Multirotor Landing Envelope Expansion using Friction Shock Absorbers

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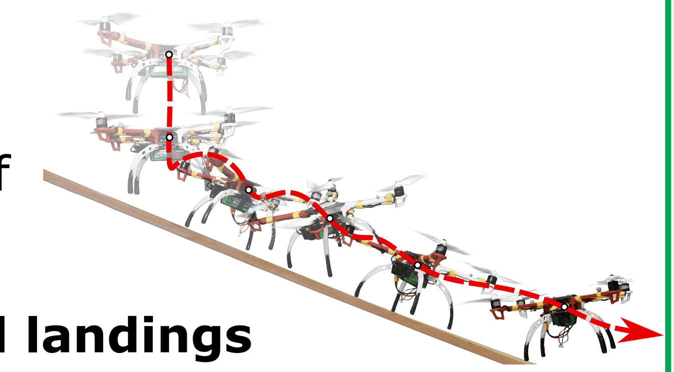
Context

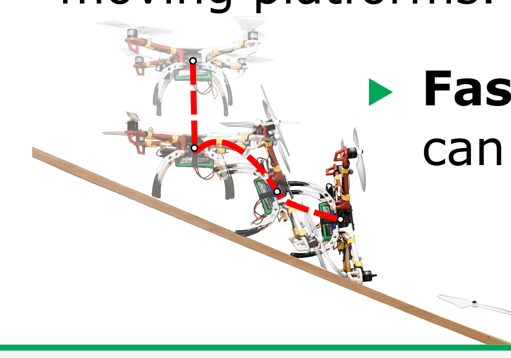
- Small multirotors are not designed to land in hazardeous situations, such as on inclined surfaces and moving platforms.
- The landing and takeoff stages are critical to drone operations.
  - 2/3 of military drone accidents occur during these phases.
- Improvements towards the landing phase could ease the use of drones for new and current applications:
  - Landing on roofs for inspection, surveillance or recharging
  - Landing on moving vehicles for scouting missions or for "last-mile" package delivery
  - Landing on boats in rough seas (e.g. for search and rescue)

Challenges

Multiple challenges need to be overcome:

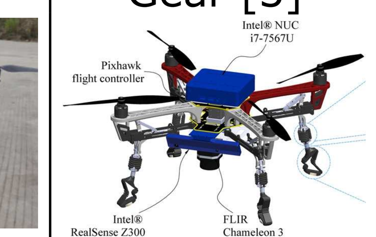
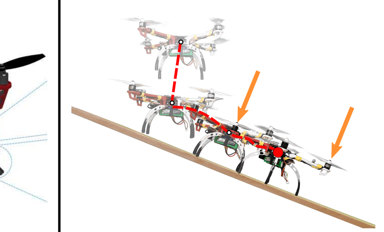
- While following a vehicle at high speeds, **high winds**, **gusts** and **turbulence** close to fast moving vehicles can disturb the approach and landing phase.
- **Drag** can rapidly build a **relative horizontal speed difference** between the drone and the vehicle that might cause the drone to tip over on contact.
- On ships, the landing area will be constantly changing orientation and can rapidly move vertically.
- **Rigid landing gears** cause small drones to **bounce,** slide down slopes and fall off moving platforms.





- **Fast vertical landings** can make the drone **flip over**.

Recent UAV Landing Technologies

Method	Lateral Rotors [1]	Actuated Landing Gear [2]	Damper Landing Gear [3]	Reverse Thrust [4]
				
Angle	30° slopes	30° slopes	Horiz. Surfaces	25° slopes
Vel.	0.5 m/s	0.5 m/s	2 m/s	1 m/s
Mass	Added mass	920 g added	410 g added	None added

[1] F. von Frankenberg, et al., *Inclined landing*, 2018
[2] J. Liu, et al., *Multi-finger robot*, 2021
[3] K. Zhang, et al., *Bioinspired design*, 2019
[4] J. Bass, et al., *Improving multirotor landing*, 2020

