ETH zürich

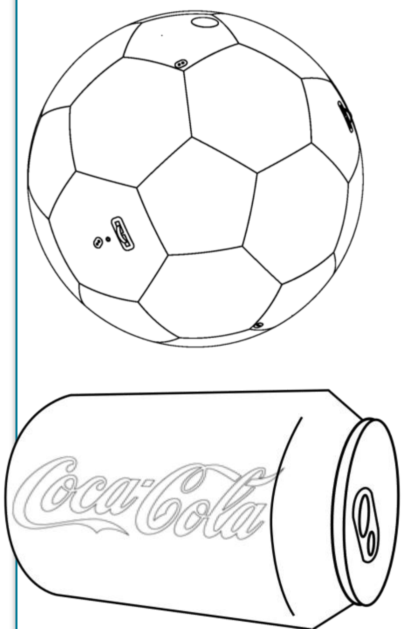
Estimation of Actuation Configuration for a Multi-Actuated Blimp

Final Presentation (Semester Thesis)

Students: Matthias Krebs, Simon Laube

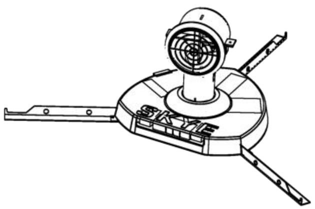
Advisors: Kostas Alexis, Markus Achtelik

