Technology Integration and Improved Technology Maturity Assessments

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The Context of the Study

- **Continuing DoD acquisition budget overruns and schedule slips**

	2000 Portfolio	2007 Portfolio
Portfolio size		
Number of programs	75	95
Total planned commitments	$790 Billion	$1,600 Billion
Portfolio performance		
Change to total RDT&E costs from first estimate	27 %	40 %
Change in total acquisition cost from first estimate	6 %	26 %
Estimated total acquisition cost growth	$42 Billion	$295 Billion
Average schedule delay to IOC	16 months	21 months

- **Bright spot: Programs with "mature" technologies and knowledge-based practices fare better**
  - **Programs with "immature" technologies undergo 44% more cost growth**

- **In 2006, Air Force launched process reengineering activities in order to find money to allow continued fleet modernization**

Source data: GAO-08-467SP Assessments of Selected Weapon Systems

Study Description

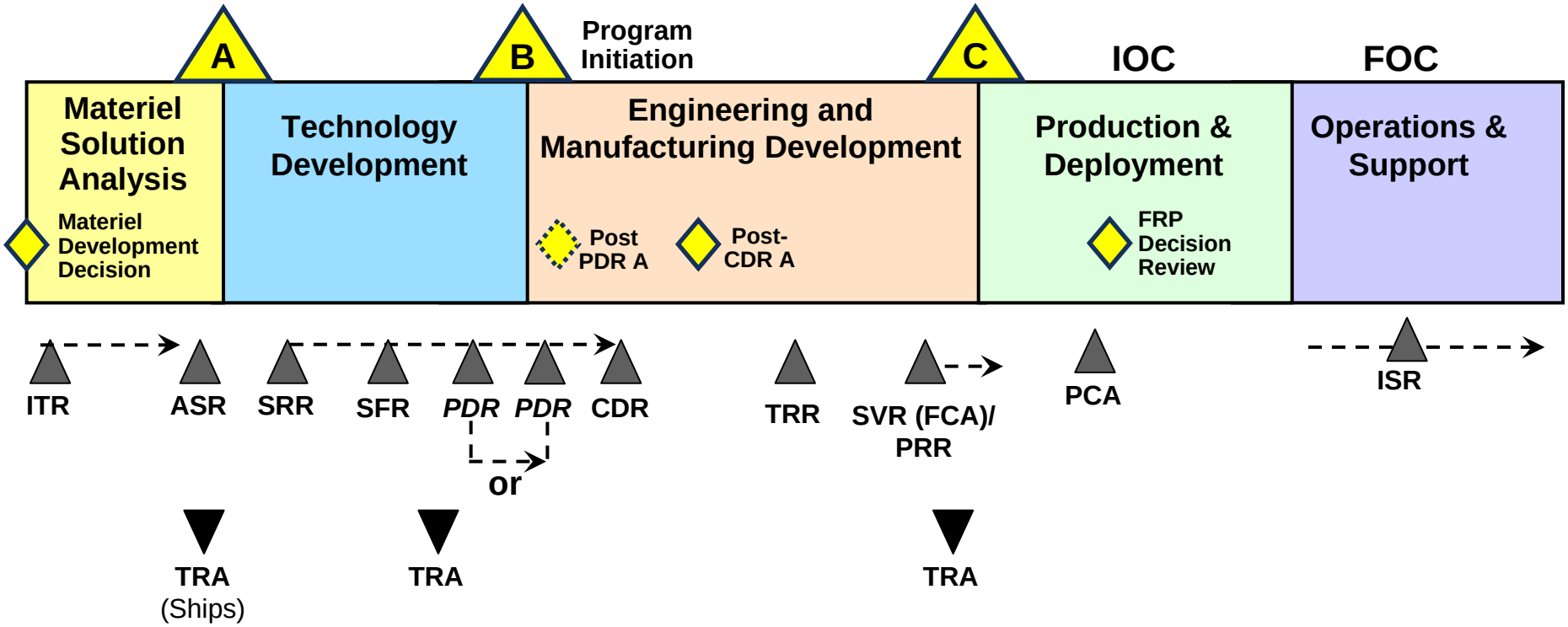
- **Goal is to reduce schedule slip and cost growth due to immature technology by**
  - **Reducing the likelihood that immature technology is accepted into acquisition programs**

  Or
  - **Better revealing upfront the risks associated with accepting immature technology**

Outline

- Background
- Existing Methodology (TRL Scale)
- Methods to Augment the TRL Scale
  - Manufacturing
  - Integration & “Ilities”
- Summary

