Earned Schedule: Utility in Major U.S. Air Force Acquisition Programs

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Overview

The AFIT of Today is the Air Force of Tomorrow.

- The Issue
- Previous Research
- Definitions
- Methodology & The Five Tests
- Analysis & Results
- Conclusions & Recommendations
- Summary
The Issue

• Earned Value Management (EVM) is an effective tool for managing cost performance: but what are its merits in forecasting schedule?

• EVM measures schedule in terms of dollars, rather than in terms of time, and is ostensibly useless over the final 1/3 of a project.

• Earned Schedule (ES) developed to combat these EVM shortcomings, but does it translate to major defense acquisition programs?
The Issue

• Major Defense Acquisition Programs (MDAP) are consistently delivered over budget and schedule.

• Delayed delivery of programs leads to increased costs.

• Earned Schedule is a 10-year old concept, developed by Walt Lipke to give greater focus to schedule performance, but its application to defense acquisition programs has not been explored.
Research Questions

• Three Research Questions:

  • To what extent is Earned Schedule currently utilized in Air Force ACAT I acquisition programs?
  
  • Does Earned Schedule provide more accurate schedule predictions than traditional DoD methods?
  
  • Does Earned Schedule provide more timely schedule predictions than traditional DoD methods?
Previous Research
Previous Research

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• Earned Schedule In Practice
  
  • Henderson - “Earned Schedule: A Breakthrough Extension to Earned Value Theory? A Retrospective Analysis of Real Project Data”
  
  • Rujirayanyong – “A comparison of Three Completion Date Predicting Methods for Construction Projects”
  
  • Lipke - “Earned Schedule Application to Small Projects”
  
  • Tzaveas, Katsavounis, Kalfakakou – “Analysis of Project Performance of a Real Case Study and Assessment of Earned Value and Earned Schedule Techniques for the Prediction of Project Completion Date”
  
  • Vanhoucke and Vandevoorde – “Measuring the Accuracy of Earned Value/Earned Schedule Forecasting Predictors”
Methodology & The Five Tests
Data Collection

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- OUSD (AT&L) system: Defense Acquisition Management Information Retrieval (DAMIR)

- Contract Performance Report Format 1
  - Cumulative BCWS
  - Cumulative BCWP
  - SPI($)  
  - SV($) 

- ACAT I Programs from Aeronautical System Center

- Qualitative Data from Electronic System Center and Space & Missile Center
### Selected Programs

**List of Program Used for Analysis**

<table>
<thead>
<tr>
<th>Program</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rockwell B-1B Lancer</td>
</tr>
<tr>
<td>Northrup Grumman B-2 Spirit</td>
</tr>
<tr>
<td>General Dynamics F-16 Fighting Falcon</td>
</tr>
<tr>
<td>McDonnell Douglas F-15 Eagle</td>
</tr>
<tr>
<td>Fairchild Republic A-10 Thunderbolt</td>
</tr>
<tr>
<td>Fairchild T-46</td>
</tr>
<tr>
<td>Boeing E-3 Sentry Airborne Warning and Control System</td>
</tr>
<tr>
<td>Boeing C-17 Globemaster III</td>
</tr>
<tr>
<td>General Dynamics/Grumman EF-111A Raven</td>
</tr>
<tr>
<td>AGM-131 Short Range Attack Missile II</td>
</tr>
<tr>
<td>AGM-86 Air Launch Cruise Missile</td>
</tr>
<tr>
<td>AGM-65 Maverick</td>
</tr>
<tr>
<td>Lockheed Martin C-130J Super Hercules Upgrade</td>
</tr>
</tbody>
</table>
## Data

