# AHS International's Igor I. Sikorsky

## 24 Hour Hover Challenge

**May 10, 2017**

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Sikorsky Innovations
AHS Aircraft Design Technical Committee
AHS Advanced Vertical Flight Technical Committee

# June 13, 2013

AeroVelo wins the AHS Igor I. Sikorsky Human Powered Helicopter Challenge 33 Years After Challenge Announcement

# What Should be the Next AHS Challenge?

- Inspire Next Generation of Engineers

- Increase Public Interest

- Based on the Heart of the AHS Mission and the Benefit of Vertical Lift Technology

# A Competition at the Heart of AHS: Hover

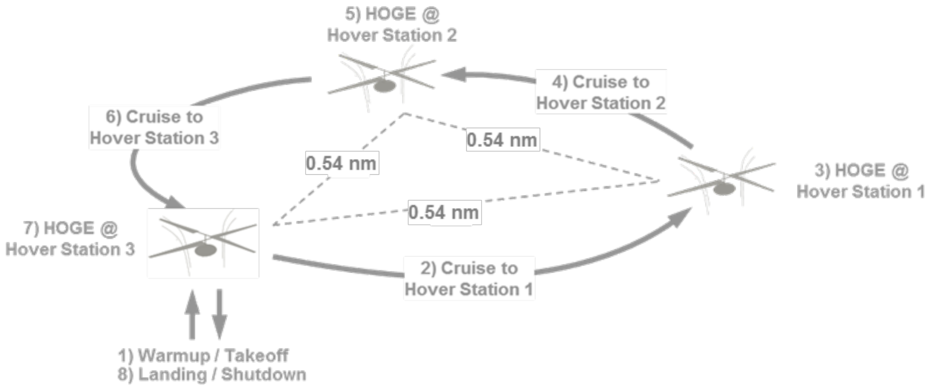

"If a man is in need of rescue, an airplane can come in and throw flowers on him, and that's just about all. **But a direct lift aircraft could come in and save his life."**

Igor I. Sikorsky

# At a Glance

- $50,000 Prize
- Unoccupied
  (80kg payload to simulate 1 human)
- 24 Hour Controlled Hover
  (OGE, within 20m sphere, winds < 5m/s)
- Real-World Capable
  (Not a Stunt: Transit to 3 Waypoints 1km apart)

