Introducing Lifecycle Cost to
Early Conceptual Tradespace Exploration

20th Annual NDIA Systems Engineering Conference
October 26, 2017

E. Alex Baylot, Research Industrial Engineer
James "Jed" Richards, Operations Research Analyst
US Army ERDC

Objective and Outline

Provide ERS Lifecycle Cost (LCC) development plan and methods for linking cost models to performance models for generating largescale tradespaces

- Objective
- Background
- Cost Estimating Techniques
- Cost Analysis Use Case
- Surrogate Model Creation Method
- Low-Cost Attritable Aircraft Use Case
- ERS Cost Model Development Plan
- Summary
- Questions

Distribution A: Approved for Public Release

Background

> *A goal of the Engineered Resilient Systems (ERS) Program is to create a capability for linking cost and performance models for early concept exploration of design alternatives*

Affordability
On Time, on Budget

Adaptability
Rapid Response to Emerging Threat
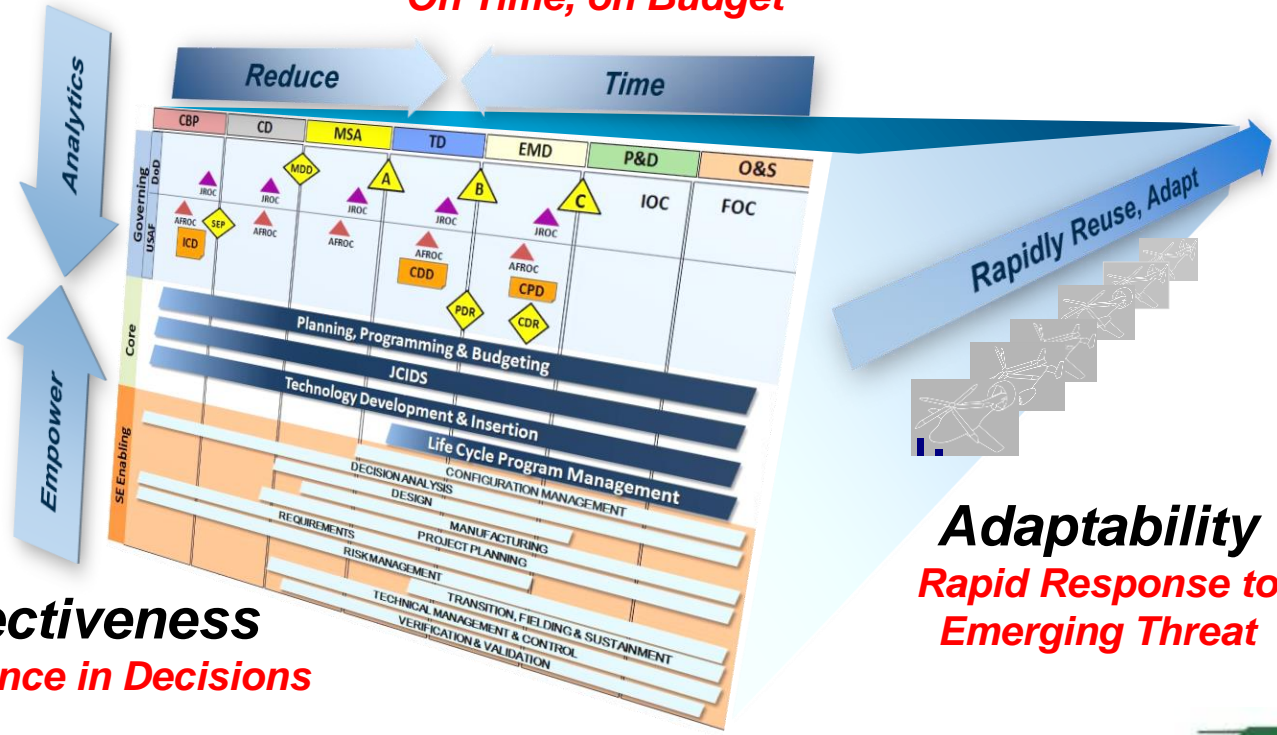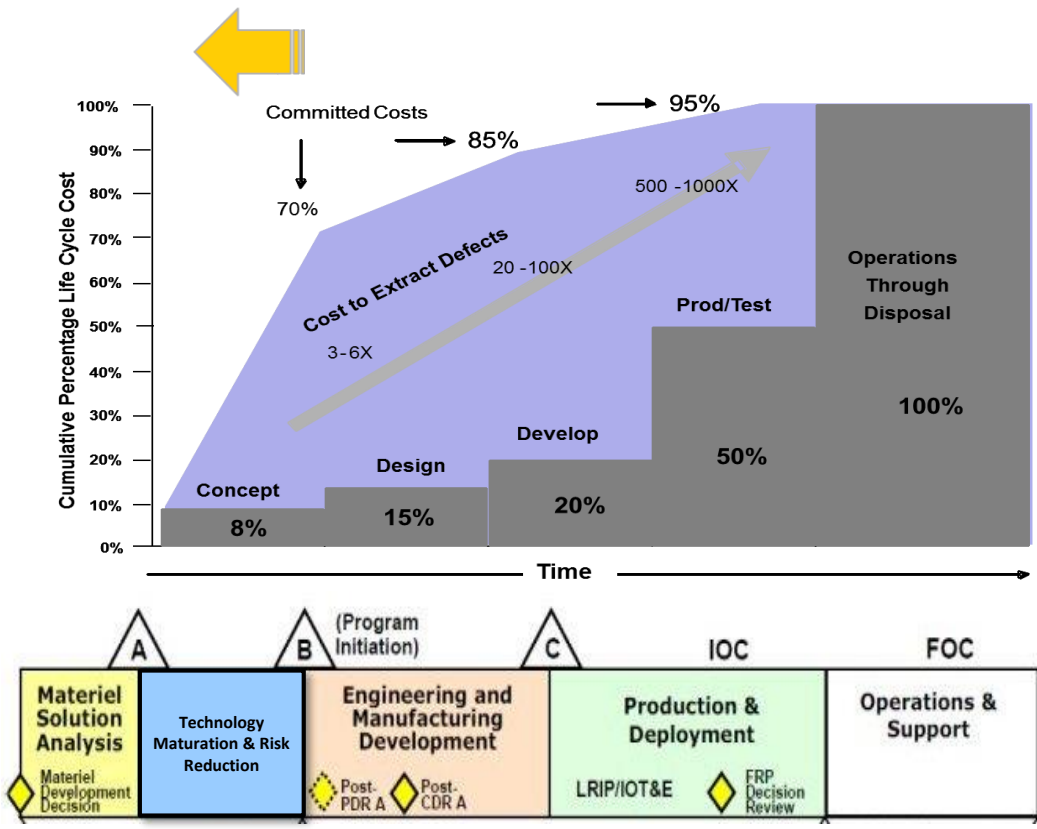
Effectiveness
Confidence in Decisions

