Practices of Managing in the Presence of Uncertainties That Create Cost, Schedule and Technical Risk

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#RAW2021

RISK AWARENESS WEEK 2021

50 Minutes is All We Have To Address how to Increase the Probability of Project Success with Risk Management

So, It's Going to Be…

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Core Elements of Project Risk Management

- Risk management is the systematic process of planning for, identifying, analyzing, responding to, and monitoring project risks.
- This activity is the means by which uncertainty – both Reducible (Epistemic) and Irreducible (Aleatory) are systematically identified and handled with preventive and corrective actions, to increase the Probability of Project Success.
- These uncertainties are related to functionality, schedule, cost, and quality variability of the end deliverable.

Towards a Contingency Theory of Enterprise Risk Management Anette Mikes Robert Kaplan, Working Paper 13–063 January 13, 2014

"Why do so many projects overspend and overrun?

Because they're managed as if they were merely *Complicated* when in fact, they are *Complex*.

They're planned as if everything is known at the start ***when in fact, they involve high levels of uncertainty that create cost, schedule, and technical risk***."

In, *Architecting Systems: Concepts, Principles and Practice*,
Hillary Sillitto, College Publications, 2014.

The Scope of Risk Management On Projects

Risk Management is essential for development and production programs. Information about key project cost, (technical) performance and schedule attributes is often uncertain or unknown until late in the program.
Risk issues that can be identified early in the program, which will potentially impact the program later, termed Known Unknowns and can be alleviated with good risk management.
– *Effective Risk Management 2nd Edition*, Edmund Conrow, AIAA, 2003

The purpose of project management is to ensure effective management of these activities to bring the expected results and benefits in the shortest time. Project management is thus the application of knowledge, skills, activities, tools, and techniques to the project so that the project will satisfy the requirements imposed on it and achieve its goals. Risk management is also an integral part of project management, which should be incorporated into.

But First We Must Understand

All Risk Comes From Uncertainty

We can only *Manage in the Presence of Uncertainty*, with Risk Handling Strategies

Since ALL Risk comes from Uncertainty.
Uncertainty on projects comes in Two forms

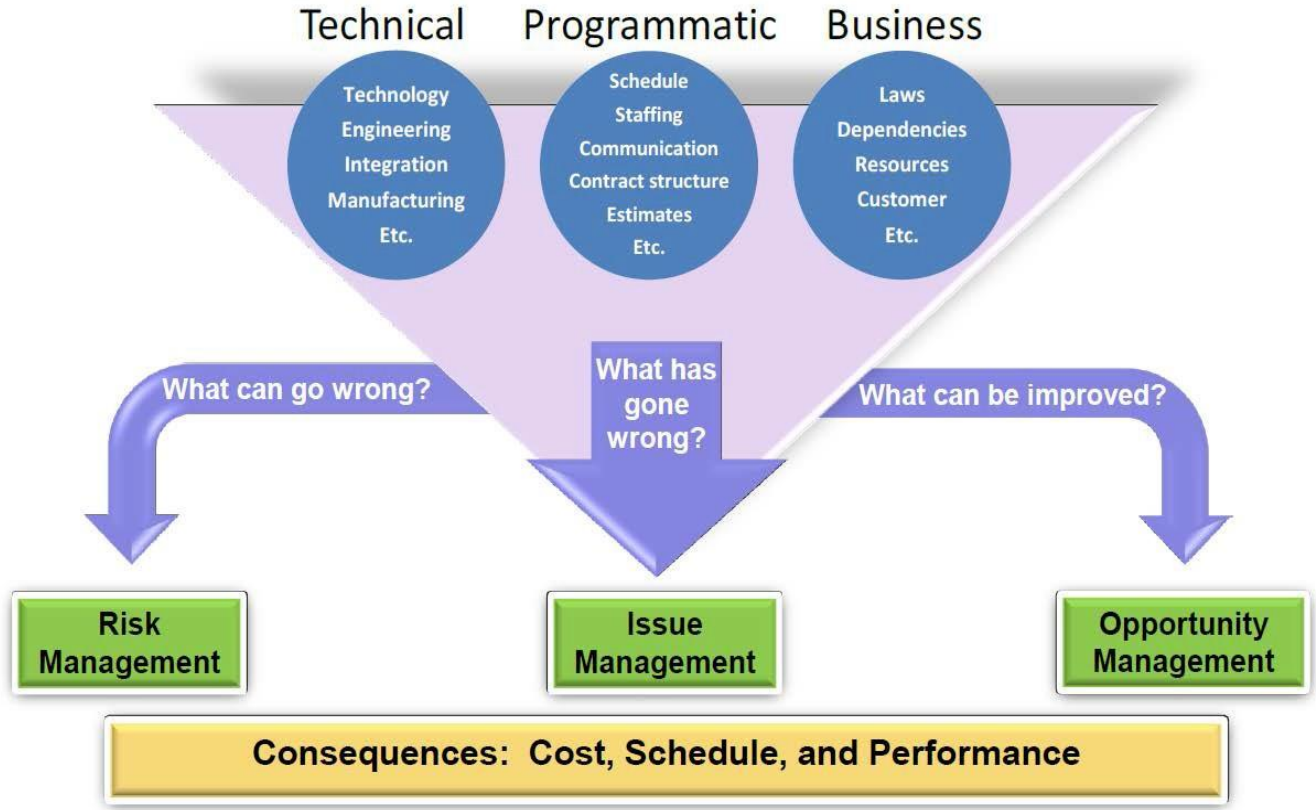
- Epistemic Uncertainty – which is reducible and can be handled with work efforts
- Aleatory Uncertainty – which is Irreducible and can Only be handled with Margin – cost, schedule, or technical margin

Five Immutable Principles of Project Success

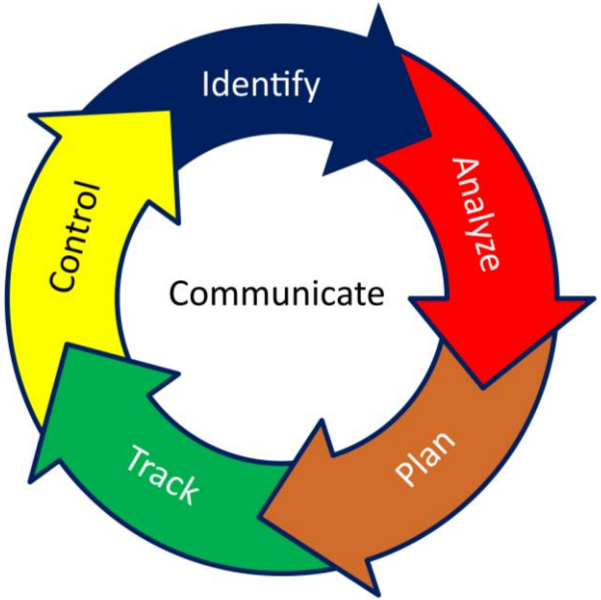
Five Credible Answers to the Questions Needed for Project Success Mean Managing Risk …

1	What does Done look like?	Capabilities and Requirements
2	How do we get there?	Master Plan and Schedule
3	Are there enough resources?	Resource Loaded Schedule
4	What are impediments to progress?	Risk Management Plan
5	How do we measure progress?	Earned Value Management

Elements of Managing Risk for the 4th Immutable Principle of Program Success



For Success, we must Manage In Presence of Uncertainty that Creates Risk



http://www.sei.cmu.edu/risk/index.html

Risk Management in Five Easy Steps

1. Hope is NOT a strategy
2. No single point assessment of cost, schedule, or Technical Performance can be correct
3. Cost, Schedule, and Technical Performance are inseparable
4. Effective Risk Handling Strategies require adherence to a well–defined process
5. Communication is the #1 success factor

But What is Risk?

Risk is the effect of uncertainty of objectives. Uncertainty is a state or condition that involves a deficiency of information and leads to inadequate or incomplete knowledge of understanding. In the context of risk management, uncertainty exists whenever the knowledge or understanding of an event, consequence, or likelihood is inadequate or incomplete
– ISO 31000:2009, ISO 17666:2016 and ISO 11231:2010

Risk is Uncertainty that Matters

All Risk Comes from Uncertainty

Uncertainties are things we can not be certain about.

Uncertainty is created by our incomplete knowledge – not by our ignorance.

Making decisions in the presence of Uncertainty requires making estimates of the impact of our decisions.

The Purpose of Risk Management †

Risk Management is under the umbrella of Systems Engineering Management

- The purpose of risk management is to reduce potential risks to an acceptable level before they occur, throughout the life of the product or project.
- Risk management is a continuous, forward-looking process that is applied to anticipate and avert risks that may adversely impact the project and can be considered both a project management and a systems engineering process.
- A balance must be achieved on each project in terms of overall risk management ownership, implementation, and day-to-day responsibility between these two top-level processes.

† "Systems Engineering Body of Knowledge (SEBOK), Risk Management," V2.4, 2021

Before We Proceed, Let's See How
Risk Management is About Finding Out What Can Go Wrong

I cannot imagine any conditions which would cause a ship to founder. I cannot conceive of any vital disaster happening to this vessel. Modern shipbuilding has gone beyond that..."

