Integrity - Service - Excellence

Status of the Air Force's Improved Technology Maturity Assessment Project (TD-1-12)

2008 Technical Maturity Conference
Virginia Beach, VA
September 9-12, 2008

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TD-1-12 Outline

- Introduction
- Improving Existing Techniques
- Methodology for Integration & ilities
- Worksheet/Tool Concepts
- Summary

D&SWS Sub-Process Teams
(Jun '08)

Changes in Red

Process Owner
Co Lead

Gen Bruce Carlson
Lt Gen Don Hoffman
CPO: MG Marshall Sabol

Institutionalize Standard Work
*ESC/CA (Ms. Duntz)
SAF/ACE Dir (Mr. DiCicco)
AFMC/IG (Col Moran)

Oversight / Command & Control
*AFMC/A2/5 (BG Wolfenbarger)
AQX Deputy (Mr. Shelton)
SAF/IEL (Ms. Walker)

Advisors:
BG Smoot (AFMC/A1)

Technology Development
*AAC/CA (Ms. Stokley)
SAF/AQR (Mr. Jaggers)
AFRL/CC (MG Bedke)

Continuous Capability Planning
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HAF/A5R (BG Mueller)
SMC/CV (BG Mashiko)

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ASC/CA (Ms. Wright)
OC-ALC/CC (MG Reno)

Test and Evaluation
*AFFTC/CA (Mr. Bond)
AFOTEC/CC (MG Sergeant)
AFMC/A3 (BG Lanni)

Supply Chain Operations
*HAF/A4I (Mr. Dunn)
AFMC/A4 (BG Bruno)
AFSPC/A4/7 (Ms. Puckett)

Sourcing
*AFMC/PK (Mr. Gill)
SAF/AQC (Mr. Correll)

* Indicates Lead

TD-1-12 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

TD-1-12 Approach, Products

Two-pronged Approach

- **First, improve existing techniques for gauging maturity**
  - **Improve quality & consistency of AF Technology Readiness Level (TRL) assessments via improved training**
    - **e.g. Help reduce the questions on what a "relevant environment" is**
    - **Applicable to formal TRA process as well as organic program office TRL assessments**
  - **Produce/promulgate training for Manufacturing Readiness Assessments (MRA)**
  - **Improve software tech readiness level descriptions → OSD**
- **Second, produce methodology to evaluate integration and the 'ilities**
  - **"Risk Identification: Integration & ilities" (RI3) methodology identifies sources and categories of technical risks in developing and incorporating new technologies**
    - **RI3 Guidebook**
    - **RI3 questionnaire tool**

Better Assessment of Technology Readiness Levels

- Assessments of Technology Readiness Levels (TRLs) occur for large and small programs
  - Small programs → Organic SPO resources
  - Large programs → Receive OSD oversight, involve independent assessment teams (TRA process)
- Improved training should lead to
  - More consistent results in Air Force programs, independent of program size
  - Less time spent discussing definition of "relevant environment" for a particular technology
- Cases studies being assembled into a new training class
  - Audience: subject matter experts who will need to conduct TRL assessment
  - Based on recent SAF/AQR TRA improvements plus assessments of programs visited by this study
  - Looking for course developer to assist AFIT

Software (Technology) Readiness Levels

- Background
  - Current definitions of Software Technology Readiness Levels in DoD TRA handbook have lead to confusion

- Software subteam of TD-1-12 identifying shortfalls in current definitions & formulating potential changes
  - Working in conjunction with AQR-funded effort at CMU/SEI to identify issues

- Goal
  - Using the current definitions, frame enough supporting materials to make the definitions useful
    - Draft output in August 08

- Future goal (if necessary): fix the definitions

Training For Manufacturing Readiness Assessments

MRL 1	MRL 2	MRL 3	MRL 4	MRL 5	MRL 6	MRL 7	MRL 8	MRL 9	MRL 10
Mfg feasibility assessed	Mfg concepts defined	Mfg concepts developed	Capability to produce the technology in a laboratory environment	Capability to produce prototype components in a production relevant environment	Capability to produce a prototype system or subsystem in a production relevant environment	Capability to produce systems, subsystems or components in a production representative environment	Pilot line capability demonstrated. Ready to begin low rate production	Low rate production demonstrated. Capability in place to begin full rate production	Full rate production demonstrated and lean production practices in place

A B C

- **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**
- **Air Force Institute of Technology is developing training and tools to enable MRAs to be conducted at each of its four product centers, based on AFRL Mantech team's work.**

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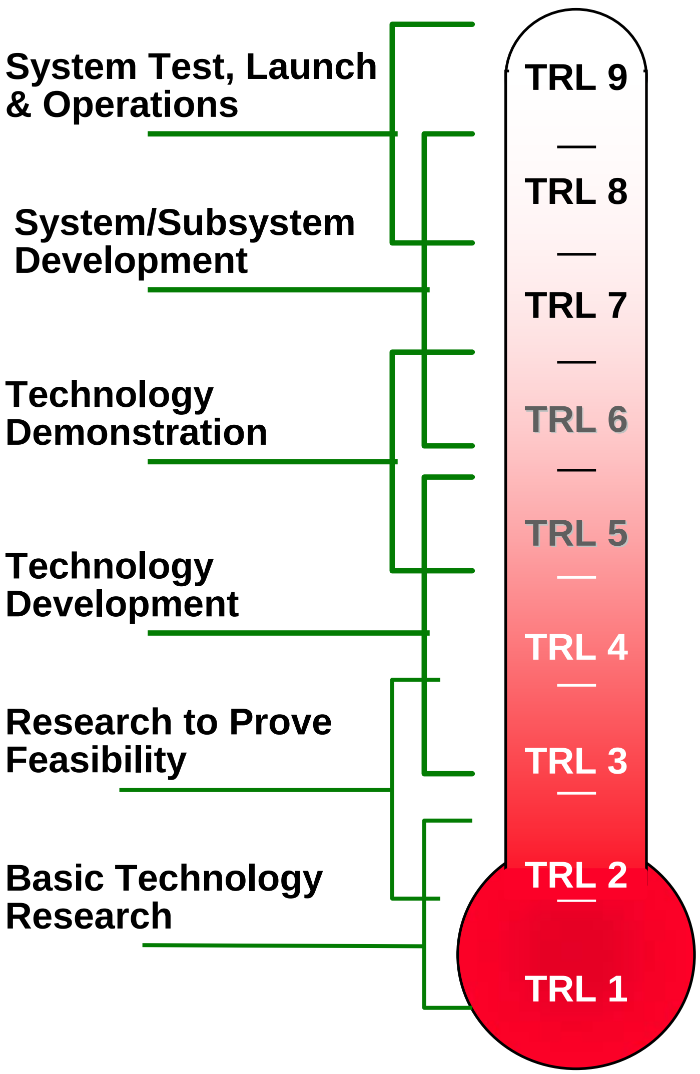
Measuring Technology Readiness

