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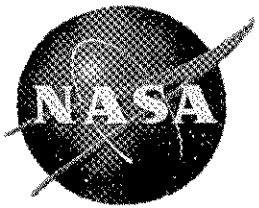

Achieving a Risk-informed Decision-making Environment at NASA:

The Emphasis of NASA's Risk Management Policy

Presented at

Eighth Space Systems Risk Management Symposium
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The Aerospace Corporation, El Segundo, CA

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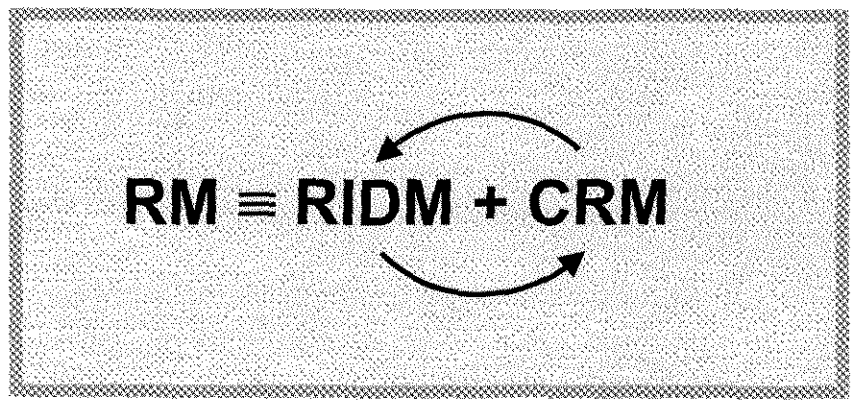
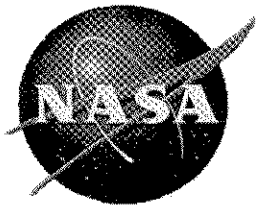
Background

- **Approved December 16, 2008, NPR 8000.4A, Agency Risk Management Procedural Requirements, evolves NASA's risk management (RM) approach to entail two complementary processes:**
  - **Risk-informed Decision Making (RIDM)**
    - To risk-inform direction-setting decisions (alternative selection)
    - To risk-inform the development of credible performance requirements as part of the overall systems engineering process
  - **Continuous Risk Management (CRM)**
    - To manage risk associated with the implementation of baseline performance requirements



Background (Cont.)

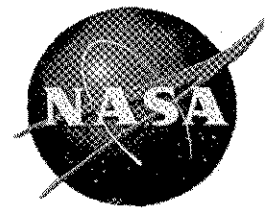


- **Approved January 15, 2009, NASA NPD 1000.5, Policy for NASA Acquisition, states:**

"It is NASA policy to incorporate in the overall Agency risk management strategy a risk- informed acquisition process that includes the identification, analysis, and management of programmatic, infrastructure, technical, environmental, safety, cost, schedule, management, industry, and external policy risks that might jeopardize the success with which the Agency executes its acquisition strategies."

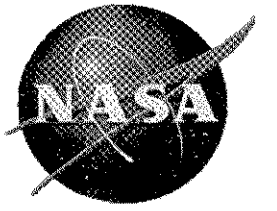
NPD 1000.5 defines "Acquisition" very broadly: "the process for obtaining the systems, research, services, construction, and supplies that the Agency needs to fulfill its mission. Acquisition--which may include procurement (contracting for products and services)--begins with an idea or proposal that aligns with the NASA Strategic Plan and fulfills an identified need and ends with the completion of the program or project or the final disposition of the product or service."

Motivating Factors



- To promote a RM approach that is heuristic, proactive , and coherent across the Agency
  - Agency strategic goals explicitly drive RM activities at all levels
  - All risk types and their interactions are considered collectively during decision-making
  - Focusing on "forest-level" risk picture, from which the tree-level "individual risks" should be derived and within the context of which the "tree-level" risks are prioritized and managed
  - RM activities are coordinated horizontally and vertically across the Agency
- To better match the stakeholder expectations and the "true" resources required to address the risks to achieve those expectations
  - To have an integrated perspective of risks when analyzing competing alternatives
  - To better comprehend the risk that a decision-maker is accepting when making commitments to stakeholders
  - To have a consistent basis for comparing alternatives
- To risk-inform the development of credible performance requirement

What is RIDM and When is it Invoked?

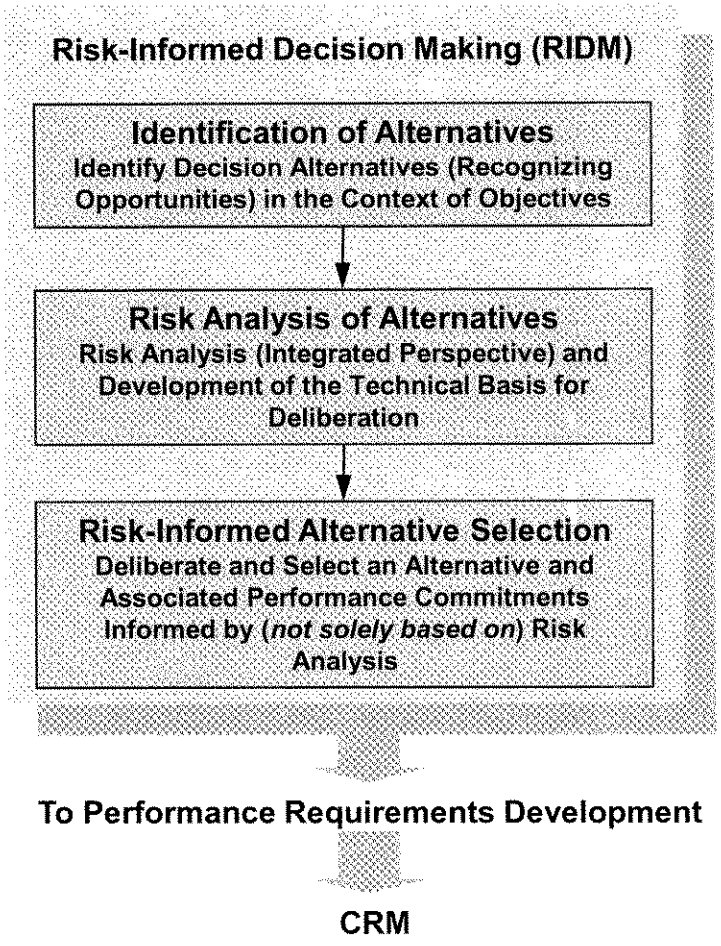


- **A risk-informed decision-making process that uses a diverse set of performance measures (some of which are model-based risk metrics) along with other considerations within a *deliberative* process to inform decision making.** *Paragraph A.14 of NASA NPR 8000.4A*
  - **Within RIDM, decisions are informed by an integrated risk perspective rather than being informed by a set of individual "risk" contributions whose cumulative significance is not understood**
  - **A decision-making process relying primarily on a narrow set of model-based risk metrics would be considered "risk-based"**
- **RIDM is invoked for key decisions such as architecture and design decisions, make-buy decisions, and budget reallocation (allocation of reserves), which typically involve requirements-setting or rebaseling of requirements**

