Data-Driven Estimating - Quantifying Electronics Complexity Using Public Data

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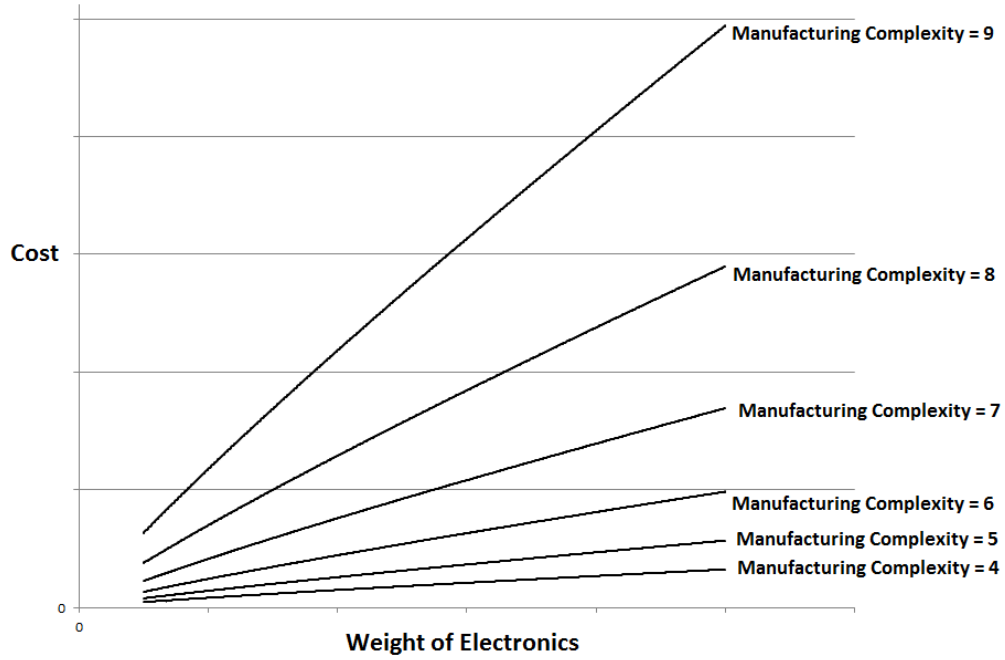
Background

- Goal: Deliver updated, defendable guidance in our cost models for the "Manufacturing Complexity for Electronics" cost driver
- Accounts for technology, producibility (component make-up, packaging density, test/reliability requirements, etc.) and yield.
- Helps determine production cost per unit of weight for electronics



Relevant Trends

- Industry challenged to increase defendability of cost estimates, mainly through comparison to analogous cost data.
- Companies seem more protective than ever of their high quality cost data
- Government/Military cost data has been made publicly available.

Requirements

- Must cover a vast majority of electronic equipment types and technologies estimated by the Aerospace and Defense market.
- Must be derived from actual electronic cost data that can be redistributed publicly.
- Must enable the user to trace recommendations back to the cost data from which it came.

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Solution Design

- Met with electronics engineer, designed a structure to cover most classifications of electronics
- Allows user to describe electronics 2 different ways:
  - Function (receiver, transmitter, filter, signal processor, detector, memory, etc.)
  - Equipment Type (radar, sonar, navigation, countermeasures, GPS, data link, etc.)
- See new Manufacturing Complexity schema

Data Collection

- U.S. Federal Supply Catalog is main data source.
  - Data from over 70 US Army, Navy, Air Force and other government, military and commercial-related databases, for all items in US Federal Supply Catalog. Contains parts, logistics, cost, and technical data. IHS Haystack tool used to organize/query data.
- Designed a data collection/analysis process, to model electronic items in TP, and calibrate to find Complexity
- MCPLXE calibration requires the following info:
  - Unit Production Cost (with quantity and date basis)
  - Weight of electronics and structure
  - Operating Specification
  - Manufacturing Complexity for Structure

Unit Production Cost

- ML-C unit price (DLA average price) data is frequently available
- ML-C unit price includes:
  - Acquisition Cost
    - *Unit Production Cost*
    - *G&A (Assumed 15%)*
    - *Fee/Profit (Assumed 15%)*
  - Material Support Division (MSD) Overhead
- Unit Production Cost = (ML-C Price – MSD Overhead) * 0.85 (G&A) * 0.85 (F/P)
- MSD Overhead is occasionally available. Used available data to find an average to apply to all data points
- Normalize by date/inflation

Determining Quantity Basis

- For electronics, DLA values generally represent replenishment spares (small batch)
- Will use average lot size from procurement histories, when available
  - If unavailable for a data point, will use average lot size for similar equipment
  - Average lot size is small, ~24
- Learning Curve assumed very slight (98%), because there is very little room for additional learning when manufacturing replenishment spares in small batches.
  - This also means quantity is not a major influence on UPC.

