# The Cost Risk/Uncertainty Exposure Determination (CRED) Model A New Approach

Cheryl Jones
Brad Clark

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# Problem Statements

1. Risk and Uncertainty on programs are not well understood. They are tied to lack of information on programs
   - There is little actual performance information and validated data

2. The increasing demands on the cost estimation community have placed stress on organizations that lack experienced estimators or have too few resources to meet mission estimation needs

- As a result, the industry needs tools and processes that *support* identification of risk and uncertainties in a cost estimate

# Background

- The mission at the DASA-CE Software Sustainment Initiative is to
  - Provide software sustainment data collection and analysis services
  - Derive Cost Estimating Relationships from sustainment data and provide them to Army Cost Estimators
  - Promote the identification of risks and uncertainties in a cost estimate
  - Investigate new development approaches (e.g., Agile, DevSecOps) and propose new cost estimating methodologies

- In support of this mission, new processes have been devised and deployed to train and assist the Army in meeting the growing needs for Life Cycle Cost Estimation support services.

# Results with Respect to Risk/Uncertainty

- An easy-to-use model for new cost estimators called the Cost Risk/Uncertainty Exposure Determination (CRED) model*
- The model assists with cost risk/uncertainty identification
- The model addresses:
  - Identifying, characterizing, and accounting for different cost performance factors
  - Making visible the “knowledge gap” between “what should be known” and “what is known”
  - Fully documents key program issues and assumptions in an estimate
- It is a useful method for a cost estimate
- It is adaptable to different industries and domains

* This work was done in collaboration with Dr. Robert Charette, ITABHI Corp

# Model Definitions of Note

- What is risk?
  - A risk is a potential future event or condition that may have a negative effect on cost, schedule, and/or performance [OSD 2020]
  - Risk is an event not in the project's baseline that is an undesirable outcome [NASA 2017]
- What is uncertainty?
  - Uncertainty is the indefiniteness of the outcome of a situation [OSD 2020]
  - Uncertainty is the indefiniteness about a project's baseline [NASA 2017]
- What is Material Information?
  - Information is *"material"* if omitting, misstating or obscuring it could reasonably be expected to influence financial decisions [IFRS 2018]
- What is Exposure?
  - Exposure is a quantification of the gap between "what should be known" and "what is actually known"

# CRED Material Information Categories

- A checklist based on the Tri-Service Assessment Systemic Analysis [McGarry 2003] and documented historical experience gained from developing a software sustainment database can be used to review potentially missed or omitted material information
- There are four material information categories in the Sustainment CRED model:
  1. Cost Environment, i.e., the WBS (8)
  2. Internal Software (5)
  3. Program & Project Management (6)
  4. External Program Environment (3)
- Each category has multiple attributes
- The CRED model approach to assessing material information uncertainty/risks is to ask two simple questions:
  1. What *"should"* I know?
  2. What *"do"* I know?
- The CRED model for sustainment is adaptable – you can use your own relevant material information categories

# Hypothetical Case Study – Chirmera Helicopter

- To explain and illustrate the use of the CRED model, a fictitious case study is presented
- The Chimera Helicopter is an ACAT I Aviation program. The helicopter and associated flight avionics are in the Operations and Sustainment (O&S) phase
- The software is in the Real Time domain
- Given its size and potential cost, an Independent Sustainment Cost Estimate is needed for the next release
- The engineering opinion is that software changes are driving the cost of sustainment. The Program Office has provided the anticipated number of software changes for the next major release
- Estimators will use the CRED model as an adjunct to their normal estimation process to better highlight the risk and uncertainty in the estimate

# 1. Software Sustainment Cost Environment

- The attributes for this category are the in-scope Sustainment WBS elements
- Rate each attribute:
  - The number of software changes is known (rate Do-Know as 10); individual exposure is 0
  - The number and cost of software licenses is not known but there is data on license cost from analogous helicopter programs (rate Do-Know as 5); exposure is 5
  - The cost for C&As is known but there are expected to be a few more additional certifications with unknown cost (rate Do-Know as 8); exposure is 2
  - The remaining attributes are out of scope for this estimate
  - Missing WBS 2.0 System Project & Technical Management is assessed as its own information category

Rating Table

| Operations and Sustainment | 1.0 Software Change Product | 3.0 Software Licenses | 4.0 C&A | 5.0 System Facilities | 6.0 Sustaining Engineering | 7.0 Field Software Engineering | 8. Other Costs | Sum |
|---|---|---|---|---|---|---|---|---|
| What Should We Know? | 10 | 10 | 10 | | | | | 30 |
| What Do We Know? | 10 | 5 | 8 | | | | | |
| Individual Exposure | 0 | 5 | 2 | | | | | 7 |
| Category Exposure | 7 / 30 = 0.23 (Sum of "Individual Exposure" / Sum of "What should we know") | | | | | | | |

