# 2023 Mid-scale Research Infrastructure (RI) Webinars
# NSF Key Messages

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# Overview - Key Messages from NSF

- **RI awards are not the same as research grants:** RI constitutes a **fixed deliverable** that is expected **on-time and within budget** whereas research grants are less constrained
- **Build your team:** Project planning and management may require finding, gaining or hiring certain expertise > **These cost are allowable in the proposal budget!**
- **Start with scientific requirements & technical scope: NOT** a **preconceived budget** or an allowable **programmatic ceiling**
- **The solicitation governs proposal submission:** Proposers are advised to read all applicable guidance documents including relevant sections of the *Research Infrastructure Guide* (RIG)
- **Ask questions:** Program Officer on the solicitation & LFO on the RIG

# Project Development, Project Definition & Risk
# Key Messages from NSF

- **Scope comes first:** Work Breakdown Structure (WBS) drives everything else!
- The schedule should describe the **complete project, at the appropriate level,** and how the elements fit together in a logical way
- **Be wary of minutia:** Schedule detail and the scheduling tool used should align with the complexity of the project and tracking/reporting needs

# Project Development, Project Definition & Risk Key Messages from NSF

- Several **allowable** mechanisms to address risks and cost uncertainties:
  - Allowances in the Basis of Estimate (BoE)
  - Budget contingency (Risk Management Plan & Risk Register)
  - Scope Management Plan
- Supplemental Funding Request:
  - **Highly undesirable** > Program may not have the funding
  - **Unnecessary** if risk/uncertainties handled properly in the proposal (See above)
  - Considered for unforeseen events
- Budget contingency is not a “slush fund”:
  - Based on known risks
  - NSF approval thresholds
  - Obligated by NSF based on need and availability of funds
  - Consider scope opportunities in the PEP (pre-approved by NSF)
  - Unused contingency de-obligated and returned to NSF

# NSF Mid-Scale Learning

## Webinar #2 - Part 1

**PEP Component 4: Project Definition**

a/k/a Project Baselines: Scope, Quality, Schedule, & Budget

Mark Warner, PE, PMP | Carol Wilkinson, PhD., SCPM

# Class Overview

## Learning Objectives:

- Understand RIG Component 4 of a Project Execution Plan:
  - "Construction Project Definition" (i.e., Project Baseline)…
  - …And Why Is It So Important?
- Methods & Best Practices For Developing & Creating *Your* Baseline:

## In This Presentation:

- PEP Component 4: Project Baseline of Scope, (Quality,) Schedule, & Cost
- Scope Management: Creating Work Breakdown Structures & Dictionaries
- Quality Management: Defining & Documenting "Good Enough"
- Time Management: Building Quality Integrated Master Schedules
- Cost Management: Creating Basis of Estimates (BOEs) & Budgets

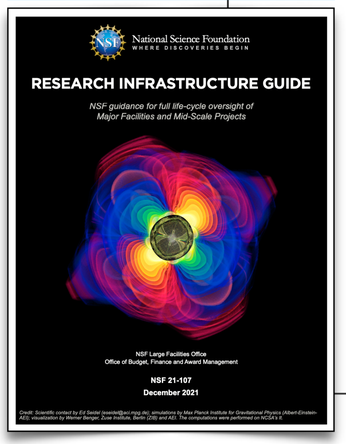
# RIG PEP Component 4: Construction Project Definition

*Scope, (Quality), Schedule, and Cost…*

| Component | Sub-Topics | Description of Sub-Section Requirements |
|---|---|---|
| 4. Construction Project Definition | 4.1 Summary of Total Project Definition | Summary at Work Breakdown Structure (WBS) level II of total construction project scope, cost, and schedule required to complete the construction or implementation project, indicating the baseline (pre-award) or Performance Measurement Baseline (PMB) (post-award) and contingencies funded by NSF as well as any associated scope supported by other funding sources. |
| | 4.2 Work Breakdown Structure (WBS) | WBS contains a product-oriented, hierarchical framework that organizes and defines the total scope of the project into individual project component that represent work to be accomplished, aggregating the smallest levels of detail into a unified project description. The WBS integrates and relates all p… thro… proj… |
| | 4.3 WBS Dictionary | WBS dictionary defining scope of each WBS element, through all levels. |
| | 4.4 Scope Management Plan and Scope Contingency | The plan describes how the scope w… be defined, developed, monitored, controlled, … nd validated, a…d how scoping opportunities and descopin… options will b… realized. Scope Contingency compiles savings from potential de-scoping options, with decision points for exercising options and time-phased cost and schedule. |
| | 4.5 Cost Estimating Plan, Executive Summary, and Baseline Budget | A plan to establish and communicate how the preparation, development, review and approval of the estimate will be completed. An executive summary provides a summary of the costs at a high level and an overall basis of estimate. |
| | 4.6 Budget Contingency | Contingency budget and description of method for calculating contingency, including confidence level for completing within budget. |
| | 4.7 Cost Book, Cost Model Data Set, and Basis of Estimate | The Cost Book is the comprehensive and well-documented compilation of Cost Book Sheets for the total project cost. The cost model data set is used as input to software tools and/or project reports to organize, correlate, and calculate different project management information. The Basis of Estimate provides supporting documentation outlining the details used in establishing project estimates such as assumptions, constraints, and estimating methods, and referencing the technical information used. |
| | 4.8 Funding Profile | Show the proposed NSF Funding Profile by year with baseline commitment and anticipated contingency allocation profiles. Also provide a total funding profile from all sources if applicable. |
| | 4.9 Baseline Schedule Basis Document and Integrated Schedule | Schedule (without contingency) for the overall project and each major subsystem, including system integration, commissioning, acceptance, testing and transition activities; as well as major milestones and milestones for reviews, critical decisions and deliverables. It uses formal scheduling programs, is based on the WBS hierarchy, and is resource-loaded before the construction/implementation stage. Baseline schedule does not include schedule contingency. |
| | 4.10 Schedule Contingency | Schedule contingency amounts and project end date with contingency; state method of calculating contingency, including confidence level for meeting project end date. |

**1.2 Scientific Requirements**
**7.2 Systems Engineering Requirements…**
**+**

**RIG Section 3.4, Component 4: Project Definition**




## The 14 Foundational Questions of Every Project:

**The Project Objectives**

- **Who** Are The Main Parties Involved In This Project?
- **Why** Do They Want and/or Need This Project?
- **What** Do They Envision as The Solution to the Problem?

**The Project Definition/Baseline**

- **What** Are The Project Deliverable(s)? — SCOPE
- **What** Are The Acceptance Criteria For Deliverable(s)? — QUALITY
- **What** Is The Cost To Create The Deliverable(s)? — BUDGET
- **What** Is The Timeline To Create The Deliverable(s)? — SCHEDULE

**Plans for Implementation**

- **How** Will The Deliverable(s) Be Created?
- **How** Will Resources Be Organized & Managed?
- **How** Will Work Be Directed, Monitored, & Controlled?
- **How** Will Project Information Be Managed & Distributed?
- **How** Will Project Risks & Issues Be Managed?

**Plans for Completion**

- **How** Will The Project Be Concluded?
- **How** Will The Deliverable Be Used After The Project?

# The Project Definition (Baseline)

*"The approved version of a work product… …used as a basis for comparison to actual results." —PMI.org*

- Scope Management Plan
- Work Breakdown Structure
- WBS Dictionary
- Scope Contingency

- Acceptance Requirements
- Verification & Validation Plans

- Integrated Master Schedule (IMS)
- Schedule Contingency

- Cost Estimating Plan
- Baseline Budget
  - Cost Book
  - Cost Model Data Set
  - Basis of Estimate (BOE)
- Funding Profile
- Budget Contingency





The "Iron Triangle" of Project Management

# TOTAL PROJECT SCOPE

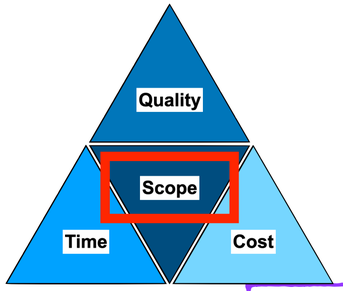
**Scope Management Plan | Work Breakdown Structure (WBS) | WBS Dictionary | Scope Contingency**

**Bill McVeigh**
Dash360.com

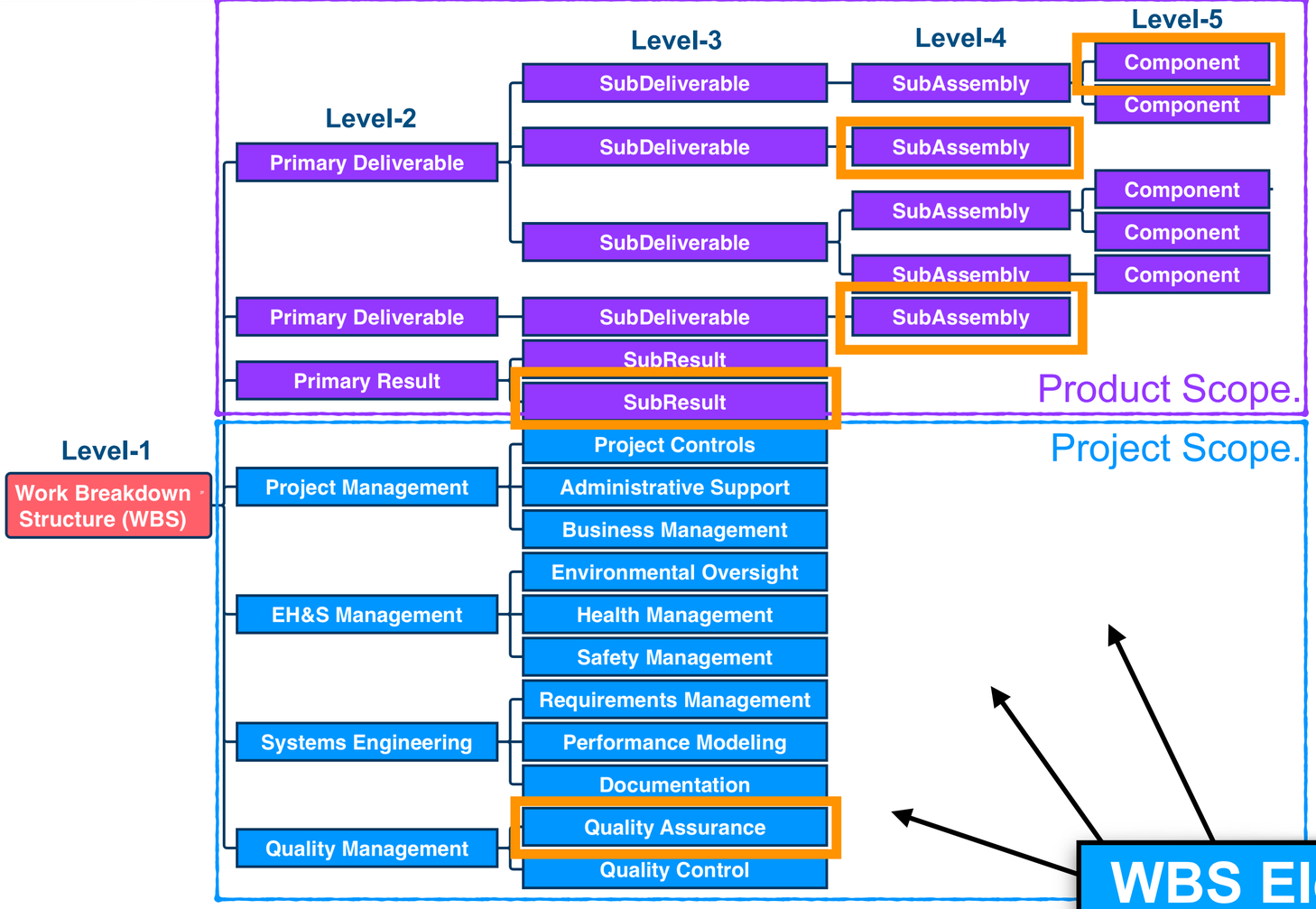
*"The first thing I'll ask a [struggling] project manager is to show me their WBS."*

