Remote Handling Best Practice

Target Technical Board Meeting

Wednesday, 16 March 2016

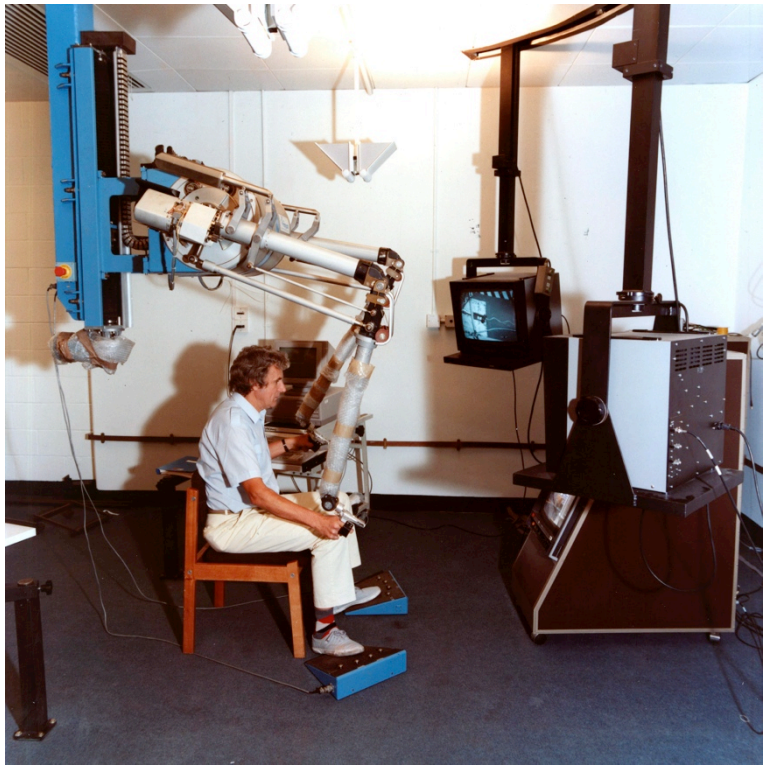
Copenhagen

Design Guides for Remote Handling

- Who is RACE
- Design Considerations for Maintenance Activities
  - Size Reduction
  - Locating Features
  - Fastening Features
  - Handling Mechanisms
  - Risks for Handling
- Future Engagement

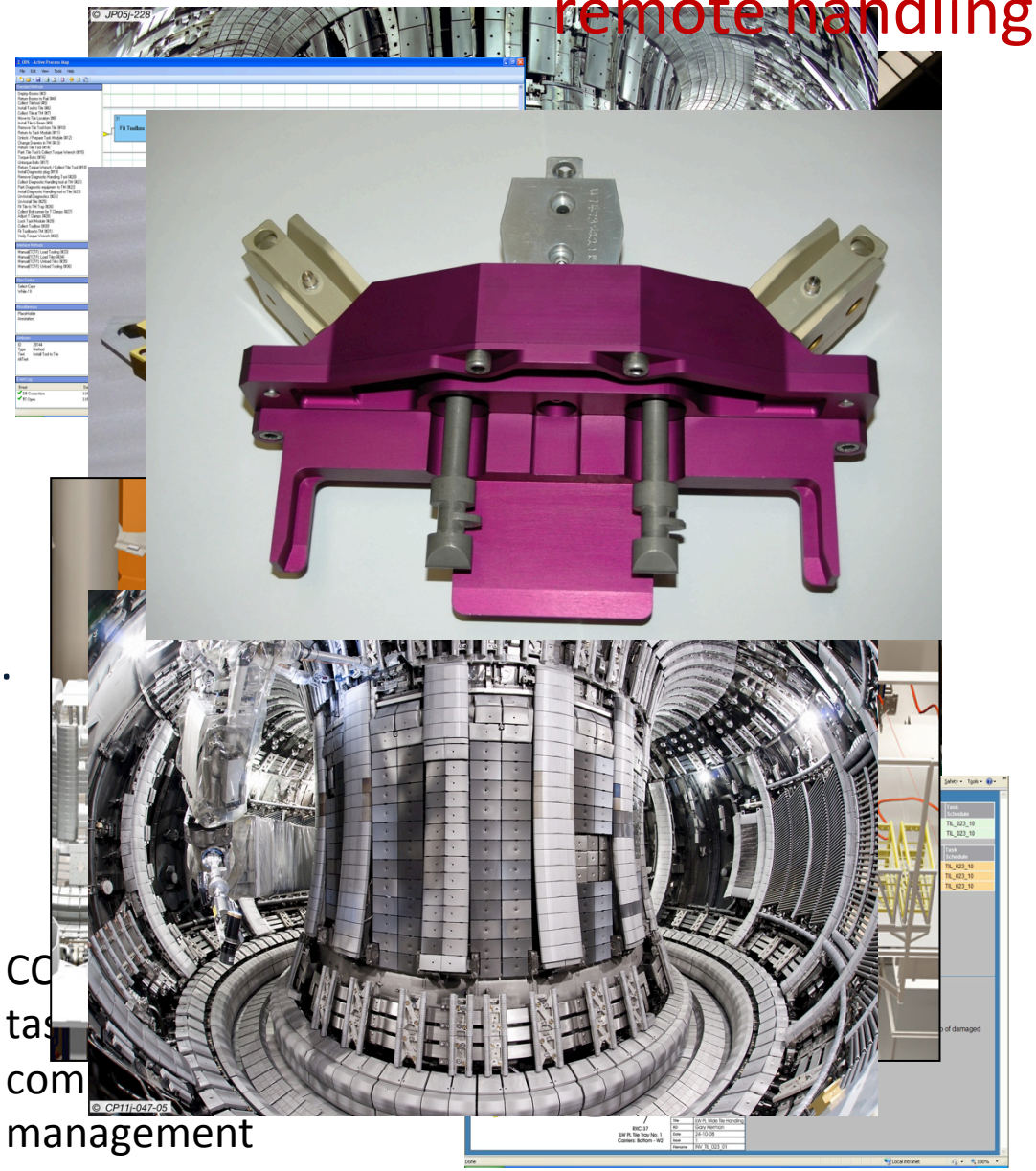
RACE Has Completed 30,000 hrs of Operations

- RACE has continually improved its remote handling expertise over at the European JET facility over 3 decades
- This experience has informed the design of components, tools, equipment and procedures
- Support international fusion development at JET, DEMO, JT6OSA and ITER.
- Involved nuclear fission and decommissioning



RACE has end to end experience of developing remote handling

- Procedure Development
- Extensive Operations
- Tool Design
  - Handling
  - Cutting
  - Welding
  - Inspection
- Design, supply and commissioning new equipment.



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Size Reduction

- Overview
- Process in cells
- Outgoing waste
- Cutting options
- Contamination hazard
- Design for compatibility
- Summary

Size reduction – overview

- Components cut up before entering waste stream
  - To fit in waste storage containers
  - To segregate materials
- Difficult, hazardous
- Component design compatibility is critical
- Cutting tool development is “work in progress”
- Cutting compatibility best practice guidelines TBC
- Early engagement is key…

Size reduction – process

- Entry > size reduction > basket filling > storage > decay > transport
- Transport containers:
  - Ext. dose limit(s)
  - Activity limit
  - Segregation…

