

# Aerial Robotics

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GRASP Lab

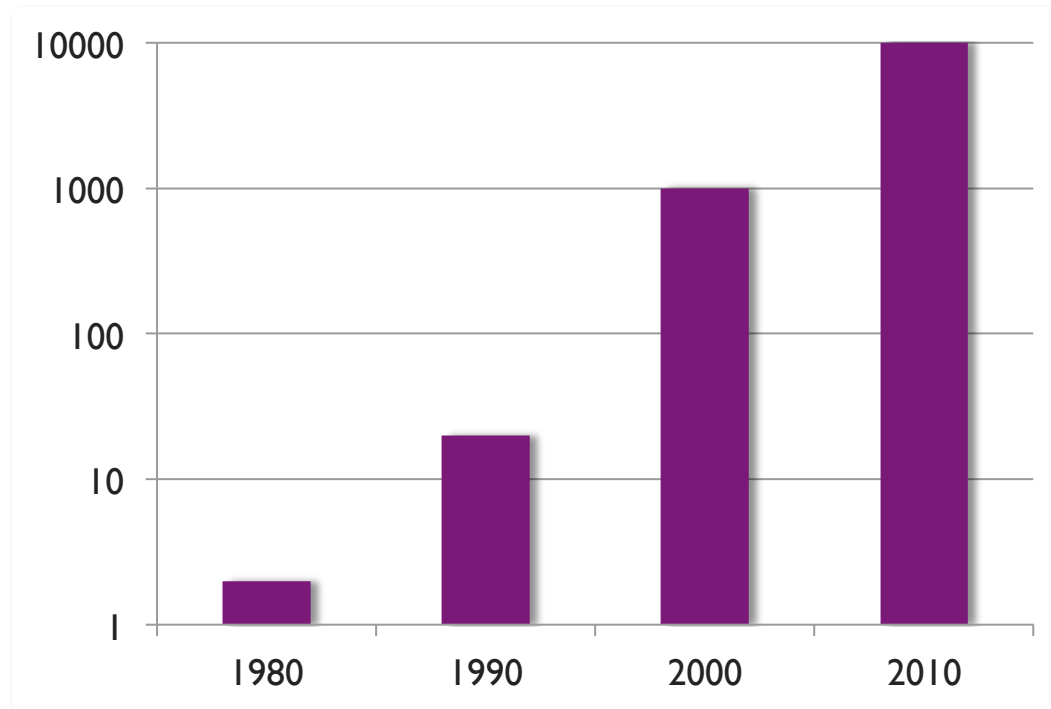
University of Pennsylvania

[http://mrsl.grasp.upenn.edu/loiannog/tutorial\\_ICRA2016/](http://mrsl.grasp.upenn.edu/loiannog/tutorial_ICRA2016/)

[aerialrobotics.org](http://aerialrobotics.org)

# Unmanned Aerial Vehicles in 2010

*Number of UAVs worldwide*



## Predictions of a \$10B industry

- Military: Surveillance, force protection, warfare
- Civilian commercial: Transport, environment
- Civilian private: DIY Drones

*FAA predicts 15,000 civilian drones by 2020*

# Unmanned Aerial Vehicles in 2015



- Over 15,000 drones sold in the US every month
- \$15B industry, projected to grow to \$25B by 2020
- Expectations for leading industry applications
  - ▼ Agriculture
  - ▼ Infrastructure Inspection
  - ▼ Border patrols
  - ▼ Photography
  - ▼ Construction
  - ▼ Film production

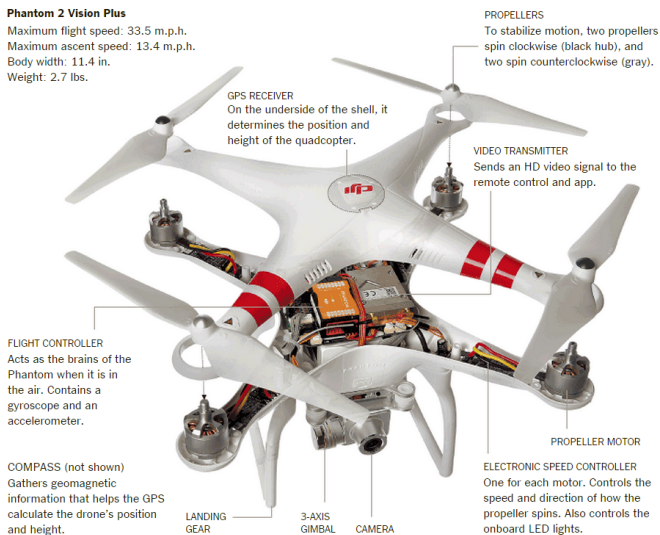
# Unmanned Aerial Vehicles

## Remotely Piloted Vehicles (RPVs)



## Aerial Robots

**Phantom 2 Vision Plus**  
 Maximum flight speed: 33.5 m.p.h.  
 Maximum ascent speed: 13.4 m.p.h.  
 Body width: 11.4 in.  
 Weight: 2.7 lbs.



