Empirical Assessment Of Technology and Design Parameters on the Schedule and Cost Risk of DoD Weapon Systems

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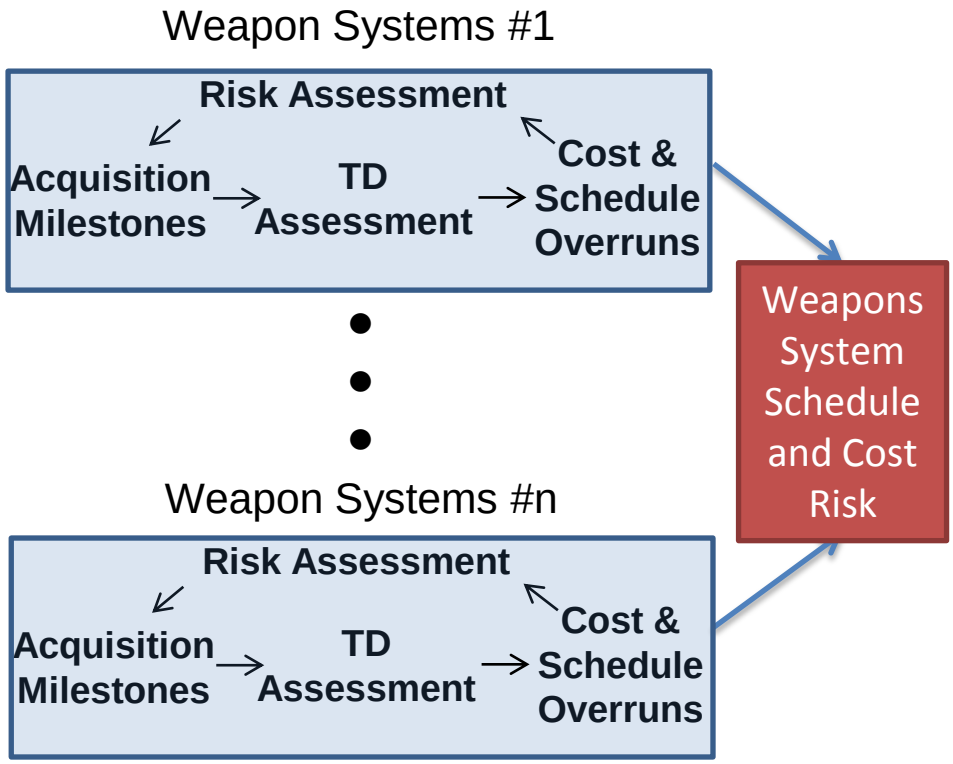
Agenda

- Problem Statement
- Motivation
- Literature Review
- Gaps in Research and Conceptual Model
- Data Collection
- Metrics
- Data Analysis
- Future Efforts
- Conclusions