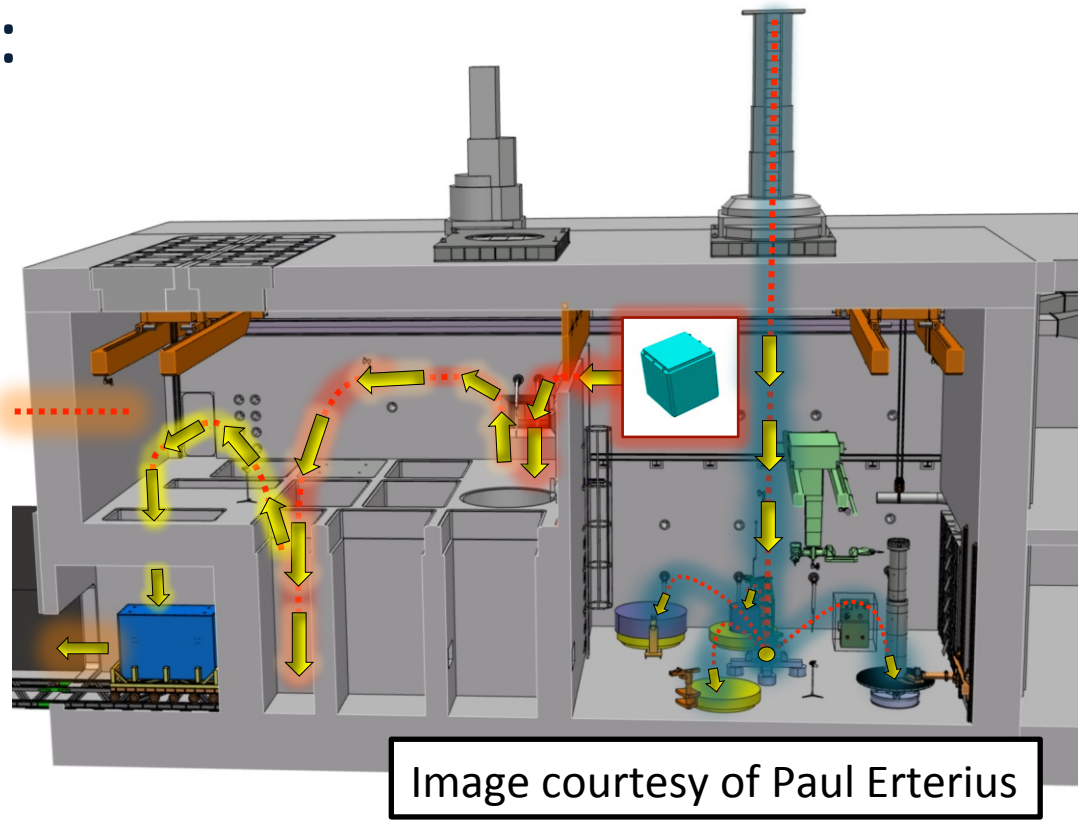


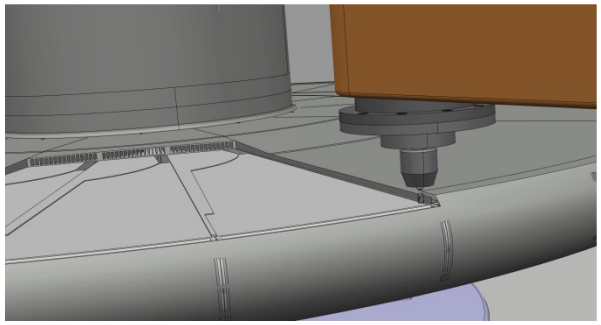
Image courtesy of Paul Erterius

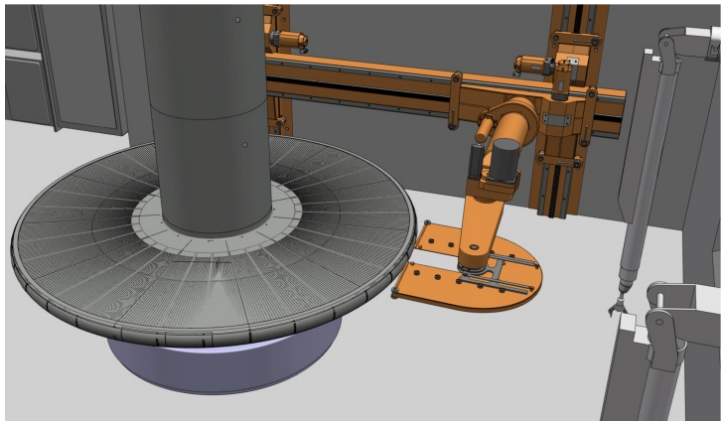
Size reduction - components

- Target Wheel
- Target Wheel Monitoring Plug
- Moderator Reflector Plug
- Proton Beam Window
- Proton Beam Instrumentation Plug
- Neutron Guides
- Neutron Guides - blind plugs
- Light shutters

Cutting options

- Concept design: saw and end-mill on articulated boom





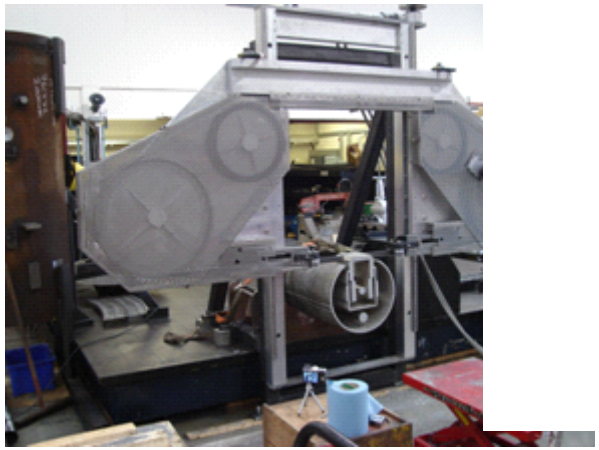
- Concerns:
  - Force reaction/deflection
  - Vibration
  - Limited depth of cut
- Ongoing feasibility assessment
- Investigating alternatives…

Cutting options

- Two tool types needed:
  - Heavy duty
    - e.g. cutting through shafts, TW shroud
    - Deep cuts, precision not top priority
  - Precision cutting
    - e.g. releasing seal welds, cutting windows & cover plates
    - Smaller, shallower cuts, but precision is critical

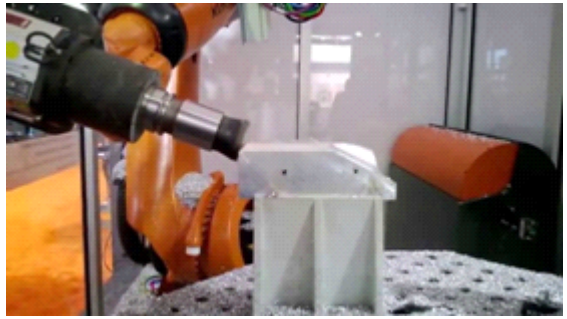
Cutting options

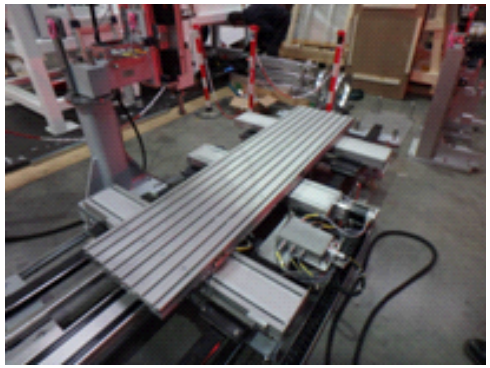
- Heavy duty tool:
  - Circular saw on articulated arm
  - Band saw
  - Wire rope saw
  - Power hacksaw
  - (5kW laser)

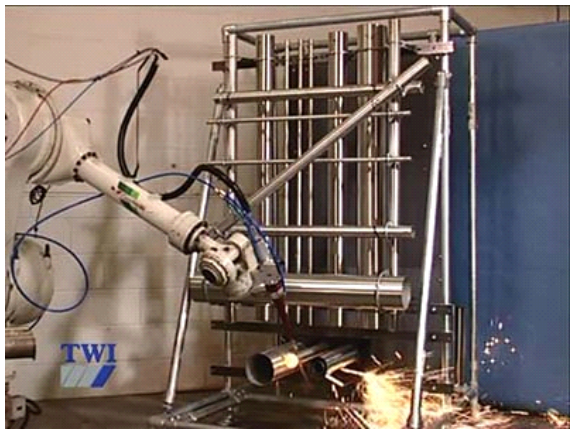


Cutting options

- Precision cutting tool
  - End mill on articulated arm (with/without saw option)
  - Movable table with end mill / slitting saw
  - Low power laser on robotic arm







Cutting options

- Selection process in progress
  - Catalogue of identified cuts needed
    - For cutting tool requirements specification
  - Contamination assessment*
    - Generation, spread, particle size, other hazards…
  - Technology Readiness Level assessment
    - Need low-risk, well-proven technology…
- Chosen tool(s) and capabilities will have an impact on component compatibility requirements
- Tool-specific requirements TBC

*Contamination hazard

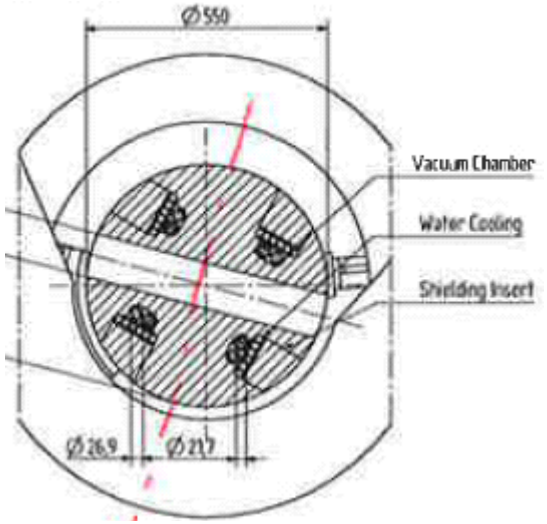
- Plan for manned access to Process Cell
  - Infrequent/unscheduled maintenance, decommissioning
- Extremely high activity components arriving
- Even very small quantities of dust/chips could be fatal in airways/bloodstream
- Need to assess contamination spread and hazard
- Primary containment structure may be needed
- Impact on tool development and components

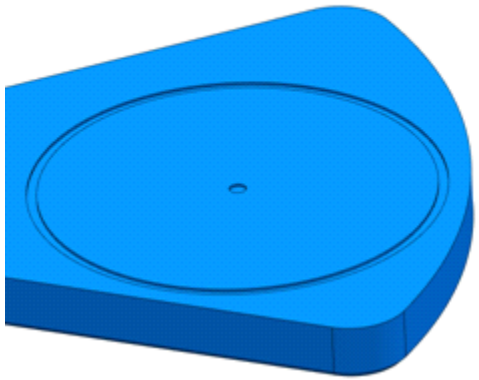
Design for compatibility

- Cells physical constraints:
  - Entry via floor valves: D_{max} 2,8m < 2,9m
  - Power manipulator reach: H_{max} 6,3m
- Avoid welds where possible
  - Bolted connections & mechanical seals preferred
  - Low processing risk, possibility of recovery/reuse

Design for compatibility

- Cut locations:
  - Agreed in advance
  - Compliant with waste constraints
  - Max size: 3m x 2m x 1m (approx!)
  - Cut as little material as possible
  - Physical grooves/guides for tooling
  - TBC: clamping features





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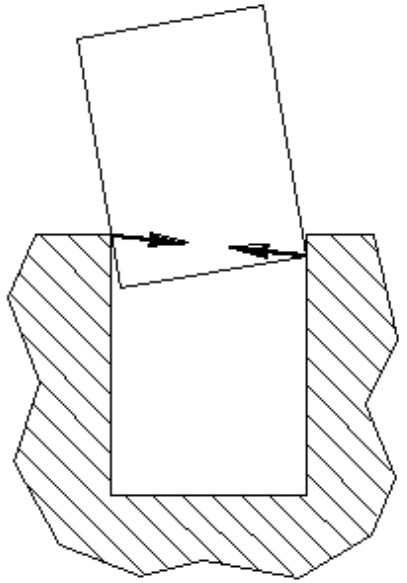
Well designed location features facilitate maintenance

