# Detector Movement System

**Andrew Cunningham**

ARUP

# Summary of Requirements

CERN

**Linear Collider Study Task 1 and 2**

Technical Basis for Study

# Summary of Requirements

## 4.1 Task 1 – Movement Platform

| Platform Design Criteria | | Value | Unit | Notes/assumptions |
|---|---|---|---|---|
| Detector | | ILD | | ILD is currently the most onerous system in terms of spatial and weight requirements |
| Detector Total Weight | | 15,500 | tonnes | Fully installed weight including services and supply etc for movement to beam. It is assumed that additional weight is not added to the detector (and therefore the platform) once on the beam line, or at the garage |
| Detector Segment Weight | Door -Z | 3,500 | tonnes | An important design case for the platform will be when the detector is split for maintenance either on the beam line, or in the garage position. Weights provided by email (Oriunno-Osbourne 27th May 2011). The SiD and ILD have different combinations of slices when split. The worst loading case will be determined from the various combinations of ILD and SiD ring maintenance arrangements |
| | Barrel -1 | 2,500 | tonnes | |
| | Barrel 0 | 3,500 | tonnes | |
| | Barrel +1 | 2,500 | tonnes | |
| | Door +Z | 3,500 | tonnes | |
| Slab Vibrations Modes | First Mode | 20 | Hz | Assumed feet and ground infinitely rigid with damping ratio of ~2% |
| | Further Modes | | | To be advised and informed by study, to include feet, invert slab and ground are expected to add compliance to the platform system |
| Magnetic field at top of platform | | <1,000 | gauss | It has been assumed that this is at the top of the platform |
| Operating Temperature Range | | $20^{o}C \pm 2^{o}C$ | | |



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# Summary of Requirements

| Platform Design Criteria (continued) | | Value | Unit | Notes/assumptions |
|---|---|---|---|---|
| Movement System | Mechanism | Rollers or air pads | | The platform design will be developed to be compatible with either roller or air pads. Should the design place any onerous performance requirement on one particular system this will be identified and where appropriate a mitigation measure identified. If a single platform design cannot service both systems clarification will be sought on the movement system to be used. |
| | Drive | Gripper jacks | | |
| Platform | Concept | Single platform per detector | | The design will be progressed on the basis that the two detectors are moved independently on separate platforms |
| | Material | Reinforced Concrete | | A Steel support truss will not be considered further |
| | Footprint | 20x20 | m | |
| | Elevation | Study to confirm this | | Beam to top of platform set by detector, platform depth below to be established during study. ILD to be used as greater beam to base distance (thinnest platform for same rail level) |
| Minimum distance between detectors | | 15 | m | Minimum proximity of detectors at any location measured from exterior of iron |



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# Summary of Requirements

| Platform Performance Requirement | | Value | Unit | Notes/assumptions |
|---|---|---|---|---|
| **Movement duration** | | 5 | hours | This is assumed to be the detector "speed" when travelling and would therefore not include preparation time to disconnect/connect detector or preparation of the movement system |
| **Speed** | | >1 | mm/s | (after acceleration). Assumed that the 5 hour requirement governs |
| **Number of movements** | | 10 | $year^{-1}$ | Assumed that both detectors will be moved an equal number of times |
| **Limit of acceleration** | | 0.05 | g | This is a limit during movement |
| **Maintenance allowances** | On Beam | 2 | m | This is the between adjacent sections (end cap to centre section) when detector opened in the beam location |
| | In Garage | 6 | m | This is the between adjacent sections (end cap to centre section) when detector opened in the garage location |
| **Static Deformation of platform** | | +-2 | mm | In all locations, including during movement (as a single element or in sections) |
| **Positioning relative to beam** | | +-1 | mm | In relation to the beam location |

Limited to under the footprint of the detector.
n/a when un-slicing



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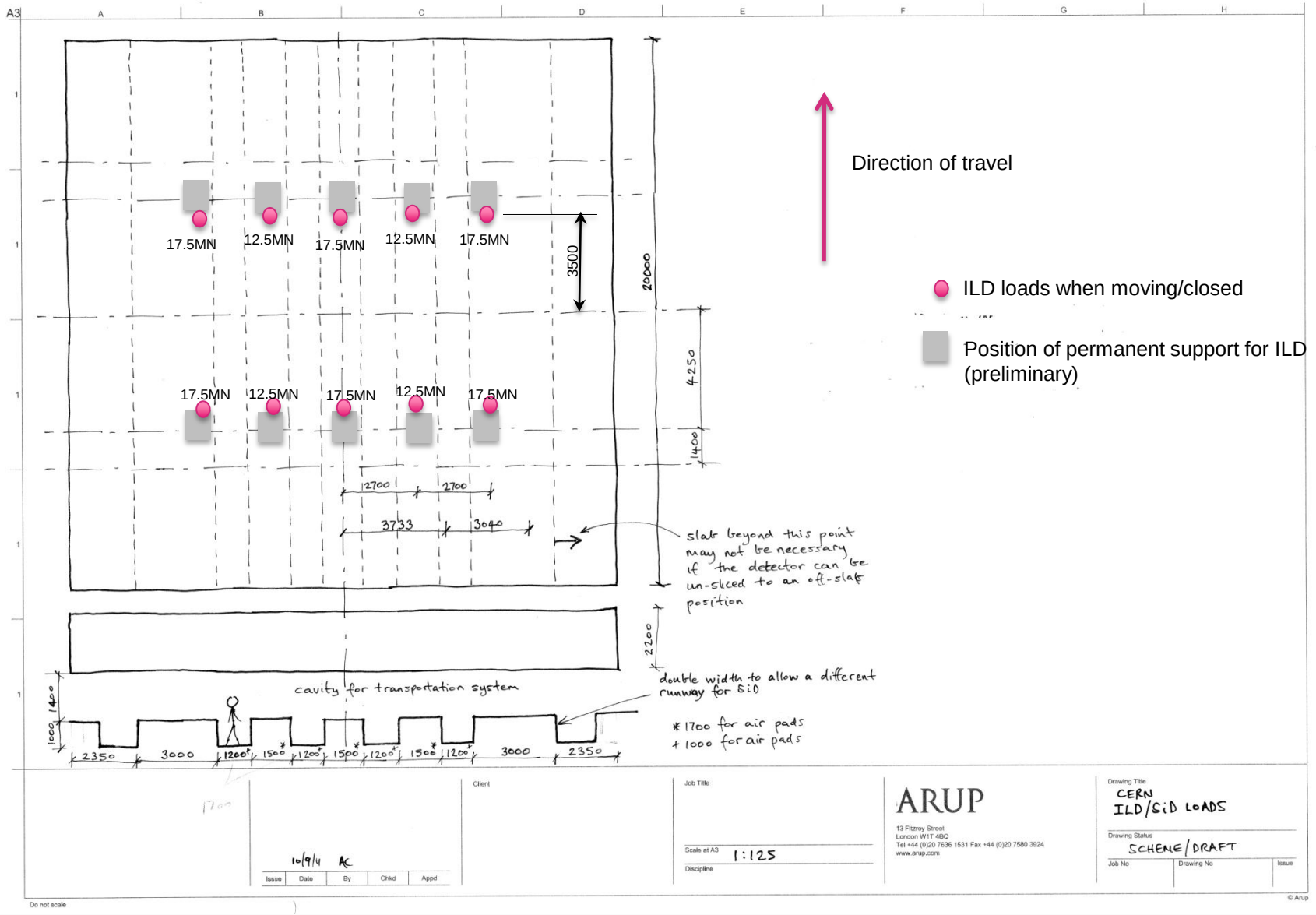
# Top Loads on the Slab

# ILD top loads when moving/closed



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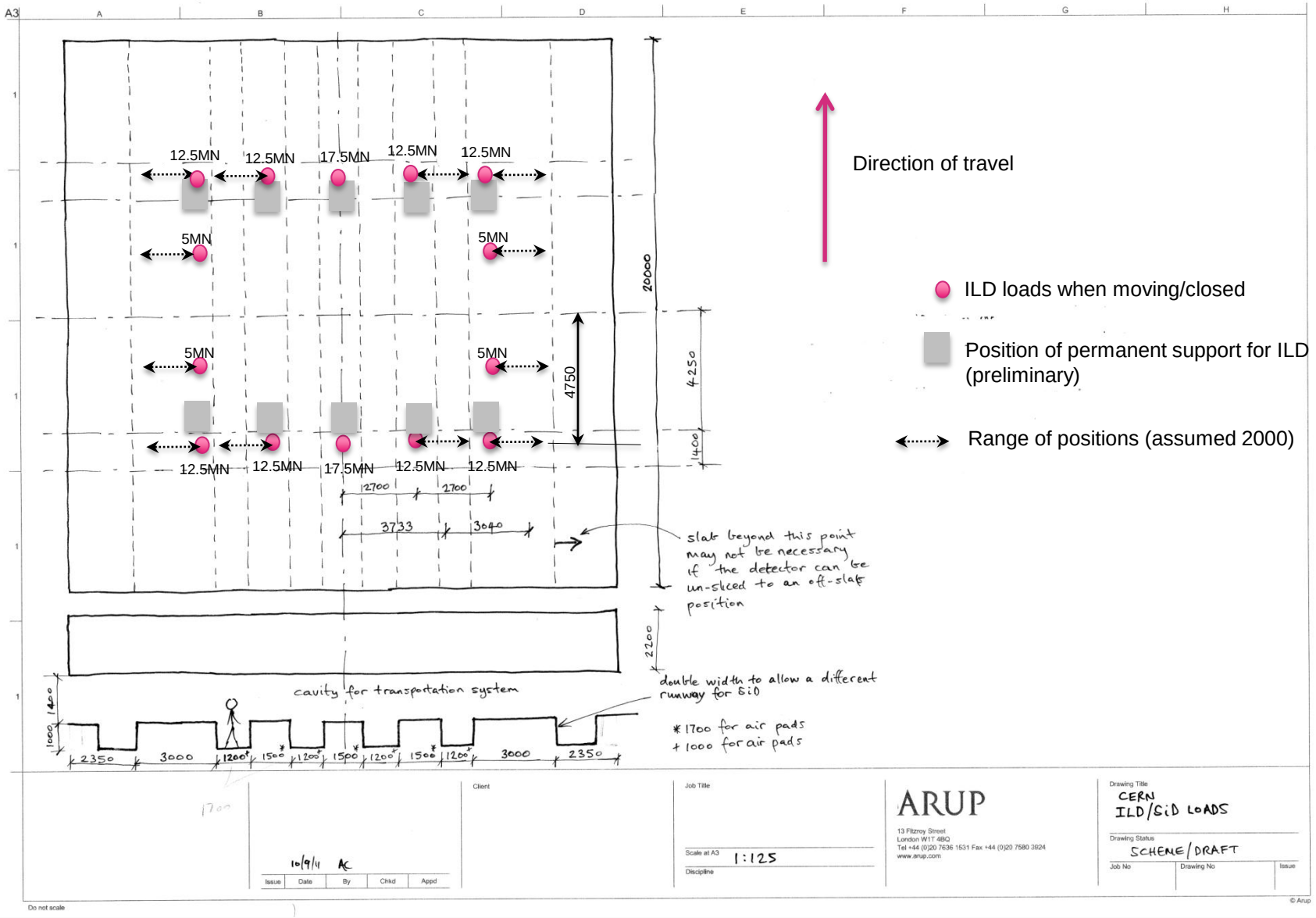
# ILD top loads when un-slicing



