Trade Space, Product Optimization and Parametric Analysis

Doug Howarth

Lockheed Martin Aeronautics Company
Advanced Development Projects Palmdale, CA

2011 ISPA/SCEA Joint Annual Conference

Where were all of These People Going?

At noon, on September 16, 1893, once the cannon went off, they were headed to Oklahoma

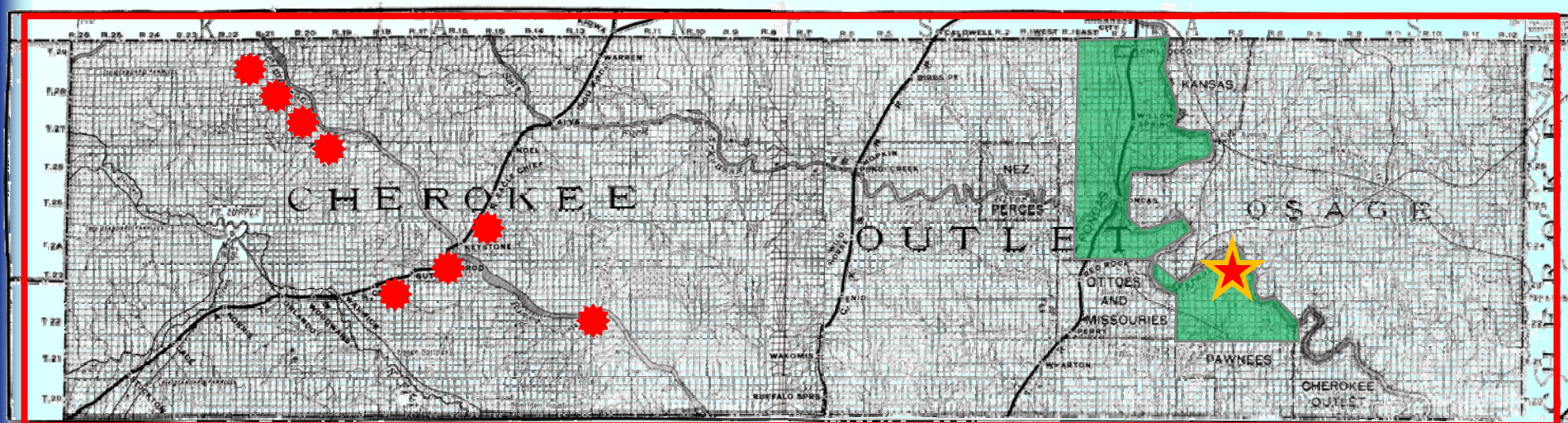# *This was the 4ᵗʰ Oklahoma Land Rush*

About 100,000 people raced for 42,000 parcels – These were "Boomers"

Some plots were already occupied by those who jumped the gun – "Sooners"

What Boomers Discovered…

Some excellent positions were already occupied…

But other promising regions were untouched…
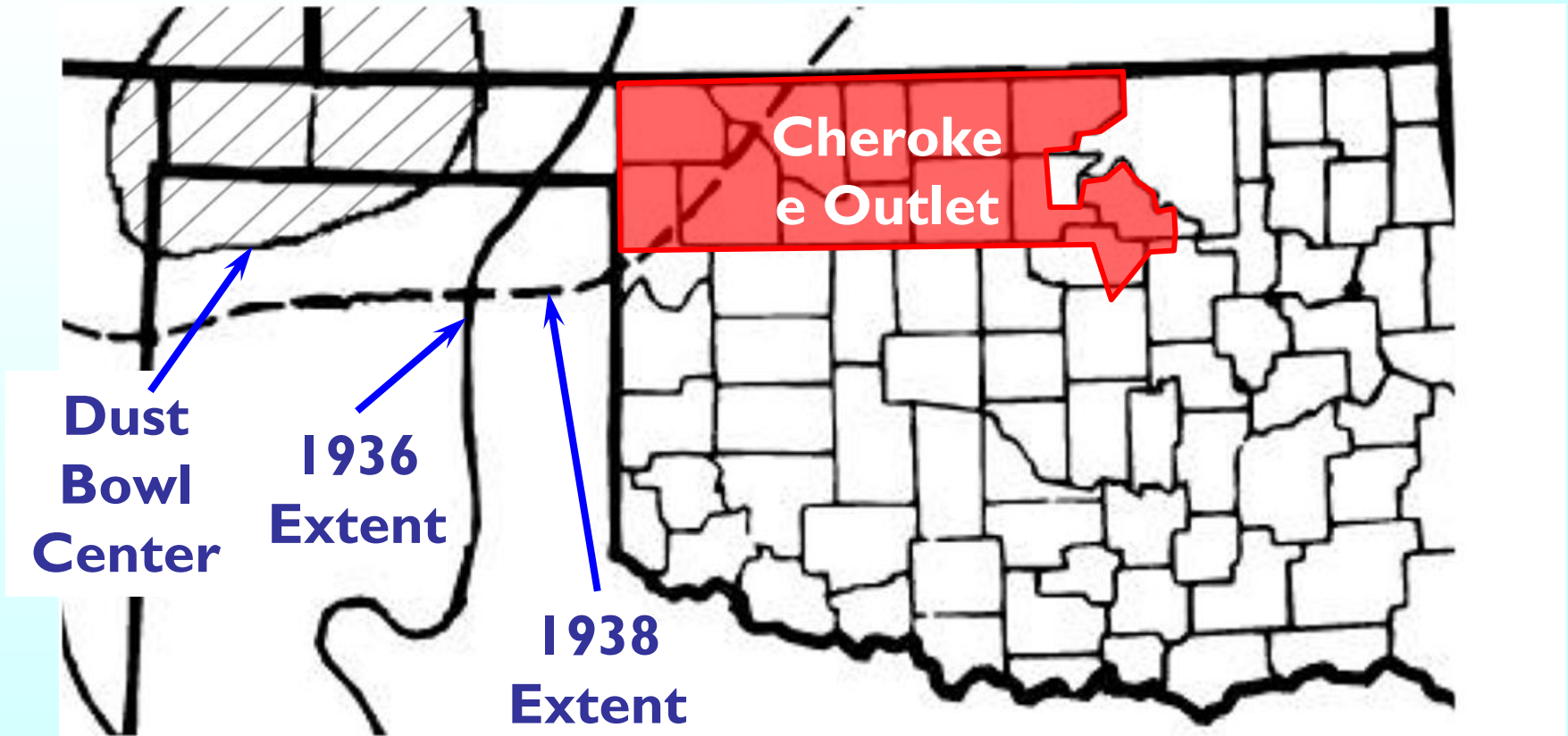

There were optimal sites that remained open

Who knew where the best spots were?