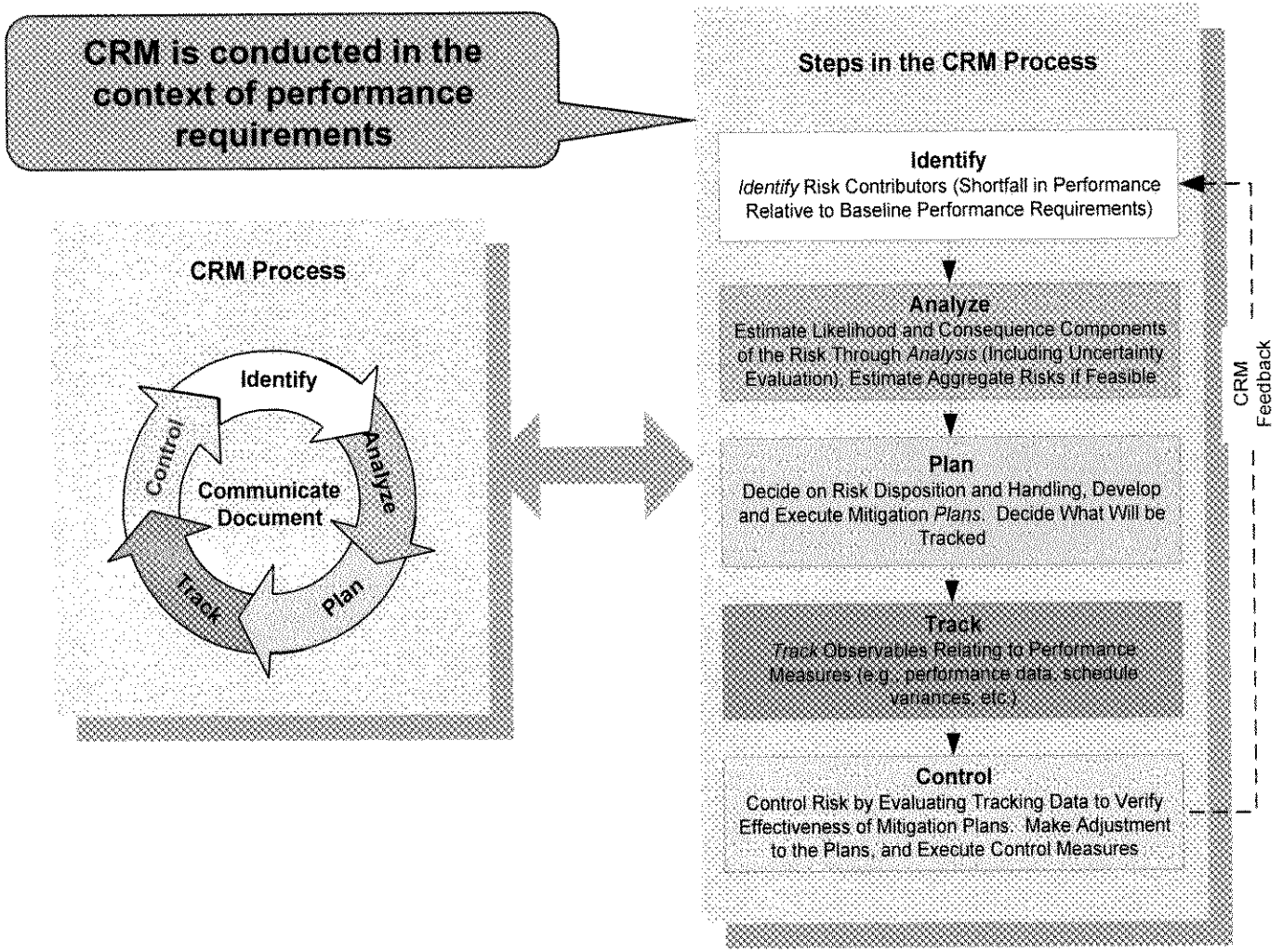
The RIDM Process

Based on NPR 8000.4A

- **Identification of decision alternatives (*decision context*) and considering a sufficient number and diversity of Performance Measures**
- ***Risk analysis* of decision alternatives (uncertainty analysis of performance associated with the alternative**
- ***Deliberation and Selection* of a decision alternative *informed by* (not solely based on) Risk Analysis Results**

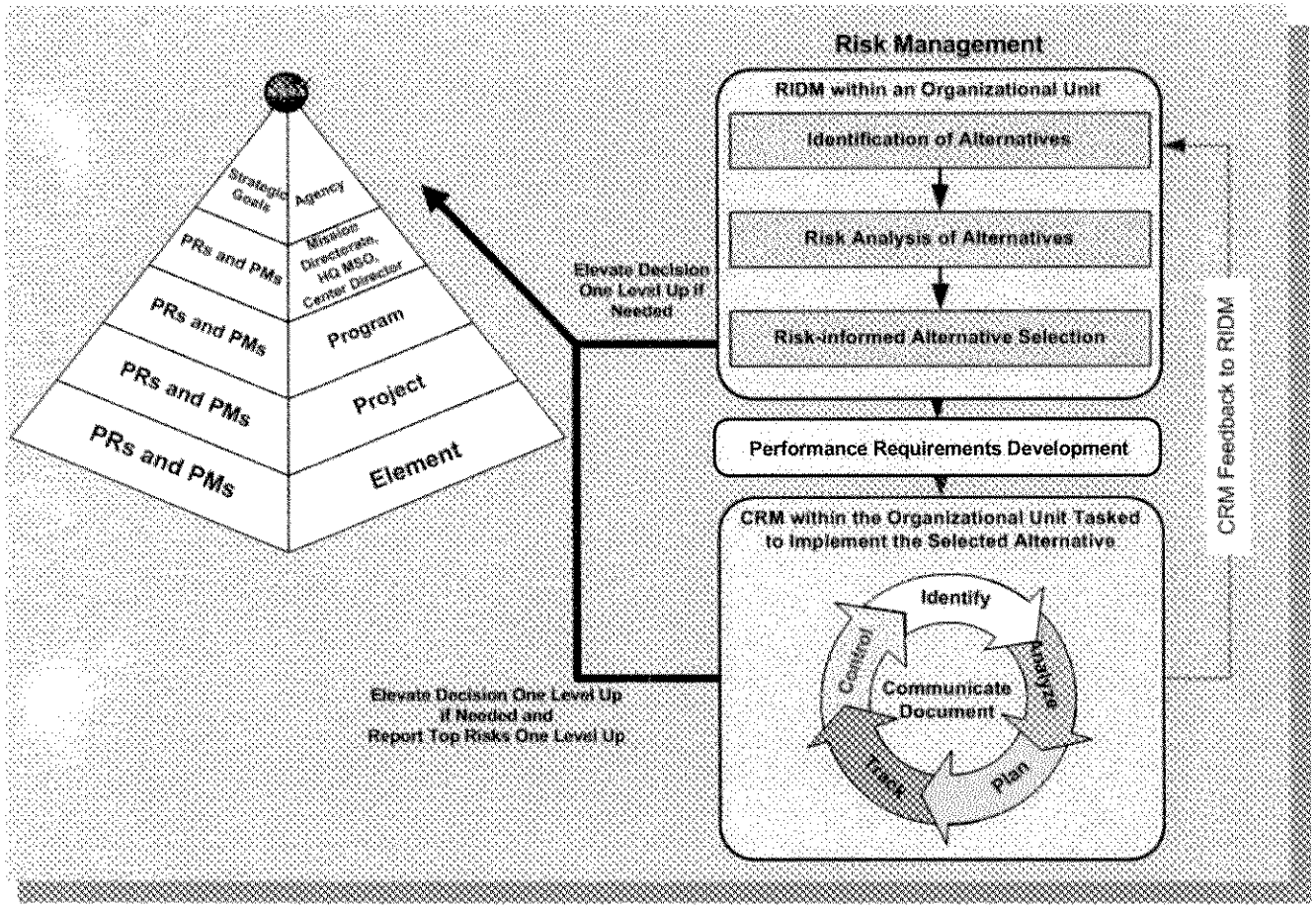


The Continuous Risk Management (CRM) Process

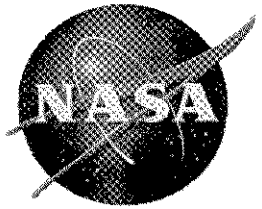


RM = RIDM + CRM

- **RIDM and CRM operate at each level of the NASA hierarchy, with interfaces for the flowdown of requirements, the elevation of risk management decisions, and the communication of risk information**

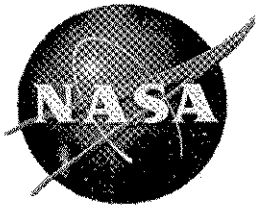


Performance Measures, Performance Objectives, and Performance Requirements



- **A Performance Measure (PM) is a metric used to quantify the extent to which a Performance Objective is fulfilled**
  - **Safety** (e.g., avoidance of injury, fatality, or destruction of key assets)
    - **Maintain Astronaut Safety → Probability of Loss of Crew (P(LOC))**
  - **Technical** (e.g., increase thrust or output, maximize amount of observational data acquired)
    - **Maximize Payload Capability → Payload Capability (kg)**
  - **Cost** (e.g., execution within minimum cost)
    - **Minimize Cost → Cost ($)**
  - **Schedule** (e.g., meeting milestones)
    - **Minimize completion time → Schedule (months)**
- **The PM values imputed to the selected alternative are Performance Requirements**
  - **They essentially define "success"**
  - **Significant shortfalls in performance are "failures"**

