Managing Risk on New, Large, Complex Projects

Insuring Against Project Perils

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Introduction

- **Topics**
  - **Revisit Concepts for Risk and Risk Management**
  - **How to Implement Risk Management in New, Large, and Complex Projects**
  - **Recent Advances in Risk Assessment**
  - **Useful Risk Metrics**

Some Concepts for Risk and Risk Management

The Concept of Risk

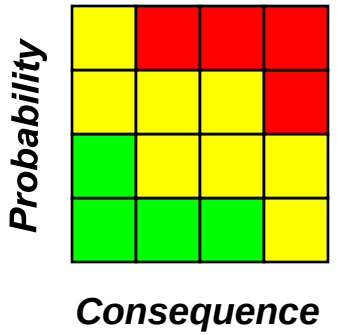
- **What is *Risk*?**
  - **Simply An Uncertain Future Consequence**
    - **The Level of the Consequence is Generally Uncertain**
    - **The *Measure* of Risk is the *Probability that the Consequence at a Specified Level will be Realized***
  - **In General, the Consequence may be Adverse, or Advantageous**
    - **If Only Adverse, We may want to *Expend Resources* to *Avoid it***
    - **If Only Advantageous, We may want to *Expend Resources* to *Make it Happen***
    - **If Both are Possible for a Single Consequence, We may want to *Expend Resources* to Push it from Adverse towards Advantageous**
- **Risk Management is the Process to Decide what to do and Execute**

The Concept of Managing Risk

- **At Heart, A Simple *Decision* Process**
  - **Three Alternatives to be Selected Based on Risk Level**
    - **High – Expend Resources to Reduce Risk Level**
    - **Moderate – Plan for Reduction and Monitor Risk Level Closely and Frequently over Time**
    - **Low – Monitor Risk Level Much Less Frequently**
  - **Must Decide what Combinations of Consequence Levels and Probability Levels Define High, Moderate, and Low**

The Familiar* n X m *Risk Matrix

- ***Green* are Low Risks**
- ***Yellow* are Moderate Risks**
- ***Red* are Unacceptable Risks**



More on the Risk Management Concept

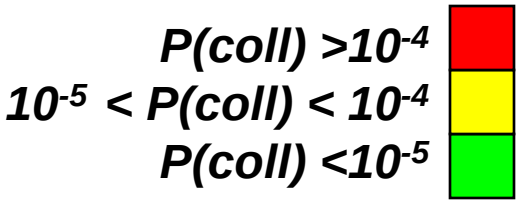
- **The Risk Matrix Illustrates the *Decision Structure***
- **Risk Assessment Provides the *Decision Discriminator***
  - **Statistically Processes Data to Produce an *Assurance* for the Level of Risk**
  - **The Level of Assurance Required for Action is Determined by the *Project Risk Strategy***

Example: NASA Orbital Debris Avoidance

- **A Collision between a Large Piece of Orbital Debris and the Space Shuttle or Space Station would be Catastrophic**
- **If the *Risk of Collision* is Too High**
  - **The Shuttle or Station can Maneuver out of the way of the Debris**
  - **But, the Maneuver ruins Microgravity Experiments and Causes Expensive Replanning**
- **NASA's *Risk Based* Decision**
  - **If P(coll) > 10^{-4}, Then Maneuver out of the Way**
  - **If 10^{-5} < P(coll) < 10^{-4}, Then Plan the Maneuver, Don't Execute, but Monitor P(coll) Frequently**
  - **If P(coll) < 10^{-5}, Just Monitor P(coll) Infrequently**