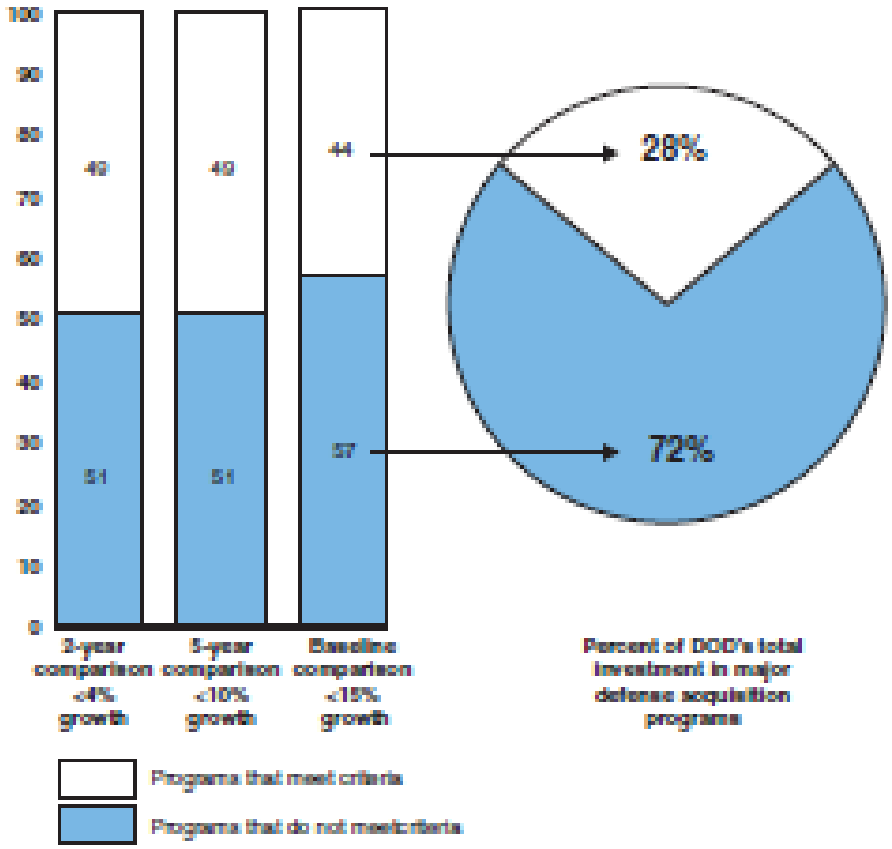
Problem Statement

- **Can schedule and cost risk of DoD weapons systems be estimated based on an assessment of its technology and design (TD) parameters?**
  - Perform an empirical assessment of historical and current DoD weapon systems
  - Compare TD parameters at acquisition milestones to realized schedule and cost overruns



Motivation

- DoD invests trillions of dollars in taxpayer money on weapon systems, but also been plagued with schedule and cost overruns (GAO 2012)
- Program managers do not have 'rules of thumb' to estimate and adjust for potential schedule and cost overruns for DoD weapon systems
- GAO assessments of weapon systems are insufficient in quantifying risk and identifying trends for financial and temporal overruns

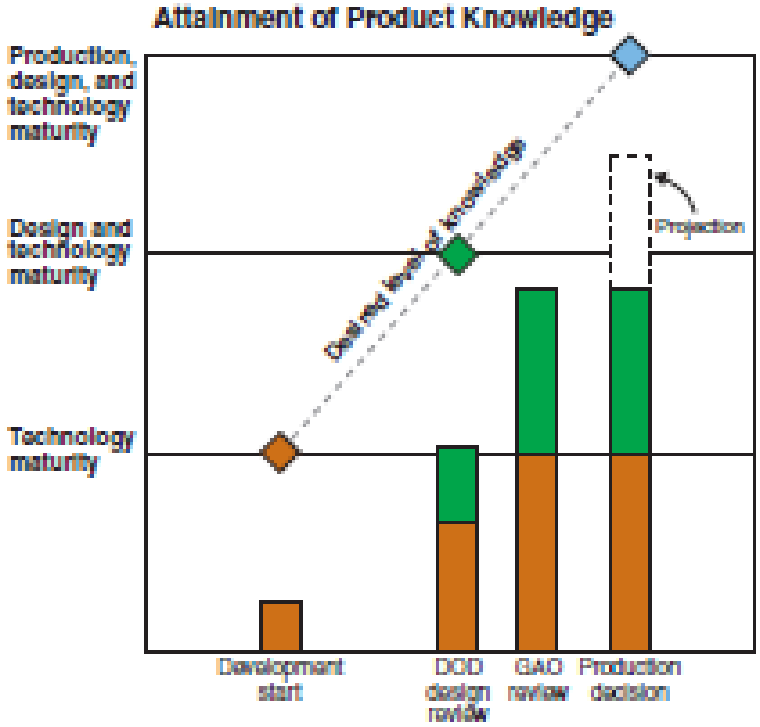


(GAO 2011)