(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

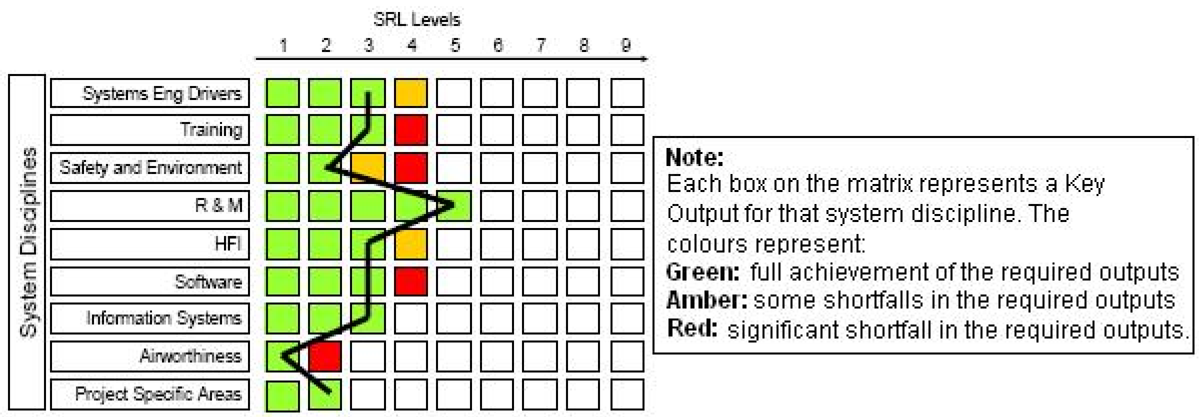
Goals of New Integration / 'ilities Criteria

- 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)

- Need a complementary methodology to give program offices better ways
  - To avoid common pitfalls
  - To report upwards (eg in PoPS)

Surveyed Globe for Good Ideas

- Efforts surveyed across DoD, other agencies, internationally, universities, corporate world
- NASA-originated AD2 methodology viewed favorably by members in OSD AT&L and SAF AQR
- British Ministry of Defence provided good input
  - British System Readiness Levels (SRLs) are used in conjunction with TRLs
    - Also in conjunction with a full-blown risk analysis assessment

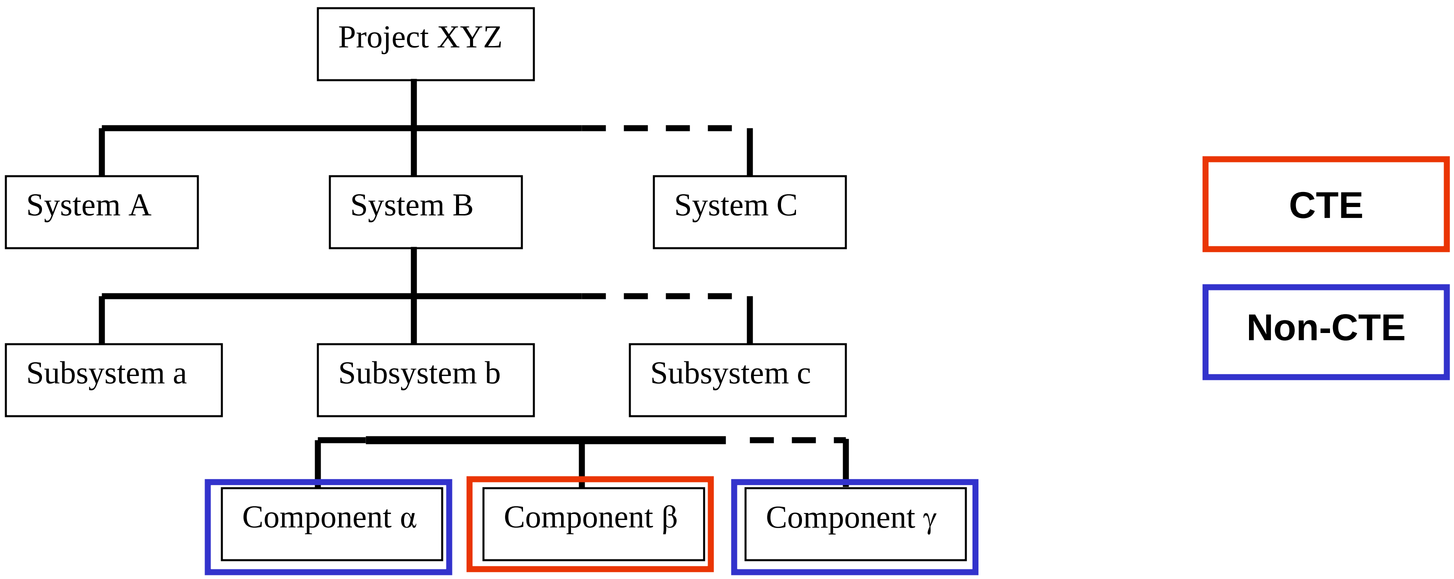


Example of an SRL 'Signature'

Examined Case Studies and Formed Opinions

- **Conducting case histories on 5 current and historical programs at 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**
- **Plan to "test" and refine methodology by using historical data from another set of programs**
- **Final judgement: 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 IRL, SRL, etc.)**
  - **Identification of risks is the key (as is done in MRAs)**

How to Begin RI3 Methodology



- Start with system level gross evaluation (top-down)
- Break down into subsystems, note Critical Technology Elements (CTEs), and evaluate TRL at appropriate level
- To assess integration and ‘ilities, must evaluate CTEs + units that interface with CTEs, even if they are not CTEs themselves
  - Then, proceed back up tree as appropriate

‘ilities Threads

- Team has downselected to the following list*
  - People, organization, & skills
  - Design Maturity and Stability (stability of rqmts)
  - Scalability & Complexity
  - Reliability
  - Maintainability
  - Software
  - Human factors
  - Integrability
  - Testability
- List culled from INCOSE standards and driven by observations of past program problems

* Some graphics on other charts are out of date

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)**

Development of Risks

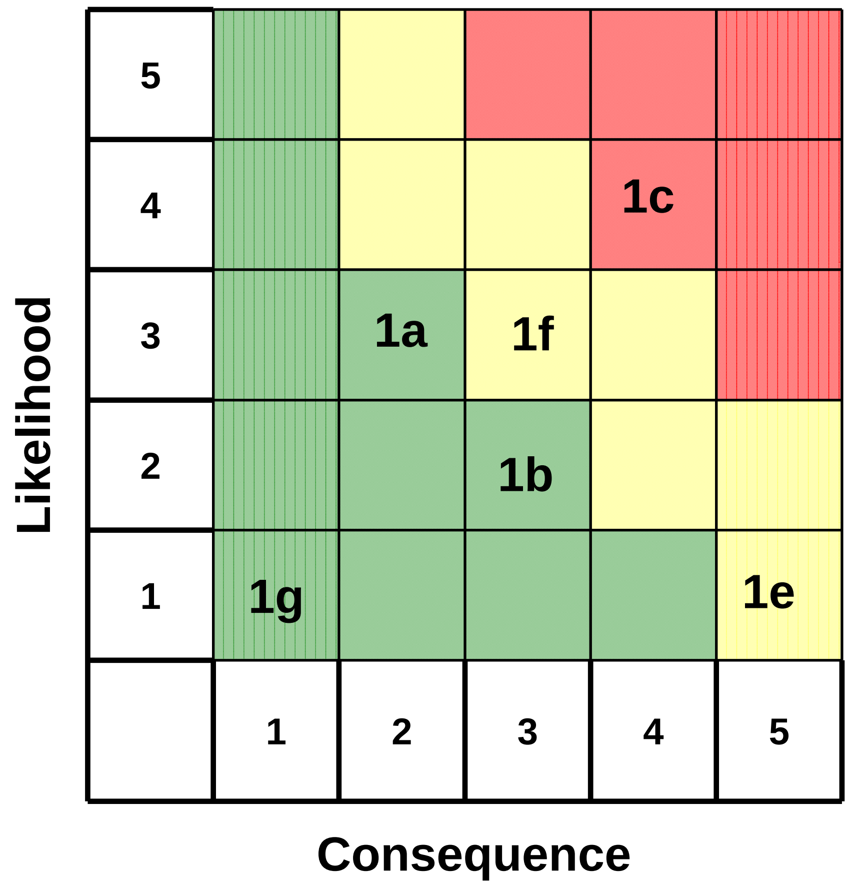
- Questions contain a best practice and are meant to prompt a program manager to consider acting accordingly
  - Questions may be answered "Yes," "No," or "not applicable"
  - If the answer is no, then the next step is to identify & describe risks that may result
  - Risks are compiled and then rated using standard likelihood, consequence methodology