Captain E.J. Smith, 1906, about the Adriatic (Captain of *Titanic* on the evening on 14 April 1912)

A Reminder of 3 Sources of Uncertainty That Create Risk to the Probability of Project Success

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Risk management in the seismic under righting business started with recognizing all risk comes from uncertainty.
These principle has come to some program and project management domain.
NASA's *Risk Informed Decision-Making* handbook is one place to look for principles, processes, and practices based on this paradigm.

Three Uncertainties That Create Risk to Probability of Project Success

- **Aleatory Uncertainty** – from the Latin *alea* (a single die) is the variation associated with a physical system or environment. Aleatory uncertainty comes from an inherent randomness, natural stochasticity, environmental or structural variation across space and time in the properties or behavior of the system under study.
- **Epistemic Uncertainty** – from the Greek *επιστημη* (episteme), is uncertainty from the lack of knowledge of a quantity or process in the system or an environment. Epistemic uncertainty is represented by a range of values for parameters, a range of workable models, the level of model detail, multiple expert interpretations, or statistical confidence.
- **Ontological Uncertainty** – is attributable to the ***complete*** lack of knowledge of the state(s) of a system. This is sometimes labeled an Unknowable Risk. Ontological uncertainty cannot be measured directly.

An Epistemic Uncertainty Statement †

- **If–Then** – if we miss our next milestone then the project will fail to achieve its business value during the next quarter.
- **Condition–Concern** – our subcontractor has not provided enough information for us to status the schedule, and our concern is the schedule is slipping and we do not know it.
- **Condition–Event–Consequence** – our status shows there are some tasks behind schedule, so we could miss our milestone, and the project will fail to achieve its business value in the next quarter.

For risk created by *Epistemic Uncertainty*, explicit or implicit risk handling strategy is needed.

† Denmark Technical University, Epistemic vs. Aleatory Uncertainty, http://apppm.man.dtu.dk/index.php/Epistemic_vs._Aleatory_uncertainty

Aleatory Uncertainty Creates Risk That Is *Irreducible* †

- For aleatory uncertainty, more information cannot be bought nor specific risk reduction actions taken to reduce the uncertainty and resulting risk – the uncertainty comes from a Stochastic process
- Only ***Margin*** can be the handling strategy for Aleatory uncertainty
- Cost margin in the form of ***Management Reserve***
- ***Schedule Margin*** is used to protect delivery dates. This margin has no budget assigned
- ***Technical Margin*** through redundancy, extra strength, extra capacity, bandwidth, or other performance factors

For risk created by *Aleatory Uncertainty*, explicit or implicit risk handling strategy is needed.

† Denmark Technical University, Epistemic vs. Aleatory Uncertainty, http://apppm.man.dtu.dk/index.php/Epistemic_vs._Aleatory_uncertainty

Modeling Risk

Since all risk comes from Uncertainty, we need a model in the presence of these uncertainties to estimate the impact of risk on Cost, Schedule, and Technical Performance elements of the project

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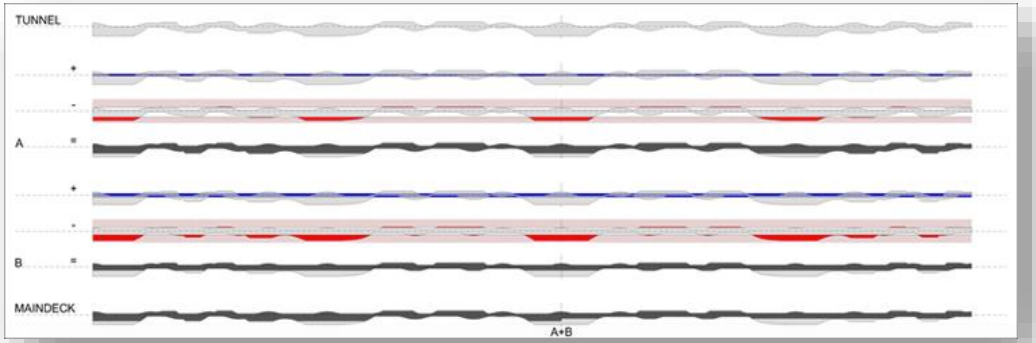
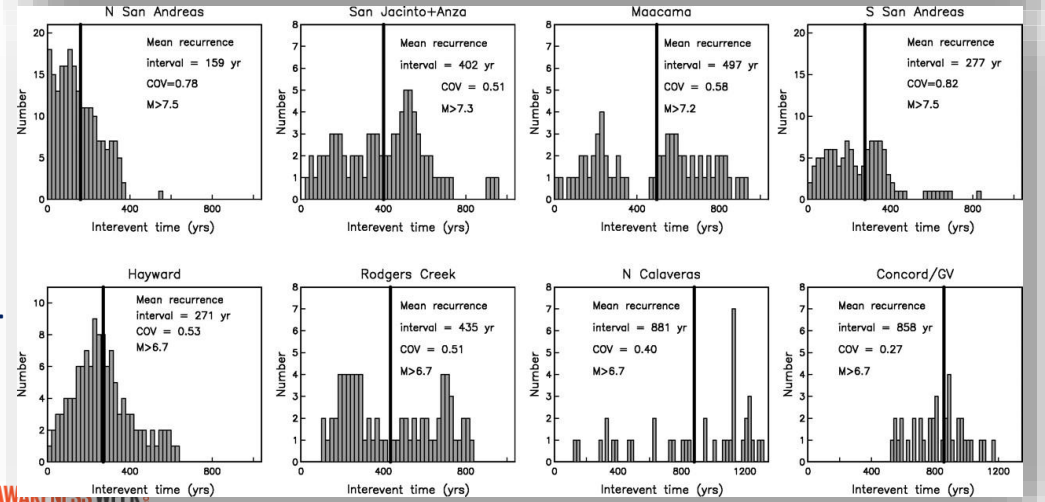
Aleatory and Epistemic Uncertainty Create Risk to Project Success

Aleatory



Natural Variance in Underlying System

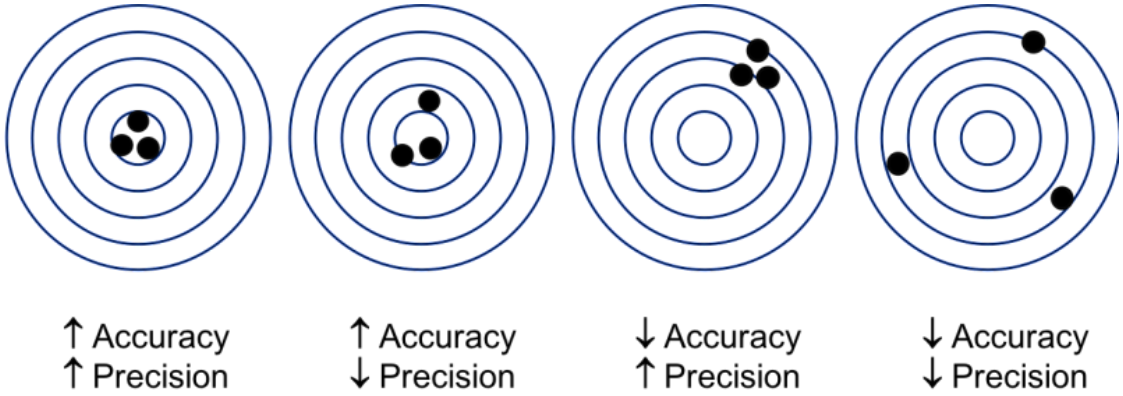
Epistemic



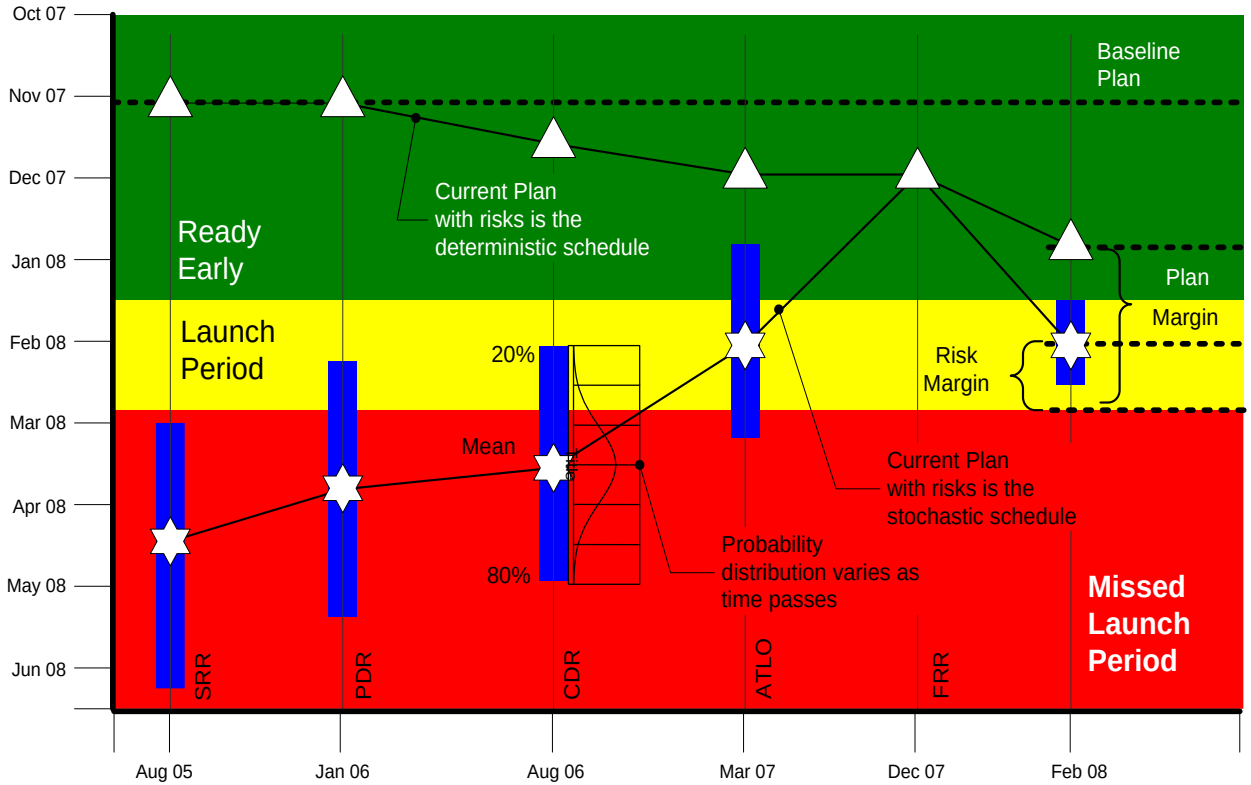
Probability of an Event impacting Cost, Schedule, or Technical Performance

