Reliability Growth Models Using System Readiness Levels

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Purpose of Presentation

❑ **Problem Statement**

Since 1998 nearly one-half of DOD systems failed reliability requirements using legacy reliability growth models that do not use system maturity metrics.

❑ **Purpose of Presentation**

Demonstrate a correlation model of System Readiness Levels (SRL) and Reliability Growth Models.

❑ **General Approach**

o Develop Monte-Carlo Optimization model
o Correlate SRL model output to Reliability parameters.

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DOD Reliability

The 2012 Director of Operational Test & Evaluation report suggests over 50% of DOD programs from 1998 -2012 failed reliability requirements.
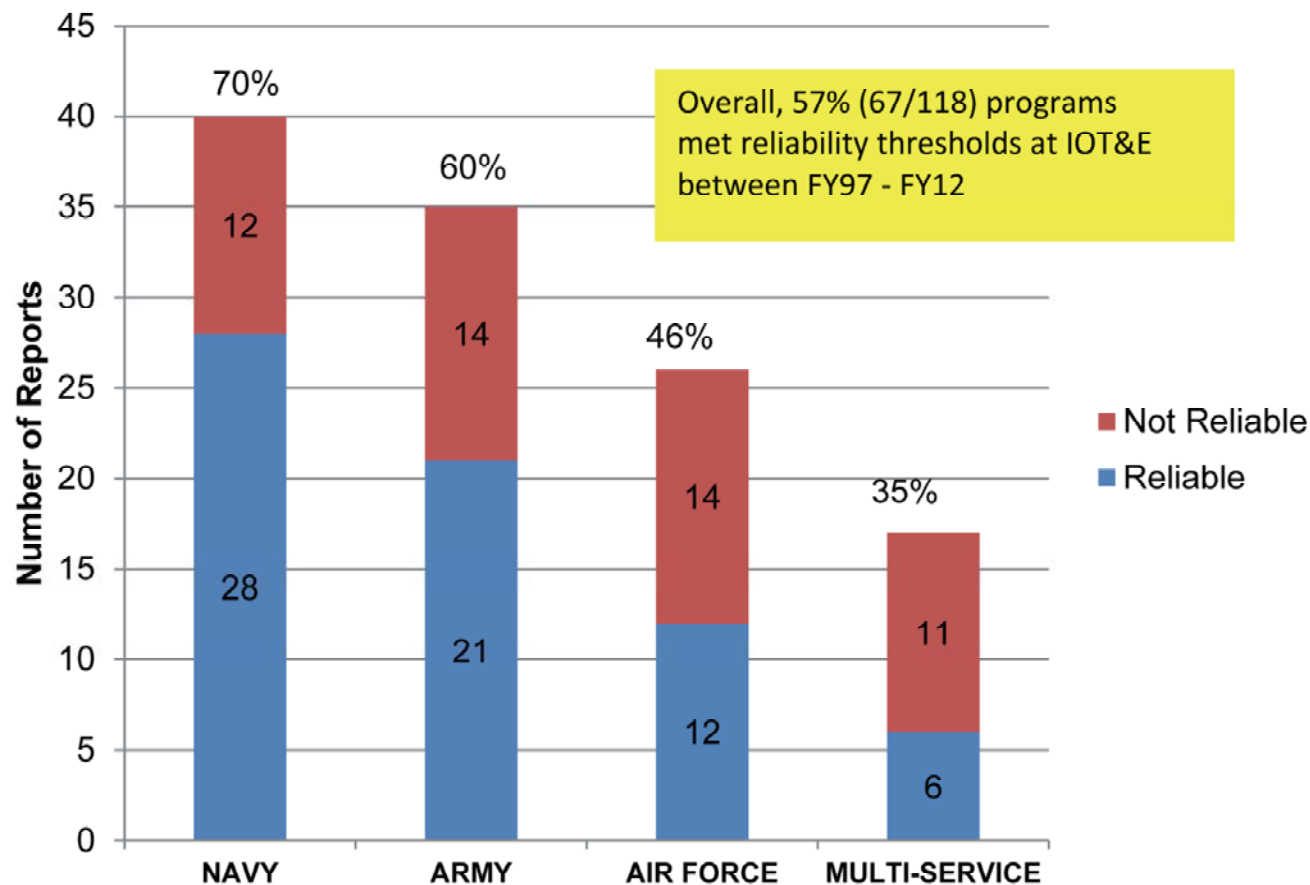