Possible NASA Strategies

- **The NASA Risk Decision:**



- **Debris and Shuttle/Station Tracking Data are Statistically Processed to Produce the *Assurance Level* for P(coll) > 10^{-4}**
- ***Strategy 1:*** **Maximize Vehicle and Crew Protection**
  - **If Assurance Level (for P(coll) > 10^{-4}) > 10%, Then Maneuver**
  - **Vehicle and Crew are more Important than Experiments**
- ***Strategy 2:*** **Maximize Experiment Protection**
  - **Don't Maneuver *Unless Assurance Level* (for P(coll) > 10^{-4}) > 90%**
  - **Experiment and Replanning Costs Worth Risk to Vehicle and Crew**

How to Implement Risk Management in New, Large, Complex Projects

The Role of Risk Management in a Project

- **All Project Plans are *Risk Management Plans***
  - **All Designed and Developed to *Maximize* the Probability of Project Success (to Minimize Risk of Failure)**
  - **If Managers are *Omniscient*, Anticipate Everything that can Possibly Happen and Account for it in the Plan, then No Need for Risk Management**
- ***However –***
  - **Nobody is Omniscient**
  - **The Problem *Always* Changes with Time**
- ***Risk Management addresses those Uncertain Future Consequences that Nobody Anticipated at the Start of the Project***

Risk Management Processes

- ***Risk Planning*** **– Establish Procedures for Conducting Risk Management on the Project**
- ***Risk Identification*** **– Discovery of Unanticipated Uncertain Future Consequences during the Project**
- ***Risk Analysis*** **– Establish Root Causes and Sensitivities**
- ***Risk Assessment*** **– Statistically Process Data to Determine Assurance of Risk Level**
- ***Risk Mitigation*** **– Plan and Execute a Project to Reduce or Eliminate Risk Level**
- ***Risk Tracking and Control*** **– Monitor and Measure Risk Management on the Project**
- ***Risk Communication*** **–** ***Explaining How Project Success is Being Assured***

How to Implement a Risk Management Process

- **Project Manager and Chief Systems Engineer Decide on *Risk Margins* for Budget and Schedule**
  - **Based on *Thoroughness* of Project Management Plan**
  - **Based on Factors related to Inherent Risks – e.g., newness of technology, complexity, size, etc.**
  - **Risk Margin Resources Primarily used for Risk Analysis, Assessment, and Mitigation**
- **Project Manager and Chief Systems Engineer Determine Project *Risk Strategy* (ies)**
- **Chief Systems Engineer Appoints a Risk Manager**
  - **Risk Manager Develops *Risk Management Plan* and Manages Risk Activities**
  - **Systems Engineering Management Plan Establishes *Risk Identification Culture* and Processes for Project Team to Identify Risks**

How to Use Risk Management in a Project

- ***All* Project Personnel and Teams should be Actively Identifying Risks as *Normal Part of Job***
- **Risk Manager and RM Team**
  - ***Review* Risks Identified by Project Personnel**
  - **Assign Risk Analysis Tasks to Engineering and Project Teams as Needed**
  - **Perform Risk Assessments as Needed (including Monitoring)**
  - **Propose Risk Mitigation Plans for Project Team to Execute**
  - **Track and Control All Risks**
  - **Prepare Risk Metrics and Risk Communications**
- **Project Manager and Chief Systems Engineer**
  - **Communicate Risk Metrics and Overall Risk Posture Project**
  - **Decide Upon Risk Mitigations, Assign Tasks to Project Teams**
  - **Manage Risk Margins, Release Resources *Only* when Project Risk Posture Diminishes with Time and Project Maturity**

Use of Risk Margins

- **95+% of Resource Expenditures on Risk Management**
  - **Performance of Risk Analyses by Engineering or Project Teams**
  - **Performance of Risk Assessments by RM Team**
  - **Performance of Risk Mitigation Plans by Project Teams**
- **< 5% of Resource Expenditures on Risk Management**
  - **Risk Planning**
  - **Risk Tracking and Control**
  - **Risk Communications**
- **Risk Identification Should be Part of Normal Job and thus not Use Risk Margin Resources**

Recent Advances in Risk Assessment

Risk Assessment

- **Risk Assessment Answers a Simple Question:**

  Based on the Available Data, How Sure can we be that the Risk Level is Unacceptable?

