



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

The Problem

Key Technologies on the Way to JMR & FVL ...

Integrated Aeromechanics and Performance Analysis

HELIOS simulation for Sikorsky coaxial X27DTM aircraft

Active Flow Control

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

JMR TECHNOLOGY

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/Dc) increase

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

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3

Bell-PC Model

DEVELOPMENT PROGRAM GROUND RULES AND AIRCRAFT CONFIGURATION

PROJECT TITLE:

PROGRAM INPUTS:

- Engineering Design Man-hour Source:
- System Weight Source:
- Number of Prototypes:
- Will there be a ground test vehicle (GTV), static test article (STA), and/or fatigue test article (FTA)?
- Will a wind tunnel test be required?
- Aircraft Application:
- Category A Certification:
- Will kit development be included in the program cost?
- Rough Order of Magnitude (ROM) adjustment:
- General & Administrative (G&A) adjustment:

AIRCRAFT CONFIGURATION:

- Aircraft Type:
- APC Installation?
- Landing Gear Type:
- Number of engines:
- Aircraft Weight Empty:

FUSELAGE:

Includes basic structure, windows, crew doors, passenger doors, etc. all cargo door, floor, bulkheads, pylon supports, vertical stabilizer, lower crew seats, passenger seats, fire extinguisher, soundproofing, and tool

FUSELAGE CONFIGURATION:

- Fuselage Material:
- Pressurized Fuselage?
- Crew Door Material:

Material Cost Summary

	Total Raw Material		
	Prediction	Adjustment	Total
1 Fuselage	\$0	\$0	\$0
2 Wing	\$0	\$0	\$0
3 Landing Gear	\$0	\$0	\$0
4 Propulsion	\$0	\$0	\$0
5 Avionics	\$0	\$0	\$0
6 Flight Controls	\$0	\$0	\$0
7 Systems	\$0	\$0	\$0
8 Electrical/Avionics	\$0	\$0	\$0
9 Drive	\$0	\$0	\$0
10 Rotor	\$0	\$0	\$0
11 Armament	\$0	\$0	\$0
12 Kits	\$0	\$0	\$0
13 Integration and Assembly	\$0	\$0	\$0
14 Sys Eng/Project Mgmt	\$0	\$0	\$0
15 Flight Test	\$0	\$0	\$0
16 Component Test	\$0	\$0	\$0
17 Core System Bench Test	\$0	\$0	\$0
18 Simulation	\$0	\$0	\$0
19 Data and Manuals	\$0	\$0	\$0
20 Logistics	\$0	\$0	\$0
21 No. GTV, STA, or FTA required	\$0	\$0	\$0
22 Total Material Cost	\$0	\$0	\$0

	Engineering Material		
	Prediction	Adjustment	Total
23 Fuselage	\$0	\$0	\$0
24 Wing	\$0	\$0	\$0
25 Landing Gear	\$0	\$0	\$0
26 Propulsion	\$0	\$0	\$0
27 Avionics	\$0	\$0	\$0
28 Flight Controls	\$0	\$0	\$0
29 Systems	\$0	\$0	\$0
30 Electrical/Avionics	\$0	\$0	\$0
31 Drive	\$0	\$0	\$0
32 Rotor	\$0	\$0	\$0
33 Armament	\$0	\$0	\$0

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4

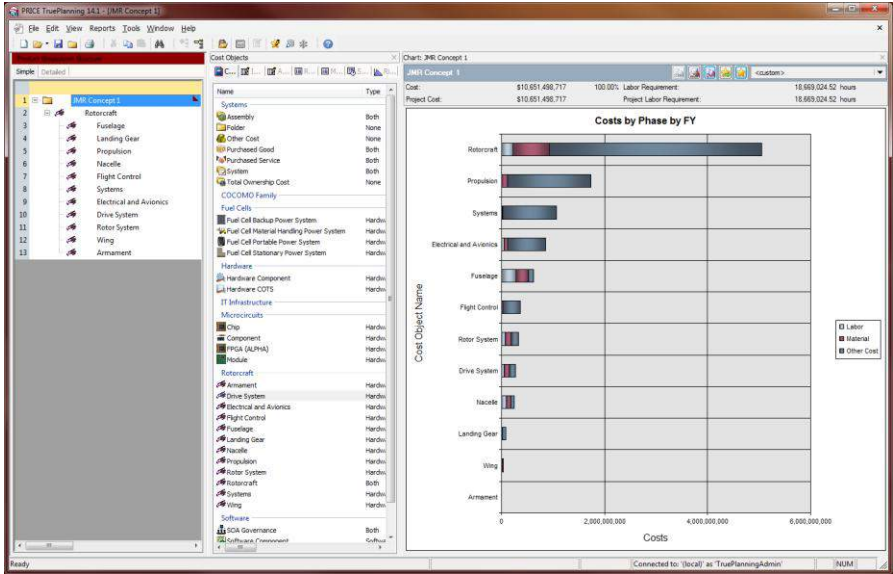
2

ICEAA 2014 Professional Development & Training Workshop

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

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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

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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.

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

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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

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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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11

Component Build Up




Concept 1:
Tilt-rotor



System1

- Airframe
- Rotors
- Wings
- Etc.


Concept 2:
Tilt-rotor /w
optimal
speed rotor



System2

- Airframe
- Rotors
- Wing
- Etc.


Concept 3:
Coax compound
/w pusher prop



System3

- Airframe
- Rotors
- Pusher Props
- Etc.

Concept 4:
Coax compound
/w ducted fan



System4

- Airframe
- Rotors
- Ducted Fans
- Etc.

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12

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

PROFUSION: (Includes engine, engine install, ejector, tailpipe, or suppressor, engine controls, engine start, engine wash, lube system, fuel, and APU.)	
PROFUSION 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
Revised 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.

PROFUSION: (Includes engine, engine install, ejector, tailpipe, or 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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13

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.

System Attribute	UH-60M baseline: GE T700-701D		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

Advanced Affordable Turbine Engine (AATE)

- +65% in power density
- 25% in SFC
- 35% in production cost
- 35% in maintenance cost

Infusing hot section technology from CT7-8


Benefits

- 2X to 3X component durability
- 5% increase in power
- Future FADEC/HUMS

US Army Qualified October 2004
Now in Production

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14


Database of Technology Candidates



DATA SOURCE	CATEGORY	CANDIDATE ADVANCED TECHNOLOGIES	IMPACTING ELEMENTS	BASILINE AIRCRAFT	BASILINE PERFORMANCE	IMPROVED PERFORMANCE	ACHIEVABLE TIME FRAME	BELL TECH FACTOR	T/R	ROSE	PROG	OS	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	117.7 25M	-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	Results Chart	
UH-60M AATE Modification	TruePlanningAdmin		
UH-60M Baseline	TruePlanningAdmin		
	Total	UH-60M AATE Modification	UH-60M Baseline
1	Development	1,339,321,580	590,865,024
2	Production	9,779,515,038	5,069,176,434
3	Operation & Support	15,714,767,025	8,004,025,753
4	Total	26,833,603,643	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
	EMPEENAGE GROUP	
	FUSELAGE GROUP	18,896
	ALIGHTING GROUP	60,463
	ENGINE SECTION OR NACELLE GROUP	52,756
	AIR INDUCTION GROUP	15176.209
	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
	AVONICS 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
	EMPEENAGE 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
	AVONICS 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


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 REPAIRABLES
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

