



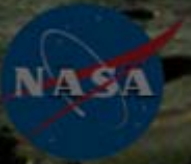
# PTIRS

Probabilistic Technology Investment Ranking System

Overview for ICEAA Conference

Peter Frederic, Tecolote Research, Inc.

6/x/2013



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



- ❑ **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 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



# 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**

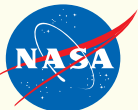
TC – Demonstrate UHB efficiency improvements to achieve 15% TSFC reduction, contributing to the 50 percent fuel burn reduction goal at the aircraft system level, while reducing engine system noise and minimizing weight, drag, NOx and integration penalties at AC system level

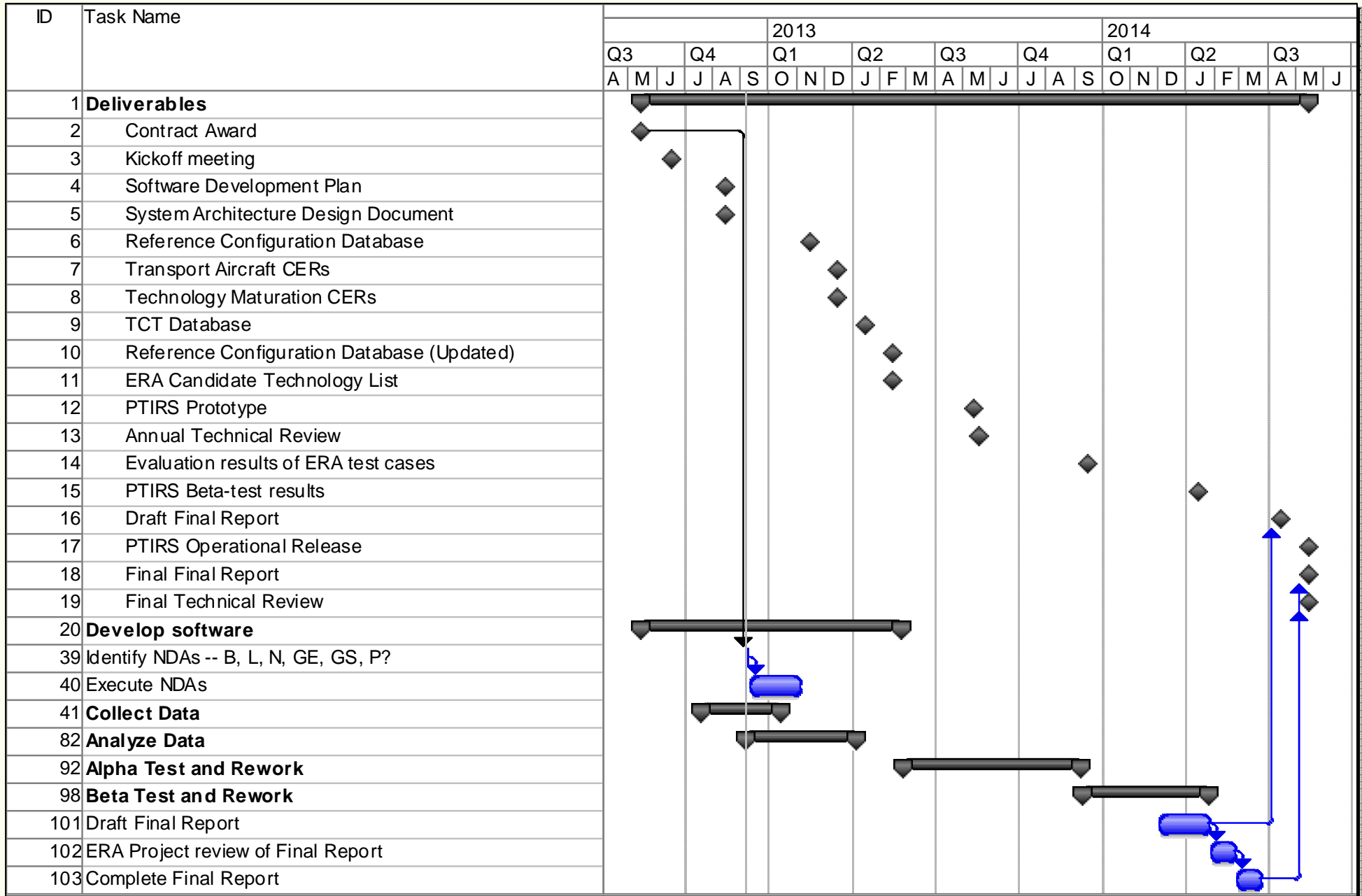
## **TFA4 Advanced Combustor Designs for Oxides of Nitrogen Reduction**

