



Are we Ready for Inspection and Maintenance with Autonomous Drones?

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Slides, Publications, Videos, Code:

<http://rpg.ifi.uzh.ch/>

My Research Group



Drone Market Today: 130B\$

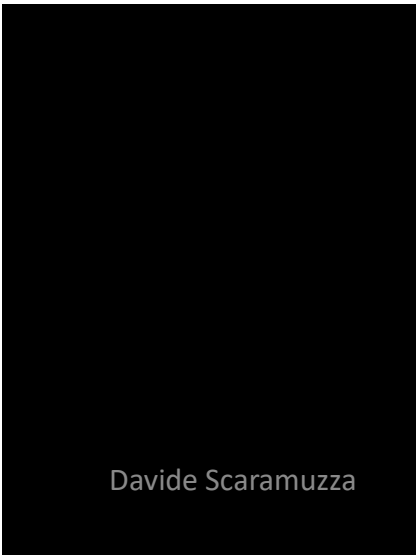
Inspection



Agriculture



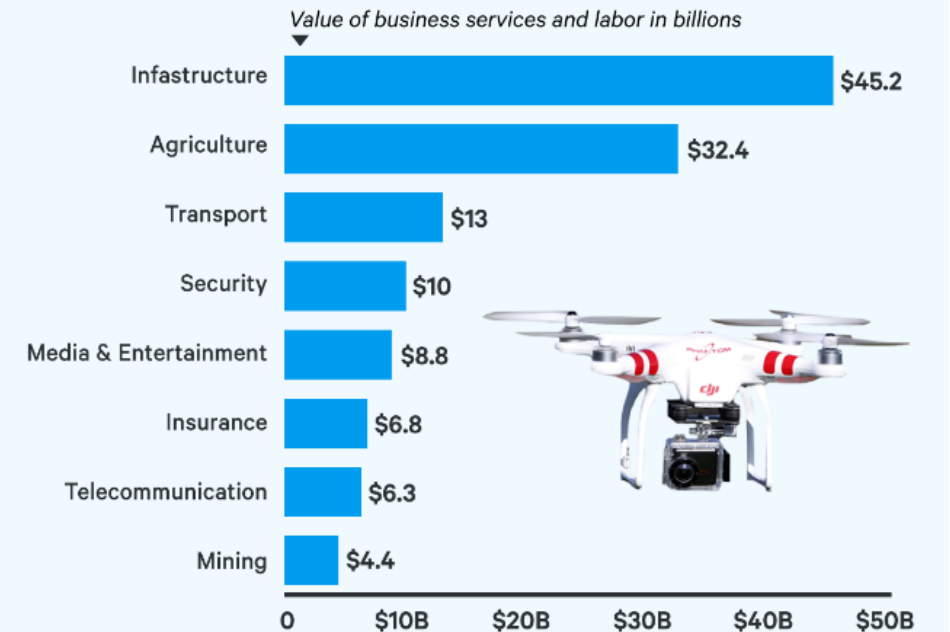
Transport



Search and Rescue



Predicted value of drones by industry



<https://www.pwc.pl/pl/pdf/clarity-from-above-pwc.pdf>

Swiss Drone Industry Map

Manufacturers

Sensors

Governance

Traffic Management

Defence & Security

Flight Systems

Electric Propulsion

Delivery

Energy

Analytics

Entertainment

Humanitarian

Taxi

High-Altitude

<https://droneindustry.ch/swiss-drone-industry-map/>

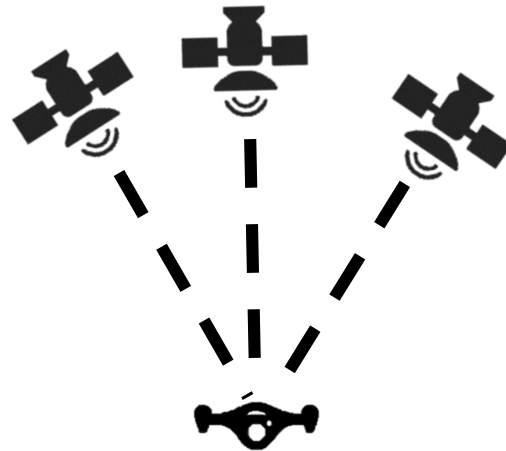
How are current commercial drones controlled?