Systems Engineering Technical Reviews



- Initial Technical Review (ITR)
- Alternative Systems Review (ASR)
- Systems Requirements Review (SRR)
- System Functional Review (SFR)
- Preliminary Design Review (PDR)
- Critical Design Review (CDR)
- Post-PDR Assessment (Post-PDRA)
- Post-CDR Assessment (PCDRA)
- Test Readiness Review (TRR)
- System Verification Review (SVR)
- Functional Configuration Audit (FCA)
- Production Readiness Review (PDR)
- Operational Test Readiness Review (OTRR)
- Physical Configuration Audit (PCA)
- Technology Readiness Assessment (TRA)
- In-Service Review (ISR)

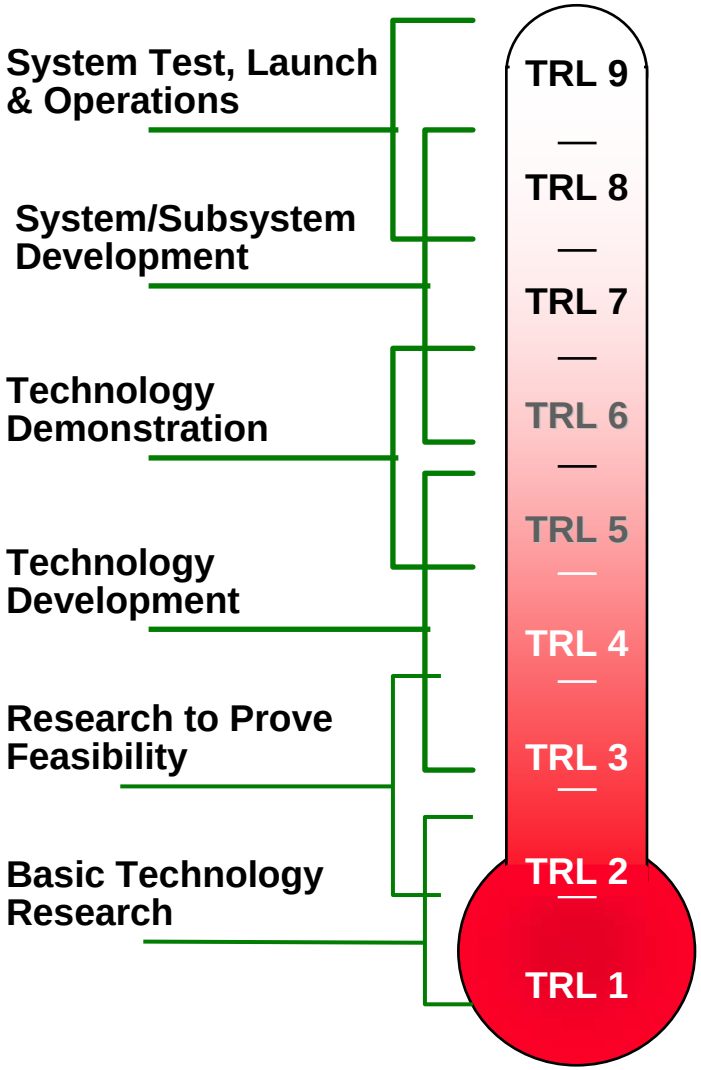
Technology Readiness Assessment (TRA)

- Prompted by continuing acquisition failures, the law now requires that "the technology in the program has been demonstrated in a relevant environment" at milestone B
  - Previously, many waivers were granted → No longer being granted except for true emergencies (e.g. MRAP)
- DoD conducts technology readiness assessment (TRA) at milestones B, C
  - Regulations have been formed around the Technology Readiness Level (TRL) scale
    - Minor generalizations from NASA scale
- TRA process & "deskbook*" formalized to address concerns about TRL assessment
  - Repeatability
  - Definition of a "relevant environment"
  - Objectivity → forced by independent team for Major programs

*See: https://acc.dau.mil/CommunityBrowser.aspx?id=18545

Measuring Technology Readiness

(DoD TRA Deskbook, May 2005)



Technology Readiness Levels (TRLs)

9. Actual system proven through successful mission operations (sw mission-proven operational capabilities)
8. Actual system completed and qualified (sw mission qualified) through test and demonstration (sw in an operational environment)
7. System prototype demonstration in an operational (sw high-fidelity) environment
6. System/subsystem model or prototype demonstration in a relevant environment (sw module and/or subsystem validation in a relevant end-to-end environment)
5. Component and/or breadboard (sw module and/or subsystem) validation in relevant environment
4. Component and/or breadboard validation in laboratory environment
3. Analytical and experimental critical function and/or characteristic proof-of-concept
2. Technology concept and/or application formulate
1. Basic principles observed and reported

