

Interior Corner Transitions with a Magnetic-Wheeled Inspection Robot

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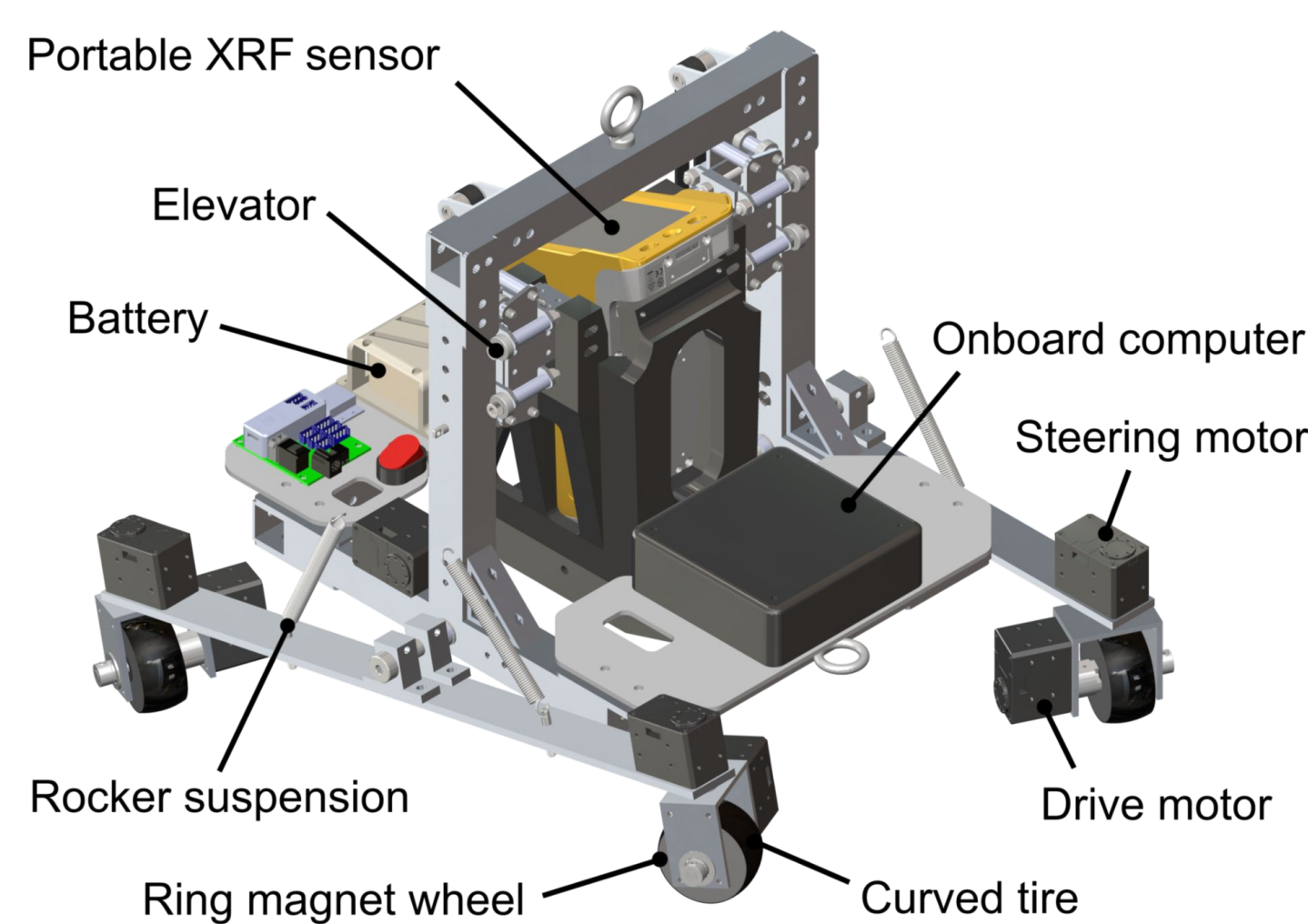
Introduction

- Automated inspection of steel structures using magnetic climbing robots can reduce costs and improve safety
- Many structures feature 90° interior corners that are challenging for wheeled or tracked robots to traverse
- We present Sally, a magnetic-wheeled robot for steel structure inspection capable of overcoming all interior corner transition types, uneven surfaces, and small obstacles