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<table>
<thead>
<tr>
<th>Platform Name</th>
<th># of Contracts</th>
<th># of Data Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>B-1</td>
<td>14</td>
<td>233</td>
</tr>
<tr>
<td>B-2</td>
<td>2</td>
<td>19</td>
</tr>
<tr>
<td>F-16</td>
<td>4</td>
<td>51</td>
</tr>
<tr>
<td>F-15</td>
<td>8</td>
<td>115</td>
</tr>
<tr>
<td>A-10</td>
<td>5</td>
<td>135</td>
</tr>
<tr>
<td>E-3</td>
<td>2</td>
<td>50</td>
</tr>
<tr>
<td>T-46</td>
<td>2</td>
<td>25</td>
</tr>
<tr>
<td>C-17</td>
<td>11</td>
<td>226</td>
</tr>
<tr>
<td>EF-111</td>
<td>2</td>
<td>36</td>
</tr>
<tr>
<td>AGM-131 (SRAM)</td>
<td>1</td>
<td>17</td>
</tr>
<tr>
<td>AGM-86 (ALCM)</td>
<td>8</td>
<td>74</td>
</tr>
<tr>
<td>AGM-65</td>
<td>4</td>
<td>41</td>
</tr>
<tr>
<td>C-130J</td>
<td>1</td>
<td>65</td>
</tr>
<tr>
<td>Sum</td>
<td>64</td>
<td>1,087</td>
</tr>
</tbody>
</table>
Methodology

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• Qualitative: Interview Program Offices to determine how schedule analysis is conducted, their familiarity with Earned Schedule, & the prevalence of Earned Schedule in their analyses.

• Quantitative: Is there a statistical difference between the SPI($) and SPI(t) values of EVM and ES? Use Paired-T Test to compare means of SPI($) and SPI(t).

• If so, run a series of five tests to determine which method provides for accurate and timely predictions of schedule overages.
The Five Tests

• Test 1: Analysis of SPI(t) and SPI($) below .90 Over Time

  • Average SPI(t) and SPI($) value calculated at 6 different project completion points (20%, 40%, 50%, 60%, 80%, 90%)

  • Addresses SPI($) inadequacies over the final third of a program.
The Five Tests

• Test 2: Analysis of Frequency of SPI(t) and SPI($) values below .90

• Calculate Completion Percentage where SPI value first dropped below .90.

• Calculate total number of data points below .90, when a program is determined to be “in trouble.”

• Addresses which method provides more timely schedule predictions.
The Five Tests

• **Test 3a: Analysis of Optimism and Accuracy in SPI(t) vs. SPI($) values**

  • Calculate which SPI value for each data point is highest. Highest SPI is the most optimistic.

  • Calculate at 6 different project completion points (20%, 40%, 50%, 60%, 80%, 90%) to see which method is more optimistic at certain points in a program.

  • Addresses issue of schedule metrics being historically optimistic.
The Five Tests

- Test 3b: Analysis of SPI(t) vs. SPI($) Points Closer to the Final Schedule Result

  - Calculate which SPI value is closest to the final schedule result.
  
  - Calculate at 6 different project completion points (20%, 40%, 50%, 60%, 80%, 90%) to see which method is more accurate at certain points in a program.
  
  - Addresses which method is more accurate.
The Five Tests

• Test 4: Analysis of TSPI Values

• Compare number of programs signaled as “in trouble” with TSPI values of 1.10, 1.05 and 1.01.

• Calculate at 6 different project completion points (20%, 40%, 50%, 60%, 80%, 90%) to see which TSPI value signals problems most accurately.
The Five Tests

Test 5: Analysis of SV(t) vs. SV($) Divergence Point

- Calculate SV(t) and SV($) for each data point.
- Calculate divergence point for each program.
Application to the Critical Path

- Application to the Critical Path

  - “Deep-Dive” Analysis on C-130J Block 7.0 Upgrade
Analysis and Results
Analysis and Results

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• **Qualitative Test**
  • Program offices use monthly EVM data and Integrated Master Schedule to perform monthly schedule analysis.
  • Most offices have heard of Earned Schedule.
  • 6/18 (33%) of program offices that responded use Earned Schedule in their analysis.
  • No programs use Earned Schedule as their *primary* schedule analysis tool; all used it as a secondary/cross-check to EVM.
Analysis and Results

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- Results of Significance Test
  - Paired T-Test as Comparison of Means
  - T-Statistic: -8.6231
  - Degrees of Freedom: 1,086
  - P-Value: 2.27467 E -17

- Reject the Null Hypothesis.

