PTIRS

Probabilistic Technology Investment Ranking System

Overview for ICEAA Conference

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6/x/2013

Agenda

- Background
- Introduction
- Software Architecture
- Project Status
- Conclusions

Background

- Sponsor: NASA Environmentally Responsible Aviation (ERA) Project, Integrated Systems Research Program, Aeronautics Research Mission Directorate
- NASA Research Announcement Topic: “Enhancement and Application of System Design and Analysis Tools”
- Period of Performance: May 2012 to May 2014
- NASA COTR: Craig Nickol
- Principal Investigator: Peter Frederic
- Program Manager: Rey Carpio

PTIRS

Introduction

- **PTIRS is a tool that will be used to build a business case for incorporating a technology or suite of technologies on a future aircraft**
- **Research topic**
  - “An area of interest for development under this NRA solicitation is technology maturation and certification cost estimation and integration of cost analyses into the conceptual design process to have a systematic way of prioritizing investment in particular technologies.”
- **Approach**
  - Develop an Excel-based tool that combines a complete life-cycle economic analysis model, an infinitely flexible technology cost estimating tool, an airframe resizing tool, and pervasive Monte Carlo risk analysis capability

ERA Project Goals and Approach

v2013.1

TECHNOLOGY BENEFITS*	TECHNOLOGY GENERATIONS (Technology Readiness Level = 4-6)		
	N+1 (2015)	N+2 (2020**)	N+3 (2025)
Noise (cum margin rel. to Stage 4)	-32 dB	-42 dB	-52 dB
LTO NOx Emissions (rel. to CAEP 6)	-60%	-75%	-80%
Cruise NOx Emissions (rel. to 2005 best in class)	-55%	-70%	-80%
Aircraft Fuel/Energy Consumption‡ (rel. to 2005 best in class)	-33%	-50%	-60%

* Projected benefits once technologies are matured and implemented by industry. Benefits vary by vehicle size and mission. N+1 and N+3 values are referenced to a 737-800 with CFM56-7B engines, N+2 values are referenced to a 777-200 with GE90 engines

** ERA's time-phased approach includes advancing "long-pole" technologies to TRL 6 by 2015

‡ CO2 emission benefits dependent on life-cycle CO2e per MJ for fuel and/or energy source used

ERA Project Approach – Focus on N+2 Timeframe

Develop vehicle concepts envisioned for integration into the fleet by 2025

SIMULTANEOUS reduction of noise, NOX, and fuel burn at vehicle level

Accelerate maturation of technologies envisioned for advanced vehicle concepts

Advance TRL and IRL for *innovative* technology-based solutions to 5 or 6 by 2015

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Technical Focus Areas and Technical Challenge Statements

TFA1 Innovative Flow Control Concepts for Drag reduction

TC – Demonstrate drag reduction of 8 percent, contributing to the 50 percent fuel burn reduction goal at the aircraft system level, without significant penalties in weight, noise, or operational complexity

TFA2 Advanced Composites for Weight reduction

TC – Demonstrate weight reduction of 10 percent compared to SOA composites, contributing to the 50 percent fuel burn reduction goal at the aircraft system level, while enabling lower drag airframes and maintaining safety margins at the aircraft system level

TFA3 Advanced UHB Engine Designs for Specific Fuel Consumption and Noise reduction

TC – Demonstrate UHB efficiency improvements to achieve 15% TSFC reduction, contributing to the 50 percent fuel burn reduction goal at the aircraft system level, while reducing engine system noise and minimizing weight, drag, NOx and integration penalties at AC system level

