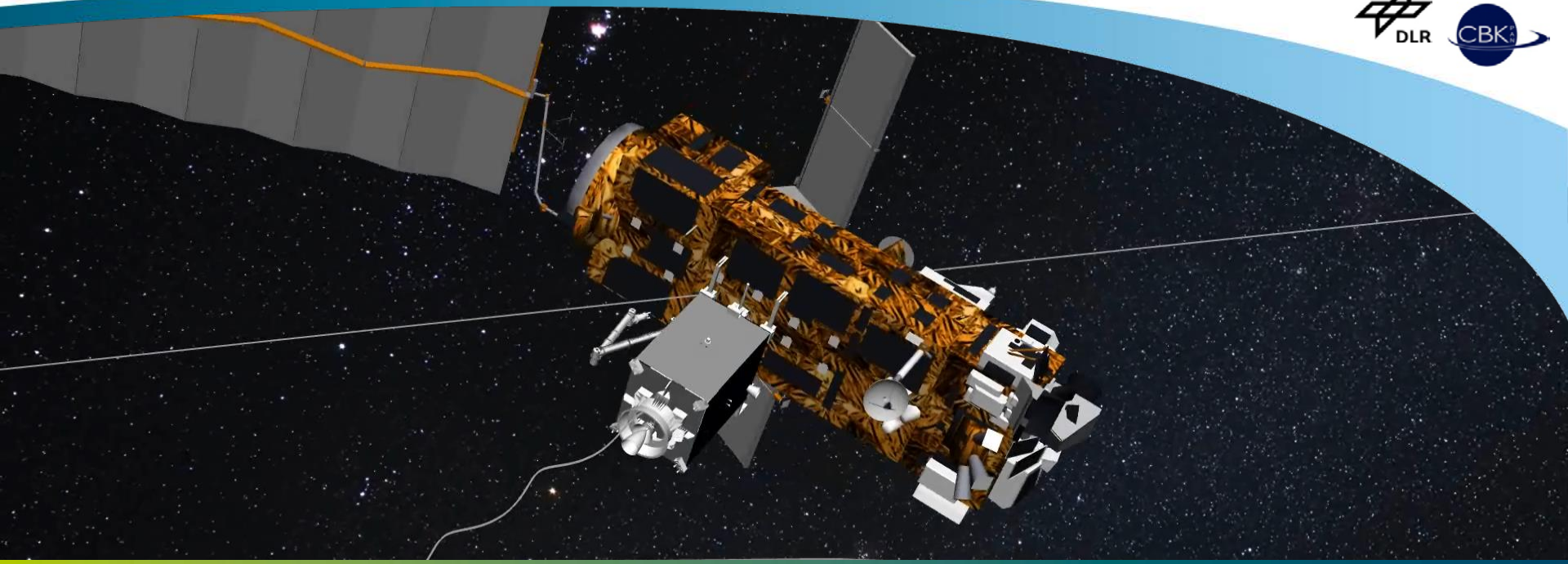
**OHB System AG**
10.04.2016, ESTEC



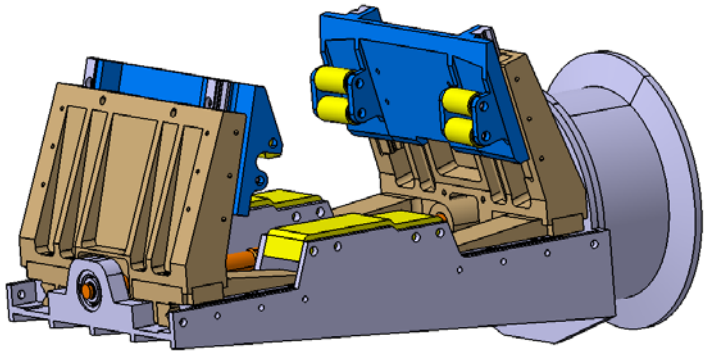
SPACE SYSTEMS

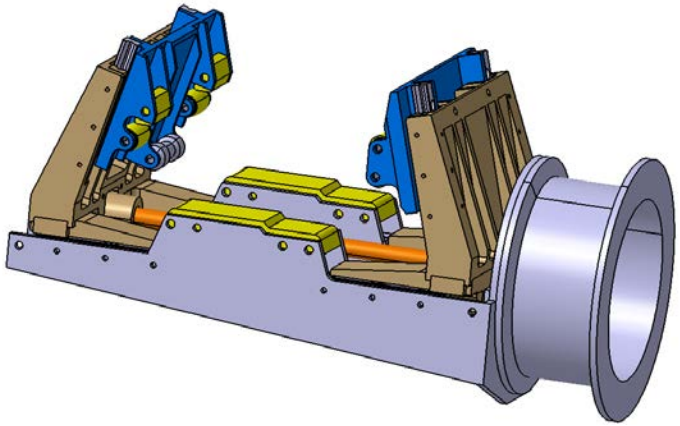
# OHB Gripper Design and Grapple Simulations