- Each attribute in every material information category is explained in the paper that accompanies this presentation

Assessment range: 10 means Full Understanding of the Attribute; 5 means Partial Understanding; 0 means Major Uncertainty

# 2. Software Internal Attributes

- The number and ownership of avionics software interfaces are known (rate Do-Know as 10); individual exposure is zero (0)
- The software is generally considered real time but there is uncertainty in the proposed enhancements (rate Do-Know as 8); exposure is 2
- COTS products are used in the software, but it is unclear how much of the system's performance relies on them (rate Do-Know as 5); exposure is 5
- The enhancements rely on new critical technology, but the readiness of this technology has not been determined (rate Do-Know as 0); exposure is 10
- There are presently no data rights issues, however, the Program Office desires to transition the maintenance of the avionics software to the Aviation Life Cycle Management Center (rate Do-Know as 0); exposure is 10

Rating Table

| Operations and Sustainment | External Interfaces | Execution Timing Constraints | COTS Product Incorporation | Critical Technology | Data Rights | Sum |
|---|---|---|---|---|---|---|
| What Should We Know? | 10 | 10 | 10 | 10 | 10 | 50 |
| What Do We Know? | 10 | 8 | 5 | 0 | 0 | |
| Individual Exposure | 0 | 2 | 5 | 10 | 10 | 27 |
| Category Exposure | 27 / 50 = 0.54 | | | | | |

Assessment range: 10 means Full Understanding of the Attribute; 5 means Partial Understanding; 0 means Major Uncertainty

# 3. Program/Project Management Factors

- The project management team has five years of experience in managing this program although there are some shortfalls in knowing about the cost of COTS products, the degree of critical technology readiness, and data rights (rate Do-Know as 8); individual exposure is 2
- The technical personnel are the same as those that developed the Chimera avionics (rate Do-Know as 10); exposure is zero (0)
- The technical processes use by the contractor are unknown possibly causing quality and delivery acceptance issues (rate Do-Know as 0); exposure is 10

Rating Table

| Operations and Sustainment | Management Personal Capability | Technical Personal Capability | Technical Process Capability | Facilities & Infrastructure Support | Sustainment / Funding Rhythm | Project & Program Management | Sum |
|---|---|---|---|---|---|---|---|
| What Should We Know? | 10 | 10 | 10 | | | | 30 |
| What Do We Know? | 8 | 10 | 0 | | | | |
| Individual Exposure | 2 | 0 | 10 | | | | 12 |
| Category Exposure | 12 / 30 = 0.4 | | | | | | |

Assessment range: 10 means Full Understanding of the Attribute; 5 means Partial Understanding; 0 means Major Uncertainty

# 4. External Program Environment Factors

- Besides the Army, the Marine Corps are a participating stakeholder. They have worked well with the management team, and they provide maintenance funding (rate Do-Know as 10); individual exposure is zero (0)
- The mandated policies and guidelines have not changed and are fully funded (rate Do-Know as 10); exposure is zero (0)
- While the funding stream for both services look secure, there has been changes in funding priorities in the past (rate Do-Know as 2); exposure is 8

Rating Table

| Operations and Sustainment | External Stakeholders | Mandates | Policy-driven Sustainment / Funding Rhythm | Sum |
|---|---|---|---|---|
| What Should We Know? | 10 | 10 | 10 | 30 |
| What Do We Know? | 10 | 10 | 2 | |
| Individual Exposure | 0 | 0 | 8 | 8 |
| Category Exposure | 8 / 30 = 0.26 | | | |

Assessment range: 10 means Full Understanding of the Attribute; 5 means Partial Understanding; 0 means Major Uncertainty

# Assessing "Do Know" – "Should Know" Knowledge Gap

- Total material information category exposure
  - Sum the "should-we-know" values across all categories
  - Sum the "individual exposure" values across all categories
  - Divide the individual sums by the should-know sums
  - The resulting value should be between 0.0 and 1.0

$$Total\ Exposure = \frac{\sum All\ Individual\ Exposures\ \ sums}{\sum All\ Should - We - Know\ sums} = \frac{54}{140} = 0.39$$

- Total exposure assessment guidelines:
  - If the percentage is between 0 – 0.2, it is satisfactory
  - If the percentage is between 0.2 – 0.5, collect more information or increase the estimate uncertainty range
  - If the percentage is above 0.5, collect more information or significantly increase the estimate uncertainty range
- For the case study:
  - Critical Technology, Data Rights, and Technical Process Capability had high individual exposures (10) indicating the need for more information