TFA4 Advanced Combustor Designs for Oxides of Nitrogen Reduction

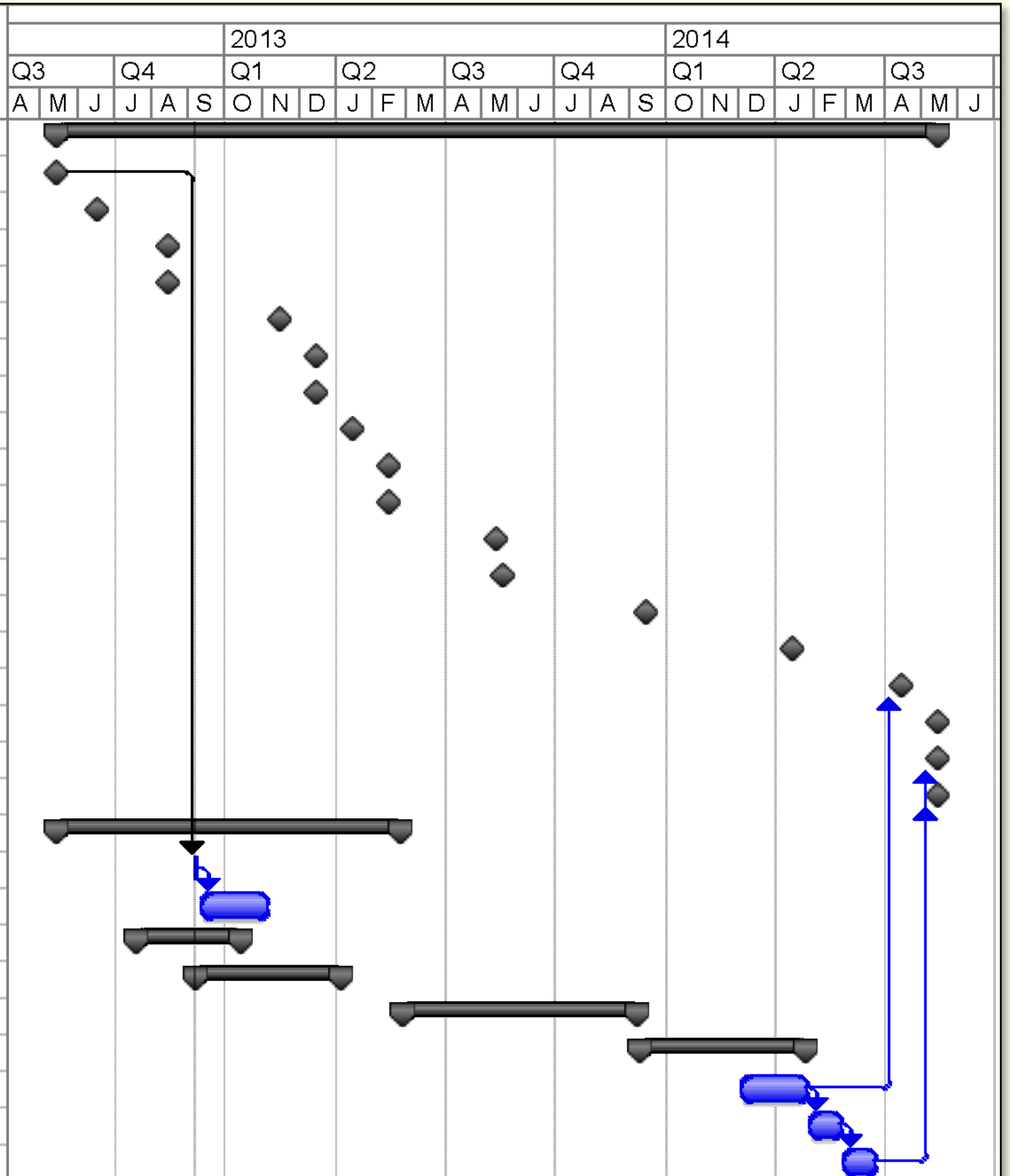
TC – Demonstrate reductions of LTO NOx by 75 percent from CAEP6 and cruise NOx by 70 percent while minimizing the impact on fuel burn at the aircraft system level, without penalties in stability and durability of the engine system

TFA5 Airframe and Engine Integration Concepts for Community Noise and Fuel Burn Reduction

TC – Demonstrate reduced component noise signatures leading to 42 EPNdB to Stage 4 noise margin for the aircraft system while minimizing weight and integration penalties to enable 50 percent fuel burn reduction at the aircraft system level

Updated: 23 Feb 2012

ID	Task Name
1	**Deliverables**
2	Contract Award
3	Kickoff meeting
4	Software Development Plan
5	System Architecture Design Document
6	Reference Configuration Database
7	Transport Aircraft CERs
8	Technology Maturation CERs
9	TCT Database
10	Reference Configuration Database (Updated)
11	ERA Candidate Technology List
12	PTIRS Prototype
13	Annual Technical Review
14	Evaluation results of ERA test cases
15	PTIRS Beta-test results
16	Draft Final Report
17	PTIRS Operational Release
18	Final Final Report
19	Final Technical Review
20	**Develop software**
39	Identify NDAs -- B, L, N, GE, GS, P?
40	Execute NDAs
41	**Collect Data**
82	**Analyze Data**
92	**Alpha Test and Rework**
98	**Beta Test and Rework**
101	Draft Final Report
102	ERA Project review of Final Report
103	Complete Final Report



