

Mechatronics Approach for the Development of a Nano-Active-Stabilization-System

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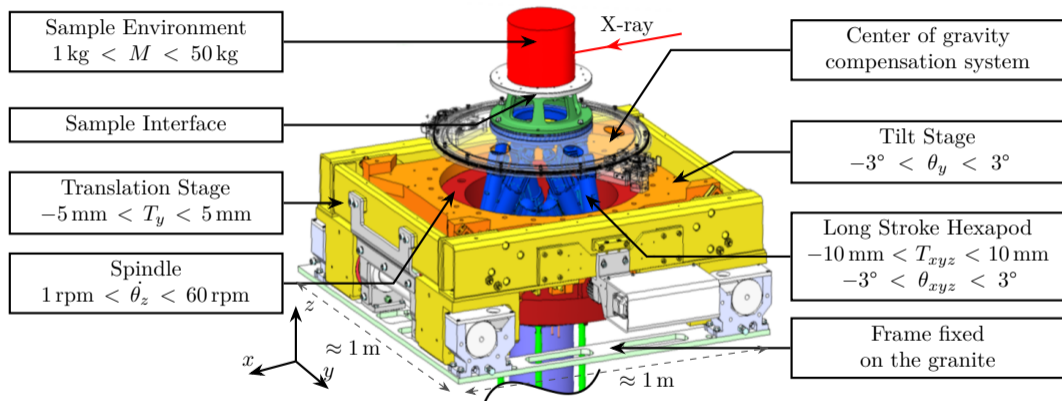
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**Precision
Mechatronics
Laboratory**



The ID31 Micro Station



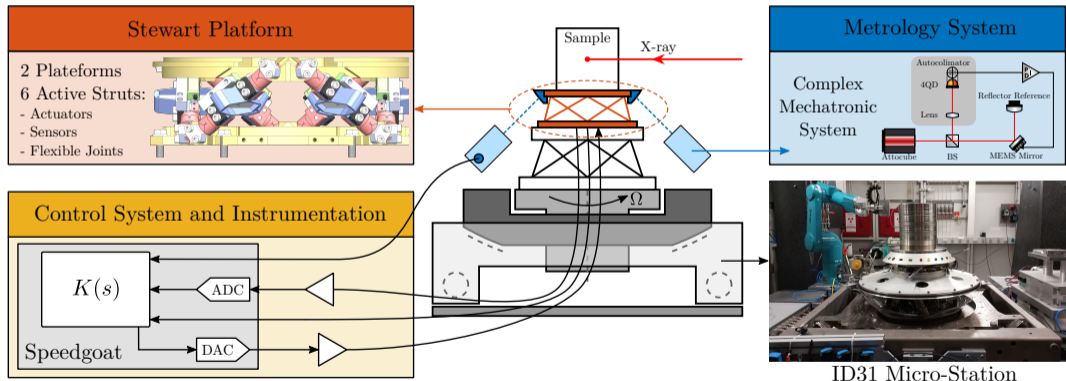
Objective: Position samples along complex trajectories with high precision

Stacked Positioning Stages: $\approx 10 \mu\text{m}$ precision limited by stages vibrations, thermal effects, ground motion, ...

Introduction - The Nano Active Stabilization System

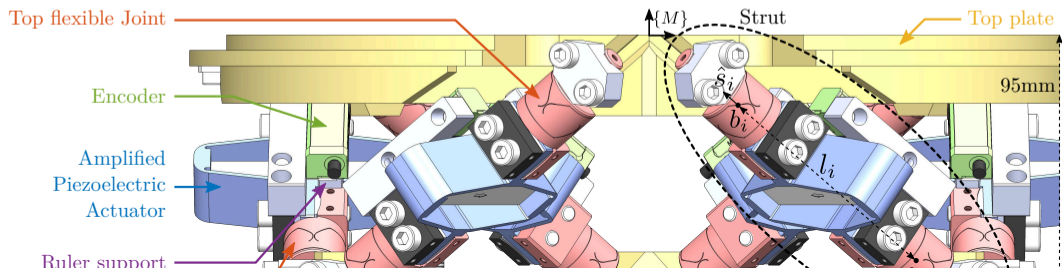
Objective: Improve the position accuracy from $\approx 10 \mu m$ down to $\approx 10 nm$

Design approach: “Model based design” (extensive use of models and test benches)