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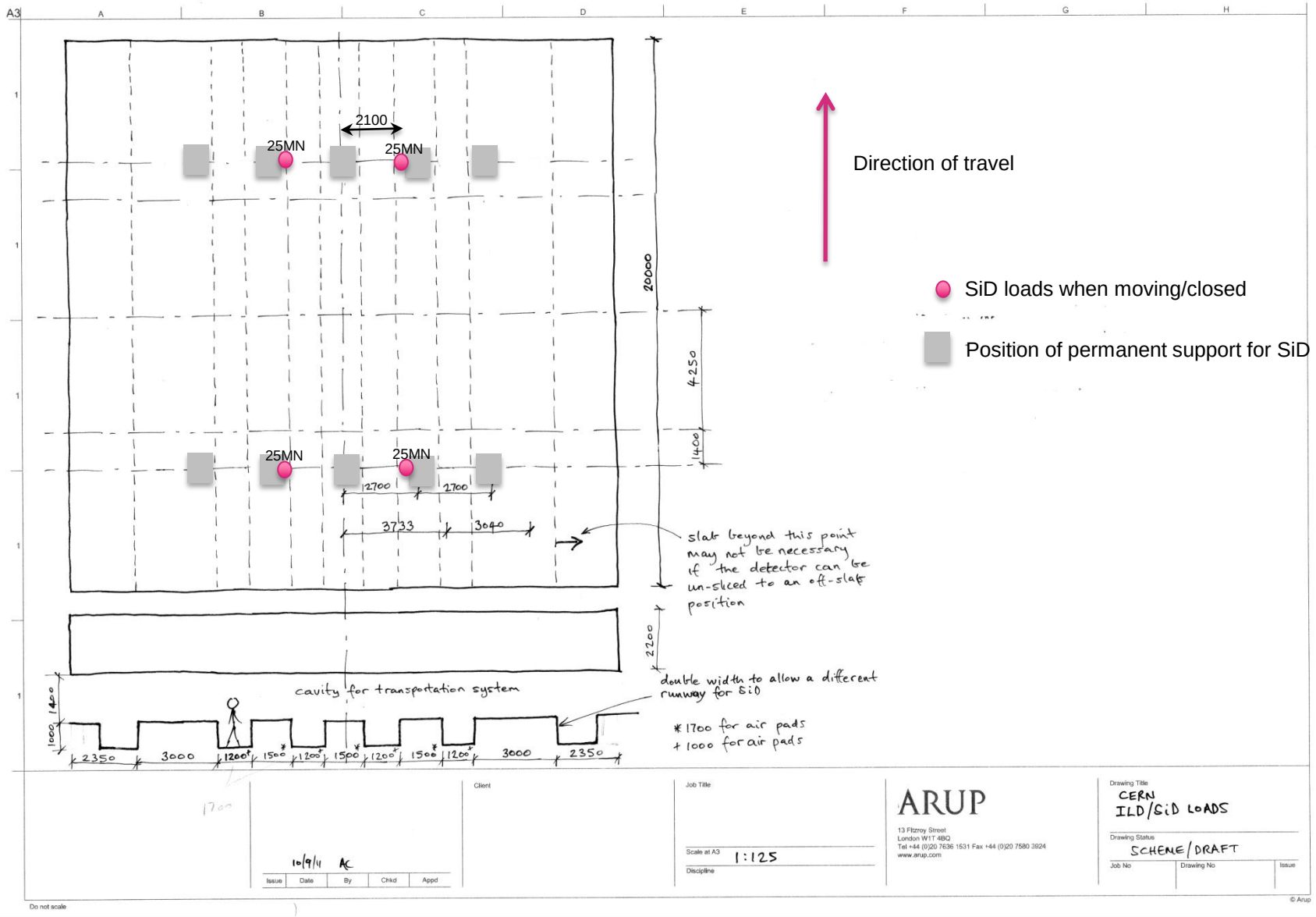
# Slab Flex with ILD

- **A lot of slab is outside the permanent supports and the detector envelope (is it all necessary?) – N/A for displacement limits**
- **The top loads change position significantly during un-slicing – displacement limit not applicable when un-slicing**

# SiD top loads when moving/closed



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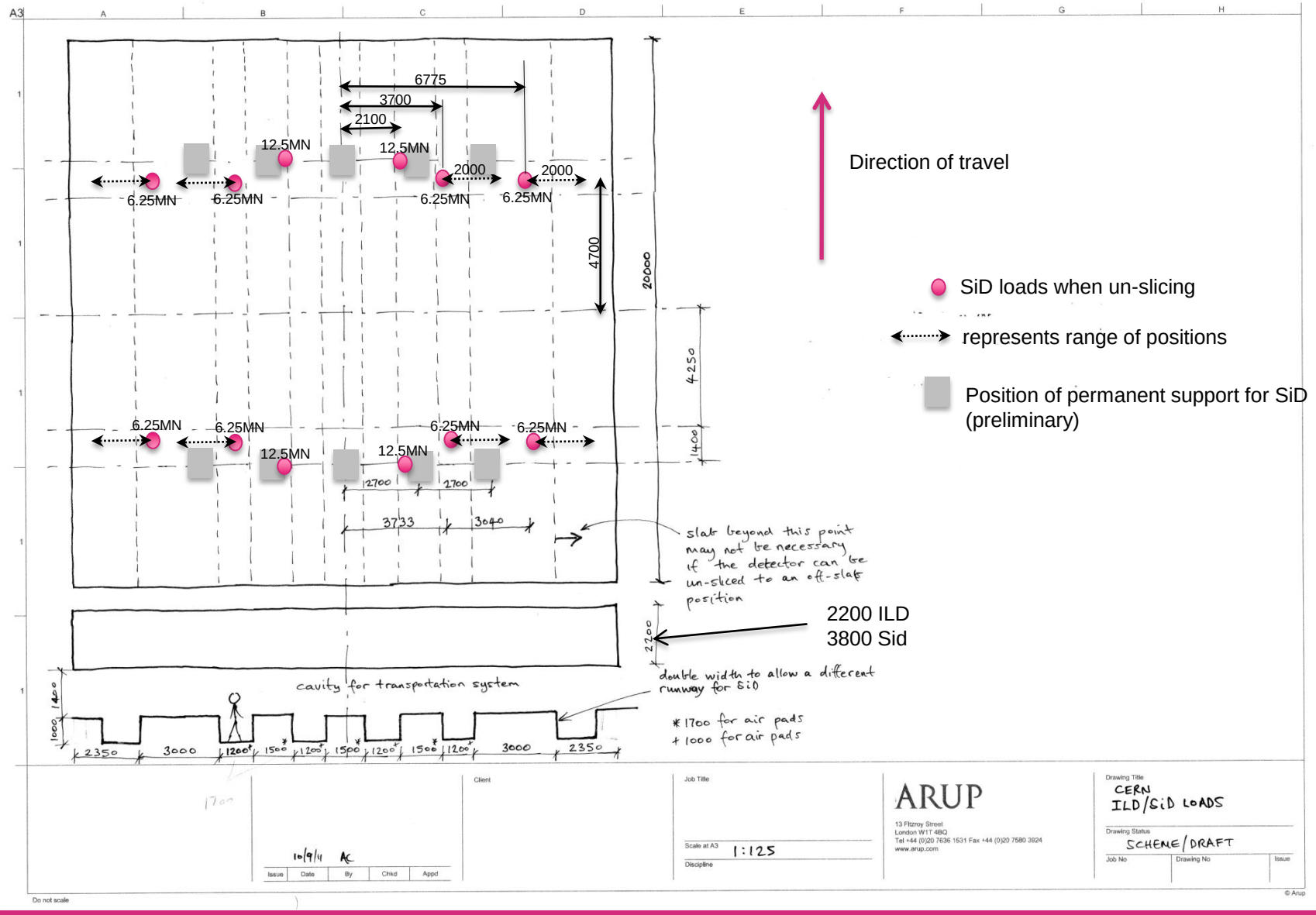
# SiD top loads when un-slicing



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# Slab flexure critical – but what is its definition?

- **Design using +/-2mm over slab – UNDER DETECTOR**
- **If the slab was smaller eg. 14x14m would it still be +/-2mm**
- **If yes, can we not just apply the +/-2mm over that part of the slab which is under the detector? – YES**
- **Does +/- 2mm mean that some part can go up by 2mm and some down by 2mm => 4mm amplitude?**
- **Is the deflection limit to be applied during un-slicing? - NO**

# Slab Flex Analysis

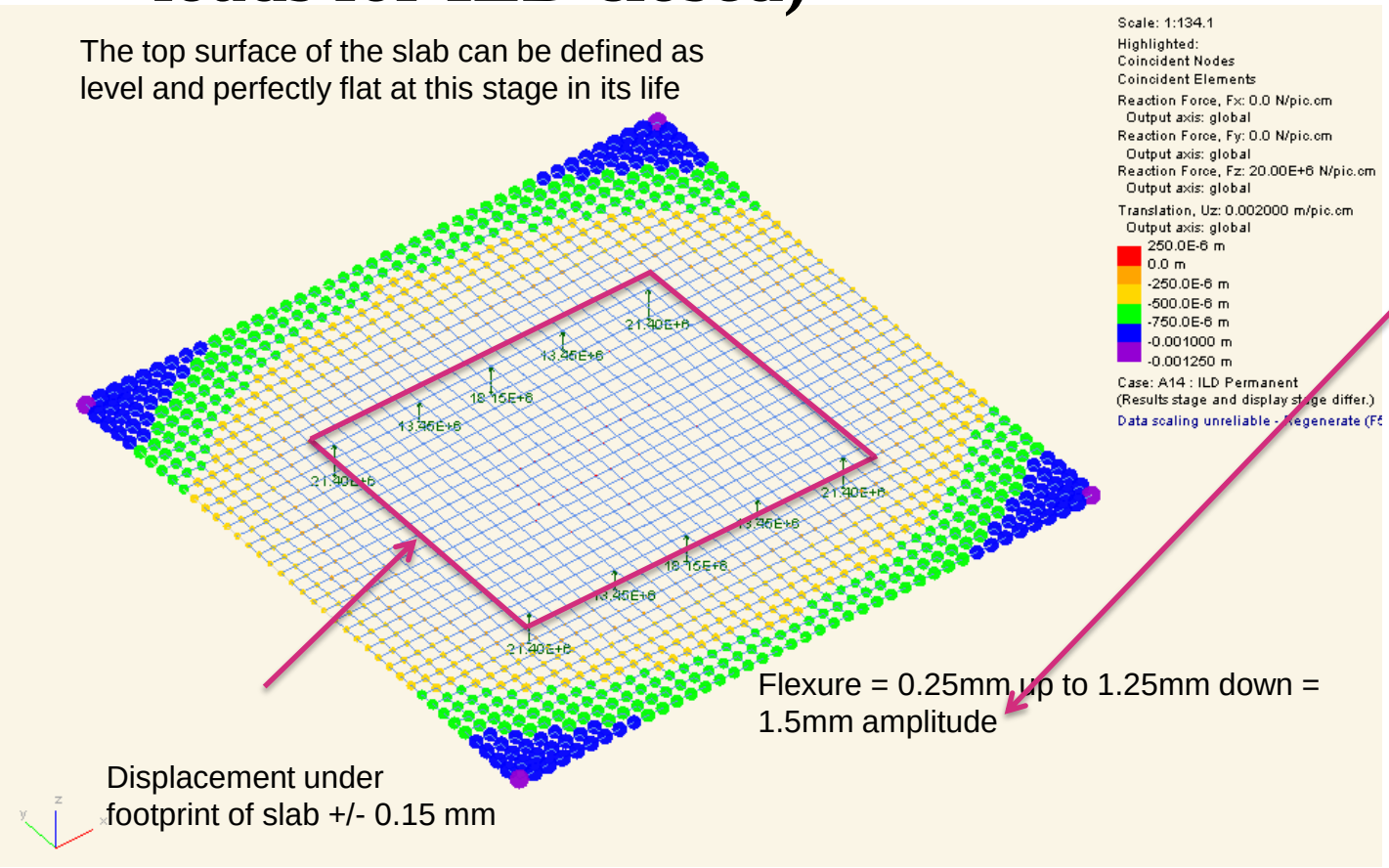
# A refined support system for ILD

- **Step 1: ILD Slab on permanent supports**
- **Step 2: Put ILD(closed) loads on top of slab**
- **Step 3: Jack onto transportation system**
- **Step 4: Consider un-slicing – not now subject to deflection limits**

