Cost-Risk Connections Between CCRM & CRM

Presentation to
NASA COST ANALYSIS SYMPOSIUM
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David R. Graham
OCFO/Cost Analysis Division
HQs NASA

Purpose

- Describe and illustrate how CRM and CCRM are complementary
- Describe to cost community how CRM procedures and resource specialists can assist CCRM in determining cost-risk
- Describe to risk management community how CCRM cost-risk quantification can assist in assessing risk mitigation costs

Focus of Briefing

- How CCRM's cost-risk quantification can augment CRM's risk mitigation costing
- Not going to focus on:
  - Early cost/performance trades (e.g., CAIV) even though both CRM and CCRM emphasize early assessment of risk in early Analysis of Alternatives trades
    - Is really a sub-set of general cost-risk quantification
  - Nor on cost-risk data collection/cost-risk database
- Will concentrate on risk identification, prioritization, assessment, quantification and management commonalities between CRM and CCRM

Continuous Cost-Risk Management

A ***System of Cost Systems*** linked together in sequence by the same risks

Incorporated in NPR 7120.5C

Preparation

Cost-Risk Feedback: Steps 1-5

Development

Cost-Risk Feedback: Steps 6-8

Application

Cost-Risk Feedback: Steps 9-12

Continuous Cost-Risk Management (CCRM)

- A cost management architecture providing:
  1. ***Identification*** of medium and high risk WBS elements, their assessment & translation of risk into cost-risk in LCCEs
     - Supports adequate budget for project
  2. ***Communication*** of identified medium and high risk WBS elements to project managers (contractor or NASA)
  3. ***Post-cost estimate tracking*** of medium and high risk WBS element cost and schedule performance Application of EVM system
     - Produces early warning of potential cost and schedule problems
     - Enables actionable intelligence for timely mitigation/management
  4. ***Updates*** of technical and cost data (including annual LCCEs)
  5. ***History*** of cost and technical data for use in updating cost models

Continuous Risk Management

CRM Definition (7120.5C)

- **Continuous Risk Management (CRM).** The process that *identifies* risk; *analyzes* their impact and prioritizes them; develops and carries out plans for risk mitigation or acceptance; *tracks* risk and the implementation of plans; supports informed, timely, and effective decisions to control risks and mitigation plans; and assures that risk information is *communicated* and *documented*.

Cost-Risk Identification & Assessment

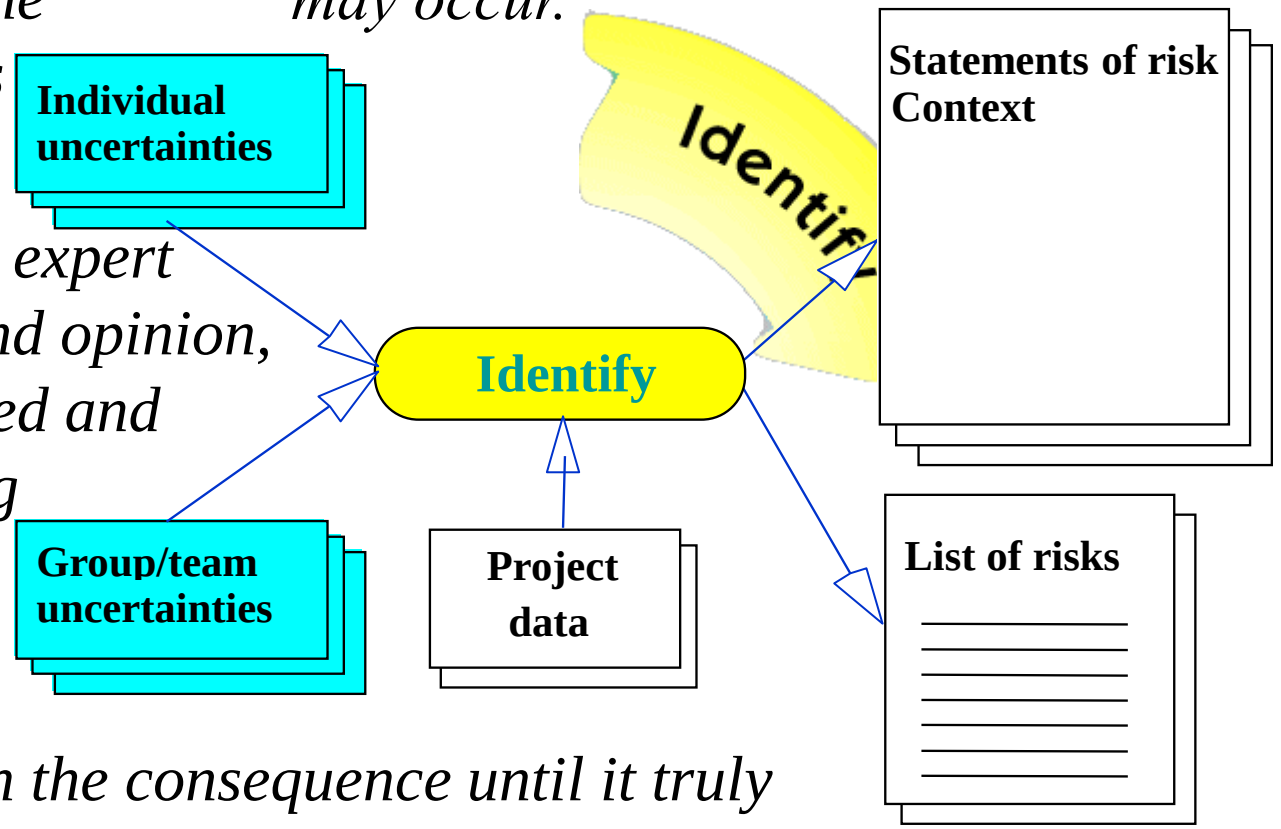
Risk Management

CRM

CRM Risk Identification

1. Search for and locate risks before they become problems

2. State risks as, "If 'event' happens due to 'cause', then 'undesirable consequence' may occur."



4. Draw from expert facilitation and opinion, lessons learned and brainstorming

3. Question the consequence until it truly affects the most important requirements

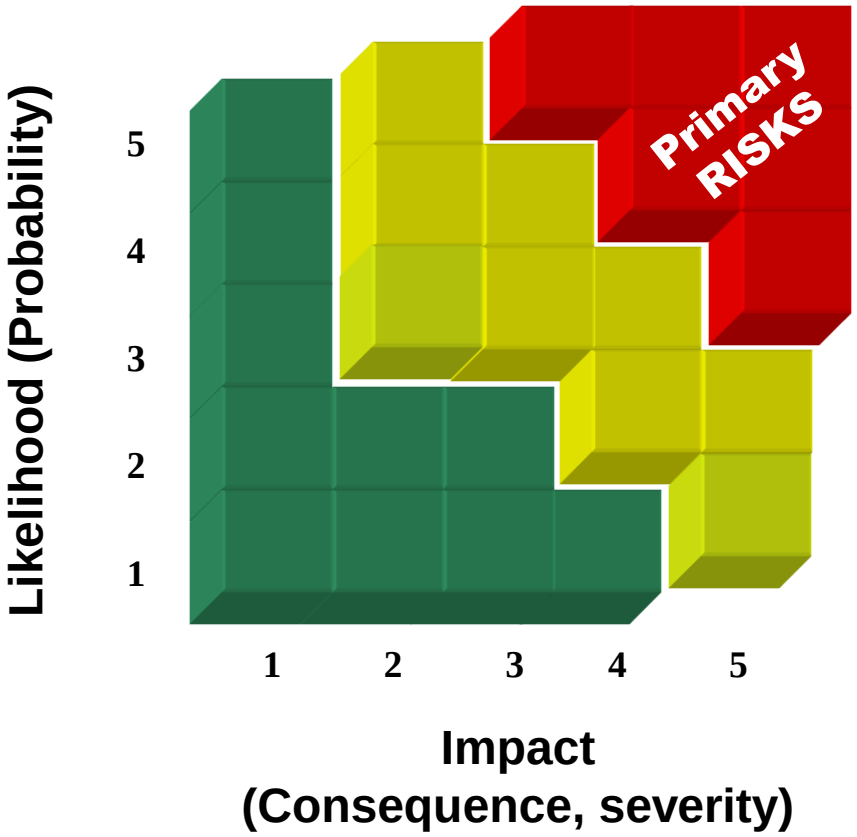
Analyze

Convert risk data into useable information for determining priorities and making decisions

Likelihood of Occurrence

Adjective Rating	Numerical Equivalent	Description
Very High Likelihood	5	Occurrence is almost certain, and may not be controlled by following existing processes, procedures, and plans.
High Likelihood	4	Occurrence is very likely, and may not be entirely controlled by following existing processes, procedures, and plans.
Moderate Likelihood	3	Occurrence is possible, and may not be entirely controlled by following existing processes, procedures, and plans.
Low Likelihood	2	Occurrence is unlikely, and may not be entirely controlled by following existing processes, procedures, and plans.
Very Low Likelihood	1	Occurrence is very unlikely, and is generally controlled by following existing processes, procedures, and plans.

