



# Intelligent perception & robotics for debris removal

Redwire Space Luxembourg

Jan Dentler - R&D Manager

**BUILD ABOVE™**

## What We Do

**Redwire is accelerating humanity's expansion into space by delivering reliable, economical and sustainable infrastructure for future generations**



### Integrated Mission Enabler

Redwire is a key mission enabler with products relevant to almost every space mission.



### Explore, Live, and Work in Space for the Benefit of Humanity

Redwire is developing capabilities that are critical for people to live and work in space.

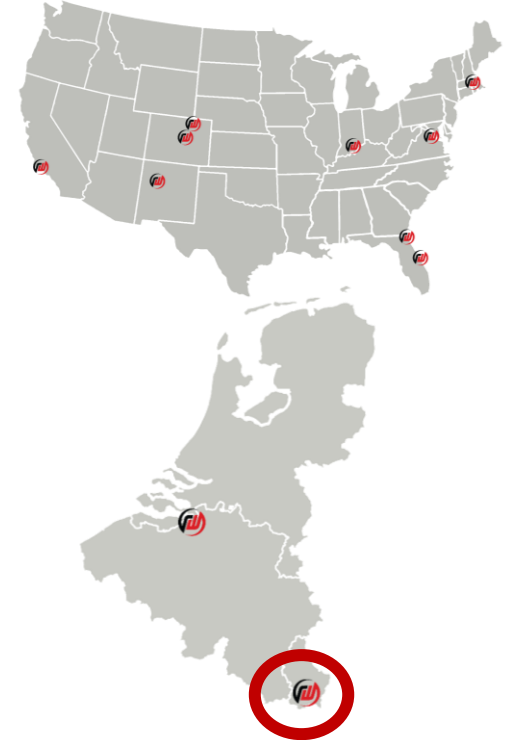


### Multinational Mission Support

Redwire is supporting ambitious, multinational space exploration.



Over 700 Employees Working at 14 Locations in U.S. and Europe



#### LUXEMBOURG

- 2,500 sq. ft facility
- Redwire Engineering & Sales Center in Europe
- Robotic Systems
- Avionics

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# Debris removal - Reasoning

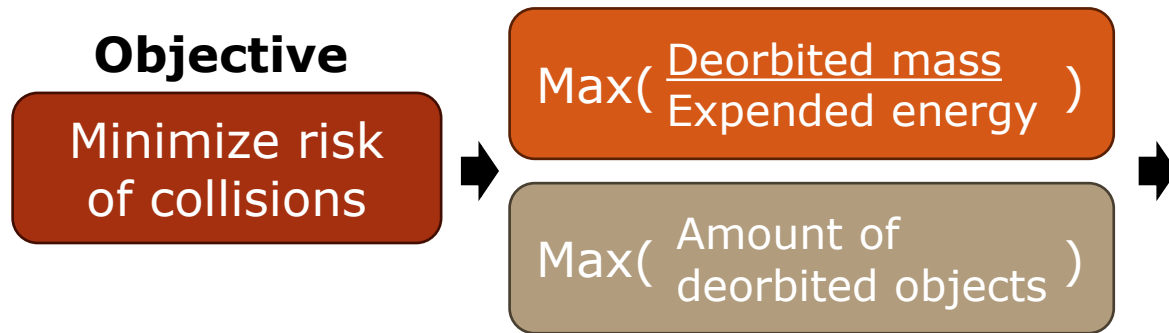
Redwire provides 50+ years of space flight heritage and innovative capabilities for Civil Space and Natural Security missions

Space Mechatronics	Spacecraft Deployables	Advanced Sensors & Components	Cameras & Distributed Avionics	Launch Accommodations	Digital Engineering	Spacecraft Subsystems
<p>Robotics arms</p> 	<p>Solar Arrays</p> 	<p>Star Tracker</p> 	<p>Cameras with On-board Processor</p> 	<p>Payload Adapters</p> 	<p>Modeling &amp; Simulation</p> 	<p>Thermal Transport</p> 
<p>Solar Array Driving Assemblies (SADA)</p> 	<p>Flexible Arrays</p> 	<p>Sun Sensor</p> 	<p>Machine Vision</p> 	<p>Custom Rideshare Hardware</p> 	<p>Digital Twins</p> 	<p>Thermal Radiator</p> 
<p>Pointing Mechanisms</p> 	<p>Antenna</p> 	<p>Micro Sun Sensor</p> 	<p>Distributed Avionics</p> 	<p>Ground Support Equipment</p> 	<p>Constellations</p> 	<p>Thermal Storage</p> 
	<p>Structural Booms</p> 	<p>Quadrant Sun Sensor</p> 	<p>Cameras for simple image capture</p> 	<p>Test and Integration Services</p> 	<p>Hybrid Architecture Labs</p> 	<p>Batteries and Power Distribution</p> 