- **Risk Assessment Can be Purely *Qualitative* (Seat of the Pants, Shoot from the Hip, Best Engineering Judgment, or just a Guess)**
- ***Quantitative* Risk Assessments are Most Effective**
  - **Unfortunately, Available Statistical Packages Do *Not* Calculate Assurance Levels for Risks, Definitely not without a Lot of Assumptions**
  - **Up until about 1995, *Impossible* to do Quantitative Risk Assessments for Real World Problems**

Quantitative Risk Assessments

- **The Problem**
  - **Risk Assessment Formulations for Real World Problems almost always *Analytically Intractable***
  - **Numerical Approaches (Monte Carlo Methods) almost always *Impossible***
- **The Solution**
  - **In the Mid 1990's, European Biomedicine Began Using New Numerical Methods for Risk Assessments**
  - **New Methods work with Analytically Intractable Risk Assessment Formulations**
  - ***Markov Chain Monte Carlo* Methods**

Markov Chain Monte Carlo

- **A *More General* Version of Monte Carlo Methods**
  - **Does *Not* Require Defined Sampling Models**
  - **Does *Not* Require Assumptions, *Completely Objective***
  - **Will Work with Analytically Intractable Formulations**
  - **Can work for Very High Dimensional Problems (up to 20,000 related sources of uncertainty)**
  - **Simple to Code, but Not Amenable to Packaging as a Computational Tool**
- **When Used in Risk Assessment, Provides *Full Quantitative Assurance of Risk Levels* for the Most Complicated Problems**

For More Information on MCMC

- **Numerous Texts, Check Amazon**
- **Contact Welcome**
  - **Articles**
  - **Examples**
- **Stevens Courses**
  - **SYS 601:** ***Probability and Statistics for Systems Engineers***
  - **SYS 660:** ***Decision and Risk Analysis for Complex Systems***
  - **Webcampus: http://webcampus.stevens.edu**

Useful Risk Metrics

The Problem with Risk Management

- **A good risk management process results in nothing happening – *the Project Succeeds!***
- **How does one *measure* RM performance?**
- **Multiple choice:**
  - **If a project meets its performance goals, then …**
    A. **It's risk management process was successful**
    B. **The project had a run of good luck**
    C. **The project was under-constrained**
    D. **All of the above**
  - **If a project overruns its cost commitments, then …**
    A. **Its risk management process failed**
    B. **The project got a bad roll of the dice**
    C. **The project was over constrained**
    D. **All of the above**

Risk Management Metrics?

- **What do you measure?**
- **How do you measure it?**
- **How do we know what is a "good" measurement, or a "bad" measurement?**
- **The International Council on Systems Engineering (INCOSE) Chartered Risk Management Working Group (RMWG) to Investigate RM Metrics**

INCOSE RMWG
RM Metrics Proposal

- **RM Metrics Classified by Usage Frequency**
  - ***Infrequent* Metrics**
    - **Usually before or after a project**
    - **When significant performance issues are noted**
    - **During the development of a Risk Management process**
  - ***Continuous* Metrics**
    - **Measure the process during execution**
    - **Measure the quality of the products during execution**
    - **Attempt to make interim corrections if needed**
  - ***On-demand* Metrics**
    - **When a measurable result is available, compare to expectations**
    - **Ad Hoc or Periodic**

Infrequent Metrics and Measurements

- **Compliance to organization's standards**
  - **Build a compliance matrix – extract "Shall" statements**
  - **Compare project's process against the organization's standards**

