Technology Cost and Schedule Estimating

Goal: Address a gap in cost and schedule estimating for early TRL development projects

Tasks
1. Identify and collect historical data for early TRL development projects
2. Develop a software tool for cost and schedule estimation

Background
- Project sponsored by NASA CAD and GCD
- 12-month research project divided into 3 phases
- Two workshops to solicit cost community input and feedback
Data Collection and Analysis
Data Collection

- Identified **76 sources** of historical technology project data after Phase I Workshop
  - Historical databases (NTIS, MATCH)
  - Project records (GCD, ETDP)

- Collected data for **3,178 individual technology projects** from these sources across all TAs (1,209 fall in the four selected TAs)

- Selected **229 projects** in four selected TAs from ESTO, ETDP, GCDPO, and SBIR III for retrospective data collection effort lead by NASA CAD
## Final Data Sources

<table>
<thead>
<tr>
<th>Source</th>
<th>Year</th>
<th>Unique Records</th>
</tr>
</thead>
<tbody>
<tr>
<td>NASA Exploration Technology Development Program</td>
<td>2012</td>
<td>42</td>
</tr>
<tr>
<td>NASA Earth Science Technology Office</td>
<td>2012</td>
<td>138</td>
</tr>
<tr>
<td>Current NASA SBIR Technologies</td>
<td>2012</td>
<td>51</td>
</tr>
<tr>
<td>Game Changing Development Technology Projects</td>
<td>2012</td>
<td>35</td>
</tr>
<tr>
<td>NASA Exploration Systems Mission Directorate ESAS Technologies</td>
<td>2005</td>
<td>304</td>
</tr>
<tr>
<td>ATLAS (Advanced Technology Lifecycle Analysis System)</td>
<td>2002</td>
<td>6</td>
</tr>
<tr>
<td>Tauri Group research into External Gov Technology Tech Maturation Data</td>
<td>2012</td>
<td>28</td>
</tr>
<tr>
<td>Constellation Program Technology Portfolio</td>
<td>2007</td>
<td>19</td>
</tr>
<tr>
<td>NASA Tech Inventory Database</td>
<td>2004</td>
<td>991</td>
</tr>
<tr>
<td>Historical SBIR and STTR data</td>
<td>2012</td>
<td>1191</td>
</tr>
<tr>
<td>NASA RLV Technology Database</td>
<td>1993</td>
<td>64</td>
</tr>
<tr>
<td>Estimates of HEOMD needed technology developments</td>
<td>2012</td>
<td>78</td>
</tr>
<tr>
<td>Mapping Applicable Technology To Exploration Challenges</td>
<td>2007</td>
<td>213</td>
</tr>
<tr>
<td>NASA/Air Force Joint Systems Study TBCC Technologies</td>
<td>2010</td>
<td>18</td>
</tr>
</tbody>
</table>
Technology Parameters

Project Characterization
1. Technology Area (TA)
2. System Hierarchy
3. Hardware vs. Software
4. Push vs. Pull
5. Evolutionary vs. Revolution
6. Defining System Characteristics

Project Results
7. Key Performance Parameter (KPP)
8. Level of Effort
9. Cost
10. Schedule

Development Metrics
11. Technology Readiness Level (TRL)
12. Research and Development Degree of Difficulty (R&D³)
13. Advancement Degree of Difficulty (AD²)

Project Execution
14. Funding Source(s)
15. Organization(s) Involved
16. Facilities and Infrastructure
17. Team Experience

Programmatic Factors
18. Estimates vs. Actuals
19. Budget Constraints and Disruptions
20. Unplanned Events
Data Analysis

Data Filtering Stages

3,178
Historical Project Data Records

1,723
...of those include Cost and Schedule information

643*
...of those records are in TA 3, 4, 8, & 12

Availability of Desired Parameters (from 643 records)

- Potentially Sufficient
- Insufficient Data to Assess (To Date)

Continued retrospective data collection can improve data quality for other parameters

+ = augmented by SpaceWorks via expert opinion
## Analysis of Variance (ANOVA) Results

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Likelihood of Relationship between Parameter and Cost?</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology Area (TA)</td>
<td><strong>Significant</strong> (p-value ≈ 0.00)</td>
<td>Samples: 605 historical + 38 retrospective</td>
</tr>
<tr>
<td>TRL (i.e. TRL Start→End)</td>
<td><strong>Significant</strong> (p-value ≈ 0.00)</td>
<td>Samples: 485 historical + 37 retrospective</td>
</tr>
<tr>
<td>Funding Source(s)</td>
<td>-</td>
<td>Insufficient commonality/uniformity within data to conduct test</td>
</tr>
<tr>
<td>Level of Effort</td>
<td>-</td>
<td>Not an independent parameter</td>
</tr>
<tr>
<td>System Hierarchy Level</td>
<td><strong>Significant</strong> (p-value = 0.03)</td>
<td>Further evaluation is required</td>
</tr>
<tr>
<td>Estimates vs. Actuals</td>
<td>-</td>
<td>Intended for classification of data only; Not predictive</td>
</tr>
<tr>
<td>KPP</td>
<td>-</td>
<td>Insufficient commonality/uniformity within data to conduct test</td>
</tr>
<tr>
<td>Performing Organization(s)</td>
<td><strong>Insignificant</strong> (p-value = 0.43)</td>
<td>Samples: 605 historical + 38 retrospective</td>
</tr>
</tbody>
</table>

**Note:** It is common practice to look for a p-value <= 0.05 (i.e. 5%) before declaring that there is a significant underlying relationship between groups of data.
TCASE Tool Development
TCASE Tool

Design Features

- Microsoft Excel® based application
- Fast-acting analogy identification algorithm based on an outranking method approach
- Built-in database search of more than 1,700 technology development projects
- Automatic generation of basic statistical summary

Tool Documentation

- Software User Manual
- Quickstart Guide
## TCASE Tool Interface

### Search Criteria
- **Technology Description**: Search by keywords and project attributes.
- **System Characteristics/Requirements**: Specify the number of years and other criteria.

