Elec 4309 Senior Design

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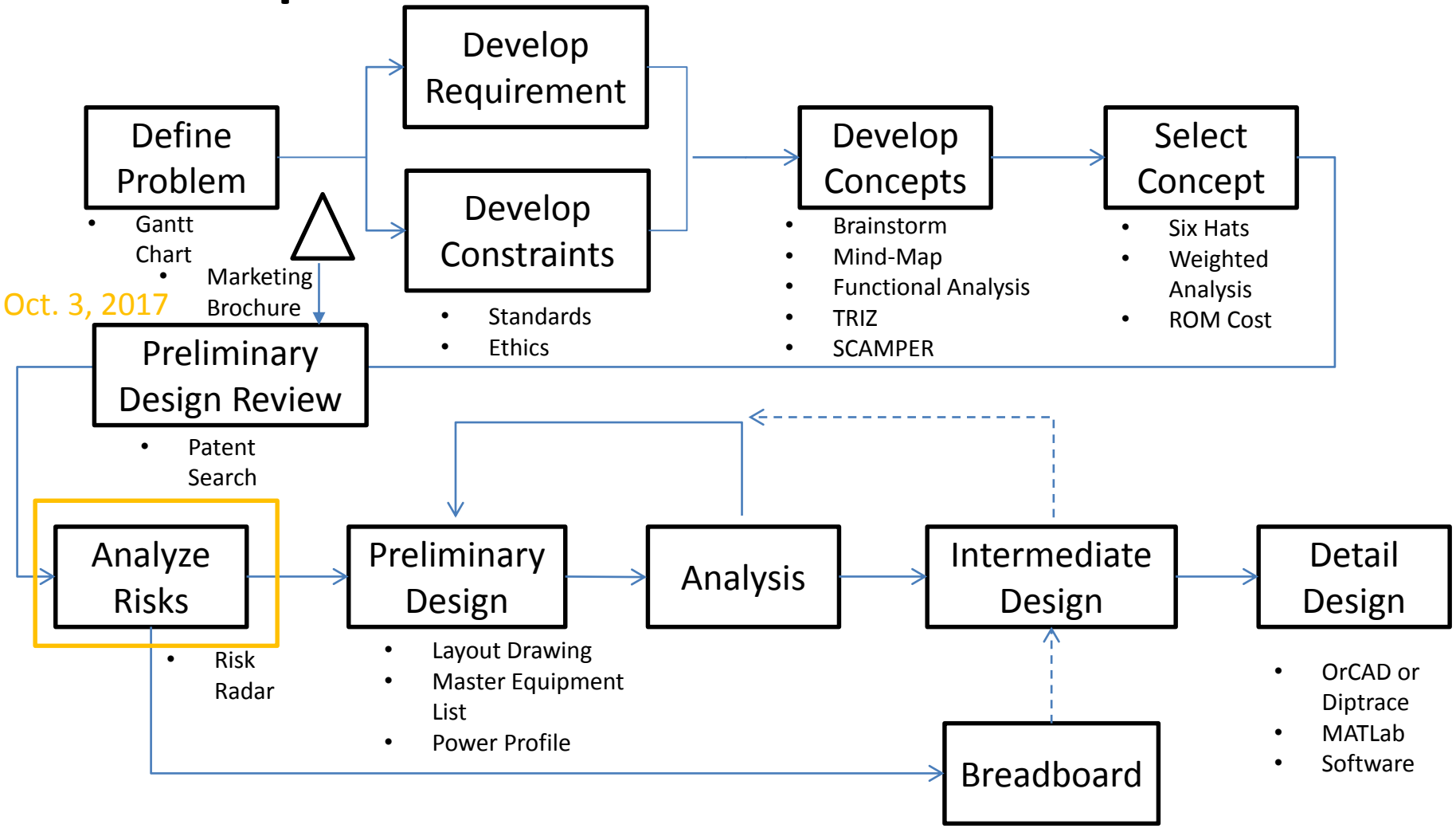
Updated Plan For This Class