24 HOUR Hover Challenge



# Can We Do This With Existing Helicopters?

**Mil Mi-26 Halo**
**The World's Largest Helicopter**

Max. Gross Weight: 123,450 lb
Empty Weight: 62,000 lb
Standard Fuel: 21,550 lb

**Hover Time w/ 1 Pilot: 4.6 hrs**

**What If All The Useful Load Were Fuel (61,450 lb) & No Pilot?**

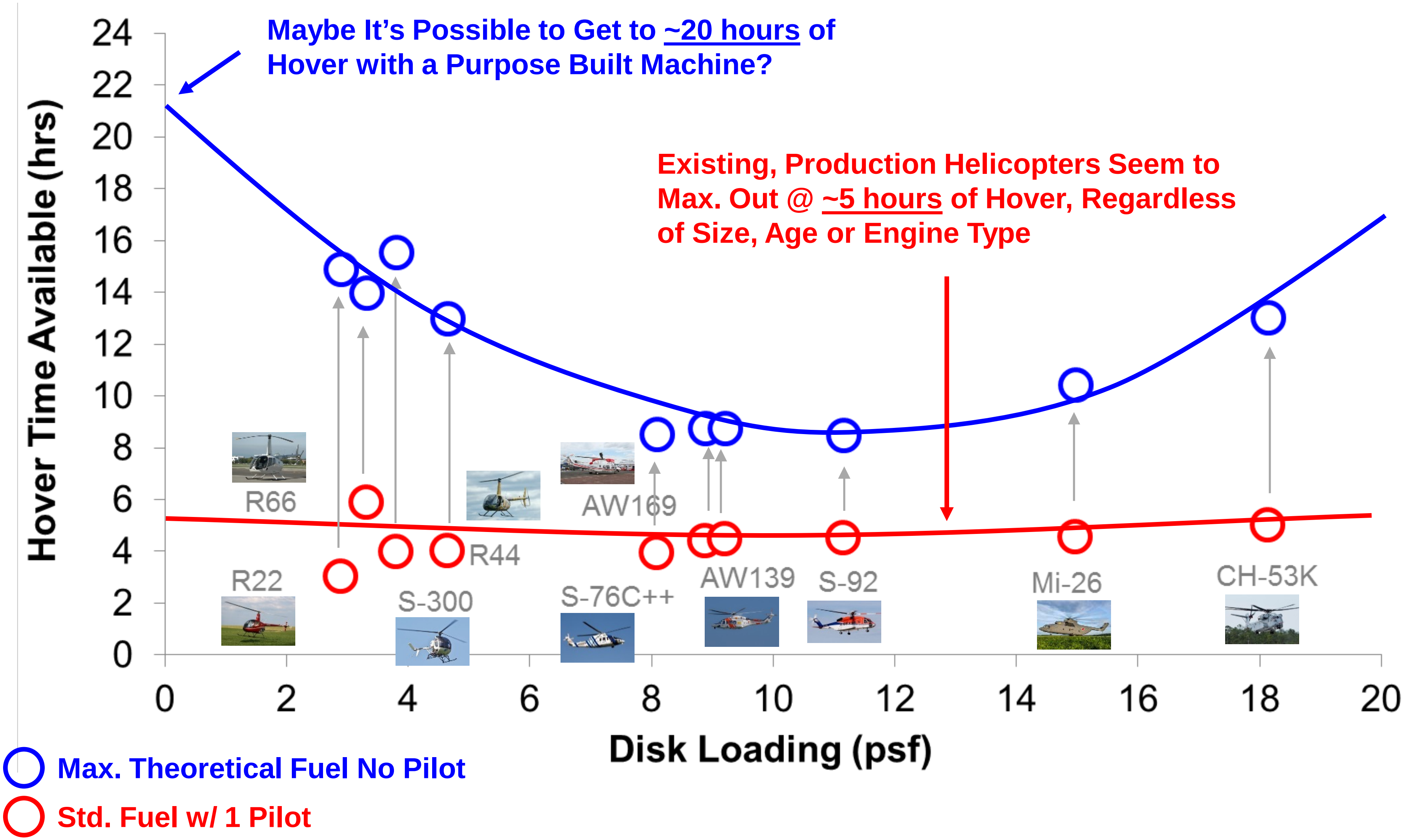
**Hover Time: 10.4 hrs**


## Does Scale Matter?  Engine Type? Rotor Technology?

# Can We Do This With Existing Helicopters?

| | Mi-26 | CH-53K | S-92 | S-76C++ | AW169 | AW139 | R66 | R44 | S-300 | R22 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Vehicle** | | | | | | | | | | |
| Max. Gross Weight | 123,450 lb | 84,700 lb | 26,500 lb | 11,700 lb | 10,500 lb | 14,110 lb | 2,700 lb | 2,500 lb | 2,050 lb | 1,370 lb |
| Empty Weight | 62,000 lb | 33,200 lb | 15,500 lb | 7,000 lb | 6,000 lb | 8,000 lb | 1,400 lb | 1,450 lb | 1,100 lb | 800 lb |
| Fuel Capacity | 21,556 lb | 15,620 lb | 5,168 lb | 1,911 lb | 2,033 lb | 2,808 lb | 500 lb | 299 lb | 221 lb | 115 lb |
| Max. Fuel Possible | 61,450 lb | 51,500 lb | 11,000 lb | 4,700 lb | 4,500 lb | 6,110 lb | 1,300 lb | 1,050 lb | 950 lb | 570 lb |
| **Rotor** | | | | | | | | | | |
| Rotor Radius | 52.5 ft | 39.5 ft | 28.2 ft | 22.0 ft | 19.9 ft | 22.6 ft | 16.5 ft | 13.4 ft | 13.4 ft | 12.6 ft |
| Disk Loading | 15.0 psf | 18.1 psf | 11.2 psf | 8.1 psf | 8.9 psf | 9.2 psf | 3.3 psf | 4.6 psf | 3.8 psf | 2.9 psf |
| **Engine** | | | | | | | | | | |
| Type | Lotarev D-136 | GE 38-1B | CT7-8A | 2S2 | PW210A | PT6C-67C | RR300 | IO-540-AE1A5 | IO-360 | O-320-A2B |
| Total Installed Power | 22,800 hp | 22,500 hp | 5,000 hp | 1,844 hp | 2,020 hp | 3,060 hp | 270 hp | 245 hp | 190 hp | 124 hp |
| Max. Thermal Efficiency | 33.9% | 36.4% | 30.1% | 27.7% | 28.0% | 29.4% | 23.9% | 30.0% | 30.0% | 30.0% |
| SFC @ Max. Power | 0.408 lb/hp/hr | 0.380 lb/hp/hr | 0.460 lb/hp/hr | 0.500 lb/hp/hr | 0.494 lb/hp/hr | 0.471 lb/hp/hr | 0.578 lb/hp/hr | 0.463 lb/hp/hr | 0.463 lb/hp/hr | 0.463 lb/hp/hr |

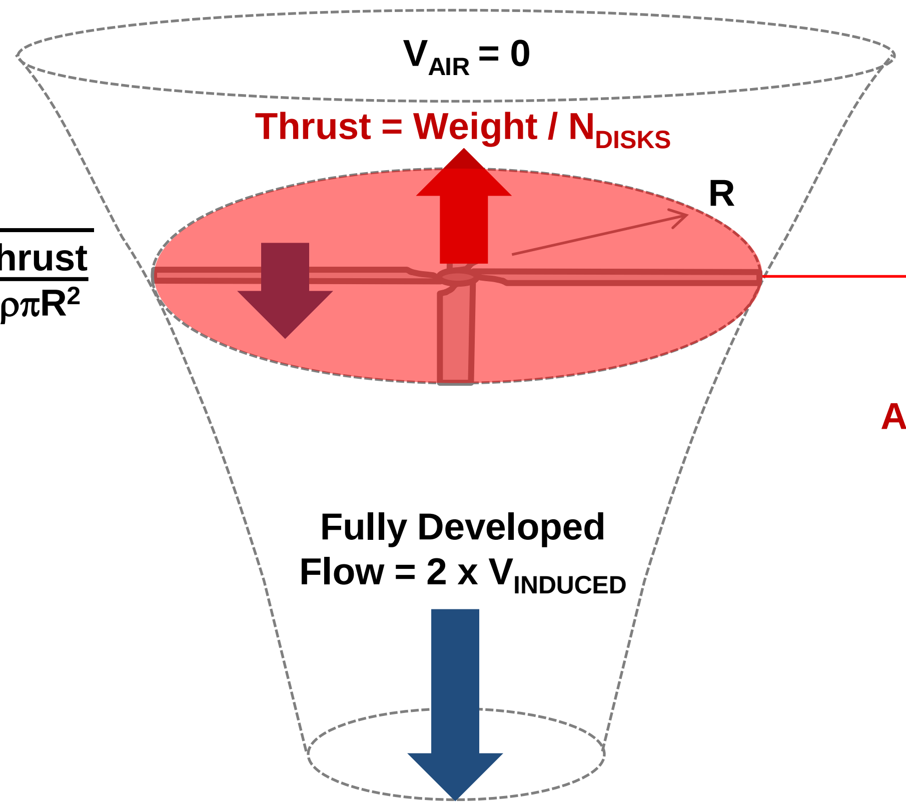
# Can We Do This With Existing Helicopters?