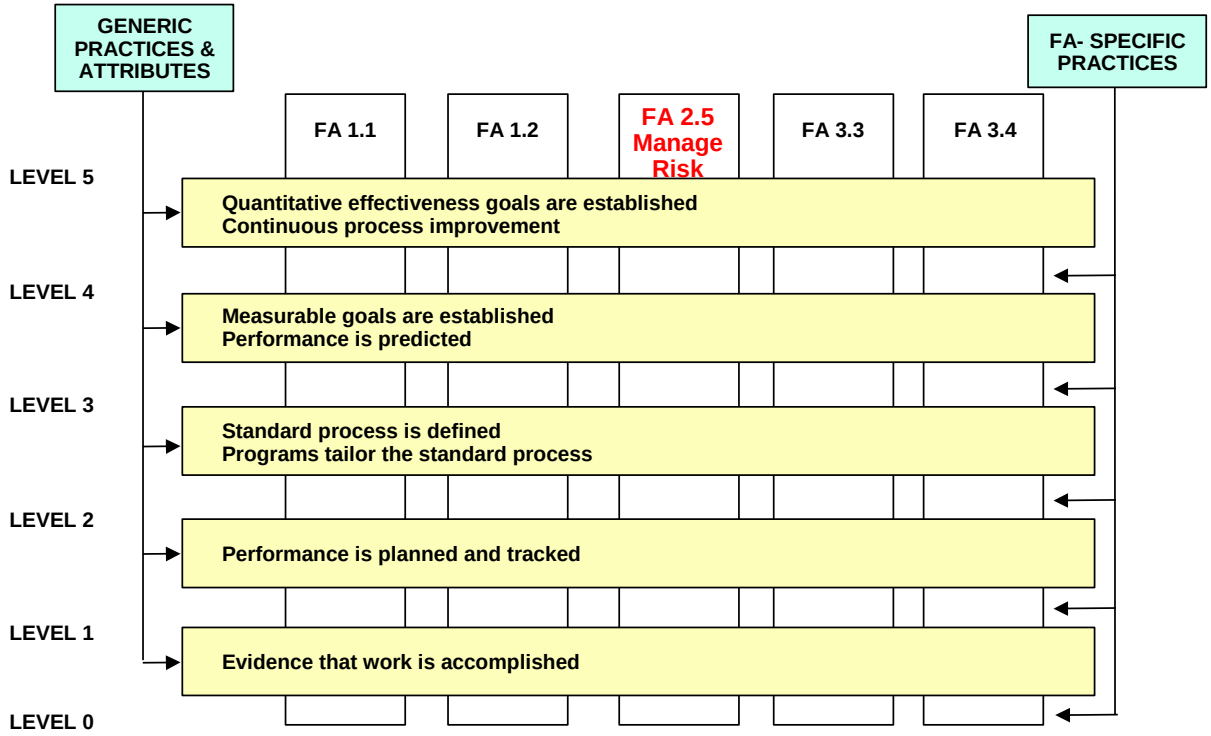
Project Compliant?	"Shall" Statement	Project RM Plan Paragraph
5	The identification of risk shall be actively encouraged at all levels in the Project Team	Pg. 2, Section 1.6
4	Risk identification shall be accomplished by entering the information into the Kepler Risk Database through the Kepler Risk Tracking Tool.	Pg. 2, Section 1.6
	ied risks shall be reviewed by Project ent on a cyclical basis and accepted, assigned to a er for action, rejected or retired.	Pg. 2, Section 1.6

A scale of 1 to 5 indicating level of compliance

Corrective Action?

Infrequent Metrics and Measurements

- **Compliance to “Best Practices”**
- **No consensus on what are “Best Practices”**
- **Use CMMs as a substitute**



Continuous Metrics

- **Compliance to Plan**
- **Performance**
  - **Effectiveness**
  - **Efficiency**
  - **Staleness**
- **Trending**

Continuous Metrics: Compliance to Plan

- ***Compliance* to RM Plan**
  - **Is the project actually doing what it said it would do?**
  - **A simple compliance matrix**
  - **Shall statements from the RM Plan for the project versus evidence that the activities are actually performed**
  - **Determine corrective action**