Affordability Analysis (Pre-Milestone A/B)

- Determine Affordability Goals/Caps

- Estimate Program Lifecycle Cost

- Establish Cost Targets

- Analyze Cost/Performance Trades

Committed Lifecycle Cost

Reference DoDI 5000.02 Defense Acquisition Life Cycle Compliance Baseline

Cost Estimating Techniques

Analogy
- Quick, inexpensive, easy-to-change
- Subjective, not precise, poor comparison between new and old systems
- Typically used pre-Milestone A through Milestone A

Parametric
- Cost estimating relationships, inexpensive, easy to do "what-if" drills
- Moderately subjective, precision only as good as databases
- Typically used pre-Milestone A through Milestone B

Engineering
- Very accurate in later stages of EMD, limited subjectivity, uses WBS
- Very expensive, very time consuming, "what-ifs" are difficult
- Typically used Milestone B through post-Milestone C

Actual Costs
- Limited subjectivity, very accurate
- Limited actual cost data, very expensive, very time consuming, "what-ifs" are difficult
- Typically used Milestone C through post-Milestone C
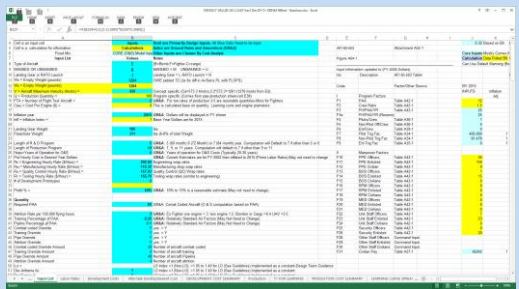
DAU ACQ 101