Definition of Risk According to NPR 8000.4A

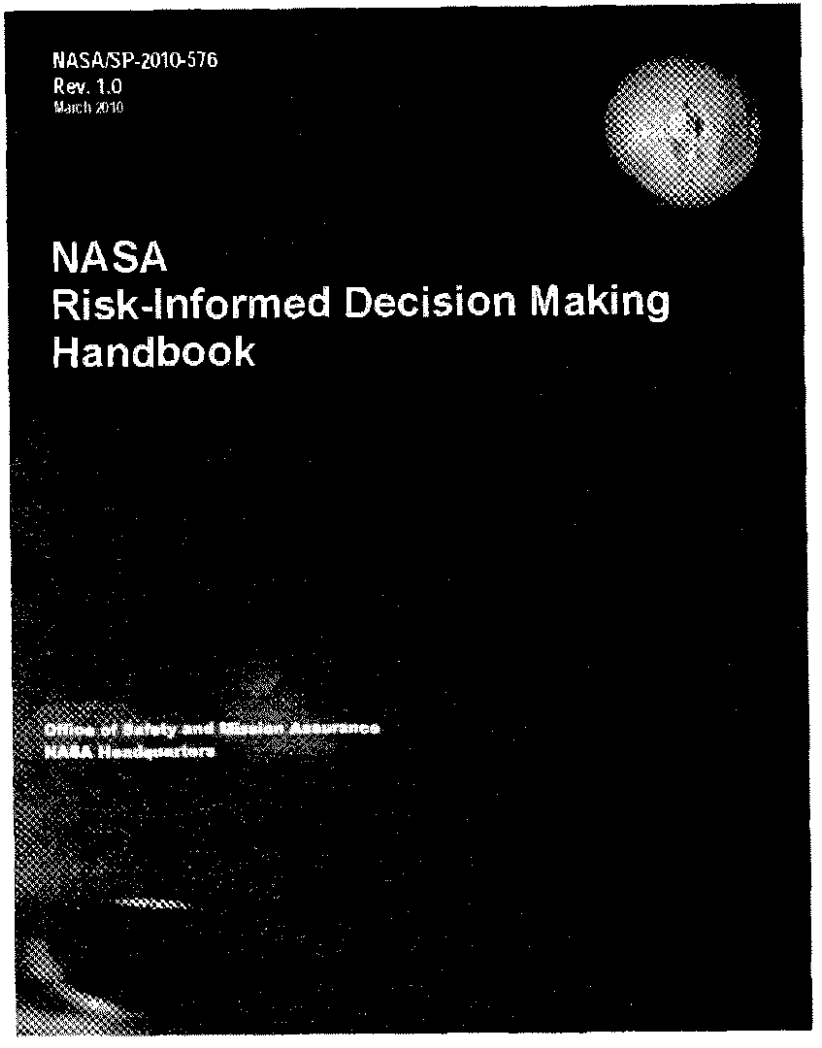


- **In general, risk is uncertainty regarding the future outcome of an undertaking of some kind, e.g., a decision alternative, a project, a launch, etc.**

- **In the context of mission execution, risk is the expression of the potential for performance shortfalls, which may be realized in the future, with respect to achieving explicitly established and stated performance requirements**
  - **The performance shortfalls may be related to any one or more of the following mission execution domains:**
    - **Safety**
    - **Technical performance**
    - **Cost**
    - **Schedule**

RIDM Process Steps

Based on NASA/SP-2010-576 (In Draft)



Risk-Informed Decision Making (RIDM)

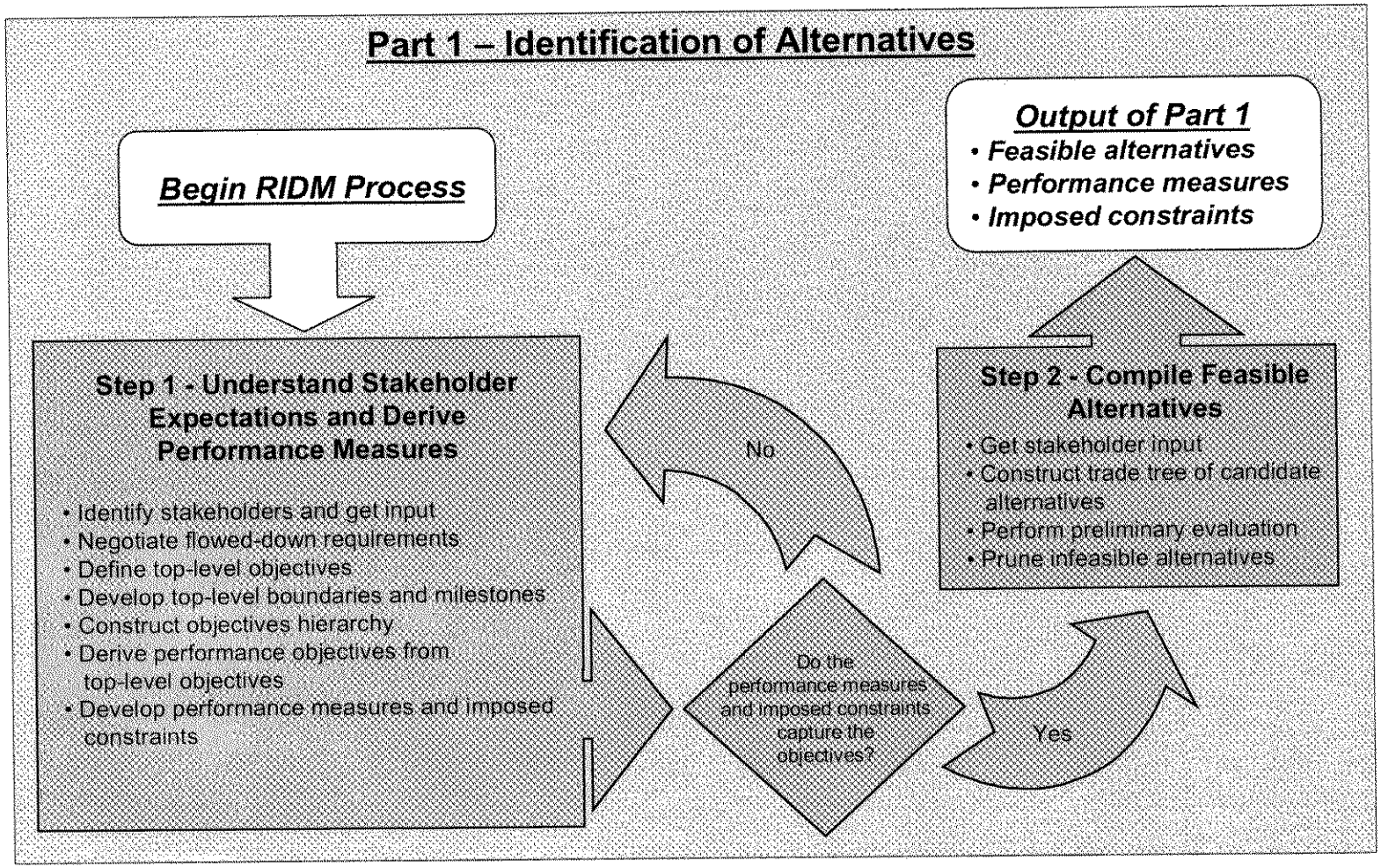
Part 1 - Identification of Alternatives
- Step 1 – Understand Stakeholder Expectations and Derive Performance Measures
- Step 2 – Compile Feasible Alternatives

Part 2 - Risk Analysis of Alternatives
- Step 3 – Set the Framework and Choose the Analysis Methodologies
- Step 4 – Conduct the Risk Analysis and Document the Results

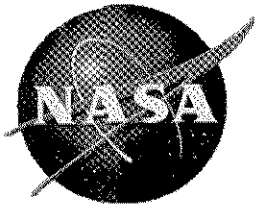
Part 3 - Risk-Informed Alternative Selection
- Step 5 – Develop Risk-Normalized Performance Commitments
- Step 6 – Deliberate, Select an Alternative, and Document the Decision Rationale

To Requirements (Re)Baselining

RIDM Process: Part 1

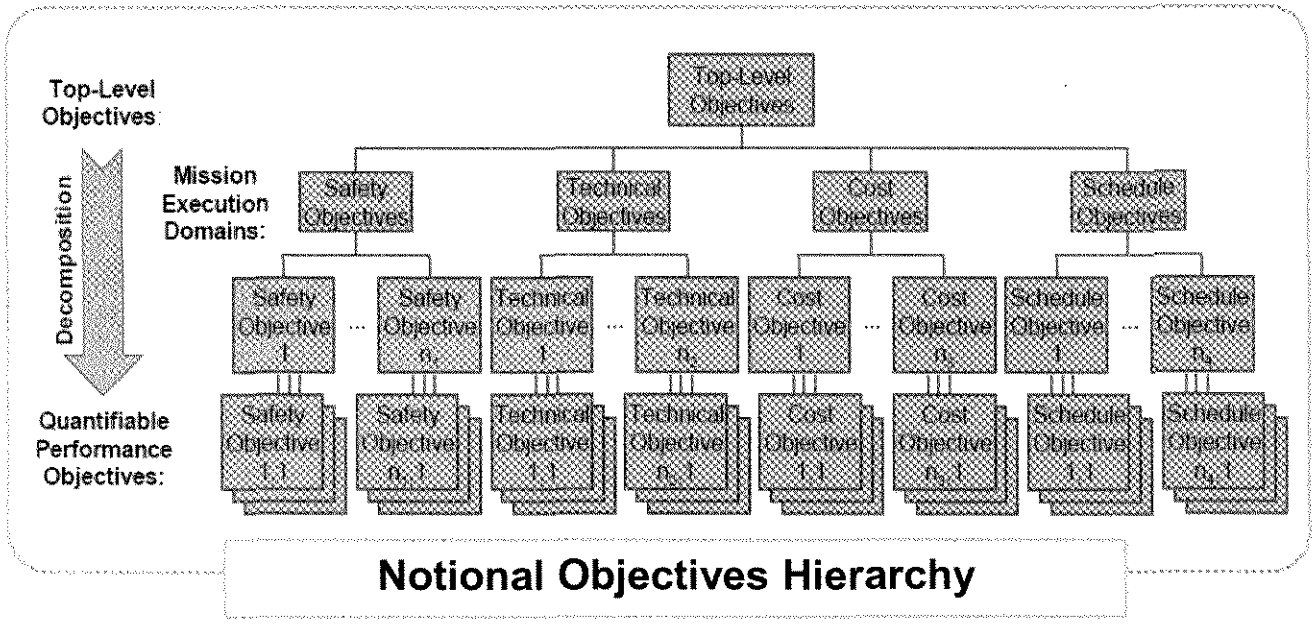


Derive Performance Measures from Objectives



- **In general, it can be difficult to assess decision alternatives against multifaceted and/or qualitative top-level objectives**