# Step 1: ILD Slab on permanent supports

- **Slab on permanent supports (directly under the top loads for ILD closed)**

The top surface of the slab can be defined as level and perfectly flat at this stage in its life




Displacement under footprint of slab +/- 0.15 mm

Flexure = 0.25mm up to 1.25mm down = 1.5mm amplitude

But note this is a long term load case and the value will increase with creep - ongoing

Model summary:
E = 32GPa
Slab 20x20mx2.2m

Load = Slab self weight



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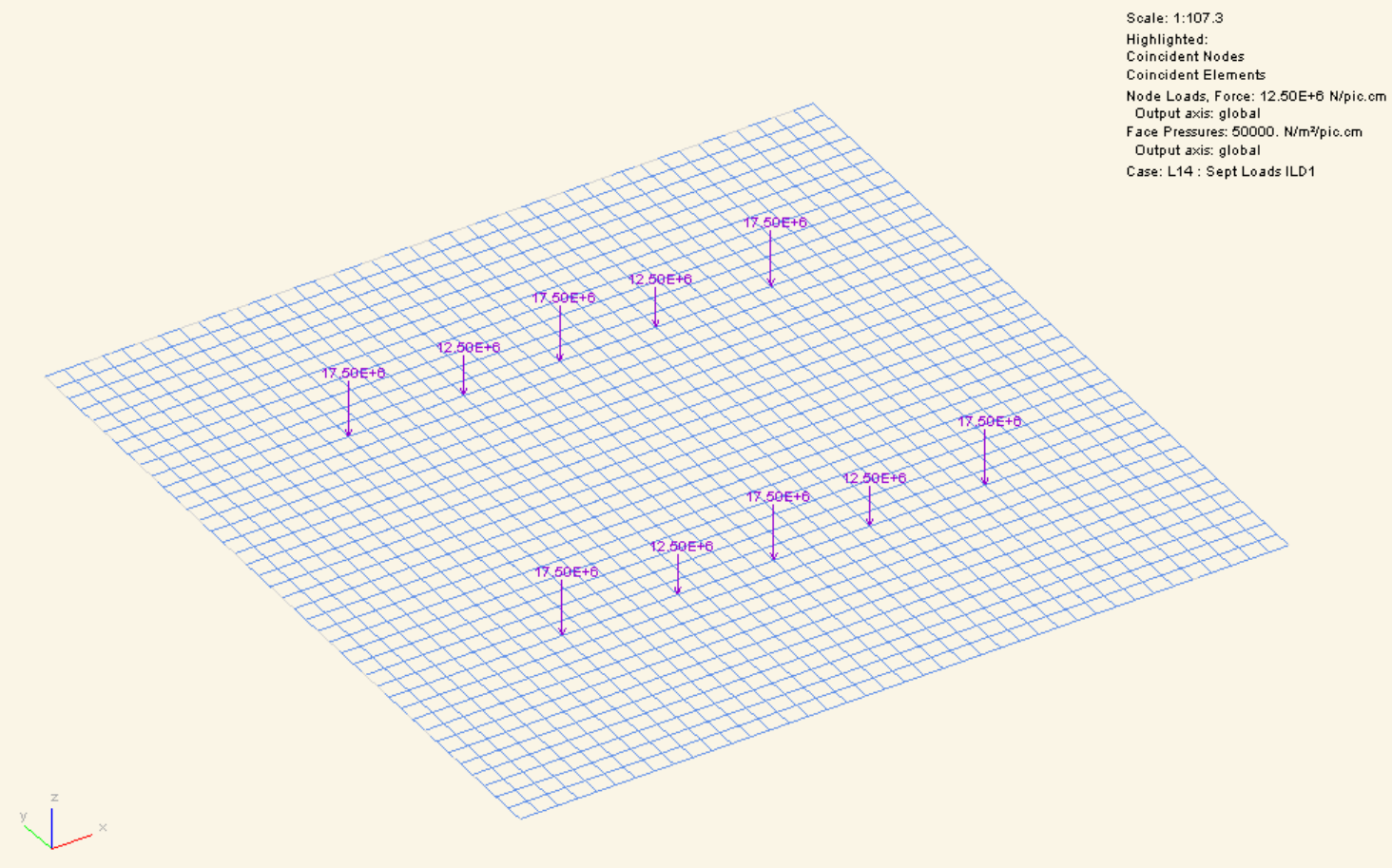
# Step 2: Put ILD(closed) loads on top of slab

- **This has negligible displacement effect because the loads are (nearly) directly above the supports**



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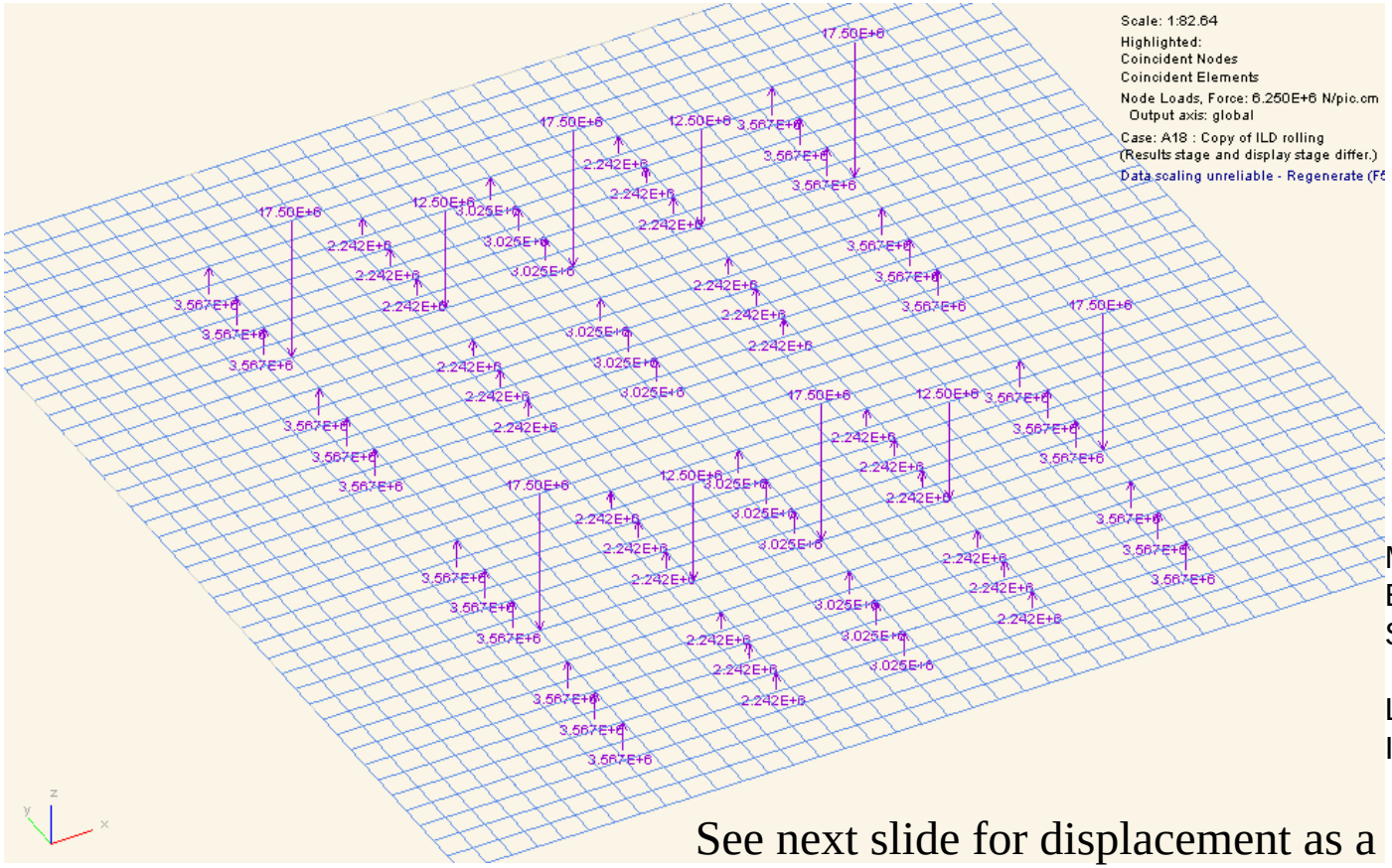
# Step 3: Jack onto transportation system

- **ILD (closed) effect upon top surface of jacking onto the transportation system (jack config 1)**




Model summary:
E = 32GPa
Slab 20x20mx2.2m

Load = Slab self weight + ILD (closed) top loads

See next slide for displacement as a result of step 3



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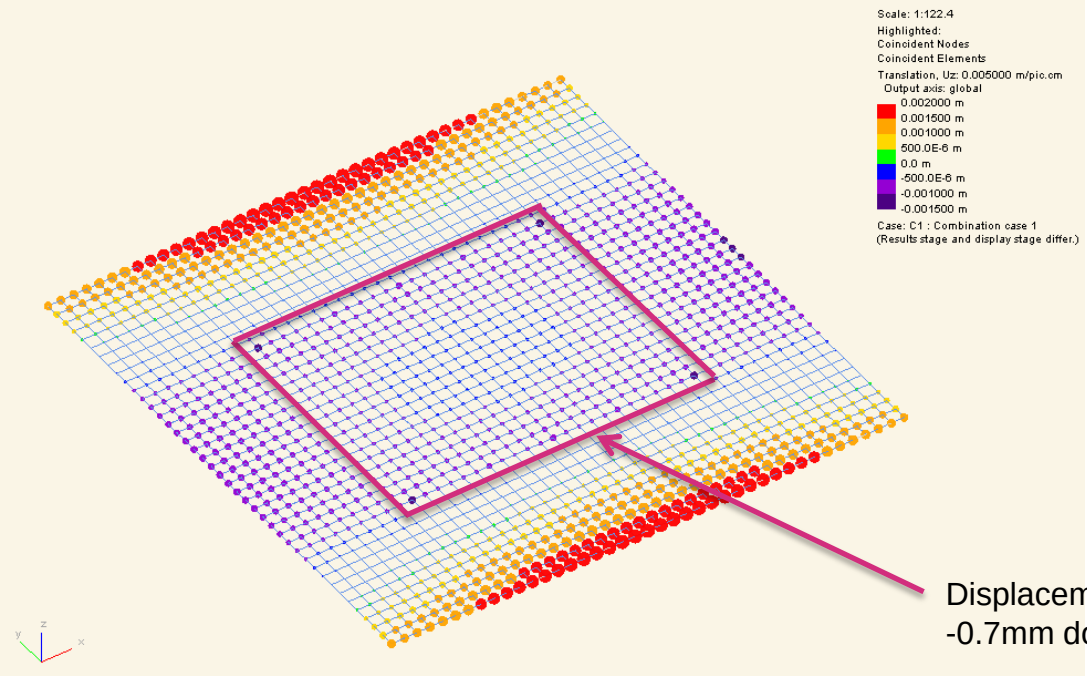
# Step 3 (continued)

- **ILD (closed) effect upon top surface of jacking onto the transportation system (jack config 1)**




Displacement under footprint of slab +0, -0.7mm down

Flexure = +1.9mm to -1.0mm

This meets the +/- 2mm tolerance

Note if the slab were smaller the reported deflection would drop significantly.