Motivation: Control Arbitrary Blimp



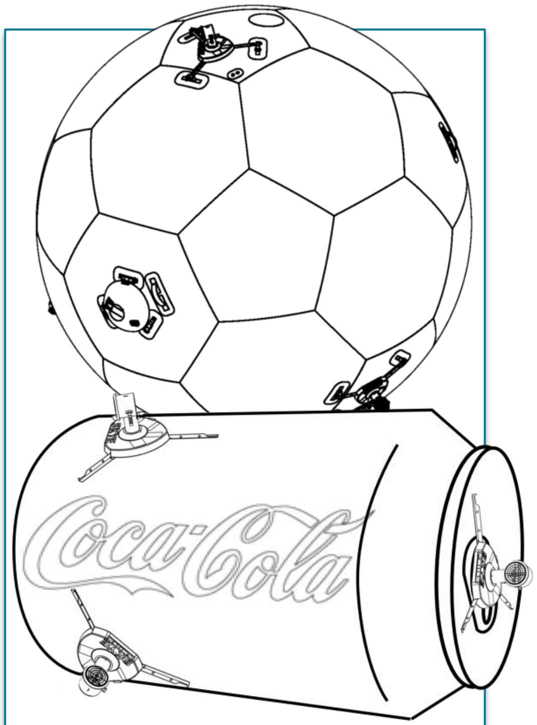
Arbitrary Blimp Hulls

+



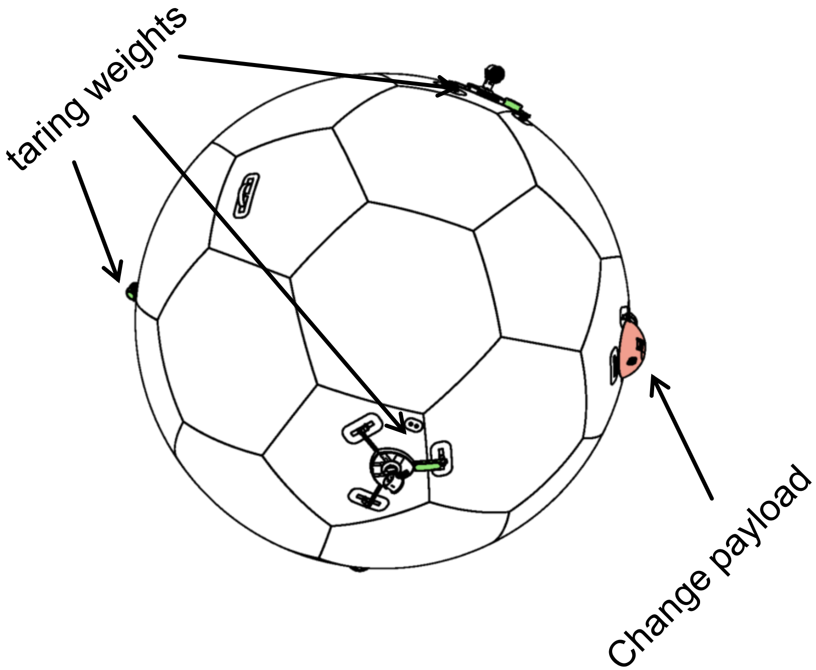
Skye Actuation Unit

Parameter Identification

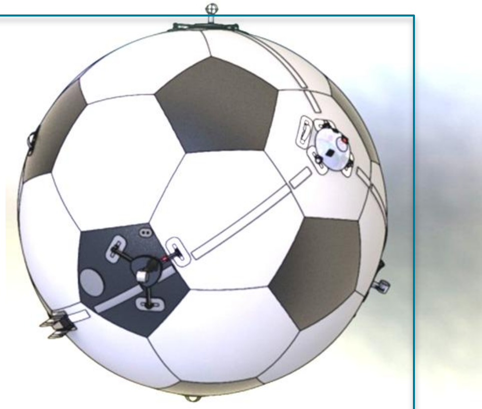


Elegant Movement

Motivation: Improve Usability & Control



Help with system taring



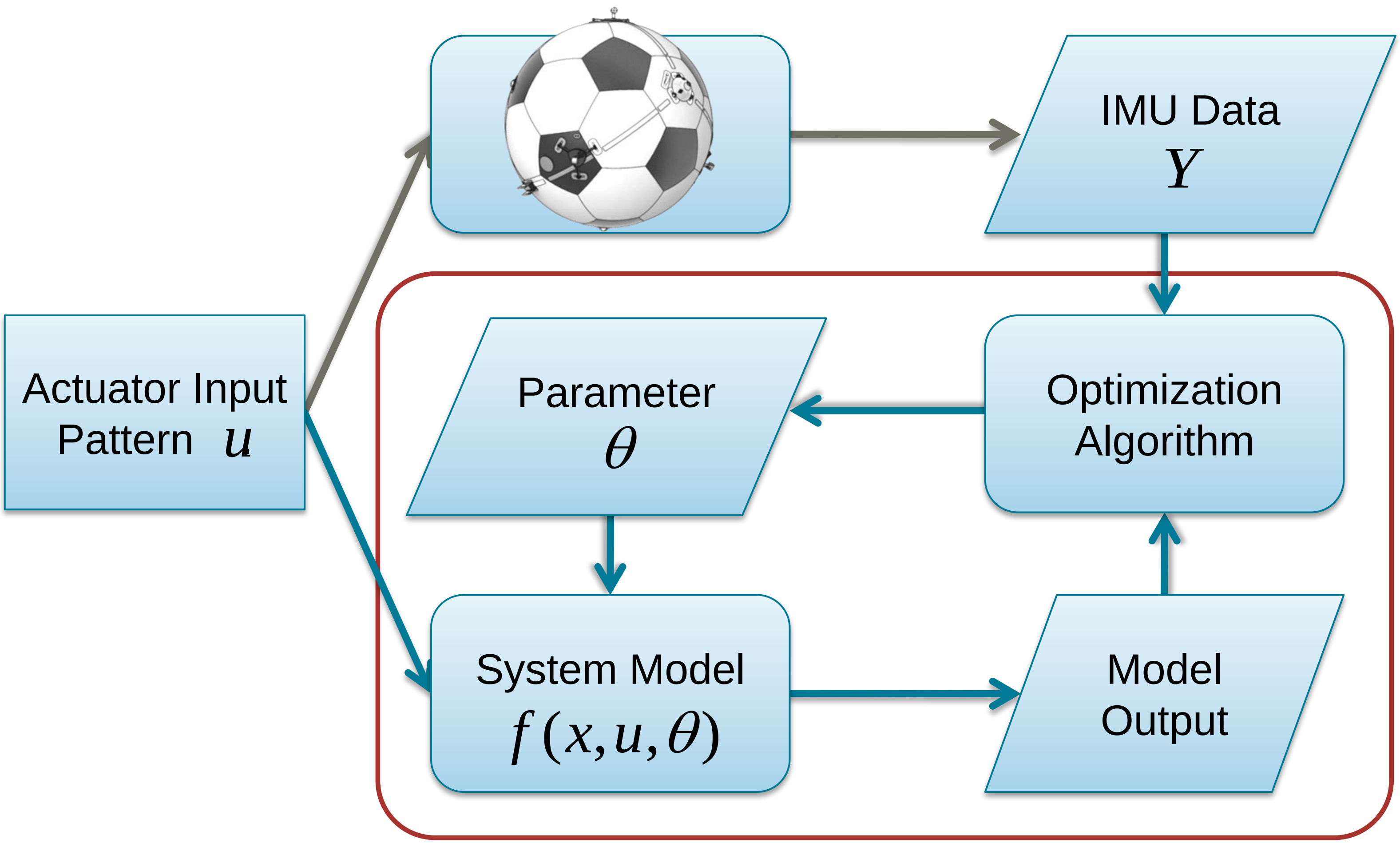
Controller

Hard to measure

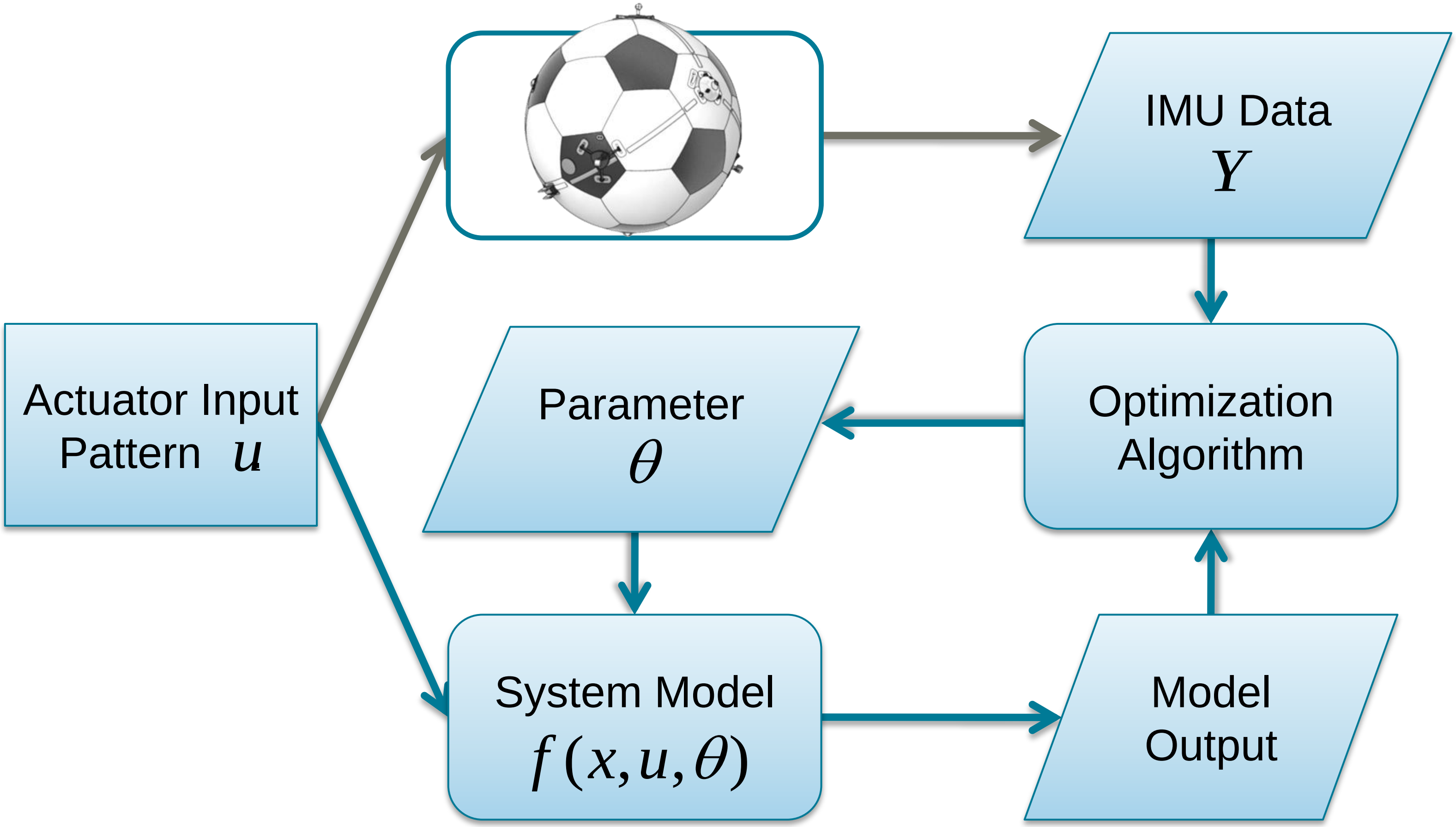
J cog C_{bm}

Determine hard to measure parameters

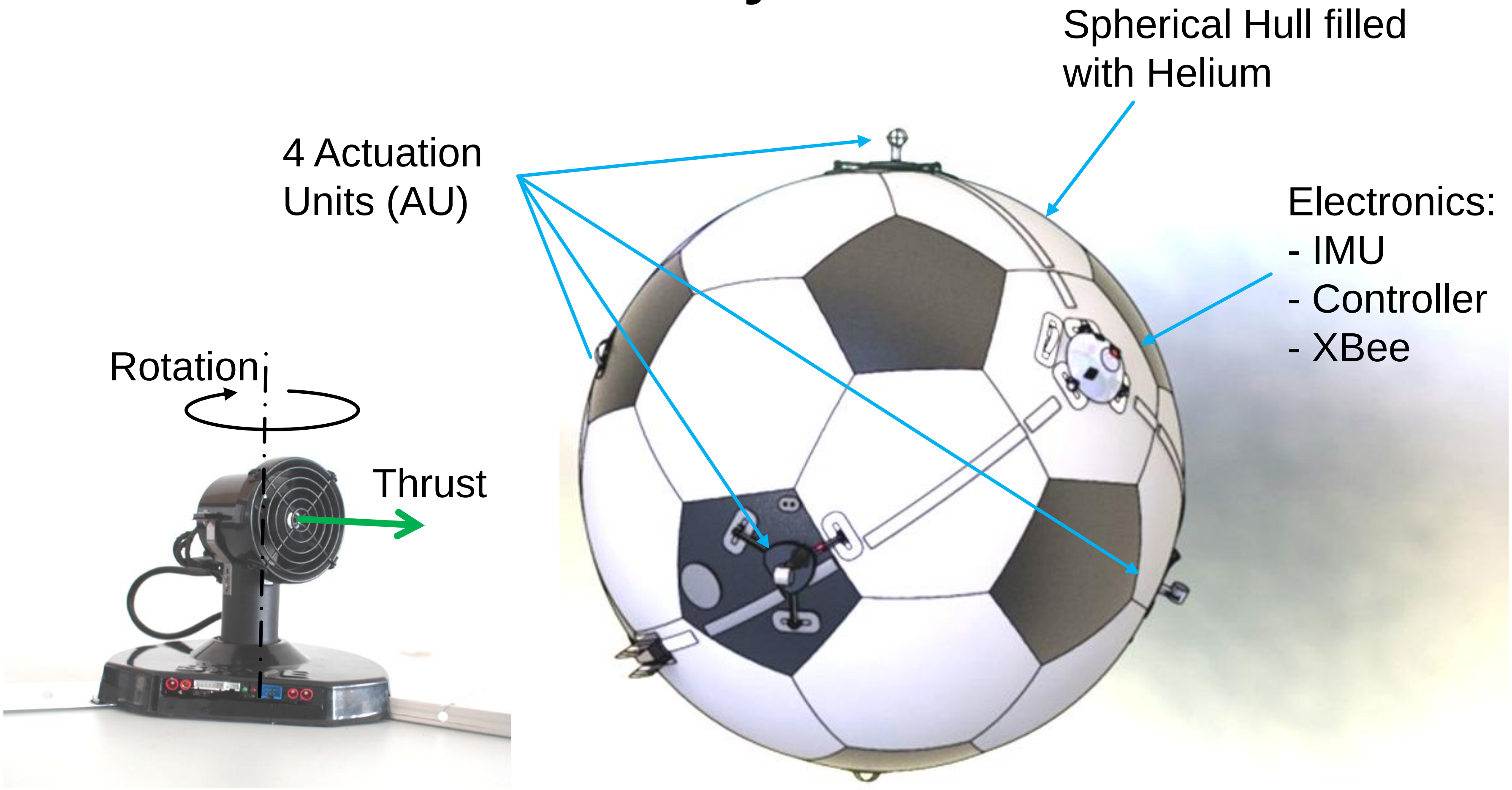
Problem Formulation



Problem Formulation

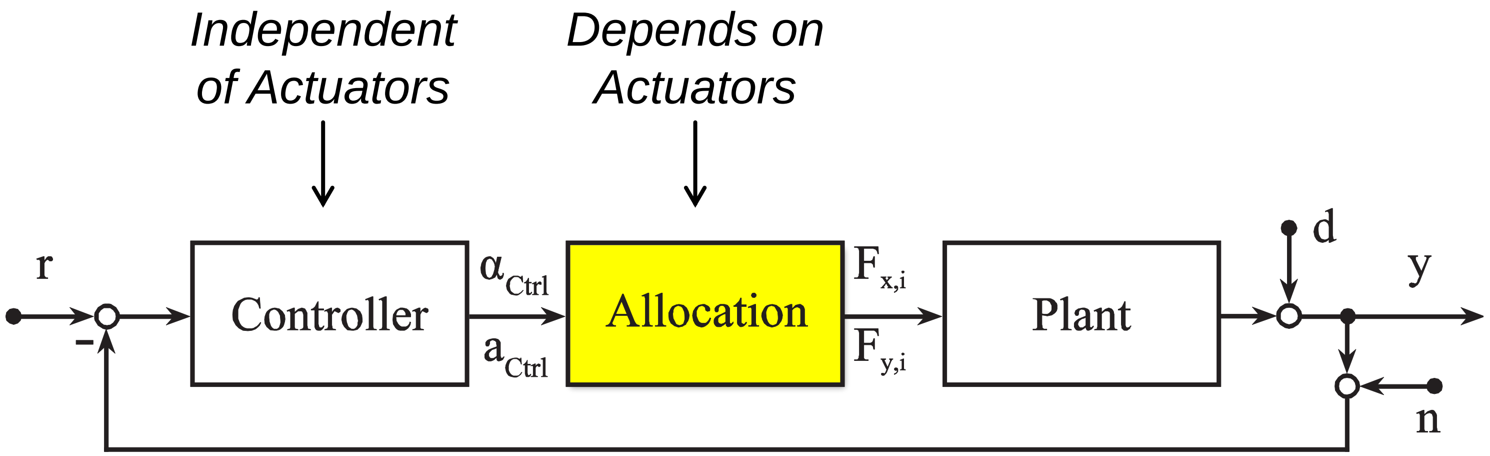


Problem Formulation: System

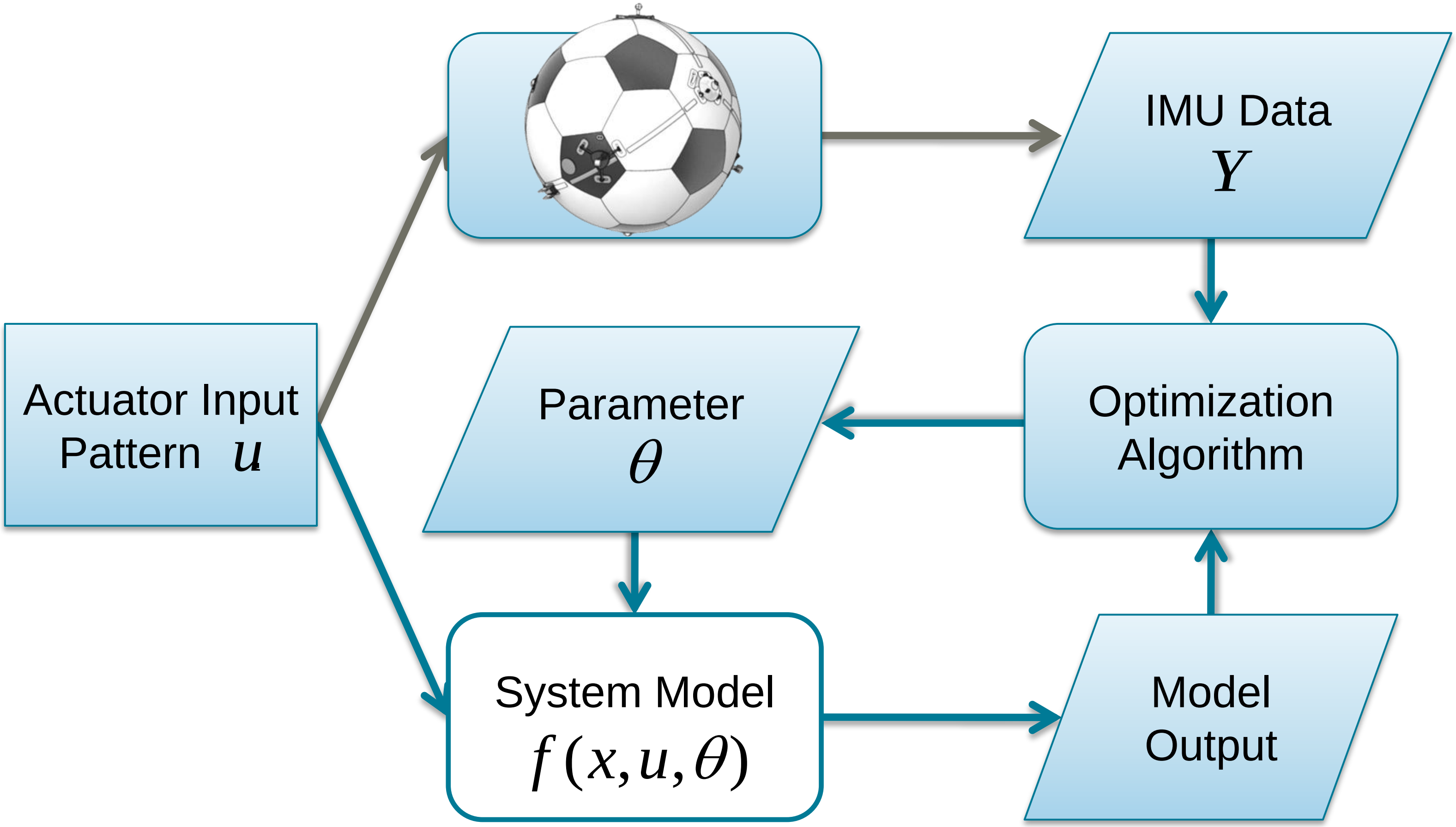


Problem Formulation: System

Control



Problem Formulation



Problem Formulation: System Model

- Angular Acceleration

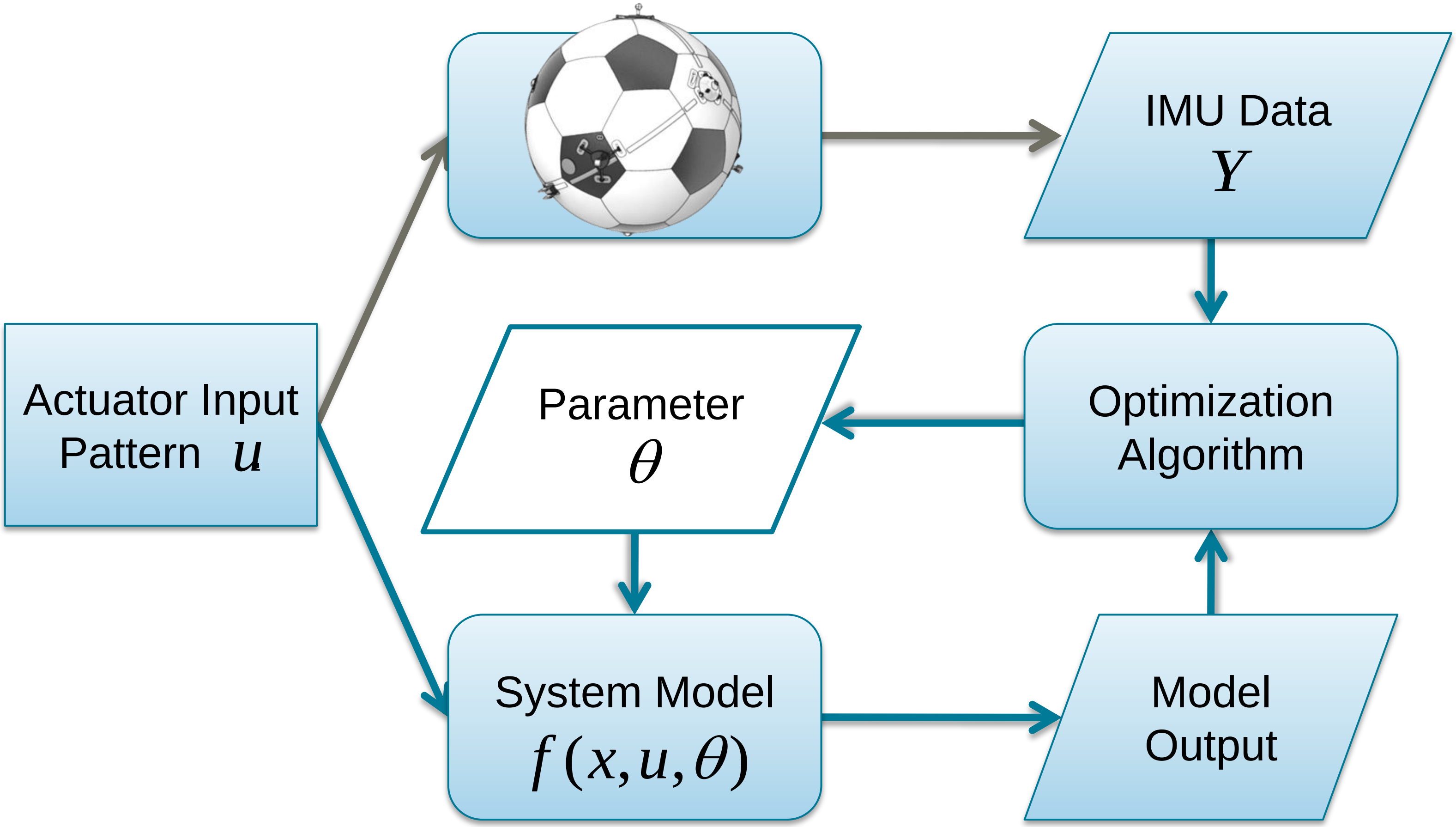