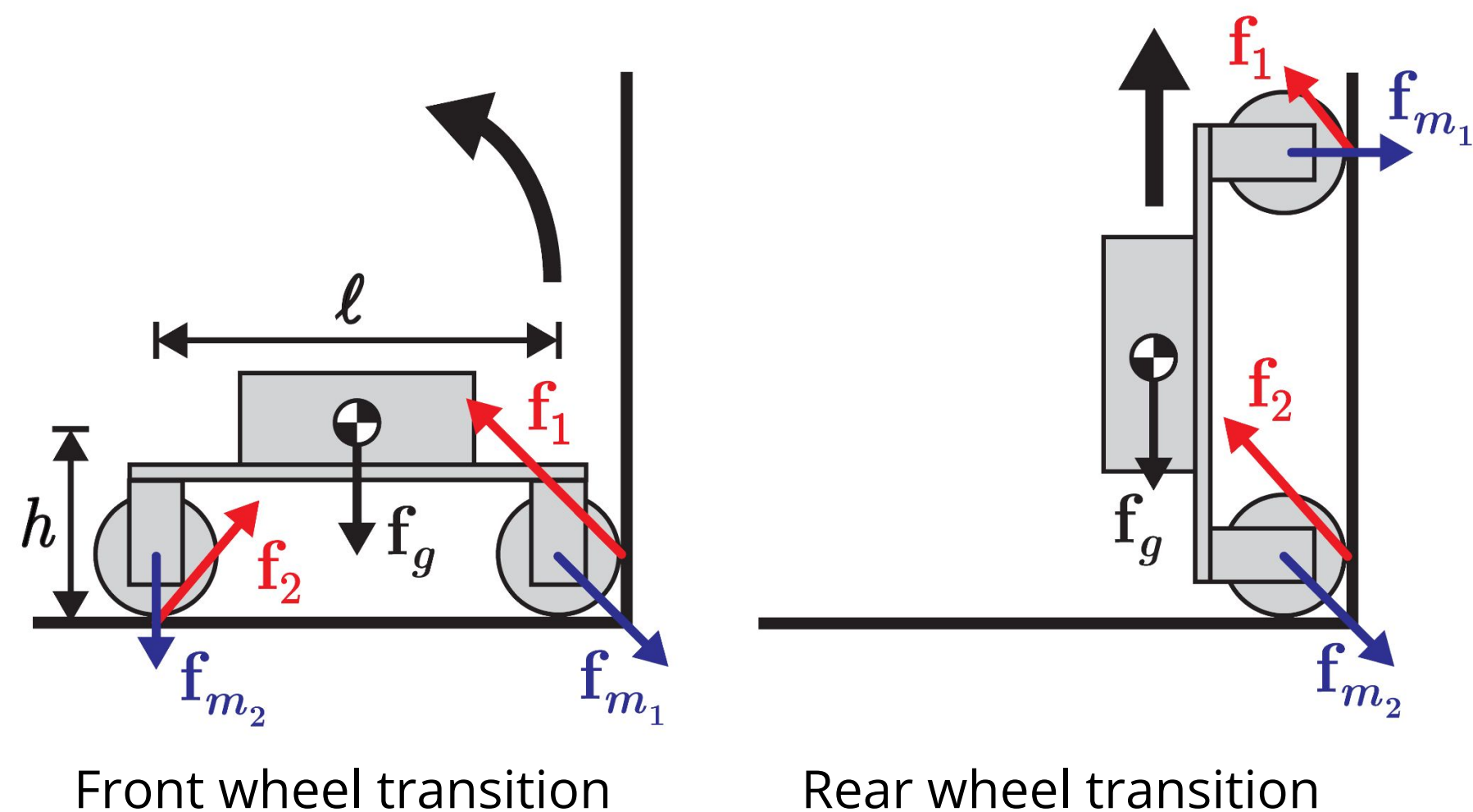
Robot Design

- Individual steering modules for all wheels enable Sally to travel omnidirectionally and aid in rear wheel transitions
- A linear belt drive is used to deploy the pXRF sensor and aid in front wheel transitions
- A rocker suspension along with curved tires enable Sally to traverse uneven surfaces and small obstacles