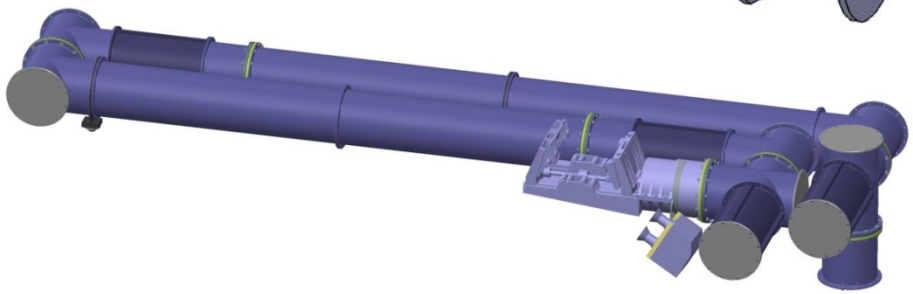
We. Create. Space.

# Gripper design

- Two spindle driven gripper brackets on spindle with right and left thread
  - Spindle lead screw on each bracket support
  - Linear cage roller guides with 35mm travel range
- Spring driven, inclined (15deg) grip jaw on each grip bracket
  - Grip jaws pushed up by springs in open position
  - Grip jaws pushed down by contact force with LAR
  - Form fit with vertical force Fv ≈ 0,25 * Fh
- Contact between gripper and LAR only on dedicated rolls
  - No surface sliding & friction
- Motor with internal break and gear (TBC)

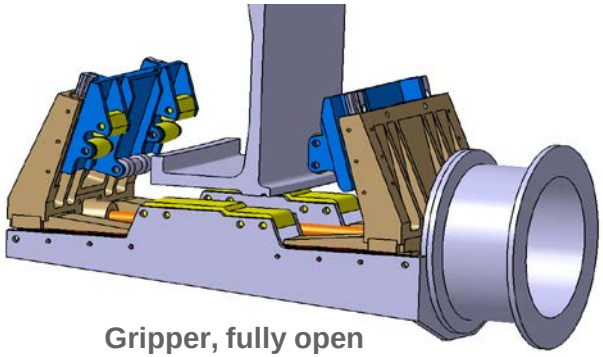




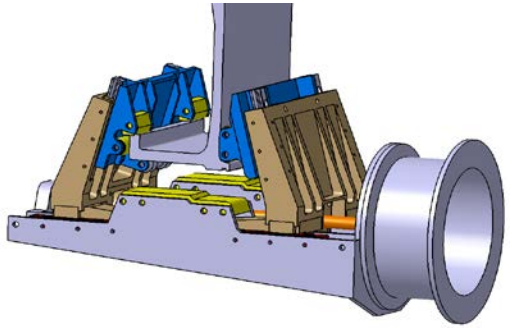


# Gripper design

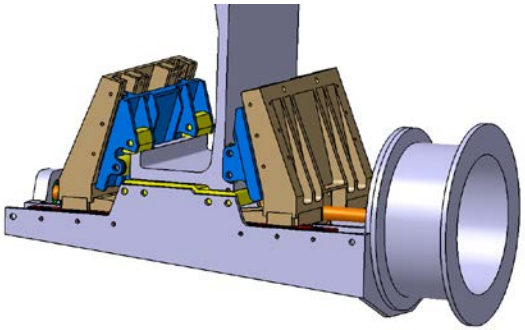
- Similar brackets front/back, only jaw geometry different
- Redundant springs with max. 2x2,5N on each jaw
- Front clamping bracket:
  - **Support rolls** to ensure that jaw has contact with LAR and engages within tolerances
  - **Horizontal rolls** for transmitting horizontal clamping force
  - **Vertical end-stops** for transmitting vertical clamping force
- Back clamping bracket:
  - **Horizontal clamping rolls** for transmitting horizontal clamping force
  - **Vertical clamping rolls** for transmitting vertical clamping force
  - No support rolls needed



