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Air Force Installation & Mission Support Center



Gotta Go Fast: Modular Open System Approach's Impact on Schedule

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**Air Force Installation Mission and
Support Center, Financial
Management Cost**



Agenda



- Interactive Survey
- Background and Scope
- Research Questions and Methodology
- Data
 - Data Sources
 - Data Collection
 - Data Set
- Comparison Results
- Regression Results
- Conclusion



Interactive Survey



- Join interactive survey via QR code or menti.com with code: 2244-4463





Background and Scope



- **Open System Architecture (OSA)** – Physical system components developed with open, non-proprietary standards
- **Modular Open System Approach (MOSA)** – Design philosophy utilizing modularity and standardization to design affordable, adaptable systems
- **Earned Value Management (EVM) Metrics**
 - Cost Performance Index (CPI)
 - = Budgeted Cost of Work Performed / Actual Cost of Work Performed
 - Schedule Performance Index (SPI)
 - = Budgeted Cost of Work Performed / Budgeted Cost of Work Scheduled
- Minimal research examining OSA's impact on EVM metrics
- Scope: Aircraft only in development phase



Research Questions and Methodology



- **Research Questions**
 - How do EVM metrics (CPI and SPI) differ between systems that do and do not employ OSA?

| Test | Hypothesis | Alpha |
|--------------------------------------|--|-------|
| Anderson-Darling | H ₀ : The distribution is approximately normal H _A : The distribution is not approximately normal | 0.05 |
| Levene | H ₀ : Variances for OSA and non-OSA efforts are comparable H _A : Variances for OSA and non-OSA efforts are not comparable | 0.05 |
| Student's t | H ₀ : The mean of CPI/SPI for OSA and non-OSA are comparable H _A : The mean of CPI/SPI for OSA and non-OSA are not comparable | 0.05 |
| Wilcoxon Rank Sum (Unequal Variance) | H ₀ : The distributions for OSA and non-OSA efforts are comparable H _A : The distributions for OSA and non-OSA efforts are not comparable | 0.05 |



Research Questions and Methodology



- **Research Questions**

- How does the presence of OSA impact EVM metrics (CPI and SPI)?
 - Methodology: Ordinary Least Squares (OLS) Regression

| Models |
|---|
| $CPI = \beta_0 + \beta_1 OSA + \beta_2 Service + \beta_3 Contract\ Type + \beta_4 WSARA + \epsilon$ |
| $SPI = \beta_0 + \beta_1 OSA + \beta_2 Service + \beta_3 Contract\ Type + \beta_4 WSARA + \epsilon$ |

- OSA – Open System Architecture, No Open System Architecture
- Service – Army, Air Force, Navy
- Contract Type – Cost-Plus, Fixed-Price
- Weapon Systems Acquisition Reform Act (WSARA) – Pre- and Post 2009

| Expected Impact | |
|-----------------------|----------------------|
| Independent Variables | EVM - OLS Regression |
| OSA | + |
| Service | Unknown |
| Contract Type | - |
| WSARA | + |



- Cost Assessment Data Enterprise (CADE)
 - OSA status validated with Cost Analysis Requirement Description (CARD) documents
 - [CADE](#)
- Earned Value Management Central Repository (EVM-CR)
 - EVM data pulled at the Work Breakdown Structure (WBS) level from OSA-related elements
 - [EVM-CR](#)



Data Collection



Aircraft identified with significant OSA contributions: AH-64E Remanufacture, MQ-1C Gray Eagle, P-8A Poseidon

| Category | Number Removed | Remaining Programs |
|---|----------------|----------------------------|
| Aircraft Programs in EVM-CR | | 57 |
| Programs with CARDs | 35 | 22 |
| Programs with Complete Contract Data | 3 | 19 |
| Programs Identified with OSA | | 14 |
| Programs Identified without OSA | | 5 |
| Work Breakdown Structure (WBS) Elements | | |
| CPI OSA WBS | | 93 |
| CPI Non-OSA WBS | | 24 |
| SPI OSA WBS | | 75 |
| SPI Non-OSA WBS | | 24 |
| Final Data Set for Analysis | | 117 (CPI), 99 (SPI) |



Aircraft identified without with significant OSA contributions: KC-46A Pegasus, CH-47F Chinook