- Methodology assumes typical systems engineering processes are in place (Systems Engineering Assessment Model [SEAM] applied)
  - Eliminates need for most process questions from RI3

Assess Likelihood and Consequence for Each Risk

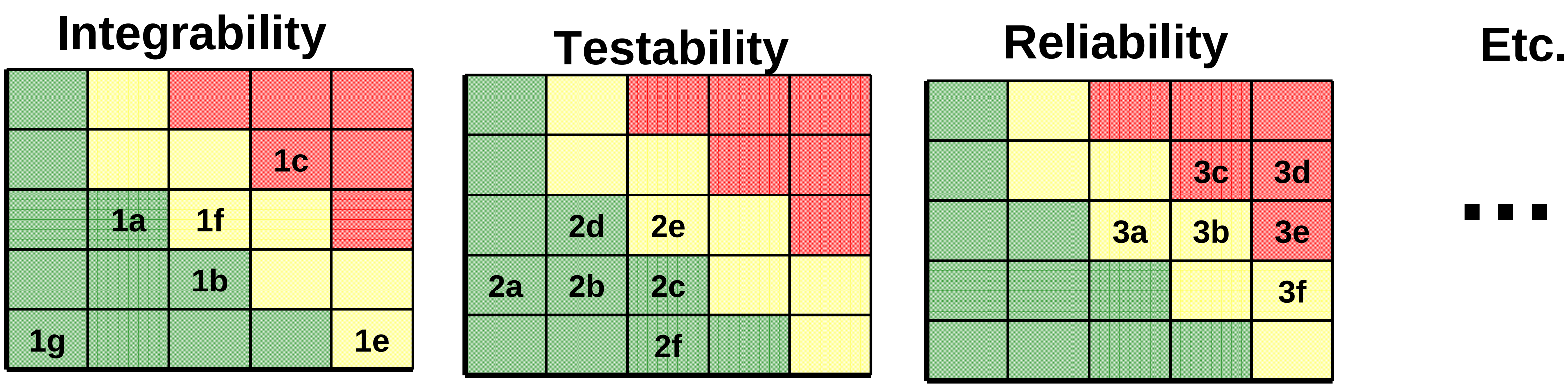
- Utilize "standard" DoD/AF definitions for "Likelihood" and "Consequence"
  - L∈[1,5]
  - C∈[1,5]
  - 2-Dimensional plot has defined R,Y,G colors
- For each question, can plot results of the risks that are spawned
  - Each 'ility area has a different spread on its own scatter plot
  - Produces 9 scatter 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 8 or 9 separate scatter plots



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

Developing Ratings

- Define an arbitrary mapping from 2-dimensional (L,C) space to an RI3 “rating” space
- From previous example
  - Risk 1C
    - Was estimated to be
      - C=4
      - L=4 (highly likely)
    - Resultant RI3 rating: R_{1c}=4
  - Risk 1e
    - Was estimated to be
      - C=5
      - L=1 (not likely)
    - Resultant RI3 rating: R_{1e}=3
- RI3 Rating is just a relative ranking
  - 5 = the most pressing
  - 1= the least pressing, but not unimportant
- If desired, could fall back to a scale from 1 to 3 (Green to Red)

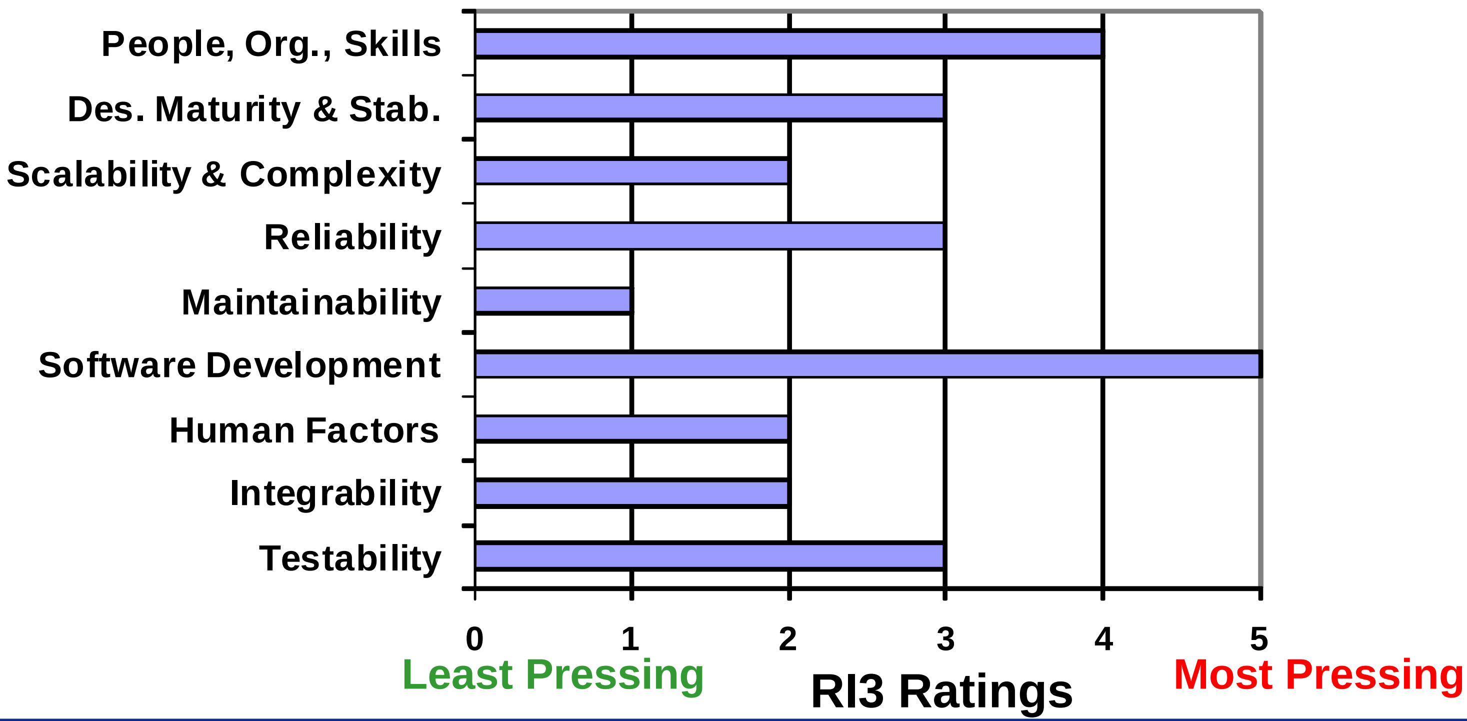
A Desirable Ratings Map

Likelihood					
5	2	3	4	4	5
4	2	3	3	4	4
3	2	2	3	3	4
2	1	2	2	3	3
1	1	1	2	2	3
	1	2	3	4	5