Gripper, fully open

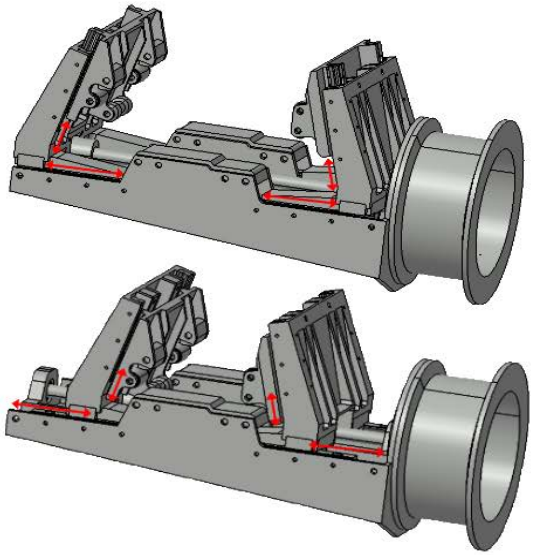


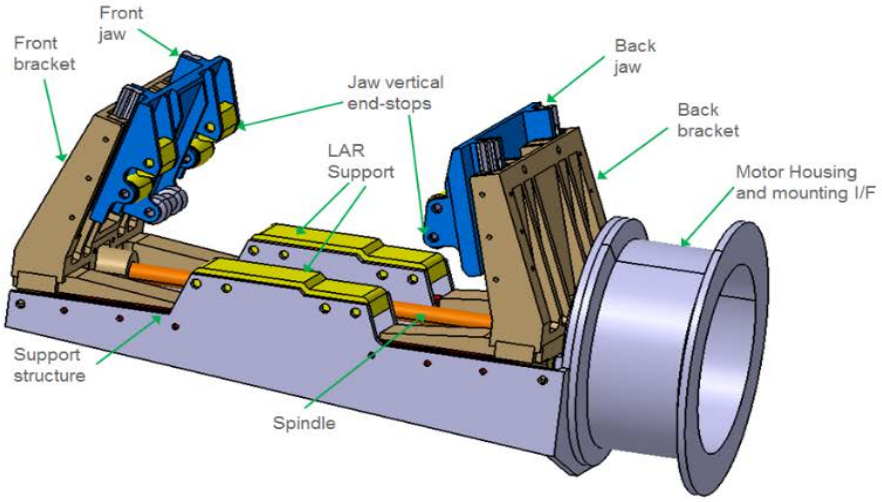
Gripper, at LAR contact

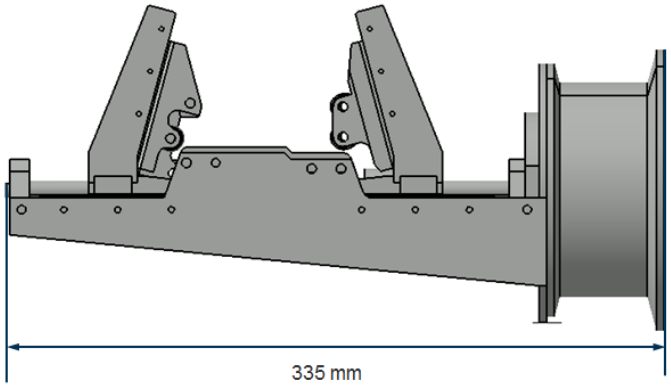


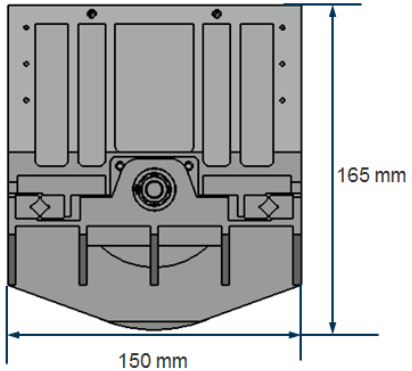
Gripper, closed with LAR

# Gripper design - overview



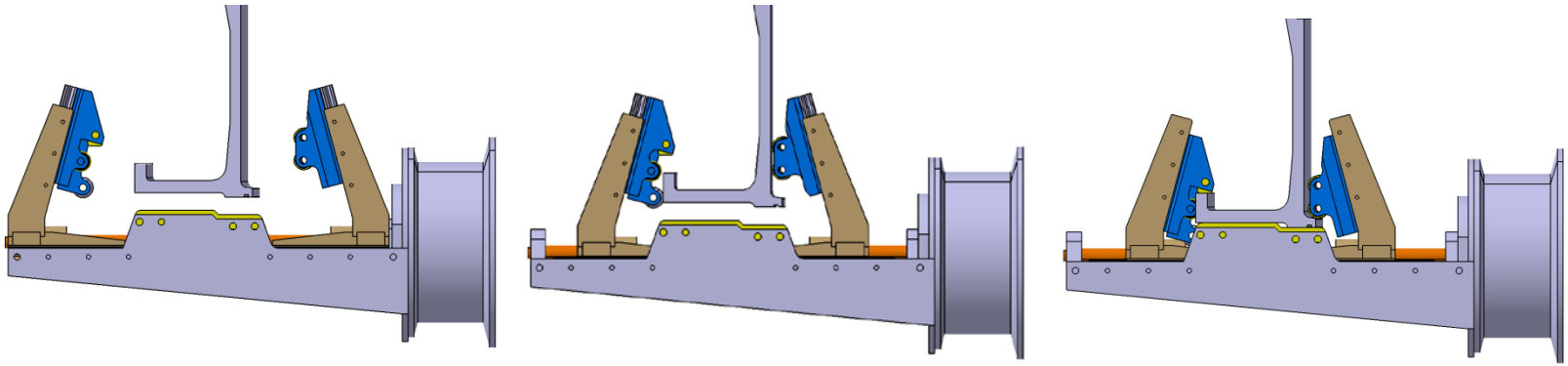


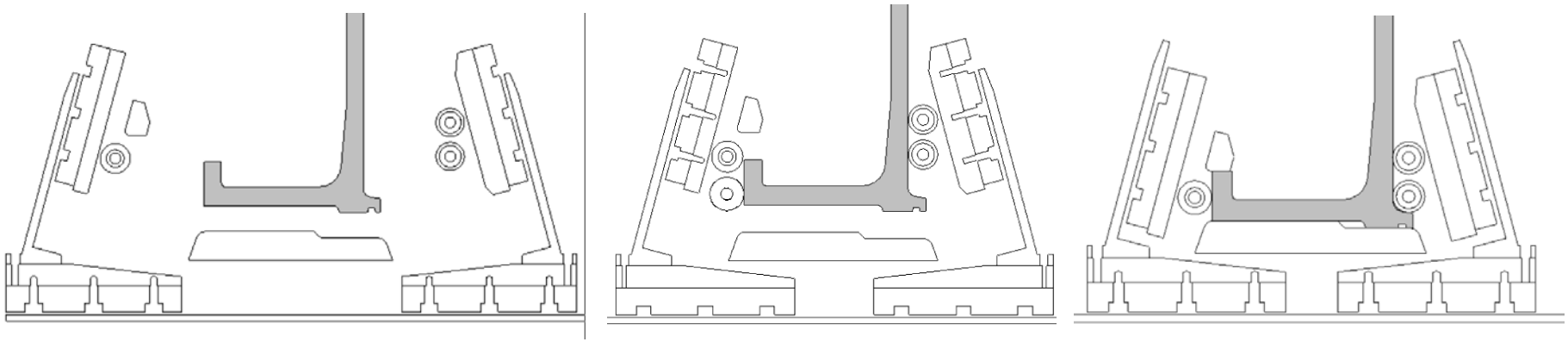
# Grappling concept

- Gripper open, jaws held by springs in „up“ position.
- Gripper TCP is placed in nominal position w.r.t. LAR
- Motor starts driving the spindle. Brackets start closing symmetrically from both sides. After 4s (TBC) jaws come in contact with LAR.
- Jaws are forced downwards by horizontal contact force. Gripper self-adjustment w.r.t. LAR.
- Motor is stopped when nominal gripping force is achieved.
- Motor break is activated.



