

# Airframe Sealing Automation using a Snake Robot

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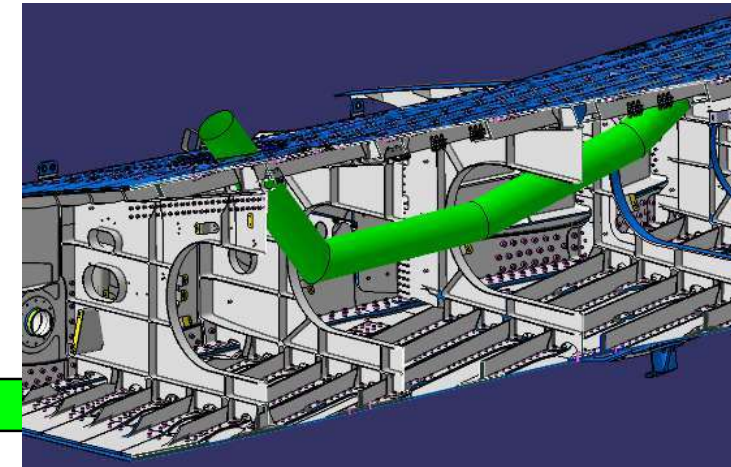
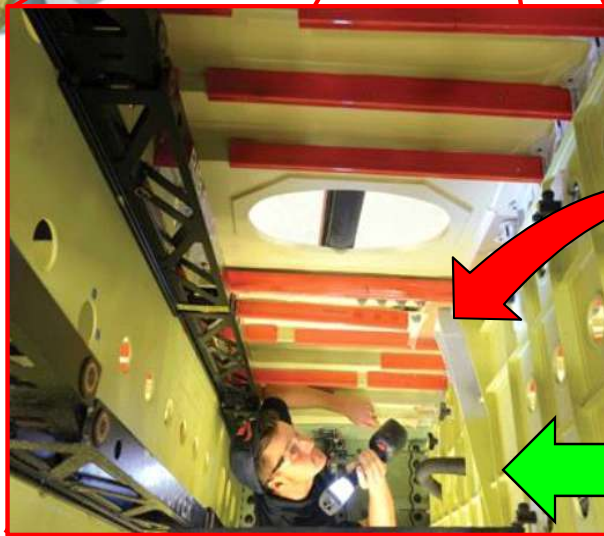
# Airframe Sealing Automation using a Snake Robot

## Introduction

- Most part of the airframe must be sealed.



- Manual sealing process.

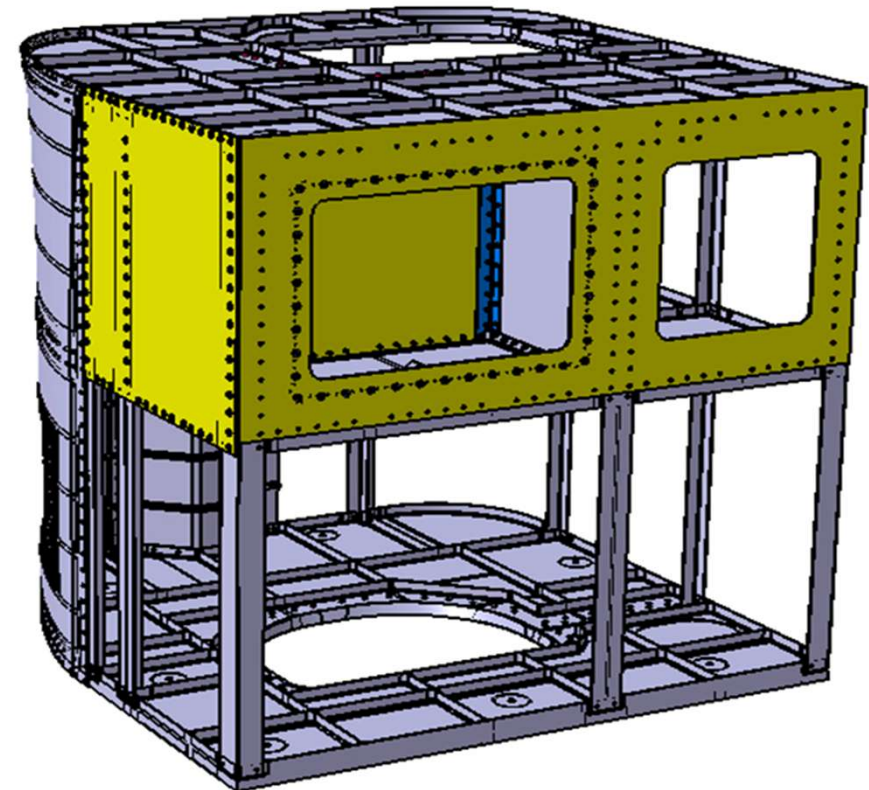


# Airframe Sealing Automation using a Snake Robot

## Project Objective

**General Objective:** Feasibility analysis of a concept of a virtual snake-robot for automatic application of sealant in aeronautical structures.

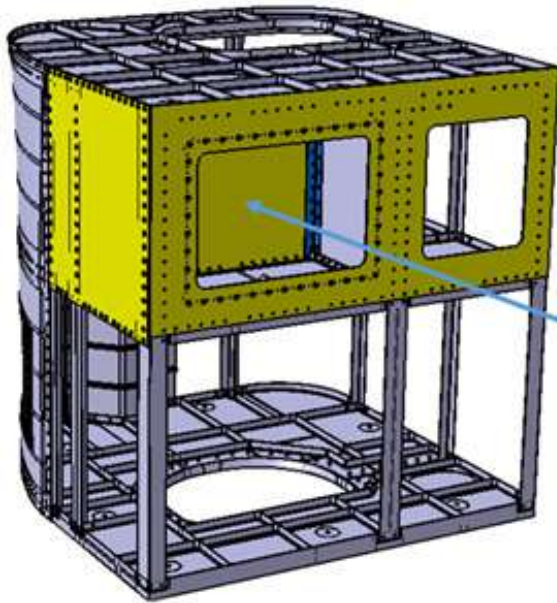
- Design of the snake-robot
  - Evaluate the design in a virtual application for automated sealing in confined spaces;
  - Reach TRL4, which will be the basis for a continued project aiming for a physical demonstration at a higher TRL (TRL6).
- Reduce the size and weight of an earlier developed/demonstrated end-effector for automated sealing (focus on fillet sealing and fastener over-coating).
  - Evaluate the design in a virtual application for automated sealing in confined spaces;
  - Reach TRL4, which will be the basis for a continued project aiming for a physical demonstration at a higher TRL (TRL6).



■ Virtual *DMU* – Digital Mock-Up

# Airframe Sealing Automation using a Snake Robot

## Scope of the project execution



Typical fuel area that must be fully sealed. This includes both the fillets and the coating of the fasteners (a hatch is attached to close the tank in real applications).



### Retainer Systems

Includes cartridges, pistons, outlet caps, end caps and retainers. For use with most assembly fluids and pastes. Sold individually.