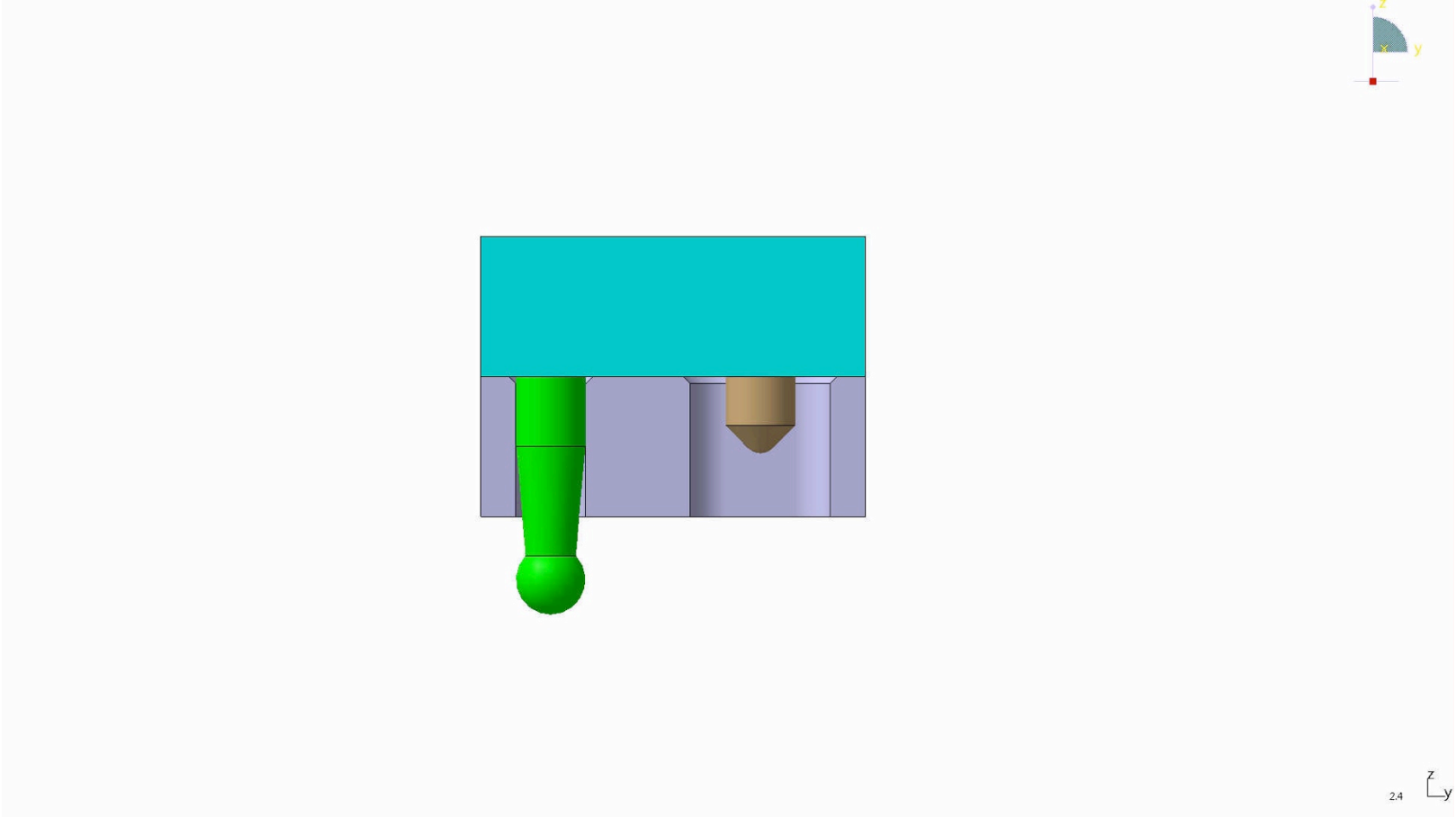
- Kinematic Design
- Avoid Jamming
- Vertical loading

Wedging is Problematic to deal with remotely

- Wedging occurs when forces between the two assembled parts are internally balanced
- A wedging condition is difficult to recover.
- Location features should be designed to suit.



Well designed location features allow precise alignment & avoid jamming.



Step	DoF's	Translation	Rotation
1. Component held in free space	6	3	3

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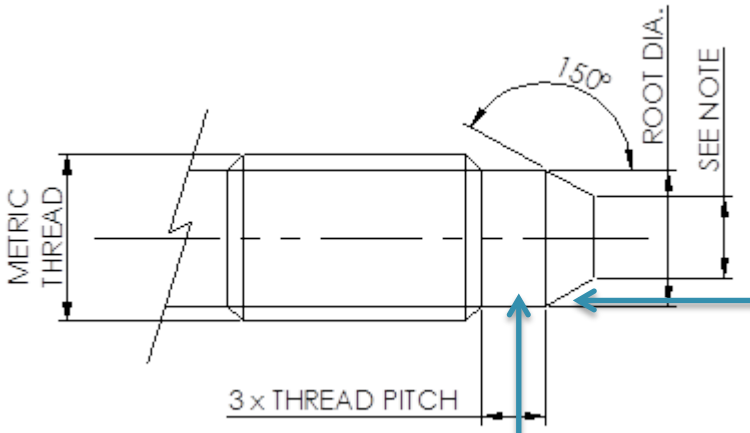
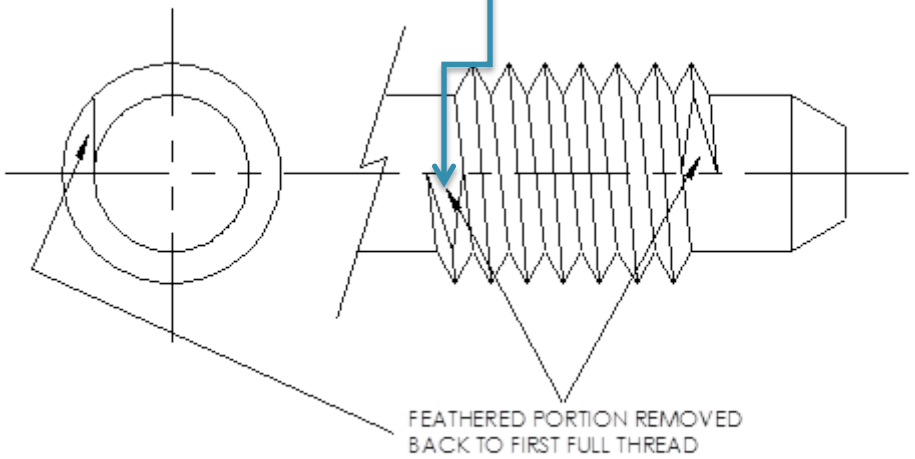
Design of Fasteners Can Prevent cross threading



Lead in assists bolt alignment

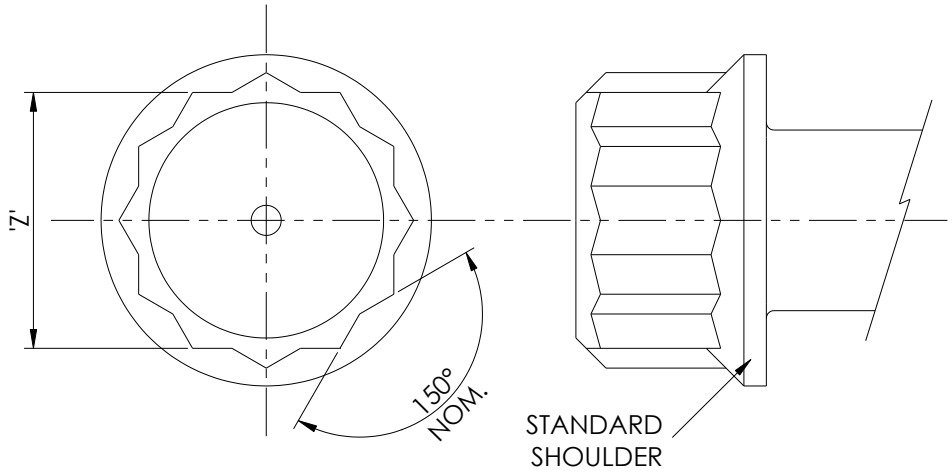
Feathering threads guides threads into groove

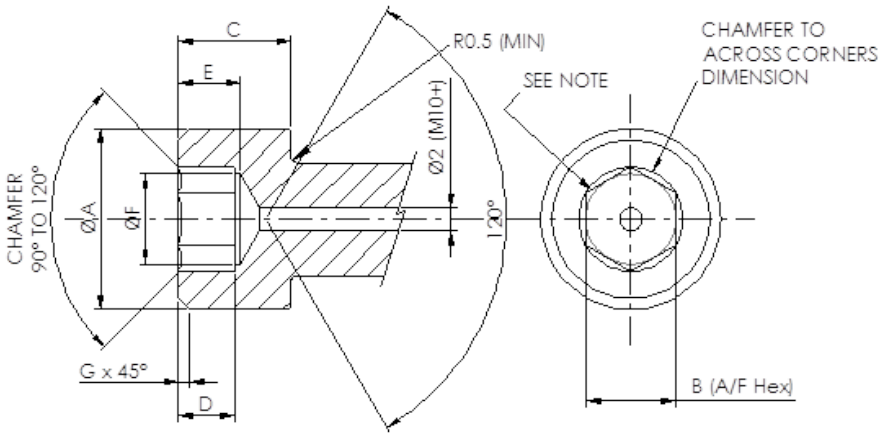
Unthreaded portion squares bolt before thread engagement.