Continuous Metrics: Performance

- **Performance – measure the performance of the process**
  - ***Effectiveness***
    - **Effective: No or very few unforeseen "problems" occur**
    - **Approach: How many "problems" occurred that were never identified as risks**
  - ***Efficiency***
    - **Efficient: Catching risks early when it is more cost effective to mitigate them**
    - **Approach: Measure the time between when a risk was identified and when it became a problem**
  - ***Staleness***
    - **How many risk products are "stuck" in a process step and how long have they been there**

The Effectiveness Metric

- **Performance – *Effectiveness***
  - **Premise: An effective risk management system will prevent unexpected problems**
  - **P_E, Process Effectiveness is the ratio of problems encountered, N_p, that were not identified as risks, to the risks identified, N_r**

    $$P_E = 1 - N_p/(N_p + N_r)$$
  - **Measure of goodness, 90% good, 80% watch, 70% Action**
  - **Action: causal analysis and process improvement**

The Efficiency Metric

- **Performance – *Efficiency***
  - **Premise: An efficient risk management system is one in which the planning and mitigation of risks occurs well before they become problems**
  - **For n realized risks, P_e, Process efficiency, is the average time lapse between all risks' identification date, T_{ID}, and the time that it is realized, T_R,**

$$P_e = \sum(T_{R,i} - T_{ID,i})/n,$$

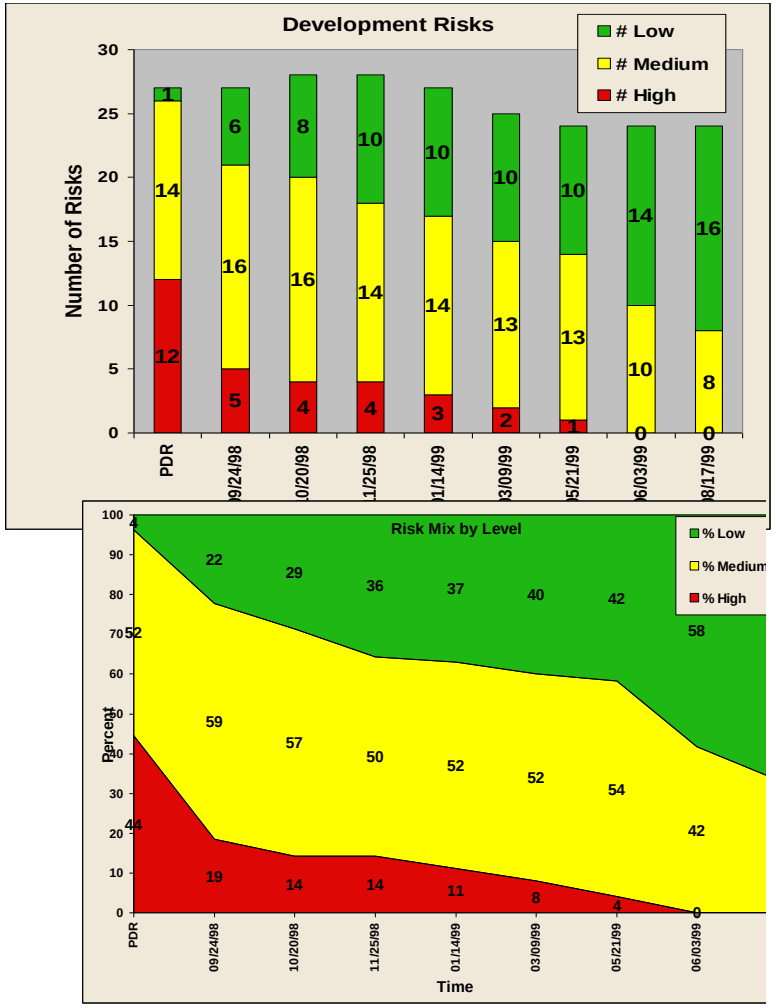
  - **Measure of goodness, the larger the better**
  - **Action: causal analysis and process improvement**