Some found the bad places...

An Oklahoma Dust Bowl storm in the "Dirty 30's"

The Dust Bowl Hit NW OK Hard…

Dust Bowl Center
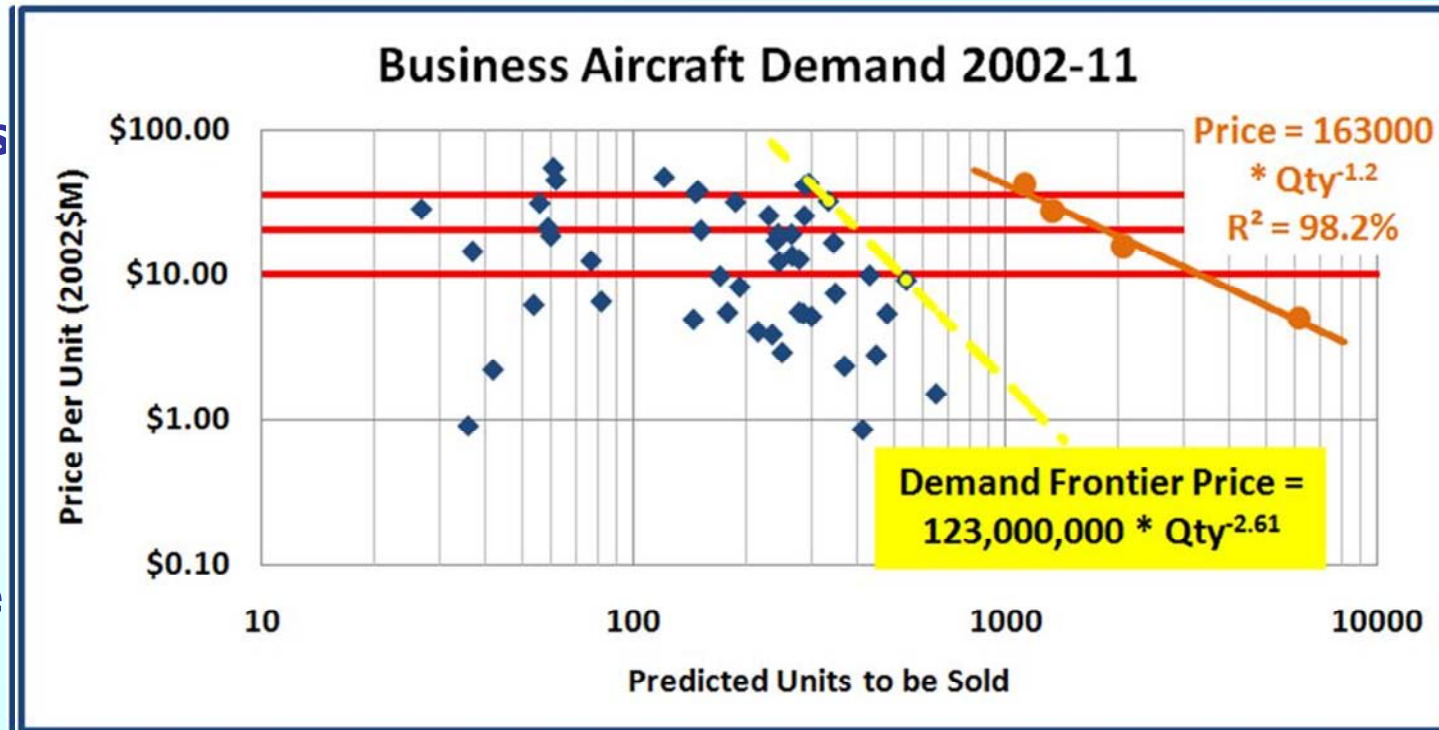
1936 Extent

1938 Extent

Cherokee Outlet

Some people discovered that they had picked a suboptimal position

Markets display similar phenomena

Consider these 46 Business Aircraft

Which range in price from <$1M to >$50M

We can parse them into bins and sum up the total quantity & average price in each bin to for Aggregate Demand

Business Aircraft Demand 2002-11

$$Price = 163000 * Qty^{-1.2}$$
$$R^2 = 98.2\%$$

Demand Frontier Price = $123{,}000{,}000 * Qty^{-2.61}$

Price Per Unit (2002$M)

$100.00 / $10.00 / $1.00 / $0.10

Predicted Units to be Sold — 10 / 100 / 1000 / 10000

By striking a line through the two outermost points, we can draw a Demand Frontier too

This data is useful, but needs augmentation

Note these Price Gaps

Business Aircraft Demand 2002-11

Demand Frontier

Preice Per Unit (2002$M)

