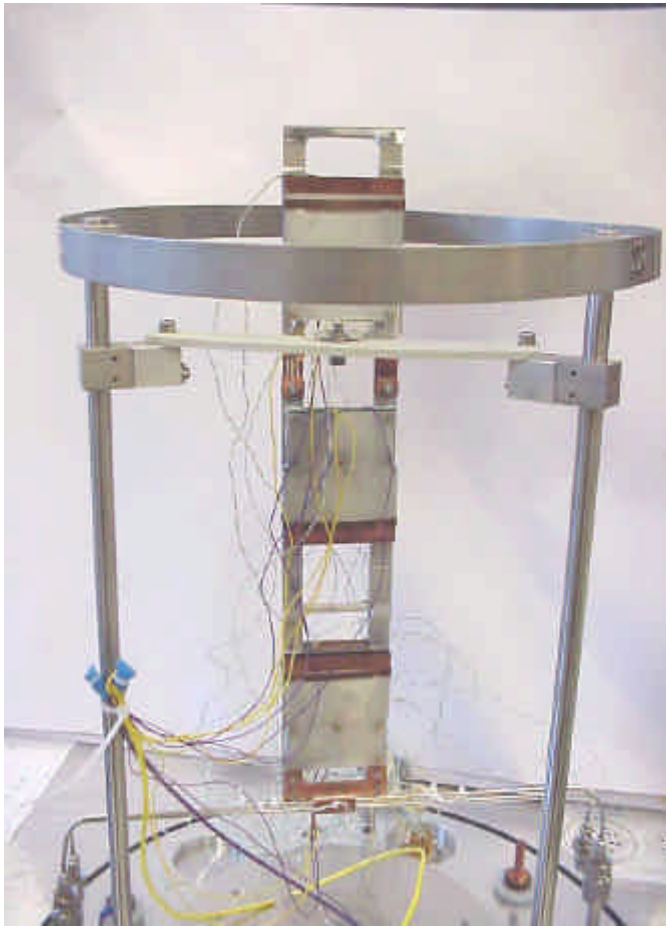



## *Evaporator tube routing on the magnet flange*

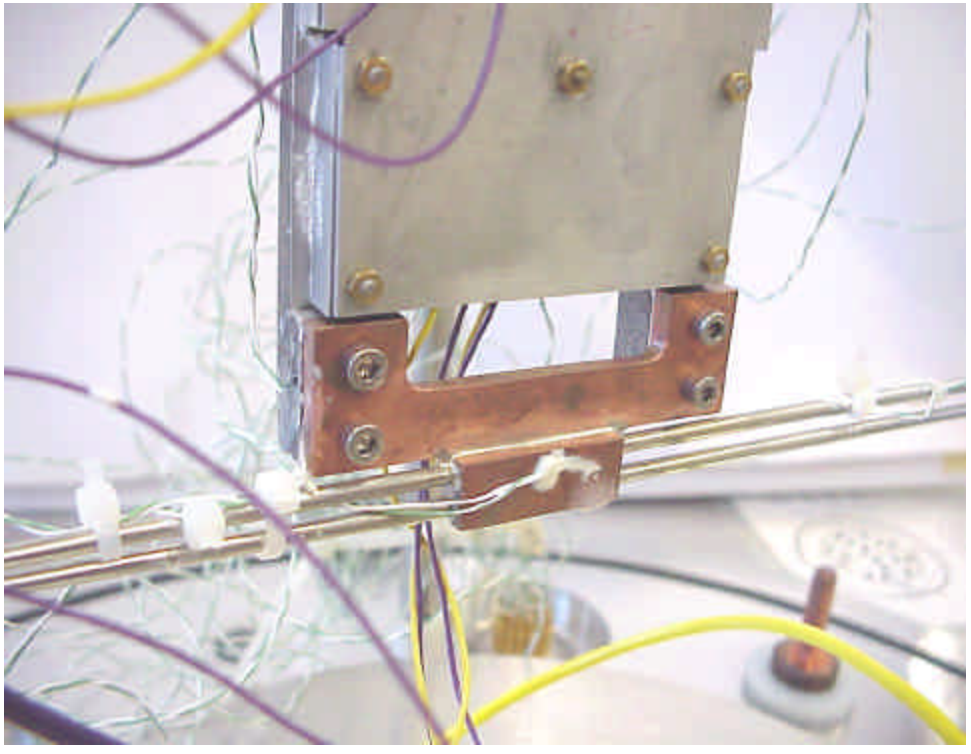
## Inner evaporator connection tubes



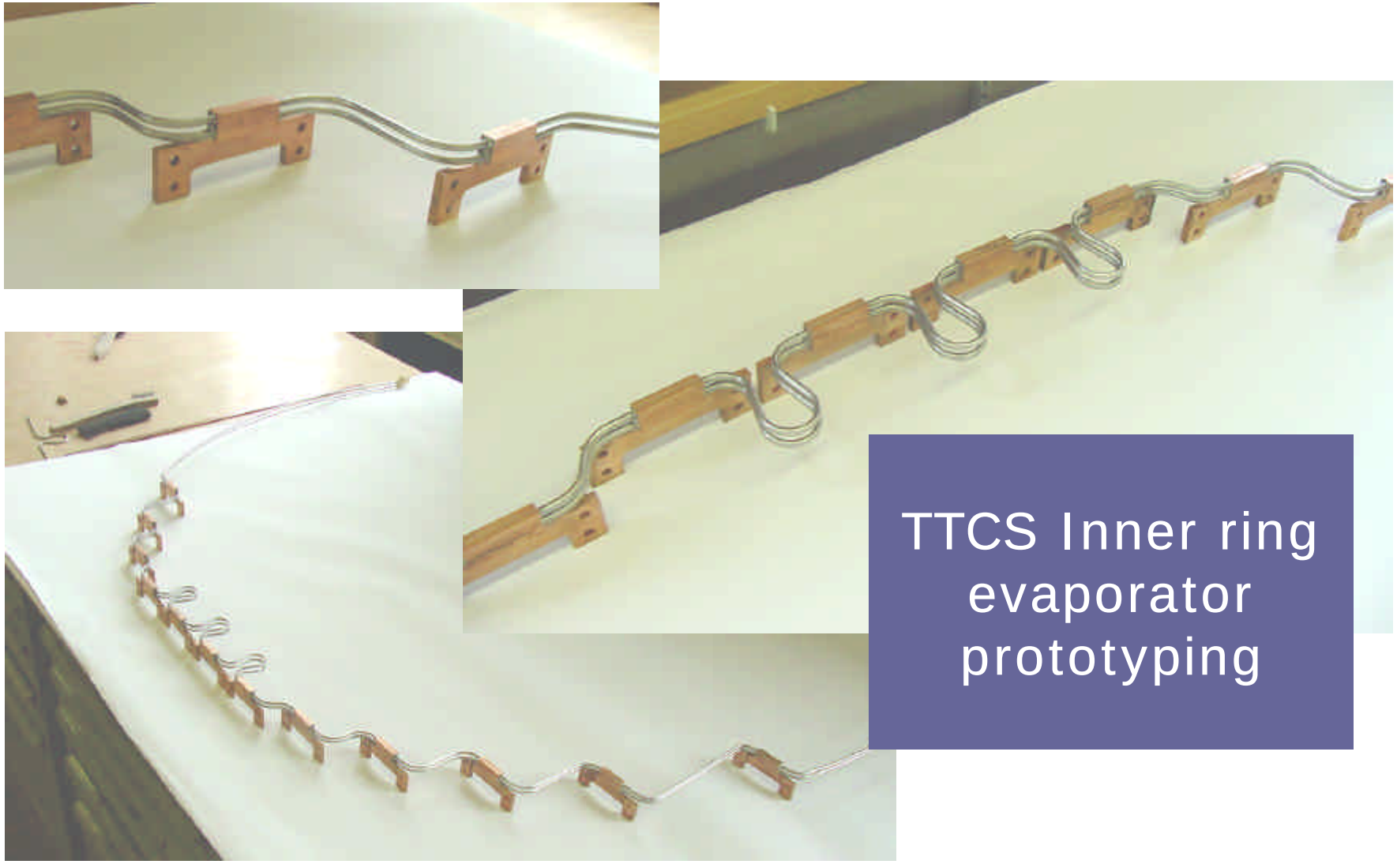
# Inner thermal bar prototyping



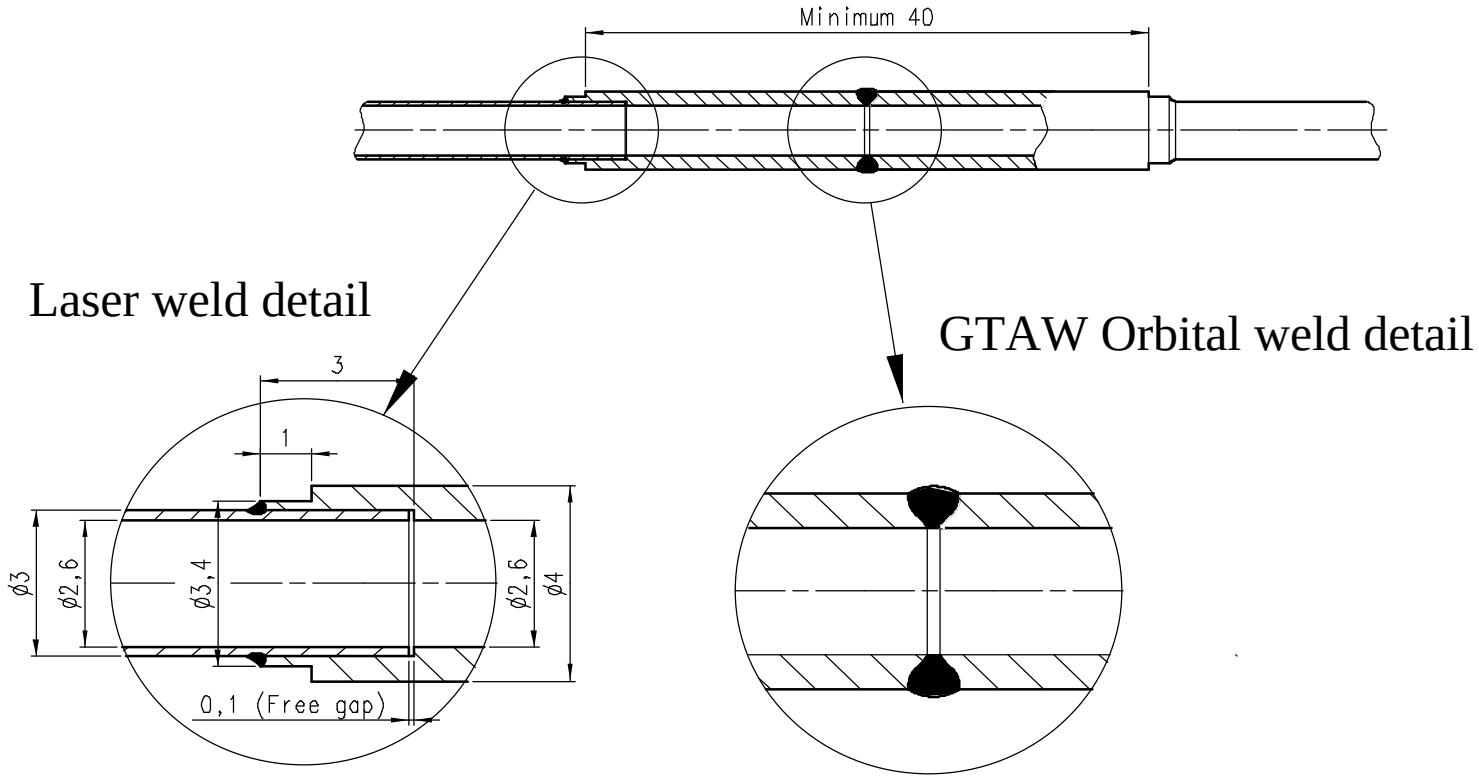
Full scale prototype of a thermal bar array in the NIKHEF Thermal vacuum chamber



Detailed view of the thermal bar evaporator interface.

