Rotorcraft Cost Model Enhancements for Future Concepts

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Agenda

- Background
- Data Collection
- TrueRotorcraft Version 1 (Technical Improvements)
- TrueRotorcraft Version 2 (New Rotorcraft Types/Technologies)
- Future Work

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The Problem

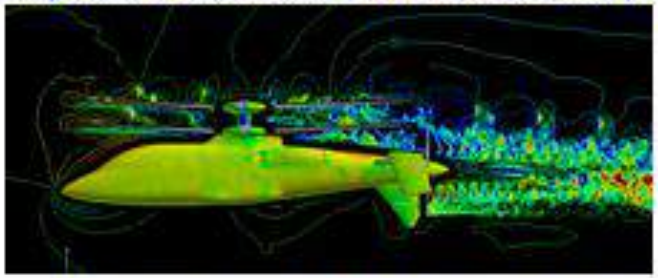
UNCLASSIFIED

US ARMY RDECOM

Key Technologies on the Way to JMR & FVL …

AMRDEC

Integrated Aeromechanics and Performance Analysis



HELIOS simulation for Sikorsky coaxial X2TD™ aircraft

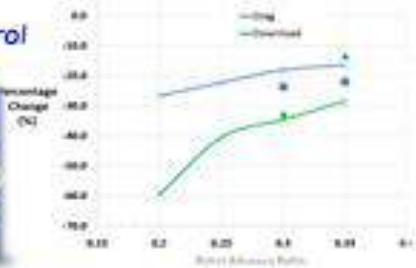
Description:

Joint DoD High Perf Computing and AMRDEC program for next-gen coupled CFD and CSD to enable accurate multi-fidelity analysis – loads, stability, vibration, acoustics.

S&T Program Objectives:

- 97% accuracy for rotor performance
- 95% accuracy for rotor loads
- 95% accuracy for aeroelastic stability
- 10,000x improvement in computational throughput

Active Flow Control



Description:

Research and exploratory development of Active Flow Control technology – actuator types, locations, , and control – to delay separation and reduce adverse aerodynamic forces.

S&T Program Objectives:

- 30% fuselage drag/download reduction
- 20% cruise efficiency (L/De) increase

JMR TECHNOLOGY DEMONSTRATOR

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TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

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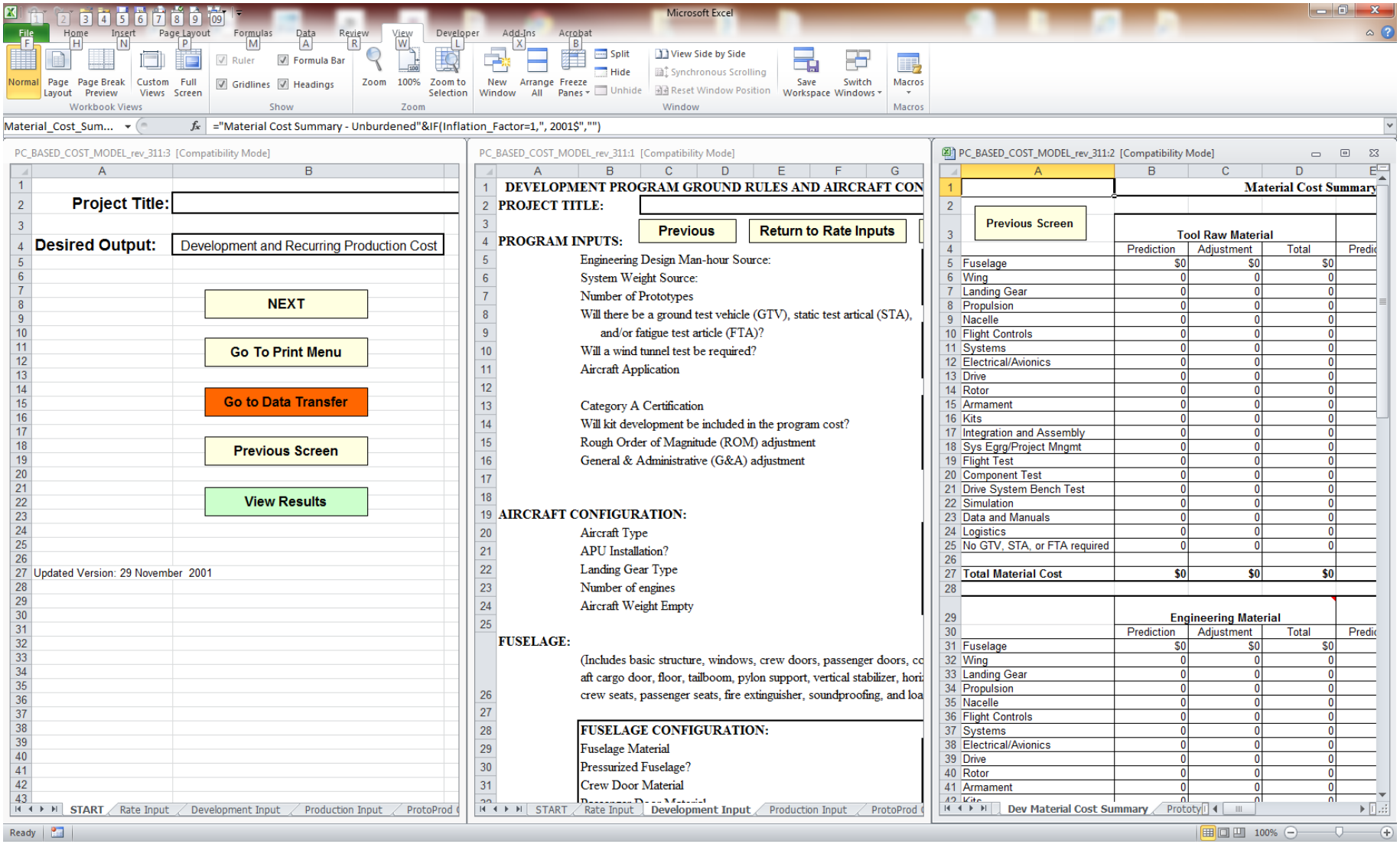
Bell-PC Model