Literature Review – DoD Weapon Systems

- **Annual GAO Weapon Systems reports evaluate each programs at different acquisition milestones**
  - Technology, design, production maturity
  - Program start, CDR, LRIP
- **GAO produces simple metrics about cost growth and schedule slippage**
  - *"The cost of the portfolio is driven by the 10 highest-cost programs, which account for 55 percent of its total cost."*
  - *"32 percent average delay in delivering initial capabilities"*
- **GAO provides historical data that could be mined for more quantitative analysis**
- **GAO moving away from quantitative to qualitative analysis**

(GAO 2012)



Sample GAO Data
(GAO 2011)

Literature Review – Advanced Growth/Slippage Metrics

- **Metrics have been developed to evaluate cost growth and schedule risk based on technical maturity**

Authors	Cost Growth or Schedule Slippage	Metric	Weapon or Space Systems
Bolten, et. al., 2008	Cost	Distribution and Central Tendency	Weapon Systems
Dubos and Saleh, 2010	Schedule	Markov Models	Space Systems
Dubos, et. al., 2008	Schedule	Negative Exponential	Space Systems
Lee and Thomas, 2001	Cost	Johnson's 4-parameter families of distributions	Space Systems
Malone, et. al., 2011	Cost	Negative Exponential	Space Systems

- **Issues**
  - No metrics look at the design maturity, or the interaction between cost growth and schedule slippage
  - Most metrics designed for space systems, not DoD weapon systems
  - Few metrics investigate project-level risk impact

Literature Review - Schedule and cost Risk

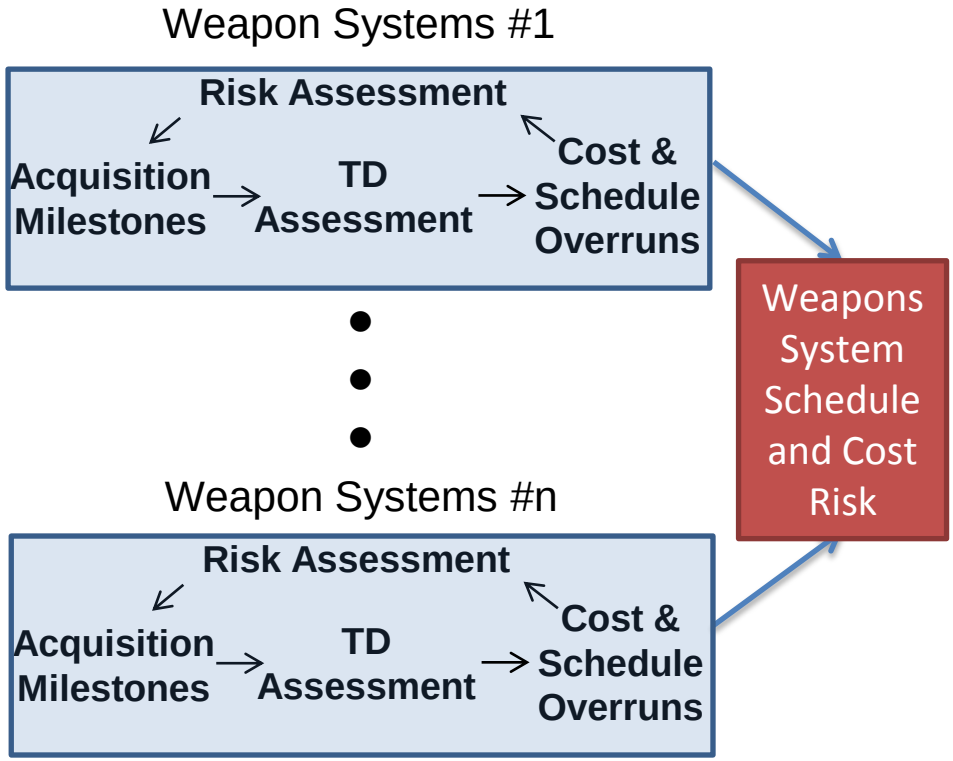
- **Schedule and cost risk are inputs into project risk**
  - Can be inputs into integrated tools to develop project risk (Smith, Malesh 2011)
- **Quantitative assessment methods exist to evaluate risk**
  - Risk curves (Dubos, et. al. 2008)
  - Bayesian Belief Networks (Kelly and Smith, 2009).
- **DoD's risk analysis methods do not attempt to quantify schedule and cost risk**
  - Limitations in using risk matrices (Cox 2008)