## Drones

**Remote Control**  
 Includes a mount for a smartphone and a range extender that allows the phone to communicate with the drone up to 2,300 feet away.



*Drones mischaracterize what these things are. They're not dumb. Nor are they unmanned, actually. They're remotely piloted aircraft. - Gen. Norton Schwarz, August 10, 2012*



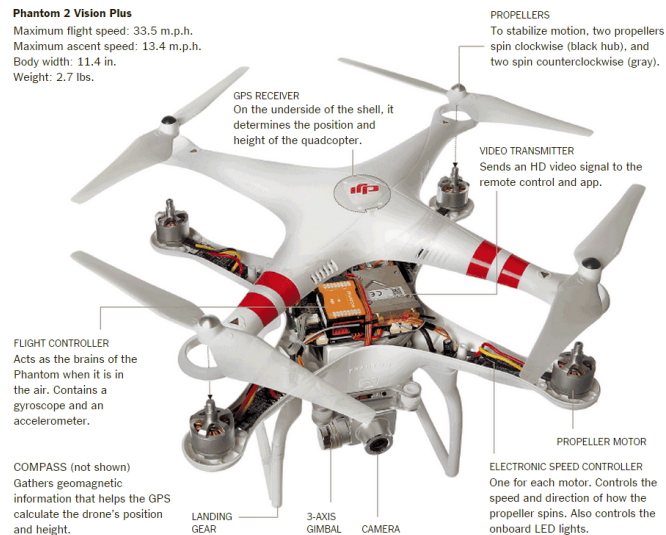
# UAVs = RPVs = Aerial Robots = Drones

## Remotely Piloted Vehicles (RPVs)



## Aerial Robots

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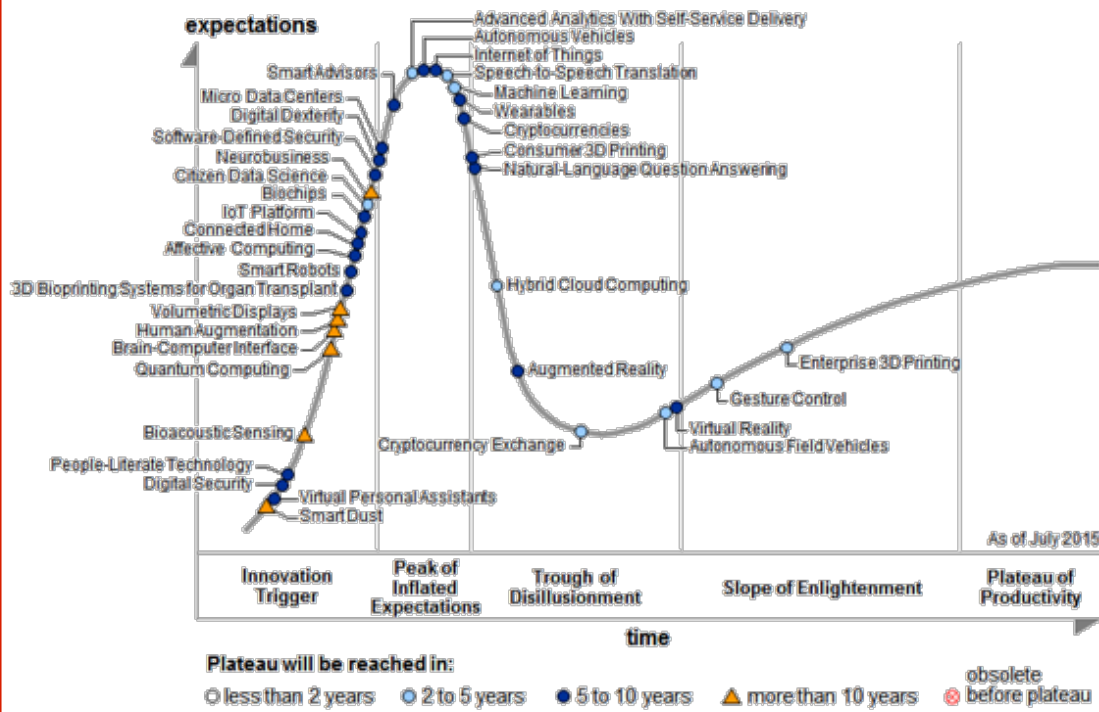