Bolt Heads Can be designed to reduce rounding risk

- Bi-Hex heads are recommended for high torque applications
  - Better socket engagement.
  - Lead-ins guide the tools.
- Standard bolt heads to ISO 4762:2004
  - Surface finish better than 1.6Ra
  - Conical base allows key to fully loaded
  - Pilot hole helps recovery



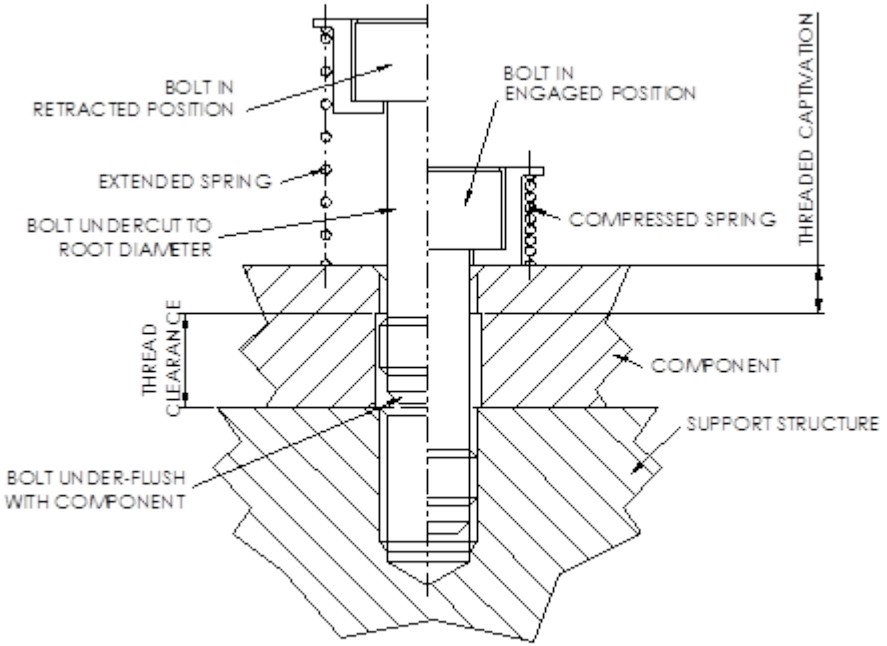


Torque reaction features need to located locally to fastening

- Manipulator cannot react high torques
- Torque Reaction mating features need to be incorporated into components

Captivated bolts assist remote handling

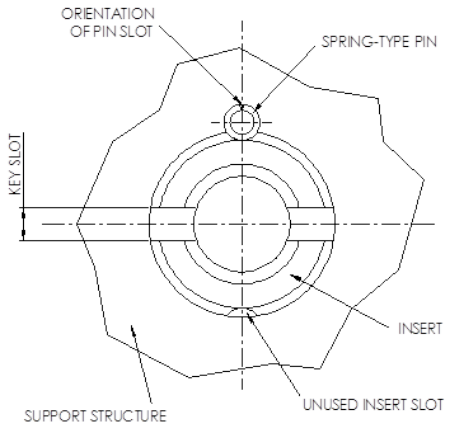
- Captivation improves efficiencey
- Captivation prevents bolts falling into undesirable inaccessible areas
- “Pop-Up” bolts help with remote handling

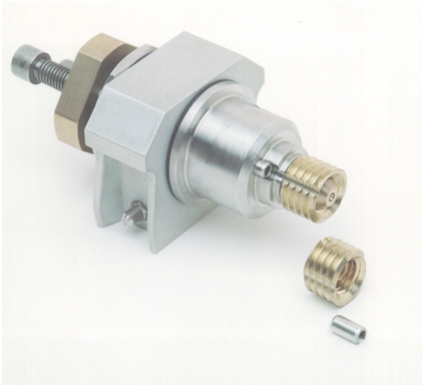


Galling is likely in Target Station.

- Factors increasing material migration & bonding.
  - High pressure
    - High torque
  - High Temperatures
  - Vacuum
  - Proton and Neutron Flux
- Release Torques up to 3 x tightening
- Mitigating Factors
  - Dissimilar materials
  - Cleanliness
  - Vacuum backing

- Prepare for recovery





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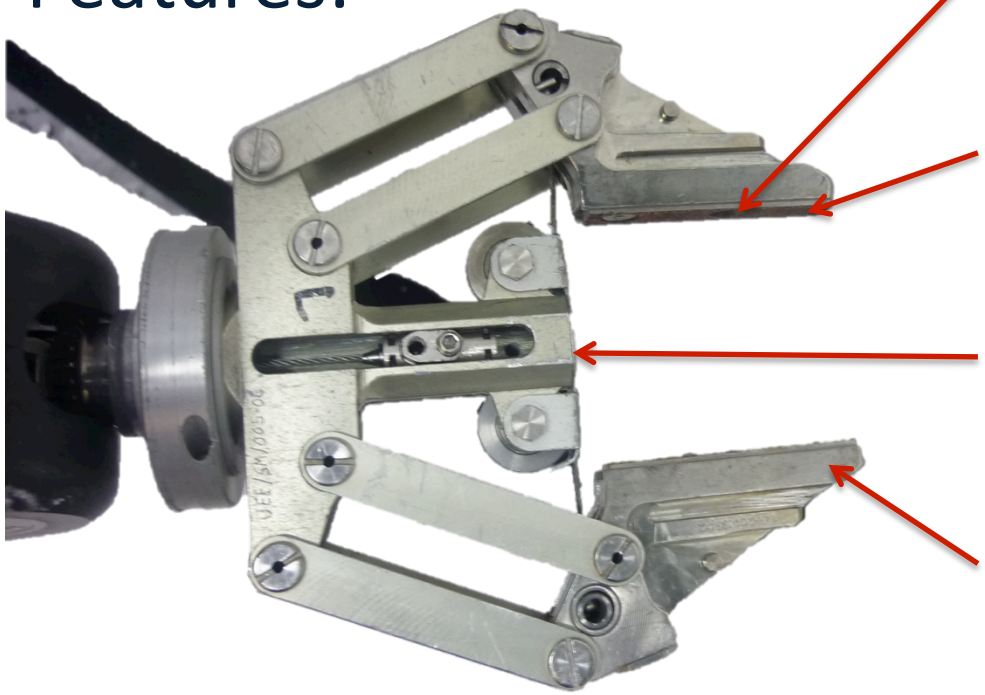
Handling components – Gripper

- Manipulators typically interface with environment with a gripper
- Features:



Securing hole: Accommodates a pin feature on gripped item so the item cannot be knocked out of grip

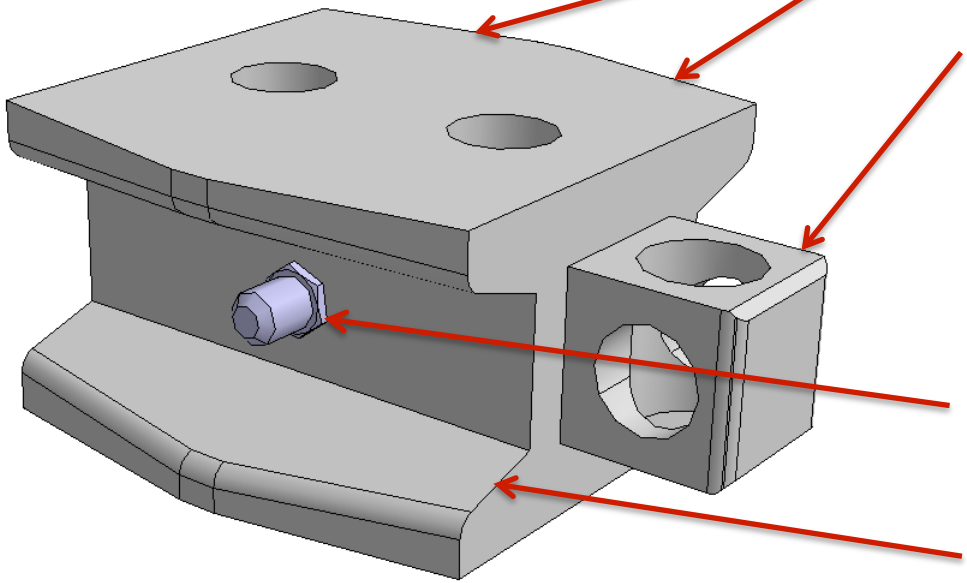
Tungsten carbide coating: High friction surface for picking up unexpected items (e.g. broken bolt)

Locating face: Positions the fingers at a known depth from item to be gripped

Angled gripping faces: Primary contact surface – smooth to not scratch the item and angled to aid alignment of grips

Grip Block

- Custom designed generic gripping interface for handling tools – becomes a standard RH part
- Features:



Angled edges: Aid alignment of grip fingers

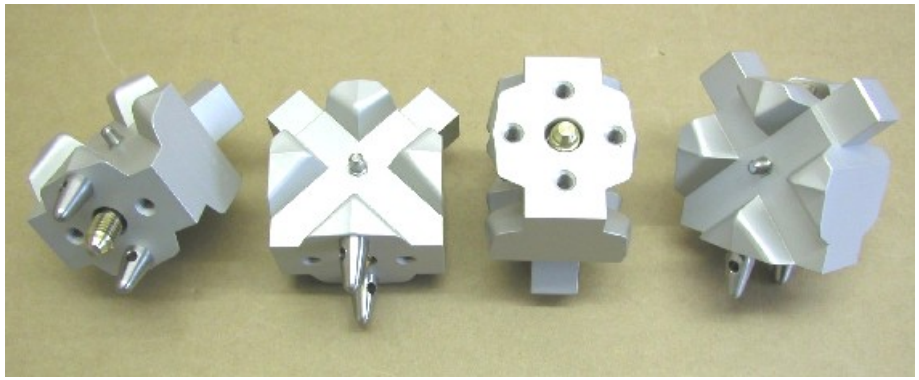
Locating end block: Touch gripper locating face onto end block and fingers will be positoned correctly. Holes can act as temporary tool storage position.