Risk Models Produce Data That Has …

- **Precision** - how small is the variance of the estimate?
- **Accuracy** - how close is the estimate to the actual value?
- **Bias** - what impacts on precision and accuracy come from human judgment or misjudgment while making the estimate?

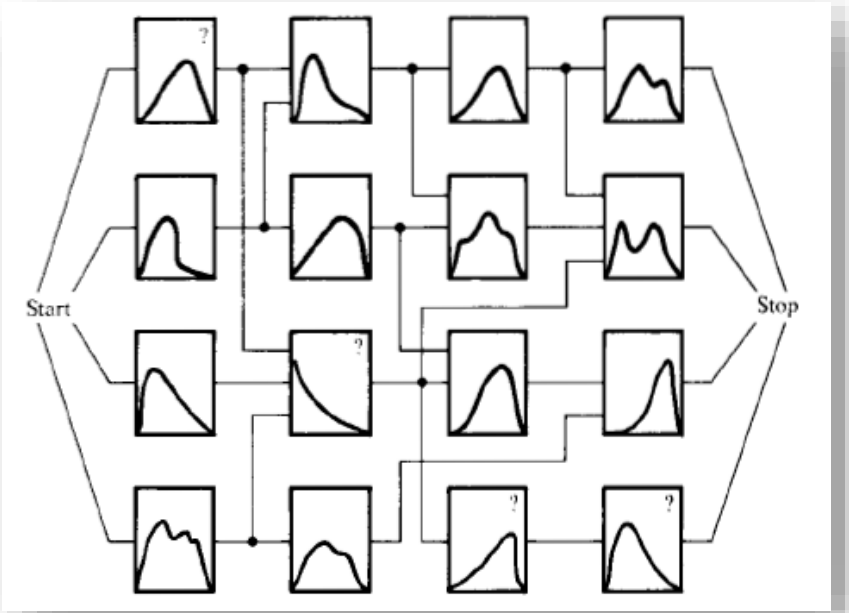


Deterministic versus Probabilistic Planning



Aleatory Uncertainty Creates Risk in the Integrated Master Schedule

- Cost
- Schedule
- Capacity for work
- Productivity
- Quality of results
- Activity correlation



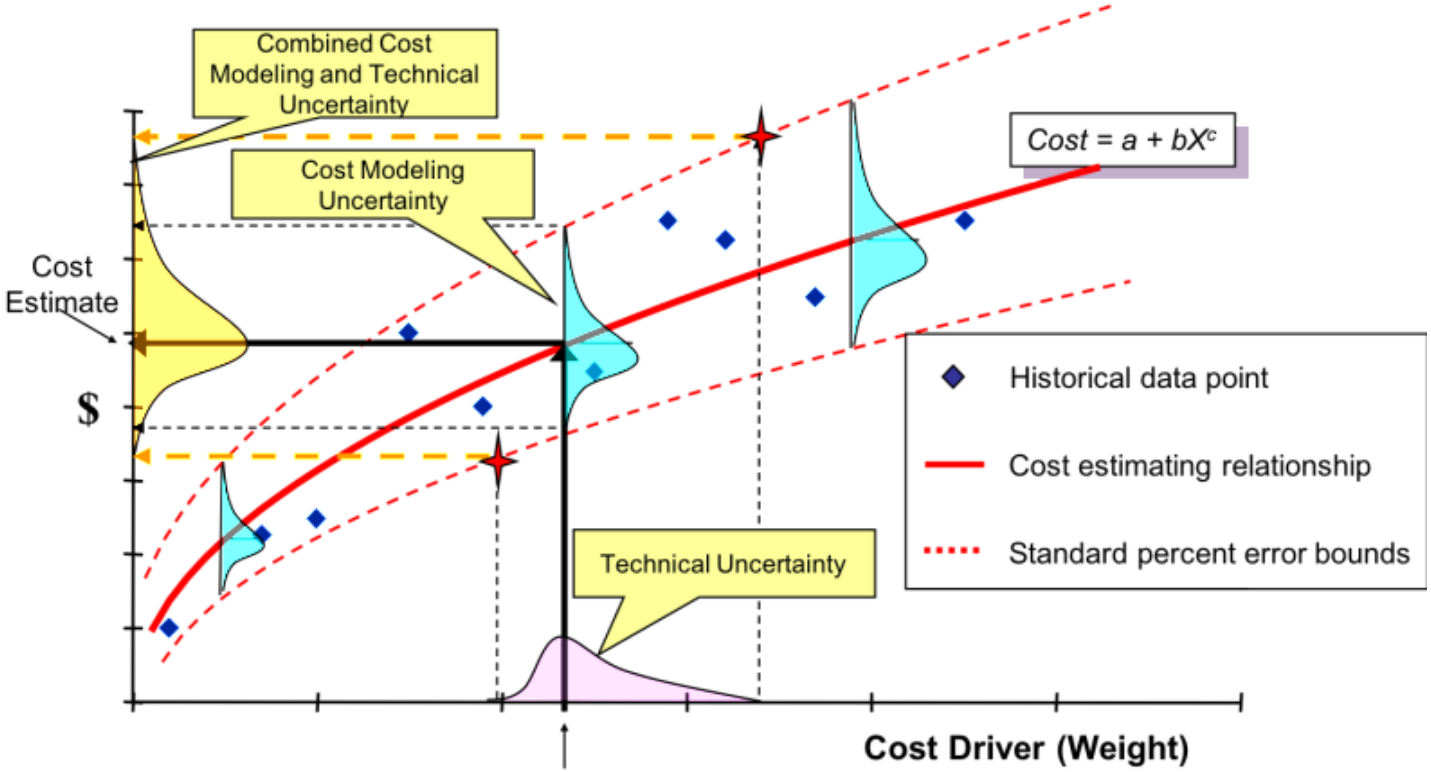
With the naturally occurring uncertainty between –5% to 20% in our work effort durations, we have an 80% confidence of completing on or before our target date – PP&C speaking to PM

Events That Have an Uncertainty of Occurring, Create Risk

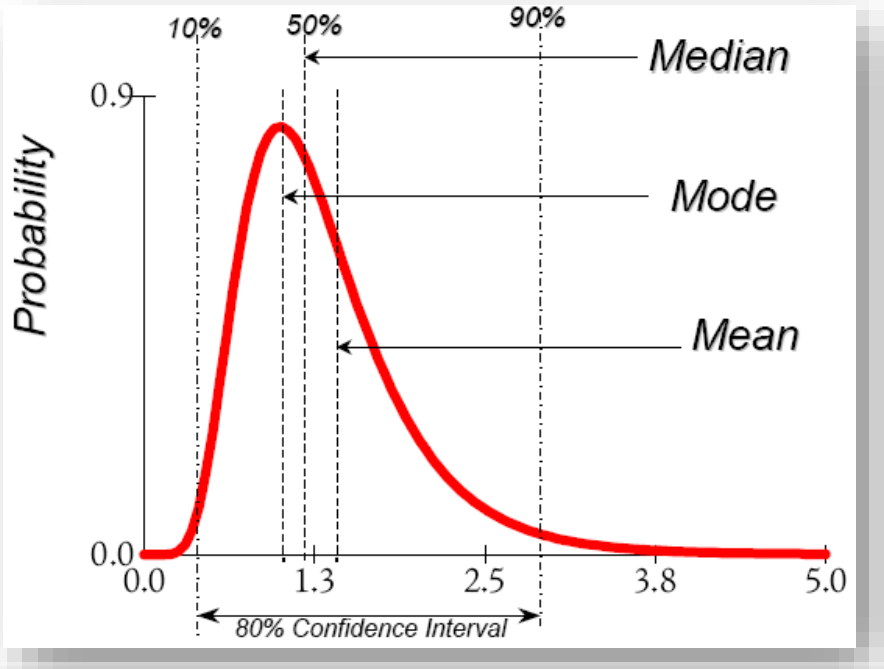
- Knowing the underlying statistics of the past, and a model of the behavior, we can forecast the probability of the future behavior.