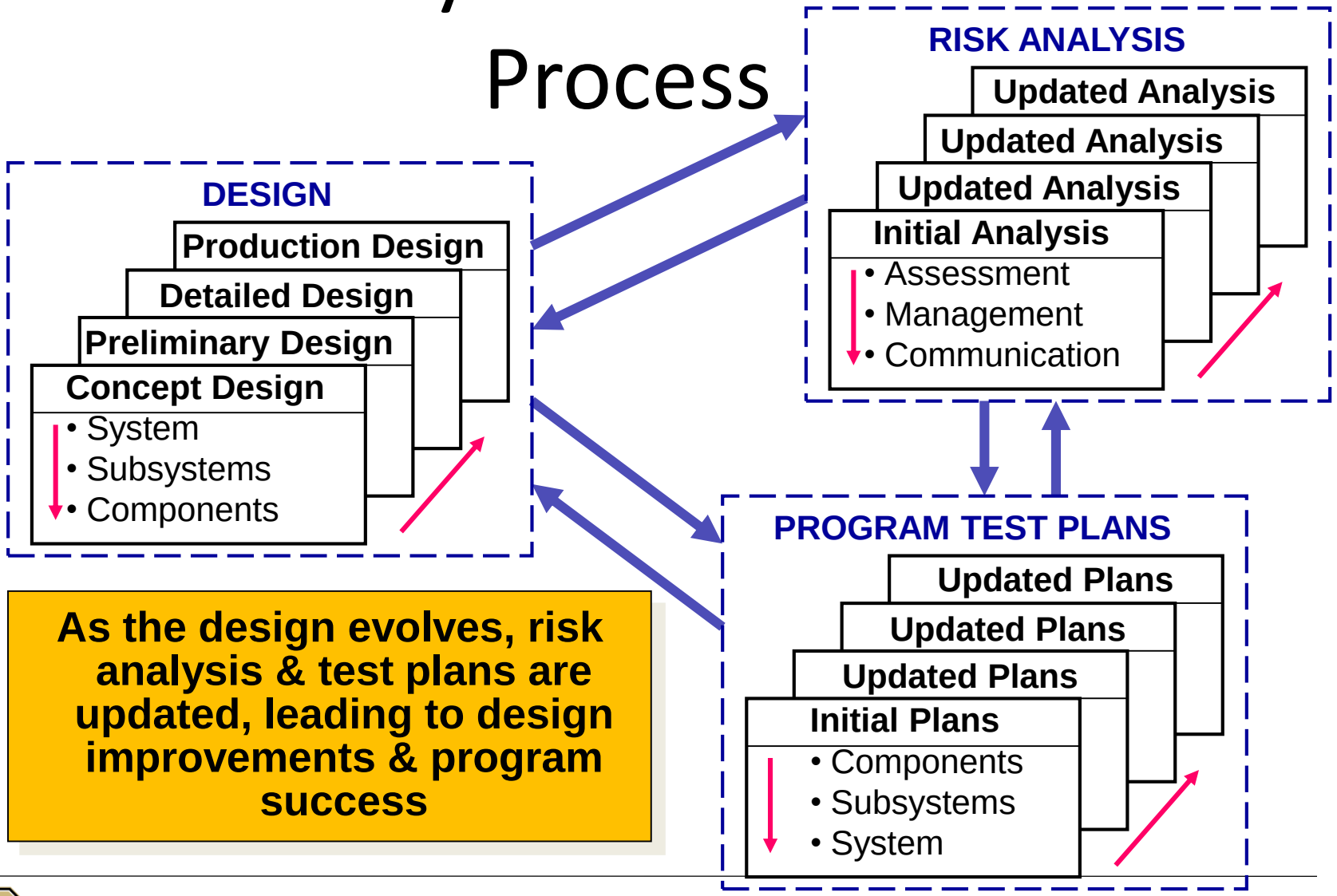


Benefits of Risk Analysis

- **Increases probability of program success**
  - Potential to reduce program schedule & cost
- Facilitates proper allocation of resources
  - Helps in program planning
- Communicates program status / health
  - Informs program / company management
  - Informs customer

Effective risk analysis is not easy, but a process and tools are available

Risk Analysis is a Continuous Process



As the design evolves, risk analysis & test plans are updated, leading to design improvements & program success

Risk Topics

- What is a Risk?
- Types of Risk
- Assessment of Risks
- Reporting & Tracking Risks
- Risk Management
- Risk Mitigation
- Example

What is Risk?

- From the dictionary:
  - The possibility of loss or injury.
  - The chance or possibility of incurring loss or misfortune.
  - The uncertainty of future returns (financial risk).

- Risk is “the potential of an adverse condition occurring on a project which will cause the project to not meet expectations”

  - University Information Services, Georgetown University

What is Risk?

"Risk is a measure of the potential harm or loss associated with an activity executed in an uncertain environment."

-*Terry Bahill*

"Risk is Uncertainty"

- *Bob Sklar*

Something that is unknown because it has not yet been designed is a design task; not a risk

What is Risk Analysis?

Risk analysis includes:

- **Risk assessment** involves identifying sources of potential harm, assessing the likelihood that harm will occur and the consequences if harm does occur.
- **Risk management** evaluates which risks identified in the risk assessment process require management and selects and implements the plans or actions that are required to ensure that those risks are controlled.
- **Risk communication** involves an interactive dialogue between stakeholders and risk assessors and risk managers which actively informs the other processes.

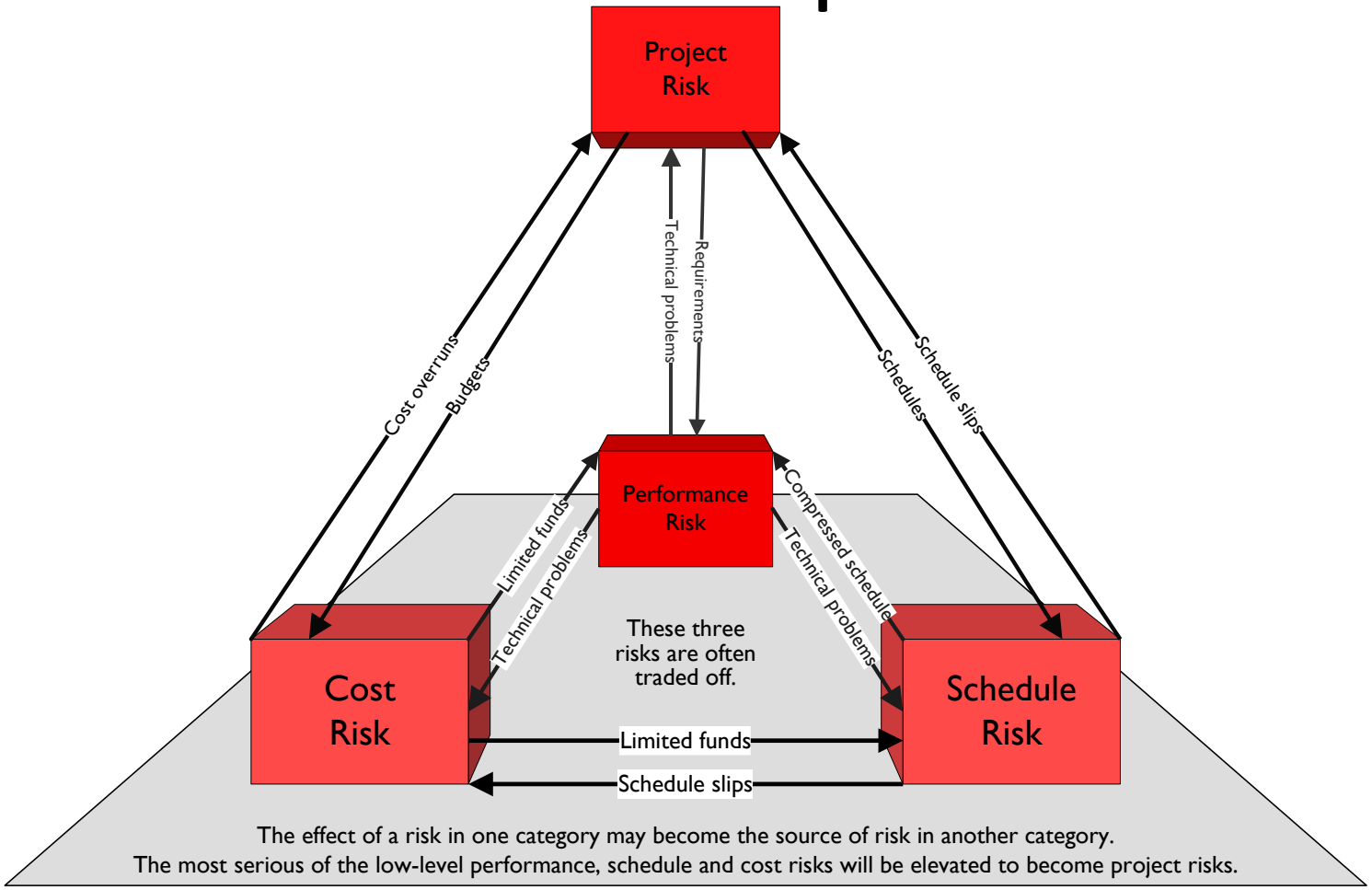
- Wikipedia

Risk analysis = risk assessment + risk management + risk communication

Different Types of Risk

- Performance Risk
  - Technical risks, normally tracked using technical performance measures. Inability to achieve technical requirements.
- Schedule Risk
  - Unforeseen delays in completing tasks.
- Cost Risk
  - Unforeseen cost overruns, often associated with performance and schedule risks.
- Project Risk
  - The potential of an adverse condition that will cause the project to not meet customer expectations

