

8D Cost Trades With Entanglement



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OVERVIEW



- The twins
- Pole position
- $3 + 2 = 4$
- $4 + 4 = 7$
- 7D trade
- $7 + 1 = 8$
- Summary



Cristina



- American expatriate living in Argentina
- Studies
 - Development costs
 - Costs/prices fall as quantities increase
 - Business jets
 - Turbofan engines



Sheila



- American expatriate living in Australia
- Studies
 - Development costs
 - Costs/prices increase as features increase
 - Business jets
 - Turbofan engines



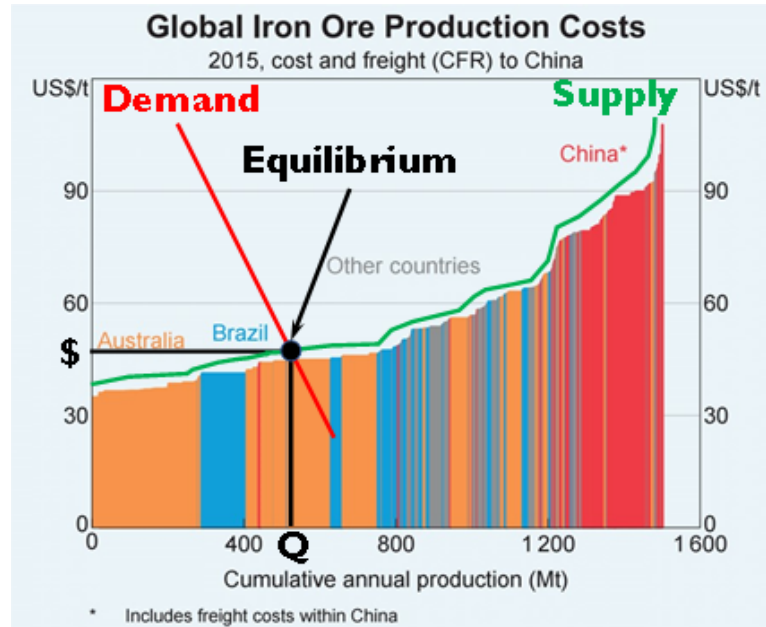


Paul Samuelson



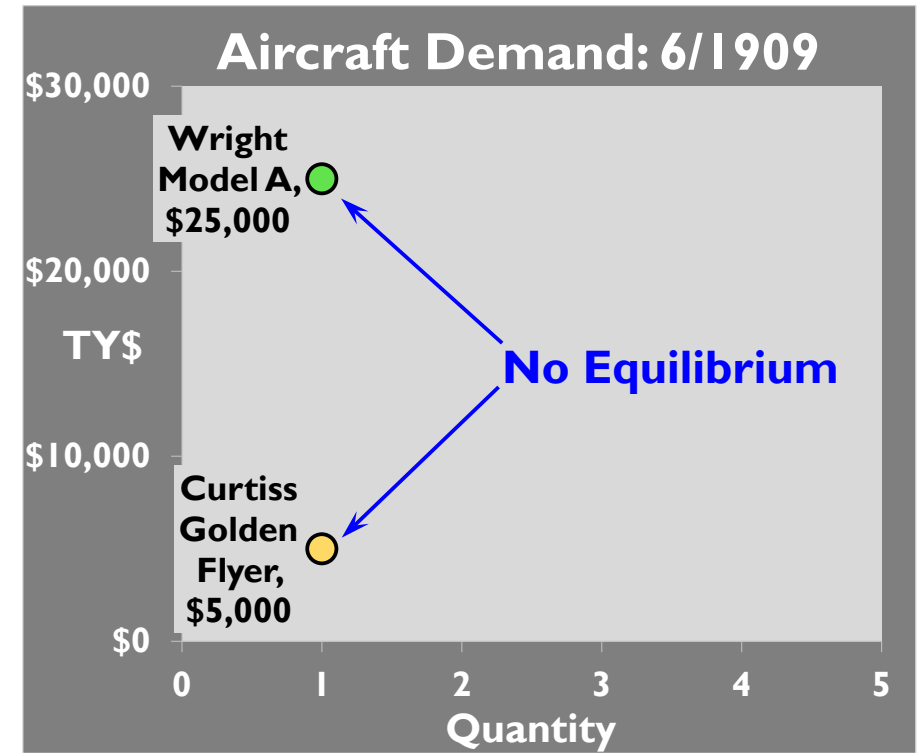
Wrote "the equilibrium price, i.e., the only price that can last... must be at this intersection point of supply and demand curves"

That construct applies to commodities



Planes use iron – what about them?

Aircraft market begins



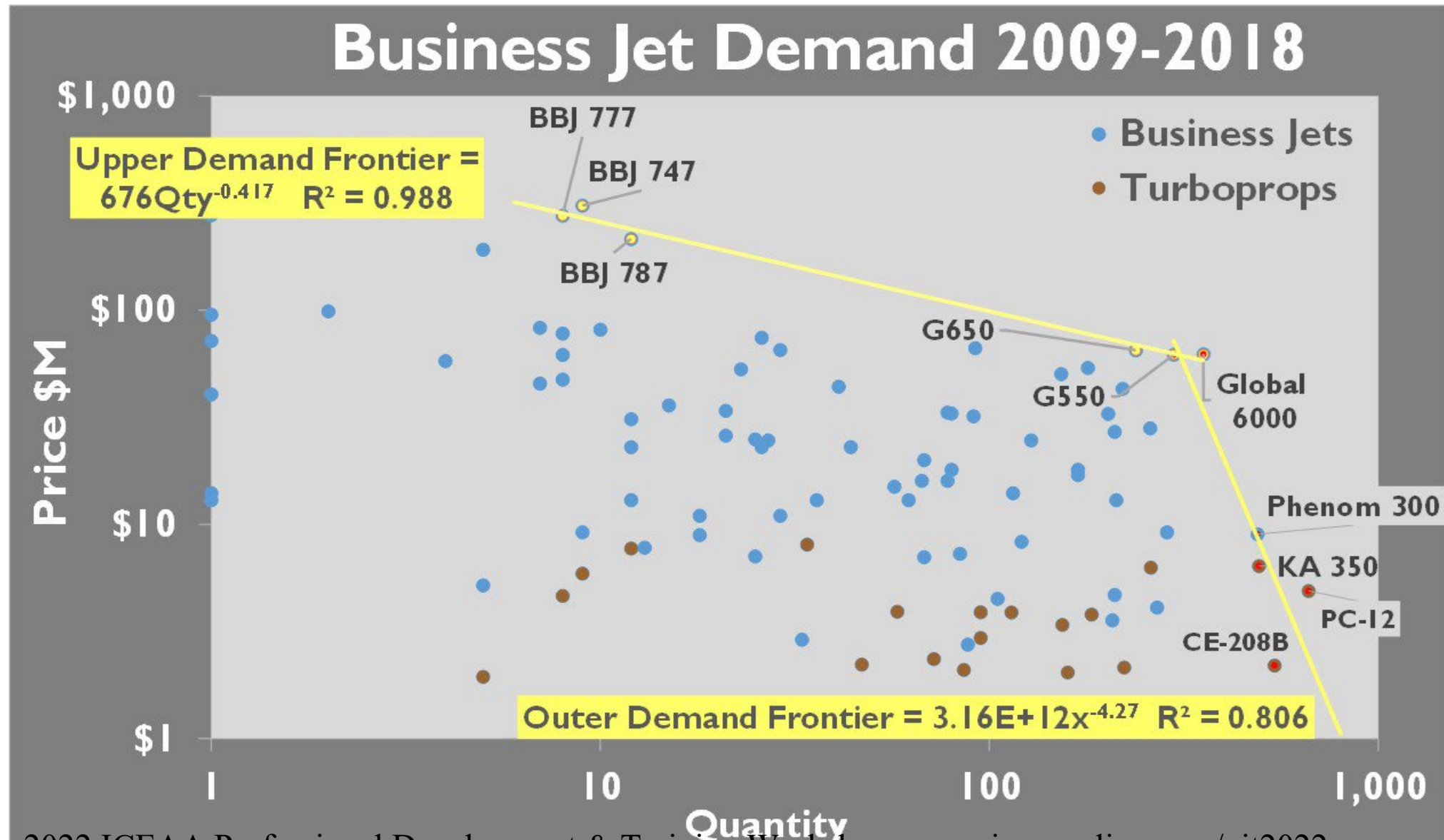
The Twins wonder – what if equilibrium states only apply to commodities? How do other markets behave?