Consequence

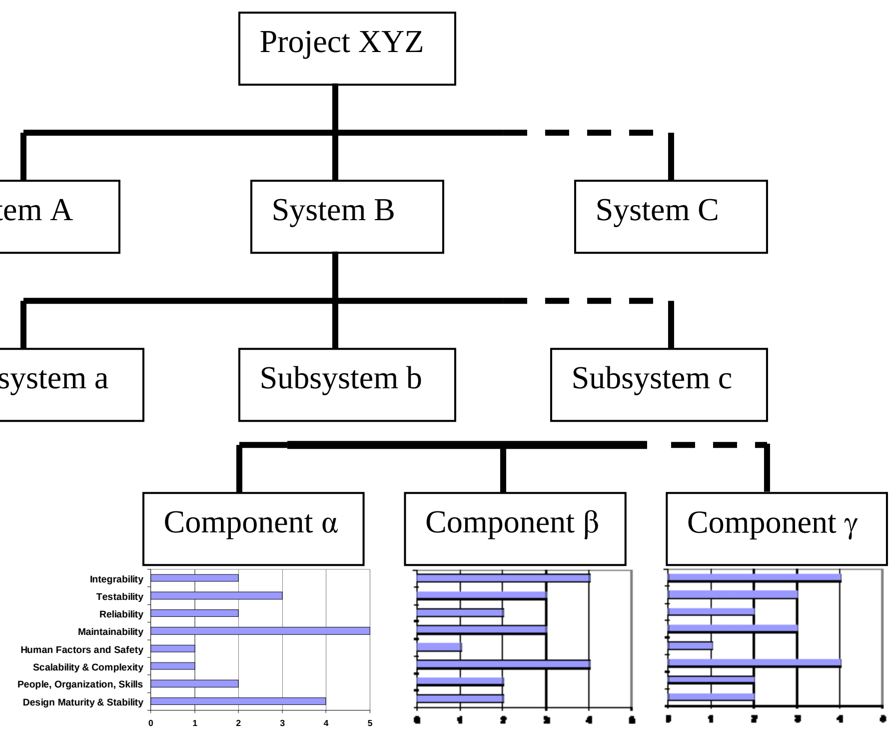
Summary Display for Unit Under Evaluation

- 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



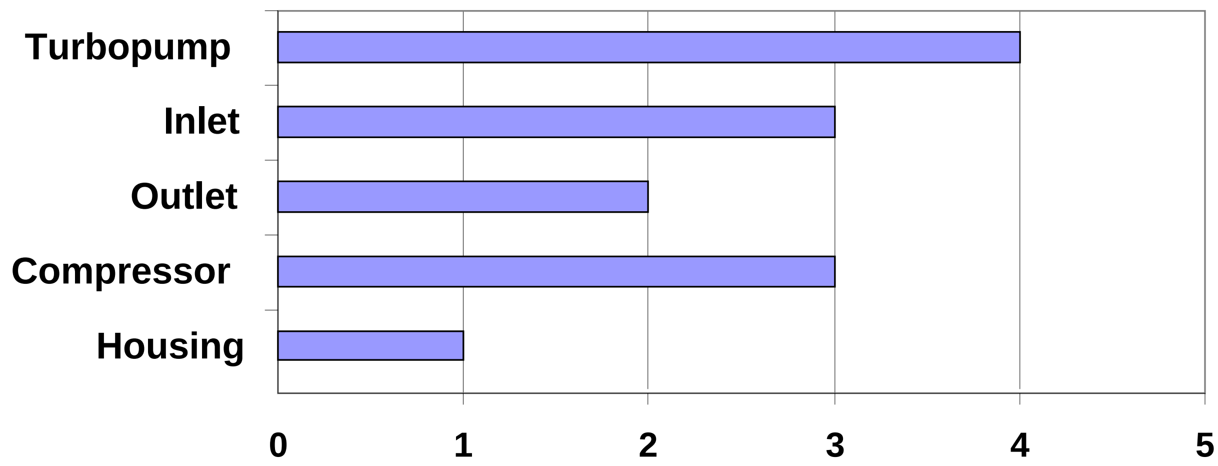
Multiple UUEs

- The SPO as a whole can look across UUEs
  - Invites drilling down for more detail



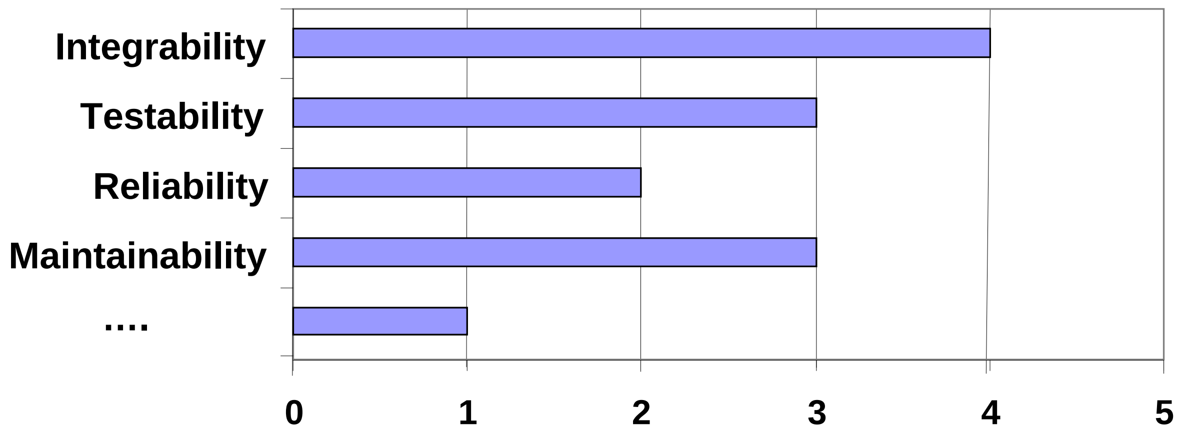
Multiple UUEs as a System UUE
Comparing Components

- **Look across components**
  - **To summarize advancement difficulty for lower level UUEs**
  - **$R(UUE_{\alpha}) = Max_{Threads}\{Integrability_{\alpha}, Testability_{\alpha}, \ldots\}$**
  - **$R(UUE_{\beta}) = Max_{Threads}\{Integrability_{\beta}, Testability_{\beta}, \ldots\}$**
- **System program manager can then ask, “which of my components needs the most help today?”**
  - **Colors are optional**