# Work Breakdown Structure (WBS)

*Documenting a Project's Total Scope…*




## Graphical "Tree" View of a WBS



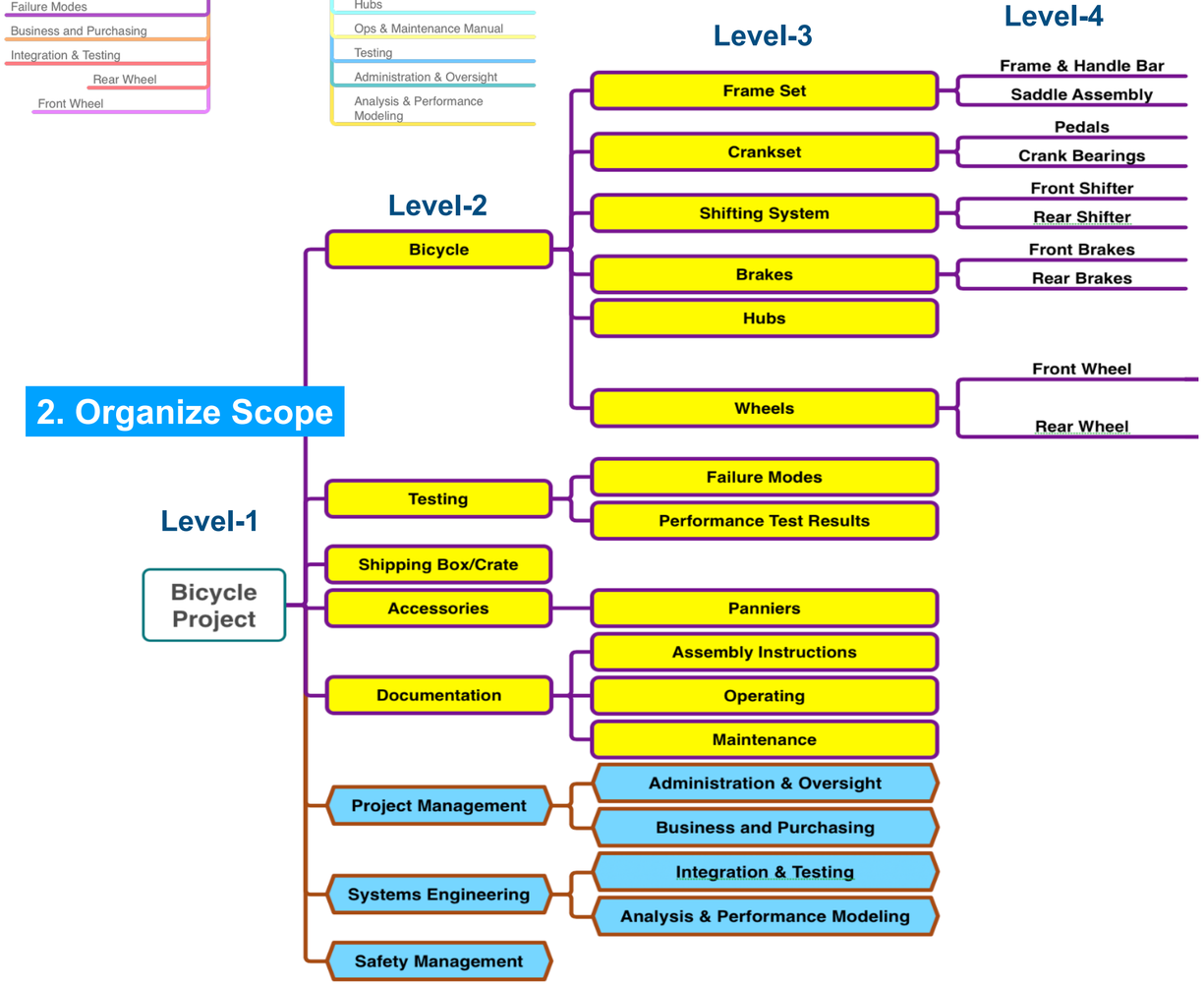

- **WBS Documents (Itemizes) Your Project's Scope**
  - What the NSF is paying you to create
- **Scope = Deliverables**
  - Products, Results, and/or Services
- **WBS Formats:**
  - Graphical (for development, presentations…)
  - Numbered Lists (for financials, CMXs,…)
- **A WBS is Hierarchical & Product-Oriented**
  - "Parents" & "Children"
  - "Level 1," "Level 2," etc…
- **Work Package:** Lowest level WBS element
  - Used for cost estimation
  - Schedule activities serve to create WPs
- **Planning Package**: WBS elements not yet fully defined
- **Product Scope:** Primarily Products & Results
- **Project Scope:** Primarily Supporting Services

**WBS Elements = Nouns (not Verbs!)**
(deliverables, not activities)

# Work Breakdown Structure (WBS)

*How to create a complete and useful WBS…*


**1. Gather Scope**




**2. Organize Scope**

## 1. Gather Scope

- Review Scope Statement
- Work with team to generate “deliverables”
- Capture it all, but focus on high-levels first
- Progressive elaboration!
- Capture: whiteboard, “sticky notes”, lists, mind-maps…

## 2. Organize Scope

- Logical, Hierarchical Structures
  - e.g., Acquisitions-Based, OBS-Aligned…
- Simple > Complex
- Progressively elaborate (by WBS Levels)
- Mind-mapping software is good solution

## Note:

- Depth of WBS vs Proposal Stage:
  - Preliminary Proposal: Level 3
  - Full Proposal: Level 4
  - Award: All Levels & Details
- The “100%-Rules”:
  - Completed WBS = 100% of what customer is paying for
  - Every parent element = 100% of children scope
- Mutual Exclusivity Rule: Scope must appear only once in WBS
- Wait to add numbers as long as possible
- What is *not* included is also very important!

# WBS Dictionary

*Documenting and describing what all the WBS elements include and exclude…*

- 1 **Product Scope Breakdown**
  - 1.1 Bicycle
    - 1.1.1 Frame Set
      - 1.1.1.1 Frame & Handlebar Assembly
      - 1.1.1.2 Saddle Assembly
    - 1.1.2 Crank Set
      - 1.1.2.1 Pedals
      - 1.1.2.2 Bearings Cranks
    - 1.1.3 Shifting System
      - 1.1.3.1 Front Shifter Assembly
      - 1.1.3.2 Rear Shifter Assembly
    - 1.1.4 Brakes
      - 1.1.4.1 Front Brakes
      - 1.1.4.2 Rear Brakes
    - 1.1.5 Wheels
      - 1.1.5.1 Front Wheel
        - 1.1.5.1.1 Rim
        - 1.1.5.1.2 Hub & Spokes
      - 1.1.5.2 Real Wheel
        - 1.1.5.2.1 Rim
        - 1.1.5.2.2 Hub & Spokes
  - 1.2 Documentation
    - 1.2.1 Assembly Instructions
    - 1.2.2 Operations & Maintenance Instructions
  - 1.3 Accessories
    - 1.3.1 Panniers
  - 1.4 Shipping Crate
  - 1.5 Test Results
    - 1.5.1 Failure Test Results
    - 1.5.2 Performance Test Results
- 2 **Project Scope Breakdown**
  - 2.1 Project Management
    - 2.1.1 Project Oversight & Administration
    - 2.1.2 Business & Purchasing Management
  - 2.2 Safety
  - 2.3 Systems Engineering
    - 2.3.1 Analysis & Performance Modeling
    - 2.3.2 Integration & Testing

- A WBS Dictionary describes, defines, & explains *every* WBS element
- Includes as much, or as little, information as required to fully & correctly plan and execute the project
  - Includes as much, or as little, information required to ***manage stakeholders' expectations***
- Dictionary format is tailored to project needs (e.g., access, search-ability, level of detail…)
  - From simple Word documents… to complex searchable databases
- Tip: Don't wait to create this; develop it in parallel with the WBS to ensure key assumptions are captured.

Example WBS Dictionary Entry

| | |
|---|---|
| **WBS Number:** | 1.1.4.1 |
| **Title:** | Front Brakes |
| **Description:** | This WBS element represents the front brake assembly for the bicycle. It includes the hand lever (right side), mounting brackets, hydraulic tubing & hose, brake calibers, and pads. |
| **Exclusions:** | This WBS element does not include any hydraulic fluid, which is to be provided separately. This element does not include any spare parts, such as spare pads. |
| **Requirements:** | There is a higher-level requirements document ("Brake System Design Requirements.doc") that specifies both front and rear brake requirements, including type, maximum pad wear rates, MTBF, and other key specifications. |
| **Interfaces:** | The front brake system will intereface to 1.1.1 Frame Set (e.g., handlebars) and 1.1.5.1 Front Wheel |
| **Acquisitions Approach:** | We currently expect to purchase commercial off-the-shelf (COTS) components. Our internal project team will design and fabricate custom mounting hardware to attache the [illegible]ent to the frame. All testing will be performed in-house by our team. |
| **Basis of Estimate:** | [illegible]DE is based on past project experience (analagous estimating) and extrapolations from other simillar project (parametric). We also have detailed cost estimates from a design trade study performed; note that these estimates are available only to authorized personnel, as they include NDA-protected information. |
| **Key Schedule Links:** | The front brake assembly is required prior to full system assembly and testing. |
| **Key Risks:** | There are no signfiicant technical risks expected. There is however a risk of staff availability when integration work occurs. |
| **Other/Misc/Thoughts:** | n/a |
| **Accountable Person:** | Brake System Group Manager (currently: Jane Doe). This person will be responsible for creating technical specifications, overseeing procurement of the components, managing the subystem budget & schedule, and developing risk estimates. |

Tailor your WBS Dictionary to your project's scale and complexity.