Fraction of DOD programs meeting reliability requirements
at IOT&E from FY97-FY12 [Gilmore 2012].

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System Readiness Levels

Numerous method of system maturity assessment have been developed.

Sample maturity assessments: [1]
- Manufacturing Readiness Level
- Integration Readiness Level
- Technology Readiness Level
- TTRL
- MDA Checklist
- AD2
- RD3
- System Readiness Level (UK)
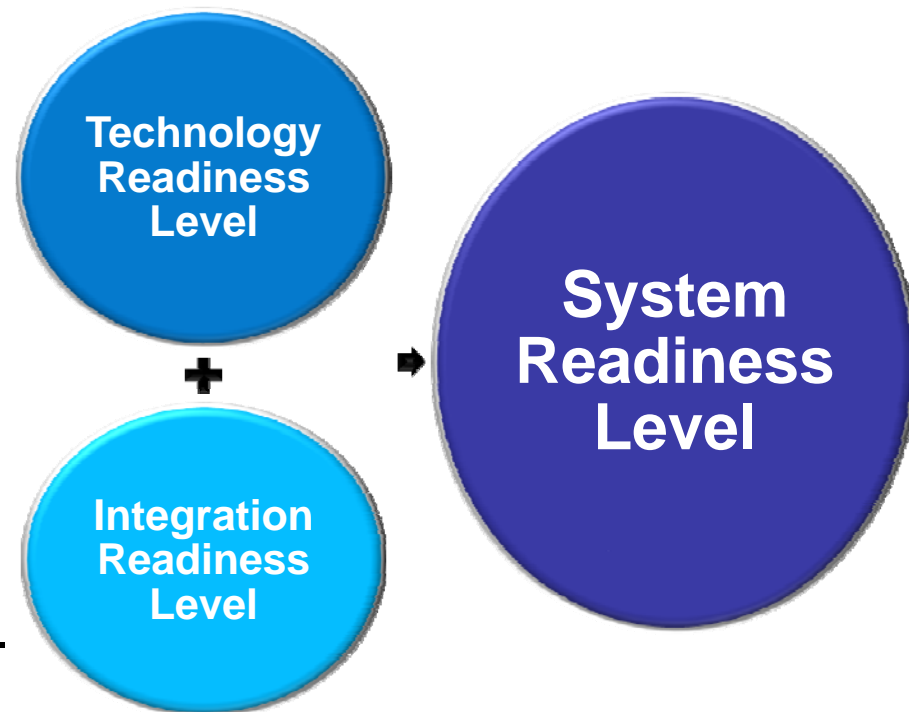- System Readiness Level (Sauser)
- TRRA
- ITAM
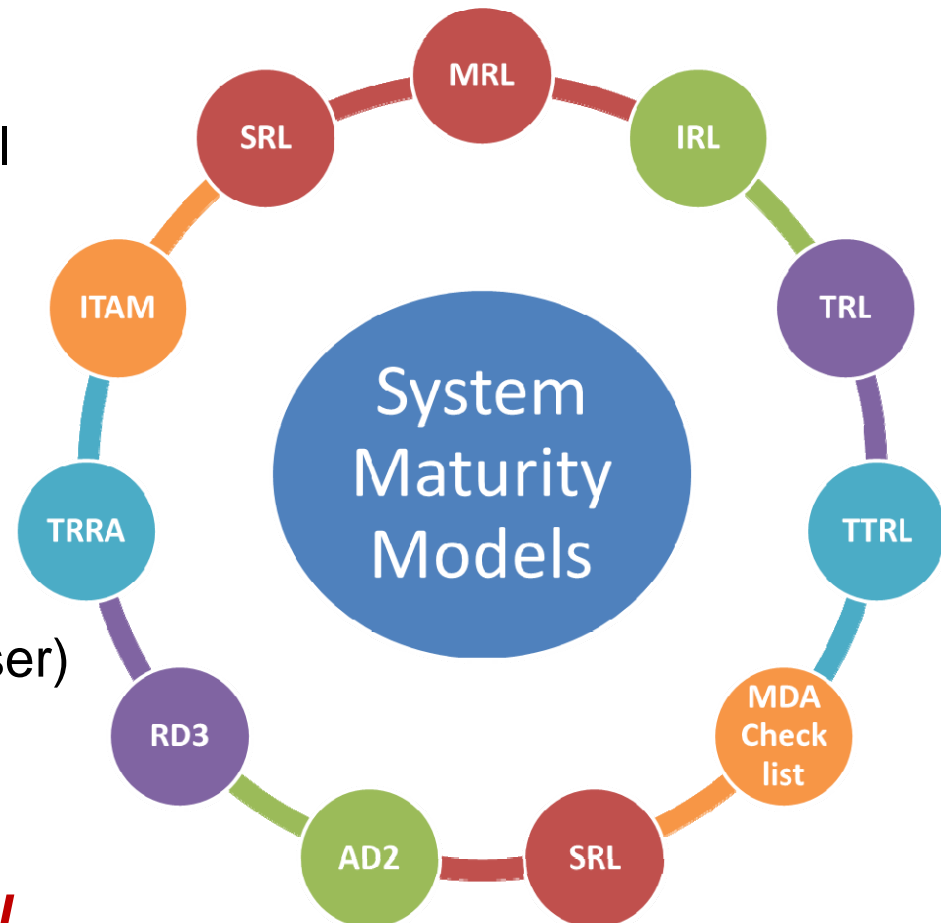
We will focus on the Sauser SRL.