Size	No Regulator	0-15 PSI Regulator	0-100 PSI Regulator
2.5 oz	7012430	7012431	7012432
6 oz	7012433	7012434	7012435
12 oz	7012436	7012437	7012438
20 oz	7012439	7013889	7012440
32 oz	7013899	-	7014100



**PR1776 B2 (PPG)**

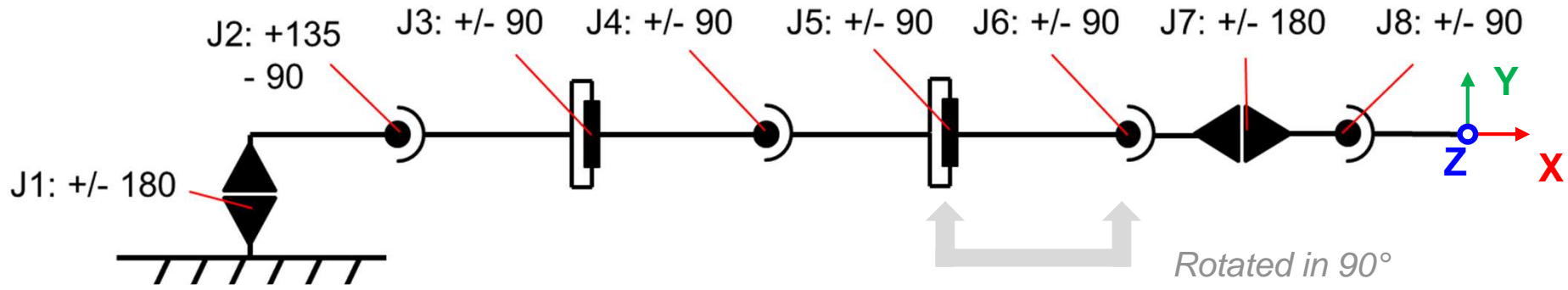


- Cycle time: 10 s/rivet;
- Minimum speed: 50 mm/s;
- Collaborative Robotics;
- Reach: 1 m;
- Maximum positioning error: +/- 2 mm;
- Offline Programming;

Definition of an application and requirements

# Airframe Sealing Automation using a Snake Robot

## Snake robot project - Kinematic model of the snake robot



D-H parameters:

Link	$\theta^{*1}$	$d^{*2}$	$a^{*2}$	$\alpha^{*1}$
# 1	$q_1$	0,022	0,277	$\pi/2$
# 2	$q_2$	0	0,249	$\pi/2$
# 3	$q_3$	0	0,212	$\pi/2$
# 4	$q_4$	0	0,196	$\pi/2$
# 5	$q_5$	0	0,196	$\pi/2$
# 6	$q_6; -\pi/2; 0$	0; 0; 0,060	0; 0; 0	0; $-\pi/2$ ; 0
# 7	$q_7; 0; \pi/2; 0$	0; 0; 0; 0	0; 0; 0; 0,165	0; $\pi/2$ ; 0; 0
# 8	$q_8$	0	0,084	0

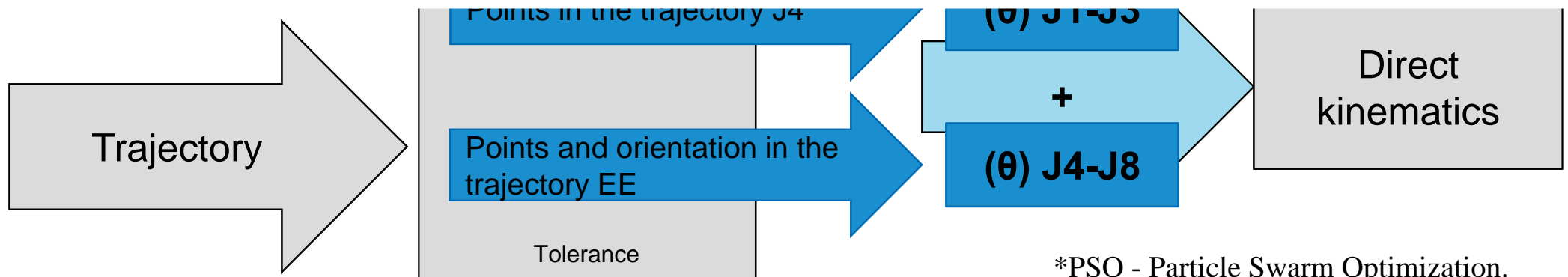
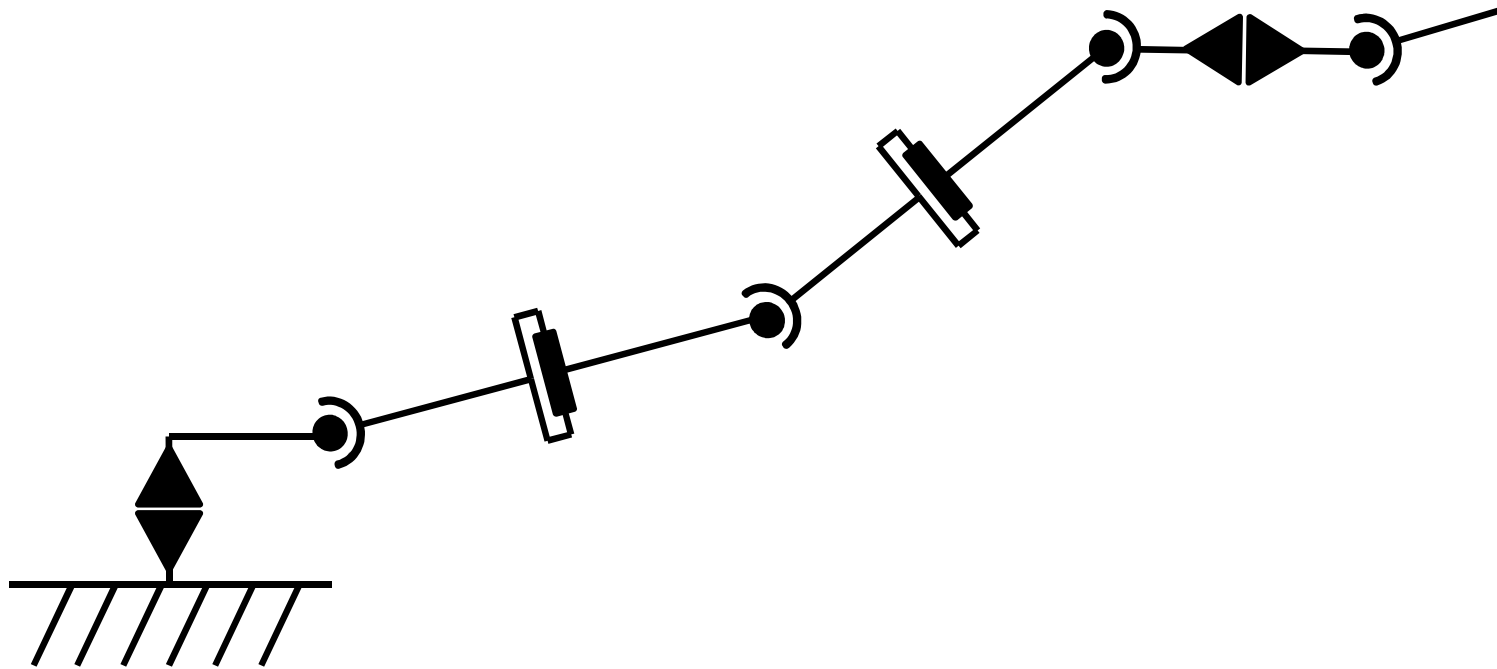
- 8 Degrees of freedom;
- High modularity (N-joints rotated by 90°);
- High ability to overcome obstacles;
- High flexibility (Large joint amplitudes).

\*1 – All input information of angles must be in radians [rad].

\*2 – All input information of length must be in meters [m].