Remaining TRL Issues

- **The TRL scale has utility for decision makers at higher levels**
  - **“Rear window mirror” – where have we been?**
  - **Helps to plan and explain development**
  - **TRL is being used by federal agencies (DoD, DoE, NASA, FAA, etc) and allies (NATO, GBR, Canada,…)**

- **It also has significant shortcomings**
  - **DoD TRA process only looks at Critical Technology Elements (CTEs)**
    - **TRL 6 definition is used for subsystems, not systems**
  - **Nonlinearity**
    - **Huge leap from 6 to 7**
    - **Almost unused after TRL 6**
  - **Does not account for integration, nor manufacturing**
  - **Does not indicate the difficulty (risk) of moving forward up the scale**

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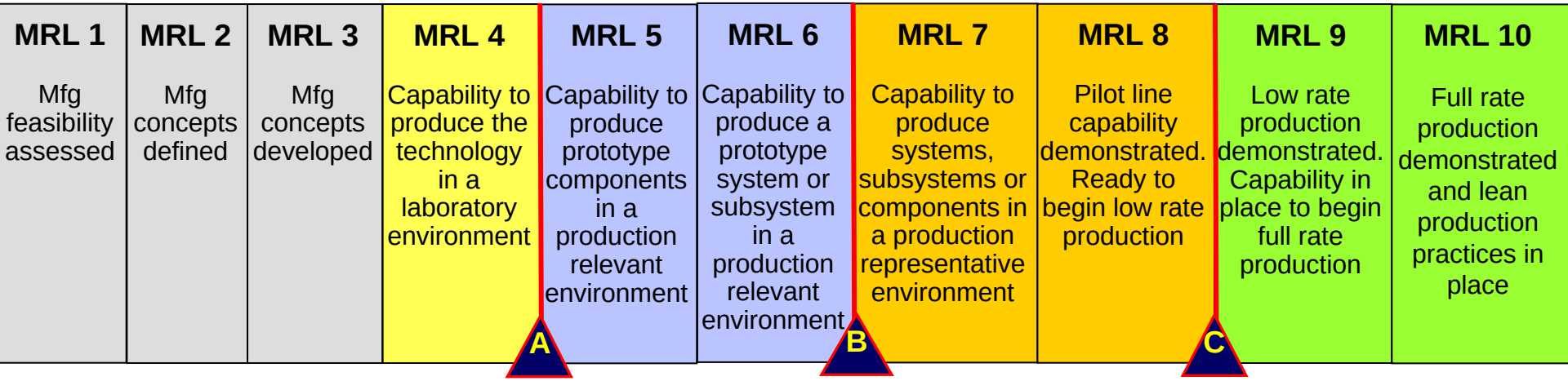
Manufacturing Readiness Levels (MRLs)



- **Tri-service working group (led by AFRL) has developed MRLs**
- **MRL scale**
  - **Early steps: planning for future production (e.g. supplier base)**
  - **Later steps: full process control with lean-manufacturing**
- **Manufacturing Readiness Assessments (MRAs) fill the vital role of predicting whether or not we will be able to produce the product in the timeframe and at the rate desired with the desired quality**
  - **Identifies risks for a program office to work on**
  - **Policy in development currently**

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Study Focus

"Our primary technical problem with the C-17 was integration. We grabbed too much off the shelf and tried to put it together"

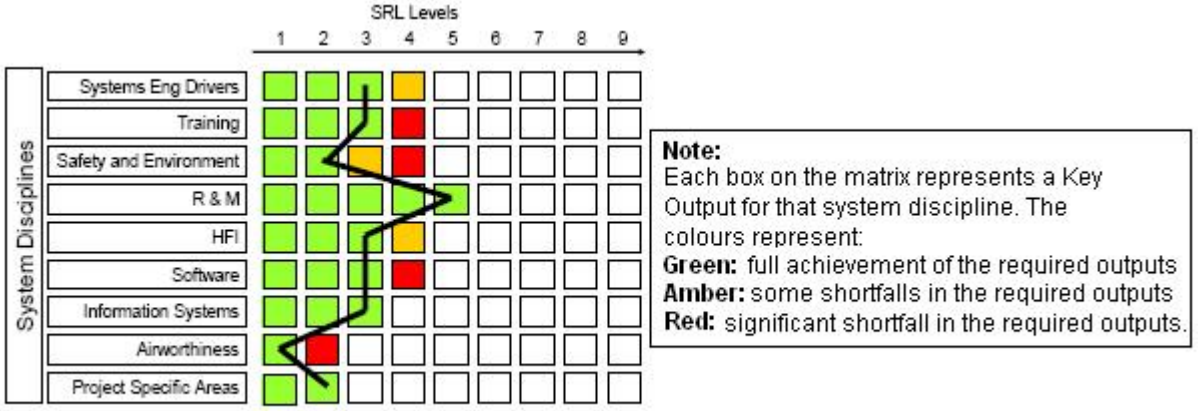
(Panton, 1994).