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# Debris removal - Reasoning

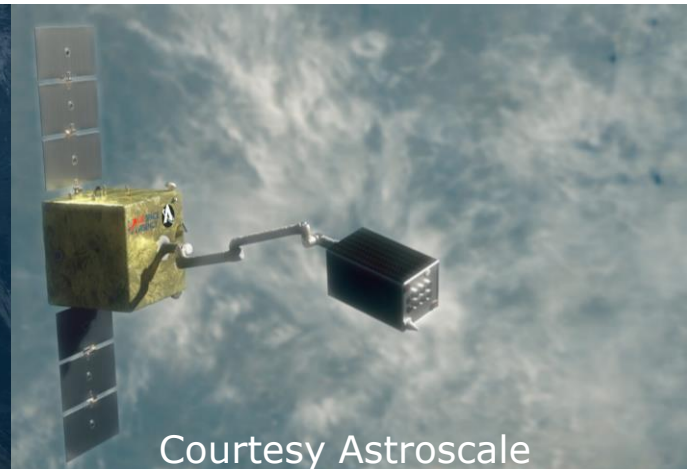
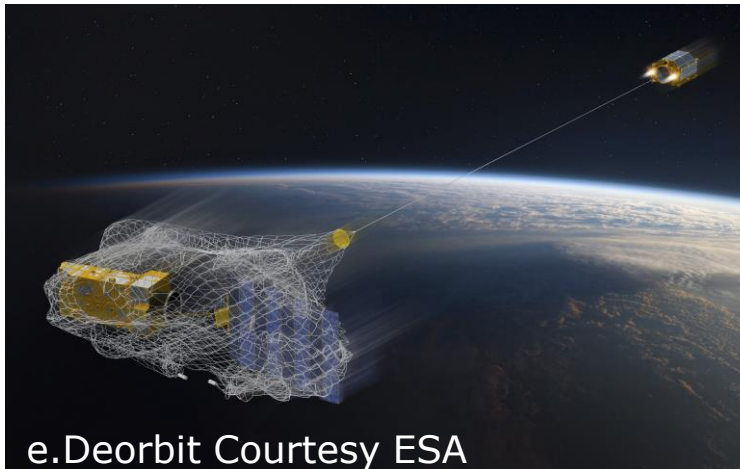


## Robotic arms:

- Complexity
- Detumble limitations
- + Adaptation to local dynamics
- + Generalizability
- + **Multi-use** / Multi-trial
- + **Interaction & Storage**

- ➔ Ability to react minimizes risk
- ➔ Limiting deformation
- ➔ Reuse

**Redwire: Full stack Intelligent systems for autonomous in space operations**



# Debris removal – Hardware Solutions



## Hardware



### 2M VERSION (MAXIMUM LENGTH)

- + **Dexterity**  
6 DoF
- + **Total Extended Reach**  
1.92 meters (without end effector)
- + **Stowage volume**  
1100 mm x 655 mm x 275 mm
- + **Mass**  
32 kg (manipulator, HDRMs + Robot Control Unit)

### FLIGHT TESTING LEVELS

- |   |  |                               |
|---|--|-------------------------------|
| <b>VIBRATION</b><br>+ <b>Quasi static loads</b><br>25 g X,Y,Z<br>+ <b>Sine loads</b><br>25 g X,Y,Z 0-100Hz<br>+ <b>Random loads</b><br>15.3 Gms. X,Y,Z 0-2000Hz | <b>TVAC</b><br>+ <b>Qualification</b><br>-30C to +50C 6 cycles<br>+ <b>Acceptance</b><br>-30C to +50C 4 cycles | <b>EMI/EMC</b><br>MIL-STD-461 |
|---|--|-------------------------------|

### OTHER FEATURES

- |                                |                                     |                      |                  |
|--------------------------------|-------------------------------------|----------------------|------------------|
| + Customized manipulator       | + Harness fixtures for end effector | + Robot Control Unit | + Vision system  |
| + HDRM-1, HDRM-2, Passive-HDRM | + Heaters                           | + Flight software    | + Planning tools |