Interrelationship of Risks



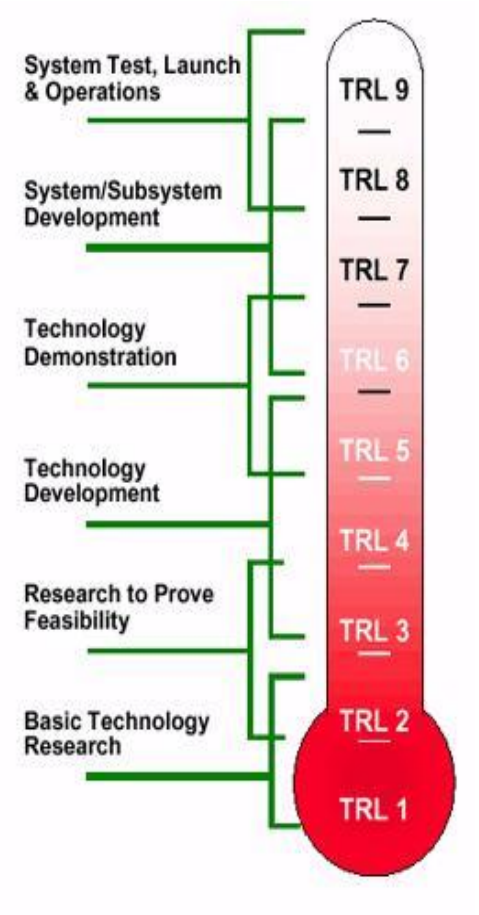
Major performance, cost & schedule risks work their way up to the overall project

Evaluating Performance Risk

- **Low Risk**
  - Technology mature and can be applied operationally. Multiple technology options available.
- **Moderate Risk**
  - Technology development required before operational application. Few technology options exist.
- **High Risk**
  - Technology immature. Extensive development needed even before laboratory demonstration. Only one plausible technology option exists.

Technology Readiness Level

Technology Readiness Level (TRL) is a measure used to assess the maturity of evolving technologies (materials, components, devices, etc.) prior to incorporating that technology into a system or subsystem.



Is Elimination of Uncertainty Sufficient?

- Suppose we conduct a test and discover that a subsystem does not meet a key requirement
- Since the uncertainty has been eliminated, has risk also been eliminated?
- No, there may be a high level of project risk caused by not meeting this requirement
- Therefore, the subsystem design must be fixed (unless the overall system can somehow accommodate this performance problem)

It is not enough to eliminate uncertainty; program requirements must still be satisfied

Accepting Risk Can Be Good

- Accepting risk is desirable if:
  - It offers the potential of large payoffs in performance, cost or schedule
    - Normally, risk buys performance potential
    - Sometimes, reduced cost or schedule is the objective
    - Rarely do all 3 benefit from accepting risk
  - The risk can be managed
    - Risk management plan is critical & must be seriously implemented
  - The risk is accepted by the customer
    - Must understand risk and potential consequences
    - Risks don't always pay off
    - Example: Use of unproven technology could provide performance improvement if successful; more cost & delayed schedule if not

Risk has 2 Components

"Fear of some harm ought to be proportional not only to the magnitude of the harm, but also to the probability of the event."

- Logic, or the Art of Thinking

Antoine Arnauld, 1662

We refer to these as:

1. Severity of Consequence
2. Relative Likelihood of Occurrence

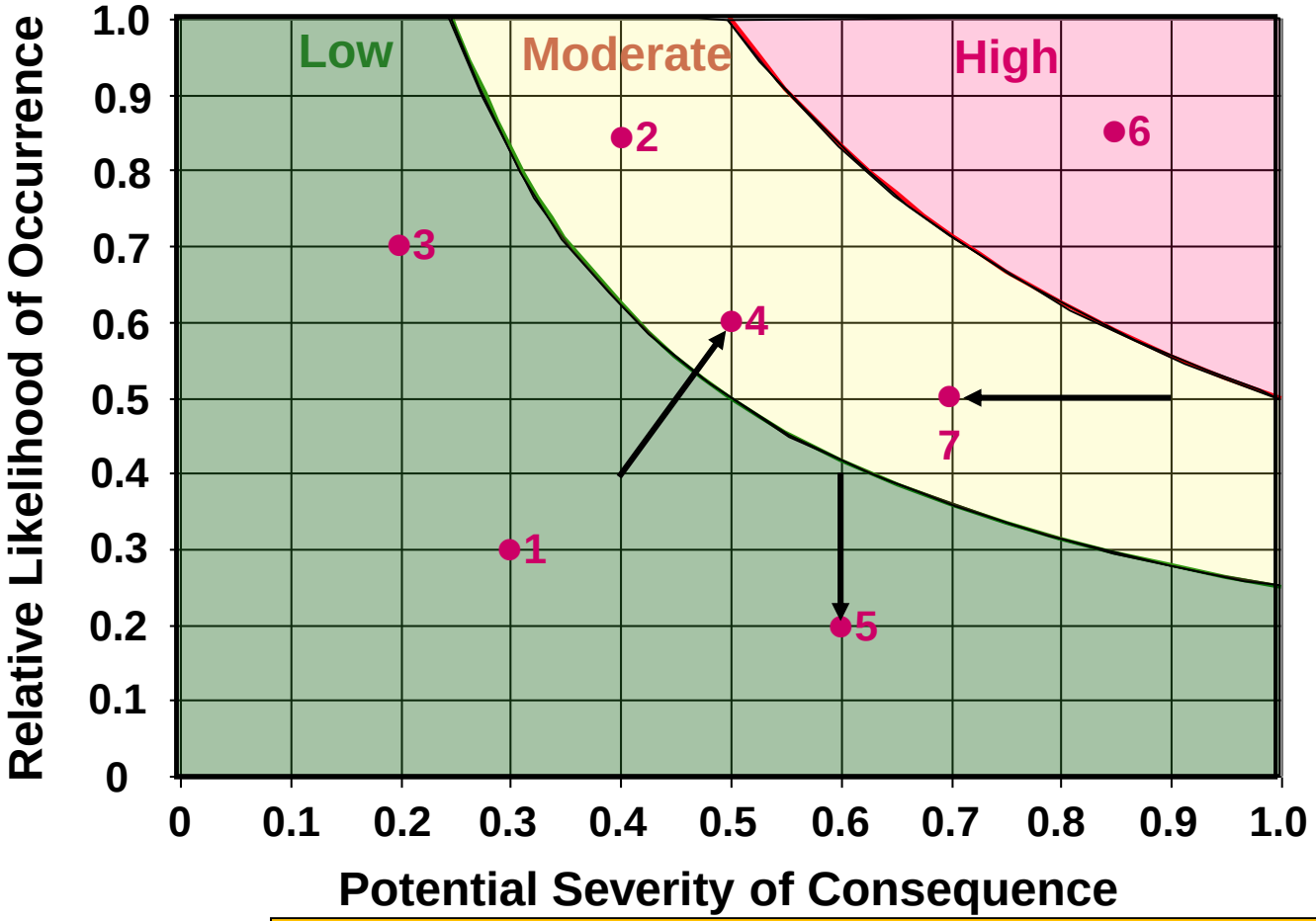
For convenience, the product of these 2 risk components is often used as an overall measure of risk

