Man-Portable Tactical Power

Report on Efforts

A Presentation Prepared for

NDIA 2011 Joint Service Power Expo

May 2 – 5, 2011

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by

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Outline

1. **Company Background**
   0.1 – 100 hp Heavy Fuel Engines, Turbine Engines, Hybrid Power Systems

2. **Need for Portable Power Solutions :** Light-Weight Heavy-Fuel Gen-Sets
   Example : ONR Goals for a 500 W – 1000 W Power System

3. **Problems with Conventional Generator Sets**
   Size, Weight, Noise, Wet-Stacking
   Challenges in Developing Small, Heavy Fuel Engines

4. **Light-Weight Power Solutions by D-STAR Engineering**
   Strategies for Developing Light-Weight Heavy-Fuel Engines
   Examples of D-STAR Heavy Fuel Power Systems
   Business and Teaming Strategies (Beneficial to the Government and Others)

5. **Conclusions**
   Technologies have been Developed and Validated
   TRL 5 Prototype Has Been Demonstrated, Delivered, Tested by the Govt.
   Teaming Opportunities are in Discussions, but are Currently Open

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D-STAR Engineering Experience Base

0.1 – 100 hp Heavy Fuel Engines, Turbine Engines, Hybrid Power Systems

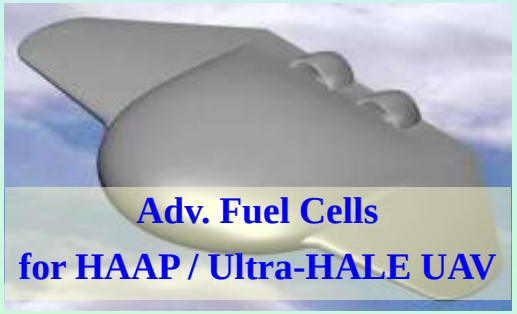
0.1 hp HFE

0.6 hp M-COTS HFE

1.5 hp HFE

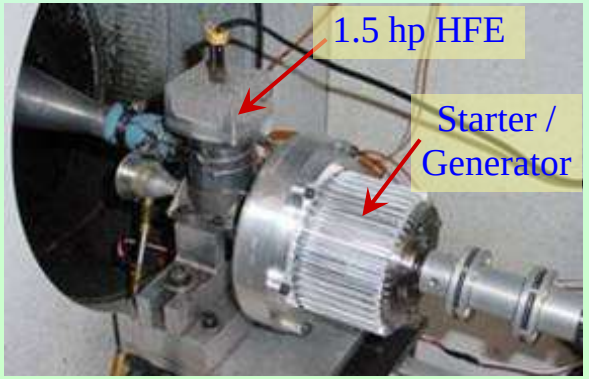
6 hp Class 4-stroke M-COTS HFE

Miniature Turbine Engine



Adv. Fuel Cells for HAAP / Ultra-HALE UAV

Mini-FADEC for 1.5 hp HFE



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ONR BAA 06-023 : Original Goals and D-STAR Prototype Capabilities

6.1 Desired Capabilities

The ideal single-person portable JP-8-fueled generator would incorporate as many of the following features as possible:

1) Provide **500-1000 Watts** power at 28VDC through a commercial grade two-wire connector output interface : **700+ Watts Demonstrated.**

2) Operate directly on **JP-8 fuel** : **Yes. Straight JP-8. No Additives.**

3) Weigh ≅ **15 pounds** : First Prototype is Heavier, Production Item can be Lighter.

4) Be highly compact, about **the size of a small lunch-box**, and able to fit in a Marine Corps backpack : First Prototype is Larger, Production Item can be Smaller.

5) **Start up in less than 10 minutes** : **Yes. < 1 minute. Often < 10 seconds.**

6) Provide **power quality** comparable to current tactical generators. **Yes.**

7) Have an acoustic signature < 70 dB at 7 meters : **Yes,** 67 – 69 dB (First Prototype)**.**

8) Operate over a broad temperature range : **Yes.** Tested to 32 F, Range to be Expanded.

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ONR BAA 06-023 2

6.1 Desired Capabilities (Continued)

9) Be able to operate from a remote standard 5 gallon military fuel container with the capability to pump fuel from that container : **Yes.**

10) Be **water neutral to the greatest extent possible** (i.e., operation should not require more than a minimal amount of water to be added to the system initially if needed, and no additional external water should be required after start-up.) : **No Water.**

11) Be able to operate for **at least 1 hour on internal fuel** : **Yes.**

12) Be able to **operate in a range of battlefield environments** (i.e., salt water atmosphere, diesel fumes, dust) : **TBD**

13) Be able to operate for **600 hours** before any major maintenance : **Expected.**

14) **Simple & highly reliable** : **Push-Button Start, Auto. Control & Optimization**.

15) Be a **cost effective** technology : **To Be Optimized.**

16) Able to be started without significant special training and can be operated by the average Marine : **Yes.**

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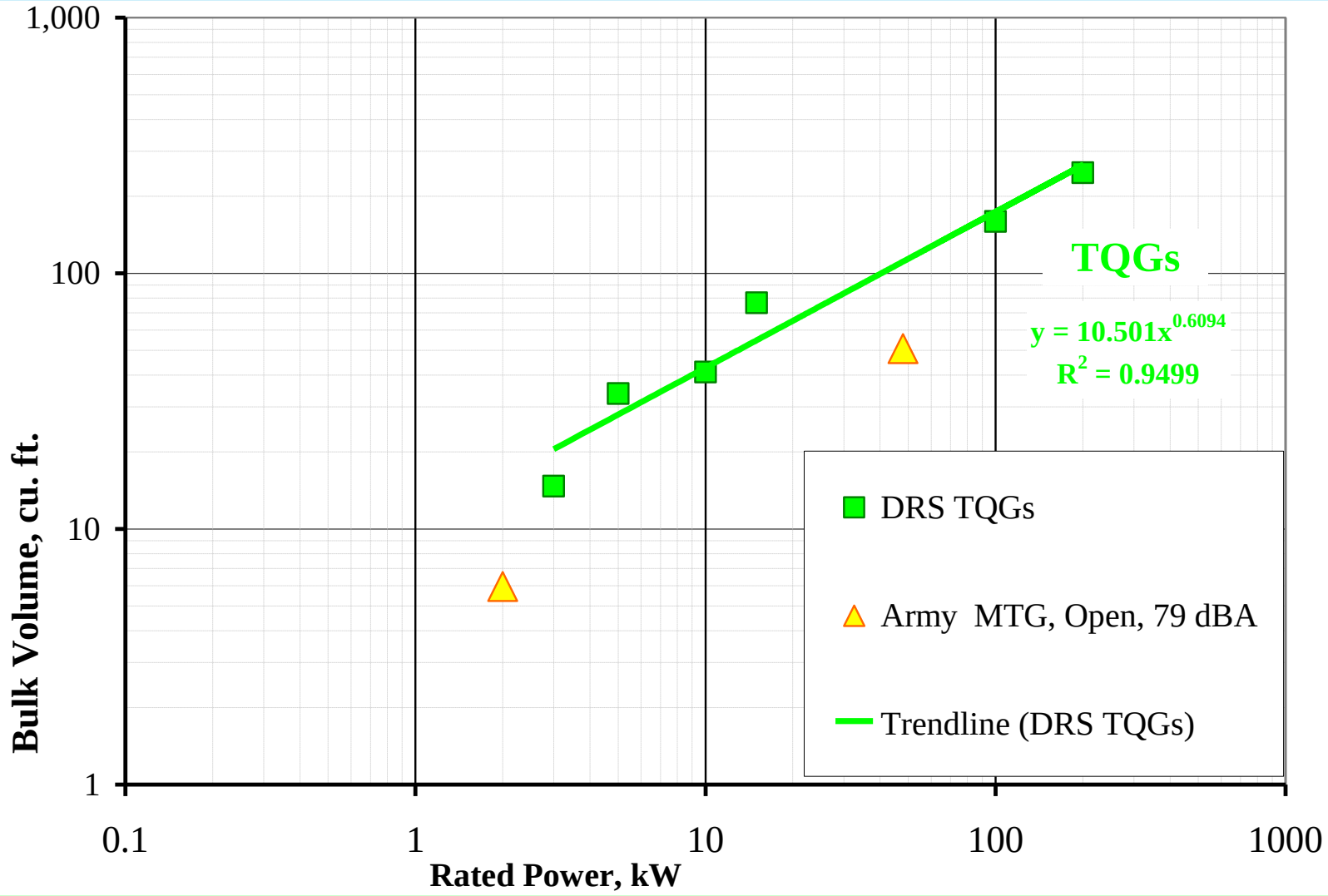
Size : Military Generator Sets are Too Large