➤ Remote control

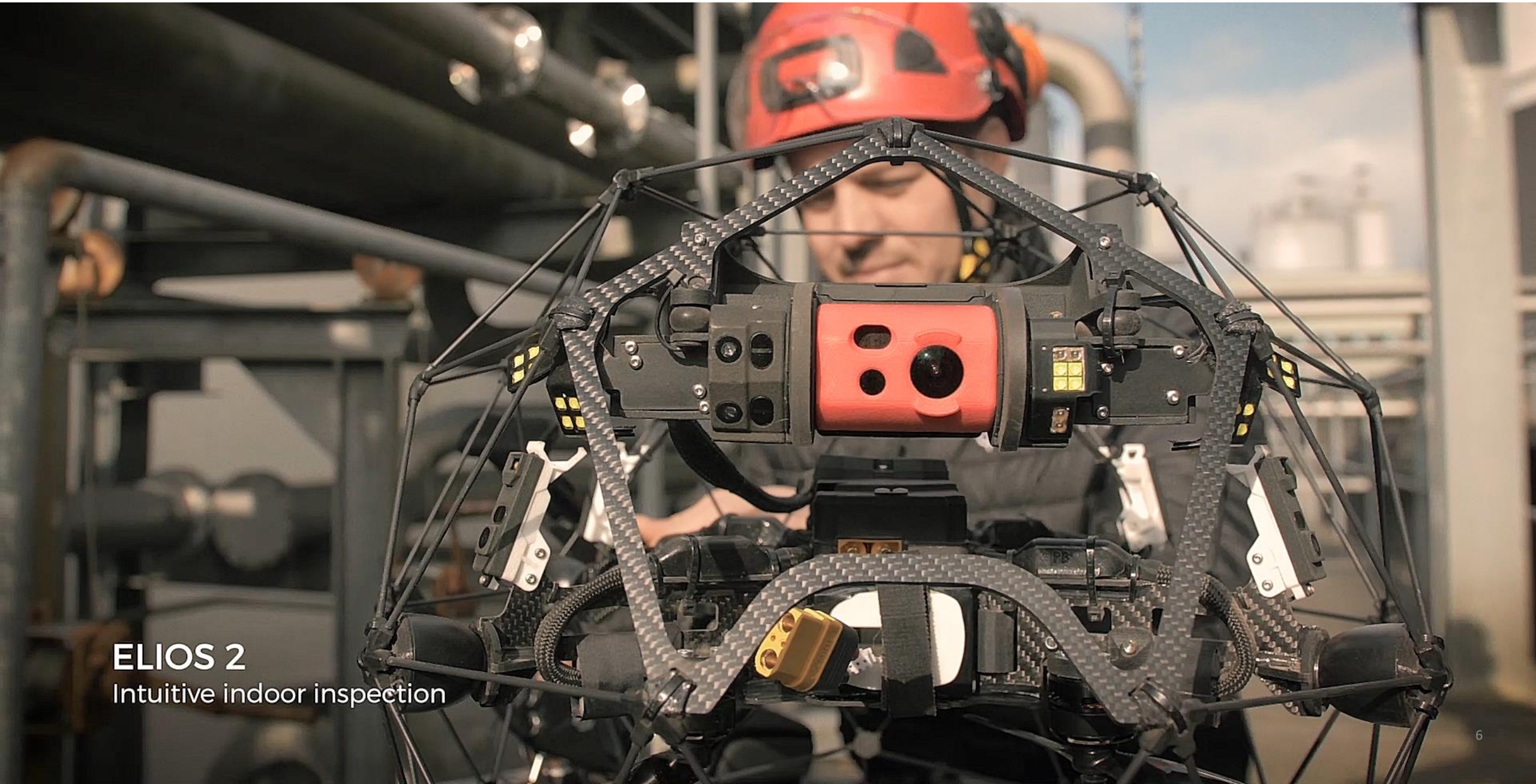
- Requires **line of sight**
- or **FPV video communication link**



➤ GPS-based navigation



Flyability (2014) - Inspection drone (remote controlled)



ELIOS 2

Intuitive indoor inspection

Flyability (2014) - Inspection drone (remote controlled)



AeroX (2019) – Contact Inspection Drone (remote controlled)

Uses ultrasonic sensors for characterizing cracks on concrete bridges, a different type of ultrasonic transducer for thickness and corrosion measurements of metallic materials, and eddy current sensors for crack detection

Working at height remains one of the biggest
causes of fatalities and major injuries

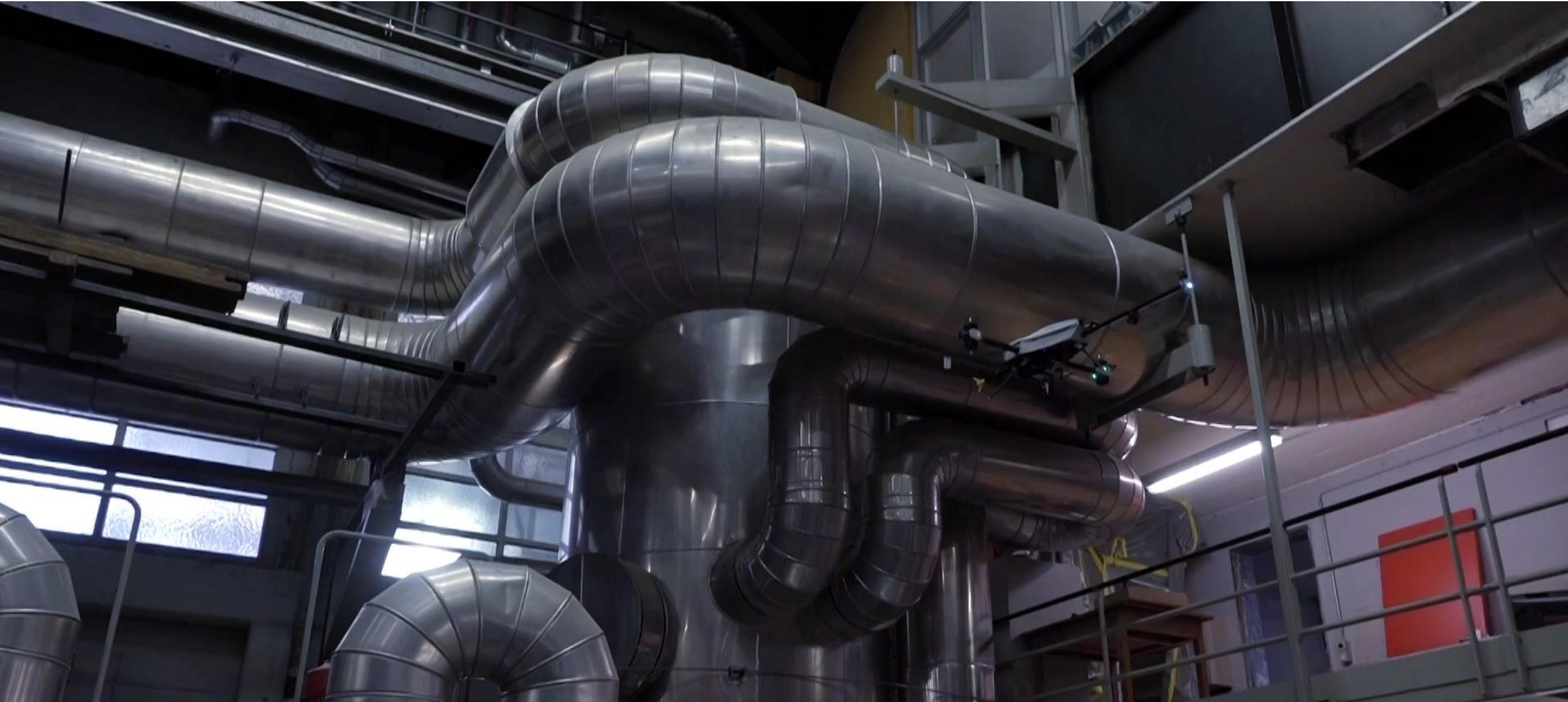
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Voliro (2019) – Contact Inspection Drone (remote controlled)