- **To deal with this situation, objectives are decomposed, using an objectives hierarchy (OH), into a set of lower-level performance objectives that any attractive alternative should have**



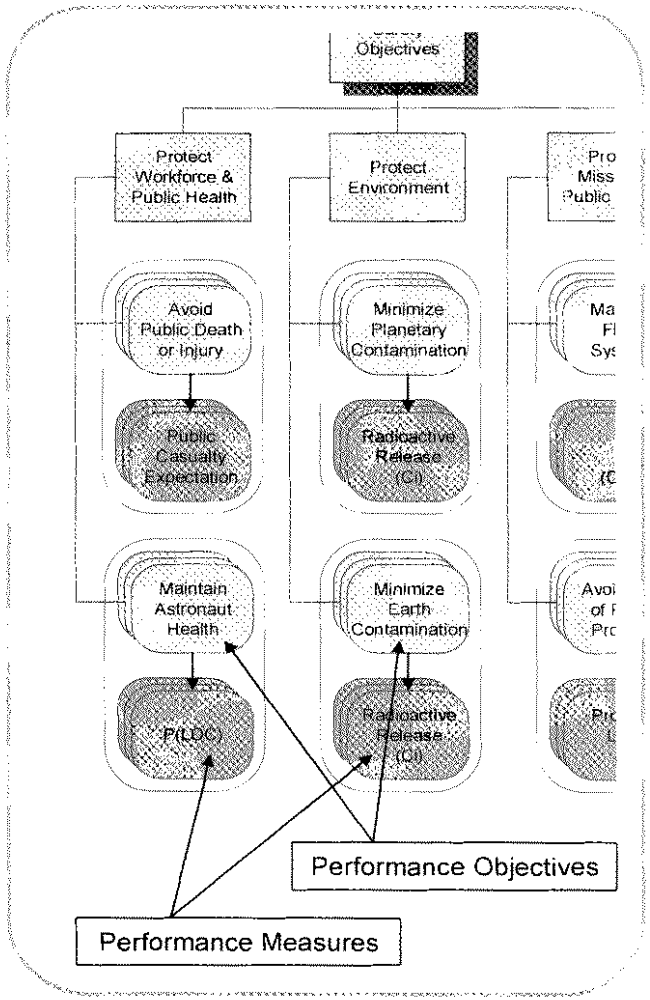
Notional Objectives Hierarchy

Derive Performance Measures from Objectives (cont.)

- A performance measure is then developed for each performance objective, as the quantity that measures the extent to which a decision alternative meets the performance objective

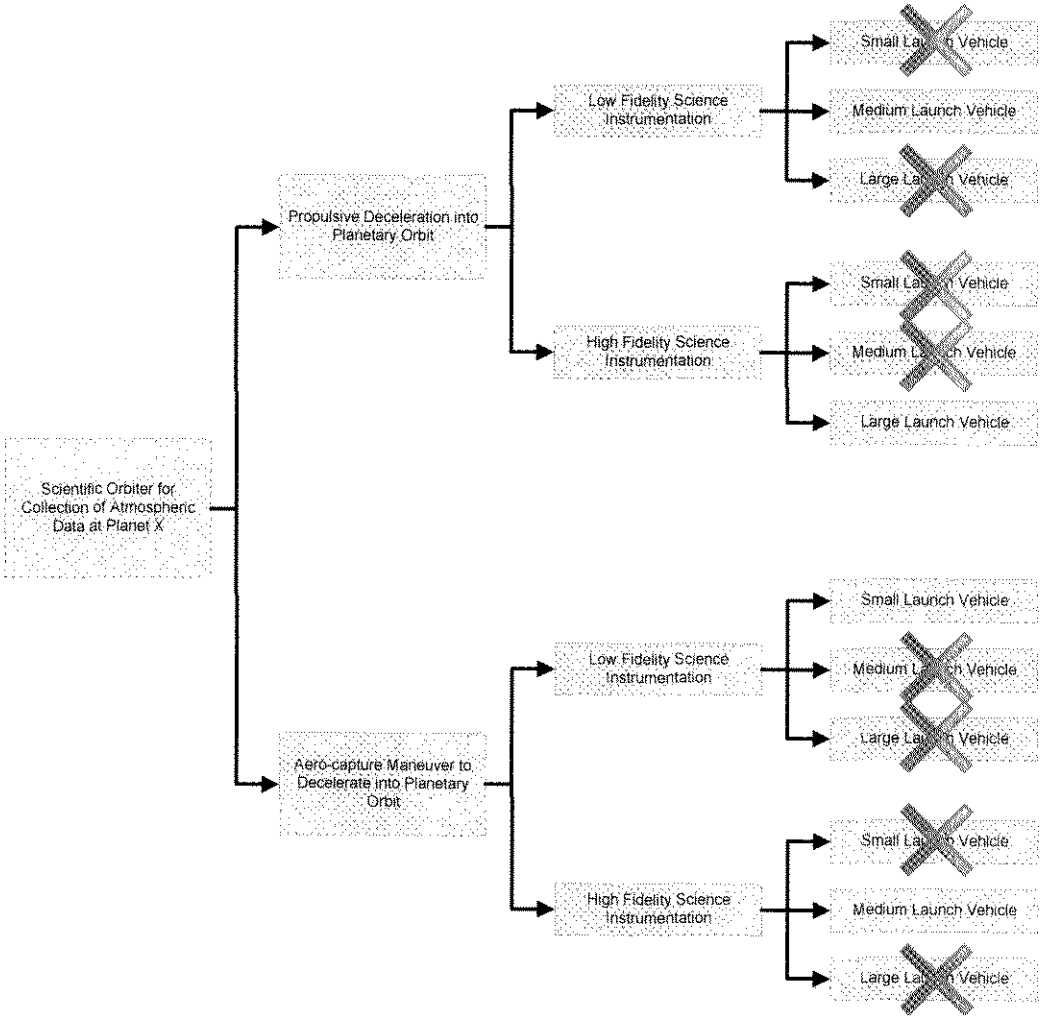
- Some performance measures may have *imposed constraints*
  - Example: A hard limit on minimum acceptable payload capability

- Some performance measures are unconstrained but have a desirable direction of goodness

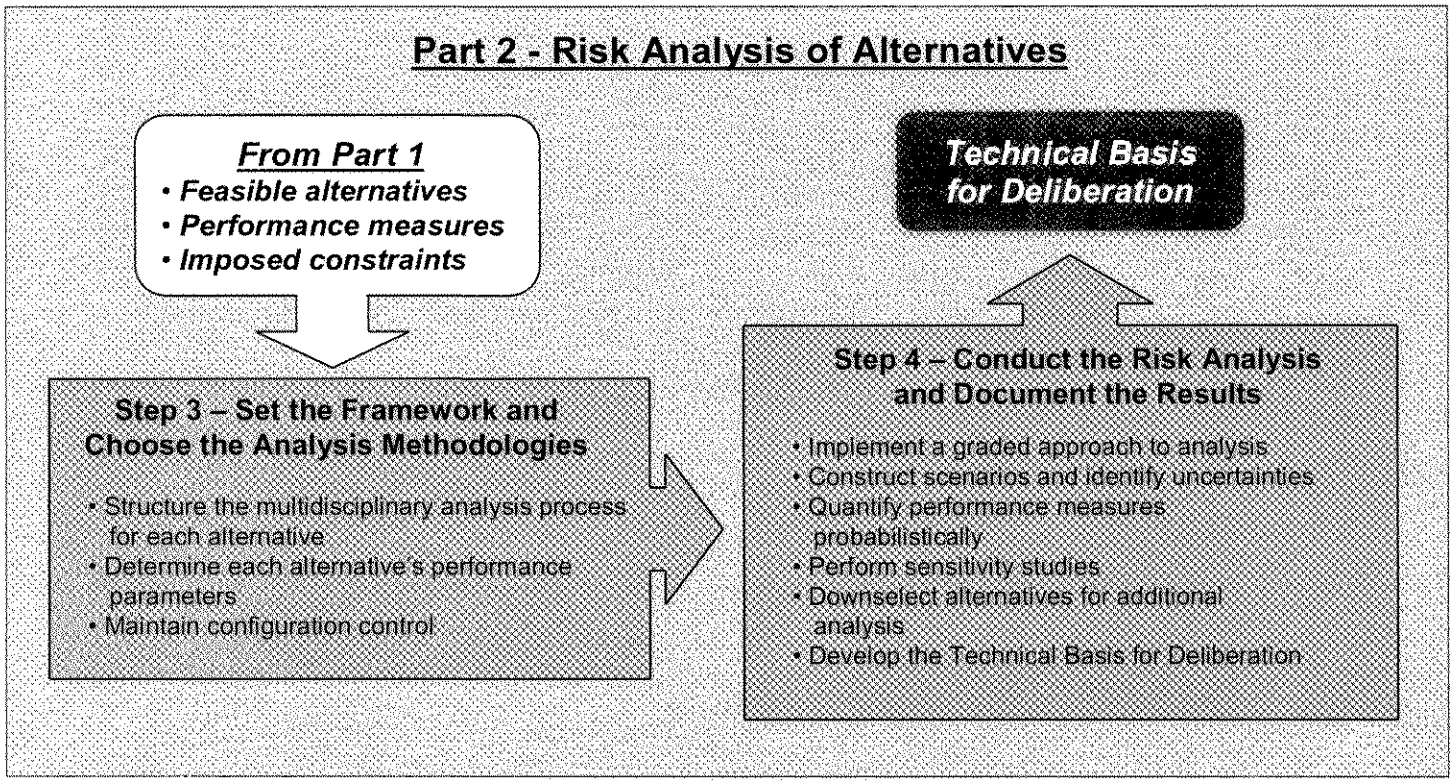


Compiling Alternatives

- **Alternative design solutions are generated as part of the Systems Engineering process**
- **Low-fidelity feasibility assessment (e.g., first-order analysis, engineering judgment) is used to prune the trade tree and narrow the set of alternatives to analyze further**