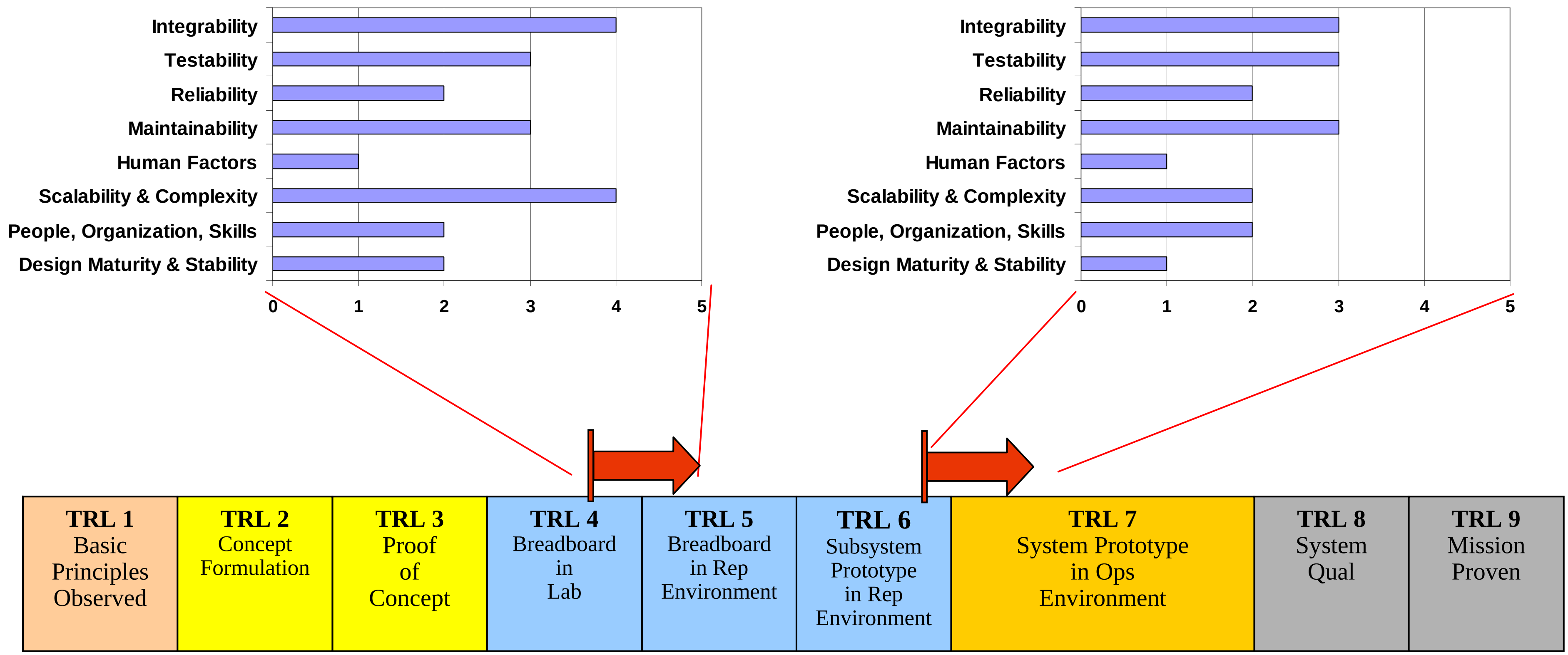
Multiple UUEs as a System UUE
Comparing Disciplines

- **Look across threads**
  - **To summarize advancement difficulty for disciplines**
  - **R(Integrability) = $\mathrm{Max}_{\mathrm{Comps}}$\{Integrability$_\alpha$, Integrability$_\beta$, …\}**
  - **R(Testability) = $\mathrm{Max}_{\mathrm{Comps}}$\{Testability$_\alpha$, Testability$_\beta$, …\}**
  - **Perhaps average instead of max?**
- **System program manager can then ask, "how are my processes working?"**
  - **Consistent?**
  - **Common issues faced by subsystems?**



RI3 “Signature” Evolves over Time

- RI3 can be used to support risk identification both in support of milestones as well as pre-MS A activity
  - Input to PoPS
  - Risks could actually increase as more knowledge is obtained



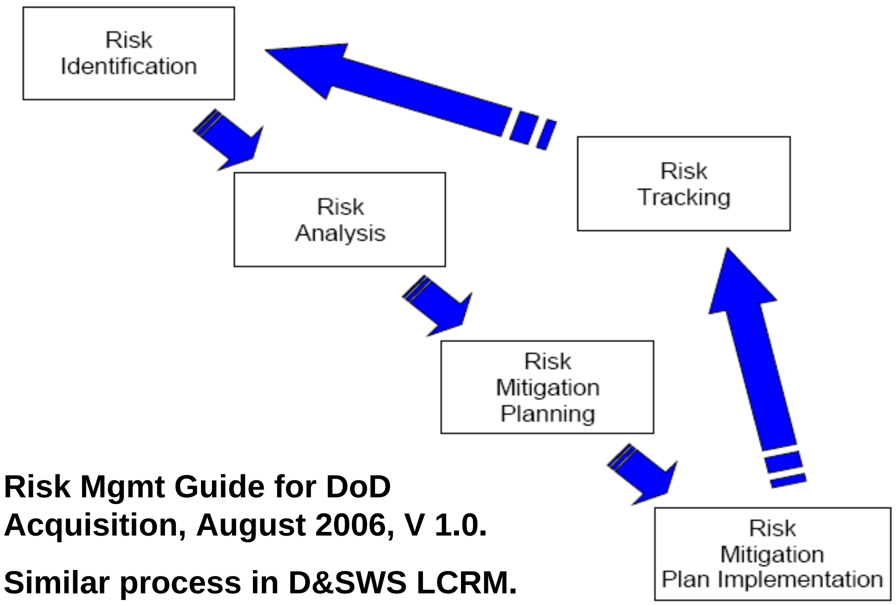
Uses of the RI3 Methodology

- Part of the usual business of a program office, XR, AFRL, or other technology developer
  - As an input to their risk/cost methodology
  - To compare and evaluate candidate technologies or concepts
  - To report upwards on status and progress (e.g. PoPS)
- Other potential venues
  - Pre-milestone A activities
  - D&SWS: LCM Sufficiency Reviews, TD-1-13 Stage Gating
  - Labs, contractors
  - Independent assessments: e.g. AFCAA, guidance for red teams
  - Source selections, Design reviews, etc…

RI3 Use By an XR or SPO

For Risk Management

- Incorporate RI3 into existing processes
- Risk Management Process
  - SMC guide: "…process can be greatly facilitated by the initial identification of categories of potential program risk initiating conditions…"
  - Supports Risk Identification
  - Helps ensure completeness of technical risks
  - Resources required
    - No additional personnel required
    - May add as little as 2 hours additional work to determine which questions are applicable
      - Subsequent work is part of normal risk processes
    - Minimal additional training required beyond risk processes
- Workload to be assessed in Fall 08 historical test



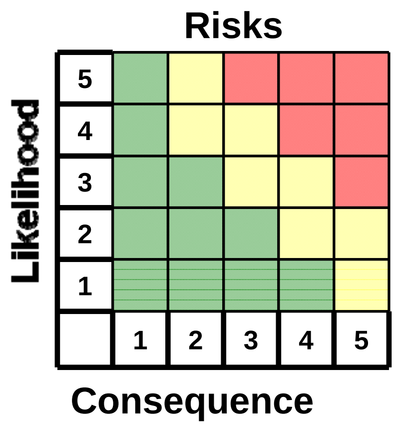
Risk Mgmt Guide for DoD Acquisition, August 2006, V 1.0.