Model summary:
E = 32GPa
Slab 20x20mx2.2m

Load = [Slab self weight + ILD (closed) top loads + jack supports] – [Slab self weight on permanent supports]



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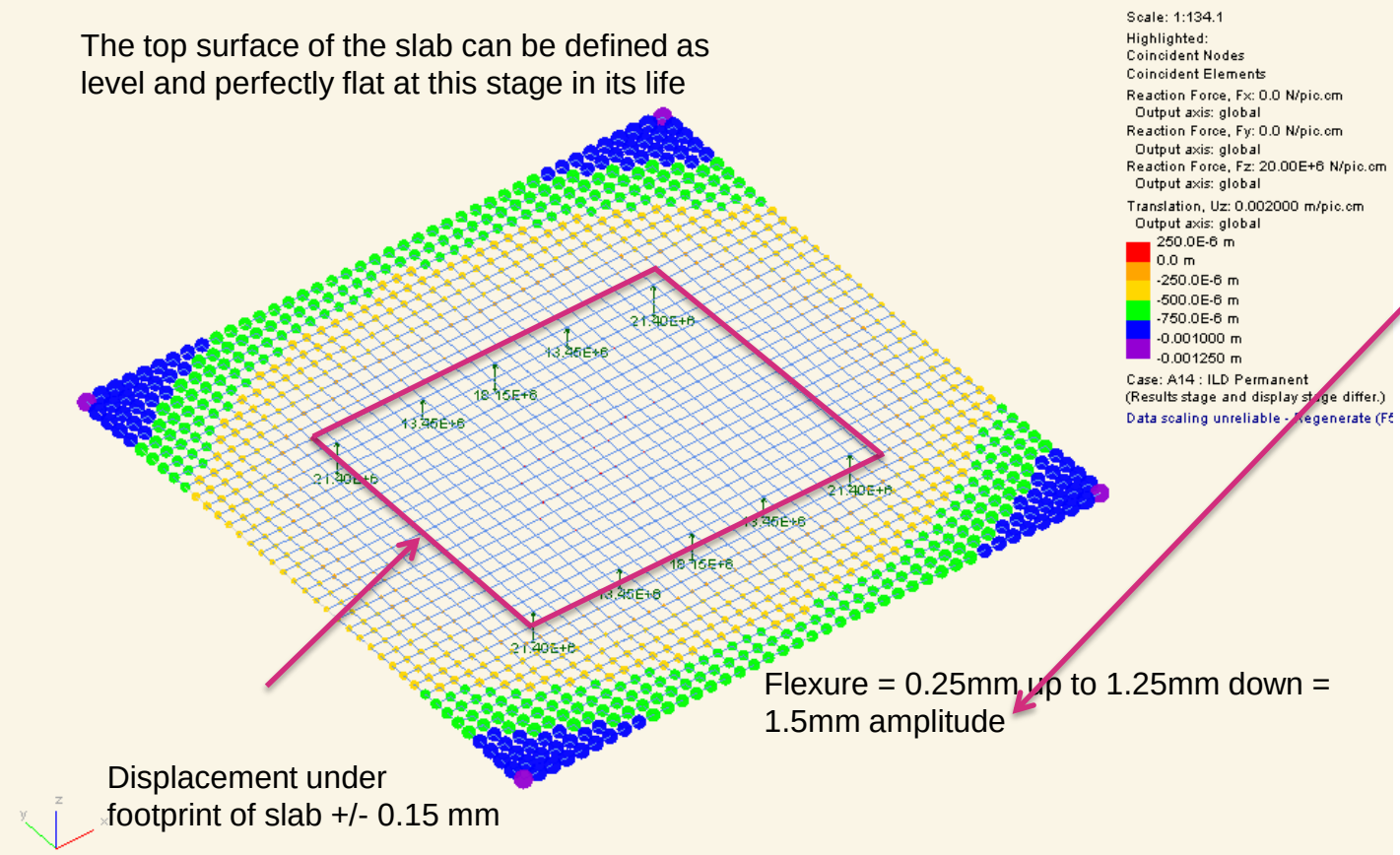
# Step 1: SiD Slab on permanent supports

- **Slab on permanent supports (directly under the top loads for ILD closed – so we use same tracks as ILD)**

The top surface of the slab can be defined as level and perfectly flat at this stage in its life

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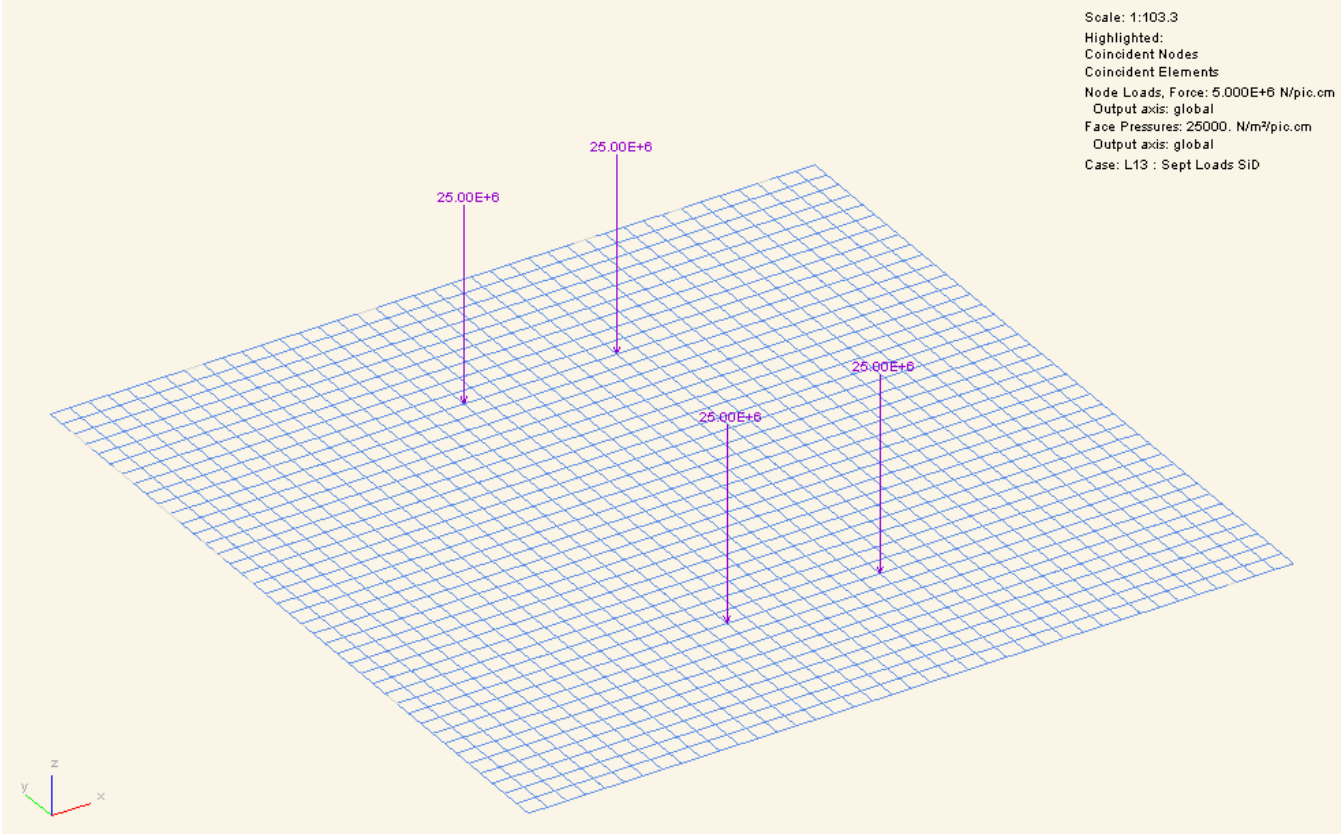




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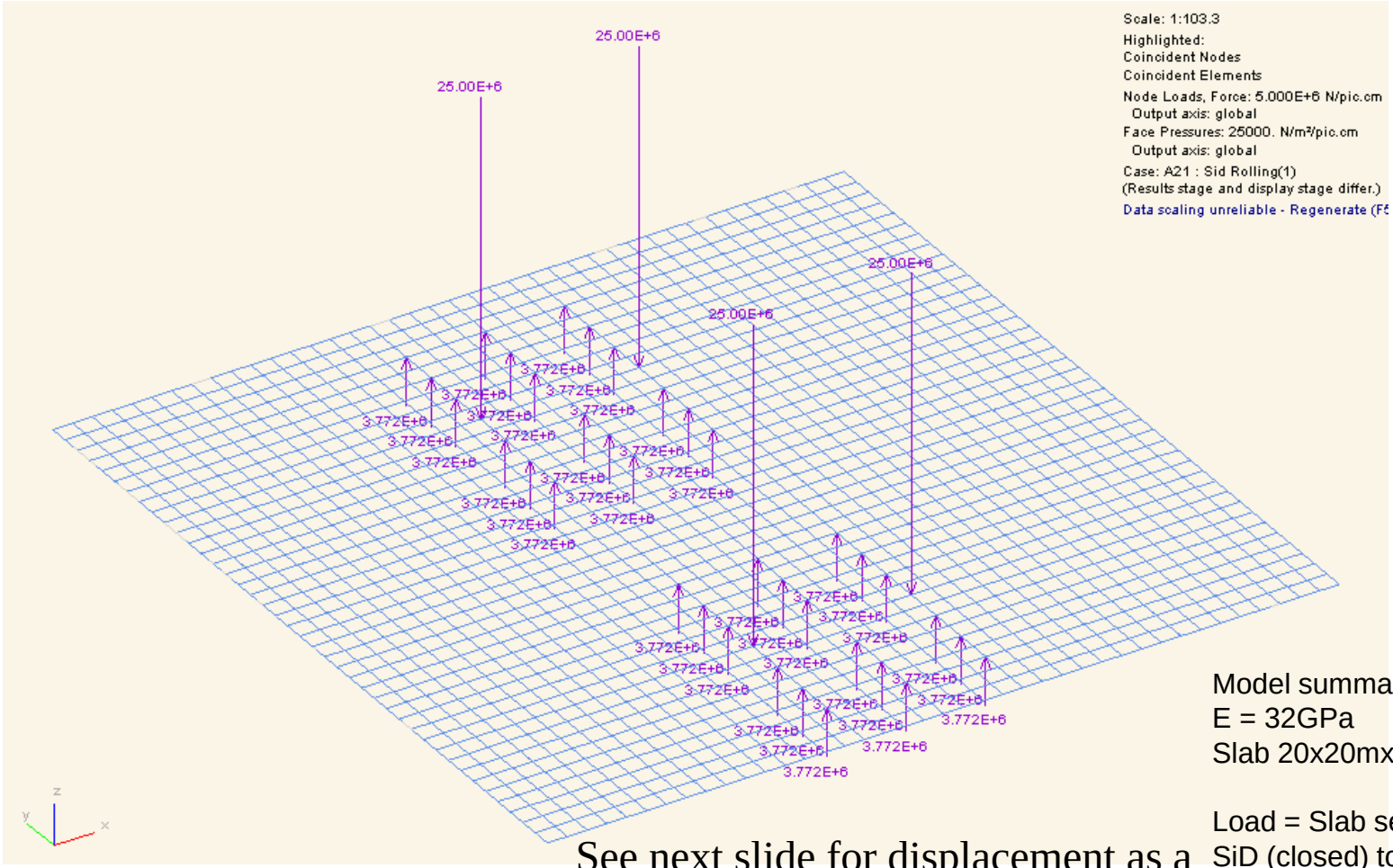
# Put SiD(closed) moving on transportation system