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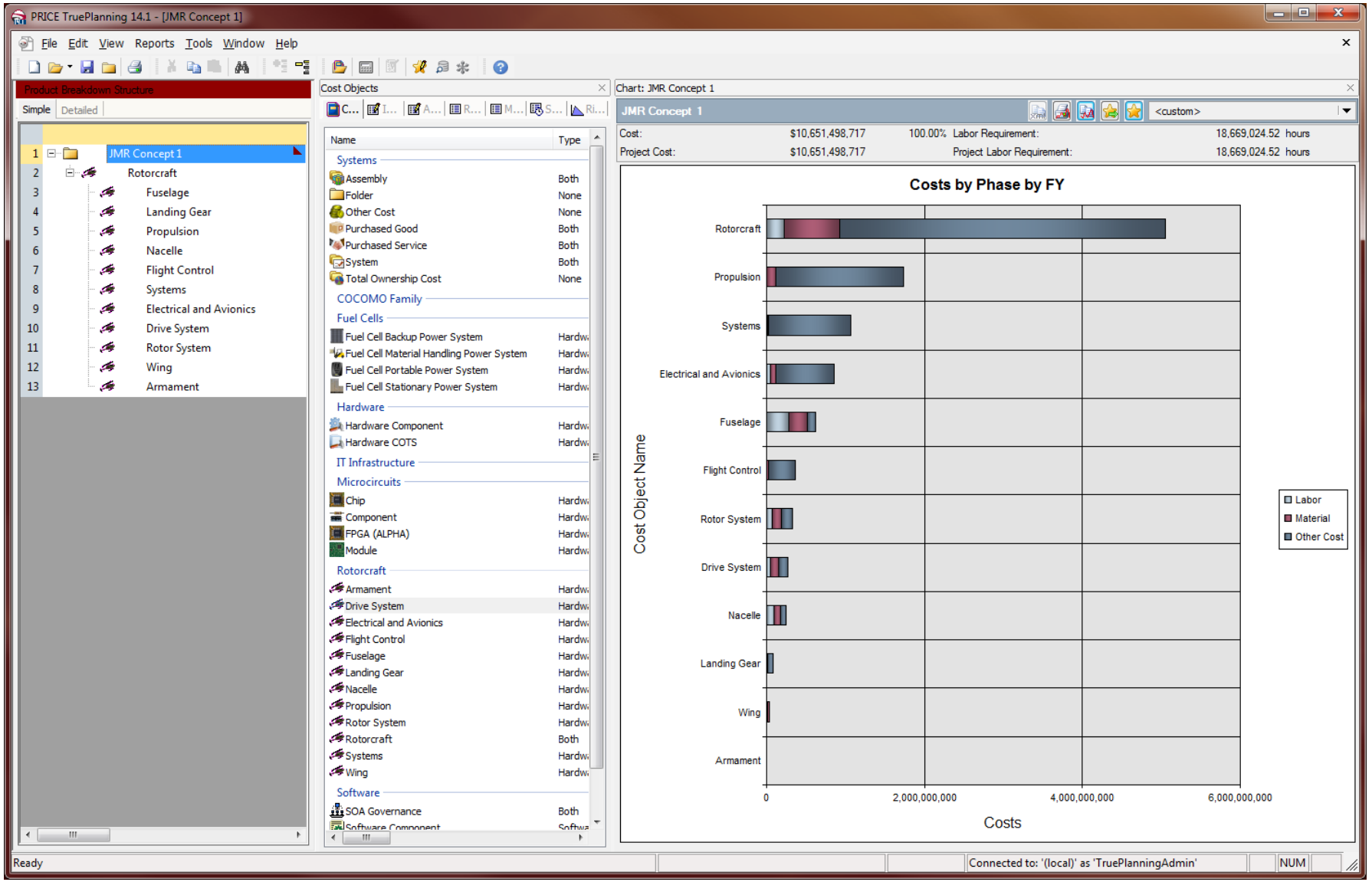
TrueRotorcraft