- Improving our knowledge with better data can be used for better models,
- Improves the forecast of the probability of impact
- Reduces damage through better preparation at a lower cost

Then Connect The Impact to Cost and Schedule



The Probability of a Future Event Impacting the Project Creates Risk



There is a 68% probability Hurricane Katrina will strike New Orleans in the next 24 to 36 hours, with an 85% confidence.

Evacuate Now

Decision Making in the Presence of Uncertainty

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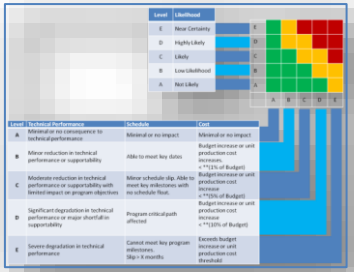
Decision Making Starts With Identifying the Source of Risk

Uncertainty

Irreducible (Aleatory)

Reducible (Epistemic)



Natural Variability

Ambiguity

Probabilistic Events

Probabilistic Impacts

Periods of Exposure

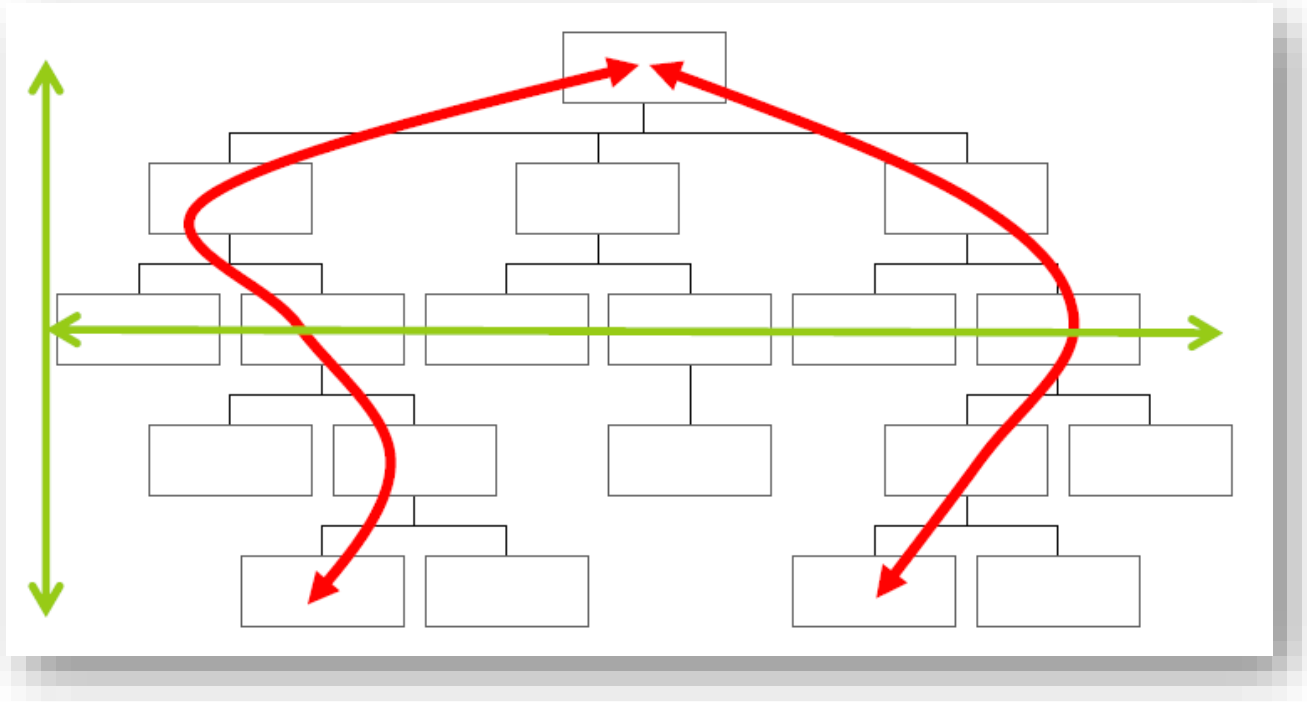
Ontological Uncertainty

Epistemic Uncertainty and Aleatory Variability are both risk drivers †

Epistemic Uncertainty	Aleatory Variability
Randomness With Probabilistic Properties	Randomness With Statistical Properties
▪ Epistemic uncertainty is is attributed to incomplete knowledge about a phenomenon in terms of a probabilistic model. ▪ Epistemic uncertainty can be reduced by the accumulation of additional information. ▪ Epistemic (or internal) uncertainty reflects the possibility of errors in our general knowledge.	▪ Aleatory uncertainties arise from nondeterministic (stochastic) processes and cannot be reduced by the accumulations of more date or additional information ▪ The knowledge of experts cannot be expected to reduce aleatory uncertainty although their knowledge may be useful in quantifying the uncertainty
The probability of occurrence can be defined through a variety of methods. The outcome is a probability of occurrence of the event	A Probability Density Function (PDF) generates a collection of random variables used to model durations and costs

† Uncertainty in Probabilistic Risk Assessment: A Review, A.R. Daneshkhan

Risk Chains – Across The WBS



Risk Indetification Starts in the Work Breakdown Structure

- Each risk identified in the elicitation process
- WBS contained deliverables assigned to risk retirement processes
- Risk here are usually Epistemic, with a Probability of Occurrence and a Known Impact and are *bought down* as the project proceeds

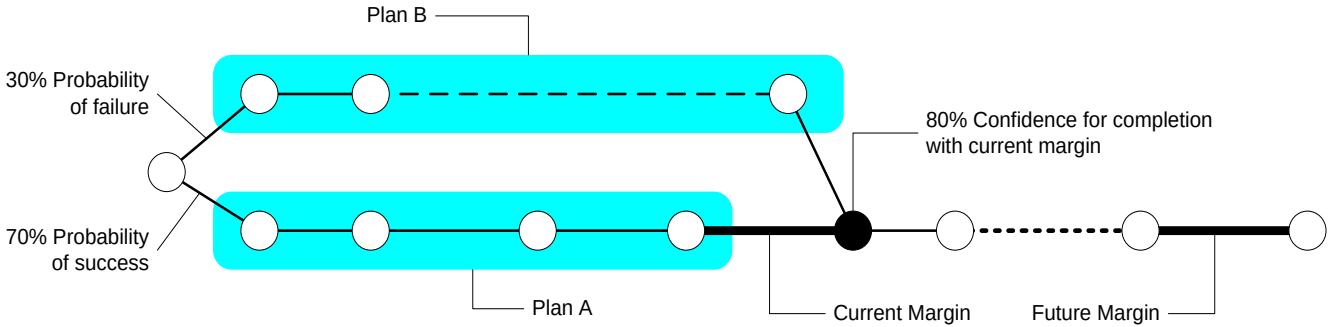
ID	Risk Title	Initial Risk	Risk at IBR	Risk at PDR	Risk Type	WBS
038	Center–of–Gravity Limits	16	15	10	Technical	2.1.5
006	Gross Liftoff Weight	16	15	10	Technical	2.1.5
090	Flight & Mission–Critical Software Development Effort	16	11	10	Schedule	2.1.4
101	Unattended launch system design	16	12	8	Schedule	6.2.14
082	Achieving Component, Subsystem– & System Quals	15	14	11	Schedule	2.1.7
244	Vehicle Production timing	12	12	10	Schedule	6.5
095	Autonomous Rendezvous flight pattern design	12	10	9	Schedule	6.2.12
017	EMI Anti–Jam Protection System Development	12	10	7	Technical	6.2.5
243	Landing and Impact Attenuation	12	12	6	Technical	6.2.11
098	Recover/Landing System (RLS) Rigging Complexity	12	12	6	Technical	6.2.11
088	Qualification of EEE Parts	12	10	4	Schedule	2.1.9.3
091	Uncertain To Achieve Payload Mounting Limits	12	8	3	Schedule	3030

A Credible Risk Register Contains

- Risk Identification Number
- Work Breakdown Structure
- Risk Owner
- Risk Category
- Risk Status
- Risk Assumptions
- Risk Probability And Basis
- Risk Level
- Risk Monitoring Trigger
- Success Metric
- Avoidance Metric
- Risk Handling Strategy
- Cost For Risk Handling
- Cost Assumptions
- Schedule For Handling Strategy
- Schedule Assumptions
- Residual Risk
- Risk Handling Strategy For Residual Risk
- Residual Risk Probability And Basis
- Residual Risk Consequence And Basis
- Residual Risk Level
- Secondary Risk
- Secondary Probability And Basis
- Secondary Risk Consequence And Basis
- Secondary Risk Level
- Trigger Date
- Trigger Metric