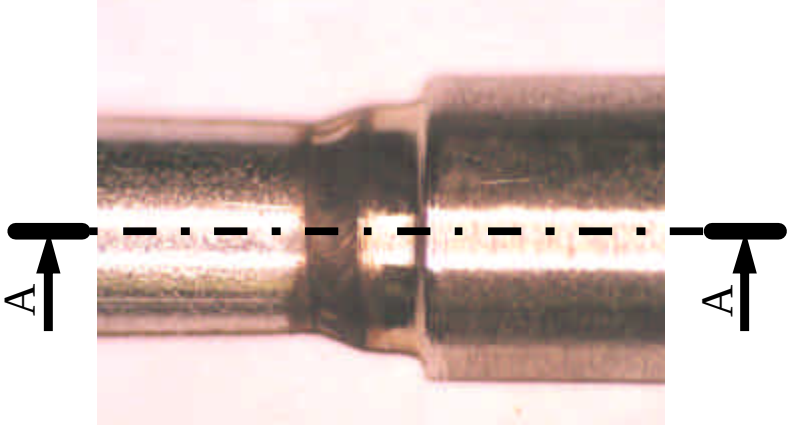


TTCS Inner ring evaporator prototyping

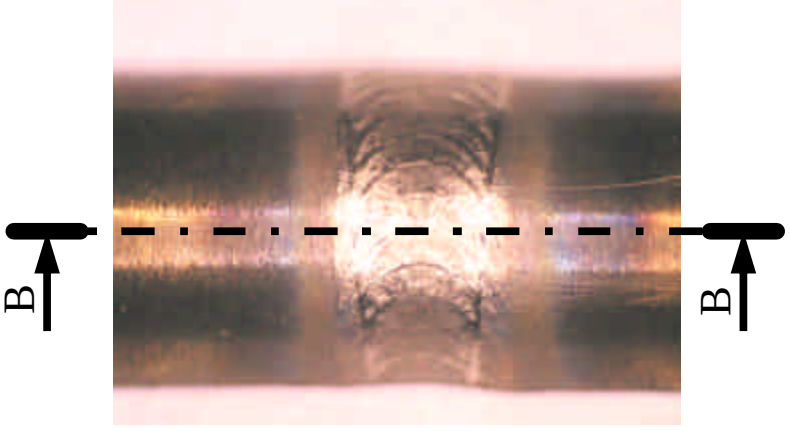



*Weld connector concept*

Evaporator laser weld qualification samples




Evaporator orbital weld qualification samples

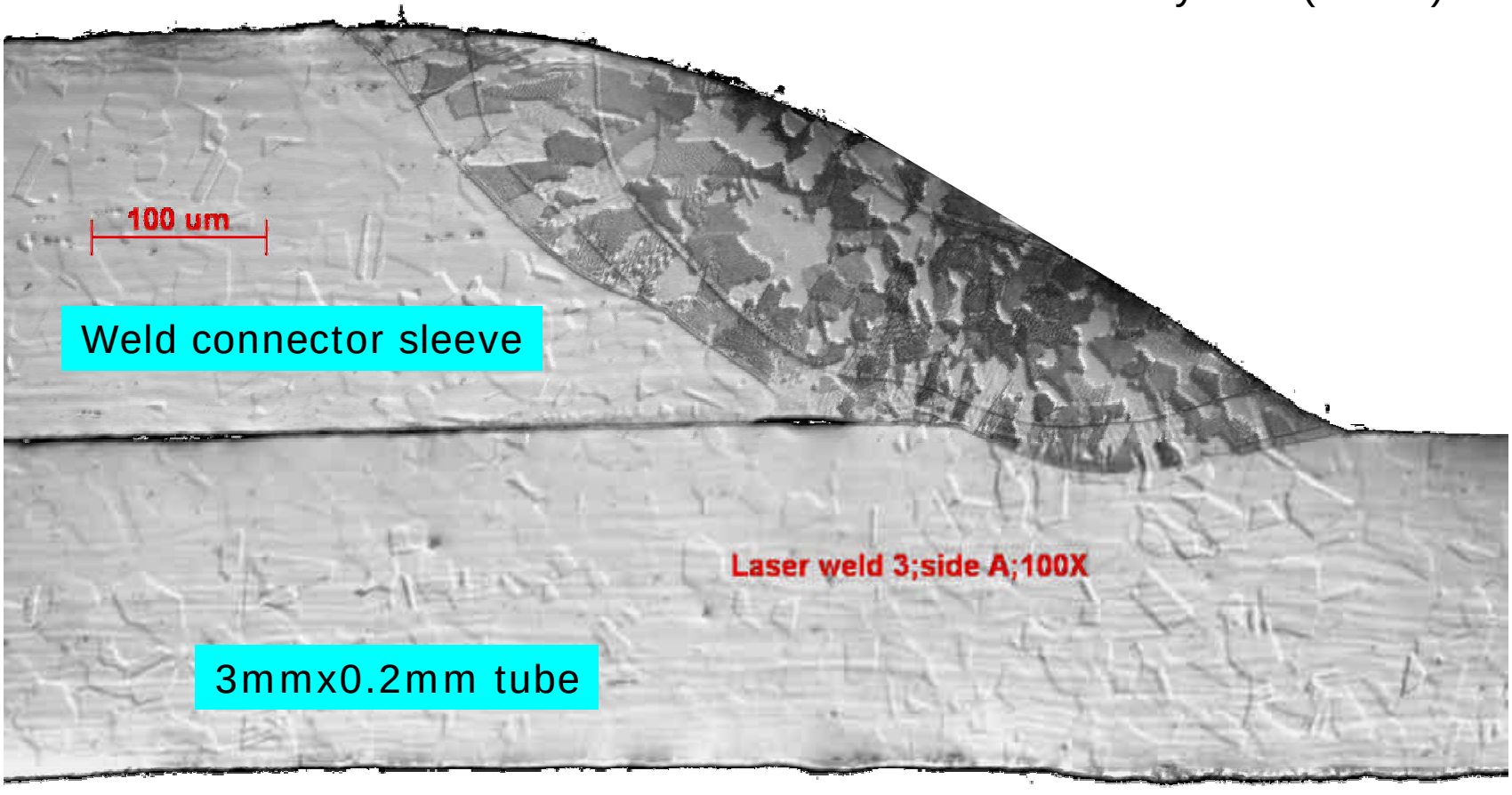


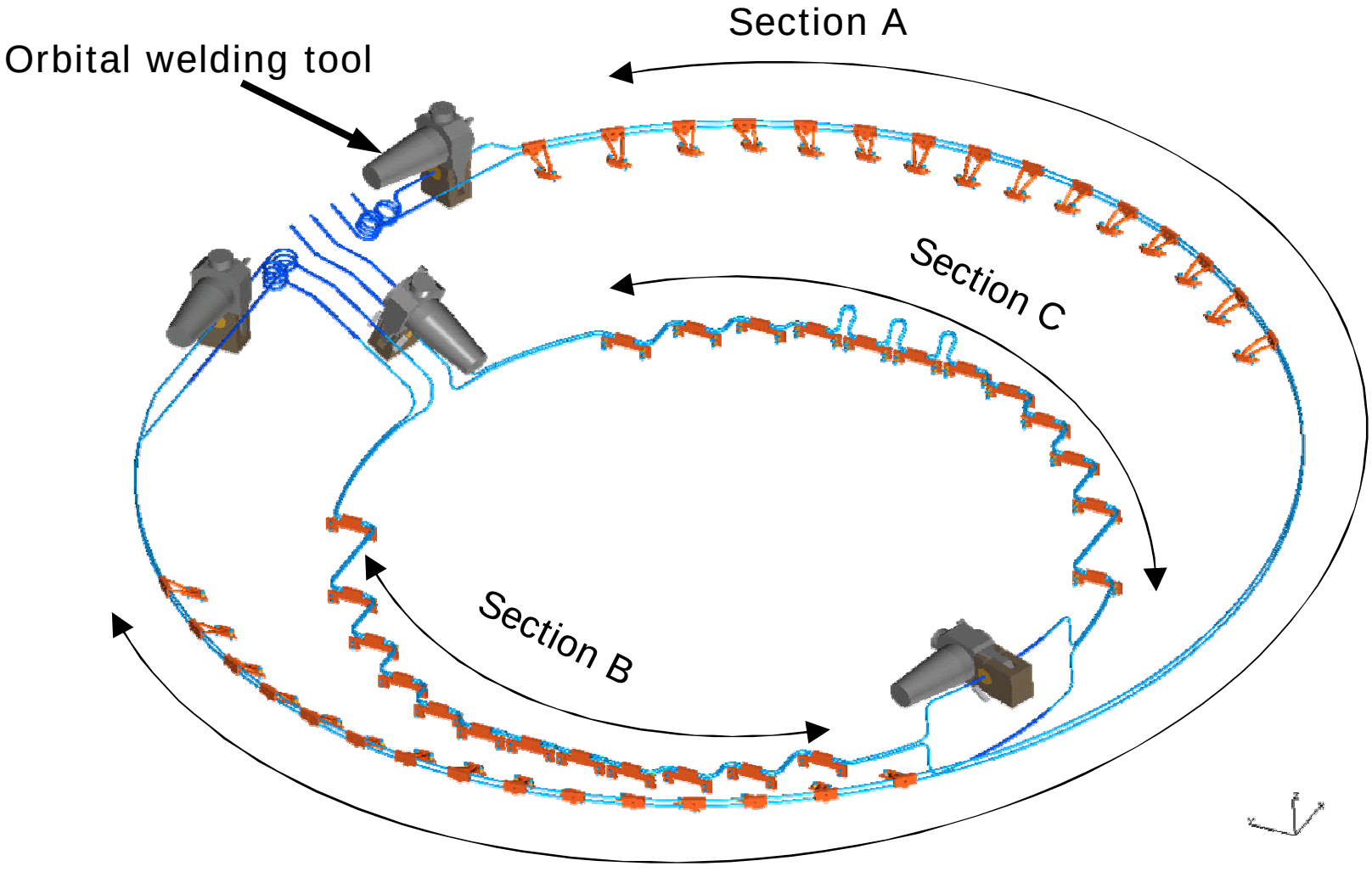

Section A-A:

Section B-B:

# Laser weld detail

Foto: Dan Rybicki (NASA)






*Evaporator sections set-up for orbital welding at Shell*

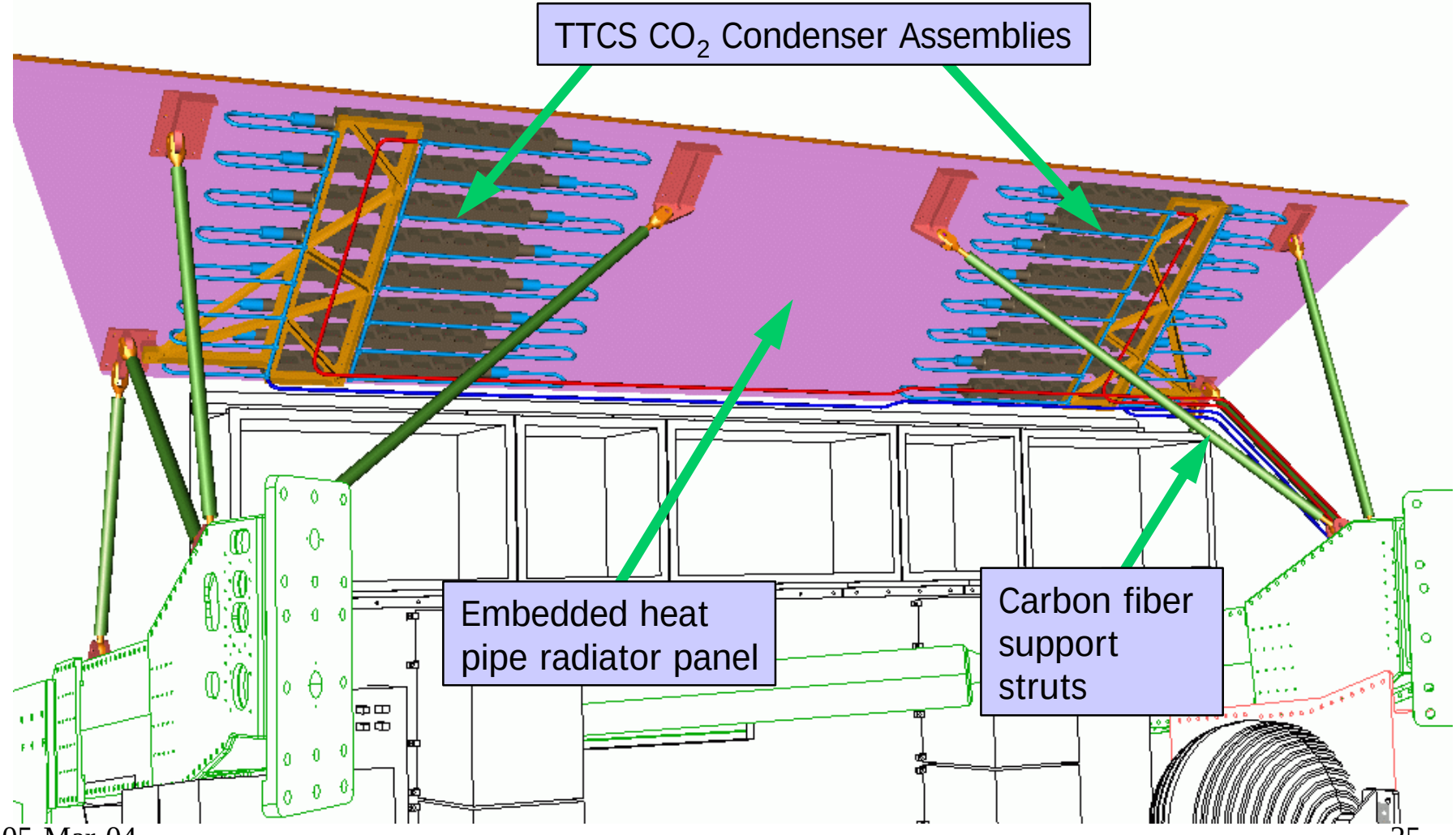
## *Orbital welding and Laser welding at KSLA (Shell research laboratory) in Amsterdam*

*Laser weld apparatus at the Shell Research Laboratory*

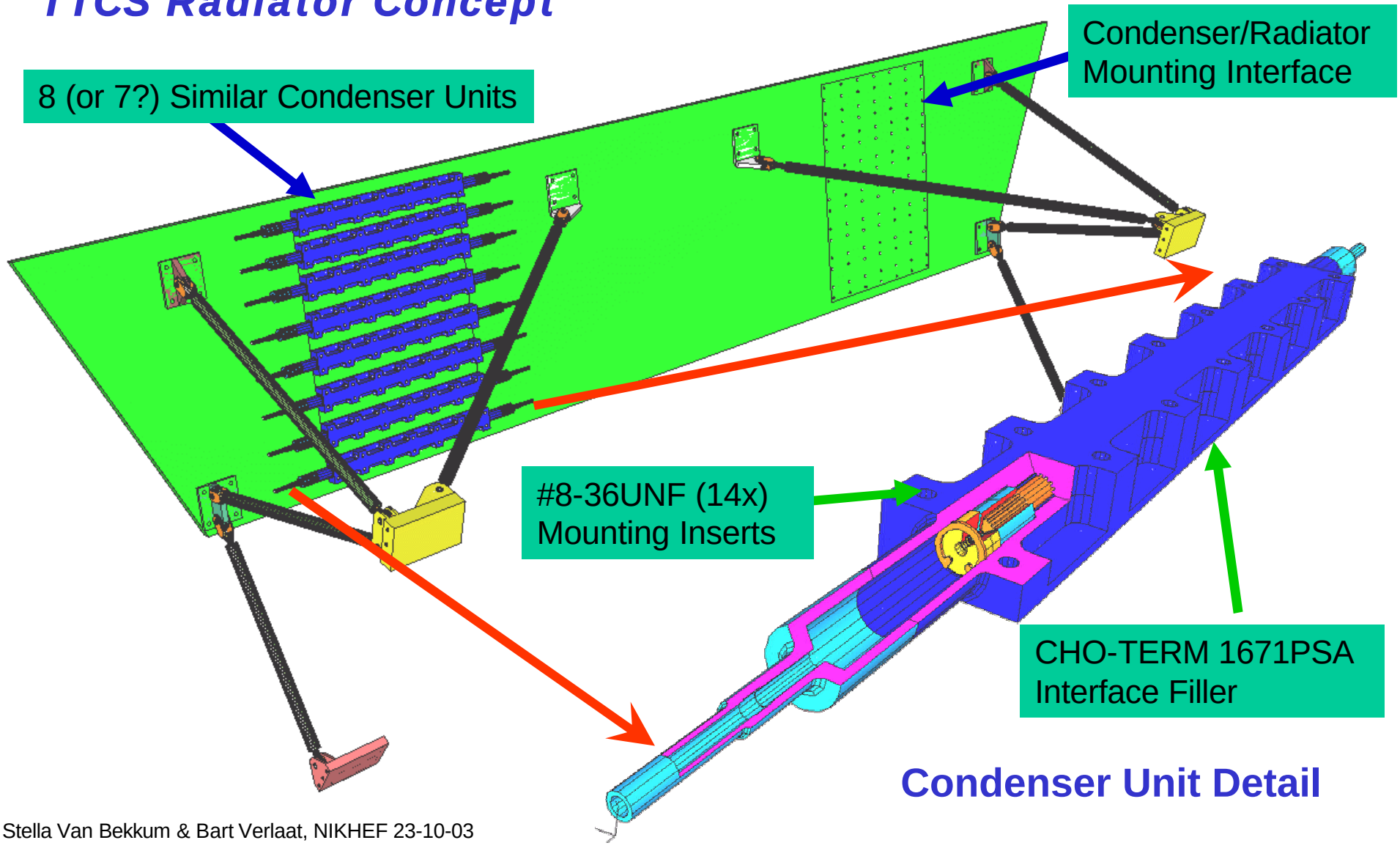
*Swagelok orbital weld apparatus at the Shell Research Laboratory*