# Idealized Hover

**Idealized Actuator Disk in Hover**

$$V_{INDUCED} = \sqrt{\frac{Thrust}{2\rho\pi R^2}}$$




**Disk Accelerates Air**

**Power = Thrust x $V_{INDUCED}$**

**<u>Disk Loading</u>:**

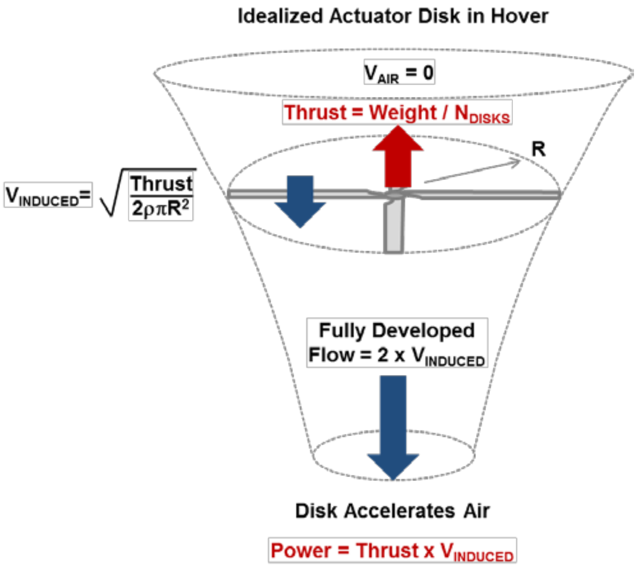
**Thrust / Area**

**As Disk Loading Reduces:**

**Velocity Reduces**
**Power Reduces**

# Disk Loading & Power Loading

## Disk Loading & Power Loading




**Disk Loading = GW / $N_{DISKS}$ / Area**

**Power Loading = GW / $Power_{TOTAL}$**

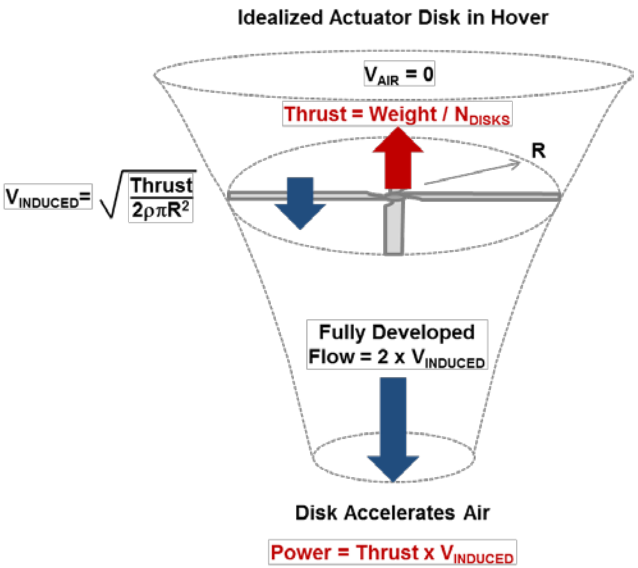
**Large Amount Of Air at Low Velocity**

**Small Amount Of Air at Very High Velocity**

| | Disk Loading (psf) | Power Loading (lb/hp) |
|---|---|---|
|  | 10 | 5 |
|  | 22 | 3 |
|  | 1,000+ | << 1 |

# Drivers of Hover Efficiency

## Ideal Power / Actual Power




(3) Reduce Airframe Blockage

$$P_{IDEAL} = N_{DISKS} \cdot \frac{(T_{ROTOR})^{3/2}}{\sqrt{2\rho\pi R^2}}$$

(1) Increase Disk Area

$$P_{ROTOR} = P_{IDEAL} \frac{1}{FM_{ROTOR}} \left[1 + \frac{D_V}{T_{ROTOR}}\right]^{3/2}$$