Cost and Schedule Margin are assigned to Handle Aleatory Risk

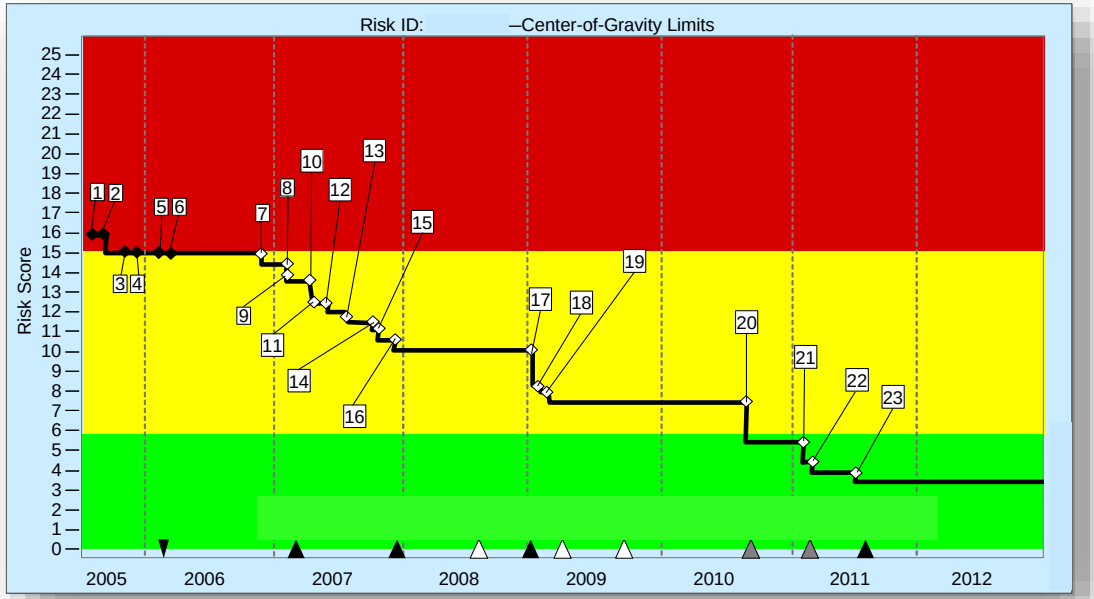
- This margin is the Performance Measurement Baseline (PMB)
- Unused margin should be capable of being shifted to the right to increase available margin in future deliverables



Duration of Plan B $\leq$ Plan A + Margin

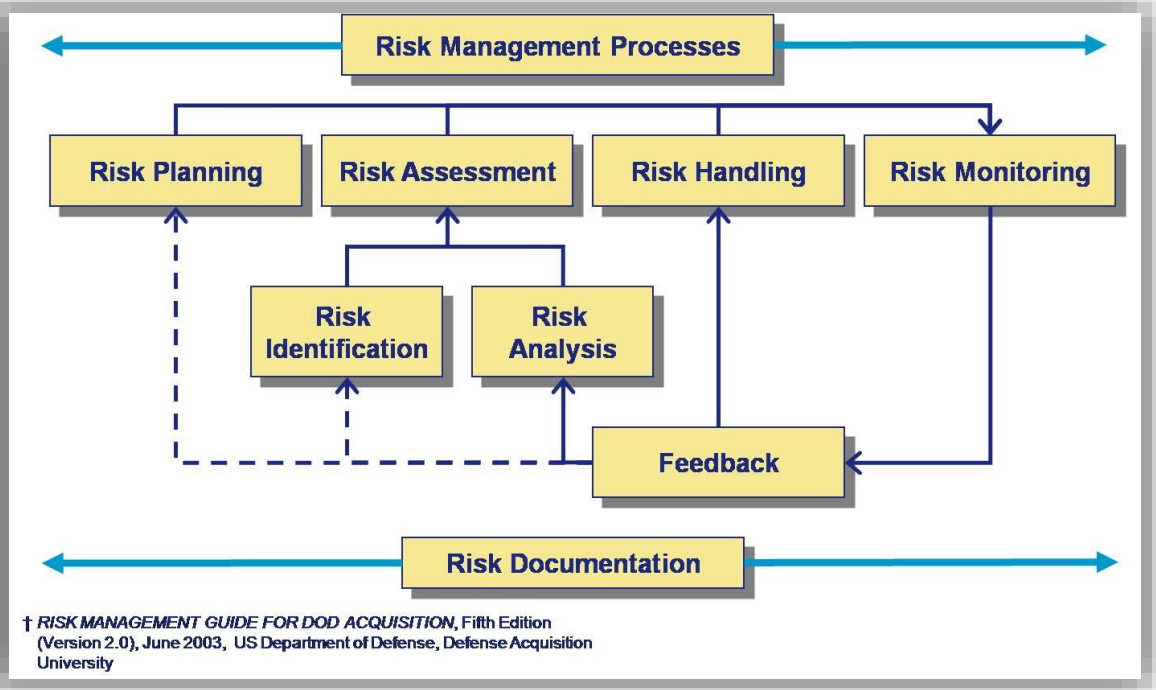
Uncertainties in the WBS, Create Risk Which are Reduced as the Project Proceeds

- These uncertainties are defined in the IMS
- They can be assigned to work activities in the IMS for reducing the risk on a planned date.
- The work then reduces or retires the risk associated with these uncertainties on the planed date.



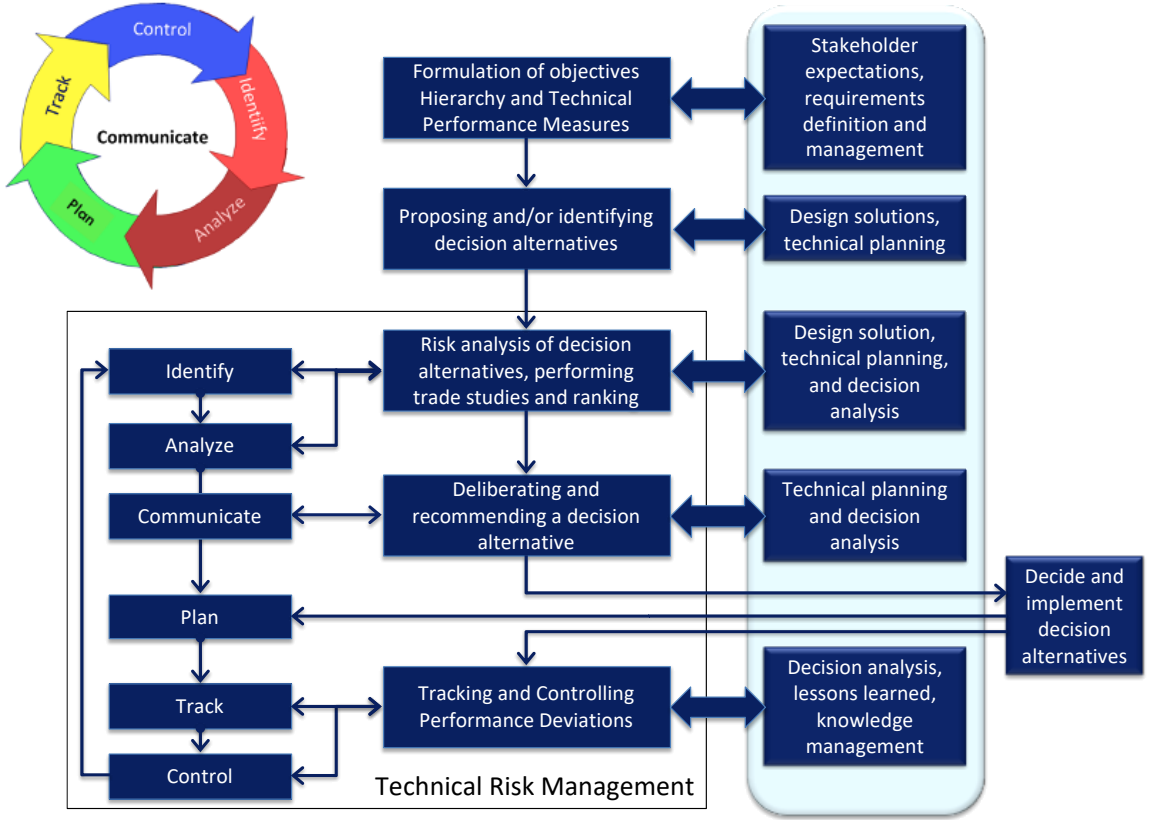
Risk Management Processes for Project Management

- An Approach to Programmatic and Technical Risk

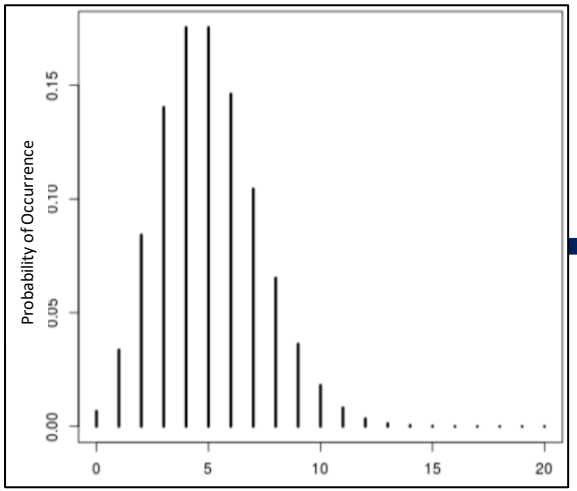


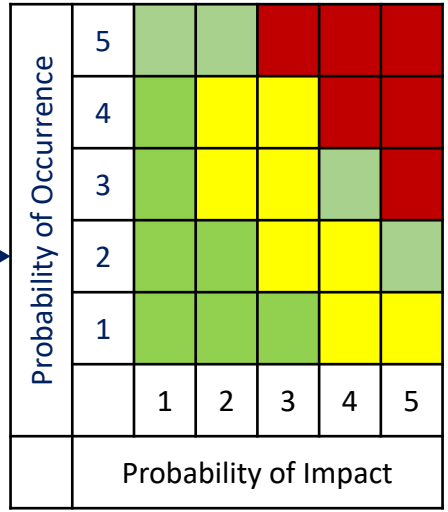
† *RISK MANAGEMENT GUIDE FOR DOD ACQUISITION*, Fifth Edition (Version 2.0), June 2003, US Department of Defense, Defense Acquisition University

Technical Risk Management Process Flow



Since All Risk Comes From Uncertainty, The Risk Matrix Elements are Probabilities Distributions





Each Matrix Element is a Probability of Occurrence and Impact

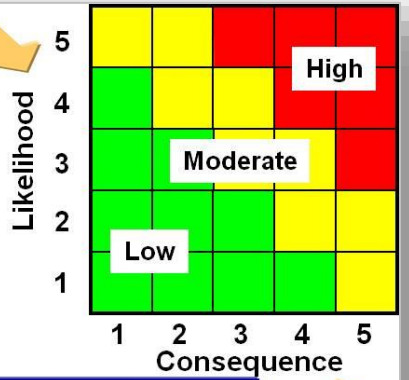
$$P(X) = \frac{\lambda^x e^{-\lambda}}{X!}$$

Multiplying or Adding the contents of the Cells is a Category error – it can't be done

Qualitative Risk Analysis – Risk can be Ranked, But NO Math Performed

What is the likelihood the Risk will occur?