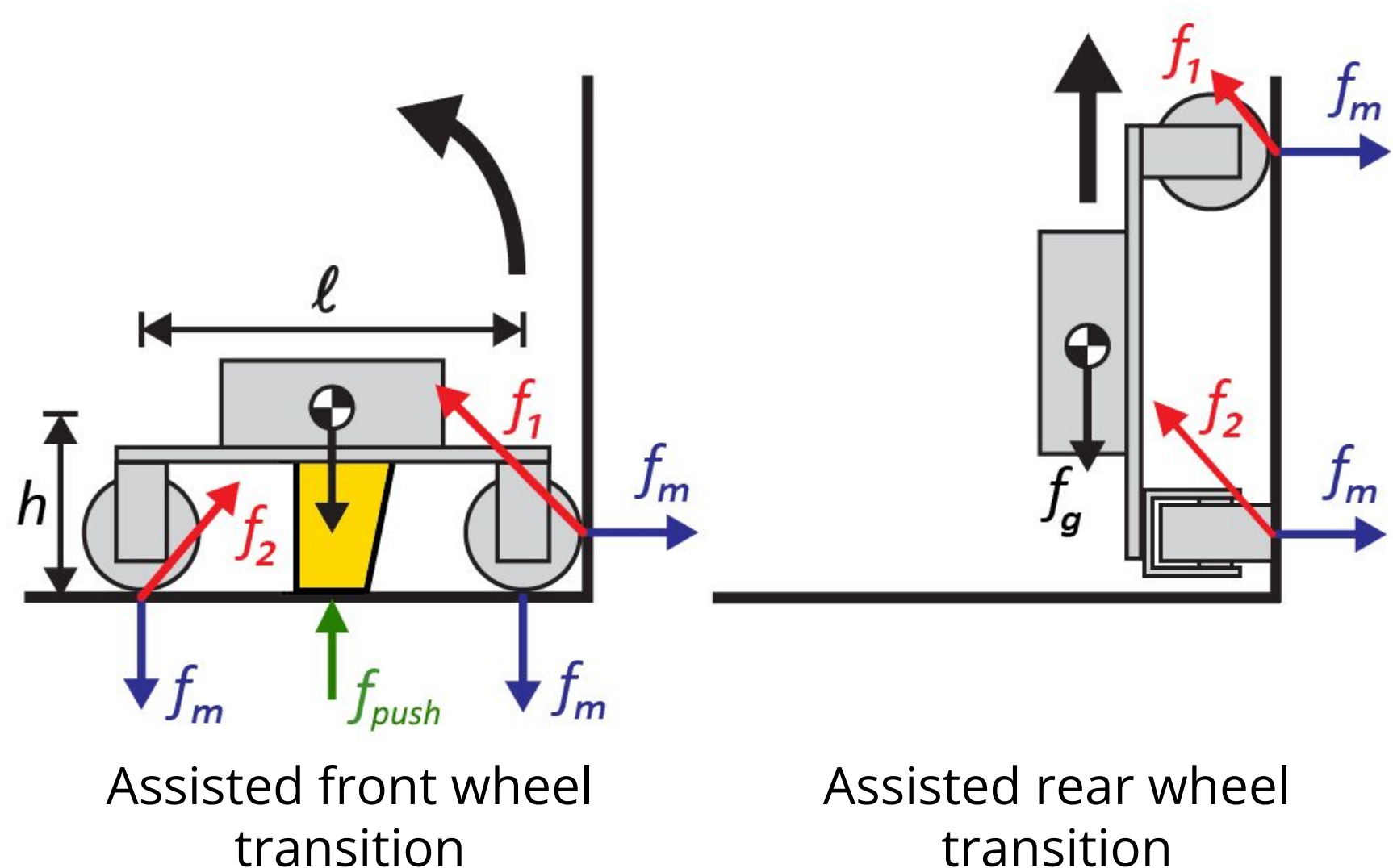


Interior Corner Transitions

- We focus on two critical moments, when the front and rear wheels respectively break contact with the initial surface
- The relationship between wheel friction and physical robot characteristics are determined via quasi-static analysis

