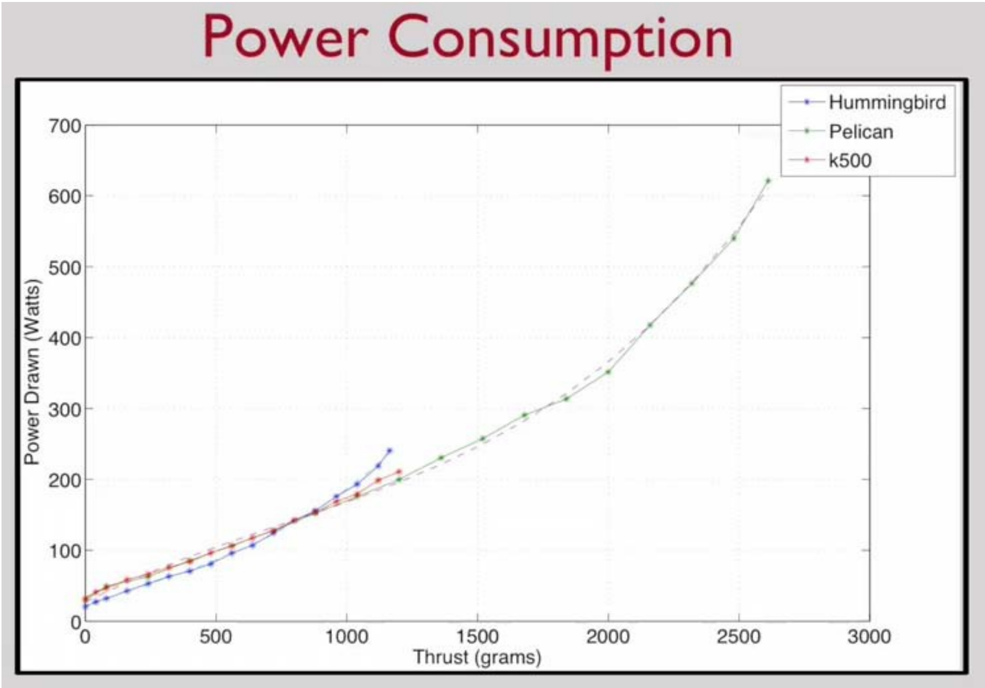
Design Considerations (Continued)

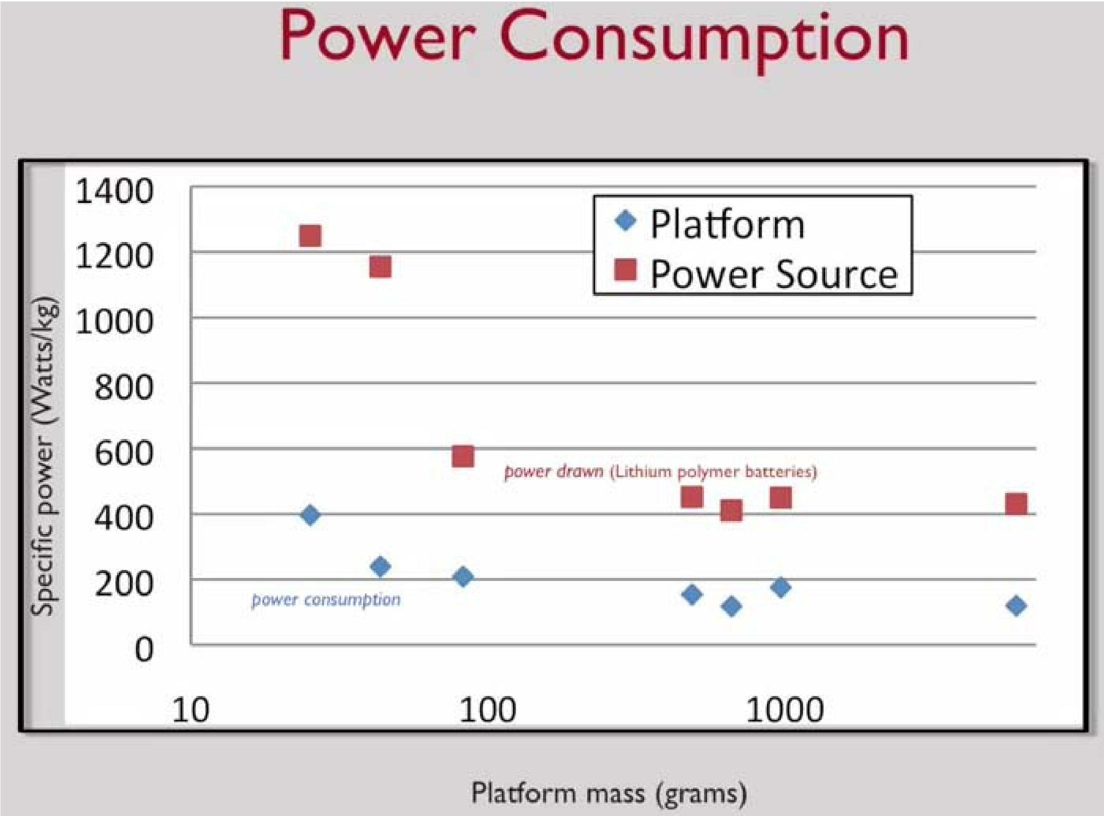
Now that we've seen the effect of the thrust to weight ratio, let's look at the power consumption of each robot.