- **Initial study team had already concluded that integration must be accounted for**
- **What other issues should be included?**
- **How should these issues be handled?**
  - **Should additional scales be developed for each?**

- **Gathered team from Air Force product centers, logistics centers, test (AFOTEC), AFRL, cost analysis, NASA, Aerospace Corp, Carnegie Mellon SEI**

Surveyed Globe for Good Ideas

- Efforts surveyed across DoD, other agencies, internationally, universities, corporate world
- NASA-originated AD2 methodology
- Independent Program Assessment process
- British Ministry of Defence (MoD) has iterated 3 times on TRL-like process
  - British System Readiness Levels (SRLs) are used in conjunction with TRLs
    - Also in conjunction with a full-blown risk analysis assessment



Example of an SRL 'Signature'

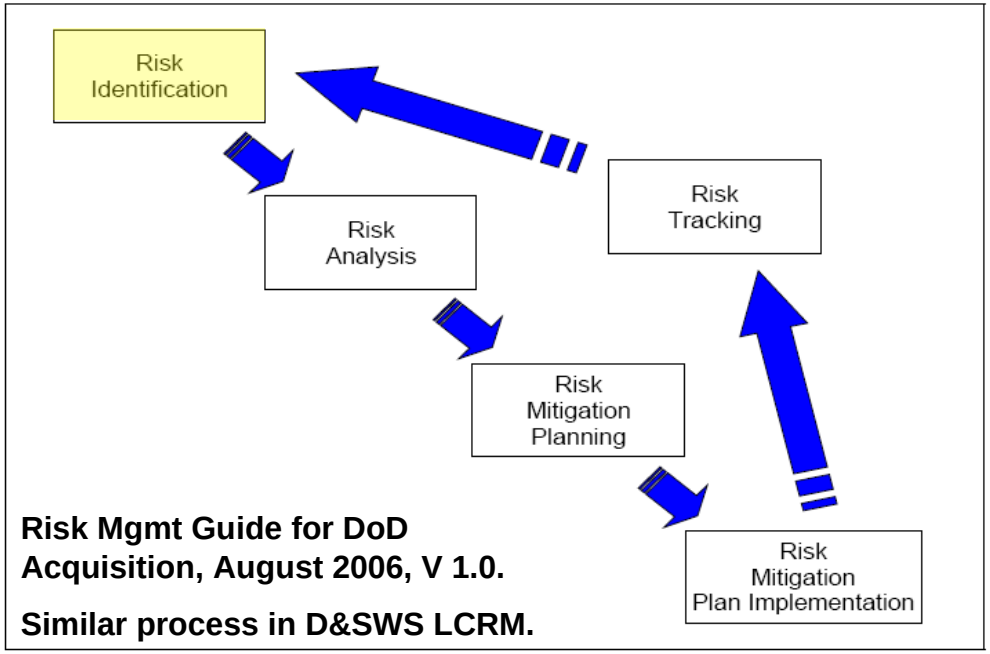
Examined Case Studies and Formed Opinions

- Conducted case histories on 5 current and historical programs at Air Force product centers and 1 at NASA
  - Mix of air and space projects (no cyber-only)
  - Program literature (eg quarterly DAES reports)
  - Live interviews
- Combined case histories with team members' knowledge to form lessons learned and identify best practices
- Final judgment: The issues that are lacking with TRL assessments are not where you are but what are the issues lying ahead
  - No new scales required (no Integration Readiness Level, etc.)
  - Identification of risks is the key (as is done in MRAs)
  - Utilize existing risk processes

- Decided to develop new methodology: **Risk Identification: Integration and Ilities (RI3)**

RI3 Use By an XR or PMO
For Risk Management

- RI3 used to support existing Risk Identification process
- Questions in nine 'ilities areas
  - Design Maturity and Stability
  - Scalability & Complexity
  - Integrability
  - Testability
  - Software
  - Reliability
  - Maintainability
  - Human factors
  - People, organization, & skills



Risk Mgmt Guide for DoD Acquisition, August 2006, V 1.0.