[1] Azizian (2009)

System Readiness Levels

SRL Combines Technology and Integration Readiness Levels

❑ SRL developed in 2000s by Brian Sauser[1].

❑ SRL assesses system readiness to proceed to subsequent phases.

❑ SRL uses matrix math to combine Technology and Integration Readiness Levels.

[1] Sauser et al, 2008.

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System Readiness Levels

TRL assess the maturity of Critical Technology Element technologies .

❑ *1980's*
NASA uses to asses space technology.

❑ *2001*
Selected for use in DOD TRA assessments.

❑ *2000s*
Used with IRL to Develop SRL metric.

(9) System Validated Via OT

(8) System Validated Via DT

(7) System Demo ~ Dynamic Operational Env.

(6) System Demo ~ Relevant Lab Env.

(5) Component/Breadboard ~ Relevant Env.

(4) Component/Breadboard ~ Lab Env.

(3) Analytical/Experimental Proof-of-Concept

(2) Technology Concept

(1) Basic Principles

TRL 9

TRL 8

TRL 7

TRL 6

TRL 5

TRL 4

TRL 3

TRL 2

TRL 1

TRL Hardware definitions[1]

[1] DOD TRA Deskbook, 2009.

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System Readiness Levels

IRL developed as a new metric to complement TRL[1, 2].

Proposed Integration Readiness Level definitions[2].

IRL Scale	IRL Scale Description
9	**Mission Proven** through successful mission operations.
8	**Mission Qualified** through test and evaluation
7	**Verified** and **Validated** with sufficient detail.
6	Integration can **Accept, Translate and Structure** information
5	Sufficient **Control** to establish, manage, and terminate the integration.
4	Sufficient detail in **Quality** and **Assurance** of the integration.
3	**Compatibility** between technologies is established.
2	**Interaction** of technologies is characterized.
1	**Interface** between technologies is established.