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Introduction

Promote ERA goals by providing compelling business cases for ERA technologies

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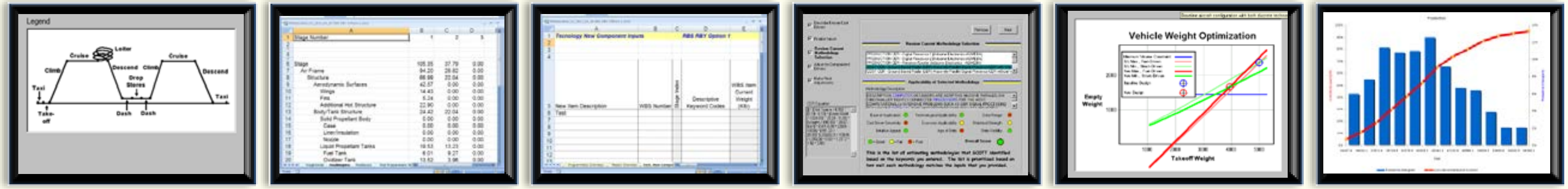
Tool Architecture



2 Mission Description → 3 Reference Configuration → 4 Technology Impacts → 5 Technology Cost Methodologies → 7 Resizing → 8 Economic Analysis

Mission Description
- Mission Profile
- Payload
- Fleet Size
- Flight Rate

Reference Configuration
- Mass Properties
- Takeoff/Landing Performance
- SFCs
- L/Ds
- Noise Footprints
- Emissions
- R & M Factors

Technology Impacts
- Impact Factors
  - Mass Properties
  - T/L Performance
  - SFCs
  - L/Ds
  - Noise Footprints
  - Emissions
  - R & M Factors
- *All impacts specified with uncertainty distributions*

Technology Cost Methodologies
- Technology Maturation CERs
- Multi-category Dev't, Prod., O&S CERs
- Interfaces to COTS Estimating Tools

Resizing
- Override Mass Properties

External Sizing Tools

Economic Analysis
- Fundamental Transport Aircraft CERs (Dev't, Prod., O&S)
- Economic & Programmatic Wraps
- Inflation Factors
- Learning Curves
- Net Present Value Factors

1 Reference Configuration Database

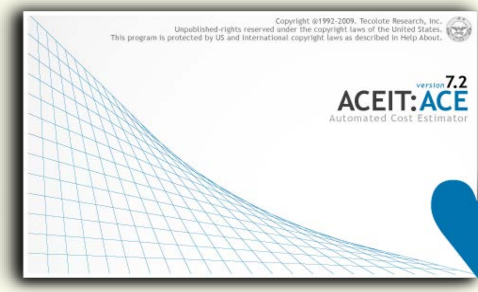
6 Ad-hoc Technology Cost Tool Database

External Engineering Tools

Weights , Aerodynamics, Structures , Propulsion, Flight Mechanics, Emissions, Acoustic, R &M

PRICE-H ™

SEER ™



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Mission Description

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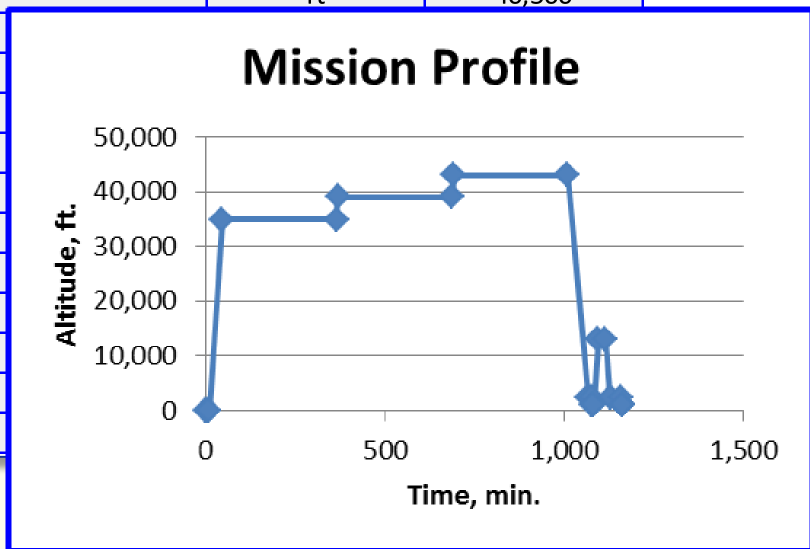
Reference Mission Description