Model summary:
E = 32GPa
Slab 20x20mx3.8m

Load = Slab self weight + SiD (closed) top loads

See next slide for displacement as a result of these loads



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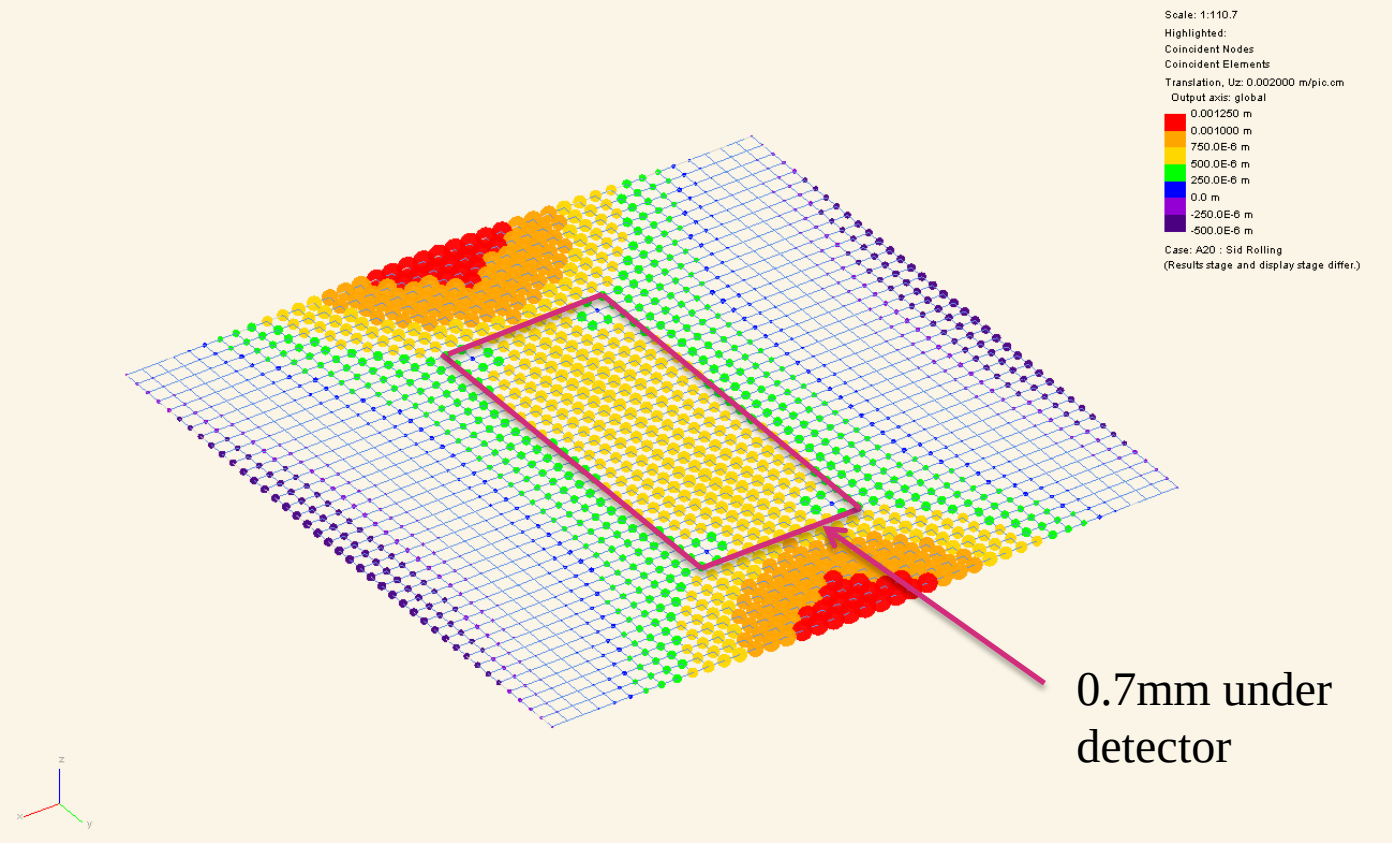
# Put SiD(closed) moving on transportation system



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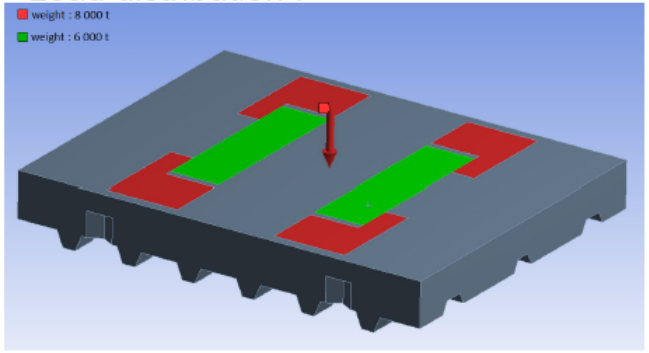
# Analysis from Granada



## Platform deformation under detector

Load distribution :



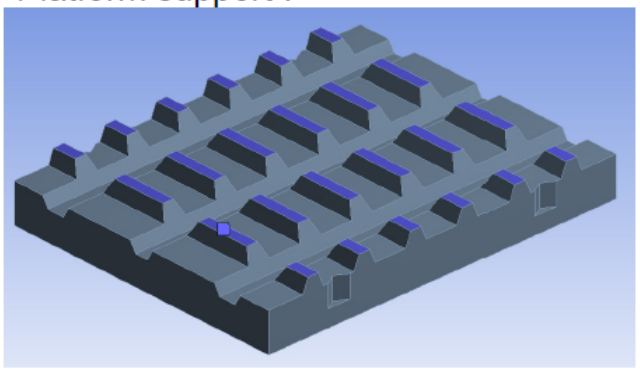

Central barrels with coil
Endcaps

Material take into analysis:
Standard Concrete
form Ansys Material library

Properties of Outline Row 3: Concrete

| Property | Value | Unit |
|---|---|---|
| Density | 2.3E+03 | kg m^-3 |
| Isotropic Secant Coefficient of Thermal Expansion | | |
| Coefficient of Thermal Expansion | 1.4E-05 | C^-1 |
| Reference Temperature | 22 | C |
| Isotropic Elasticity | | |
| Derive from | Young's ... | |
| Young's Modulus | 3E+10 | Pa |
| Poisson's Ratio | 0.18 | |
| Bulk Modulus | 1.56E+10 | Pa |
| Shear Modulus | 1.27E+10 | Pa |

Platform support :



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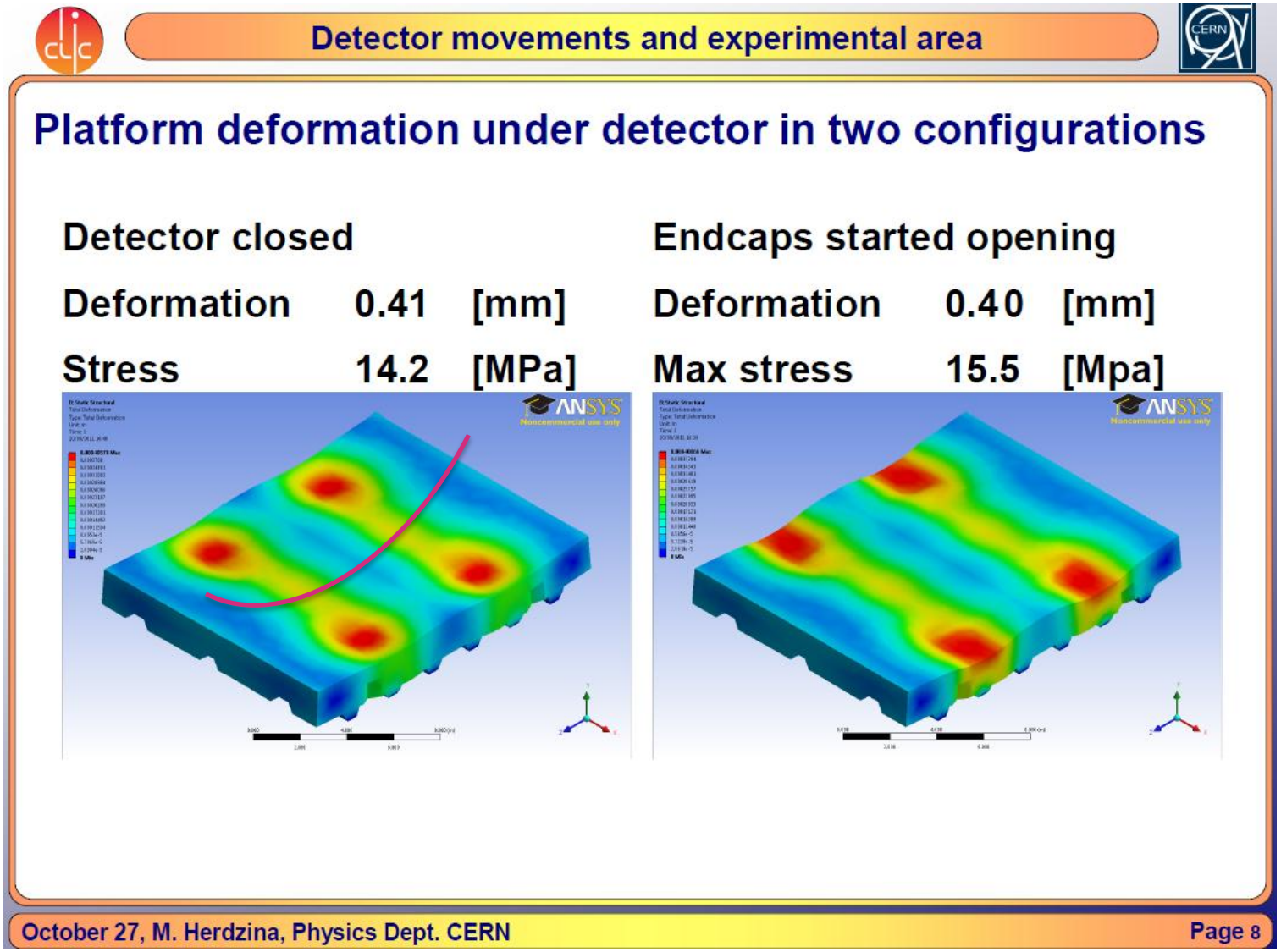




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# Un-slicing

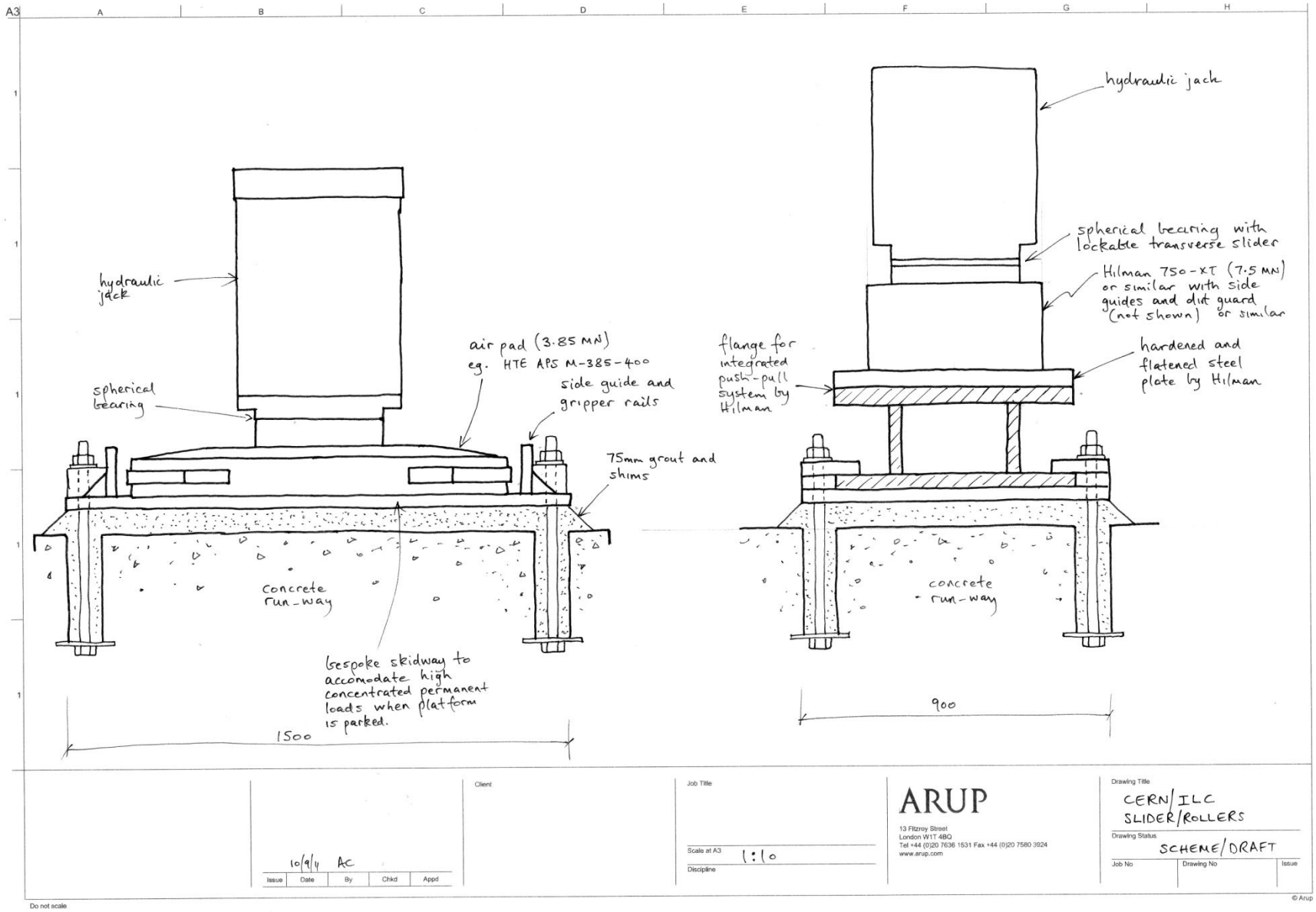
- **Un-slicing causes top loads to move away from the permanent supports.**
- **Because of this, un-slicing would cause displacement limits to be exceeded if supported only by the permanent supports. Displacement limits N/A**