Weight of S/E

- The only weight data generally available is Unit Pack Weight (with an associated quantity), and Packaging Type
- Unit Pack Weight includes:
  - Weight of Structure
  - Weight of Electronics
  - Weight of packaging
- Weight of Packaging estimated according to table (see excel sheet)
- Structure/Electronic ratio determined by:
  - Refer to PRICE historical dataset for similar items
  - SME estimate

Other Drivers

- **Operating Specification**
  - Determined by looking for clues in “Technical Characteristics” database. The “End Item” is often known.
- **Manufacturing Complexity for Structure (MCPLXS)**
  - Determined by MCPLXS generator, or
  - Use MCPLXS of similar items from original PRICE dataset.

Adjustment Equations

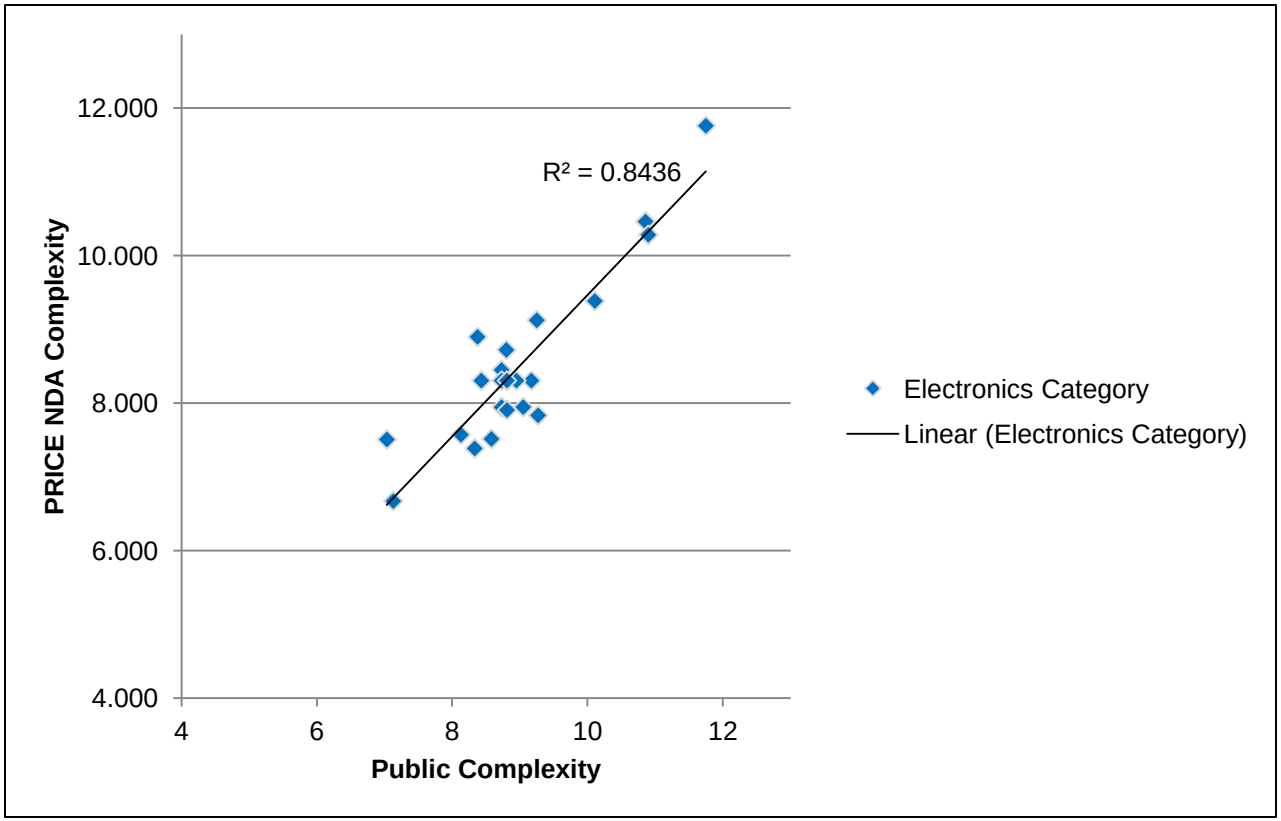
- **Variance exists in the calculated Complexity values that could be explained by other variables**
- **For almost every item, Operating Specification found to be a significant variable in explaining variation – implemented as an additional adjustment equation.**
- **Additional Adjustments by category**
  - Frequency
  - Nuclear Hardening

Adjustment Equations (cont.)