# Airframe Sealing Automation using a Snake Robot

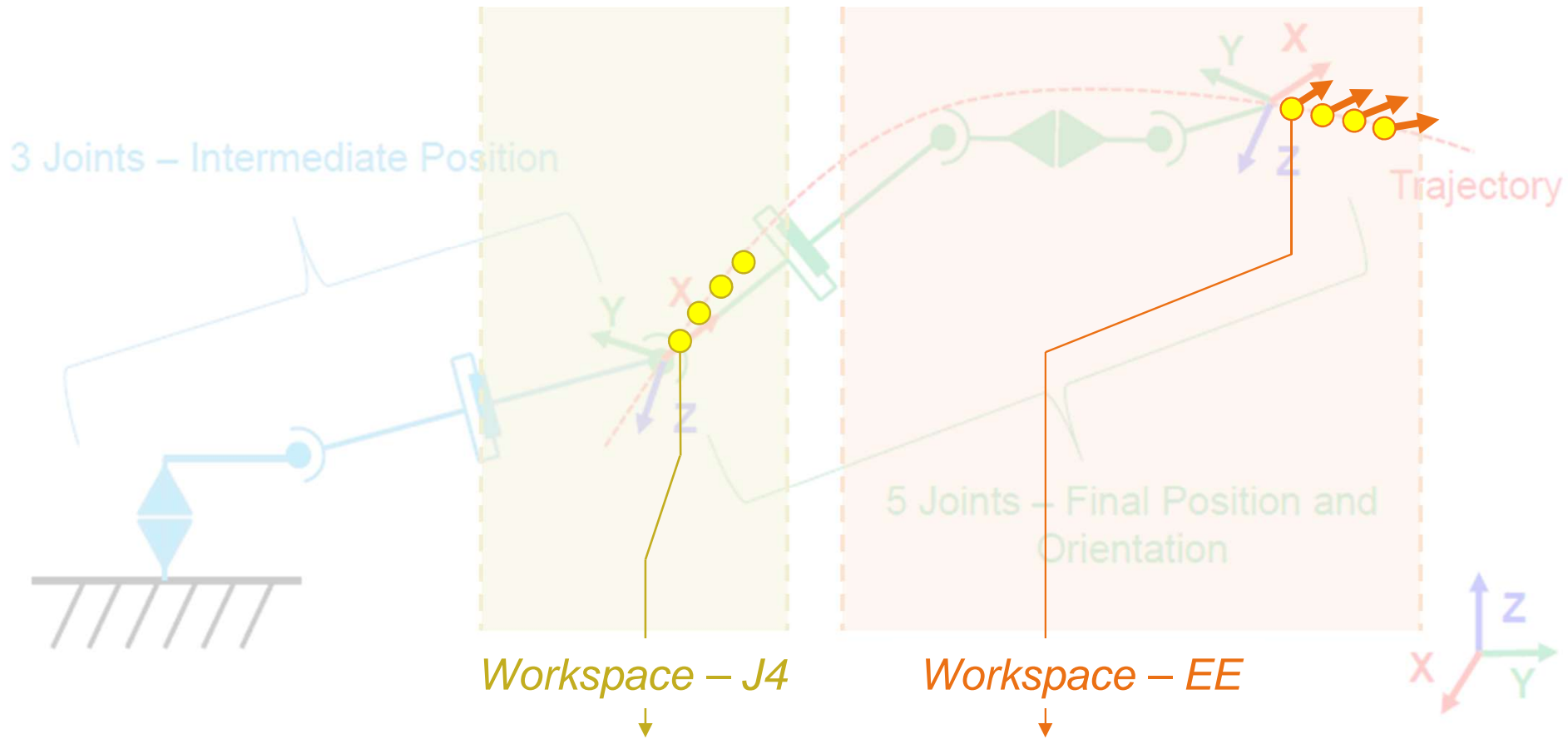
## Snake robot project - Inverse kinematics



\*PSO - Particle Swarm Optimization.

# Airframe Sealing Automation using a Snake Robot

## Snake robot project - Trajectory strategy for inverse kinematics



Commanded Pose

= 1 point

+ 1 point & 1 vector

= 2 points & 1 vector

Commanded Trajectory

= N points

+ N points & N vectors

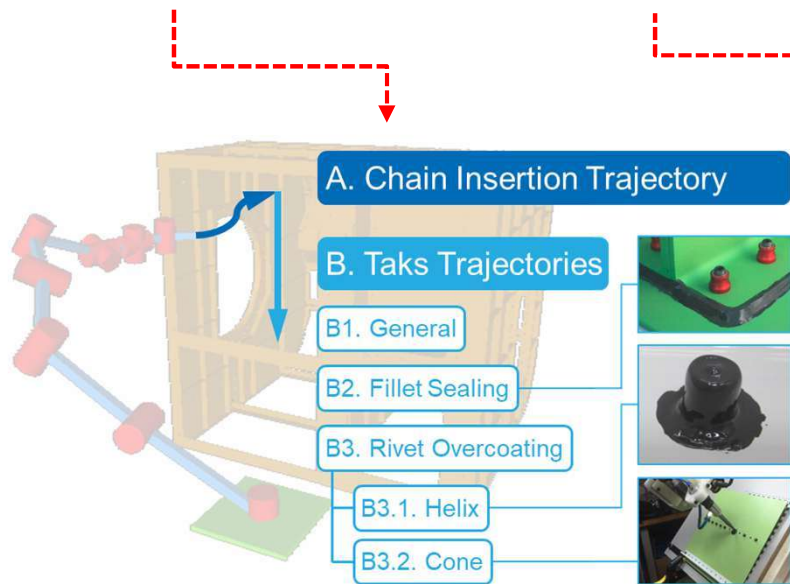
= 2N points & N vector

# Airframe Sealing Automation using a Snake Robot

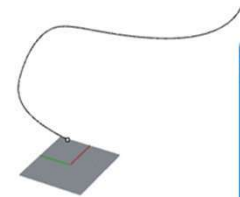
## Snake robot project - Generation of trajectories