$$\mathbf{f}(\mathbf{x}, \mathbf{u}, \boldsymbol{\theta}) = \hat{\boldsymbol{\alpha}}_b = \mathbf{J}_b^{-1}(\mathbf{M}_b - \boldsymbol{\omega}_b \times \mathbf{J}_b \boldsymbol{\omega}_b)$$

with

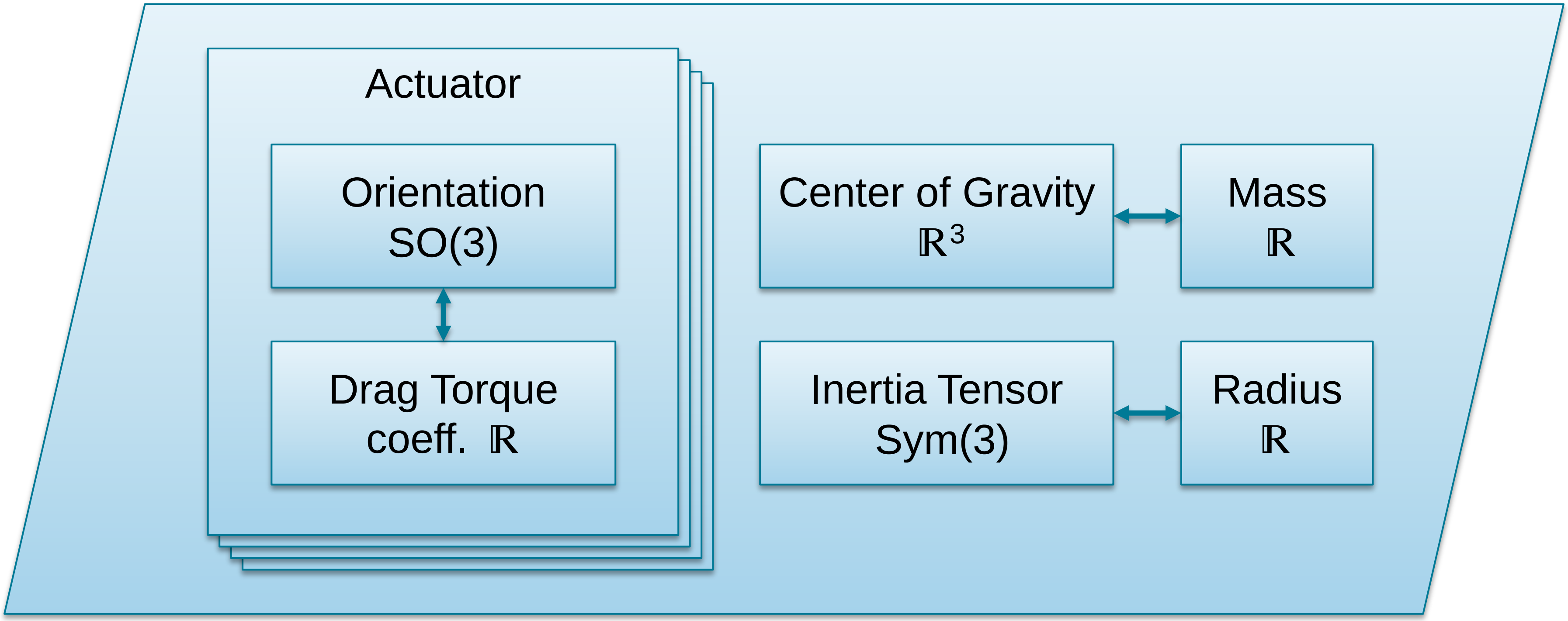
$$\mathbf{M}_b = \underbrace{\sum_{k=1}^{N} \left[\mathbf{C}_{b,m_k} \left(\mathbf{p}_{m_k}^{m_k,cog} \times \mathbf{F}_{m_k} \right) \right]}_{\mathbf{M}^{actuation}} - \underbrace{\left(\mathbf{p}_b^{cob,cog} \times \left(\mathbf{C}_{b,w} m \mathbf{g}_w \right) \right)}_{\mathbf{M}^{gravity}}$$

  - Aerodynamic effects on rotation neglected ($\mathbf{M}^{aero} << \mathbf{M}^{actuation}$)

Problem Formulation

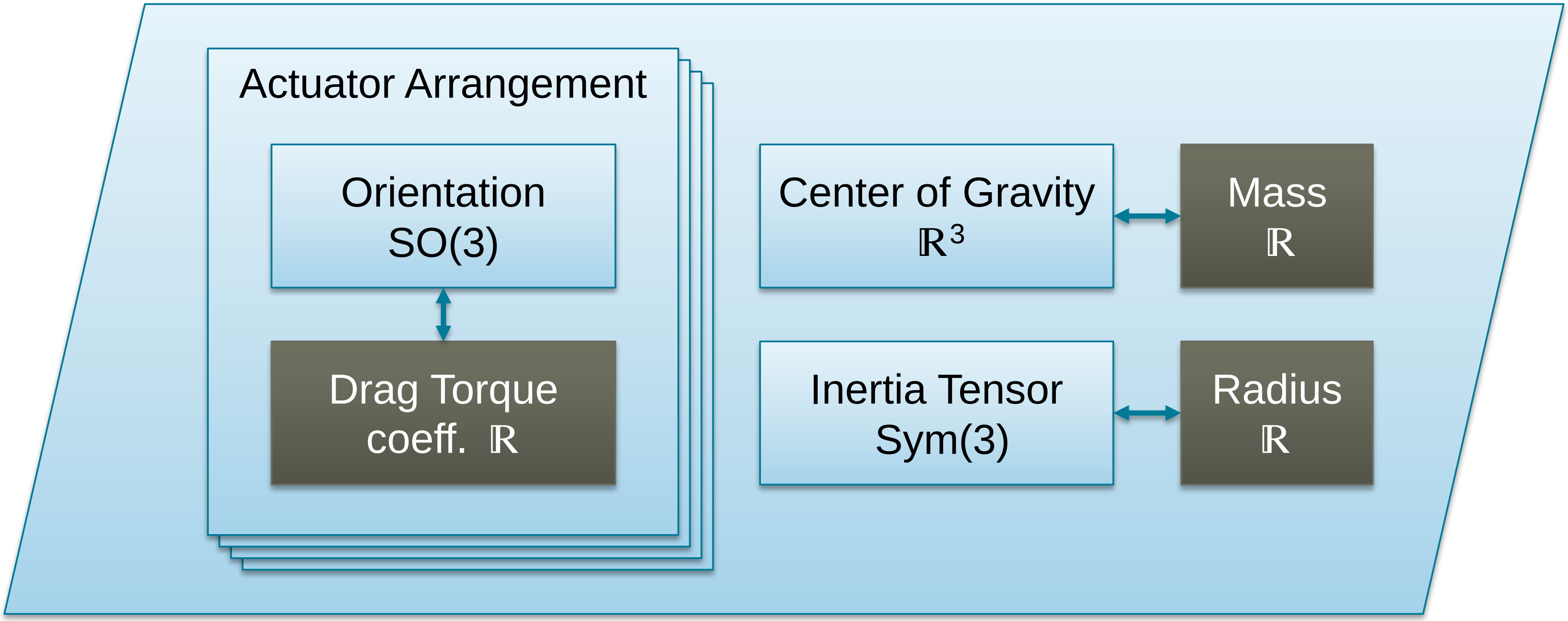


Problem Formulation: Parameters



- Full Parameter set is only jointly observable

Problem Formulation: Parameters



- Assume jointly observable parameters as known

For 4AUs: 21 Parameters

Problem Formulation: Parameters

Parameter

Constant (known)