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





# PTIRS

# Introduction



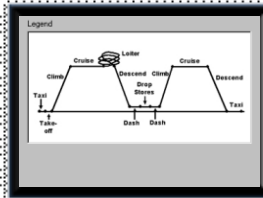
Promote ERA goals by providing compelling business cases for ERA technologies





# PTIRS

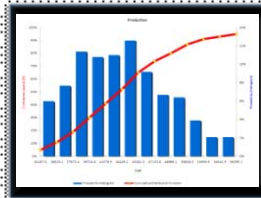
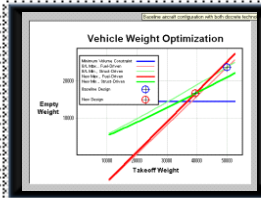
# Tool Architecture



Large Number	A	B	C	D
Stage	100.00	37.76	0.00	
Air Frame	94.20	29.82	0.00	
Wings	48.00	22.04	0.00	
Aerodynamic Surfaces	42.57	0.00	0.00	
Fuselage	21.42	0.00	0.00	
Additional Air Structure	21.42	22.04	0.00	
Basic Propellant Body	0.00	0.00	0.00	
Case	0.00	0.00	0.00	
Undercarriage	0.00	0.00	0.00	
Naval	18.83	13.23	0.00	
Legend Propellant Tanks	8.01	0.27	0.00	
Fuel Tank	8.01	0.27	0.00	
Orbiter Tank	13.52	3.98	0.00	
Orbiters				

New Item Description	WBS Number	Description	Weight (lbs)
Test			

Applicability of External Methodologies	Methodology	Applicable
Development	Technology Maturity CERs	Yes
Production	Multi-category Dev't, Prod., O&S CERs	Yes
Operational	Interfaces to COTS Estimating Tools	Yes



- Mission Profile
- Payload
- Fleet Size
- Flight Rate

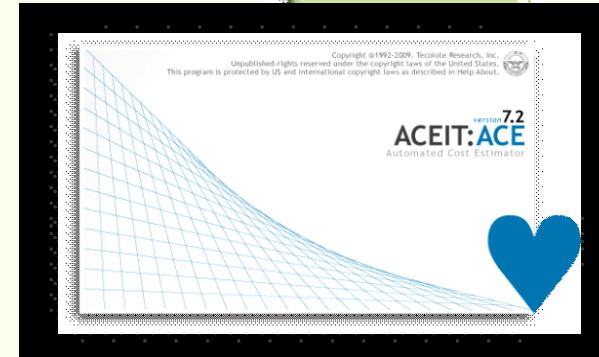
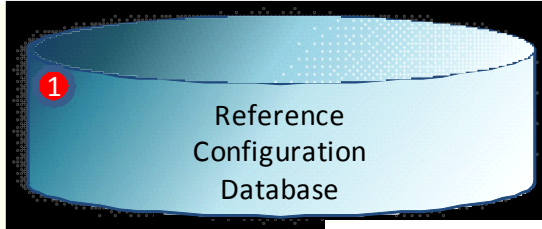
- Mass Properties
- Takeoff/Landing Performance
- SFCs
- L/Ds
- Noise Footprints
- Emissions
- R & M Factors

