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

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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.
NAF-COM11

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 NASCOM 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

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

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

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
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 thruputs.
  – 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

The graph compares the actual and projected development and testing efforts for different components of the LV. The components include SRM, SRB, SIVB, SII, and SIC, along with the Shuttle Orbiter. The graph uses different colored bars to represent actual and projected efforts for the years 2007, 2008, and 2011.
Log-Log Scatterplot—LV DDT&E

NAFCOM Launch Vehicle Benchmarking - DDT&E Cost

Estimated vs. Actual

- SRB
- S-IVB
- S-II
- S-IC
- Orbiter

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

NAFCOM Launch Vehicle Benchmarking - Flight Unit Cost

- SRB
- S-IVB
- S-IC
- SRM
- S-II
- Orbiter

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

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

- Trend shows reduced error with latest NAFCOM releases
Benchmarks 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)

NASA Traditional Development

Space Act Agreement

- Vt
- Contingency
- PS
- Fee
- 2nd Stage 2 Test Unit
- 1st Stage 2 Test Units
- 2nd Stage DDT&E
- 1st Stage DDT&E

SAIC NASA
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
Log-Log Scatterplot

NAFCOM EO & PL Benchmarking - Total Bus Cost