Categorizing Risks



Examine each risk to isolate the cause and determine the likelihood and consequence

Cost-Risk Identification & Assessment

Risk Management

CCRM

CCRM STEP 2: IDENTIFY THE RISKS
ALLOCATING FUNCTIONS TO WBS ELEMENTS

FUNCTION-TO-WBS ELEMENT MATRIX

WBS ELEMENTS	FUNCTIONS	Solar Array	Pointing & Control	Transmitter/Receive	Power Mgmt & Dist	
Transmit Payload						
- Solar Power Collector		X	X		X	Medium Risk
- Solar Power Converter		X	X		X	High Risk
- Pointing & Control System		X	X	X	X	High Risk
- Laser Amplifier/Transmitter			X	X	X	High Risk
- Laser Transmit Antenna		X	X	X	X	Medium Risk
Receive Payload			X			
- Microwave Receive Antenna			X	X	X	Medium Risk
- Laser Receive Antenna		X	X	X	X	High Risk
- Tracking & Control system			X	X	X	High Risk
- Laser Conditioning Receiver			X	X	X	High Risk
- Laser Rectifier/Converter			X	X	X	High Risk
- Flywheel Storage System			X	X	X	Medium Risk

Cost-Risk Assessment in CCRM

- Assessment areas
  1. ***Cost model uncertainty***
     - Cost estimators handle this
  2. ***Input parameter uncertainty***
     - Engineering and CRM assessment needed
  3. ***Indigenous/Programmatic uncertainty***
     - Engineering and CRM assessment needed for application of Relative Risk Weighting (RRW)
     - 3 WBS element risk profiles (pessimistic, optimistic & reference) in terms of their Key Engineering Performance Parameters (KEPPs)
  4. ***Correlation uncertainty***
     - Engineering/CRM/cost estimator assessment needed

KEPPs as Discrete Risks

- A KEPP is a technical or operational parameter that can be described as a requirement
- An advantage to defining any risk profile in terms of KEPPs is that a more discrete picture of a WBS risk emerges
  - e.g., *The radiation resistance for a power subsystem's ASIC has never been designed for this level of tolerance so there's likely to be engineering challenges*
- This discrete picture is more intuitively attractive to a project manager than vague statistical notions of risk
- *These profiles document the statistical representations of the risks behind the "S"-curve*

Key Engineering Performance Parameters[1] (KEPP) Examples

- KEPPs for new electronic component for a S/C
  - Dynamic load resistance
  - Operating voltage
  - Power regulation
  - Radiation resistance
  - Emissivity
  - Component mass
  - Operating temperature range
  - Operating efficiency
- KEPPs for a Laser/Amplifier Transmitter
  - Wave front sensing
  - Wave generation
  - Mirror coatings and gratings
  - Autonomous resonator alignment
  - Bore sighting
  - Electrical power generation

[1]The Technology Puzzle: Quantitative Methods for Developing Advanced Aerospace Technology; Liam Sarsfield (RAND)

CORRELATION

- What is Correlation?[2]
  - A measure of association between two variables
  - It measures how strongly the variables are related, or change, with each other
- Engineers and CRM specialists can assist cost estimators in identifying and quantifying correlation between WBS elements

[2] www.statlets.com/usermanual/glossary.htm

Cost-Risk Quantification

CRM

CRM Cost-Risk Quantification

- Limited to grassroots/bottoms-up valuation of specific, discrete risk mitigation costs
- Advantage is that defining discrete risks and identifying probabilities for their occurrence is intuitively attractive to the project manager
  - Can understand in more concrete terms what she will be getting for her risk dollars
  - What her risk dollars are being spent on
  - Similar to risk profiles in RRW

Cost-Risk Quantification

Risk Management

CCRM

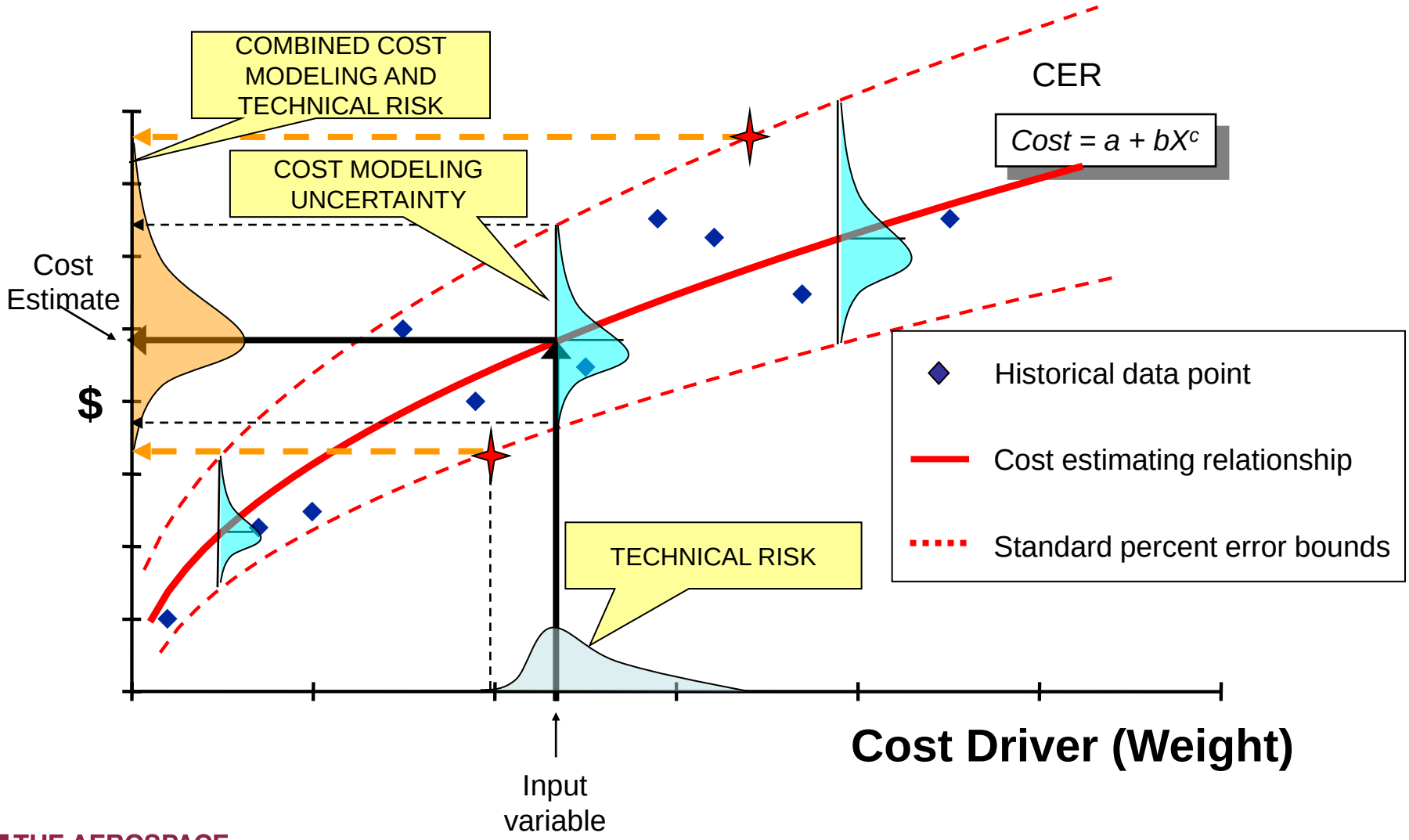
Continuous Cost-Risk Management

A ***System of Cost Systems*** linked together in sequence by the same risks

Risk Management

Cost Model and Input Parameter Uncertainty Cost Quantification

Risk Management



Indigenous/Programmatic Uncertainty Quantification Using RRW

Risk Management

For Indigenous/Programmatic Risk

Risk Rating Matrix

WBS ELEMENT PROFILES	TECHNLGY	DES/ENG	COMPLEXITY	SCHEDULE	TOTAL
	0.35	0.25	0.2	0.2	1.0
1. PESSIMISTIC PROFILE	HIGH	VERY HIGH	VERY HIGH	HIGH	5.9
2. REFERENCE PROFILE	MOD	MOD	MOD	MOD	2.9
3. OPTIMISTIC PROFILE	LOW	MOD LOW	MOD	MOD	2.0