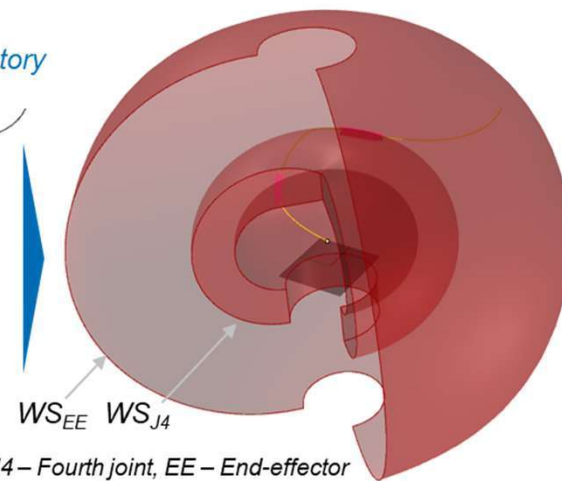
Programmer



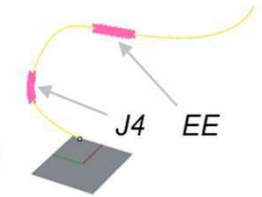
Complete trajectory



Legend:  
WS – Workspace, J4 – Fourth joint, EE – End-effector



Trajectory points



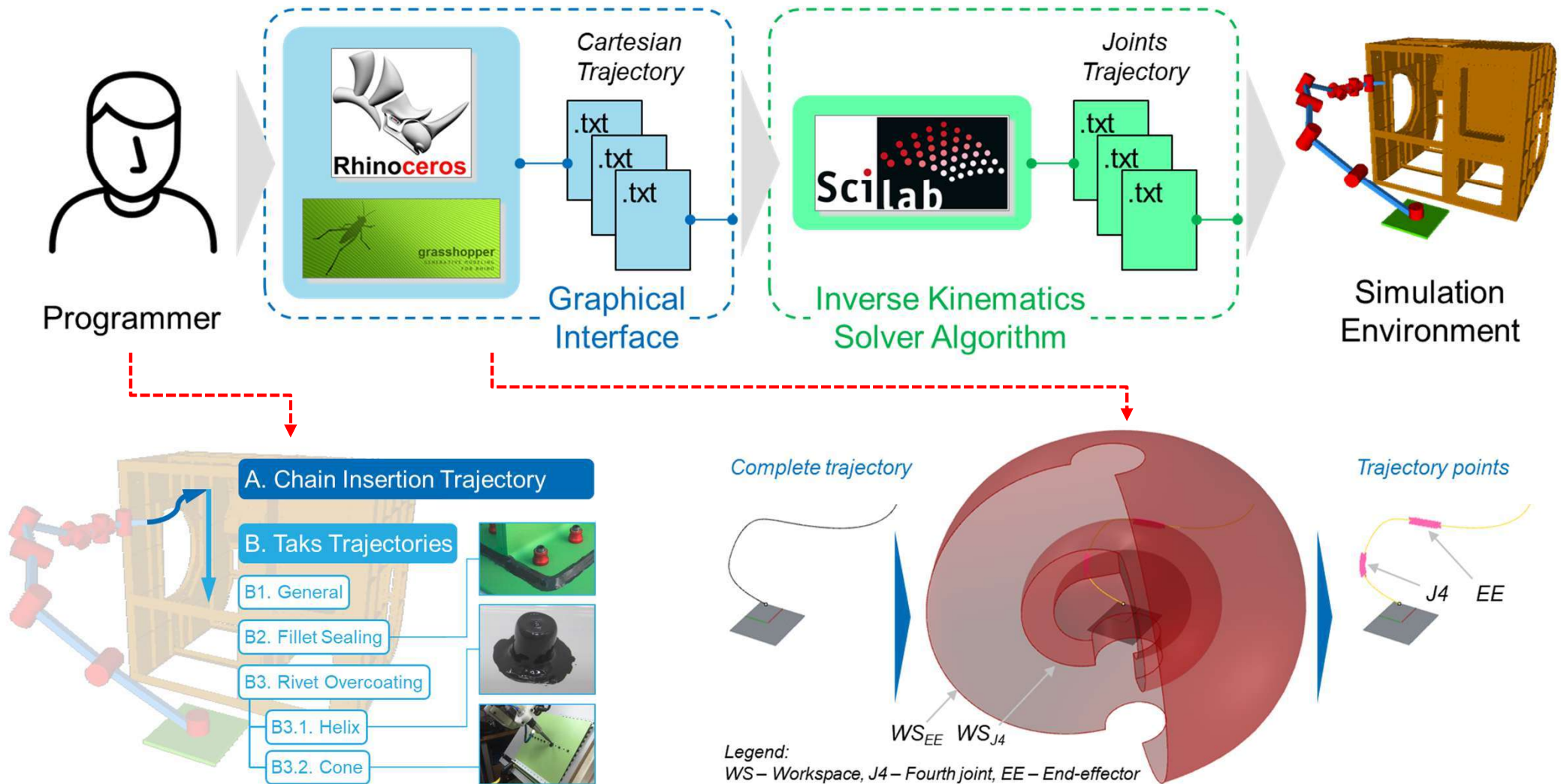
■ Select appropriate trajectory;

■ Select appropriate trajectory



# Airframe Sealing Automation using a Snake Robot

## Snake robot project - Inverse kinematics verification



■ Select appropriate trajectory;