State (known)

- Angular Acceleration

$$\mathbf{f}(\mathbf{x},\mathbf{u},\boldsymbol{\theta}) = \hat{\boldsymbol{\alpha}}_b = \mathbf{J}_b^{-1}(\mathbf{M}_b - \boldsymbol{\omega}_b \times \mathbf{J}_b \boldsymbol{\omega}_b)$$

with

$$\mathbf{M}_b = \underbrace{\sum_{k=1}^{N} \left[\mathbf{C}_{b,m_k} \left(\mathbf{p}_{m_k}^{m_k,cog} \times \mathbf{F}_{m_k}\right)\right]}_{\mathbf{M}^{actuation}} - \underbrace{\left(\mathbf{p}_b^{cob,cog} \times \left(\mathbf{C}_{b,w} m \mathbf{g}_w\right)\right)}_{\mathbf{M}^{gravity}}$$

Problem Formulation: Parameters

Parameter

Constant (known)

State (known)

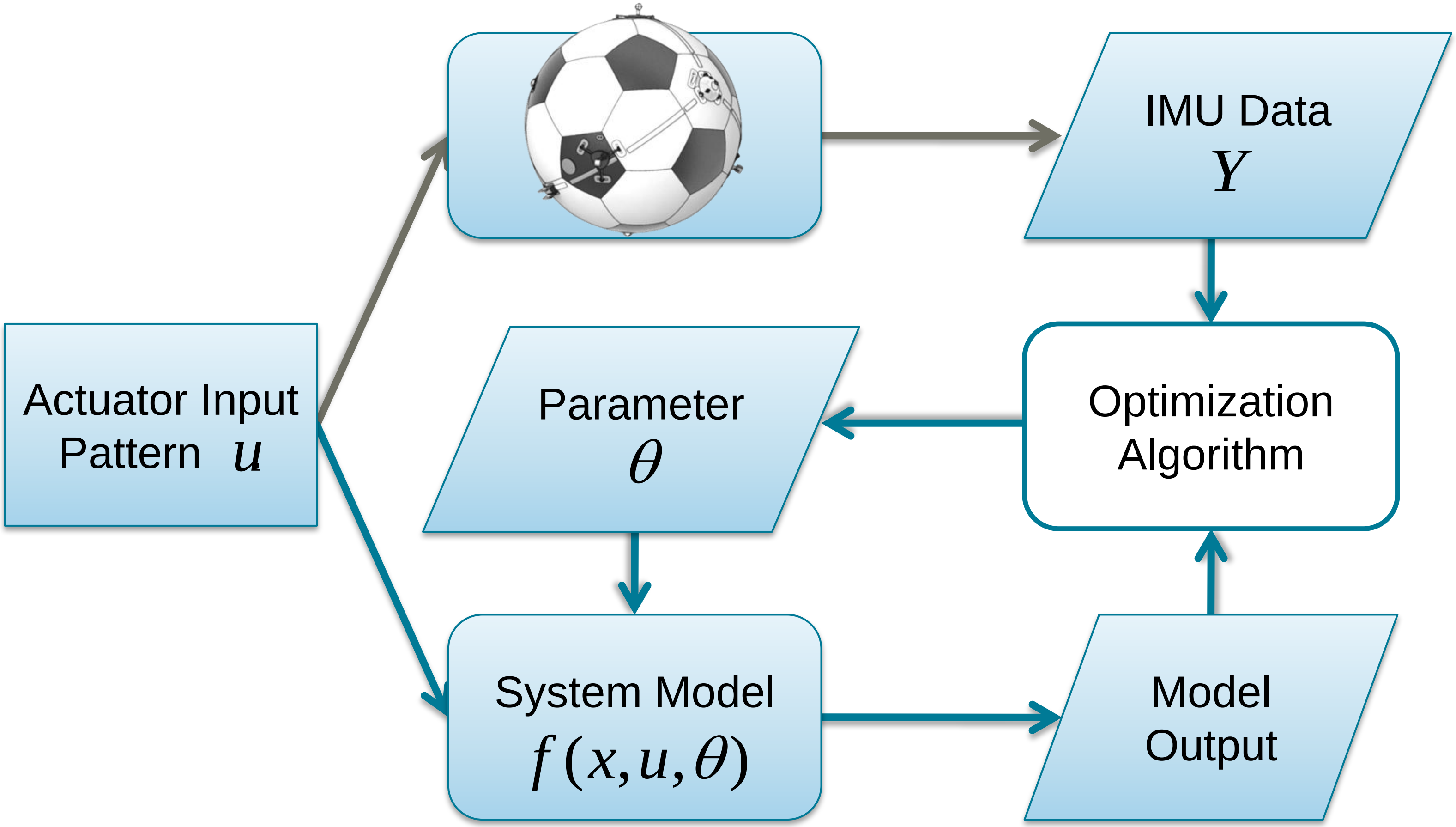
- Angular Acceleration

$$\mathbf{f}(\mathbf{x},\mathbf{u},\boldsymbol{\theta}) = \hat{\boldsymbol{\alpha}}_b = \mathbf{J}_b^{-1}(\mathbf{M}_b - \boldsymbol{\omega}_b \times \mathbf{J}_b \boldsymbol{\omega}_b)$$

with

$$\mathbf{M}_b = \sum_{k=1}^{N} \left[\mathbf{C}_{b,m_k} \left(\begin{bmatrix} 0 \\ 0 \\ -r \end{bmatrix} \times \begin{bmatrix} F_x^{m_k} \\ F_y^{m_k} \\ 0 \end{bmatrix} \right) \right] - \underbrace{\left(\mathbf{p}_b^{cob,cog} \times (\mathbf{C}_{b,w} m \mathbf{g}_w) \right)}_{\mathbf{M}^{gravity}}$$

Problem Formulation



Problem Formulation: Optimization

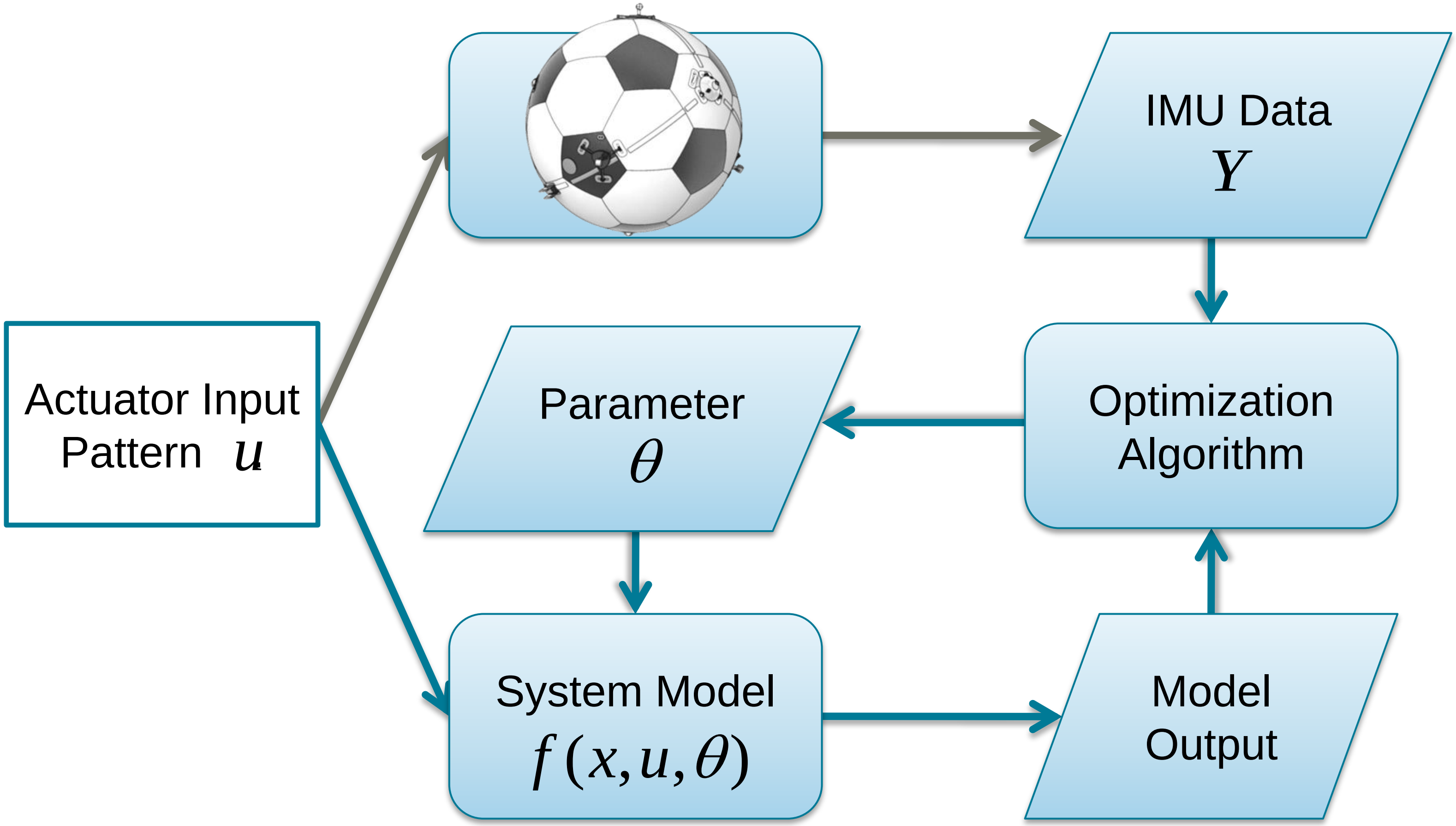
- Nonlinear Least Squares

$$S(\boldsymbol{\theta}) = \sum_{i=1}^{N} \|\mathbf{y}_i - \mathbf{f}(\mathbf{x}_i, \boldsymbol{\theta})\|^2$$

- Levenberg-Marquardt
  - Gradient based minimization
  - Robust and fast convergence

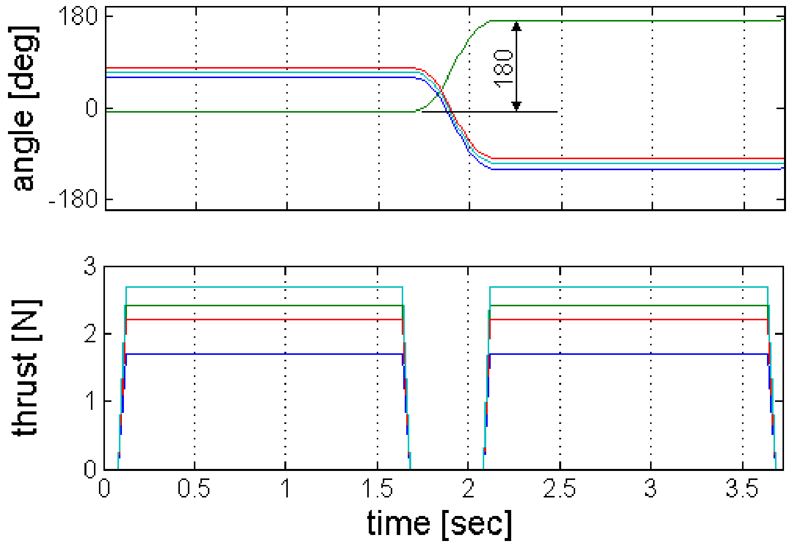
$$(\mathbf{J}^\top \mathbf{J} + \lambda \mathrm{diag}(\mathbf{J}^\top \mathbf{J}))\boldsymbol{\delta} = \mathbf{J}^\top [\mathbf{y} - \mathbf{f}(\boldsymbol{\theta})]$$