## Drones

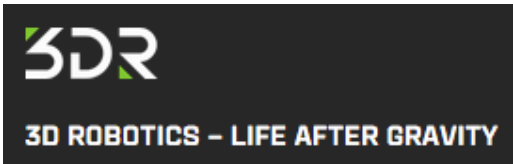
**Remote Control**  
Includes a mount for a smartphone and a range extender that allows the phone to communicate with the drone up to 2,300 feet away.



# The Skies will be Abuzz with Drones!



Parrot®



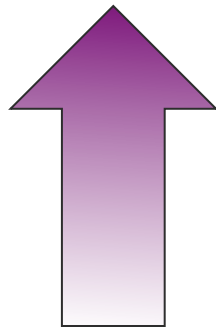
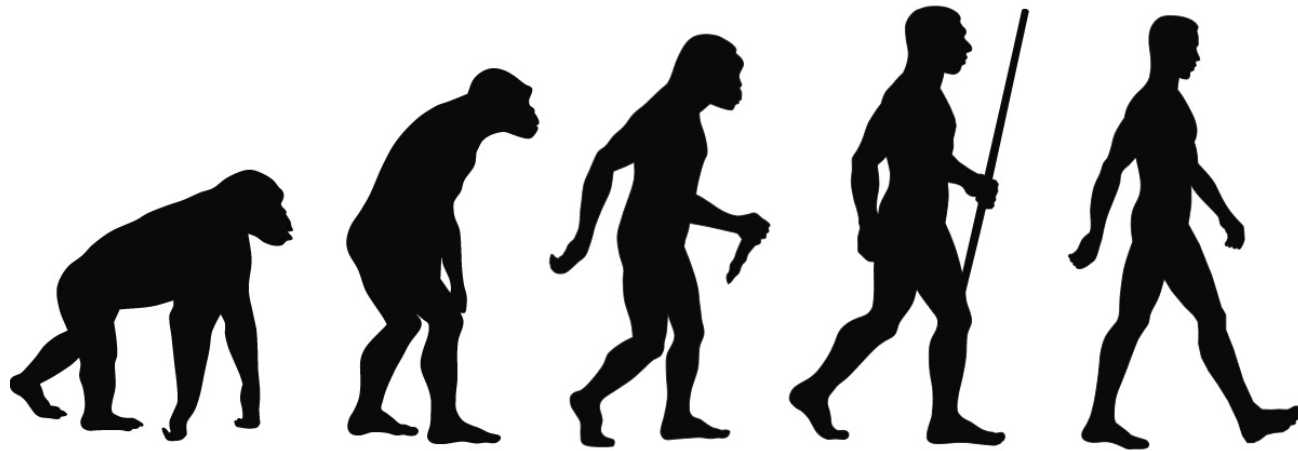
Gartner's 2015 Hype Cycle for Emerging Technologies