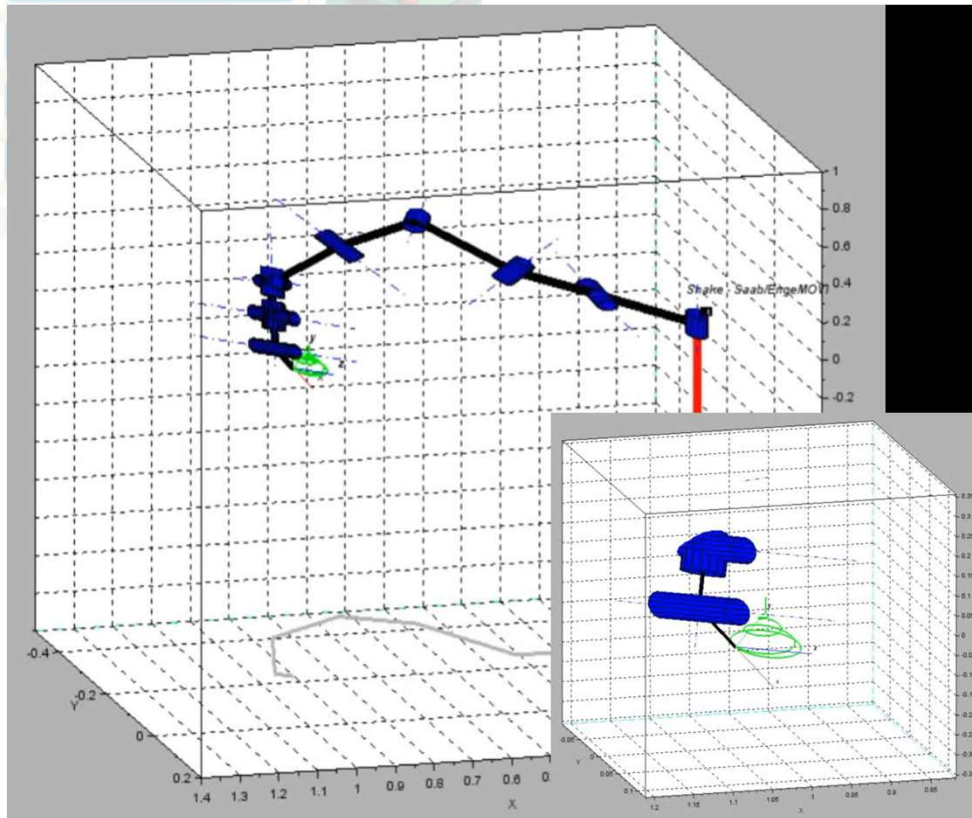
■ Select appropriate trajectory







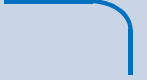





# Airframe Sealing Automation using a Snake Robot

## Snake robot project - Inverse kinematics verification

A. Chain Insertion Trajectory

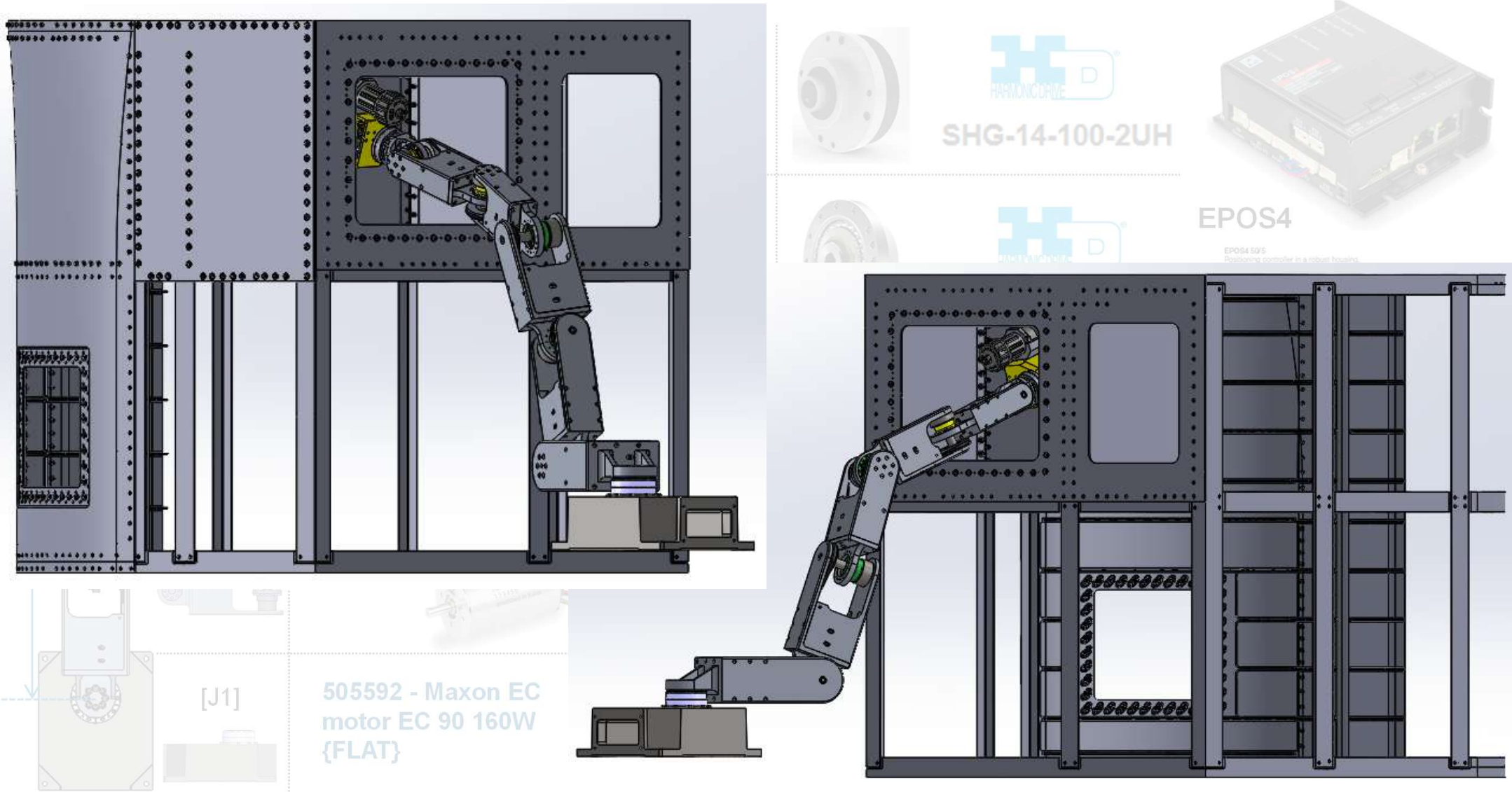
B. Taks Trajectories



Traj.	Solved	Result
		
		
		
		
		
		

# Airframe Sealing Automation using a Snake Robot

## Snake robot project - Dimensioning and CAD model of the snake robot

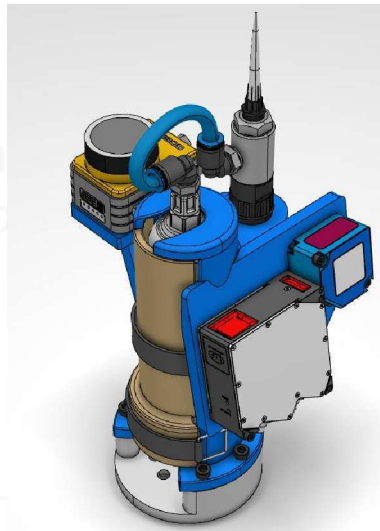


# Airframe Sealing Automation using a Snake Robot

## Snake robot project - Weight and dimensions reduction of the sealant dispenser 2K

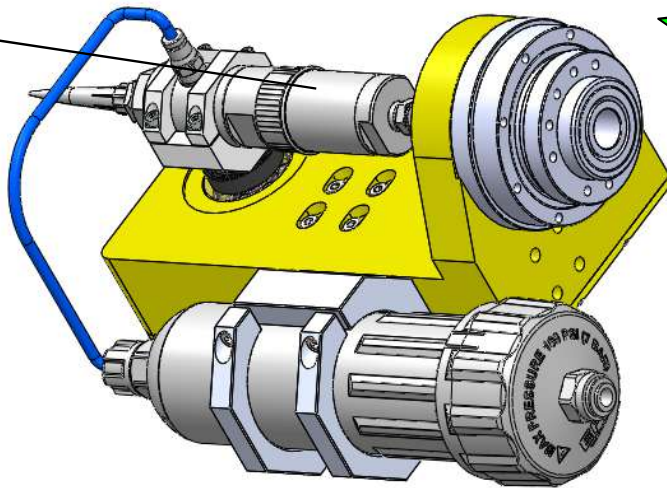


