

Conference Paper

# Best Practices in Aerospace Cost Estimation: Observations from US Air Force and NASA

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Albuquerque, NM  
June, 2011

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The Society of Cost Estimating and Analysis

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- ▶ Commonality between NASA and Air Force Programs
- ▶ Overview of the NASA experience with cost growth
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- ▶ Changes implemented by NASA to improve cost analysis
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## **We shall focus on the best practices for improving cost analysis with regard to federal aerospace agencies**

- ▶ Provide a background on the challenges faced by both the United States Air Forces (USAF) and the National Aeronautics and Space Administration (NASA) in managing cost analysis on their projects
- ▶ Examine how the USAF and NASA have responded to the challenge with an overview of the steps they have taken to improve their cost analysis capabilities

## The Air Force and NASA both deal with complex aerospace projects that have frequently cost more than expected

- ▶ There is considerable overlap in the types of systems they design, which means that challenges with technology drive the cost for both
- ▶ Both the Air Force and NASA deal with immature technologies, typically measured by Technology Readiness Level (TRL), a scale developed by NASA but also used by the USAF
- ▶ The USAF developed experimental vehicles such as the X-1 and X-15 that were critical stepping stones towards the development of the space shuttle
- ▶ Both the Air Force and NASA have developed satellites and utilized commercial launch services
- ▶ The recognition of overlap has led to synergy in industry working groups
  - The Space System Cost Analysis Group (SSCAG) was co-founded by the USAF and NASA and recently celebrated its ten year anniversary
  - It establishes a regular forum for USAF, NASA and National Reconnaissance Office (NRO) cost personnel to meet with the consulting industry to share ideas and research

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## NASA has experienced cost growth on large-scale Projects

- ▶ The International Space Station (ISS), deemed the largest and most challenging global engineering project ever attempted, has been dogged by cost overruns and schedule slips from its inception
- ▶ In 1984, the original estimate for the completed station was \$8 billion
- ▶ Following the station's 1993 redesign, the target date for its completion was 2002
  - Sourced from an article by Leonard David in Aerospace America written April 2002
- ▶ By 2002, a fully outfitted ISS had a roughly \$30 billion price tag
  - ▶ By 2008 the cost of the ISS had risen to \$35 billion
- ▶ Finally completed in 2011 at a cost in excess of \$35 billion
- ▶ These numbers represent a 438% increase in cost and a nine-year slip in schedule

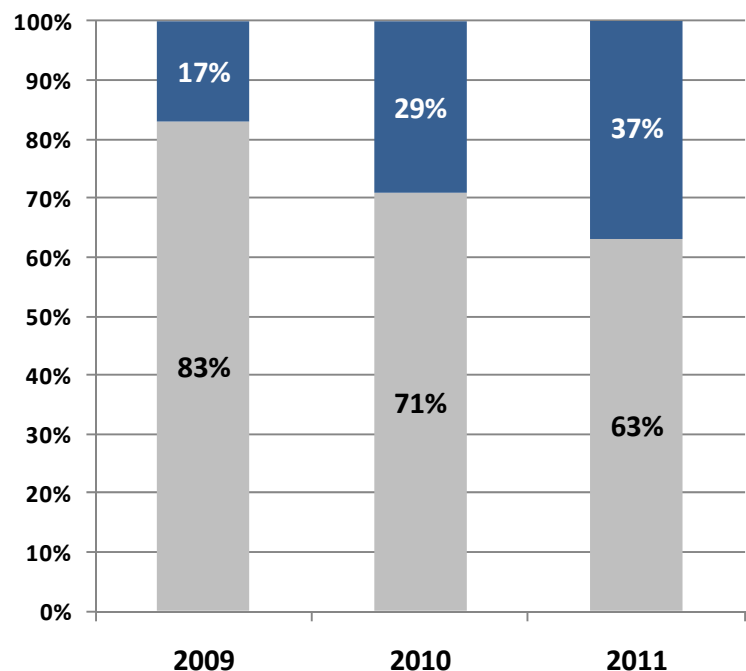
## Cost growth of selected NASA projects currently in the implementation phase shows continued challenges