How do We Quantify Risk?

- Since risk represents uncertainty, its components are difficult to explicitly quantify
- Engineers with appropriate expertise can use their experience and judgment to estimate relative risk levels
- Relative risk levels, while not precise probabilities, provide a means of tracking and communicating areas needing special attention

Risk assessments highlight areas demanding special attention

Reporting & Tracking Risk



Arrows indicate changes from previous report

Legend

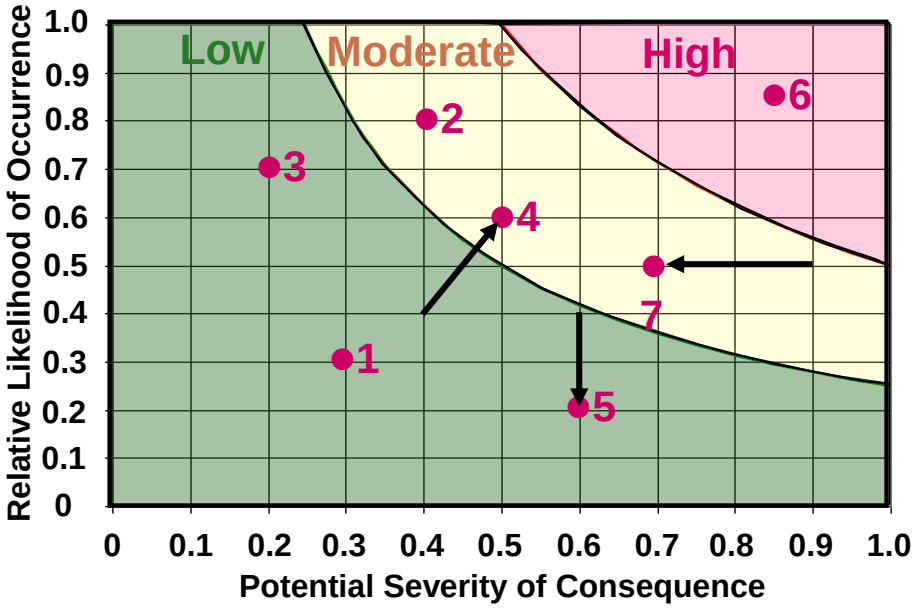
1 =
2 =
3 =
4 =
5 =
6 =
7 =

(Brief descriptions)

The goal is to reduce all risks to low levels during the development process

Some Observations on Risk Plot

- The ordinate (vertical axis) is *not* probability
- Probabilities cannot be calculated because of uncertainty and unknown unknowns
- This axis is labeled *relative likelihood*
  - Relative because it concerns relationships between risks
  - Likelihood not in the mathematical sense, but in the dictionary sense indicating risks that are most likely