Level	Technical Performance	Schedule	Cost
1	Minimal or no consequence to technical performance	Minimal or no impact	Minimal or no impact
2	Minor reduction in technical performance or supportability; can be tolerated with little or no impact on the program	Able to meet key dates **Slip < _ months**	Budget increase or unit production cost increases **< _ (1% of Budget)**
3	Moderate reduction in technical performance or supportability with limited impact on program objectives	Minor schedule slip. Able to meet key milestones with no schedule float. **Slip < _ months Sub-system slip > _ months plus available float**	Budget increase or unit production cost increase **< _ (5% of Budget)**
4	Significant degradation in technical performance or major shortfall in supportability; may jeopardize program success	Program critical path affected. **Slip < _ months**	Budget increase or unit production cost increase **< _ (10% of Budget)**
5	Severe degradation in technical performance; Cannot meet KPP or key technical/supportability threshold; will jeopardize program success	Cannot meet key program milestones. **Slip > _ months**	Exceeds APB threshold **> _ (10% of Budget)**

(DoD 2006)

Gaps in Research and Conceptual Model

- Schedule and cost risk has not previously been measured based on design and production parameters
- Schedule and cost risk (based on technology maturity) has not been quantified for DoD weapon systems
- Current risk assessments for DoD weapon systems do not look at acquisition milestones to modify and identify trends of the risk profile of systems
- Lack of research in the interactions between schedule and cost risk, as it applies to project risk



Data Collection – Weapon Systems

128
GAO Reports

⇩

120
Non-Ship Systems

⇩

80
Data for 3+ Years

⇩

54
Sufficient Metric Data

Future analysis will consider more weapon systems

32 (Randomly Chosen)
Data Analysis

- **Branch**
  - Air Force = 8
  - Army = 8
  - Joint = 8
  - Navy = 8
- **Size of Program (Unit Cost)**
  - < $10M = 16
  - > $10M = 16
  - Equal breakdown per branch
- **Last Achieved Milestone**
  - Design Review = 9
  - LRIP = 16
  - FRIP = 2
  - IOC = 5
- **Current Status**
  - Completed/Cancelled = 15
  - In Progress = 17

Metrics

- **Relative Schedule Slippage**
  - Percentage of schedule slippage, given initial duration estimate between two acquisition milestones
- **Relative Unit Cost Growth**
  - Percentage of unit cost growth, given initial unit cost estimate between two acquisition milestones

- **Group weapon systems by maturity value**
- **Treat RSS/RUCG as a random variable**

