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ICEAA 2019

Five Steps for Improving the Accuracy of Rough Order of Magnitude Estimates

*Bell V-280 Valor Wing
Predictive Cost Analytics Case Study*

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Estimate with Confidence™

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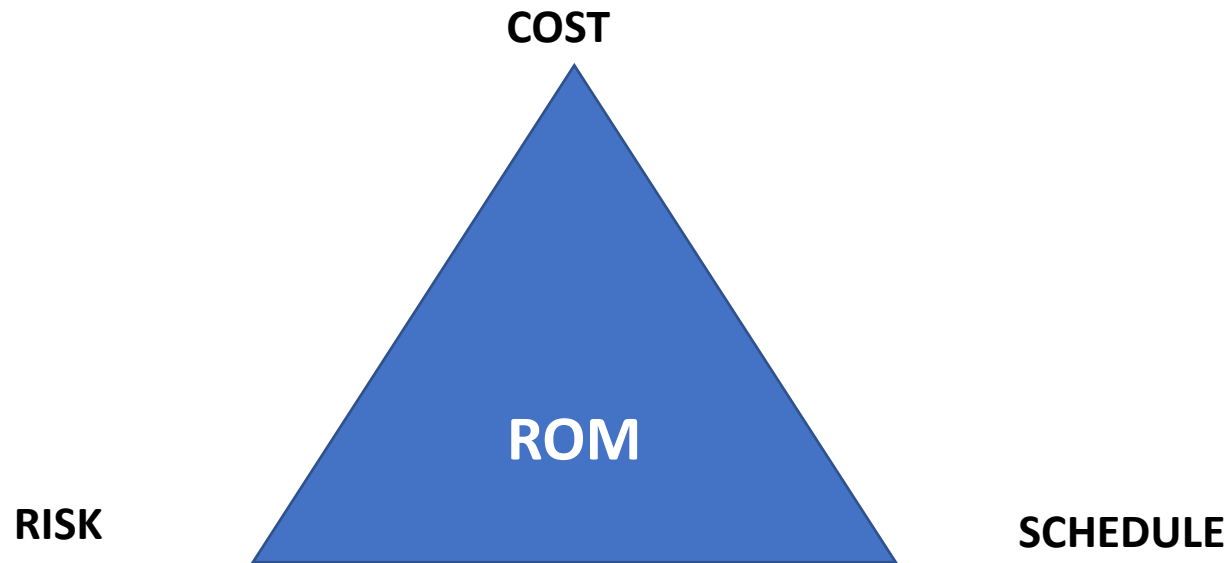
Agenda

- What is a ROM?
- How are ROMS used?
- Precision vs. Accuracy in ROMs
- Characteristics of ROMS
- Challenges with ROM Estimating
- Asking the right questions for effective ROMS
- Case Study – V-280 Valor Wing – Predictive Cost Analytics
- Wrap Up / Conclusions



What is a ROM ?

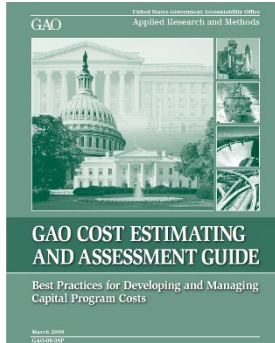
- A “Rough Order of Magnitude” estimate answers the fundamental question of early project feasibility given a set budget. Often before much is known about the project details



- ROMS seek to evaluate and balance Cost / Schedule / Risk during early program phases



GAO view on ROM Estimating



GAO Cost Estimating and Assessment Guide - ROMS

Developed when a quick estimate is needed and few details are available.

Usually based on historical ratio information, it is typically developed to support what-if analyses and can be developed for a particular phase or portion of an estimate to the entire cost estimate, depending on available data.

It is helpful for examining differences in high-level alternatives to see which are the most feasible.

Because it is developed from limited data and a short time, a rough order of magnitude analysis should never be considered a budget-quality cost estimate

May be by a small group or one person; can be done in hours, days, or weeks; and may cover only a portion of the LCCE



How are ROMS Used?

- Produced in relatively short timeframes
- Useful in assessing programs in the early concept stages where little technical data is known , or data is rapidly changing.
- Estimated at a high level, but does not confuse precision with accuracy.
- Can be used to do rapid excursions, trades, what-if analysis
- Not considered sufficient for proposal quality or budgetary estimating.
- Useful in responding to RFIs, Bid/No Bid decisions.