# Debris removal – Perception Solutions



## Perception Applications – Pose Estimation

### Marker-based

- + Easy of use
- + Well established
- + Algorithm explainability
- Low information density
- Only image sensing
- Feature loss susceptibility

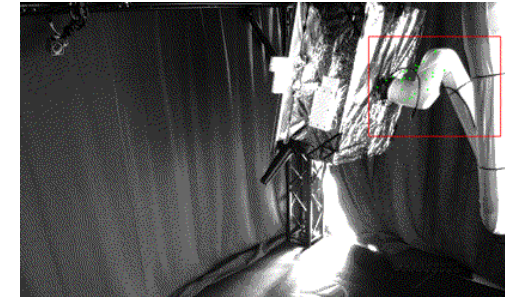
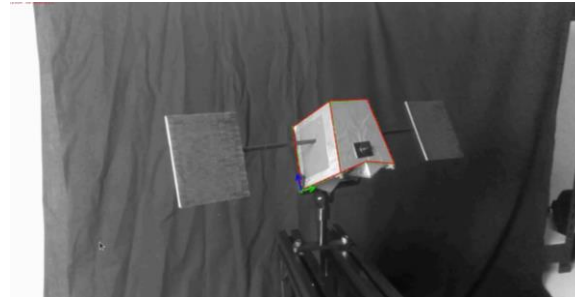
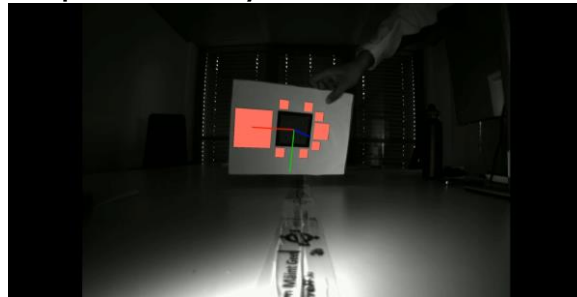
### Structure-based

- + Higher information density
- + Algorithm explainability
- + Sensor fusion
- Low information density
- Manual feature selection
- Feature loss susceptibility

### Structure-based (AI)

- + High information density
- + Robust feature extraction
- + Sensor fusion
- Algorithm qualification
- Training effort
- Limited resilience to feature loss