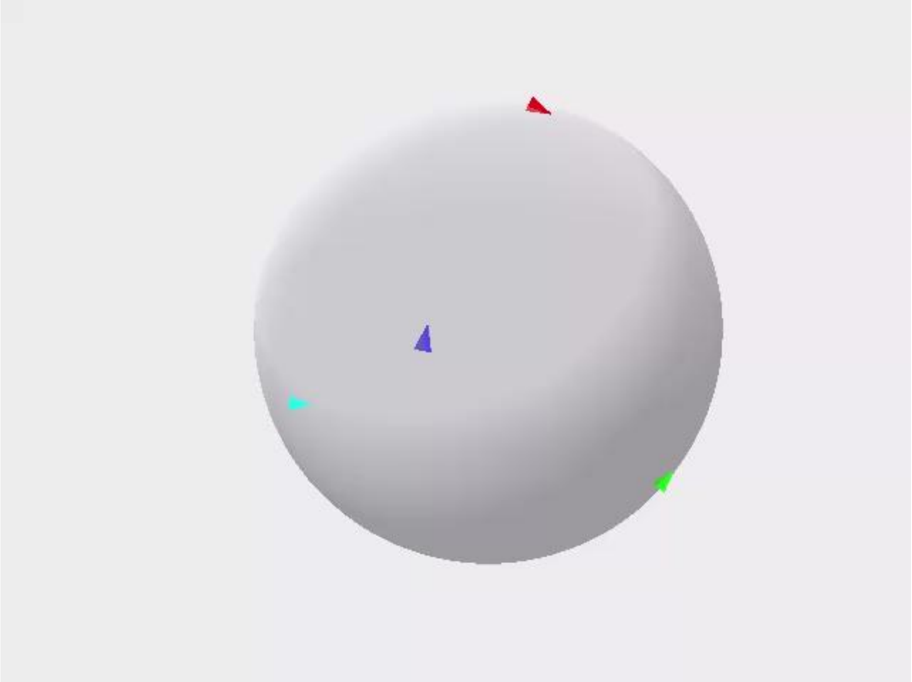
Problem Formulation



Problem Formulation: Input Pattern

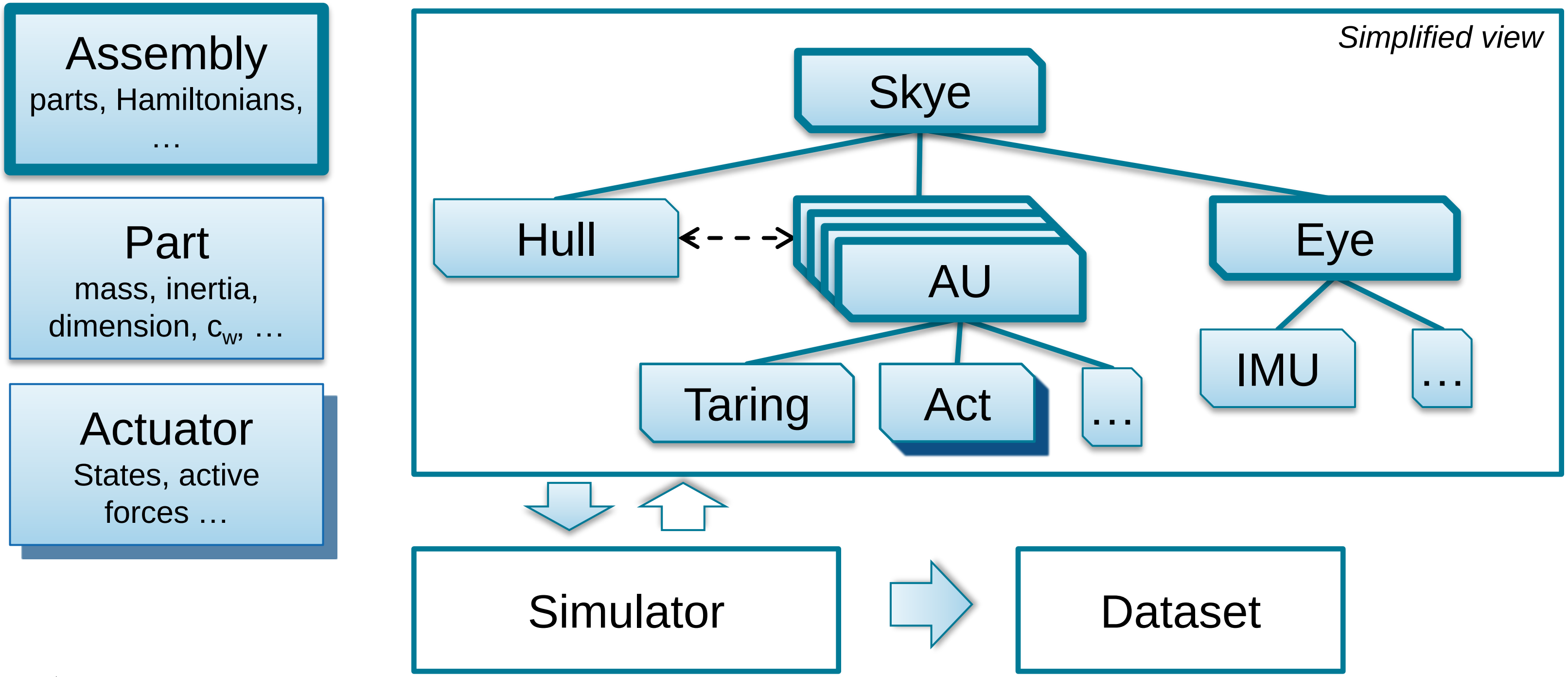
- Inputs must be **applicable** and **sufficiently excited**
  - **Forward/backward**
  - **Varying directions**
  - Steady state motor dynamics





Simulator

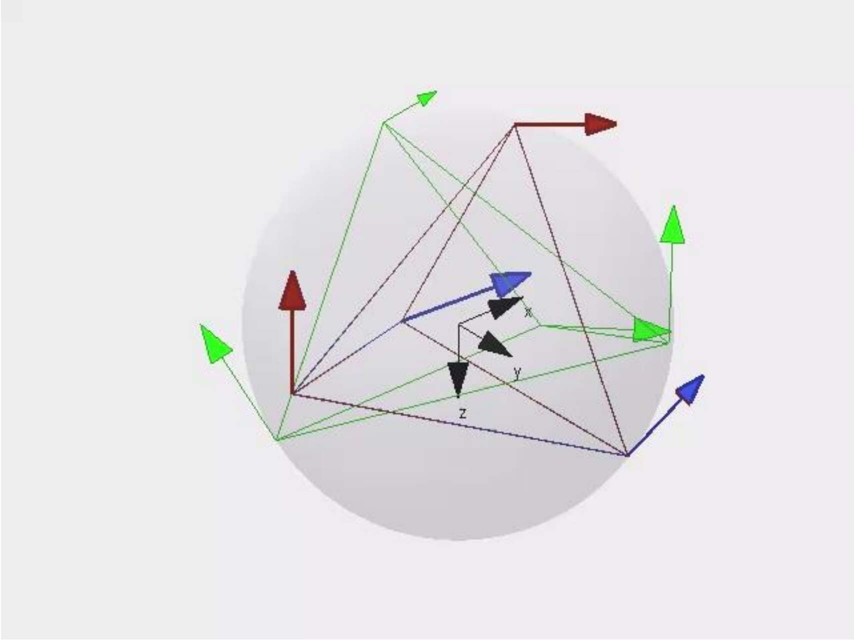
- Object oriented simulator in MATLAB
- Modular concept for (almost) arbitrary blimps