Predicted Units to be Sold
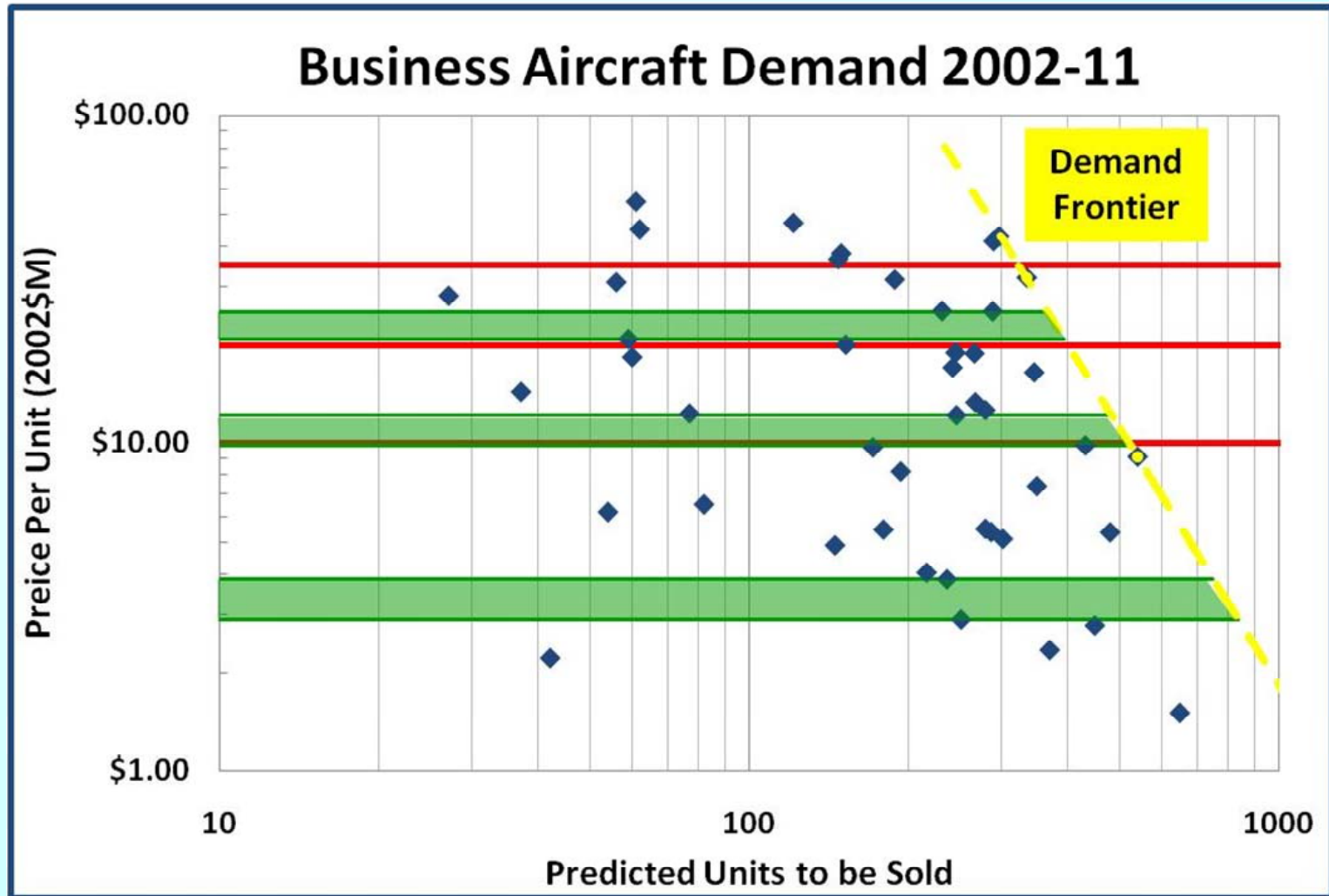
Question: What supports these prices?

Why Does…

A Boeing Business Jet[1] Sell for > a Socata TBM 700[2]?

Value Theorists explain value in terms of *Currency ($, £, €, etc.)*
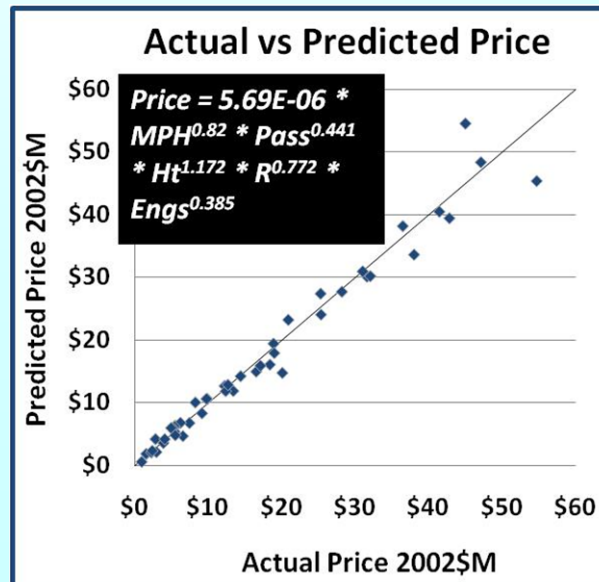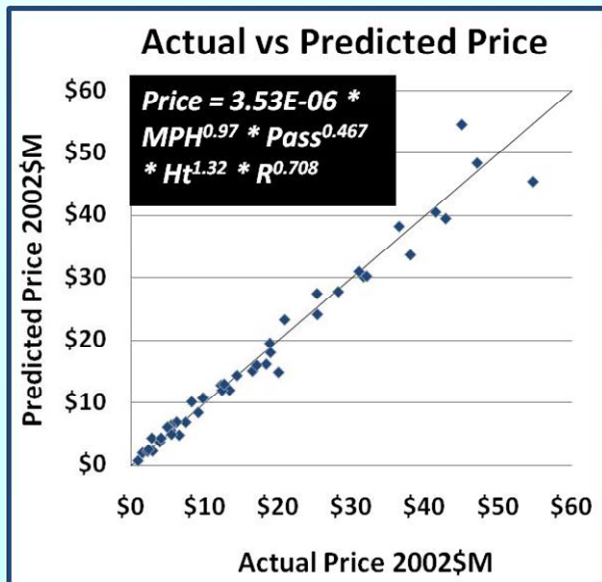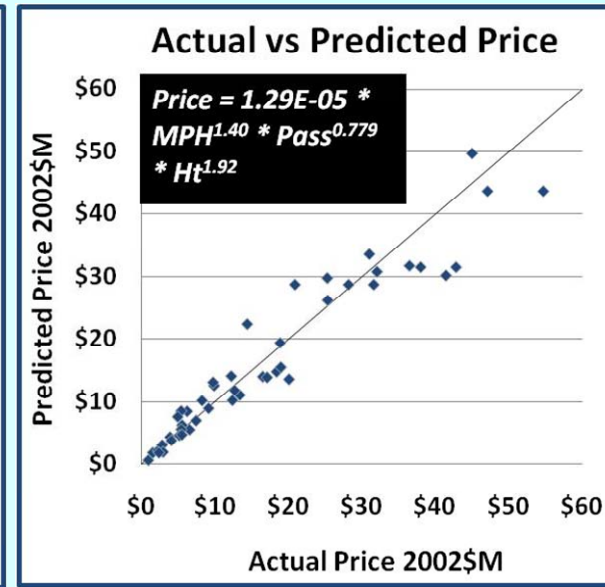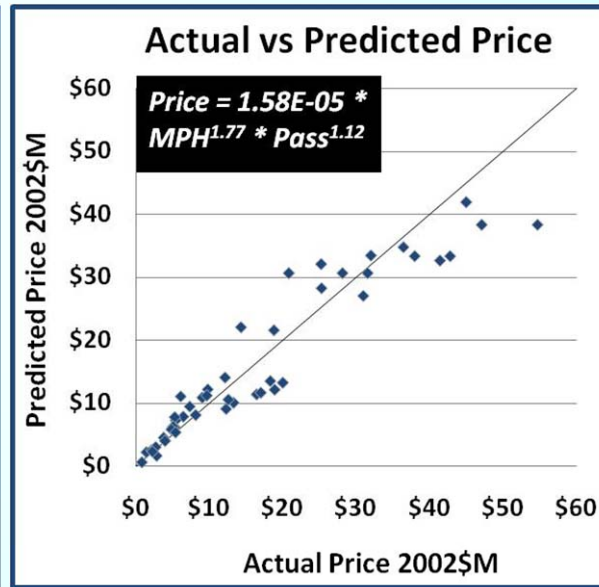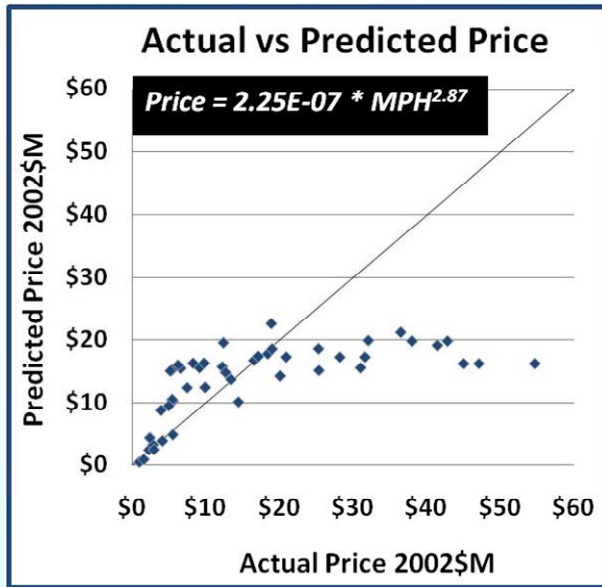
$$V_m = A_1 * A_2 * …A_i * e_j$$