On average, 31% of WBS elements involved OSA



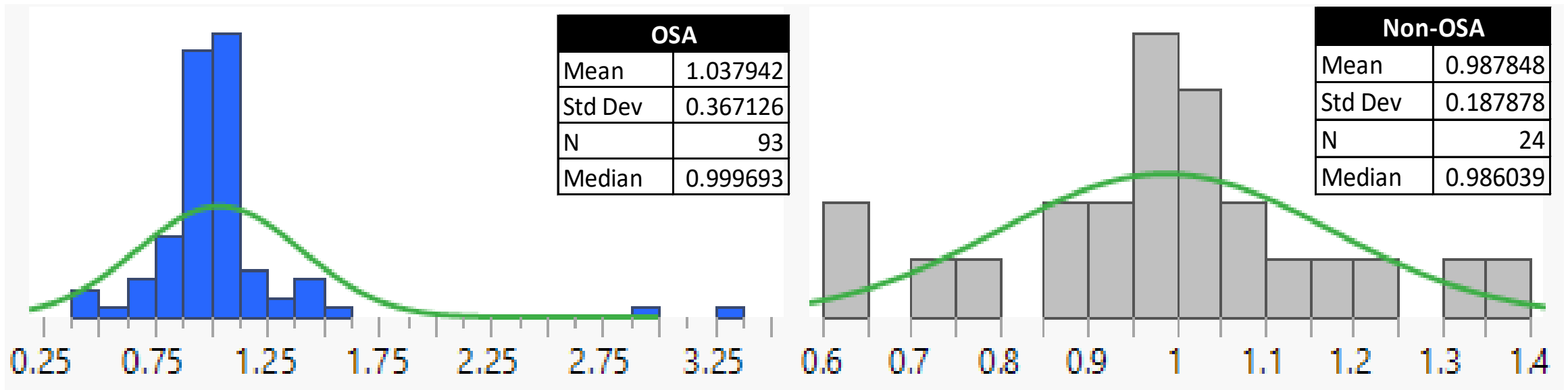
| Programs | WBS |
|---|--|
| OSA | |
| AH-64E Remanufacture | OSA, Communications, Aviation Mission Planning, Mission Computer |
| APT - Advanced Pilot Training T-7A | Communications/Identification, Navigation/Guidance, Mission Computer/Embedded Training, Automatic Flight Control |
| ARH - Armed Reconnaissance Helicopter | Communications, Data Displays |
| BLACK HAWK UPGRADE (UH-60M) | MFD Software, System Integration |
| C-130 AMP Avionics Modernization Program | Avionics Hardware, System Integration |
| C-5 RERP - C-5 Aircraft Reliability Enhancement and Re-engining Program | Avionics |
| CH-53K - Heavy Lift Replacement | Avionics, Systems Engineering, Communications/Identification, Air Vehicle Applications |
| CRH - Combat Rescue Helicopter | Avionics |
| E-2D AHE - E-2D Advanced Hawkeye | Avionics, Systems Engineering |
| F-22 - RAPTOR Advanced Tactical Fighter Aircraft/F-22A Increment 3.2B Modernization | Avionics, Systems Engineering |
| MQ-1C GRAY EAGLE - Unmanned Aircraft System | Avionics, Air Vehicle Software, Systems Engineering |
| MQ-4C Triton - Unmanned Aircraft System | AV Application, Systems Engineering, Communications/Identification, Mission Control |
| P-8A Poseidon Multi-Mission Maritime Aircraft | AV Application, Communications/Identification, Systems Engineering, Mission Computer |
| PAR - Presidential Aircraft Recapitalization (VC-25B) | Avionics, Systems Engineering |
| UH-60M Upgrades | Air Vehicle System Software, Systems Engineering |
| Non-OSA | |
| C-17A - GLOBEMASTER III Flexible Cargo Aircraft | Avionics/Flight, Systems Engineering and Integration |
| CH-47F Modernized Cargo Helicopter | Avionics Subsystem, Systems Integration |
| F/A-18E/F Super Hornet Aircraft | Systems Engineering |
| HC/MC-130 Recapitalization Aircraft | AV Applications Software, Communications/Identification, Systems Engineering |
| KC-46A Tanker Modernization | Aircraft Systems, Systems, Engineering, Communications/Identification, Central Computer |



Comparison Results - Cost



- How do EVM metrics (CPI and SPI) differ between systems that do and do not employ OSA?



| | Test | P-Value |
|-----|-------------|---------|
| CPI | Student's t | 0.5199 |