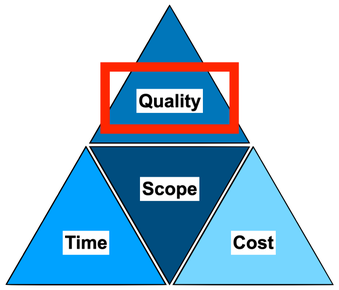
Get SMEs to write first drafts.

Progressively Elaborate!

# ACCEPTANCE QUALITY

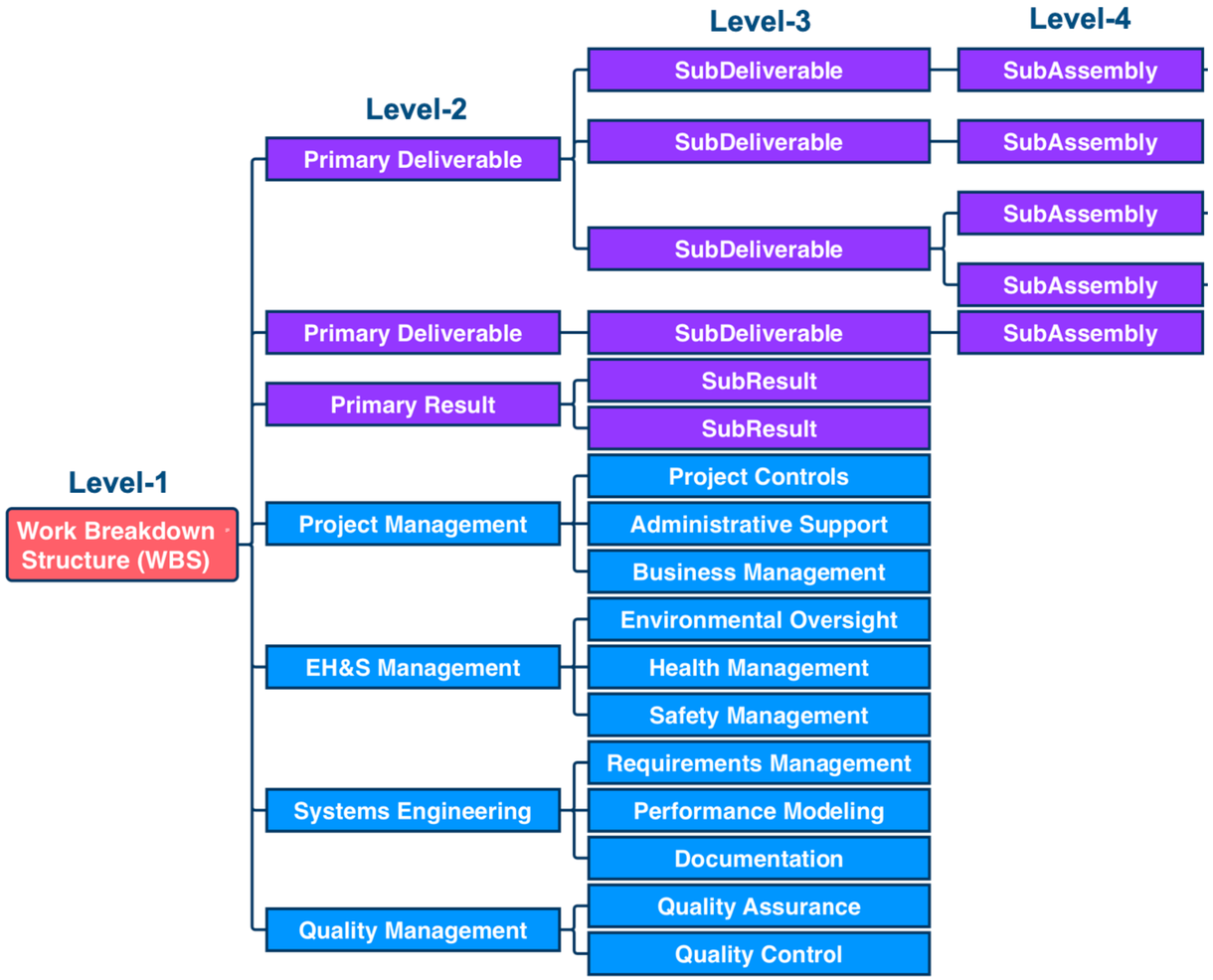
**Acceptance Requirements | Verification & Validation Plans**

**Voltaire** *“Better is the enemy of good.”*




# Quality (Acceptance) Requirements

*Pre-establishing what "good enough" looks like for every WBS element…*




- **Every WBS Element Has Acceptance Requirements**
  - Either directly or in a parent document
- **Quality Requirements (Pre)Define "Fitness for Purpose"**
  - Objective measures of "good enough"
- **Design Requirements Documents, Specifications:**
  - Form, Fit, Function, Performance, RAMS, EH&S, Vibration, Accessibility, Engineering Standards, Codes…
  - SMARTTT Specs:
    - **S**pecific - Clear & Unambiguous
    - **M**easurable - "Testable"
    - **A**chievable - Possible w/in Project Constraints
    - **R**elevant - Suitable & Germane
    - **T**raceable - Stems from Higher Requirement
    - **T**iered - Numbered & Aligned with WBS
    - **T**otal - Complete & Standalone
- **Think Test Procedures & Methods:**
  - Internal Verification vs. External Validation
  - Documentation (e.g., Compliance Matrices)

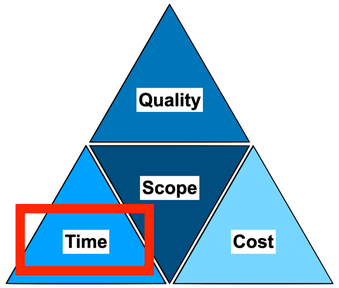
# PROJECT SCHEDULE

**Integrated Master Schedule (IMS) | Schedule Contingency**

**Stephen Covey** *"The key is not to prioritize what's on your schedule, but to schedule your priorities."*

# Integrated Master Schedule (IMS)

*The logical, ordered set of activities required to deliver the Scope…*




- An **Integrated Master Schedule** (**IMS**) describes all primary activities necessary to create & provide Scope
- A complete and accurate IMS is required to develop other key elements of the project (e.g., the Budget)
- Project Schedules can be presented in a variety of formats: Text List, Milestone Table, Bar Chart, Network Diagram, PERT Diagram, CPM Chart, **Gantt Chart**
  - Gantt Charts comprised of logically-linked and sequenced activities (with durations, resources, etc…)

1 **Product Scope Breakdown**
- 1.1 Bicycle
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  - 2.3.1 Analysis & Performance Modeling
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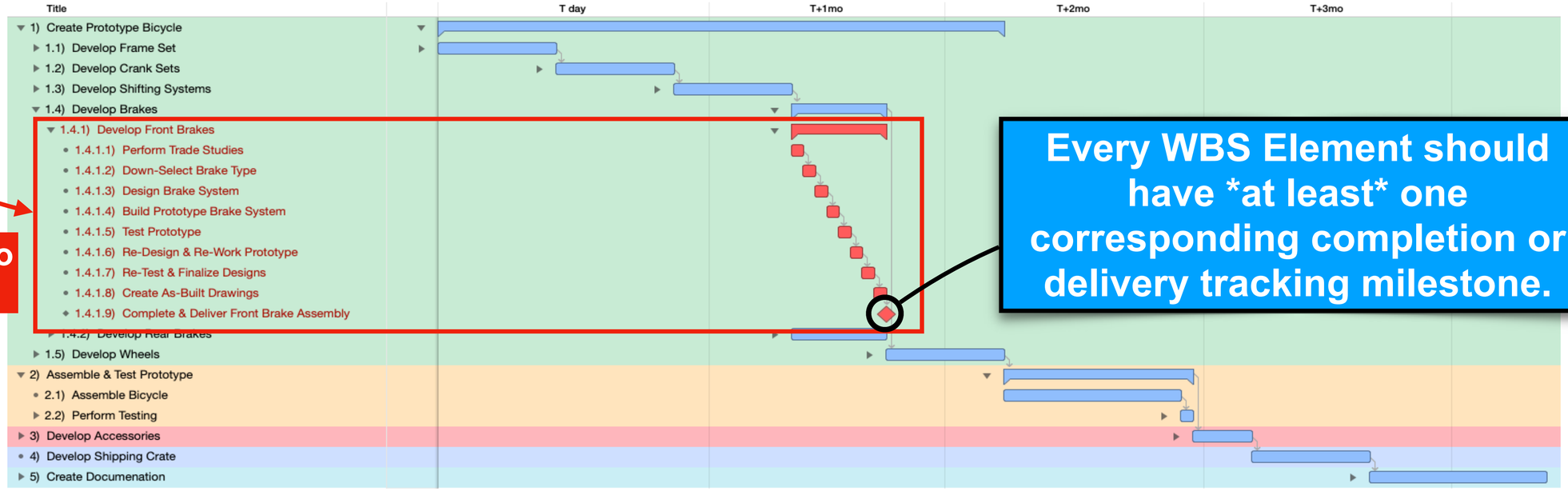
**Nouns**

**Get Turned Into Action Verbs**

**Work Package Element** → **Quality Requirements** → **Acquisition Approach** → **Resource Requirements** → **Schedule Activities**

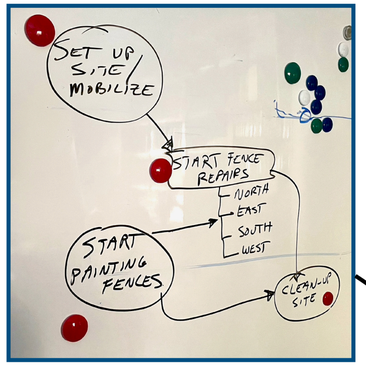



**Every WBS Element should have *at least* one corresponding completion or delivery tracking milestone.**

# Integrated Master Schedule (IMS)

*How to create an IMS from a blank sheet of paper….*

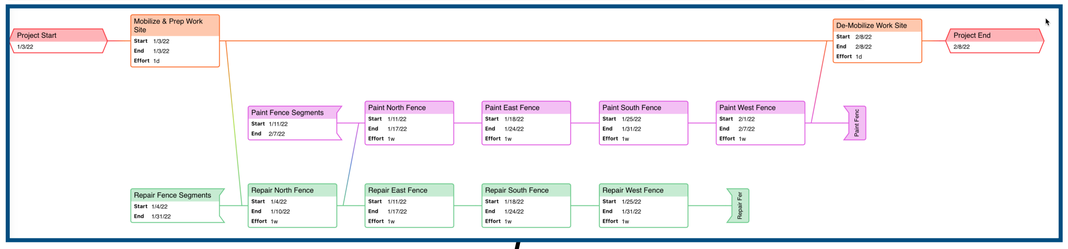
## 1. Create Individual Work Package-Specific "Deliverable" Flowcharts