Uses tiltable propellers for omnidirectional navigation, scanning, drilling, and painting



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Fotokite (2014) – Power-over-tether drone for aerial filming

- **Pilot-free tethered aerial camera system** with **limitless flight time** and data bandwidth
- **1st and only system approved by the FAA for Public Safety teams** to use **without a pilot license**
- Patented localization enables automatic launch, flight, & landing from enclosure **without GPS + Operator**



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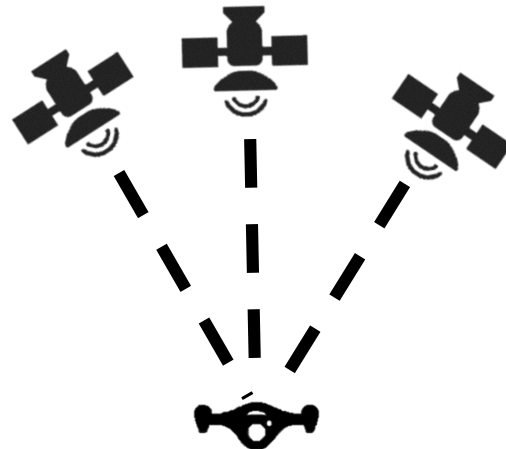
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Why Should a Drone Localize?



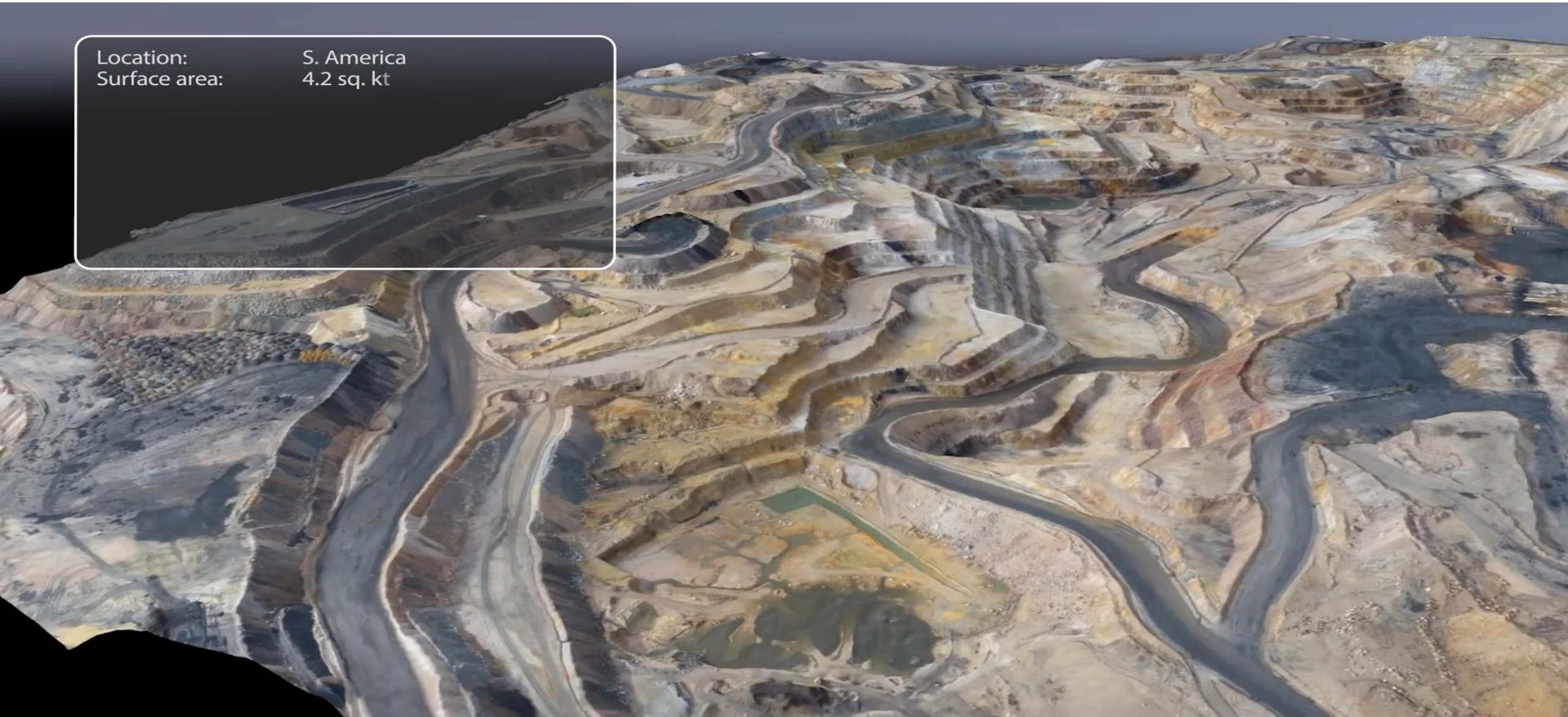
SenseFly-Parrot (2012) - Autonomous Mapping & Surveying

World's leader in drone-based large-scale mapping and surveying. 3D mapping by PIX4D



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Location: S. America
Surface area: 4.2 sq. kt

What if a Propeller Fails?



Mueller, D'Andrea, *Stability and control of a quadrocopter despite the complete loss of one, two, or three propellers*, Proceedings of IEEE ICRA'19
US Patent by Verity Studios AG. **WARNING: needs localization system**

What is GPS suddenly stops working?

SWI swissinfo.ch

MEDICAL TRANSPORT DRONES

Drone carrying blood falls in lake during test

JAN 25, 2019 - 20:31



Switzerland is pioneering the use of drone couriers, especially for exchange of medical samples between hospitals and laboratories.