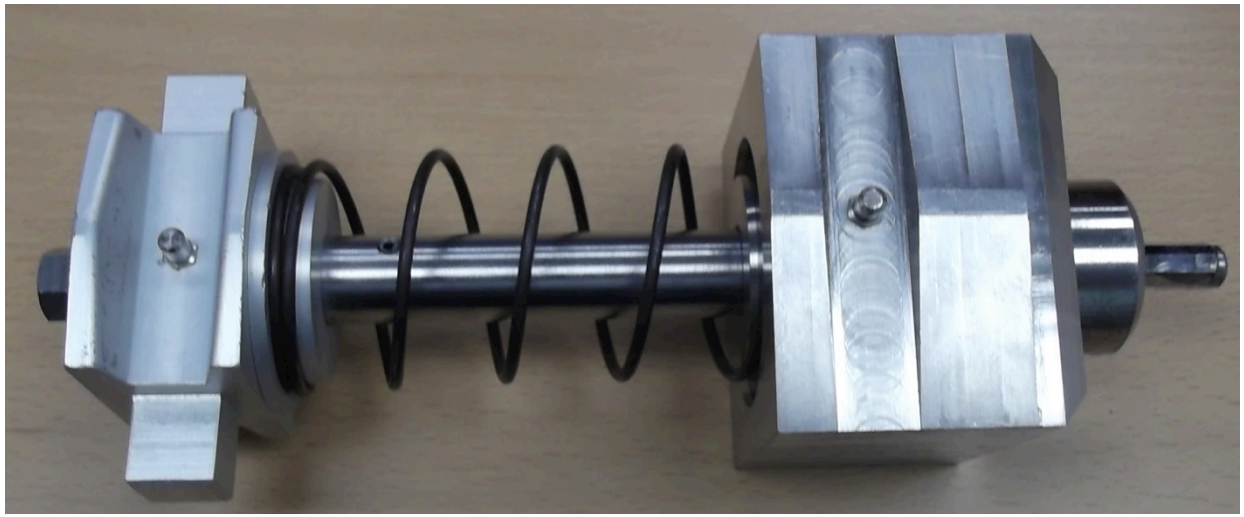
Securing pin: Fits into securing hole in gripper fingers

Angled gripping faces: Primary contact surface

Grip block features

- Grip block interface can be machined directly into tools



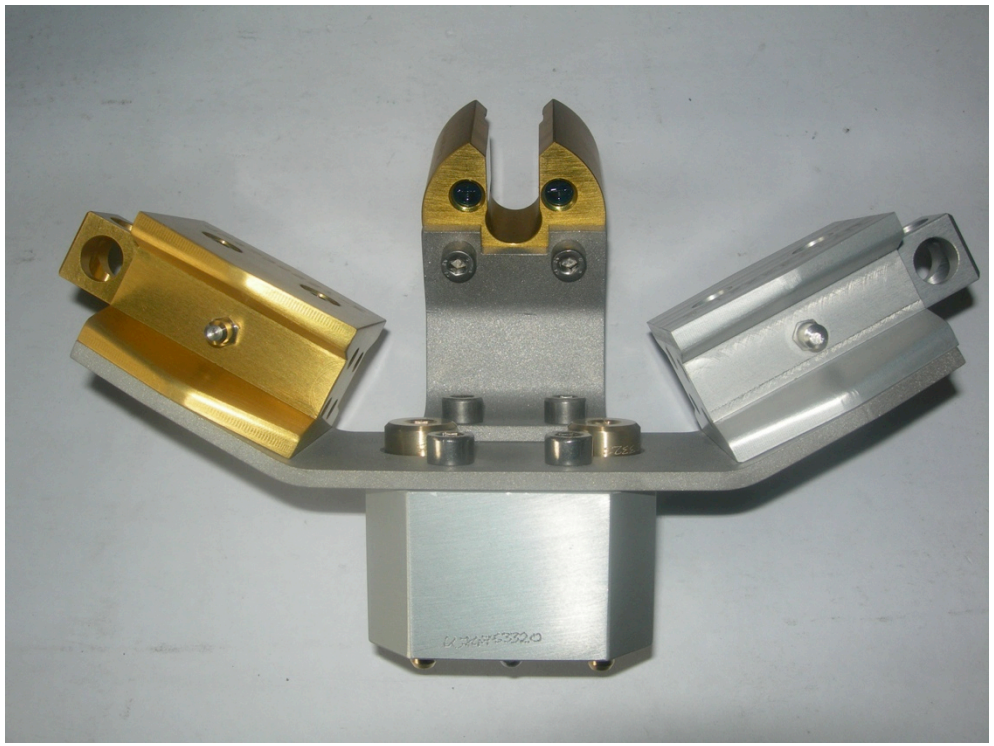


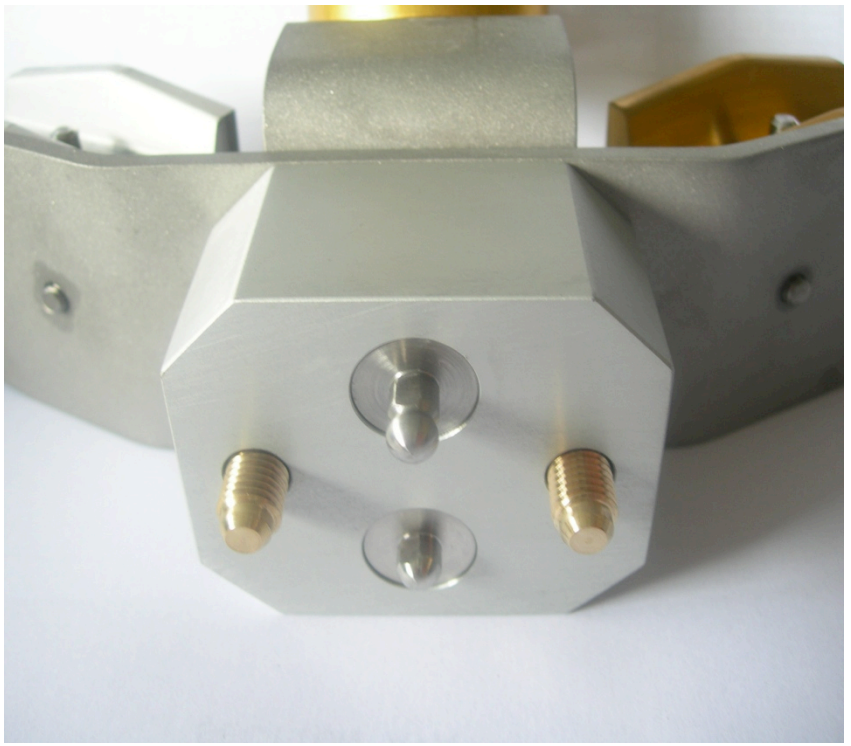
Bolting

- Provide a tapped hole on component and attach a handling tool using one or more bolts
  - Dowels and alignment features included to align bolts over holes
  - Pop-up bolts lift bolts out of bolt holes meaning tool removal is easy

Bolting examples

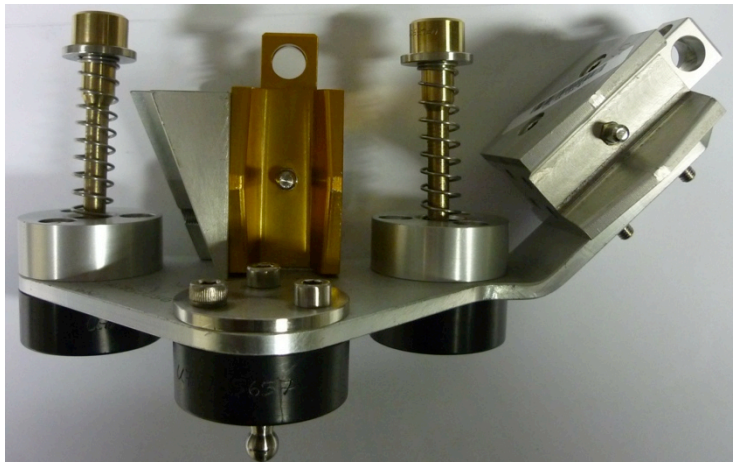
- Alignment features:





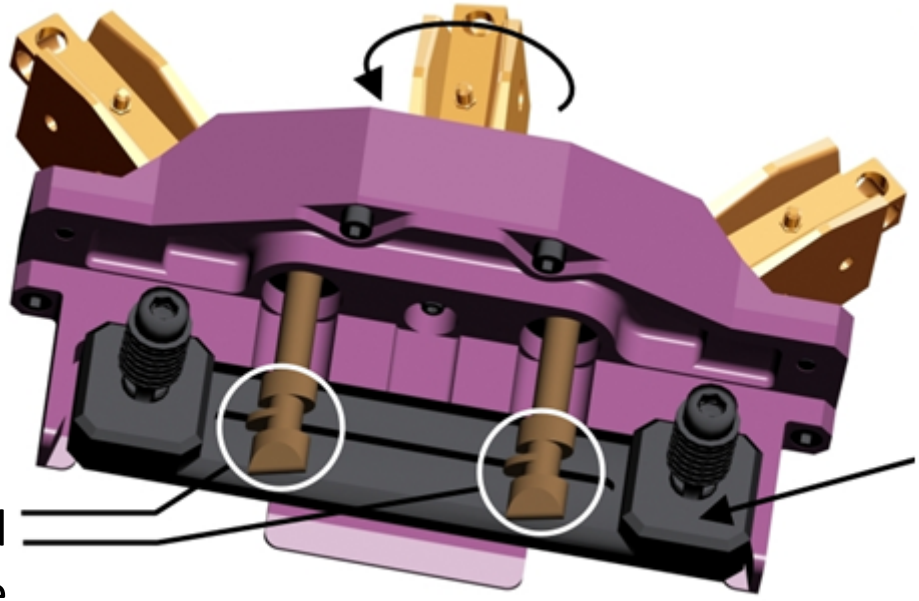
Bolting examples

- Pop-up bolts:

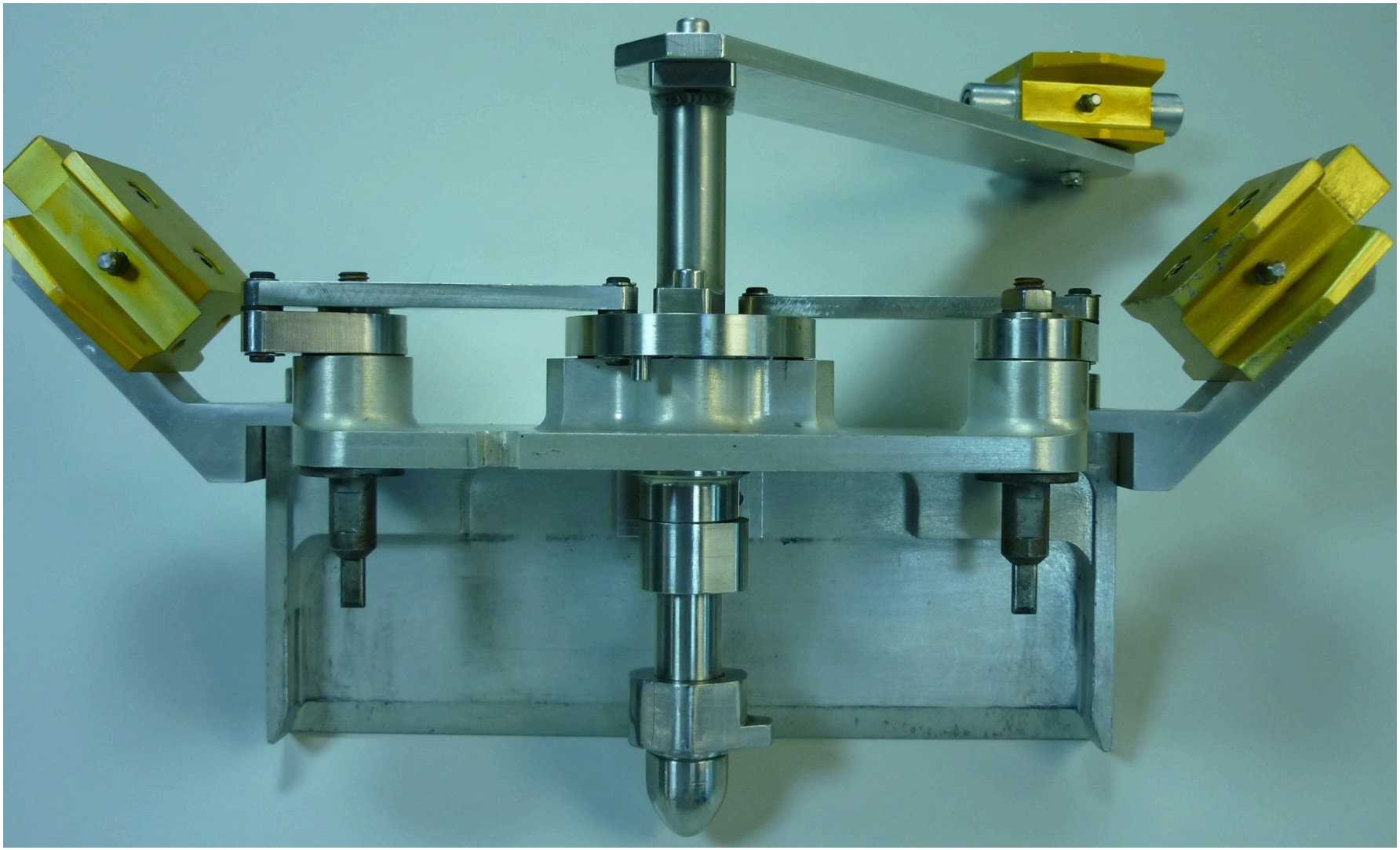


Twist Locks

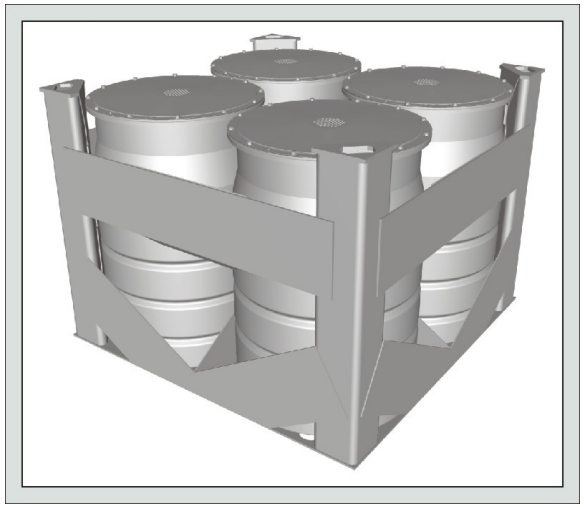
- Tabs or flats on a rotating shaft that lock into/ onto corresponding flats on the component