- Subject Matter Experts (SMEs) to provide first drafts and basic logical flow or activities
- Devolve WBS deliverables (nouns) into a series of "creating" activities (verbs):
  - WBS Deliverable: House Foundation
  - IMS Activities: *"Excavate Soil," "Install Formwork," "Install Rebar," "Pour Concrete"…*
- Ignore activity durations, resources, fine details
- Focus on flow of work, key points of schedule interfaces (inputs & outputs)…

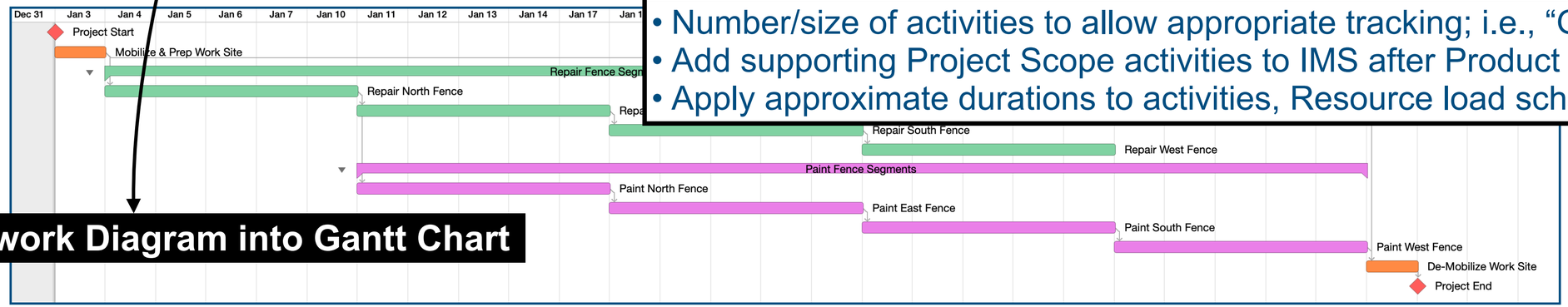
**Use "Rolling Wave" (Progressive Elaboration) for Levels of Detail for out years activities…**

## 2. Combine Into Global Network Diagram




- Work w/ team to combine individual flowcharts into comprehensive flowchart
- Begin grouping activities into logical "procurements based" collections
- Keep at relatively high-level; progressively elaborate as required.
- Establish key milestone points (e.g., Level-0 tracking milestones, external key dates…)
- Ensure every network activity has at least 1 predecessor and 1 successor

## 3. Convert Network Diagram into Gantt Chart




- Number/size of activities to allow appropriate tracking; i.e., "Goldilocks" tasks
- Add supporting Project Scope activities to IMS after Product Scope
- Apply approximate durations to activities, Resource load schedule

# Integrated Master Schedule (IMS)

*Government Accountability Office (GAO) Criteria for Acceptable Schedules…*

## Is the Schedule Comprehensive?

- All product scope (deliverables) addressed?
- All project scope included
- All required supporting activities captured?

## Is the Schedule Controlled?

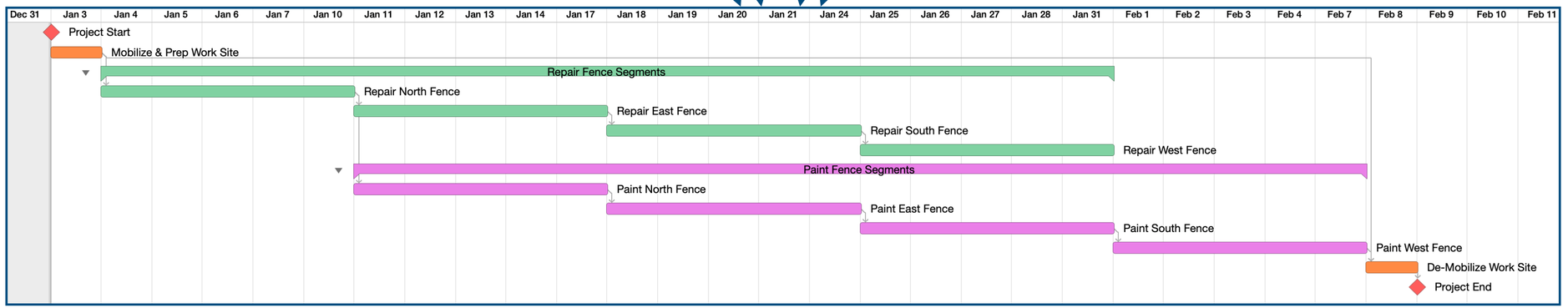
- Schedule is formally baselined?
- Schedule is regularly reviewed and updated?
- Change-control process in place?

## Is the Schedule Well-Constructed?

- Created/checked with SMEs?
- Goldilocks-level of detail?
- Milestones utilized, tied to deliverables?
- All activities have predecessors & successors?
- No (or minimal) hard constraints?
- Critical- & near-critical paths identifiable?
- Float (slack) is reasonable throughout?

## Is the Schedule Credible?

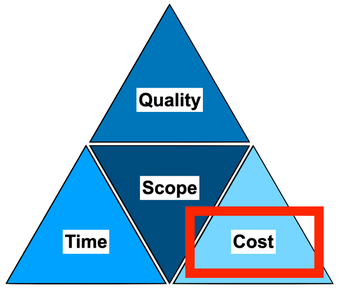
- All activities have correct logic?
- All activities have reasonable durations?
- All activities have assigned resources?
- Critical path is understood & appropriate?
- Near-critical path elements are reasonable?
- Schedule contingency is appropriate?
- Schedule externally reviewed?



# PROJECT BUDGETS

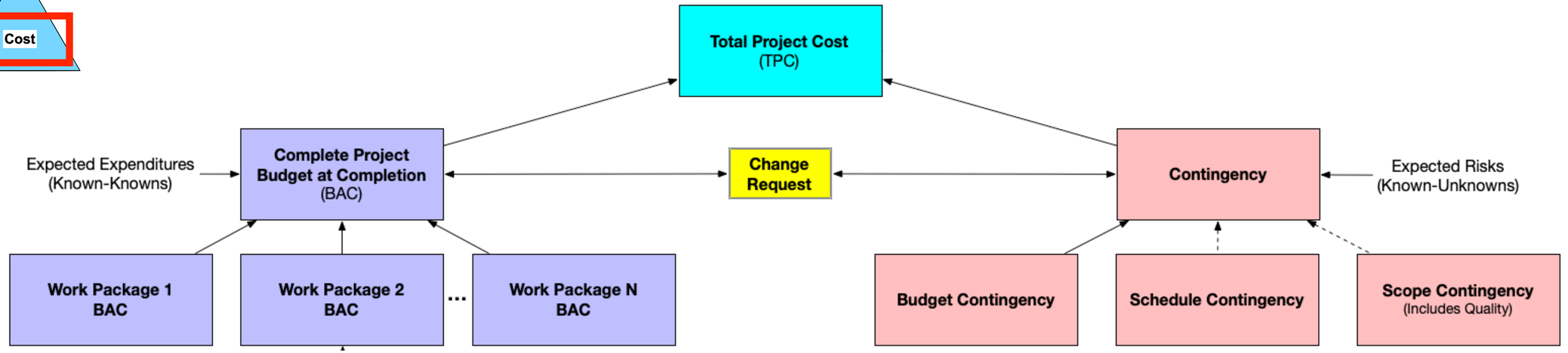
**Cost Estimating Plan | Baseline Budget (Cost Book, Data, BOEs) | Funding Profile | Budget Contingency**

**R.J. Timmons** *"Choose the appropriate estimating method, and always show your work."*




# Baseline Budgets

*Total Project Cost = Budgets at Completion + Contingency*

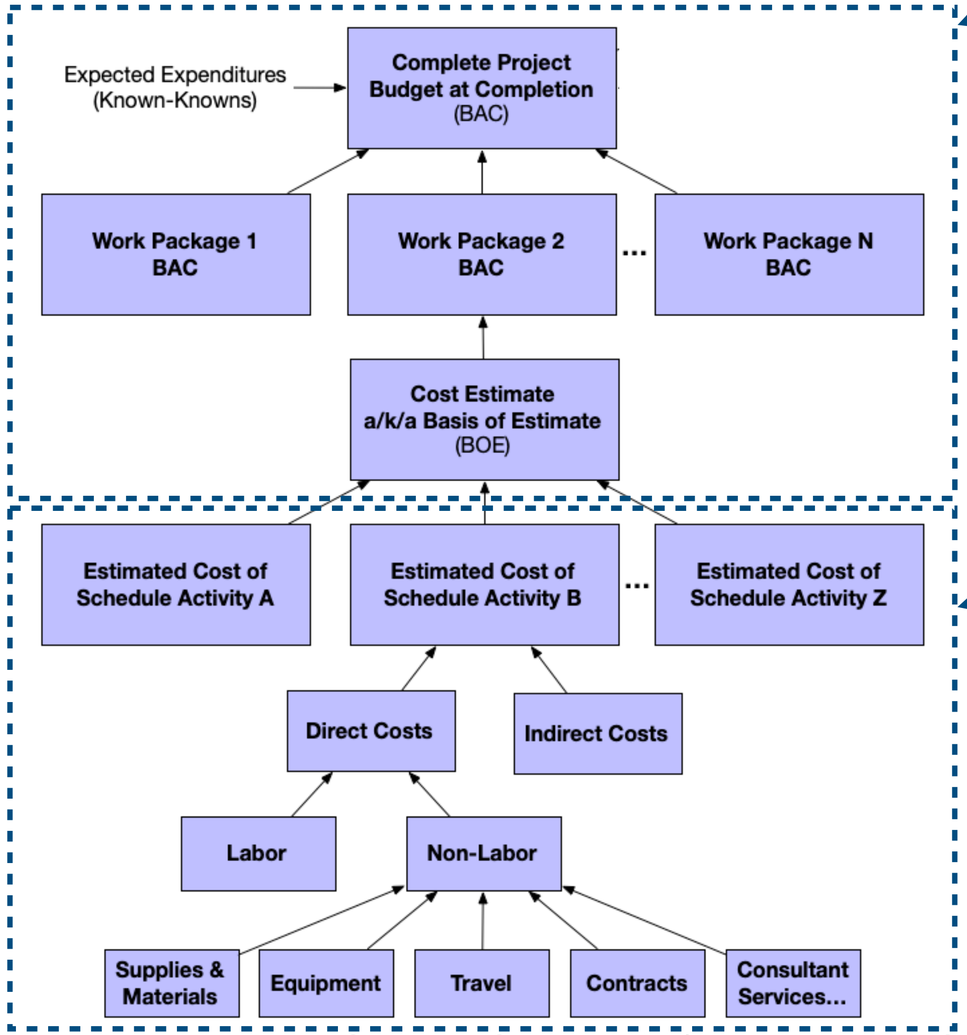



- Total Project Cost (TPC) = Budget + Contingency (Managed by Project)
- Management Reserve (Managed by NSF)
- The Baseline Budget describes the planned (and pre-approved) expenditures for each WBS area
  - Budget is created from Cost Estimates
  - Cost estimates (Basis of Estimates, or BOEs) are performed at the Work Package Level
  - Rolled up into higher-level WBS elements
- Contingency can be estimated a variety of ways; intended to cover risk exposure & approved changes