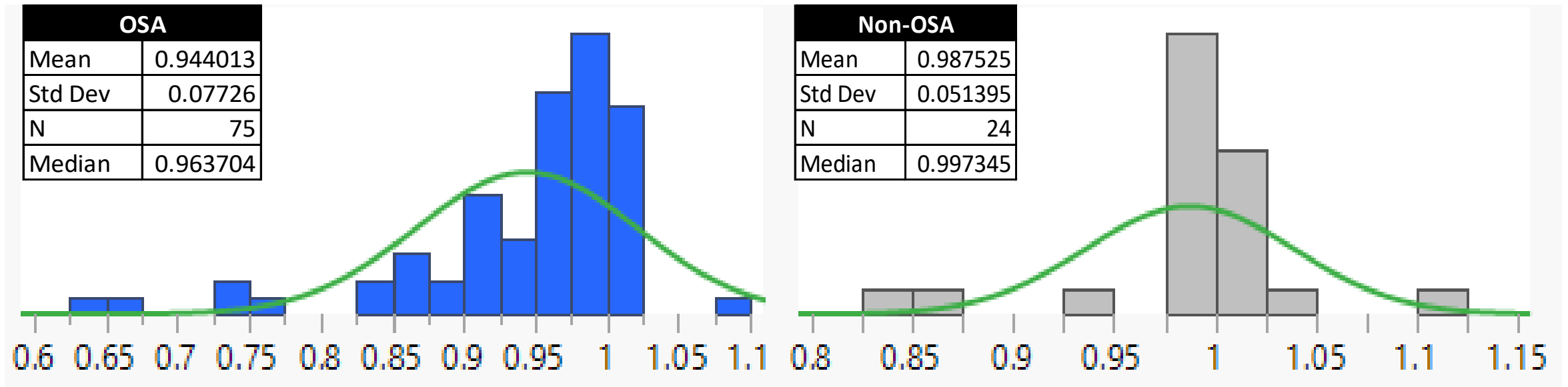
Mean of OSA and Non-OSA distributions are not significantly different for CPI



Comparison Results - Schedule



- How do EVM metrics (CPI and SPI) differ between systems that do and do not employ OSA?



| | Test | P-Value |
|-----|-------------------|---------|
| SPI | Wilcoxon Rank Sum | 0.0016 |

Significant difference in SPI distributions between OSA and Non-OSA programs



Regression Results Overview

- How does the presence of OSA impact EVM metrics (CPI and SPI)?

| Models |
|---|
| $CPI = \beta_0 + \beta_1 OSA + \beta_2 Service + \beta_3 Contract\ Type + \beta_4 WSARA + \epsilon$ |
| $SPI = \beta_0 + \beta_1 OSA + \beta_2 Service + \beta_3 Contract\ Type + \beta_4 WSARA + \epsilon$ |

| Independent Variables | Expected Impact | Actual Impact | |
|-----------------------|----------------------|----------------------|---------------------|
| | EVM - OLS Regression | EVM - OLS Regression | Significant |
| OSA | + | CPI, SPI: - | CPI: No SPI: Yes |
| Service | Unknown | CPI: - SPI: + | CPI: No SPI: No |
| Contract Type | - | CPI, SPI: + | CPI: Yes SPI: No |
| WSARA | + | CPI: + SPI: - | CPI: No SPI: No |

SPI:
Round 1:
P-Value: .0312
R² = .11

Round 2 (Without Outliers):
P Value: .0169
R² = .11

OSA is not a significant factor for influencing CPI, but it is significant for SPI



- Research Goal: Investigate the impact of a modular open system approach and open system architecture on program management of cost and schedule
- OSA associated with decreases in SPI for aircraft contracts in development phase
 - OSA can still allow for faster acquisition timelines overall compared to programs that do not utilize OSA
 - However, there may be some overoptimism about exactly how much OSA helps improve schedule

Cost community may need to temper expectations about OSA's impact on schedule



Questions



Backup



OLS Assumptions and Outlier Assessment



| | OLS Assumptions | Assessment Tool | Considerations/Hypothesis | Alpha |
|---|--|-----------------|---|-------|
| 1 | The model is linear in parameters | Logic | Models only contain linear paramters. | NA |
| 2 | The data are collected through independent, random sampling | Logic | Data collection process features independent, random sampling because data was retrieved from separate aircraft programs. | NA |
| 3 | The data are not perfectly multicollinear | VIF | VIF Score > 5 indicates multicollinearity. | NA |
| 4 | The error term has zero mean | Logic | the inclusion of a y-intercept forces the mean of the residuals to equal zero, thus satisfying the assumption of the error term having zero mean. | NA |
| 5 | The error term is uncorrelated with each independent variable and all functions of each independent variable | Logic | Exogeneity is assumed to be satisfied because the variables included in the model are not expected to be significantly correlated with those in the error term. Furthermore, prior research shows that all relevant variables for cost and schedule growth are included in the model, mitigating omitted variable bias. | NA |
| 6 | The error term has constant variance | Breusch-Pagan | H ₀ : The residuals have constant variance H _A : The residuals do not have constant variance | 0.05 |