# Grappling concept

- Gripper open, jaws held by springs in „up“ position.
- Gripper TCP is placed in nominal position w.r.t. LAR
- Motor starts driving the spindle. Brackets start closing symmetrically from both sides. After 4s (TBC) jaws come in contact with LAR.
- Jaws are forced downwards by horizontal contact force. Gripper self-adjustment w.r.t. LAR.
- Motor is stopped when nominal gripping force is achieved.
- Motor break is activated.

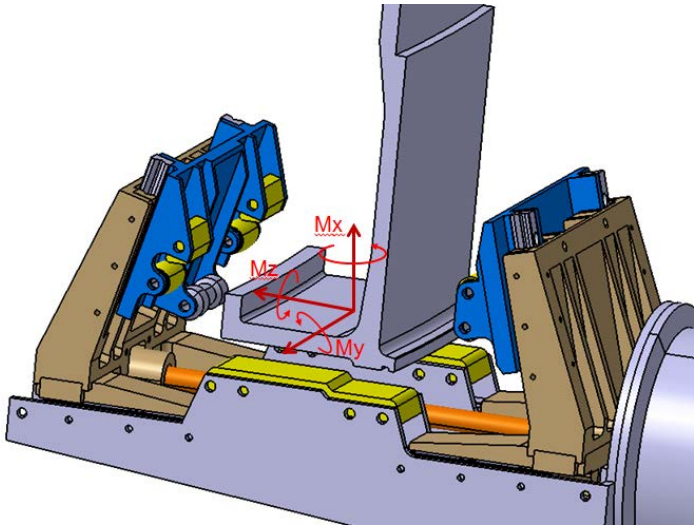


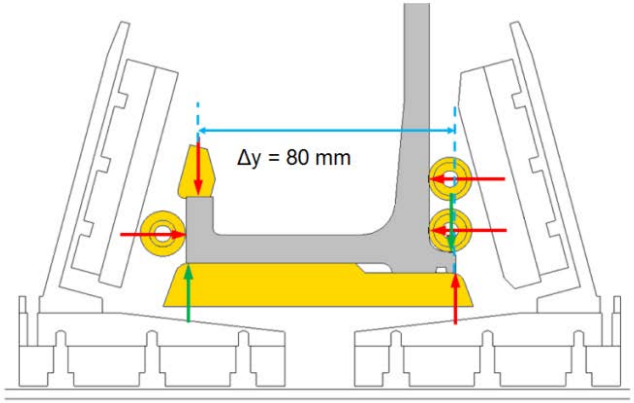
# Gripper Forces and Torques

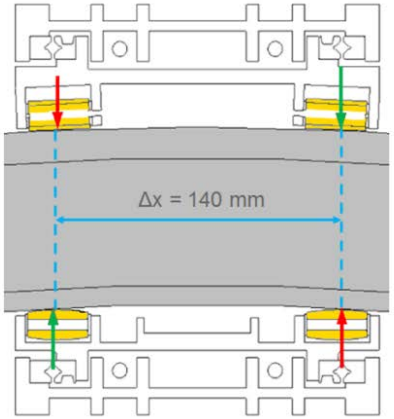
- Reaction torque is a major design driver w.r.t. size of the Gripper.
- Current assumption: **140Nm on arbitrary axis.**

- Mx: 1000N each contact point.
- My: 500N per contact point.
- Mz: 850N per contact point.