Similar process in D&SWS LCRM.

Usage of RI3 to Feed Risk Management Processes

RI3 Guidebook

Questions:
- Integration
- ilities



Tool

Active Risk Manager (ARM) compatible file

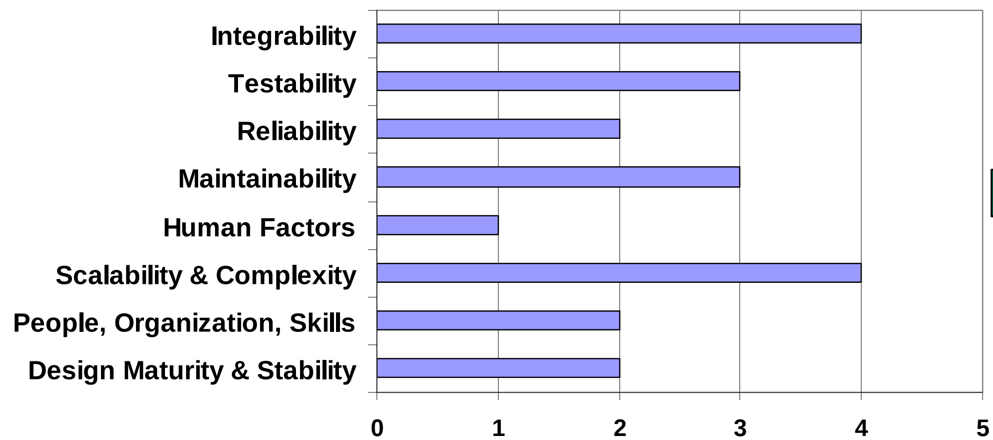
Risk Management

Step 2. Risk Identification

Similar output for cost estimation being investigated

Tool

Additional Summary Displays



Tool

PoPS

TD-1-12 Team Members

Name		Organization
Dorothy	Arbiter	Aerospace Corp
Joseph	Baker	AFMC/EN
Greg	Barnette	AAC/EN
Jim	Bilbro	NASA (ret.)
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Tom	Christian	ASC/EN
Toby	Edison	ESC
Bob	Frueholz	Aerospace Corp
Suzanne	Garcia	CMU/SEI
Peter	Hantos	Aerospace Corp
Jim	Morgan	AFRL Mantech
Bill	Nolte	AFRL/RY
Paul	Phister	AFRL/RI
Duane	Sauve	Ogden ALC
George	Sarmiento	AFMC/A5S

Name		Organization
Marc	Smith	AFMC/A2
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Kyle	Yang	MIT Lincoln Lab
Larry	Butterbaugh	AFRL/RHOX
Stacey	Carswell	AFRL/RWMI
Bob	Matthews	AFRL/RYZC
John	Mistretta	AFMC/EN
Dieter	Multhopp	AFRL/RBAA
John	Remen	AFRL/RZS
Peter	Roberts	AFRL/RDHE
Donna	Senft	AFRL/RVSV
Mike	Sorial	AAC
Charles	Skira	AFRL/RZTP
Linda	Taylor	SMC/EA
Jim	Jeter	Warner Robbins ALC
Art	Chin	SMC

Summary & Discussion

- TD-1-12 consists of
  - Training for TRL Assessments, MRAs, future RI3
  - Software TRL definition clarification
  - Risk Identification: Integration & ‘ilities (RI3) methodology

- Road Ahead
  - RI3 should be ready for external application in January 09
    - Engagments on D&SWS Pilot Projects should commence
  - Potential RI3 implications and touchpoints
    - Risk Management
    - Cost Analysis
    - Systems Engineering
      - Potential future policy implications for AF not yet determined

- Questions / Comments?