[1, 2] Sauser et al., 2008 & 2010.

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SRL Applied to Reliability Growth

Applying SRL to Reliability Growth model parameters

Step #1: Optimization Model
- ❑ Monte-Carlo model evaluates SRL parameters over time
- ❑ Eventually develop a full Constrained Optimization model

Step #2: Correlation of SRL and RGM parameters
- ❑ SRL and RGM parameter relationships are NOT causally related!
- ❑ Correlation analysis supports SRL integration with RGM evaluations

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SRL Applied to Reliability Growth

Step #1: Optimization Model

❑ Prior research [1, 2] applies SRL to program cost/schedule.

❑ We expand SRL applications to Reliability Growth.

Sample SRL system and Reliability Growth Model parameters.

SRL Model Parameters	Reliability Growth Model Data Parameters
3-Component TRL system	Exponential data
Monte-Carlo model for TRL & IRL	Component reliability increases with increased system complexity
TRL & IRL transition probabilities P[TRL+}, P[IRL+]	Series-Reliability System model assumed

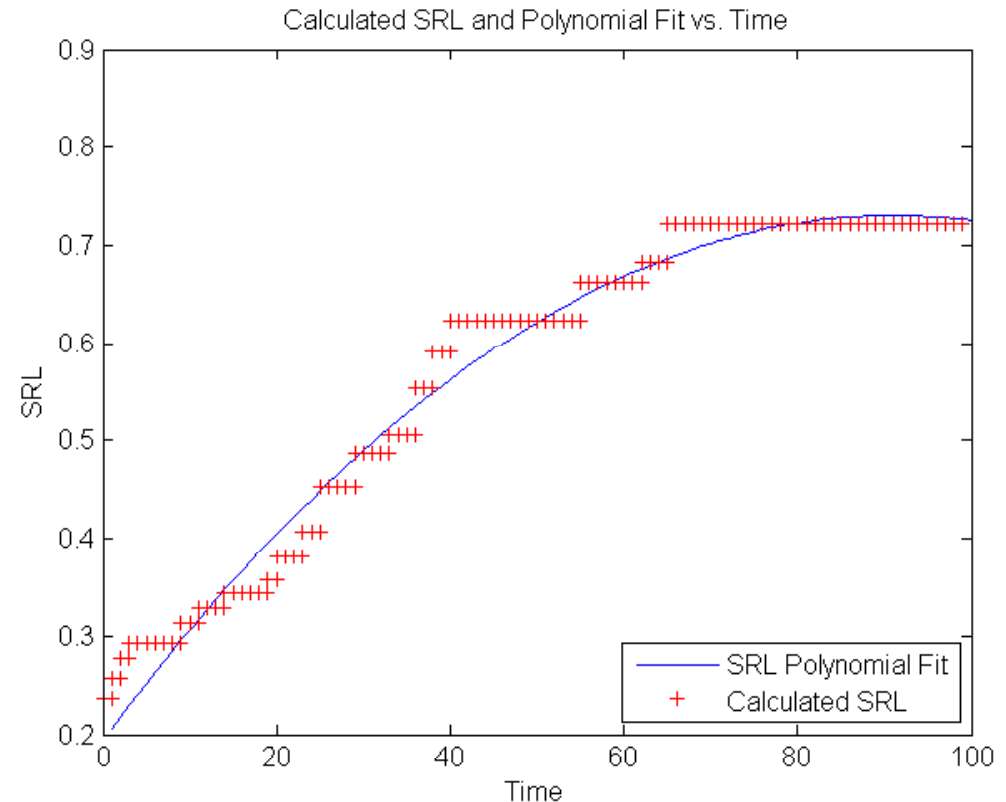10

[1, 2] Ramirez-Marquez et al., 2008 & 2009.