### 725D Piston Valves



**Weight: 3,8 kg**

**Reduction:  
~1,1 kg**



**Weight: 2,7 kg**

### Retainer Systems

Includes cartridges, pistons, outlet caps, end caps and retainers. For use with most assembly fluids and pastes. Sold individually.



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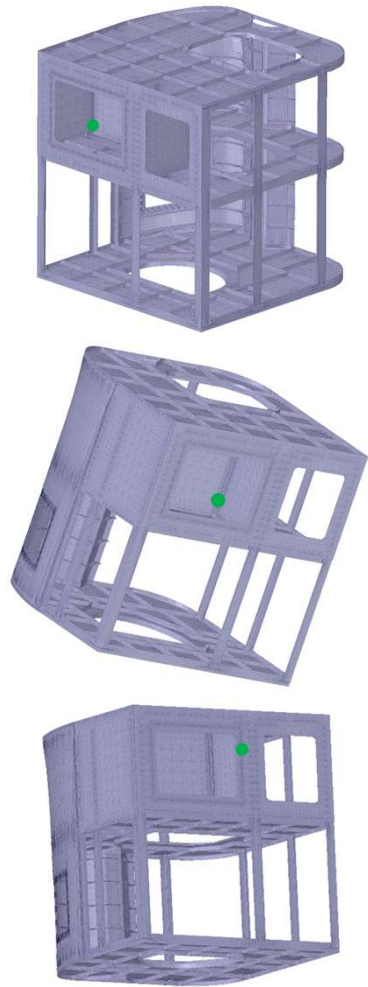


Suppliers  
Developed by ITA

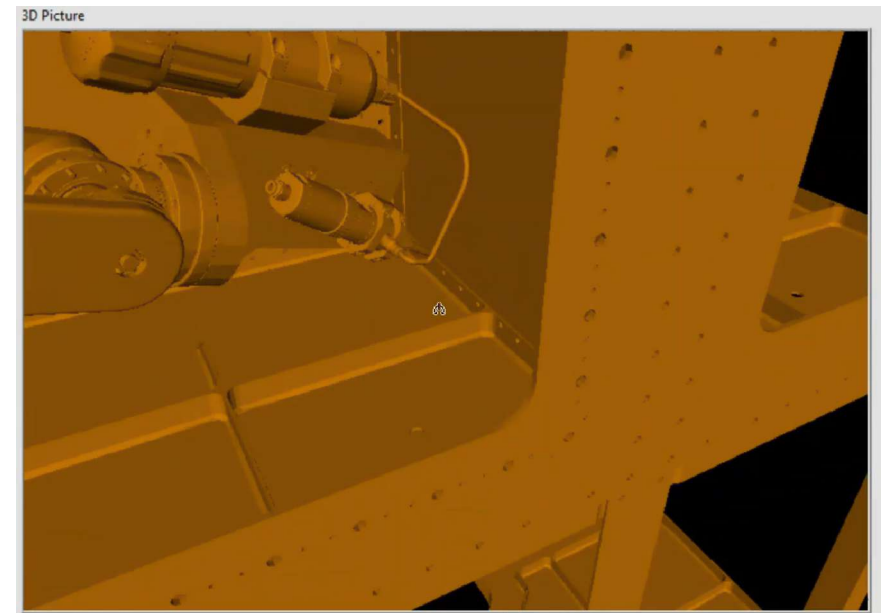
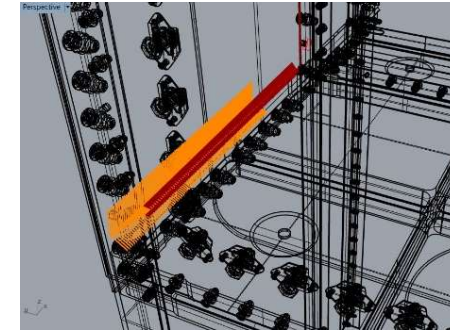
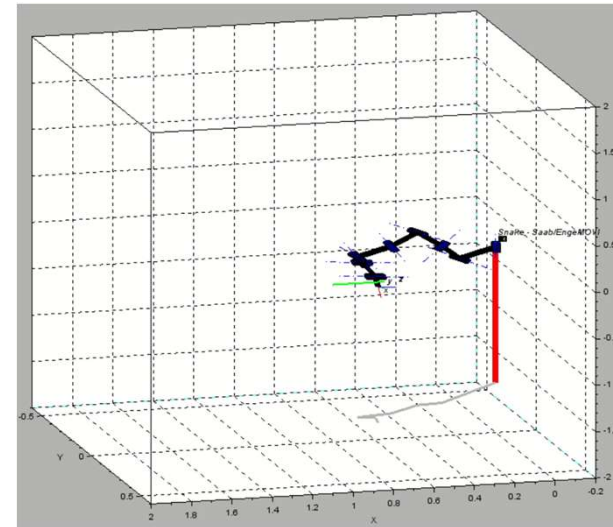
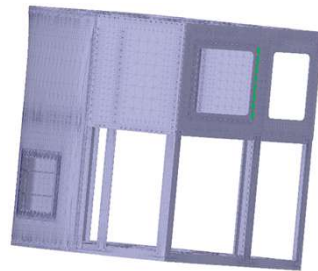
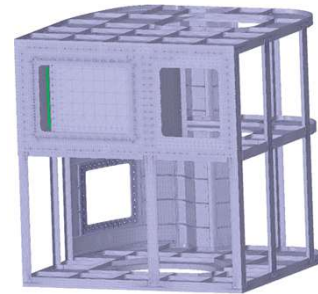
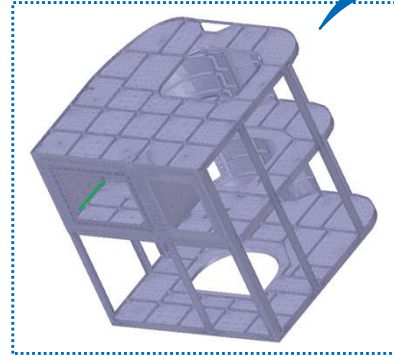
# Airframe Sealing Automation using a Snake Robot