(Keystone)

A drone carrying a blood sample has fallen into Lake Zurich during the test phase of a medical deliveries programme.

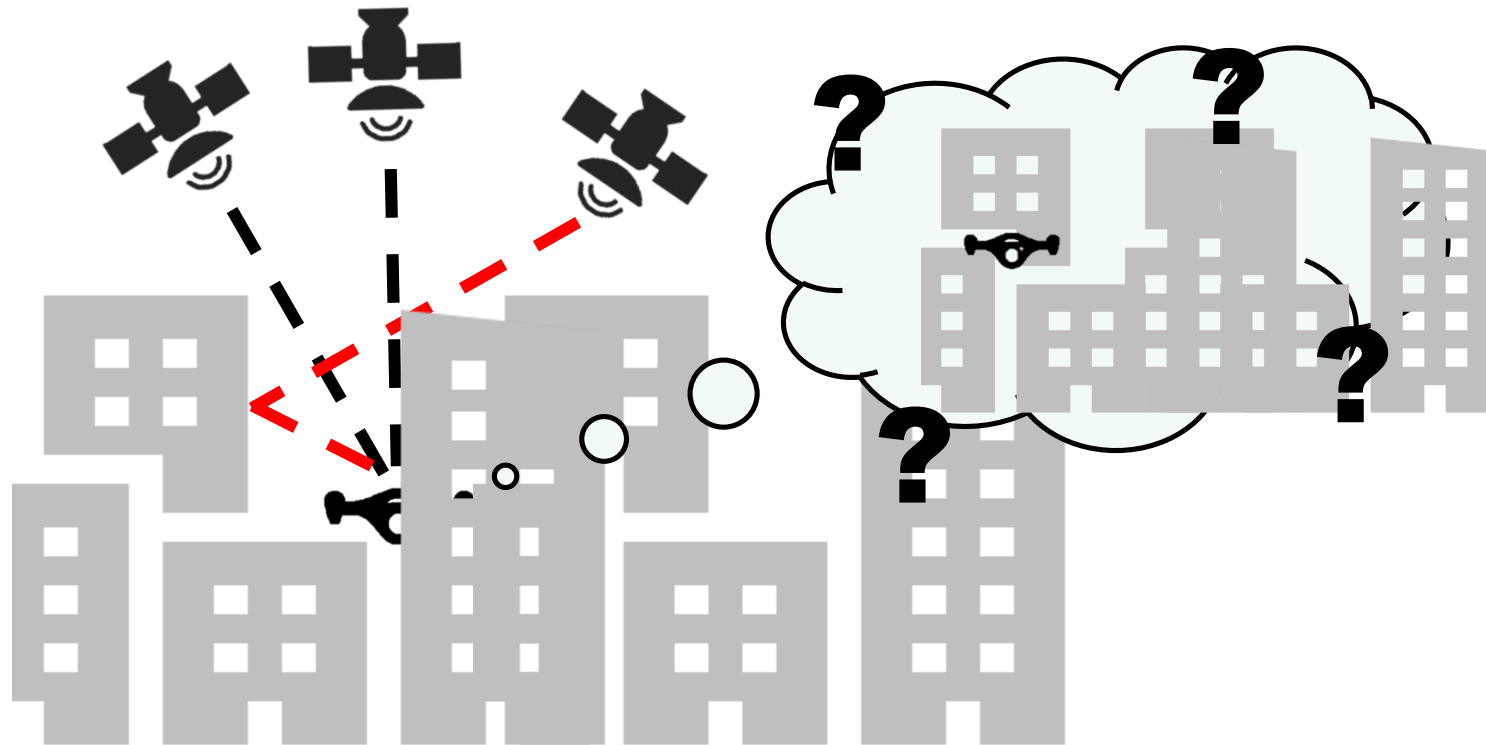


“On January 25, 2019, a SwissPost drone (operated by Matternet) crashed into Lake Zurich due to a short circuit that interrupted power to the drone’s GPS.”

<https://spectrum.ieee.org/automaton/robotics/drones/swiss-post-suspends-drone-delivery-service-after-second-crash>

What if GPS is obstructed or just not available?

- Does not work indoors
- Even outdoors it is not a reliable service
 - Satellite coverage
 - Multipath problem: GPS signal arrives at receiver via reflection on near-by surfaces, causing error in position estimate (up to 100 meters)