Likelihood Level		Current Plan, Approach and Processes.
5	Near Certainty	...Cannot avoid this type of risk; no known processes or workarounds are available
4	Highly Likely	...Cannot avoid this risk, but a different approach might
3	Likely	...May avoid this risk, but workarounds will be required
2	Low Likelihood	...Have usually avoided this type of risk with minimal oversight in similar cases
1	Not Likely	...Will effectively avoid this risk based on standard practices



Given the Risk is realized, what would be the magnitude of the impact?

Consequence Type \ Level	1	2	3	4	5
Technical	Minimal or no impact	Minor perf. shortfall, same approach retained	Moderate perform. shortfall, but workarounds available	Unacceptable, but workarounds available	Unacceptable; no alternatives exist
Schedule	Minimal or no impact	Additional activities required; able to meet key dates	Minor schedule slip; will miss need date	Program critical path affected	Cannot achieve key program milestone
Cost	Minimal or no impact	Budget increase or unit production cost increase <1%	Budget increase or unit production cost increase <5%	Budget increase or unit production cost increase <10%	Budget increase or unit production cost increase >10%

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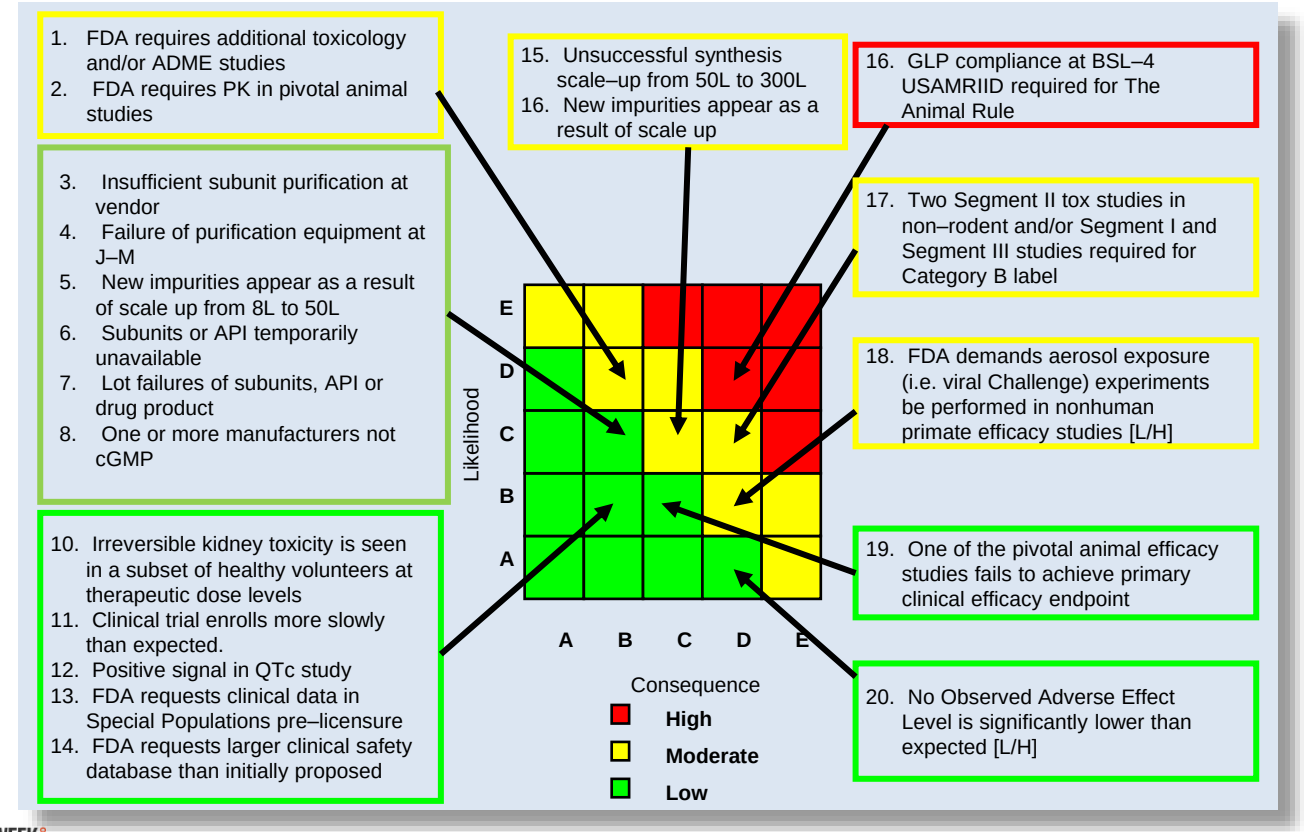
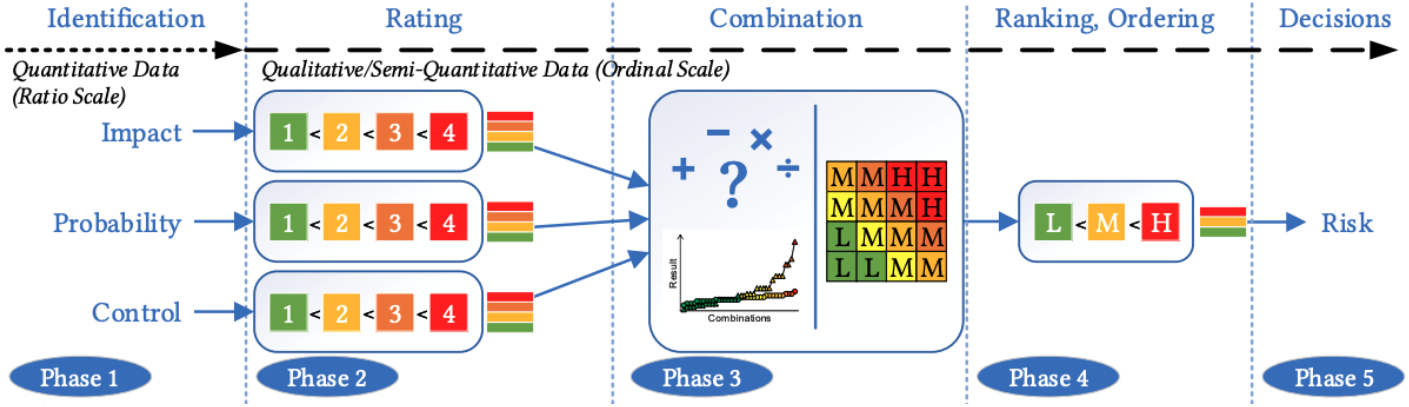
Join The Global Initiative To Promote Risk Based Decision Making

Example Qualitative Risk Matrix



The Qualitative Solution and Its Problems †



- Incompleteness
- Correlations
- Irrelevance
- Non-Linear Behaviors

- Ordinal Scales
- Scale-Definition & Distribution
- Range Compression
- Ambiguity
- Neglecting uncertainty
- Quantification Errors
- Human Bias
- Human inconsistency

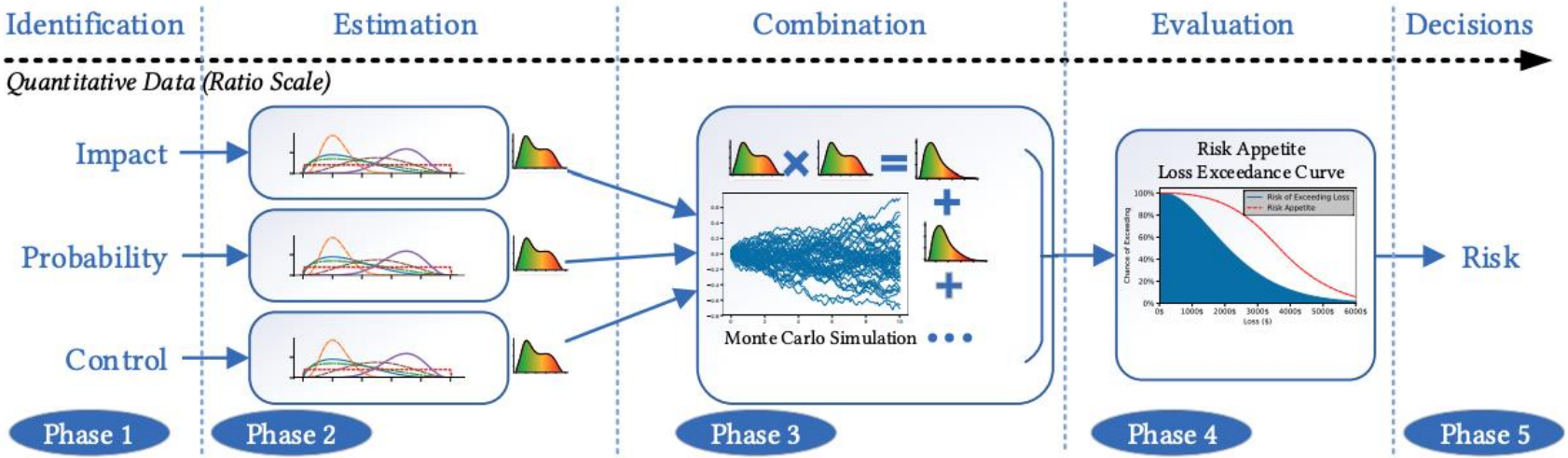
- Arithmetic Operations not defined
- Arbitrary selection of combinations
- Dominating components
- Neglecting Correlations