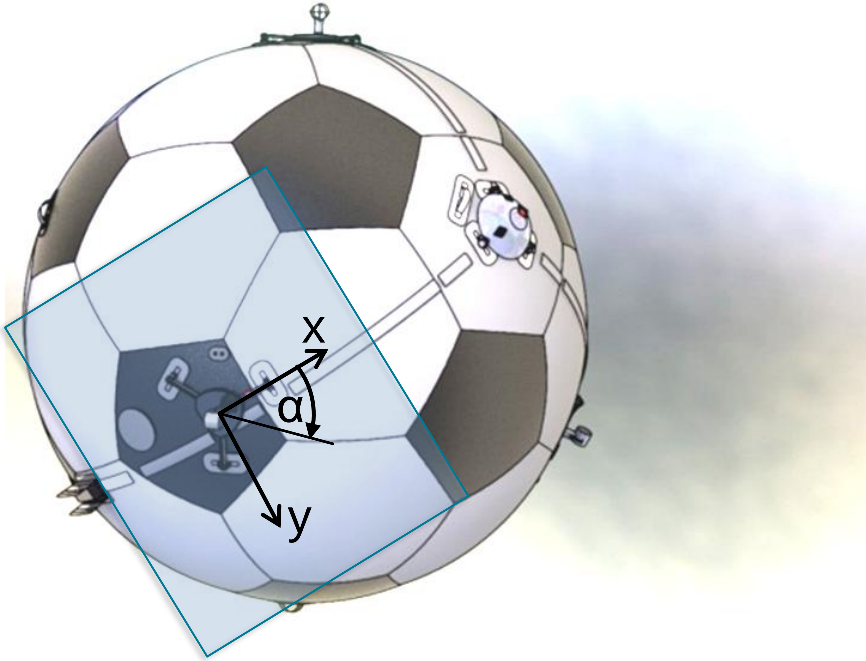
Results

- Simulation Results
- Experimental Results
- Groundtruth with Leica

Results

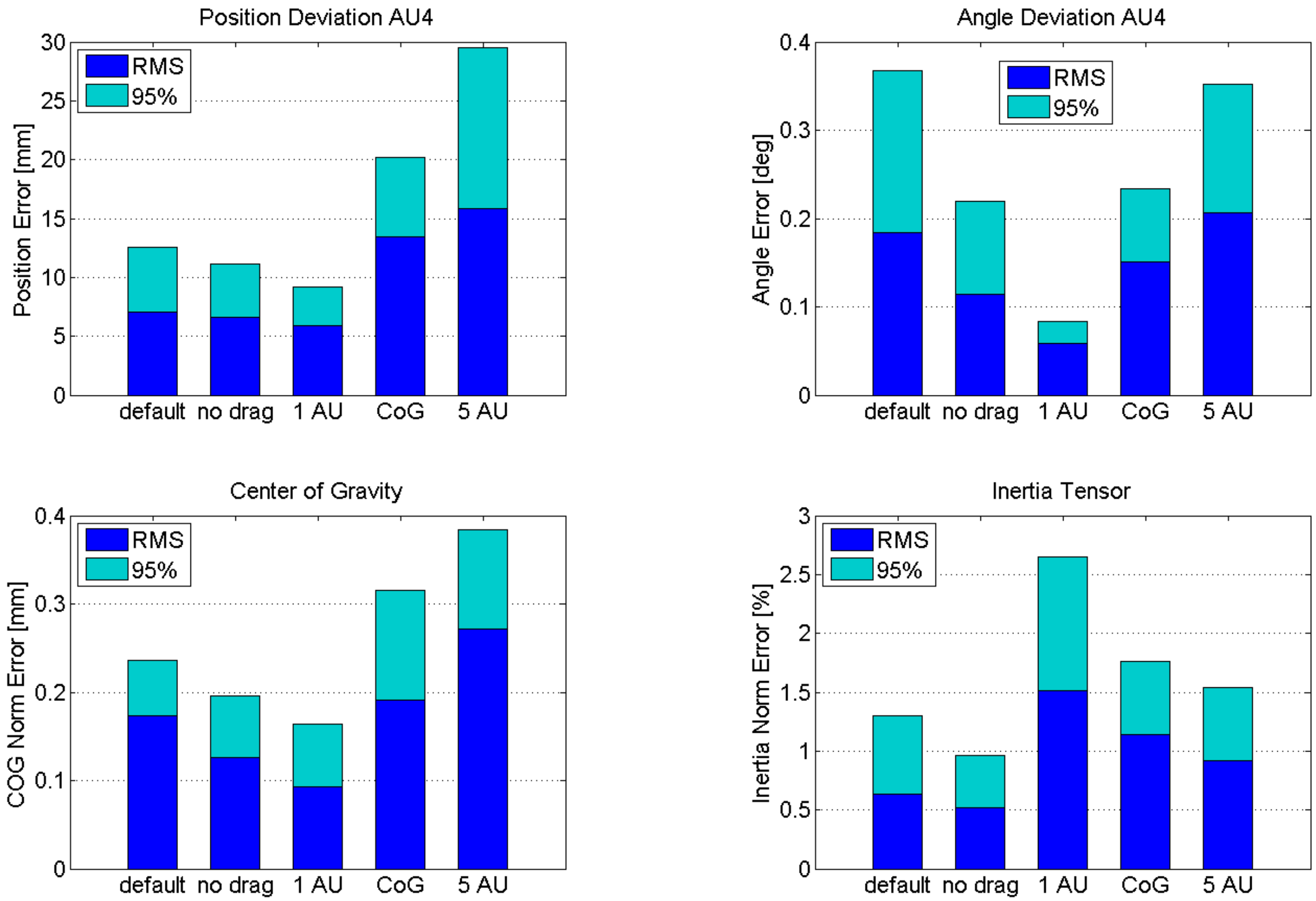


6 LMA Iterations



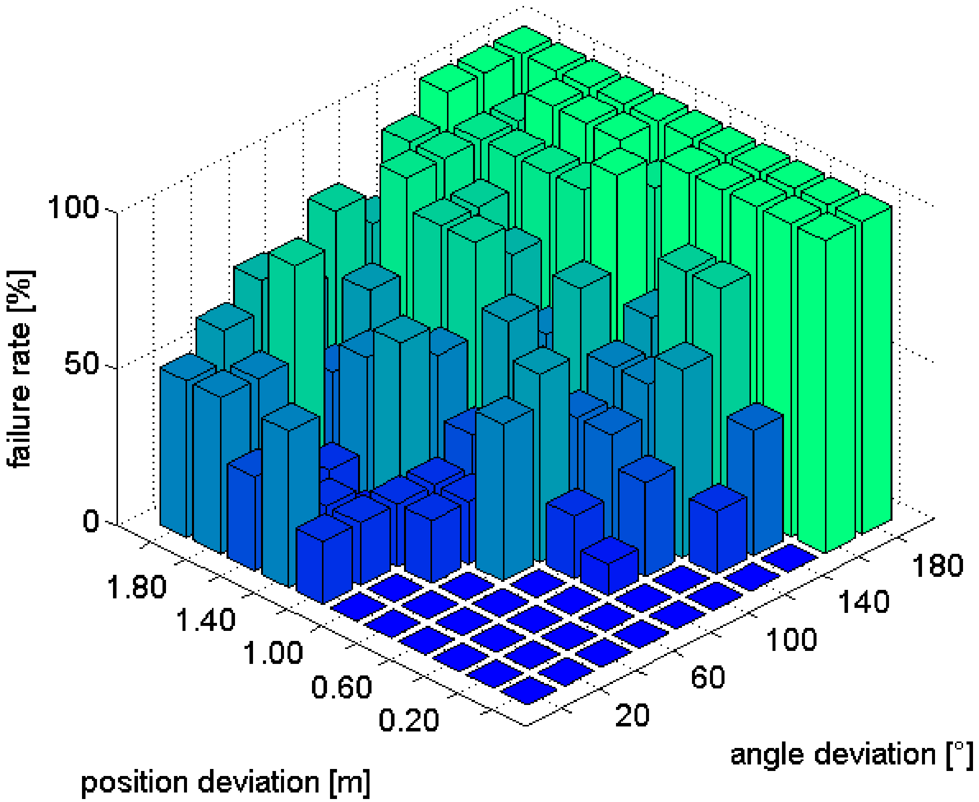
Init
True
Batch

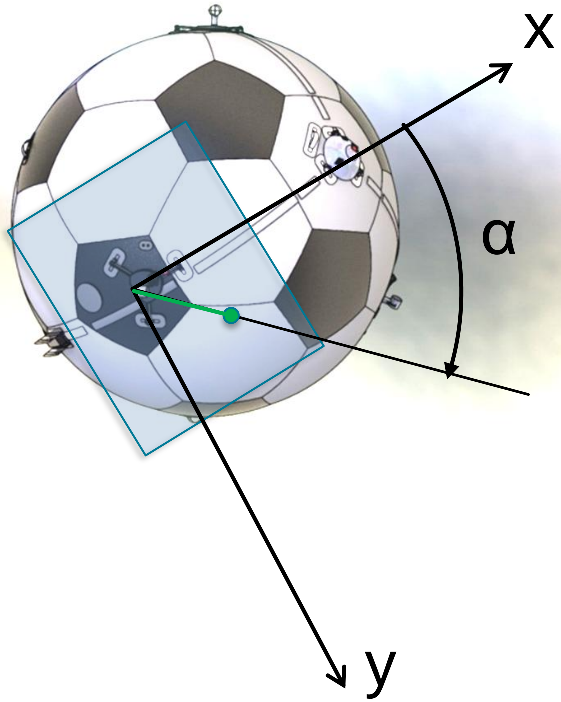
Simulation: Casestudies



16 simulations à 40 seconds

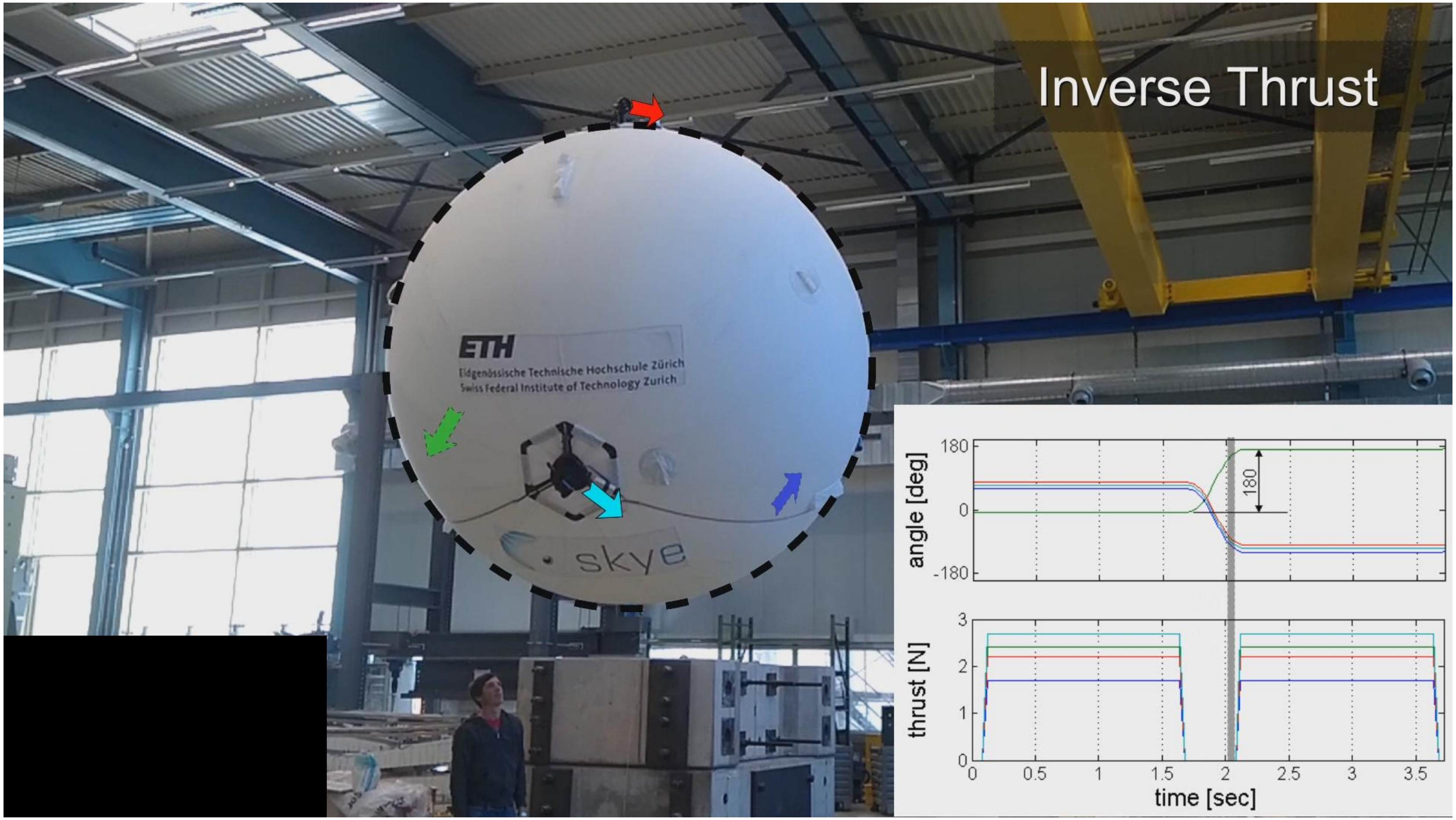
Simulation: Convergence Region



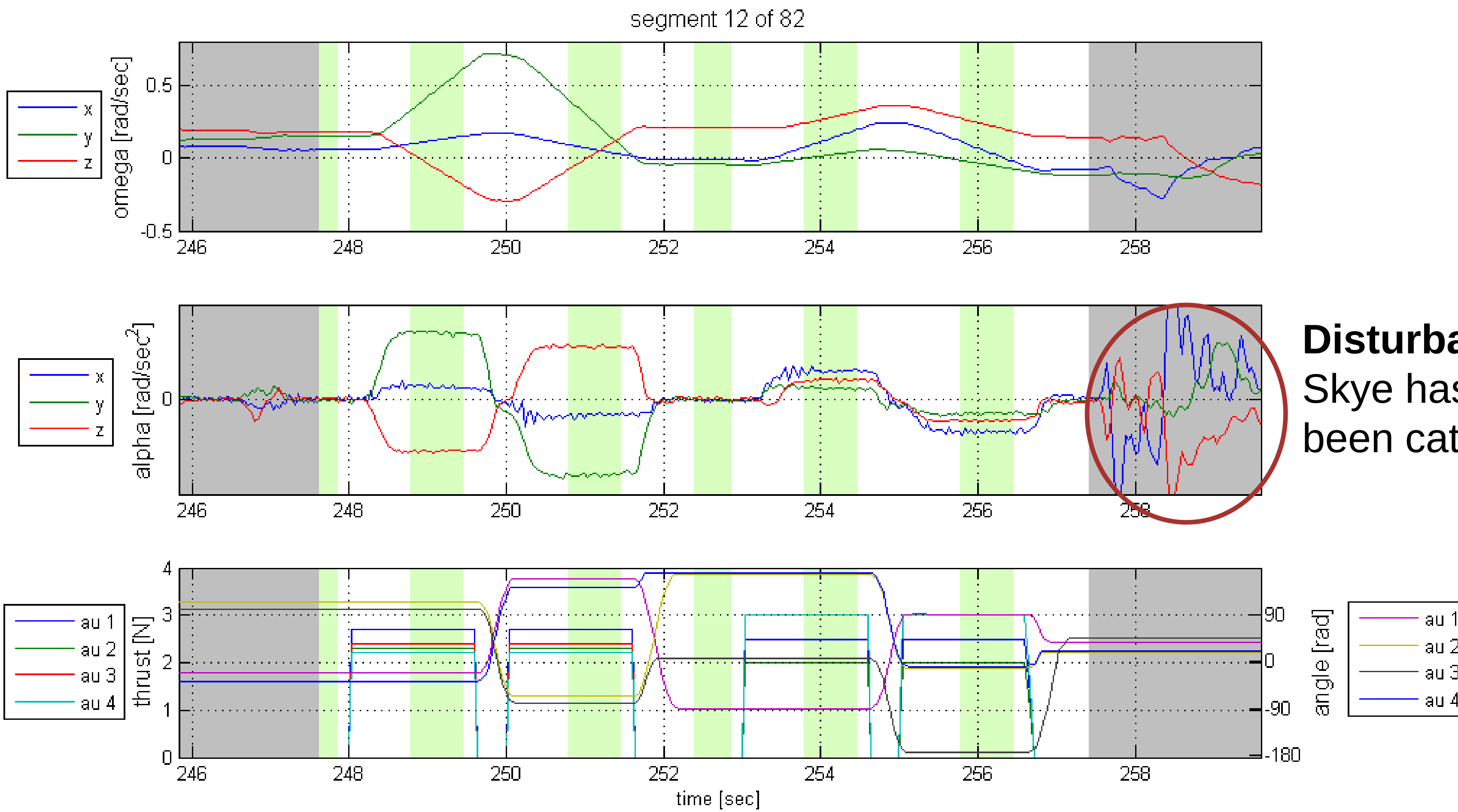


Initial Parameters can be about **1m or 120°** apart of the true value

Data Acquisition

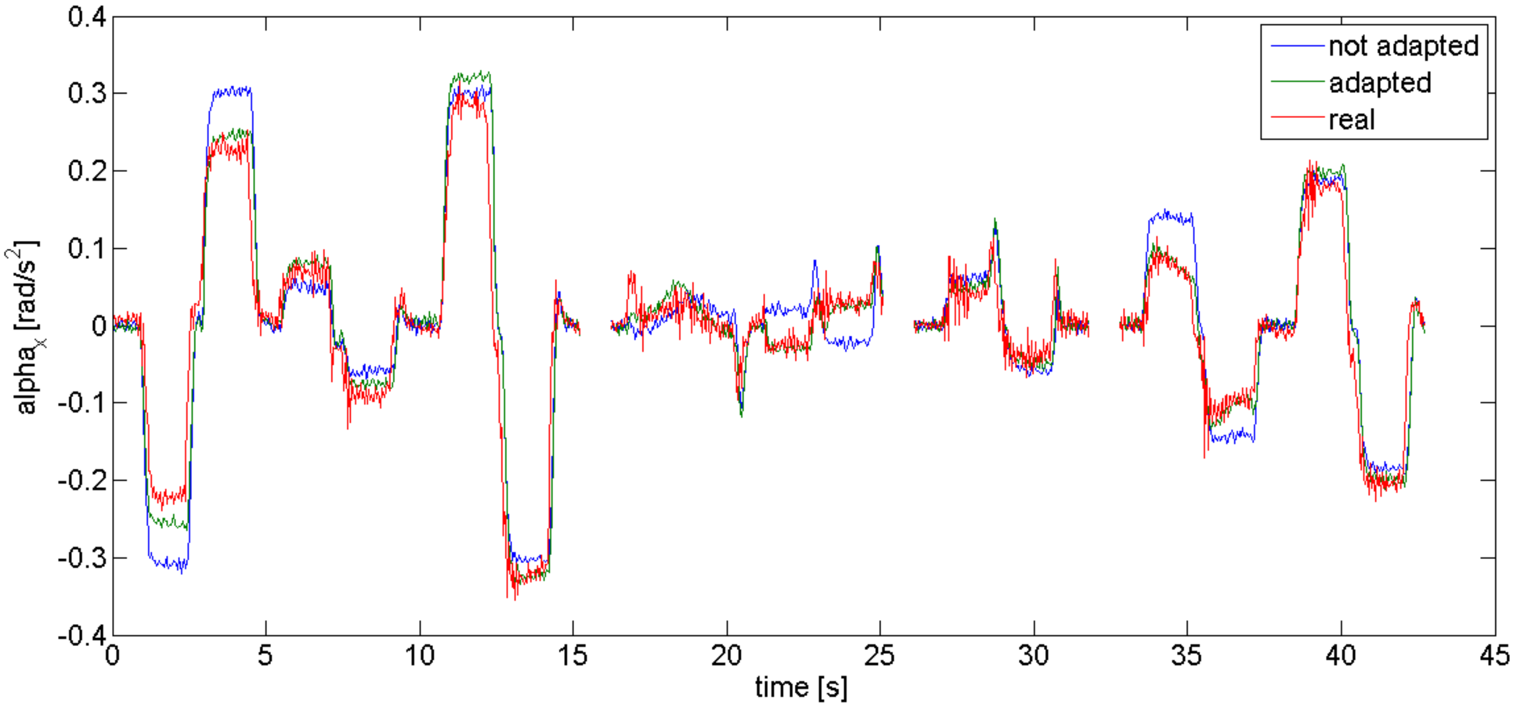