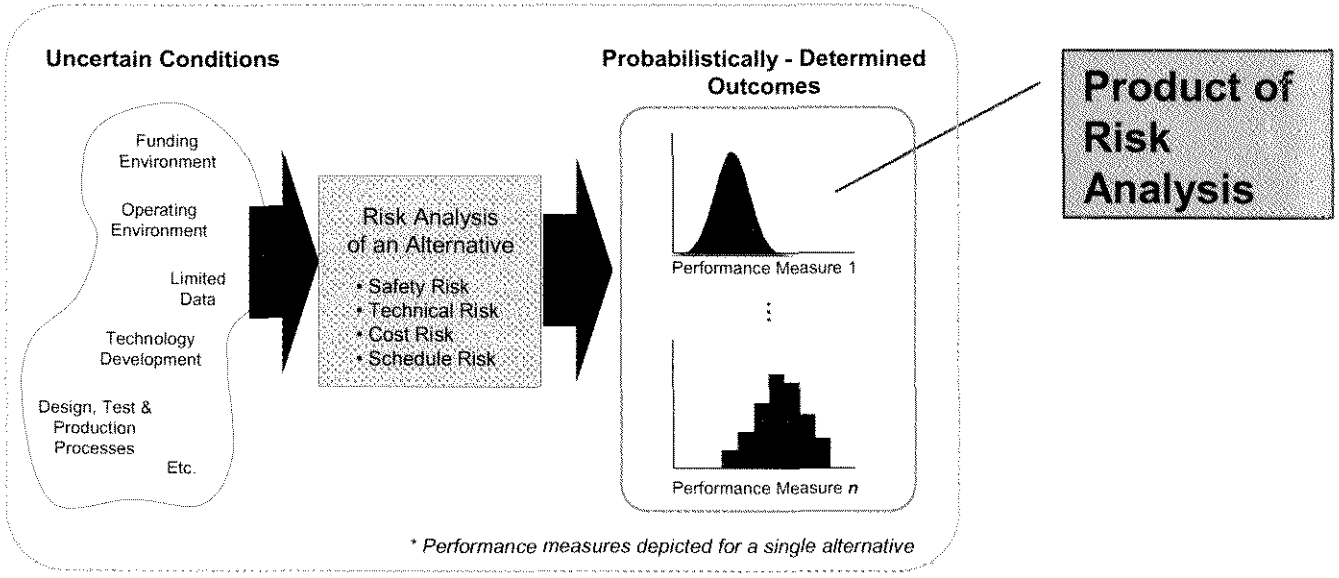


RIDM Process: Part 2



Risk Analysis of Alternatives

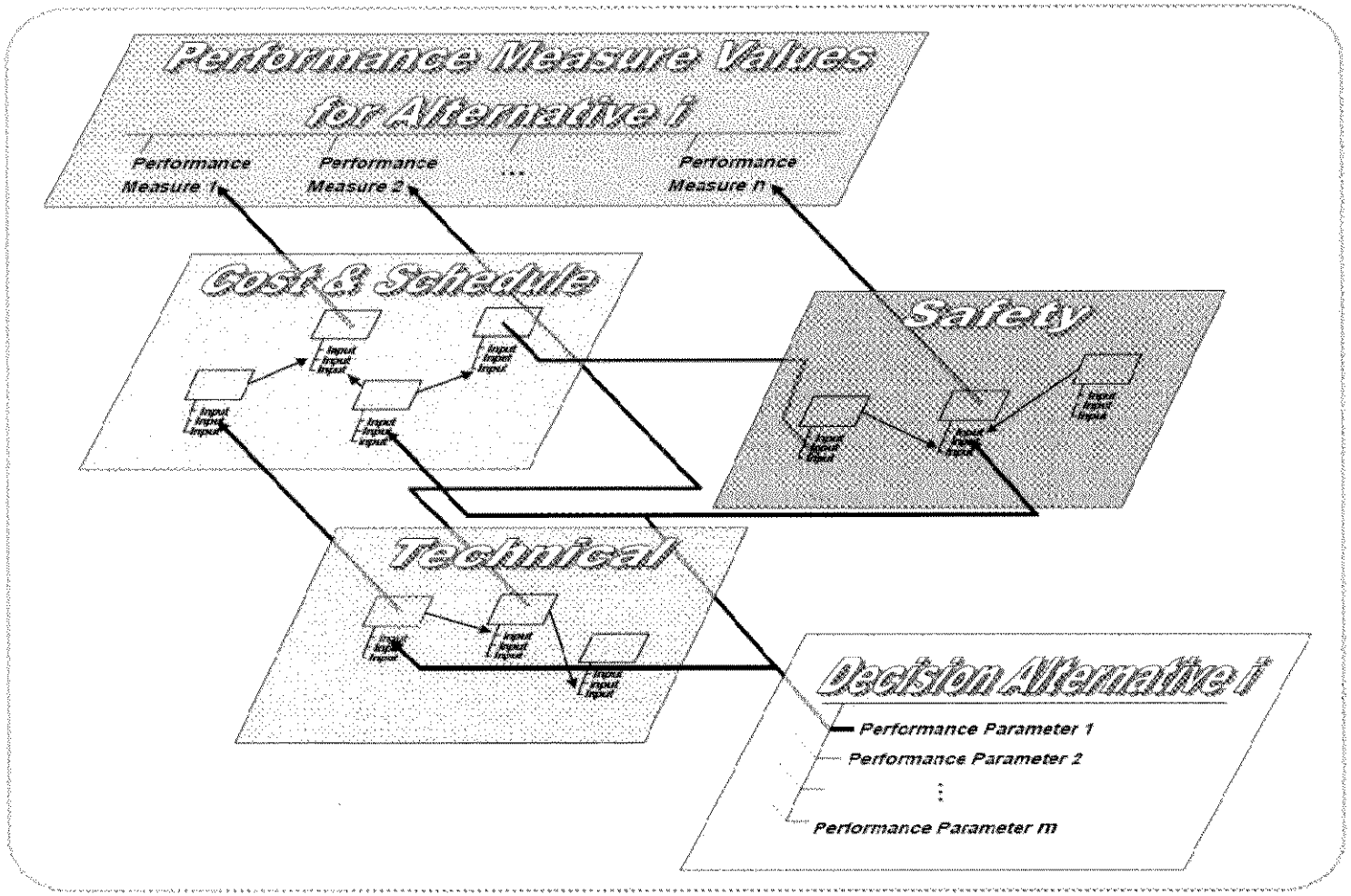
- **The goal is to develop a risk analysis framework that integrates domain-specific performance assessments and quantifies the performance measures**
  - **Risk Analysis** - probabilistic modeling of performance