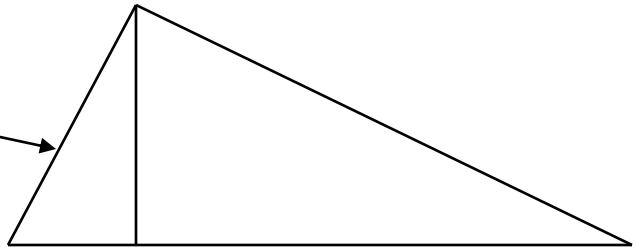
Cost-risk categories (could be more)

$$\frac{\text{PESSIMISTIC "SCORE"}}{\text{REFERENCE "SCORE"}} = \frac{5.9}{2.9} = 2.0 = \text{LOW END RISK FACTOR FOR } \mathbf{S/C}$$

$$\frac{\text{OPTIMISTIC "SCORE"}}{\text{REFERENCE "SCORE"}} = \frac{2.0}{2.9} = 0.7 = \text{HIGH END RISK FACTOR FOR } \mathbf{S/C}$$

THESE FACTORS ARE THEN APPLIED TO THE RPE TO OBTAIN THE "LOW AND HIGH END" COSTS

Translation To Cost



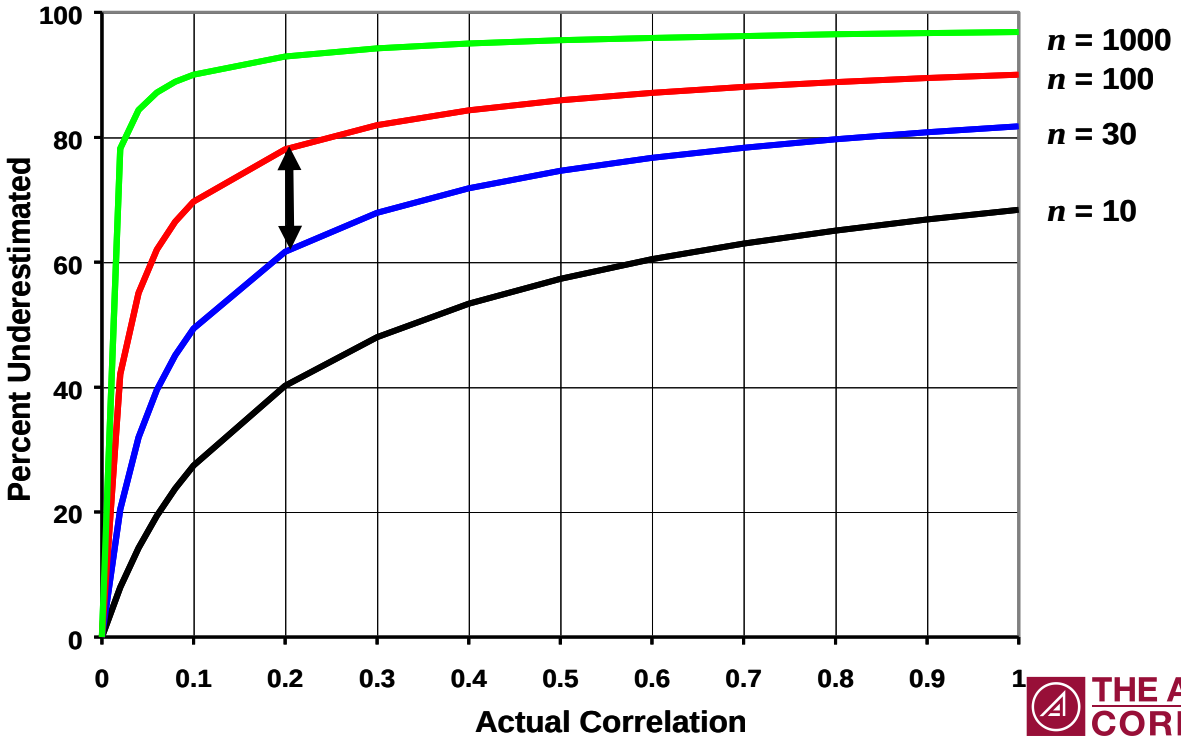
0.7 * RPE RPE 2.0 * RPE

("LOW END" COST) ("HIGH END" COST)

Correlation

- Dr. Stephen Book (MCR) plotted the theoretical underestimation of percent total cost standard deviation (y-axis) when correlation (x-axis) is assumed to be zero rather than its true value, ρ.
  - In cost estimates we would underestimate % SD ~60%-80% @ 0.2 actual correlation

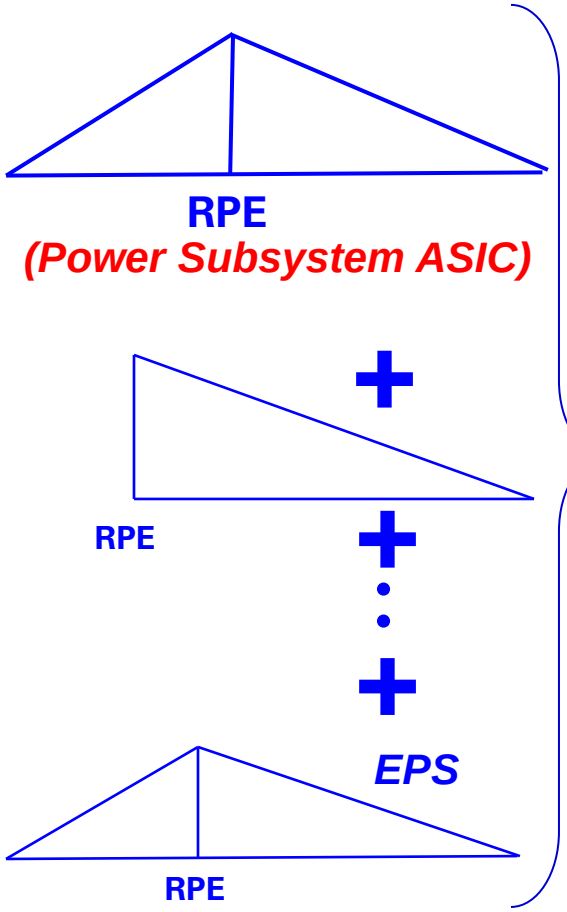
% Underestimated Theoretical Total Cost Standard Deviation