Build PBS from Catalogs of Models to create estimates



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Data Collection - Purpose

- Collect and analyze data from in-service rotorcraft
- Create a process for data collection that is:
  - Well defined (to allow apples-to-apples comparison)
  - Repeatable
  - User friendly
- Create a database of Rotorcraft data that represent definitive data that will support future estimates
- Perform analysis on collected data to….
  - Validate existing cost estimating relationships for rotorcraft
  - Identify weaknesses in existing cost estimating relationships and update these based on the analysis

Data Collection Form

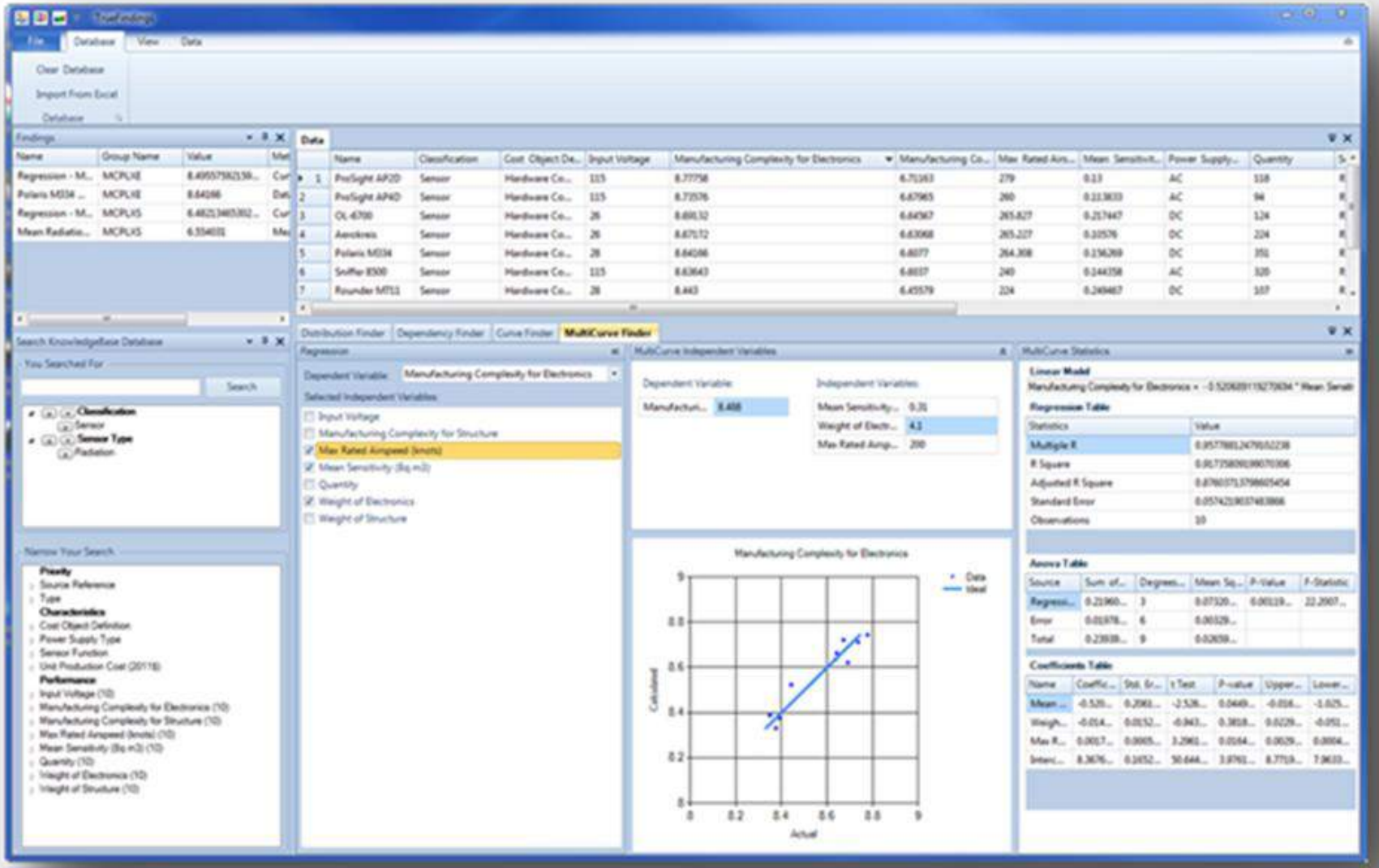
- Used the Bell PC model as a starting point
- Extended beyond the Bell PC model to accommodate for new technologies, materials, and anything Army/Industry suggested may drive cost.
- Data collection form has tabs representing the following data that might be available
  - Aircraft and Subsystem
  - Weight breakdown by subsystem (via Bell PC model and Society of Allied Weight Engineers – standard RP-8A)
  - Cost and Effort Summary
  - Development Cost Details
  - Prototype Details
  - Production Details
  - Reliability and Maintainability
  - Maintenance Manhours and Parts cost
  - Other O&S Data
  - Detailed Subsystem Data

Data Collection

- Data Collection Forms distributed to Army and OEMS
  - Actual data collection has been a slow starter but looks promising going forward