Cristina Decides To Study Business Aircraft Demand



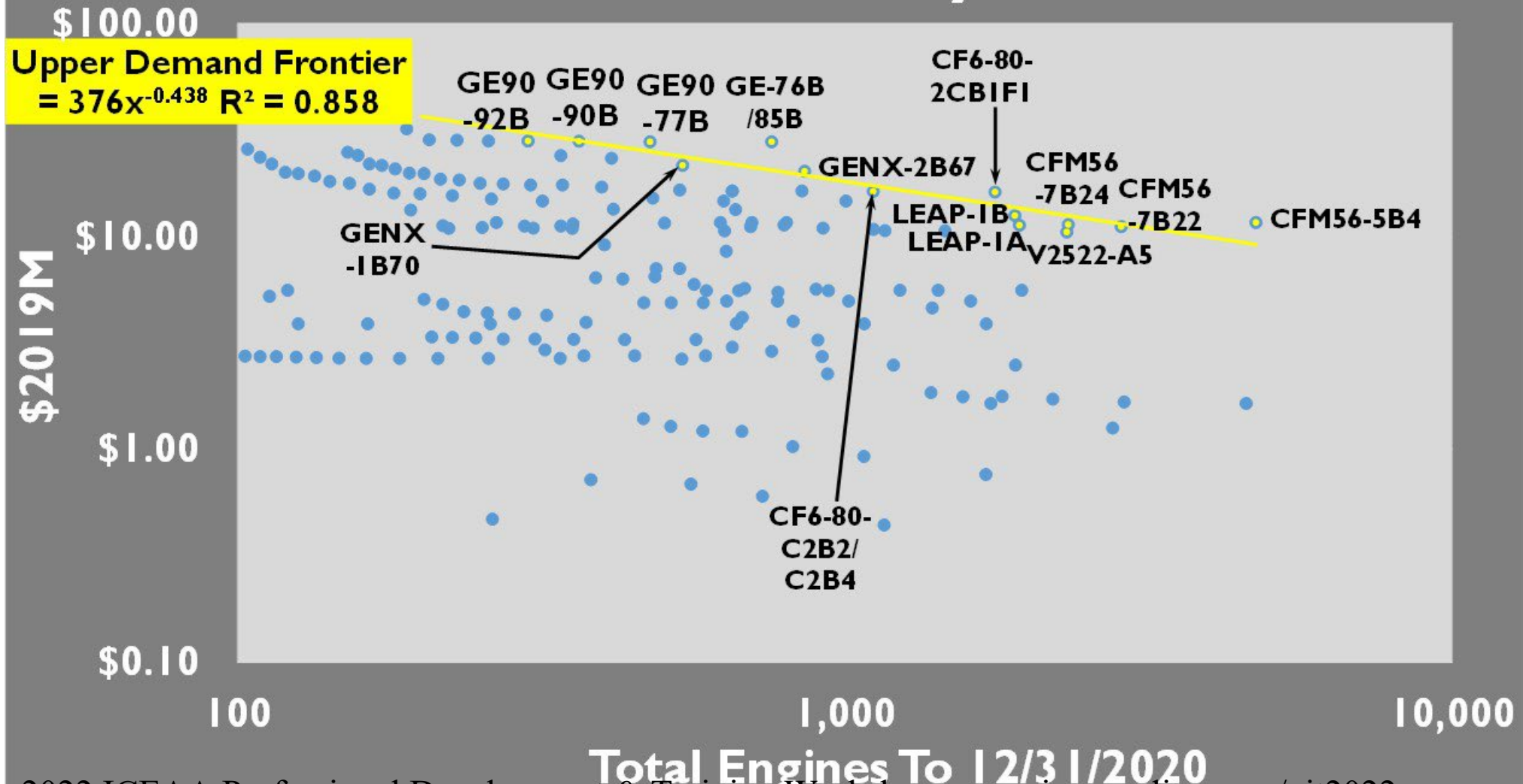
She finds a market with dozens of models in sustainable disequilibria (where their prices > their costs), one that self-imposes limits known as Upper and Outer Demand Frontiers, respectively



She Extends Her Analysis Into Their Turbofan Engines



Turbofan Demand By 12/31/2020



This market has a well-defined upper boundary as well

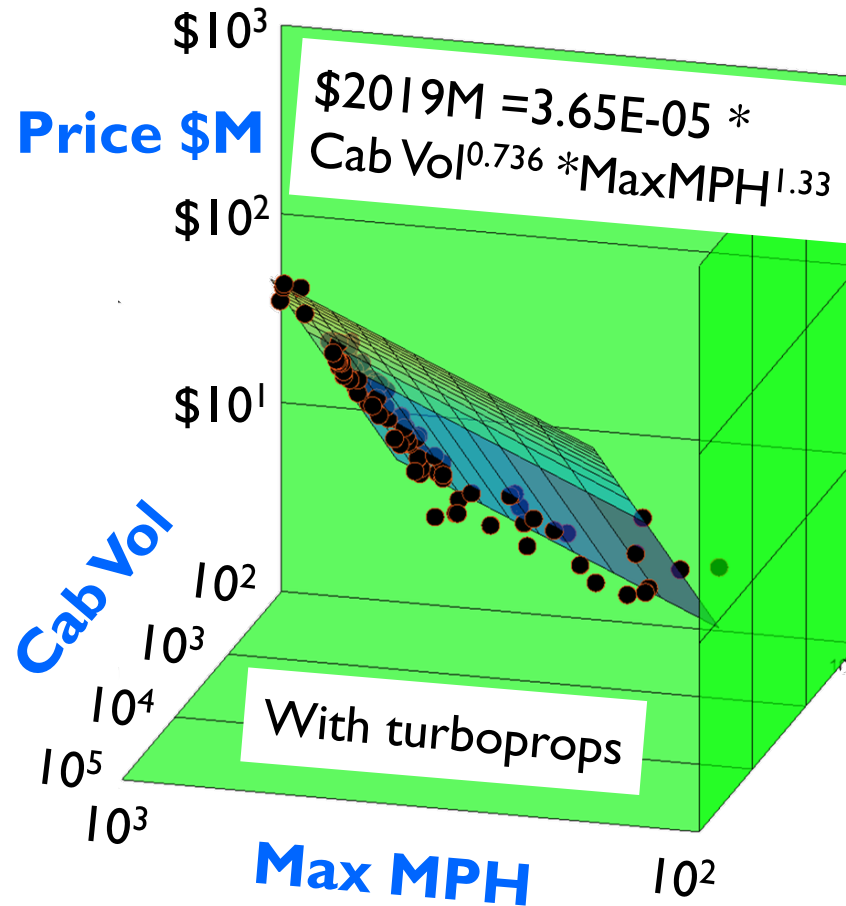


Sheila Examines Business Aircraft Features And Prices

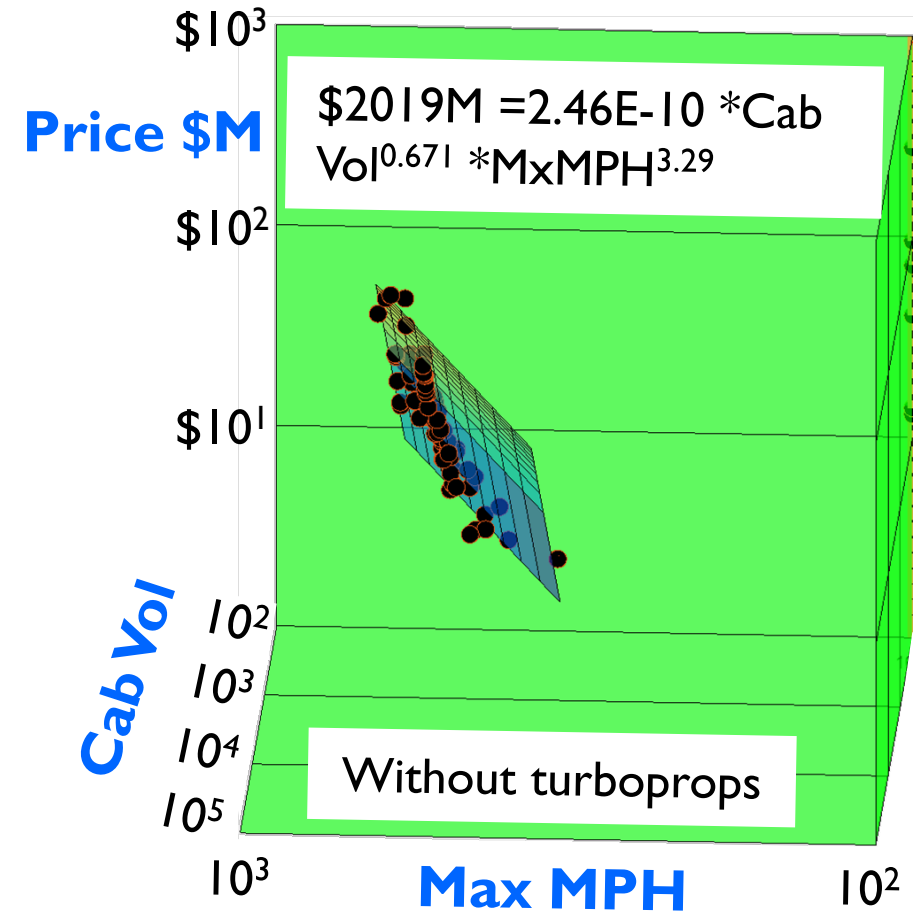


Sheila gets excellent results when she combines jets and turboprops

Her statistics improve when she removes turboprops, as jet owners place a high value on added top speed