acquired by



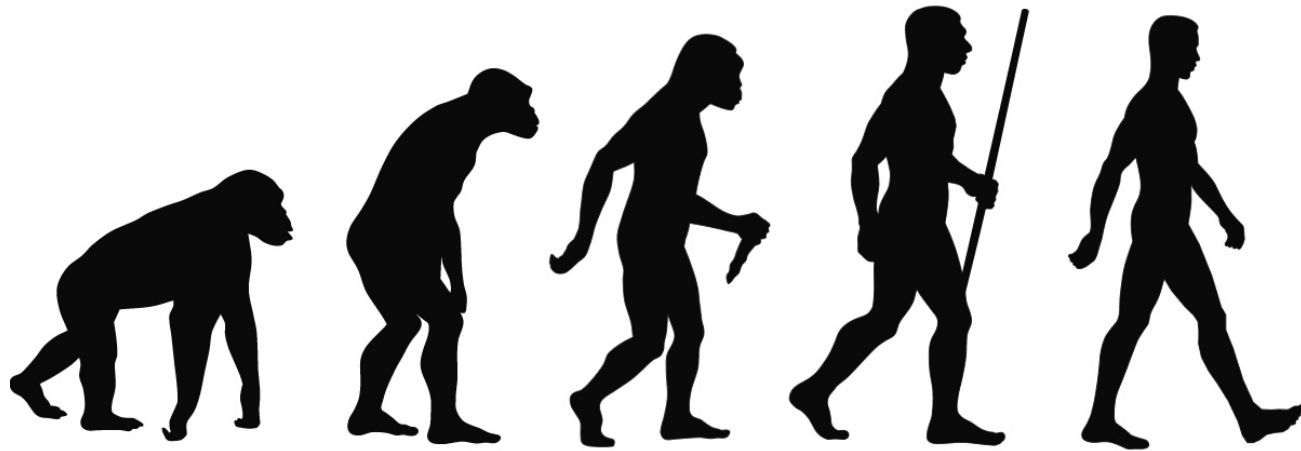
# Aerial Robotics



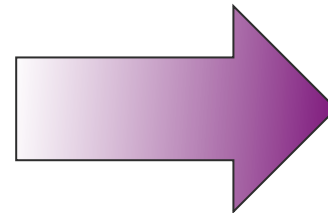
*We are here!*



# Aerial Robotics



*Size*



*Safety*

*Smart*

*Speed*

# Types of Micro Air Vehicles

- Fixed wing

- Flapping wing

- Rotor crafts

- Insect flight
- Avian flight

- Helicopter
- Ducted fan
- Co-axial
- Quad rotor
- Hexa rotor



# Quadrotor



# Aerial Robotics Tutorial

This tutorial provides an introduction to the theory and practice of aerial robots, with a mix of fundamentals and application. It will expose participants to the state of the art in robot design , mechanics, design, mechanics, control, estimation, perception and planning.

- Introduction (15 mins)
- Multi rotor aircrafts: modeling and control (35 mins)
- Fixed wing aircrafts: modeling and control (20 mins)
- Visual odometry (35 mins)
- State estimation (20 mins)
- Low cost platforms (20 mins)
- Aerial manipulation (20 mins)

Discussion



## Aerial Robotics (Kumar)



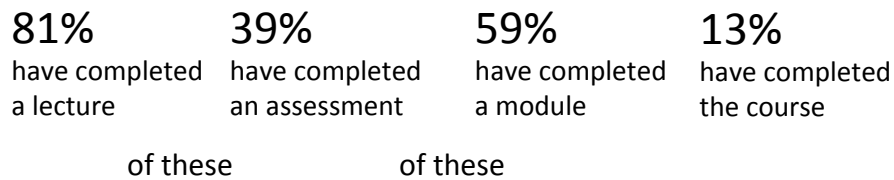
### Reach

Visitors: 60,306 Active: 18,739  
Payments: 1,995 Completers: 1,135

### Likes and Dislikes

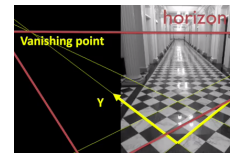


### Retention



### Demographics

Asia 33% North America 31% Europe 21%  
South America 8.2% Africa 6.3% Oceania 1.3%  
75.8% Bachelor's + 9.1% Female 91% Male



## Perception (Daniilidis)



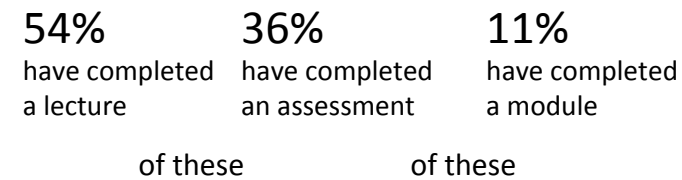
### Reach

Visitors: 13,316 Active: 1,646  
Payments: 659 Completers: 116

### Likes and Dislikes



### Retention



### Demographics

Asia 33% North America 31% Europe 25%  
South America 5.3% Africa 4.7% Oceania 1.5%  
81.7% Bachelor's + 6.0% Women 93% Men