### Statistical Results
- **Cost Summary Stats**:
  - **Mean**: $8,396,860
  - **Median**: $677,848
  - **MoE**: $332,489
- **Schedule Summary Stats**:
  - **Mean**: 5.0 years
  - **Median**: 1.0 years
  - **MoE**: 1.0 years

### Top Analogies (of 15 total analogies)
- **RANK 1**: 
  - **Project Name**: 1
  - **Start Date**: 2001
  - **Total Cost**: $107,094
- **RANK 2**: 
  - **Project Name**: 2
  - **Start Date**: 2001
  - **Total Cost**: $177,005
- **RANK 3**: 
  - **Project Name**: 3
  - **Start Date**: 1999
  - **Total Cost**: $73,000

### Data Breakdown
- **System Hierarchy**
- **Analogy Breakdown**

---

Enter search criteria | Explore summary results | Review top analogies
User Interface Details

**Search Criteria**

- **Technology Description**
  - Title Keywords: battery
  - Description Keywords: battery
  - System Characteristics Keywords: yes
  - Key Performance Parameter Keywords: yes
  - Start TRL: yes
  - End TRL: yes
  - System Hierarchy: yes

- **Project Description**
  - NASA Program: yes
  - Primary TA: yes
  - Secondary TA: yes
  - Tertiary TA: yes
  - Earliest Start Year: yes
  - Latest Start Year: yes
  - Minimum Duration (years): yes
  - Maximum Duration (years): yes
  - Minimum Total Cost ($): yes
  - Maximum Total Cost ($): yes
  - Ask/Estimate: actual
  - Single Project/Portfolio: yes

- **Project Management**
  - NASA Directorate or Office: yes
  - NASA Center: yes
  - Performing Organization: yes
  - Facilities & Infrastructure: yes
  - Comment Keywords: yes

- **Search Settings**
  - Minimum Score for Analogy Matching: 50%
  - Maximum Number of Analogy Results: yes

**Search using keywords [optional]**

**Apply a weighting factor to each search term**

**Match search term exactly [optional]**

**Statistical Results**

- **Cost Summary Stats**
  - Count: 15
  - Maximum: $8,206,860
  - 75% percentile: $1,756,852
  - Median: $677,843
  - 25% percentile: $232,489
  - Minimum: $85,899

- **Schedule Summary Stats**
  - Count: 15
  - Maximum: 5.0 years
  - 75% percentile: 1.0 years
  - Median: 1.0 years
  - 25% percentile: 1.0 years
  - Minimum: 1.0 years

- **Box plots indicate center and spread of analogy cost and schedule data**

- **Breakdown plots provide high-level summary of analogy results**

- **Clearly indicates number of data records (analogies) returned by your search**
Search Criteria

Technology Description
- Title and Description
- System Characteristics
- Key Performance Parameters
- Technology Readiness Level (TRL)
- Research and Development Degree of Difficulty (R&D3)
- System Hierarchy

Project Description
- Technology Area
- Actual or Estimate
- Single Project or Portfolio

Project Management
- NASA Program, Directorate, or Office
- Performing Organization(s)
- Facilities and Infrastructure
Preliminary analogy identification methodology was implemented to search for, identify, and rank analogous projects based on the user inputs.

- As the tool matures, this methodology may be refined and expanded

User inputs search criteria, weightings, and filters

- Technology parameters are used as search criteria
- Importance weighting for each parameter
- Explicitly filter out projects that do not satisfy a particular parameter value

Each project in the database is scored against search criteria parameters on range from 0 to 1

- Projects with the same value as the desired value receive a 1
- Similar value yields a score between 0 and 1 depending on the level of similarity
- Significantly different value yields a 0
Analogy Identification Methodology (2 of 2)

- Individual parameter scores are weighted using the user-defined relative importance values, normalized, and combined using a weighted sum approach to yield a final score between 0 and 1.

- Scores are then weighted using the user-defined relative importance values, normalized, and combined using a weighted sum approach to yield a final OEC between 0 and 1.

- Analogous technology projects are ranked in order by OEC, from highest to lowest.
  
  - Those that meet a user-defined OEC threshold value are displayed to the user as an analogy.
  
  - Additional data parameters associated with these analogies are also provided on the front end.
Going Forward
Next Steps

- Continue collecting and compiling technology project data from NASA and other organizations across all TAs

- Investigate the potential for developing Cost Estimating Relationships (CERs) from these data

- Enhance TCASE by broadening the database and incorporating new estimating methods such as CERs to supplement the current analogy-based approach