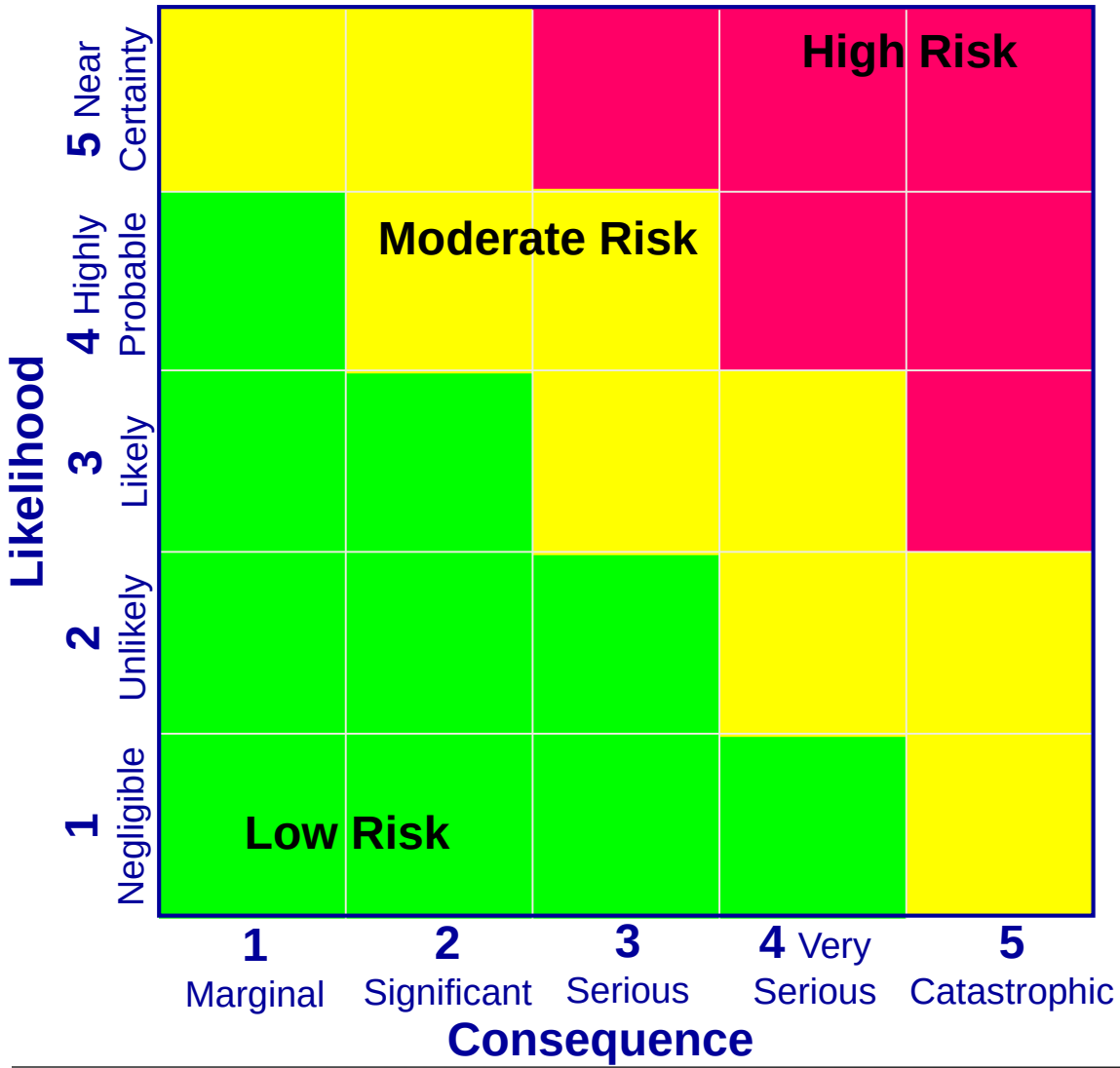


What Causes Risks to Change?

- Estimated risks could increase or decrease due to:
  - Design changes
  - Analysis or test results
  - Other new information

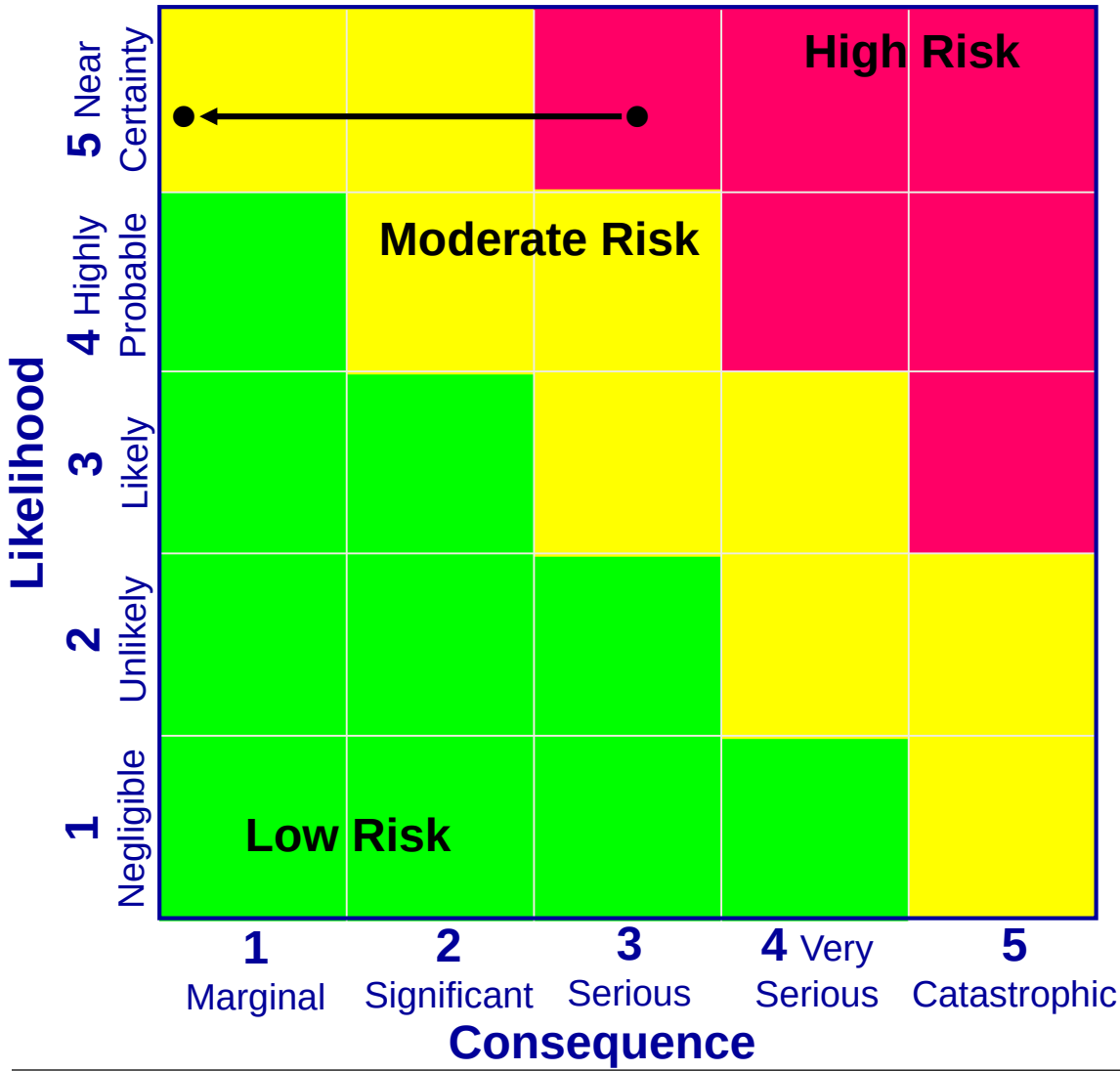
The design evolves; knowledge evolves – always look for new risks & better estimates for previously known risks