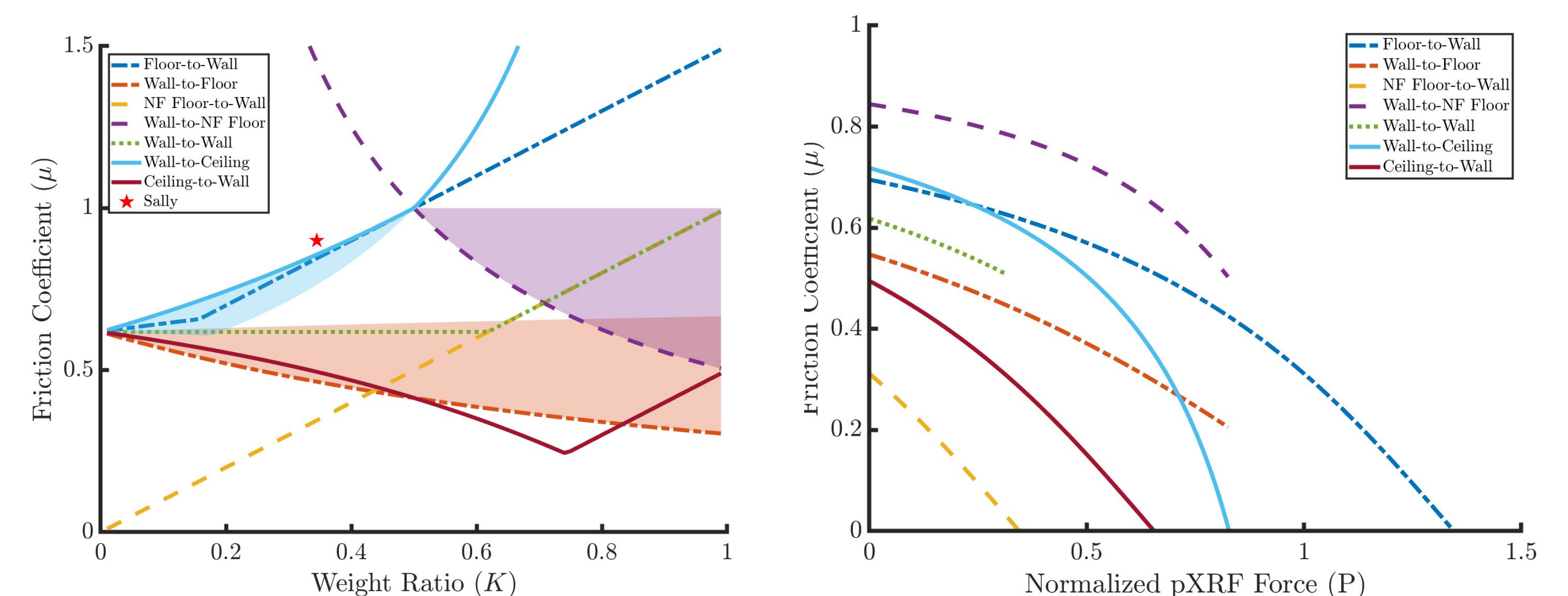


- We fully characterize the design with 2 dimensionless parameters: the **aspect ratio** between the height of the COM of the robot and the wheel base, and the **weight ratio** between the weight of the robot and the magnetic force of all wheels
- Transitions can be assisted by pushing against the initial surface with the sensor deployment mechanism, or by rotating the rear wheels to break contact with the initial surface