Insert Segment | Delete Segment

Ctrl-e to edit/add/delete comments

Segment	Input	Units	Baseline	Override	Final
Start	N/A	N/A	0		
Taxi	Duration	min	9		9
Takeoff	N/A	N/A	0		
Climb	Altitude Change	ft	35,000		35,000
Cruise	Range	nmi	2,567		2,567
Climb	Altitude Change	ft	4,000		4,000
Cruise	Range	nmi	2,567		2,567
Climb	Altitude Change	ft	4,000		4,000
Cruise	Range	nmi	2,567		2,567
Descend	Altitude Change	ft	40,500		40,500
Loiter	Duration				12
Descend	Altitude Change				1,500
Land	N/A				
Reserve	Additional Fuel				5%
Takeoff	N/A				
Climb	Altitude Change				12,000
Cruise	Range				160
Descend	Altitude Change				10,500
Loiter	Duration				30
Descend	Altitude Change				1,500
Land	N/A				



Reference Configuration

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Reference Vehicle Basic Configuration Inputs

Ctrl-e to e

Input	Units	Baseline
Aircraft Type		
Configuration		
Number of Engines		
Propulsion Type		
Engine Position		
Fuselage		
Wing		
Empennage		
Landing Gear		
Capacity		
Cockpit Crew		
Cabin Crew		
Passengers		
Cargo and Baggage		
Ejected Payload		

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Reference Vehicle Performance Inputs

Input	Units	Baseline
Cruise		
Cruise Speed		
Cruise Alt		
Cruise Thrust Spec		
Cruise Lift-to-Drag		
Climb		
Climb Rate		
Climb Speed		
Climb Thrust Speci		
Climb L/D		
Descent		
Descent Rate		
Descent Speed		
Descent Thrust Spe		

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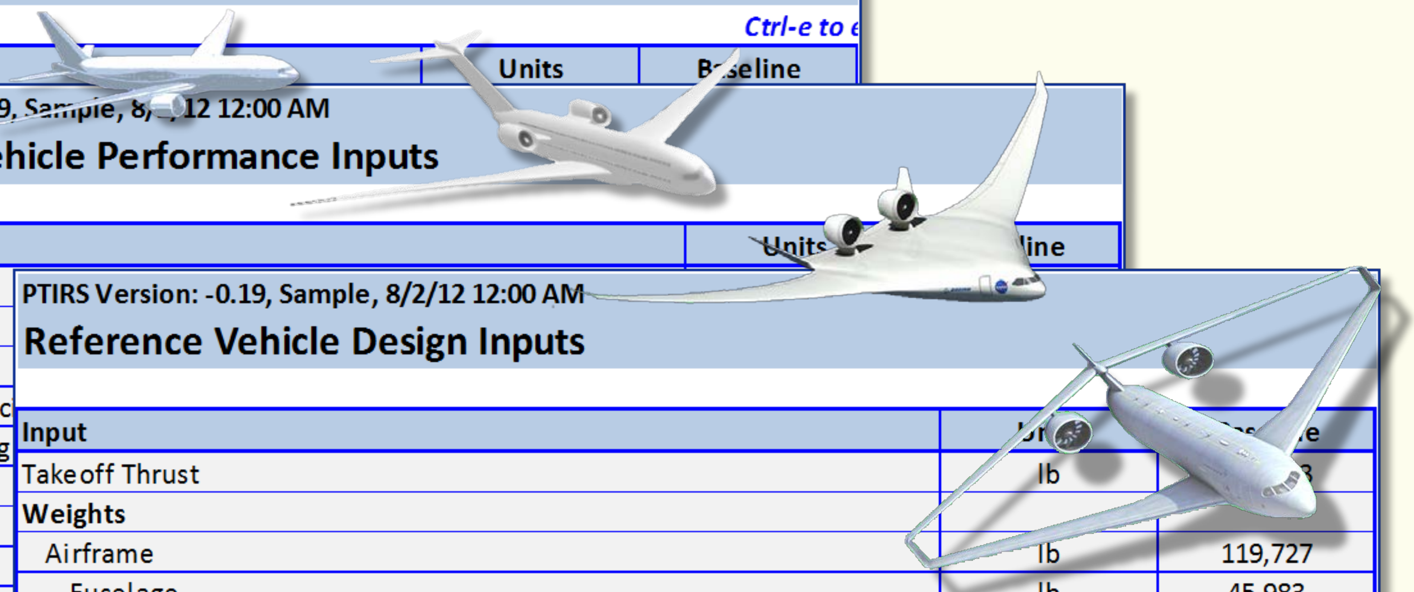
Reference Vehicle Design Inputs