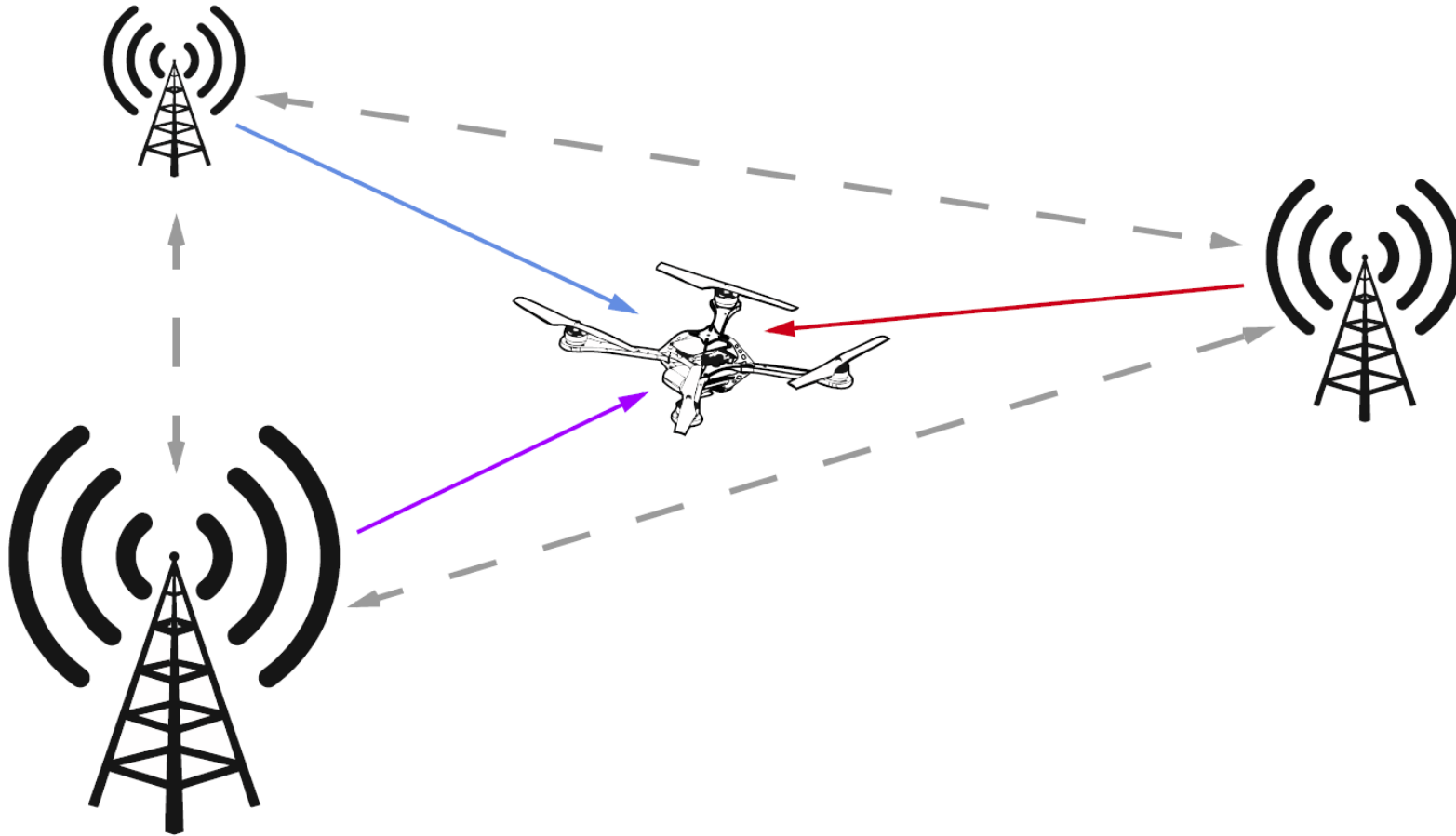


How to do Inspection of Construction Sites in GPS-degraded Environments?



Ultra-Wide-Band Localization

- Uses trilateration from at least three ground-based antennas
- Issues: similarly to GPS, signal is obstructed by obstructing objects (multipath)