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

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

- Override Mass Properties

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



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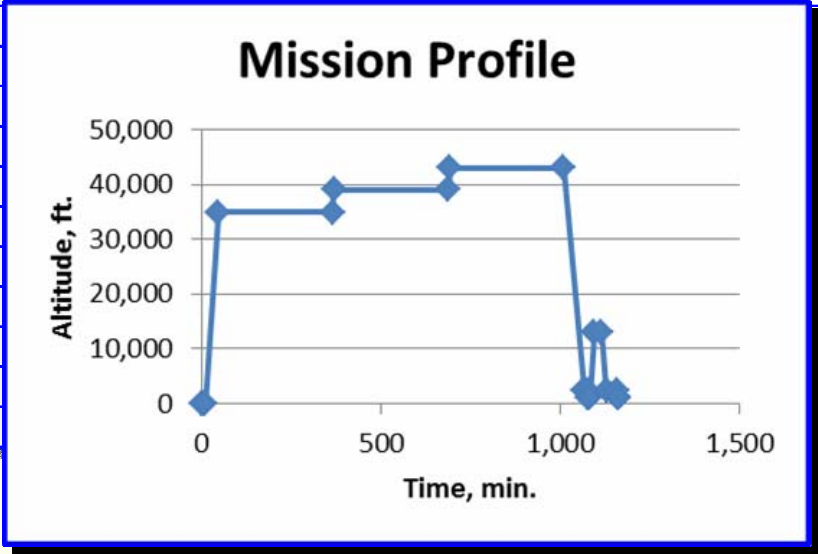
Insert Segment

Delete Segment

## Reference Mission Description

*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				



PTIRS Version: -0.19, Sample, 8/2/12 12:00 AM

## Reference Vehicle Basic Configuration Inputs

Input	Units	Baseline
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Aircraft Type PTIRS Version: -0.19, Sample, 8/2/12 12:00 AM

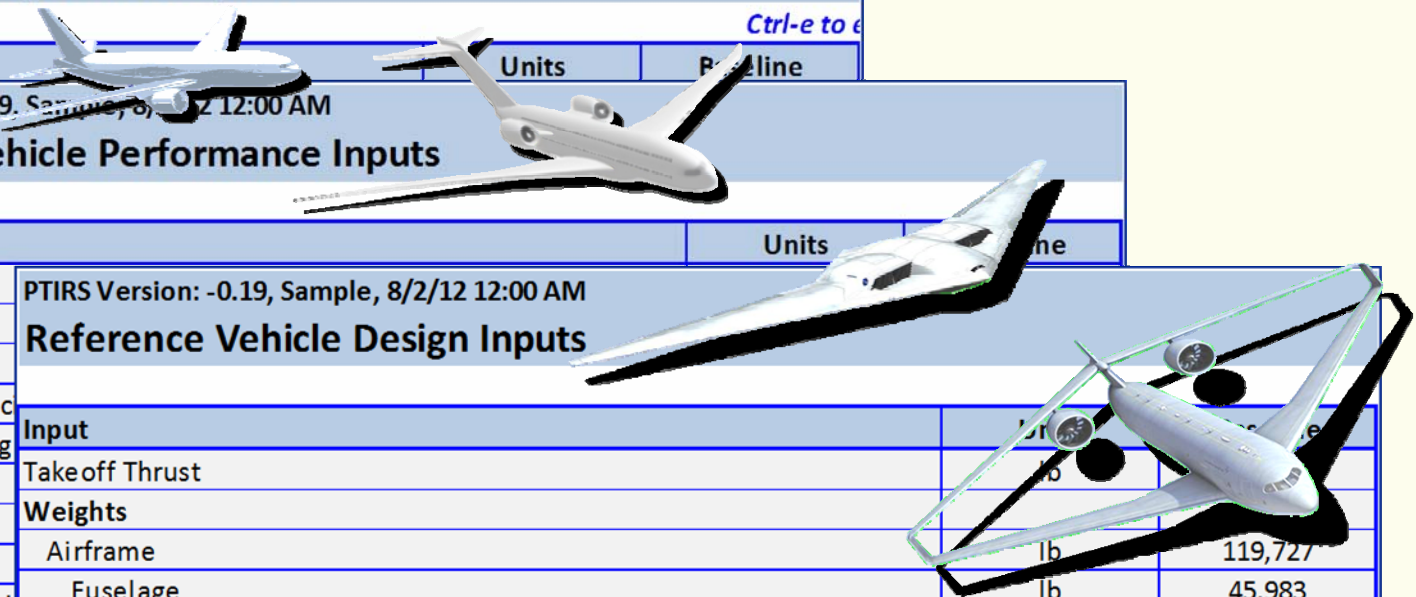
## Reference Vehicle Performance Inputs

Input	Units	Baseline
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Cruise PTIRS Version: -0.19, Sample, 8/2/12 12:00 AM