# TTCS Radiator & Condenser

## TTCS Radiator Concept

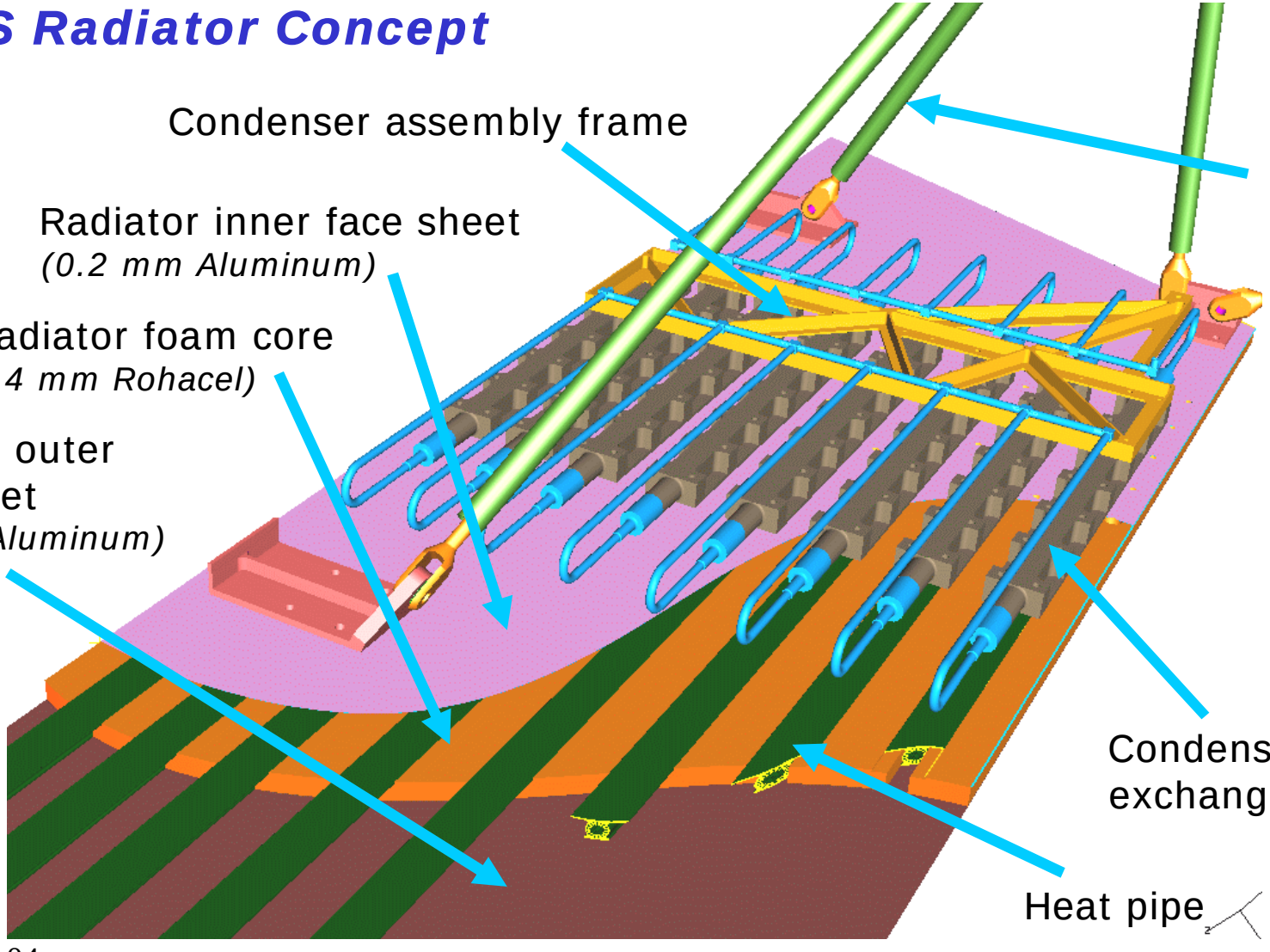


## TTCS Radiator Concept

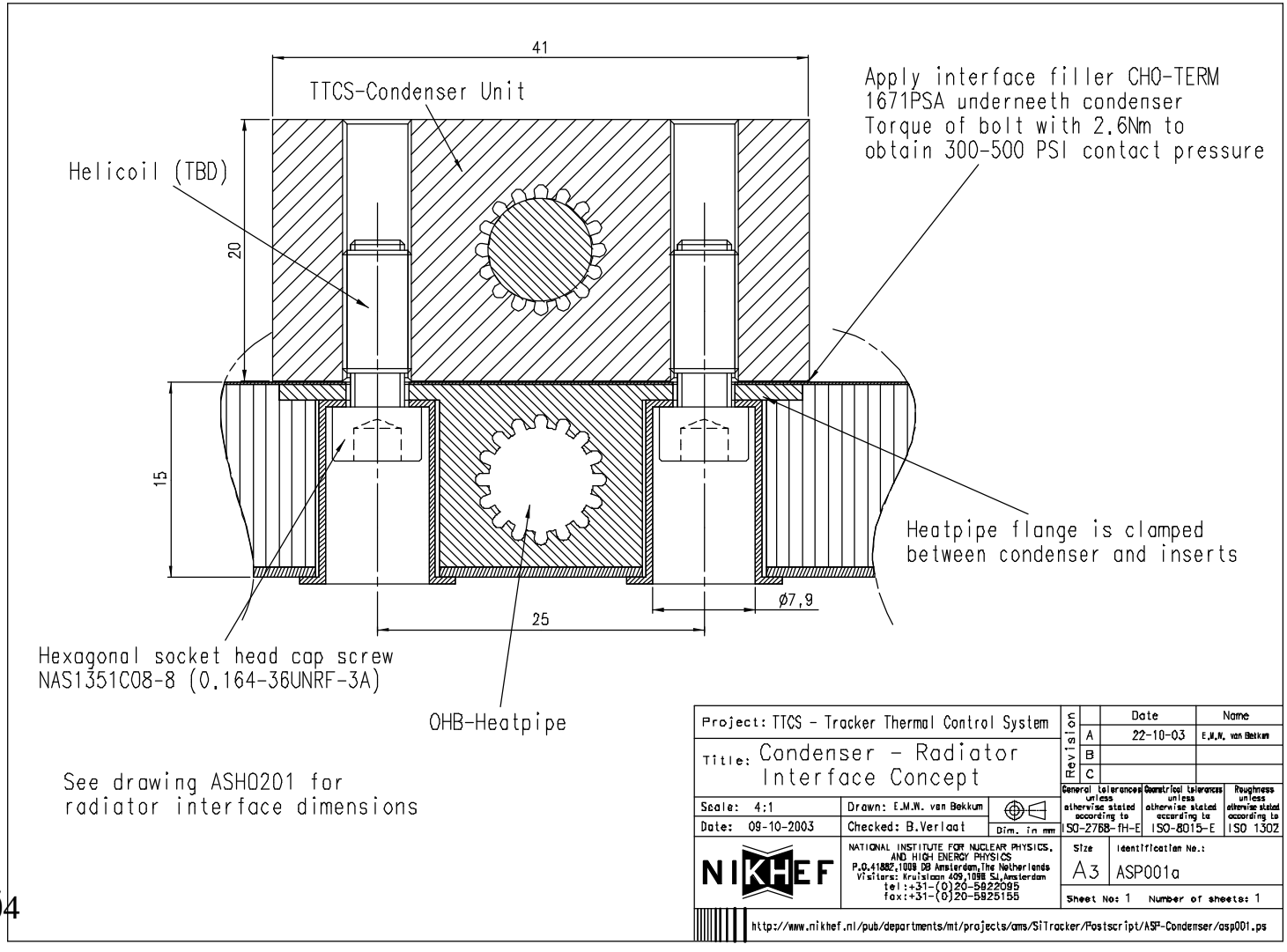


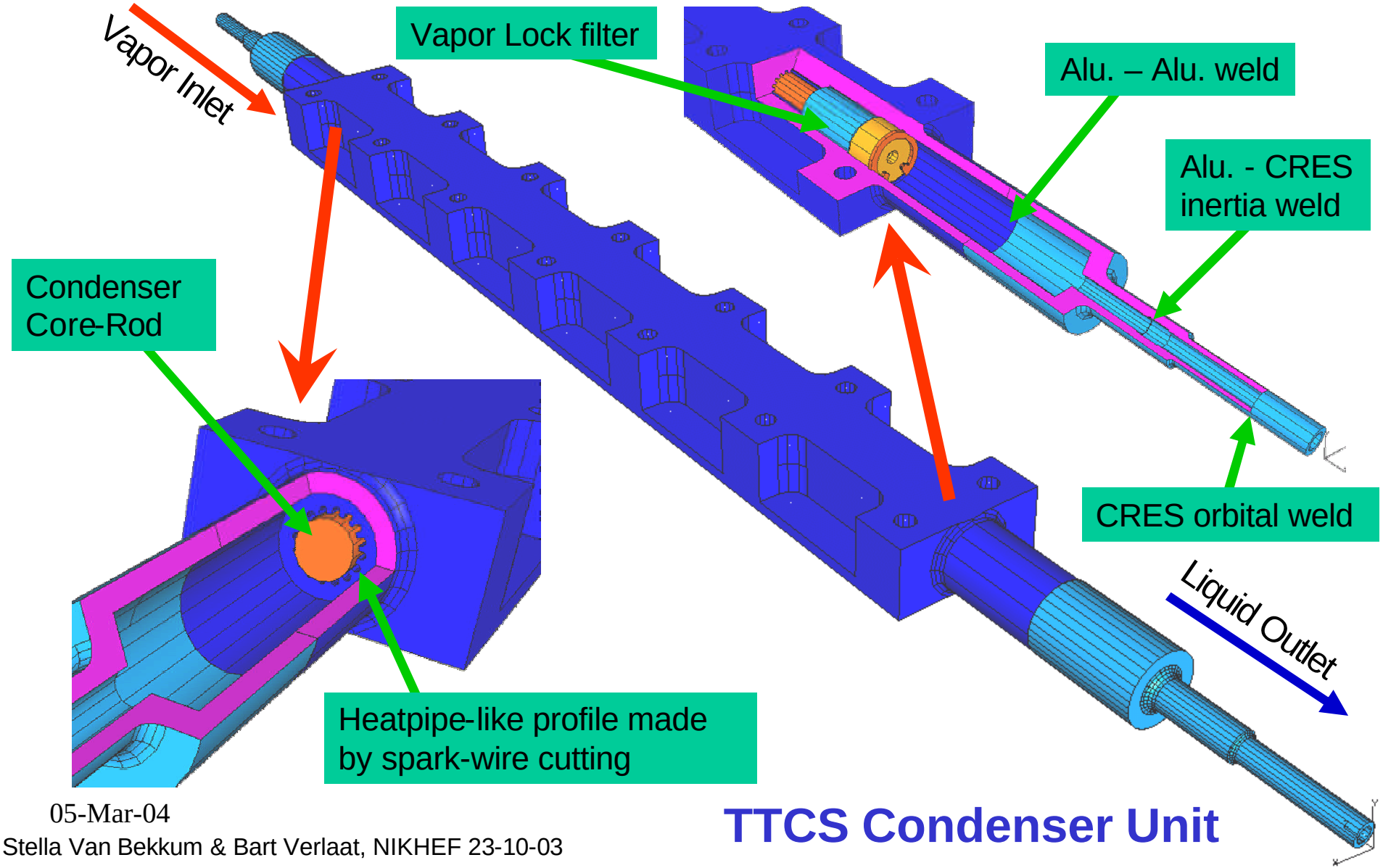

**Condenser Unit Detail**

## TTCS Radiator Concept



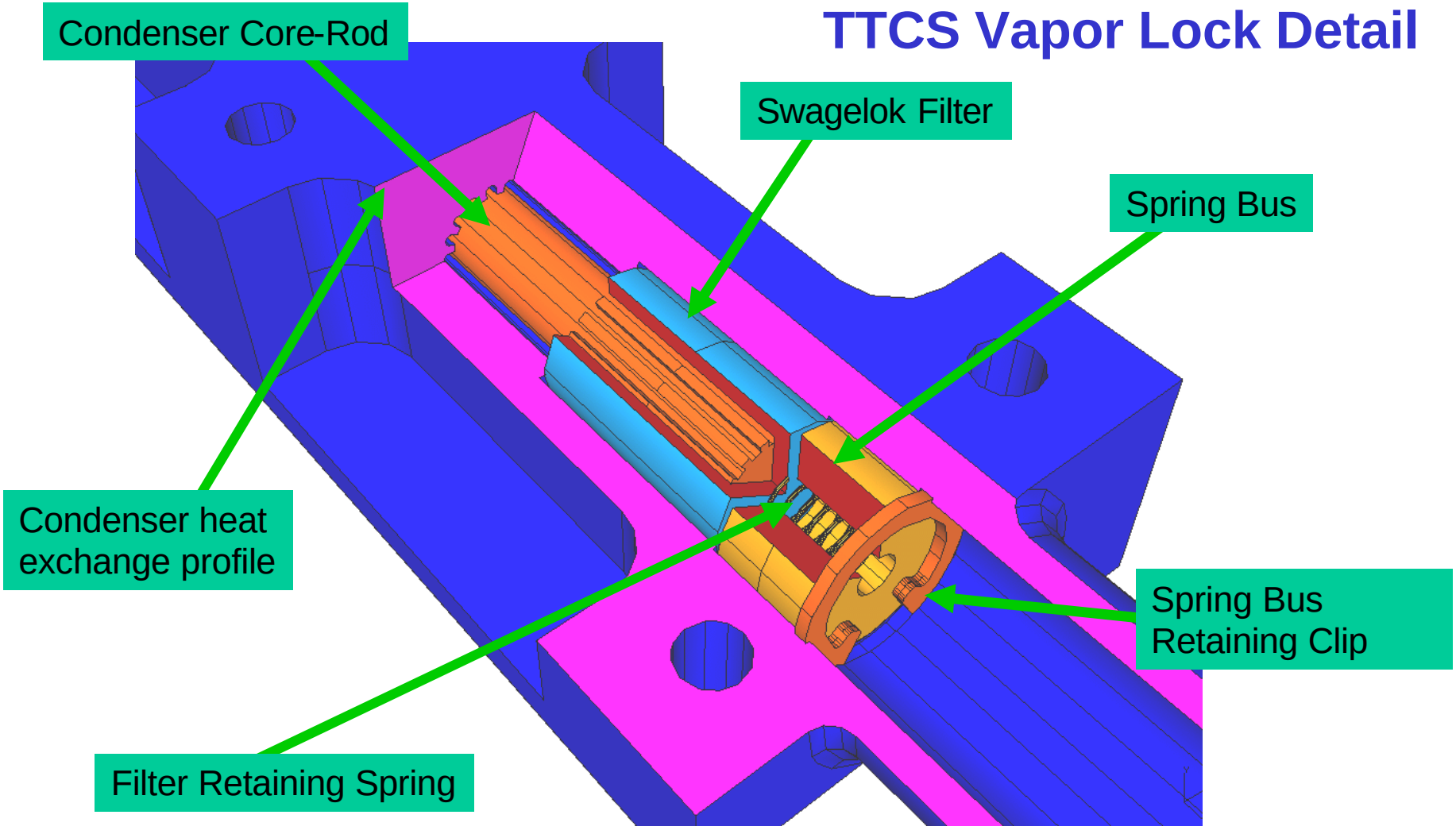
# Condenser mounting concept

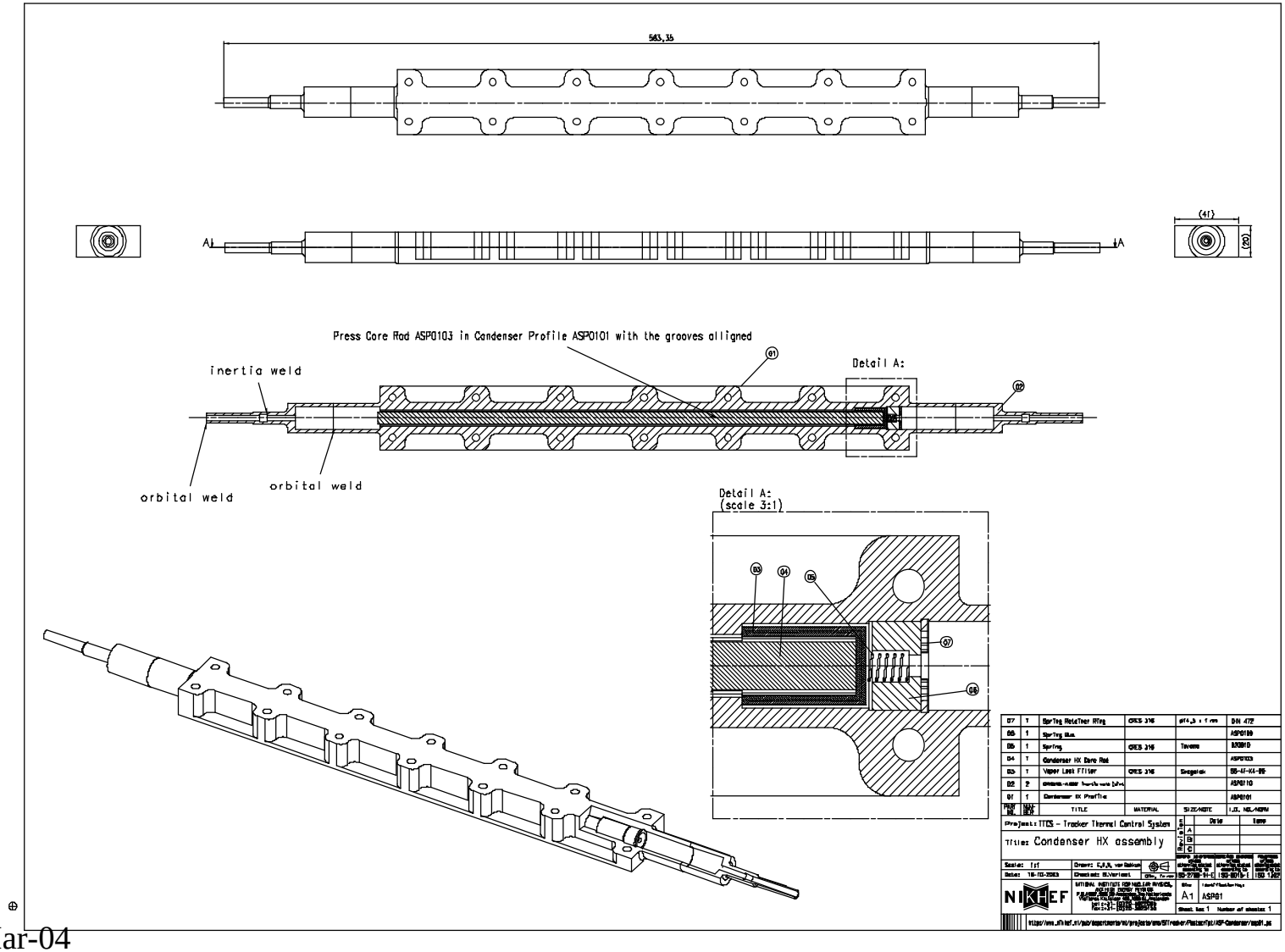




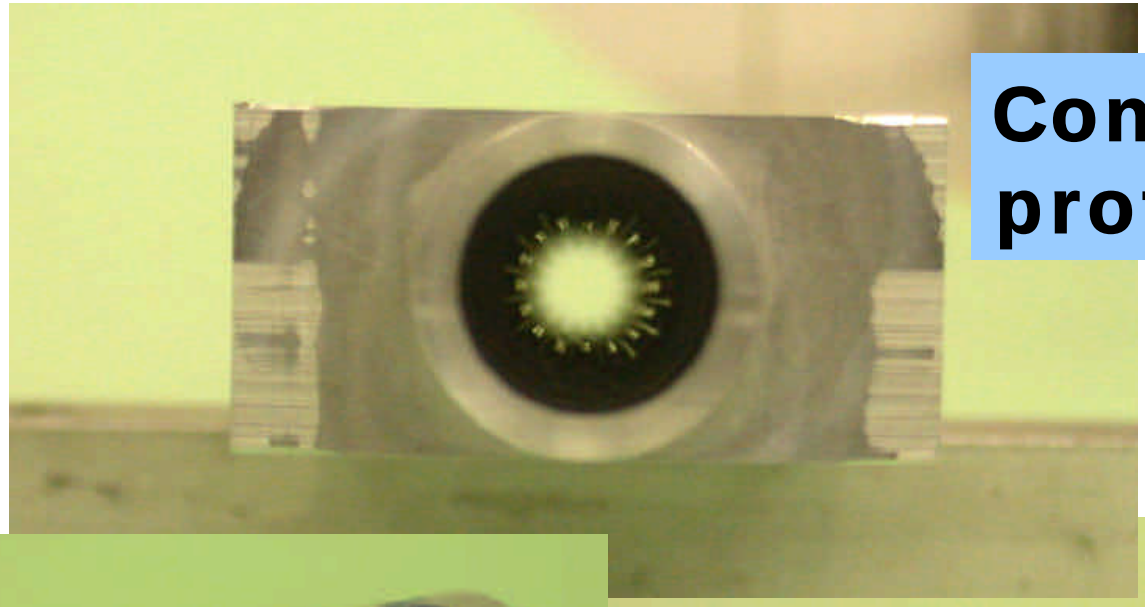

# TTCS Condenser Unit

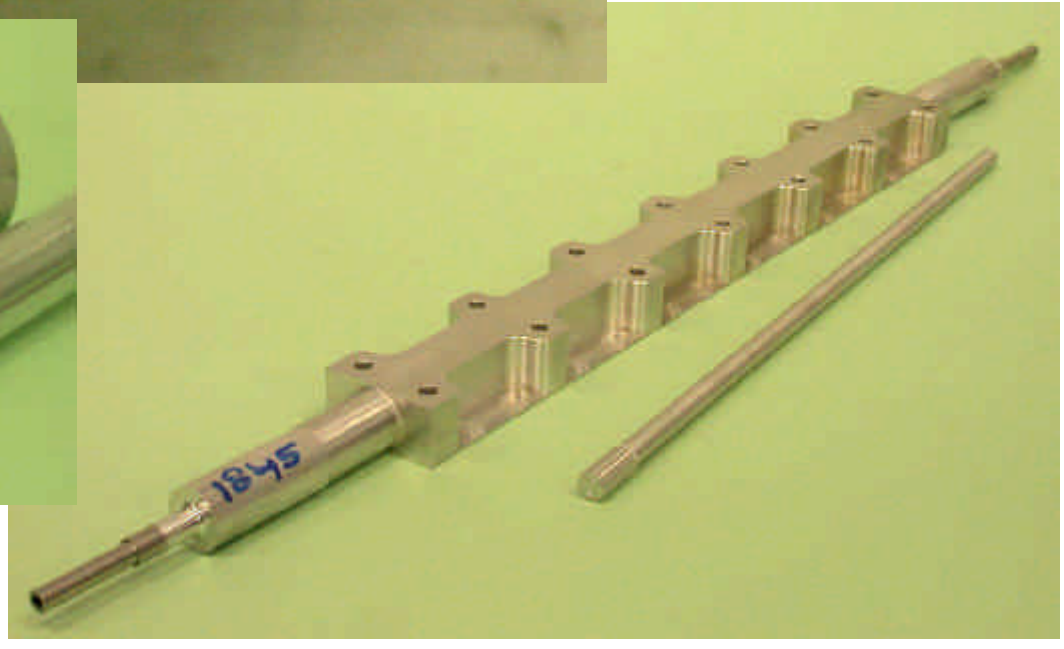
# TTCS Vapor Lock Detail




563,35
A
A
(41)
(20)
Press Core Rod ASP0103 in Condenser Profile ASP0101 with the grooves alligned
inertia weld
Detail A:
orbital weld
orbital weld
Detail A:
(scale 3:1)
Condenser HX assembly
ASP01
A1