The Staleness Metric

- **Performance – *Staleness***
  - **Residence time for risks in major steps**
  - **Short residence times: < ~30 days, are "Excellent"; long residence times: ~180 are "Very Poor"**
  - **Measure of goodness: 90% short: good, 80% short: watch, < 70% short: Action**
  - **Action: directed project management attention to insure actions**
- **Example measures:**
  - ***First Latency*: Time identified to time first action by project management**
  - ***Second Latency*: Time from assignment to a Risk Owner to time the project "Accepts" the risk mitigation plan**
  - ***Subsequent Latencies*: Lateness tracked against dates on the steps in the risk mitigation plan**

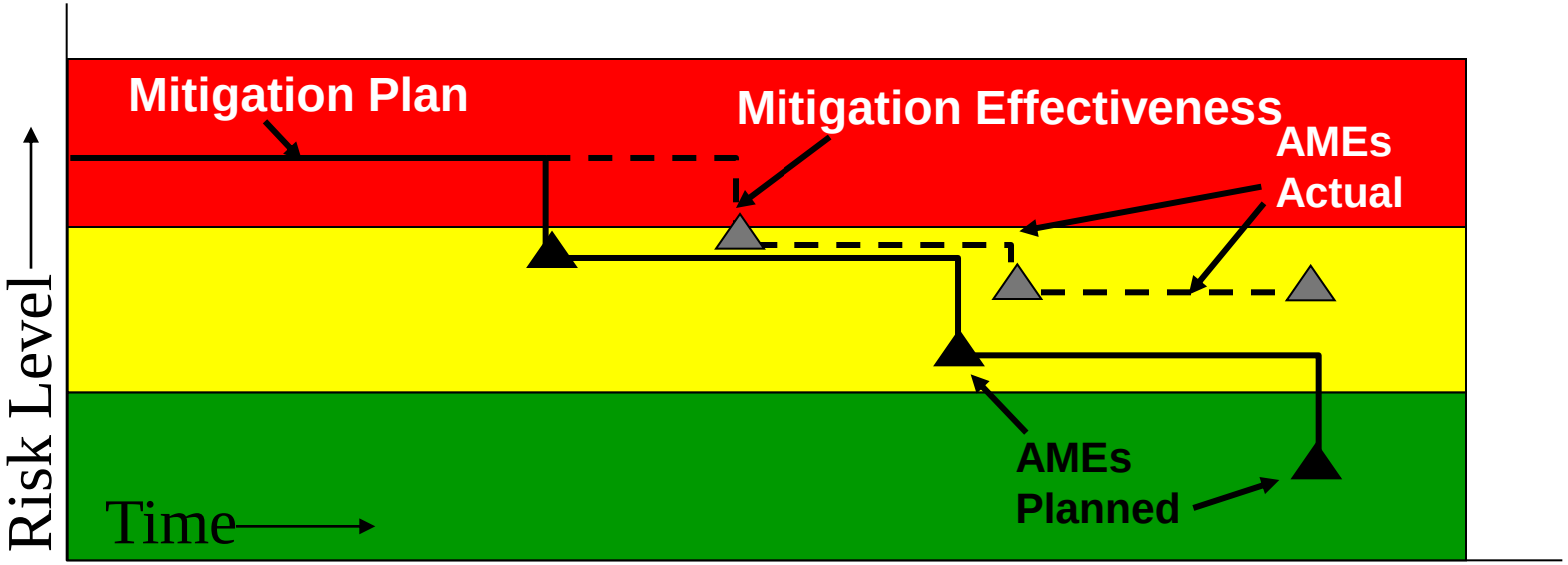
Trending Metrics

- Body Count versus time
- Measure Risk Level Changes
- Goodness is more vague on this one
  - No change is “bad”
  - Increasing risk numbers may be “bad”
  - A decreasing trend in the red and yellow is good
- Action: directed project management attention to insure actions