Input	Units	Baseline
Takeoff Thrust	lb	[illegible]
Weights		
Airframe	lb	119,727
Fuselage	lb	45,983
Forward Fuselage	lb	15,328
Center Fuselage	lb	15,328
Aft Fuselage	lb	15,328
Wing	lb	53,586
Wing Structure	lb	42,869
Wing Control Surfaces	lb	10,717
Empennage	lb	3,062
Horizontal Empennage	lb	0
Vertical Empennage	lb	3,062
Canard	lb	0
Landing Gear	lb	17,096
Main Landing Gear	lb	14,532

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Technology Impacts

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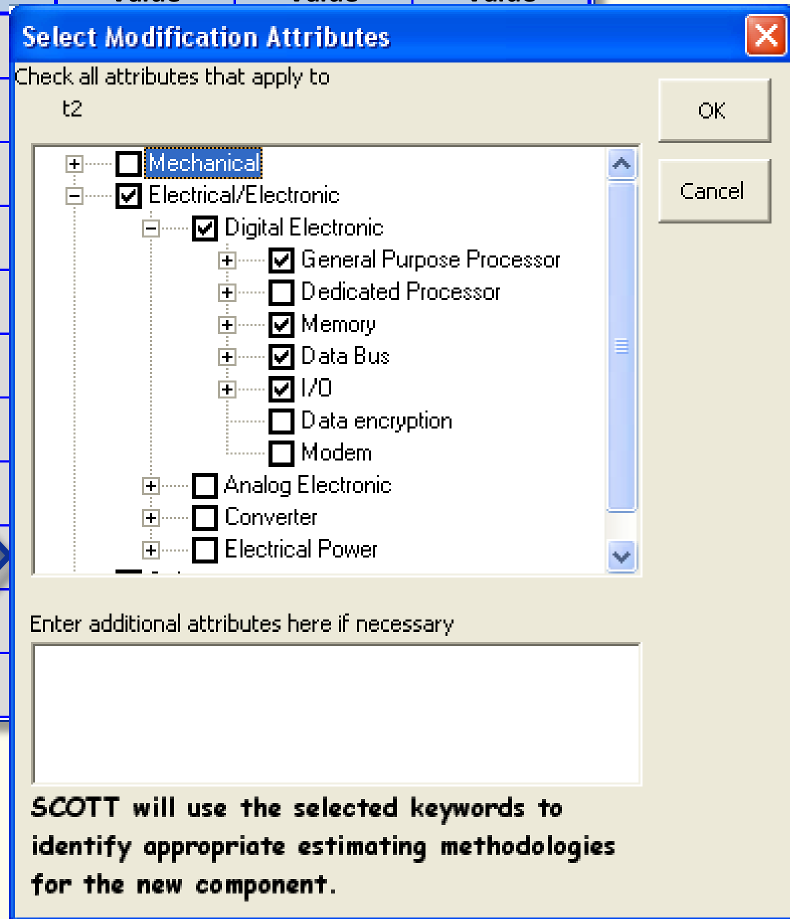
Assembly-level Technology Impacts, Additions

Add Assembly | Delete Selected Assembly | Print CER/Input Report

Ctrl-e to edit/add/delete comment

Input		Units	Assembly #1 Minimum Value	Assembly #1 Most Likely Value	Assembly #1 Maximum Value
AssemblyID					
New Item Description		N/A			
Technology ID		N/A			
WBS Number	Choose WBS	N/A			
WBS Description		N/A			
Descriptive Keyword Codes	Choose Keywords	N/A			
WBS Item Current Weight		lb			
New Item Weight		lb			
WBS Item Current Software Code Size		KSLOC			
New Item Software New Code Size		KSLOC			
New Item Software Modified Code Size		KSLOC			



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Technology Cost Tool

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Finalize methodology selection:

Cancel | Next

The box below contains a "pull-down" list of estimating methodologies that PTIRS identified based on the keywords you entered. The list is prioritized based on how well each methodology matches the inputs that you proveided. The information below the list pertains to the selected methodology.