# Baseline Budgets

*How to create accurate cost estimates…*

**Cost of Schedule Activities Roll Up Into Work Package Costs**
**Work Package Costs Roll Up Into Project Budget**




**Collection of Cost Sheets = Cost Book**

## Typical Estimating Techniques

- Fixed-Price Vendor Quotes
- Vendor Estimates
- Adjusted Bottom-Ups
- Bottom-Up / Engineering Build-Up
- Parametric Analyses
- Multi-Expert (Delphi) Techniques
- Historical Data
- Single Expert Judgement
- Analogous Methods
- Allowances
- Top-Down Budget Allocations

(Higher)

Relative Accuracy

(Lower)

# Baseline Budgets

*The four key criteria for acceptable budgets…*

**GAO Cost Estimating & Assessment Guide - GAO-20-195G:**

## Comprehensive:

- Includes all costs?
- Is based on a technical baseline description that completely defines the program, reflects the current schedule, and is technically reasonable?
- Is based on a WBS that is product-oriented, traceable to the statement of work, and at an appropriate level of detail to ensure that cost elements are neither omitted nor double-counted?
- Documents all cost-influencing ground rules and assumptions?

## Well-Documented:

- Shows the source data used, the reliability of the data, and the estimating methodology used to derive each element's cost?
- Describes how the estimate was developed so that a cost analyst unfamiliar with the program could understand what was done and replicate it?
- Discusses the technical baseline description and the data in the technical baseline are consistent with the cost estimate?
- Provides evidence that the cost estimate was reviewed and accepted by management?

## Accurate:

- Is based on a model developed by estimating each WBS element using the best methodology from the data collected
- Is adjusted properly for inflation
- Contains few, if any, minor mistakes
- Is regularly updated to ensure it reflects program changes and actual costs
- Documents, explains, and reviews variances between planned and actual costs
- Is based on a historical record of cost estimating and actual experiences from other comparable programs.

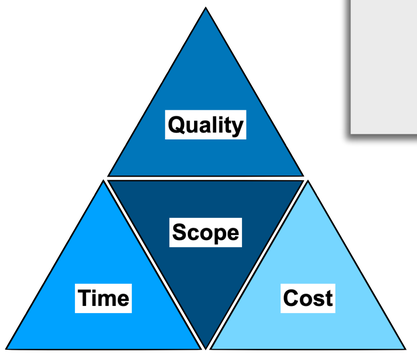
## Credible:

- Identifies a range based on varying major assumptions, parameters, and data inputs;
- Includes a risk and uncertainty analysis that quantifies the imperfectly understood risks and identifies the effects of changing key cost driver assumptions and factors;
- Employs cross-checks or alternate methodologies on major cost elements to validate results
- Is compared to an independent cost estimate… …by a group outside the acquiring organization

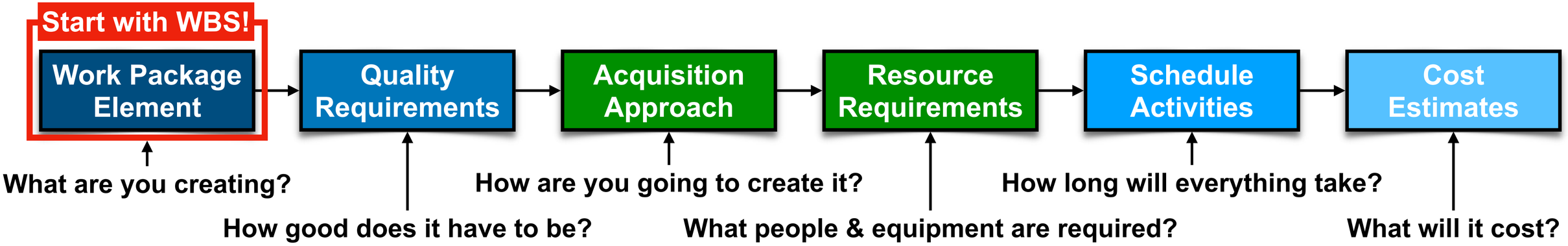
# KEY TAKEAWAYS

# The Key Takeaways

*What did we learn…*




- **Project Definition/Baseline = Project Success Foundation**
- **Start Building Baseline w/ Work Breakdown Structure (WBS)**
  - "…product-oriented, hierarchical framework…"




- **Develop Work Package Deliverable-Based Schedule Activities**
  - 1 Work Package = Many Schedule Activities, Delivery Milestones
  - Comprehensive, Well-Constructed, Credible, & Controlled
- **Create Budget at Completion (BAC) from Basis of Estimates (BOEs)**
  - Bottom-Up Work Package BOEs
  - Comprehensive, Well-Documented, Accurate, & Credible

Next Up:

**Risk Management & Contingency Estimation**

Carol Wilkinson, PhD., SCPM

# NSF Mid-Scale Learning

## Webinar #2 – Part 2

PEP Components 4 & 6: Risk and Contingency Management

Carol Wilkinson, PhD, SCPM and Mark Warner, PE, PMP

March 28, 2023

# Risk and Contingency Management Key Points

*Risks are inherent in the type of unique and challenging projects that NSF sponsors*

**NSF requires RI Recipients to develop and follow formalized Risk and Contingency Management during the Design and Implementation of RI projects**

- Increases the probability of a successful project outcome by using contingencies to manage risks and uncertainties
- RIG Section 5.0 *Guidance for Midscale Infrastructure Projects*
- RIG Section 3.4 *Project Execution Plan*

*Good project management includes realistic assessment of risks, ready adoption of proactive means to avoid threats when possible, and plans to deal with threats that can't be avoided*

Hint: reviewers take your approach to risk management into account when judging your management capabilities

Risk Management planning for RI projects results in four products:

1. Risk Management Plan (RMP)
2. Risk Register
3. Risk Exposure Estimate
4. Contingency Management Plan (CMP)

Hint: Plans and processes should be tailored to each individual project. Overly formal or burdensome plans, even if considered "best practices", are not cost effective.

# PEP 6: Risk Management and PEP 4: Contingency Management

| Component | Sub-Topics | Description of Sub-Section Requirements |
|---|---|---|
| 4. Construction Project Definition | 4.1 Summary of Total Project Definition | Summary at Work Breakdown Structure (WBS) level II of total construction project scope, cost, and schedule required to complete the construction or implementation project, indicating the baseline (pre-award) or Performance Measurement Baseline (PMB) (post-award) and contingencies funded by NSF as well as any associated scope supported by other funding sources. |
| | 4.2 Work Breakdown Structure (WBS) | WBS contains a product-oriented, hierarchical framework that organizes and defines the total scope of the project into individual project component that represent work to be accomplished, aggregating the smallest levels of detail into a unified project description. The WBS integrates and relates all project work (cost, schedule and scope) and is used throughout the project management to identify and monitor project progress. |
| | 4.3 WBS Dictionary | WBS dictionary defining scope of each WBS element, through all levels |
| | 4.4 Scope Management Plan and Scope Contingency | The plan describes how the scope will be defined, developed, monitored, controlled, and validated, and how scoping opportunities and descoping options will be realized. Scope Contingency compiles savings from potential de-scoping options, with decision points for exercising options and time-phased cost and schedule. |
| | 4.5 Cost Estimating Plan, Executive Summary, and Baseline Budget | A plan to establish and communicate how the preparation, development, review and approval of the estimate will be completed. An executive summary provides a summary of the costs at a high level and an overall basis of estimate. |
| | 4.6 Budget Contingency | Contingency budget and description of method for calculating contingency, including confidence level for completing within budget. |
| | 4.7 Cost Book, Cost Model Data Set, and Basis of Estimate | The Cost Book is the comprehensive and well-documented compilation of Cost Book Sheets for the total project cost. The cost model data set is used as input to software tools and/or project reports to organize, correlate, and calculate different project management information. The Basis of Estimate provides supporting documentation outlining the details used in establishing project estimates such as assumptions, constraints, and estimating methods, and referencing the technical information used. |
| | 4.8 Funding Profile | Show the proposed NSF Funding Profile by year with baseline commitment and anticipated contingency allocation profiles. Also provide a total funding profile from all sources if applicable. |
| | 4.9 Baseline Schedule Basis Document and Integrated Schedule | Schedule (without contingency) for the overall project and each major subsystem, including system integration, commissioning, acceptance, testing and transition activities; as well as major milestones and milestones for reviews, critical decisions and deliverables. It uses formal scheduling programs, is based on the WBS hierarchy, and is resource-loaded before the construction/implementation stage. Baseline schedule does not include schedule contingency. |
| | 4.10 Schedule Contingency | Schedule contingency amounts and project end date with contingency; state method of calculating contingency, including confidence level for meeting project end date. |

| Component | Sub-Topics | Description of Sub-Section Requirements |
|---|---|---|
| 6. Risk and Opportunity Mgt | 6.1 Risk Management Plan | Risk Management Plan describes the methodology/process for identifying, ranking, analyzing, tracking, controlling, and mitigating risks. Describes both qualitative assessment and quantitative analysis methods. |
| | 6.2 Risk Register | A tracking document or tool that provides a ranked list of identified risks, with risk impact analysis and prioritization, responsibilities, mitigation plans and opportunities of risk reduction, and risk status over time. Documents data and assumptions used in risk analysis. |
| | 6.3 Contingency Management Plan | Contingency management plans and approval process using change control. Describe NSF approval requirements per cooperative agreements (CAs). |

## Within RIG Section *3.4 Project Execution Plan:*

- Risk Management is found in Component 6.0 *Risk and Opportunity Management*
- Contingency Management is in the Subcomponents of Component 4. *Construction Project Definition*

### Detailed Guidance

- RIG Section **6.2: *Risk Management Guidelines for Construction Stage***
- RIG Section **4.2.5.4 *Contingency Planning and Assessment during Preliminary Design***
- RIG Section **9 *Lexicon***

Hint: Many processes described are advanced/most applicable to large infrastructure projects. We'll go over the fundamentals applicable to most Midscale projects

### Start with Risk Management

- **Risk** - A discrete, uncertain event that has a positive or negative effect on project objectives. Probability of occurrence varies
  - **Threats and Opportunities**, manageable by the Recipient ("known-unknowns" )
  - Catastrophic events are not included (war, pandemics, global economic crises, ….
- **Uncertainty** - Inherent variability in estimating events in the future. Probability of 100% (the future is always uncertain)