- Arbitrary thresholds
- Inconsistency
- Incoherence
- Ambiguous order
- Risk inversion
- Unknown uncertainty and confidence

- Wrongly perceived impression of benefit
- Deferred feedback

† "Problems with Risk Matrices Using Ordinal Scales," Michael Krisper, Institute of Technical Informatics, Graz University, arXiv:2013.05440v1, https://arxiv.org/abs/2103.05440

The Quantitative Solution to Managing in the Presence of Uncertainty †



Quantitative risk assessment uses ratio scales, probability distributions, Monte Carlo Simulation, Method of Moments, Principal Component Analysis and Loss Exceedance Curves

This is How Adults Manage Projects in the Presence of Uncertainty

† "Problems with Risk Matrices Using Ordinal Scales," Michael Krisper, Institute of Technical Informatics, Graz University, arXiv:2013.05440v1, https://arxiv.org/abs/2103.05440

A Core Flaw of Risk Modeling
Actual projects have *Fat Tail* distributions †

- Modeling random data is not the same as modeling random processes
- Data modeling assumes convenient functional forms and makes best fits to historical data
  - Functional forms might be arbitrarily chosen
  - Functional forms may have built–in bias
  - Goodness of fit is the only criterion (and is not falsifiable)
  - No theoretical justification is derived from the nature of the process
- Data modeling considers only project outcomes; process modeling considers how we get to the outcomes and provides testable ideas
  - Improve predictability and understanding by using knowledge of the nature of the process to guide data modeling random processes

† "Fat Tailed Distributions For Cost And Schedule Risks," John Neatrour, SCEA: January 19, 2011

Three Mandatory Steps in Successful Risk Management †

- A high–quality project schedule
  - Represents all work
  - Logically linked
  - No constraints
  - Resource loaded
  - Unbiased duration estimates
- A contingency–free cost estimate
  - Items do not have padding built in to accommodate risk
  - No below–the–line contingency included.
- Good quality risk data
  - Qualitatively identified risks
  - Probability and impact data

† Integrated Cost and Schedule Risk Analysis using Monte Carlo Simulation of a CPM Model, AACEI No. 57R–09

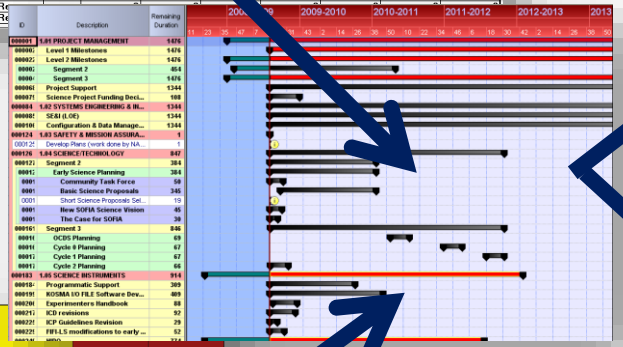
Outputs of a Successful Risk Management Process

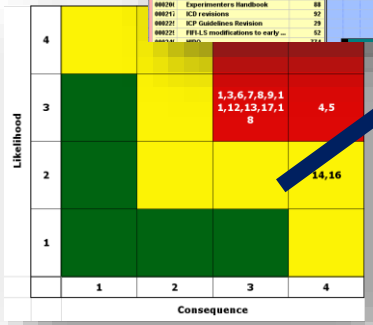
- Likelihood the project's cost and schedule targets can be met
- Time and cost margin needed to meet the risk threshold
- Risk priorities to be handled to achieve schedule and cost estimates
- Joint time and schedule analysis showing the probability of meeting time and cost targets jointly – the Joint Confidence Level (JCL)

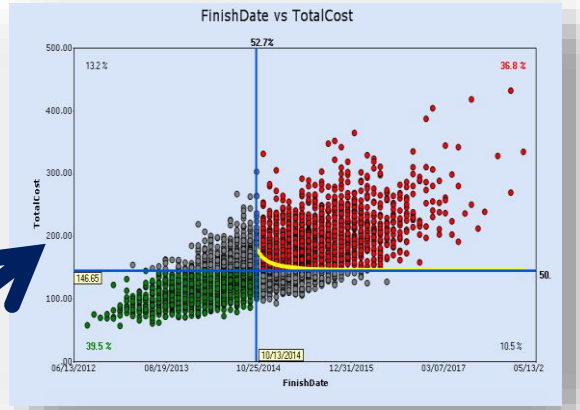
Integrating Cost, Schedule and Risk

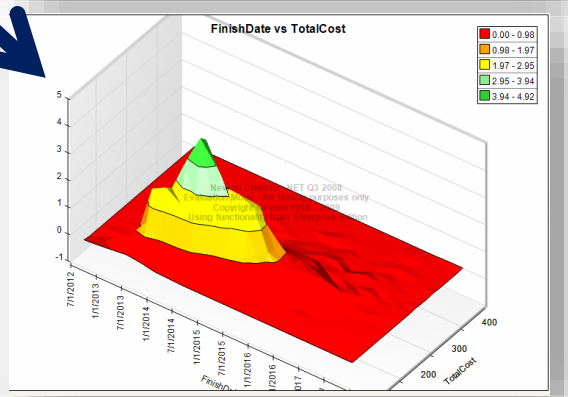
SOFIA Program Total (Dollars in K)

Description	Tech WBS	FY09	FY10	FY11	FY12	FY13	FY14	FY15
Program/Project Mgmt	1.01	0	0	0	0	0	0	0
Systems Engineering & Integration	1.02	0	0	0	0	0	0	0
Safety & Mission Assurance	1.03	0	0	0	0	0	0	0
Science / Technology	1.04	0	0	0	0	0	0	0
Science Instruments	1.05	0	0	0	0	0	0	0
Aircraft / Spacecraft	1.06	0	0	0	0	0	0	0
Mission Operations	1.07	0	0	0	0	0	0	0
Launch Vehicles & Services	1.08	0	0	0	0	0	0	0
Ground Systems	1.09	0	0	0	0	0	0	0
Systems Integration & Testing	1.10	0	0	0	0	0	0	0
Education and Public Outreach	1.11	0	0	0	0	0	0	0
Total Plan		0	0	0	0	0	0	0
Program Re								
Total Program Budget w/Re								