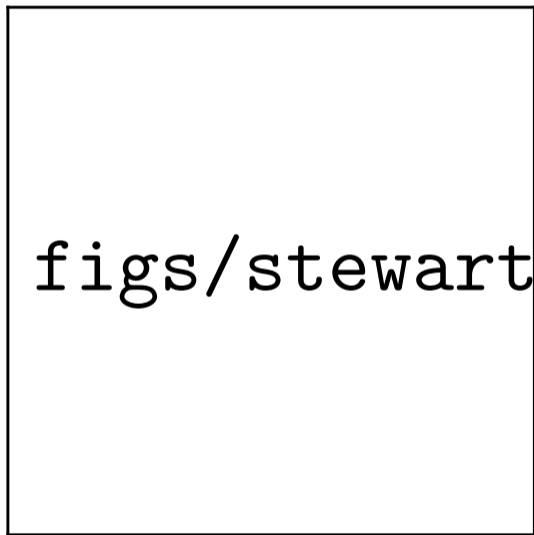


The Nano-Hexapod - Why such mechanical architecture?

- Why stewart architecture
 - 6 DoF to control / 6 actuators
 - Only flexible elements
 - no backlash
 - no play
 - How it is working
 - Jacobian matrix both for actuation and sensing
 - Forward / Inverse kinematics : meaning. Easy to compute for small displacements
- Schematic of Stewart platform



Stewart Platforms Architecture



Definition of the Geometry

- \mathbf{a}_i : position of the attachment points on the fixed base
- \mathbf{b}_i : position of moving attachment points
- l_i : length of each limb
- $\hat{\mathbf{s}}_i$: unit vector representing the direction of each limb

Stewart Platform Architecture - Kinematics

- $\mathcal{L} = [l_1, l_2, \dots, l_6]^T$: vector of actuated joint coordinates
- $\mathcal{X} = [{}^A\mathbf{P}, {}^A\hat{\mathbf{s}}]^T$: vector of platform motion variables

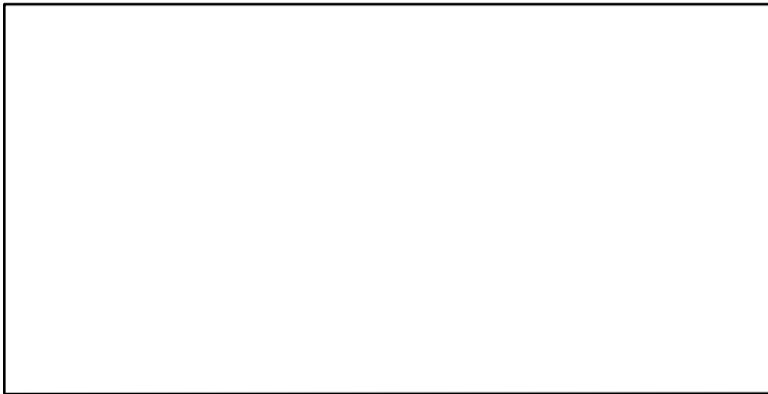
$$\mathcal{X} \xrightarrow[\text{Simple}]{\text{Inverse Kinematics}} \mathcal{L}$$
$$\mathcal{L} \xrightarrow[\text{Complex}]{\text{Forward Kinematics}} \mathcal{X}$$

For small displacements: **Jacobian** matrix

$$\mathbf{J} = \begin{bmatrix} \hat{\mathbf{s}}_1^T & (\mathbf{b}_1 \times \hat{\mathbf{s}}_1)^T \\ \hat{\mathbf{s}}_2^T & (\mathbf{b}_2 \times \hat{\mathbf{s}}_2)^T \\ \hat{\mathbf{s}}_3^T & (\mathbf{b}_3 \times \hat{\mathbf{s}}_3)^T \\ \hat{\mathbf{s}}_4^T & (\mathbf{b}_4 \times \hat{\mathbf{s}}_4)^T \\ \hat{\mathbf{s}}_5^T & (\mathbf{b}_5 \times \hat{\mathbf{s}}_5)^T \\ \hat{\mathbf{s}}_6^T & (\mathbf{b}_6 \times \hat{\mathbf{s}}_6)^T \end{bmatrix}$$