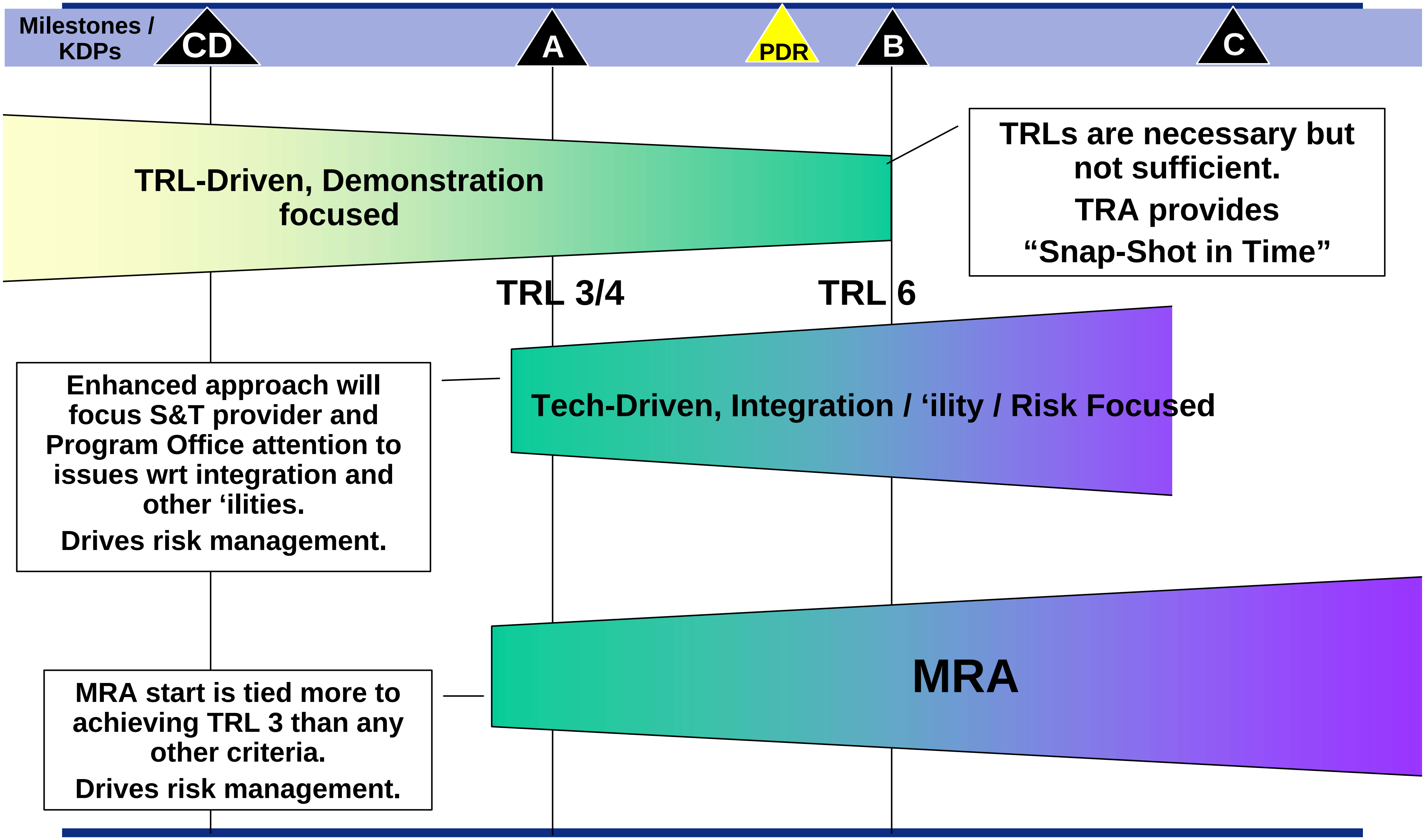
Backups Follow

Relationship to OSD Checklists

- Various OSD checklists are available on the DAU website
  - TRA – deals primarily with setting up for a TRA, not how to conduct a TRA
  - PRR – in discussion with MRA team
  - PDR, CDR
  - Only Navy NAVAIR appears to use the checklists
- Observations on checklists
  - Checklists are excellent sets of questions
  - Checklists are much broader in scope than RI3
  - But
    - Checklists are too long for day-to-day usage by a SPO
      - 800+ questions: if everything is important, then nothing is important
    - Checklists use a non-standard risk definition set (1-dimensional)
- Comments on RI3
  - RI3 cherry-picked & derived some questions from checklists
  - RI3 emphasizes some issues that checklists appear to leave out, e.g. Skills of developers (not just maintainers)
  - RI3 more geared for internal SPO usage than checklists are
  - RI3 geared toward feeding internal SPO risks
    - More open-ended questions, geared toward promoting best detailed practices, as opposed to checking the box: “Do you have a SEP?”

New Criteria to Cover Integration / 'ilities

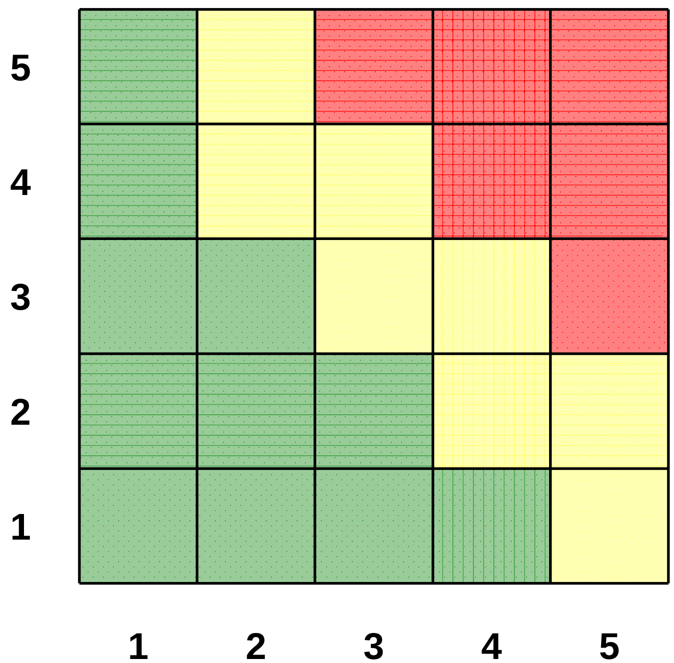
Overview/Description



Ratings versus Colors

- These ratings could be thought of as creating 2 intermediate colors
  - Red/Yellow
    - Reduces tendency to try to avoid high numbers because they're red
  - Green/Yellow
    - Reduce items that get ignored because they're green