Project	Development Cost Growth (\$M)	Percentage Cost Growth	Launch Delay (months)
▶ Glory	▶ 168.7	▶ 99.9	▶ 27
▶ Mars Science Laboratory (MSL)	▶ 833.4	▶ 86.0	▶ 26
▶ NPOESS Preparatory Project (NPP)	▶ 187.1	▶ 31.6	▶ 42
▶ Stratospheric Observatory of Infrared Astronomy (SOFIA)	▶ 208.9	▶ 22.7	▶ 12
▶ Aquarius	▶ 34.6	▶ 18.0	▶ 23
▶ James Webb Space Telescope (JWST)	▶ 129.8	▶ 5.0	▶ 0
▶ <b>Average</b>	▶ <b>260.4</b>	▶ <b>43.9</b>	▶ <b>22</b>
▶ <b>Total Development Cost Growth</b>	▶ <b>1,562.5</b>	▶	▶

*Note: Glory established a new baseline in fiscal year 2009 after being reauthorized by Congress and MSL established a new baseline in fiscal year 2010 after being reauthorized by Congress*

*Source: General Accounting Office (GAO)-11-239SP*

## Moving into implementation with immature technologies at the preliminary design review is a significant factor in cost growth



■ Projects not meeting technology maturity criteria  
■ Projects meeting technology maturity criteria

Source: GAO-11-239SP

- ▶ GAO best practices show that a technology readiness level (TRL) of 6, demonstrating a technology as a fully integrated & prototyped in a relevant environment, is the level of maturity needed to minimize risks for space systems entering product development
- ▶ Nearly two-thirds of the projects in the GAO review did not meet this standard
- ▶ This graph illustrates a 3 year period of large-scale projects that held their preliminary design review (PDR) and the percentage of those projects that moved into implementation with immature technologies
- ▶ NASA is making progress with regard to adhering to best practices standards for technology maturity at the PDR as the number of projects not meeting this criteria has decreased in recent years