## Results - Fillet sealing

Overcoating of Fastener



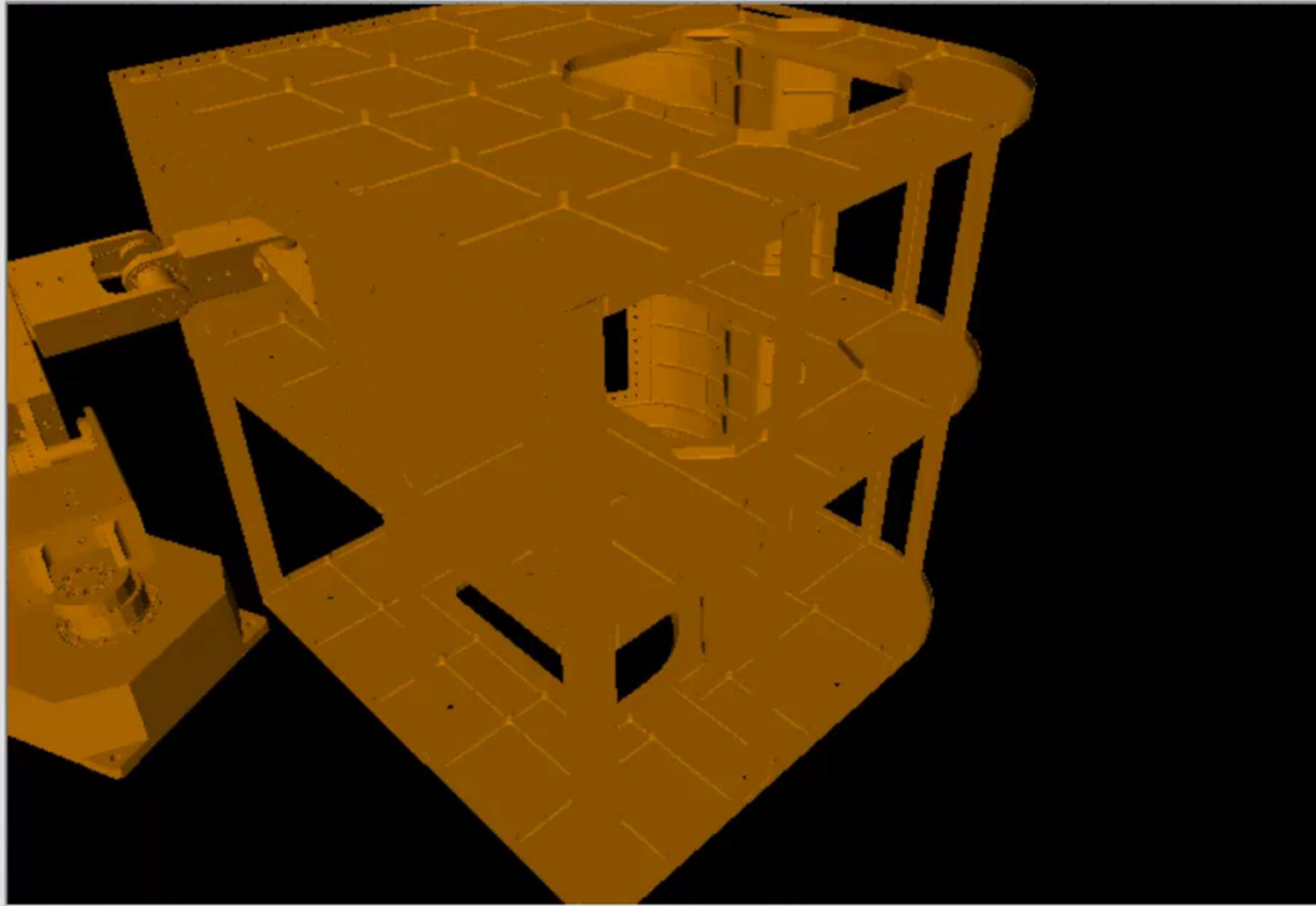
Fillet



# Airframe Sealing Automation using a Snake Robot

## Results - Fillet sealing

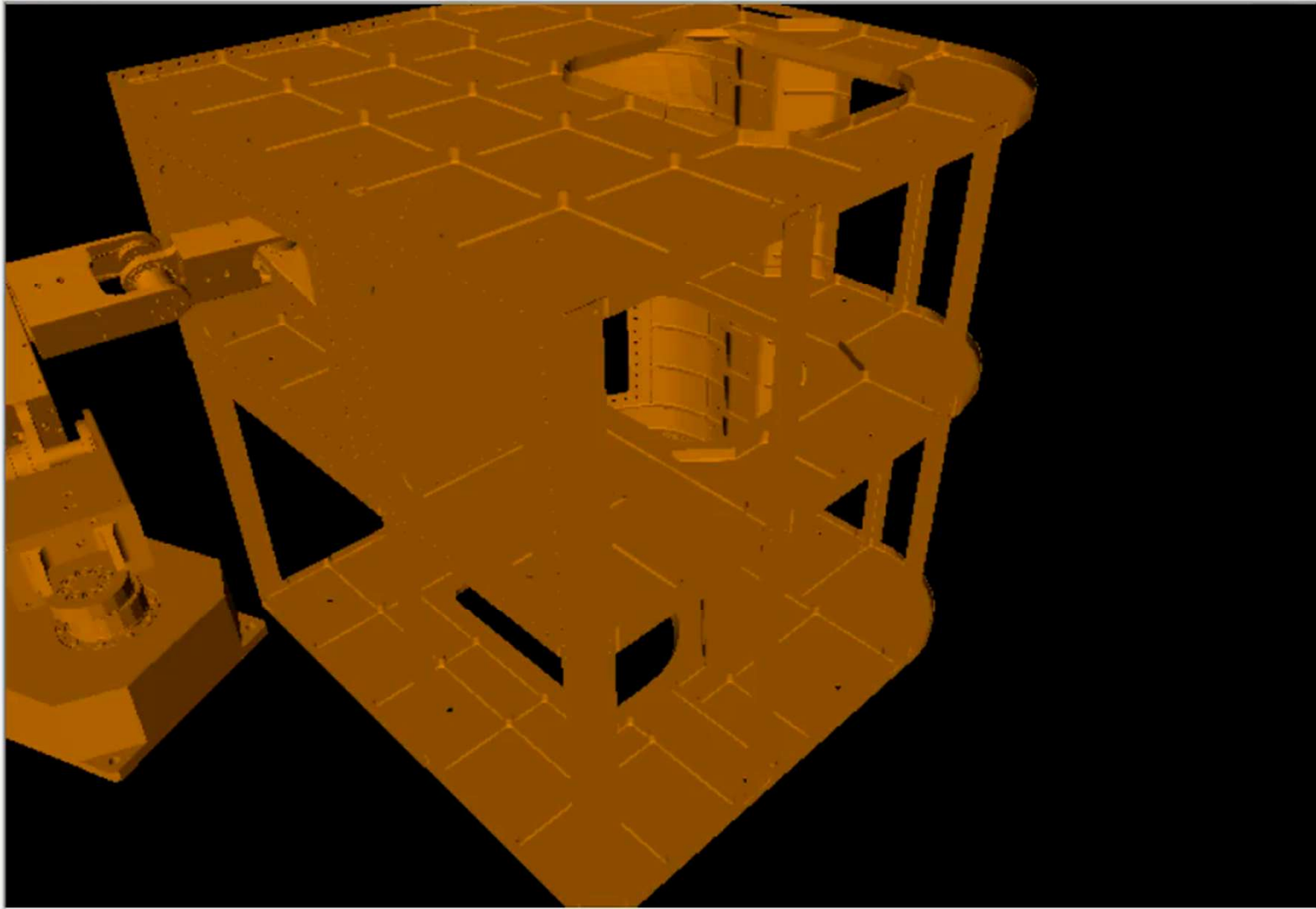
3D Picture



# Airframe Sealing Automation using a Snake Robot

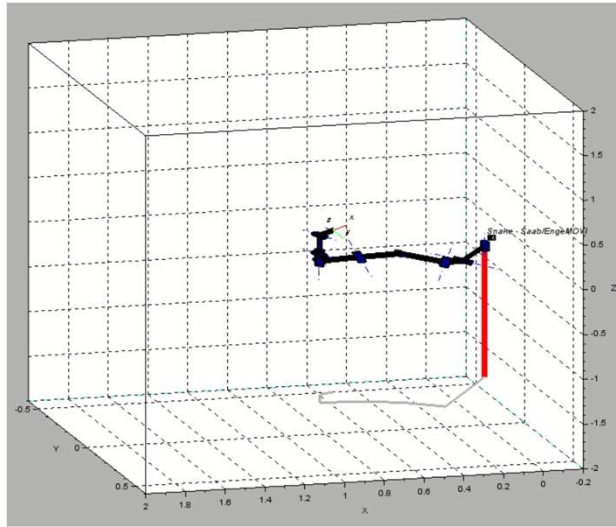
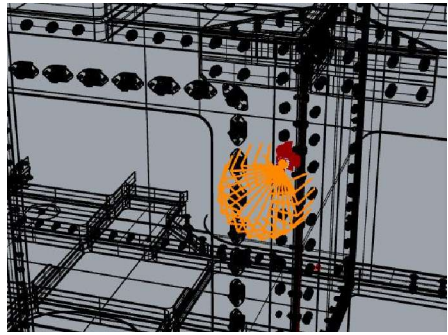
## Results - Fillet sealing (No Collision)

3D Picture

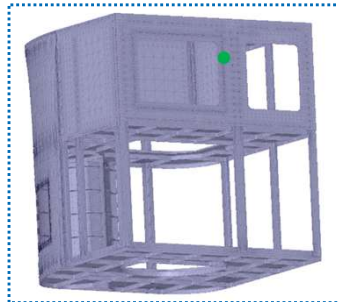
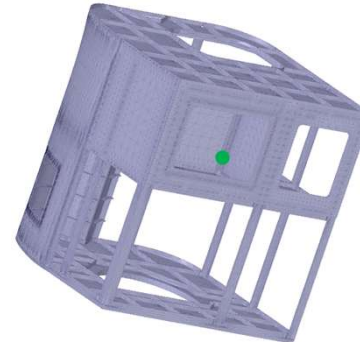
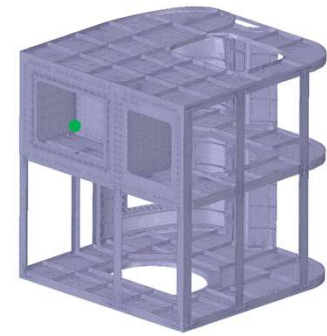


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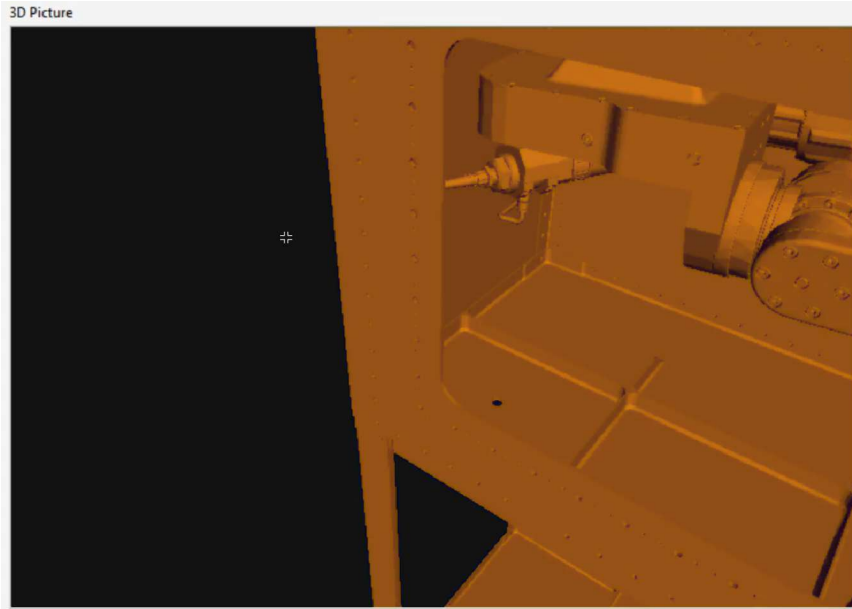
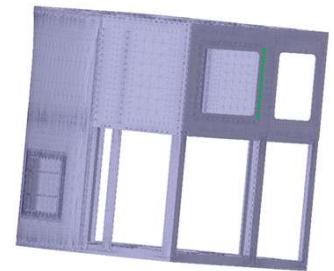
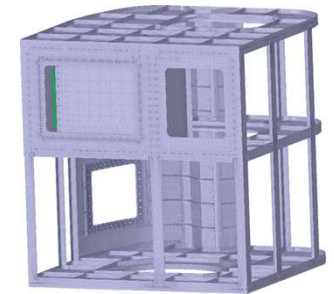
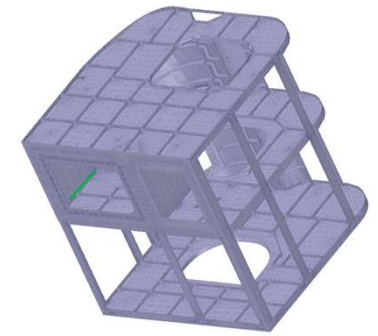
## Results - Overcoating of Fastener