# Condenser prototype

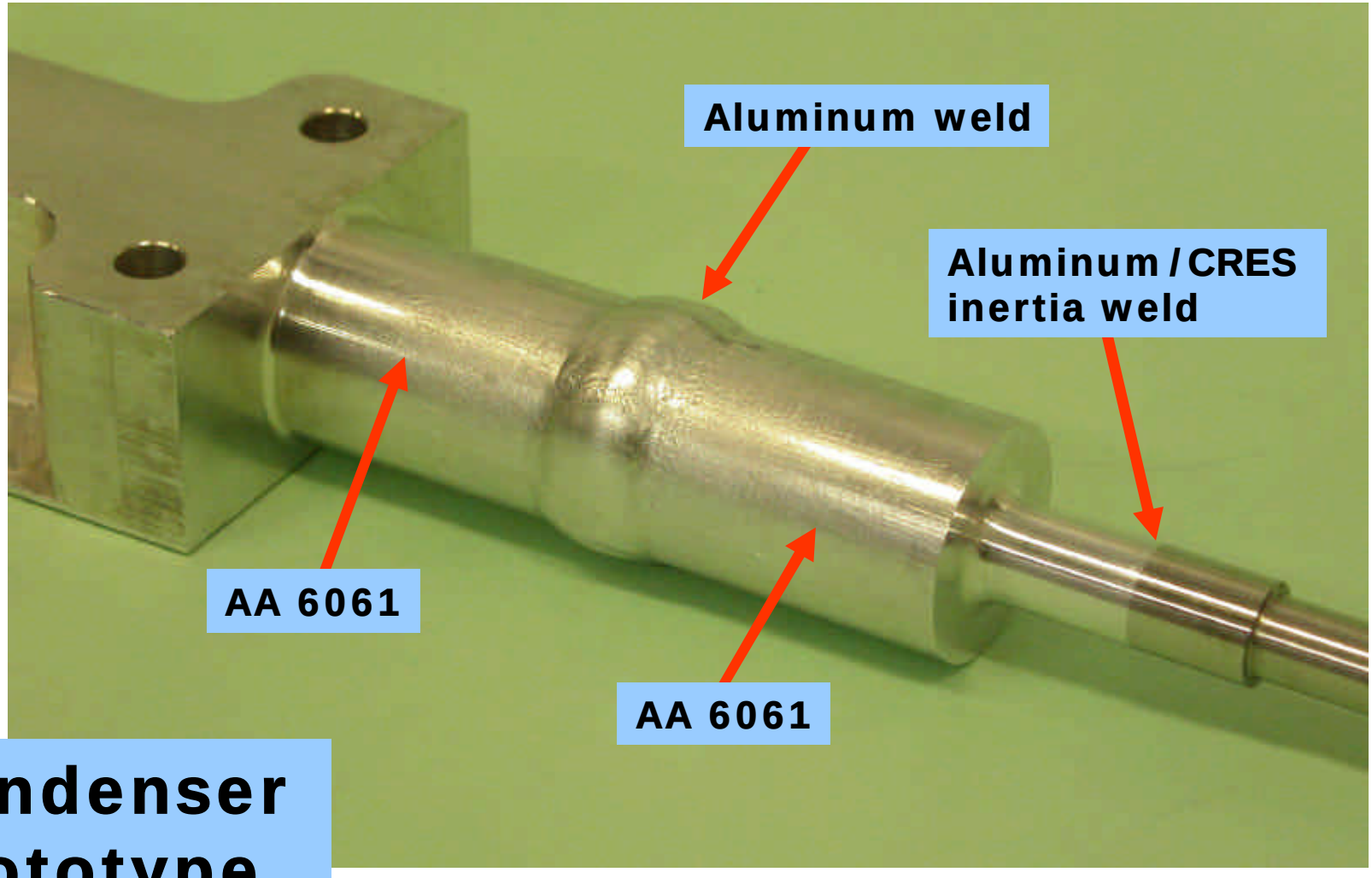




# Condenser prototype

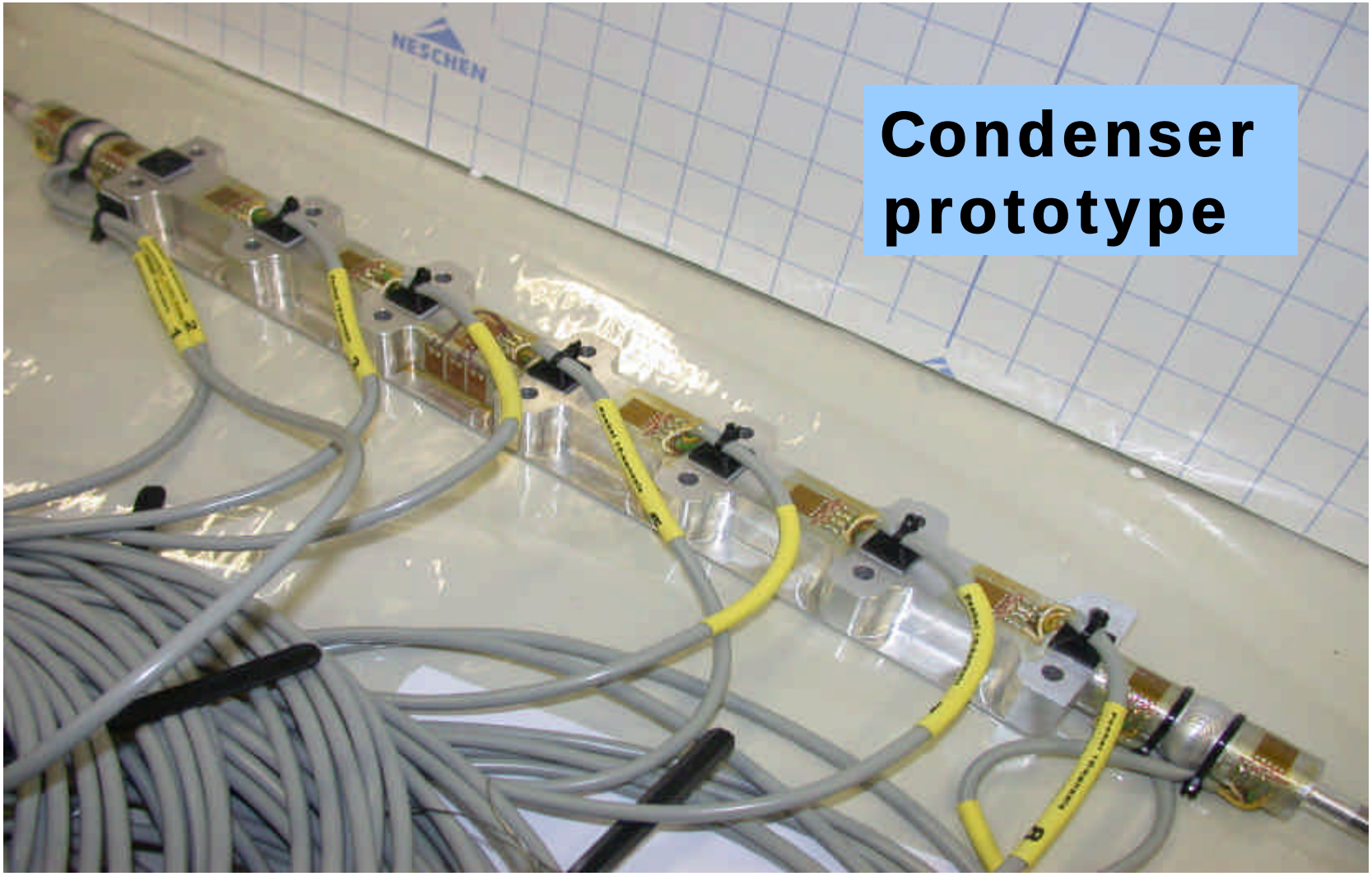
Liquid outlet internal detail

Vapor inlet internal detail

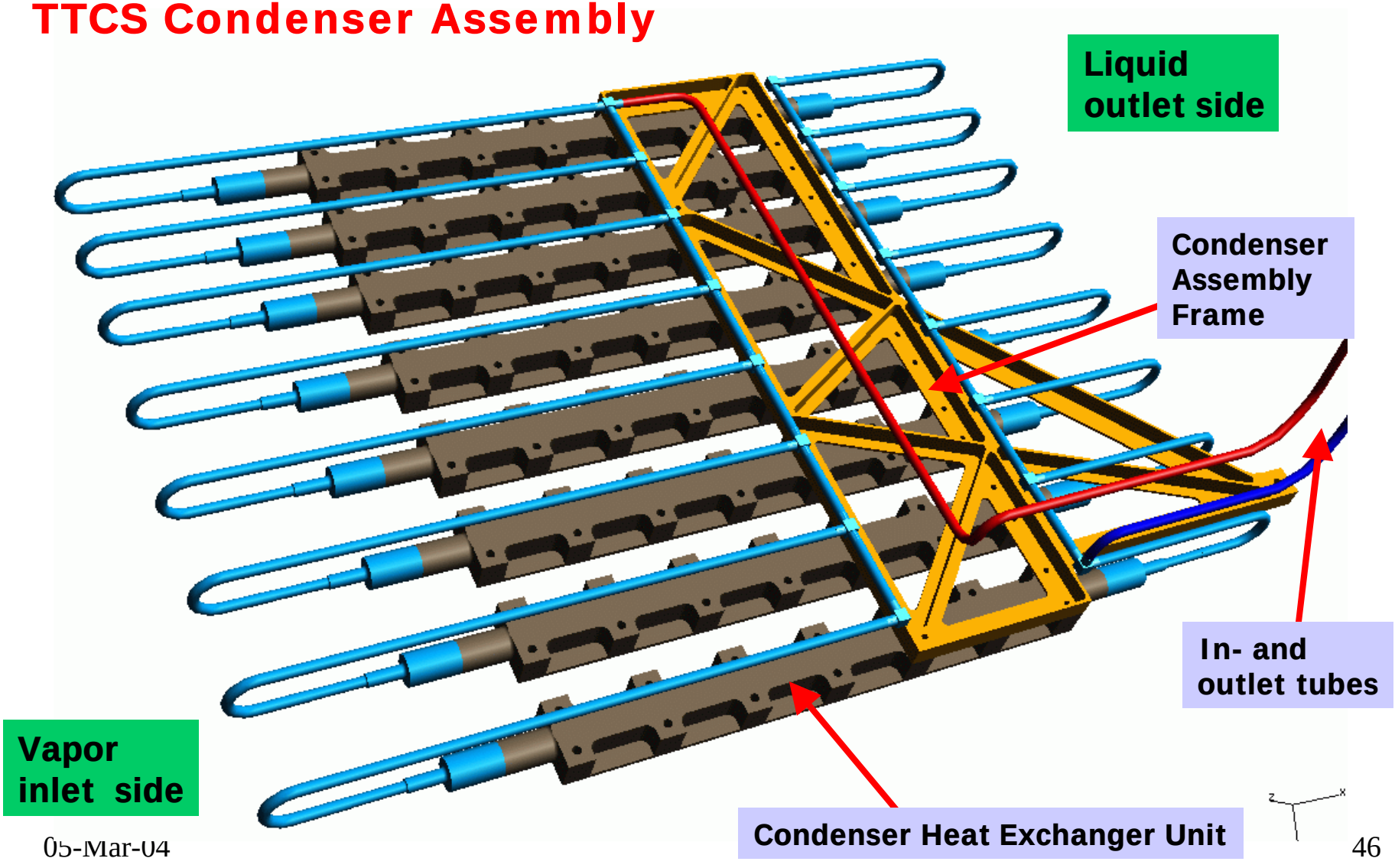



# Condenser prototype

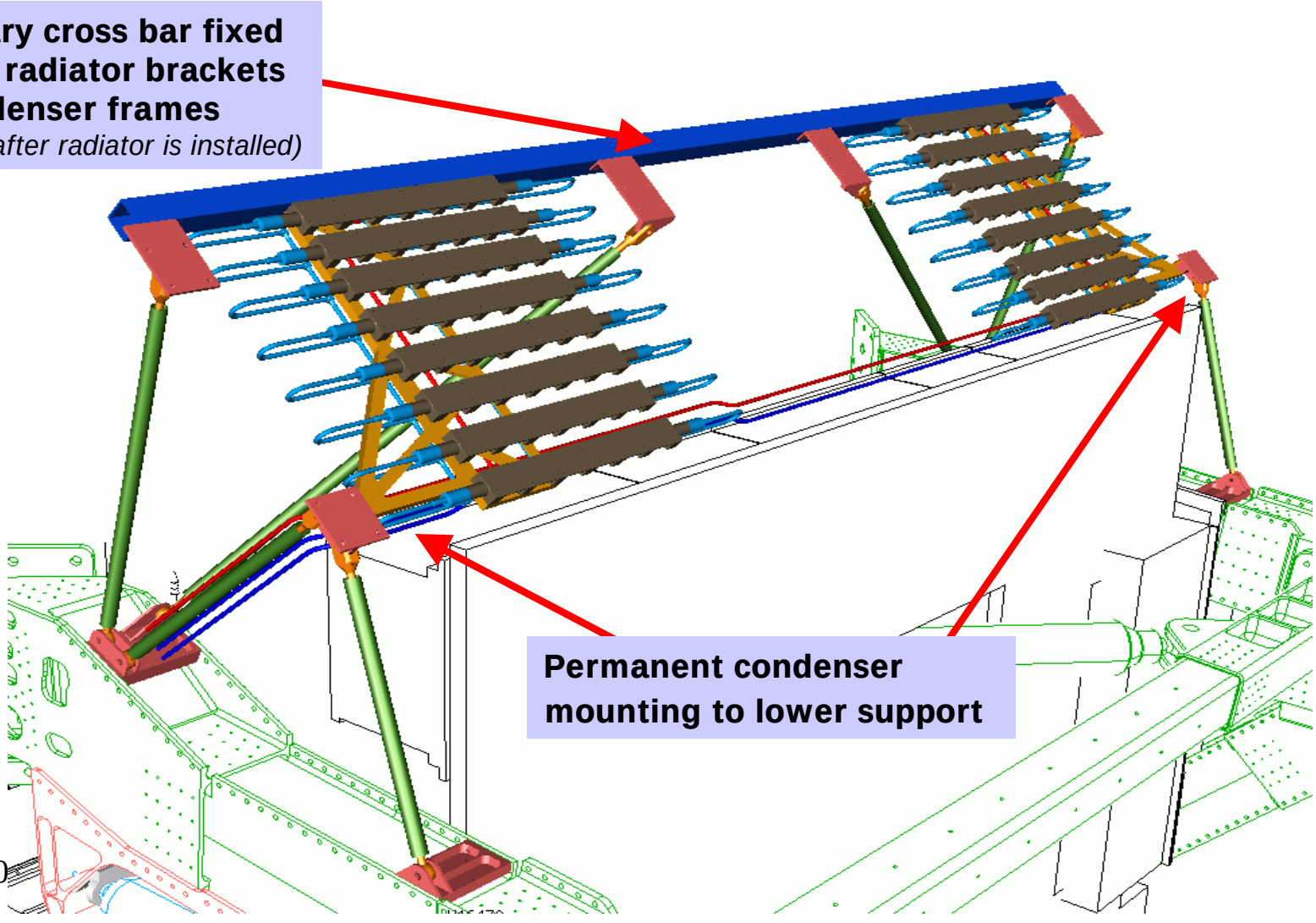
## Condenser: Freezing test set-up with strain gauges

