Crew and Space Transportation Systems Cost Model (CASTS)

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Outline

- Overview of CASTS
  - NASA's Project Cost Estimating Capability (PCEC)
- Model Development Approach
- Historical Database
- Primary Features
- Future Plans
- Conclusion

Overview
What is CASTS?

- CASTS is a new, unique parametric cost estimating *capability* for use in estimating space transportation systems, including crewed systems, and earth-to-orbit and in-space transportation systems.
  - Capability includes parametric cost model and historical database
    - Model estimates Non-recurring development (DDT&E) and Flight Unit/Recurring Production of launch vehicle hardware/software at subsystem level
- Developed as part of NASA's Project Cost Estimating Capability (PCEC).
- Emphasis on Basis of Estimate: Historical database consisting exclusively of transportation/crew systems.
  - Traceability and transparency of estimate to database
  - Development and documentation of the database and analytical processes behind the CERs incorporated in the model

Overview
Why CASTS?

– CASTS is being developed to reflect the general PCEC philosophical move from a ***Model Centric*** to ***Data Centric*** estimating approach.

Data Centric

- Focus is on how to use the model
- Model becomes a medium for communication with the technical community
- Model gets all the credit (or blame) for the estimate
- **Estimate becomes an evaluation of the present, rather than a prediction of the future**

- Focus is on the relationship of the data to the estimating problem
- Analyst must access and know the underlying data
- Puts onus for the quality of the estimate on the estimator
- **Done properly, can lead to value-added solutions**

Overview
CASTS Philosophical Approach

– CASTS reflects the overall PCEC philosophical framework.

- **Use the Best Data Possible**
  - Verified and Validated Crewed and Space Transportation Systems (CASTS) Data from REDSTAR
  - NASA Cost Analysis and Data Requirements (CADRe) Data for Spacecraft Model
- **Total Transparency in the Analysis of the Data and the Development of the CERs**
- **No Cherry Picking the Data Points**
- **Minimize or Eliminate Subjective Inputs**
  - Follow a Data Driven Process for the Derivation of Subjective Inputs
  - Allow the User to Follow the same Process for Determining Input Values
- **Emphasize Quality of Input Parameters over Quantity**
- **Expect the User to Develop the Rationale for the Estimate**
  - Know the Data

***GOAL: Credible, Supportable, Defendable* estimates**

CASTS Within the Overall PCEC Architecture

– As part of PCEC, CASTS is a set of tools, including a parametric cost model and historical database
  - Model is available to entire user community
  - Historical database available to NASA-approved user community

SOURCE DATABASES

Cost Model Backup
- CASTS User's Guide - Restricted
- CASTS "Virtual Blackbooks"
- Robotic spacecraft data analysis spreadsheets and cost analysis reports*
- Cost Analysis Data Requirements (CADRe) documents

PCEC COST MODELS

Launch Vehicles/Human Spaceflight Missions
- CASTS CERs
- CASTS User's Guide - Unrestricted

Robotic Science Missions
- Spacecraft Subsystem CERs
- PM/SE/MA/I&T CERs*
- NASA Instrument Cost Model