This picture shows six different robots that we've built in a laboratory:

Each robot uses a different motor, has a different frame and has a different payload. As a result, the thrust-to-weight ratio is different in each case, & the power consumed is also different in each case. If you plot the power drawn as a function of thrust for a given robot, you'll find that the slope of this curve is roughly 200 watts per kilogram:



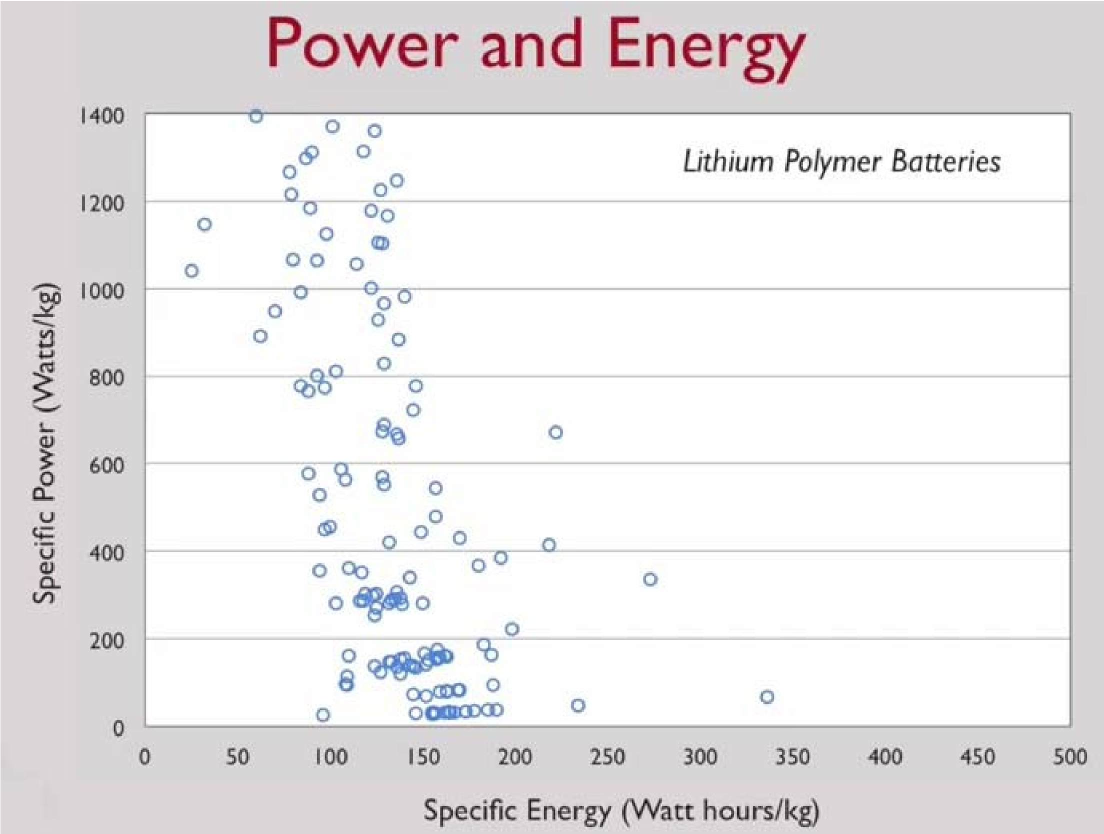
This image compares the power consumed and also the power delivered by different types of batteries:



The blue dots show the power consumption, which is around 200 watts per kilogram, and the red dots different batteries. Thankfully, the batteries produce more than 200 watts per kilo!

This gives some idea of how to pick batteries so that we can actually support the power consumption of the motors and provide extended life for the quadrotor. Battery selection is an important part of system design, and when we think about battery selection, we have to consider the power consumption.

In addition to power consumption, you also have to consider the total energy stored in the battery. This plot shows the specific power plotted against the specific energy for a variety of batteries:



On the y axis denotes the Specific Power in watts per kilogram and the x axis shows the Specific Energy in Watt hours per kilogram. Most lithium polymer batteries produce about 200 watt hours per kilogram.

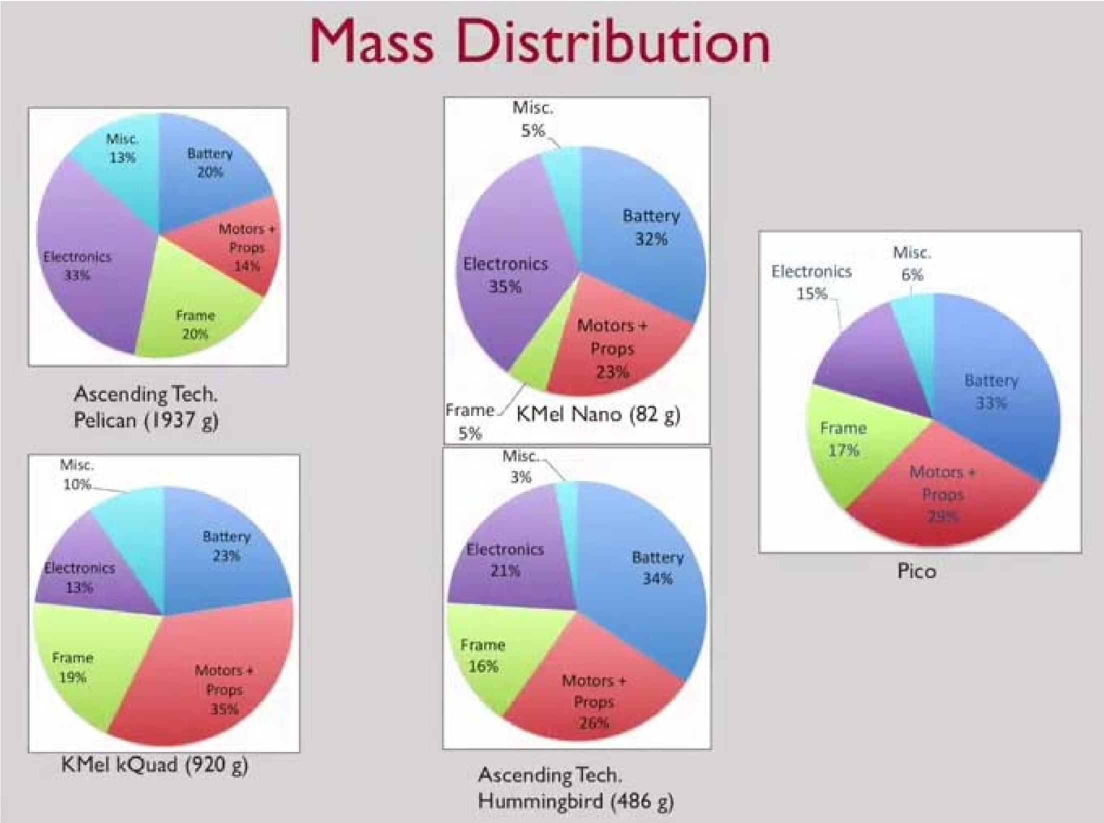
To contrast that with how humans perform, adipose tissue or fat carries about 10,000 watt hours per kilogram. This is several orders-of-magnitude more energy then is carried by batteries.