Adj R² 96.4%; MAPE 19.3%

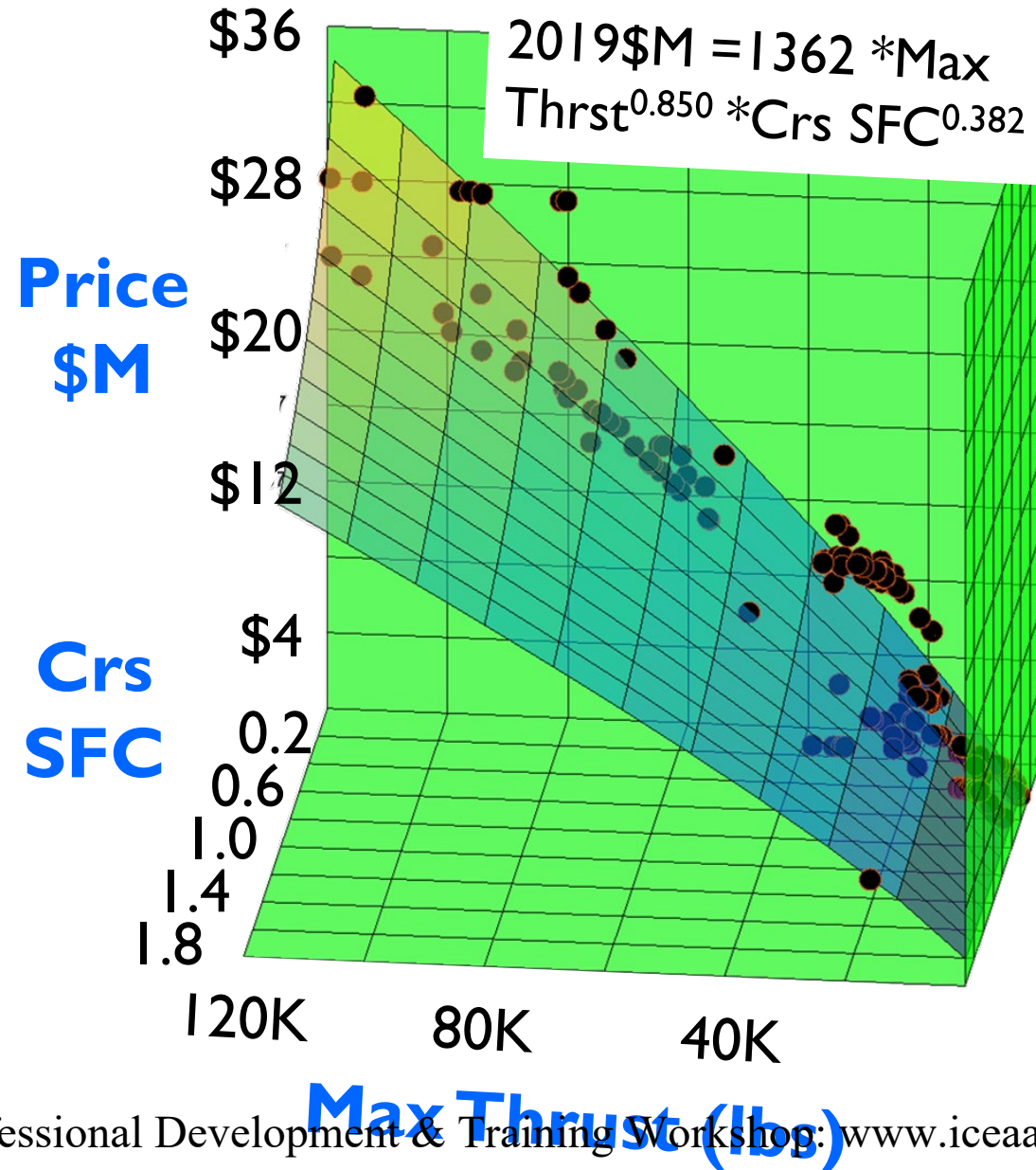


Adj R² 97.5%; MAPE 13.7%

Sheila Also Studies Turbofan Features And Prices



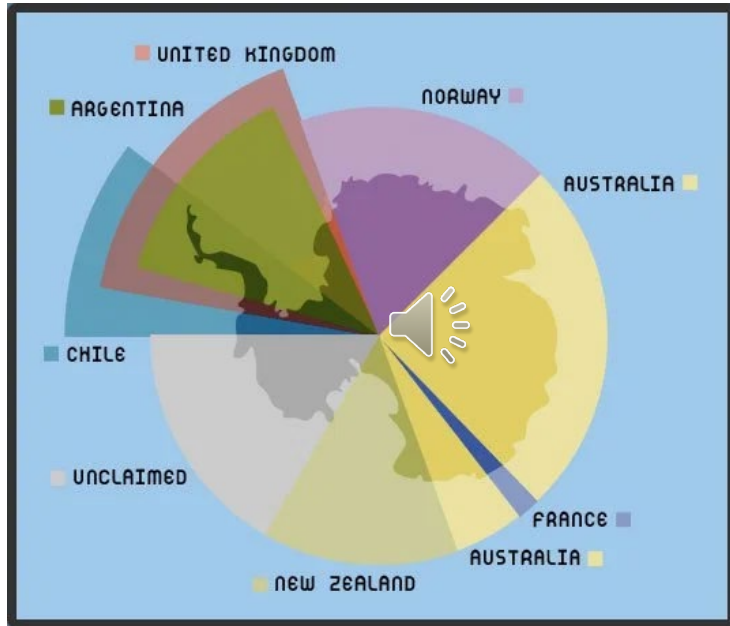
This market has stellar statistics as well, with an Adj. R² of 94.6%, a MAPE of 18.2%, and P-Values for Thrust and SFC of 9.51E-116 and 2.52E-06, respectively



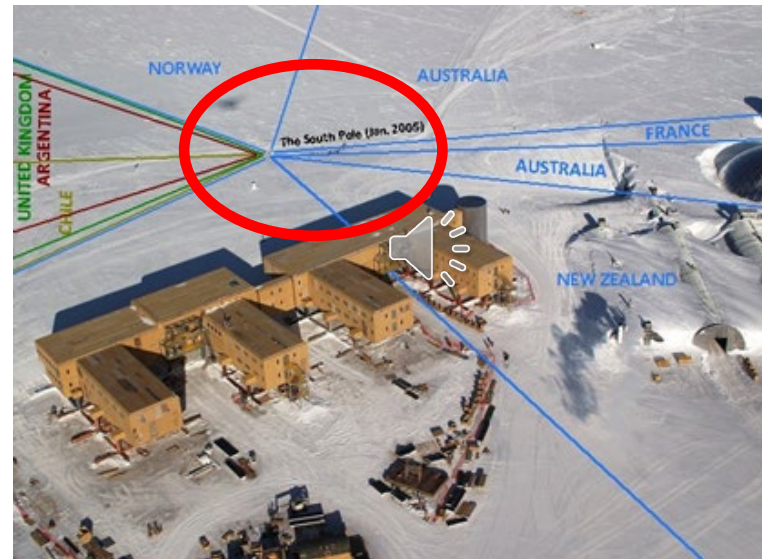
The Twins Want To View Their Analyses Side By Side



Australia and Argentina don't share a border



The Pole Position is close to the Amundsen-Scott South Pole Station



The South Pole marker...



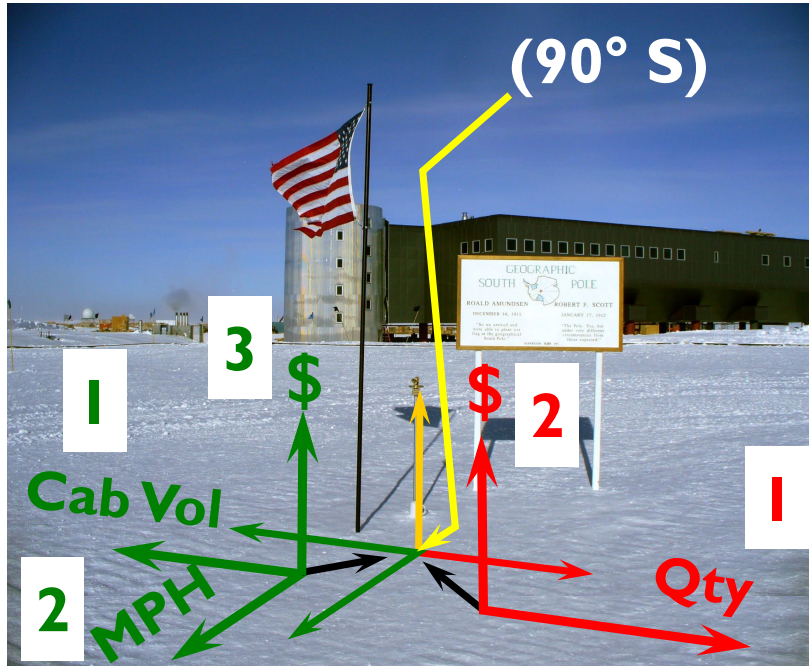
is repositioned as the ice moves over the continent