Alternate Form of Risk Plot



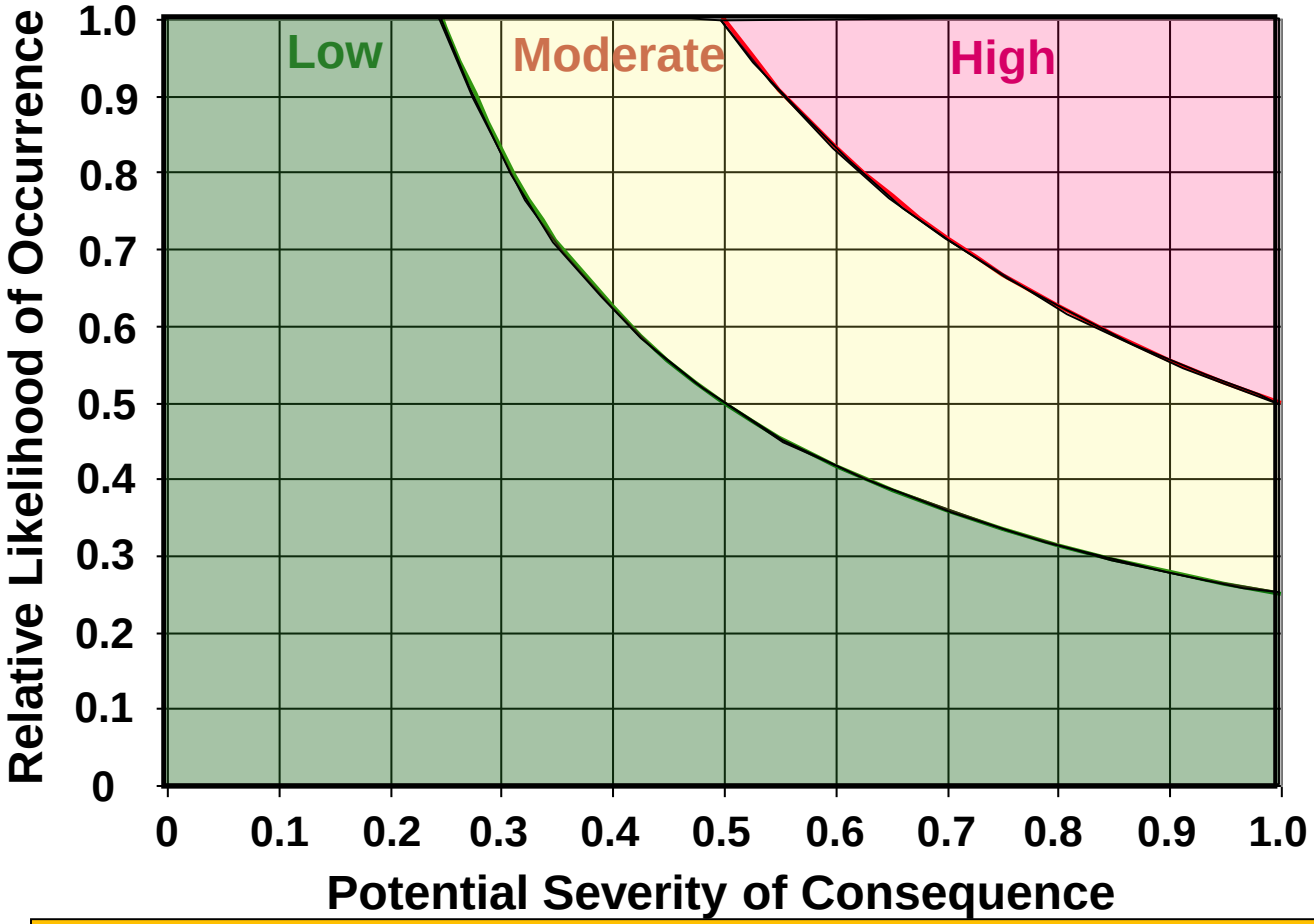
Some customers prefer this form

Alternate Form of Risk Plot



Some customers prefer this form - but it has the disadvantage that risks with potential catastrophic consequences can never be retired

The other Preferred Form of Risk Plot



This is basically a communications aid, so do it the best way for your customer

Risk Management

"Good risk management will not prevent bad things from happening. But when bad things happen, good risk management will have anticipated them and will reduce their negative effects."

-Terry Bahill

Performance, schedule and cost risks at the lower (subsystem) levels can often be accommodated at the project level by reallocating resources or requirements, but this requires that program management be aware of problems early.

Ways to Manage Risk

- Develop comprehensive risk management plan
  - Risks identified; mitigation plans developed
    - By engineers with related expertise
- Assign each risk to a responsible engineer
  - In design area impacted by this risk
  - Manages risk mitigation plan; reports status
- Conduct tests at all levels as early as possible
  - Uncover design problems in time to fix deficiencies
  - Validate or refine analytic models (confidence)
- Keep customer informed
  - Focus on moderate and high risks; report status & program impact

Risk Mitigation

- Develop program plan, schedule, and budgets that can accommodate risk:
  - Test intensive (all levels & early; prototypes)
  - Spare parts (to preserve schedule if failures)
  - Back-up plans (work-arounds)
  - Anticipate failures
  - Ample design margins
- Continually search for new risks as knowledge evolves over time

The program plan must tradeoff performance risk and the cost of additional tests

Risk Mitigation Plan Development

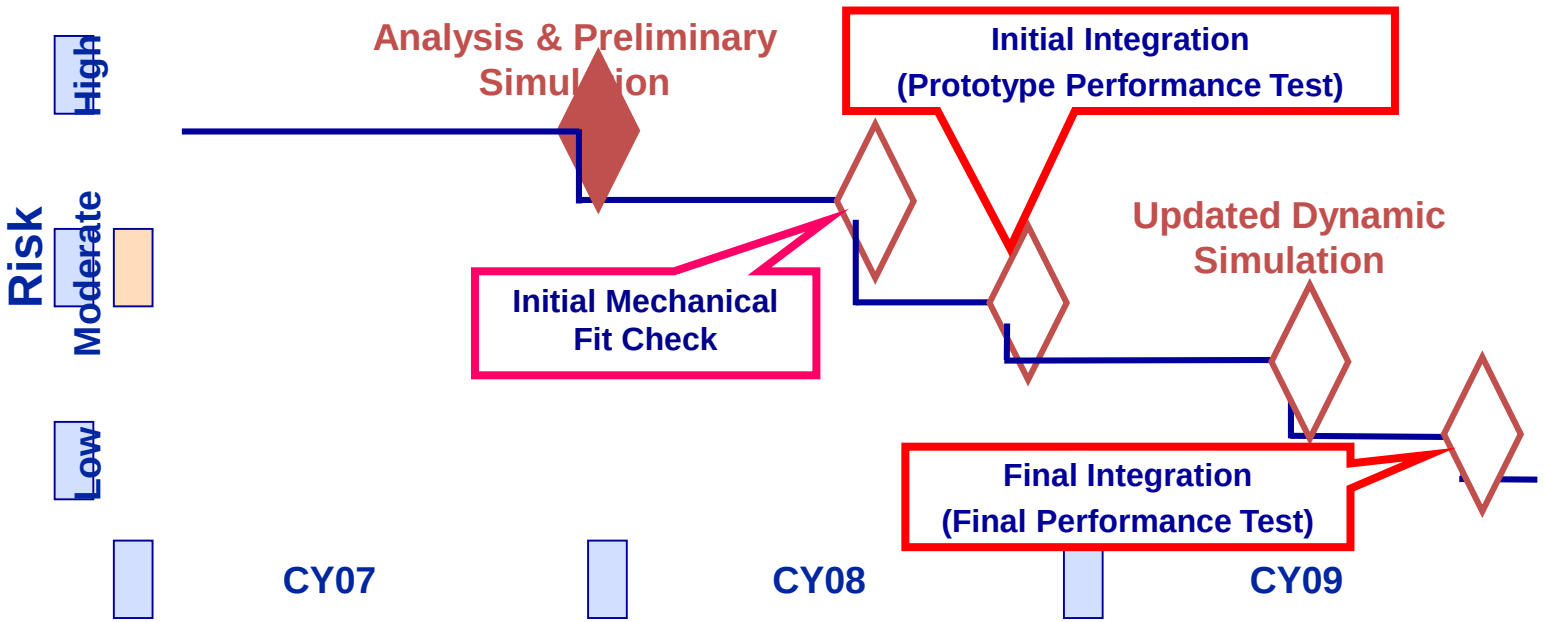
- For each high or moderate risk area, the plan should include:
  - Analysis, simulations, tests and other activities capable of progressively reducing uncertainty
    - Plan for each activity should include detailed schedule and required resources (including personnel)
  - Activities should be conducted as soon as allowed by available hardware/software
  - Reassess risks based on results of activities
  - Have backup plan in case activity fails