Cost Analysis Use Cases

|	Use Cases	ERS Partner
Create/Adapt Cost Model	1 – <u>Manual CER</u>: User manually enters Cost Estimating Relationships (CER) to build a cost model	UAS (NCCA, UAS Handbook)
	2 – <u>Existing Menu</u>: User choses an existing cost constraint component and adjusts (calibrates) for specific cost generation	Helicopter (GTRI, Commercial rotorcraft cost model)
	3 – <u>Historic Cost Data</u>: cost model from user provided historic cost data	Ground Vehicle (TACOM, CADE data)
Link Existing Cost Model	4 – <u>Existing Model Surrogate</u>: Allows user to provide an existing cost data set derived from any source to generate meta model for cost domain tradespace generation (surrogate cost modeling)	Surface Ship (NSWC Carderock, Surface Combatant Performance Based Cost Model)
	5 – <u>Excel Cost Model</u>: Allows user to provide an existing excel based cost model to link to tradespace generation	Un-Manned Aircraft (AFRL – LCAAT)
	6 – <u>COTS Cost Model</u>: User provides a COTS integrated tools model	[development pending]

Distribution A: Approved for Public Release

Connecting cost models to other tradespace models

I/O Combinations

Python Wrapper/Parser

Surrogate Model

+100K

Use existing spreadsheet cost model
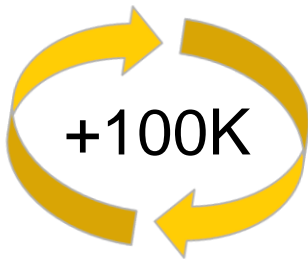
Use Monte-Carlo techniques
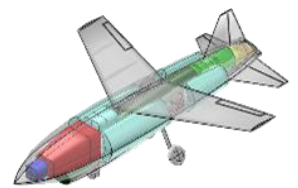
Generate surrogate-regression model

Low-Cost Attritable Aircraft Use Case

Current Method*

Computer-language cost model derived from spreadsheet to MATLAB or Python

- 4 months development
- Slow response to changes

Surrogate Method

Surrogate Model

- 24 hours development
- Quick response to changes

*Not typical
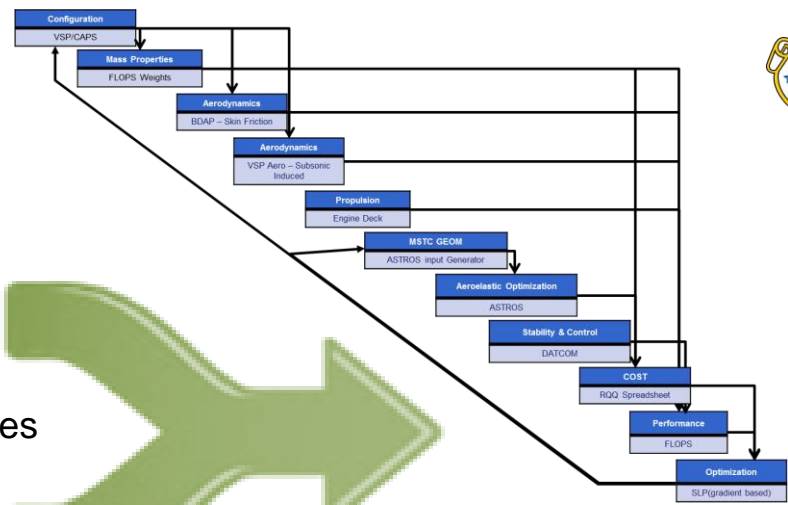
- ☐ **Aeroelasticity**
- ☐ **Structural sizing**
- ☐ **Cost**
- ☐ **Stability & Control**
- ☐ **Multi-Fidelity**
- ☐ **Parametric Analysis Optimization**
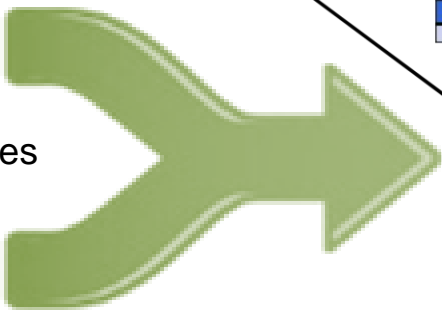
Model Execution