- Plan B being executed – gathering CSDR data directly from Army, and matching up as best as possible to data collection forms.

Rotorcraft Cost Database

use TrueFindings for statistics to support model parameters, CERs and Results



TrueRotorcraft v1.0 Improvements

- User friendly, visual, drag-n-drop, plug-n-play environment
- Rapid tradeoff & input sensitivity analysis
- Years of Planned Production capability, O&S Deployment, and basic Schedule Estimating Relationships
- Enhanced reporting features
- New capabilities for economic considerations
  - *Inflation data built-in, or can be supplied by the estimator*
  - *View costs as-spent, or in any specific FY*
  - *Net Present Value*
  - *Costs vs. Budget*
- Complete Review of Algorithms
  - *10+ cost-changing bugs found in original model, fixes ready for v2.0*
- Automated Testing
  - *Over 1000 automated tests and counting*
  - *Enables updating /enhancing of models with greatly reduced danger of introducing bugs in existing algorithms.*
- Improved Help System

TrueRotorcraft v2.0 Improvements

- Introduce Component Build-up Capability
- Improve Technology Factors (Georgia Tech PhD's provide research and guidance)
- O&S Model – Move to MTBF-Driven Methodology (Georgia Tech)
- Map MIL-STD-881C and CAPE Cost Element Structure

Recommendations for Model Improvement

Recommended Changes	Schedule Risk	Benefits
1. Component build-up capability	★★☆☆☆	★★★★★
2. Complexity factor calculator	★★★☆☆	★★★★☆
3. Technology profile	★★★☆☆	★★★★☆
4. RAM Allocation	★★★★☆	★★★★★
5. Update O&S WBS	★★☆☆☆	★★★★☆
6. Software module	★★☆☆☆	★☆☆☆☆