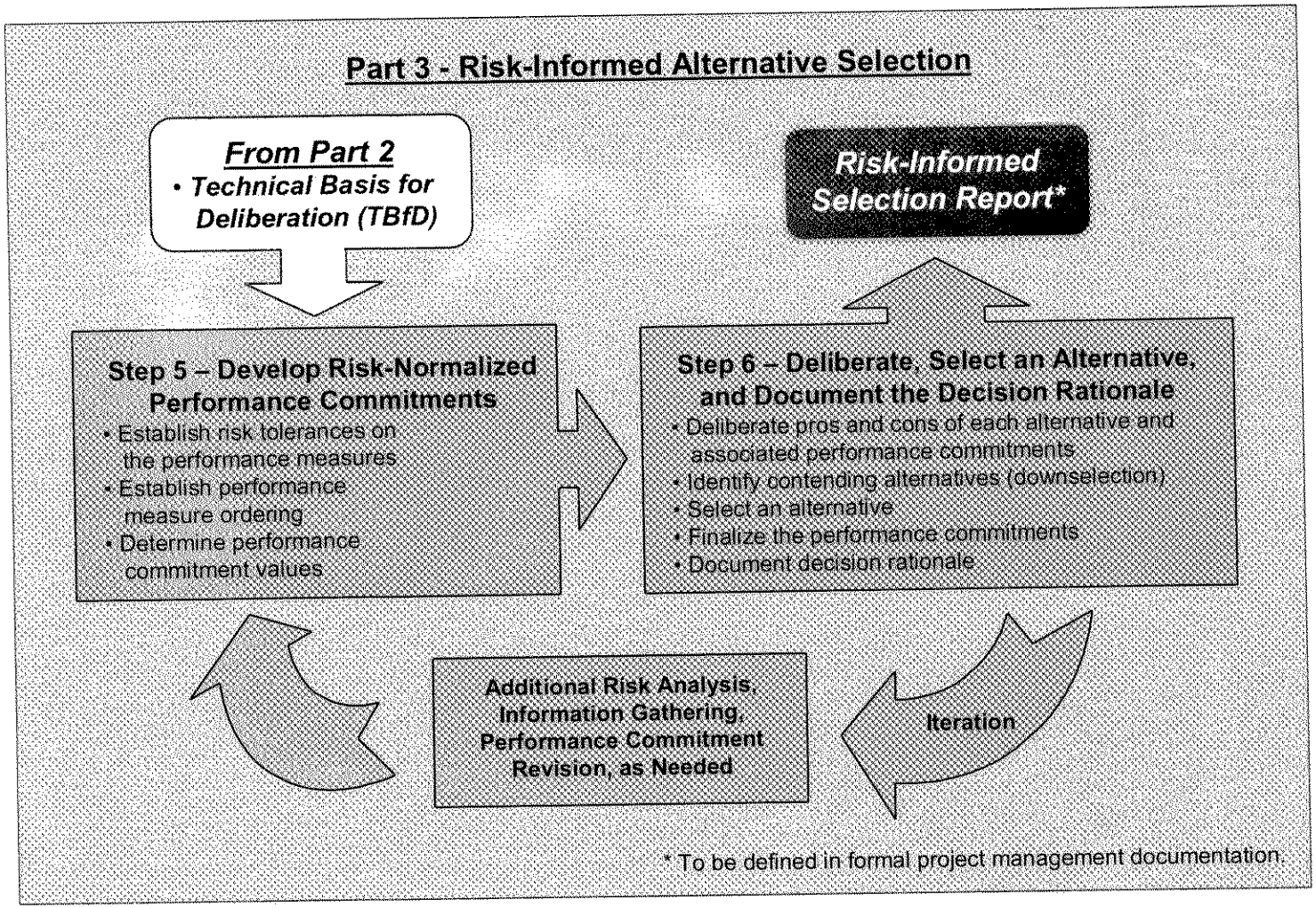
- **The challenge is to establish a transparent framework that:**
  - Operates on a common set of performance parameters for each alternative
  - Consistently addresses uncertainties across mission execution domains and across alternatives
  - Preserves correlations between performance measures

Setting Risk Analysis Framework

- **Setting the risk analysis framework (alternative specific)**

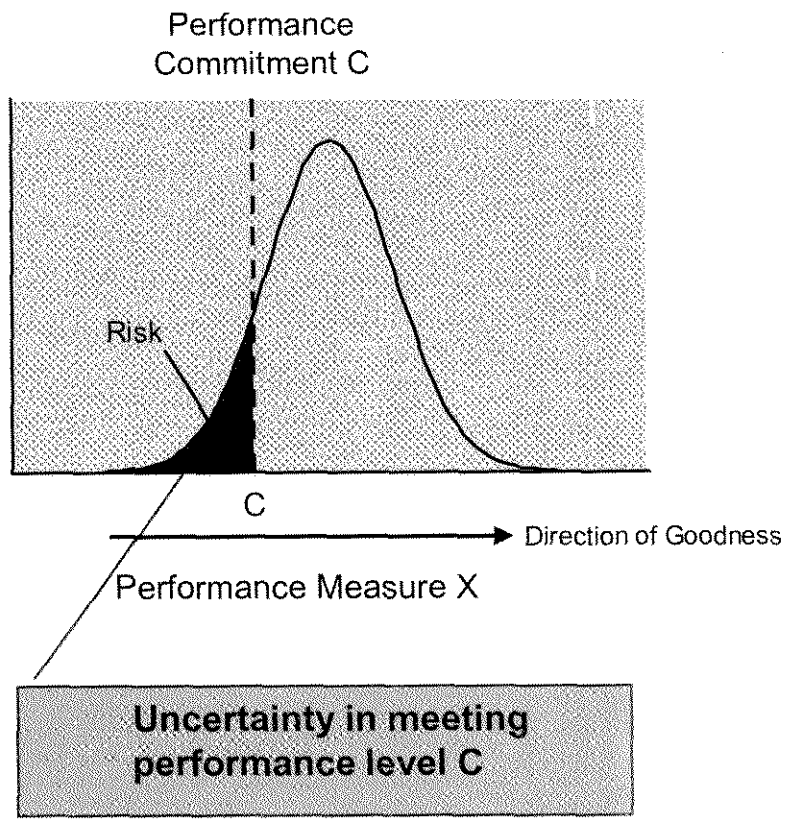


RIDM Process: Part 3

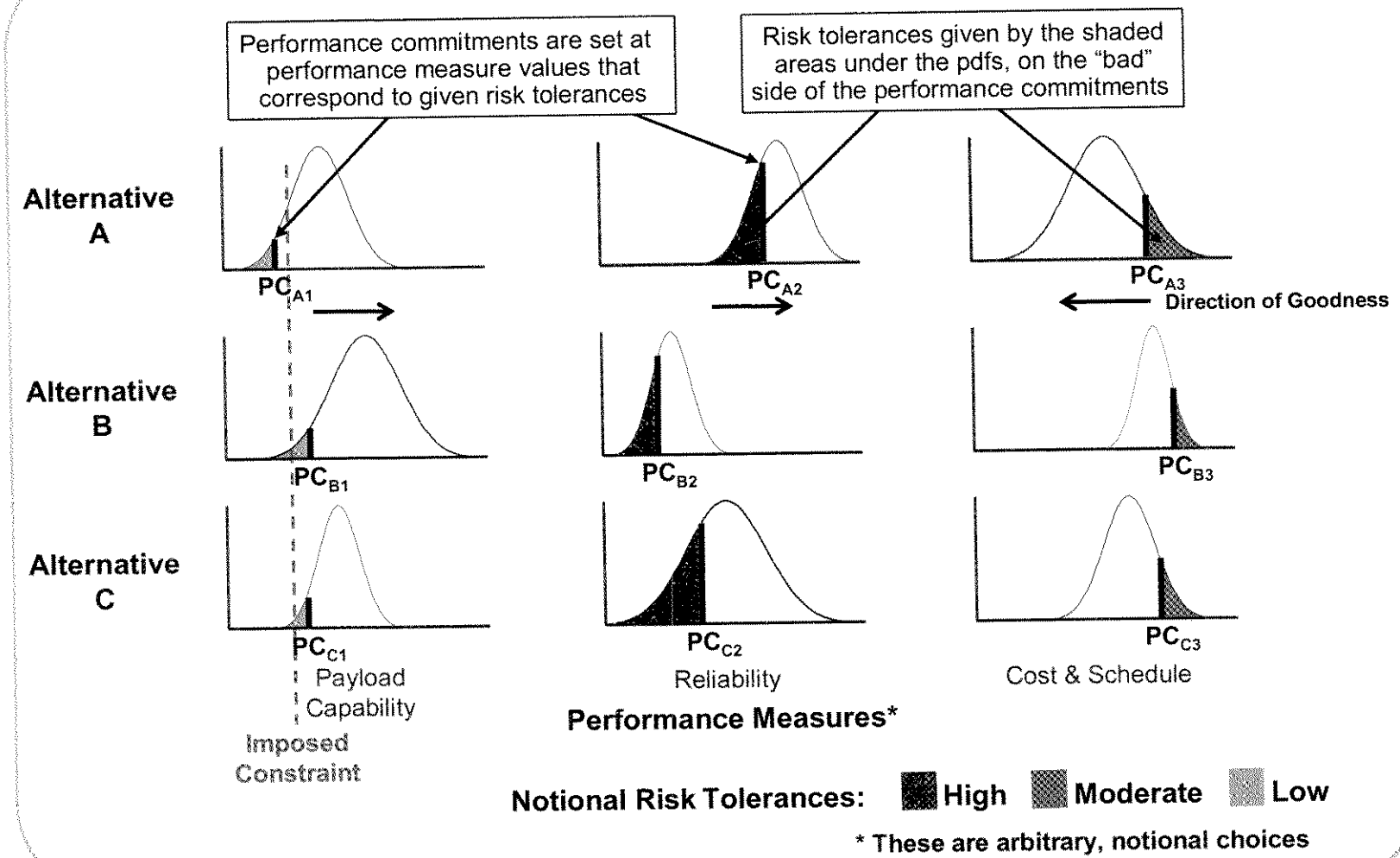


Performance Commitment

- A *Performance Commitment* is the level of performance whose probability of not being achieved matches the decision maker's risk tolerance
  - Anchors the commitment the decision maker (DM) is willing to make for that performance measure
- Allow comparisons of decision alternatives in terms of performance capability at the specified risk tolerances of each performance measure
- Serve as the starting point for requirements development, so that a linkage exists between the selected alternative, the risk tolerance of the decision-maker, and the requirements that define the objective to be accomplished