- Nominal grasping force = 1000N.



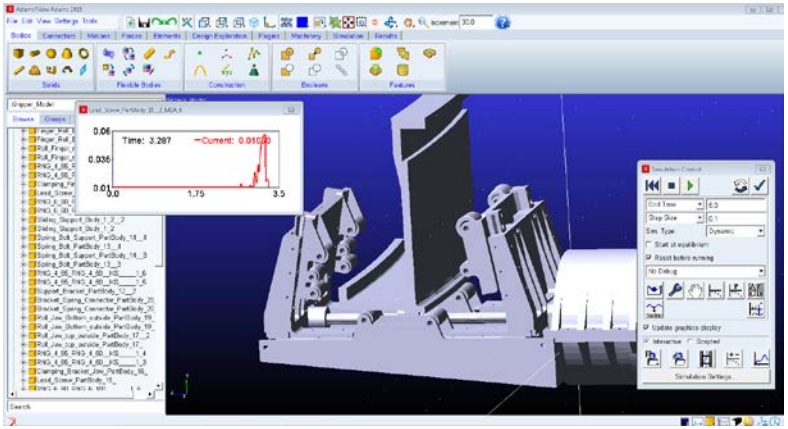
# Gripper Simulations, Analyses & Results

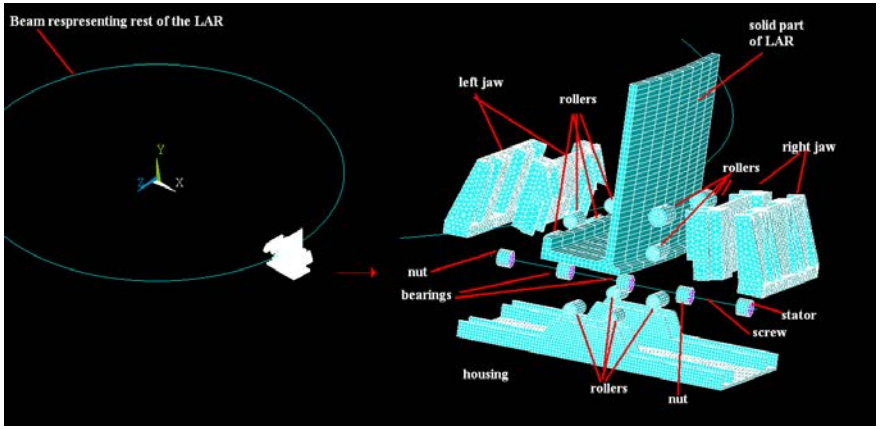
## Dynamic contact and multi-body simulation:

- Succesfull grasping from all worst case initial orientations.
- Successfull holding and verification of expected kinematic behaviour for all load cases.

## FEM Analysis (by CBK):

- Peak local structural force of approx. 3500N occurs in case Mx=140Nm. Peak local von Misses stresses in this case is 134 Mpa.
- 10 x 3 mm spindle with ball screw shows sufficient margin in all load cases.
- 1st Gripper frequency is observed at 130.5Hz.



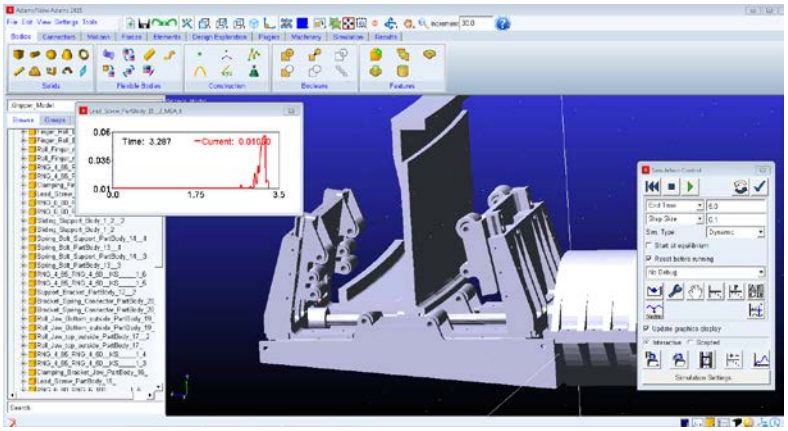


# Gripper Simulations, Analyses & Results

**Dynamic contact and multi-body simulation:**

- All potential contact points are modelled by penalty based collisions.
- Friction neglegible due to rolling contacts
- Constraint modelling of all DoFs:
  - Linear translation joints between brackets and support structure.
  - Linear translation joints between brackets and jaws.
  - Preloaded linear spring between brackets and jaws.
  - Screw joint between brackets and spindle
  - Revolute joints between spindle and support structure
  - Constant velocity drive (limited torque) for spindle.