If we consider the power consumption, robots consume about 200 watts per kilo per hour. Humans consume a lot less than that. In fact, the fastest man on Earth, Usain Bolt, is estimated to consume only about 20 watts per kilo. So our robots are ten times more inefficient, than possibly the most inefficient man on Earth, as he runs the 100 meters race in 10 seconds. Cyclists like Lance Armstrong, only consume about six watts per kilo.

The moral of the story is that our robots are really inefficient. In fact, hovering is an inefficient mechanism, so we need a lot of power to sustain our robots. And lithium polymer batteries, which represent the best choice of batteries today, don't carry a lot of energy.

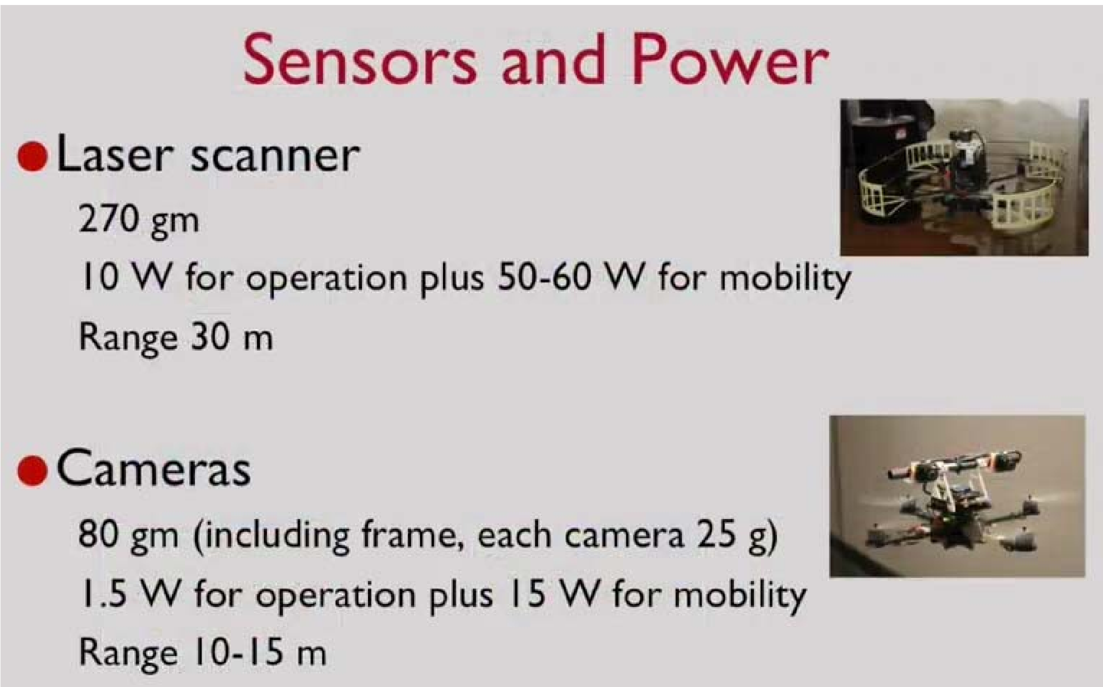
So what can we do when we need a lot of power, and our batteries don’t carry a lot of energy? Well, we can try to reduce our weight. That's what we try to do in the lab. We try to build smaller and lighter quad-rotors.

If we look at mass distribution in a quad-rotor and look at how different components contribute to the total mass, you will see a lot of variability:



The batteries contribute about 33% of the total mass and the motors-plus-propellers contribute about another 25% of the total mass.

Of course, if you add sensors like laser scanners and cameras, the increases the total mass also:



A laser scanner with a range of about 30 meters consumes about 10 watts for operation but, because it weighs 270 grams, it takes another 50-60 watts to lift it. A camera system that weighs about 80 grams costs us 1.5 watts to operate plus an additional 15 watts for mobility.

So when we think about the payload we also need to consider the power consumed in addition to the thrust to weight ratio.