# 1st Product: RMP- Quick Overview

*Find detailed info in the RIG and PM literature – details not covered here*

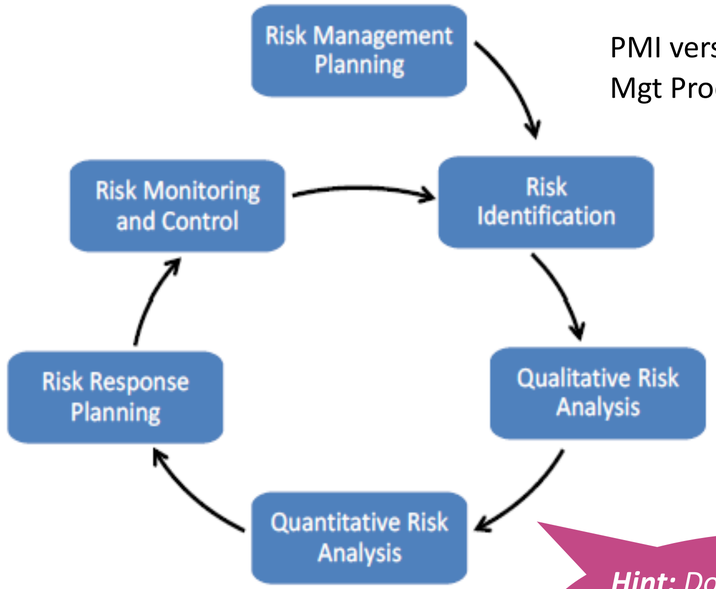
| Component | Sub-Topics | Description of Sub-Section Requirements |
|---|---|---|
| 6. Risk and Opportunity Mgt | 6.1 Risk Management Plan | Risk Management Plan describes the methodology/process for identifying, ranking, analyzing, tracking, controlling, and mitigating risks. Describes both qualitative assessment and quantitative analysis methods. |
| | 6.2 Risk Register | A tracking document or tool that provides a ranked list of identified risks, with risk impact analysis and prioritization, responsibilities, mitigation plans and opportunities of risk reduction, and risk status over time. Documents data and assumptions used in risk analysis. |
| | 6.3 Contingency Management Plan | Contingency management plans and approval process using change control. Describe NSF approval requirements per cooperative agreements (CAs). |

- Everyone on a project is responsible for managing risk
- Identifying and monitoring risks is a cyclical activity

Risk Management Plan (RMP) should include the following elements:

- Risk Management Strategy and Approach
- The Risk Management process
- Resources assigned with Roles and Responsibilities
- Schedule for risk management activities
- Calculation of Risk Exposure and Contingency needs
- Contingency Management

Risk management is iterative and repetitive throughout proposal and implementation. It may evolve and change over time.




PMI version of Risk Mgt Process Cycle

***Hint:*** *Don't just copy boiler plate RM descriptions. Adapt them to your project and processes.*

# 2nd Product: Risk Register - Basic RM Building Block

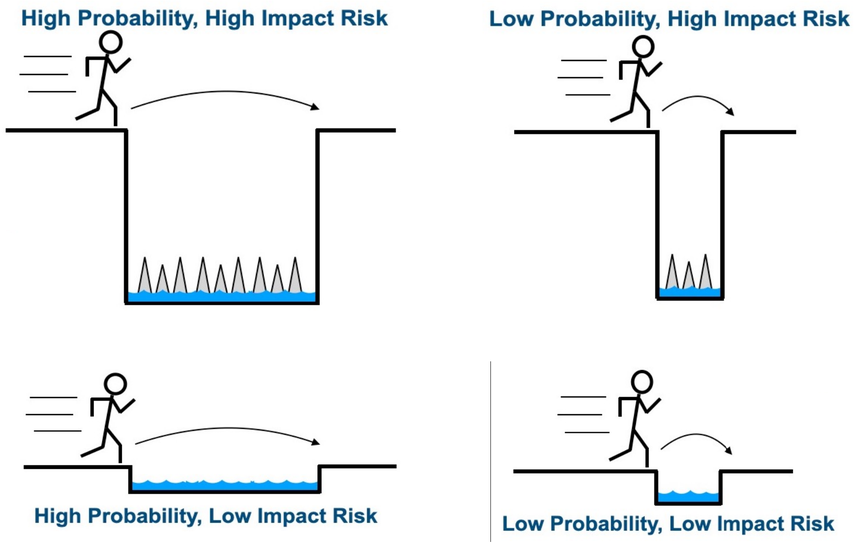
| Component | Sub-Topics | Description of Sub-Section Requirements |
|---|---|---|
| 6. Risk and Opportunity Mgt | 6.1 Risk Management Plan | Risk Management Plan describes the methodology/process for identifying, ranking, analyzing, tracking, controlling, and mitigating risks. Describes both qualitative assessment and quantitative analysis methods. |
| | 6.2 Risk Register | A tracking document or tool that provides a ranked list of identified risks, with risk impact analysis and prioritization, responsibilities, mitigation plans and opportunities of risk reduction, and risk status over time. Documents data and assumptions used in risk analysis. |
| | 6.3 Contingency Management Plan | Contingency management plans and approval process using change control. Describe NSF approval requirements per cooperative agreements (CAs). |

- Management tool for tracking and control of impacts from identified risks
- Ranked list of identified risks and assessments of impacts, with specified responsibilities and actions for mitigation
- Should be quantitative in nature (probabilities, impacts)
- Provides input to contingency estimates on discrete risk events

## First steps toward building a Risk Register

1. Pick a tool/format (software, spreadsheet, or data base ) for Risk Register
2. Create Ranking Matrix for probability and impacts (i.e., Heat Map)

***Hint:*** *Pick tools that are commensurate with the size and complexity of the project Don't do more than you need to do.*



# Identify, Analyze, and Rank Risks

*Hint: The more developed and complete the risk identification is at Pre-proposal stage, the less work to advance to Full Proposal in a limited amount of time*

## Next, fill in the Risk Register with threats and opportunities

### RM Example for a Threat

**Identify:** **If** the welded aluminum frame breaks during testing, **then** the CASABI bike will either not meet requirements or incur additional costs to change to steel.

**Analyze:** Impacts for Redesign / rebuild with 2 engineers + 2 technicians for 3 weeks = $34K; + $1,500 new parts; total 4 weeks delay; 30% probability of occurrence

**Rank:** Moderate risk for cost of $35.5K and 4 weeks of schedule; High for Scope/Quality

**Response:** Reduce impact by adding activities to baseline to buy, build, and perform frame destructive testing before completing design and procurements at a cost of $3K for testing + $0.5K for parts. Residual risk is then 1 week delay and $.5K to switch to steel frame

| Probability | RISK RANKING | | | |
|---|---|---|---|---|
| 75% - 100% | HIGH | HIGH | VERY HIGH | VERY HIGH |
| 45% - 75% | MOD | HIGH | VERY HIGH | VERY HIGH |
| 15% - 45% | LOW | MOD | HIGH | VERY HIGH |
| 0 - 15% | LOW | MOD | HIGH | HIGH |
| Cost Impact | < $20 K | $20 K - $100 K | $100 K - $250 K | > $250 K |
| Schedule Impact | < 3 weeks | 1 - 2 months | 2 - 5 months | > 5 months |
| Scope/ Quality Impact | Barely Noticable | Minor Impact Scope/ Science | Major Impact Scope/ Science | Unacceptable / Project Failure |

**Example of a Combined Ranking Matrix for Cost, Schedule, and Scope/Quality. Such heat maps typically contain 3 to 5 levels per side.**

*Hint: At a minimum for Pre-proposal, list major threats with best estimates / range of impacts. For Full Proposal, all risks, both threats and opportunities, should be captured in a risk register.*

# Risk Responses / Residual Risk

***Hint:*** *Need to identify and reduce risk continuously throughout the project. "Risk Registers are always incomplete. New risks are found in interviews". David Hulett*

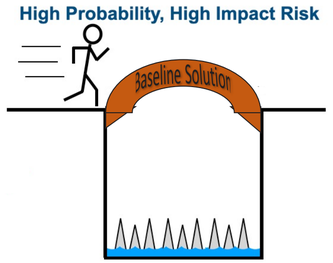
**Be proactive: reduce each risk until you reach acceptable level of Residual Risk, during both proposal and implementation stages**

## Start with Initial Risk Identification and impacts

**Adopt one of the four standard Risk response actions for threats :**

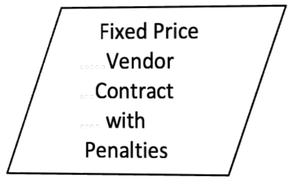
- **Avoid** – Change the project to eliminate the threat from identified risk
- **Mitigate** – Take early action to reduce the likelihood and/or impact of risk

} Change Baseline



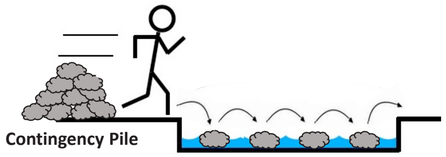

- **Transfer** – Purchase insurance (*seldom used for NSF projects*) or require vendors and any partners funded outside the award to assume risk

} Pay for any cost impacts




- **Accept** – Acknowledge the threat, accept the consequences, and plan response, including any need for contingency.

} Manage if/when it occurs




**End with updated Risk Register reflecting Residual Risk + responses**

# Example Risk Register

*Hint: There are many acceptable ways to create a RR, including commercial software programs.*

Example: Excel spreadsheet with included heat map/ranking for full proposal to combine qualitative ranking with quantitative impacts and probability of occurrence.