Selected Methodology

DEVELOPMENT CER - Communications (COMM) subsystem Digital Electronics Suite (Nonrecurring) (13)

Equation Form

194.122*CDIGIWT^0.804*LINKS^0.825

Applicability of Selected Methodology

Ease of Application	▲	Technological Applicability	▲	Data Range	◆
Cost Driver Sensitivity	◆	Economic Applicability	▲	Statistical Strength	●
Intuitive Appeal	▲	Age of Data	▲	Data Visibility	▲

Overall Score ▲

◆ = Good ● = Fair ▲ = Poor

Methodology Description

DESCRIPTION - This USCM7 CER estimates the Communications/ Telemetry, Tracking and Command (COMM/TT&C) Digital Electronics Suite cost in thousands of FY92 dollars excluding fee. Cost is estimated as a function of both the Digital Electronics Suite Weight and the Number of Links supported.

This CER estimates Nonrecurring costs which are associated with all of the effort/activity of designing, developing, manufacturing and testing of a space vehicle qualification model. For those systems which use a protoflight concept, nonrecurring costs include only that portion of the protoflight costs which can be identified as nonrecurring. Additionally, the cost of acquiring program peculiar support equipment such as mechanical and electrical aerospace ground equipment (AGE) are also considered nonrecurring.

SOURCE DATA - Military, NASA and commercial unmanned satellite programs are included in the database. The database has been normalized for inflation using OSD published inflation rates. All data point costs included in this CER are end-of-program actual costs or estimates of mature programs (with at least one launch).

This CER is based on eleven data points: DMSP-5D1, DSCS 1&2 (2 points), Intelsat IV, MARISAT, OSO I, S3, TACSAT (2 points), and TDRSS (2 points).

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Resizing

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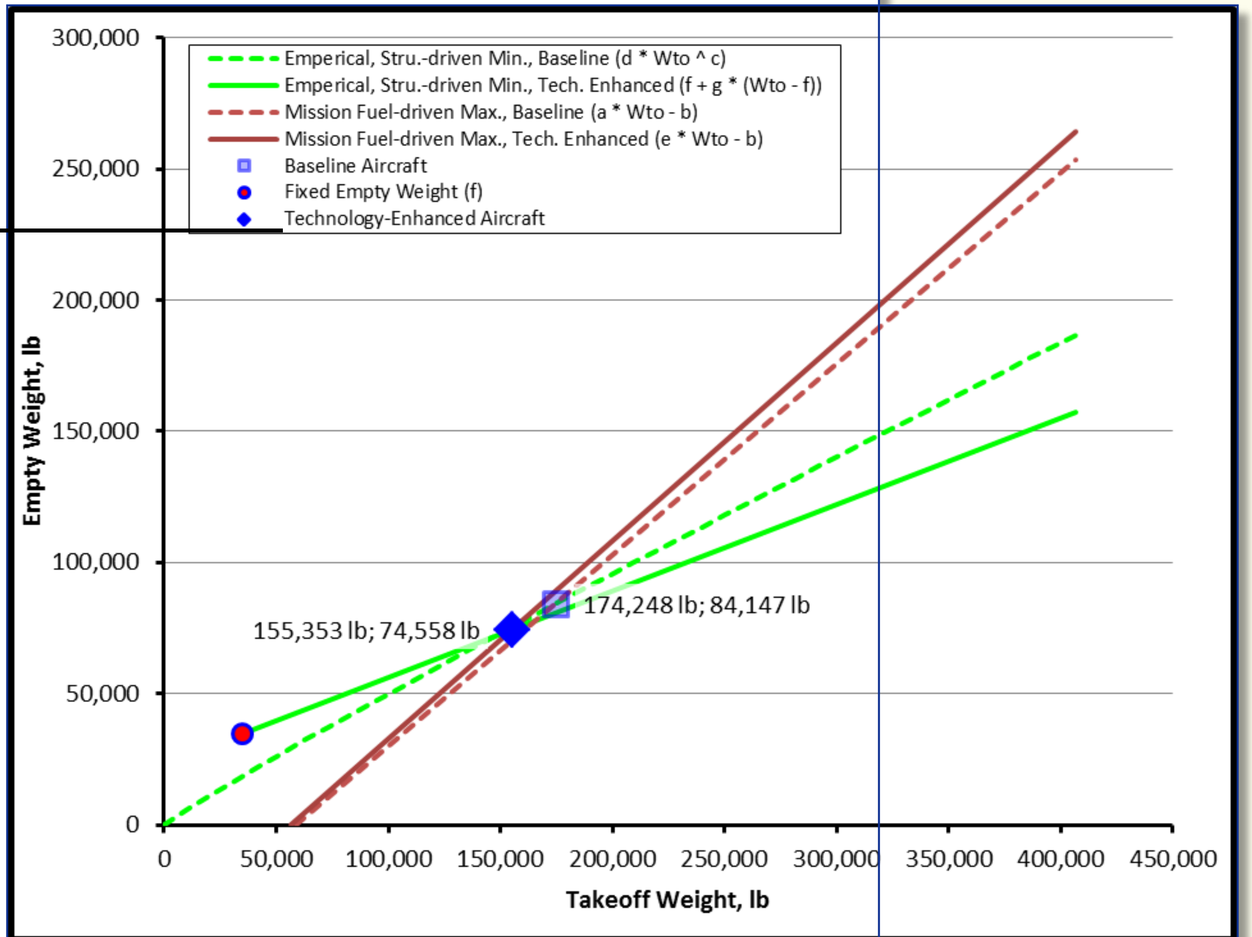
Aircraft First-Order Resizing