$$\delta\mathcal{L} = \mathbf{J}\delta\mathcal{X}$$

Control Challenges - Analogy

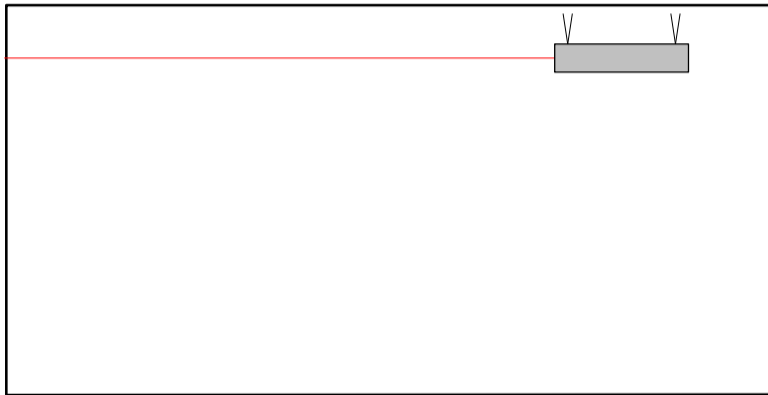


Control Challenges - Analogy



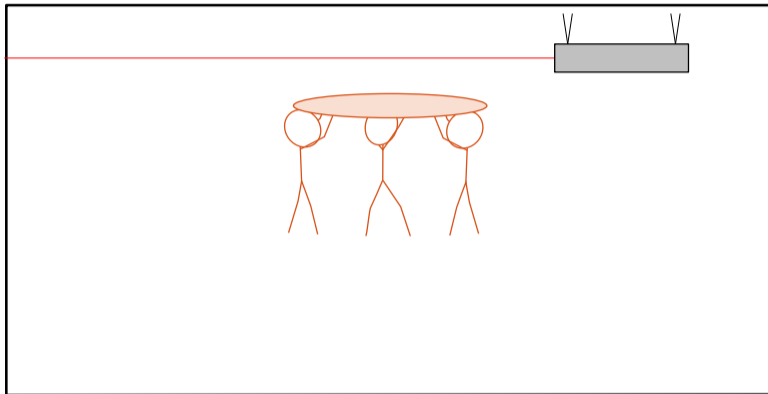
| Analogies | |
|-----------|---------|
| Room | Granite |

Control Challenges - Analogy



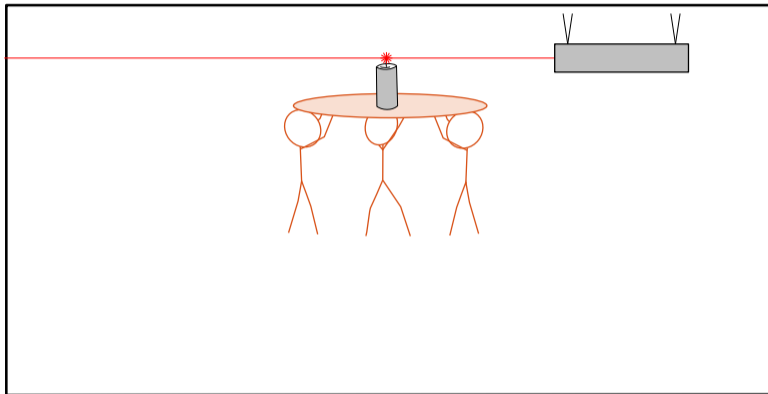
| Analogies | |
|-----------|---------|
| Room | Granite |
| Laser | X-ray |

Control Challenges - Analogy



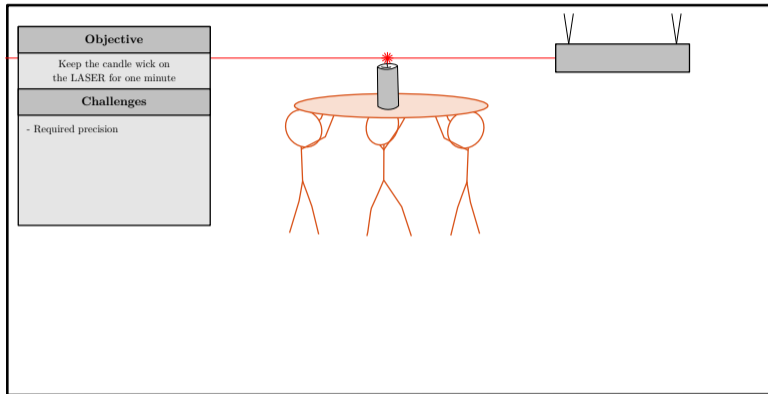
| Analogies | |
|-----------|--------------|
| Room | Granite |
| Laser | X-ray |
| 3 peoples | Nano-Hexapod |