Precision vs. Accuracy

- No estimate is “free from mistake or error”
 - Probability of achieving a given estimate is exactly zero! In other words, our cost estimates will always be exactly wrong!
- In cost estimating, accuracy is best thought of as achieving a given level of confidence based on the degree of inherent uncertainty in underlying parameters.
- A key decision early in an estimate is “appropriate” level of modeling of the Product Breakdown Structure.
 - Sets the stage for everything else including the “fidelity” of the estimate
 - Need to consider the ultimate outcome of the estimate.



What are the Characteristics of ROMs?

- **Level of Estimate:** Typically high level 2 or 4 of the WBS
- **Timeframe:** ROMs are produced within very short timelines using known, high level available data.
- **Assumptions:** May not be well defined or known but can cover the entire Lifecycle.
- **Fidelity:** Heavily informed and based on past project historical data combined with Subject Matter Experts opinion
- **Accuracy:** According to PMBOK® ROMs are typically have an uncertainty range of -50% to +50%.



What Estimating Techniques are used for ROMs?

ROM Estimating Technique	Strength	Weakness
Analogy*	Based on actual data Reasonably Quick Good Audit Trail	Subjective - Accuracy Depends on Similarity Blind to Cost Drivers
SME Opinion / Dephi *	Very quick to perform Leverages SME project knowledge	Subjective Does not take into account actual past performance
Parametric	Reasonably quick, mainly done via EXCEL	Simple Cost Estimating Relationships like \$/lb fails to account for part count and design complexity.
Predictive Cost Analytics	<p>Clear visibility to cost drivers. Quick to perform estimates.</p> <p>Rapidly analyzes past performance, fully informing the estimate.</p> <p>Estimates are data-driven taking into account performance / design complexity.</p> <p>Transparent audit trail tied to historical cost / performance data.</p>	<p>Can be limited by insufficient or inaccurate data / data collection .</p> <p>Requires organizational commitment to software tools and methodology.</p>



Challenges with ROM Estimating

- More complex technical parameters are difficult to assess with simpler estimating techniques.
- Often required early in the program lifecycle where not much technical data is available, or only available at high level.
- Estimators given a very short time to produce the estimate, but results get “locked in”.
- Difficult to assess the impact of schedule and risk – even if the estimate is in the ballpark.
- Methods such as “Analogy” , “ Delphi:” or Expert Opinion fail to consider significant changes to technology and scope.



Five Steps for Improving the Accuracy of ROM Estimates – Asking the Right Questions

Audience: Who is the ultimate “consumer” of the estimate and requirements?

What: What is being estimated (entire program, subsystem, acquisition, LCC)?

Why? What is the “Question” asked and level of detail required ?.

Program phase?: At what level does the existing data and technical parameters exist?

Data? What is the depth and accuracy of historical costs / performance / technical data of similar programs.

Importance of not confusing precision with accuracy when producing a ROM estimate is critical!



Predictive Power for Effective ROM Estimates

- **Data Collection**— Based on past project experience, collect actual delivered cost data for all program phases.
- **Normalization / Benchmarking** - determine the key benchmark “cost drivers” used to inform future estimates. Benchmarks should be correlated to delivered technology.
- **Review program and technical data** – determine the key cost and schedule drivers. Assess the technology and align with benchmark data. Gather high level existing data.
- **Developed the ROM Product Estimating Structure** – match the level of the PBS to the level of known data.
- **Produce the first “point estimate”** – identify cost driver inputs, perform sensitivity analysis.
- **Prepare an uncertainty analysis** – determine the confidence level in the estimate.



