Improving Systems Engineering Effectiveness on the C-17 Program

Mr. Nick Mansur
Director C-17 Avionics/Flight Controls/Support Equipment IPT
Nick.Mansur@Boeing.com

Mr. Sivam Paramanathan
Sr Manager Systems Engineering
C-17 Air Vehicle IPT
Sivam.Paramanathan@Boeing.com

Mr. Christian Stillings
Lead Systems Engineer
ASC C-17 Division
A.Stillings@US.AF.MIL

Issues in Product Development

C-17 software-intensive projects often missed major milestones. Contributing factors determined at Joint Customer-Boeing off-sites were:

- **Significant requirements volatility after CDR**
- **Product defects found late – later than they could have been**
  - **High number of V&V anomalies late in test program**
- **Engineering culture did not embrace risk management**
  - **Some risks existed but went unidentified**
  - **Some mitigation steps didn't reduce risk level**
- **Value of metrics desensitized by measuring & reporting on everything**
- **Process deficiencies addressed symptom-by-symptom resulting in unnecessary complexity**

Reducing Requirements Volatility

- **What was done:**
  - **Method for assessing requirement quality developed**
    - » **Eight elements individually assessed: 1) inputs & triggers, 2) bounds & conditions, 3) outputs & effects, 4) performance spec, 5) verifiability, 6) traceability, 7) rationale/decision, 8) change impact analysis**
    - » **For each element, four criteria defined and rated: Poor (1), Low (2), Moderate (3), High (4)**
  - **Predictive metrics developed**
    - » **Plotted trend of multiple assessments for quality predicted when review can be conducted**
    - » **Standard adopted: Requirements sufficiently mature to proceed to milestone review when average quality score > 3.5**
- **What resulted:**
  - **Earlier discovery of problems with requirement statements**
  - **Increased collaboration between system and software developers**
  - **300% reduction in post-CDR volatility (from 12% to 4%)**

Improving Test Strategies

- **What was done:**
  - **Multi-level test strategy developed & established as a best practice**
  - **Integrated Systems, SW, HW, & Test engineering teams deployed on projects to review requirement correctness & testability**
  - **Greater emphasis placed on low level SW testing**
  - **Boundary & off-nominal robustness testing incorporated**
- **What resulted:**
  - **In general:**
    - » **Much greater collaboration among sub-teams**
    - » **Much quicker ramp up & response in facing problems & issues early on**
  - **On one project:**
    - » **1000% reduction in defects per test case; 600% improvement in system-level productivity; flight test completed with no major anomalies; avoided 2nd SW build, 2nd TRR, 2nd qual & flight tests; EAC savings of $1.7M & schedule savings of 3 months realized**
  - **At the program level:**
    - » **Opportunity realized for consolidating 4 project test plans into one with significant cost and schedule savings**

Improving Risk Management (1)

- **What was done:**
  - **Workshops conducted by risk SMEs with project teams**
    - » **Most complex projects selected: 8-10 hours/week, 3-4 weeks**
    - » **Reviewed & worked existing risks posted to risk database**
    - » **Risk process applied step by step**
    - » **Existing risk descriptions refined & revised**
    - » **Risk sources reviewed & new risks identified as needed**
    - » **Risk mitigation actions & plans scrutinized & revised or developed**
    - » **Mitigation tasks with no significant impact on risk reduction eliminated**
  - **Integrated mitigation plan with project schedule**
  - **Risk dictionary compiled**
    - » **Recurring patterns of risk identified from individual project risks and summarized & abstracted into common risk areas & sources**
    - » **Rationale: Common C-17 sources & areas much easier for domain engineer to work with than generic, difficult to interpret sources & areas**
    - » **Rationale: Commonalities in areas & sources lead to common handlings & similar mitigations**

Improving Risk Management (2)

- **What was done:**
  - **Lessons Learned database improved**
    - **Access improved providing wider view of projects with similar circumstances, aiding in risk identification & effective mitigation actions**
  - **Risk metrics developed**
    - **Metrics focused on risk / issue relationship (risk realized = issue)**
    - **First metric: Identification Effectiveness measured how many issues resulted from unidentified risks (expressed as %)**
    - **Second metric: Mitigation Effectiveness measured how many identified risks were realized as issues (expressed as %)**
- **What resulted:**
  - **Positive feedback from workshop participants**
    - **Key concepts clearer**
    - **Complex subjects better understood**
    - **Skills in executing process improved**
  - **Risk Dictionary defined**
  - **Formal guidelines for mitigation / schedule integration established**

Improving Process & Metrics

- **What was done:**
  - **Developed list of "Things to Stop"**
    - » **Helped to shine light on processes without a customer and on products no one needed**
    - » **Forced questions to be asked about value vs. cost**
    - » **Questioned "required" data to defend data that was already defensible**
  - **Addressed processes holistically rather than symptom-by-symptom**
- **What resulted:**
  - **Eliminated requirement to gather and publish metrics & data with little or no value**
    - » **Helped everyone see what could be done, what's useful & what's not, and changed the culture as a result**
    - » **Increased understanding of key metrics**
    - » **Clearer understanding of "WHY" things are done**
  - **Eliminated multiple processes no longer deemed necessary**
    - » **Improved understanding of applicable processes**
    - » **Clearer understanding of "WHY" things are done**

Conclusion

- **Summary of Accomplishments**
  - **Requirements Management: Method for assessing requirement quality, early discovery & resolution of issues, increase in system-software collaboration**
  - **V&V: Multi-level test strategy best practice, integrated Systems, HW, SW, & Test sub-teams, early discovery & resolution of issues, increase in collaboration**
  - **Risk Management: Workshops as standard practice, effective mitigation plans integrated with project schedules, development of key risk metrics**
  - **Metrics & Process: Improved metrics & processes**
- **Key Results**
  - **Key Systems Engineering activities moved to the left**
  - **Schedule and cost savings realized**
- **Key Tools**
  - **Systems Engineering**
  - **Lean + Principles**
- **Ultimate Goal**
  - **DELIVERING FIRST-TIME QUALITY TO THE WAR FIGHTER SOONER RATHER THAN LATER**