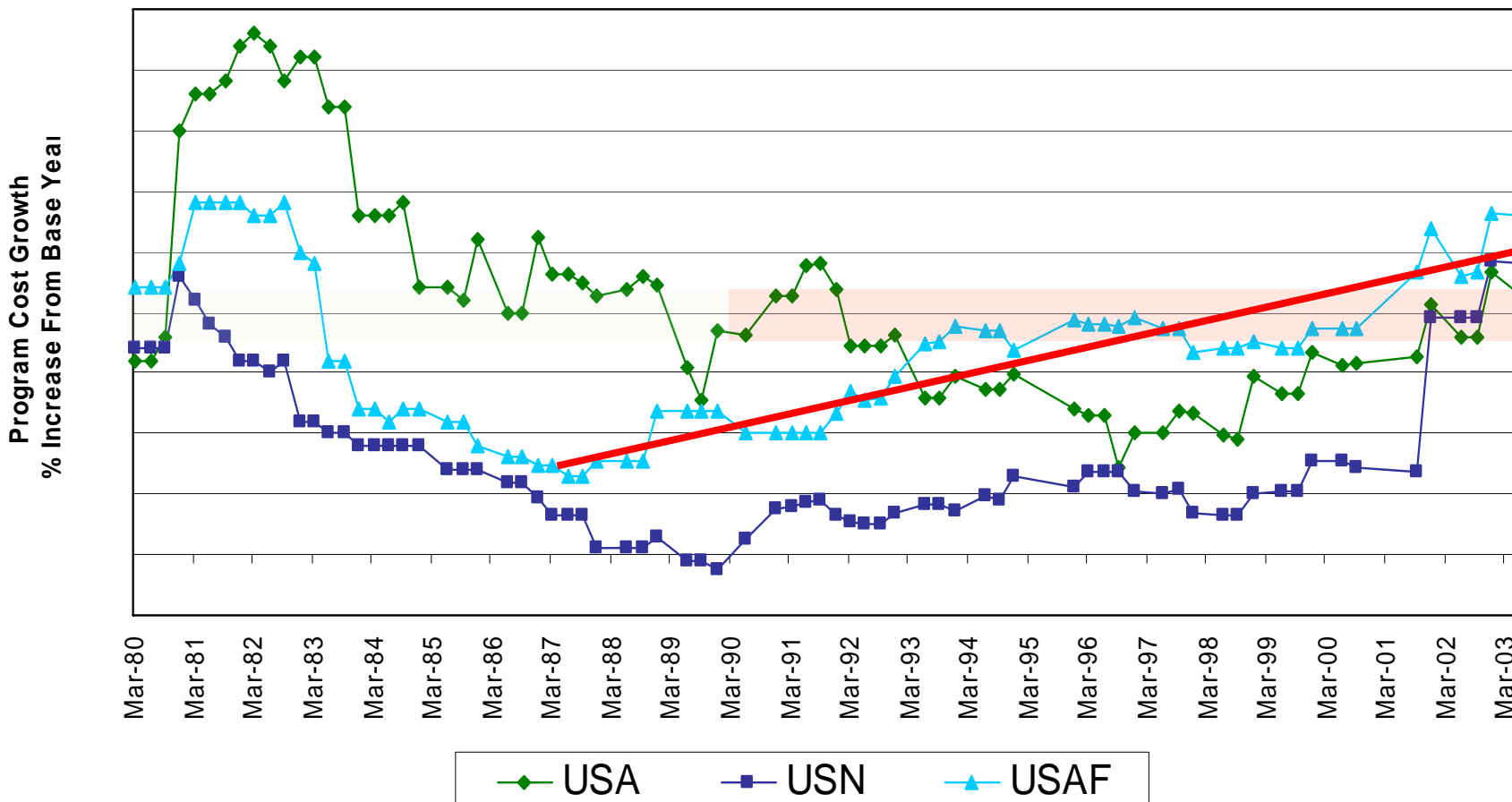
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## In the previous decade USAF cost over runs were frequently cited by Congress as an issue that had to be addressed

- ▶ For example, the FY2006 National Defense Authorization Act stated:
  - “The committee is troubled by the Dept of the AF’s ability to provide objective, credible, and competent cost estimates ... the [AF] has neither a formal training program nor a career development program for its cost analysts ... the AF Cost Analysis Agency has insufficient resources – funding, personnel, and data, to develop a robust cost analysis capability ... The committee directs the Secretary of the AF to take the steps necessary to address the deficiencies in the area of cost analysis.”
  
- ▶ The Joint Strike Fighter (JSF) System Design and Development (SDD) estimate has increased dramatically
  - In Fall 1996 it was estimated at Then Year (TY) \$21.2 billion
  - At Milestone B in Fall 2001 it was estimated at TY \$30.2 billion
  - In December 2004, it was estimated at TY \$41.5 billion
  - In December 2009, it was estimated at TY \$50.2 billion
  - In March 2011, it was estimated at TY \$56.4 billion

## Department of Defense (DoD) program cost growth had improved in the 1980's before steadily degrading again



Source: Col. Dupre, "Efforts to Improve Air Force Cost Analysis", PowerPoint Presentation, 2011

## The USAF was the poorest DoD performer

- ▶ Trends on current USAF programs showing Projected Total Program growth rising to ~ 76%
- ▶ The USAF identified cost estimating as a significant contributor to the error but one that it could manage

### Actual Cost versus Milestone II, 1968 - 2002

Phase	Air Force	DoD
▶ Total Program	▶ 47%	▶ 46%
▶ Development	▶ 78%	▶ 58%

Source: Col. Dupre, "Efforts to Improve Air Force Cost Analysis", PowerPoint Presentation, 2011