Segment	Driver	Driver Value				
Start	N/A	0				
Taxi	min	9				
Takeoff	N/A	0				
Climb	ft	35,000				
Cruise	nmi	2,567				
Climb	ft	4,000				
Cruise	nmi	2,567				
Climb	ft	4,000				
Cruise	nmi	2,567				
Descend	ft	40,500				
Loiter	min	12				
Descend	ft	1,500				
Land	N/A	0				
Reserve	%	5%				
Takeoff	N/A	0				
Climb	ft	12,000				
Cruise	nmi	160				
Descend	ft	10,500				
Loiter	min	30	0.988	0.988	**Takeoff Weight, lb**	**497,781**
Descend	ft	1,500	0.999	0.999	**Empty Weight, lb**	**200,235**
Land	N/A	0	0.998	0.998	**Useable Fuel Weight, lb**	**240,944**



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Economic Analysis

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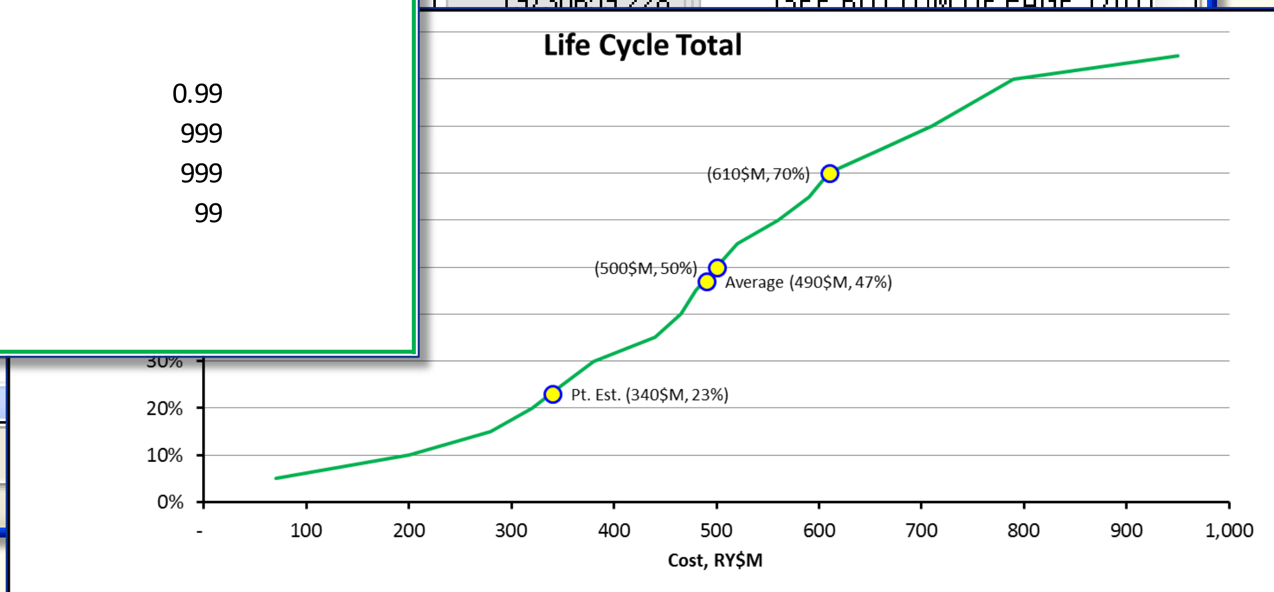
Key Cost Metrics	Baseline Aircraft	Technology Enhanced Aircraft	Savings (+ is good)
First Unit Production Cost	9,999	9,999	9,999
Average Unit Production Cost	9,999	9,999	9,999
Flyaway Unit Cost	9,999	9,999	9,999
Operating Cost Per Flight Hour	9,999	9,999	9,999
Cost per Available Seat Mile	9,999	9,999	9,999