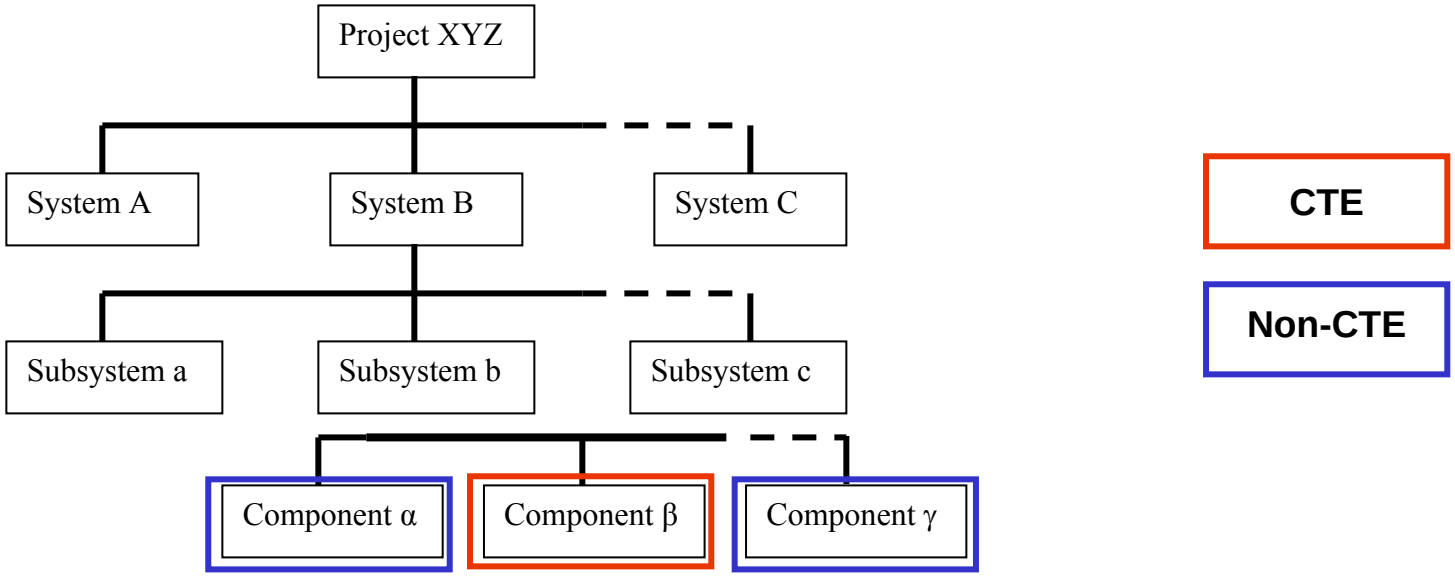
Similar process in D&SWS LCRM.

- Questions contained in a guidebook and interim tool
  - Questions are based on repeated problems in past
  - Helps ensure completeness of technical risks
  - Deconflicted from TRA, MRA, SEAM, LHA

Some Sample Questions:

- **Integrability**
  - ***Are there interactions / integration issues that could be affected by proprietary or trust issues between/ among suppliers?***
  - ***Have key sub-systems, at whatever level of readiness (breadboard, brassboard, prototype), been tested together in an integrated test environment and have they met test objectives?***
- **Software**
  - ***Are personnel with development-level knowledge of the existing, reused software part of the new software development team?***
- **Maintainability**
  - ***Is modeling and simulation used to simulate and validate maintenance procedures for the unit under test and higher levels of integration?***
- **Explanatory discussion with potential best practices on each question are included in RI3 guidebook and Excel-like worksheet/tool**
- **Questions are technical and shy away from programmatic**
- **Approximately 90 questions under development (~10 per 'ility)**
  - **Approximately 2 hours required to answer questions**