## The organizational structure and process for cost estimation is critical to effective results

- ▶ To address the issue of cost over runs and schedule slips both the USAF and NASA strengthened or stood up offices focused on improving reviews and cost estimates
- ▶ The NASA the Office of Independent Program and Cost Evaluation (IPCE), established in 2005, is tasked with providing objective, transparent, and multidisciplinary analysis of NASA programs to inform decision makers
- ▶ The USAF direction in 2003 (CORONA Top Tasker) identified the need for staffing cost analysis positions within the Air Force Cost Analysis Agency, improving the cost estimating process, and improving education and certification standards

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## One of NASA's largest program's became a pathfinder for cost analysis improvements in 2003

- ▶ In 2001 the International Space Station (ISS) Management and Cost Evaluation (IMCE) Task Force was established due to significant cost growth on the ISS Program
- ▶ The task forces key findings resulted in the ISS Re-Engineering contract with Booz Allen
- ▶ Key components of the Re-Engineering were:
  - Aligning organizations and contract structure with the activities
  - Defining performance requirements for the program and activities to establish criteria for product development and on-going activities
  - Establishing business management processes to support cost vs. performance measures
- ▶ The Business Office, Configuration Management and IT office were combined into a new Project Planning & Control (PP&C) organization
- ▶ Within PP&C a new Assessments, Cost Estimating & Schedules office (ACES) was stood up to support credible budgeting and contract negotiation positions

## A key function of PP&C ACES for the International Space Station Project is cost estimation

- ▶ Since 2001, the ISS PP&C Office has been actively using project controls to help contain costs, provide trade study inputs, and help managers make decisions in terms of costs, schedule and technical attributes
- ▶ Cost estimation is part of the overall project management function within the Program Planning and Control Office
  - This allows estimators to be on par with engineers
  - Cost estimates can be non-advocate of technical agendas
  - Provides a checks and balances process



## The Assessment, Cost Estimating and Schedules (ACES) team within PP&C provides the function of cost estimation for the ISSP

- ▶ All of the ACES team members are certified in various cost estimation tools – including PRICE-H<sup>®</sup> and SEER-SEM<sup>®</sup>
- ▶ Most are also cross-trained in the other disciplines such as scheduling and risk analysis
- ▶ The cost estimators are responsible for a variety of cost analysis
- ▶ With the volume of changes in a dynamic environment such as ISS, parametric tools allow us to create estimates with high fidelity in short time frames

Cost Estimates	Assessments	Schedules
<ul style="list-style-type: none"> <li>▪ Cost Estimates of Baseline Changes                             <ul style="list-style-type: none"> <li>▪ Cost Estimates of Threats</li> </ul> </li> <li>▪ Quantitative Risk Assessment of Threats/Budget                             <ul style="list-style-type: none"> <li>▪ Documentation of Processes                                     <ul style="list-style-type: none"> <li>▪ Utilization of Cost Models</li> </ul> </li> </ul> </li> <li>▪ Government Estimates for Procurements                             <ul style="list-style-type: none"> <li>▪ Cost/Benefit Analysis</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>▪ Early Warning System – Monthly and Quarterly Reports</li> <li>▪ Earned Value Management Analysis                             <ul style="list-style-type: none"> <li>▪ Program Metrics</li> </ul> </li> <li>▪ Program Performance Measurement System                             <ul style="list-style-type: none"> <li>▪ Assessments of Budget, Contracting and Processes</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>▪ Integrated Schedules                             <ul style="list-style-type: none"> <li>▪ Cost/Schedule Risk Analysis</li> <li>▪ Schedule Assessments</li> </ul> </li> </ul>

## ACES frequently validates the models they use and their cost estimates have several uses within the program

- ▶ Regarding model validity
  - NASA HQ, Galorath and PRICE® have provided jumpstarts with the cost estimators and engineers to promote understanding of tool functions
  - ACES calibrates the models using project technical data
  