But their Antarctic claims meet at the South Pole, 90°S

Working Together, They Find A New Coordinate System

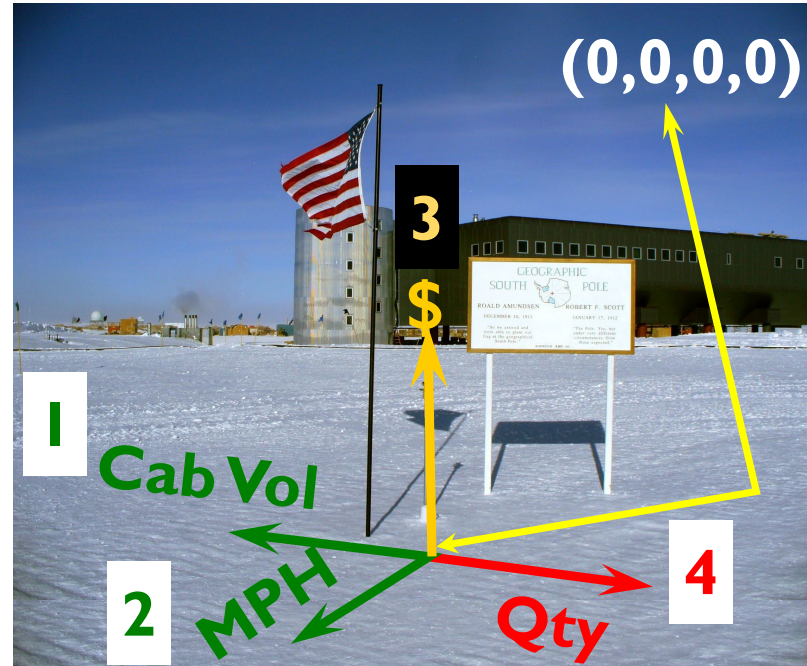


Each twin can put her model in her territory



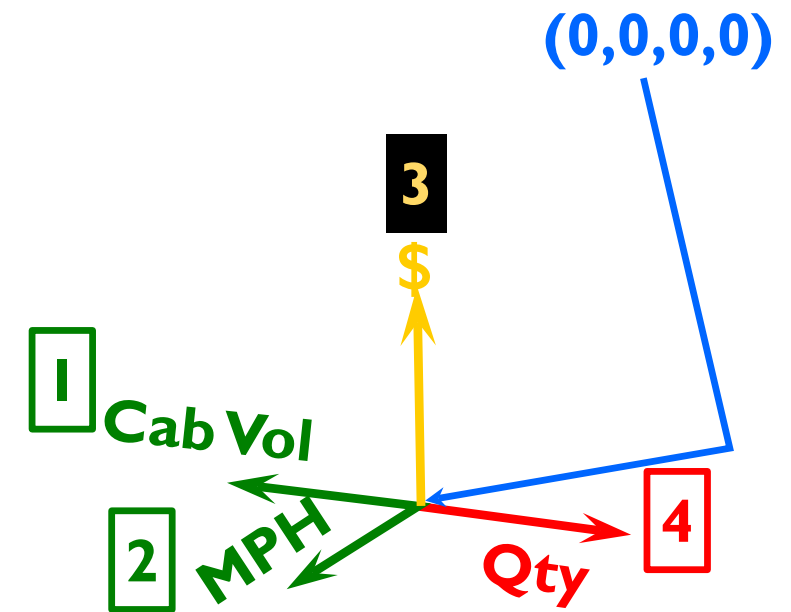
Cristina's 2D model falls in the Argentine claim, while Sheila's 3D model is within Australia's

They make some important observations



As 3D Value Spaces and 2D Demand Planes share a Price Axis, $3 + 2 = 4$, their origin changes from $90^\circ S$ to $(0,0,0,0)$

They find they do not need a physical reference



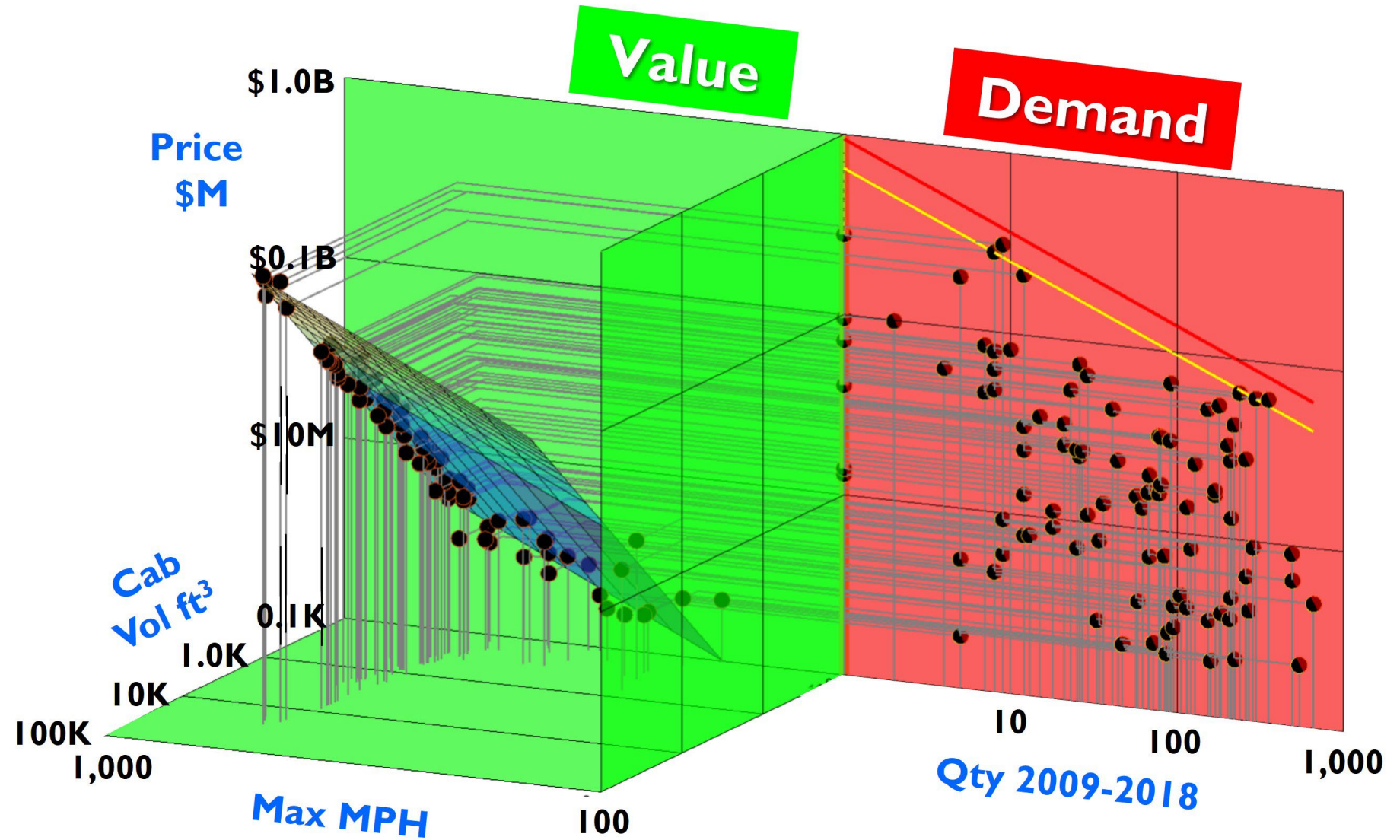
4D market models stand by themselves, with 2 Valued Features, Quantity, and Price, as their axes

They Plot Each Side And Realize They're Entangled



Every point in Business Aircraft Value Space has a match on the Business Aircraft Demand Plane

Every model has an ordered quad, as (Max MPH, Cab Volume, \$, Qty), or, more generally, (Valued Feature 1, Valued Feature 2, Price, Quantity)



Entanglement Reveals The Law Of Value And Demand

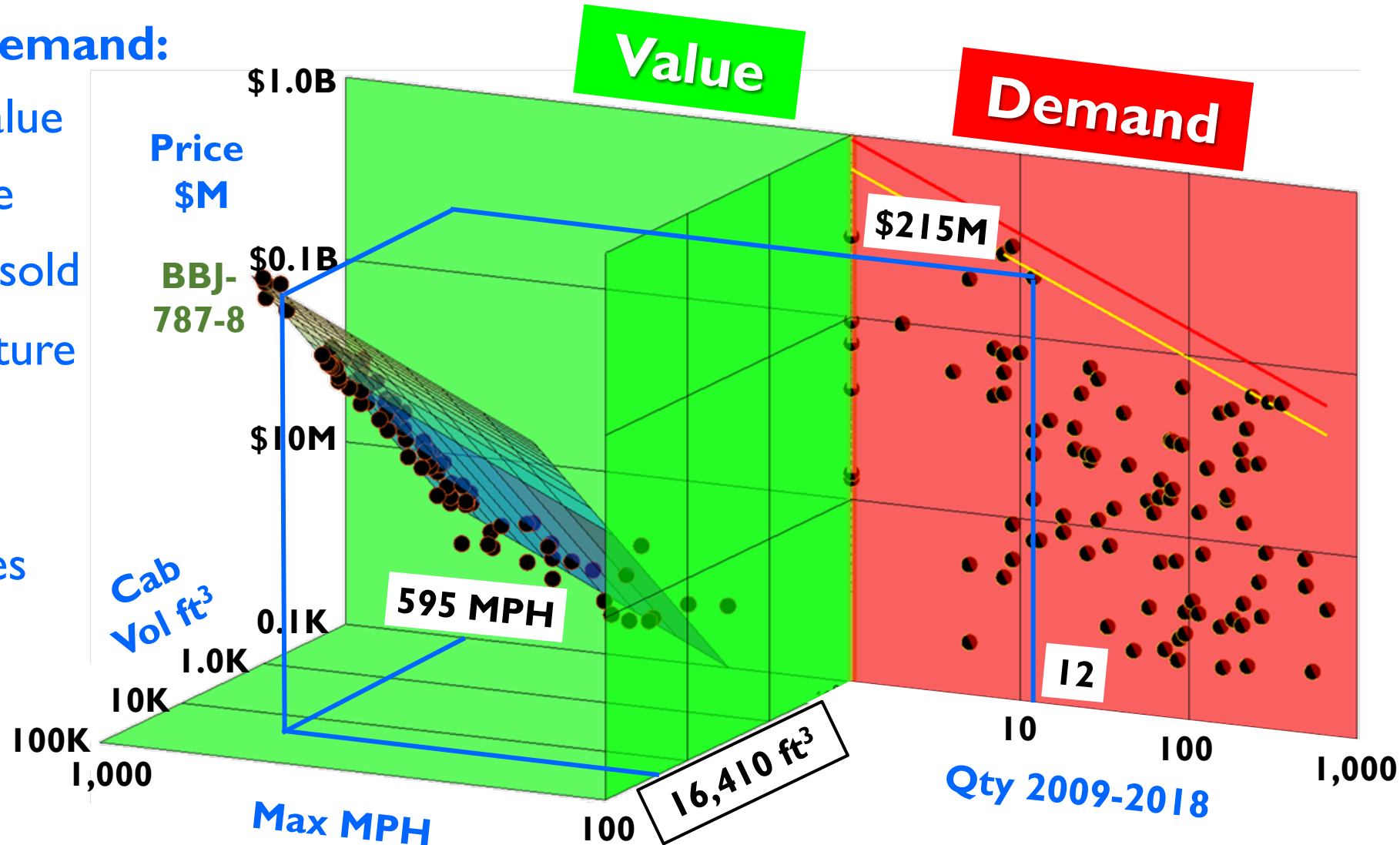


The Law of Value and Demand:

1. Features determine Value
2. Value determines Price
3. Price drives Quantity sold
4. Quantity sold is a Feature

Here's an example

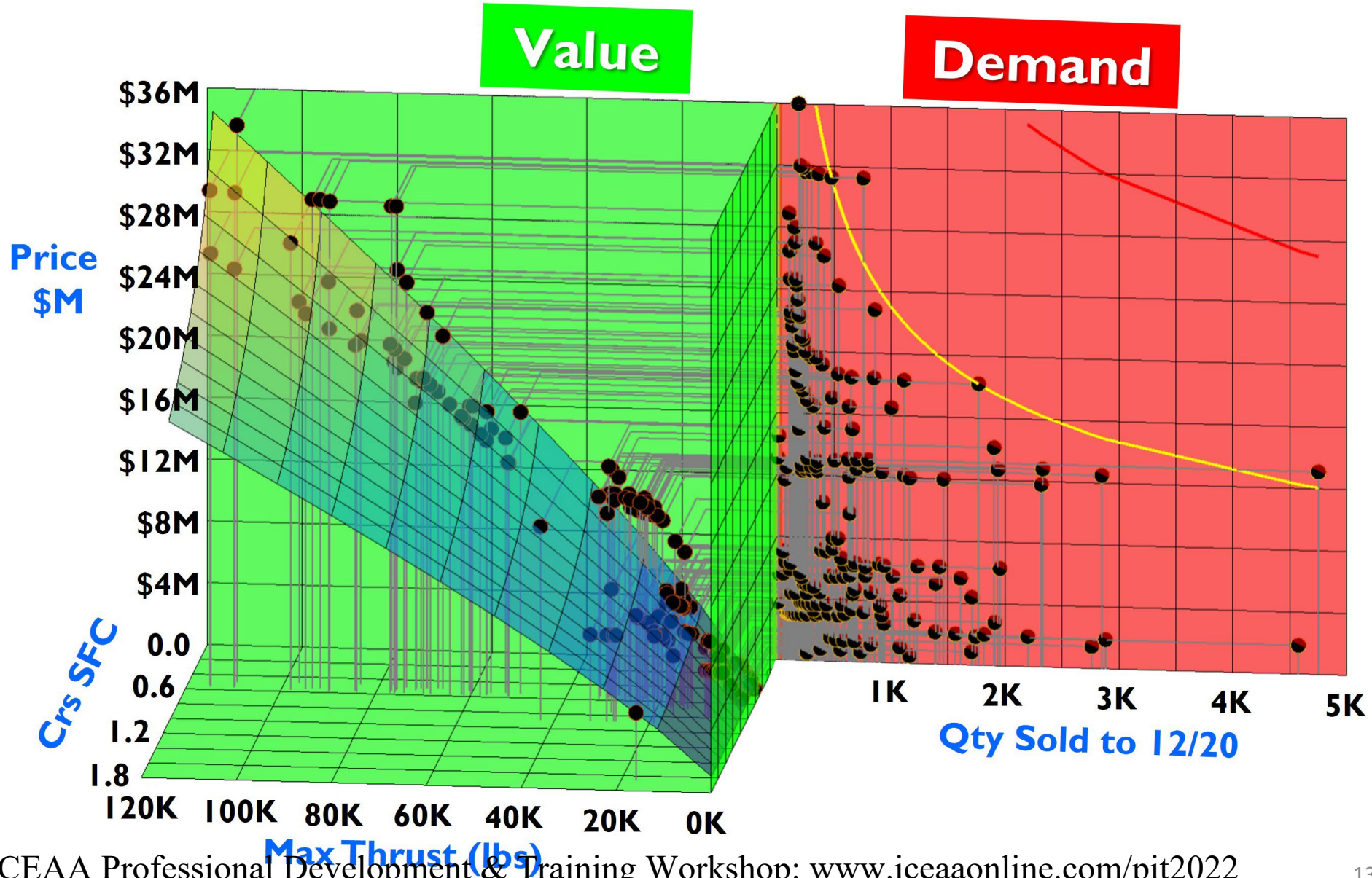
1. Valued BBJ 787-8 features
2. Those features set price
3. That price limits sales
4. Qty sold is a feature



Their Turbofan Work Reveals Entanglement As Well



If Value goes up,
Demand goes
down, as each
side entangles
with the other

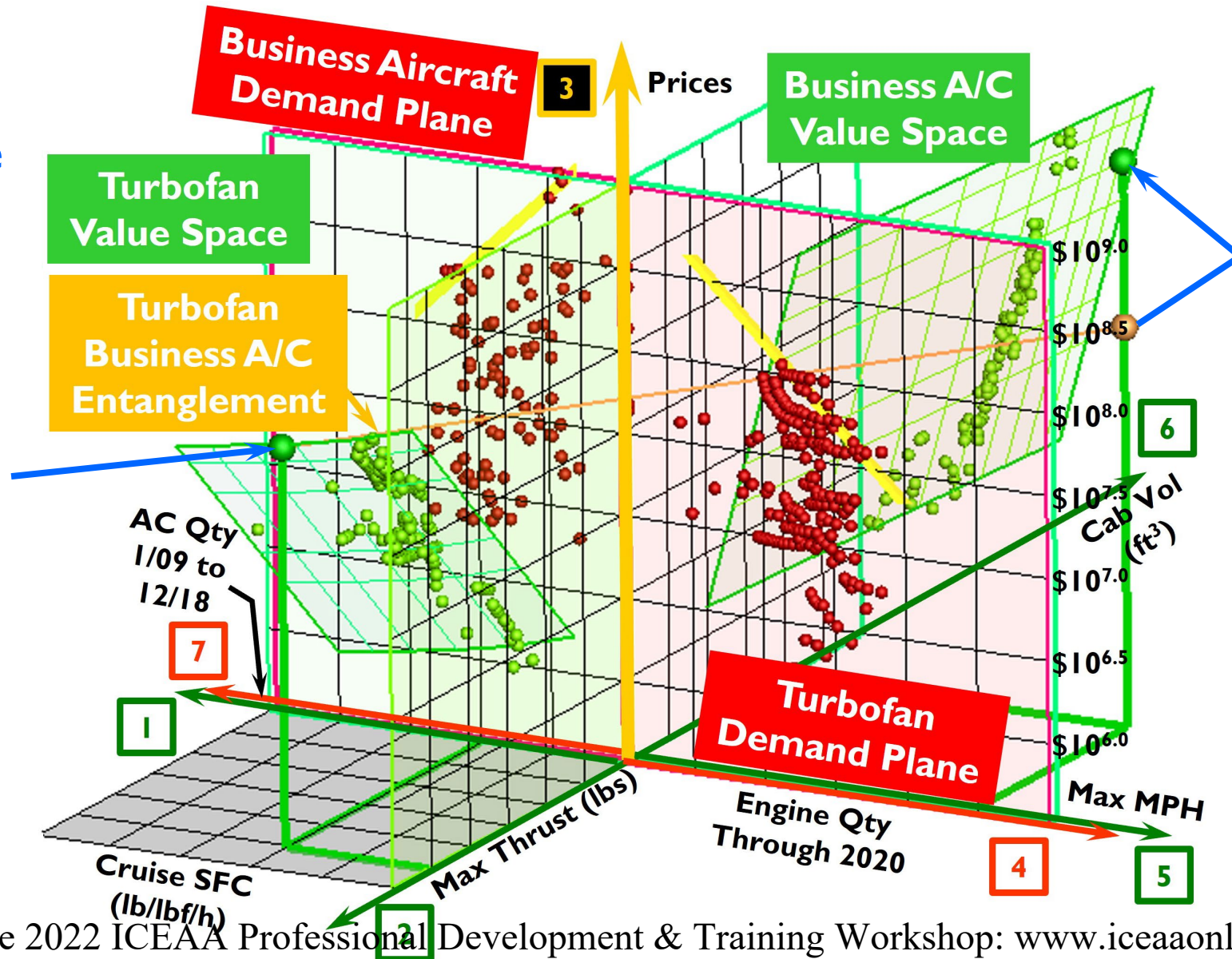


Since Jets And Turbofans Are Entangled, 4 + 4 = 7



The 4D turbofan market shares the Price axis with the 4D business aircraft market, thus, $4 + 4 = 7$

Any new engine



Needs at least 1 jet aircraft model to use it; engines are a large portion of a jet's cost