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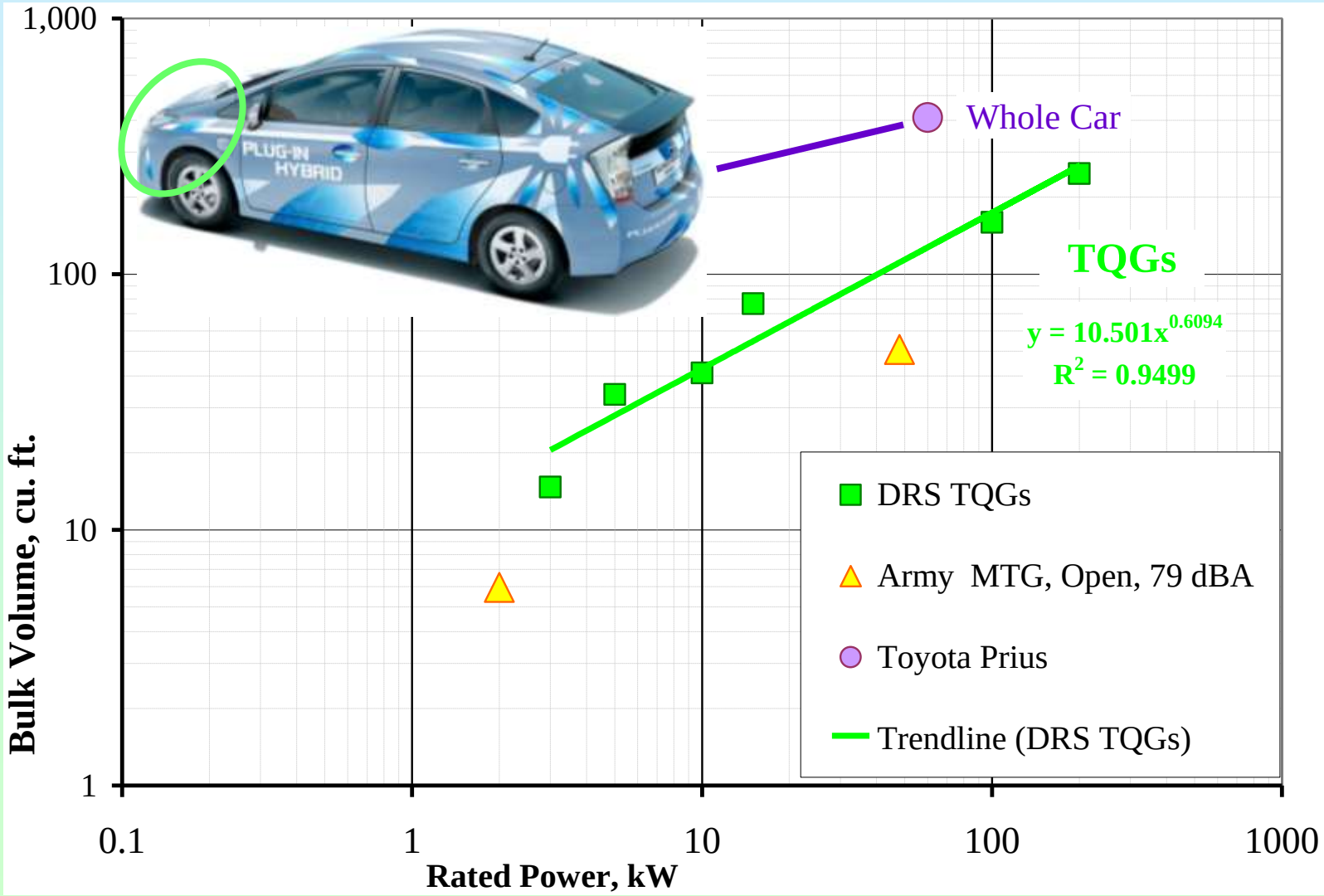

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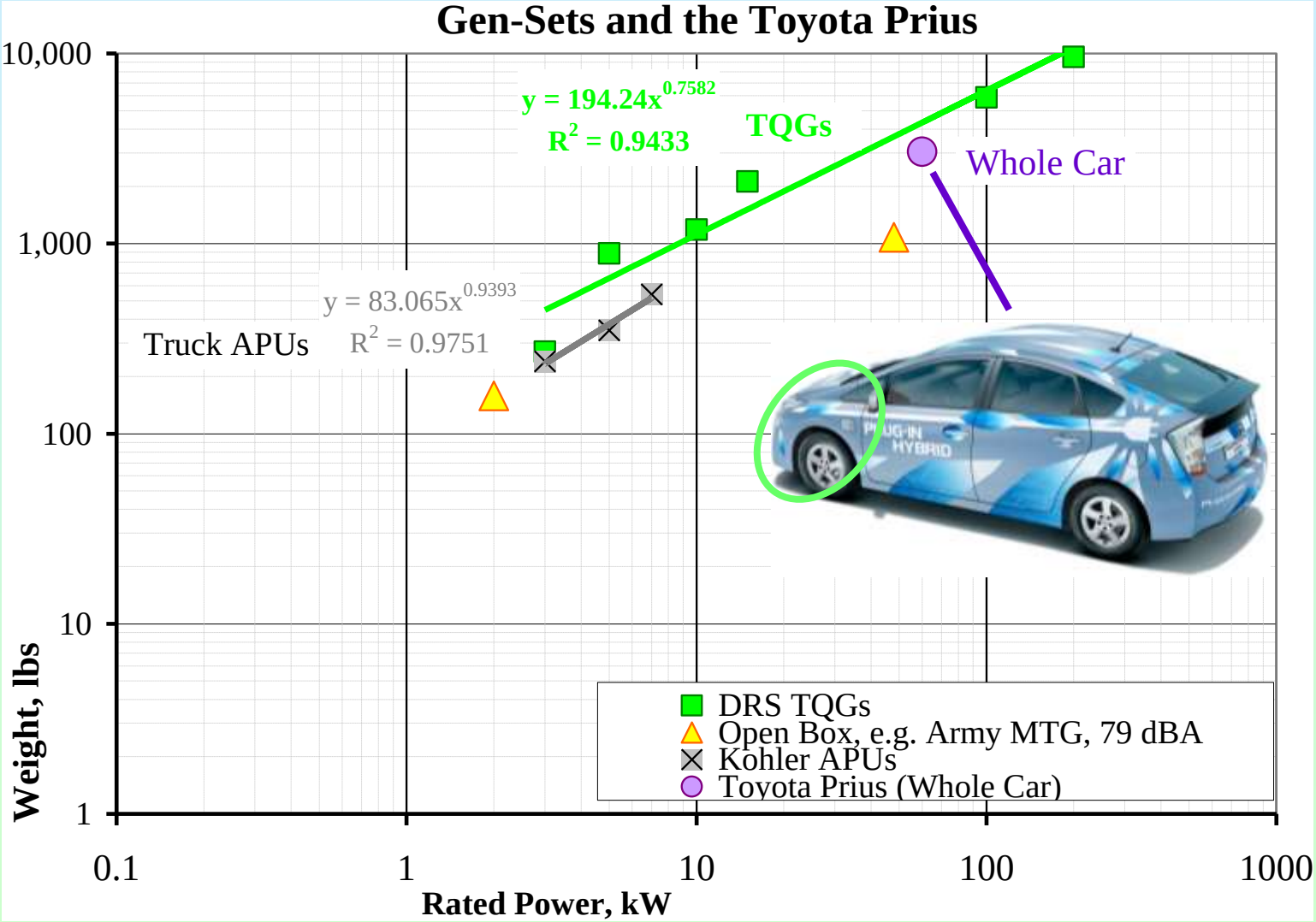
Weight : Military Generator Sets Weight Too Much