From: 1999 Cost Risk Analysis Seminar, Manhattan Beach, CA

CONVOLVE ALL COST-RISK DISTRIBUTIONS IN MONTE CARLO

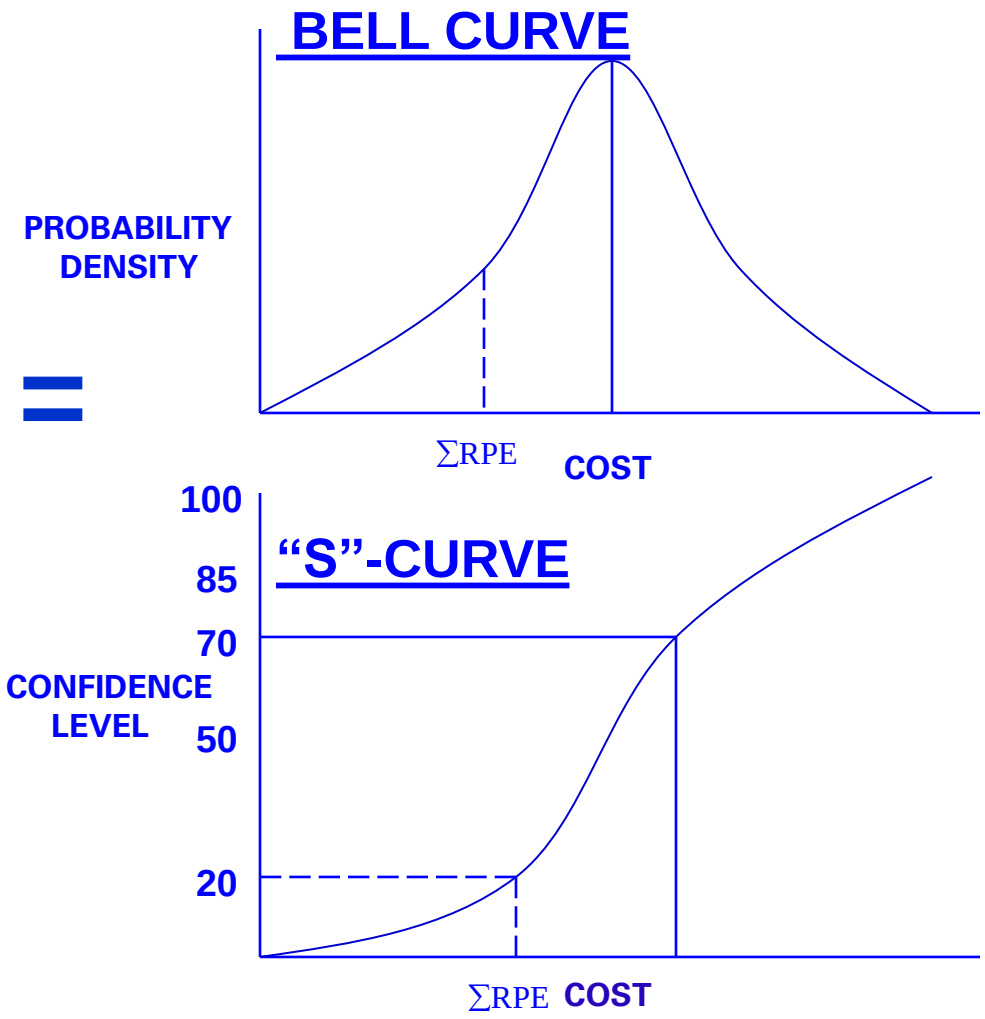
CORRELATED SUBSYSTEM COST DISTRIBUTIONS:



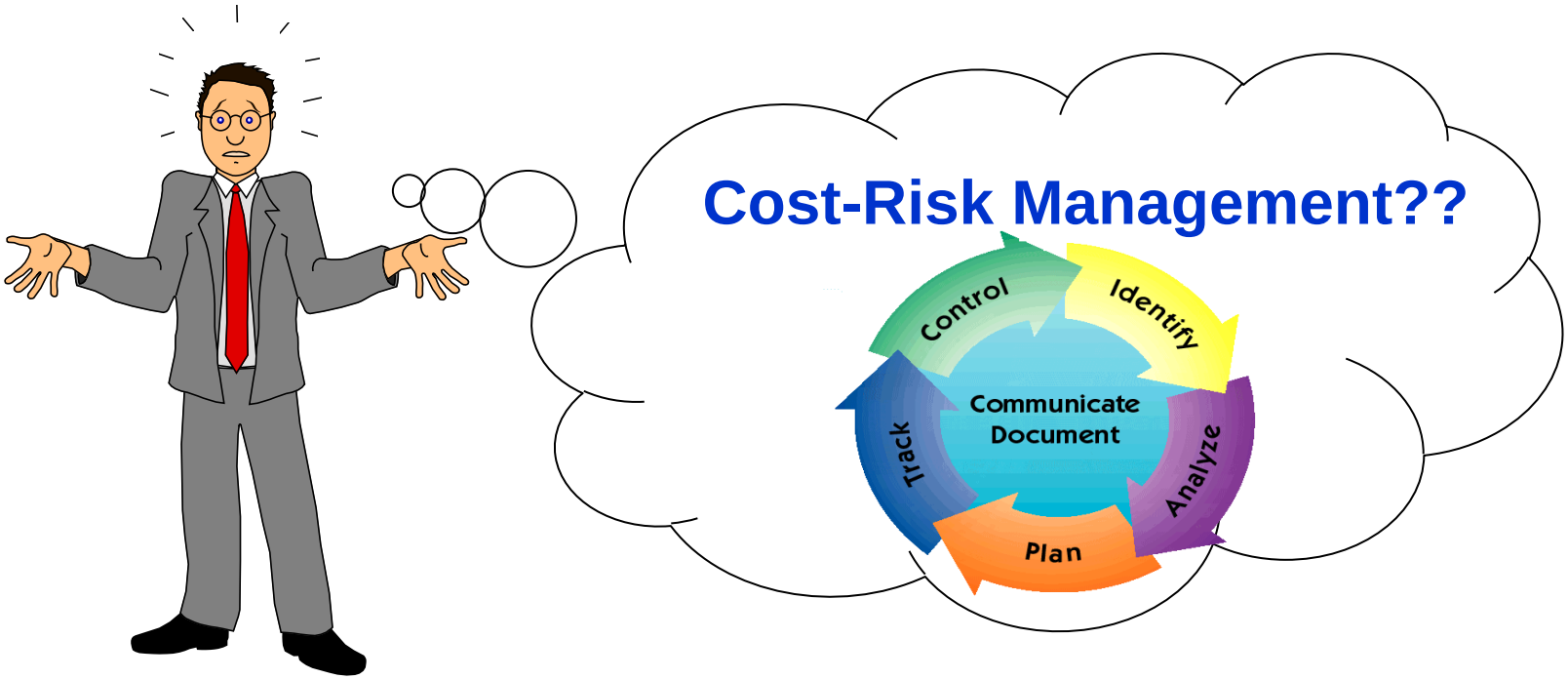
CER, Parameter Input, and RRW Cost-Risk Distributions on Lower Level WBS Elements

=

SUMMARY COST DISTRIBUTIONS:



Cost-Risk Management in CRM



In simplest terms, Cost-Risk Management is an organized process within project management to uncover cost-risks and severity, their likelihood, and deal with them upfront

Managing Cost-Risk leads to successful projects

Track

- Acquire Data
  - Determine what information is required
  - Obtain the data
- Compile Data
  - Organize data into understandable information
  - Develop trends
  - Format data in a form that is consistent with what is being used on other projects, and that the reviewers are use to seeing
- Report Data
  - Communicate the compiled data to the Risk Management Board
  - Make recommendations on the status of each risk and any modifications that may be required

Control

Project
Data

Cost-Risk Management

Risk Management

CCRM

Continuous Cost-Risk Management

A ***System of Cost Systems*** linked together in sequence by the same risks

Risk Management

CPR Data Requirements Description

- For cost-risk feedback, the contractor or performing organization needs to be informed in the RFP/Project Plan about:
  - Medium and high-risk systems, subsystems and/or WBS elements identified initially in the cost estimate
  - EVM performance measurement requirements against these specific risky WBS elements
    - e.g., WBS element reporting levels (NPR 7120.5C)
- An EVM CPR DRD template is available on the Cost Estimating Handbook website
  - www.ceh.nasa.gov

Example of Earned Value DRD Instructions
Paragraph 1: High Risk WBS List & Reporting Criteria

1. Earned value insight (BCWS, BCWP, ACWP on Format 1 and narrative status on Format 5) for the following high risk WBS elements shall be provided every month regardless of variance percentage levels until the system program office (SPO) informs the contractor otherwise:

Power Subsystem ASIC; Solar Power Converter; Pointing & Control System Laser Amplifier/Transmitter; Laser Transmit Antenna; Microwave Receive Antenna; Laser Receive Antenna; Tracking & Control System; Laser Conditioning Receiver; Laser Rectifier/Converter; Flywheel Storage System

If WBS elements, other than those identified here, begin to experience variances exceeding 10% at one or two levels above the control account (source of risk) for two consecutive months in current month performance measurement, the contractor/performing organization will inform the Project Manager and a consensus reached on adding them to the group of high risk WBS elements identified for monthly cost performance reporting and analysis purposes.