- There is a statistical difference between the Earned Value Management and Earned Schedule methods.
Analysis and Results

- Test 1: Analysis of SPI(t) and SPI($) below .90 Over Time
  - Typical Program: B-1B Propulsion Lot 1
Analysis and Results

- Test 1: Analysis of SPI(t) and SPI($) below .90 Over Time
  - SPI Comparison Over Time

![SPI Comparison Over Time Graph]
## Analysis and Results

**The AFIT of Today is the Air Force of Tomorrow.**

- **Test 2: Analysis of Frequency of SPI(t) and SPI($)** values below .90

<table>
<thead>
<tr>
<th></th>
<th>Percent Complete (Mean)</th>
<th>Programs with no SPI value below .90</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earned Schedule</td>
<td>29.89%</td>
<td>21</td>
</tr>
<tr>
<td>Earned Value Management</td>
<td>17.89%</td>
<td>30</td>
</tr>
</tbody>
</table>
## Analysis and Results

**The AFIT of Today is the Air Force of Tomorrow.**

- **Test 2: Analysis of Frequency of SPI(t) and SPI($) values below .90**

<table>
<thead>
<tr>
<th></th>
<th>Total Points &lt; .90</th>
<th>Percentage of Overall Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earned Value Management</td>
<td>135</td>
<td>12.42</td>
</tr>
<tr>
<td>Earned Schedule</td>
<td>220</td>
<td>20.24</td>
</tr>
</tbody>
</table>
Analysis and Results

• Test 2: Analysis of Frequency of SPI(t) and SPI($) values below .90
Analysis and Results

Test 3a: Analysis of Optimism and Accuracy in SPI(t) vs. SPI($) values

<table>
<thead>
<tr>
<th></th>
<th>Number of Occurrences</th>
<th>Percentage of Overall (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earned Value Management</td>
<td>646</td>
<td>59.43</td>
</tr>
<tr>
<td>Earned Schedule</td>
<td>381</td>
<td>35.05</td>
</tr>
<tr>
<td>EVM = ES</td>
<td>60</td>
<td>5.52</td>
</tr>
</tbody>
</table>
Analysis and Results

• Test 3a: Analysis of Optimism and Accuracy in SPI(t) vs. SPI($) values

EVM More Optimistic
Analysis and Results

- Test 3a: Analysis of Optimism and Accuracy in SPI(t) vs. SPI($) values
Analysis and Results

- Test 3a: Analysis of Optimism and Accuracy in SPI(t) vs. SPI($) values

Comparison of More Optimistic Method Over Time

Number of Programs

Program Completion Percentage

SPI(t)

SPI($)
• Test 3b: Analysis of SPI(t) vs. SPI($) Points Closer to the Final Schedule Result

<table>
<thead>
<tr>
<th></th>
<th>Number of Occurrences</th>
<th>Percentage of Overall Occurrences (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earned Value Management</td>
<td>403</td>
<td>37.07</td>
</tr>
<tr>
<td>Earned Schedule</td>
<td>624</td>
<td>57.41</td>
</tr>
<tr>
<td>EVM = ES</td>
<td>60</td>
<td>5.52</td>
</tr>
</tbody>
</table>
Analysis and Results

Test 3b: Analysis of SPI(t) vs. SPI($) Points Closer to the Final Schedule Result

EVM Closer to Final

% of Points Closer to Final Result in a Program

Frequency
Analysis and Results

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- Test 3b: Analysis of SPI(t) vs. SPI($) Points Closer to the Final Schedule Result

![Bar Chart](chart.png)

ES Closer to Final

- Frequency

% of Points Closer to Final Result in a Program

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Analysis and Results

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- Test 3b: Analysis of SPI(t) vs. SPI($) Points Closer to the Final Schedule Result
Analysis and Results

Test 4: Analysis of TSPI Values

Mean: 64.22%
Analysis and Results

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- Test 4: Analysis of TSPI Values