## Reference Vehicle Design Inputs

Input	Units	Baseline
Take off Thrust	lb	119,727
<b>Weights</b>		
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



PTIRS Version: -0.19, Sample, 8/2/12 12:00 AM		Add Assembly	Delete Selected Assembly	Print CER/Input Report
<b>Assembly-level Technology Impacts, Additions</b>				
<i>Ctrl-e to edit/add/delete comment</i>				
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	N/A			
WBS Description	N/A			
Descriptive Keyword Codes	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			

**Select Modification Attributes**

Check all attributes that apply to  
t2

- Mechanical
- Electrical/Electronic
  - Digital Electronic
    - General Purpose Processor
    - Dedicated Processor
    - Memory
    - Data Bus
    - I/O
    - Data encryption
    - Modem
  - Analog Electronic
  - Converter
  - Electrical Power

Enter additional attributes here if necessary

**SCOTT will use the selected keywords to identify appropriate estimating methodologies for the new component.**



PTIRS Version: -0.19, Sample, 8/2/12 12:00 AM

Cancel Next

### Finalize methodology selection:

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 provided. 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 ◆	Overall Score ▲
Cost Driver Sensitivity ◆	Economic Applicability ▲	Statistical Strength ●	
Intuitive Appeal ▲	Age of Data ▲	Data Visibility ▲	

◆ = 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).

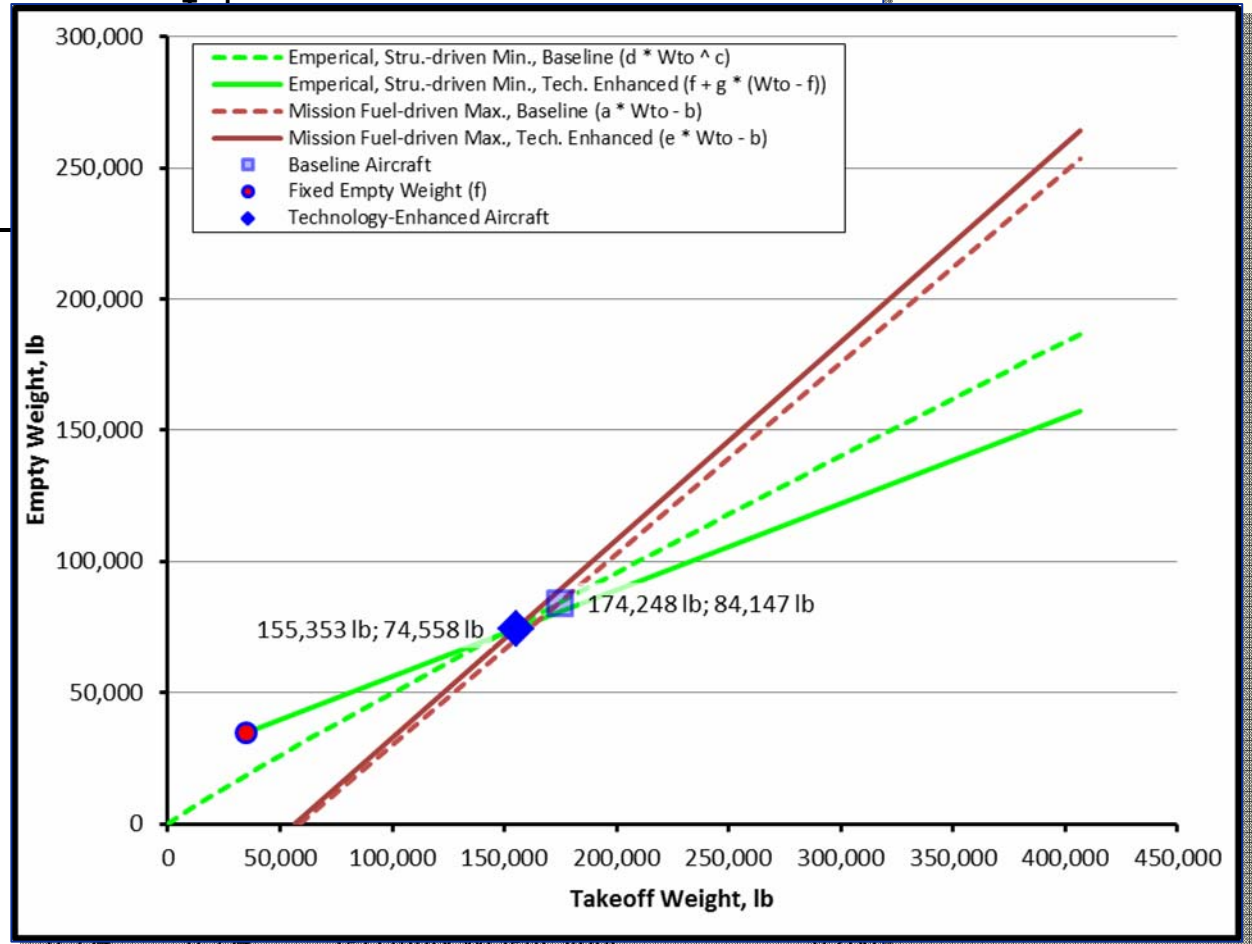
This CER is based on eleven data points: DMSP-5D1, DSCS 1&2 (2 points), Intelsat IV, MARISAT, OSO I, S3, TACSAT (2 points), and TDRSS (2 points).