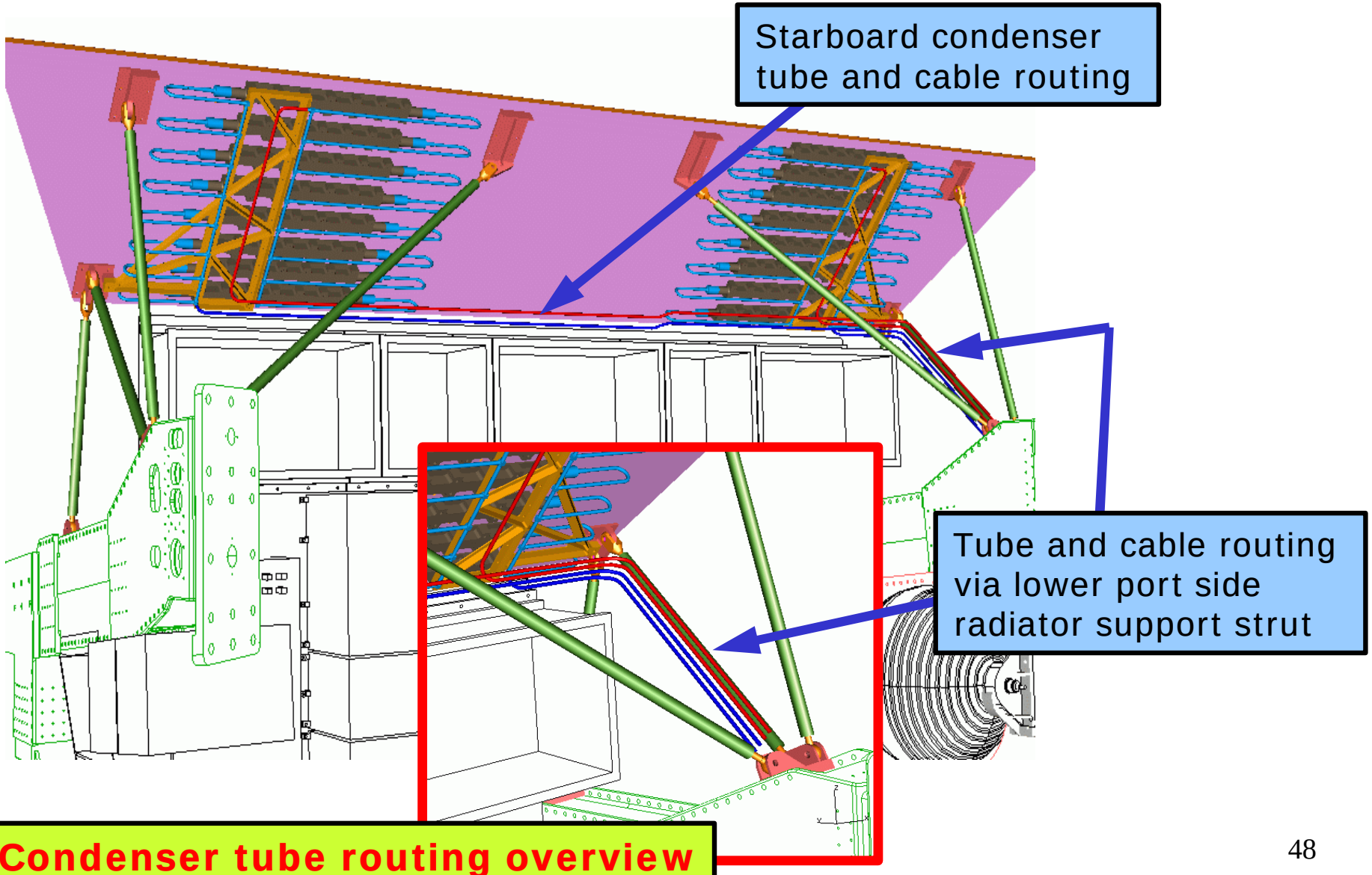


# TTCS Condenser Assembly

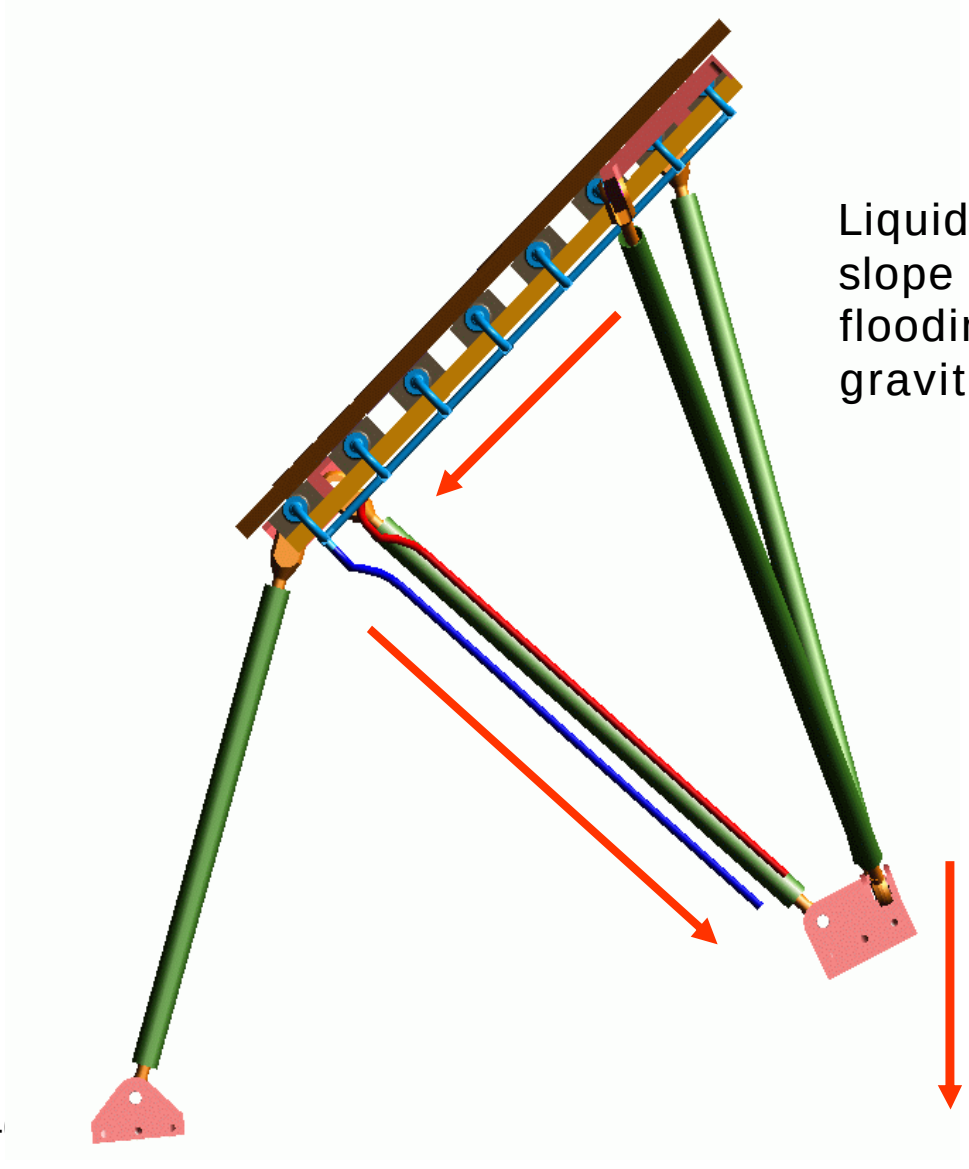


## Condenser installation in radiator support bars without radiator panel





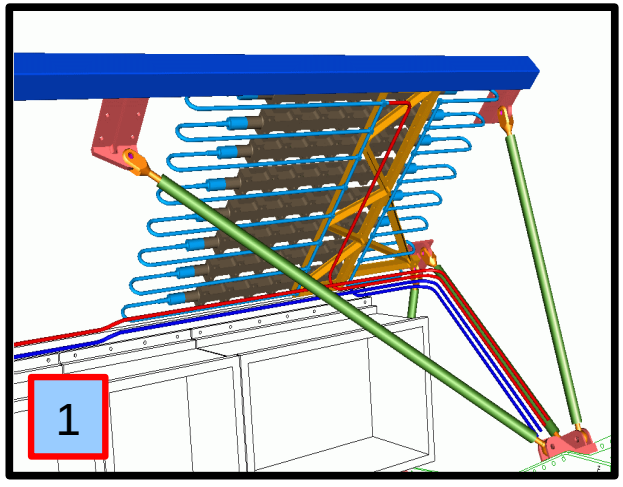

**Condenser tube routing overview**



Liquid outlet tubes have down slope routing only, no condenser flooding is possible due to gravitation during ground testing

Liquid to TTCS box and pump

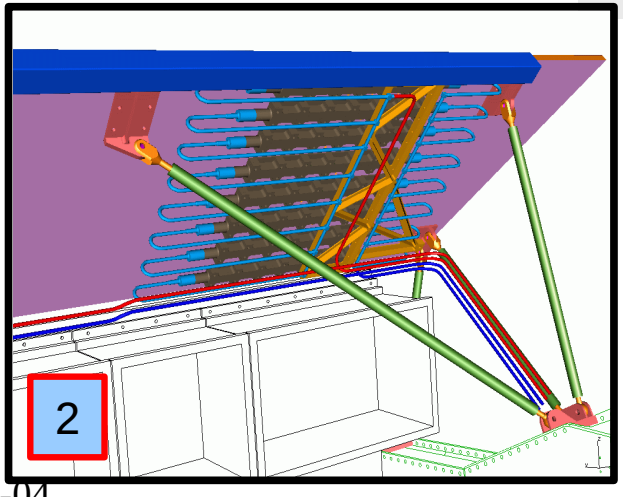
## TTCS & Radiator installation overview

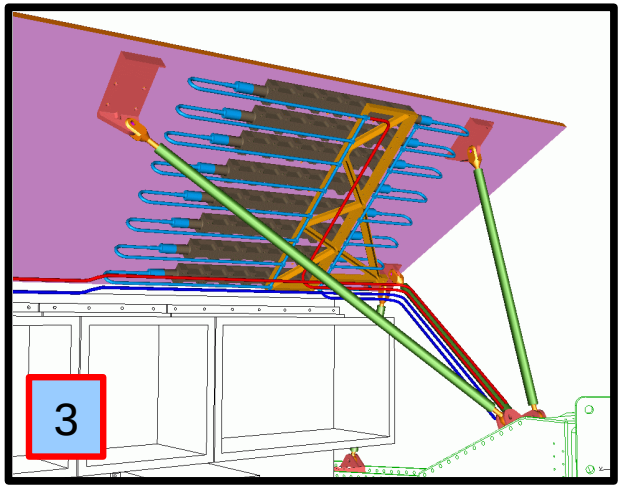


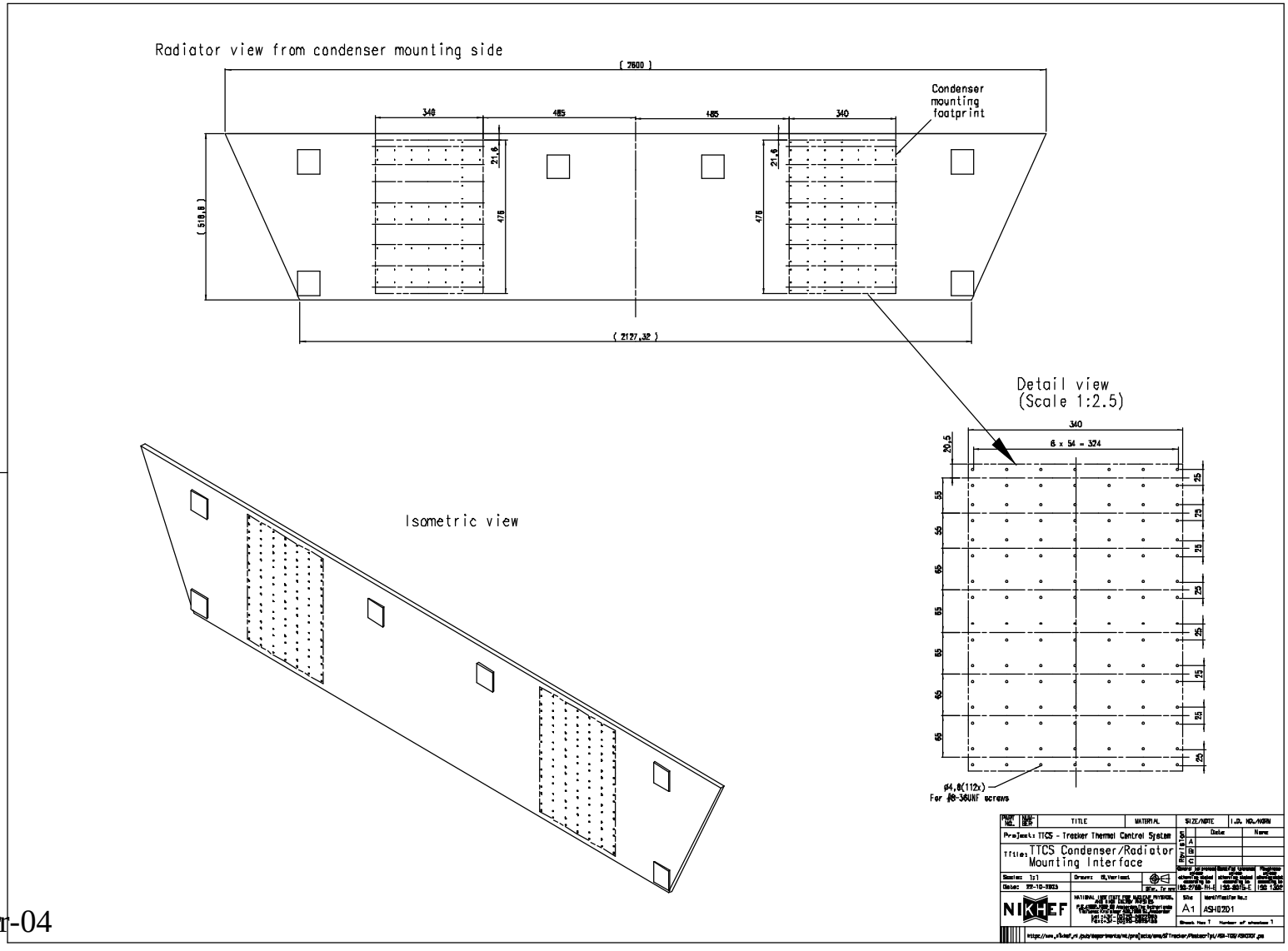

1. Condenser is installed in its final location, using the radiator support struts and a GSE cross bar. The radiator panel is not in place allowing easy access to TTCS hardware for installation and testing purposes. A cold plate will be installed on condensers for TTCS performance testing.

2. Once the TTCS is completely installed and tested, the radiator panel can be installed. The condensers will be clamped to the panel via bolts from the outside.

3. The GSE cross bar will be removed after final mounting of the radiator panel.



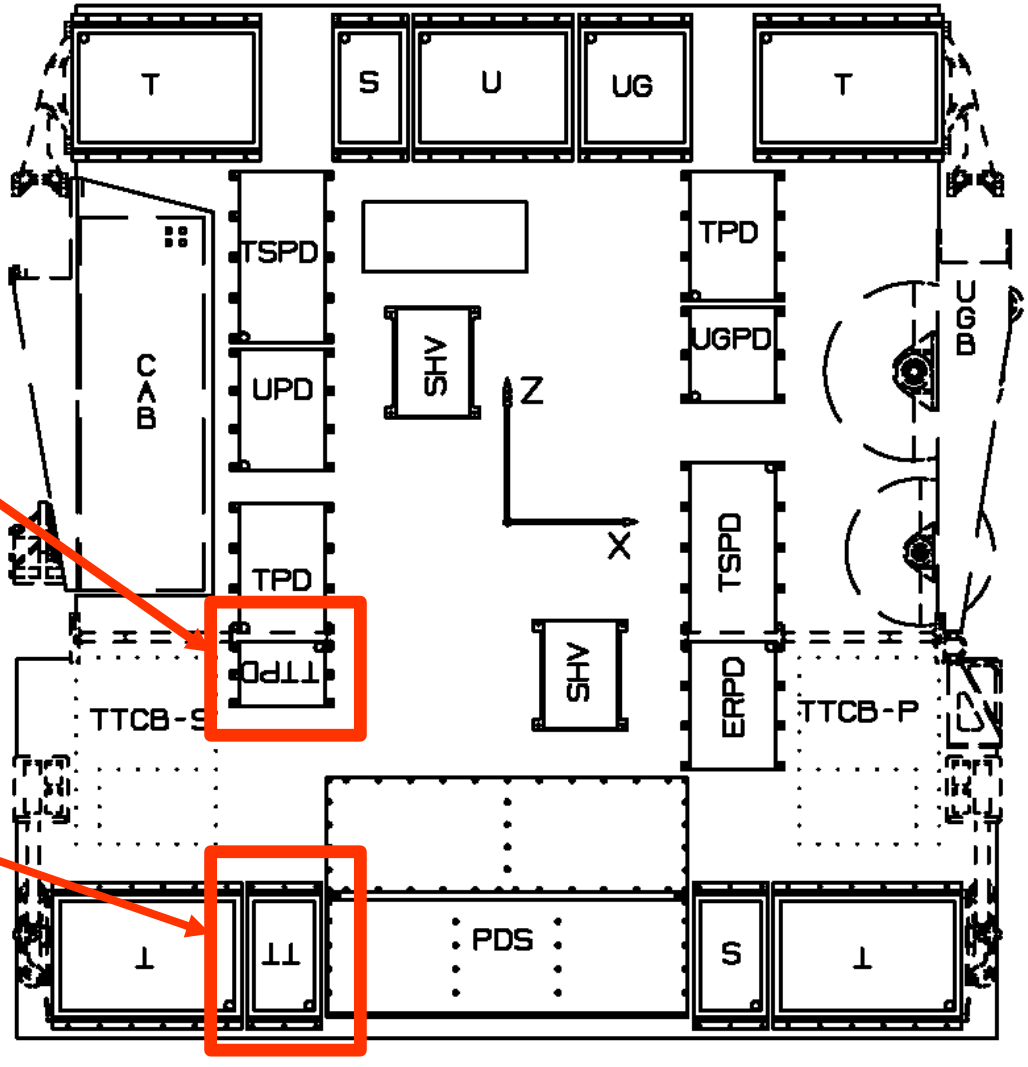

Radiator view from condenser mounting side
( 2600 )
Condenser mounting footprint
340
485
485
340
21,6
476
( 518,8 )
( 2127,32 )
Detail view
(Scale 1:2.5)
340
6 x 54 = 324
20,5
Isometric view
ø4,8(112x)
For #8-36UNF screws
TITLE
MATERIAL
SIZE/NOTE
Project: TTCS - Tracker Thermal Control System
Title: TTCS Condenser/Radiator Mounting Interface
Date
Name
A1
ASH02D1