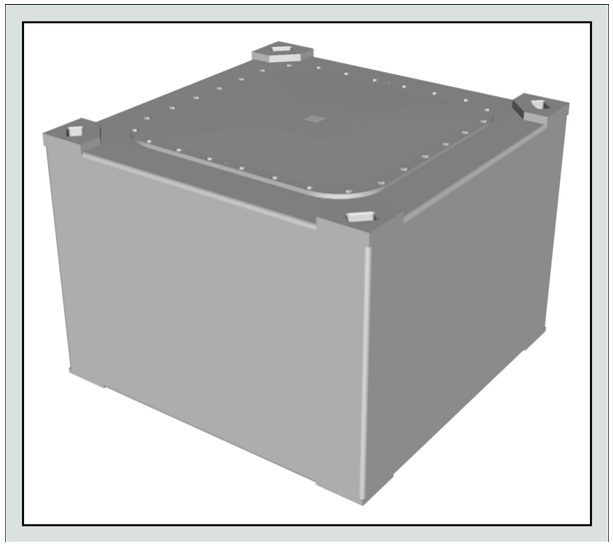


Twist Locks Examples



Twist Locks Are recommended for lifting features

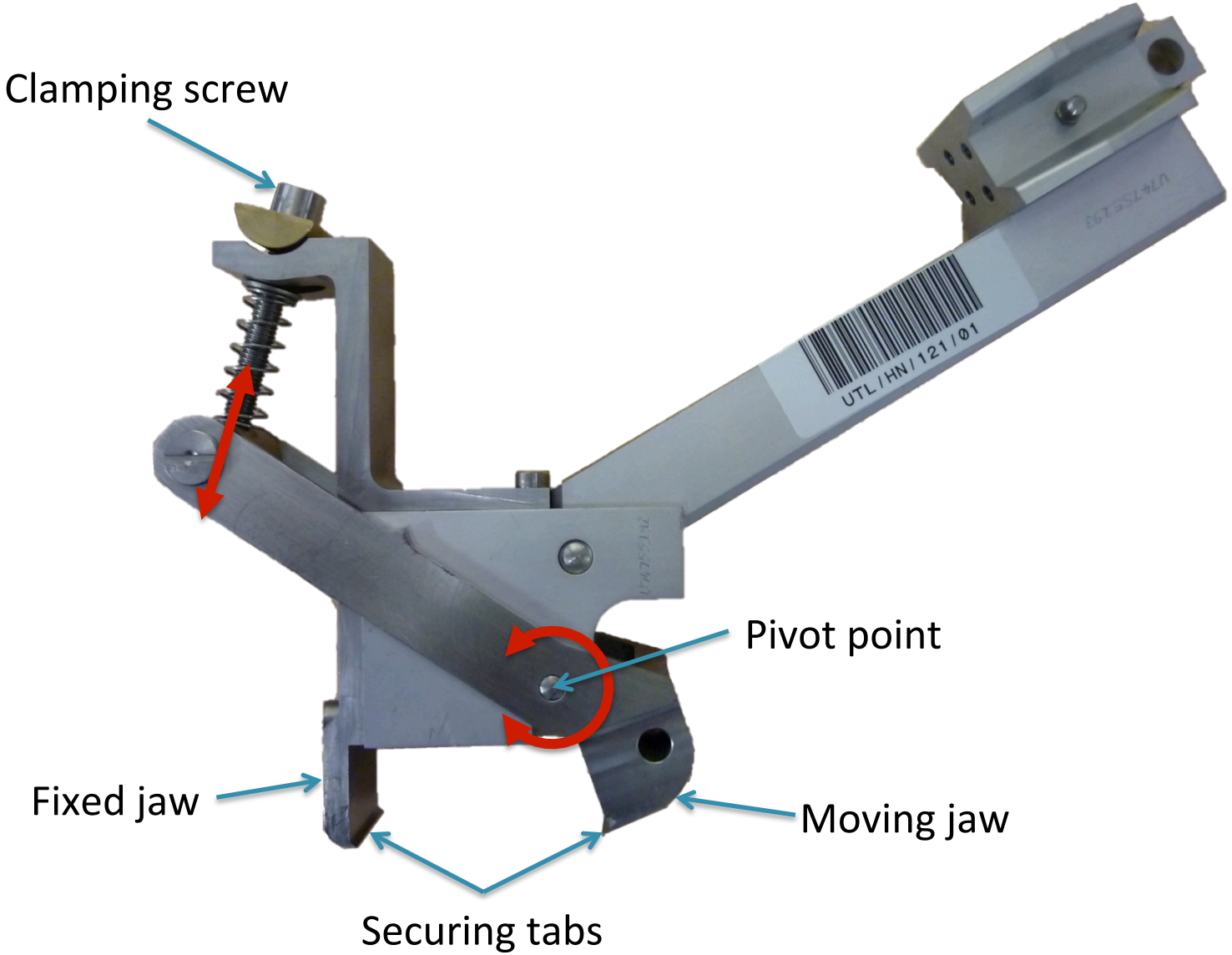




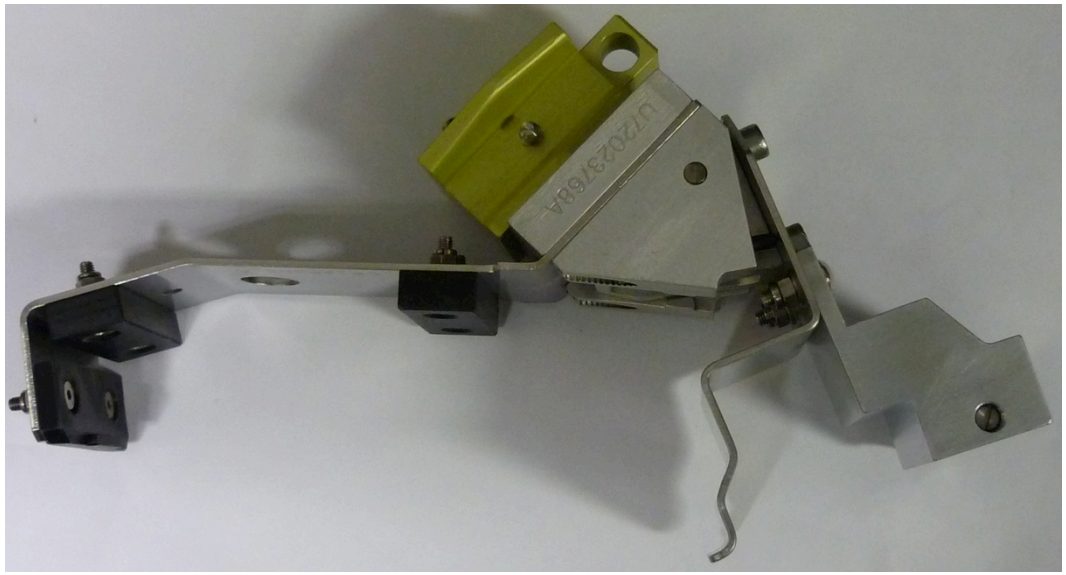
Clamping

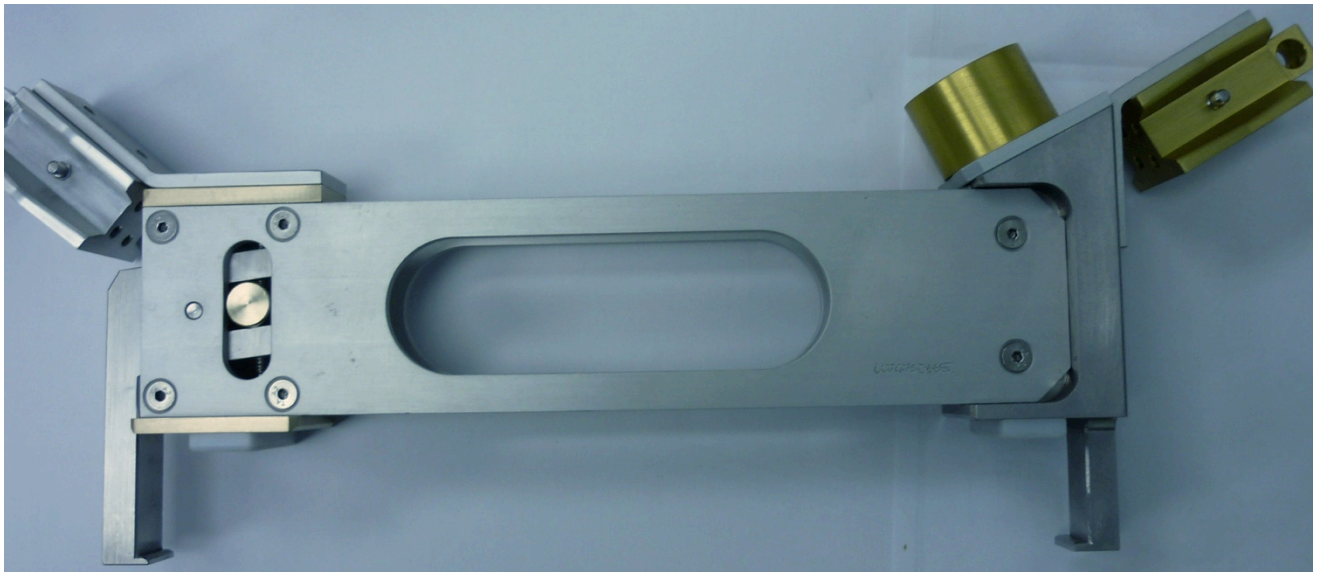
- Clamping involves two jaws – one fixed and one moving
- Movement is controlled in both directions by a mechanism – typically rotating a bolt in either direction
  - Spring-return mechanisms can become stuck in the closed position
- Tabs on the jaws often included to secure component at the back usually when using low clamping forces for a delicate component

