Better Requirements Decomposition Guidelines Can Improve Cost Estimation of Systems Engineering and Human Systems Integration

2ndLt. Kevin Liu, USMC
MIT Graduate Research Assistant
Systems Engineering Advancement Research Initiative (SEArI)
Co-Authors: Dr. Ricardo Valerdi, MIT and Dr. Phillip A. Laplante, Penn State

8th Annual Conference on Systems Engineering Research
March 17-19, 2010 | Hoboken, New Jersey

The views expressed in this presentation are those of the authors and do not reflect the official policy or position of the United States Marine Corps, Air Force, Department of Defense, or the U.S. Government

© 2010 Massachusetts Institute of Technology
Outline

Motivation

Research Questions

Background

Data Collection Workshop
  Design
  Results

Conclusions/Future Work
Motivation-HSI

HSI requirements include, but are not limited to, any requirement pertaining to one or more domains of HSI, or the integration of those domains. Broadly, the term encompasses any requirement that contributes to the integration of human considerations into the system being developed.

Research Questions

Hypothesis: Human Systems Integration effort can be estimated as a function of total Systems Engineering Effort
Research Questions

Hypothesis: Human Systems Integration effort can be estimated as a function of total Systems Engineering Effort

Human Systems Integration effort can be estimated by counting “number of HSI requirements”
Research Questions

Hypothesis: Human Systems Integration effort can be estimated as a function of total Systems Engineering Effort

Human Systems Integration effort can be estimated by counting “number of HSI requirements”

Existing counting rules can be adapted to better account for Human Systems Integration requirements
Research Questions

Hypothesis: Human Systems Integration effort can be estimated as a function of total Systems Engineering Effort

Human Systems Integration effort can be estimated by counting “number of HSI requirements”

Existing counting rules can be adapted to better account for Human Systems Integration requirements

Research Question: How can existing COSYSMO decomposition guidelines be modified to improve counting of HSI requirements?
Background-Cost Model

### Size Drivers

- # Requirements
- # Interfaces
- # Scenarios
- # Algorithms
- + 3 Volatility Factors

### Effort Multipliers

- Application factors
  - 8 factors
- Team factors
  - 6 factors
- Schedule driver

COSYSMO

SE Effort

Calibration

Presented to the Conference on Systems Engineering Research 2010
Effort Multipliers
- Application factors
  - 8 factors
- Team factors
  - 6 factors
- Schedule driver

Size Drivers
- # Requirements
- # Interfaces
- # Scenarios
- # Algorithms
  + 3 Volatility Factors
Background-Cost Model

Size Drivers

| # Requirements |
| # Interfaces  |
| # Scenarios   |
| # Algorithms  |
| 3 Volatility Factors |

Effort Multipliers

- Application factors
  - 8 factors
- Team factors
  - 6 factors
- Schedule driver

COSYSMO

SE Effort

Calibration

Presented to the Conference on Systems Engineering Research 2010
Background-Cost Model

Size Drivers
- # Requirements
- # Interfaces
- # Scenarios
- # Algorithms
- 3 Volatility Factors

Effort Multipliers
- Application factors
  - 8 factors
- Team factors
  - 6 factors
- Schedule driver

COSYSMO

Calibration

SE Effort

Presented to the Conference on Systems Engineering Research 2010
Background-Cost Model

Size Drivers

# Requirements
# Interactions
# Scenarios

Effort Multipliers
- Application factors
- 8 factors
- Team factors
- 6 factors
- Schedule driver

3 Volatility Factors

COSYSMO

Calibration

SE Effort

Presented to the Conference on Systems Engineering Research 2010
Workshop Research Design

Research Question: How can existing COSYSMO decomposition guidelines be modified to improve counting of HSI requirements?

24th International Forum on COCOMO and Systems/Software Cost Modeling, MIT, Nov 2-5 2009
Workshop Research Design

Research Question: How can existing COSYSMO decomposition guidelines be modified to improve counting of HSI requirements?

Method:
- Provide sample requirements related to example system
- Ask participants to analyze using existing guidelines
Research Question: How can existing COSYSMO decomposition guidelines be modified to improve counting of HSI requirements?