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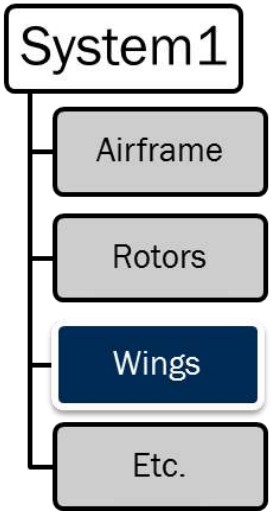
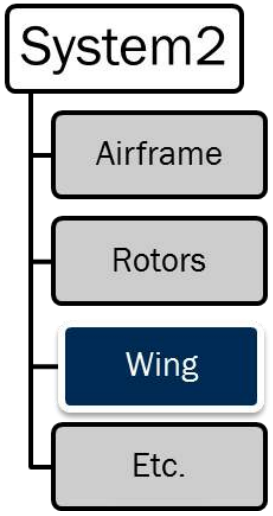
Component Build Up

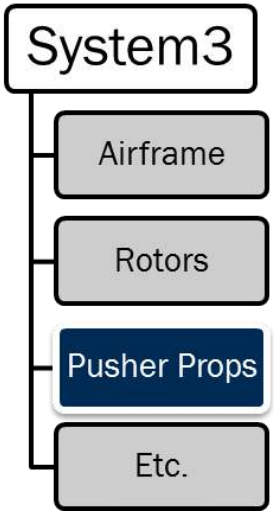
Concept 1:
Tilt-rotor



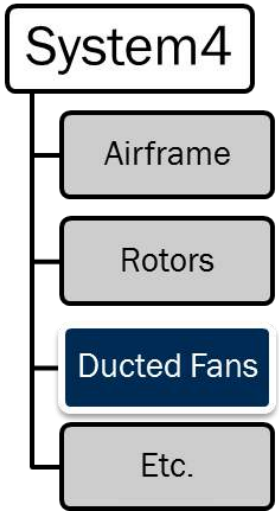
Concept 2:
Tilt-rotor /w
optimal
speed rotor



Concept 3:
Coax compound
/w pusher prop



Concept 4:
Coax compound
/w ducted fan



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Current Use of Technology Factor

- Technology Factors and Manufacturing Technology Factors are used to account for increased RDT&E and Production costs due to advanced technology
- However, these factors cannot be used to influence O&S costs

RDT&E - Engineering Design

O&S Costs ?

Production – Labor and Subcontract Costs

PROPULSION: (Includes engine, engine install, ejector, tailpipe, ir suppressor, engine controls, engine start, engine wash, lube system, fuel, and APU.)

PROPULSION CONFIGURATION:	
New engine installation?	Yes
Will engine cost be included in prototype cost?	Yes
Is engine cost provided by manufacturer or calculated?	Calculated
Does the engine manufacturer supply the combining gearbox?	No
Does aircraft have an engine FADEC installation?	Yes
Percent New Design	100%
Technology Factor	1.1
Labor and Burden Rate Designation	Rate1

This is an assessment of unknowns in the new design due to an introduction of new technology or difficulties that may be encountered with system integration. A value of 1.0 adds no technology penalty. This is a linear adjustment; a value of 1.25 will increase program cost for this system by 25%. Also, the upper risk level is also increased.

PROPULSION:
(Includes engine, engine install, ejector, tailpipe, ir suppressor, engine controls, engine start, engine wash, lube system, fuel, and APU.)

Is engine cost included in production cost or GFE?	GFE
Does the engine manufacturer supply the combining gearbox?	No
Does aircraft have an engine FADEC installation?	Yes
Labor and Burden Rate Designation for Propulsion	Rate1
Labor and Burden Rate Designation for Engine	Rate1
Manufacturing Technology Factor	1

This is an assessment of improvements to manufacturing technology as compared to current manufacturing methods. The default value yields no improvement. A value of 1 is one year of improvement, 2 is 2 years of improvement, etc.