- Remaining variability may be due to different intended uses that require more advanced technology.
  - Example: RF Amplifiers might be used in walkie talkies (low complexity), in state-of-the-art electronic warfare equipment (high complexity), or anywhere inbetween
  - This is why RF amplifiers have such a large standard deviation
- "Technology Adjustment" accounts for remaining variability
  - The magnitude of effect for this input depends on the standard deviation in our dataset.

Final Calibration Step

By comparing to our private PRICE dataset (protected by NDA), we can see that relative complexities seem correct



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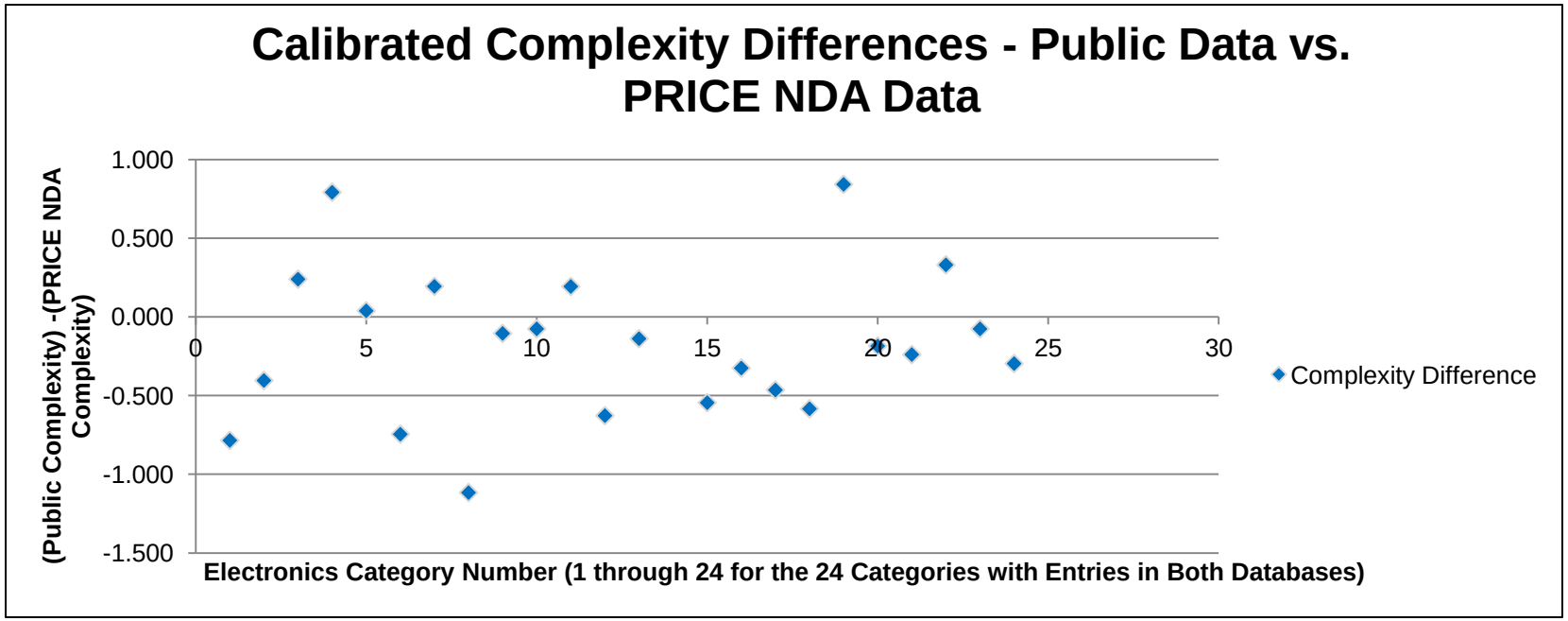
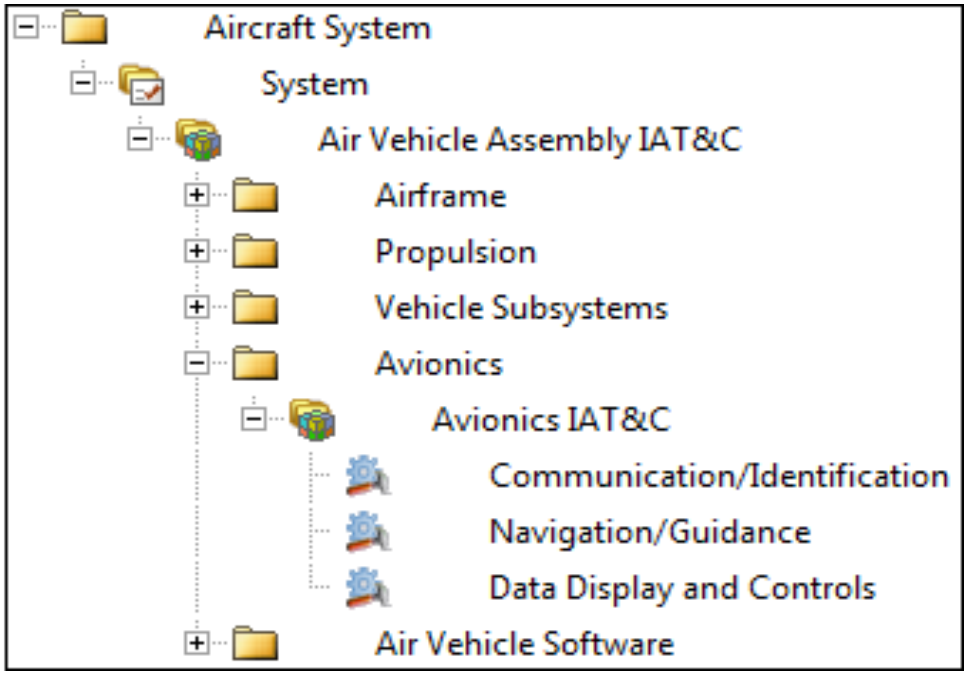
Final Calibration Step