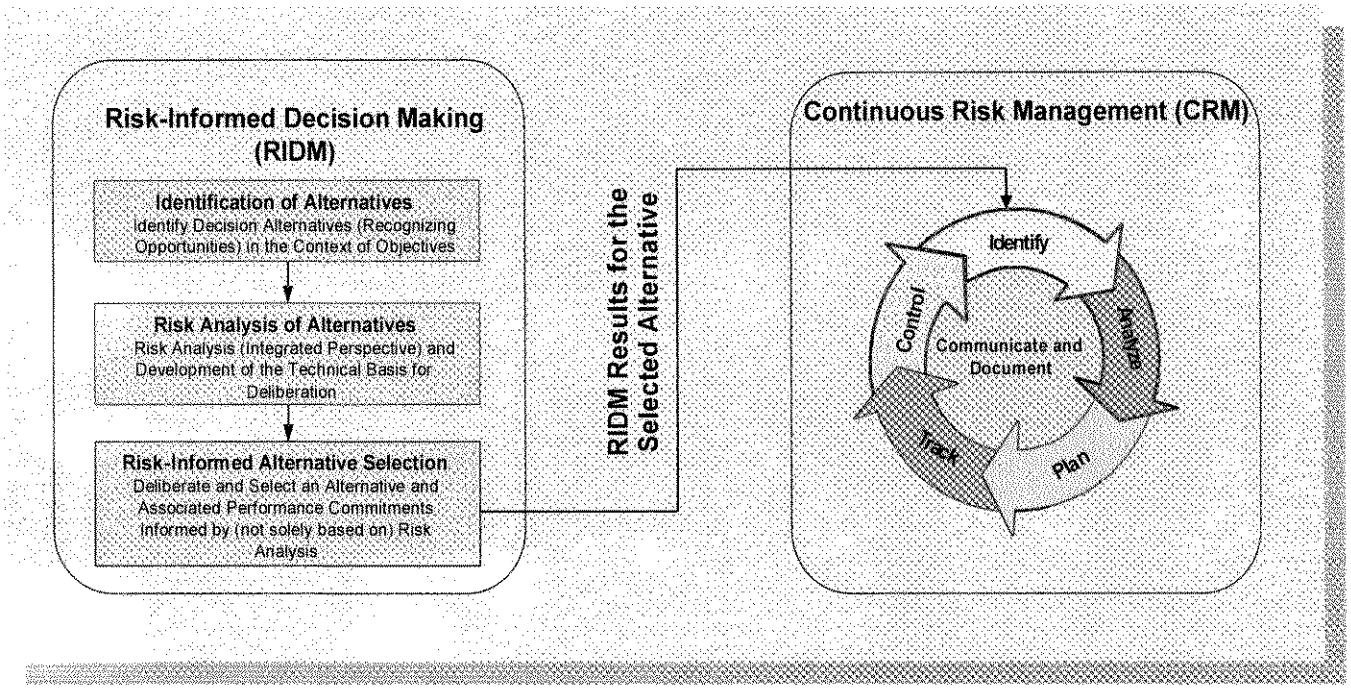


Develop Risk-Normalized Performance Commitments



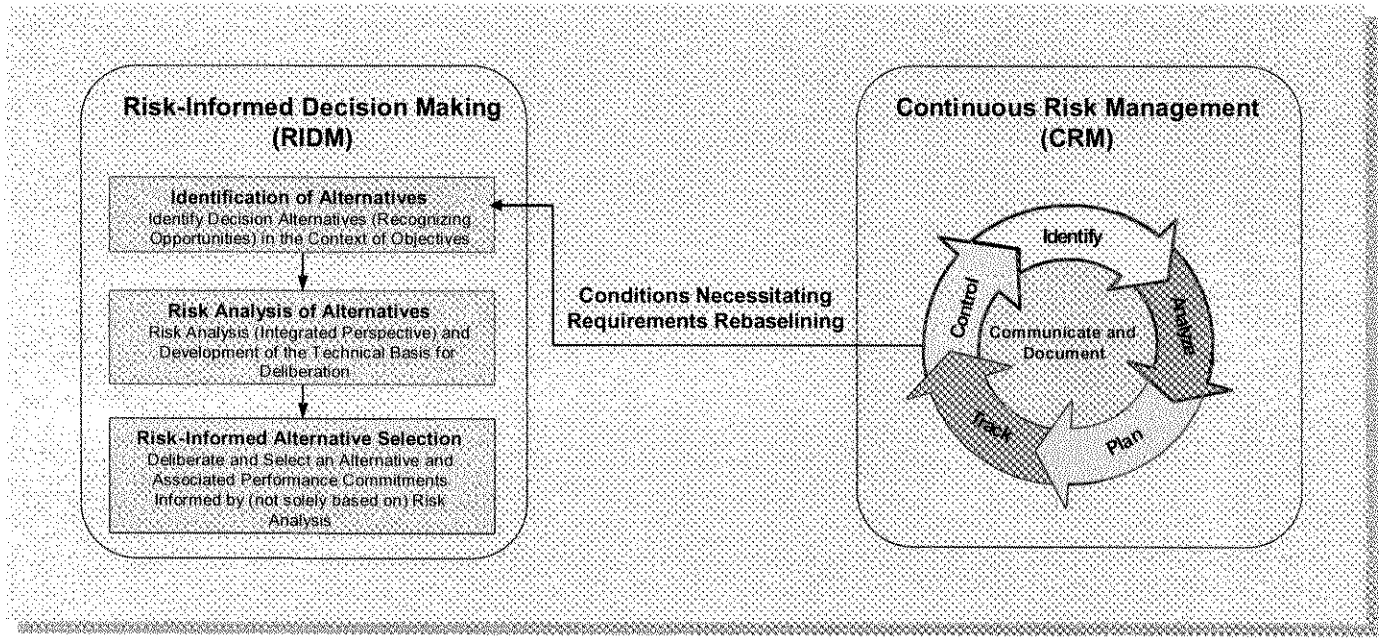
Initialization of the CRM Process

- **RIDM represents an initial identification and assessment of risk significant uncertainties, and the scenarios modeled in the risk analysis imply initial strategies for managing off nominal conditions.**
- **This information is available to the CRM process to initialize its Identify, Analyze, and Plan activities.**

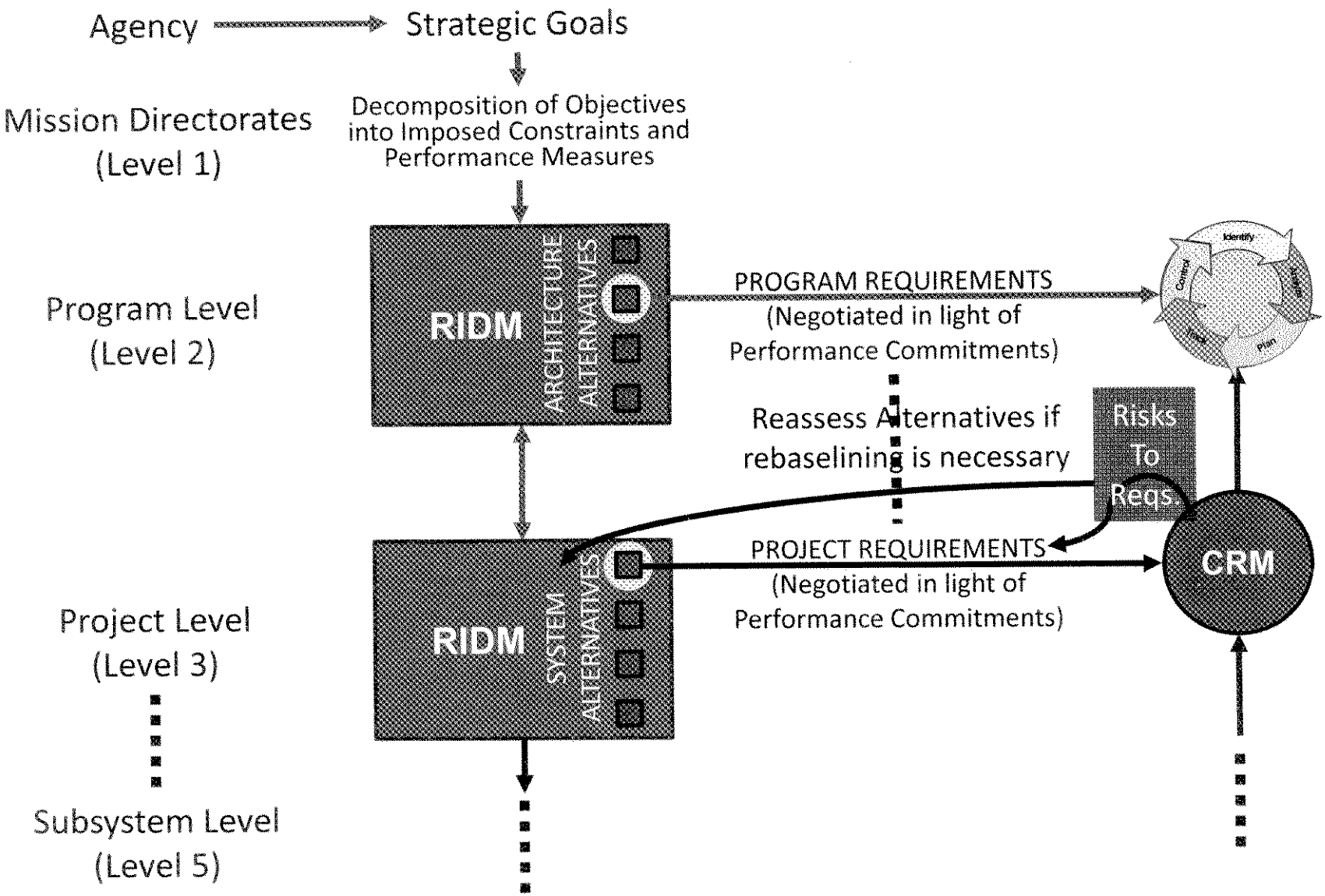


Need for Rebaselining of Requirements

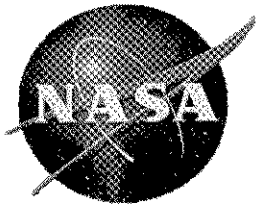
- **A newly identified risk issue for which no mitigation is available within the scope of the current requirements; or**
- **An emerging inability to control a previously identified risk issue.**