Proposed Work

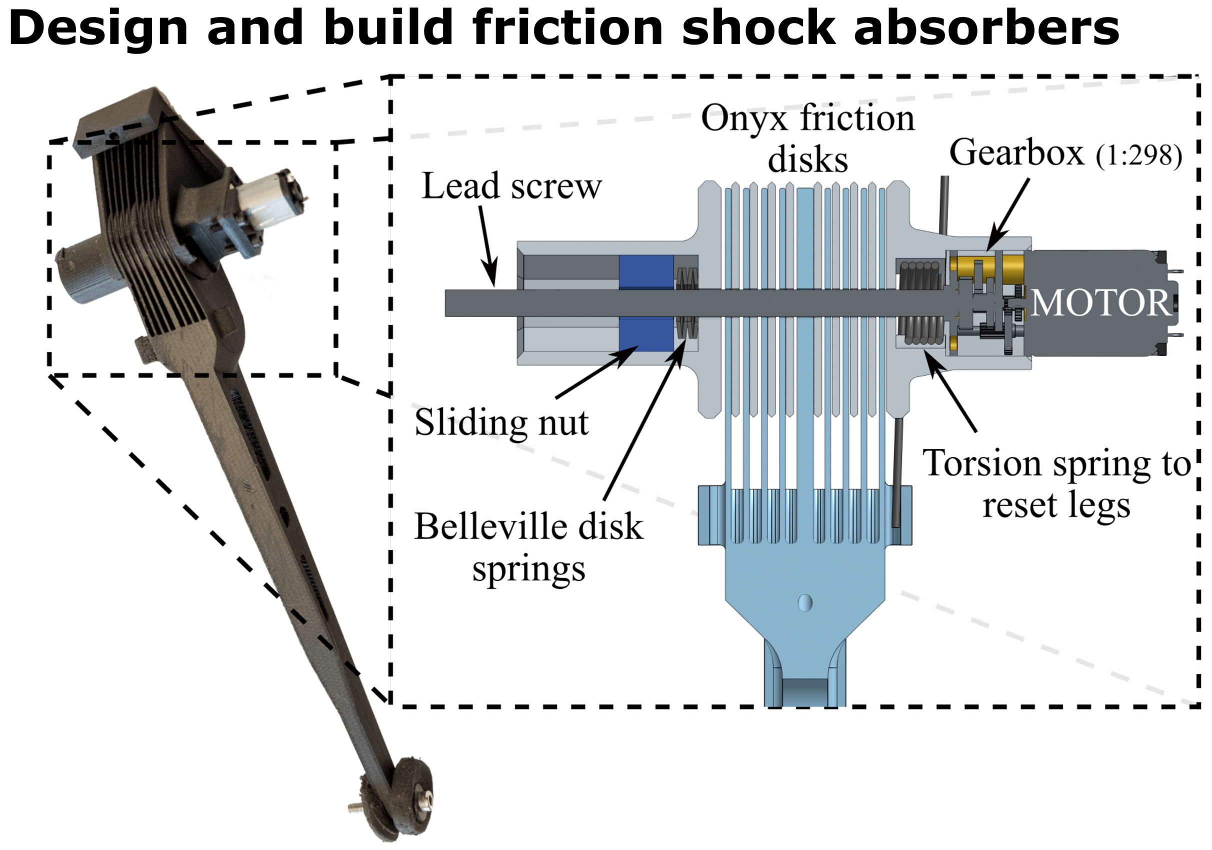
Design, build and test a landing gear which would allow small multirotors to land in **extreme conditions**, such as :

- On inclined surfaces
- With a relative horizontal velocity
- With a high descent velocity
- On rotating surfaces
- In high winds

Friction shock absorbers can dampen high velocity impacts, while **reverse thrust** can help adhere to surfaces.