Bell V-280 Valor Wing

Predictive Cost Analytics

Case Study

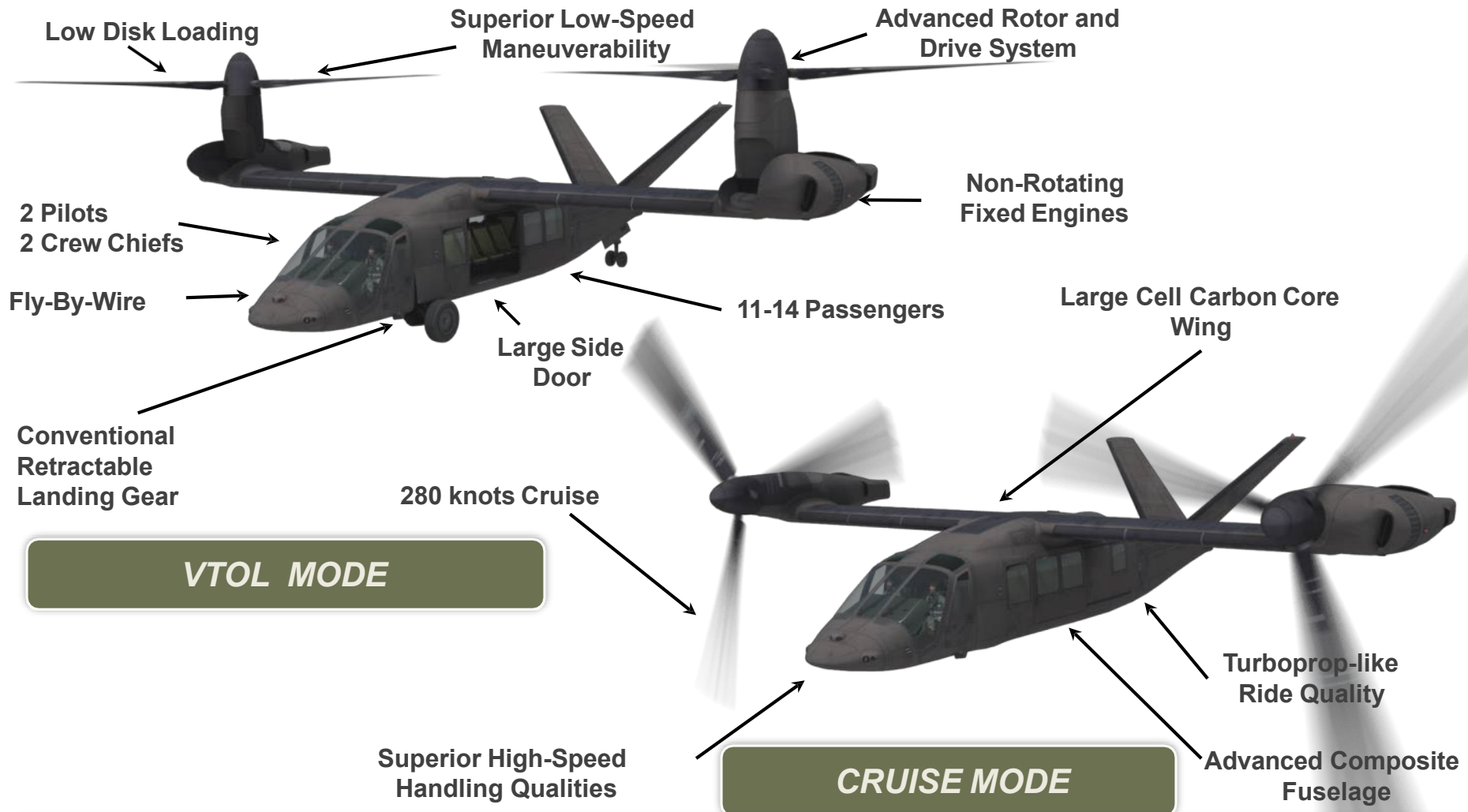


ROM PCA Case Study : Bell V-280 Valor Wing

Question	Response
Who?	Bell V-280 Valor - Wing Design IPT
What?	Subsystem ROM Cost Estimate - Predictive Cost Analytics
Questions Asked?	How do part count and design complexity reductions affect ROM cost estimates at the aircraft system level?
Program Phase	Development
Depth/Accuracy of historical data	Based upon 50+ years of Bell tiltrotor design, flight test, and manufacturing experience
Product Breakdown Structure	PCA modeled to the detailed elements (wing spars, ribs, and skins)