Modelling and simulation in MSC ADAMS, based on Gripper CAD model



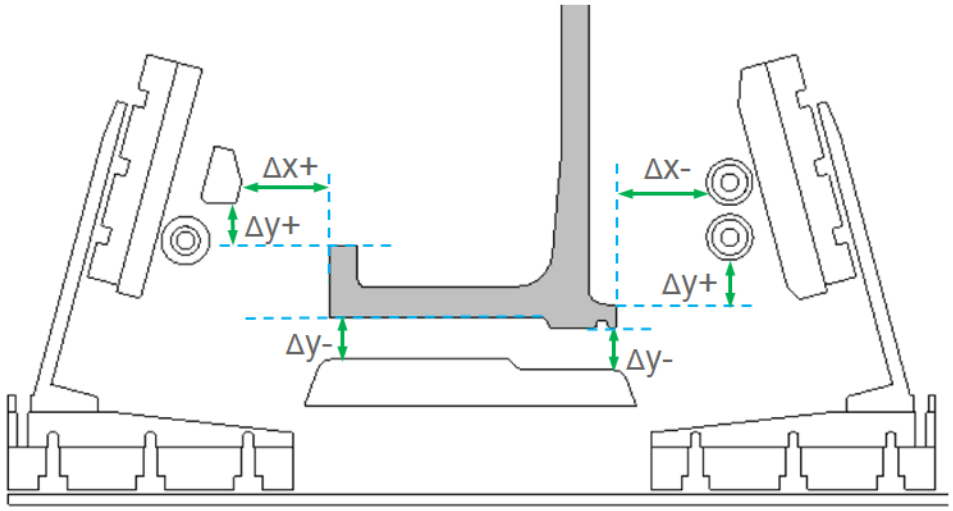
# Gripper tolerances

- Gripper TCP tolerance:
  - Horizontal Δx ± 20mm
  - Vertical Δy ± 20mm
- Compliant with positioning accuracy even in open-loop control (closed-loop is nominal)
- Tolerances can be adapted by scaling of bracket and jaw strokes

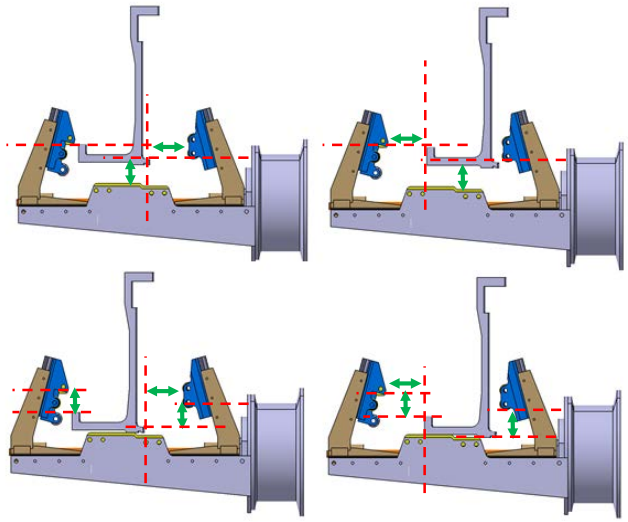
| Parameter | Value |
|---|---|
| Absolute position accuracy | 14mm |
| Absolute orientation accuracy | 1deg |
| Relative position accuracy | 0.5mm |
| Relative orientation accuracy | 0.1deg |

| | | |
|---|---|---|
| Max. occuring initial grasp positioning error [m] | 0,006 | *=pos_error_arm_rel + pos_error_servoing* |
| Max. occuring initial grasp orientation error [deg] | 0,300 | *=orient_error_arm_rel + orient_error_servoing* |