A Ledergerber, M Hamer, R D'Andrea,
A robot self-localization system using one-way ultra-wideband communication, IROS 2015

Ultra-Wide-Band Localization (Verity Studios AG)

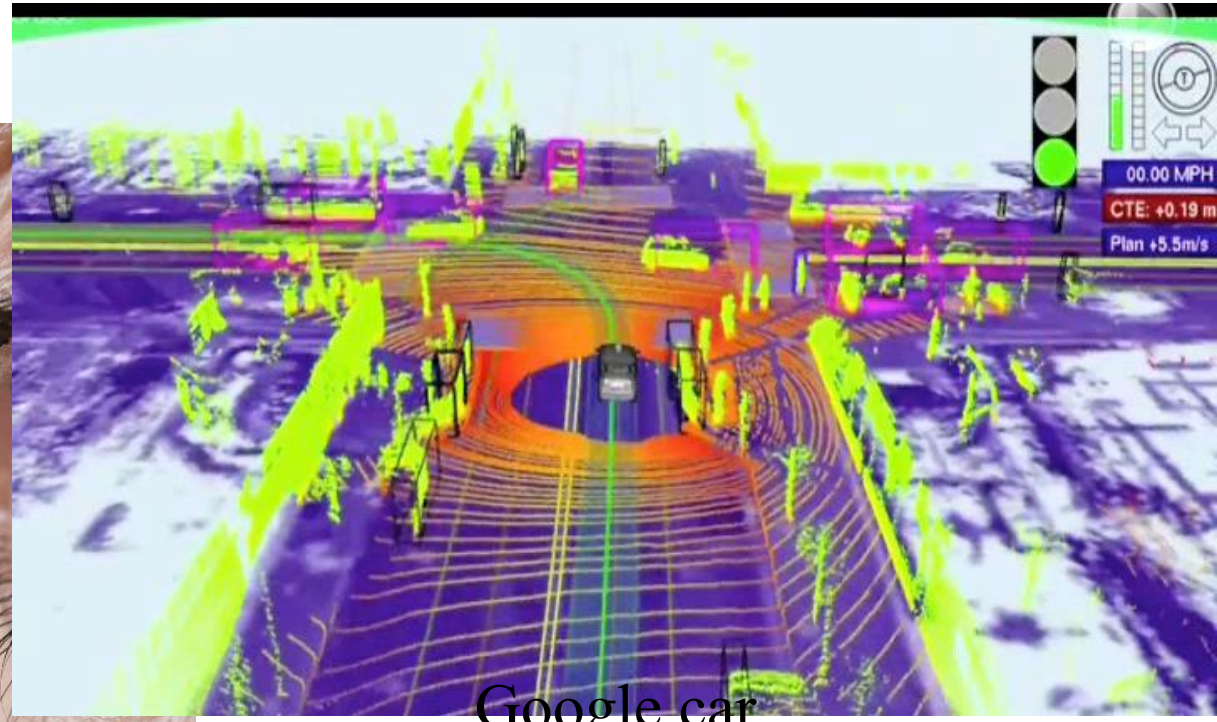
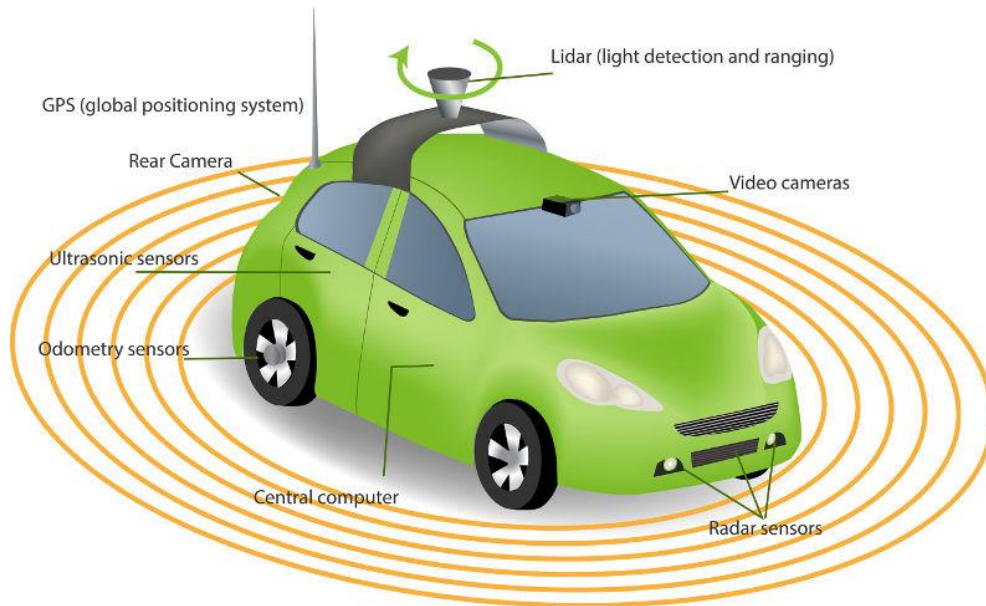
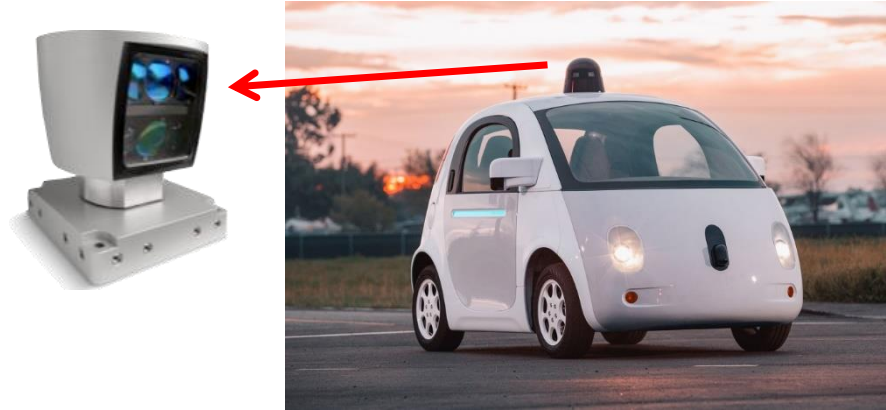