Explainability



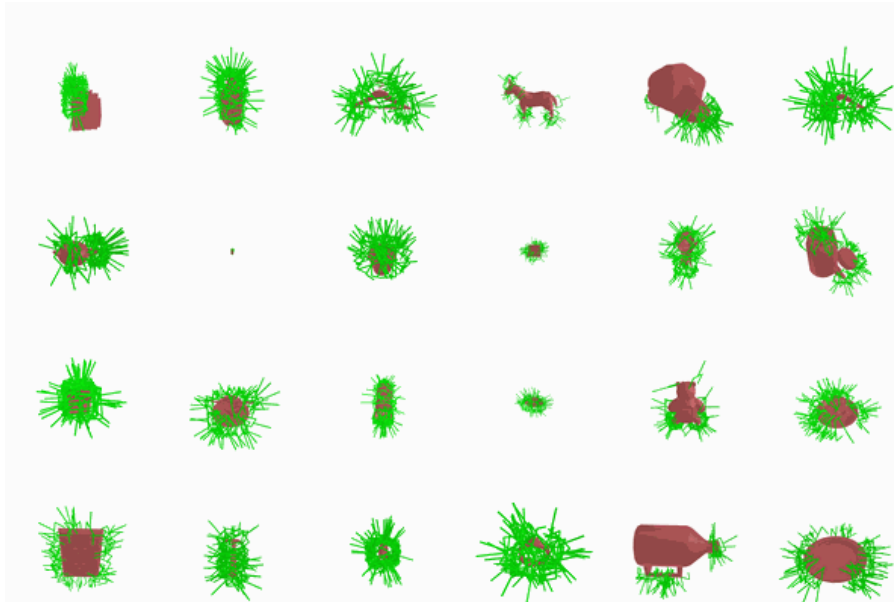
Reliability

# Debris removal – Perception Solutions

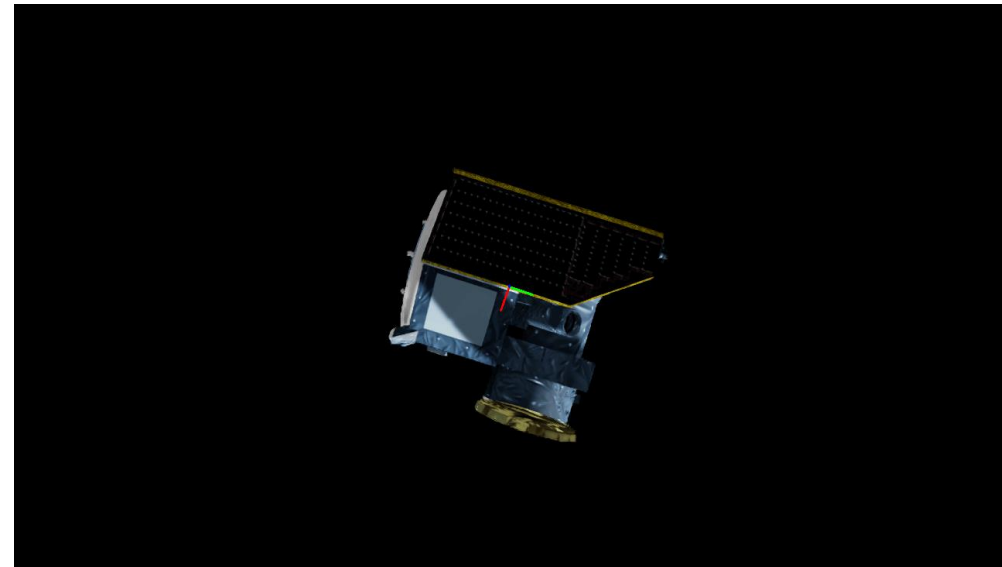


## Perception Applications – Unknown object manipulation

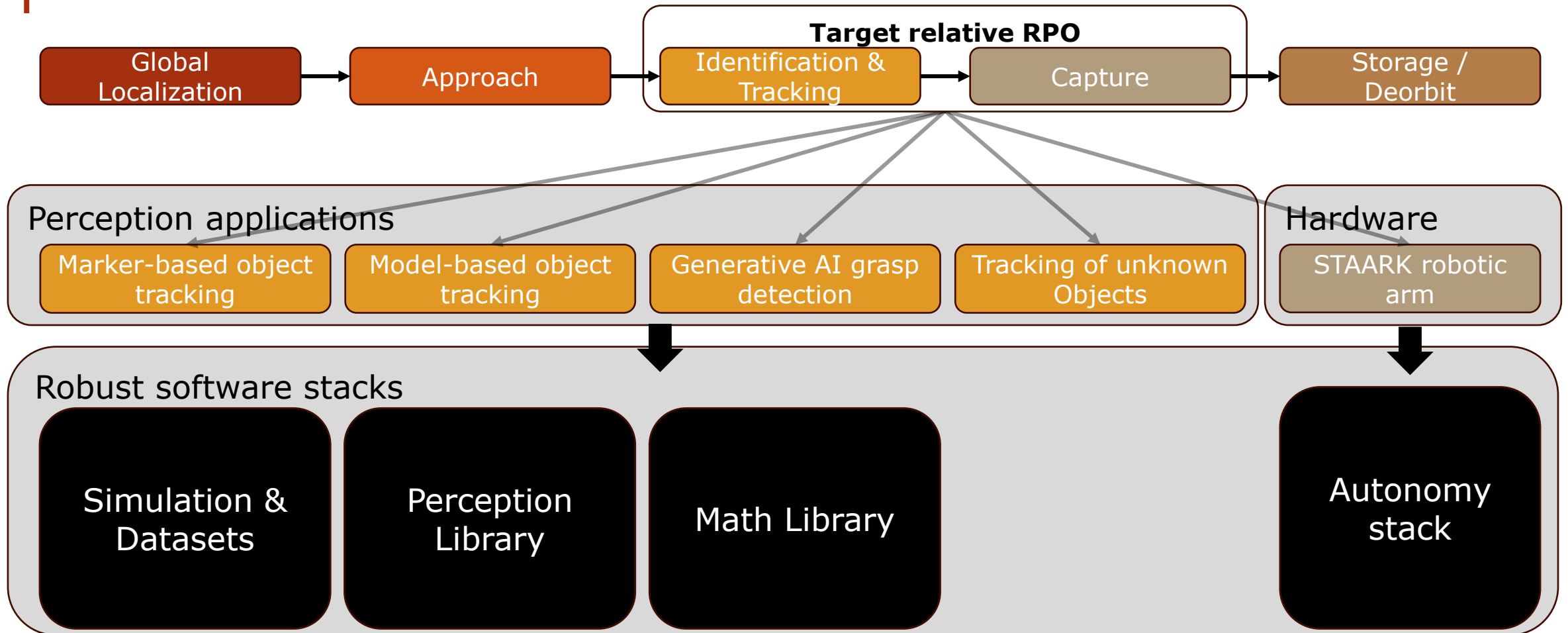
Object centric grasp detection



Spatiotemporal consistent object tracking



# Debris removal – Software Solutions





# Debris removal – Autonomy Solutions

## Basic STAARK capabilities

- Software infrastructure
- Joint space control
- System housekeeping
- Basic TMTC

## Enhanced STAARK capabilities

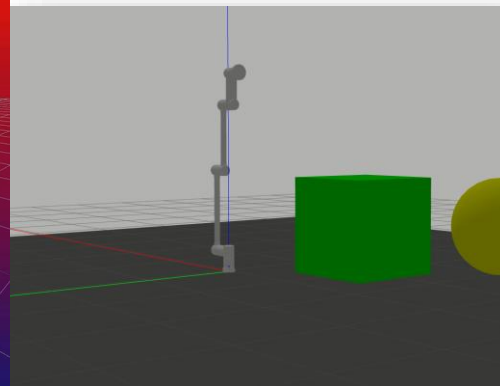