**TCP accuracy requirements (±) according to Phase A DDF & DJF**



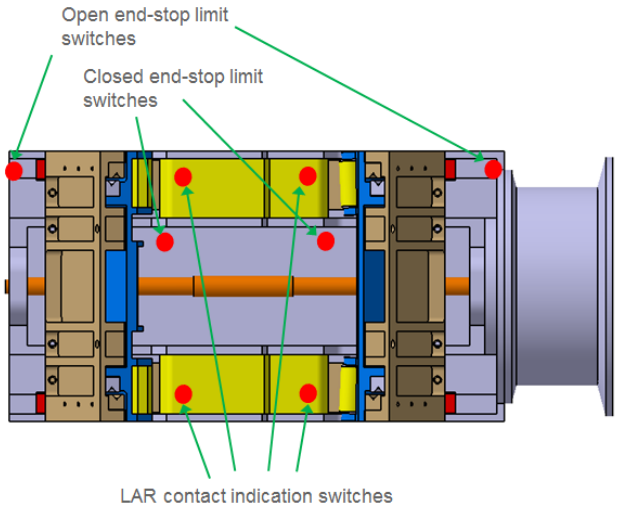

**Gripper open nominal**

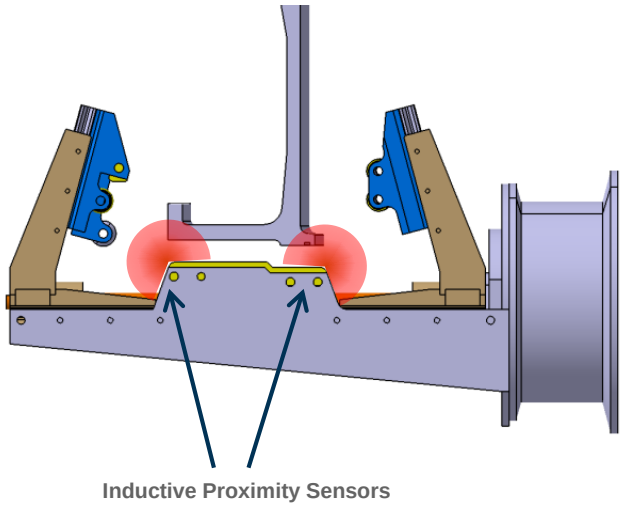


**LAR worst case positions and misalignment tolerances**

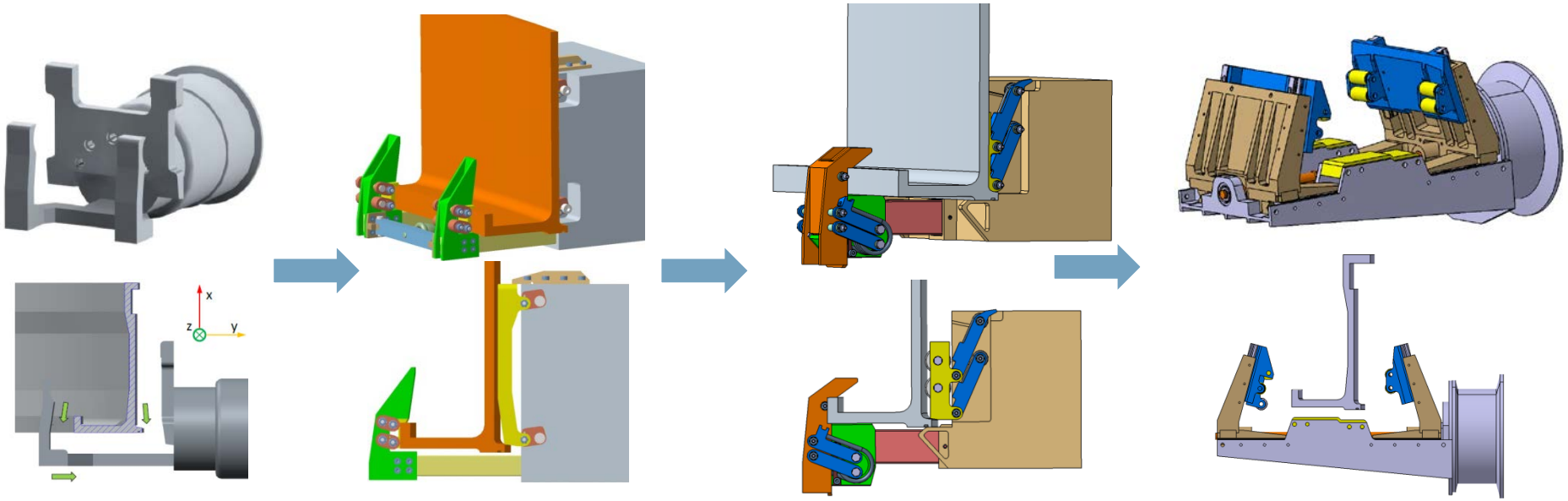
# Sensor concept

- **Micro switches**
  - Positive LAR capturing indication below LAR support
  - “Open” configuration limit switch at hard end-stop
  - “Closed” configuration limit switch at hard end-stop
- **Motor Torque Sensor:**
  - Measuring of nominal holding force to the LAR.
- **Encoder/Resolver:**
  - Encoder and resolver are used for position determination of brackets.
- **Inductive proximity sensors**
  - Verification of nominal grapple position
- *(Optional) Optical marker on brackets and jaws:*
  - *Markings indicating specific positions on the jaws and brackets allow visual verification of the Gripper components position.*
- *(Optional) Light curtain sensors:*
  - *verification that LAR lower surface is located within the alignment tolerance envelope.*