Mean: 50.81%
Analysis and Results

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- Test 4: Analysis of TSPI Values

Mean: 24.24%
Analysis and Results

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- Test 4: Analysis of TSPI Values

<table>
<thead>
<tr>
<th>TSPI &gt;</th>
<th>20%</th>
<th>40%</th>
<th>50%</th>
<th>60%</th>
<th>80%</th>
<th>90%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.01</td>
<td>35</td>
<td>46</td>
<td>51</td>
<td>51</td>
<td>62</td>
<td>57</td>
</tr>
<tr>
<td>1.05</td>
<td>9</td>
<td>21</td>
<td>31</td>
<td>40</td>
<td>53</td>
<td>55</td>
</tr>
<tr>
<td>1.10</td>
<td>3</td>
<td>9</td>
<td>14</td>
<td>25</td>
<td>45</td>
<td>51</td>
</tr>
</tbody>
</table>
Analysis and Results

• Test 4: Analysis of TSPI Values

TSPI Comparison Over Time

- Blue line: TSPI > 1.01
- Red line: TSPI > 1.05
- Green line: TSPI > 1.10
Analysis and Results

• Test 5: Analysis of SV(t) vs. SV($) Divergence Point
  • Typical Program: B-1B Propulsion Lot 1

B1B Propulsion Lot 1 SV(t) vs. SV($)
Analysis and Results

Test 5: Analysis of SV(t) vs. SV($) Divergence Point

Comparison of SV(t) vs. SV($) Divergence Point
Analysis and Results

- Critical Path Method

  - Disconnect between how EVM data collected and Critical Path data used by Program Office.

  - EV data collected at WBS Level 3 vs. Critical Path data collected deeper (i.e. WBS Level 7).

  - Doesn’t suggest ES doesn’t apply to Critical Path Method, but conclusive research needs more detailed EVM data.
Research Questions Answered

To what extent is Earned Schedule currently utilized in Air Force ACAT I acquisition programs?

- Only 1/3 of program offices that we spoke with use Earned Schedule in any capacity, and those who do use it exclusively as a secondary/cross-check tool.
Research Questions Answered

• Does Earned Schedule provide more accurate schedule predictions than traditional DoD methods?

• Yes. Earned Schedule provides more accurate schedule predictions than Earned Value Management. It is more frequently the method that delivers closer to the final schedule result, is often the more pessimistic/realistic measure, and more frequently detects problems in programs that eventually are late in their delivery.
Research Questions Answered

• Does Earned Schedule provide more timely schedule predictions than traditional DoD methods?

  • Yes. On average, in the programs where EVM detected a problem, it did so earlier than ES. However, ES detected problems with greater frequency, and the detection occurred with greater consistency earlier in the programs.
Conclusion

• Earned Schedule is a relatively new phenomenon, previous not studied with respect to Air Force ACAT I programs.

• The benefits to the implementation of Earned Schedule, outlined in the literature of Walt Lipke, Kym Henderson, and others, manifested themselves when applied to this research.

• Earned Schedule provides valuable information regarding schedule performance analogous with Earned Value’s ability to manage a program’s cost performance.
Significance of Research

- Highlights the inadequacies of Earned Value Management as a schedule performance tool on ACAT I Programs.

- Outlines the advantages to implementation of Earned Schedule.

- Details what useful information Earned Schedule offers program managers, and how it can better equip them to make decisions with substantial financial implications.
  - ES is more accurate & timely than EVM
Recommendation for Action

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• Implement Earned Schedule as, at least, a secondary tool for schedule analysis.

• Incorporate TSPI as a tracked metric, using TSPI > 1.01 as a trigger for change on a program.

• Expand research into how Earned Schedule applies to the critical path.
Overview

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• Conclusions
• Summary
• U.S. Air Force’s graduate school for engineering and management

• Defense-focused technical graduate/continuing education and research

• Cost Analysis graduate program is the only one of its kind in the United States
Contact Information

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Questions

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