Examples of Columns to Include:

- Risk ID and Risk Event Title
- WBS element and Owner
- Risk Description
- BOE for impacts
- Probability of Occurrence
- Impacts on Cost/Schedule/Quality
- Risk Rank color code
- Probability-weighted impacts
- Major risks identifier
- Responses
- Trigger/decision watch dates
- Risk Status

| Scope / Quality Impact Matrix | | |
|---|---|---|
| | High | Major impact on scope or quality / project fails |
| | Med | Moderate impact on scope or quality |
| | Low | Negligable or minor impact on scope or quality |

| Cost and Schedule Risk Ranking Matrix | | | | |
|---|---|---|---|---|
| High | > 2 mos. Delay | | > $80,000 |
| Med | 2 mos. < > 1 mos. | | $80,000 < > $20,000 |
| Low | < 1 mos. delay | | < $20,000 |

| |
|---|
| Descopes shown in salmon |
| Retired Risks shown in gray |
| Upscopes shown in green |

Last update 7-Mar-23

| Risk ID | Risk Event Title | WBS | Risk Owner | Risk Threat/Opportunity Description | Impact BOE | Prob-ability | Cost Impact | Schedule Impact (months) | Scope/ Quality Impact | Prob. Weighted Cost Impact | Probability Weighted Schedule Impact (months) | Major Threat Watch List | Mitigation/Control | Descope Cost Savings | Upscope Cost | Decision/ Retire Date | Risk Status |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RT-1 | Prototype 1 Test Failure | 1.4.2 | MM | If CASABI prototype 1 fails to pass testing such that a major redesign cycle is required, then project cost and schedule will be significantly impacted | 3 months delay; 2 design engineers @ 400 hrs each = $105k; 3 months PM office staff = $50k; 3 weeks assembly and testing staff = $48k; additional materials $2k. Total cost = $205k | 5% | $205,000 | 3.00 | Low | $10,250 | 0.15 | | Monitor design process and follow review and QA/QC practices in baseline. Use contingency and / or descope options to cover new costs if risk is realized | | | Q2 PY2 | Active |
| RT-2 | Donated wheels/tires incompatibility | 1.2.4 | TR | If donated wheels and tires are not compatible with design or do not meet requirements, then additonal costs for replacement wheels will occur | Estimated cost for 8 new new wheels @ $450 ea = $3.6k and 3 weeks of schedule delay to order | 10% | $3,600 | 0.75 | None | $360 | 0.08 | | Accept risk impacts and use schedule float and budget contingency | | | Q3 PY1 | Active |
| RT-3 | Aluminum Welds Break | 1.4.2 | MM | If the welded aluminum frame breaks during testing, then the CASABI bike will either not meet requirements or incur additional costs to change to steel. | 1 week delay and $.5K to switch to steel frame parts | 30% | $500 | 0.25 | Low | $125 | 0.08 | | Make decision after destructive testing results. Use contingency if switch to steel frame is required | | | Q3 PY1 | Active |
| RD-1 | Descope cargo box | 1.2.5 | TR | If the cargo box design is simplified, cost and schedule savings can be gained | Reduced time savings of 1 week with 80 hours of engineering time = $10.5k; assembly and testing time savings of 2 weeks and 60 hours of staff time = $5.4k | 100% | $15,900 | 0.75 | Low | | | | Buy pre-assembled cargo box without detachable seats | $15,900 | | Q4 PY1 | Active |
| RU-2 | Add Perch for Passenger | 1.2.6 | BW | If a perch is added to the frame between seat and handlebars, then cargo and passenger can be simultaneously accomodated. | Engineering design cost of 1 week with 40 hours = $5.25k; additional parts $320; additional assembly and testing labor 20 hours = $1,800 | 100% | $7,370 | 0.00 | Low | | | | Use assigned contingnecy or budget underrun if schedule allows | | $7,370 | Q2 PY2 | Active |
| RT-4 | Cost increase - Bicycle Assembly Shop | 1.1.4 | FL | If rental market costs increase above inflation, then the budget may be exceeded | Assume rental cost increase of 25% of estimated $100k per year for 2.5 years = $62.5k | 20% | $20,000 | 0.00 | Low | | | | Use Descope/cost savings options to cover overall project cost increase. | | | Feb-23 | Retired: subaward agreement |
| | | | | | | | | Risk Exposure | | $10,735 | 0.30 | mos. | Potential Up- or Down-scope Cost | $15,900 | $7,370 | | |

*Note: the sum of individual probability-weighted impacts equals discrete risk exposure*

# 3rd Product: Risk Exposure / Contingency Estimating

| Component | Sub-Topics | Description of Sub-Section Requirements |
|---|---|---|
| 4. Construction Project Definition | 4.1 Summary of Total Project Definition | Summary at Work Breakdown Structure (WBS) level II of total construction project scope, cost, and schedule required to complete the construction or implementation project, indicating the baseline (pre-award) or Performance Measurement Baseline (PMB) (post-award) and contingencies funded by NSF as well as any associated scope supported by other funding sources. |
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| | 4.3 WBS Dictionary | WBS dictionary defining scope of each WBS element, through all levels |
| | 4.4 Scope Management Plan and Scope Contingency | The plan describes how the scope will be defined, developed, monitored, controlled, and validated, and how scoping opportunities and descoping options will be realized. Scope Contingency compiles savings from potential de-scoping options, with decision points for exercising options and time-phased cost and schedule. |
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| | 4.8 Funding Profile | Show the proposed NSF Funding Profile by year with baseline commitment and anticipated contingency allocation profiles. Also provide a total funding profile from all sources if applicable. |
| | 4.9 Baseline Schedule Basis Document and Integrated Schedule | Schedule (without contingency) for the overall project and each major subsystem, including system integration, commissioning, acceptance, testing and transition activities; as well as major milestones and milestones for reviews, critical decisions and deliverables. It uses formal scheduling programs, is based on the WBS hierarchy, and is resource-loaded before the construction/implementation stage. Baseline schedule does not include schedule contingency. |
| | 4.10 Schedule Contingency | Schedule contingency amounts and project end date with contingency; state method of calculating contingency, including confidence level for meeting project end date. |

## NSF allows projects to use Contingencies to manage risk and uncertainty

- **Budget and Schedule Contingencies** in the Total Project Cost and Schedule
  - Part of Total Project Cost and Duration but separate from baseline cost and schedule
  - Based on quantitative analysis of known risks and estimate uncertainties **(Risk Exposure)**
  - Controlled by Project Manager
  - Can be used to cover risk impacts (moved into the baseline) with NSF approval
  - Unused contingency funds are returned to NSF at project end
- **Scope Contingency can provide additional budget and schedule contingency**
  - De-scoping of deliverables in the baseline frees up resources, budget, and schedule
  - Removal of scope entails some level of negative impact on project deliverables
  - Scope contingency is the risk management method for projects that don't request budget and schedule contingency

*Note: NSF does not allow Management Reserve, i.e., money or time included as part of the Total Project Cost to address unforeseen events or uncertainties that are beyond the control of the Recipient or agency.*

Risk Exposure uses statistical methods yielding a total amount (pool) of contingency needed. Not all risks will be realized; which ones will can't be predicted. Therefore, the pool of contingency is held and controlled by the PM and not by the owners of the risk elements used in the calculation.

## Risk Exposure is used to set/validate Budget and Schedule contingency amounts

- Both discrete risks and uncertainty contribute to the overall risk exposure
- Diminishes over time as risks are realized or avoided
- Should always be less than or equal to remaining contingency amounts

# Total Risk Exposure/Algorithmic Estimating

**Total Risk Exposure = Estimate Uncertainty + Discrete Risk Exposure ≈ Project Contingency**

Estimate uncertainty is usually determined by applying an appropriate cost and schedule factor to each budget or schedule item and summing

**Simple Algorithmic methods are adequate for many midscale projects**

**Two Examples of Algorithmic Methods**

1. Sum of individual probability-weighted estimates in the risk register plus the sum of estimated uncertainties from lookup factor tables

*Risk Exposure = ∑ probability-weighted risk impact + ∑ item cost x uncertainty factor*

- Better accuracy with 10 or more risks in the register

2. Industry standard risk factor tables ( aka Maxwell's or Gary Sander's) method to obtain risk exposure/contingency estimates. *(See backup slide for more details)*

- Combines uncertainty and risks into factors based on compilation of actual outcomes from many projects

| Type of Estimate | Maturity Code | % Uncertainty |
|---|---|---|
| Actual cost / existing PO | L1/M1 | 0 |
| LoE and associated support | L2/M2 | 0-20% |
| Advanced | L3/M3 | 10% -20 % |
| Preliminary | L4/M4 | 20% – 40% |
| Conceptual | L5/M5 | 40% – 60% |
| Pre-conceptual (common work) | L6/M6 | 60% – 80% |
| Rough estimate / pre-conceptual | L7/M7 | 80% – 200% |
| Beyond state of the art | L8/M8 | > 200% |

Sample Uncertainty Factor Table, where "L" codes refer to labor estimates and "M" codes refer to materials and equipment. Most midscale projects are mature enough to use factors for L5/M5 and above.

Example Estimate Uncertainty Table

| Cost Item | Maturity Code | Uncertainty Factor | Cost Estimate | Estimated Uncertainty |
|---|---|---|---|---|
| **Project Office Labor** | **L2** | **10%** | **$378,000** | **$37,800** |
| **Software Licenses** | **M1** | **0%** | **$35,400** | **$0** |
| **Refrigeration System** | **M4** | **30%** | **$782,000** | **$234,600** |
| **Centrifuge** | **M3** | **15%** | **$4,320** | **$648** |
| **Fabrication Contract** | **M5** | **45%** | **$284,600** | **$128,070** |
| | **Estimated Uncertainty Sum** | | | **$401,118** |

Hint: Using another algorithmic method or a simple Monte Carlo simulation can help validate or extend the range of the estimate

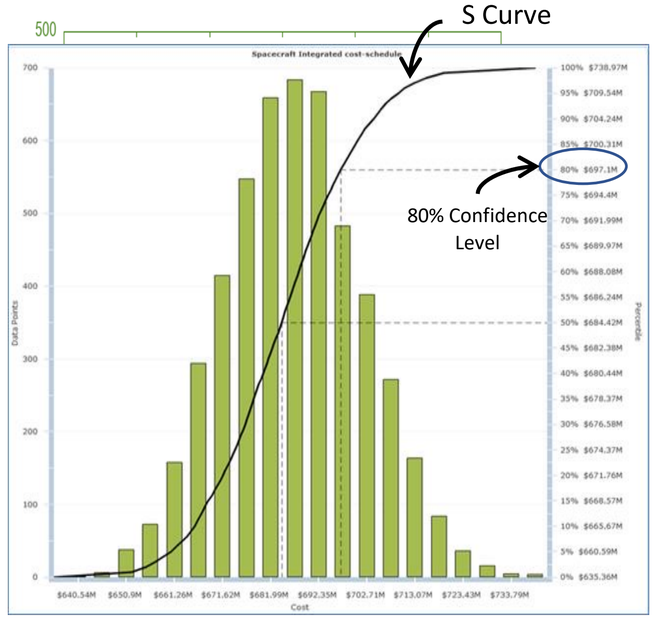
# Risk Exposure/Monte Carlo Methods

Hint: See the RIG Section 6.2 .8 for Monte Carlo risk analyses methods and analyses

## The Monte Carlo method uses multiple simulations of summed costs or schedule activity durations to determine predicted total cost and project end dates

- For schedule, for example, each task in a logically linked schedule is assigned a most likely duration (the baseline) and a range of durations based on the risk register and uncertainty analyses.
- The program is run thru thousands of schedule versions with varying durations for each task, yielding a histogram of expected end dates
- An end date is chosen from the distribution. If the end date with 80% confidence level is chosen, then the project ends before that date in 80% of the simulations
- The difference between the baseline end date and the 80% confidence level represents desired contingency

**Sample distribution of total project cost from multiple iterations of a Monte Carlo simulation of project base costs, risks, and uncertainties (from RIG Section 6.2.8)**




Simple Monte Carlo methods involving summary schedules with defined critical paths and/or budget spreadsheets may be appropriate for most Midscale projects.