Where:

V_m = Market value of aircraft

A_i = contribution of ith attribute

e_j = error term of the equation

How might we explain Value?

Actual vs Predicted Price

$$Price = 2.25E\text{-}07 * MPH^{2.87}$$

Actual vs Predicted Price

$$Price = 1.58E\text{-}05 * MPH^{1.77} * Pass^{1.12}$$

Actual vs Predicted Price

$$Price = 1.29E\text{-}05 * MPH^{1.40} * Pass^{0.779} * Ht^{1.92}$$

Actual vs Predicted Price

$$Price = 3.53E\text{-}06 * MPH^{0.97} * Pass^{0.467} * Ht^{1.32} * R^{0.708}$$

Actual vs Predicted Price

$$Price = 5.69E\text{-}06 * MPH^{0.82} * Pass^{0.441} * Ht^{1.172} * R^{0.772} * Engs^{0.385}$$

At least five variables explain business aircraft value – at least seven variables explain the value of all civil aircraft

How good are our equations?

MAD/Adjusted R² for Value Estimating Relationships

Bar chart showing MAD (red) and Adjusted R² (blue) percentages:

	MPH	MPH, Pass	MPH, Pass, Ht	MPH, Pass, Ht, Range	MPH, Pass, Ht, Range, Engs
Adjusted R²	64.4%	92.6%	95.0%	97.6%	98.1%
MAD	54.0%	22.4%	18.5%	11.3%	10.7%
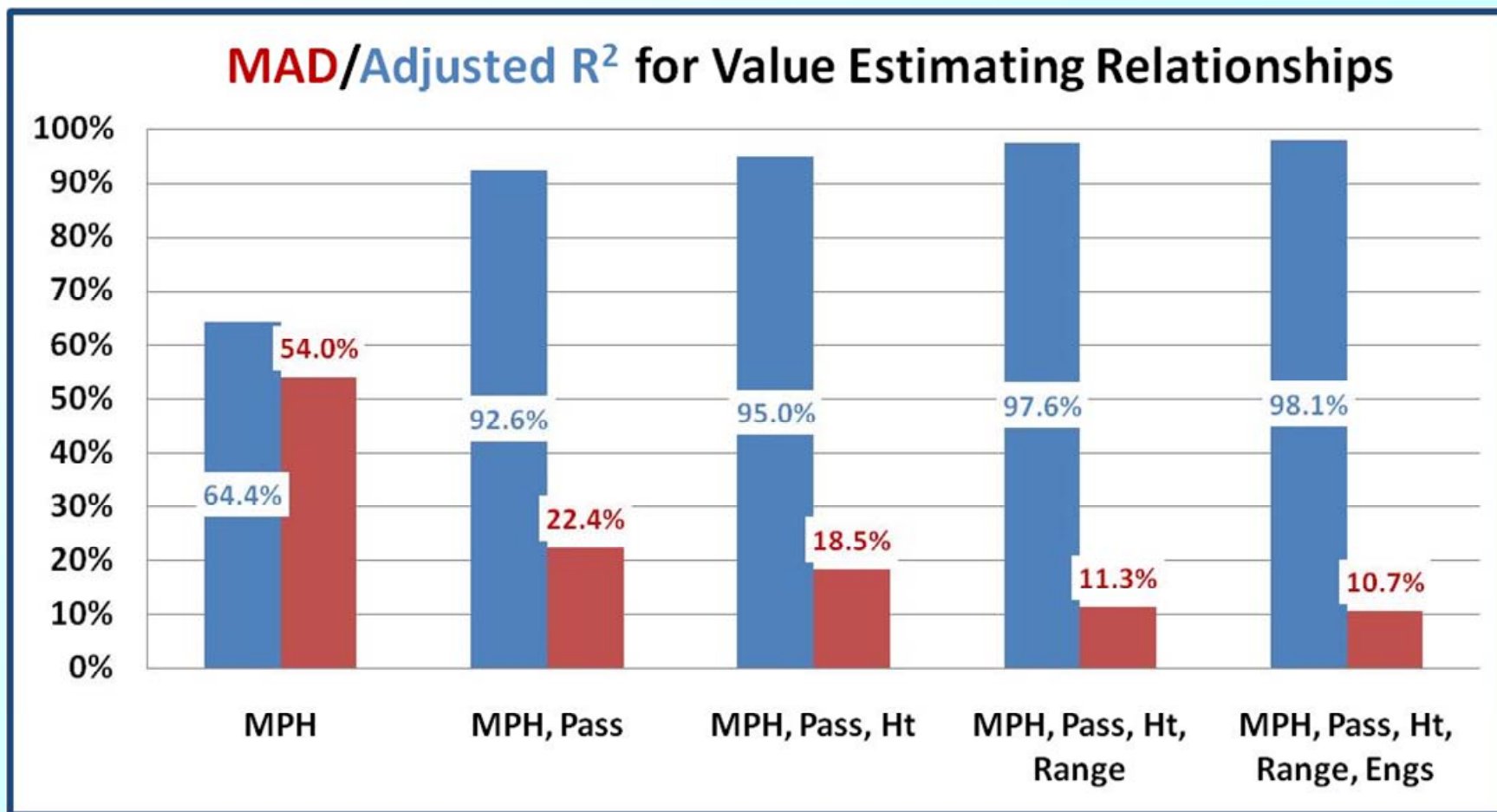
For the five variable equation:

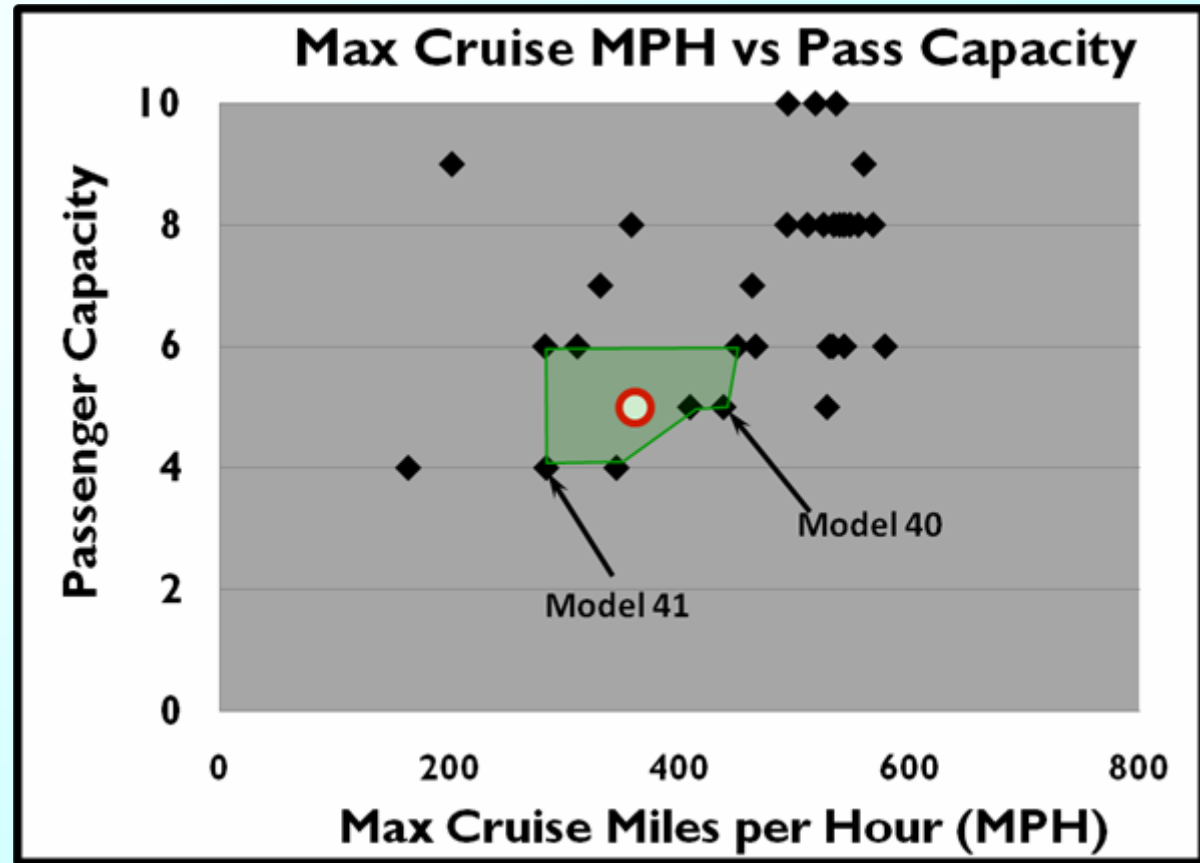|	MPH	Pass	Height	Range	Engines
P-value	4.82E-08	8.91E-07	1.19E-04	4.69E-10	1.93E-03

What other Information might be Useful?

Plot competitor positions in the low gap ($2.9M -$3.9M)

Note attributes of the nearest competitors

Map a nearby open region

Study designs that use attributes in this region

Max Cruise MPH vs Pass Capacity

Passenger Capacity vs Max Cruise Miles per Hour (MPH)

Model 40

Model 41

We can combine this information with value, cost & demand models

How many Combinations?

If we fix engines (to 1, 2 or 3, consistent with the database), then

The general form:

$$x = n!/(r!(n-r)!)$$

Where:
x = combinations
n = variable pool
r = variables combined

For this case:
x = 4!/(2!(4-2)!) = 6

CASE	Engines	Height	Range	Pass	MPH
1	Fixed-1	Vary	Vary	Fixed	Fixed
2	Fixed-1	Vary	Fixed	Vary	Fixed
3	Fixed-1	Vary	Fixed	Fixed	Vary
4	Fixed-1	Fixed	Vary	Vary	Fixed
5	Fixed-1	Fixed	Vary	Fixed	Vary
6	Fixed-1	Fixed	Fixed	Vary	Vary
7	Fixed-2	Vary	Vary	Fixed	Fixed
8	Fixed-2	Vary	Fixed	Vary	Fixed
9	Fixed-2	Vary	Fixed	Fixed	Vary
10	Fixed-2	Fixed	Vary	Vary	Fixed
11	Fixed-2	Fixed	Vary	Fixed	Vary
12	Fixed-2	Fixed	Fixed	Vary	Vary
13	Fixed-3	Vary	Vary	Fixed	Fixed
14	Fixed-3	Vary	Fixed	Vary	Fixed
15	Fixed-3	Vary	Fixed	Fixed	Vary
16	Fixed-3	Fixed	Vary	Vary	Fixed
17	Fixed-3	Fixed	Vary	Fixed	Vary
18	Fixed-3	Fixed	Fixed	Vary	Vary