| Assessment | Tool | Considerations/Hypothesis |
|-----------------------------|-----------------------|--|
| OLS Influential Data Points | Cook's D | Influential Point = Any data point greater than $4/n$ |
| OLS Outliers | Studentized Residuals | Outlier = Any data points more than three standard deviations away from the mean |



Regression Results CPI



$$CPI = \beta_0 + \beta_1 OSA + \beta_2 Service + \beta_3 Contract Type + \beta_4 WSARA + \epsilon$$

| Parameter Estimates | | | | |
|---------------------|----------|-----------|-----------|---------|
| Variable | Estimate | Lower 95% | Upper 95% | P-Value |
| Intercept | 0.799545 | 0.5169602 | 1.0821297 | <.0001 |
| OSA | -0.00035 | -0.15839 | 0.1576907 | 0.9965 |
| Air Force | -0.04178 | -0.19783 | 0.114269 | 0.5968 |
| Navy | -0.0836 | -0.257714 | 0.0905115 | 0.3434 |
| CP | 0.240543 | 0.0375253 | 0.4435609 | 0.0207 |
| WSARA | 0.09274 | -0.044289 | 0.2297688 | 0.1826 |



| Parameter Estimates (Without Outliers) | | | | |
|--|----------|-----------|-----------|---------|
| Variable | Estimate | Lower 95% | Upper 95% | P-Value |
| Intercept | 0.862206 | 0.70137 | 1.0230419 | <.0001 |
| OSA | -0.03433 | -0.123789 | 0.0551217 | 0.4485 |
| Air Force | -0.01991 | -0.109376 | 0.0695598 | 0.6601 |
| Navy | -0.00749 | -0.106708 | 0.0917215 | 0.8813 |
| CP | 0.173292 | 0.0580584 | 0.2885259 | 0.0035 |
| WSARA | 0.02869 | -0.049229 | 0.1066085 | 0.4671 |

| Influential Data Points/Outliers | | | |
|----------------------------------|------|-------|---------------------|
| Program | CPI | Phase | WBS Element |
| CH-53K | 3.33 | RDT&E | Systems Engineering |
| F-22 | 2.91 | RDT&E | Avionics |



Regression Results SPI



$$CPI = \beta_0 + \beta_1 OSA + \beta_2 Service + \beta_3 Contract Type + \beta_4 WSARA + \epsilon$$

| Parameter Estimates | | | | |
|---------------------|----------|-----------|-----------|---------|
| Variable | Estimate | Lower 95% | Upper 95% | P-Value |
| Intercept | 0.974952 | 0.9105022 | 1.0394009 | <.0001 |
| OSA | -0.03893 | -0.074263 | -0.003598 | 0.0312 |
| Air Force | 0.019508 | -0.016428 | 0.0554438 | 0.2838 |
| Navy | 0.01275 | -0.02812 | 0.0536192 | 0.5371 |
| CP | 0.017221 | -0.028158 | 0.0626003 | 0.453 |
| WSARA | -0.02406 | -0.058664 | 0.0105453 | 0.1707 |



| Parameter Estimates (Without Outliers) | | | | |
|--|----------|-----------|-----------|---------|
| Variable | Estimate | Lower 95% | Upper 95% | P-Value |
| Intercept | 0.972765 | 0.9198399 | 1.0256908 | <.0001 |
| OSA | -0.03556 | -0.064564 | -0.006547 | 0.0169 |
| Air Force | 0.011385 | -0.018317 | 0.0410876 | 0.4484 |
| Navy | 0.015893 | -0.018365 | 0.0501512 | 0.3592 |
| CP | 0.020903 | -0.016351 | 0.0581569 | 0.268 |
| WSARA | -0.01616 | -0.04465 | 0.0123352 | 0.2629 |

| Influential Data Points/Outliers | | | |
|----------------------------------|-------|-------|---------------------|
| Program | SPI | Phase | WBS Element |
| CH-53K | 0.647 | RDT&E | Systems Engineering |
| P-8A | 0.665 | RDT&E | Mission Computer |