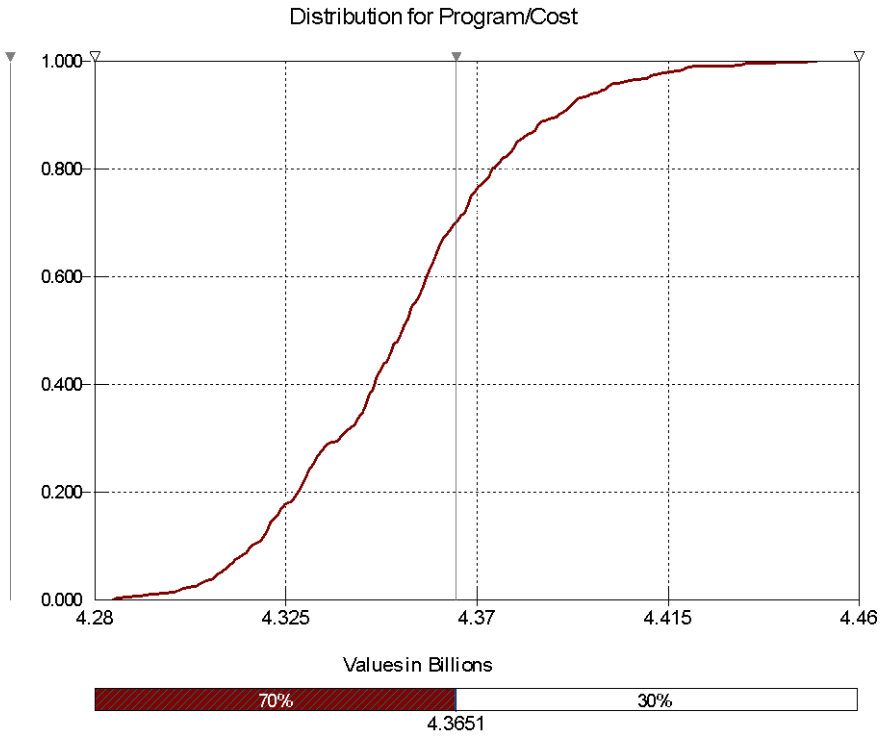
More Trending Metrics

- Waterfall charts
- Measure
  - Latency (Calculated elsewhere)
  - Errors in prediction of impact or effectiveness of mitigation
- Goodness: Miss residual risk by “half a color”
- Action: directed project management attention to correct



On-Demand Metrics: Results

- **Based on risks that have been accepted by the project either with or without mitigation**
- **Should those risks be realized, the impact is measured**
- **Compare the measured impact with the predicted impact**
- **Action: causal analysis and process improvement**



Summary of Metrics

- ***Infrequent***
  - **Measure the quality of the process**
  - **Compliance to the organization's standards**
  - **Comparison with Best Practices**
- ***Continuous***
  - **Compliance to plan**
  - **Performance**
    - **Effectiveness**
    - **Efficiency**
    - **Staleness**
  - **Trending**
- ***On-demand***
  - **Results - for "accepted" risks that are realized, compare actual risk outcomes with predictions.**

INCOSE RMWG Recommendation

- **A *Proper Combination* of Metrics should be Selected**
  - **Individual Metrics are Not Sufficient**
  - **Should Include Each Frequency Type**
- **Risk Management Performance is Measurable and Hence Manageable**
- **Risk Management Can be *Justified***

Summary and Conclusions

- **Risk Management *Insures Against Project Perils* to *Ensure Project Success***
- **Proper Risk Management and Risk Communications *Improve Customer and Line Management Confidence***
- **New Numerical Methods Enable *Quantitative Risk Assessment* without Assumptions to Make Risk Management More *Effective* and *Efficient***
- **A Good Set of Risk Management Metrics Enable Effective Management of the RM Process, and *Good Communications***

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