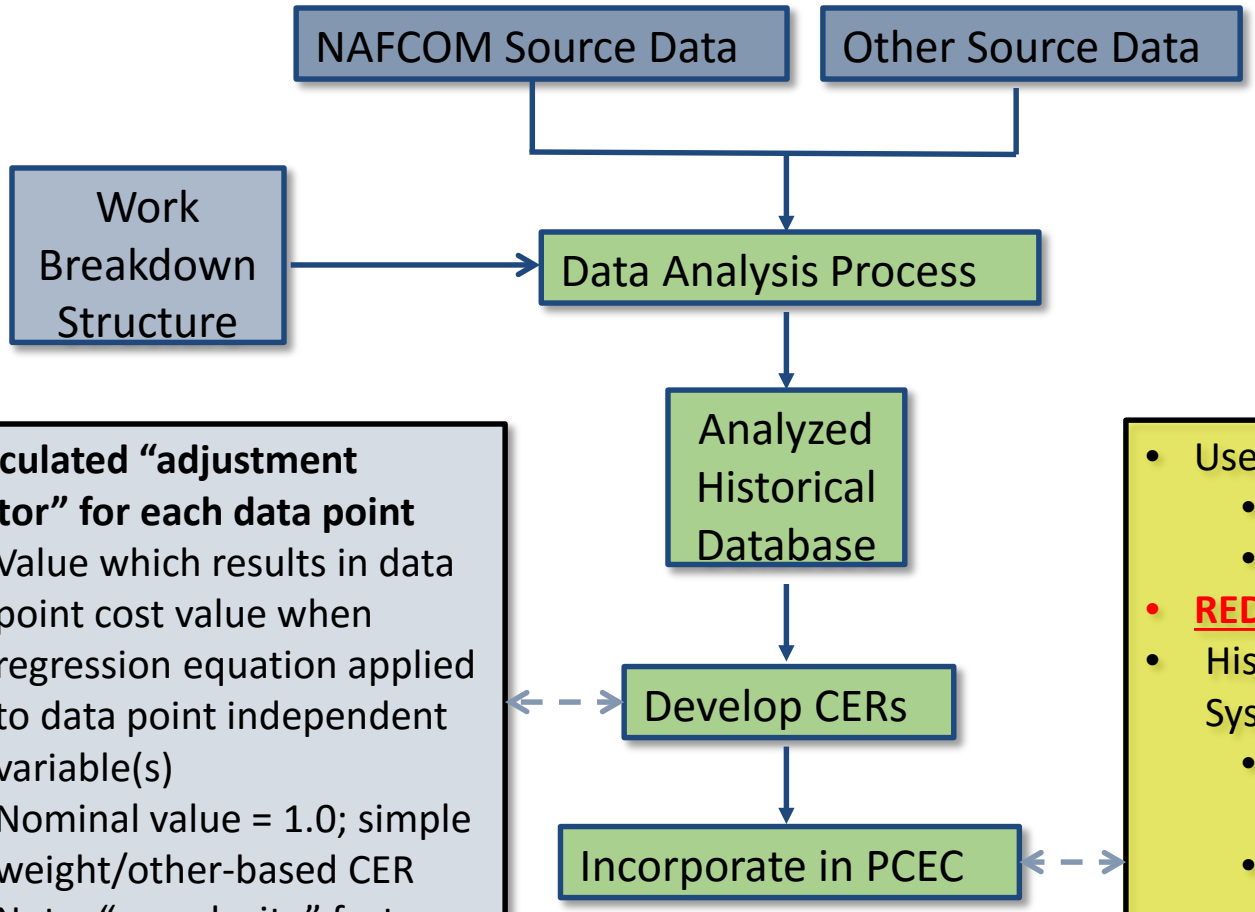
Estimating Support
- CER Library
- WBS Templates
- Help File
- Inflation Index
- Cost Phasing

NASA IT Security Interface

Accessible with NASA User ID and Account Approval

Publically Releasable via NASA Software Release Authority Process

CASTS
Model Development Process



- **Calculated "adjustment factor" for each data point**
  - Value which results in data point cost value when regression equation applied to data point independent variable(s)
  - Nominal value = 1.0; simple weight/other-based CER
  - Not a "complexity" factor – says nothing about why value is what it is

- User's Guides
  - Restricted/Unrestricted
  - WBS/CERs
- **REDSTAR Virtual Black Books**
- Historical Source Data By System
  - Cost Analysis Worksheets
  - Technical Information Summary
  - REDSTAR Bibliography

CASTS
Historical Database

- NAFCOM heritage: trace back to source documents
- New systems: Develop suitability for inclusion in database
- *DOCUMENTATION* – from sources to CERs – Virtual Black Books

Roster of systems currently included in CASTS CER datasets

Launch Vehicles
Atlas V Common Core Booster
Atlas V Centaur
Apollo Command/Service Module
Apollo Lunar Module
Centaur D
Centaur G' (Shuttle Centaur)
Centaur G' CISS - ASE
Shuttle External Tank
Shuttle Orbiter
Shuttle Solid Rocket Motor
Shuttle Solid Rocket Booster
Saturn V 1st Stage (SIC)
Saturn V 2nd Stage (SII)
Saturn V 3rd Stage (SIVB)
Titan Centaur
Titan IV 5m Fairing
Atlas I, II, IIA, IIAS
Super Lightweight External Tank

Liquid Engines
F1
J2
J2X
RS27
RD180
RL10
RS68
SSME

Solids
Titan IV SRMU
Athena Castor 120
Trident D5
Shuttle RSRM
Atlas IIAS Castor 4A
Atlas V SRM
Ariane V EAP-P230
Pegasus

Software
SSME Adv Health Mgt Sys
Orbiter Cockpit Avionics Upgrade
Orbiter Primary Avionics Software Sys
Orbiter Backup Flight Software
BRAHMS
DART
X33
Centaur G'
Atlas II
Atlas V

CASTS
Work Breakdown Structure

- Currently no standard NASA WBS for transportation systems.