- Relative complexities match our data, but absolute complexity is off.
  - If absolute complexities were correct, these points would be scattered randomly about the line y=0, but actually are scattered about y = -0.178
  - Our complexity values are, on average 0.178 points too low on the complexity scale. Assumptions were modified to remove this bias.



Defending Your Estimate

- The goal is to empower users to defend their estimates
- Example: Aircraft Avionics Cost Estimate



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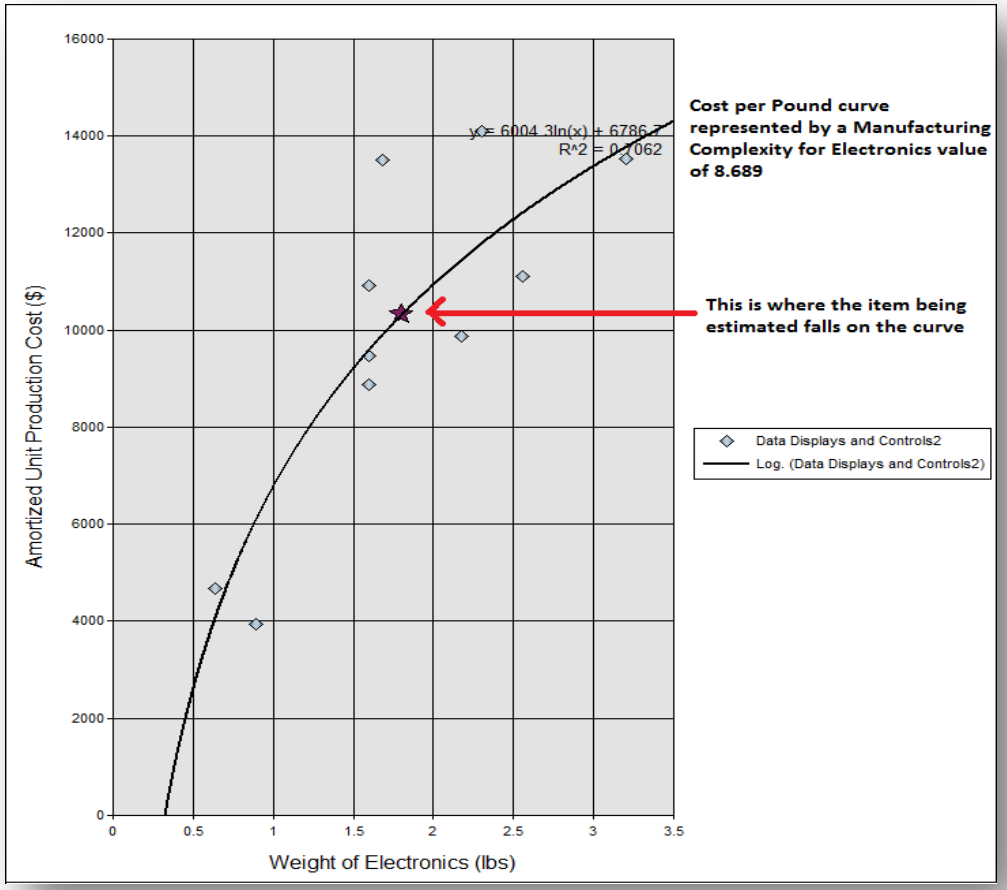
Defending Your Estimate