- ▶ How are the estimates used for a diverse program in the operational phase?
  - Provides 'should costs' in comparison to contractor cost ROMs
  - Provides trade study/what if analysis
  - Provides support for estimating baseline changes
  - Provides procurement insight for negotiations

## NASA has taken additional steps to address cost analysis

- ▶ Early last decade NASA created a pipeline for new cost analysis job positions
- ▶ In 2003 NASA authored the first Cost Estimating Handbook for the Agency
- ▶ In response to GAO's designation of NASA's acquisition management as a high risk area, NASA has developed a corrective action plan to improve the effectiveness of acquisition project management
  - The agency is continuing its implementation of a new cost estimation tool, the Joint Cost and Schedule Confidence Level, to help project officials with management, cost and schedule estimating, and maintenance of adequate levels of reserves

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## Similar to NASA the Air Force began to address improving cost estimation in the previous decade

- ▶ The CORONA Top Tasker in December 2003 identified that cost analysis was significantly under staffed and required an USAF-wide plan for improving Business Case Analysis and cost analysis capability
  - USAF-wide policy in 2003 did not consistently require adequate, objective cost analysis or review
  - Cost analysis was limited to infrequent milestone reviews
  - There was inconsistent leadership value placed on cost analysis
  - The resources to perform cost analysis were down 60% since 1992 -- approximately 400 positions!
  - The study found inexperienced analysts “isolated” in programs with little functional support -- fractured estimating methods, databases, models -- inconsistent data/estimate quality, analyst qualifications
  
- ▶ As a result the Secretary of the Air Force, Financial Management Directorate decided to implement corrective action starting in FY2007

Source: Col. Dupre, “Efforts to Improve Air Force Cost Analysis”, PowerPoint Presentation, 2011

## The Secretary of the Air Force took steps to bolster the cost analysis workforce

- ▶ Fifty personnel were added in 2007 and the FY2008 Program Operating Memorandum (POM) added a further 65 positions
  
- ▶ Reforms were also made to Education, Training, and Certification to provide analysts the tools to succeed including:
  - Specific cost analysis courses
  - Enabling courses (decision support)
  - On-the-job training through apprenticeships
  - Certification program
  - A dedicated career path and new job series

Source: Col. Dupre, "Efforts to Improve Air Force Cost Analysis", PowerPoint Presentation, 2011

## Concerns with the lack of cost analysis were addressed with a new Air Force Policy Directive (AFPD)

- ▶ The changes to the AFPD constituted a complete policy directive update
- ▶ AFPD-65 was rewritten and implemented in August 2008
  - Directed the use of Independent Cost Estimates (ICE) and Component Cost Analyses (CCA) for Major Defense Acquisition Programs (MDAP) and Major Automated Information Systems (MAIS) milestones where decision authority has been delegated to the Service Acquisition Executive (SAE)
  - Accompanying Air Force Instructions (AFI) and Air Force Manuals (AFMAN) were also updated

Source: Col. Dupre, "Efforts to Improve Air Force Cost Analysis", PowerPoint Presentation, 2011

## The role of the Air Force Cost Analysis Agency (AFCAA) was also expanded

- ▶ AFCAA is a Directorate of Office of the Deputy Assistant Secretary for Cost and Economics (SAF/FMC)
  
- ▶ AFCAA provides:
  - Collaborative program cost estimates
  - Builds cost models
  - Researches new cost estimating relationships
  - Develops risk analysis
  
- ▶ Center FMC and AFCAA are strategic partners
  - AFCAA has operating locations at each of the USAF Center FMC

Source: Col. Dupre, "Efforts to Improve Air Force Cost Analysis", PowerPoint Presentation, 2011



## There were also new provisions for the cost analysis capability for Analysis of Alternatives

- ▶ AoA are accomplished to help justify the need for starting, stopping or continuing an acquisition effort
- ▶ Under the guidance of the Office of Aerospace Studies (OAS), oldest continuously operating USAF analysis organization (since 1954)
  - Supports all ongoing USAF AoAs (some Joint)
  - Acts as sole source for USAF AoA training
  - Serves as technical review group for most AoAs
  - Provides unbiased guidance and products
  - Ensures consistent quality AoAs
- ▶ Acquisition Process DoDI 5000-2 (approved 12 May 2003) established new requirements