Bell V-280 Valor – Future Vertical Lift

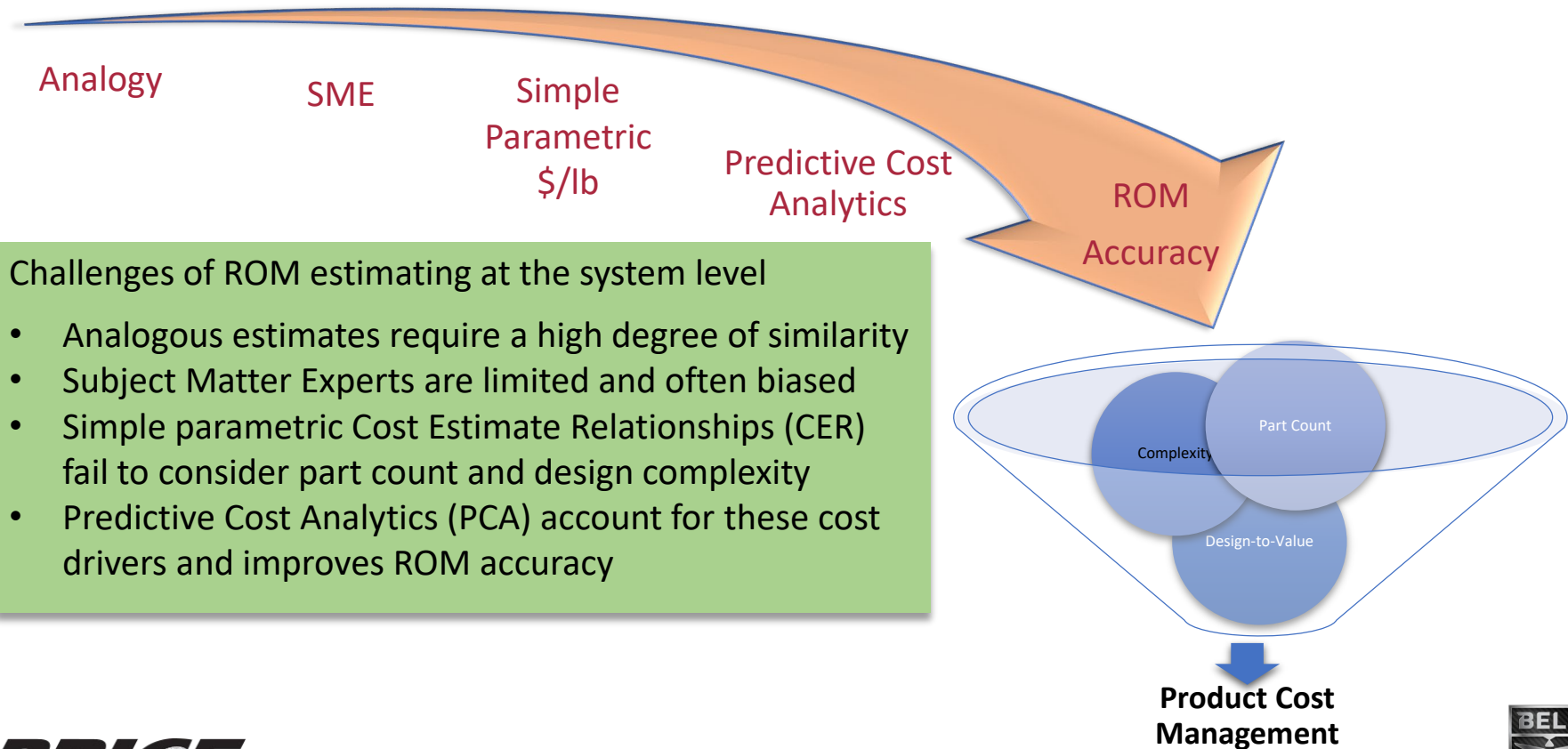


V-280 air combat vehicle technology provides warfighters strategic options, operational reach, and tactical agility and overmatch at the point of decision

Bell V-280 Valor

ROM Estimating at the Aircraft System Level

Challenge: Given two systems of similar size, weight, and function...
How do part count and design complexity affect the ROM estimate?



Bell Legacy Tiltrotor Wing Historical Data

Baseline Assembly Analysis

Legacy Tiltrotor Wing Design

- Wing Spars – 50 detail parts
- Wing Ribs – 500 detail parts
- Wing Skins – 6,000 parts

Complexity Factor

6.31

6.92

7.32

Tables and Calculators

Manufacturing Complexity for Structure

The Manufacturing Complexity for Structure represents a technology index for the structural portion of the component being described. Manufacturing Complexity is a measure of the component's technology, its producibility (material machining and assembly tolerances, machining difficulty, surface finish, etc.), and yield. Manufacturing Complexity is a major cost and schedule driver.

The value for Manufacturing Complexity for Structure should be determined either through calibration using historical data from past projects or by taking advantage of one of the many tools in the product designed to help with this critical input. Values can be selected from the PRICE Reference table for Manufacturing Complexity for Structure, by using the Conceptual Complexity generator which uses top level descriptions of the components, or the Detailed Complexity Generator which allows for a detailed description of the many parts that comprise the component.