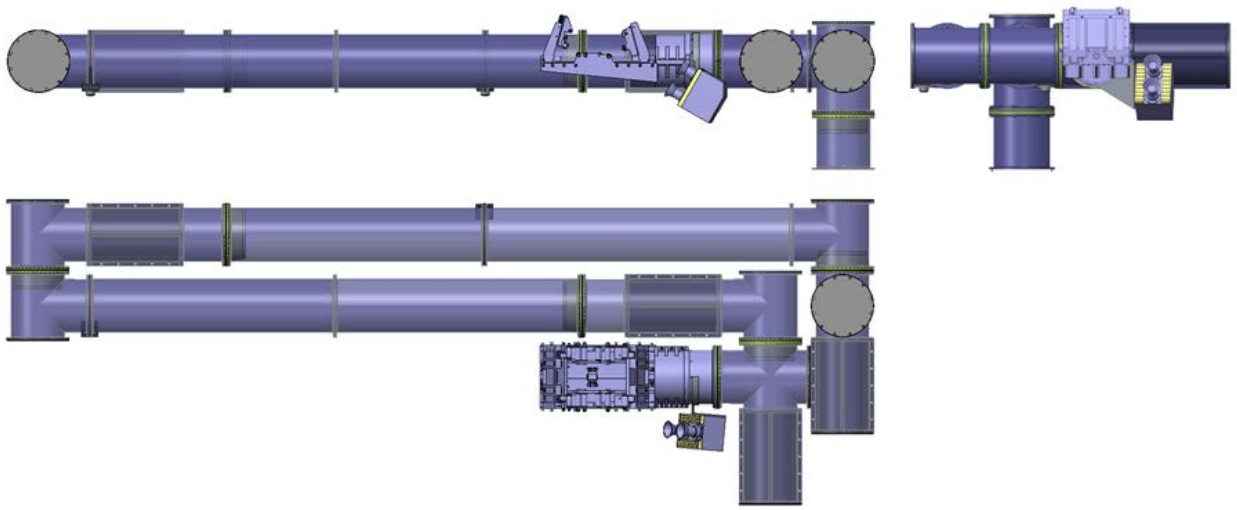
# Design Evolution and trade-offs



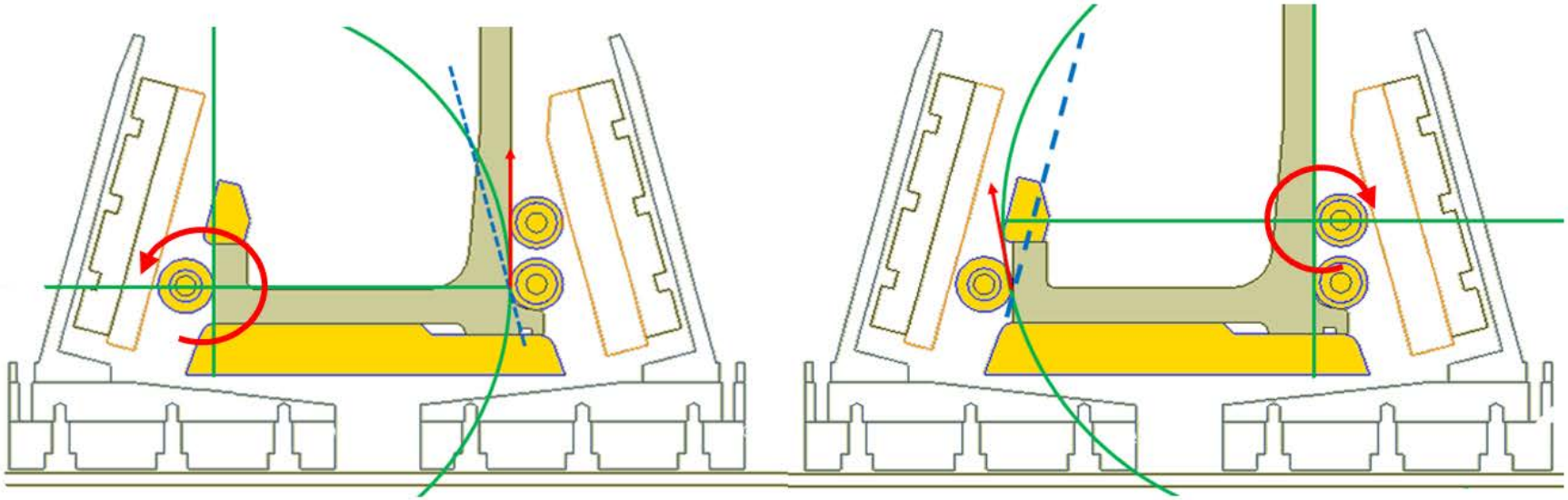

Phase A Baseline | Preliminary re-design | Modified design (80Nm) | Current Baseline (140Nm)

# Gripper Summary

- All requirements can be fulfilled with margin.
- Scalable design to meet requirement updates.
- Analyses show good confirmation of kinematic and structural behaviour.
- No mass optimization performed yet -> high mass saving potential



# Gripper Backup - Kinematics



Gripper kinematic clamping concept

# Gripper Backup – Design Details