NPV Metrics	
Probability of Cost Savings Over Total Life Cycle	0.99
Acquisition Break-even Quantity	999
Life Cycle Break-even Quantity	999
Break-even Operating Year	99



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Project Status

- **Accomplishments**
  - Developed and populated Reference Configuration Database
  - Developed aeronautical technology maturation CERs
  - Selected/developed/compiled transport aircraft development and production CERs
  - Developed commercial aircraft operations and maintenance CERs based on historical airline cost data
  - Developed and populated Technology Cost Tool database including ACEIT™, SEER-SEM ™, and PRICE-H ™ methodologies
  - Developed PTIRS economic analysis module in ACEIT
  - Developed and Delivered PTIRS user interface screens and software in MS Excel
- **Future work**
  - Test, refine, test, refine, test, refine…!

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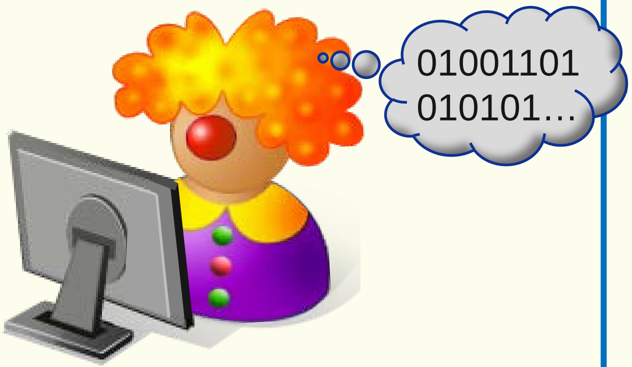
Test Plan

Unit Test, Integration Test



PI, Programmers

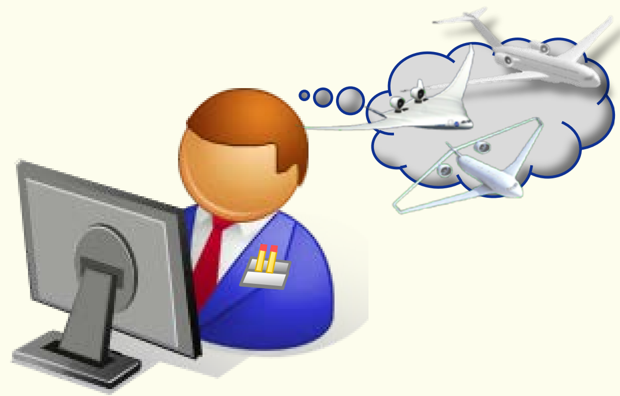
1. Individual requirements tested in isolation as code is developed
2. Individual requirements verified in integrated system

Alpha Test

PI, COTR, Tecolote Analysts

1. Requirements demonstrated to COTR
2. Results validated by comparison to known aircraft
3. Performance verified by test case involving insertion of sample technology(s)

Beta Test



ERA Technologists

1. ITD leads use PTIRS to develop business cases for individual technologies
2. ERA management team uses PTIRS to develop business case for technology suite
3. Tecolote provides training, modifications and maintenance
4. Requirements re-demonstrated at end of beta test

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Conclusions

- PTIRS helps technologies bridge the “valley of death” by providing compelling business cases for incorporating the technologies on future commercial aircraft
- PTIRS is a unique system that allows the strongest capabilities of several industry-leading cost estimating tools to be applied to technology insertion cost estimating