# Coursera Emphasis



# Experimental Platforms



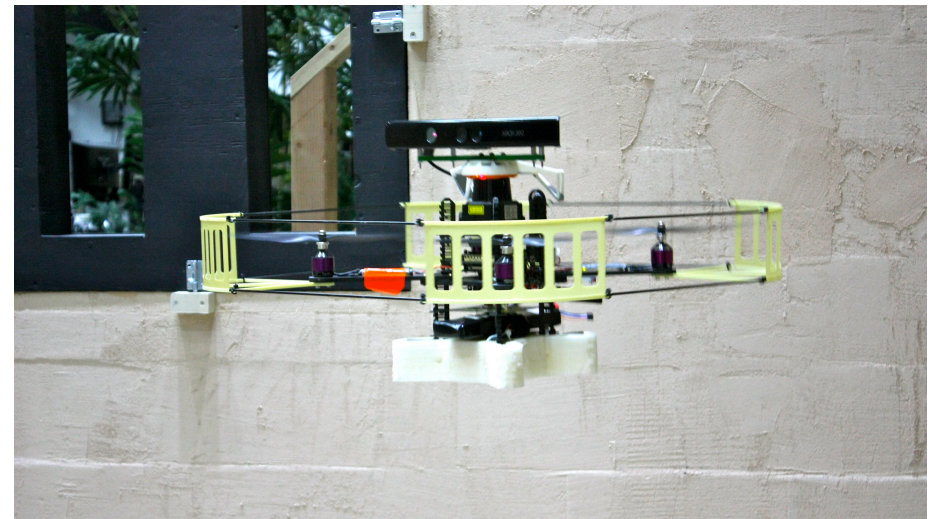
1750 g (laser, 3 cameras, GPS, IMU)



650 g (camera, IMU)