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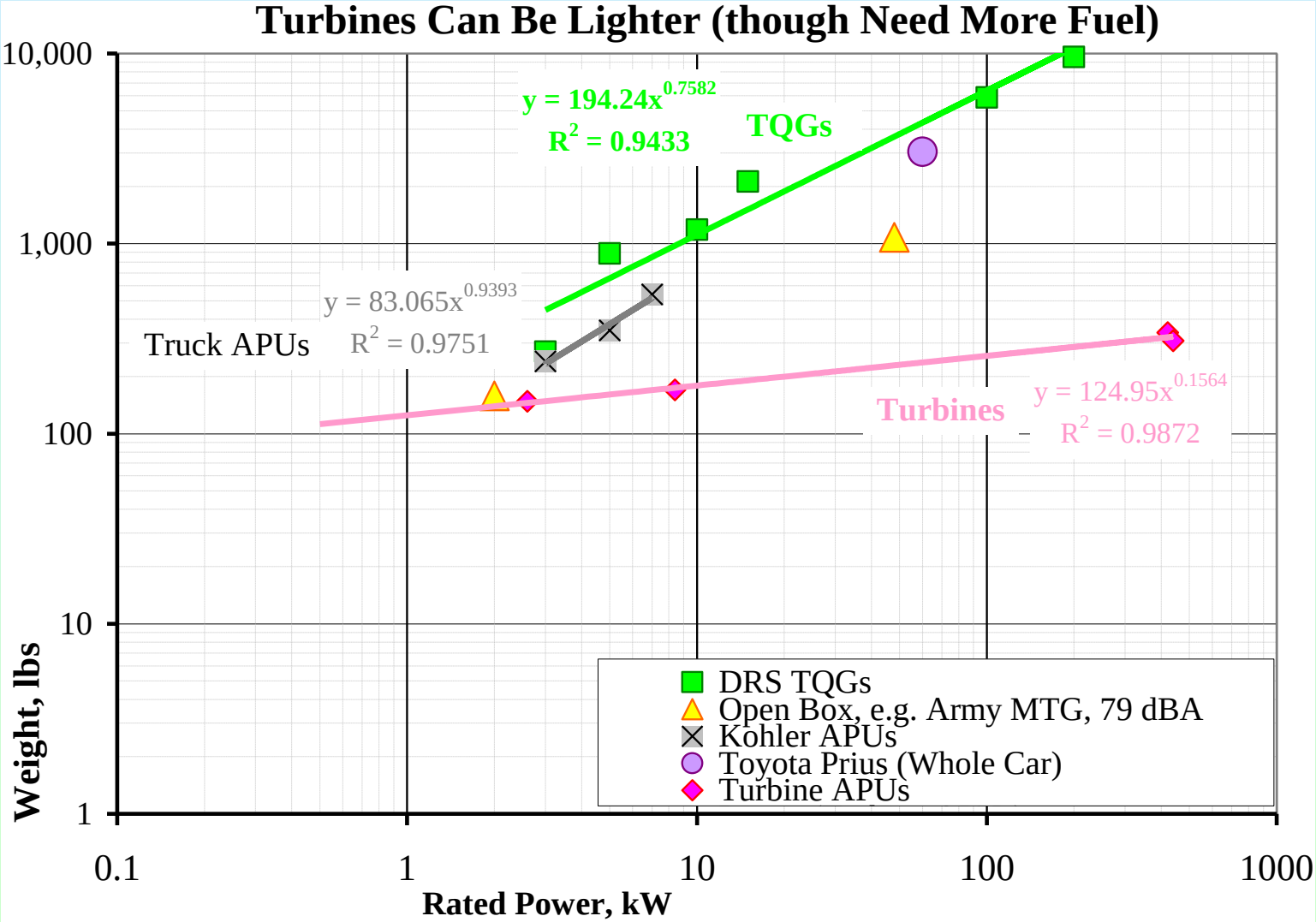

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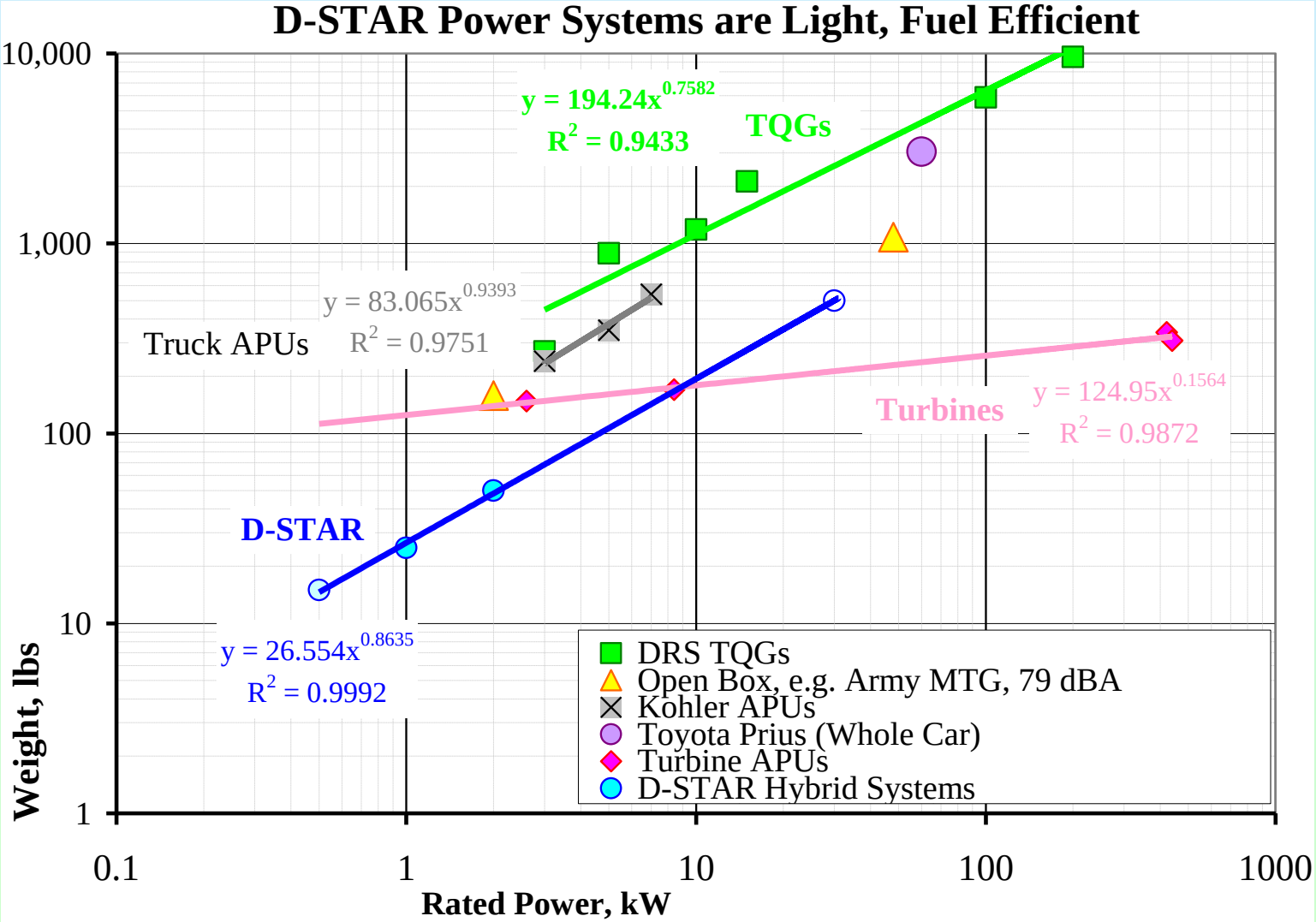

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Problems with Conventional Generator Sets

Noise : The Enemy of Stealth and Military Success.

The 2 kW MTG Makes 79 dB at 7 m

TQGs Achieve 70 dB, but are 2x Heavier (per kW) than MTG.

Wet Stacking : Maintenance Problems with Exhaust Systems.