What to Evaluate with the RI3 Methodology

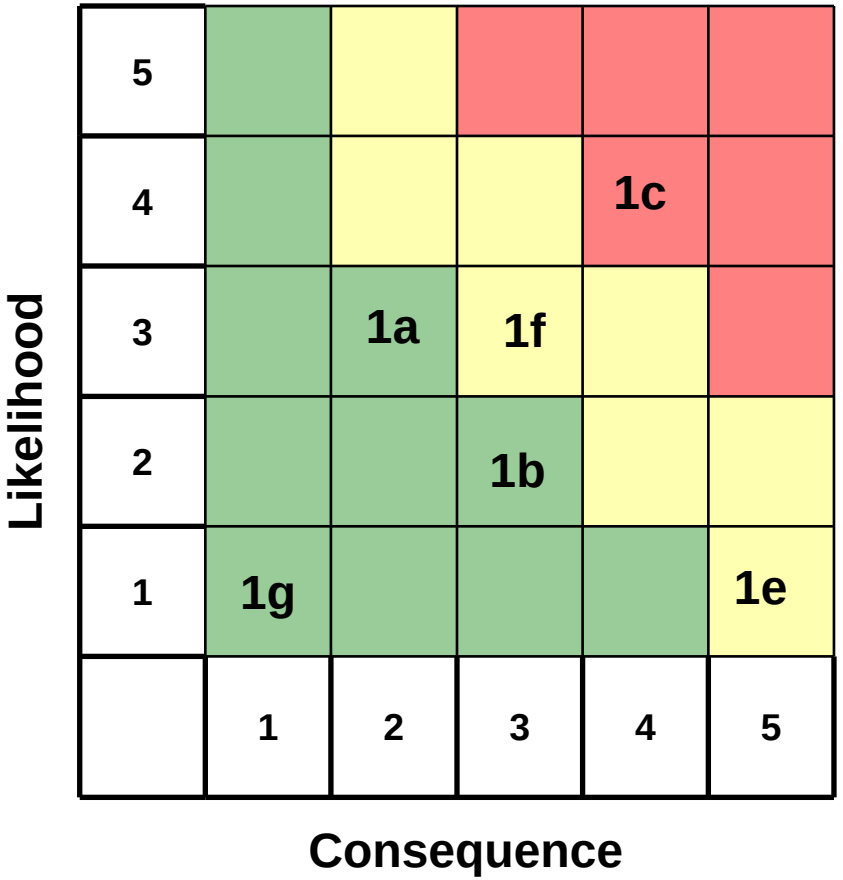


- **To assess integration and 'ilities, evaluate Critical Technology Elements (CTEs) + units that interface with CTEs, even if they are not CTEs themselves**
- **Rules of thumb:**
  - **If a unit is important enough to have an engineer or a billet assigned to it, then it's important enough to assess risks for it**
  - **In early phases of a program, may only be able to assess RI3 at a top or system level**
  - **For practical reasons, typically easier to ask RI3 questions for lower level units before doing higher levels of integration**
  - **If starting at the top level, run RI3 separately from the unit engineer's own evaluations, or this leads unit engineers to merely parrot back risks apparent at the top level**

Assess Likelihood and Consequence for Each Risk

- Utilize “standard” DoD/AF definitions for “Likelihood” and “Consequence”
  - L∈[1,5]
  - C∈[1,5]
  - 2-Dimensional plot has defined R,Y,G colors
- For each question, can plot results of the risks that are spawned
  - Each ‘ility area has a different spread on its own scatter plot
  - Produces 9 scatter plots for a UUE
- Utility
  - Within a thread, concentrates program manager on area (question) that needs work
  - L,C outputs should be used as inputs to a risk assessment process

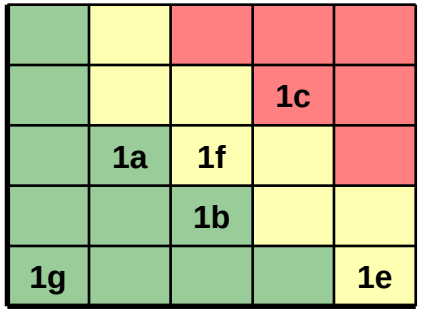
Example Results: Integrability for UUE



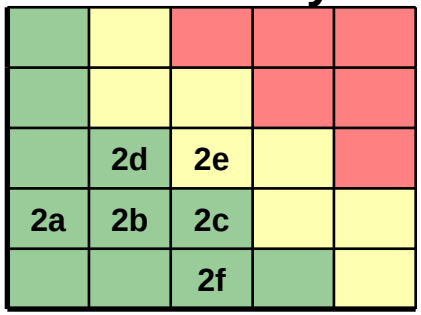
Why Summarize Each ‘ility Area?