Approach and Results

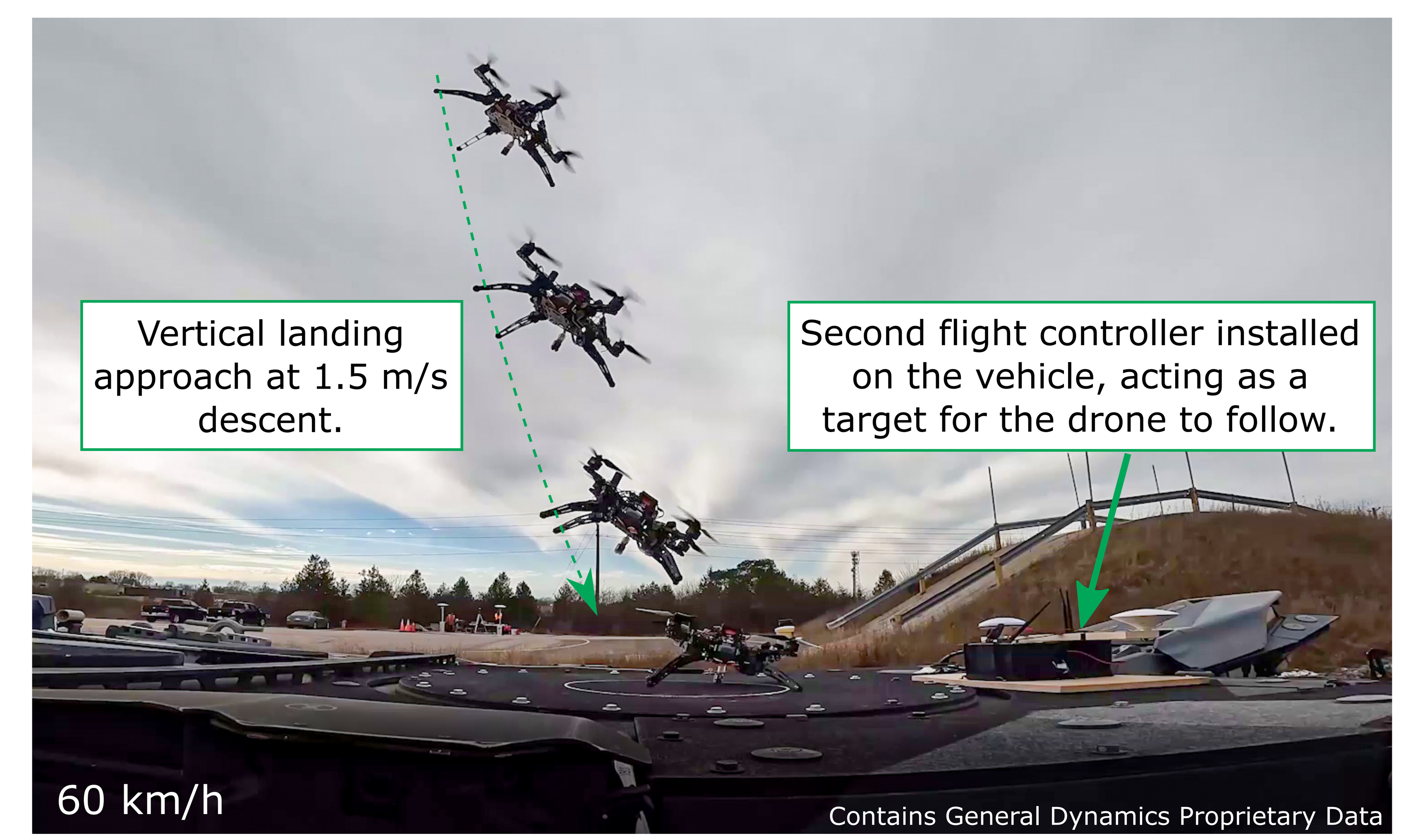
Design and build friction shock absorbers