Data Acquisition

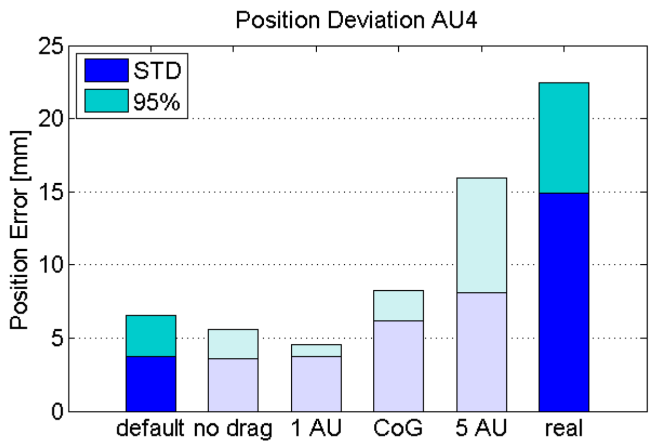


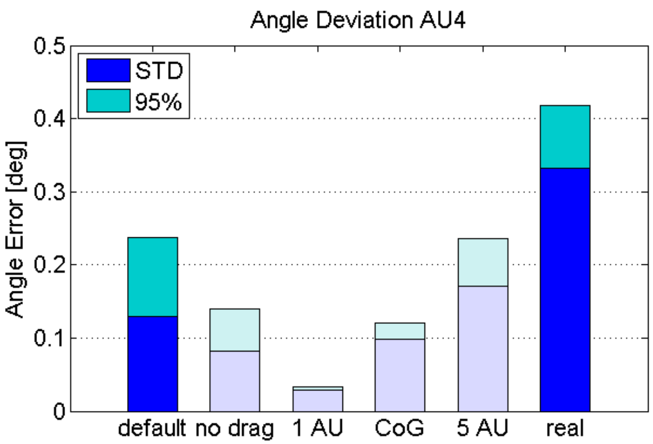
Disturbance: Skye has been catched

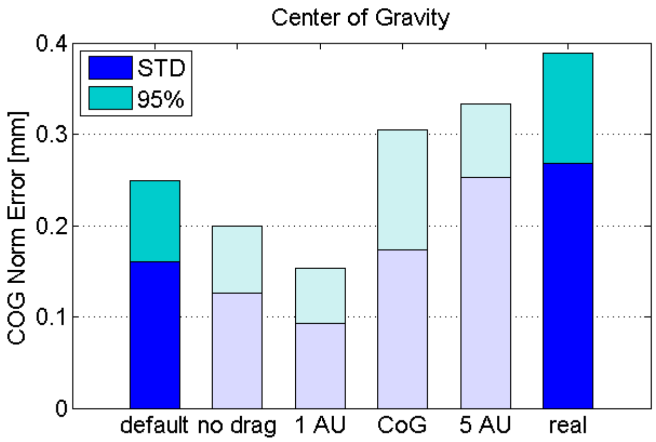
Results: Real Data vs. Simulation Data

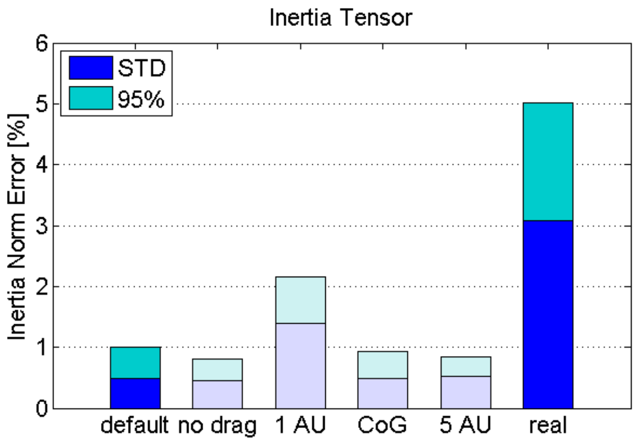


Results: Real Data vs. Simulation Data



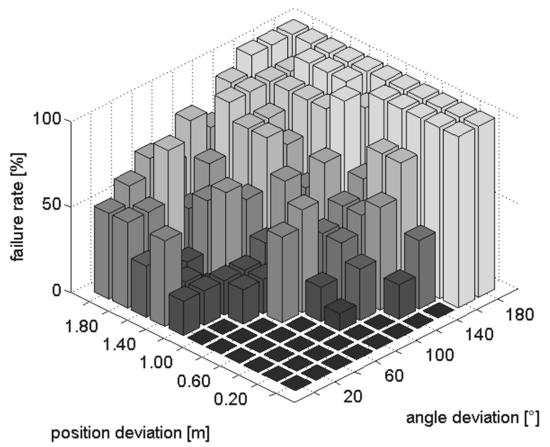


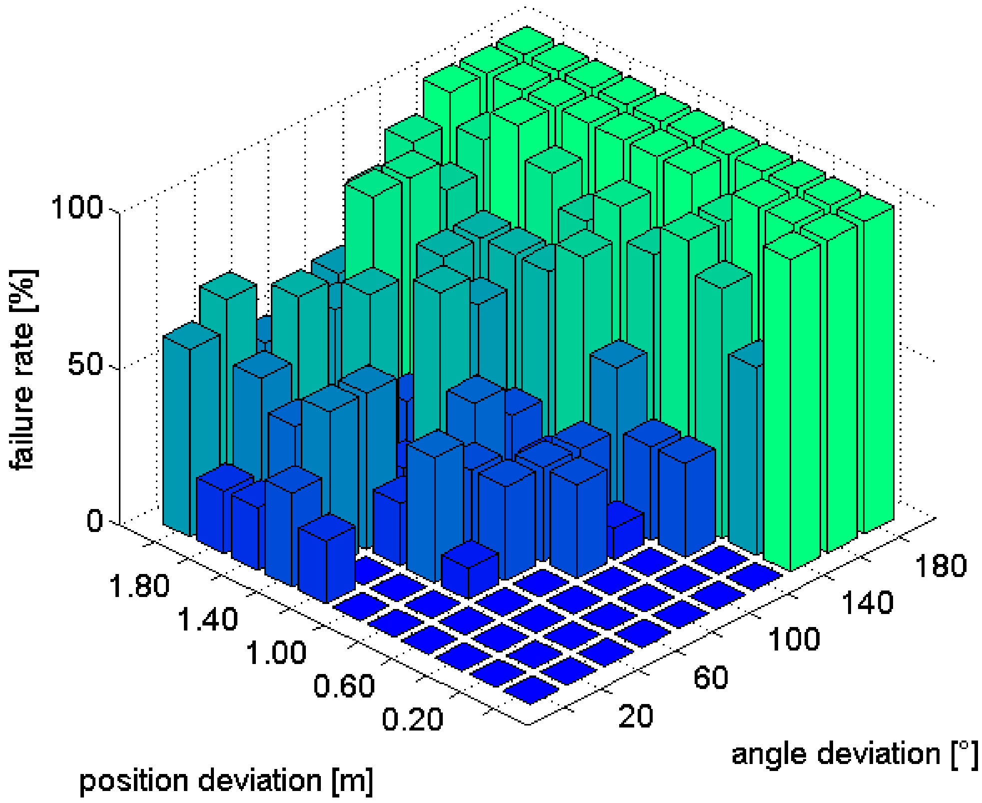




16 datasets à 40 seconds

Experiment: Convergence Region



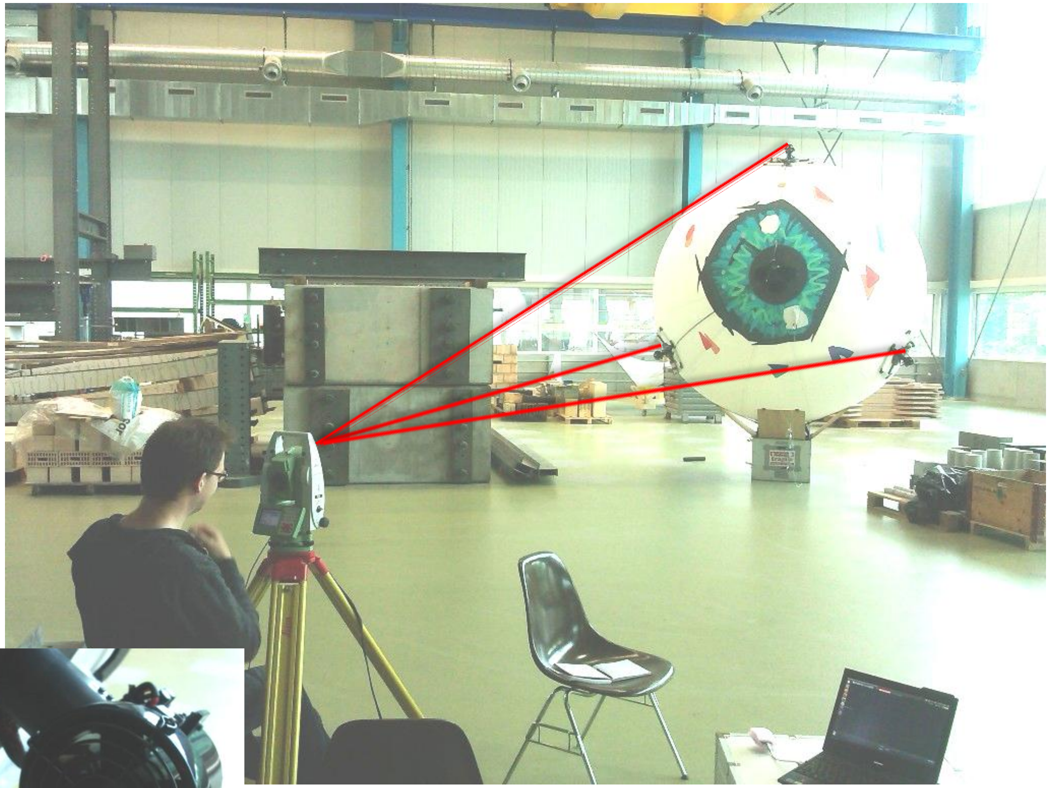


Very similar to simulation data.

Results: „Ground Truth“ (Leica)

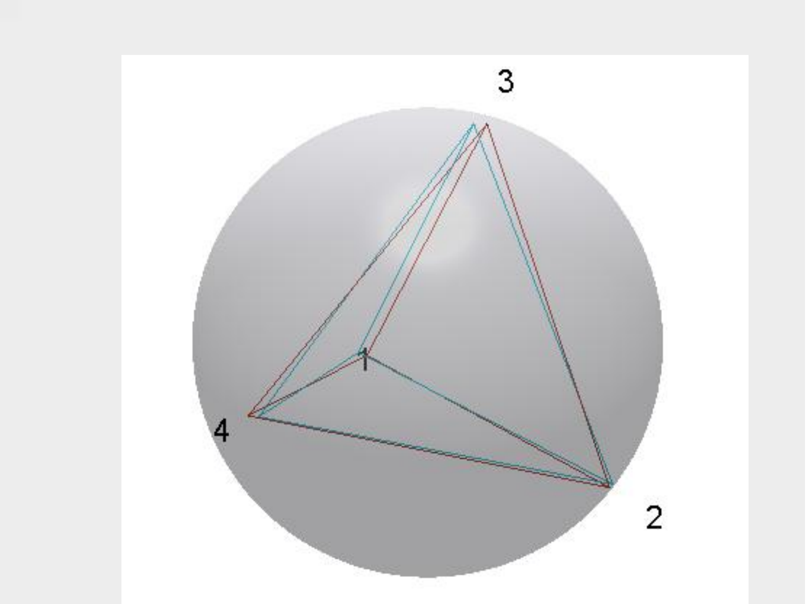