Control Challenges - Analogy



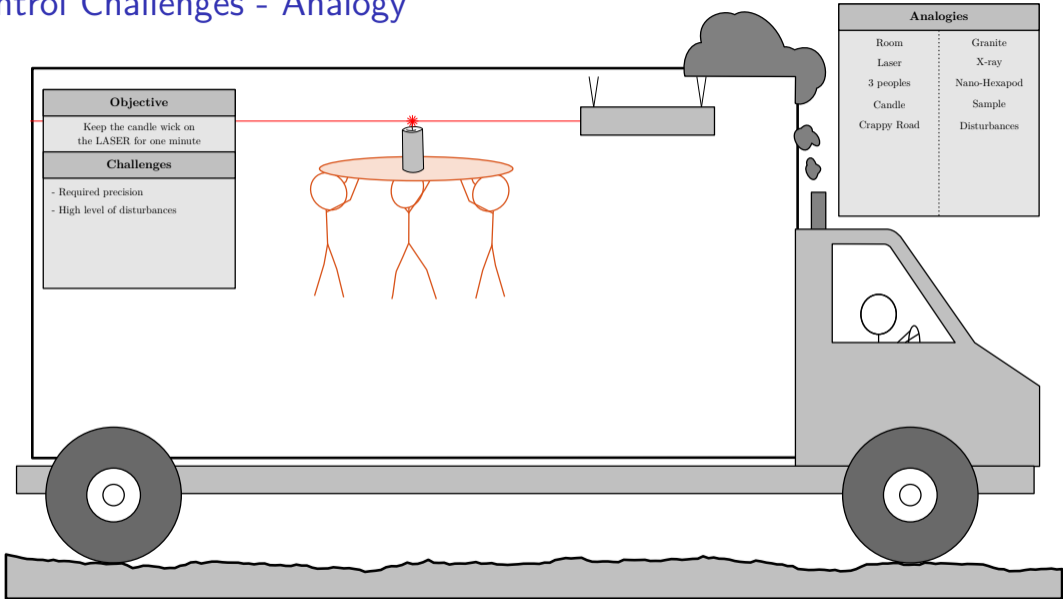
| Analogies | |
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| Room | Granite |
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| 3 peoples | Nano-Hexapod |
| Candle | Sample |