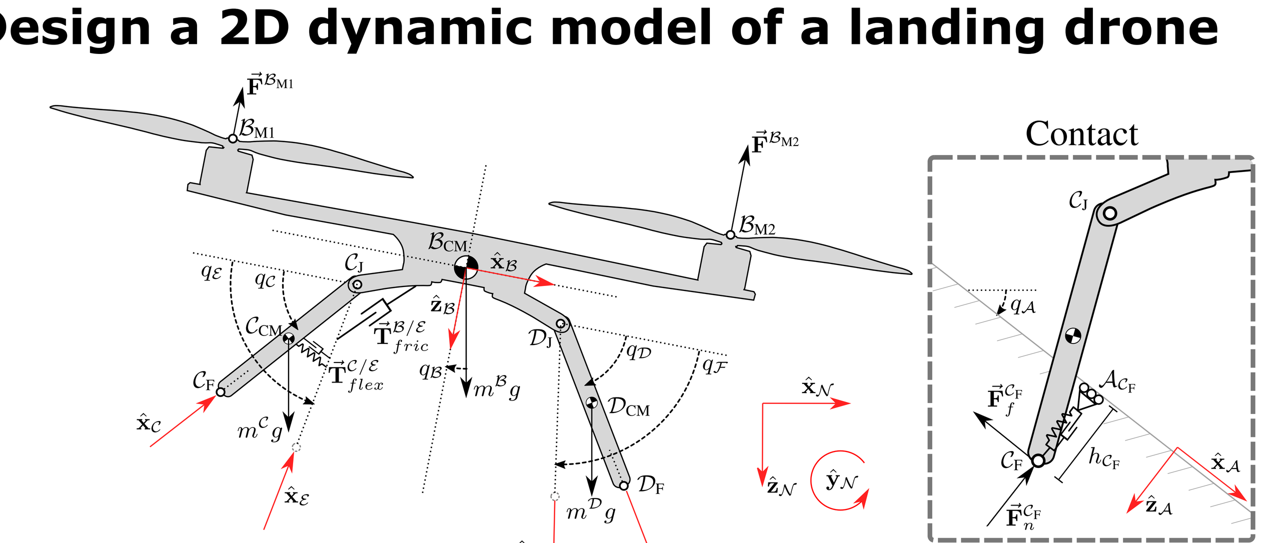
- A small DC motor squeezes a **series of disks** to create a friction torque in a rotary joint.
- The motor can loosen the joint to reset the landing gear's position.

Adapt drone for high speed vehicle landing

- Upgraded landing gear designed for **3 m/s impacts**.
- Upgraded propulsion for high power and maneuverability.
- Vehicle tracking using **cm-precise GPS** and latency compensation.
- Preliminary trials at GDLS
  - **23 successful landings (10-65 km/h)**
  - No bouncing after touchdown
  - 10-20 cm from center of target

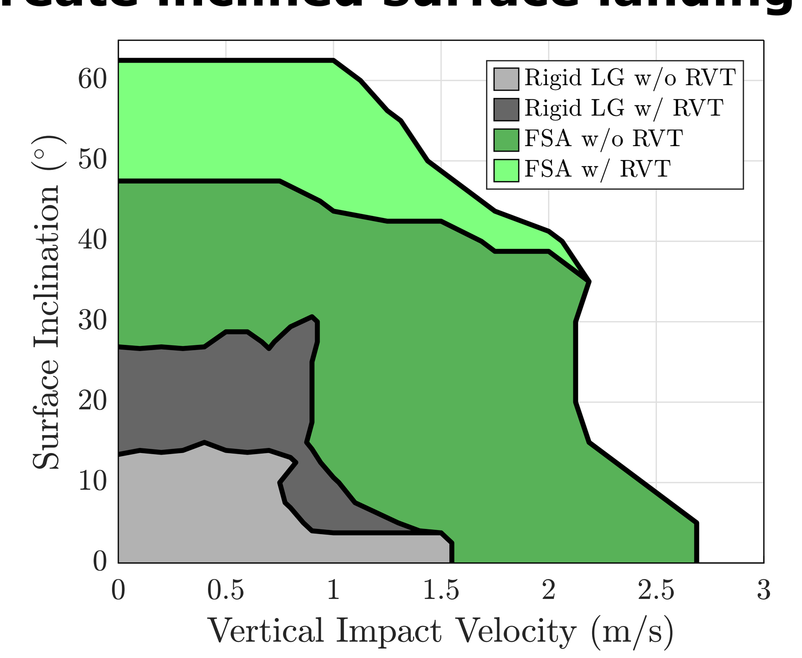


Design a 2D dynamic model of a landing drone



- The model considers the friction in the joints, as well as the **undesirable flexibility** of the landing gears.
- It includes a dynamic rotor model to simulate the thrust **reversal delay**.

Create inclined surface landing envelope



Adaptative Friction Shock Absorbers and Reverse Thrust for Fast Multirotor Landing on Inclined Surfaces, in IEEE RA-L, 2022.

- Friction shock absorbers and reverse thrust increase the landing envelope by a **factor of 8!**

Future Work

- Land on vehicles at **80+km/h.**
  - Dealing with high drone pitch angles (> 50°) will require mechanical modifications to the landing gear or a dynamic maneuver approach.
- Land on **ships** in rough seas at 30 knots.
- Land on **icebergs**.

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