The Equipment Type drop down input contains typical Manufacturing Complexity values for many equipment types and should be used for guidance in the absence of actual complexity data.

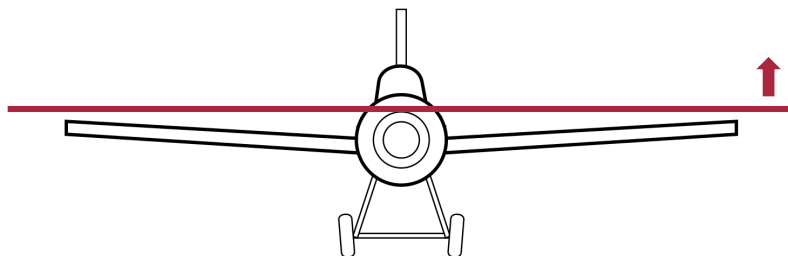
☒ Show Descriptions

Section Name	Input Field	Units	Description
Construction	Laminated Construction		Describes the construction of the structure.
Function	Structural frames, supports, b...		Describes the functional attributes of the structure.
Weight Range	Over 500 lb / 200 kg		Describes the weight range of the structure.
Primary Material	None		Describes the primary material to build the structure.
Operating Specification	1,800		Operating Specification is the variable that describes the end user's requirements stemming from the planned operating environment. It is a measure of the portability, reliability, sturdiness, testing and documentation required for acceptable contract performance. Operating Specification has a significant impact on development engineering costs, production costs are only slightly impacted.
Number of Parts	50		Number of Parts is the number of fabricated parts contained in an assembly. Fasteners (bolts, nuts, rivets, etc.) should not be included in the parts count. For composites, each layer or application should be counted as an additional "part".
Machinability Index	18		The Machinability Index parameter describes the difficulty in machining different material types. The scale used to determine Machinability Index is that established by Battelle Memorial Institute. This scale assigns a value of 100 to Carbon and Alloy Steel (C 1214), a value greater than 100 to materials easier to machine than Carbon and Alloy Steel (C 1214) and values less than 100 for materials more difficult to machine than Carbon and Alloy Steel (C 1214).
Calibration Factor	0.000000		This input is usually obtained by running the calibration portion of the calculator or using historical data when available. To get the value from the calculator, set a value for the "Calibration Manufacturing Complexity" input and the value for "Calibration Factor" will be generated.
Calibration Manufacturing Complexity	0.000000		The Structural Complexity can be calibrated to your organization's mechanical processing efficiencies. In this way you can numerically classify techniques such as welding, oven brazing, adhesive bonding and other processes according to your organization's past cost history.
Calculated Complexity			6.307962

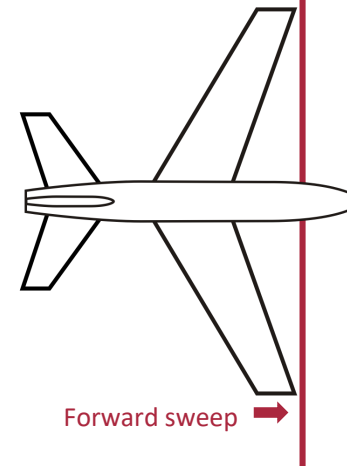
OK Cancel

- Average Unit Production Cost = 100% (normalized baseline)

Note: Detail part counts are representative values (not actual)



Upward dihedral



Forward sweep



Bell V-280 Valor Wing

Predictive Cost Analysis

V-280 Wing Design

- Wing Spars – 10 detail parts
- Wing Ribs – 100 detail parts
- Wing Skins – 1,500 parts
- Average Unit Production Cost = 43%

Complexity Factor

5.91

6.49

6.93

Tables and Calculators

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The value for Manufacturing Complexity for Structure should be determined either through calibration using historical data from past projects or by taking advantage of one of the many tools in the product designed to help with this critical input. Values can be selected from the PRICE Reference table for Manufacturing Complexity for Structure, by using the Conceptual Complexity generator which uses top level descriptions of the components, or the Detailed Complexity Generator which allows for a detailed description of the many parts that comprise the component.