We need to do this for each gap

Value Analysis: Low Gap

Begin with Model 40 attributes
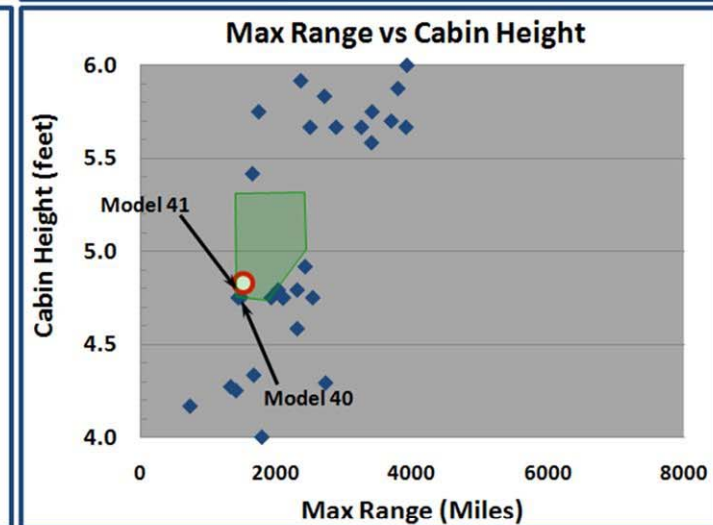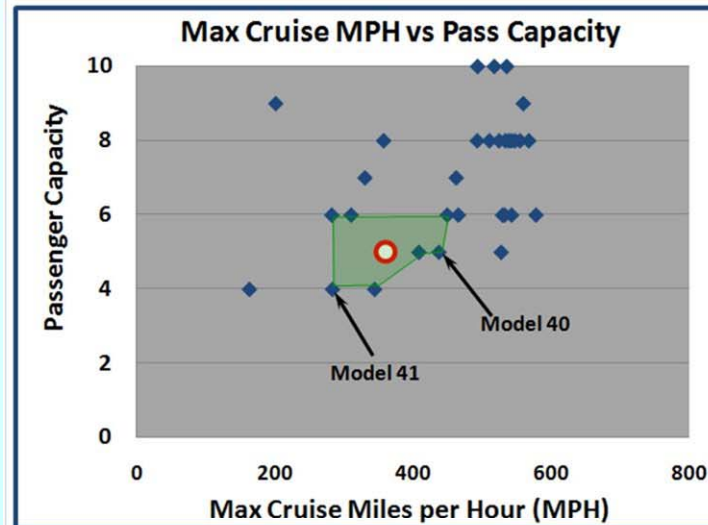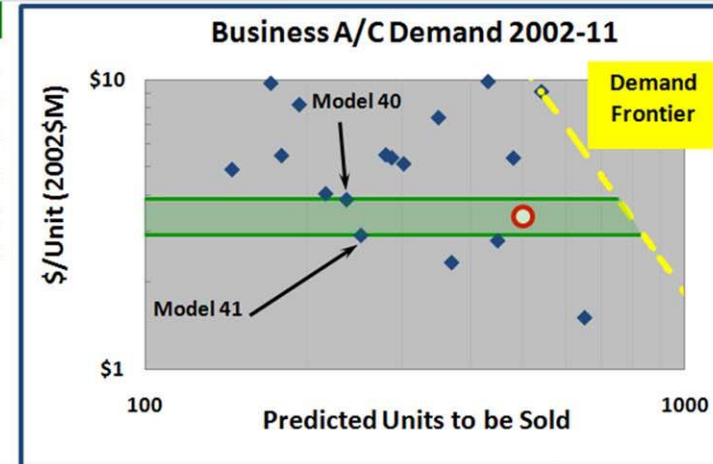
Note MPH attribute gap

Modulate Cruise MPH variable

Add Range

Add Cabin Height

Add Predicted Sales

Variable			Value	Model 40	Model 41
Quantity			500	236	251
Cruise MPH			361	438	284
Passengers			5	5	4
Range (miles)			1520	1435	1475
No. of Engines			2	2	2
Cabin Ht (feet)			4.83	4.75	4.75

	Target		Price Gap Range Upper	Lower
Projected Price	$3.38		$3.86	$2.90
Price % of Gap	50%			
Qty % of Frontier	63%			