Can be Avoided by Variable Speed Operation.

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Key Handicaps of Conventional Diesel Generator Sets and APUs

Large Size : Large, Low Speed Engine, Large Generator

Heavy Weight : Large Diesel Engine
Low Speed
Low Air Utilization, Low BMEP
Heavy Construction
High Peak Combustion Pressures

High Cost : Large Size & Weight, Greater Cost

High Noise : Combustion Shock Noise
Low Frequency Noise Difficult to Attenuate.

Exhaust Emissions : Stratified Charge Produces Smoke
High Peak Combustion Temperature Produces NOx.

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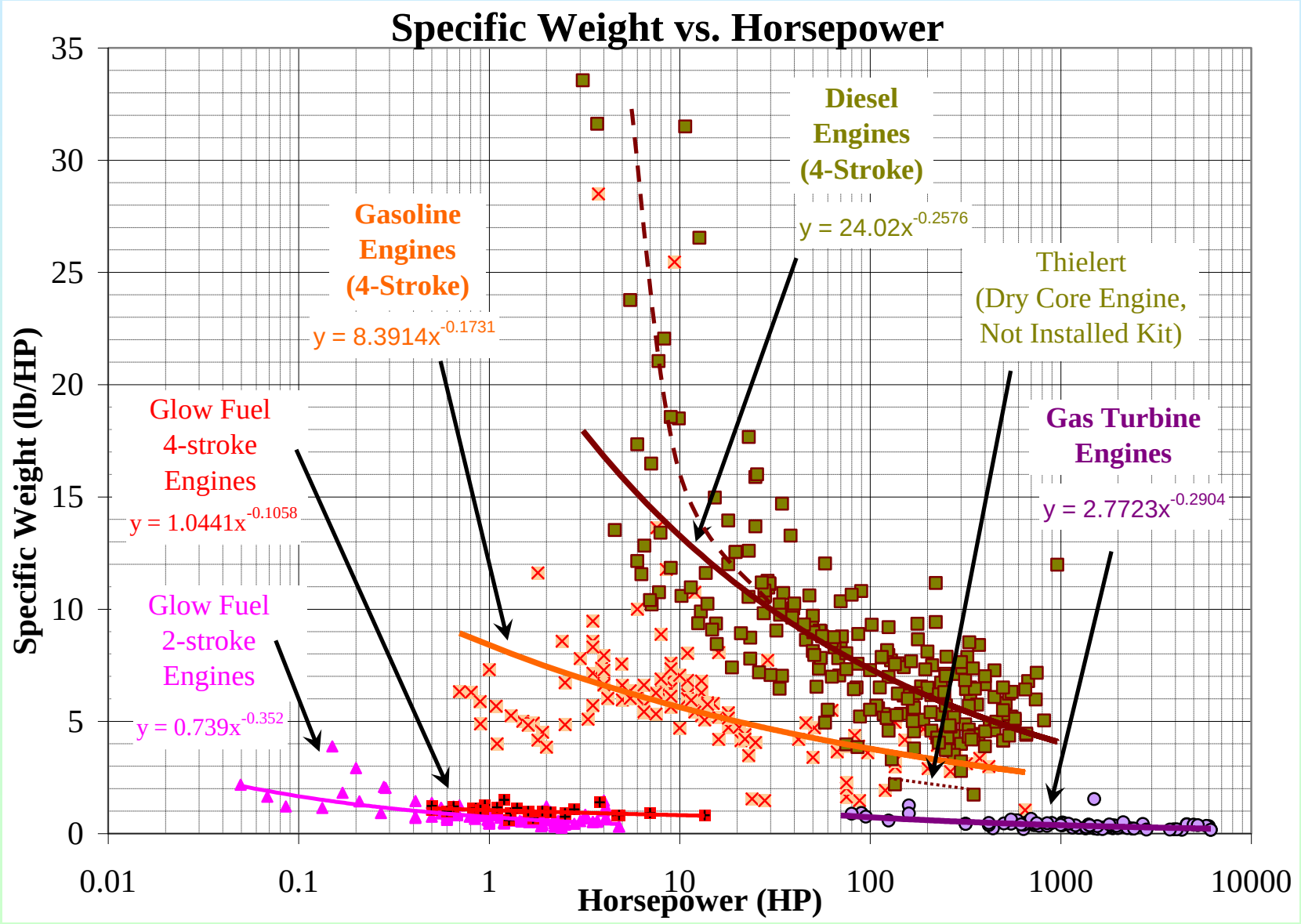
Handicaps of Conventional Heavy Fuel Engines : Weight



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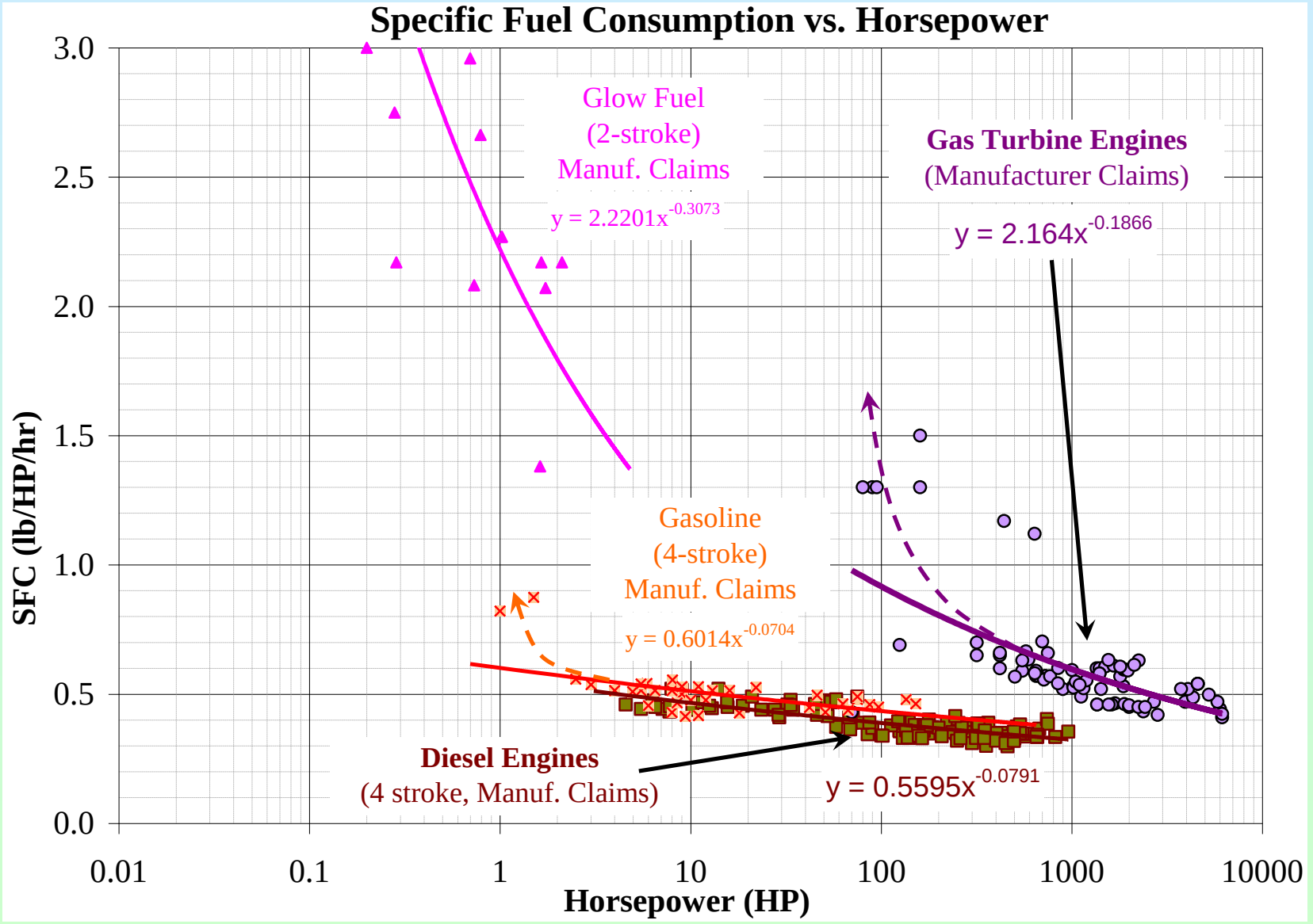
Turbine Engines Weigh Less, but Small Turbines have Excess Fuel Use