# CRED Limitations

- Has been applied experimentally on several test cases
  - Research still needs to be conducted to recommend a cost estimate uncertainty range, e.g., increase the estimate by 25%
- Weighting of material information attributes (0 to 10) may need to be tailored.
  - Each attribute is currently weighted equally but in reality may be different
- It is possible that material information attributes may not cover all the unknowns
  - Specific program vulnerabilities may not be represented as an attribute
- If attributes interact in specific situations, there is a possibility of double counting or discounting
  - Ex: Lack of material information in the Cost Environment could interact with the assessment of Management Capability

# Conclusions

- The CRED model makes visible the "knowledge gap" (if any) between "what should be known" and "what is known" about the system under estimation – *the specific number isn't important as much as understanding that a gap exists and whether it affects the credibility of the cost estimate*
- By using the assessment tables, the CRED model provides documentation on what is known and unknown
  - The model, as its name implies, highlights how much credibility and trust a given cost estimate should be given
  - A cost estimate where large knowledge gaps exist should be treated with extreme caution
- The CRED model is highly adaptable to other domains
  - There is the ability to create material information categories and add/remove attributes
  - Any domain where knowledge uncertainty exists is a candidate for use
  - Categories and attributes could be created as the result of
    - Conducting retrospectives on past projects
    - Lessons learned from prior cost estimates that have underperformed
    - Brainstorming session with experienced cost estimators

# Next Steps

- Research still needs to be conducted to recommend a cost estimate uncertainty range based on total exposure
- Total Exposure

$$Total\ Exposure = \frac{\sum Individual\ Exposures\ \ sums}{\sum Should - We - Know\ sums}$$

  - Low: If the percentage is between 0 – 0.2
  - Medium: If the percentage is between 0.2 – 0.5
  - High: If the percentage is above 0.5

Early Lifecycle Estimation Uncertainty Ranges

| Total Exposure | Best Case | Most Likely | Worst Case |
|---|---|---|---|
| Low | 1.00 | 1.25 | 1.50 |
| Medium | 1.00 | 1.50 | 1.90 |
| High | 1.00 | 1.75 | 2.50 |

Late Lifecycle Estimation Uncertainty Ranges

| Total Exposure | Best Case | Most Likely | Worst Case |
|---|---|---|---|
| Low | 0.95 | 1.05 | 1.10 |
| Medium | 1.00 | 1.10 | 1.15 |
| High | 1.00 | 1.15 | 1.25 |

- We need DATA!
  - Once enough programs have been completed using CRED with the estimate, what was the:
    - Total Exposure score
    - Estimation accuracy
  - With this data, we can determine values for the tables above
- Please contact Cheryl Jones if you are interested in participating cheryl.l.jones128.civ@army.mil

# References


- Boehm 1981 Barry Boehm, “Software Engineering Economics,” Prentice-Hall, Englewood Cliffs, NJ, 1981.
- Fox 2011 J. Ronald Fox, “Defense Acquisition Reform 1960-2009: An Elusive Goal,” Center of Military History, United States Army, CHM Pub 51-3-1, 2011.
- Garvey 2000 Paul Garvey, “Probability Methods for Cost Uncertainty Analysis,” Marcel Dekker, Inc., New York, 2000.
- IFRS 2018 International Financial Reporting Standards, “Definition of Material,” https://www.ifrs.org/content/dam/ifrs/project/definition-of-materiality/definition-of-material-feedback-statement.pdf, October 2018.
- Kendall 2013 Frank Kendall, “Use of Fixed-Price Incentive Firm (FPIF) Contracts in Development and Production,” Defense AT&L a publication of the Defense Acquisition University, March-April, 2013. https://www.dau.edu/sites/default/files/Migrate/DATLFiles/Mar-Apr2013/DATL_mar-apr2013.pdf
- McGarry 2002 John McGarry, “System Analysis of Software Intensive System Acquisition Issues,” Software Technology Conference, April 29, 2003.
- NASA 2017 “NASA Cost Estimating Handbook,” Version 4.0, 2017
- OSD 2020 “DOD COST ESTIMATING GUIDE,” OSD Cost Assessment and Program Evaluation, Version 1.0, December 2020
- Smart 2020 Christian Smart, “Solving for Project Risk Management: Understanding the Critical Role of Uncertainty in Project Management,” McGraw Hill, 1st Ed., October 2020.

# Contributors

**Cheryl Jones**
US Army Futures Command
973-724-2644

**Dr. Robert Charette**
ITABHI Corp

**Dr. Bradford Clark**
Galorath Federal

**Paul Janusz**
US Army Futures Command

**Sariyu Marfo**
ODASA-CE

**James Judy**
NISEC Division Chief
ODASA-CE