# TTCS Electro Mechanics

## Crates on the main wake radiator

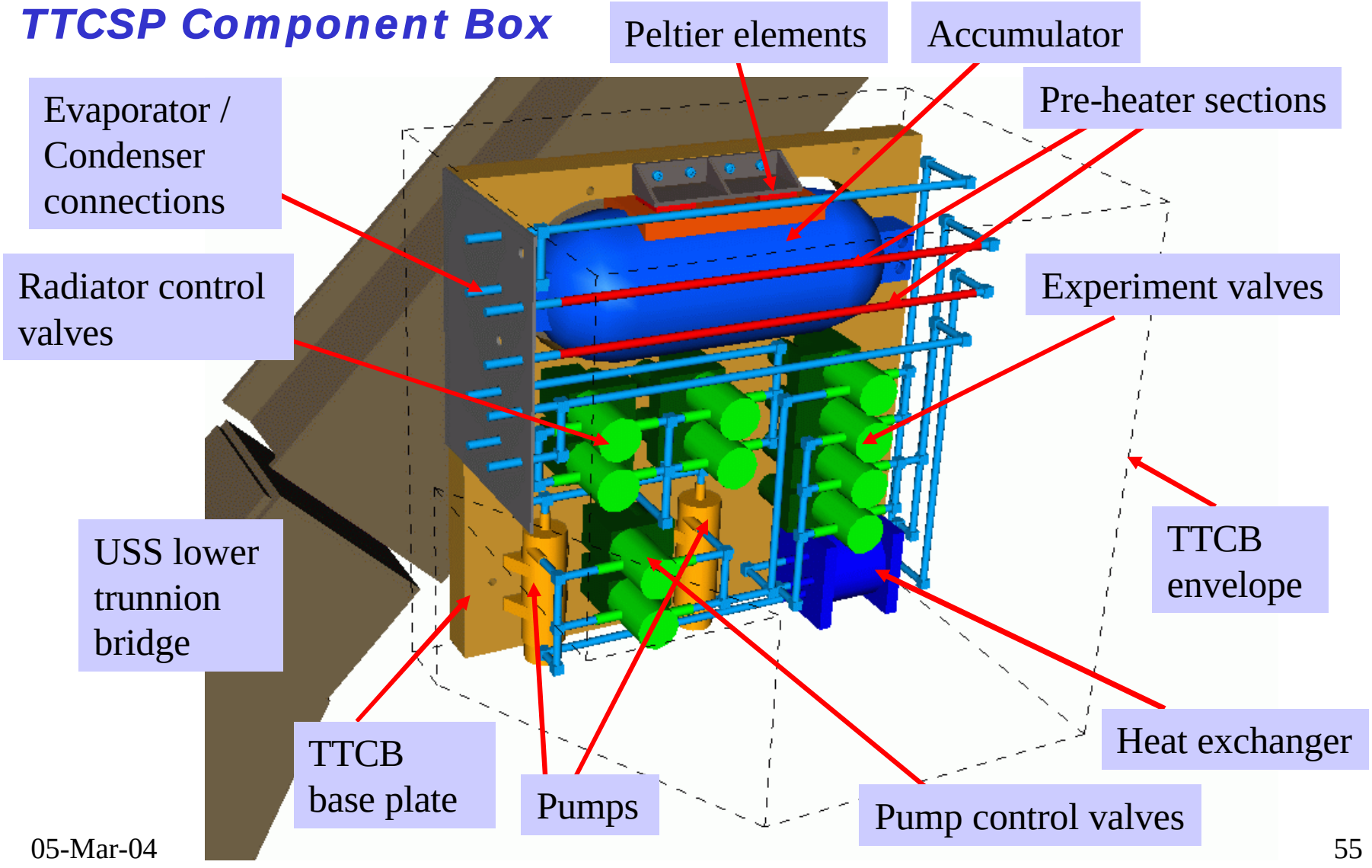
TTCS power distribution box (TTPD)

TTCS Control Electronics box (TTCE)

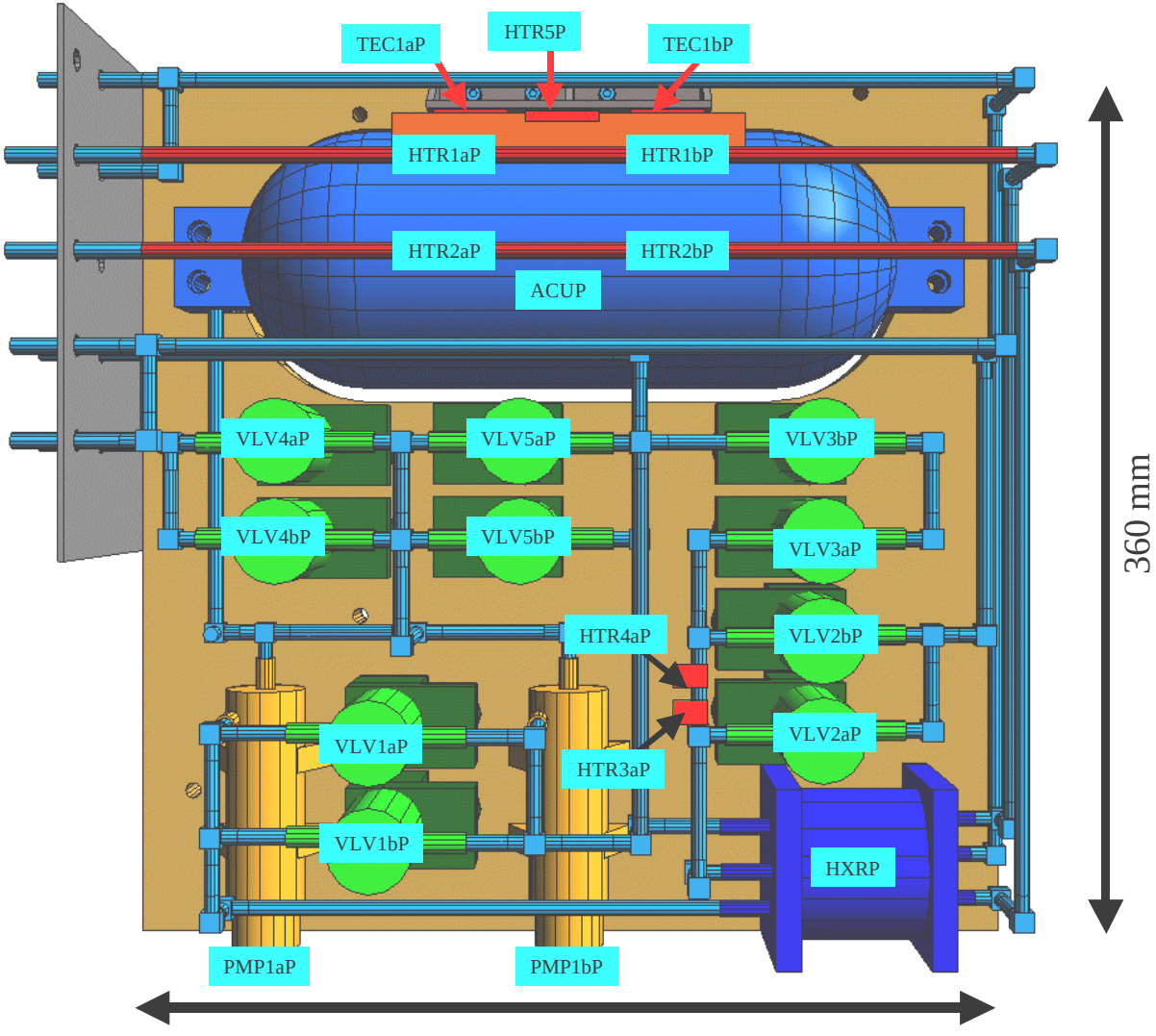


# TTCS Component Box

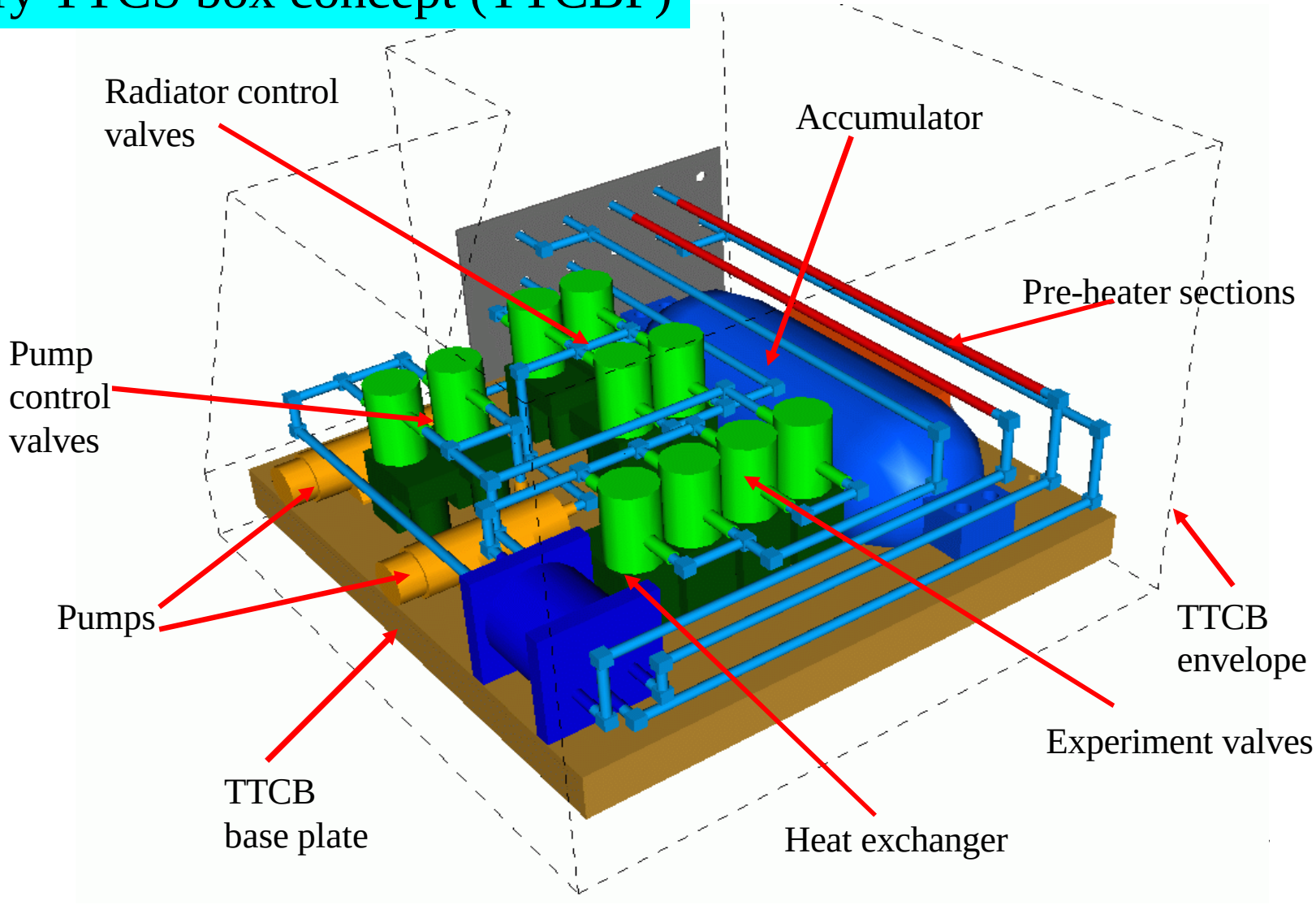
## TTCSP Component Box



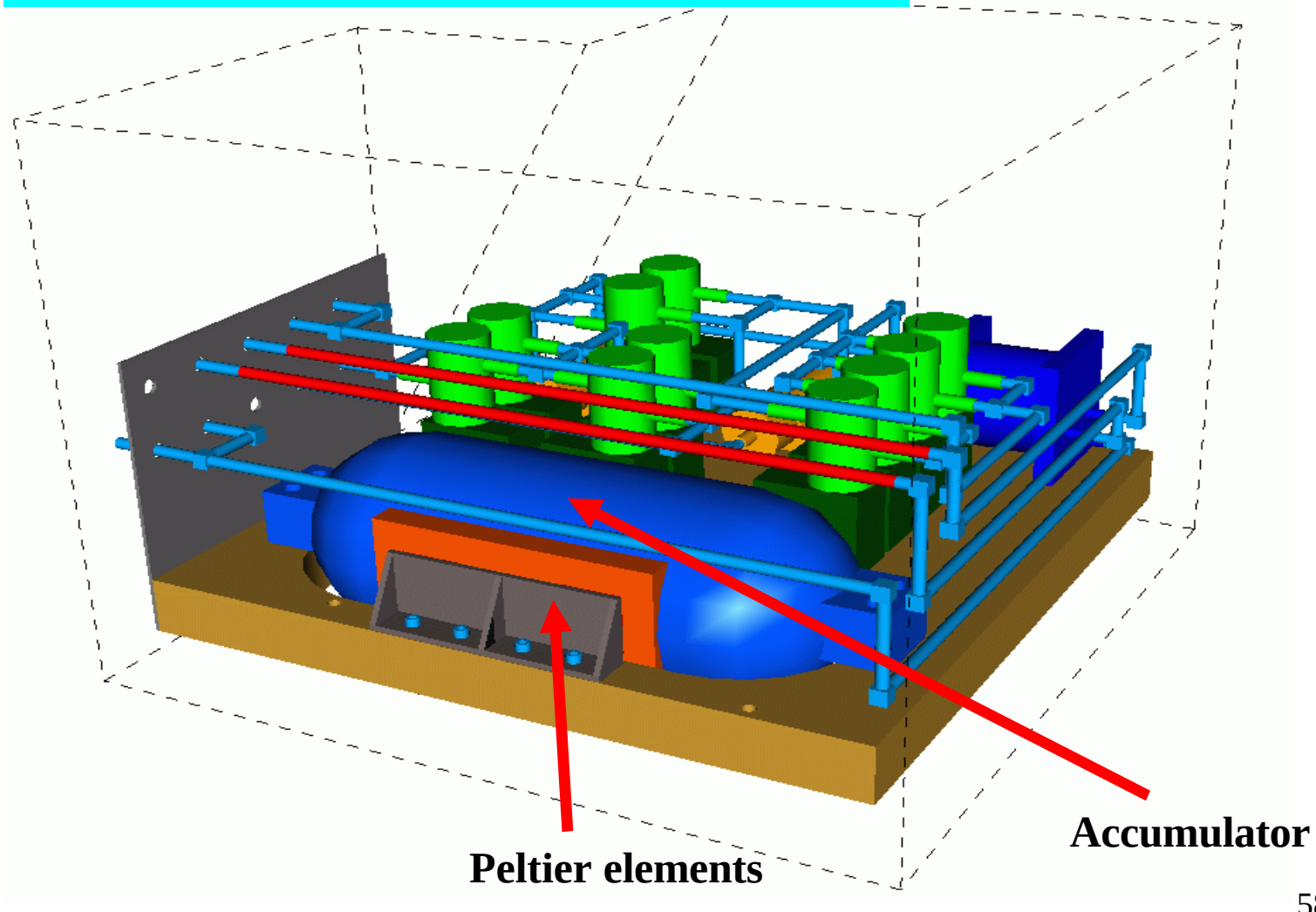
# TTCS System Overview



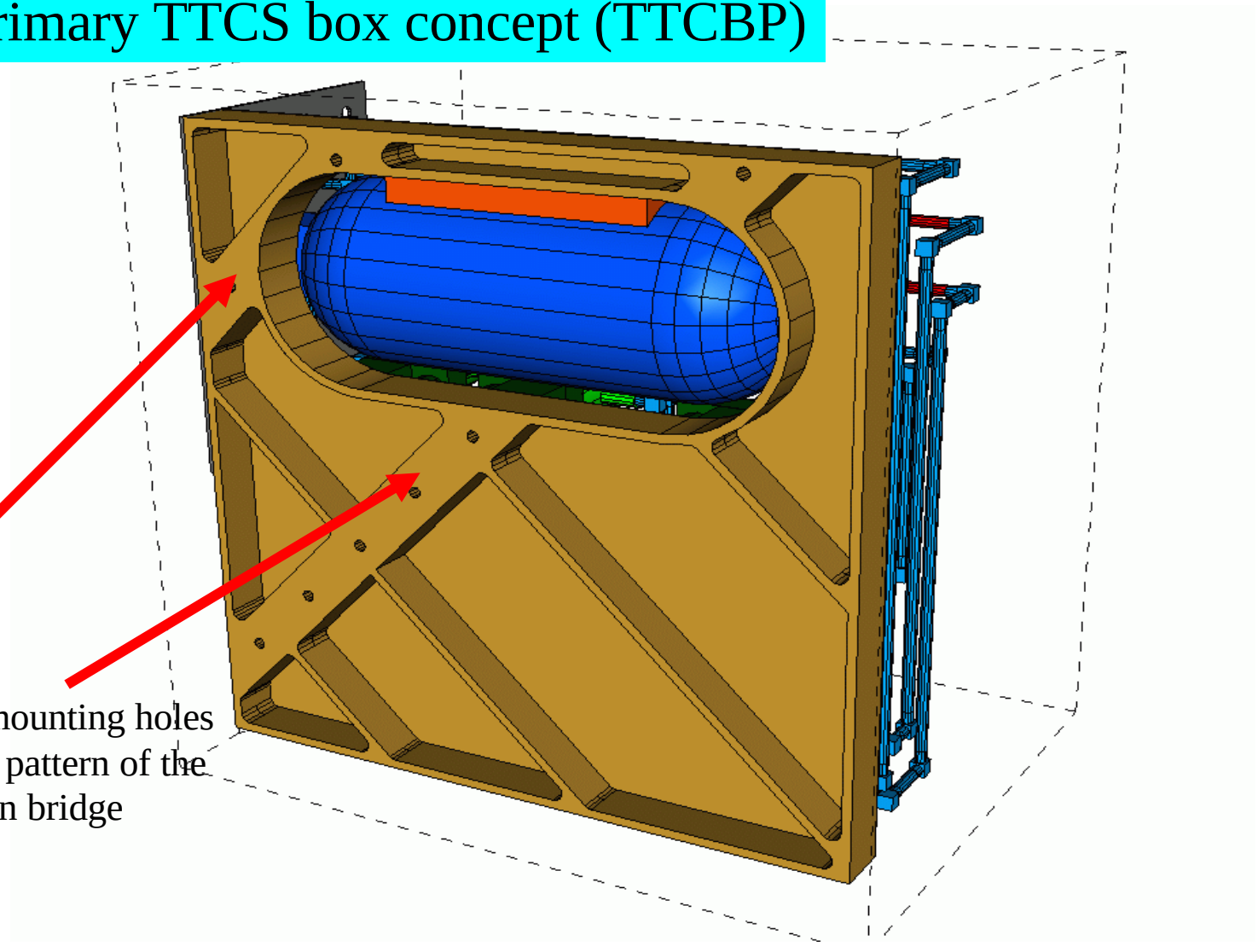
# Primary TTCS box concept (TTCBP)