SRL Applied to Reliability Growth

SRL Monte-Carlo Model
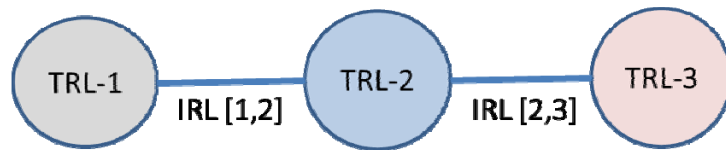
□ Model run: 100 time steps.

□ TRL & IRL = 5 @ t = 0.

□ P(TRL+) = P(IRL+) = 0.10.

□ *SRL changes over time.*

$$SRL(t) \approx -0.0001 \cdot t^2 + 0.0116 \cdot t + 0.2064$$

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SRL Applied to Reliability Growth

Step #2: Correlation of SRL and RGM parameters

❑ Optimization model provides SRL parameters for Correlation analysis.
❑ MIL-HDBK-189C[1] provides selected RGM parameters.

SRL and RGM parameters for correlation analysis.

| SRL Parameters	Selected RGM Parameters [1]
SRL vs. time - $SRL(t)$	MTBF Growth Rate - $MTBF_{dt}(t)$
SRL Growth - $SRL_{dt}(t)$	MTBF Growth Ratio - $M_o/M_I(t)$
SRL Growth Potential - $SRL_{GP}(t)$ $= 1 - SRL(t)$	MTBF Growth Potential - $MTBF_{GP}(t)$ $= 1 - MTBF_{OBJ}$

[1] MIL-HDBK-189C (2011).

SRL Applied to Reliability Growth

Correlation Analysis of SRL & RGM parameters.

Consider the same system but from a Reliability perspective

TRL-1 — IRL [1,2] — TRL-2 — IRL [2,3] — TRL-3

SRL system definition
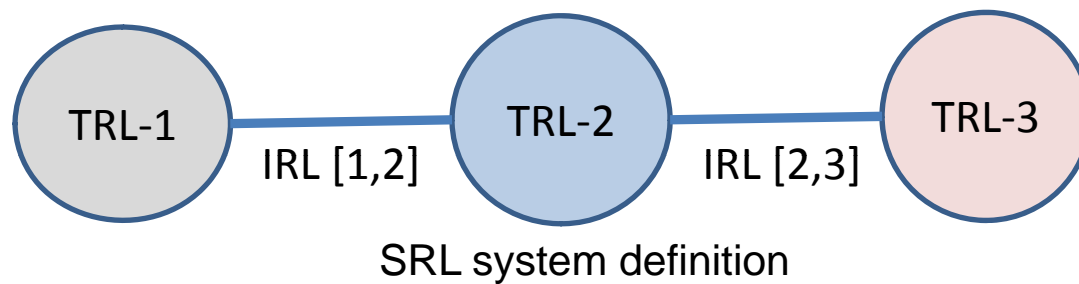
…using a Series Reliability system assumption…
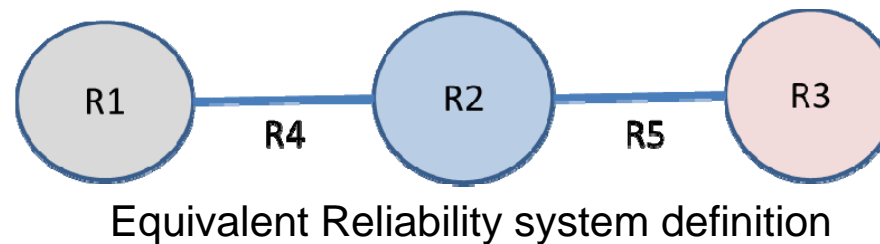
R1 — R4 — R2 — R5 — R3

Equivalent Reliability system definition

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SRL Applied to Reliability Growth

Notional System Mean-Time-Between-Failure Data

❑ MTBF increases as IRL & TRL increase [1,2]
❑ Assumes Exponential failure rates [3]
❑ Equally weights components

Component MTBF vs. Component Readiness Level

Legend:
- TRL-1 Reliability
- TRL-2 Reliability
- TRL-3 Reliability
- IRL-1,2 Reliability
- IRL-2,3 Reliability