Program Segment
Program Mgt & Support
Systems Engr & Integ
Vehicle Segment
Integration, Ass'y, Checkout
Crew Structures
Wing
Tail
Fuselage/Body
Capsule Structures
Thrust Structure
Adapters
Secondary/Support Structs
Tanks
Intertank

Vehicle Segment (cont'd)
Mechanisms
Thrust Vector/Flight Control
Separation
Recovery
Other
Main Propulsion Systems
Thermal Protection
Passive
Re-Entry Leading Edges
Re-Entry Heat Shield
Propulsion
Liquid Engines
Solid Motors
Reaction Ctl/Orb Maneuv Sys

Vehicle Segment (cont'd)
Avionics & Power
Guidance, Nav, & Control
Telemetry & Tracking
Command, Ctl, Data Handling
Range Safety/Flt Termination
Electric Power
Shroud/Fairing
Crew Systems
Environ Ctl & Life Supt
Displays/Controls
Software Segment
Flight Software
Ground Software
Test Segment
System Test Operations
System Test Hardware
Ground Segment
Ground/Test Support Equip
Tooling

CASTS
Work Breakdown Structure CERs

- Open PCEC architecture allows user to easily add/delete/modify CERs to suit.

Program Segment
Program Mgt & Support
Systems Engr & Integ
Vehicle Segment
Integration, Ass'y, Checkout
Crew Structures
Wing
Tail
Fuselage/Body
Capsule Structures
Thrust Structure
Adapters
Secondary/Support Structs
Tanks
Intertank

Vehicle Segment (cont'd)
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Avionics & Power
Guidance, Nav, & Control
Telemetry & Tracking
Command, Ctl, Data Handling
Range Safety/Flt Termination
Electric Power
Shroud/Fairing
Crew Systems
Environ Ctl & Life Supt
Displays/Controls
Software Segment
Flight Software
Ground Software
Test Segment
System Test Operations
System Test Hardware
Ground Segment
Ground/Test Support Equip
Tooling

CER Type
Cost-to-Cost
Des & Dev + Flt Unit (wt/other)
Adjustment Factor
Multi Var CER (DD & FU)

CASTS
User's Guides

- Unrestricted – includes model overview, definitions, description of modeling processes, and for each WBS element: CER equations, descriptions, data set Adjustment Factors
- Restricted – includes Unrestricted information plus scatter plots, CER source data set

CASTS User's Guide - Unrestricted
PCEC version 2.0.1 **January 2016**

WBS Element: Main Propulsion Systems

CER Equations: D&D $ = .7008 x Weight$^{.6919}$ x AF FU $ = .0102 x Weight$^{.8342}$ x AF

Inputs:

Dry weight (Weight), Adjustment Factor (AF)

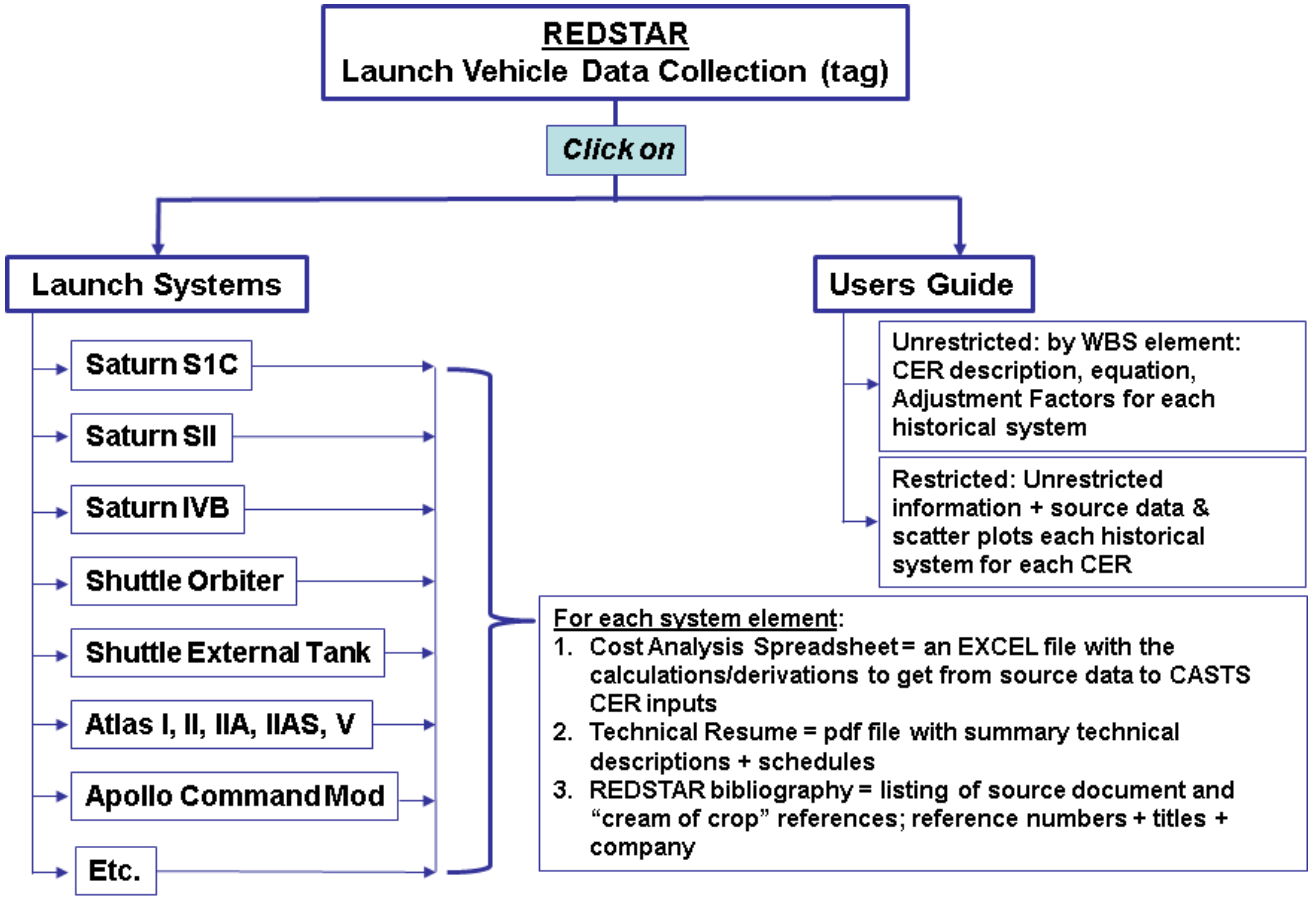
Description:

This CER estimates the Design and Development and Flight Unit costs of the Main Propulsion System (MPS) of a launch vehicle element and includes (as applicable) feed lines, fill and drain, purge and vent, and pressurization subsystems. The Apollo CSM and LM data points were excluded from the CER calculation data set base due to the significant difference in requirements, design, complexity, and overall nature of those subsystems relative to the rest of the data set. As such the Apollo adjustment factors are essentially factors to adjust for analogous MPS systems comparable to the Apollo systems.

ent Factors:

System	Description	DD	TFU
AV CCB	RP1	1.5620	0.3907
External Tank	LH2	0.7529	0.4280
SIC	RP1	0.7611	0.9420
Centaur D	LH2	2.2395	1.9872
Orbiter	LH2	1.1903	4.1059
AV Cent	LH2	2.7944	3.0632
SIVB	LH2	2.1854	0.5304
Titan Cent	LH2	0.4081	0.3005
Centaur G'	MPS-G' LH2	0.3331	1.9150
Centaur G' CISS	MPS-CISS LH2	0.4072	0.5143
SII	LH2	1.2450	1.5678
Apollo CSM	Main Propulsion	11.8526	11.6432
Apollo LM	Ascent	6.9662	10.6624
Apollo LM	Descent	5.9231	10.6106

CASTS
Virtual Black Books



CASTS
Future Plans (1)

- Cost delineated by functions (Engineering, Touch, Manufacturing Support, Quality Assurance, etc.) rather than end items (weight, thrust, lines of code)
  - Much historical data is in this format; not always by end item

- Many (most?) cost reduction/affordability approaches relate most directly to functions, not end items
  - E.g. Touch labor vs. automated welding; SR&QA vs. reduction in Gov't Mandated Inspection Points (GMIPS); Facility O&M vs. shared facilities

- Schedule tasks usually address functions directly, not end items
  - E.g. "design", "analyze", "test", "fabricate", "inspect", etc.

- FBS capability will allow more visibility/flexibility regarding estimates of (for instance):
  - Potential cost/savings of affordability initiatives
  - Integration of parametric-based estimates with JCL schedules

CASTS
Future Plans (2)

- Expand historical database/incorporate in CERs
- Explore meaningful independent variables
  - Replace Adjustment Factors
- Investigate development of objective Complexity Generators

- Time dimension - Full life cycle cost estimating capability: "sand charts"
- Spread vs. non-spread cost
- Cost as function of flight/production rates over time
- (Capability) Nonrecurring facilities, mission and launch ops

CASTS
Conclusion

- Our primary initial emphasis has been on database development rather than model development.
- Our overall goal is to provide Traceability and Transparency of both model and data.
- At the same time we are working to develop an estimating capability that provides both Depth and Breadth of data and model.

Ultimately: Credible, Supportable, Defendable