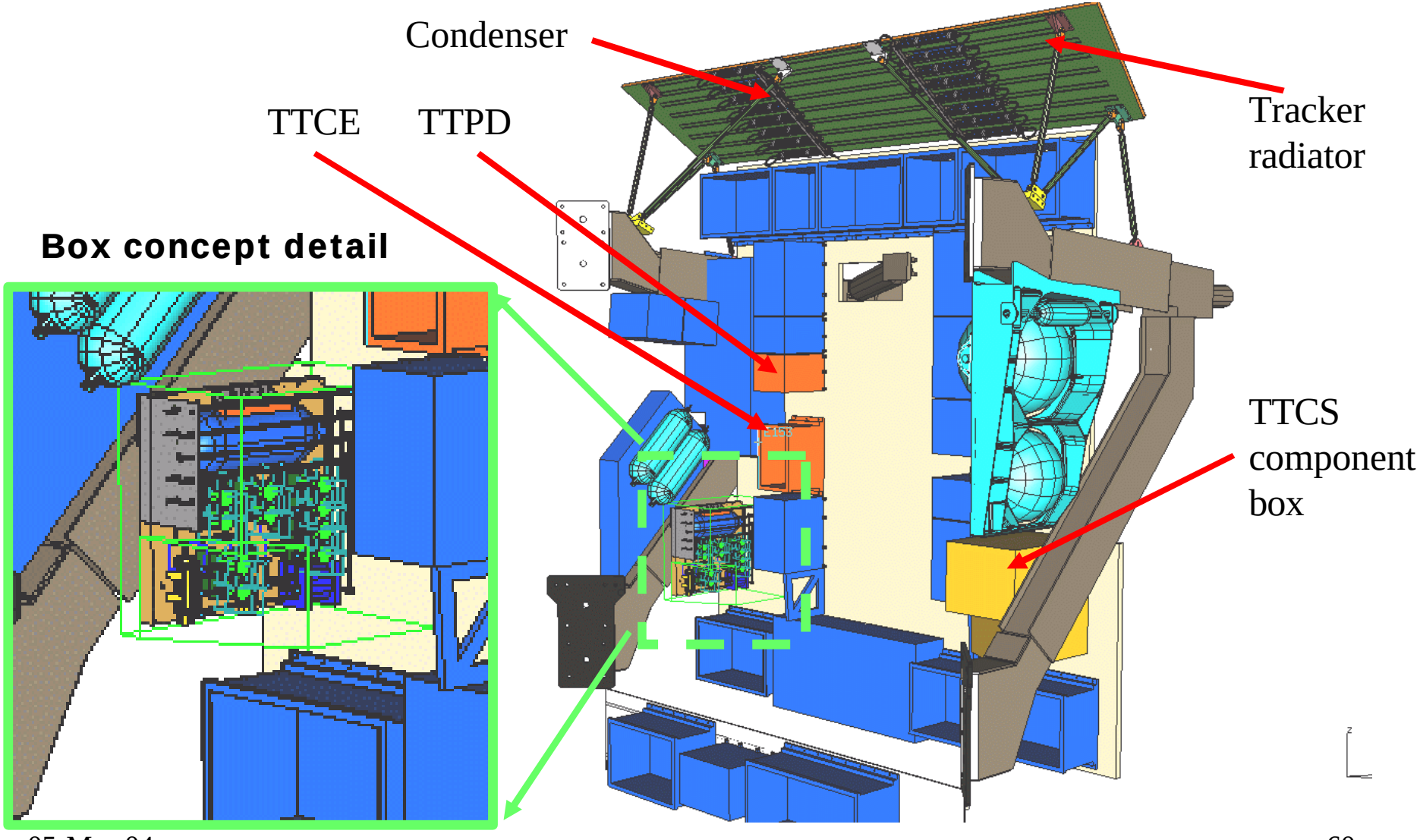
# Primary TTCS box concept (TTCBP)

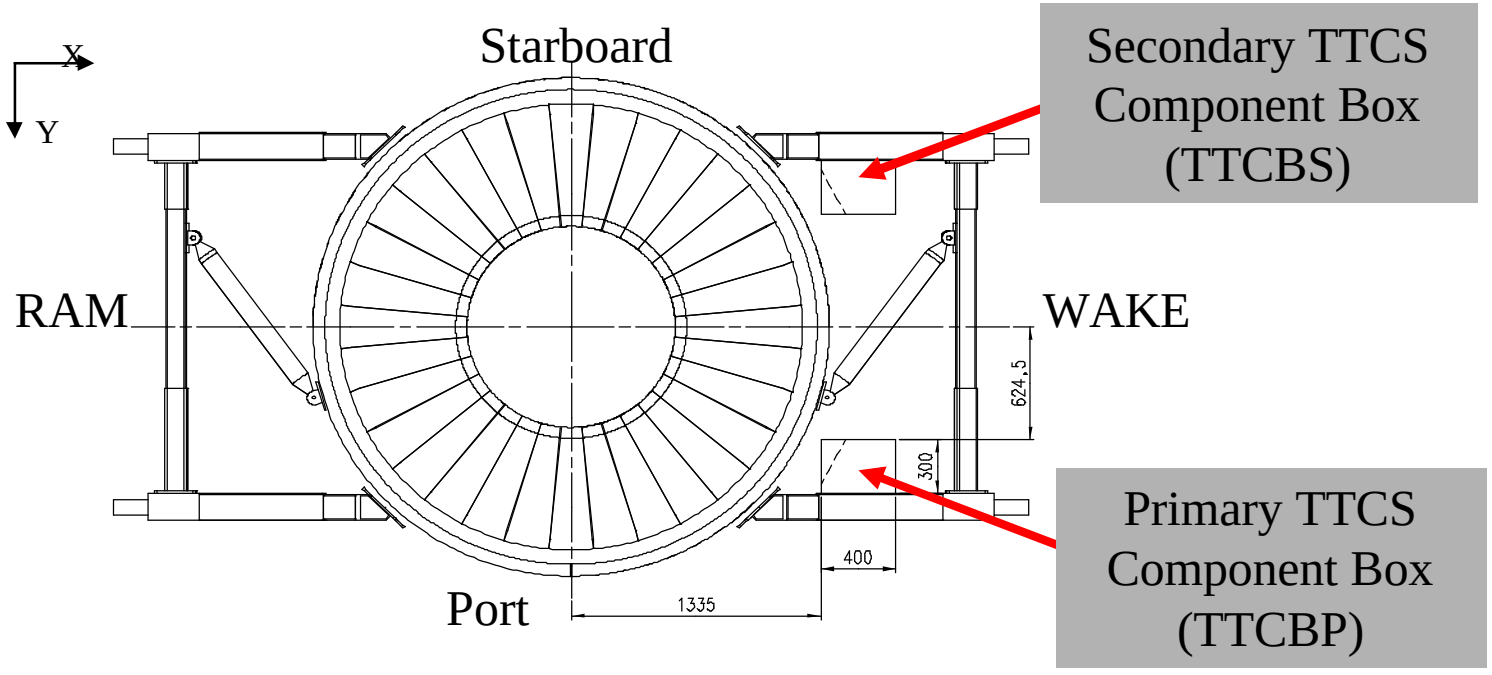


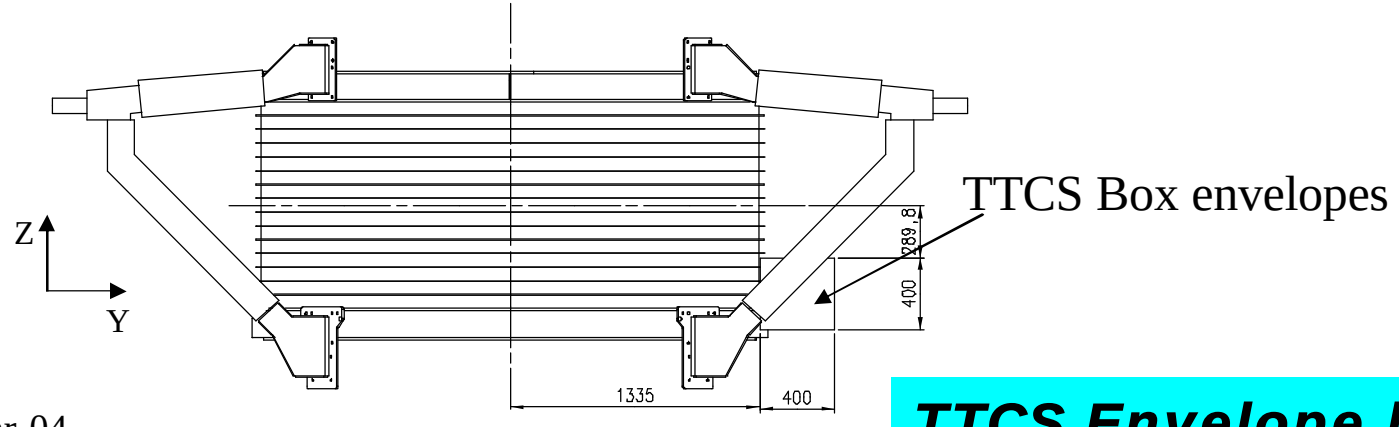
# Primary TTCS box concept (TTCBP)



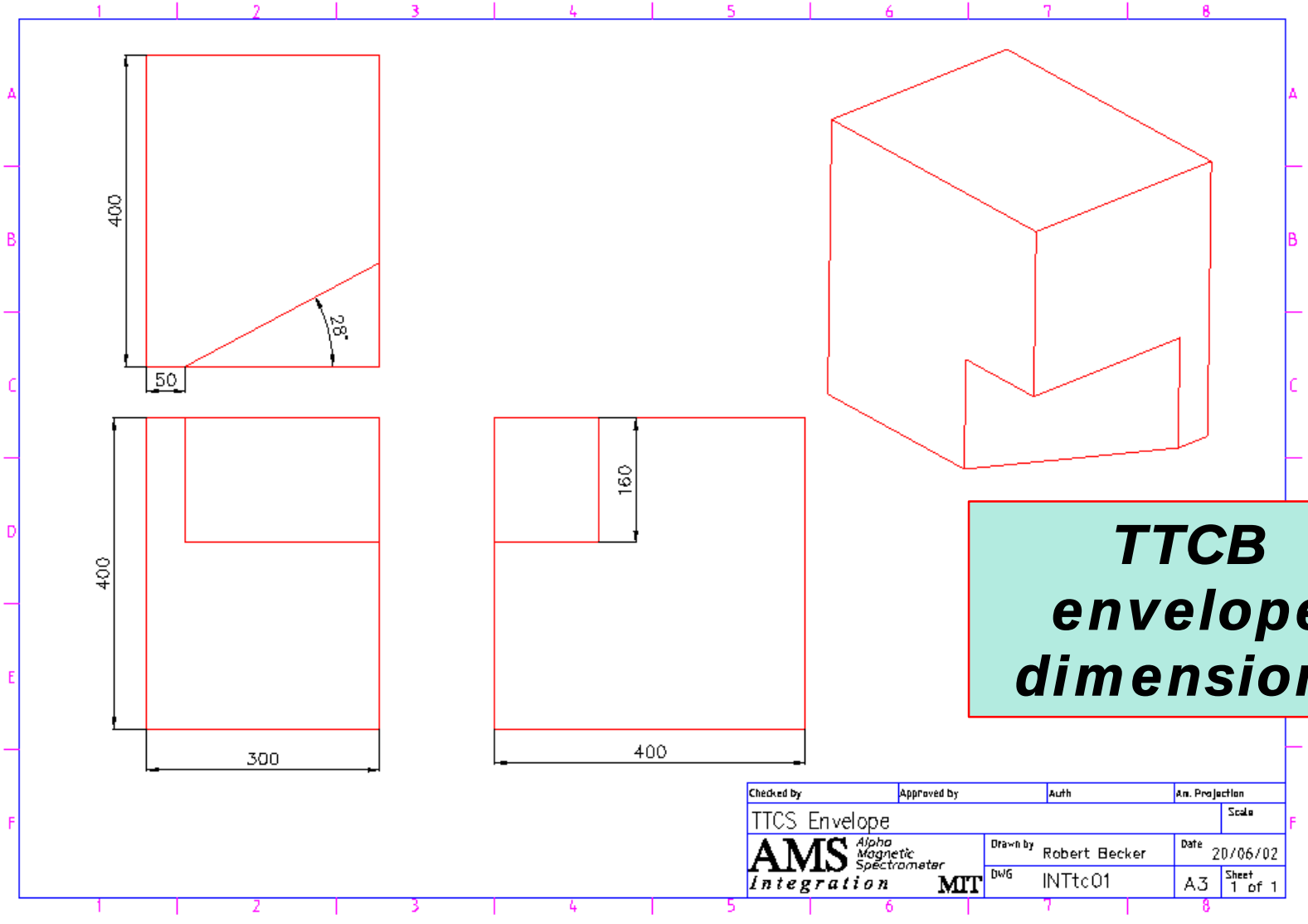
TTCB base plate mounting holes to the generic hole pattern of the USS lower trunnion bridge


Condenser
TTCE
TTPD
Tracker radiator
Box concept detail
TTCS component box



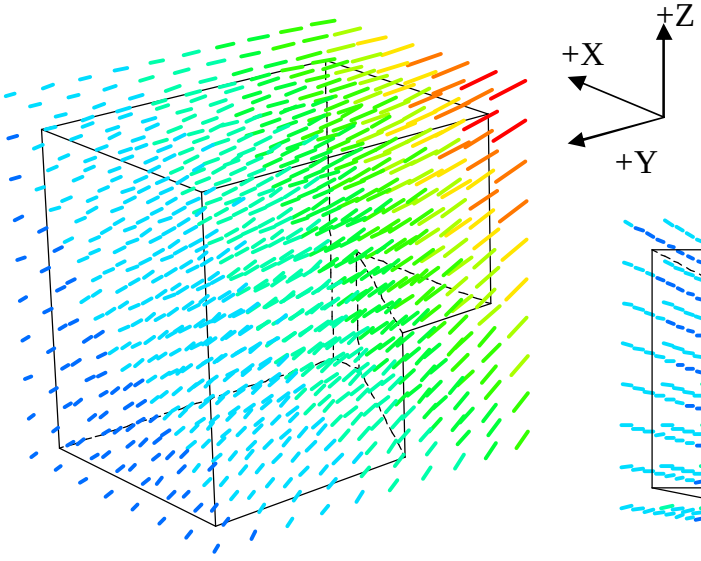



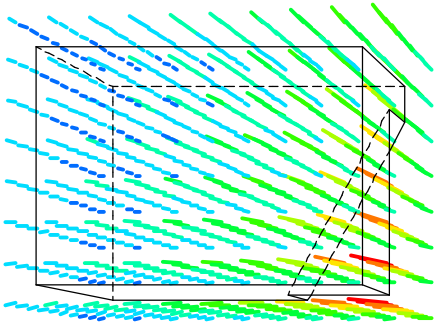

**TTCS Envelope location**



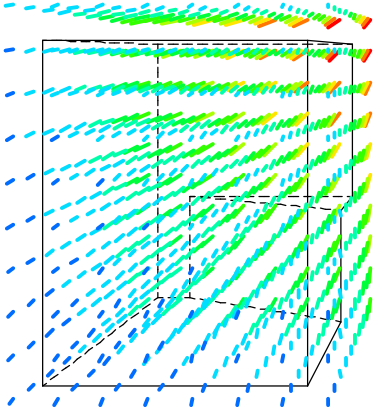

**TTCB envelope dimensions**

# TTCS Box magnetic field map

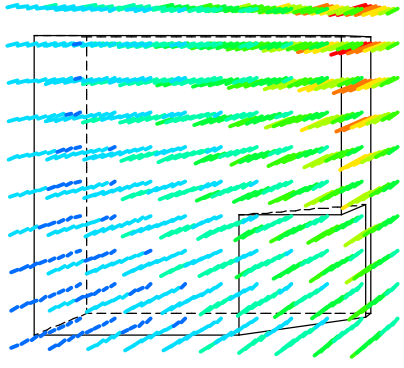


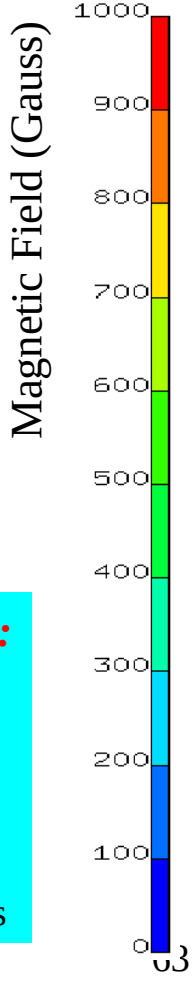
Top View (–Z)



Back View (–Y)