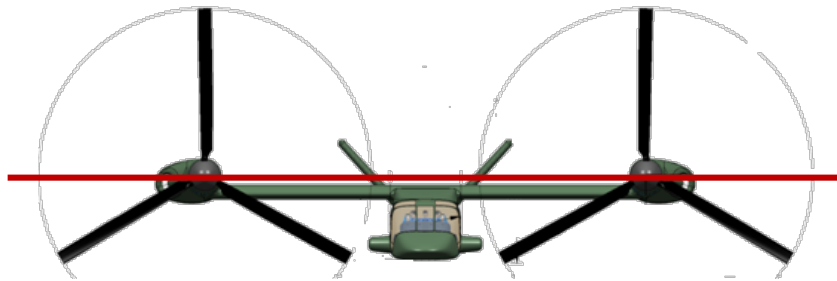
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☒ Show Descriptions

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Function	Structural frames, supports, b...		Describes the functional attributes of the structure.
Weight Range	Over 500 lb / 200 kg		Describes the weight range of the structure.
Primary Material	None		Describes the primary material to build the structure.
Operating Specification	1.800		Operating Specification is the variable that describes the end user's requirements stemming from the planned operating environment. It is a measure of the portability, reliability, structuring, testing and documentation required for acceptable contract performance. Operating Specification has a significant impact on development engineering costs, production costs are only slightly impacted.
Number of Parts	10		Number of Parts is the number of fabricated parts contained in an assembly. Fasteners (bolts, nuts, rivets, etc.) should not be included in the parts count. For composites, each layer or application should be counted as an additional "part".
Machinability Index	18		The Machinability Index parameter describes the difficulty in machining different material types. The scale used to determine Machinability Index is that established by Battelle Memorial Institute. This scale assigns a value of 100 to Carbon and Alloy Steel (C 1214), a value greater than 100 to materials easier to machine than Carbon and Alloy Steel (C 1214) and values less than 100 for materials more difficult to machine than Carbon and Alloy Steel (C 1214).
Calibration Factor	0.000000		This input is usually obtained by running the calibration portion of the calculator or using historical data when available. To get the value from the calculator, set a value for the "Calibration Manufacturing Complexity" input and the value for "Calibration Factor" will be generated.
Calibration Manufacturing Complexity	0.000000		The Structural Complexity can be calibrated to your organization's mechanical processing efficiencies. In this way you can numerically classify techniques such as welding, oven brazing, adhesive bonding and other processes according to your organization's past cost history.
Calculated Complexity			5.914666

OK Cancel

Note: Detail part counts are representative values (not actual)



Straight & level



No forward sweep

To demonstrate PCA estimating capabilities, the V-280 wing structural weight was inflated in this case study to match the Legacy Tiltrotor wing weight. Setting these weights equal allows us to isolate the affect of part count and design complexity reductions on the average production unit cost estimate.

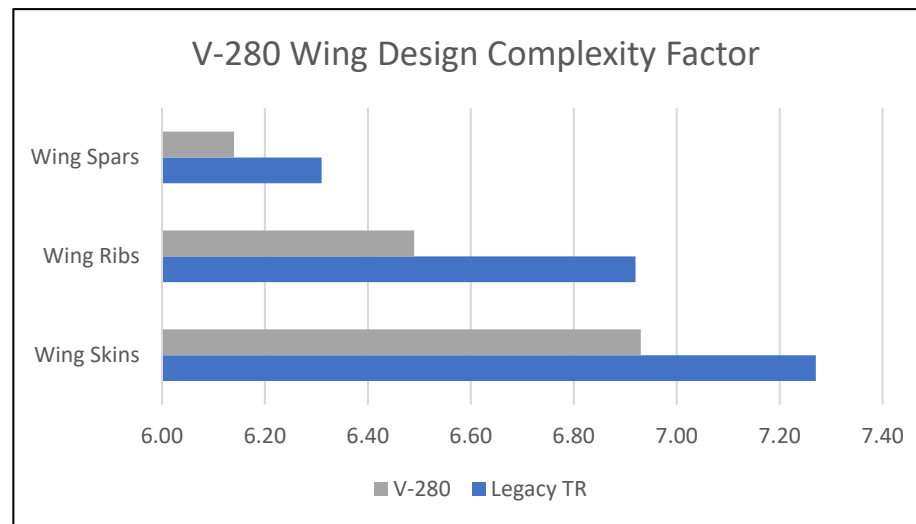
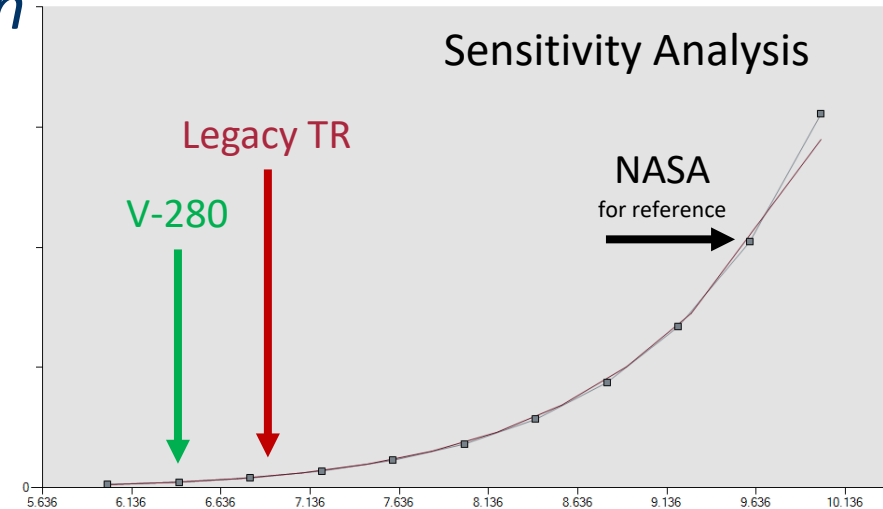
Bell V-280 Valor vs. Legacy Tiltrotor Wing