PTIRS Version: -0.19, Sample, 8/2/12 12:00 AM

## 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
Descend	ft	1,500
Land	N/A	0



0.998	0.998	Takeoff Weight, lb	497,781
0.999	0.999	Empty Weight, lb	200,235
0.998	0.998	Useable Fuel Weight, lb	240,944



ACE 7.3 - [Aircraft.aceit - Methodology (BY1989\$M)]

File Edit View Documentation Calc Cases Reports Tools Window Help

Microsoft Sans Serif

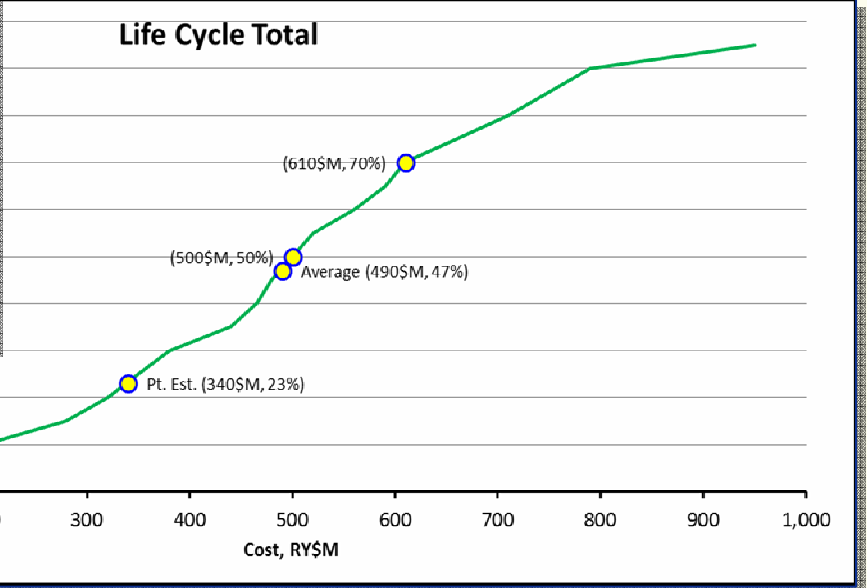
Key Cost Metrics	Baseline Aircraft	Technology Enhanced Aircraft	Savings (+ is good)
First Unit Production Cost	9,999	9,999	9,999
Average Unit Production Cost	9,999	9,999	9,999
Flyaway Unit Cost	9,999	9,999	9,999
Operating Cost Per Flight Hour	9,999	9,999	9,999
Cost per Available Seat Mile	9,999	9,999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

BASELINE      Equation / Throughput

19730659.228\*      ISEE BOTTOM OF PAGE 170.0

**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



Air Induction Fin

Methodology / Yearly Phasing /

Ready



## ❑ 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...!





## 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



- ❑ **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**