$$\langle \overline{RSS} \rangle = \alpha e^{-\lambda x}$$

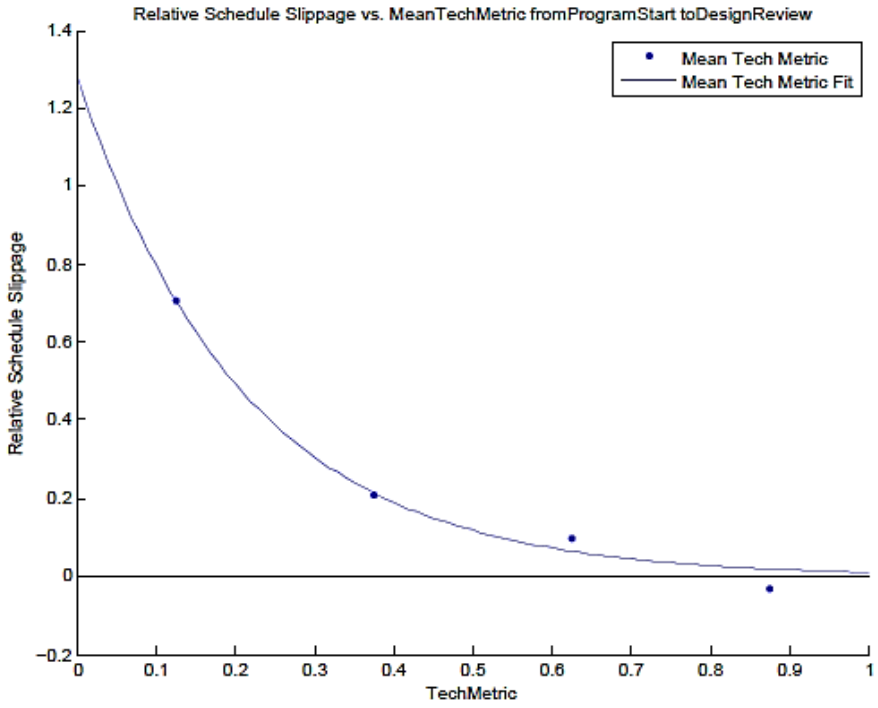
$$\langle \overline{RUCG} \rangle = \alpha e^{-\lambda x}$$

α = constant
λ = constant
x = technology or design maturity value

Dubos, et. al. 2008

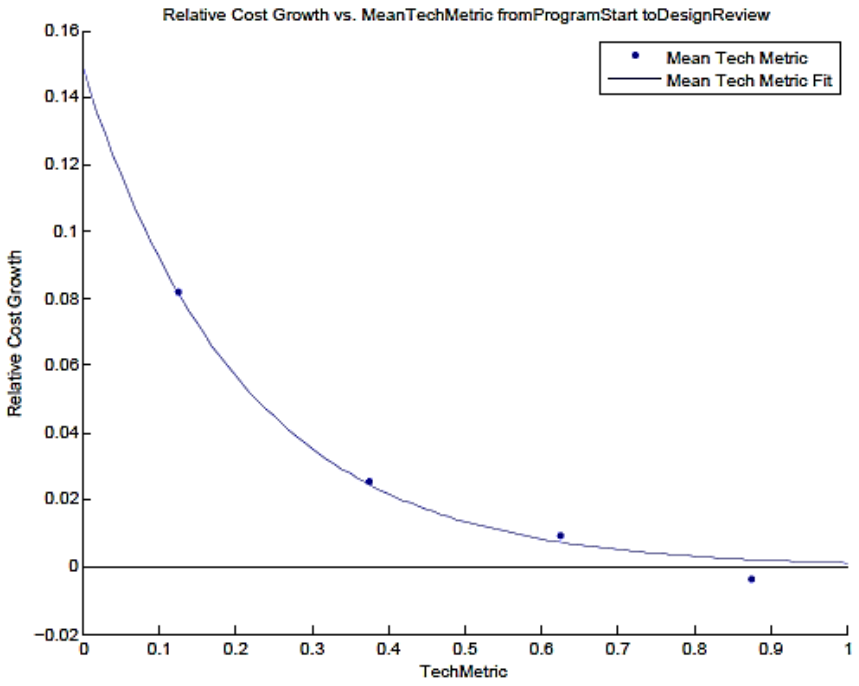
Data Analysis – Schedule Slippage

- **Independent variable**
  - Technology metric at program start
- **Dependent variable**
  - Relative schedule slippage from program start to design review
- **Fit negative exponential model to data**
  - $R^2 = 0.988$
- **Delays to design review are impacted by technology maturity**
- **Comparison to schedule slippage at LRIP**
  - $R^2 = 0.925$