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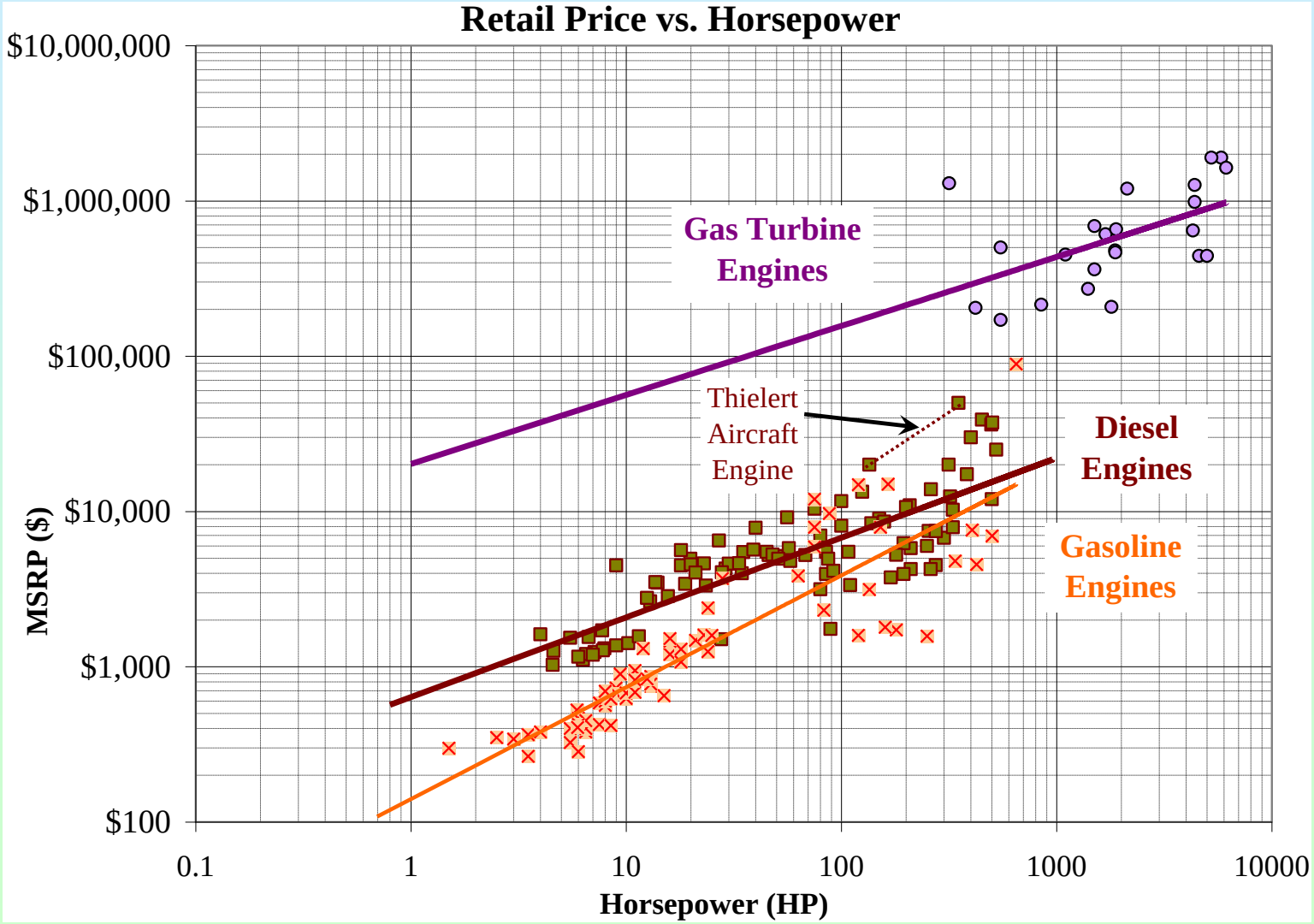
Heavy Fuel Engines are 2x – 3x More Expensive Than Gasoline Engines
Turbines are 10x – 20 x More Expensive than Diesel Engines



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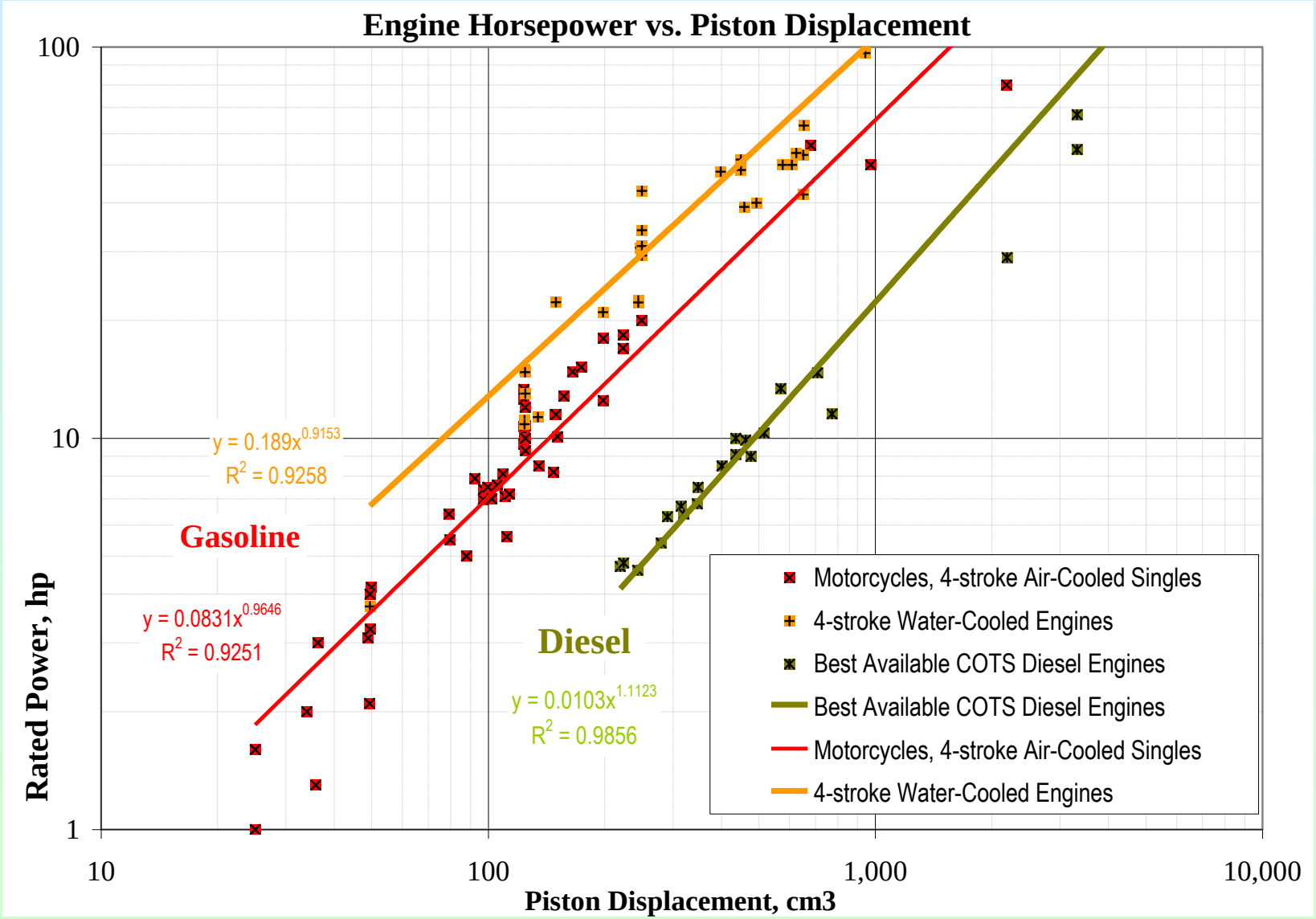
Heavy Fuel Engines Need to be 5x Larger Than Gasoline Engines