# Conclusion on ILD movement

- **Can achieve disp limits of +/-2mm when moving**
- **Limits n/a when un-slicing**
- **But props/shims will be needed under tracks when un-slicing to avoid a step**

# Support System During Movement

# Pads and Rollers



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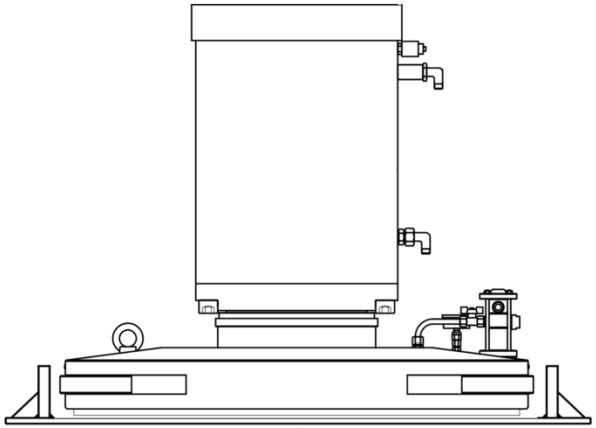
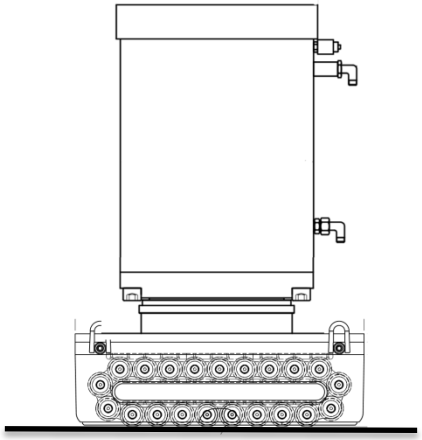
# The movement support system

- **Air pads or rollers**







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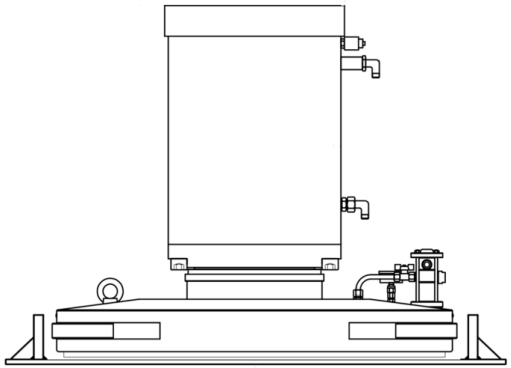
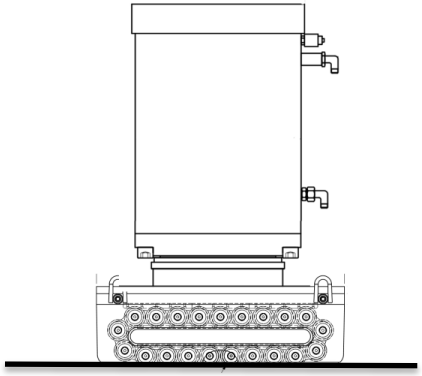
# Meeting with Hilman Rollers 15 Sept 2011

- **Self-driven rollers now available presently in use in the nuclear industry;**
- **Heavy version to be confirmed (only 100 tonne presently available);**
- **Hilman advised 3% friction for internal use;**
- **Hilman provide a suitable hydraulic push-pull system**
  - Awaiting details from Hilman;
- **Hilman provide a lateral slider (necessary for final lateral adjustment)**
  - This locks during main movement but can be unlocked to allow lateral adjustment. Awaiting details from Hilman.

# Comparison ot the two

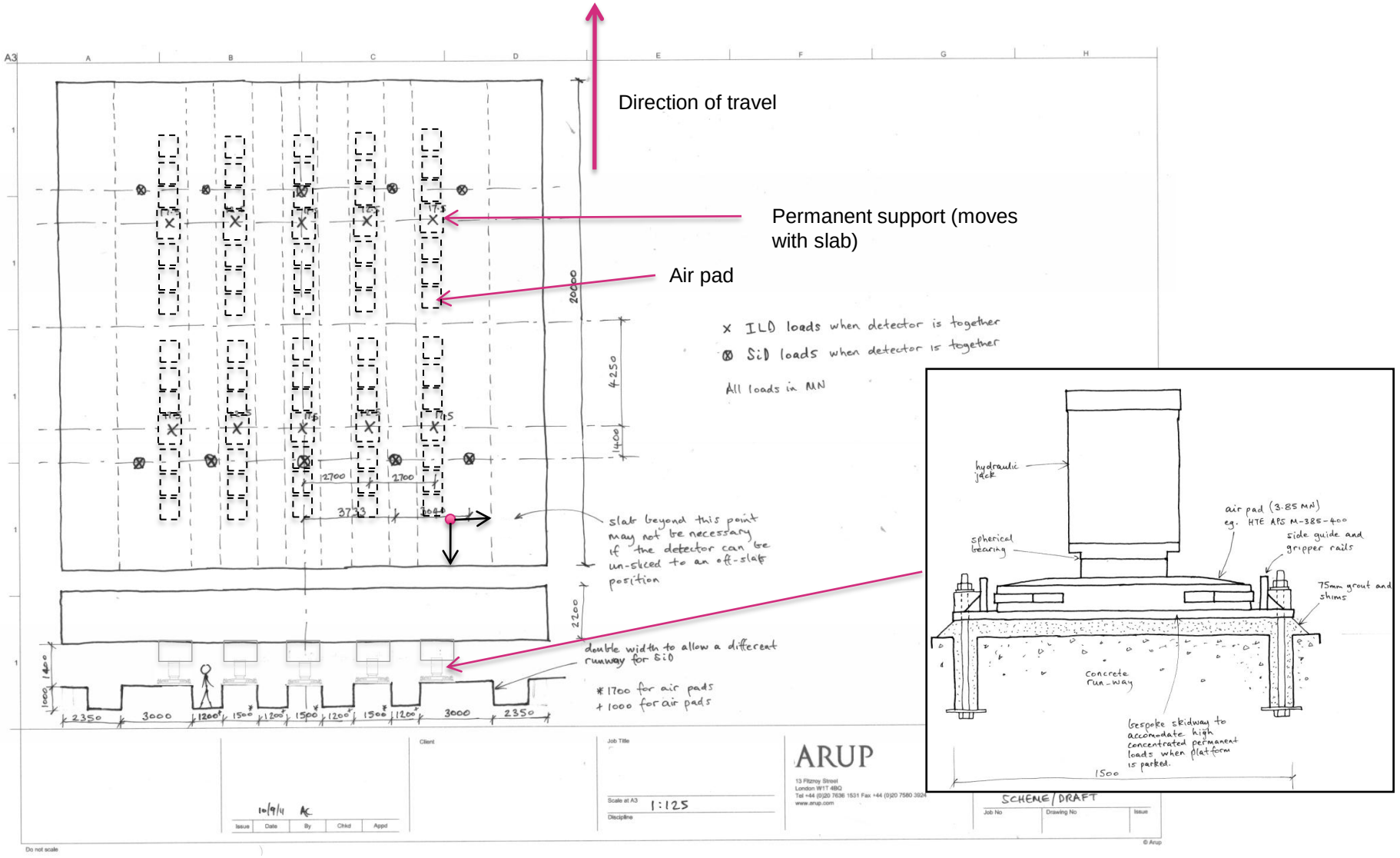
- **Air pads or rollers**





| Pads | Rollers |
|---|---|
| Min 50 required | Min 18 required |
| No hardened track->can accommodate minor steps | Specialist hardened and flattened track |
| Design for 1% friction | Design for 3% friction |
| Pressure infrastructure | Larger propulsion infrastructure |
| Run-away | Higher friction ->less run-away |
| Extra complication of air system | |

# The movement support system – ILD, Airpads



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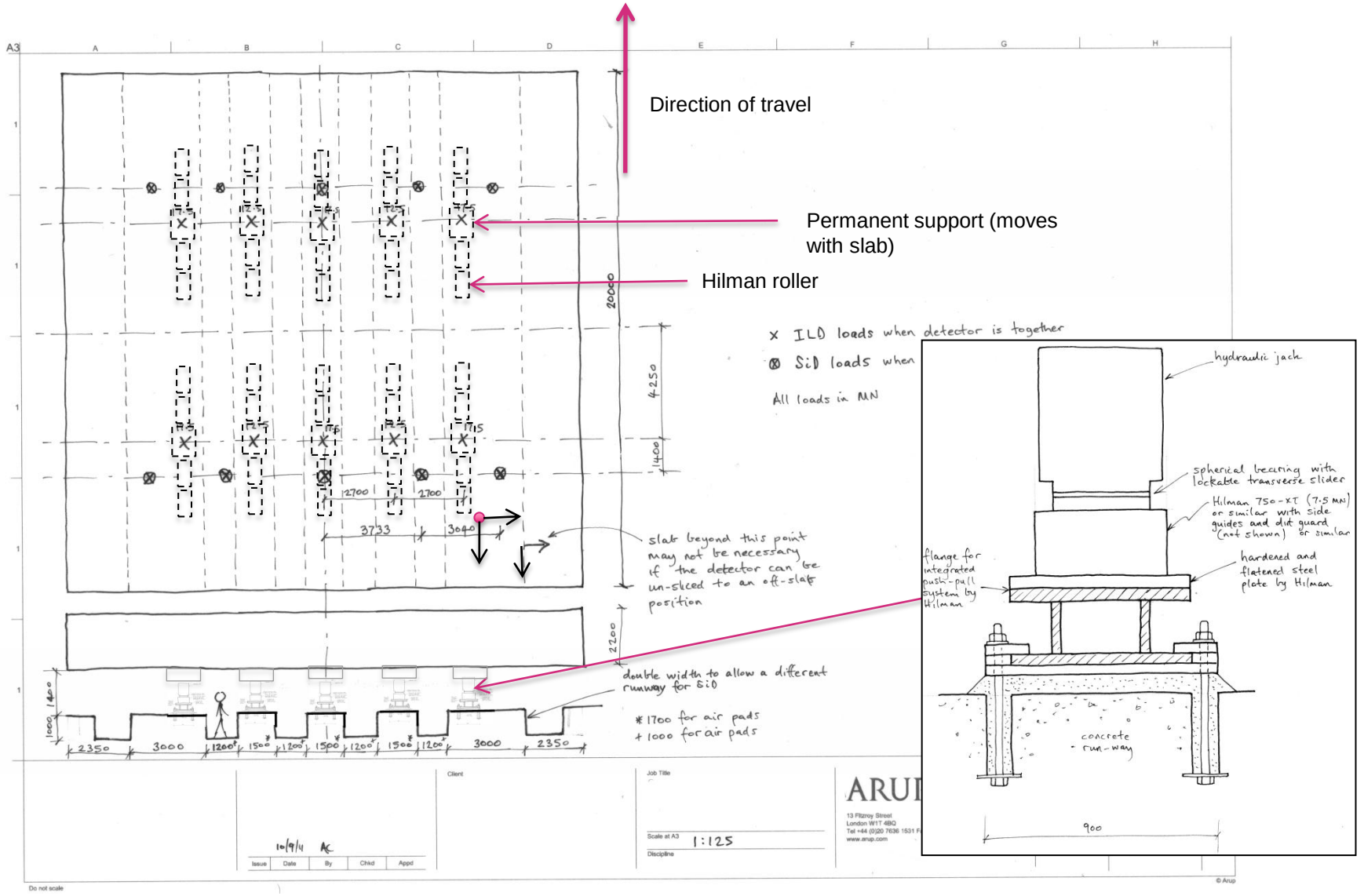
# The movement support system – ILD, Rollers