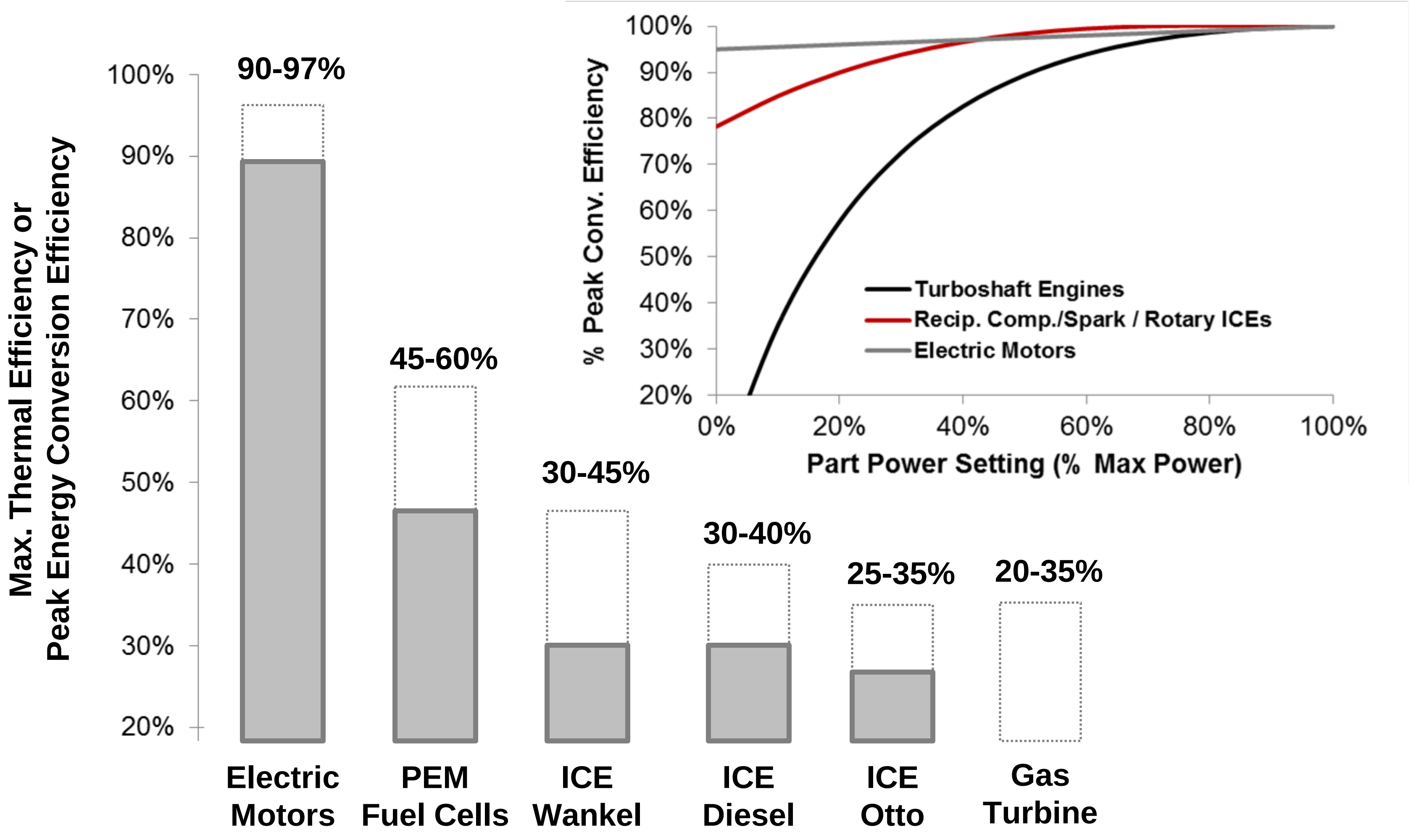
(2) Increase Rotor Efficiency

$$\eta_{HOVER} = \frac{P_{IDEAL}}{P_{SYSTEM}} = \frac{P_{IDEAL}}{P_{ROTOR} + P_{ANTI-TORQUE} + P_{XMSN\_LOSS} + P_{ACC.}}$$

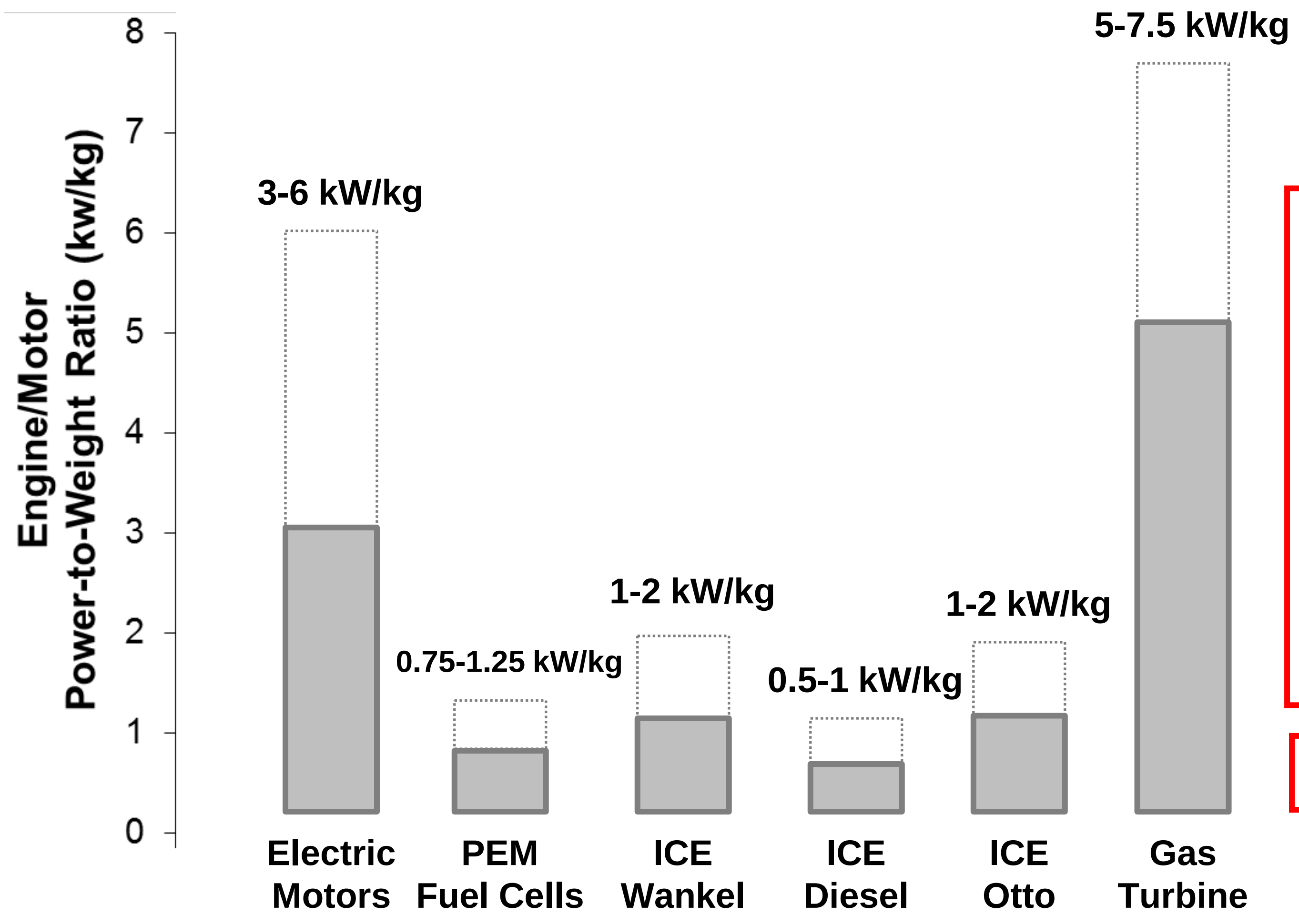
(4) Eliminate Additional Power "Losses"

