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

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Objectives

- The objective of this model is to improve the credibility of and trust in a software sustainment project cost estimate by:

1. Identifying, characterizing, and accounting for different cost performance factors that may be sources of risk/uncertainty that can result in creating material impacts on a software sustainment and maintenance cost estimate.

2. This approach makes visible the "knowledge gap" (if any) between "what should be known" and "what is known" about the system under assessment - this "gap" is an input used to aid in the assessment of the degree of uncertainty associated with the estimate.

3. It also fully documents the key program issues, assumptions and related performance factors that may influence the cost estimate and why.

Topics

- Background
- Definitions
- Assessing Risk/Uncertainty with CRED
  1. Cost environment
  2. Internal software
  3. Program and project management
  4. External program environment
- Assessing the Knowledge Gap
- CRED Application Example
- Limitations
- Conclusions
- Next Steps

Background

- The Cost Risk/Uncertainty Exposure Determination (CRED) model* attempts to account for risks/uncertainties that may be overlooked or understated
- The CRED model documents the key program issues and related performance factors derived from analysis of scores of DoD program risk assessments that may influence the quality of a cost estimate
- "The project manager often views risks as mere expected challenges
  - The tendency is to not highlight risks
  - There is fear that highlighting risks may make their project more costly, and possibly increase the likelihood of its postponement or cancellation." [Fox 2011]

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

Definitions

- 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"

Assessing Risk & Uncertainty

- The CRED model approach to assessing material information uncertainty/risks is to ask two questions:
  1. What "*should*" I know?
  2. What "*do*" I know?
- 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*"
  1. Cost Environment
  2. Internal Software
  3. Program & Project Management
  4. External Program Environment
- The model was developed to find the risks & uncertainties in Operations & Sustainment (O&S) software cost estimates
  - It can be modified for other lifecycle estimates and to other domains

1. Cost Environment Attributes

What's your confidence that the program/project in O&S has addressed the issues in the SWS WBS?

WBS Element	What Should I know	What Do I know
1.0 Software Change Product	Size (e.g., SCs), Service Count, ACAT Level, etc.	
2.0 System Project & Technical Management	Assessed in the Program/Project Management material information category	
3.0 Software Licenses	# and cost of each COTS product for use in Development and Operations (even if the Program does not pay for it)	
4.0 Certification and Accreditation	Number, cost, and timing of required C&As	
5.0 System Facilities	Required equipment and labs with associated costs (for Dev., Int., & Test)	
6.0 Sustaining Engineering	Cost of Help Desk, Hosting, anticipated Engineering and User Support	
7.0 Field Software Engineering	Cost of on-site installation, technical and training assistance (travel & labor)	
8.0 Support Infrastructure	Cost of Organizational Management, e.g., organizational tax	

1. Cost Environment Attributes Table

- The assessment of the Cost Environment uses a table based on "What Should We Know" versus "What Do We Know" as shown in the table below
- Full understanding of the attribute is assigned a value of 10 in the "What Should We Know" row
- In the "What Do We Know" row, a subjective assessment is made by the cost estimator on what is known about that attribute. A rating of 10 means full understanding, a rating of 5 means a partial understanding, and a rating of zero (0) means major uncertainty
- The difference between what should be known and what is known is the Individual Exposure value for each attribute

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
What Should We Know?	10	10	10	10	10	10	10
What Do We Know?							
Individual Exposure							

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

2. Software Internal Attributes

- Number Of External Interfaces and Ownership
  - What are the number of interfaces to other systems?
  - Who owns the interfaces?
  - What is the percentage of system data received and or passed to other systems?
- Execution Timing Constraints
  - What percentage of key system performance parameters are dependent on real-time execution?
  - What percentage of key system performance parameters depend on non-stop processing?
- COTS Product Incorporation
  - What percentage of key system performance parameters is met by COTS software?
  - What percentage of the system functionality depends on COTS software?
- Critical Technology
  - What is the software system technology readiness level of the software required to meet key system performance parameters?
  - What percentage of software system components in use are approaching obsolescence?
  - What is the complexity resulting from security or legal mandates?
- Data Rights
  - What rights, including copyright and other intellectual property, does the government have to the technical data and computer software delivered as part of the contract?
  - What is the extent of the various Government license rights (e.g., unlimited, restricted, or none)?
  - Does non-access to data rights affect the long-term cost of sustainment or sustainment?