- Manager of the Unit Under Evaluation (UUE) is left with 9 separate risk scatter plots

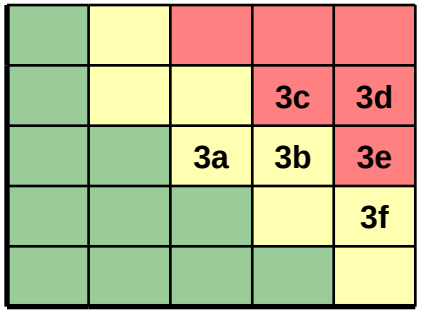
Integrability



Testability



Reliability



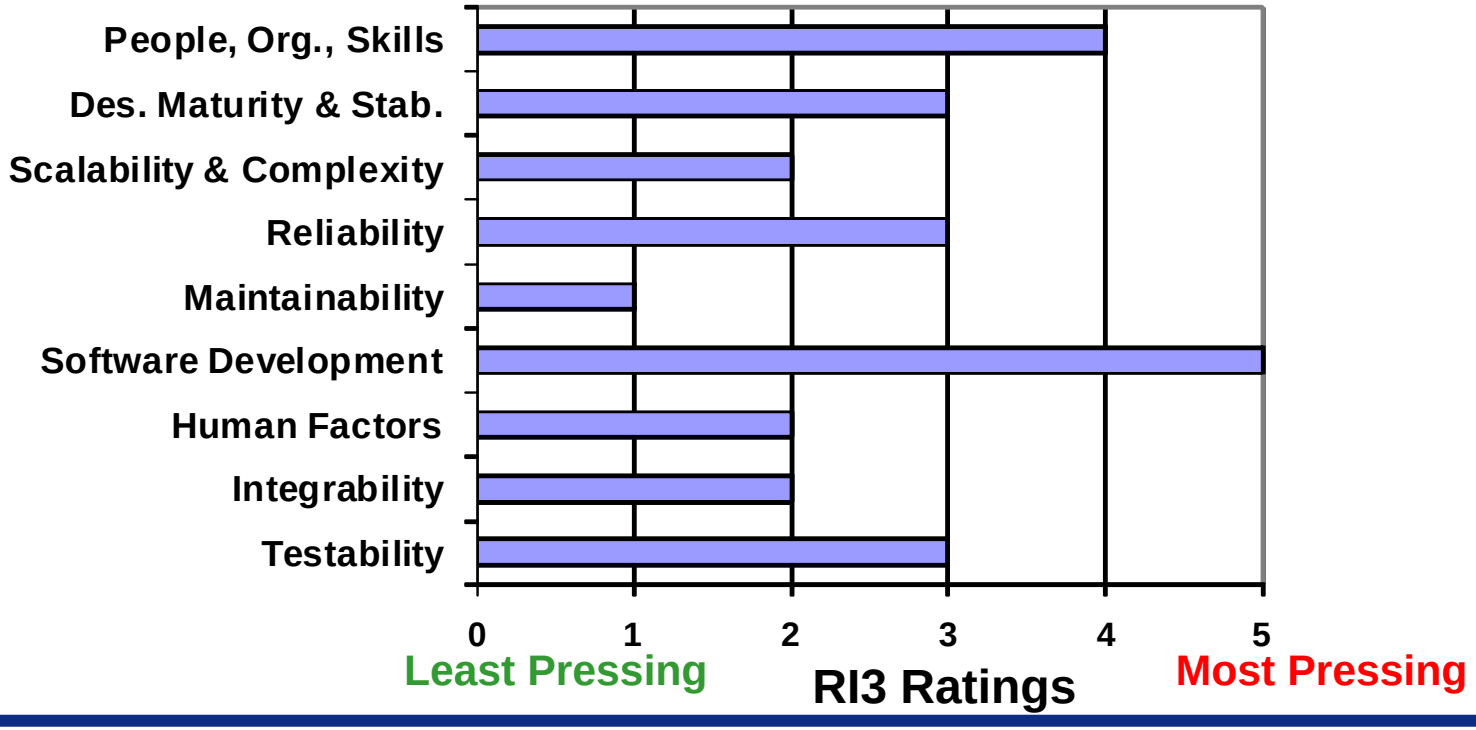
Etc.

...