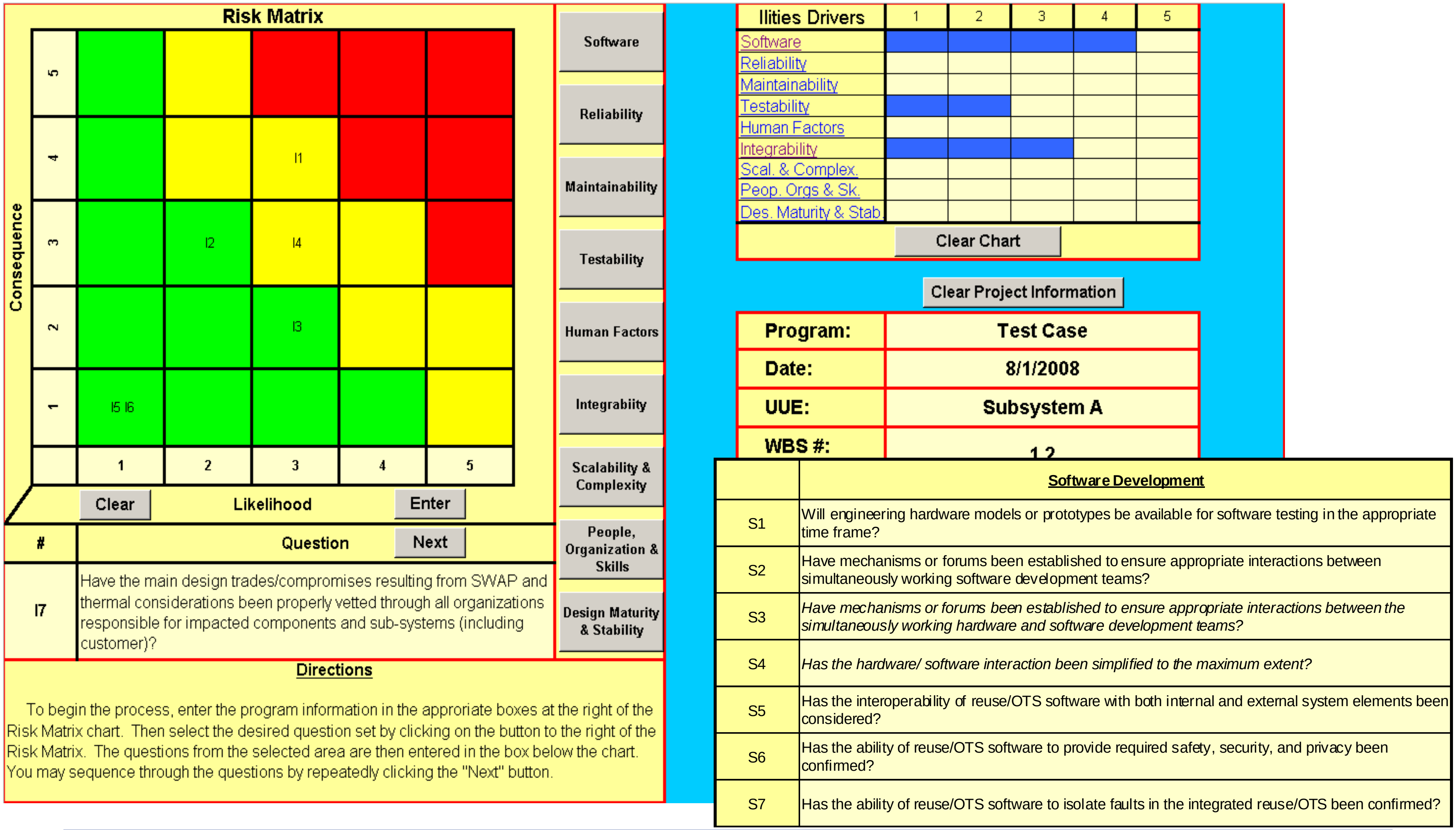
Original Colors



Proposed RI3 Ratings

	1	2	3	4	5
5	2	3	4	4	5
4	2	3	3	4	4
3	2	2	3	3	4
2	1	2	2	3	3
1	1	1	2	2	3

A Glimpse at a Potential RI3 Tool Instantiation



A Sample Tool:
Excerpt from DoD PRR Checklist

Legend:	R	Y	G	U	N	Item	Comments / Mitigation
1. Engineering and Product Design	0	0	0	0	0	1	
Technical Documentation, Systems Integration, and Coordination							
a. Technical Documentation, Systems Integration, and Coordination	0	0	0	0	0	1.a	
(1) Are the contractor's engineering drawings and documents complete for describing the equipment and the applicable software to be delivered under this program?						1.a(1)	
(2) Are there provisions to assure that obsolete drawings are removed and discarded?						1.a(2)	
(3) Are there procedures to assure that all engineering drawings are consistently prepared and that all revisions and Class I engineering changes are incorporated into the drawings?						1.a(3)	

PRR Worksheet exists in Excel format

- **RI3 could be similar, but prefer to leverage existing AFRL effort to upgrade TRL and MRL calculators to be web-based questionnaires**

Likelihood – DoD Guide

LEVEL	LIKELIHOOD	PROBABILITY OF OCCURRENCE
1	Not Likely	1%-20%
2	Low Likelihood	21%-40%
3	Likely	41%-60%
4	Highly Likely	61%-80%
5	Near Certainty	81%-99 %

Consequence – Performance

	DoD Guide	Proposed AF Definition
1	Minimal or no consequence to technical performance	Minimal consequence to technical performance but no overall impact to the program success. A successful outcome is not dependent on this issue; the technical performance goals will still be met.
2	Minor reduction in technical performance or supportability, can be tolerated with little or no impact on program	Minor reduction in technical performance or supportability, can be tolerated with little impact on program success. Technical performance will be below the goal but within acceptable limits.
3	Moderate reduction in technical performance or supportability with limited impact on program objectives	Moderate shortfall in technical performance or supportability with limited impact on program success. Technical performance will be below the goal, but approaching unacceptable limits.
4	Significant degradation in technical performance or major shortfall in supportability; may jeopardize program success	Significant degradation in technical performance or major shortfall in supportability with a moderate impact on program success. Technical performance is unacceptably below the goal.
5	Severe degradation in technical performance; Cannot meet KPP or key technical/supportability threshold; will jeopardize program success	Severe degradation in technical/supportability threshold performance; will jeopardize program success; or will cause one of the triggers listed below

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Mandatory Technical Performance Consequence Category 5 Triggers

- Any root cause that, when evaluated by the cross-functional team, has a likelihood of generating one of the following consequences must be rated at Consequence Level Five:
  - Will not meet KPP
  - CTE will not be at TRL 4 at MS/KDP A
  - CTE will not be at TRL 6 at MS/KDP B
  - CTE will not be at TRL 7 at MS/KDP C
  - CTE will not be at TRL 8 at the Full-rate Production Decision point
  - MRL will not be at 8 by Milestone C
  - MRL will not be at 9 by Full-rate Production Decision point
  - System availability goal will not be met

Consequence – Schedule

LEVEL	DoD Guide	AF Definition
1	Minimal or no impact	Negligible schedule slip
2	Able to meet key dates. Slip < * month(s)	Schedule slip, but able to meet key dates (e.g. PDR, CDR, FRP, FOC)
3	Minor schedule slip. Able to meet key milestones with no schedule float. Slip < * month(s) Sub-system slip > * month(s) plus available float	Schedule slip that impacts ability to meet key dates (e.g. PDR, CDR, FRP, FOC)
4	Program critical path affected. Slip < * months	Will require change to program or project critical path.
5	Cannot meet key program milestones. Slip > * months	Cannot meet key program or project milestones.

Consequence – Cost

LEVEL	DoD Guide	AF Definition
1	Minimal or no impact	For A-B Programs: <5% increase from last approved cost estimate For Post-B Programs: <X% increase in PAUC or APUC from last approved cost estimate or program cost baseline
2	Budget increase or unit production cost increases. < ** (1% of Budget)	For A-B Programs: <10% but >5% increase from last approved cost estimate For Post-B Programs: <1% but greater than X% increase in PAUC or APUC from last approved cost estimate or program cost baseline
3	Budget increase or unit production cost increase < ** (5% of Budget)	For A-B Programs: <15% but >10% increase from last approved cost estimate For Post-B Programs: <5% but greater than 1% increase in PAUC or APUC from last approved cost estimate or program cost baseline
4	Budget increase or unit production cost increase < ** (10% of Budget)	For A-B Programs: <20% but >15% increase from last approved cost estimate For Post-B Programs: <10% but greater than 5% increase in PAUC or APUC from last approved cost estimate or program cost baseline For O&S Programs and Sustainment Activities:
5	Exceeds APB threshold > ** (10% of Budget)	For A-B Programs: >=20% increase from the MS A approved cost estimate For MS Post B Programs: >=10% increase in PAUC or APUC from last approved cost estimate or program cost baseline (in danger zone for Nunn-McCurdy Breach)

MRL Definitions

MRL 1	MRL 2	MRL 3	MRL 4	MRL 5	MRL 6	MRL 7	MRL 8	MRL 9	MRL 10
Mfg feasibility assessed	Mfg concepts defined	Mfg concepts developed	Capability to produce the technology in a laboratory environment	Capability to produce prototype components in a production relevant environment	Capability to produce a prototype system or subsystem in a production relevant environment	Capability to produce systems, subsystems or components in a production representative environment	Pilot line capability demonstrated. Ready to begin low rate production	Low rate production demonstrated. Capability in place to begin full rate production	Full rate production demonstrated and lean production practices in place

A B C

• Production relevant environment – An environment normally found during MRL 5 and 6 that contains key elements of production realism not normally found in the laboratory environment (e.g. uses production personnel, materials or equipment or tooling, or process steps, or work instructions, stated cycle time, etc.). May occur in a laboratory or model shop if key elements or production realism are added.

•Production representative environment – An environment normally found during MRL 7 (probably on the manufacturing floor) that contains most of the key elements (tooling, equipment, temperature, cleanliness, lighting, personnel skill levels, materials, work instructions, etc) that will be present in the shop floor production areas where low rate production will eventually take place.

•Pilot line environment – An environment normally found during MRL 8 in a manufacturing floor production area that incorporates all of the key elements (equipment, personnel skill levels, materials, components, work instructions, tooling, etc.) required to produce production configuration items, subsystems or systems that meet design requirements in low rate production. To the maximum extent practical, the pilot line should utilize rate production processes.