Method:
- Provide sample requirements related to example system
- Ask participants to analyze using existing guidelines

Contribution:
- Identify improvements to COSYSMO decomposition guidelines
- Assess impact of HSI requirements on SE effort
Criteria Used to Judge Requirements

1. Determine the system of interest.

2. Decompose system objectives, capabilities, or measures of effectiveness into requirements that can be tested, verified, or designed.

3. Provide a graphical or narrative representation of the system of interest and how it relates to the rest of the system.

4. Count the number of requirements in the system/marketing specification or the verification test matrix for the level of design in which systems engineering is taking place, given the desired system of interest.

5. Determine the complexity of requirements.

Is the requirement at the level of the system-of-interest?

Can the requirement be tested, verified or designed?

Does the HSI requirement decompose to none, one, or many requirements?
Requirements Counting Workshop

16 Participants
Split into 8 groups of 2

3 Phases
8 requirements/phase

Cautions and Warnings. Method for displaying system warnings, cautions, and alarms must be appropriate given the importance of the situation (Threshold).
Hypothesis #1

Research Question: How can existing COSYSMO decomposition guidelines be modified to improve counting of HSI requirements?

Hypothesis #1: Using the cost estimation decomposition steps will produce requirements counts with high reliability across respondents.
Workshop-Question 1

Is the Requirement at the Sea Level?

adapted from Cockburn (2001). Writing effective use cases
Workshop-Question 2

Can the Requirement be Tested, Designed, or Verified?

![Bar chart showing responses to the question]

- **Requirement #1**: No (8 responses)
- **Requirement #2**: Unsure (2 responses), Yes (2 responses)
- **Requirement #3**: Unsure (2 responses), Yes (3 responses)
- **Requirement #4**: No (3 responses), Unsure (2 responses), Yes (2 responses)
- **Requirement #5**: No (4 responses), Unsure (2 responses)
- **Requirement #6**: Yes (2 responses), Unsure (2 responses), No (1 response)
- **Requirement #7**: Yes (1 response), Unsure (2 responses), No (1 response)
- **Requirement #8**: Yes (2 responses), Unsure (2 responses), No (1 response)
Conclusions #1

Hypothesis: Using the cost estimation decomposition steps will produce requirements counts that are common across users.

Partially supported

Discussion:
- Understanding of “sea level”
- Differences in test and verify
- How to deal with “bad” requirements
Hypothesis #2

Research Question: How can existing COSYSMO decomposition guidelines be modified to improve counting of (HSI) requirements?

Hypothesis #2: The cost estimation decomposition steps will help users quantify the number of HSI requirements to be input into COSYSMO.
Workshop-Question 3

How many requirements does this HSI Requirement decompose to?

- None
- One Requirement
- Many Requirements

# of responses
Conclusions #2

Hypothesis: The cost estimation decomposition steps will help users quantify the number of HSI requirements to be input into COSYSMO.

Partially supported

Discussion:
- HSI requirements could be a major driver of cost.
  Many respondents answered “many requirements”
What is the impact of the HSI requirement compared to a nominal requirement?

**Requirement #2**

<table>
<thead>
<tr>
<th>Effort (x)</th>
<th>Number of Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>5</td>
<td>12</td>
</tr>
<tr>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>9</td>
<td>2</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
</tr>
</tbody>
</table>
What is the impact of the HSI requirement compared to a nominal requirement?

![Diagram showing the impact of Requirement #2 on effort and number of responses.](image-url)
What is the impact of the HSI requirement compared to a nominal requirement?

**Requirement #2**

<table>
<thead>
<tr>
<th>Effort (x)</th>
<th>Number of Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
</tr>
</tbody>
</table>
Conclusion

Next Steps

- Provide more guidance on “sea level”

- Adopt Defense Acquisition Guide definition of “verify”, remove “test”

- Perform additional analysis of impact of nonfunctional/HSI requirements

How can Human Systems Integration effort can be estimated as a function of total Systems Engineering Effort?