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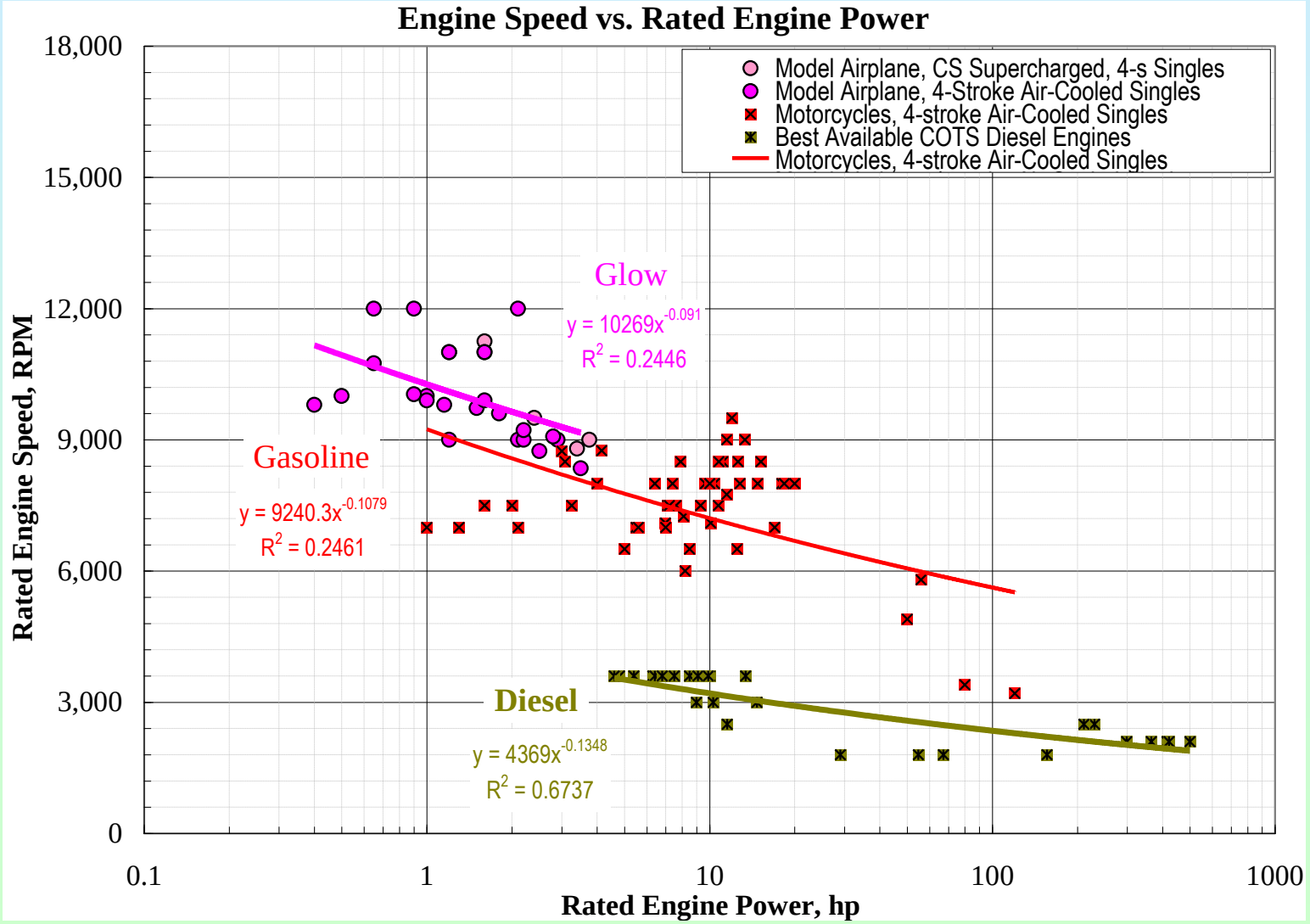
Why Do Heavy Fuel Engines Need to Be Larger than Gasoline Engines?

Low Speed and Low Air Utilization



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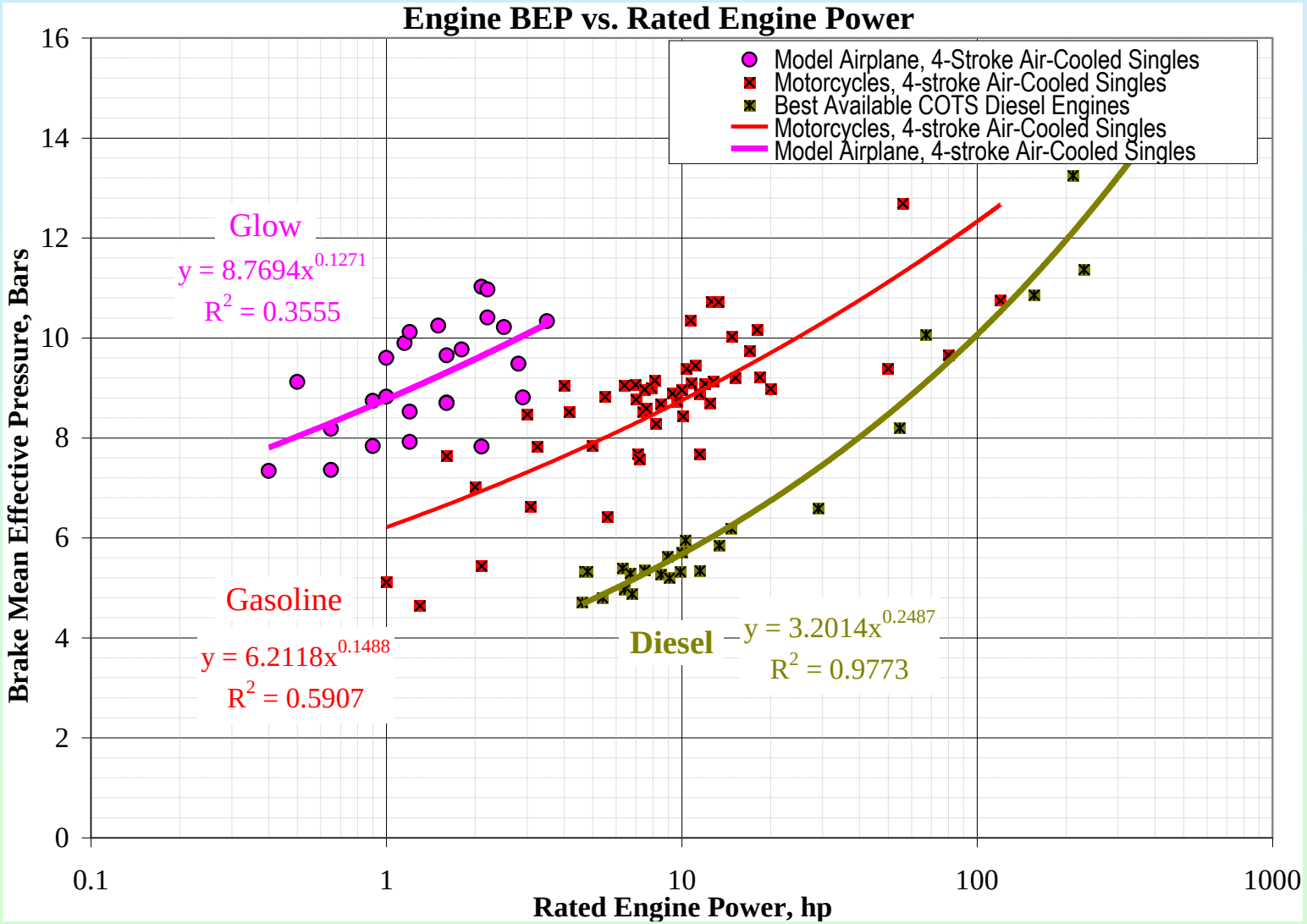