A Ledergerber, M Hamer, R D'Andrea,
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How can Drones localize
without GPS or UWB?

LIDAR-based Localization

Lidar-based Localization



Google car

Exyn (2015) - Lidar-based Localization for Drones (autonomous)



Exyn A3Rs enable safe and efficient data collection.

Issues with Lidar-based Localization

- Costly: 10,000 USD
- Very heavy (1Kg) & bulky: requires large drones (solid state lidars are much lighter but still have poor resolution)
- Power hungry (10-20 W)
- Unreliable with low-sun angle
- Unreliable in ambiguous environments (e.g., long, straight pipes that look the same everywhere)

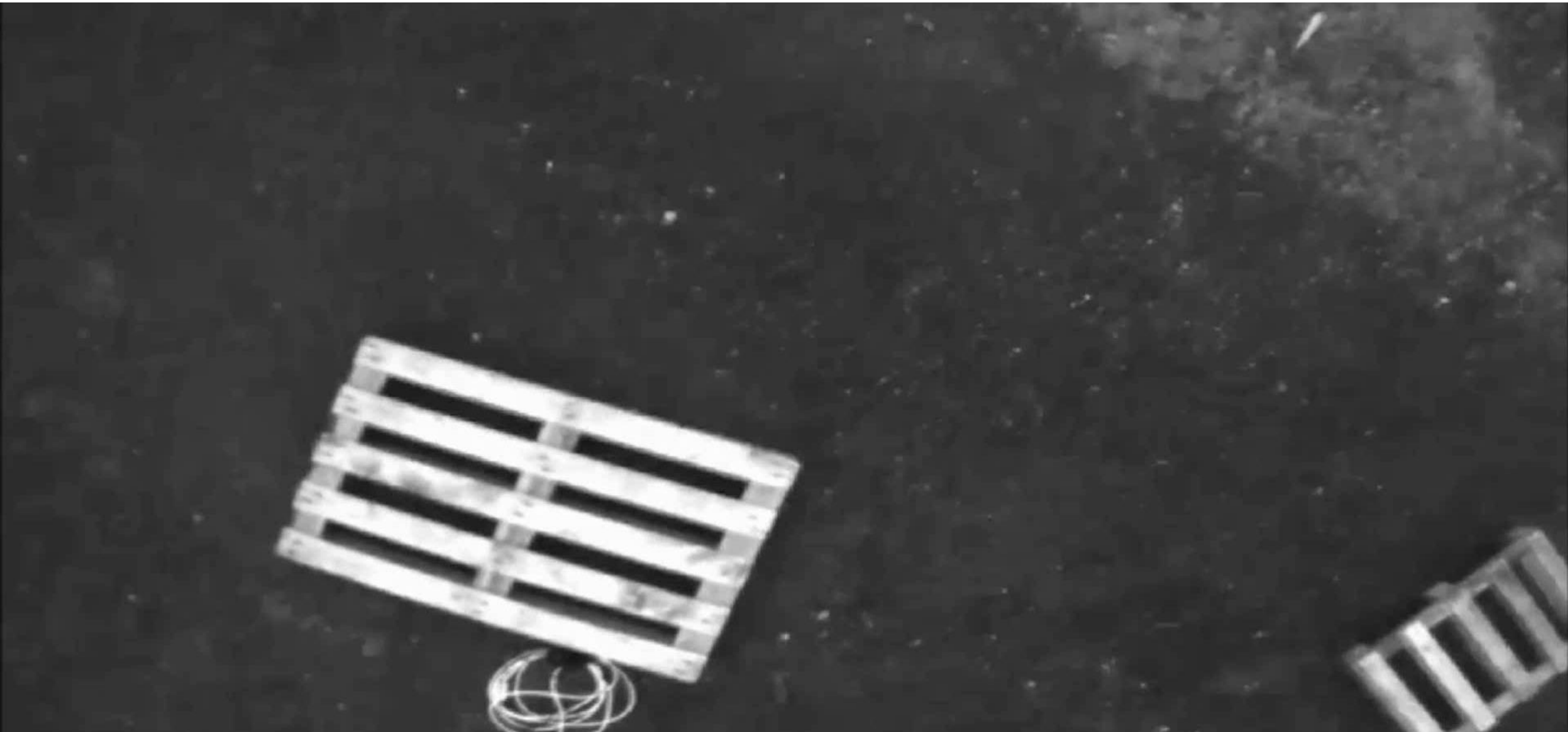
Vision-based Localization

Vision-based Localization





Vision-based Localization



Issues with Vision-based Localization

- Low texture
- High Dynamic Range (HDR) scenarios
- Motion blur in low light
- Does not work in the darkness (alternatives: use light source, infrared or thermal cameras)



Commercial Applications

SenseFly Albris Drone (2015) – Vision-assisted Drone



Automated take off,
self-check & calibration

<https://youtu.be/mYKrR8pihAQ>

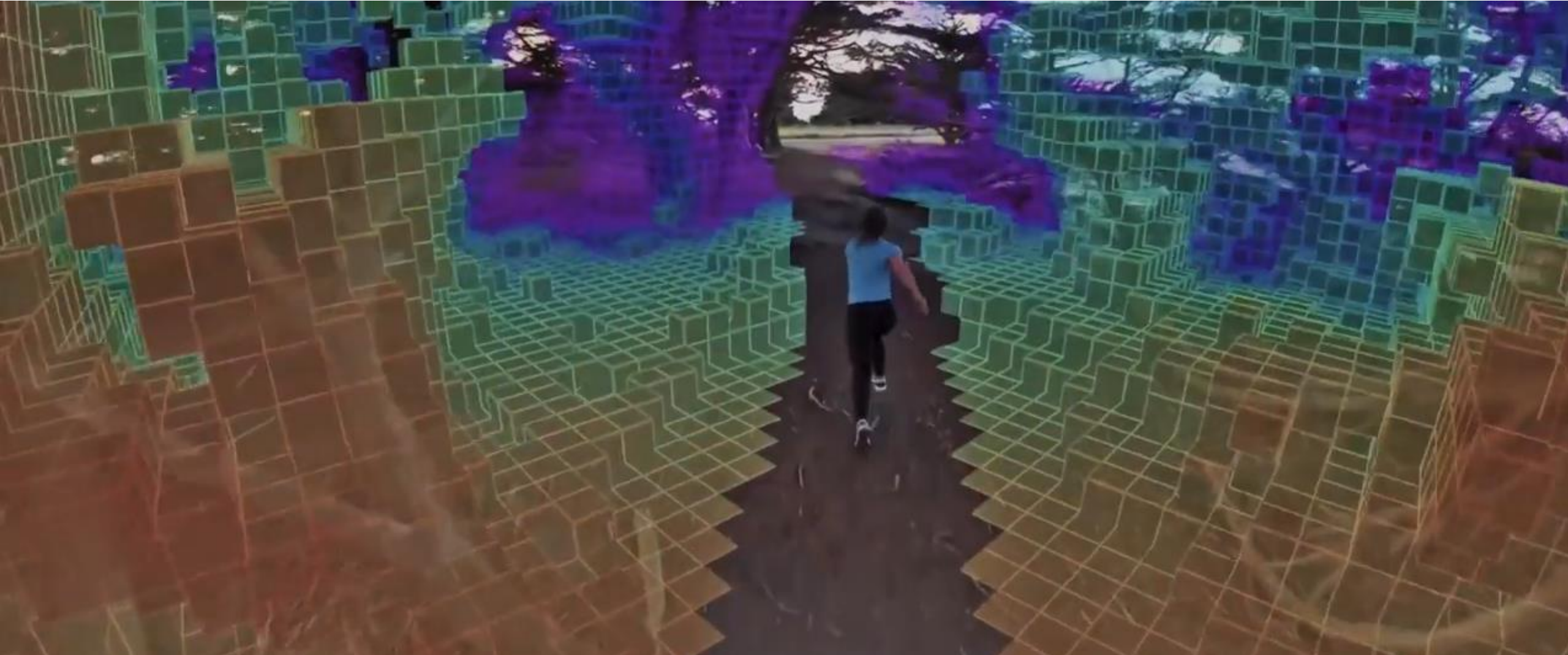
Skydio R1

- 13 cameras for obstacle avoidance, VIO, and “follow me”
- SDK and simulator to be released soon