- 3 AU‘s visible at once
- Use different views

- Fit data to get tetrahedral‘s edge length
  - Residual below 0.01m



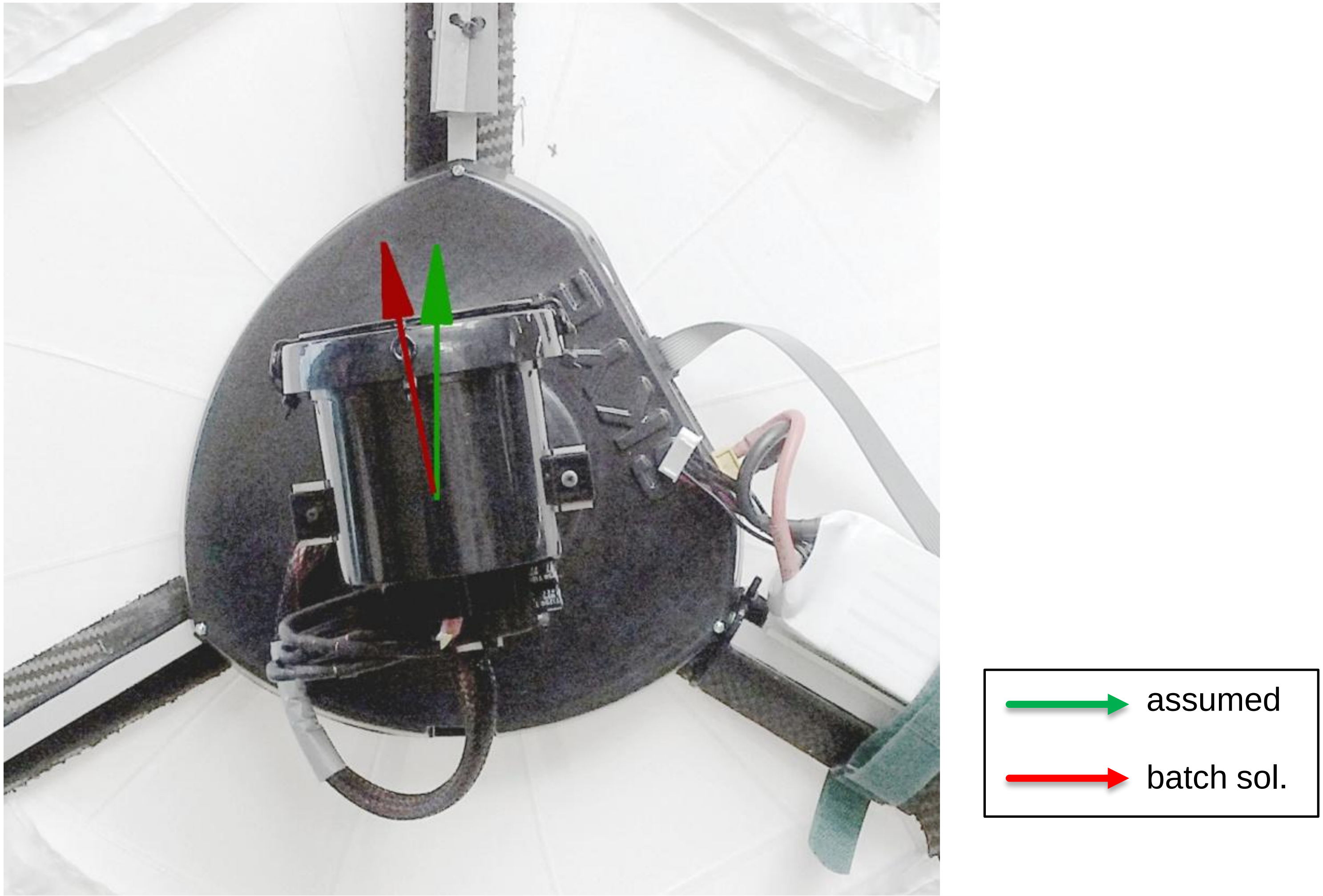
Results: Compare Leica and Batch Solution

Relative tetrahedral edge length error			
%	AU2	AU3	AU4
AU1	1.68	0.86	2.76
AU2		0.67	2.47
AU3			3.78



Leica
Batch

...


assumed
batch sol.

Conclusion

- **What did we do?**
  - Showed applicable method to estimate actuator configuration
- **How accurate?**
  - Actuator positions can be estimated within centimeters
- **Where to use?**
  - Automatically update parameters before flight within minutes

Thanks