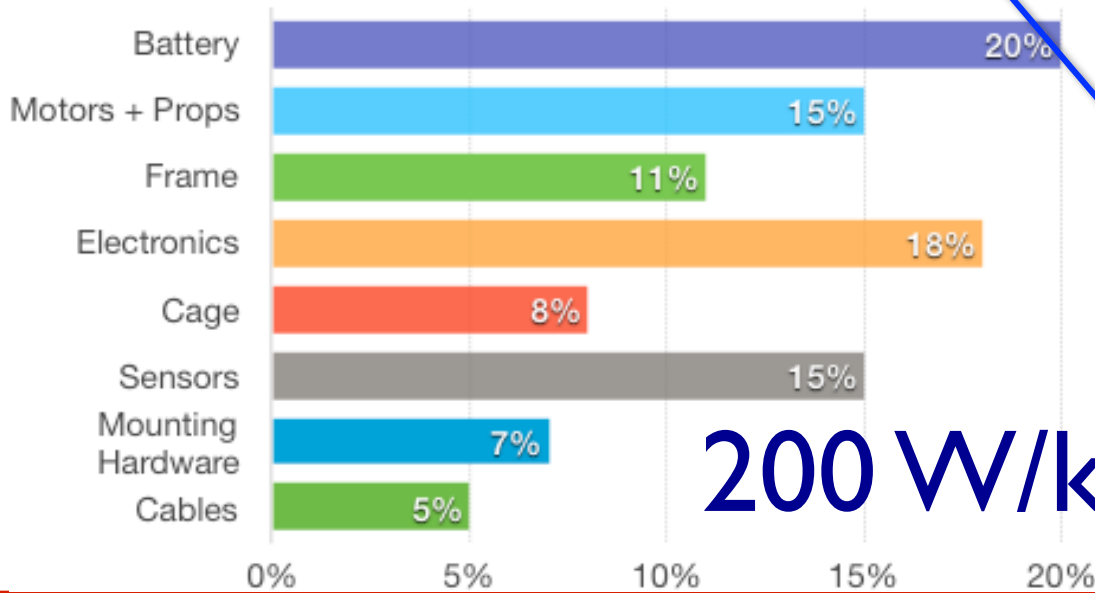
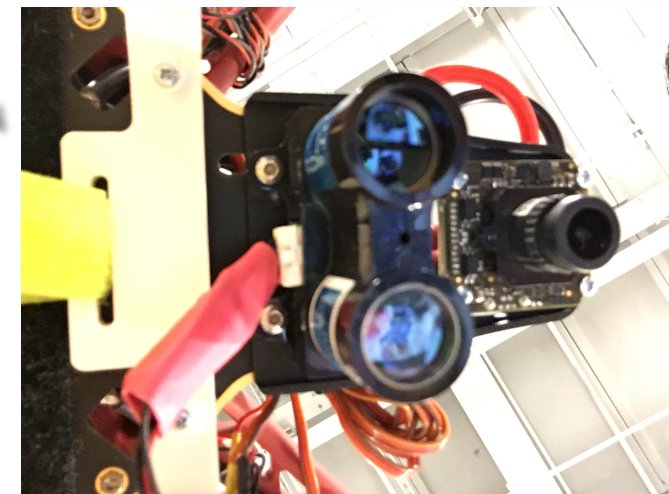
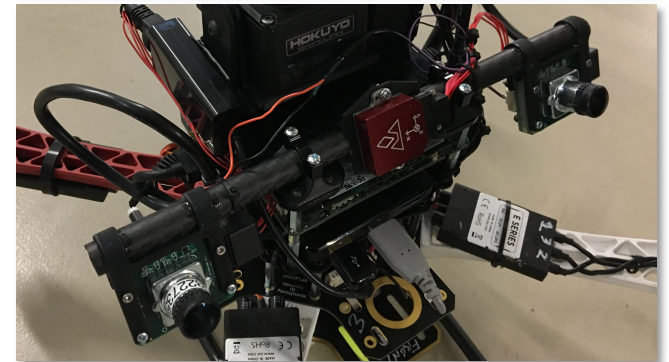
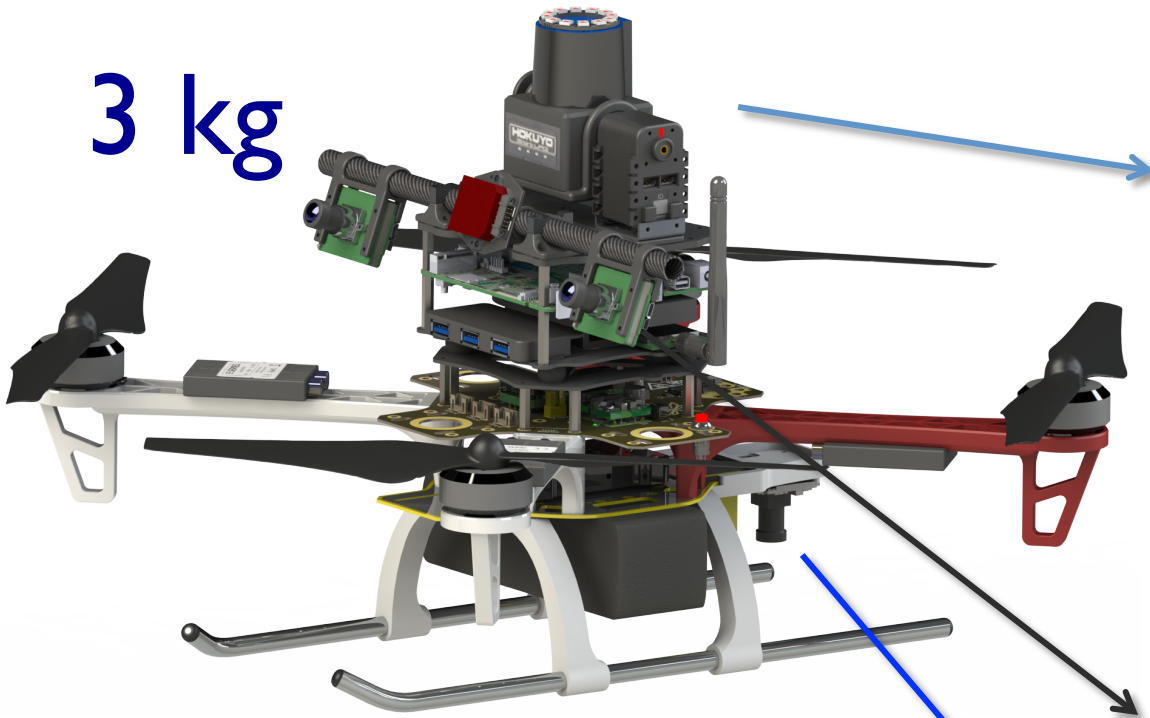
740 g (2 cameras, IMU)



1800 g (laser, Kinect, IMU)



3 kg



200 W/kg

A custom-built drone, referred to as 'The Falcon', is shown in flight within a cardboard box. The drone is a quadcopter with a black frame and red arms. It features a camera mounted on the front, a battery pack, and various electronic components. The drone is tilted, suggesting it is in the middle of a maneuver. The background is the brown interior of the cardboard box, with the top and bottom flaps visible. The text 'The Falcon' is overlaid in white at the bottom center of the image.

The Falcon