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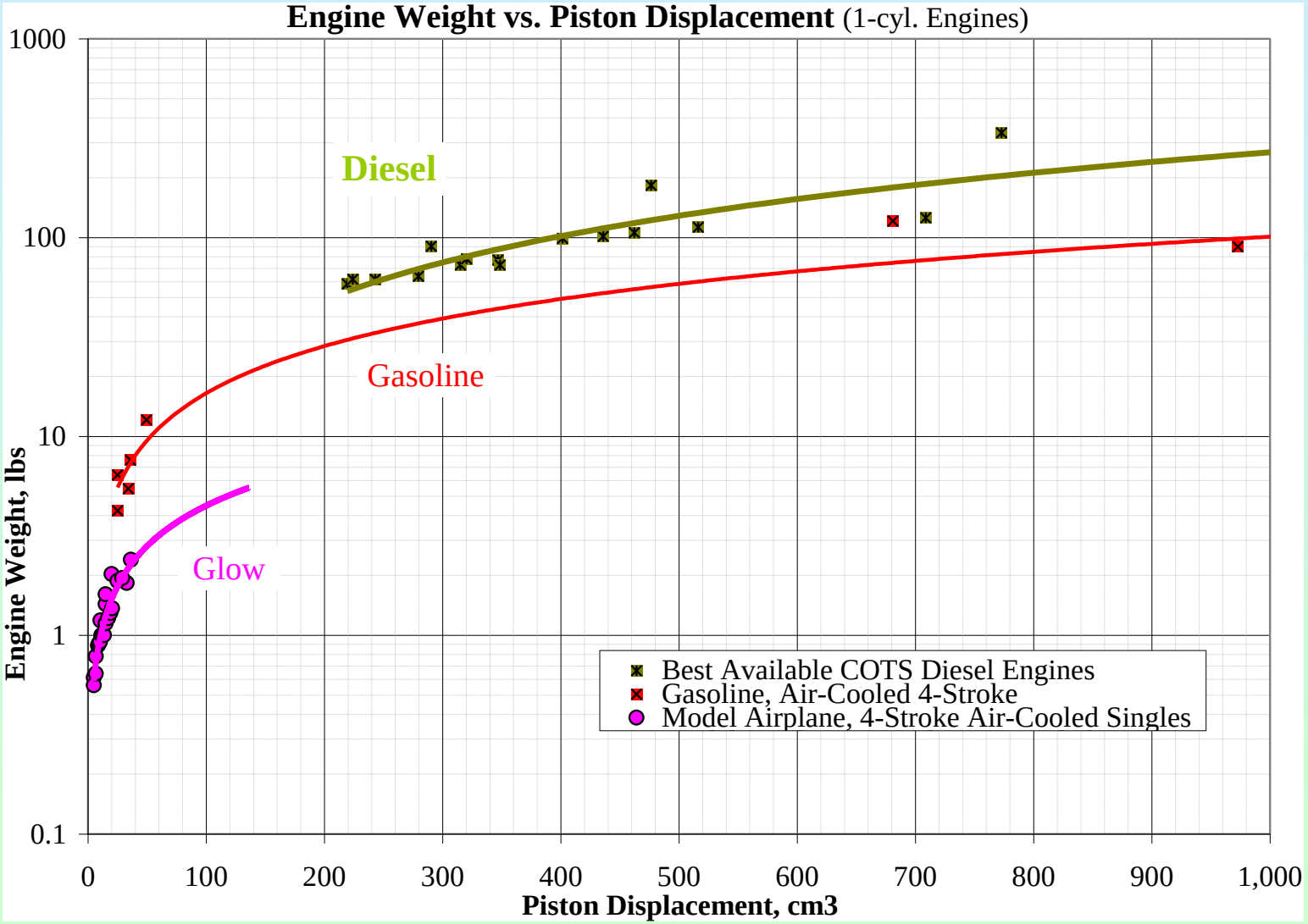
Even at Equal Size, Diesel Engines Weigh More
Because of High Compression Ratios, Very High Peak Pressures.



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So, Diesel Engines are Large and Heavy Because of Low Speed, Low Air Utilization, High Peak Pressures.

What Can Most Improve Heavy Fuel Engines?
Lower End (Mechanism) or Upper End (Combustion)?

Piston-Rod-Crank System is

- ✓ **95% Efficient, Very Light Weight**
- ✓ **Has 100-year History, $100 Billion R&D Investment**
- ✓ **Sealing, Lubrication and Heat Transfer Problems are Well Understood, Solved.**

'Barrel' Engines, 'Butterfly' Engines, 'Cat-and-Mouse' Engines (real names) ...

- ✘ **Are Not More Efficient, Not Much Lighter**
- ✘ **Have Large Challenges of Sealing, Lubrication and Heat Transfer.**

Improving the Upper End (Combustion) Can Enable

- ✓ **Faster Operating Speeds for Higher Power Density**
- ✓ **Greater Air Utilization (BMEP) for Greater Power, Greater Efficiency.**
- ✓ **Reduced Peak Pressures for Lighter Weight, Lower Friction.**

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D-STAR Strategies for Developing Light-Weight Heavy-Fuel Engines

1. **Enable High Speed Operation**, even with Heavy Fuels (e.g. JP-8)
   Conventional Diesel Engines Operate at < 3600 RPM
   D-STAR HFEs Operate at 6,000 – 18,000 RPM.

2. **Enable Full Air Utilization**
   Conventional Diesel Engines Operate at Phi < 0.6 (Smoke Limit)
   D-STAR HFEs Operate at Phi up to 1.0 (without Smoke).

3. **Enable Combustion at Low Pressures**
   Conventional Diesel Engines Operate at High CR, High Pmax.
   D-STAR HFEs Operate at Lower CR, Much Lower Pmax

4. **Ensure Active Optimization** of Engine Operating Parameters **(mini-FADEC)**

5. **Reduce Cost** Through Use of Gasoline Engine Components Where Feasible.
   Use Custom Components Where Needed.

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Examples of D-STAR Heavy Fuel Power Systems

Current 2 kW Generator Set
Used by Army, Others
AC Only
158 lbs

D-STAR / Army 2 kW
✓ Power Core Demonstrated
50 lbs

D-STAR / ONR 1 kW
✓ Power Core Demonstrated
✓ Endurance Test Completed
✓ Prototype Delivered
✓ Performance Verified by Govt.

D-STAR / Army 500 W
✓ Phase 2 in Process
15 lbs

D-STAR / Army 300 W
✓ Selected for Phase 1

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D-STAR / ONR / USMC 500 W – 1000 W

✓ **Power Core Demonstrated, ≅ 50 lbs. Demonstrated 1600W Cont., 1800 W Peak**

Potential

for

2+ kW

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D-STAR / ONR 500 W – 1000 W

Phase 2.0 : Ended September ’09 : Technology Validation & Down-Selection

✓ **Heavy Fuel Engine Demonstrated, Technologies Down-Selected.**

Phase 2.1 : Nov. ’09 to Apr. ’10 : Demonstrate Power Cores, Endurance Ability

✓ **Power Core Built, Straight-JP8 to 1080 Watts DC Achieved (2 hours non-stop)**

Phase 2.2 : July ’10 to Jan. ’11 : Build Laboratory Prototypes of Generator Set

✓ **Endurance Testing (100+ Hours) Successfully Completed (> 700 Watts Avg.)**

✓ **Fully Integrated Desktop Unit Built and Tested, with All Systems Operational**

✓ **First Prototype Delivered, Successfully Tested by the Government.**

Phase 3 : Support Testing of Prototype + In-House Testing

Phase 4 : EMD / SDD

Engineering & Manufacturing Development / System Development & Demonstrations

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✓ Endurance Test Done, ✓ Prototype Delivered, ✓ Performance Verified by Govt.