Complexity Factor Comparison

Wing Design

- Wing Spars
- Wing Ribs
- Wing Skins

V-280	Legacy TR
5.91	6.31
6.49	6.92
6.93	7.32



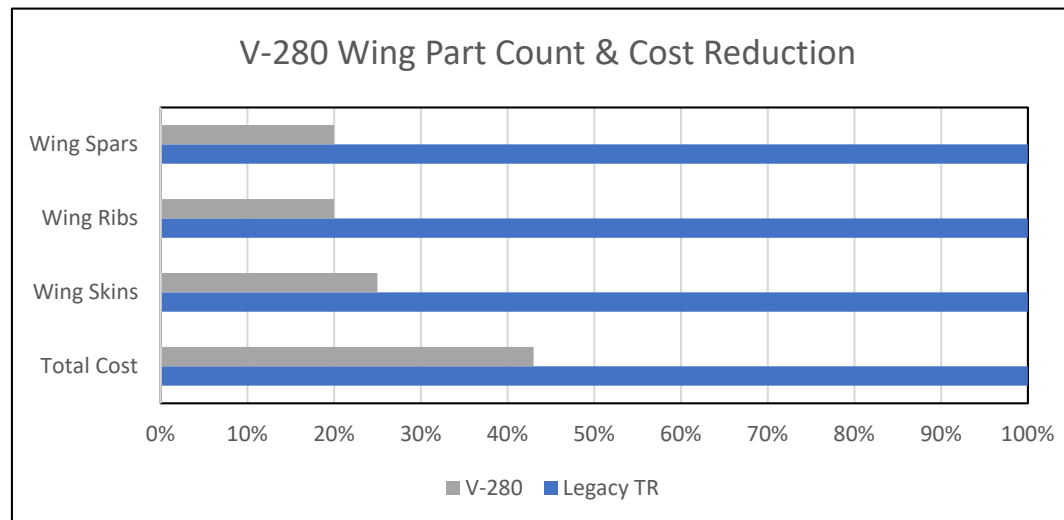
Bell V-280 Valor PCA Opportunity

Part Count & Complexity Reduction

Case Study Outcome

- Wing assembly total part count reduction of approximately 70%
- Projected total labor hour reduction of 57%
- Projected development tool cost reduction of 50%
- Projected total assembly cost reduction of greater than 50%

Note: Detail part counts are representative values (not actual)



Bell V-280 Valor

- Life cycle affordability
- Revolutionary capability
- Reduced acquisition risk

<https://vimeo.com/307065235>



For additional information on Bell's V-280 Valor Wing affordability effort, please check out Vertical Flight Society, "Affordable Design and Manufacturing of the V-280 Wing"

Authors: Ryan Decker, Andrew Baines, Dave Carlson, James Kooiman, Keith Stanney, and Doug Wolfe

<https://vtol.org/store/product/affordable-design-and-manufacturing-of-the-v280-wing-12100.cfm>

Utilizing Product Cost Management to exceed Customer affordability expectations