Data Analysis – Cost Growth

- **Independent variable**
  - Technology metric at program start
- **Dependent variable**
  - Relative unit cost growth from program start to design review
- **Fit negative exponential model to data**
  - $R^2 = 0.991$
- **Delays to design review are mostly impacted by technology maturity**
- **Comparison to schedule slippage at LRIP**
  - $R^2 = 0.841$



Project Risk

- **Schedule Risk**
  - Probability that a weapon system exceeds a defined schedule margin between two acquisition milestones
- **Cost Risk**
  - Probability that a weapon system exceeds a defined cost margin between two acquisition milestones

- **Assume RSG/RCUG is normally distributed at each maturity value**

$$\mu_v \approx \langle \overline{RSS} \rangle_v, \langle \overline{RUCG} \rangle_v$$
$$\sigma \approx \frac{\text{range}}{4}$$

- **Develop risk curves as a function of margins**

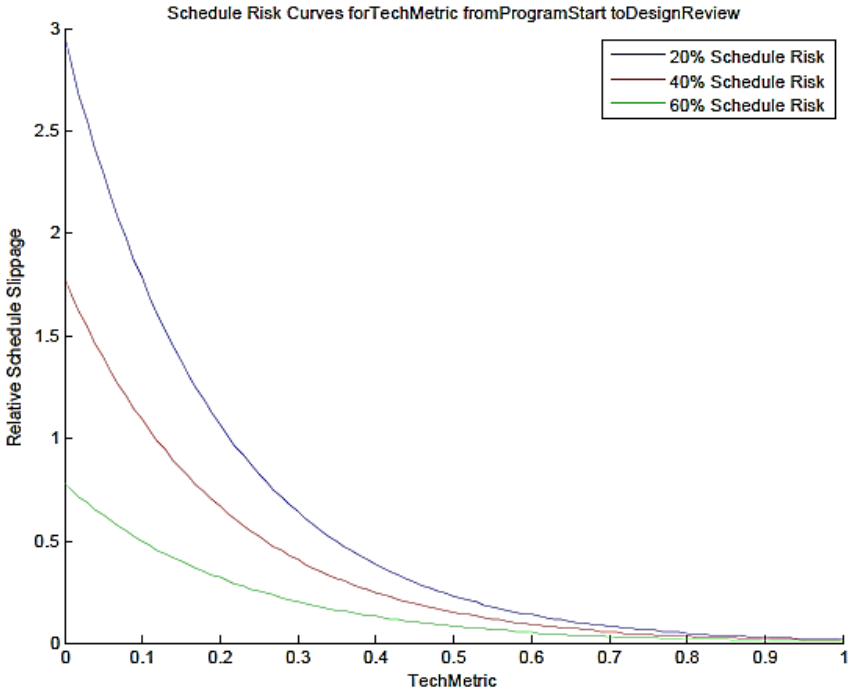
$$\text{risk}_v = 1 - \phi\left(\frac{m_v - \mu_v}{\sigma_v}\right)$$