### Overcoating of Fastener



### Fillet

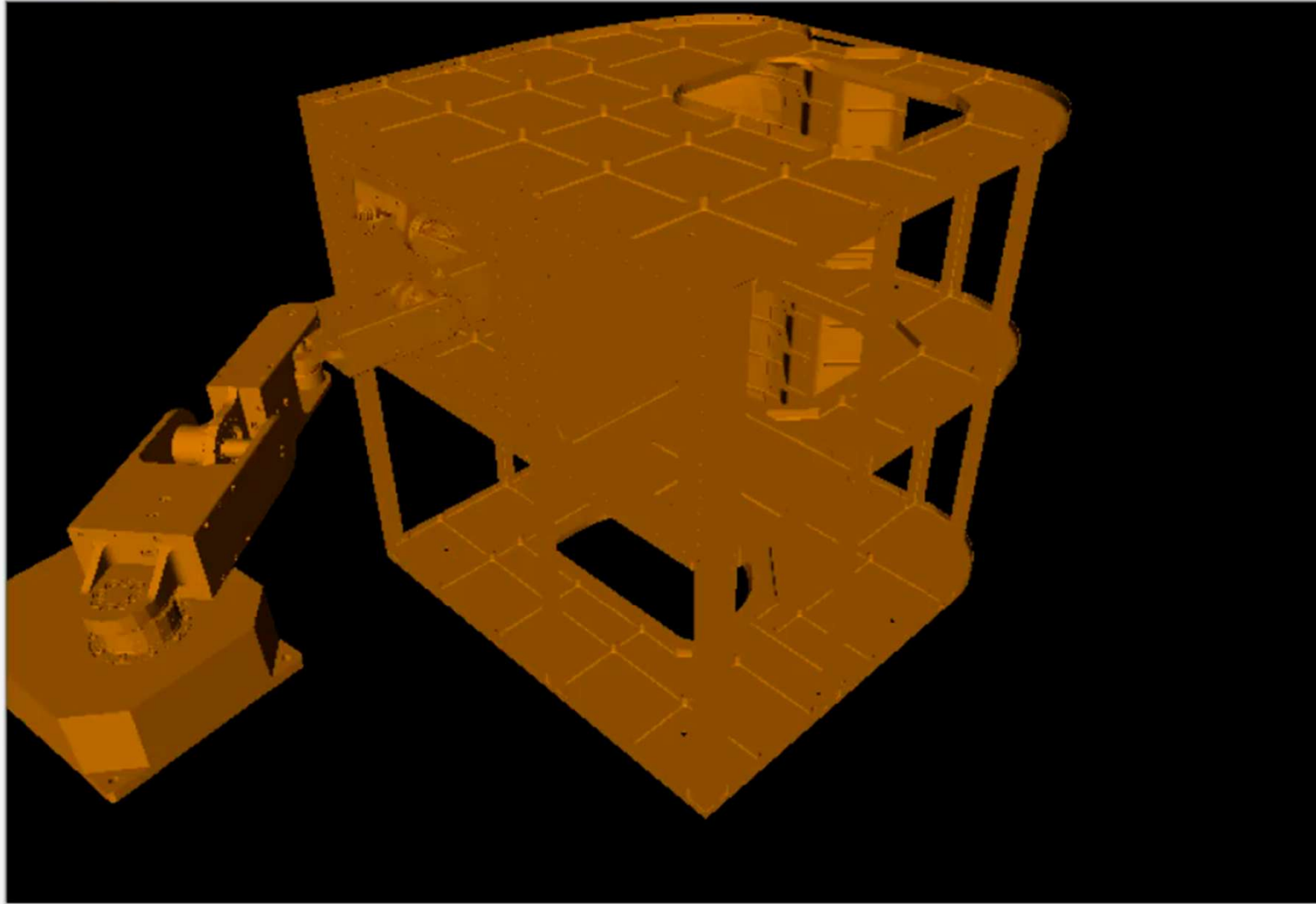




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## Results - Overcoating of Fastener

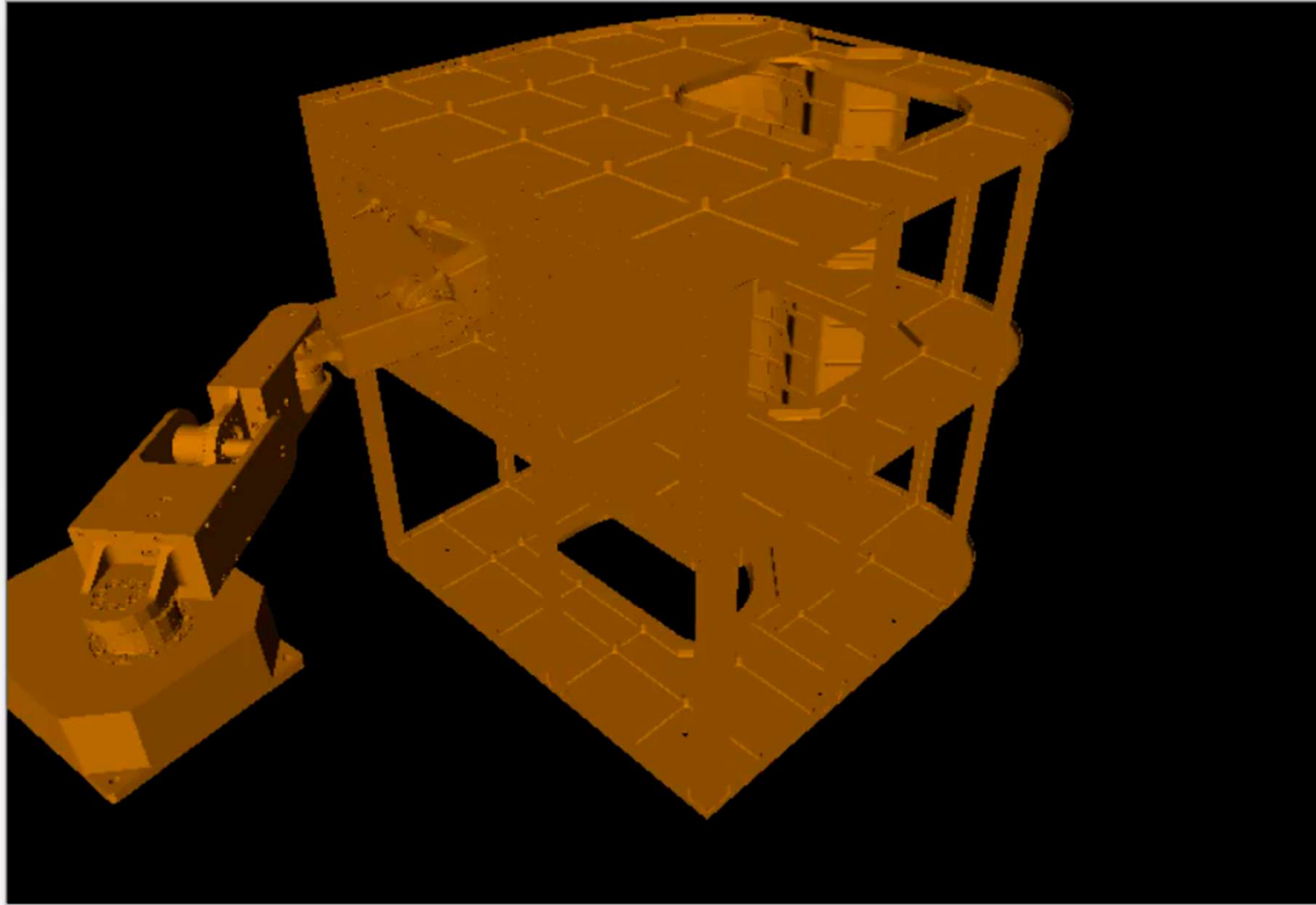
3D Picture



# Airframe Sealing Automation using a Snake Robot

## Results - Overcoating of Fastener (No Collision)

3D Picture



- In terms of the technical feasibility of the project, the designed solution proved to be adequate for carrying out the proposed operation;
- The trajectories of application of sealant in fillets (union of two plates of the fuselage) and fasteners were tested by simulation, and were very well executed by the robot in a virtual environment, without collisions;
- For the economic feasibility, although the estimated cost of a unit snake robot is higher than the IIWA and the UR10e, the project is feasible when the snake robot is scaled up in production;
- An analysis for reducing the dimensions and mass in the sealant dispenser was carried out: cartridge case and the sealant application valve were assembled directly to the snake structure, yielding a 1.1 kg mass reduction of the sealant dispenser.

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