Risk management is an integral part of the overall program plan. It is a continuous & iterative process.

Mitigation Plan (Risk Waterfall Chart)

Risk 352: Mechanical integration
Subsystem: Staging Assembly
Responsible Engineer: John Stager

Activities are introduced to progressively reduce risk



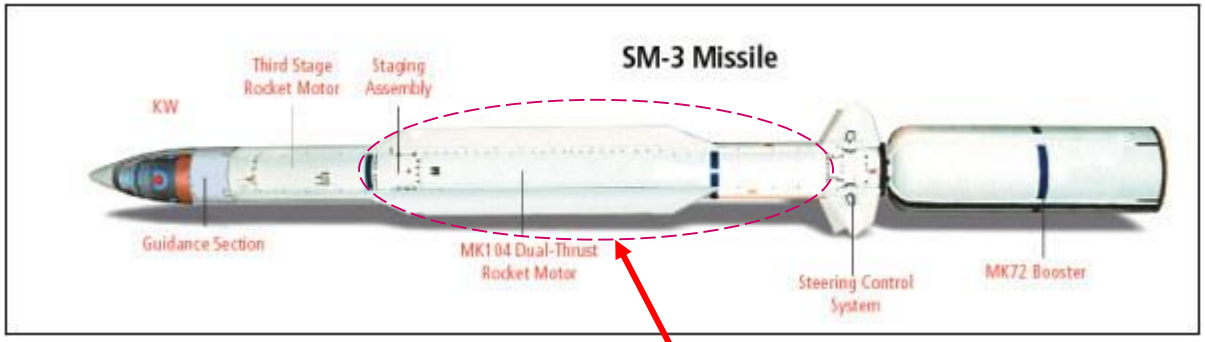
Plan should include detailed descriptions of each mitigation activity

Every risk item is assigned to a specific responsible design engineer

Reporting Risk

- If you are the responsible engineer for a missile subsystem and need to make a risk status presentation at the monthly meeting with your customer, consider presenting the following:
  - Overview – list key changes from last month
  - Updated risk register
    - Subsystem risks & risk assessments; highlight changes
  - Risk plot (likelihood vs. severity)
    - Indicate changes from previous month
  - Risk waterfall charts for high/medium risks
    - Indicate changes from previous month
  - Results of any risk mitigation activities completed in last month, justifying risk assessment changes

Example: Risk Analysis



Public Released Raytheon Images

For this risk example, we will address the MK104 Dual-Thrust Rocket Motor (2nd stage)

Example intended to illustrate risk analysis process, not actual SM-3 history

Some Design Status Assumption

- Initial design trades and at least preliminary subsystem designs have been completed:
  - Rocket motor size (consistent with other missile stages)
  - Case materials
  - Propellant type (solid)
  - Propellant design (thrust profile)
  - Stage interfaces (mechanical/electrical)