- Quantities, Schedule? From Project Office or RFQ
- Weight? From Weight Statement
- Manufacturing Complexity for Electronics?



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Questions

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Results

Category	Num Data Points	Manufacturing Complexity for Electronics*	Standard Deviation
Power Conditioner	10	6.154776578	1.19525629
Audio Amplifier	27	6.208079802	0.979081936
Power Supply	145	6.3557719	1.090955705
Synthesizer	82	6.544656608	1.032723835
Voltage Regulator	75	6.629465325	0.885271514
RF Transmitter	96	6.702774434	0.993555936
RF Receiver	71	6.746439609	0.829168948
Mixed D/A Video Processor	30	6.791345709	0.74008084
Power Converter	5	6.890780013	0.369498016
Oscillator	57	6.987830237	0.97229506
Digital Signal Processor	44	7.081429253	1.101185924
EO/IR Sensor/Detector	9	7.260876653	0.363067991
Video Display	6	7.402333909	0.53818612
EO/IR Processor		7.442158046	
Ultrasonic Transducer	6	7.529813476	0.636400073
EO/IR Emitter	7	7.598368662	0.433360929
Audio Switch	3	7.629424353	0.393068325
RF Signal Processor	10	7.800013495	0.702039194
Video Driver	1	7.929532911	
Frequency Standard	26	8.083545568	0.648417382
RF Exciter	1	8.094213312	
RF Amplifier	73	8.137796495	1.169005187
MPU/MCU	13	8.150449724	1.218219117
Video Detector	3	8.687779413	0.75226649
Digital Memory Board	4	9.027724378	0.235315531
Analog Video Processor	3	9.046034185	0.481859389

Results

Category	Num Data Points	Manufacturing Complexity for Electronics*	Standard Deviation
Airborne - Lightning Suppression	6	5.762940987	0.407623702
Airborne - Electronic Support Measure (ESM)	3	6.129258417	0.260687555
Airborne - Flight Control	58	6.185697015	0.520708061
Airborne - Navigation	392	6.272999504	0.923189725
VHF Radio	2	6.42068119	0.040243295
Airborne - Communications	424	6.914947268	0.90243602
Airborne - Weather Radar	6	6.946707275	0.350885595
Airborne - Sonar	29	6.974934999	0.837385382
Airborne - Electro-Optics HUD (Heads Up Display)	12	7.09312102	0.634987788
Data Link	7	7.136505423	0.209276285
Airborne - Flight Recorder	27	7.213370726	0.587365522
GPS - User Equipment	17	7.29520859	0.570078611
Airborne - Stores Management	66	7.491644913	0.519213774
Ship - Sonar	166	7.747004778	1.189338818
Airborne - Electro-Optics FLIR (Forward Looking Infrared)	3	7.797057796	0.459371757
Ships - Countermeasures	1	7.807983496	
Airborne - Countermeasures	45	7.836132703	1.011362172
Ships - Radar - Fire Control	16	7.848501344	0.830717999
Compass	7	7.896540028	0.727163525
Airborne - Radar	50	7.942435312	0.901197942
GPS - Control System	3	8.044322193	0.184820143
Telemetry	3	8.120325391	0.517551849
Airborne - Displays	10	8.183459087	0.588284599
Ships - Radar - Navigation/Search/Detection	11	8.186943705	1.001803383
Airborne - Defensive Aid System (DAS)	5	8.514391888	0.836116994