v = maturity value
ϕ = standard normal cdf
m = schedule/cost margin

Dubos, et. al. 2008

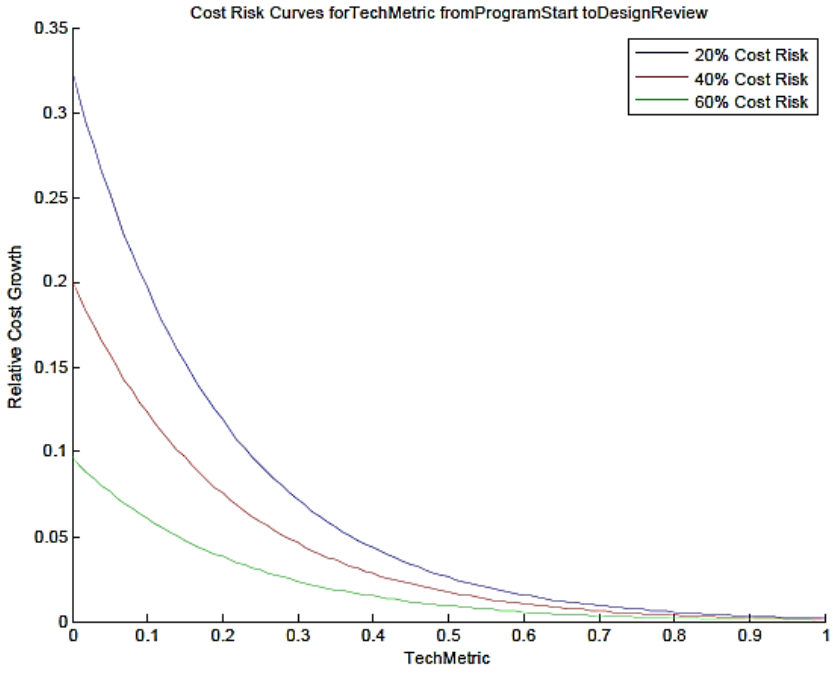
Data Analysis – Schedule Risk

- Relative schedule slippage curve transforms to family of schedule risk curves
- Vertical cuts determine if schedule margins reduce schedule risk
- For technology immature systems, increase in margins will reduce risk
- For technology mature systems, increase in margins does not reduce risk



Data Analysis – Cost Risk

- **Relative unit cost growth curve transform to family of cost risk curves**
- **Horizontal cuts determine impact of maturity on cost risk**
- **Accepting a 1.0% relative unit cost growth**
  - Low maturity systems have 20% cost risk
  - Immature systems have 60% cost risk



Future Efforts

- Continue investigation of schedule slippage and cost growth based on design maturity
  - Consider additional cost growth models
- Apply logistic regression model to investigate relationship between technology and design maturity
- Increase data set to include all DoD weapon systems with sufficient data
- Implement error analysis (e.g., confidence bands) into models
- Computation and discussion of schedule and cost risk metrics that are relevant to future DoD acquisition

Conclusions

- Schedule and cost risk, based on technology and design maturity, has not been quantified for DoD weapon systems
- Current risk assessments for DoD weapon systems do not look at acquisition milestones to modify and identify trends of the risk profile of systems
- Correlation exists between technology maturity and relative schedule slippage
- Correlation exists between technology maturity and relative unit cost growth
- Initial analysis indicates schedule or cost margins are not needed for technology mature systems

BACKUP

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Weapon Systems

- Advanced Precision Kill Weapon System
- AGM-88E Advanced Anti-Radiation Guide Missile
- Armed Reconnaissance Helicopter
- B-2 Radar Modernization Program
- C-130 Avionics Modernization Program
- C-5 Reliability Enhancement and Reengineering Program
- CH-47F Improved Cargo Helicopter
- E-2D Advanced Hawkeye
- EA-18G Growler
- Extended Range Munitions
- F-35 Joint Strike Fighter
- Family of Advanced Beyond Line-of-Sight Terminals
- Global Hawk Unmanned Aerial Vehicle
- Global Positioning Systems Block III
- Gray Eagle
- Joint Air-to-Surface Standoff Missile
- Joint Land Attack Cruise Missile Defense Elevated Netted Sensor System
- Joint Precision Approach and Landing System
- Joint Tactical Radio System Airborne, Maritime, Fixed-Site
- Joint Tactical Radio System Ground Mobile Radio
- JTRS Handheld, Manpack, Small Form Fit
- Longbow Apache Block III
- Medium Extended Air Defense System
- Minuteman III Guidance Replacement Program
- Mobile User Objective System
- MQ-9 Reaper Unmanned Aircraft System
- National Polar-orbiting Operational Environmental Satellite System
- Navy Multiband Terminal Program
- P-8A Multi-mission Maritime Aircraft
- Small Diameter Bomb
- Tactical Tomahawk Missile
- Warfighter Information Network-Tactical, Increment 2