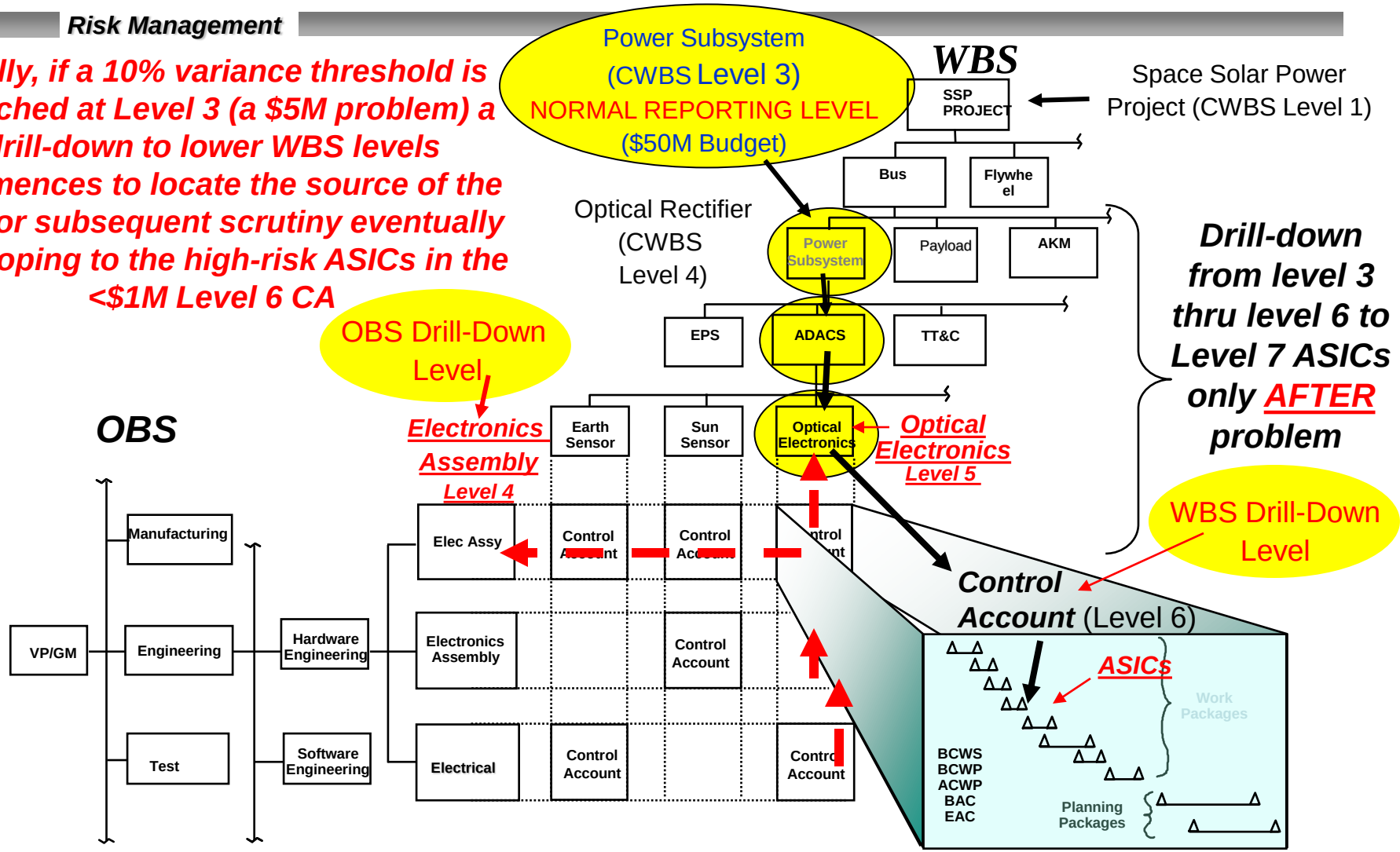
All other WBS elements shall have earned value (BCWS, BCWP, ACWP) reported at level 3 of the WBS to satisfy observing and monitoring requirements

Traditional Level 3 Reporting

10% Variance Reporting

Risk Management

Normally, if a 10% variance threshold is breached at Level 3 (a $5M problem) a drill-down to lower WBS levels commences to locate the source of the risk for subsequent scrutiny eventually developing to the high-risk ASICs in the <$1M Level 6 CA

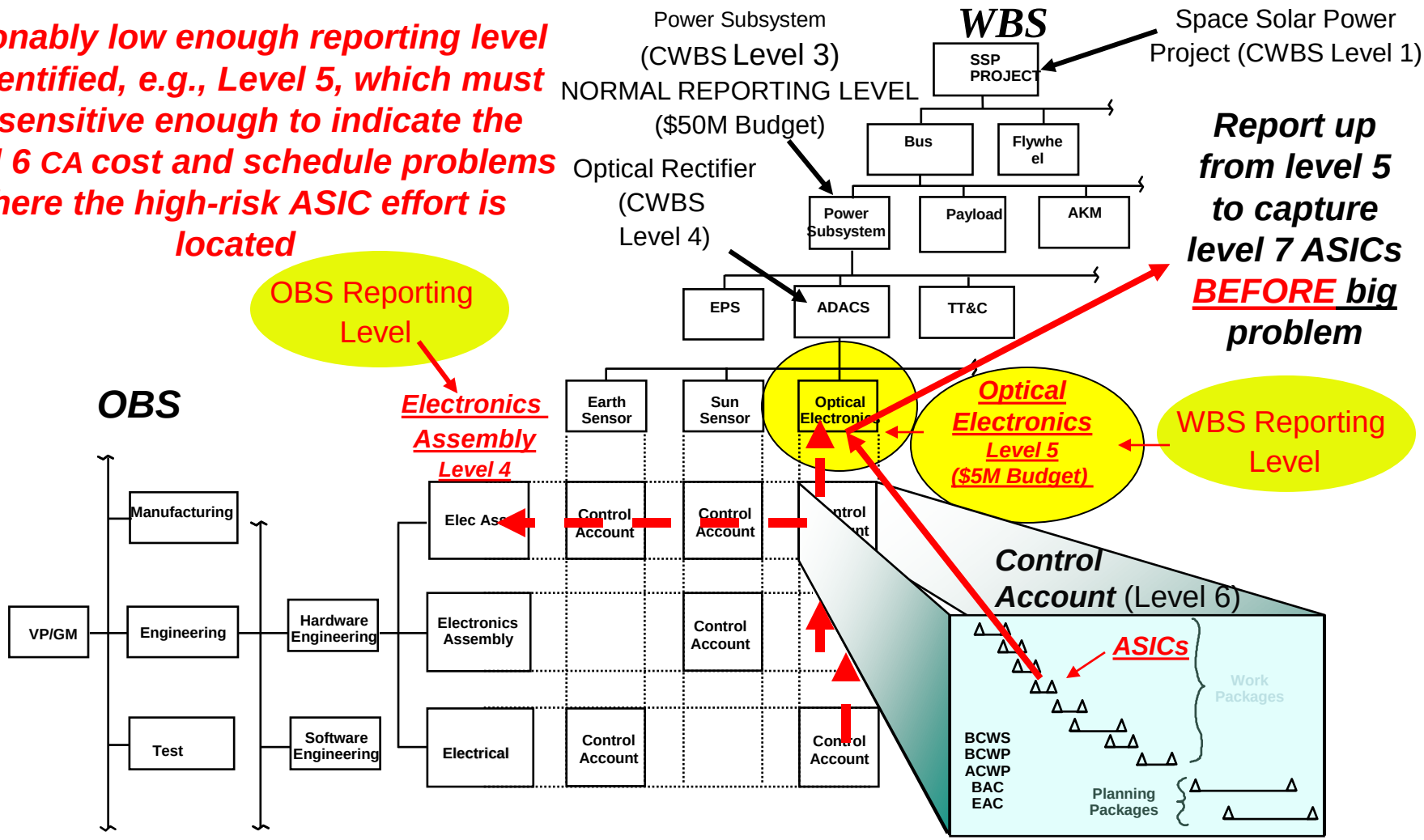


CCRM Med/High Risk Reporting

High-Risk No-Threshold Variance Reporting[3]

Risk Management

A reasonably low enough reporting level is identified, e.g., Level 5, which must be sensitive enough to indicate the Level 6 CA cost and schedule problems where the high-risk ASIC effort is located



[3]*Until risk is no longer a threat or is retired*

CCRM Cost-Risk Management

- CPR will deliver *key performance measurement* data on *medium and high risk WBS* elements monthly
- This will enable the project managers to *determine actions to take* to mitigate potential problems
- The *NASA project manager* works closely with the *in-house NASA control account managers (CAMs) and contractor CAMs* to determine what mitigation actions to take
- The *NASA project manager* works with both *in-house and contactor CAMs* to determine if *performance measurement can be dropped* on previously risky WBS elements due to risk retirement

Conclusion

- Focused only on cost-risk between CRM and CCRM
- There are other areas CRM and CCRM have in common for future discussions
  - Cost/performance trades; requirements allocation to functions and WBS elements; risk data collection; risk databases
- Bottom line: CRM and CCRM are complementary processes
  - CCRM needs CRM input
  - CCRM can provide CRM with valuable cost-risk quantification