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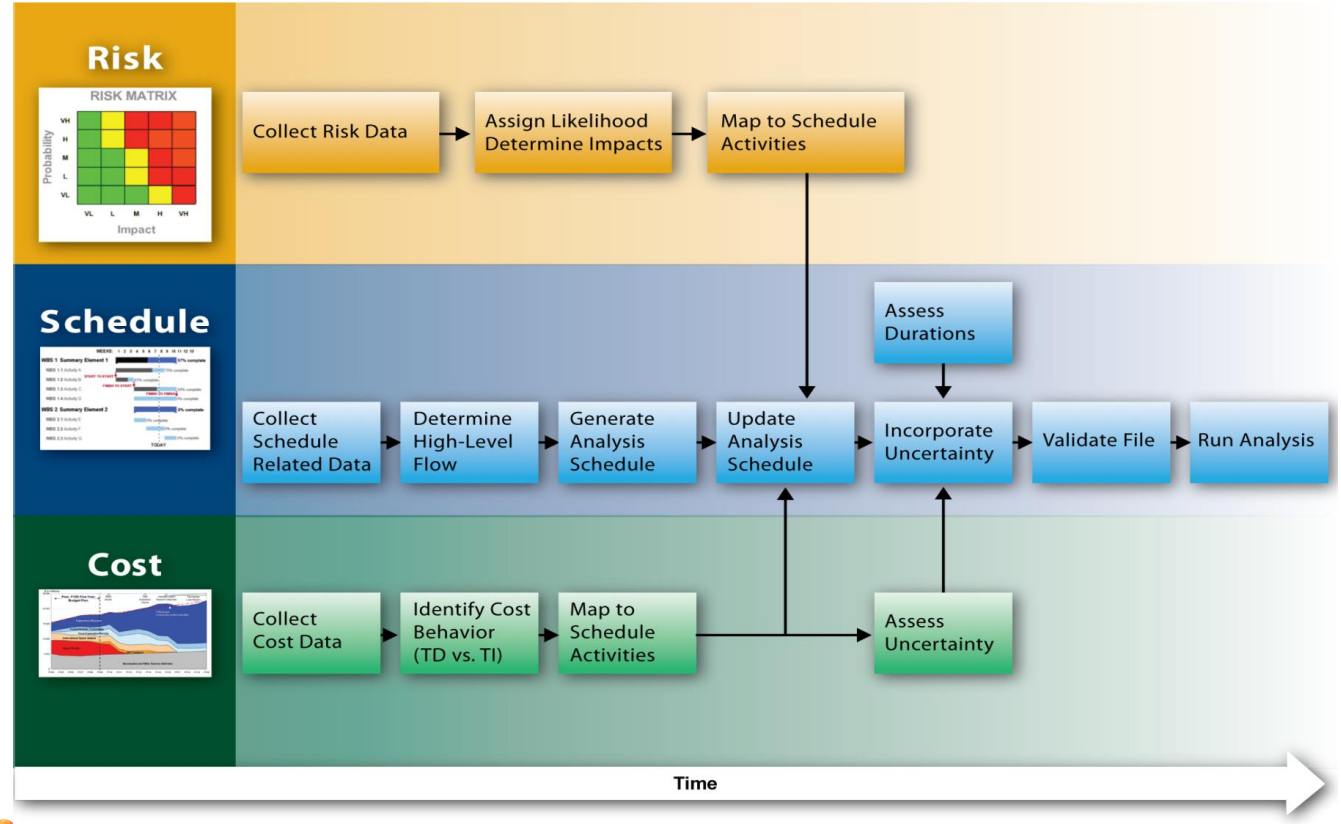
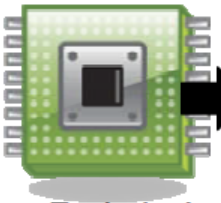
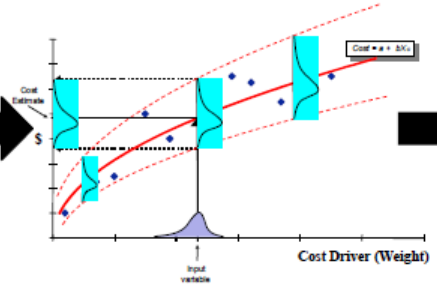
All Cost, Schedule, and Risk Management Processes Performed In Parallel



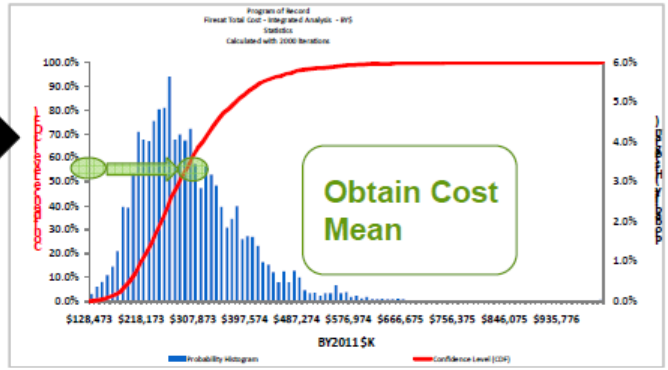
Risks Connected in a Resource Loaded Integrated Master Schedule



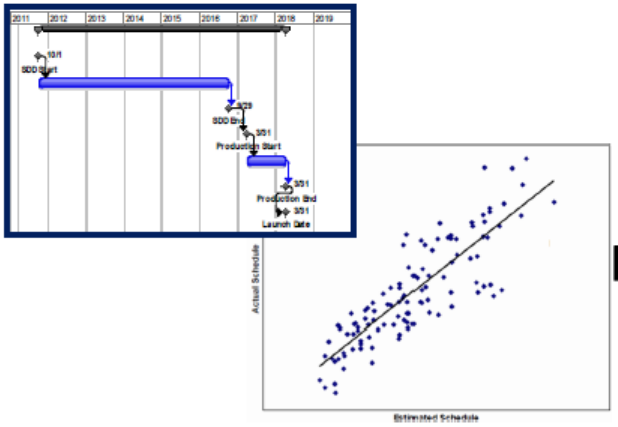
Technical Parameters



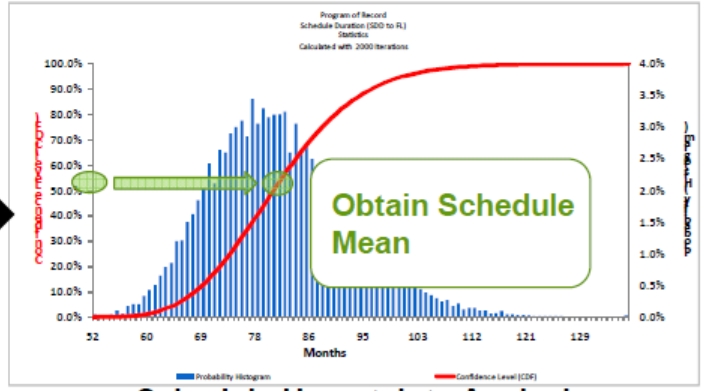
CERs / Cost Model



Cost Uncertainty Analysis



SER/ Schedule Risk Analysis



Schedule Uncertainty Analysis

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Risk Management Pitfalls †

Name	Description
Over-Reliance on Process	Over-reliance on the process side of risk management without sufficient attention to human and organizational behavioral considerations.
Lack of Continuity	Failure to implement risk management as a continuous process. Risk management will be ineffective if it's done just to satisfy project reviews or other discrete criteria.
Over-Reliance on Tool and Technique	Over-reliance on tools and techniques, with insufficient thought and resources expended on how the process will be implemented and run on a day-to-day basis.
Lack of Vigilance	A comprehensive risk identification will generally not capture all risks; some risks will always escape detection, which reinforces the need for risk identification to be performed continuously.
Automatic Mitigation Selection	Automatically select the risk handling mitigation option, rather than evaluating all four options in an unbiased fashion and choosing the "best" option.
Sea of Green	Tracking progress of the risk handling plan, while the plan itself may not adequately include steps to reduce the risk to an acceptable level.
Band-Aid Risk Handling	Handling risks (e.g., interoperability problems with changes in external systems) by patching each instance, rather than addressing the root cause(s) and reducing the likelihood of future instances.

† "Risk Management, Guide to the Systems Engineering Body of Knowledge," https://www.sebokwiki.org/wiki/Risk_Management

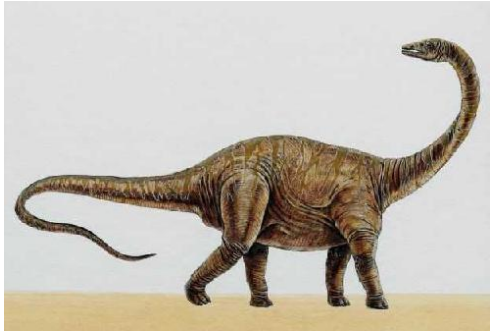
Risk Management Good Practices †

Name	Description
Top Down and Bottom Up	Risk management should be both “top down” and “bottom up” in order to be effective.
Early Planning	Include the planning process step in the risk management process. Failure to adequately perform risk planning early in the project phase contributes to ineffective risk management.
Risk Analysis Limitations	Understand the limitations of risk analysis tools and techniques. Risk analysis results should be challenged because considerable input uncertainty and/or potential errors may exist.
Robust Risk Handling Strategy	The risk handling strategy should attempt to reduce both the probability and consequence of occurrence terms.
Structured Risk Monitoring	Risk monitoring should be a structured approach to compare actual vs. anticipated cost, performance, schedule, and risk outcomes associated with implementing the RHP.
Update Risk Database	The risk management database (registry) should be updated throughout the course of the program, striking a balance between excessive resources required and insufficient updates performed. Database updates should occur at both a tailored, regular interval and following major program changes.

† “Risk Management, Guide to the Systems Engineering Body of Knowledge,” https://www.sebokwiki.org/wiki/Risk_Management

Regression to the Mean? No – Regression to the Tail †

- We speak about risk management in terms of probability (Epistemic Uncertainty) and statistics (Aleatory Uncertainty)
- Unknowingly we use numbers from these distributions that are *Regress to the Mean* – The Most Likely number
  - The Duration value in MSFT Project is the *Most Likely* duration
  - The PERT formula uses {(Minimum + 4 x Most Likely + Maximum)} / 6
  - But in our Risk Management Business, we must address the Regression to the Tail
  - Regression to the Mean is many times simply the combination



† "The Law of Regression to the Tail: How to Survive Covid-19, the Climate Crisis, and Other Disasters," Bent Flyvbjerg, *Environmental Science and Policy,* Octob

But Always – Beware the Black Swan

Risk Bibliography

- Compendium of Risk Management Papers, Books, and Resources
  - https://herdingcats.typepad.com/my_weblog/2021/08/a-compendium-of-risk-management-resources-1.html
- Compendium of Blog Posts on Managing in the Presence of Risk
  - https://herdingcats.typepad.com/my_weblog/2021/07/compendium-of-blog-topics.html
- Presentations, Conference Briefings, Client Briefings on Risk
  - https://herdingcats.typepad.com/my_weblog/2019/04/the-collected-works-to-increase-the-probabilty-of-project-success.html#RM
  - Give the Blog server 15 to 20 seconds to take you to the right spot on the page for Risks.