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ONR BAA 06-023 : Original Goals and D-STAR Prototype Capabilities

6.1 Desired Capabilities

The ideal single-person portable JP-8-fueled generator would incorporate as many of the following features as possible:

1) Provide **500-1000 Watts** power at 28VDC through a commercial grade two-wire connector output interface : **700+ Watts Demonstrated.**

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10) Be **water neutral to the greatest extent possible** (i.e., operation should not require more than a minimal amount of water to be added to the system initially if needed, and no additional external water should be required after start-up.) : **No Water.**

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ONR BAA 06-023

II. AWARD INFORMATION [As Planned]

Anticipated Award Information is as follows:

Total Amount of Funding Available for the Program: $16.5M over 4 years

Total Amount of Funding Available for each Award:

Phase 1 (Base) :	$200-300K	**Successfully Completed**
Phase 2 (Option 1) :	Up to $3M	**On-Time, On-Budget**
Phase 3 (Option 2) :	Up to $200K	**Teaming**
Phase 4 (Option 3) :	Up to $4.5M	**Under Consideration**

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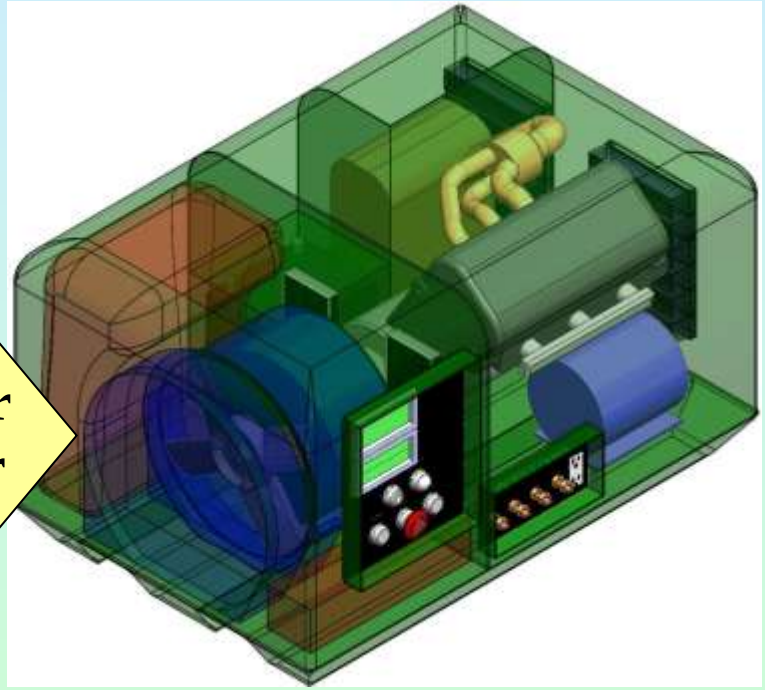
30 kW Heavy Fuel Power System : Conventional vs. D-STAR Technology

In-service 30 kW Gen-Set
80” L x 36” W x 55” H
3015 lbs basic
70 dB(A) @ 7m

6 x Smaller
6 x Lighter



Future 30 kW Gen-Set
by D-STAR Team
42” L x 28” W x 24” H
≅ 500 lbs basic
67 dB(A) @ 7m

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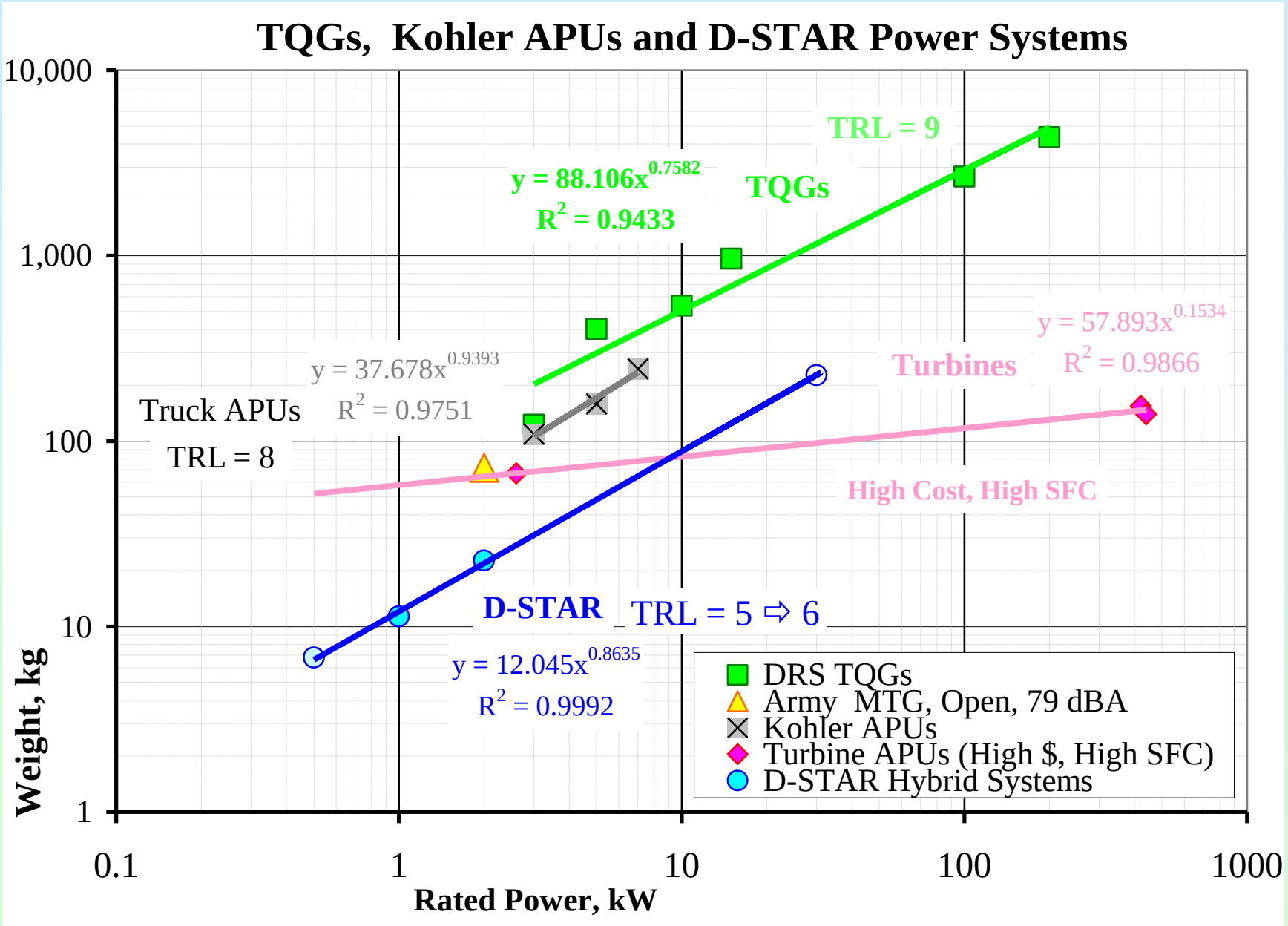

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D-STAR Business and Teaming Strategies

Open to Teaming with Any and All ‘Good’ Candidates.

Potential Team Mate Must Bring Value Added to the Table.

The Goal is to Maximize Benefits

for All Three Stakeholders :

ONR / USMC / Government (Large Cumulative Investment)

D-STAR Engineering (twenty years of expertise and investment)

Potential Team Member (for their Investment).

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Portable Power Solutions

by

D-STAR Engineering Corporation

- ☆ **Extensive Prior Experience with Engines and Power Systems**
- ✓ **Delivered First Prototype for ONR 1 kW Portable Gen-Set, On Schedule, On Budget (BAA). Successfully Tested by the Government.**
- ✓ **Demonstrated 2 kW Power Core (limited by SBIR Funding)**
- ✓ **Developing a 2 hp HFE. Can be Basis of 0.5 kW, 15 lb Gen-Set**
- ✓ **Selected for a 300 – 500 Watt Hybrid Power System (10 lb Gen-Set)**
- ✓ **Designed a 30 kW, 500 lb Gen-Set.**
- ☆ **We Specialize in Light-Weight Heavy Fuel Power Solutions.**

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D-STAR has Developed Key Enabling Technologies

for Lighter, More Portable Generator Sets / APUs that can

- **Use Diesel / JP-8 / Jet-A and Other Heavy Fuels**
- **Offer a Potential for Reduced Fuel Consumption**
- **Offer a Potential for Reduced and Cleaner Exhaust Emissions**
- **Offer a Potential for Cost Reduction.**

D-STAR Would Like to Team with a Larger Company

to Bring its Products to Market

Starting with the U.S., Expanding Globally.

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