BACKUPS

CRM Risk Identification

- Clearly define objectives (everyone understands)
- Brainstorm issues/concerns to meeting objectives (what can go wrong)
- Decide which issues/concerns are real
- Develop risk statement from each issue/concern
- Assign attributes to the risk
- Brainstorm potential mitigations

Be sure to follow rules for brainstorming

CRM Risk Identification Tools

- Some tools to help identify and manage Risk:
  - Brainstorming (identifying issues)
  - Decision Analysis (mapping decision paths)
  - Lessons Learned
  - Personal knowledge and experience (gut feeling)
  - Expert Interviews and Independent Assessments
  - Questionnaires. Topic or taxonomy based
  - WBS, EVM, budgets and schedules
  - FTA, FMEA's, PRA, Monte Carlo (reliability tools)
  - Safety / Hazard analysis

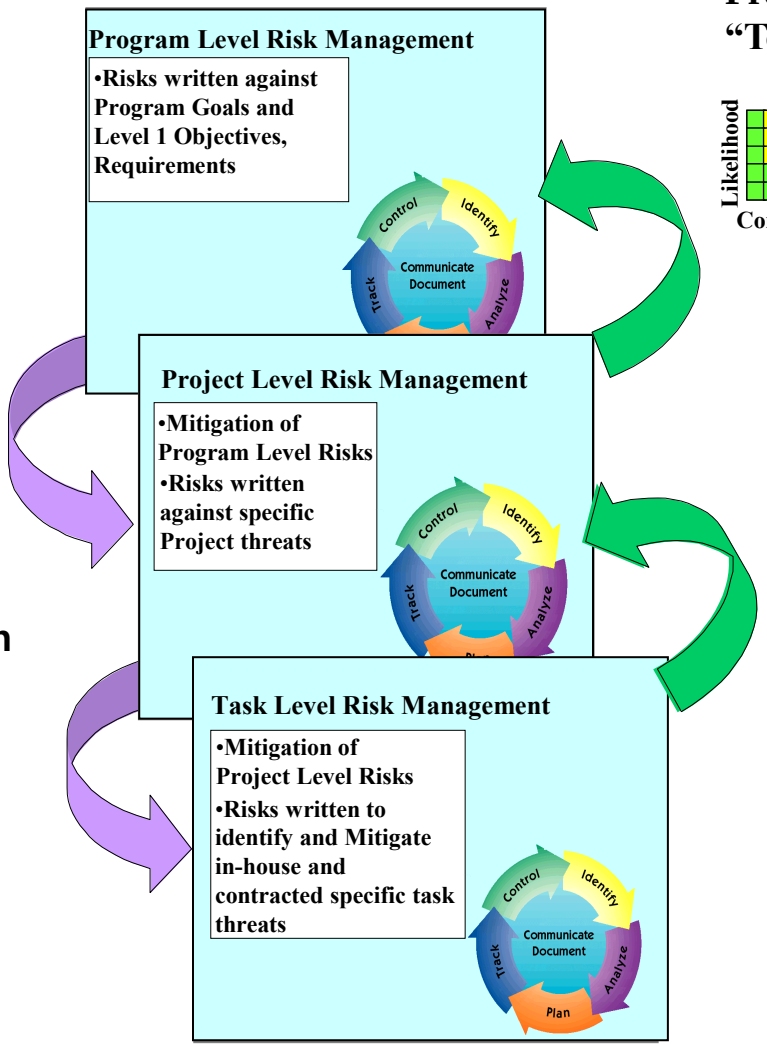
- These tools also help identify problems

Evaluate Risks at the Appropriate Level

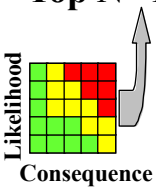
Requirements Flow-down

Program Goals, Objectives, Mission Success Criteria and Requirements

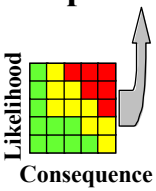
Project Goals, Objectives, Mission Success Criteria and Requirements



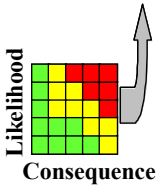
Program Level "Top N" Risks



Project Level "Top N" Risks



Project Level "Top N" Risks



Risk Reporting

Indigenous/Programmatic Risk

Build a Risk Rating Matrix

Example risk influences (could be more)

WBS ELEMENT PROFILES	TRL	DES/ENG	COMPLEXITY	SCHEDULE	TOTALS
	0.35	0.25	0.2	0.2	1.0
1. PESSIMISTIC PROFILE	HIGH	VERY HIGH	VERY HIGH	HIGH	5.9
2. REFERENCE PROFILE	MOD	MOD	MOD	MOD	2.9
3. OPTIMISTIC PROFILE	LOW	MOD LOW	MOD	MOD	2.0

Need definitions of: pessimistic, optimistic & reference profiles

CORRELATION

- What is Correlation?[2]
  - A measure of association between two variables.
  - It measures how strongly the variables are related, or change, with each other.
  - If two variables tend to move up or down together, they are said to be positively correlated. If they tend to move in opposite directions, they are said to be negatively correlated.
  - The most common statistic for measuring association is the Pearson correlation coefficient, ρ_P.
- Engineers and CRM specialists can assist cost estimators in identifying and quantifying correlation between WBS elements

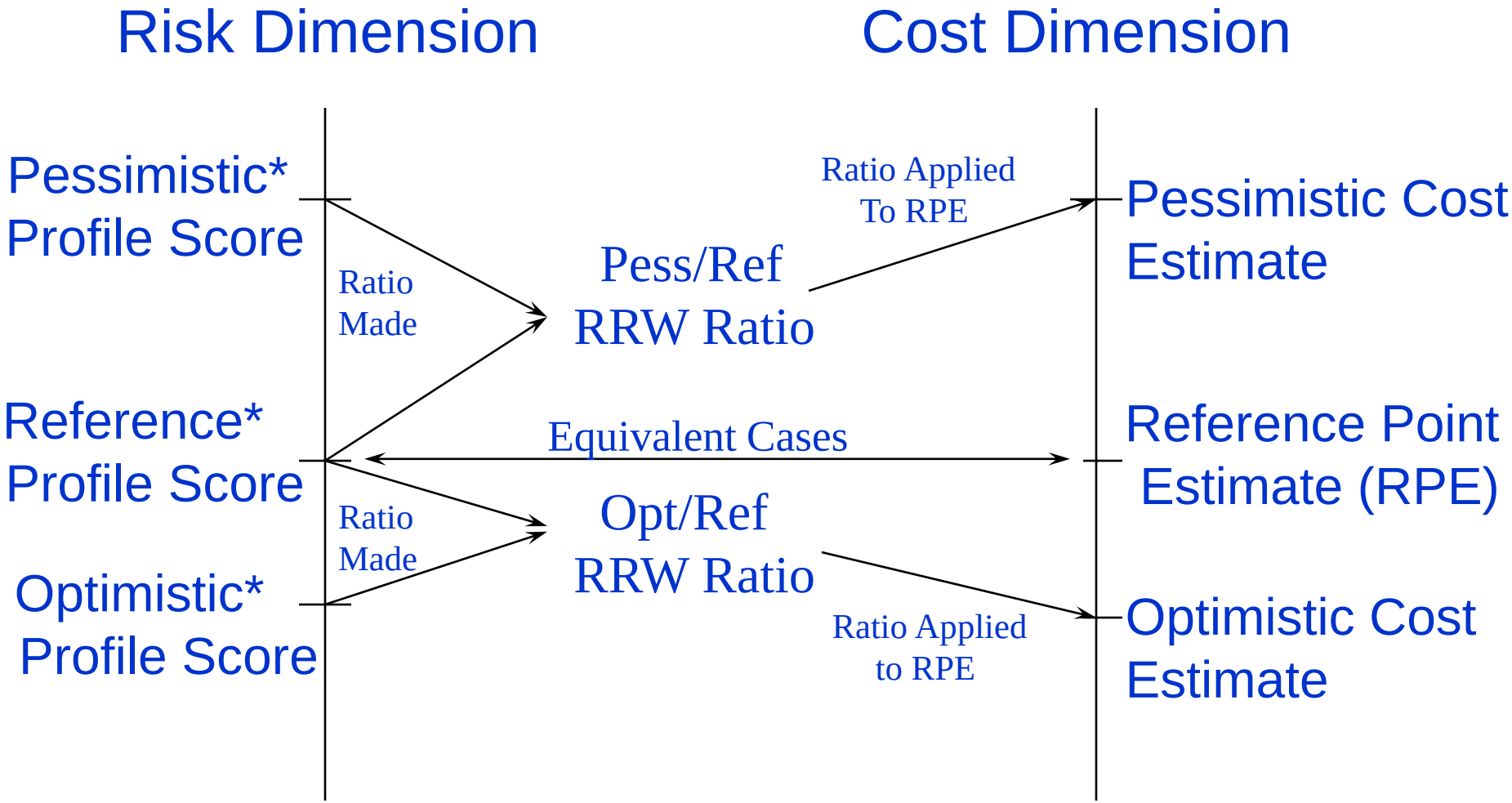
[2] www.statlets.com/usermanual/glossary.htm