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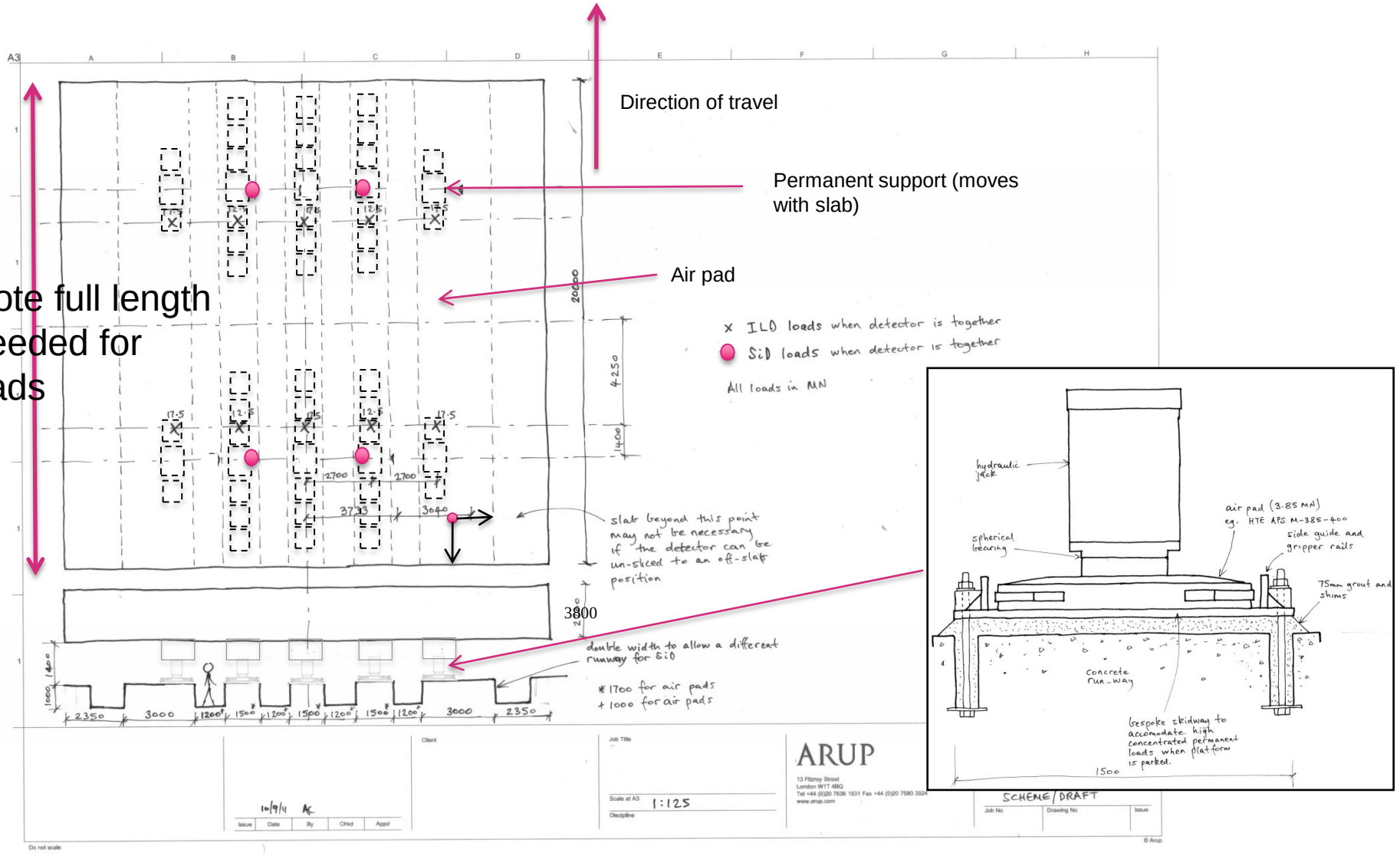
# The movement support system – SiD, Airpads

Note full length needed for pads



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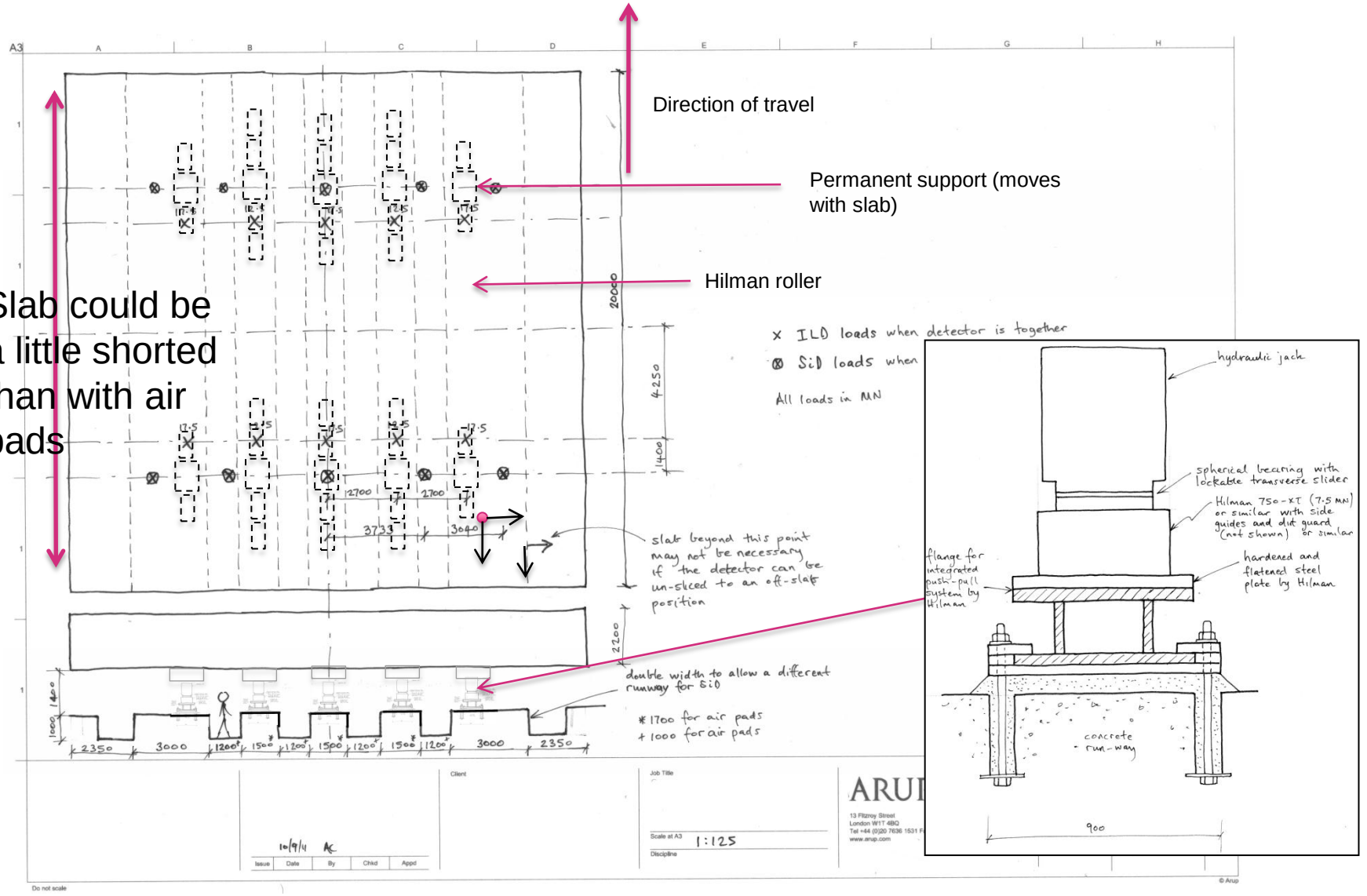
# The movement support system – SiD, Rollers

Slab could be a little shorted than with air pads



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# Slab Construction

# The Drive System

# The movement drive system for pads

- **Grip jack 2No. PPU-160 (1.6MN capacity each) with air pads. Larger system required for Rollers.**

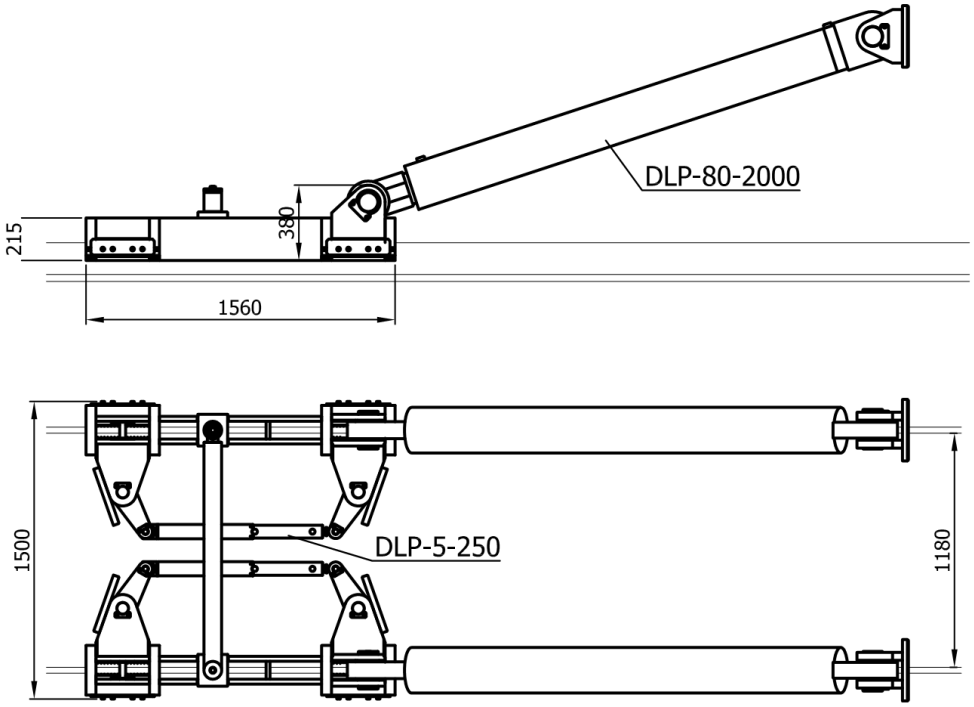


Photo of smaller unit in use



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# The movement drive system for rollers