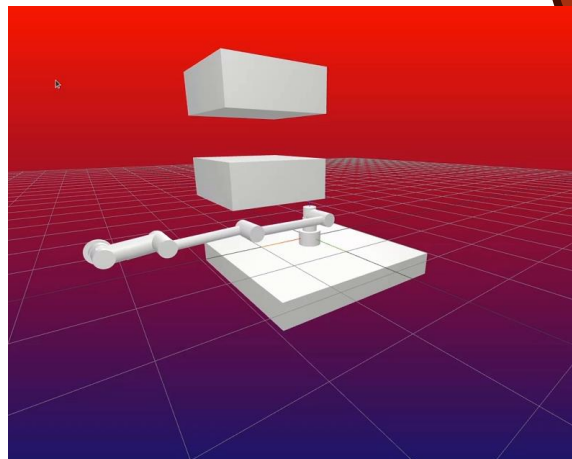
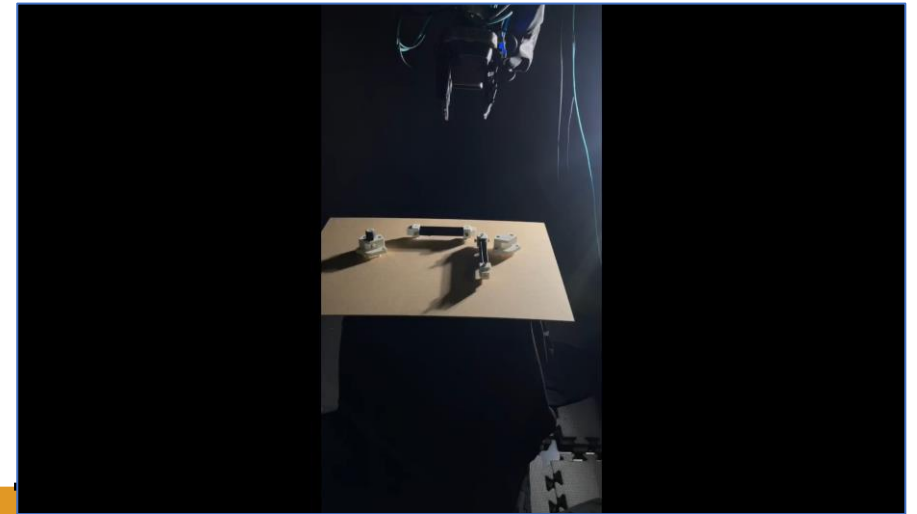
- Task management
- Path planning
- Static collision detection
- Cartesian space control
- Space Packet Protocol
- Kinematic simulator

## Advanced STAARK capabilities

- Perception integration
- Fiducial marker pose e
- Tool integration
- Visual servoing
- Compliance control
- Dynamic simulator
- Advanced FDIR

## Future STAARK capabilities

- Grasping of unknown object
- Advanced behaviours (assembly, etc.)



Q4 2019

Q2 2023

2025

2027

*Depends on safety requirements*

# Thank you! 2020-2024