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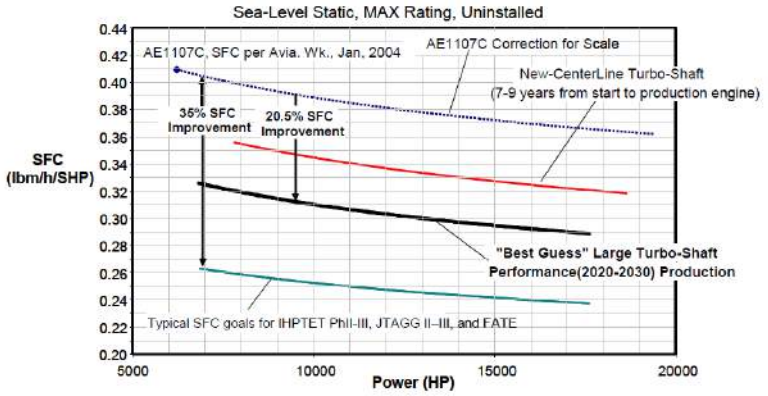
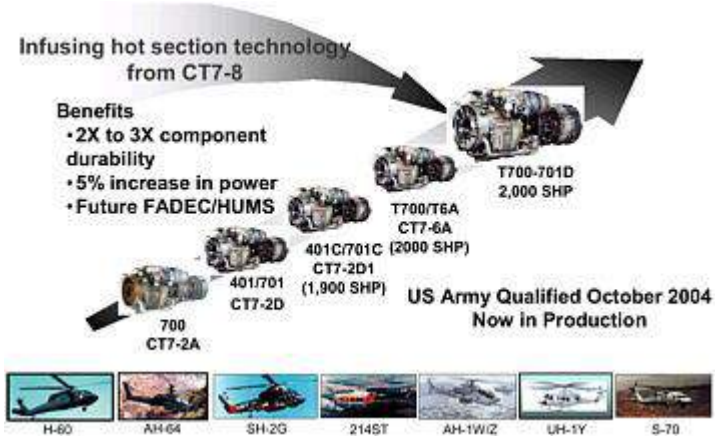
Technology Factor

- Trends of Advanced Technology
  - Provide realistic boundaries to quantify technology factors guided by actual data
  - Include a range of possibility -- optimistic/most likely/pessimistic
  - Impacts throughout life cycle can be defined



- Technology database
  - User-define technology impacts
  - Include specific S&T programs or any product development efforts
  - Establish risk level based on technology trends, schedule, TRL, and etc.

Advanced Affordable Turbine Engine (AATE)
- **+65% in power density**
- **-25% in SFC**
- **-35% in production cost**
- **-35% in maintenance cost**



UH-60M baseline: GE T700-701D			
System Attribute	**AATE Goals**	**Actual**	**Note**
R&D Cost	117.72	0	$M FY2013
SFC	0.3465	0.462	At max. power
T/W	6.8376	4.144	At max. power
Engines Price	$ 1,056,965	$ 1,626,100	FY2013 DoD Budget
O&S (engine only)	$ 780.19	$ 1,200	FY2013/FH Estimated using Harris '12
TRL	6	9	Assumed

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Database of Technology Candidates

