NASA Air Force Cost Model (NAFCOM): Capabilities and Results

Julie McAfee, SAIC
George Culver, SAIC
Mahmoud Naderi, MSFC Cost Office
NAFCOM Description

- NAFCOM is a parametric estimating tool for space hardware.
- Uses cost estimating relationships (CERs) which correlate historical costs to mission characteristics to predict new project costs.
- It is based on historical NASA and Air Force space projects.
- It is intended to be used in the very early phases of a development project.
- NAFCOM can be used at the subsystem or component levels and estimates development and production costs.
- NAFCOM is applicable to various types of missions (crewed spacecraft, uncrewed spacecraft, and launch vehicles).
- There are two versions of the model: a government version that is restricted and a contractor releasable version.
Extensive Historical Database
• Based solely on historic NASA and Air Force space flight hardware projects
• Database contains 149 Missions
• Applicable to broad spectrum of missions (launch vehicles, crewed and uncrewed spacecraft, engines)

User Friendly Interface
• Wizard for novice users
• Interface allows rapid risk analysis, time phasing, and cost trades
• Extensive reporting features

Various Estimating Methods
• Multi-variable
  • Cost is a function of technical, performance, and management metrics
• Weight-based Analogies
• User-defined

There are currently over 1000 registered NAFCOM users.
• Training classes are provided at multiple NASA sites each year.
• Technical support and senior level analytical support are also provided.
1990
- NASCOM database in hardcopy only
- Estimators hand-entered data into spreadsheets
- Database contained 65 data points

1992
- Allowed online searches and copying of data
- Cost estimates developed in spreadsheets with CERs created by individuals
- Database contained 70 data points

1994
- Fully functional cost model with user defined WBS and data access
- CERs built automatically within NASCOM using “1st Pound” method
- Database contained 91 data points

1996
- Combined NASA and Air Force data
- Enhanced search and filtering of data
- Standardized WBS elements created
- Database contained 102 data points

1999
- First non-weight based CERs for five subsystems (multi-variable CERs)
- Government and contractor versions distributed
- Database contained 114 data points

2002
- Total re-write of all NAFCOM program code
- multi-variable CERs for all subsystems
- Major user interface improvements
- Database contains 122 data points

2004-2006
- Cost Risk Analysis Module
- CER Improvements
- SOCM
- Component level multi-variable CER
- Allocation of Risk Dollars by WBS Elements
- WBS Generator
- Expanded Drag and Drop manipulation
- Dynamic display of Weight Based standard errors

2008
- 17 New Component Level multi-variable CERs
- New statistics integrated into database
- Historical Schedule Data integrated into toolbar
- Converted to .NET Platform and SQL Databases
- New interface for risk analysis outputs
- Database contains 135 data points

2007
- Calibration Module
- Matrix Consistency Checker
- Ability to send full NAFCOM Cost Report directly to Excel
- Database contains 133 data points

2011
- Thruput $ in any fiscal year
- Historical weight units sensitive to global selection
- Two new templates (Earth Orbiting and Planetary)
- Historical Database QA
- Multi-Variable CER Mission indicator
- Database contains 149 data points

2011
- Historical Database QA
- Multi-Variable CER Mission indicator
- Database contains 149 data points

2011
- Throughput $ in any fiscal year
- Historical weight units sensitive to global selection
- Two new templates (Earth Orbiting and Planetary)
- Historical Database QA
- Multi-Variable CER Mission indicator
- Database contains 149 data points
New Features

- 14 New Missions were added to NAFCOM 11’s Historical Database bringing the mission total to 149:
  - CloudSat
  - ECLS (OGS, WRS)
  - IBEX
  - LCROSS
  - MAP
  - Messenger
  - MRO
  - New Horizon
  - RHESSI
  - SLWT
  - Spitzer
  - STEREO
  - TRMM
New Features

• New Multi-variable CER – Composite Structures
• Historical weight units are now sensitive to global selection.
• Users now have the ability to thruput costs in any fiscal year.
• While in the multi-variable CER methodology the missions that were utilized to create the active CER will be bolded in the on-screen dataview. This gives users immediate access to which historical datapoints were used in the CER creation.
New Features

• Real Year Time Phasing
• Two new templates have been added: Earth Orbiting and Planetary.
• Total mission weight, cost and developing organization have been added to the historical schedule database.
New Features

- The NAFCOM historical database has undergone an extensive review. All historical technical data has been verified and updated if necessary.
- A new visual prompt has been incorporated to remind user’s that costs do not change when making database selections when using the multi-variable CER methodology.
- A new “Quick Entry” tool has been integrated into the NAFCOM toolbar. This tool will provide the user quick access to major technical fields in one screen.
- The F1 help has been improved.
- The latest NASA and Air Force inflation indices have been incorporated.
NAFCOM Access