7D Analysis Enables 7D Trades

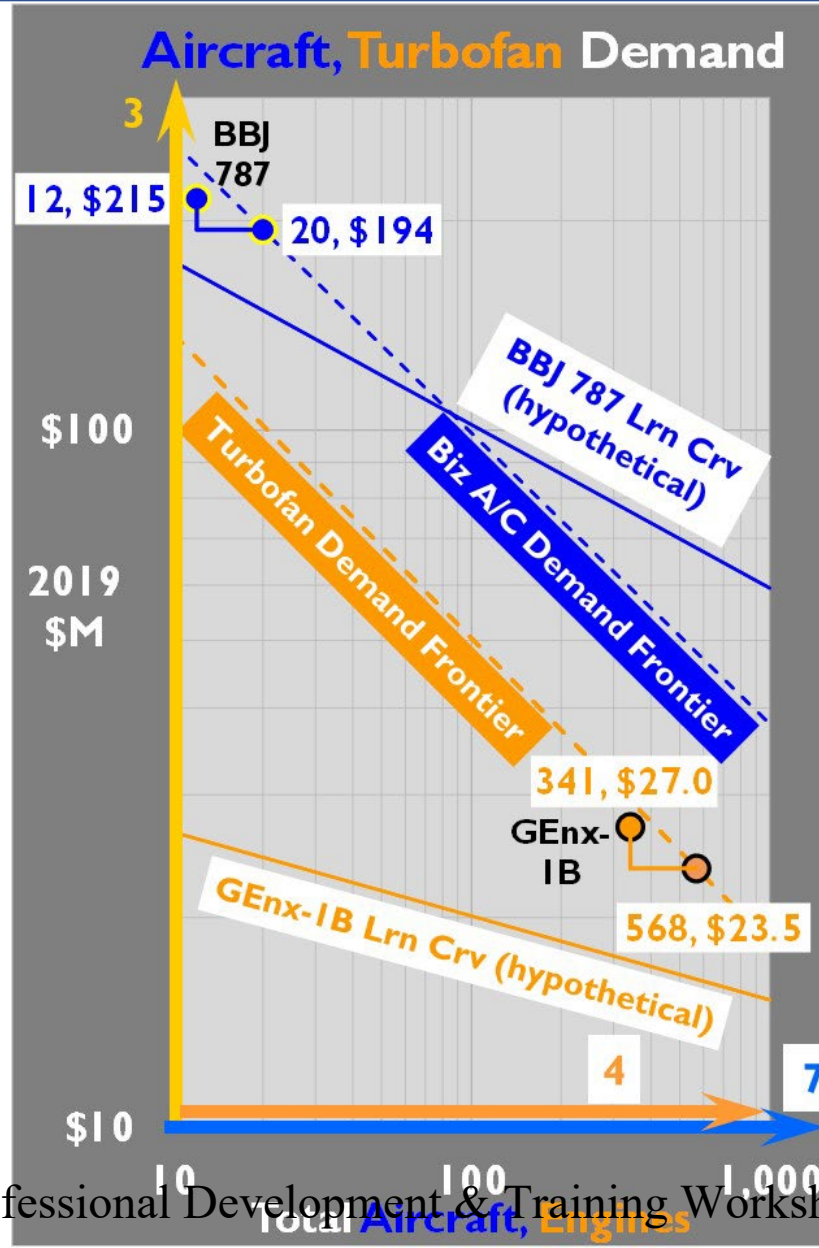


Consider the BBJ 787



Its Demand Plane uses Dimensions 3 and 7

The Demand Plane for one of its engines, the GEnx-1B, uses Dimensions 3 and 4 (here, those Demand Planes are superimposed on each other)



BBJ 787 presses its Frontier – More sales require price drop; to do this profitably, Boeing must know its learning curve

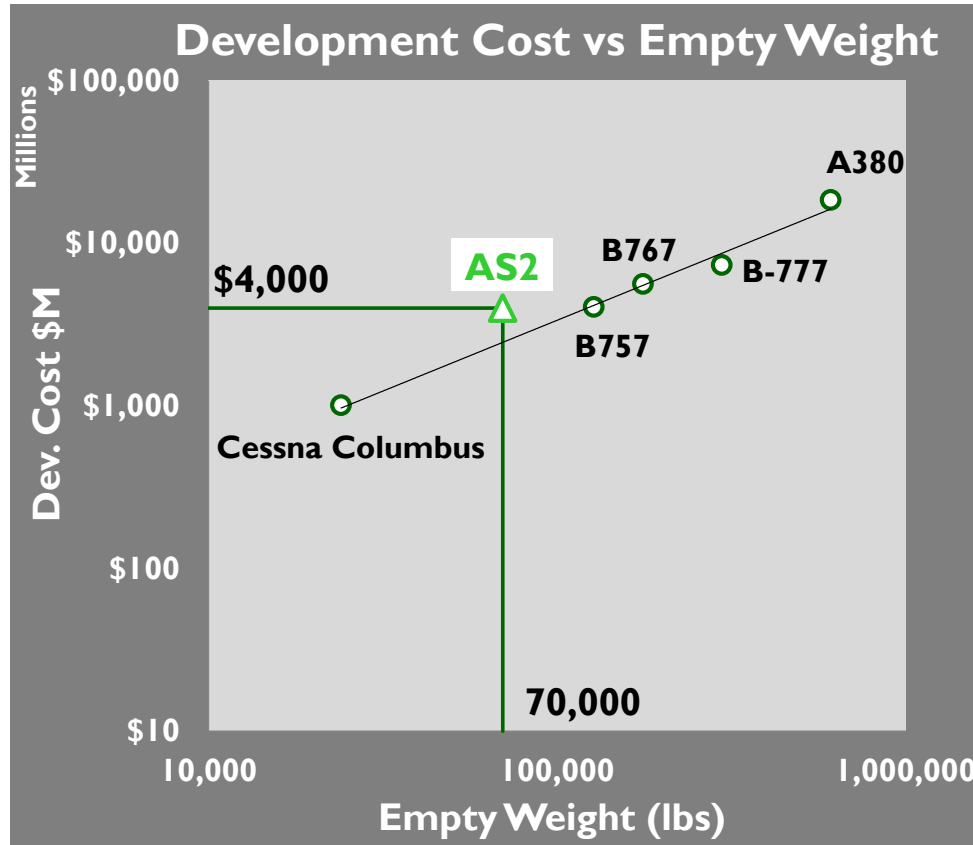
~ 25% of BBJ 787 cost is in its engines – Boeing needs lower costs to sell more BBJ 787s

Lower GEnx-1B prices could help GE; that engine abuts its Demand Frontier

The Twins Study Aerion AS2 Supersonic Business Jet



Aerion AS2, 925 Max MPH, 1146 ft³ volume, 70K lbs empty weight



They compare its projected development cost to other models, find it 62% higher

Using 1987 RAND model (with supersonic jets) they find cost ratios for the added AS2 speed

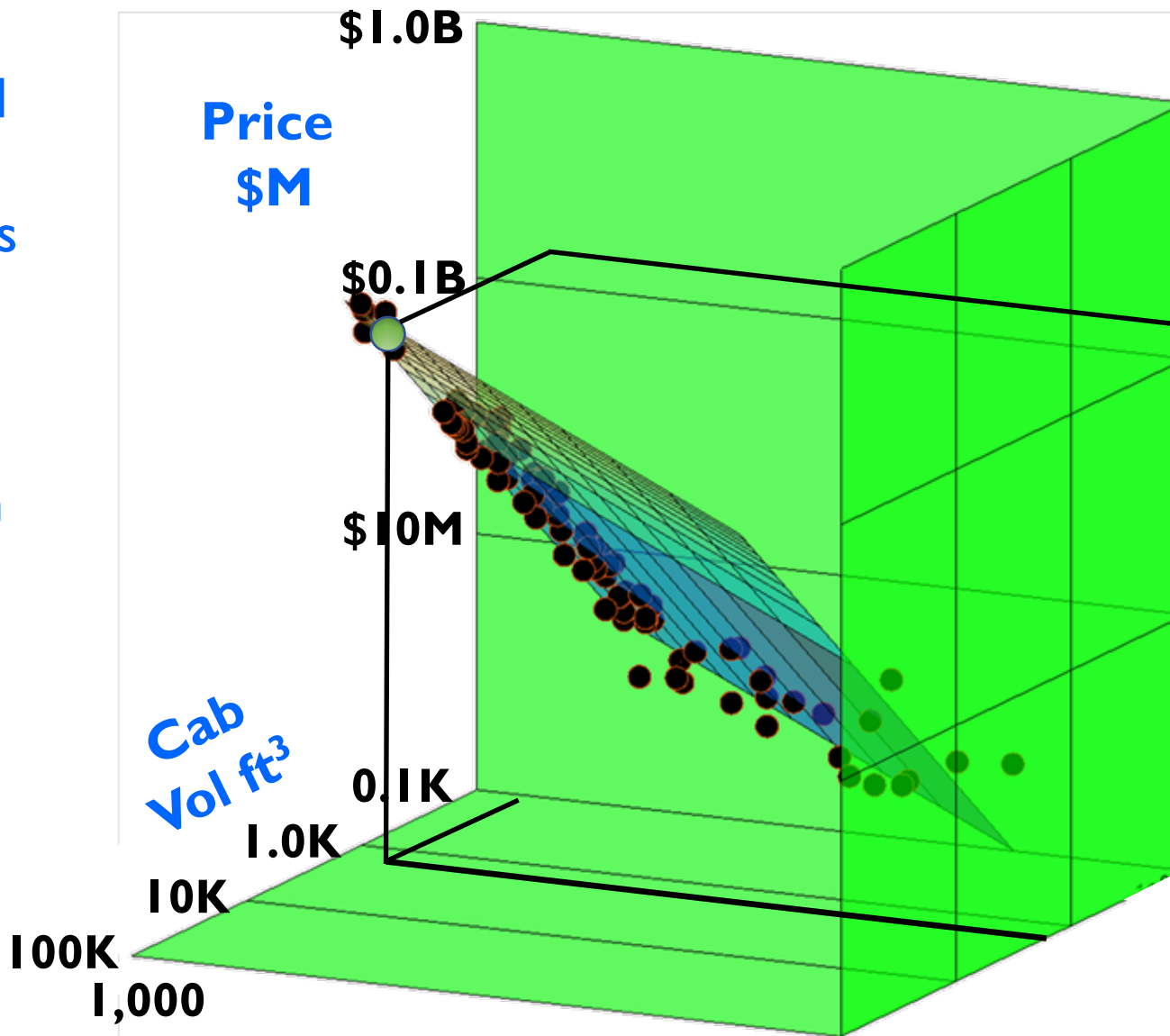
Discipline	RAND Exponent	Cost Ratio
Engineering	1.030	160%
Tooling	0.609	132%
Mfg. Labor	0.429	122%
Material	0.811	145%
Design Supt.	1.280	179%
Flight Test	1.270	178%
Program	0.745	140%

They conclude its development cost estimate appears sound

Sheila Calculates AS2 Value



Using the second equation from Slide 7, she figures the sustainable price of the Aerion AS2 to \$160M, based on its top speed of 925 MPH, and cabin volume of 1146 feet³



With a top speed ~ 50% higher than any other plane, this \$160M estimate is an extrapolation

But this analysis, and their 20 firm orders from Flexjet seems to justify their \$120M price tag

But what about Demand?