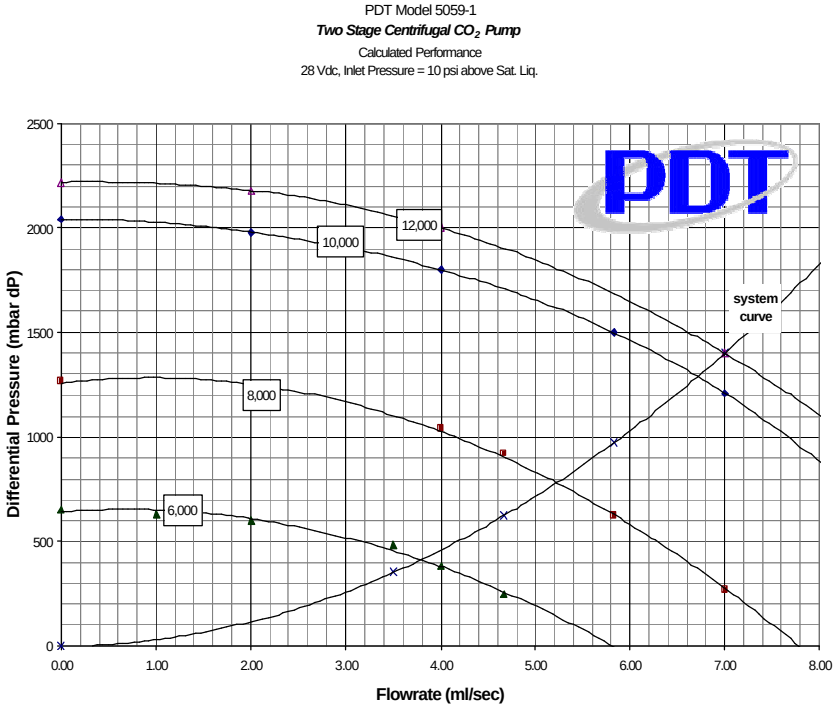
Side View (+X)

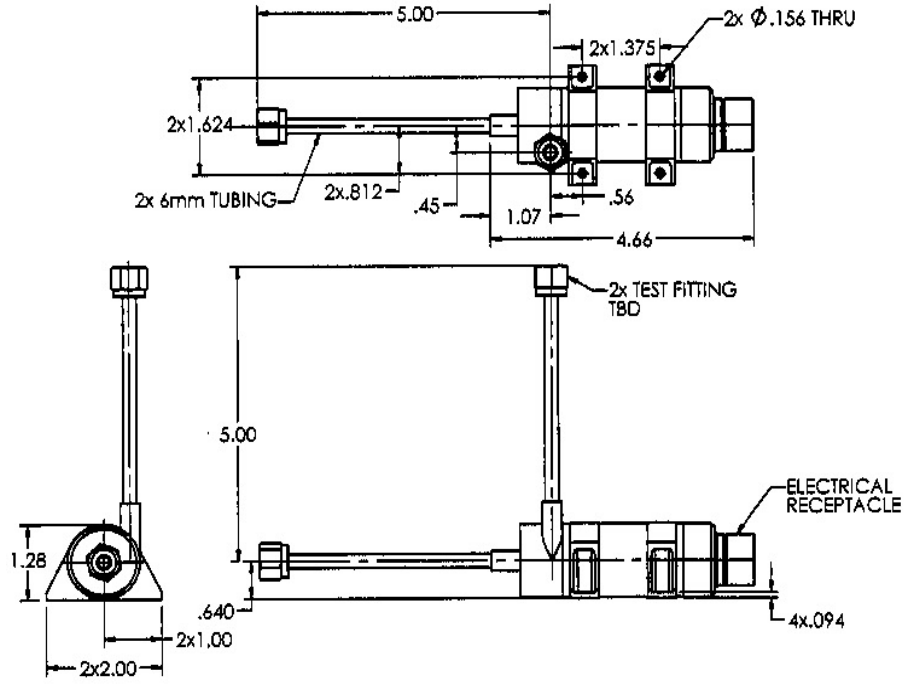



***Magnetic field facts:***

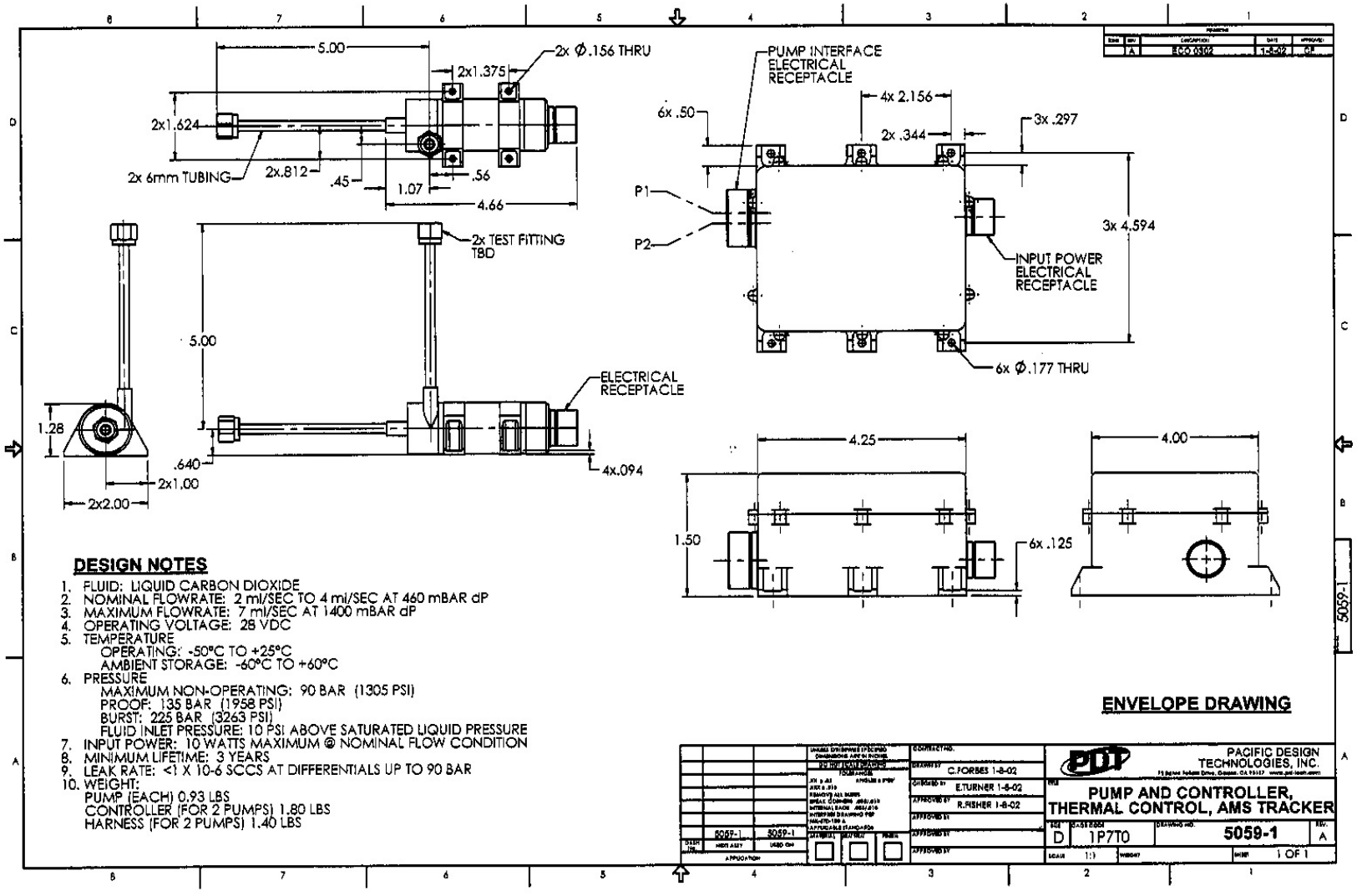
- Min: 141 Gauss
- Max: 998 Gauss
- Average: 371 Gauss
- Average X: 100 Gauss
- Average Y: 308 Gauss
- Average Z: -150 Gauss

# TTCS Circulation pump



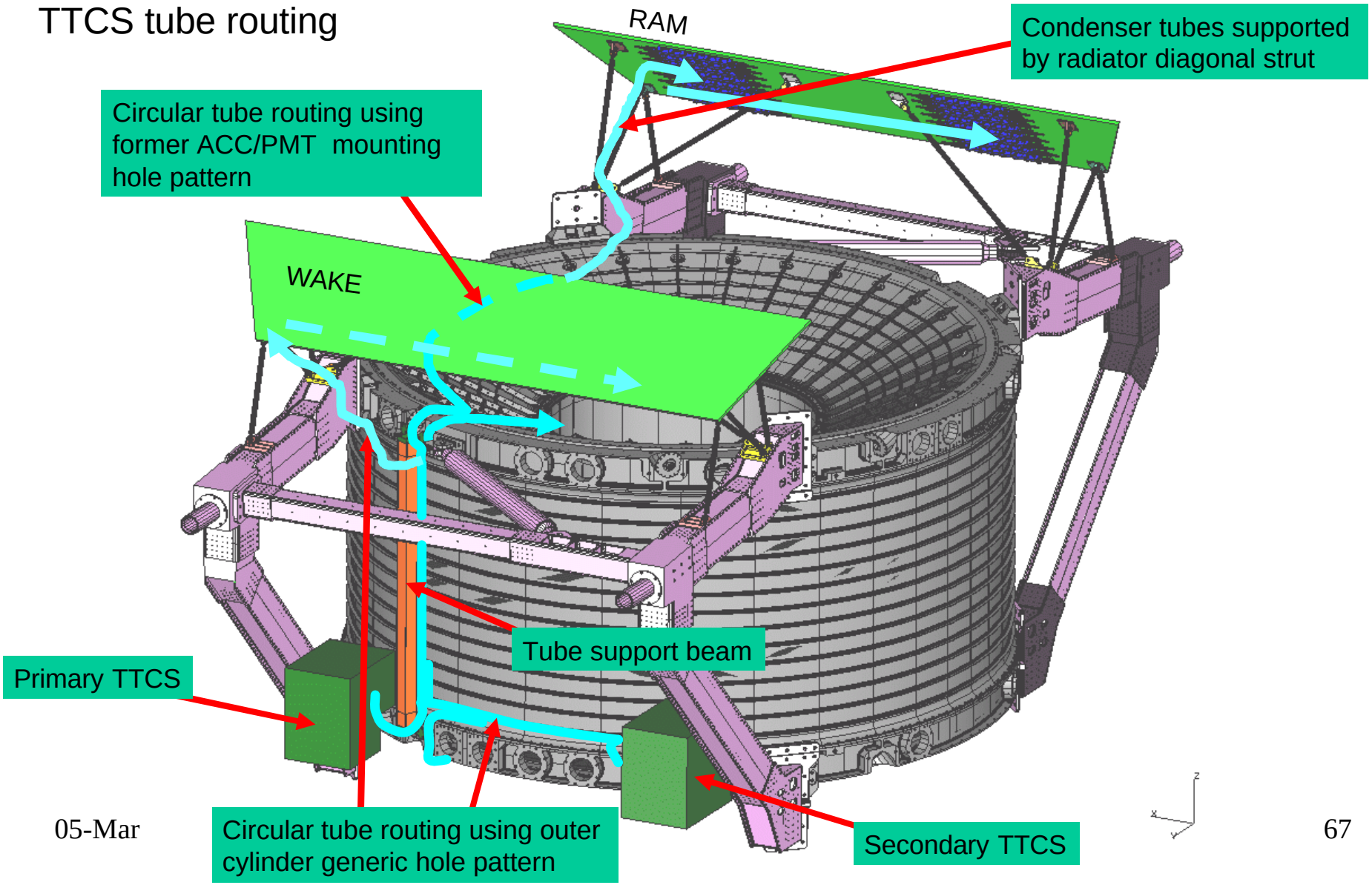




- Pacific Design Technologies (PDT) in Goleta(Ca) has been contracted to develop the TTCS pumps.
- The TTCS pump will be a modified Mars Pathfinder and MER centrifugal pump, optimized for the TTCS flow- and differential- and system pressure range, but with the reliability of the proven Mars pumps, which have operated successfully during the missions to Mars in 1997 and 2003.

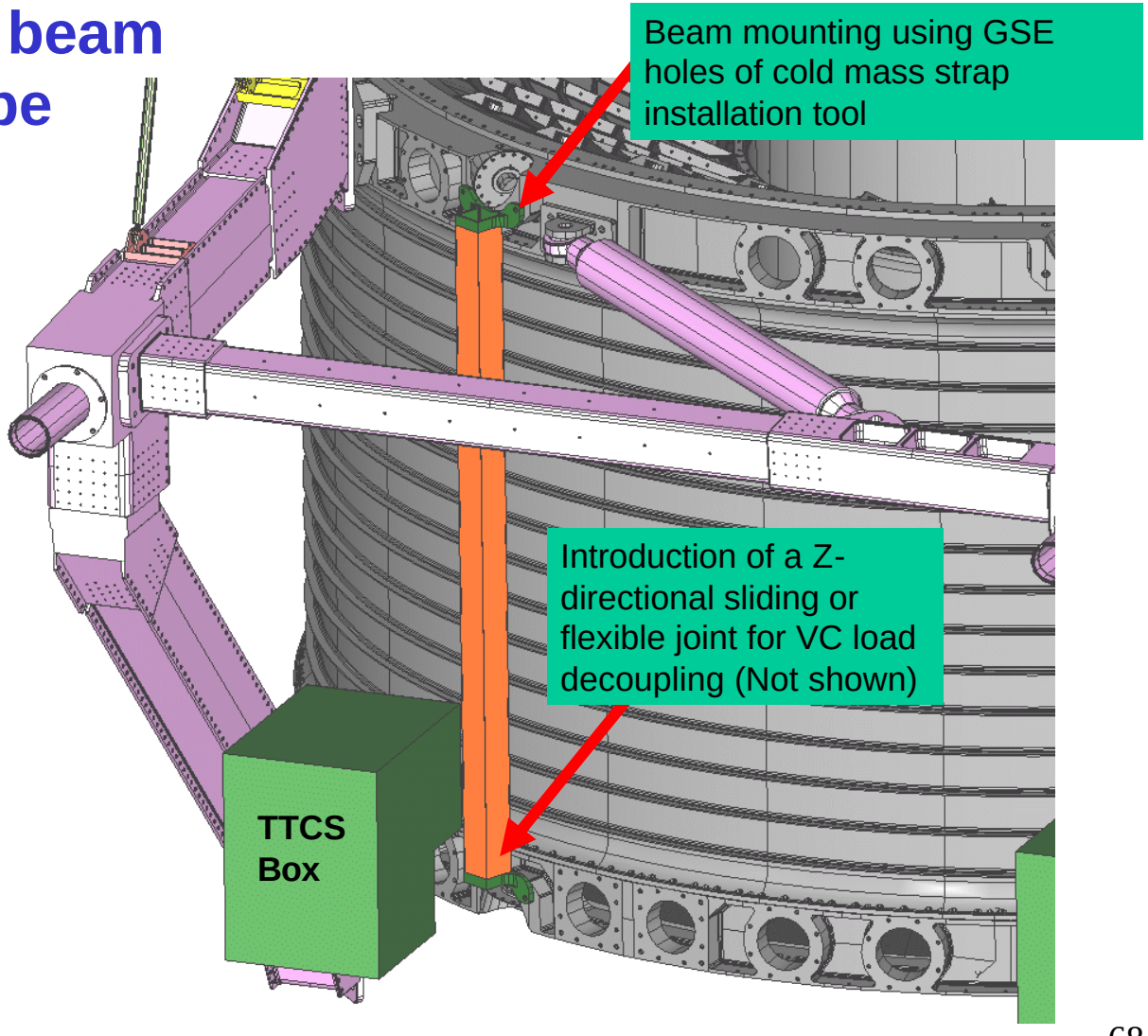

5.00
2x1.375
2x Ø.156 THRU
2x1.624
2x 6mm TUBING
2x.812
.45
1.07
.56
4.66
PUMP INTERFACE ELECTRICAL RECEPTACLE
6x .50
4x 2.156
2x .344
3x .297
P1
P2
3x 4.594
INPUT POWER ELECTRICAL RECEPTACLE
6x Ø.177 THRU
2x TEST FITTING TBD
5.00
ELECTRICAL RECEPTACLE
1.28
.640
4x.094
2x1.00
2x2.00
4.25
4.00
1.50
6x .125
DESIGN NOTES
1. FLUID: LIQUID CARBON DIOXIDE
2. NOMINAL FLOWRATE: 2 ml/SEC TO 4 ml/SEC AT 460 mBAR dP
3. MAXIMUM FLOWRATE: 7 ml/SEC AT 1400 mBAR dP
4. OPERATING VOLTAGE: 28 VDC
5. TEMPERATURE
OPERATING: -50°C TO +25°C
AMBIENT STORAGE: -60°C TO +60°C
6. PRESSURE
MAXIMUM NON-OPERATING: 90 BAR (1305 PSI)
PROOF: 135 BAR (1958 PSI)
BURST: 225 BAR (3263 PSI)
FLUID INLET PRESSURE: 10 PSI ABOVE SATURATED LIQUID PRESSURE
7. INPUT POWER: 10 WATTS MAXIMUM @ NOMINAL FLOW CONDITION
8. MINIMUM LIFETIME: 3 YEARS
9. LEAK RATE: <1 X 10-6 SCCS AT DIFFERENTIALS UP TO 90 BAR
10. WEIGHT:
PUMP (EACH) 0.93 LBS
CONTROLLER (FOR 2 PUMPS) 1.80 LBS
HARNESS (FOR 2 PUMPS) 1.40 LBS
ENVELOPE DRAWING
PACIFIC DESIGN TECHNOLOGIES, INC.
C.FORBES 1-8-02
E.TURNER 1-8-02
R.FISHER 1-8-02
PUMP AND CONTROLLER, THERMAL CONTROL, AMS TRACKER
D
1P7T0
5059-1
A
1:1
1 OF 1
5059-1

# TTCS Tube Routing

# TTCS tube routing



# TTCS tube support beam for Z-directional tube routing




**Tube Support Beam Properties:**

- Square tube: 60x60x2mm,
- Length: 1.3mm
- Material: AA6061
- Beam assembly mass: 2 kg
- 1st resonance frequency: 62 Hz
- Displacement under 40g: 2.6mm
- Tube and fastener load: 2.3 kg
- MS (Ultimate): 2.6
- MS (Yield): 3.3