$P_{IDEAL}$ is the power of an actuator disk of equivalent area given by momentum theory (hp). $P_{ROTOR}$ is the power consumed by the rotor (hp). Actual rotor power also uses a modified rotor thrust that includes the additional thrust required due to the vertical drag, $D_V$, developed from vehicle components enveloped in the rotor downwash (which are not present in the idealized actuator disk). The rotor hovering efficiency, $FM_{ROTOR}$, represents the ratio of actual rotor power required to the idealized actuator disk of the same area. The remainder of the aircraft power, $P_{SYSTEM}$, is comprised of any other power consumption required to keep the aircraft aloft and include: anti-torque power required, $P_{ANTI\text{-}TORQUE}$, transmission losses in transmitting engine power through the drivetrain to the rotor system, $P_{XMSN\_LOSS}$, and accessory power, $P_{ACC.}$, consumed by electrical generators, hydraulic pumps and any other ancillary systems like thermal management blowers.

# Getting Power to the Rotors



# Engine Power to Weight



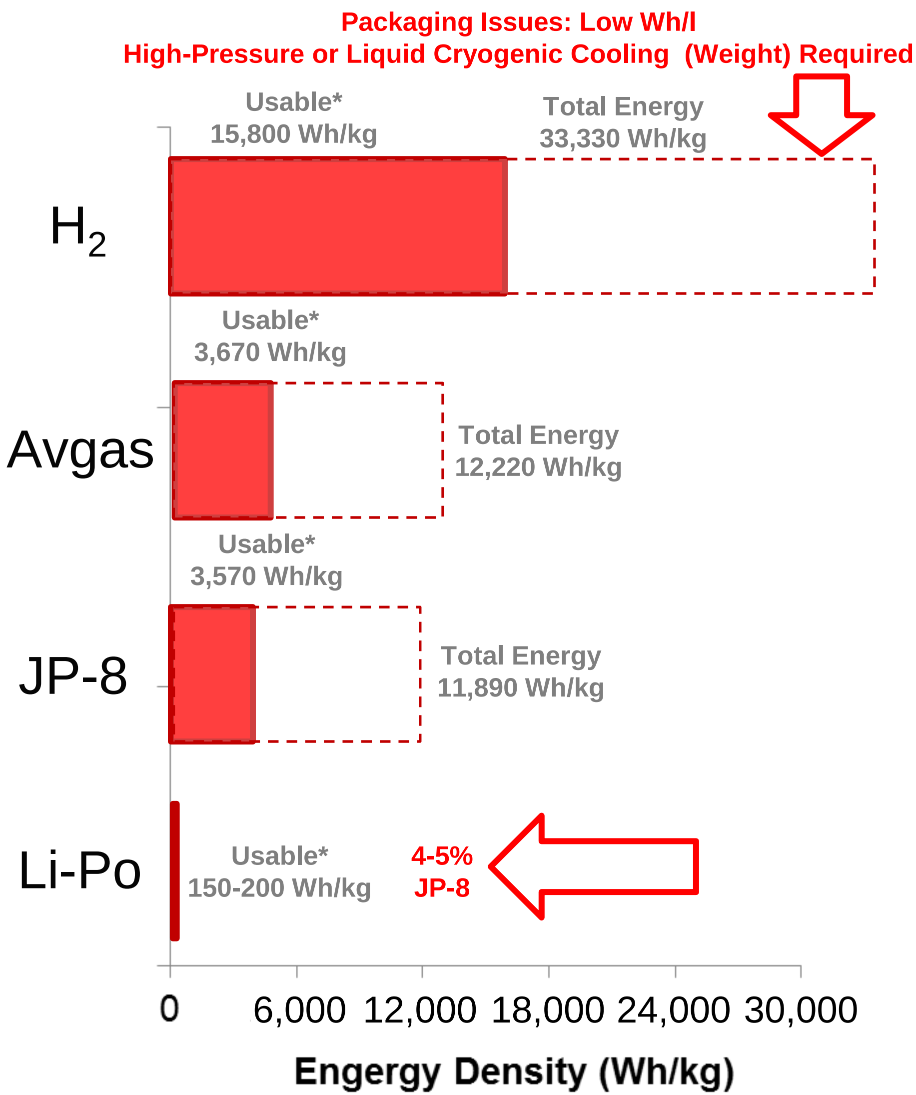

## Don't Forget

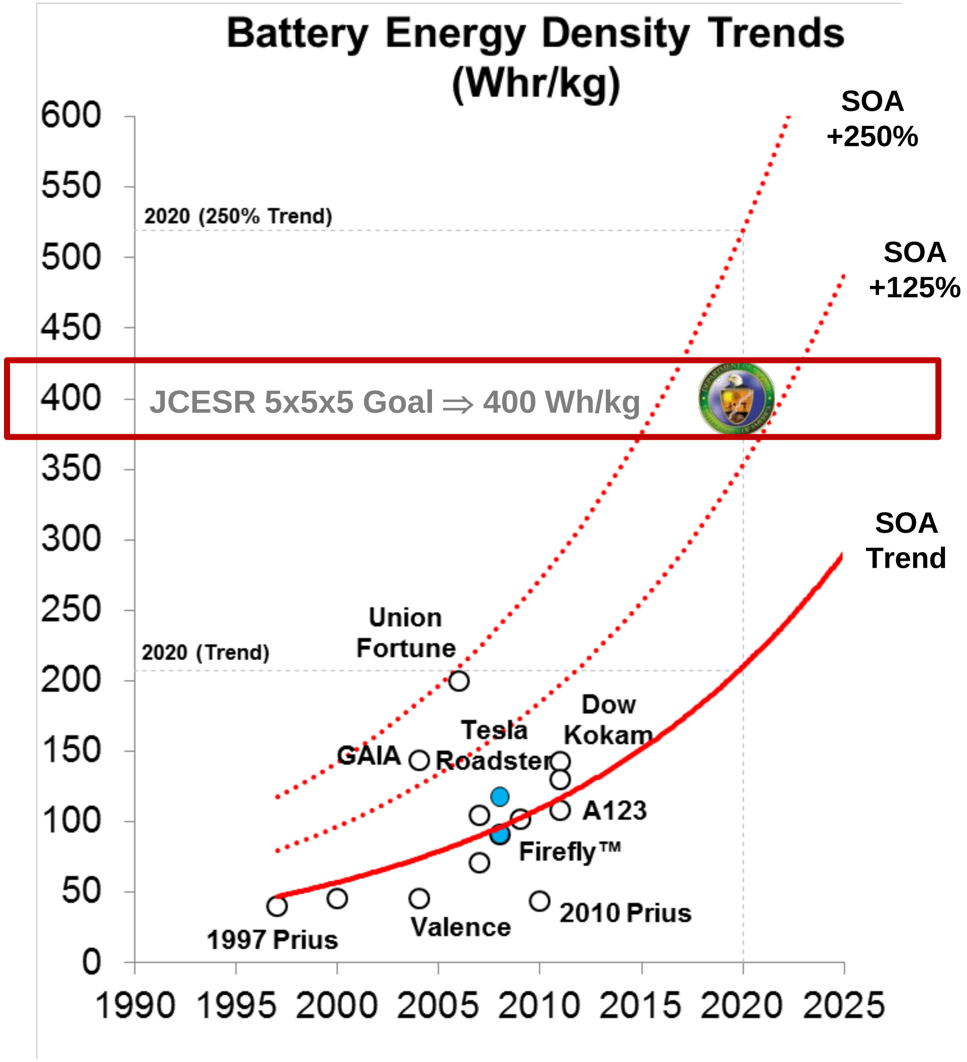
**Ancillary Systems:**

- HEXs
- Pumps
- Thermal MGMT
- Housings
- Firewalls
- Inlets
- Exhaust
- Lubrication
- Starting Systems
- Electronic Controllers
- Gearboxes
- etc…

**Energy Media Type!**

# Energy Sources

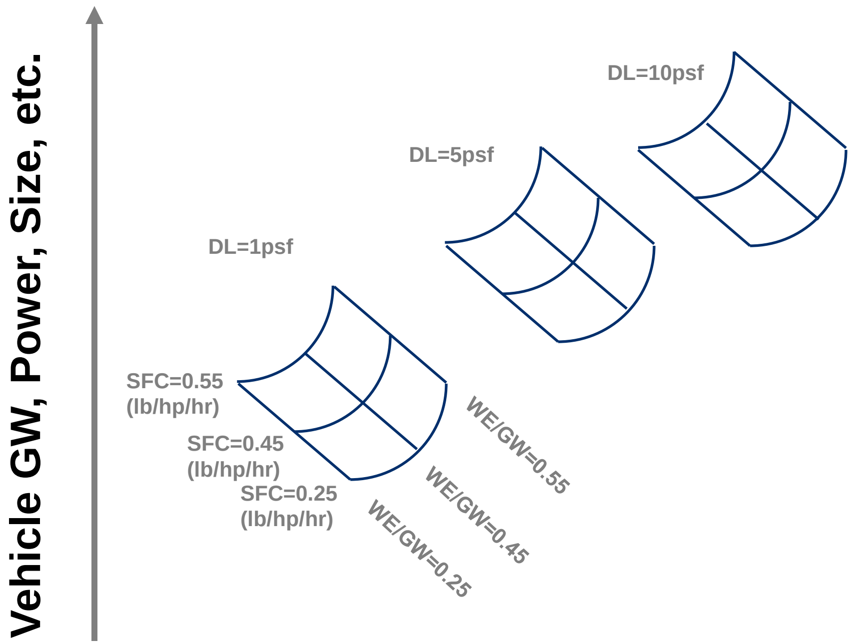


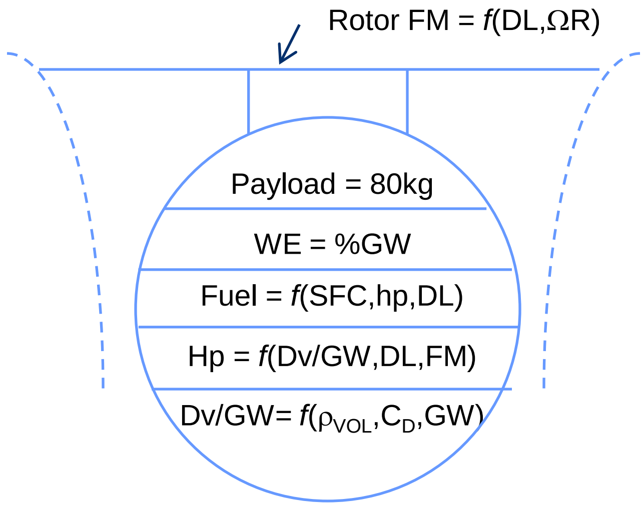




* PEM Fuel Cell Conversion Efficiency = 50%
Electric Motor Conversion Efficiency = 95%
Thermal Engine Conversion Efficiency = 30%

# Is This Really Feasible?

Explore the Design Space:

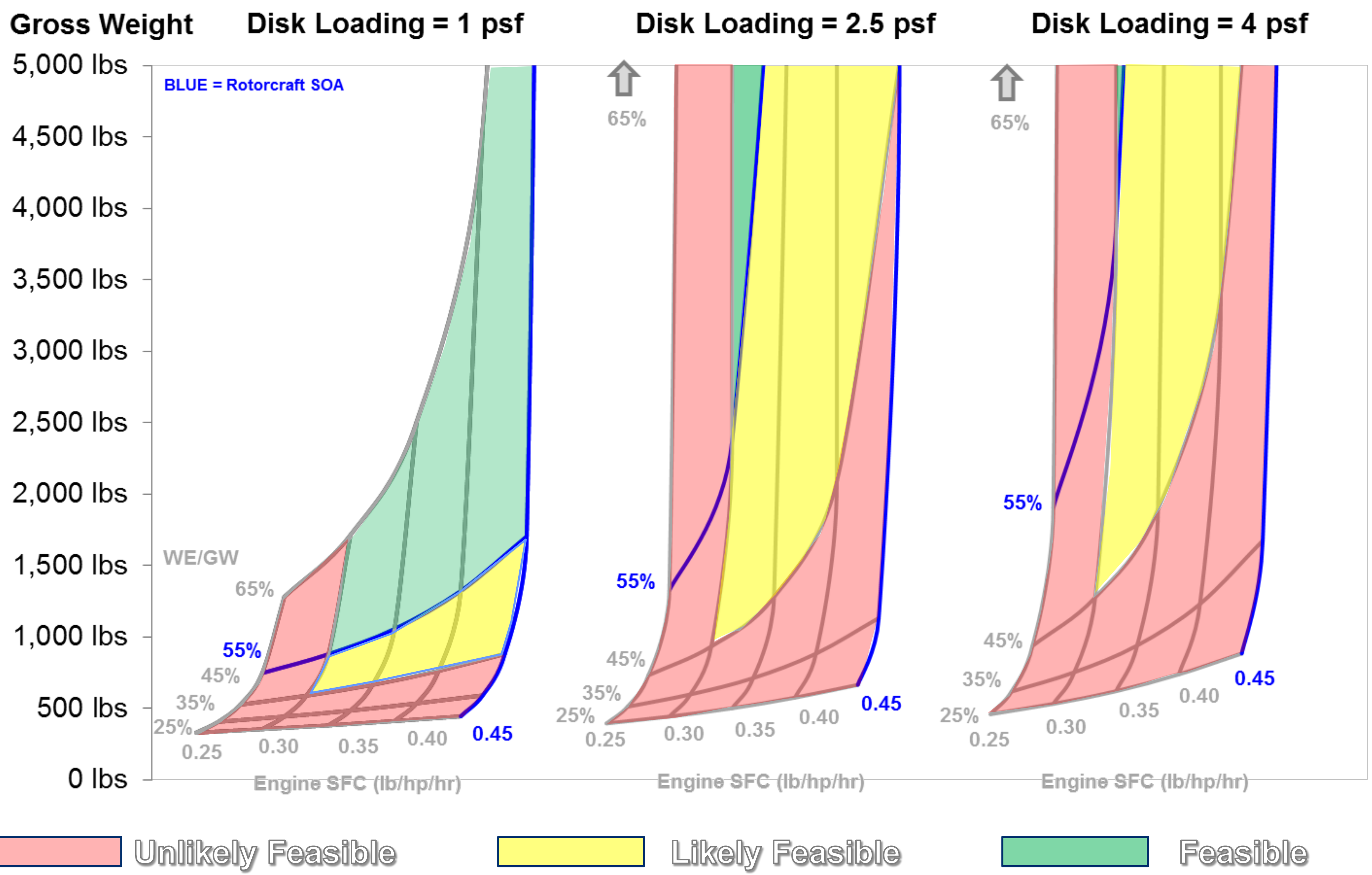


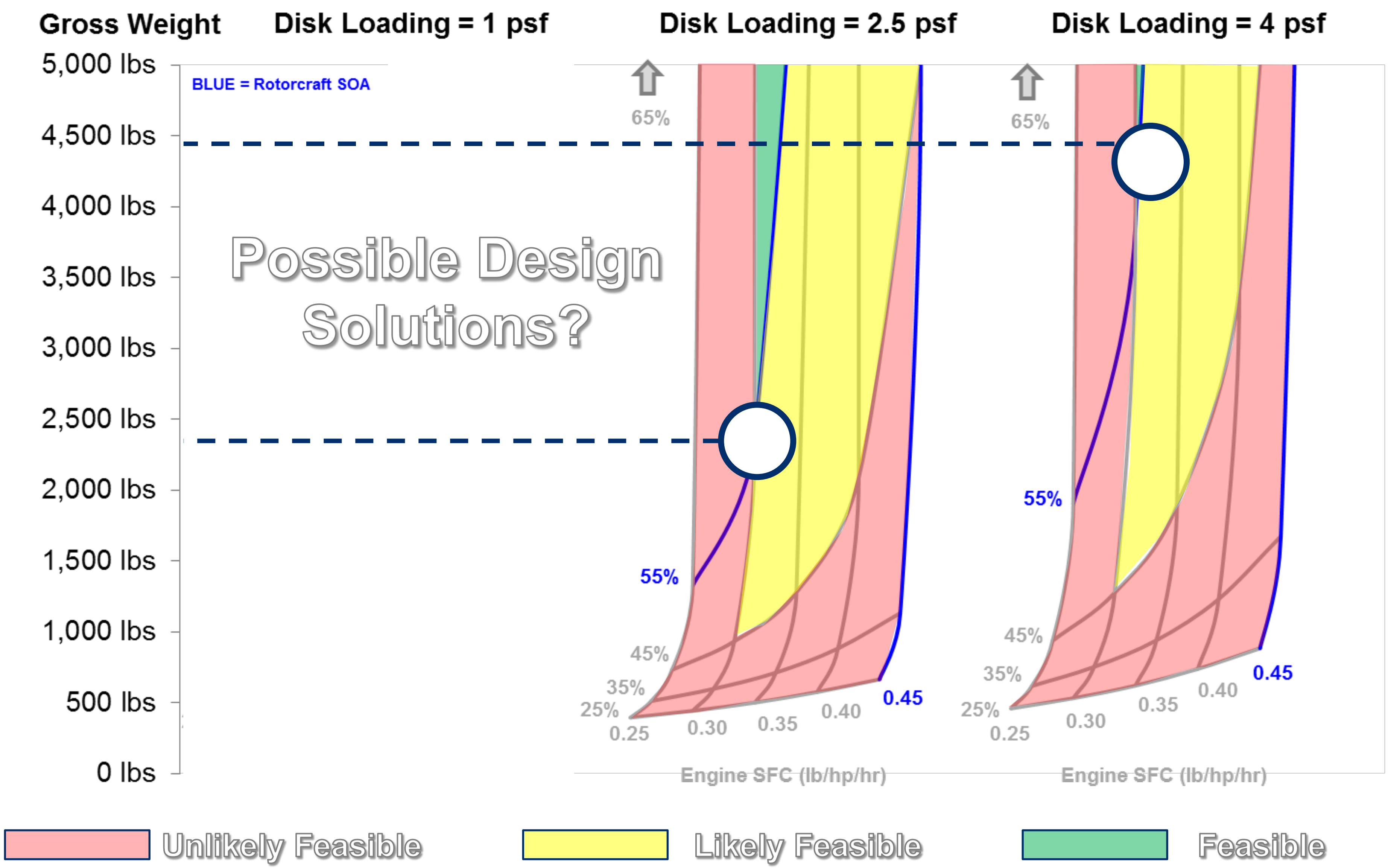

1. **Engine SFC** => Fuel Required
2. **WE Empty Fraction** => Gross Weight
3. **Disk Loading** => Rotor Power & Efficiency

**<u>State of the Art Values:</u>**
**SFC = 0.35 (Diesel)**
**SFC = 0.45-0.55 (turboshaft)**
**DL = 5-7 psf**
**WE/GW = 0.55-0.70**

# First Pass Sizing



# First Pass Sizing



# Observations

**Disk Loading**

- Conventional rotorcraft do not have disk loadings below 2 psf. DL scales w/ GW.
- Lower disk loading requires lower rotor rpm, which makes rotor controllability very difficult and causes autorotative issues.

**Fuel Consumption (SFC)**

- Diesel engines with SFCs of 0.35 have power to weight ratios of 0.5 hp/lb, while gas turbine engines with SFCs of 0.45-0.55 have power to weight ratios of 4-6 hp/lb.
- A propulsion system invention is necessary to get the SFC and P/W to match the WE/GW required
- The AeroVelo Altas HPH propulsion system (T. Reichert) included the energy and motive system

**Weight Empty Fraction**

- The lowest WE fraction on a real helicopter is 50% (Mosquito Aviation XE)
- The AeroVelo Altas HPH, with peak power of 1-2 hp, and a WE fraction of ~50% and broke apart on several occasions, making flights of <60 seconds.
- An invention is necessary to get the high-strength, lightweight structure and that can withstand a helicopter vibratory environment for 24hrs and meet the WE/GW required

# Summary

The AHS International

Igor I. Sikorsky 24 Hour Hover Challenge

24 HOUR Hover Challenge

www.vtol.org/challenge
#Hover24

**Official Rules**
Released Oct. 19, 2016

AHS International's 24 Hour Hover Challenge — Home » Awards and Contests » AHS International's 24 Hour Hover Challenge

***The Official Rules for***
***AHS International's Igor I. Sikorsky 24 Hour Hover Challenge***
***are now available!***

On May 18, 2016, AHS International and Sikorsky Aircraft announced a new vertical flight competition:
**The AHS International Igor I. Sikorsky 24 Hour Hover Challenge.** [Sikorsky press release]

This competition will be conducted in the same vein as AHS International's Igor I. Sikorsky Human Powered Helicopter Competition, also sponsored by Sikorsky, and also honoring the company founder, Igor I. Sikorsky. This prize was won after 33 years by AeroVelo in June 2013.

"Just like the Human Powered Helicopter Competition, the statement is simple, but the solution may be technically very complex. We hope the Challenge sparks the next generation of aviation engineers with great ideas to try to do something that may be impossible," said Mike Hirschberg, Executive Director of AHS International.

AHS International — *The Vertical Flight Technical Society* — is partnering with Sikorsky, a Lockheed Martin Company for this competition in order to inspire innovative thinkers with an incredibly difficult challenge: hover a heavier-than-air flying machine for 24 hours, while still demonstrating other typical helicopter attributes.

We're very excited to kick off this new challenge. The Official Rules for the AHS International Igor I. Sikorsky 24 Hour Hover Challenge go into the competition details, but in summary, the requirements are to demonstrate the following key characteristics in flight:

- **Hover for at least 24 hours**, over three different stations that are 1 km apart
- **Carry 80 kg payload**, simulating the approximate weight of an adult human (176.4 lb)
- **Unoccupied**, to minimize the risk of injury

**Questions about the Rules?** Please send them to the 24-Hour Hover Challenge Team. All questions and their answers *will be posted within 10 days*, linked from this page.

Founded in 1943 as the "American Helicopter Society," AHS International today is the world's premier vertical flight technical society. The Society is the global resource for information on vertical flight technology. It provides global leadership for scientific, technical, educational and legislative initiatives that advance the state of the art of vertical flight.

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https://vtol.org/awards-and-contests/24-hour-hover-challenge