The Twins Imagine Markets As Regions In Space

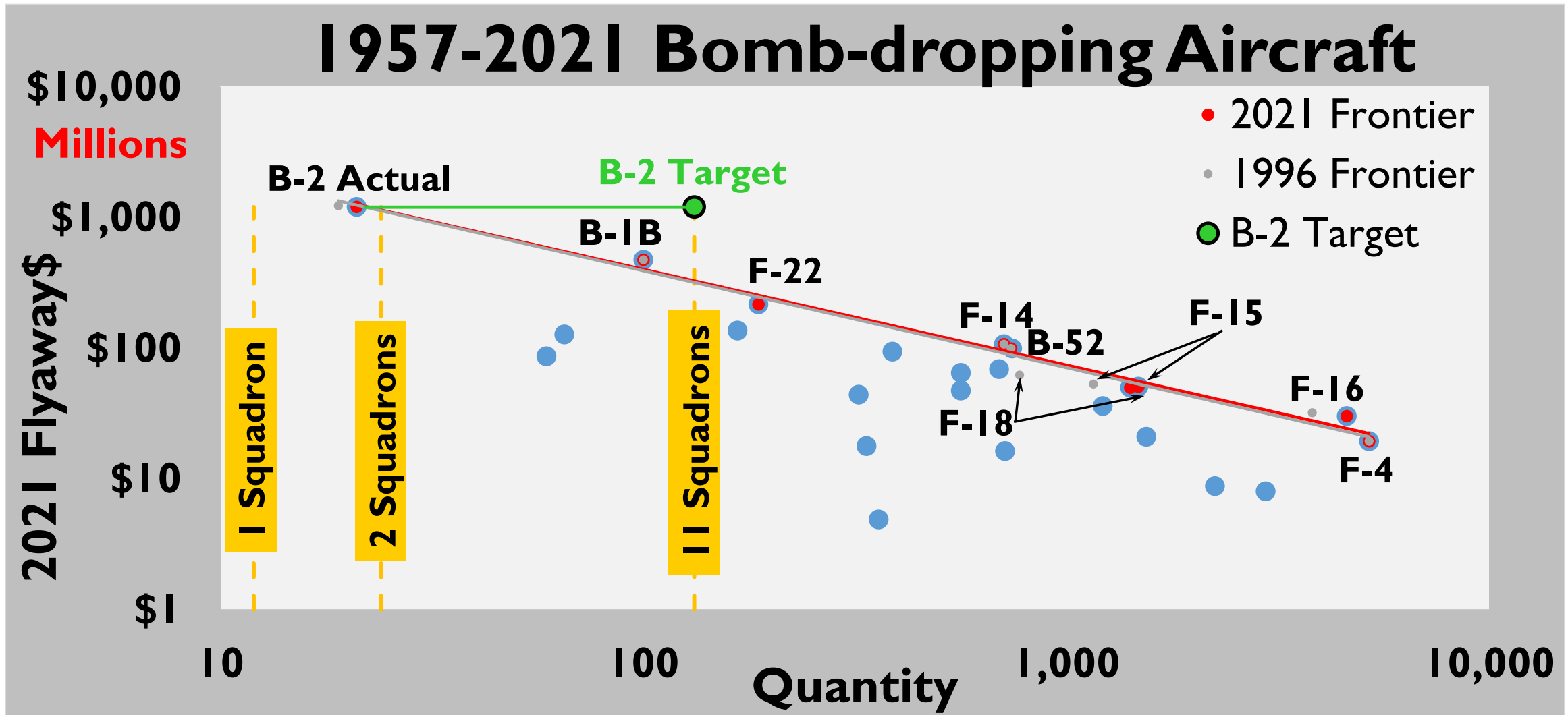


They hypothesize that markets may observe the economic equivalent of Newton's First Law of Motion:

An object at rest remains at rest, and a moving object will continue to move straight and with constant velocity, if and only if there is no net force acting on that object.



Demand Moves Slowly, If At All, In Some Markets



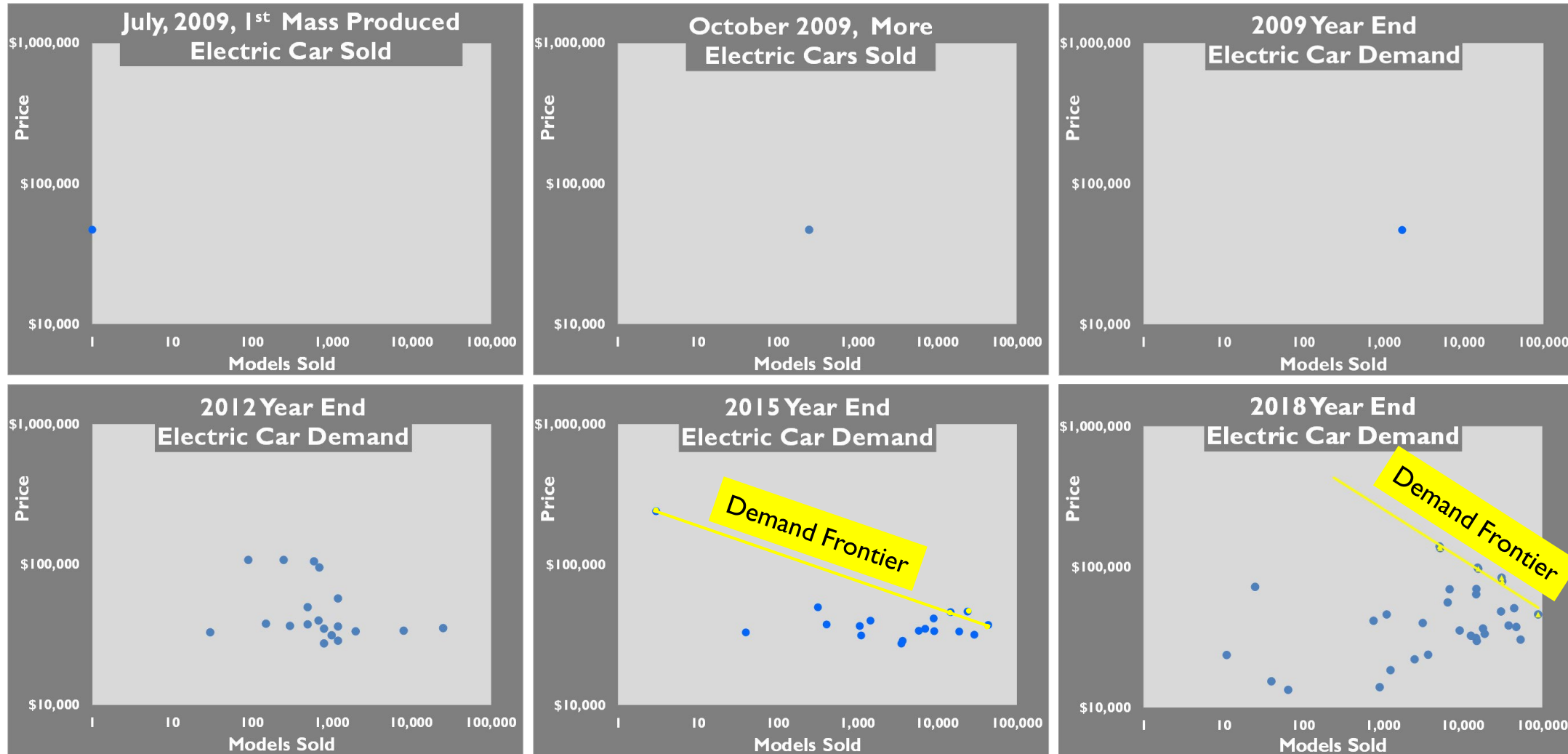
The US bomber-dropping aircraft Demand Frontier moved 2% in 25 years. Its stability explains why the B-2 bomber only sold 21 of 132 units bought - its Demand Frontier is at 2023.