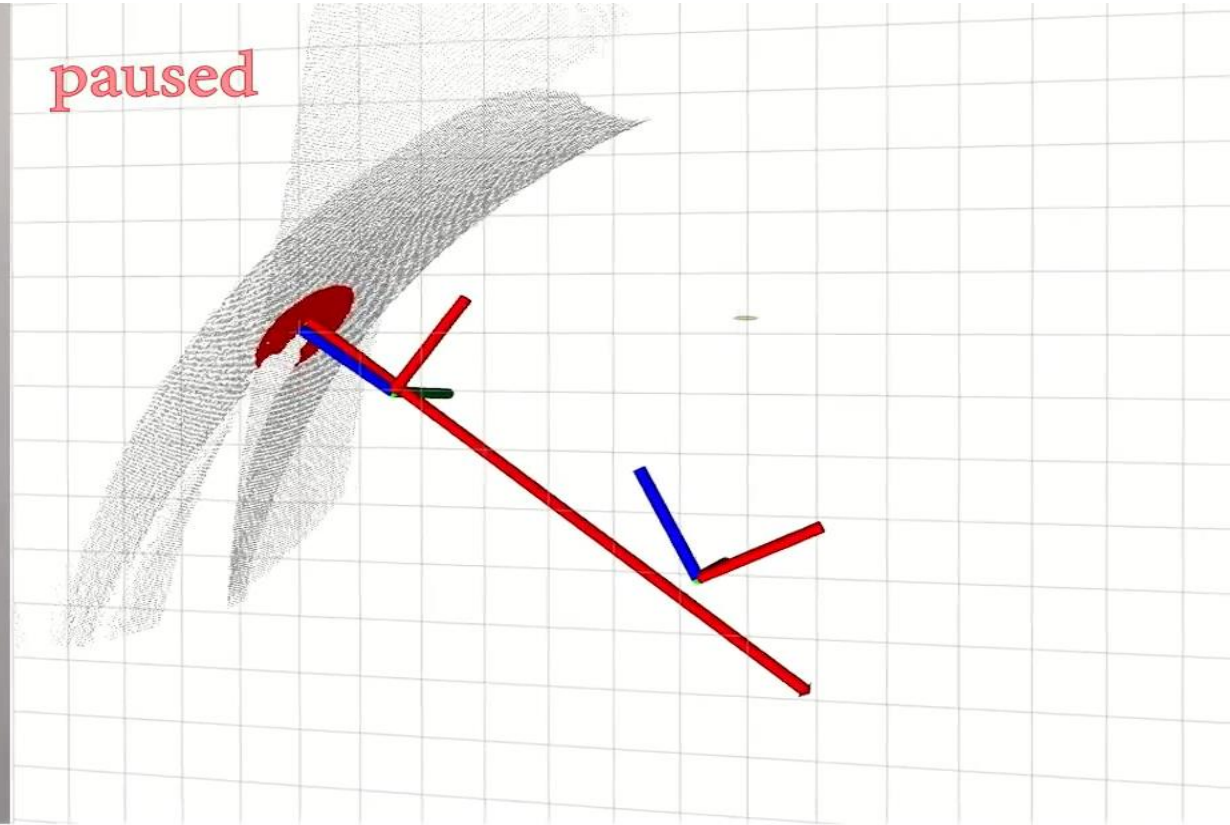
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What are the next challenges for
autonomous drones?

Autonomous aerial manipulation



Depth Servoing for Contact with Unknown Surfaces

- Maintain orientation to local surface normal
- Use field-deployable state estimation strategy

(onboard state estimation)

Autonomous navigation within small structures



Falanga, Kleber, Mintchev, Floreano, Scaramuzza,

*An Autonomous Vision-based Foldable Quadrotor that can Squeeze and Fly, **IEEE Robotics and Automation Letters** 2018, under review*

My Vision (10 years?): Fast, Lightweight, Autonomous



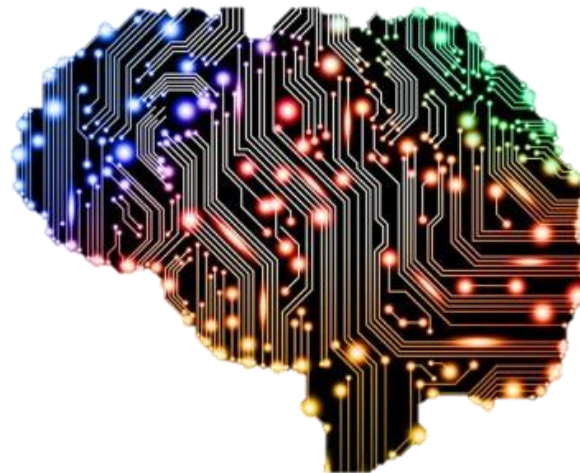
LEXUS commercial, 2013

WARNING!

There are 50 drones in this video but 40 are CGI and
10 are controlled via a Motion Capture System

Artificial Intelligence

- Currently solved by **Machine Learning**, i.e., programming by examples: *Show the computer what to do, without explaining how to do it!*
 - The **robot programs itself** to imitate the examples at best.
 - **Continuous self improvement** via more data/experience.



Deep Networks Can Help Cope with Inaccurate Models



[Giusti, RAL'16], [Smolyanskiy, IROS 2017]

Future: Autonomous Drone Racing?



WARNING!

This drone flown is NOT autonomous; it is operated by a human pilot.
Human pilots take years to acquire the skills shown in this video.

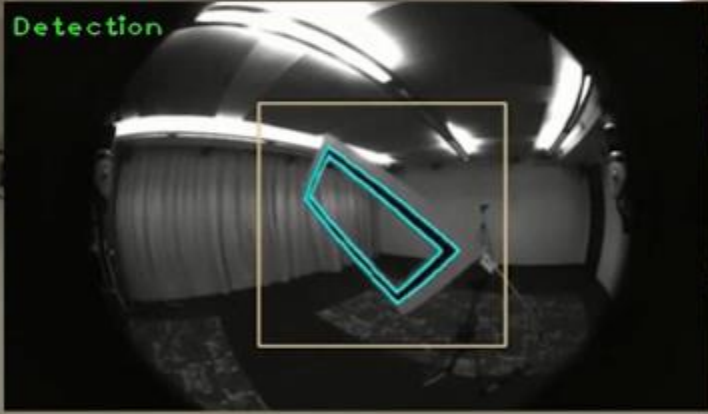
Can we use drone racing as a proxy to learn agile flight?





Falanga et al. *How Fast is too fast? The role of perception latency in high speed sense and avoid*, RAL'19.
[PDF](#). [Video](#). Featured in [IEEE Spectrum](#).

Onboard Image



Window at 45° (roll)

Falanga et al., Aggressive Quadrotor Flight through Narrow Gaps with Onboard Sensing and Computing using Active Vision, ICRA'17. [PDF](#). [Video](#).
Featured in [IEEE Spectrum](#).