- Summarization of the details would improve
  - Understanding of overall status
  - Reporting upwards

Summary Display for Unit Under Evaluation

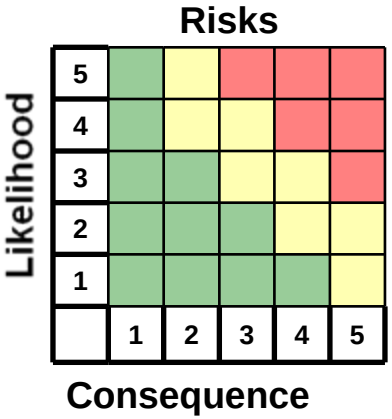
- Summary display for decision makers
  - Uses unique 2D-> 1D mapping of (L,C) to ratings
  - For each ‘ility, display the worst case rating of any risk
- Highlights most pressing issues
  - Complements underlying risk-methodology data
  - Invites reader to investigate further



Usage of RI3 to Feed AF Risk Management Processes

RI3 Guidebook

Questions:
- Integration
- ilities



Tool

Active Risk Manager (ARM) compatible file

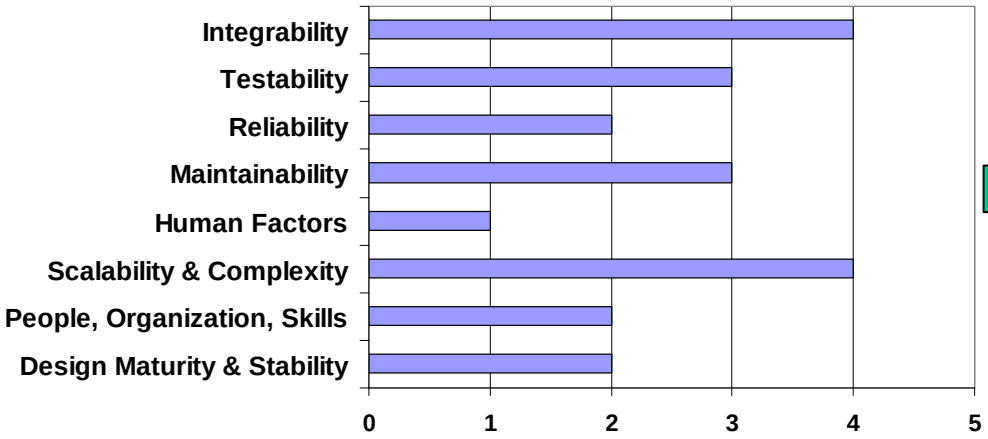
Risk Management

Step 2. Risk Identification

Similar output for cost estimation being investigated

Tool

Additional Summary Displays



Tool

PoPS

Description of RI3 Historical "Test"

Historical Program

Full Historical Documentation

Extract Partial Info

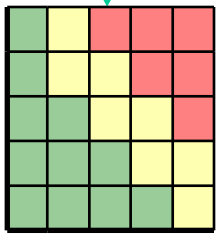
Documentation up to PDR Only

Stayback Team

Review Materials

RI3 Guidebook, Tool

Predict Risks



Review Full History

Omniscient Team

Full Team

- Interview Program Office,
- Compare Predictions to Truth

Results

- Test Metrics
- RI3 Revisions

Results: RI3 Historical "Test"
Completed Nov 21, 2008

	Number	Correctly Predicted by Team	Could be Predicted by Program Office	Escaped Prediction (Type 1 Error)
Realized Risks / Issues	22	13	6	3

RI3 v1.0 Tool could have predicted 86% of Issues

Modified tool to be more perceptive

- Correctly Predicted by Team
  - Team members predicted a risk, which in fact became an issue
- Could be Predicted by Program Office
  - If the program personnel had the RI3 tool available, issue that arose would likely have been predicted as a risk by RI3
    - Team did not predict risk in exercise due to lack of information
- Escaped Prediction
  - Questions did not yet capture an issue that arose

RI3 Deliverables

- RI3 Guidebook issued
  - Methodology description
  - 101 questions in 9 “ilities”
- RI3 Interim Tool
  - Currently in a spreadsheet
  - AFRL to make a “web” version
- RI3 training
  - In development at AFIT
- Status
  - RI3 Guidebook to be included as an appendix to a new AF acquisition book
  - AF Systems Engr policy to be changed to reference
  - RI3 under test right now in 3 of 4 AF product centers plus top 50% of AFRL portfolio
    - Early feedback from one product center indicates that RI3 has identified 10% more risk items than previously identified

Available for public release as of April 2009

Summary

- **TRL tells you where you are, but is not an indicator of future success**
  - **Data shows that programs reaching MS B with TRL 5 or 6 fare no better (7 does fare better)**
- **MRLs add analysis to determine manufacturability and identify related risks**
- **RI3 provides a complementary methodology**
  - **To avoid common pitfalls in integration and the “ilities”**
  - **To report upwards**
  - **That is in test right now in the Air Force and should be publically available soon**

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