DATA SOURCE	CATEGORY	CANDIDATE ADVANCED TECHNOLOGIES	IMPACTING ELEMENTS	BASELINE AIRCRAFT	BASELINE PERFORMANCE	IMPROVED PERFORMANCE	ACHIEVABLE TIME FRAME	BELL TECH FACTOR	TRL	RDT&E	PROD	O&S	BASE YEAR DOLLAR
BOEING STUDY	ENGINE FUEL FLOW	REDUCE ENGINE SFC	SFC	AE1107C ENGINE ON V-22	0.41 lbm/h/hp	20.50%	2020-2030		9	-	-	-	2001
FATE	ENGINE POWER DENSITY	INCREASE POWER/WEIGHT RATIO	REDUCE EMPTY WEIGHT	GE T700-701D ON BLACKHAWK	100%	35.00%	2015		6	-	-	-	2001
AATE	ENGINE	AATE	SFC T/W	GE T700-701D ON BLACKHAWK	0.3465 6.8376	-35% 65%	2013		6	117.72$M	-35%	-35%	2013
BOEING STUDY	STRUCTURAL WEIGHT	ADVANCED MATERIALS, AIRFRAME DESIGN AND OPTIMIZATION, AND MANUFACTURING TECHNIQUES FOR LIGHTER STRUCTURE	AIRFRAME WEIGHT	V-22 AIRFRAME	100%	-17.80%	2023		9	-	-	-	2001
BOEING STUDY	DRIVE SYSTEM	DRIVE CONFIG, ADV COMPONENT, MAT. AND PROCESS, INFRASTRUCTURE AND SUPPORT SYSTEM	DRIVE SYSTEM WEIGHT	SINGLE SPEED XMSN	100%	-30%	2023		9	35%	15%	-30%	2009
BOEING STUDY	DRIVE SYSTEM	DRIVE CONFIG, ADV COMPONENT, MAT. AND PROCESS, INFRASTRUCTURE AND SUPPORT SYSTEM	DRIVE SYSTEM WEIGHT	VARIABLE SPEED XMSN	100%	-22.00%	2023		9	45%	25%	5%	2009
BOEING STUDY	ROTOR TECHNOLOGY	ADVANCED ROTOR BLADE AND HUB	ROTOR BLADE WEIGHT	V-22 ROTOR BLADE	100%	-15%	2023		9	-	-	-	2001

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Technology Factor Implementation

31	**AATE Program**					
32	Include AATE Costs/Benefits?	**Yes**				
33	AATE R&D Cost	117,720,000	$			
34	Fuel Consumption Factor	0.750				
35	Engine Price Factor	0.650				
36	AATE Maintenance Cost Factor (Parts and Overhaul)	0.650				

Cross Project Reports

Name	Owner
UH-60M AATE Modification	TruePlanningAdmin
UH-60M Baseline	TruePlanningAdmin

Results | Chart

		Total	UH-60M AATE Modification	UH-60M Baseline
1	Development	**1,339,321,580**	748,456,557	590,865,024
2	Production	**9,779,515,038**	4,710,338,604	5,069,176,434
3	Operation & Support	**15,714,767,025**	7,710,741,272	8,004,025,753
4	**Total**	**26,833,603,643**	**13,169,536,432**	**13,664,067,211**

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Enhance Methodology to be MTBF-driven

RAM Input

- **Option 1** : System Level RAM Allocation
- **Option 2** : Sub-system level input

Operational Inputs

Peacetime	Month	Year
Flying Hours/AC (Operational)	18	216
Flying Hours/AC (TDA)	30	360
ALDT (Peacetime hours)	22	

Wartime	Month	Year
Flying Hours/AC (Operational)	183	2196
ALDT (Wartime hours)	3.4	

Reliability Input

System	Component Name	MTBEMA Predicted
Air Vehicle	WING GROUP	
	ROTOR GROUP	15.226
	EMPENNAGE GROUP	
	FUSELAGE GROUP	18.806
	ALIGHTING GROUP	60.463
	ENGINE SECTION OR NACELLE GROUP	52.756
	AIR INDUCTION GROUP	15176.200
	PROPULSION GROUP	44.322
	AUXILIARY POWER GROUP	1785.435
	FLIGHT CONTROLS GROUP	68.533
	INSTRUMENT GROUP	240.072
	HYDRAULIC GROUP	97.596
	PNEUMATIC GROUP	
	ELECTRICAL GROUP	66.687
	AVIONICS GROUP	84.277
	ARMAMENT GROUP	
	FURNISHINGS & EQUIPMENT GROUP	63.462
	ENVIRONMENTAL CONTROL GROUP	2385.693
	PHOTOGRAPHIC GROUP	
	LOAD & HANDLING GROUP	155.285
	ANTI - ICING GROUP	194.567
	MTBEMA Adjustment Factor	1.000
	Total Aircraft MTBEMA	3.829