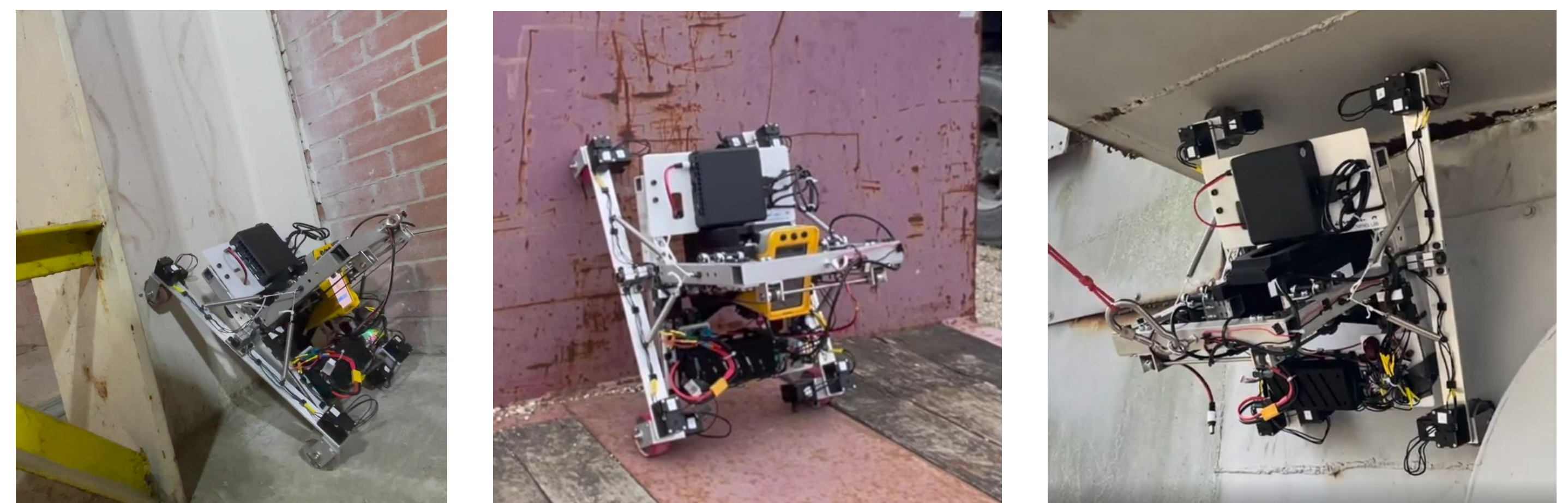
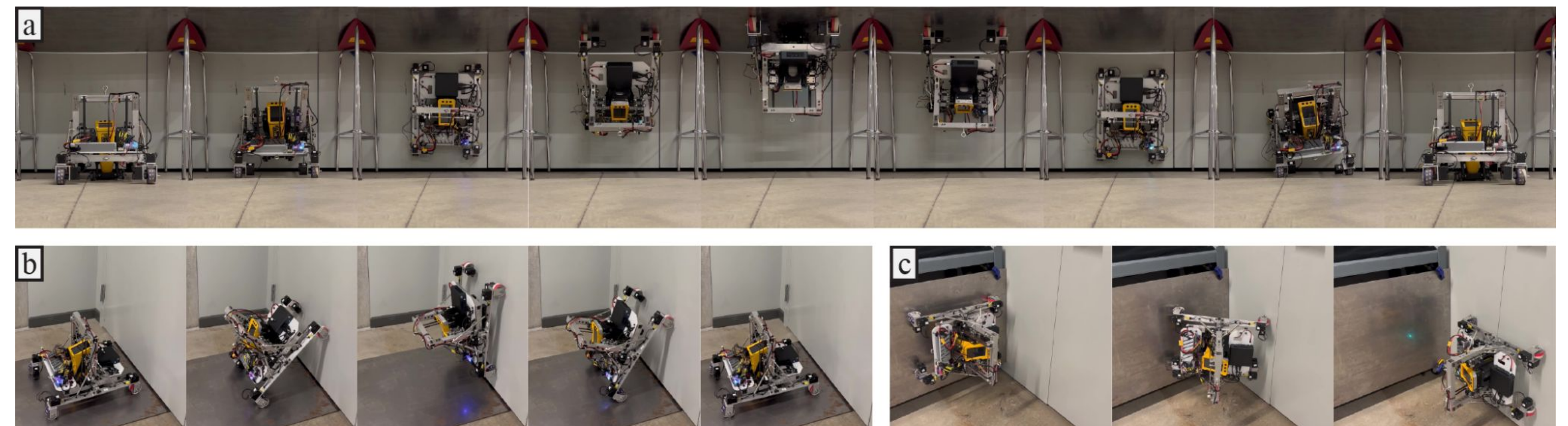


Simulation Results

- We simulate the minimum friction required to achieve static equilibrium for 7 different interior corner transition types
- For each type of transition, we find the minimum required friction coefficient as a function of the weight ratio. We also demonstrate how this boundary moves as the aspect ratio varies from 0 to 0.5
- Applying a force with the sensor deployment mechanism decreases the friction required for transitions, but the force that can be applied is limited by the magnetic force of the wheels



Transition Performance



- Sally attempted all 7 interior corner transitions in lab experiments (top) and in the field (bottom) at an industrial site
- Lab results matched analysis expectations and Sally successfully performed all interior corner transitions
- Field results did not always match the simulated capabilities due to inconsistencies in wheel friction caused by variable surfaces, wheel cover wear, and debris accumulation on the magnetic wheels
- A switching torque-velocity controller accounts for differences in speed between the front and rear wheels during transitions

- Velocity control is used to break contact with the previous surface during the front and rear wheel transitions
- Torque control is used in between to maintain rear wheel contact as the relative speeds vary