Control Challenges - Analogy

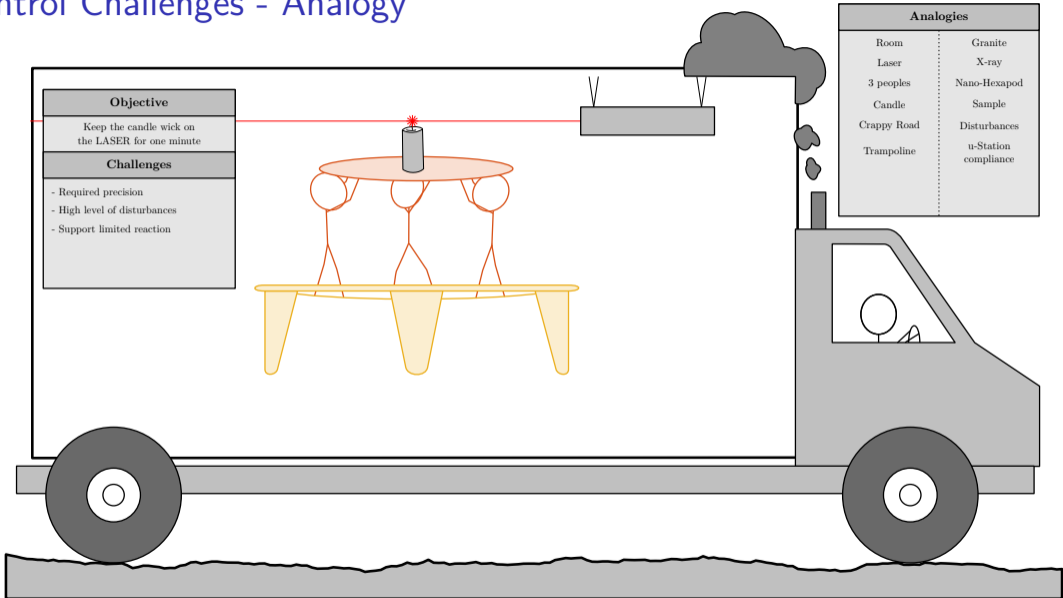


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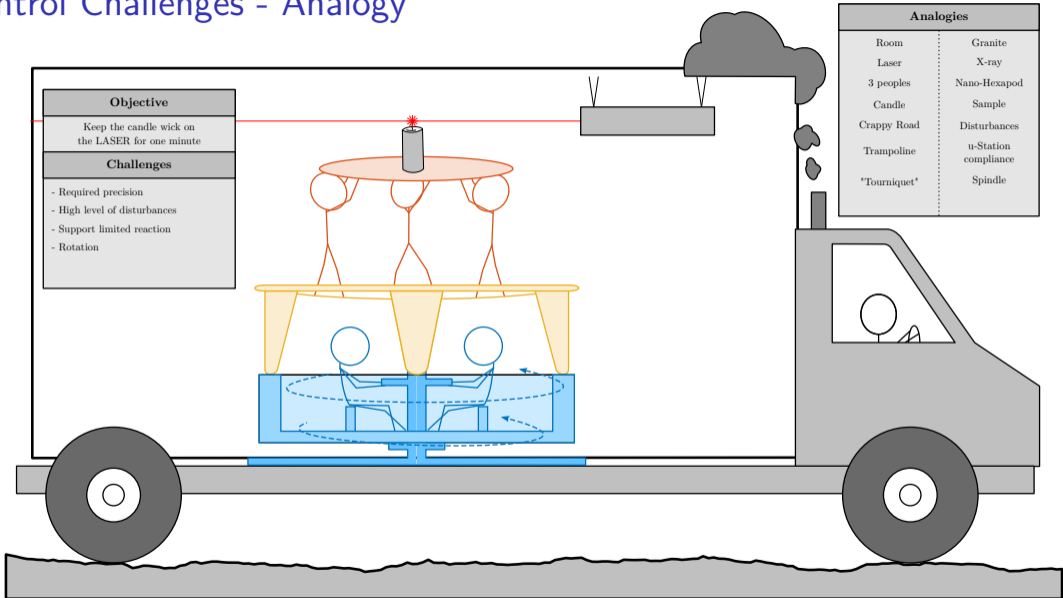
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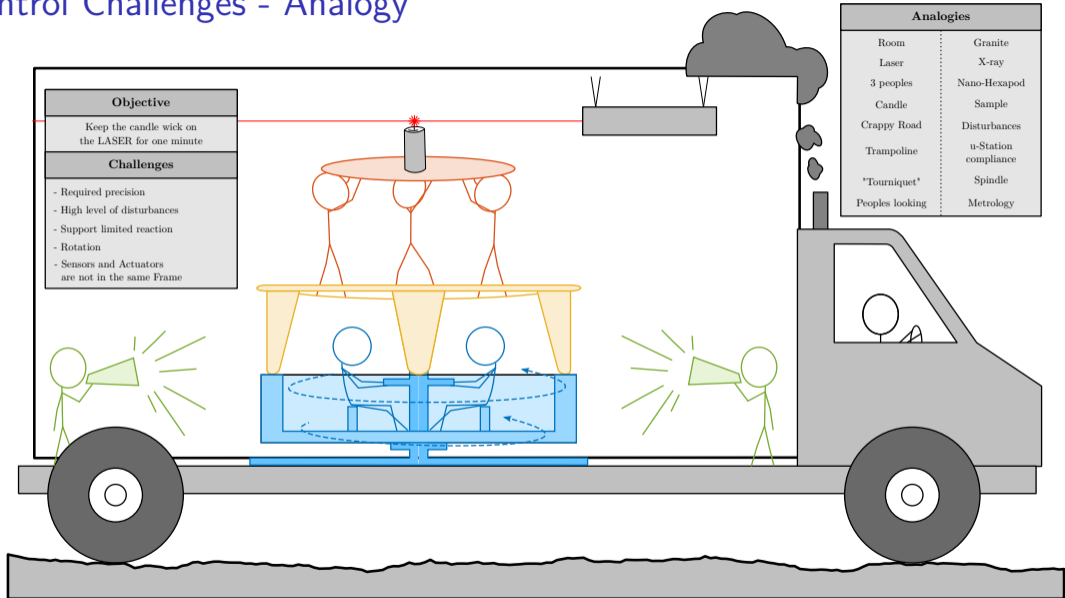
Control Challenges - Analogy



