Better Early Estimation of Human Systems Integration Effort as a Means of Reducing Life Cycle Cost

2ndLt. Kevin Liu, USMC
MIT Graduate Research Assistant
Research Advisors: R. Valerdi and D. H. Rhodes
Co-Author: Dr. Fran Greene, Air Force HSI Office

24th International Forum on COCOMO and Systems/Software Cost Modeling
November 2-5, 2009 | MIT, Cambridge, MA
What is HSI?
History of HSI

1980’s- Present

Industrial Revolution

Human Factors Societies

WWII

Industrial Engineering
Human Factors Engineering (HFE)

Manpower

Personnel Capabilities

Training
Why Measure SE/HSI Cost?

Aircraft SE/PM as a Percentage of Total Aircraft Development Cost Minus Outlier Development Programs, 1960s–1990s

“Systems Engineering and Program Management Trends and Costs for Aircraft and Guided Weapons Programs” – RAND Corp.
Why Measure SE/HSI Cost?

Use #1: “Are my ballpark estimates of SE/PM and HSI reasonable?”

Use #2: “What is the right amount of SE/PM and HSI for my system?”

Required Inputs

*Existing SE/PM Cost Estimate (rule-of-thumb, analogy, etc.)*
*Existing draft requirements document*
*Existing IPT or expert analysis*
*Calibration data from previous systems*
*Decomposition of requirements*

Useful Outputs

*Identify SE/PM and HSI cost drivers*
*Identify major issues/discrepancies (risk, technology maturity, difficulty)*
*Improved cost estimate compared to existing methods*
*Plan for SE/PM and HSI work*

Application

*Pre-Milestone A*
*Whole life cycle: update as new info created*
Current Estimation Methods: Government

Factors influencing Estimate
- Expert opinion
- Technology Changes
- Aircraft Weight
- # Units
- Material Complexity

“Rule of Thumb”

Estimate of SE/PM as Ratio of Total

Hours, total engineering development

Data from Historical Systems
Current Estimation Methods: Industry

"Rule of Thumb"

<table>
<thead>
<tr>
<th>Actual Design Hours</th>
<th>SE/PM %</th>
</tr>
</thead>
</table>

# People/Task × =
1. Disconnect between Top-Down “Rough Estimate” and SE/PM in WBS

MIL-HDBK-881: “the overall planning, directing, and controlling of the definition, development, and production of a system or program... [It] excludes systems engineering/program management effort that can be associated specifically with the equipment (hardware/software) element.

2. Existing approaches do not help plan SE/PM and HSI
Disconnect Between SE/PM Estimate and Life Cycle Cost


Comparison of System Life Cycle Costs

Surface Combatants Life Cycle Costs (from 2000 NAVSEA TOC)

- Procurement: 34%
- O&M: 55%
- MilPers: 9%
- RDT&E: 2%
Comparison of System Life Cycle Costs

Major Recent UAS

- RDT&E
- O&M
- MilPers
- Procurement

= SE/PM Costs

UAS Performance

Table 3.1 Class A Mishap Rates Per 100,000 Flight Hours

<table>
<thead>
<tr>
<th>UAV Mishaps</th>
<th>Aircraft Mishaps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predator – 32*</td>
<td>F-16 – 3</td>
</tr>
<tr>
<td>Pioneer – 334*</td>
<td>General Aviation – 1</td>
</tr>
<tr>
<td>Hunter – 55°</td>
<td>Regional Commuter – 0.1</td>
</tr>
</tbody>
</table>

* much less than 100,000 flight hours
Large airliners – 0.01
Comparison of System Life Cycle Costs

Cargo Plane

- RDT&E
- O&M
- Procurement
- MilPers

Averaged over 5 years
Total Budget > $20B
“Essentially, all models are wrong, but some are useful”

George E. P. Box, statistician
Existing approaches do not help plan SE/PM and HSI

**NDIA Survey of SE Effectiveness**

![Project Performance vs. Systems Engineering Capability](chart)

**Methodology:**
Surveys assessing awareness/strength in various SE processes

Identified practices and products from CMMI

**MULTI-YEAR EFFORT**

SE/HSI is not the answer alone
Parametric Estimation of SE: COSYSMO

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
Inputs Needed to Implement COSYSMO

Effort Multipliers

Requirements understanding
Architecture understanding
Level of service requirements
Migration complexity
Technology risk
Documentation to match life cycle
Tool support

# and Diversity of installations/platforms
# of Recursive levels in the design
Stakeholder team cohesion
Personnel/team capability
Personnel experience/continuity
Process capability
Multisite coordination needs

Data source: input from high-level IPT.
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.
Application of COSYSMO to HSI
Notional Example

Human factors. Human factors engineering principles such as specified in MIL-STD-1472 shall be employed in each XXX system solution (Threshold = Objective).

Shall’s + Will’s + Must’s

Human Interfaces

H

S

I

} <-“hard”

} <-“nominal”

} <-“easy”

“hard”

“nominal”

“easy”
Application of COSYSMO to HSI
Notional Example

Shall’s + Will’s + Must’s

238 Person-Months
Application of COSYSMO to HSI
Notional Example

HSI

SYSTEMS ENGINEERING PERSON MONTHS: 156 Person-Months
Addressing Downsides of Current Estimation Methods

Disconnect between Top-Down “Rough Estimate” and SE/PM in WBS

COSYSMO defines SE cost/size drivers
Allows analysis at different level-of-interest or HSI Domains
More work needed to incorporate O&S into early planning

Existing approaches do not help plan SE/PM and HSI

Decomposition of Requirements, interfaces
IPT involvement in assigning complexity, cost drivers
Early SE/HSI analysis (AoA) copy-pasted into SEP/HSIP
HSI Already Integrated Into Systems Engineering

F119 Engine
On time
Within Cost
Superior Performance

Recently Developed Resources Useful for Implementation of COSYSMO for HSI
The views expressed in this presentation are those of the authors and do not reflect the official policy or position of the United States Air Force, Marine Corps, Department of Defense, or the U.S. Government.
Back-Up Slides
Application of COSYSMO to HSI Application to HSI Domains

How complex are the safety requirements?

What tools are available for survivability analyses?

How verifiable are the environmental requirements?

How do these factors affect level of effort?

HSI-related requirements found in Government-furnished requirements documents.

Adapted from “Airman Performance Integration Capability Document Analysis”, 311th Human Systems Wing, September 2007
Determine System of Interest
Determine System of Interest

Can Requirements be: Tested? Verified? Designed?

Yes

Re-define requirement

No
1. Determine System of Interest

2. Can Requirements be:
   - Tested?
   - Verified?
   - Designed?

   Yes
   - Re-define requirement

   No
   - Omit/Guess (bad)
     - Decompose
     - Assign High Uncertainty

requirements

Re-define requirement
1. Determine System of Interest

2. Can Requirements be:
   - Tested?
   - Verified?
   - Designed?
   - No

3. Sketch System of Interest’s Relationship to Rest of System
Determine System of Interest

Can Requirements be:
- Tested? Yes/No
- Verified? Yes/No
- Designed? Yes/No

Sketch System of Interest’s Relationship to Rest of System

Count Only Requirements at the Level of the System of Interest

Shall’s Will’s Must’s
Determine System of Interest

Can Requirements be:
- Tested?
- Verified?
- Designed?

Yes

No

Sketch System of Interest’s Relationship to Rest of System

Count Only Requirements at the Level of the System of Interest

Assess Complexity

Shall’s

Will’s

Must’s