# The Aeronautical Systems Center Capabilities Integration Directorate has become the source for pre Milestone A cost analysis

- ▶ The arrangement between the division (ASC/XRE) and USAF FM started in 2003
- ▶ Cost analysis results are reviewed with FM
- ▶ Experienced contractor analysts obtain via Information Analysis Centers
  - Booz Allen Hamilton staff
- ▶ Developed the Aircraft Conceptual Design Cost (ACDC) Model in house for Aircraft LCC
  - Started in 2003 in collaborative effort with RAND and AFCAA
  - Reviewed with OSD/Cost Analysis Program Evaluation (CAPE), AFCAA, RAND and the Institute for Defense Analyses (IDA)
  - Utilizes RAND CER and factors based on IDA estimates for Low Observability (stealth) impacts
  - Designed for Alternatives comparison
  - Possesses a phasing capability for Program Element Managers (PEM) to rephase BY cost for budget what-if exercises

## ASC/XR Cost & Risk Capabilities are provided across USAF centers for pre Major Defense Acquisition Programs (MDAP)

### Small Sample of Products

Topic	Product	Client
▶ Air Superiority Target AoA	▶ LCC	▶ Air Combat Command (ACC)
▶ KC-135 Replacement RFI	▶ Assessment	▶ KC-X Program
▶ Airborne Electronic Attack	▶ LCC	▶ ACC
▶ Presidential Airlift Recapitalization (PAR) AoA	▶ LCC	▶ Air Mobility Command (AMC)
▶ C-17B Concept for Advanced Joint Air Combat System (AJACS)	▶ LCC	▶ AMC
▶ Senior Leadership Command, Control, Communications Systems (SLC3) Airborne Wideband AoA	▶ LCC	▶ Air Force Office of Warfighting Integration and Chief Information Officer (SAF/XC)
▶ A-400M Concept for Joint Future Theater Lift (JFTL)	▶ LCC	▶ AMC
▶ Stinger AoA	▶ Operation & Support estimates	▶
▶ Next Generation Unmanned Aerial Systems (NG UAS)	▶ LCC	▶ ACC
▶ E-4B Replacement AoA	▶ LCC	▶ Directorate of Plans and Requirements AF/A5
▶ Common Vertical Lift Support Platform (CVLSP)	▶ LCC	▶ ASC

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## It is still too early to definitively determine if the previous decade of improvements to cost analysis has led to lower cost growth

- ▶ Data from DoD sources does show that the average cost growth of projects has leveled off, is better than from the 1950s, and that the standard deviation of the actual cost from the estimated cost has improved

Number of Projects in Dataset	Decade	Average Cost Growth	Standard Deviation from Estimate
▶ 22	▶ 1950	▶ 312%	▶ 236%
▶ 11	▶ 1960	▶ 144%	▶ 45%
▶ 7	▶ 1970	▶ 143%	▶ 49%
▶ 30	▶ 1980	▶ 147%	▶ 57%
▶ Unknown	▶ 1990	▶ 134%	▶ 46%
▶ 7	▶ 2000	▶ 140%	▶ 39%

- ▶ Actual cost for new projects under the ISS Program have also tracked the cost estimates for the past seven years

## Conclusions

- ▶ Both NASA and the Air Force have a renewed focus on improving cost analysis
- ▶ The best of all worlds would be to leverage the best practices from both

Best Practice	NASA/ISSP	USAF
▶ Agency/Department Level Cost Expertise	▶ ✓	▶ ✓
▶ Agency/Departmental Level Cost Oversight	▶	▶ ✓
▶ Cost Estimation Handbooks	▶ ✓	▶ ✓
▶ Program Office Should Cost Estimates for Contractor Negotiations	▶ ✓	▶