X-axis: ITRL Component Readiness Level
Y-axis: Component MTBF (hrs.)
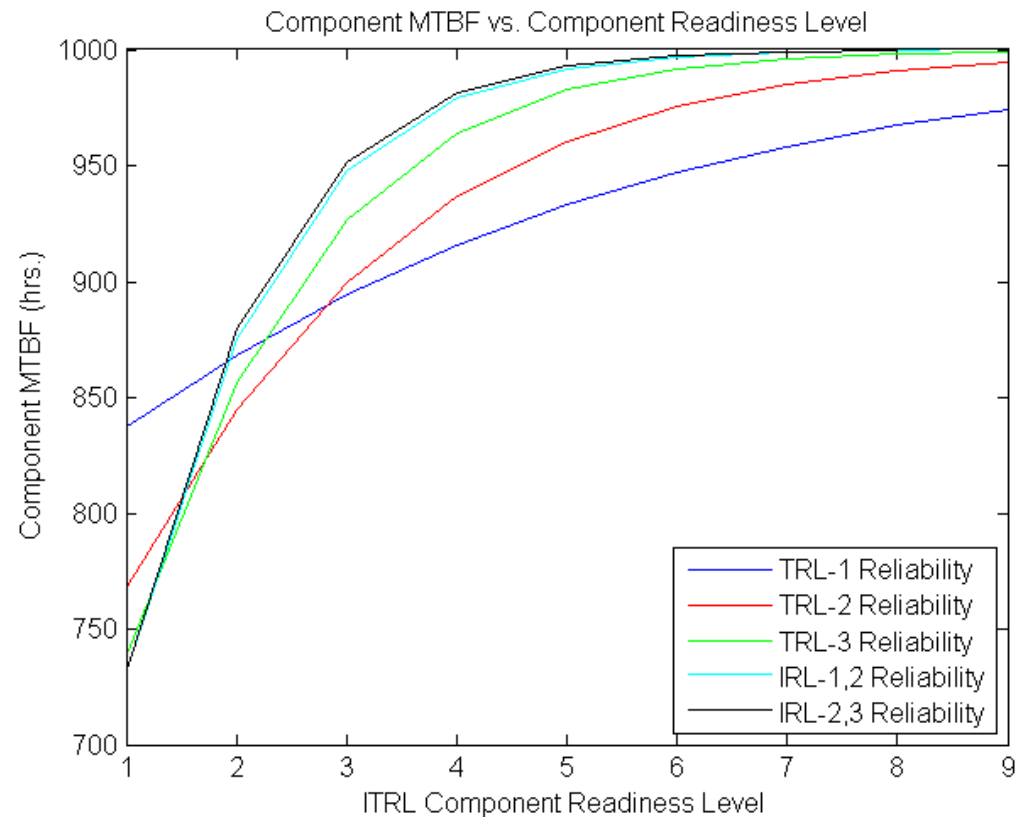
[1] Ramirez-Marquez (2008).
[2] Ramirez-Marquez (2009).
[3] Kececioglu (1993).

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Results and Conclusions

Results

❑ Provided a Monte-Carlo SRL correlation model for Reliability Growth

❑ Demonstrated strong correlation of SRL and Reliability parameters

➢ Positive correlation of $MTBF_{SYS}(t)$ vs. $SRL(t)$ = **+0.9297**

➢ Positive correlation of $MTBF_{GP}(t)$ vs. $SRL_{GP}(t)$ = **+0.9257**

➢ Negative correlation of $MTBF_{GP}(t)$ vs. $SRL(t)$ = **-0.9297**

➢ Negative correlation of $MTBF_{SYS}(t)$ vs. $SRL_{GP}(t)$ = **-0.9297**

Conclusions

❑ Extend SRL models to Reliability and T&E resource allocation

❑ Expand SRL mathematics beyond current approaches

❑ Real SRL and Reliability data needed for full analysis

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