Clamping

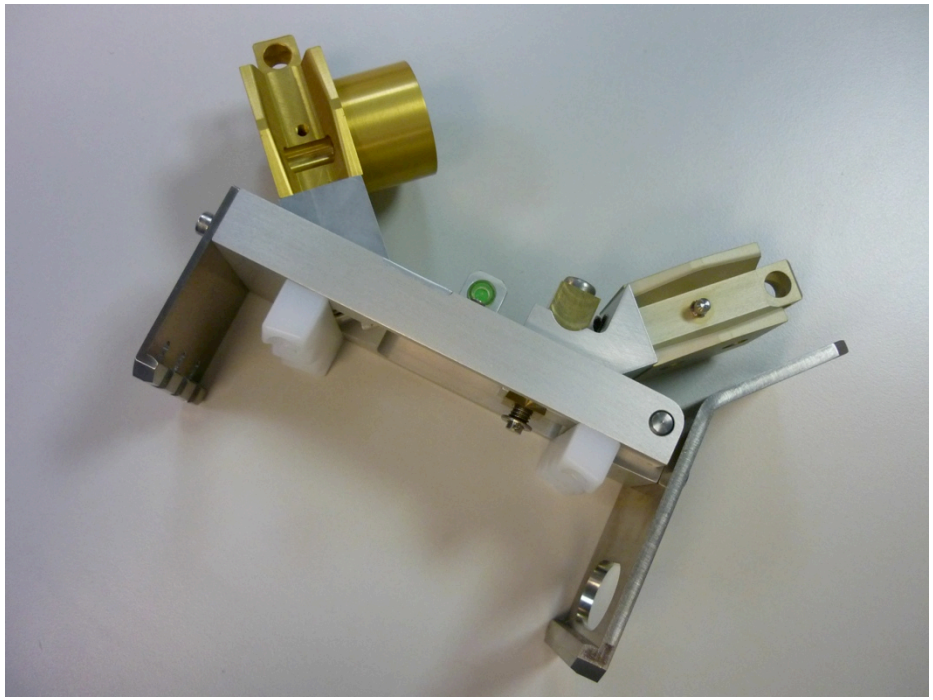

Clamping screw
Pivot point
Fixed jaw
Moving jaw
Securing tabs

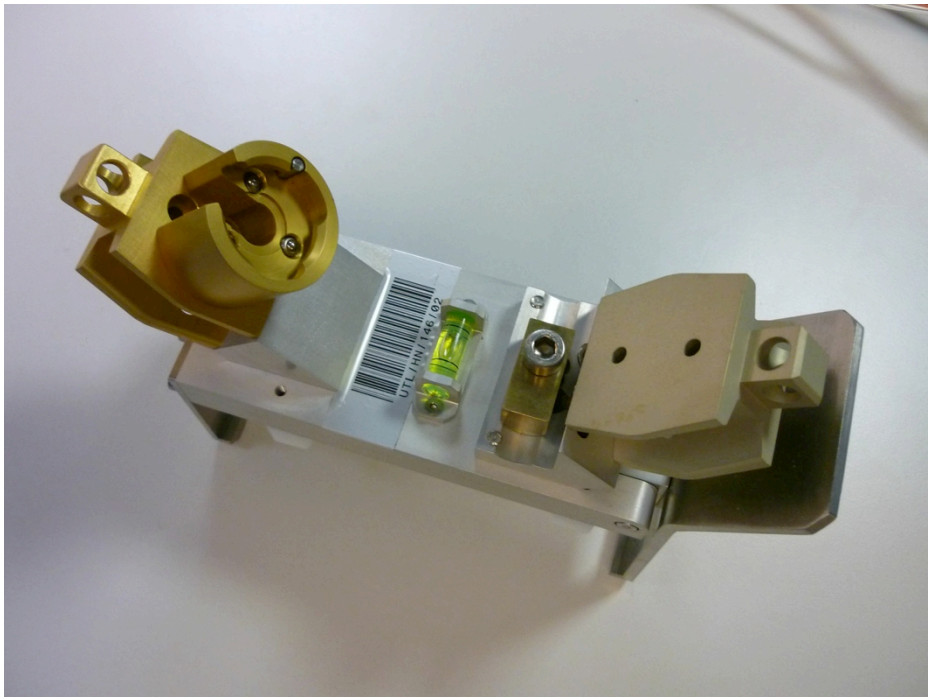
Clamping Examples





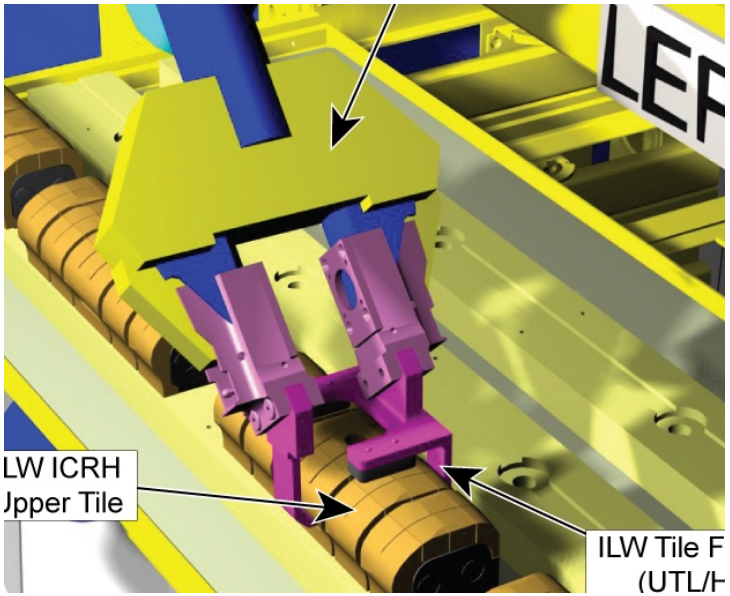
Clamping Examples

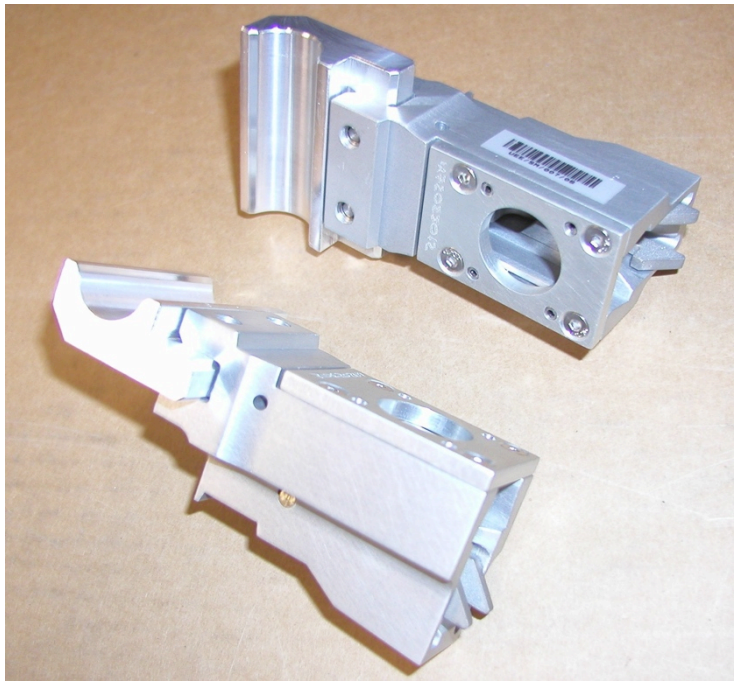




Adapted Fingers

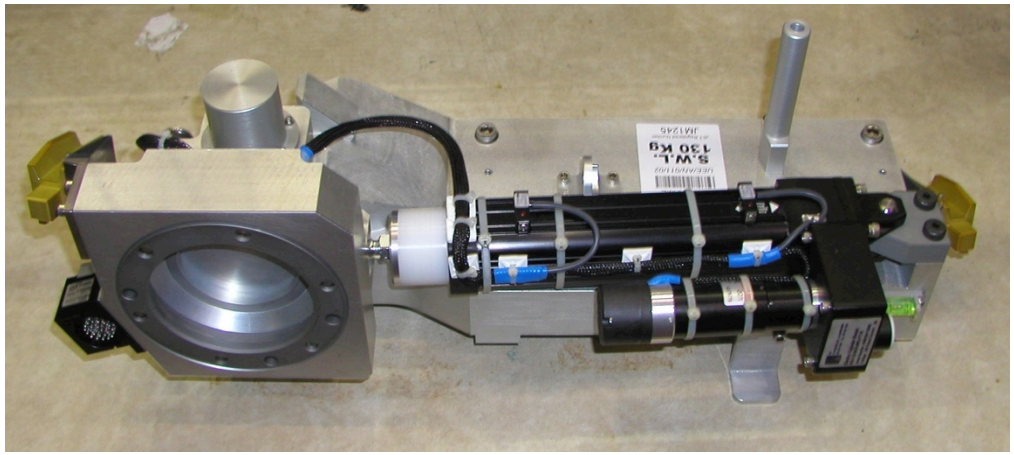
- Customisable add-ons to the grippers
- Can be configured for many different geometries
- Used for handling lots of the same components over and over

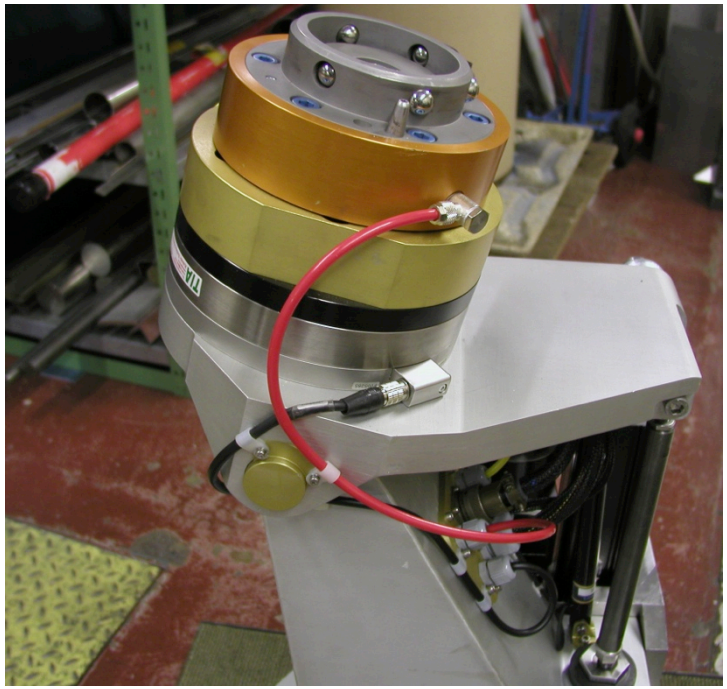




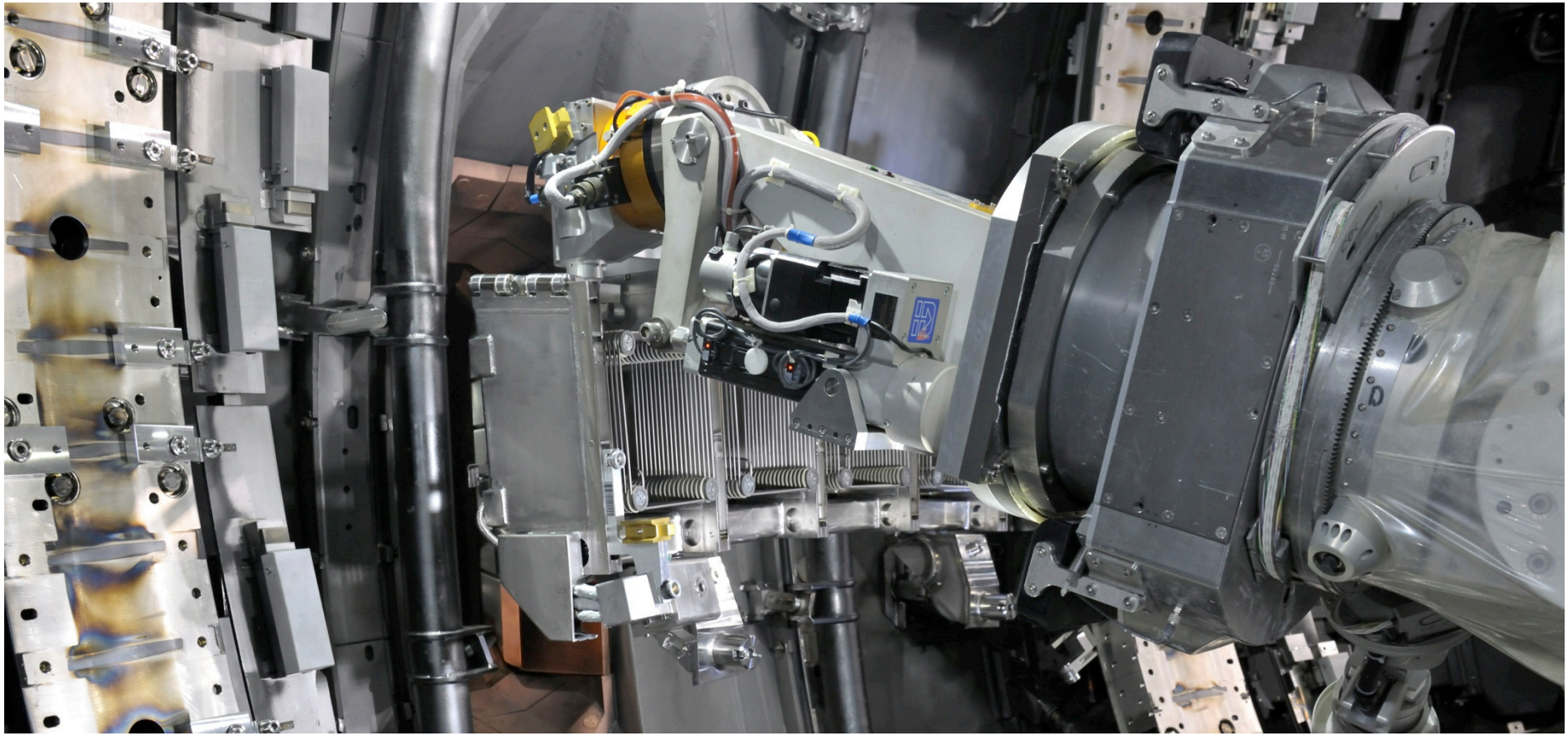
Tool Changer

- Pneumatic remote docking interface
- Includes a six-axis force moment sensor
- Used for handling bigger components





Tool Changer Examples



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Risks to be avoided

- No possibility for any items (e.g. internal pipes) to come loose from the final individual element or remaining structure during any processing step.
- Any brittle materials to be fully enclosed in a protective ductile container.
- Components will be “dry” of any fluid systems as far as reasonably practical.
- No flammable, volatile or explosive materials anywhere within the component.

We would like to engage with you to develop your designs in collaboration


RACE