Hint: Complex, formal Monte Carlo methods may impose an administrative burden not cost effective for Midscale projects. Requires advanced cost book and resource-loaded schedule as well as Risk Management Experts.

Hint: For examples of commercial MC software, see footnotes in RIG 6.2.8.2 *Key Elements in Quantitative Risk Analysis*

# 4th Product: Contingency Mgt Plan

| Component | Sub-Topics | Description of Sub-Section Requirements |
|---|---|---|
| 6. Risk and Opportunity Mgt | 6.1 Risk Management Plan | Risk Management Plan describes the methodology/process for identifying, ranking, analyzing, tracking, controlling, and mitigating risks. Describes both qualitative assessment and quantitative analysis methods. |
| | 6.2 Risk Register | A tracking document or tool that provides a ranked list of identified risks, with risk impact analysis and prioritization, responsibilities, mitigation plans and opportunities of risk reduction, and risk status over time. Documents data and assumptions used in risk analysis. |
| | 6.3 Contingency Management Plan | Contingency management plans and approval process using change control. Describe NSF approval requirements per cooperative agreements (CAs). |

**Hint: Refer to both the project Change Control Plan (**PEP component 8.2) **and the Cooperative Agreement terms and conditions**

**The CMP describes the specific processes and controls for adjustments to budget and schedule contingency amounts (both in and out)**

- Complies with the Change Control Plan in the Configuration/ Change Control Process (CCCP)
  - Roles and Responsibilities
  - Project and NSF Approval Levels
- Describes tracking and documentation of Contingency adjustments, including keeping a change log and reporting to NSF
- Describes processes for maintaining contingency levels comparable to calculated risk exposure
  - Periodic re-estimation of risk exposure
  - Processes to replenish contingencies as needed (descoping, cost savings, value engineering, maximizing efficiencies)
- Contingency is obligated by NSF based on need and availability of funds

# Scope Management and Contingency Plan

| Component | Sub-Topics | Description of Sub-Section Requirements |
|---|---|---|
| 4. Construction Project Definition | 4.4 Scope Management Plan and Scope Contingency | The plan describes how the scope will be defined, developed, monitored, controlled, and validated, and how scoping opportunities and descoping options will be realized. Scope Contingency compiles savings from potential de-scoping options, with decision points for exercising options and time-phased cost and schedule. |

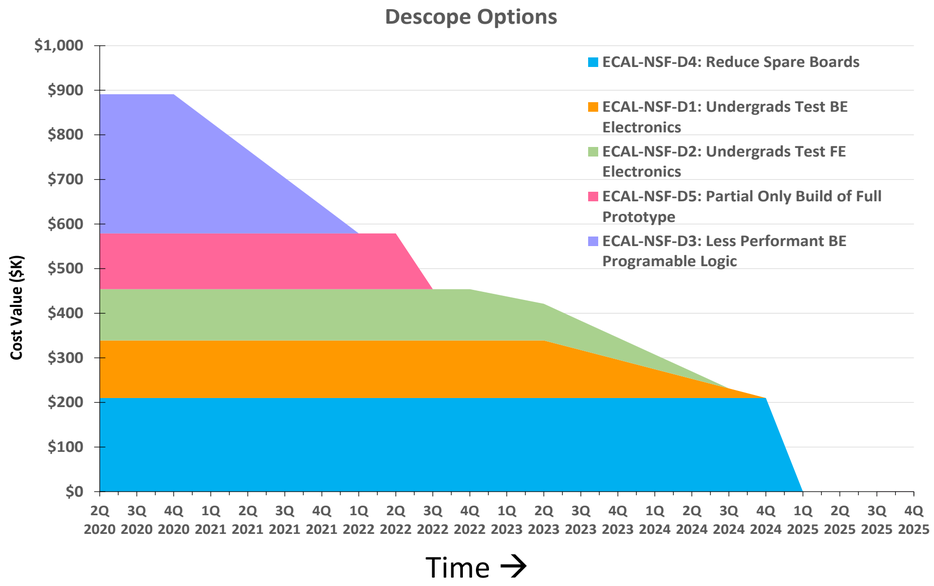
***Hint: Examples of** descope and upscope options are included in the Risk Register on slide 8.*

- Descopes => additional cost and schedule contingency
  - Recover from cost and schedule overruns/stay within project baseline
  - Boost contingency when risk exposure is greater than remaining contingency
  - Move Descope options to upscope options in case they can be reinstated
- Upscopes/opportunities take advantage of favorable progress and contingency
  - Must be improvements to existing scope or related enhancements

The Scope Management Plan details handling of project scope as a key part of risk and contingency management. It should include the following elements:

- Scope Management Strategy and Approach
- Roles and Responsibilities
- A list of identified up- and down- scope options
  - Description of the scope involved
  - Associated WBS element
  - Estimated cost and schedule impact
  - Impact on science goals, performance or quality
  - Time frame in which the option is viable
  - Decision dates in the schedule
  - Optional – priority list

***Hint:** "Sand Charts" (stacked area charts) are helpful in demonstrating reduction in options over time.*



# Summary

- NSF requires risk management practices that include four products
  1. Risk Management Plan (RMP)
  2. Risk Register
  3. Risk Exposure Estimate
  4. Contingency Management Plan (CMP)

**Hint: Risk is real – you can't ignore it; but don't be afraid of it. It's a manageable fact of life for the unique projects that NSF supports.**

- Emphasis is placed on proactive and iterative risk management, taking advantage of opportunities as well as managing threats
  - Reduce or avoid risk impacts as soon as they are identified

- NSF allows the use of cost, schedule, and scope contingencies to manage risk impacts
  - Amounts backed by risk exposure and estimate uncertainty determinations
  - Both algorithmic and probabilistic methods are allowed

- Proposal timeline to develop mature cost, schedule, scope, and contingency is aggressive
  - Risk management planning starts early in the pre-proposal process and matures with the full proposal submission
  - Proposers may want to continue working on project planning while waiting for an invite to submit full proposal

- Risk management effort can be significant; plan for it in both proposal and implementation stages
  - Recruitment of Subject Matter Expert in Risk Management is advised

**"Proactive Risk Management: Planned, Early, Continuous"**

# Additional Sources for Guidance

- Government Accountability Office (GAO) Cost Estimating and Assessment Guide, 2009 (in revision)
- Government Accountability Office (GAO) Schedule Assessment Guide, 2013
- Guide to the Project Management Body of Knowledge, (PMBOK® Guide), Project Management Institute

Warning: Although principles and methodologies in the above guides are similar to those of NSF, there are significant differences in terminology for, and handling of, contingencies.

- See the Research Infrastructure Guide (RIG), Section 6 for additional references and the Lexicon in Section 8 for NSF terminology.

# Maxwell or Sander's Algorithmic Method

## Example using Gay Sanders method of estimating project uncertainty/contingency needs

Contingency calculated using two tools:

- Cost Uncertainty/Risk tables

  Contingency Factor = (Technical factor)*(Technical risk multiplier)
  + (Cost factor)*(Cost risk multiplier)
  + (Schedule factor)*(Schedule risk multiplier)

- Simple Monte Carlo simulation using base estimate, uncertainty estimate, and Risk Register impacts to determine range of estimates
  - Used as validation for algorithmic result
  - Contingency adjusted upward to match MC result since algorithmic methods often underestimate uncertainty

| Tech | | Proc | | Sched | | Uncertainty | Risk | Contingency (Uncert + Risk) |
|---|---|---|---|---|---|---|---|---|
| Factor | Value | Factor | Value | Factor | Value | | | |
| 3 | 4 | 4 | 2 | 2 | 1 | 22% | 2% | 24% |

**Estimators use tables for Technical & Procurement uncertainties at the activity level**

**Estimators use tables for Schedule uncertainty at the WBS level**

**Uncertainty (sum of products of factor x value) at activity level**

**Monte Carlo simulation on cost estimates ranges yields additional project risk which is distributed at subsystem level**

**RISK FACTORS DEFINITIONS AND PERCENTAGES**

**COST RISK**

| Cost Pct | Cost Pct Description | Cost Pct Text |
|---|---|---|
| 1.00% | Material cost or labor rate concern | 1.00% |
| 2.00% | Material cost and labor rate concern | 2.00% |

| Cost Factor | Cost Factor Description | Cost Factor Definition |
|---|---|---|
| 1 | Off-the-shelf or catalog item | Off-the-shelf or catalog item |
| 2 | Vendor quote from established drwgs | Vendor quote from established drawings |
| 3 | Vendor quote some design sketches | Vendor quote with some design sketches |
| 4 | Current production item | In-house estimate for item within current production line |
| 6 | Min company experience, capabilities exist | experience but related to existing capabilities |
| 8 | Min company experience, minimal capability | experience and minimal in-house capability |
| 10 | Top down estimate from analogous programs | Top down estimate from analogous programs |
| 15 | Engineering judgment | Engineering judgment |

**SCHEDULE RISK**

| Sched Pct | Schedule Pct Description | Schedule Pct Text |
|---|---|---|
| 1.00% | | 1.00% |

| Sched Factor | Schedule Factor Description | Schedule Factor Definition |
|---|---|---|
| 2 | Very low risk - delays completion of noncritical path items | Approx 2 week delay to completion noncritical path of subsystem items |
| 4 | Low risk - delays completion of critical-path items | Approx 2 week delay to completion of critical path of subsystem items |
| 6 | Moderate risk - delays completion of critical-path items | Approx 1 month delay to completion of critical path of subsystem items |
| 8 | High risk - delays completion of critical-path item | Approx 3 month delay to completion of critical-path subsystem item |
| 10 | Very high risk - delays completion of critical-path item | Approx 6 month delay to completion of critical-path subsystem item |

**TECHNICAL RISK**

| Tech Pct | Technical Pct Description | Technical Pct Text |
|---|---|---|
| 2.00% | Design or manufacturing concerns only | 2.00% |
| 4.00% | Design and manufacturing concerns | 4.00% |

| Tech Factor | Technical Factor Description | Technical Factor Definition |
|---|---|---|
| 1 | Existing design and off-the-shelf hardware | Existing design and off-the-shelf hardware |
| 2 | Minor modifications to an existing design | Minor modifications to an existing design |
| 3 | Extensive modifications to existing design | Extensive modifications to an existing design |
| 4 | New design within established product line | New design within established product line |
| 6 | Different product line, technology exists | New design different from product line. Existing technology |
| 8 | New design, requires some R&D | New design, requires R&D but does not advance state-of-the-art |
| 10 | New design, advances the state-of-the-art | New design. Development of new technology which advances the state-of-the-art |
| 15 | New design way beyond state-of-the-art | New design way beyond the current state-of-the-art |

- Risk factors and values lookup table for the Gary Sanders method of Algorithmic risk exposure calculation