Maintainability Input

System	Component Name	MTTRe Predicted
Air Vehicle	WING GROUP	
	ROTOR GROUP	1.526
	EMPENNAGE GROUP	
	FUSELAGE GROUP	1.705
	ALIGHTING GROUP	1.558
	ENGINE SECTION OR NACELLE GROUP	2.820
	AIR INDUCTION GROUP	0.683
	PROPULSION GROUP	2.082
	AUXILIARY POWER GROUP	2.540
	FLIGHT CONTROLS GROUP	2.275
	INSTRUMENT GROUP	0.549
	HYDRAULIC GROUP	1.650
	PNEUMATIC GROUP	
	ELECTRICAL GROUP	1.228
	AVIONICS GROUP	0.827
	ARMAMENT GROUP	
	FURNISHINGS & EQUIPMENT GROUP	0.953
	ENVIRONMENTAL CONTROL GROUP	0.689
	PHOTOGRAPHIC GROUP	
	LOAD & HANDLING GROUP	1.233
	ANTI - ICING GROUP	1.626
	MTTRe Adjustment Factor	1.000
	Total Aircraft MTTRe	1.650

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Mapping to MIL-STD-881C and CAPE O&S CES

- One-to-one mapping between existing Bell PC Model and CAPE cost structure

BELL O&S Cost Elements

- **MISSION PERSONNEL**
  - **OFFICERS**
    - AVIATION
    - NON-AVIATION
  - **ENLISTED**
    - AIRCREW
    - MAINTENANCE - See CLS below
    - OTHER
- **UNIT LEVEL CONSUMPTION**
  - PETROLEUM, OIL, AND LUBRICANTS (POL)
  - CONSUMABLES AND REPAIR PARTS (All Maint. Levels)
  - TRAINING EXPENDABLES
  - OTHER UNIT LEVEL CONSUMPTION
- **INTERMEDIATE LEVEL MAINTENANCE**
- **DEPOT MAINTENANCE**
  - AIRFRAME PREVENTATIVE MAINTENANCE
  - ENGINE OVERHAUL
  - OTHER DEPOT MAINTENANCE
- **SUSTAINING SUPPORT**
  - SUPPORT EQUIPMENT MAINTENANCE
  - MODIFICATIONS
  - TECHNICAL SERVICES
  - SOFTWARE MAINTENANCE
  - MANUAL UPDATES
  - SIMULATOR OPERATIONS
  - OTHER SUSTAINING SUPPORT
- **INDIRECT SUPPORT**
  - BASE OPERATIONS PERSONNEL
  - HEALTH CARE PERSONNEL
  - PERSONNEL SUPPORT SUPPLEMENT
  - HEALTH CARE SUPPORT SUPPLEMENT
  - OTHER INDIRECT SUPPORT
- **CONTRACTOR LOGISTICS SUPPORT**

CAPE O&S Cost Elements

1.0 **MISSION PERSONNEL**
- 1.1 OPERATIONS
- 1.2 MAINTENANCE
- 1.3 OTHER MISSION PERSONNEL

2.0 **UNIT-LEVEL CONSUMPTION**
- 2.1 POL/ENERGY CONSUMPTION
- 2.2 CONSUMABLE MATERIAL/REPAIR PARTS
- 2.3 DEPOT-LEVEL REPARABLES
- 2.4 TRAINING MUNITIONS/EXPENDABLE STORES
- 2.5 OTHER

3.0 **INTERMEDIATE MAINTENANCE (EXTERNAL TO UNIT)**
- 3.1 MAINTENANCE
- 3.2 CONSUMABLE MATERIAL/REPAIR PARTS
- 3.3 OTHER

4.0 **DEPOT MAINTENANCE**
- 4.1 OVERHAUL/REWORK
- 4.2 OTHER

5.0 **CONTRACTOR SUPPORT**
- 5.1 INTERIM CONTRACTOR SUPPORT
- 5.2 CONTRACTOR LOGISTICS SUPPORT
- 5.3 OTHER

6.0 **SUSTAINING SUPPORT**
- 6.1 SUPPORT EQUIPMENT REPLACEMENT
- 6.2 MODIFICATION KIT PROCUREMENT/INSTALLATION
- 6.3 OTHER RECURRING INVESTMENT
- 6.4 SUSTAINING ENGINEERING SUPPORT
- 6.5 SOFTWARE MAINTENANCE SUPPORT
- 6.6 SIMULATOR OPERATIONS
- 6.7 OTHER

7.0 **INDIRECT SUPPORT**
- 7.1 PERSONNEL SUPPORT
- 7.2 INSTALLATION SUPPORT

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Questions?