Indigenous/Programmatic Uncertainty Quantification

Relative Risk Weighting

- *Task 1: Identify and prioritize cost-risk drivers and intensity scales*
- *Task 2: Define pessimistic, reference, and optimistic risk profiles for each WBS element and "score" them against the prioritized cost-risk drivers Applying the intensity scales*
- Task 3: Create two ratios {pessimistic/reference} and {optimistic/reference} from profile score ratios to scale the reference point *cost* estimate to create pessimistic and optimistic cost estimates
- Task 4: Use results as cost-risk triangular distribution endpoints

How the RRW Works

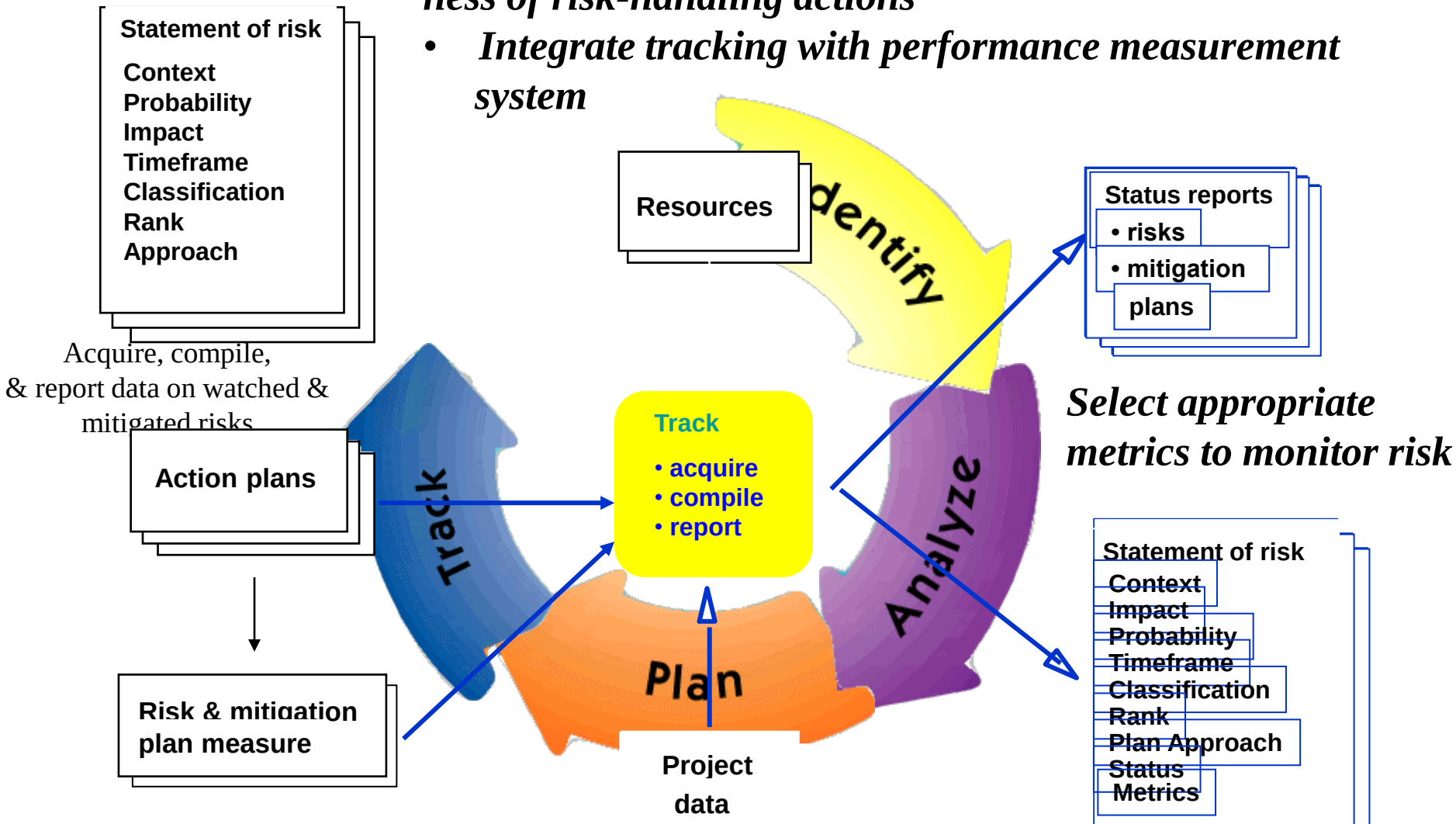


*Cost Analysis Data Requirement (CADRe)

Track

Systematically track and evaluate the progress and effectiveness of risk-handling actions