Business A/C Demand 2002-11

Max Cruise MPH vs Pass Capacity

Max Range vs Cabin Height

Now we can compare Value to Cost

New Low Gap Configuration Value vs. Cost
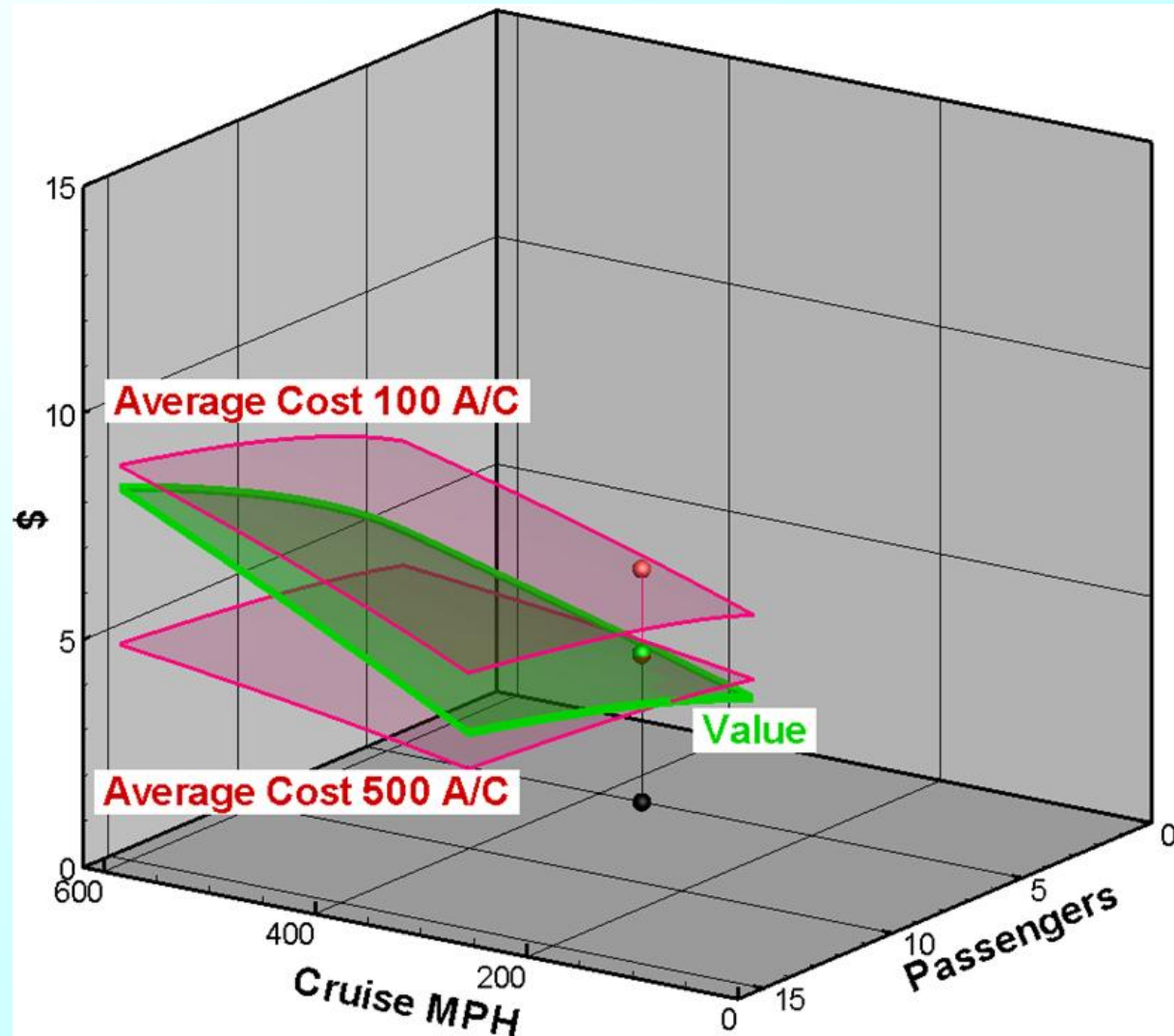
If we let:

Engines   = 2

Range   = 1520 miles

Cabin Ht = 4.83'

This configuration's value offers a small profit compared to the DAPCA IV cost forecast at Unit 500

Other cost predictions may vary

We should look at the mid gap now
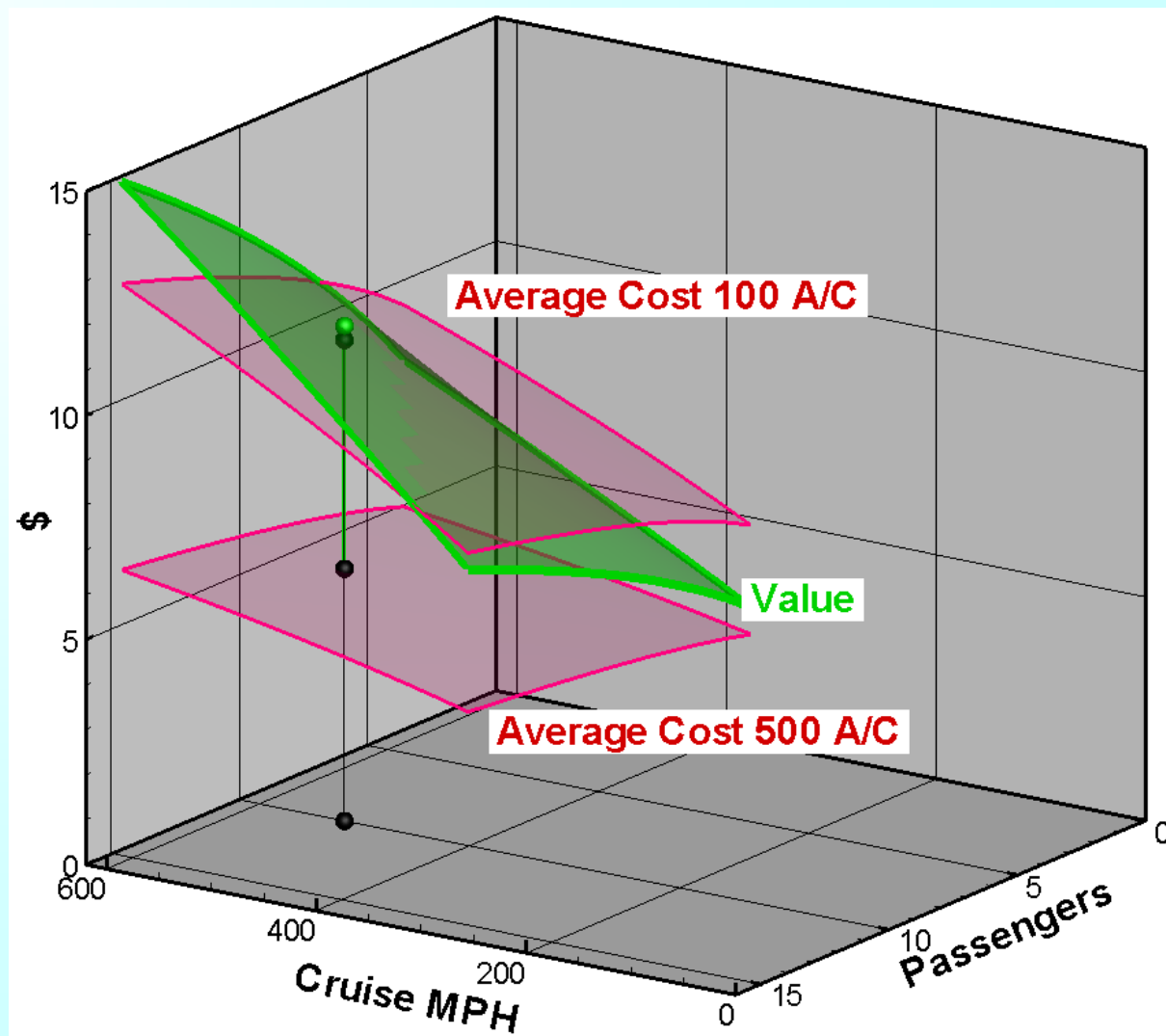
A Mid Gap Configuration Value vs. Cost

If we let:

Engines   = 2

Range   = 2521 miles

Cabin Ht = 5.67'