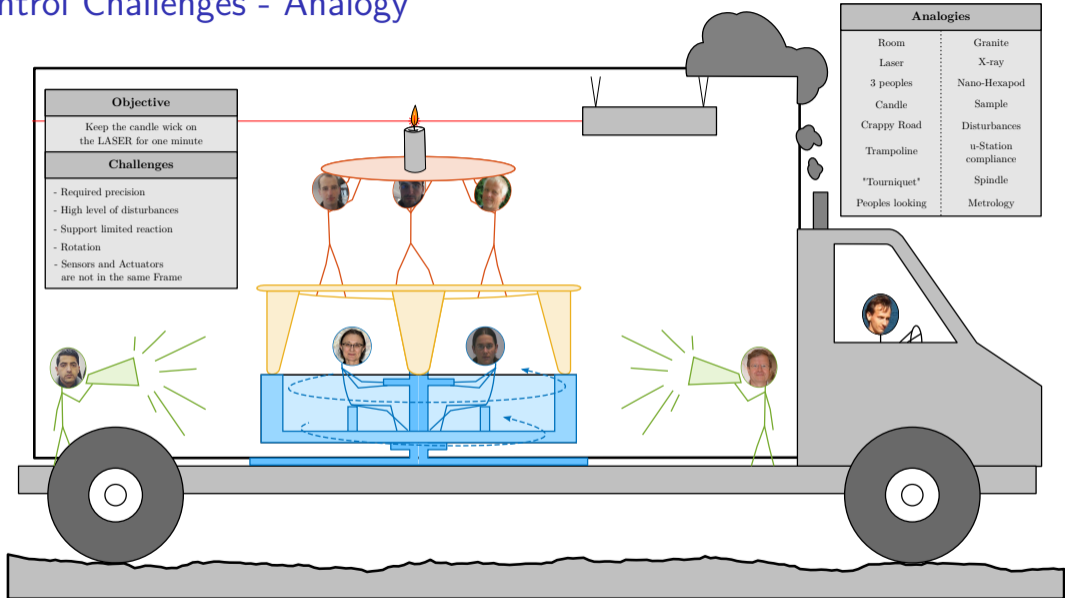
Control Challenges - Analogy



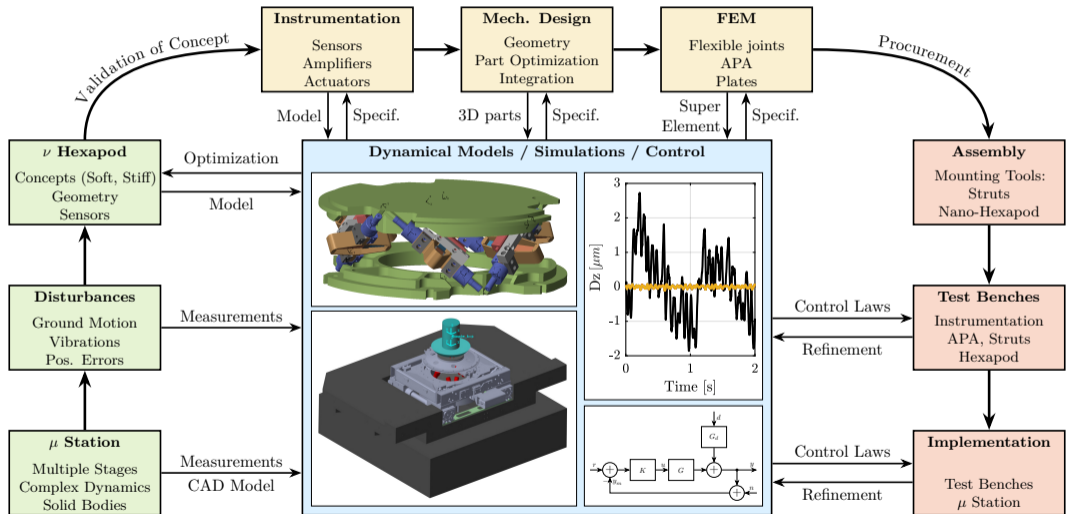
Control Challenges - Analogy



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Overview of the Mechatronic Approach - Model Based Design



Outline