- **Awaiting response from Hilman following meeting with Hilman 15 Sept 2011**
- **Two options being available:**
  - Hydraulic push-pull details similar to that for air pads;
  - Self-driven Hilman rollers (awaiting confirmation on capacity)

# The movement drive system for rollers – Lateral Slide



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# The movement drive system for rollers – Lateral Slide



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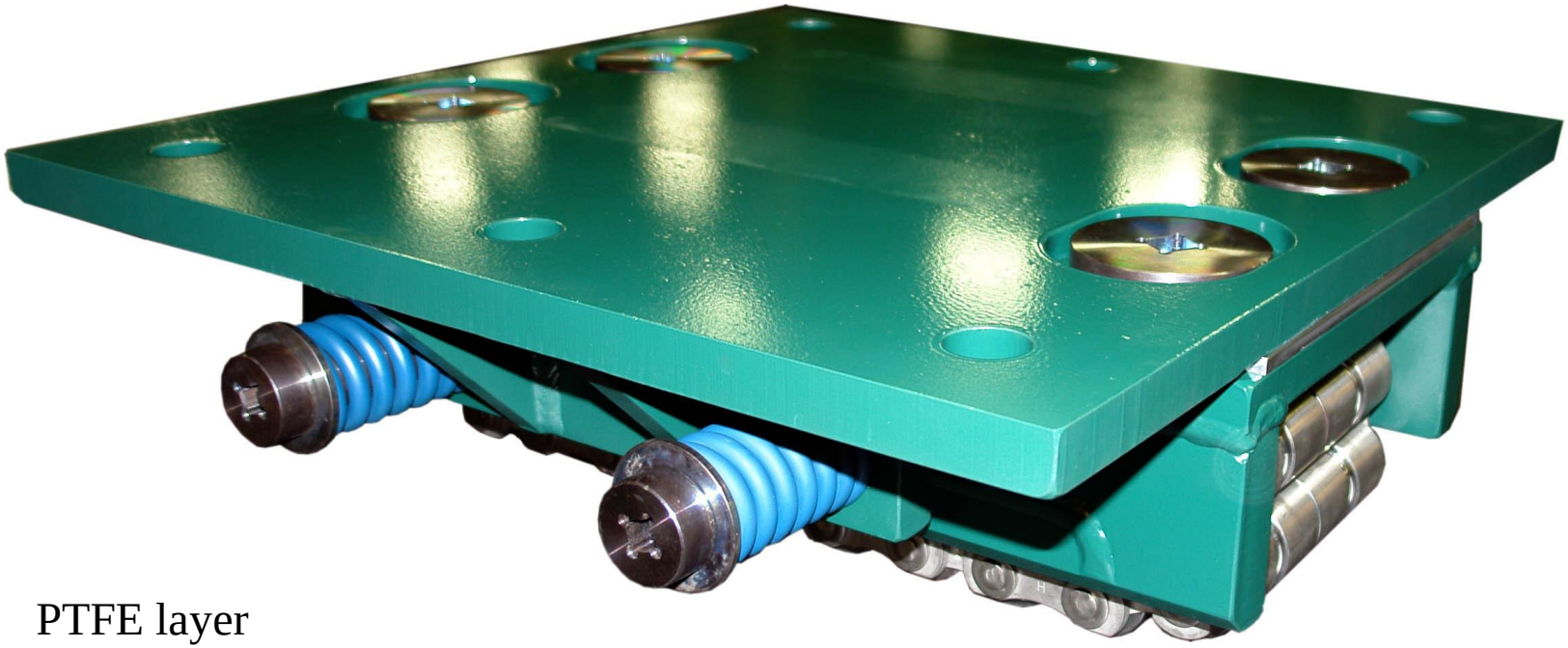
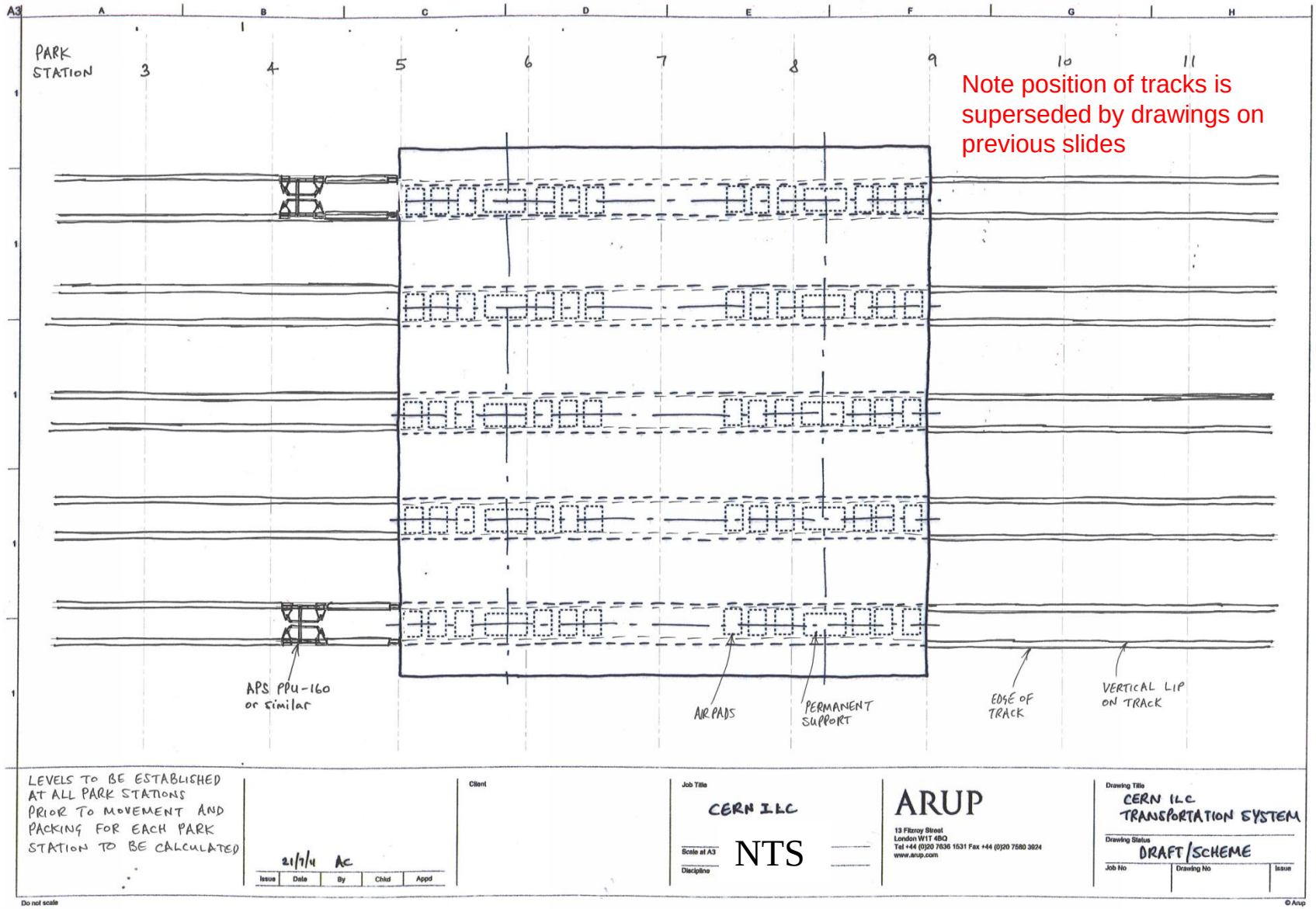
# The movement drive system for rollers – Lateral Slide



PTFE layer

Note that stiction could cause accel > 0.

# Movement Drive System



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# Movement Drive System

- **Pair of hydraulic rams allow rotational correction**
- **Control system to avoid on-plan rotation**
- **Bar code encoder or laser to tell the control system how much each side of the slab has moved**
- **Lateral guides to be investigated**

# The final positioning system



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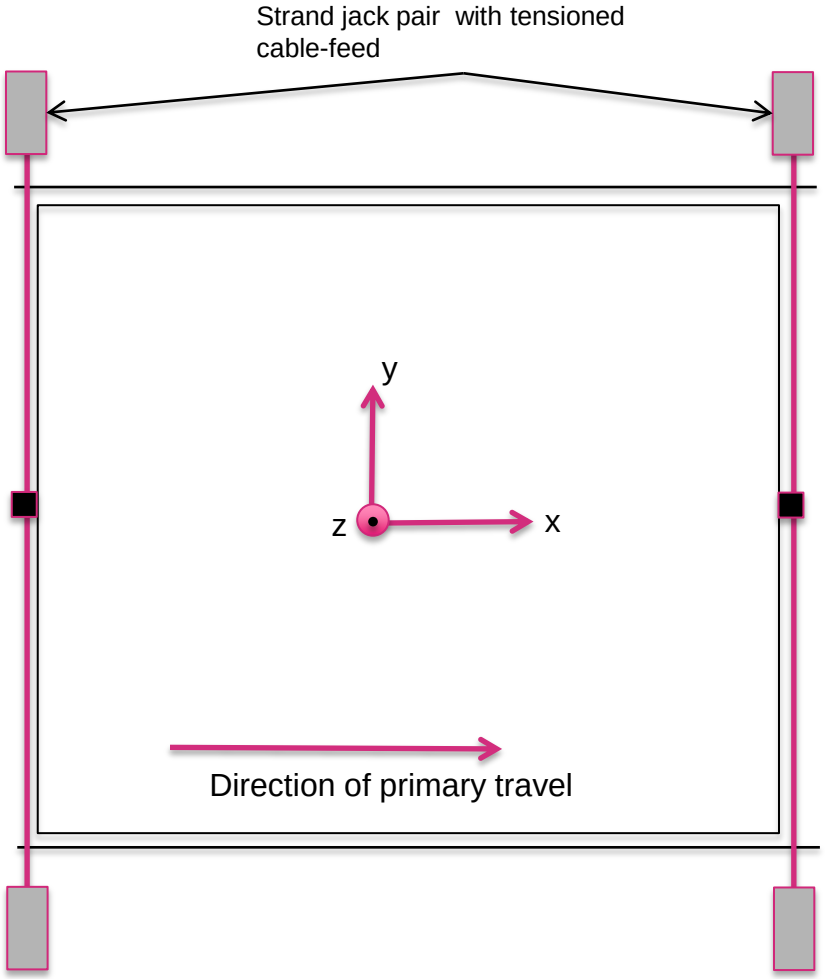
# The final positioning system




| Degree of freedom | Methodology |
|---|---|
| x, Rzz | Push pull system |
| z, Rxx, Ryy | Pack adjustment under slab |
| y (air-pads) *illustrated* | Lateral pull with strand jacks whilst air pads are active |
| y (rollers) *illustrated* | Lateral pull with strand jacks whilst the lateral slider (on the roller) is un-locked |

Note, Rxx is rotation about the x-axis, etc



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# Conclusions

- **ILD ok to jack and move on 2.2m slab with pads or rollers**
- **SiD ok to jack and move on 3.8m slab with pads or rollers**
- **To mitigate this some ways forward are:**
  - Jacking and packing if the invert does flex (to keep the slab permanent supports plane)
  - Provide 50mm packing from the start to allow the height to be reduced
- **Displacement criteria not applicable when un-slicing**
- **Some slab is not necessary if un-slicing to an off-slab position is possible**

# Further Questions

- **Will we know the exact lateral position before the move?**
- **Or might we need to put the slab in position and then discover that it needs to move laterally?**