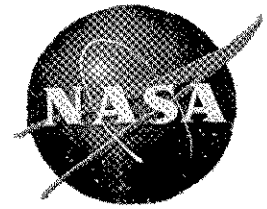
Interaction of RIDM & CRM



Acronyms

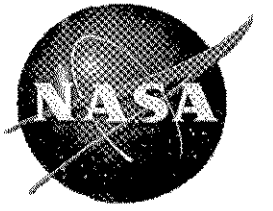


- CRM — Continuous Risk Management
- DM — Decision Maker
- LEO — Low Earth Orbit
- P(LOC) — Probability of Loss of Crew
- pdf — Probability Density Function
- PM_i — Performance Measure i
- PRA — Probabilistic Risk Assessment
- RIDM — Risk-Informed Decision Making
- RISR — Risk-Informed Selection Report
- RM — Risk Management
- MO — Means Objectives
- OH — Objectives Hierarchy
- OSMA — Office of Safety and Mission Assurance
- SP — Special Publication
- TBfD — Technical Basis for Decision



Backups

How is an OH Different from a Means Objectives Network?

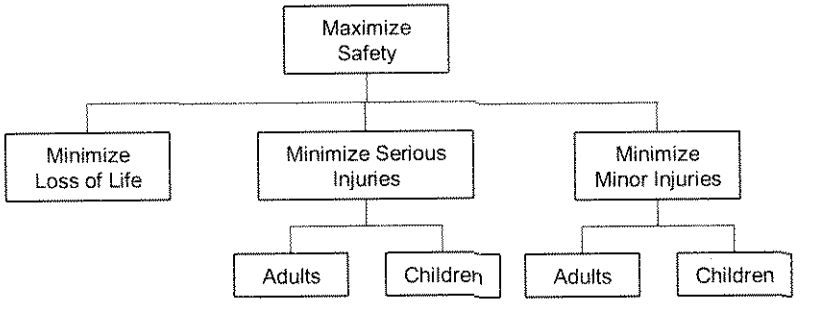


Objectives Hierarchy (OH)

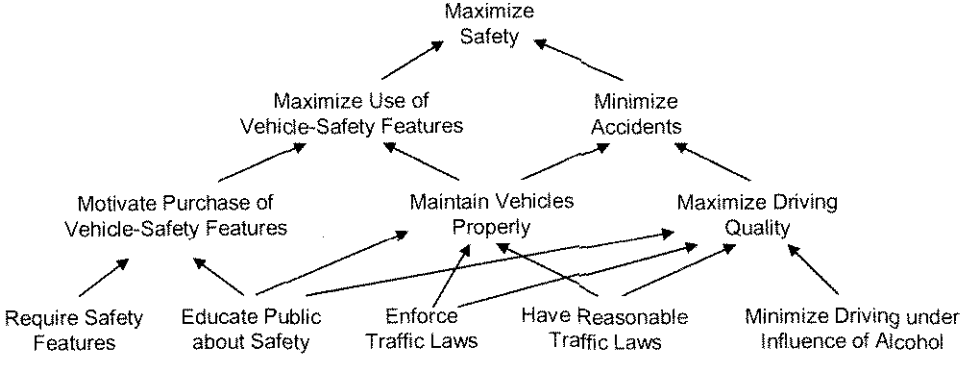
- Explains what is meant by the higher-level objective
- Partitions the higher-level objective into its constituent parts
- Doesn't impose a solution
- Is structured as a hierarchy

Means Objectives (MO) Network

- Shows ways of accomplishing higher-level objectives
- May relate to multiple higher-level objectives
- Implies a solution
- *Is structured as a network*



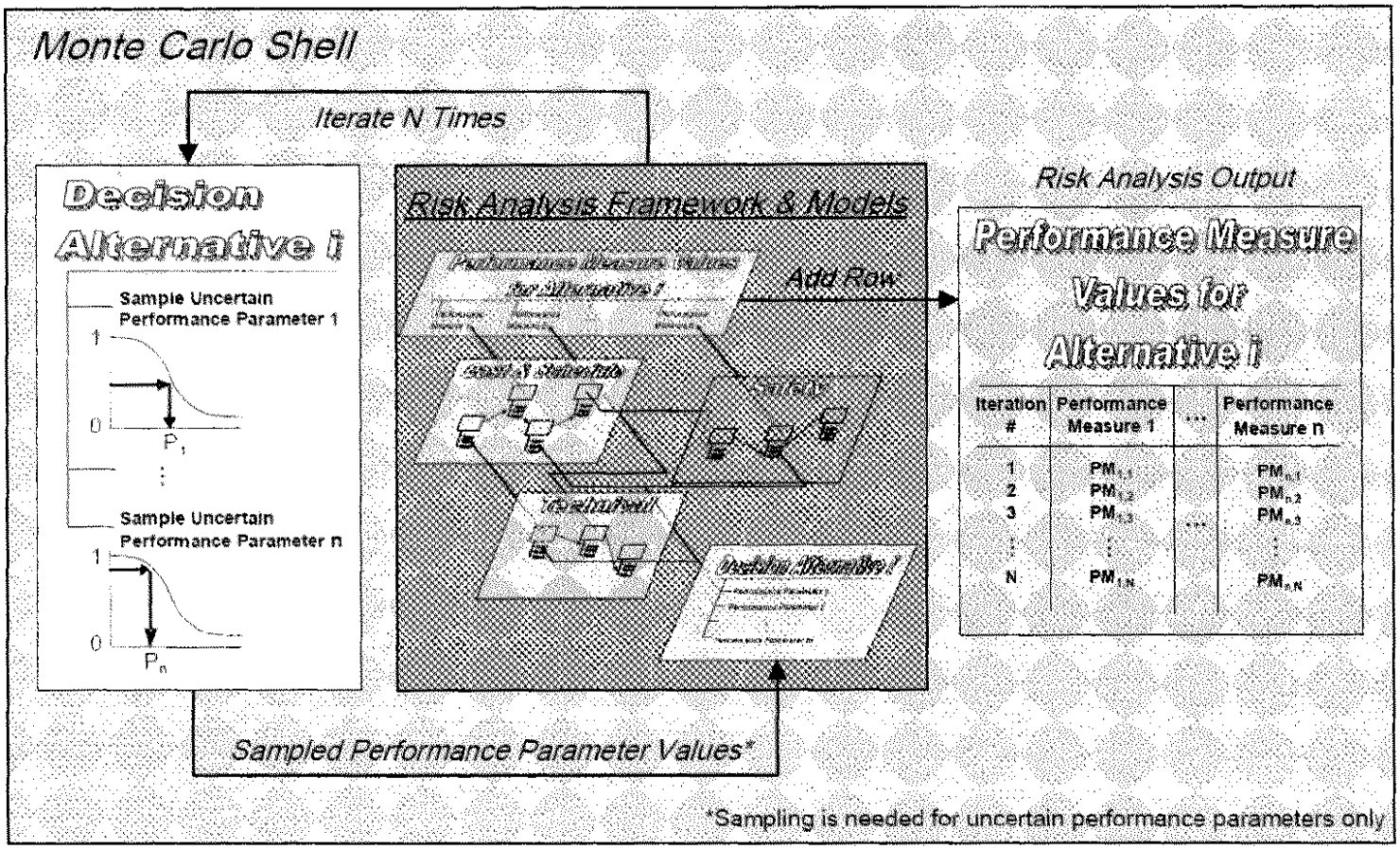
(Fundamental) Objectives Hierarchy



Means Objectives Network

Setting Risk Analysis Framework

- **Quantification via probabilistic modeling of performance**



Risk Analysis Methods

- **Domain-specific general guidance on applying a graded approach to selection of analysis methodologies as a function of life cycle phase**

The RIDM Handbook contains general guidance on methods, with reference to existing domain-specific NASA guidance documents