Design Challenges are tasks, not risks

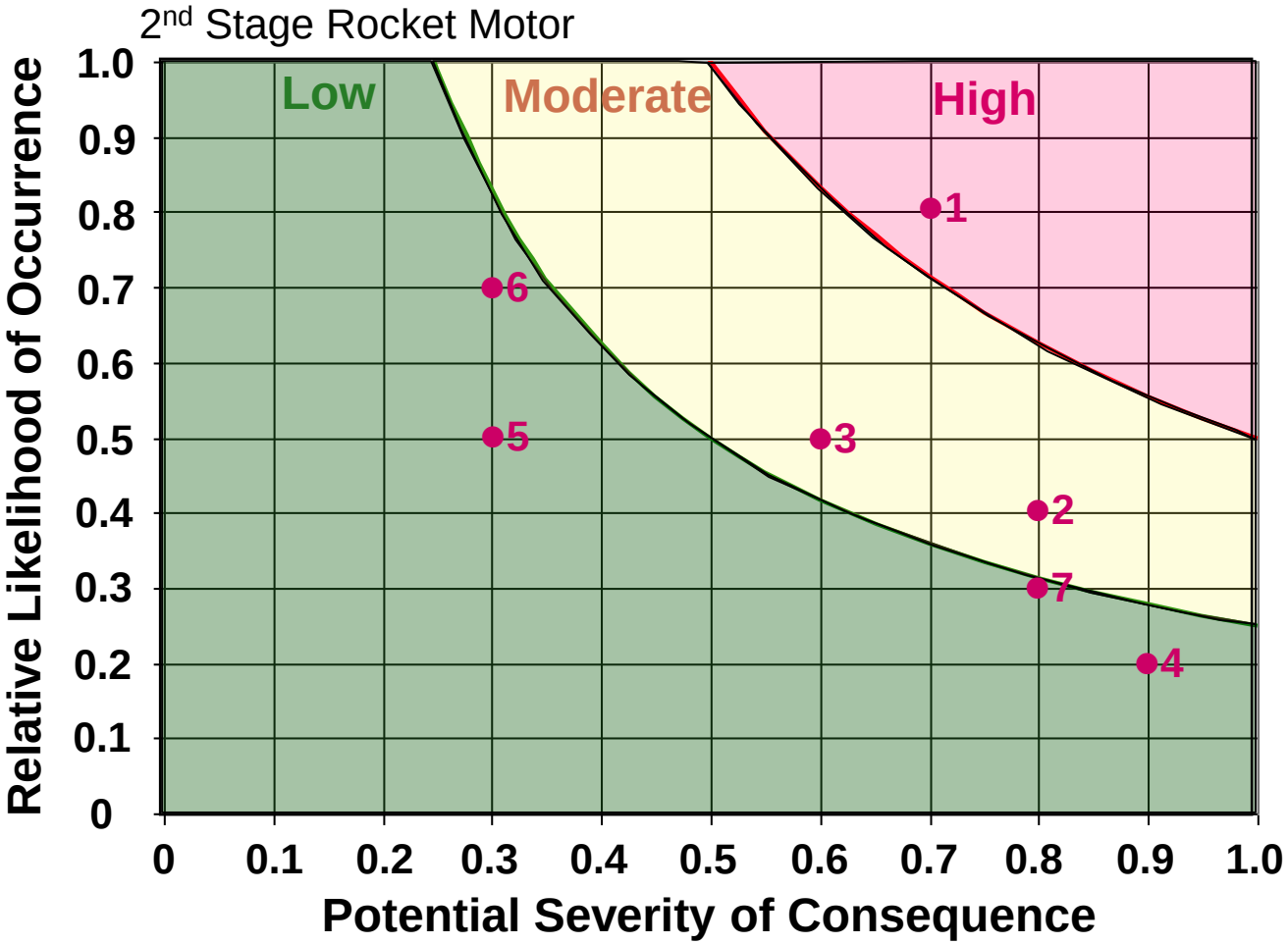
Risk Register Example

2nd Stage Rocket Motor

Risk No.	Risk	Consequences	Likelihood	Severity	Risk Factor
1	May not achieve specified total impulse	Overall missile performance may not be acceptable	0.80	0.70	0.56
2	2nd thrust may not initiate properly	Would reduce mission effectiveness	0.40	0.80	0.32
3	May exceed weight allowance	Overall missile performance may not be acceptable	0.50	0.60	0.30
4	Mechanical interfaces with other stages may be inadequate	Missile failure during transportation, launch or flight	0.20	0.90	0.18
5	Stage production cost may exceed allowance	Total missile cost may not be acceptable	0.50	0.30	0.15
6	Propulsion development time may exceed plan	Development time (and associated cost) may not meet program objectives	0.70	0.30	0.21
7	Propulsion stage may not meet safety requirements	Missile may not be acceptable to customer	0.30	0.80	0.24

Risk Factor = Likelihood x Severity

Example Risk Assessment

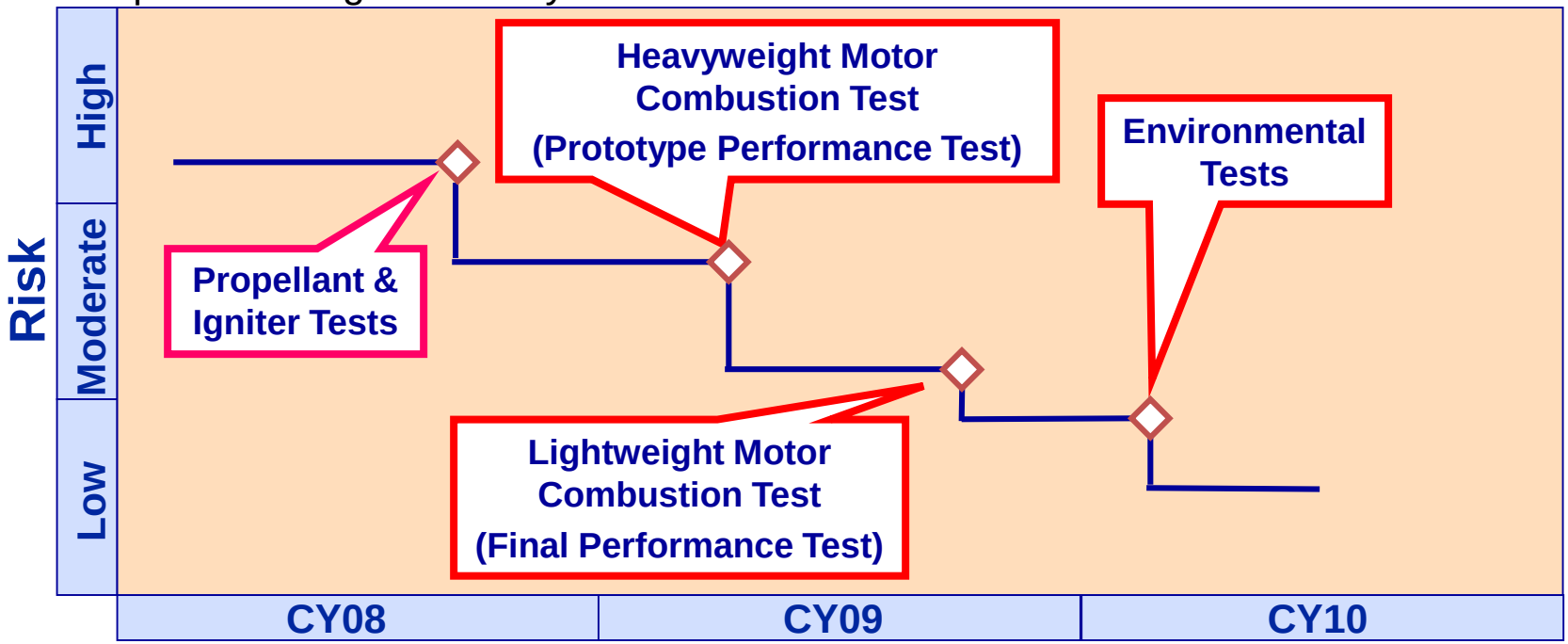


Legend
1 = Total impulse
2 = 2nd thrust
3 = Stage weight
4 = Interfaces
5 = Stage cost
6 = Schedule
7 = Safety

These estimates, based on judgment, may not reflect reality

Example Risk Waterfall Chart

Subsystem: 2nd Stage Rocket Motor
Risk 1 (may not achieve specified total impulse)
Responsible Engineer: Mary Burns



Descriptions of <u>each</u> mitigation activity should be included as part of the plan (with detailed description, schedule, required resources, etc.)

Each high or moderate risk needs a mitigation plan

Some Final Thoughts on Risk

"The parts of risk analysis we observe are only the communication tools. That is why they don't have to be precise. Real risk analysis takes place at lower levels, where design & test engineers are busy at their work. Systems engineers facilitate this process."

"Risks cannot really be controlled – bad things happen. But the anticipation of risks and the control of their consequences can indeed be managed."

- Bob Sklar