This configuration predicts a small profit at Unit 100, more at Unit 500

Now we should examine Demand

Mid Gap: Value vs. Cost vs. Demand

If we keep the attributes of the previous configuration and assume that we might be able to sell 500 aircraft, then …

Business Aircraft Demand 2002-11

Demand Frontier Price = $123,000,000 * Qty^{-2.61}$

Average Cost 100 A/C

Average Cost 500 A/C
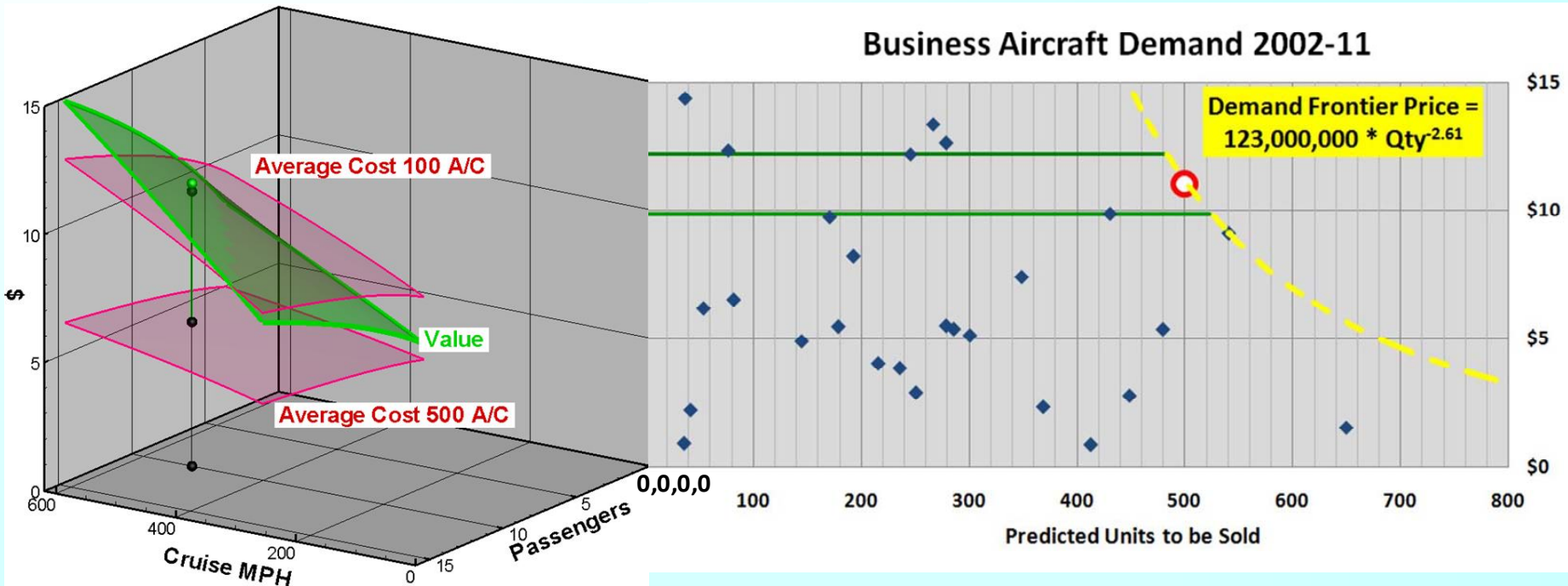
Value

0,0,0,0

This is a 4-Dimensional economic system of all positive values (Qty, $, Passengers, MPH), with an origin of (0,0,0,0)

Goal of 500 Units pushes the Demand Limit of 501 Units

Summary

- **Many markets offer new product openings**
- **Open Spaces in these markets can be mapped with respect to**
  - **Price**
  - **Valued Attributes**
- **Many attributes combine for overall value**
- **Programs should never add cost > value**
- **Parametricians should examine all viable combinations – in so doing they can lead their trade studies**

References

1) http://www.google.com/imgres?imgurl=http://www.privatejetcharter.com/images/aircrafts/exterior/boeingbbj-ext.jpg&imgrefurl=http://www.privatejetcharter.com/private-jet/boeing-business-jet-bbj-bbj-2.php&usg=__eitRyoJlsFvKcQGVfSIqJs2gaqk=&h=330&w=558&sz=26&hl=en&start=0&sig2=jscnEGK6pEJmLeAFvxtYIw&zoom=1&tbnid=tvvvXEyCBN4Q-M:&tbnh=93&tbnw=157&ei=tFONTfT6Jo3QsAPj-pmTCQ&prev=/search%3Fq%3Dboeing%2Bbusiness%2Bjet%2B2%26hl%3Den%26client%3Dfirefox-a%26hs%3DKOK%26sa%3DX%26rls%3Dorg.mozilla:en-US:official%26biw%3D1920%26bih%3D944%26tbm%3Disch&itbs=1&iact=hc&vpx=101&vpy=519&dur=6306&hovh=173&hovw=292&tx=194&ty=122&oei=tFONTfT6Jo3QsAPj-pmTCQ&page=1&ndsp=48&ved=1t:429,r:0,s:0

2) http://www.google.com/imgres?imgurl=http://www.avbuyer.com/images/AircraftImages/27889.1.1.jpg&imgrefurl=http://www.avbuyer.com/aircraft/Results.asp%3FListId%3D%26ManId%3D%26ModelId%3D423%26Corp%3Dtrue%26Gen%3D%26NumberPerPage%3D100&usg=__DPy_sIZ9cU0kAZi6beYj6CqXa5A=&h=327&w=576&sz=29&hl=en&start=0&sig2=ssNrzaUb2eiuFsuOt__HHA&zoom=1&tbnid=2dI5yLC0mfzIUM:&tbnh=93&tbnw=164&ei=wISNTffCN42CsQPHys3zCA&prev=/images%3Fq%3DSocata%2BTBM%2B700%2Bexecutive%26um%3D1%26hl%3Den%26client%3Dfirefox-a%26rls%3Dorg.mozilla:en-US:official%26biw%3D1920%26bih%3D944%26tbm%3Disch&um=1&itbs=1&iact=hc&vpx=271&vpy=242&dur=2412&hovh=169&hovw=298&tx=155&ty=101&oei=wISNTffCN42CsQPHys3zCA&page=1&ndsp=60&ved=1t:429,r:11,s:0