100X reduction in cost model integration period

ERS Cost Model Development Plan

FY17				FY18				FY19			
1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q

LCC TradeBuilder Module v1.0 (parse constraints from models, CERs, add functions via GUI)

LCC TradeBuilder Module v1.1 (link LCC Python and surrogate models)

LCC TradeBuilder Module v2.0 (link CADE Enterprise for historic data and increase DoD system LCC model portfolio, cost as a function of Ilities (RAM)

LCC TradeBuilder Module v3.0 (Use CADE Enterprise data to build LCC models by analogy, additional total cost influence from Ilities (Mfg/Production, etc.)

UAS (NCCA)
Manual CER
Completed

Surrogate cost modeling R&D
Transform Spreadsheets

CADE Enterprise
Historic data & CERs

LCC by Analogy
Historic data & CERs

Light-Wheeled GV model (TACOM)

LCAAT (AFRL)
Python Models built from Spreadsheets
Completed

Universal Wheeled GV model (TACOM)
Generalizable component built directly in python framework

Initial Commodity Areas (MILSTD-881)
GV model (TACOM)
Aircraft-UAS model (AFRL & NAVAIR)
Surface Ship (NSWC)
Models (Python, Spreadsheets, etc.)

Remaining Commodity Areas (MILSTD-881 Systems) (priority TBD of 13)
Models (Python, Spreadsheets, etc.)

Create/Adapt Cost Model

Link existing Cost Model

Reliability, Availability, Maintainability R&D (w/Boeing, AFRL, AMSAA, MSU)   Mfg/Producibility, Affordability (MSU, industry, OSD-CAPE)

Summary

- DoDI 5000.02 identifies the requirement at Milestone (MS) A for an Affordability analysis in addition to a cost analysis and is driving more accurate cost analysis to the left

- ERS is developing methods to better integrate cost models into conceptual tradespace exploration using existing models or surrogate models

- Surrogate modeling methods show promise to greatly accelerate the integration process into tradespace exploration for pre-MS A & at MS A

- The ERS cost model development plan strives to provide a capability for all system commodities supporting all Services and OSD-CAPE

Ground Vehicle
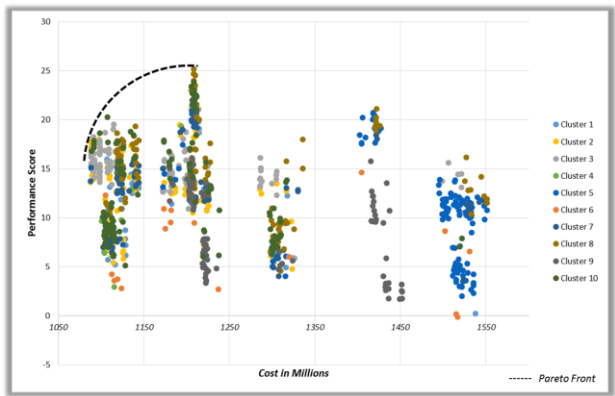
UAS
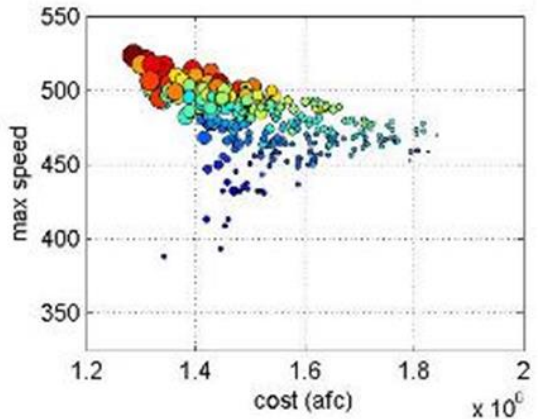
Questions

Mr. E. Alex Baylot, US Army ERDC
Alex.Baylot@usace.army.mil

Mr. James "Jed" Richards, US Army ERDC
James.E.Richards@erdc.dren.mil