2. Software Internal Attributes Table

- Each attribute is rated between 0 (major uncertainty), 5 (partial understanding) and 10 (full understanding of the attribute) in the "What Do We Know" row
- The difference between what should be known and what is known is the individual exposure
- For exposures greater than zero (0), a rationale should be recorded for what additional information is needed
  - The table and associated rationales become documentation for recording the risk/uncertainty in the Software Internal material information category

Rating Table

Operations and Sustainment	Number Of External Interfaces	Execution Timing Constraints	COTS Product Incorporation	Critical Technology	Data Rights
What Should We Know?	10	10	10	10	10
What Do We Know?	0	0	0	0	0
Individual Exposure	10	10	10	10	10

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

3. Program/Project Management Attributes

- Management Personnel Capability (WBS 2.0 Project Management)
  - What percent of management is moderately to highly-experienced in software sustainment?
  - What percent of management has worked on this type of system before?
- Technical Personnel Capability
  - What percent of the personnel is moderately to highly-experienced in software sustainment?
  - What percent of the personnel is moderately to highly-experienced with this type of system?
- Technical Processes Capability
  - What percent of the sustainment processes are useful/effective?
  - What percent of software trouble reports are traceable to process shortfalls?
- Facilities & Infrastructure Support
  - What percent of the support tools are considered useful?
  - What percent of needed planned capital equipment (e.g., for SILs, simulators, and emulators) is available?
- Sustainment/Funding Rhythm
  - What percent of the sustainment work is discretionary as opposed to legally mandated?
  - What percent of funding has been changed in the past fiscal year?
  - What percent of current sustainment work is attributed to backlog?
  - What percent of current sustainment work is attributed to technical debt?
- Project & Program Management
  - How experienced is the project/program management?
  - Is the project/program management team stable or changing?

3. Program/Project Management Attributes Table

Rating Table

Operations and Sustainment	Management Personal Capability	Technical Personal Capability	Technical Process Capability	Facilities & Infrastructure Support	Sustainment / Funding Rhythm	Project & Program Management
What Should We Know?	10	10	10	10	10	10
What Do We Know?						
Individual Exposure						

4. External Program Environment Attributes Table

Rating Table

Operations and Sustainment	External Stakeholders	Mandates	Policy-driven Sustainment / Funding Rhythm
What Should We Know?	10	10	10
What Do We Know?	0	0	0
Individual Exposure	10	10	10

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

4. External Program Environment Attributes

- External Stakeholders
  - How many external stakeholders are there?
  - Do external stakeholders provide funding, set requirements, or both? (Number of funding streams)
  - Is there agreement or conflict among different stakeholders as to the system's mission priorities?
- Mandated Requirements
  - How stable are mandated policies and guidelines and do they conflict?
  - Are mandated policies, like security, fully funded? (e.g., Organizational funding)
- Policy-driven Sustainment/Funding Rhythm
  - How long does the project/program funding stream look secure?
  - Are there planned and funded system upgrades?

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

- Individual material information category exposure
  - Sum the row of should-we-know values
  - Sum the row of individual exposure values
  - Divide the individual value sum by the should-know value sum
  - The resulting value should be between 0.0 and 1.0

$$Category\ Exposure = \frac{\sum_{i=1}^{n} Individual\ Exposure\ \ values}{\sum_{j=1}^{n} Should - We - Know\ values}$$

- This value provides an assessment of the attributes that may increase or decrease the overall risk/uncertainty for that material information category
- A low value would indicate a decrease in risk/uncertainty and a high value would indicate major risk/uncertainty
- Explicitly list any attribute with a high Individual Exposure

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

$$Total\ Exposure = \frac{\sum_{i=1}^{n} Individual\ Exposure\ sums}{\sum_{j=1}^{n} Should - We - Know\ sums}$$

- Total exposure assessment
  - 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 the estimate uncertainty range
- The amount of added cost uncertainty range will be based estimator experience

CRED Model Application Example

- To illustrate the use of the CRED model, a fictitious case study is presented
- The Chimera Helicopter is an ACAT I Aviation program. The program and associated flight avionics are in the Operations and Sustainment (O&S) phase
- The software is in the Real Time domain
- 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
- Given its size and potential cost, a sustainment cost estimate is needed for the next 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 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 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 (rate Do-Know as 8); exposure is 2
- The remaining attributes are out of scope for this estimate

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")							

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

2. Software Internal Attributes

- The number 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 information 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	Number Of 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 Corp 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

Total Exposure

- 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

$$Total\ Exposure = \frac{7}{30} + \frac{27}{50} + \frac{12}{30} + \frac{8}{30} = \frac{54}{140} = 0.39$$

- Total exposure assessment
  - If the percentage is between 0.2 – 0.5, collect more information or increase the estimate uncertainty range
  - 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
  - Lack of material information in the Cost Environment could interact 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
- 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
- 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

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

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