Presented at the 2022 ICEAA Professional Development & Training Workshop. www.iceaonline.com/pit2022

Demand Changes Quickly In Some Markets

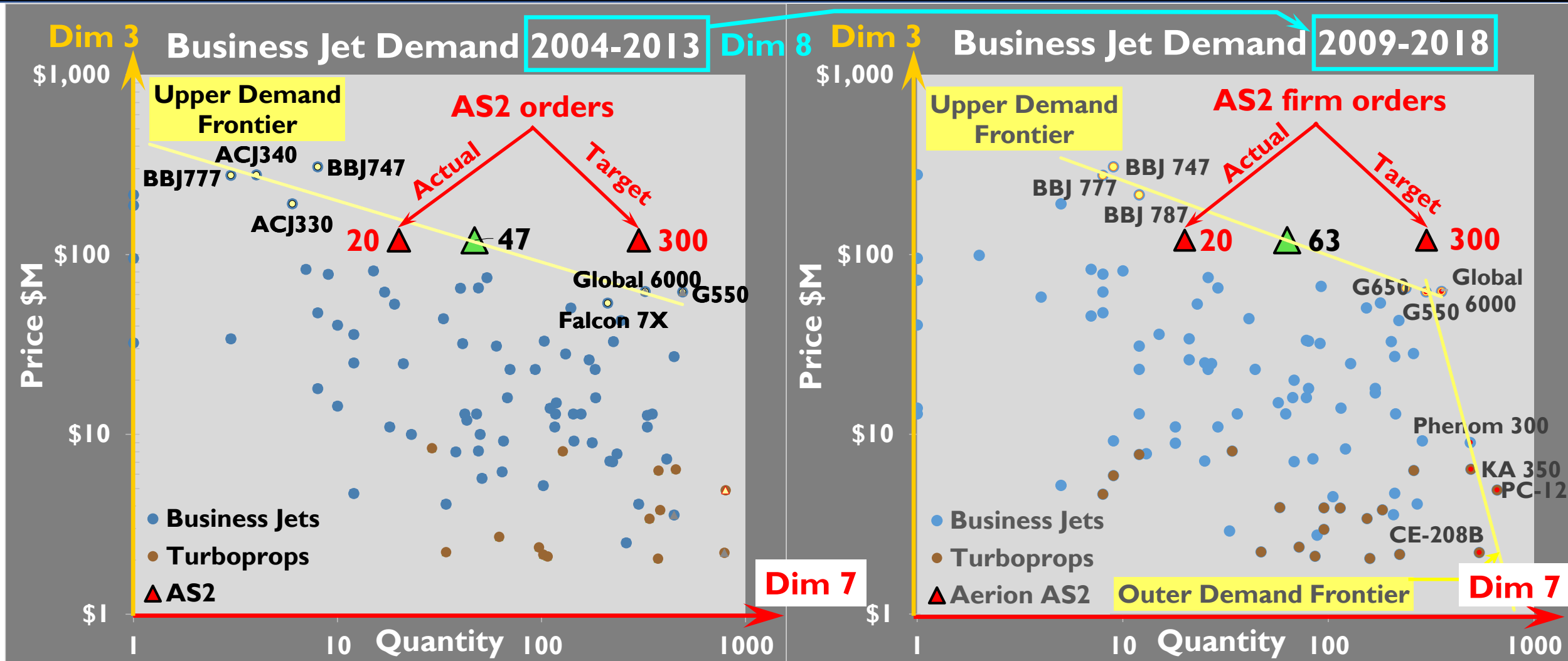


The mass-produced electric car market began with a single model, the Mitsubishi I-MiEV, and grew from there



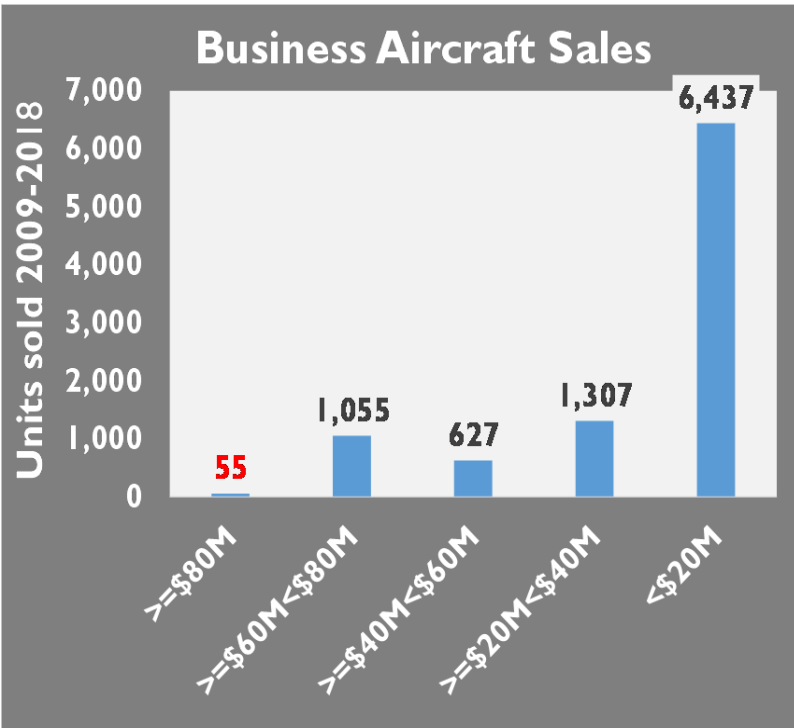
Demand for electric cars accelerated from 2015 to 2018. Future predictions need complete 2021 data to project Demand Frontiers over time.

Bizjet Demand Moves Slowly, As 7 + 1 = 8 Reveals

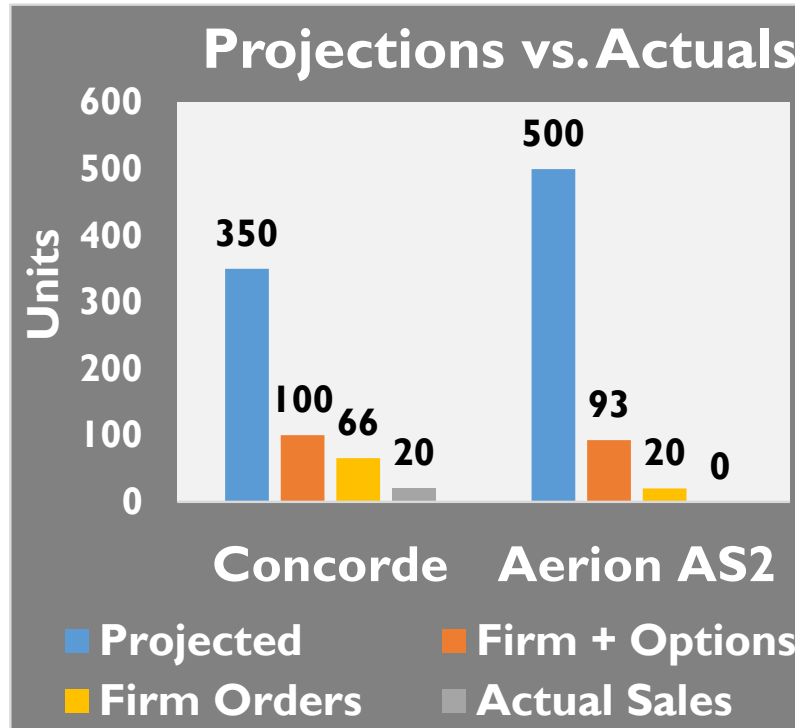


Take Slide 13's 7D view (right), add Time (back 5 years, left) to get an 8D market view. Half of the right-hand data is in the left's; the timeframes entangle. They reveal slim target chances.

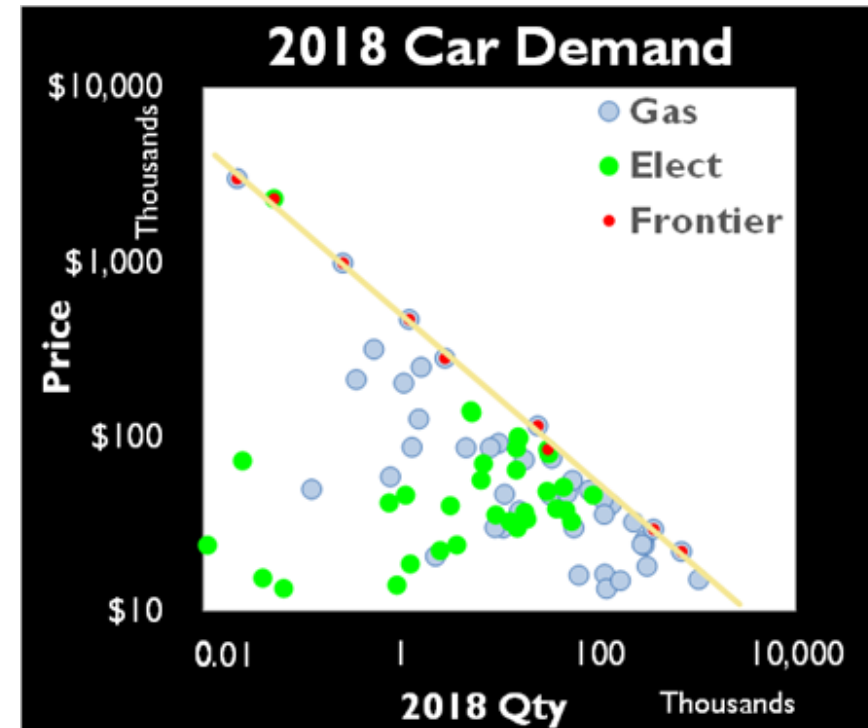
Other Ways To Evaluate The Demand Frontier Include...



The twins find the business aircraft market only sustained 55 units worth \$80M or more for a decade; market support for 300 units at \$120M is not apparent



Comparisons to the last supersonic commercial jet are useful; the Concorde had government backing and did slightly better than the AS2



Some argue supersonic aircraft form an entirely new market; proponents of electric cars may claim the same thing, but as of 2018, electric and gas cars had the same Demand Frontier



- Economic entanglement is ubiquitous
 - Value entangles with Demand
 - Markets entangle with each other
 - One company's prices is another's costs
 - Often, especially at the market limits, known as Demand Frontiers, one product cannot sell more units without supplier cost concessions
 - Yesterday and today entangle with tomorrow
- An accurate cost estimate is not a sufficient condition for success – see AS2
- Thorough estimators will analyze not only their target product, but their prime market and those of their important and closely tied suppliers as well
- Broad estimates should consider: Cost, Schedule, Risk, Value, Demand, & Time