- Please contact Julie McAfee (mcafeej@saic.com) for information on obtaining the NAFCOM model.
- NAFCOM website: https://nafcom-government.saic.com
NAFCOM Benchmarking Activity
Intent & Guidelines

• Purpose of this exercise was to create benchmark estimates of selected missions in their final state to compare against historical actuals

• Several guidelines placed on this activity
  – Keep estimates at subsystem level, no throughputs
  – Initial focus of only Launch Vehicle projects expanded to include Earth Orbiting and Planetary
  – Don’t “doctor” the outcomes—level playing field
Methodology

- Extract historical subsystem data and actual costs from NAFCOM database for identified missions
- Model these missions in NAFCOM07 to estimate subsystem costs
  - Deflate to FY06 as common denominator
- Model same missions in NAFCOM08 and 11 with identical technical inputs (NAFCOM file converter)
- Collect all subsystem data in summary database
- Aggregate cost to system level & report results
Selected Mission Set

• Launch Vehicles (focus of this presentation)
  – SRM, SRB, S-IVB, S-IC, S-II, Shuttle Orbiter

• Science Missions (results in backup)
  – Aqua, Chandra, DART, IBEX, STEREO, CONTOUR, Deep Impact, Genesis, LCROSS, MRO
Comparison to Actual—LV DDT&E

- Struct/Mech
- Elec Power and Sys Integration
- STH
- Shuttle Orbiter

Legend:
- Actual
- NAFCOM 07
- NAFCOM 08
- NAFCOM 11
Comparison to Actual—LV TFU

- Struct/Mech and Sys Integration
- GNC and Elec Power
- Struct/Mech and Sys Integration

Legend:
- Actual
- NAFCOM 07
- NAFCOM 08
- NAFCOM 11

Shuttle Orbiter
Log-Log Scatterplot—LV TFU

NAFCOM Launch Vehicle Benchmarking - Flight Unit Cost

Estimated vs. Actual for various components:
- SRB
- S-IVB
- S-IC
- SRM
- S-II
- Orbiter

Legend:
- NAFCOM 07
- NAFCOM 08
- NAFCOM 11
- Reference Line
Scorecard

- Standard Percent Error of sample set can be calculated as square root of sum of squares of percent error divided by degrees of freedom, or in equation form:

\[
\text{Std\%Err} = \sqrt{\frac{\left(\frac{\text{Act} - \text{Est}}{\text{Act}}\right)^2}{\text{dof}}}
\]

- Trend shows reduced error with latest NAFCOM releases.
Benchmarking Results

• Benchmarking activity highlights general improvement in estimating tools
  – Helped with additional data points and CER improvements

• Relatively consistent outcomes across mission classes in NAFCOM 11
NAFCOM And Commercial Projects

- NAFCOM database does not currently contain any commercial projects data
- NAFCOM database does contain X-projects data
- NAFCOM technical inputs provide a wide range of settings which when used properly, can capture various development environments
- NAFCOM recently used to capture/estimate a commercial launch vehicle development cost
NAFCOM Estimate of SpaceX Falcon 9

- NASA HQ developed two cost estimates using Falcon 9 technical information:
  - A commercial approach (SpaceX Space Act Agreement/Firm Fixed Price like acquisition)
  - A traditional NASA development approach (cost plus fee acquisition)
- NAFCOM technical inputs settings were adjusted to represent the different approach in each estimate
- Commercial approach result within 13% of the Space Act Agreement
- NASA environment estimate nearly three times higher
Falcon 9 NAFCOM Cost Estimate results

Falcon 9 NAFCOM Cost Estimate Update
NASA Traditional Development Vs. Space Act Agreement
DDT&E + Two Test Flight Unit (Engines Included)

FY2010 $M

NASA Traditional Development

Space Act Agreement

- VI
- Contingency
- PS
- Fee
- 2nd Stage 2 Test Unit
- 1st Stage 2 Test Units
- 2nd Stage DDT&E
- 1st Stage DDT&E
Science Missions

• Less concern on separating DDT&E from production for one-off missions
• This analysis combines both to assess total hardware cost
• Note: instruments, launch vehicle/services, and Phase E (operations) excluded
  – Spacecraft bus only estimated with multi-variable CERs
Comparisons to Actual

Challenging Low-Cost Missions

- Aqua
- DART
- IBEX
- STEREO
- CONTOUR
- Deep Impact
- Genesis
- LCROSS
- MRO
Log-Log Scatterplot

NAFCOM EO & PL Benchmarking - Total Bus Cost

- IBEX
- CONTOUR
- Deep Impact
- MRO
- Chandra
- LCROSS
- Aqua
- STEREO
- Genesis
- DART
- IBEX

Legend:
- NAFCOM 07
- NAFCOM 08
- NAFCOM 11
- Reference