- ***Integrate tracking with performance measurement system***

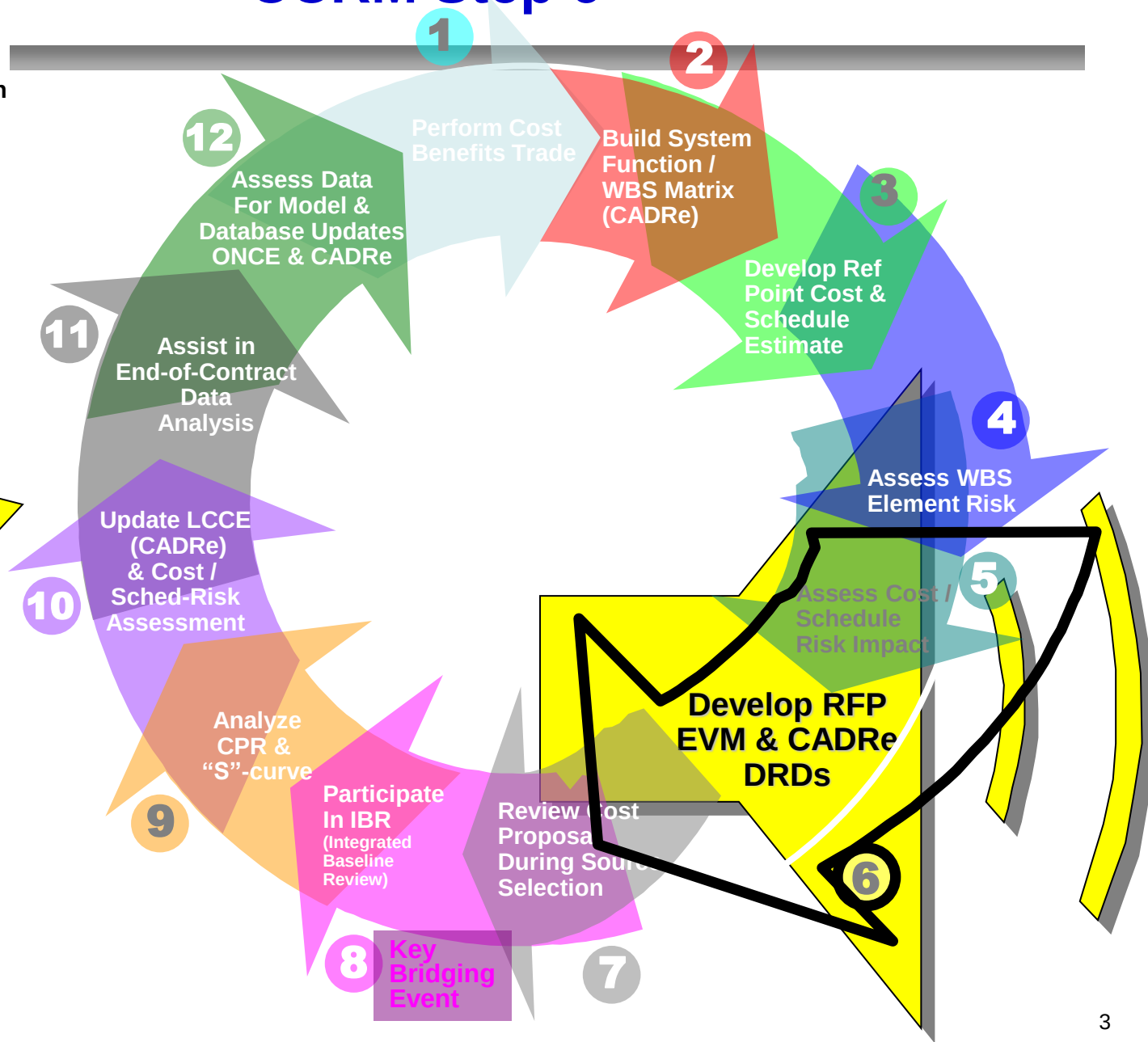


Track overall risk environment and specific risks

Communicating Cost & Schedule Requirements
CCRM Step 6

Risk Management

- Requirements-to-Mission Allocation
- Organize estimate: requirements / functions / WBS allocation
- Develop cost and schedule estimate
- Analyze risk
- Translate risk into cost and schedule impacts
- **Communicate cost and schedule requirements**
- Choose contractor
- Cement risk management plans and chosen contractor
- Monitor cost / schedule performance
- Update cost, schedule, and risk
- Use past data for better future estimates
- Perform V&V



Continuous Cost-Risk Management

System of Cost Systems linked together in sequence by the same risks

Risk Management

Incorporated in NPG 7120.5C

Set Up
Cost-Risk Feedback: Steps 1-5

Use
Cost-Risk Feedback: Steps 9-12

Get
Cost-Risk Feedback: Steps 6-8

Cost-Risk Assessment

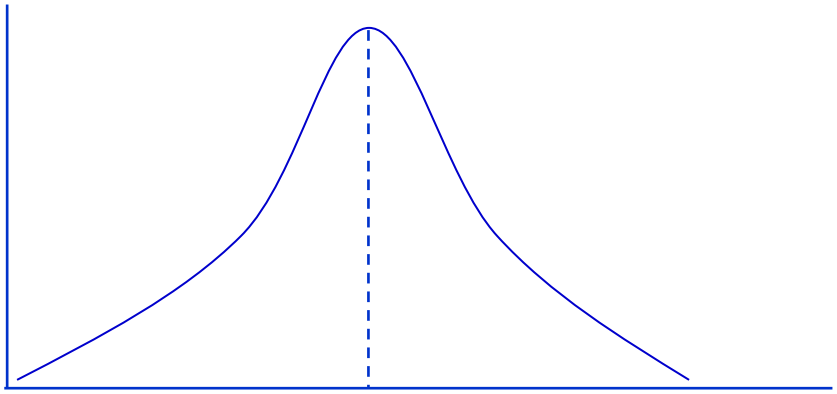
CRM

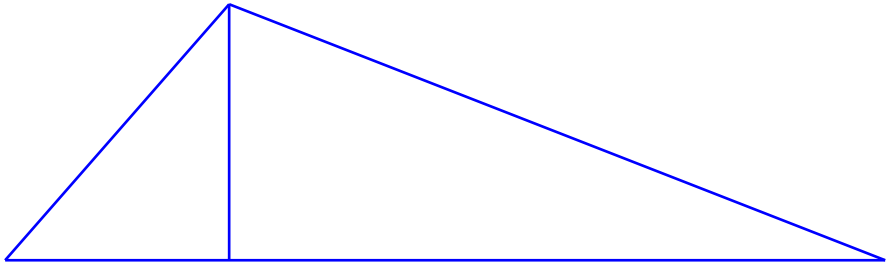
Cost-Risk Assessment

CCRM

Cost Model Uncertainty

- Due to the “spread” of the underlying CER or analogy data, estimating error must be accounted for:

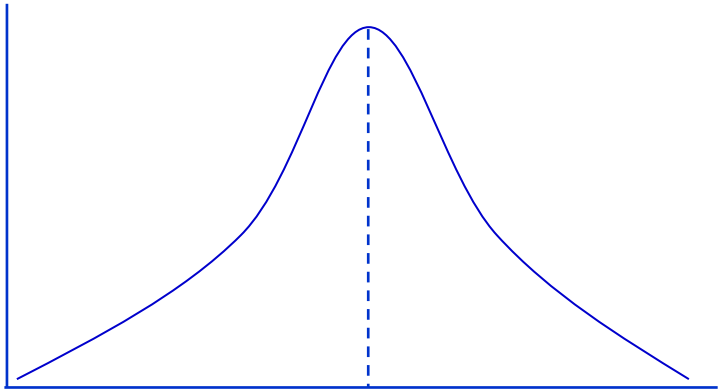




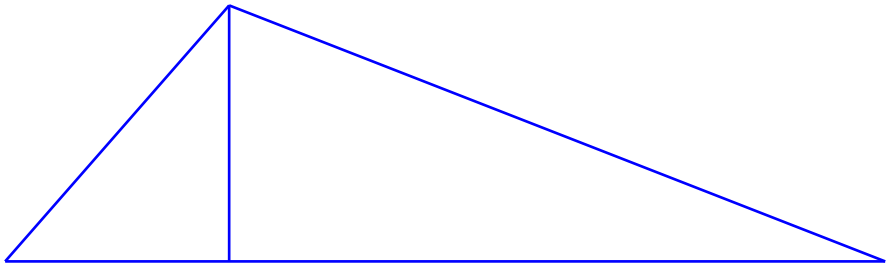
- Type of distribution is dependent on statistical data available

Input Parameter Uncertainty

- Due to uncertainty about the deterministic nature of an estimated CER-driving parameter value, its indeterminate nature must be accounted for:



CER
Estimate



Analogy
Estimate

- e.g., mass, power, volume, S/W productivity, etc.
- Type of distribution is dependent on statistical data available

Define WBS Element Risk Profiles (In Writing)

- 'Pessimistic'
  - A situation surrounding the development of the WBS element's Key Engineering Performance Parameters (KEPPs) that assumes the realization of the worst conditions under each category of risk affecting the element in meeting the WBS performance expectations documented in Parts 1 & 2 of the CADRe
- 'Optimistic'
  - A situation surrounding the development of the WBS element's KEPPs that assumes the realization of the best conditions under each category of risk affecting the element in meeting the WBS performance expectations documented in Parts 1 & 2 of the CADRe
- 'Reference'
  - A situation surrounding the development of the WBS element's KEPPs that assumes the realization of the most likely conditions under each category of risk in meeting the WBS performance expectations as documented in Parts 1 & 2 of the CADRe

Need a definition of KEPPs

Indigenous/Programmatic Uncertainty

- May need a unique technique for processing this type of uncertainty
- e.g., Relative Risk Weighting
  - A process whereby WBS element-appropriate cost-impacting influences are taken into account in a subjective yet quantitative manner
  - Examples of influences;
    - TRL; Design/Engineering; Schedule; Integration; Requirements Stability; Complexity; Manufacturing, Supportability, etc.

Indigenous/Programmatic Risk

	TRL (0.35)	DES/ENG (0.25)	COMPLEXITY (0.2)	SCHEDULE (0.2)	TOTAL RISK SCORE
Pessimistic Profile	High (5)	VH *(7.5)*	VH *(6)*	HIGH *(5.3)*	*5.9*
Reference Profile	MOD (3)	MOD *(3.5)*	MOD *(2.7)*	MOD *(2.2)*	*2.9*
Optimistic Profile	LOW *(1)*	ML *(2.5)*	MOD *(2.7)*	MOD *(2.2)*	*2.0*

Ref Profile Calc: (0.35)(3) + (0.25)(3.5) + (0.2)(2.7) + (0.2)(2.2) = 2.9

CCRM Risk Assessment

- Estimators know the uncertainty in cost methodology
- Talk to those involved in performing Continuous Risk Management (CRM)
- Talk to engineers on the project
  - They understand the risks in:
    - CER input parameters values (e.g., weight)
    - Correlations between input parameters and between WBS elements
    - Technology state of the art (TRL)
    - Designs that use the technologies
    - Engineering necessary to implement the technologies used in the designs
    - Adequacy of the schedule to design and implement the technologies
    - Integration involved at the box, component, subsystem and system levels